CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY

REPORT FOR
BUREAU OF MINES
DEPARTMENT OF THE INTERIOR

THE SYNTHETIC LIQUID FUEL POTENTIAL OF KENTUCKY

DECEMBER 14, 1951

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK PHILADELPHIA CHICAGO LOS ANGELES

U.S. Engineer Dept.

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NEW YORK
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CONSTRUCTION VALUATIONS REPORTS MANAGEMENT

PHILADELPHIA
LOS ANGELES

39 BROADWAY
NEW YORK 6

New York, December 14, 1951

The Chief of Engineers
Department of the Army
Washington 25, D. C.

Dear Sirs:

We submit herewith our report upon "The Synthetic Liquid Fuel Potential of Kentucky", in accordance with Contract No. W 49-129 eng-137 concluded between us May 3, 1949.

Our survey disclosed widespread interest in synthetic liquid fuels. Informed public opinion recognizes the need for utilizing to the utmost all possible resources for the maintenance of our national welfare and security. Both public and private agencies have been very helpful in supplying data and entering into frank discussions with us on the subject. We welcome this opportunity to thank them for their cooperation.

Supplies of crude petroleum, the source of liquid fuels, are not inexhaustible. Provision must be made for the day when such fuel reserves become dangerously low. Foresight is required of all of us in facing this problem.

Over-all requirements of our natural resources are constantly changing. Obviously, no survey can do more than describe conditions in the light of present knowledge.

We believe that this report will be of value in formulating policy with respect to the future development of synthetic liquid fuels.

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Very truly yours,

(Signed) Ford, Bacon & Davis, Inc.

REPORT

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IDENTIFICATION OF GENERAL AREAS

No.	General Area
1	Johnson-Magoffin
2	Pike
3	Floyd-Magoffin
4	Knott-Breathitt
5	Perry-Breathitt
6	Leslie-Harlan
7	North Letcher
8	Harlan-Letcher
9	Bell
10	Daviess
11	Henderson
12	Union
13	Webster
14	Hopkins-Christian
15	Muhlenberg-McLean
16	Ohio

SCALE OF MILES
10 0 10 20 30 40

REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF

KENTUCKY

LOCATION OF
SUITABLE GENERAL AREAS
FOR
SYNTHETIC LIQUID FUEL MANUFACTURE

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK · PHILADELPHIA
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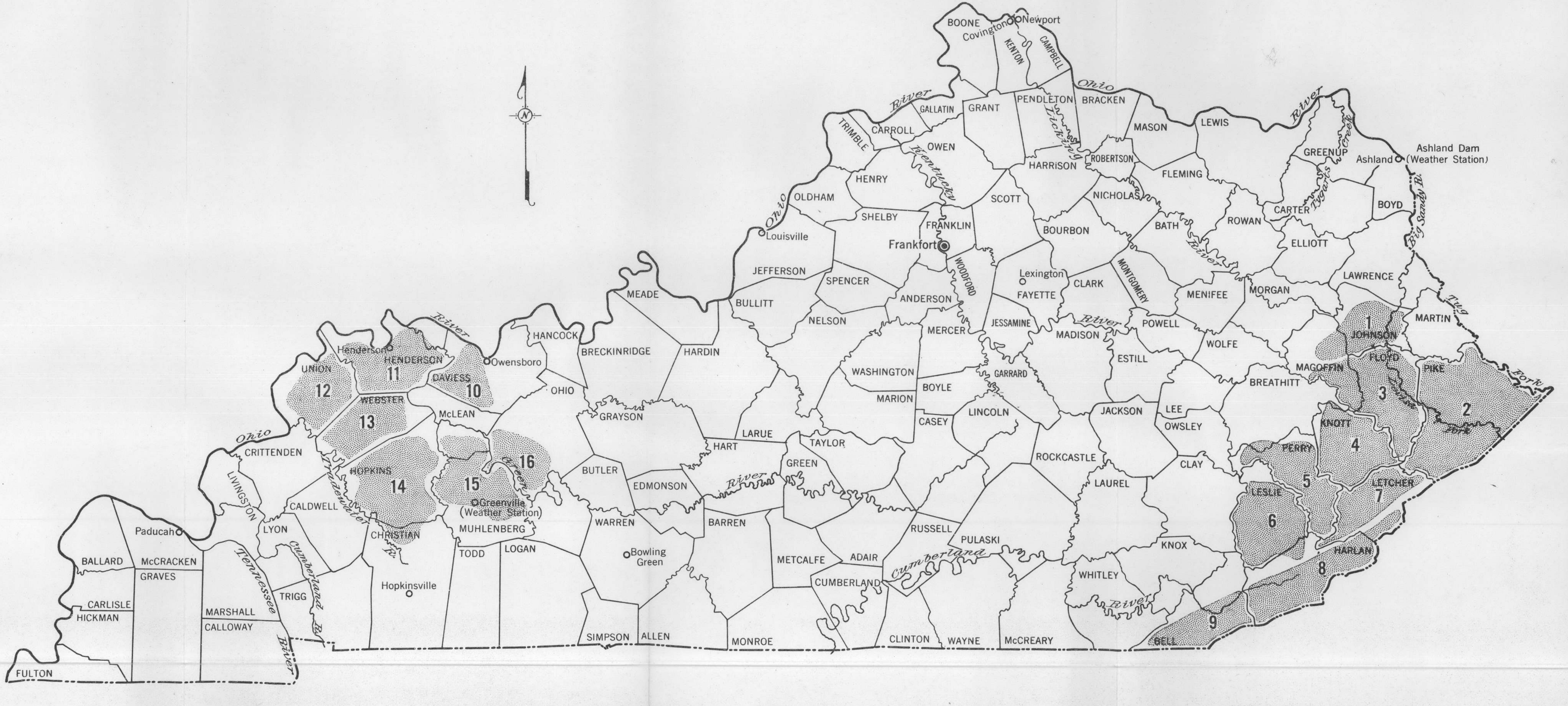

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CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY

REPORT FOR
BUREAU OF MINES
DEPARTMENT OF THE INTERIOR

THE SYNTHETIC LIQUID FUEL POTENTIAL OF KENTUCKY

DECEMBER 14, 1951

SUMMARY

Introduction

The Department of the Interior, as part of its broad program of synthetic liquid fuels research, requested the Department of the Army in 1947 to assist in the development of the synthetic liquid fuels program. This investigation and report on Kentucky are in part fulfillment of a contract to that effect awarded by the Corps of Engineers of the Department of the Army. The contract calls for a survey of 37 states and Alaska to determine Suitable General Areas and their potential capacity for the production of synthetic liquid fuels from coal, natural gas, oil shale, and oil-impregnated strippable deposits.

For General Areas containing raw materials and water supply of proper quantity and quality required by synthetic liquid fuels plants, various economic factors further affecting the suitability of such Areas for plant location are critically examined. No core drillings, extensive sampling, or detailed field examinations were made, and studies are based on information now available. Suitable General Areas as indicated on the map on the facing page were determined and defined but no specific plant sites are selected.

Raw Materials

The raw materials considered in this survey of Kentucky are coal, natural gas, oil shale, and oil-impregnated strippable deposits.

Coal. Of the four raw materials considered, coal was found to be the most important from the standpoint of meeting the survey requirements for synthetic liquid fuels production.

Oil-Impregnated Strippable Deposits. Eighteen counties in Kentucky contain oil-impregnated strippable deposits, the second raw material under consideration. The largest deposits in the State, in Edmonson and Logan Counties, comprise 434 million tons of oil-impregnated material in place or 347 million tons recoverable, occurring in beds 15 to 35 feet thick with less than an equal footage of overburden. These deposits contain from 10 to 15 gallons of oil per ton. Of the 347 million tons recoverable, 196 million are within an area of 4,220 acres in Edmonson County and the remainder in 2,253 acres of Logan County. The following table gives a few pertinent data about the major Edmonson and Logan County deposits:

Oil-impregnated Strippable Deposits in
Edmonson and Logan Counties, Kentucky
(As of January 1, 1950)

Description	Edmonson County	Logan County
Number of Local Areas	7	6
Total Area (Acres)	4,220	2,253
Thickness of Beds (Feet)	15-30	20-35
Thickness of Overburden (Feet)	15-30	15-35
Dip of Beds	Horizontal	Horizontal
Oil (Bitumen) Content (Gallons per Ton)	10-15	10-14.4
Recoverable Reserves (Tons):		
Indicated, Tertiary	125,885,000	27,752,000
Inferred, Secondary	21,648,000	-
Inferred, Tertiary	48,018,000	123,508,000
Total	195,551,000	151,260,000
Equivalent Oil (Bitumen) Content (Thousands of Gallons):		
Indicated, Tertiary	1,258,850	324,090
Inferred, Secondary	324,720	-
Inferred, Tertiary	524,026	1,235,080
Total (1,000 Gallons)	2,107,596	1,559,170
Total (1,000 Barrels)	50,000	37,000

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Both Edmonson and Logan Counties are General Areas of Raw Material Availability.

No other deposits of such material were found meeting the minimum requirements of this survey, which specify at least 10 million tons within 5 square miles in beds at least 15 feet thick under no more than their own thickness of overburden and averaging not less than 10 gallons of oil per ton.

The scope of this investigation with respect to oil-impregnated strippable deposits is limited to a general determination of the nature and extent of such deposits and their suitability or unsuitability for the manufacture of synthetic liquid fuels.

Natural Gas. The total reserves of natural gas in Kentucky, as of January 1, 1949, are estimated at 1,684,300,000 Mcf under standard conditions. All of the gas reserves are either under contract or will be used in field operations. Consequently, none could be considered to meet the survey requirements, which call for undedicated deposits, within a radius of 40 miles, of at least 225 trillion Btu (225,000,000 Mcf of 1,000-Btu gas) with a heating value of at least 400 Btu per cubic foot at standard conditions.

Oil Shale. The limited deposits of oil shale in Kentucky are not of sufficient richness or thickness to meet the survey's minimum requirements of 100,000,000 tons within a 5-square-mile area in beds at least 25 feet thick and yielding an average of at least 15 gallons of oil per ton.

General Features

The surface of Kentucky rises gradually from the Mississippi River to the western slope of the Appalachian Mountain province. The region west of the Tennessee River is low, the central portion is rolling, and the entire eastern part is much dissected, being part of the Allegheny Mountain region. The State has many rivers, among the principal of which are the Mississippi, Ohio, Cumberland, Tennessee, and Kentucky. Drainage from the State is to the west and northwest, emptying into the Ohio and Mississippi Rivers. Forty-six percent of the State is forested, and coal production is confined to 31 counties in the eastern part and 14 counties in the west. Within the region underlain by coal, there are ample water resources. The 1950 population density averages 72.8 persons per square mile throughout the 40,109 square miles (land area) of the State.

In the eastern coal-bearing section of Kentucky, the principal economic activities are agriculture and coal mining. In the western coal-bearing section, there is considerable manufacturing in the two counties immediately south of Evansville, Indiana; in the balance of the western counties, agriculture and coal mining predominate.

Processes

Since coal is found to be the most important raw material available in requisite quantities, only two processes of synthetic liquid fuels manufacture are considered, namely, hydrogenation and the synthine process.

In hydrogenation, coal is liquefied by combination with hydrogen at high pressures and temperatures in the presence of a catalyst. In the synthine process, coal is first converted to a gaseous mixture of carbon monoxide and hydrogen, which gases, in the presence of a suitable catalyst, combine to form liquid fuels. Both processes require major quantities of coal for direct conversion to liquid fuels and to provide energy for such conversion, and also of water, chiefly as a cooling medium. The unit plant size, adopted in this survey as a basis for estimates for comparison, is 10,000-barrel-per-day capacity.

As a synthetic liquid fuels program of any magnitude must necessarily require a considerable period of years for its realization, estimates of unit quantities of raw materials required and unit costs of plant construction and operation, used in this survey for determining ultimate production potential and relative desirability of the General Areas have been based on the assumed use of certain improvements in equipment and process which are still under development but which seem reasonably likely to be available by the time such a program could be well under way, such as direct pressure gasification of coal, and in the case of hydrogenation, some methods of equipment construction not now in general use in this country. Moreover, the estimated data and costs for the coal synthine process have been taken from preliminary studies made by the U.S. Bureau of Mines for a report which is not yet completed. The final estimates of the Bureau, when available, may differ materially from these preliminary figures. While the data used have been selected as offering a fair basis of comparison it must be understood that if synthetic liquid fuels plants were to be built at the present day, using only equipment and processes already commercially available, coal requirements and plant and product costs could be considerably greater than those shown in this report.

Subject to the above comments, daily requirements of Kentucky coals, as received at the synthetic liquid fuels plants, should average about 3,800 tons for a hydrogenation unit plant and about 4,900 tons for a coal synthine unit plant.

General Areas of Coal Availability

The coal-bearing formations of Kentucky are in two distinct areas, of which the larger is in eastern Kentucky and the smaller in western Kentucky. The eastern Kentucky field occupies approximately 10,450 square miles in all or parts of 37 counties. In the west, the coal-bearing formations extend under an area of about 4,680 square miles in all or parts of 21 counties.

In eastern Kentucky, five counties are eliminated from consideration because of their location in a fringe position too near the outer most limits of the coal-bearing area. In this part of the State, 18 other counties are eliminated because of insufficient or isolated reserves. In eastern Kentucky, 14 counties remained for consideration. In the west, six counties have been eliminated due to their outer most fringe position and five more due to insufficient or isolated reserves. In this part of the State, 10 counties remain for further consideration, making 24 counties in the State as a whole.

Of the 24 counties, 20 are found to contain 16 areas, each not larger than a county or 1,000 square miles, in each of which there are estimated adequate coal reserves for a 40 years' supply of at least one 10,000-barrel-per-day synthetic liquid fuels plant. These are designated General Areas of Coal Availability. Identified by the names of the counties in which important portions lie, these General Areas are:

Johnson-Magoffin	Bell
Pike	Daviess
Floyd-Magoffin	Henderson
Knott-Breathitt	Union
Perry-Breathitt	Webster
Leslie-Harlan	Hopkins-Christian
Northern-Letcher	Muhlenberg-McLean
Harlan-Letcher	Ohio

The total tonnage of coal considered for synthetic liquid fuels production in Kentucky as of January 1, 1949, based on available information and within the limits of reserves specified for this survey, as described in Part II of this report under "Definitions" and in Part IV under "Survey Methods and Procedure", was estimated at 22,932,403,000 tons in place or 12,826,094,000 tons recoverable (380,726,000 tons by strip mining and 12,445,368,000 tons by underground methods). These estimates are, therefore, not comparable with other coal estimates which generally include the total coal reserves in Kentucky without the limitations imposed by this survey. For example, in Circular 94 of the U.S. Geological Survey, the total recoverable reserves for all coal areas in Kentucky, as of January 1, 1950, (assuming 50 percent recovery) are reported as 59,711,697,000 tons. The estimate of the U.S. Geological Survey is based on one of those prepared by M.R. Campbell in the years prior to 1928, for which a new appraisal was not available.

After giving consideration to isolated areas with insufficient reserves to provide at least one synthetic liquid fuels unit plant for 40 years, providing commercial requirements for the next 50 years, and further contract limitations as to the use of primary and secondary reserves, the total tonnage of coal recoverable and available for the manufacture of synthetic liquid fuels in the 16 General Areas of Coal Availability in Kentucky was estimated to be 11,910,205,000 tons, all suitable for conversion by either hydrogenation or the coal synthine process.

The recoverable coal reserves in Kentucky are distributed by counties, in total and as contained within the 16 General Areas of Coal Availability, as follows:

Estimated Tonnage of Recoverable Coal Reserves
Considered for Synthetic Liquid Fuels Manufacture
as of January 1, 1949
(1,000 Tons)

County	Coal-bearing Counties (A)	In the 16 General Areas of Coal Availability (B)	
		Including All Secondary Reserves	Eliminating Excess Secondary Reserves
Eastern Kentucky			
Bell	228,544	221,622	221,622
Breathitt	107,687	21,796	21,796
Clay	49,719	-	-
Floyd	1,004,168	987,211	987,211
Johnson	189,621	189,621	189,621
Harlan	1,033,164	989,083	989,083
Knott	749,057	701,274	650,026
Knox	41,950	-	-
Leslie	362,033	340,286	340,286
Letcher	550,945	492,198	492,198
Magoffin	129,618	96,545	96,545
Martin	20,673	-	-
Perry	529,055	490,893	490,893
Pike	2,782,395	2,560,579	2,560,579
Total Eastern Kentucky	7,778,629	7,091,108	7,039,860
Western Kentucky			
Butler	12,862	-	-
Christian	23,232	23,232	23,232
Daviess	76,567	76,567	76,567
Henderson	498,271	480,074	459,866
Hopkins	1,377,784	1,377,784	1,377,784
McLean	137,620	113,737	113,737
Muhlenberg	957,832	925,739	925,739
Ohio	529,135	508,943	508,943
Union	599,491	599,491	599,491
Webster	834,671	794,247	784,986
Total Western Kentucky	5,047,465	4,899,814	4,870,345
State Total	12,826,094	11,990,922	11,910,205

Notes: (A) Before elimination of unsatisfactory areas.
(B) After elimination of unsatisfactory areas.

The following table lists for each of the 16 General Areas the recoverable coal reserves, the average heating value of the coal and the potential synthetic liquid fuels production in total and as a daily average over a 40-year period. These estimates are presented individually for both the hydrogenation and coal synthine process, but the potential production is not additive.

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Recoverable Coal Reserves and Equivalent Synthetic Liquid Fuels Potential by General Areas of Coal Availability and by Process, in Total and as a Daily Average Over 40 Years
(As of January 1, 1949)

General Areas of Coal Availability	Available Coal Reserves (1,000 Tons)	Average Btu per Pound (As Received)	Equivalent Potential: Total (1,000,000 Barrels)	Equivalent Potential: Average Daily Plant Capacity 40-year Period (1,000 Bbl)
Hydrogenation Process				
Johnson-Magoffin	212,552	13,730	596	41
Pike	2,560,579	14,090	7,363	504
Floyd-Magoffin	1,060,825	13,430	2,908	199
Knott-Breathitt	660,814	13,750	1,854	127
Perry-Breathitt	501,901	13,490	1,382	95
Leslie-Harlan	353,679	13,680	987	68
Northern Letcher	378,834	13,970	1,080	74
Harlan-Letcher	1,089,054	13,980	3,107	213
Bell	221,622	13,800	624	43
Daviess	76,567	10,790	169	12
Henderson	459,866	10,960	1,029	70
Union	599,491	12,340	1,510	103
Webster	784,986	12,400	1,986	136
Hopkins-Christian	1,401,016	11,990	3,428	235
Muhlenberg-McLean	1,039,476	12,120	2,571	176
Ohio	508,943	11,640	1,209	82
Total	11,910,205		31,803	2,178
Coal Synthine Process				
Johnson-Magoffin	212,552	13,730	463	32
Pike	2,560,579	14,090	5,727	392
Floyd-Magoffin	1,060,825	13,430	2,261	155
Knott-Breathitt	660,814	13,750	1,442	99
Perry-Breathitt	501,901	13,490	1,075	74
Leslie-Harlan	353,679	13,680	768	53
Northern Letcher	378,834	13,970	840	58
Harlan-Letcher	1,089,054	13,980	2,417	166
Bell	221,622	13,800	485	33
Daviess	76,567	10,790	131	9(A)
Henderson	459,866	10,960	800	55
Union	599,491	12,340	1,174	80
Webster	784,986	12,400	1,545	106
Hopkins-Christian	1,401,016	11,990	2,666	183
Muhlenberg-McLean	1,039,476	12,120	2,000	137
Ohio	508,943	11,640	940	64
Total	11,910,205		24,734	1,696

Note: (A) Recoverable Coal Reserves in the Daviess General Area are insufficient for a 40-year supply of one coal synthine unit plant.

Five of the sixteen General Areas of Coal Availability contain varying amounts of coal minable by stripping methods. Of the total capacities, reserves considered so minable could support, over a full 40-year period, a production capacity of 63,000 barrels per day using the hydrogenation process or 49,000 barrels per day using the coal synthine process. The remaining capacity previously reported could be supported by underground-mined reserves.

The coal reserves in the 16 General Areas of Coal Availability are in 7 principal beds and vary in rank from high-volatile A bituminous to high-volatile C bituminous. Btu content, as received, ranges from a minimum of 10,790 Btu per pound to a maximum of 14,290 Btu per pound.

The value of petrography in predicting hydrogenation yield lies in the fact that the degree of heterogeneity of lithologic components is readily indicated and the approximate proportions of anthraxylon and translucent attritus (easy to liquefy) as well as of high-carbon opaque constituents (difficult to liquefy) are revealed.

The U.S. Bureau of Mines has reported results of several petrographic assays on representative Kentucky coals indicating that the eastern Kentucky coals range from the "bright" petrographic type, wherein anthraxylon and translucent attritus predominate, with opaque attritus and fusain being present in minor amounts, to predominantly attrital types with moderately high percentages of opaque attritus indicating a composition approaching that of semisplint coal. The western Kentucky coals are largely of the "bright" petrographic type. Since most of the coals of the 16 General Areas are similar in rank, appearance, and chemical composition to the above coals for which petrographic analyses are available, there is no reason to expect any substantial differences in the degree of heterogeneity or adaptability to hydrogenation of Kentucky coals.

The Bureau of Mines publications contain relatively comprehensive information on the organic and inorganic sulfur content of representative Kentucky coals. Available information indicates that inorganic sulfur, which is considered amenable to reduction by mechanical cleaning, may range from 34 to 87 percent, averaging 66 percent of the total sulfur in eastern Kentucky coal
beds, and from 38 to 52 percent, averaging 43 percent of the total Ky
sulfur in western Kentucky coal beds. The complete removal of
pyritic (inorganic) sulfur by mechanical cleaning of the coal, if 11
possible, would result in decreasing the total sulfur content in 12
eastern Kentucky coals by approximately 34 percent. However,
further study of these coals is necessary to evaluate the reduction 7002
of total sulfur that might result from mechanical cleaning.

Representative chemical analyses of coals from the 16 General Areas show the following values for selected items:

Representative Analyses of Coal Reserves in the 16 General Areas (Mine Samples, As-received Basis)

General Area	Moisture (Percent)	Ash (Percent)	Sulfur (Percent)	Btu per Pound
Eastern Kentucky:				
Johnson-Magoffin	4.7%	3.0%	1.2%	13,730
Pike	3.1	4.3	1.0	14,090
Floyd-Magoffin	3.9	6.1	1.5	13,430
Knott-Breathitt	3.7	4.9	1.0	13,750
Perry-Breathitt	4.3	5.3	0.7	13,490
Leslie-Harlan	3.9	4.4	0.7	13,680
Northern Letcher	3.5	4.0	0.9	13,970
Harlan-Letcher	3.3	4.2	0.7	13,980
Bell	2.8	5.0	1.2	13,800
Western Kentucky:				
Daviess	12.1	11.7	3.0	10,790
Henderson	10.7	12.8	3.4	10,960
Union	5.9	10.0	3.7	12,340
Webster	6.1	9.3	3.3	12,400
Hopkins-Christian	8.5	8.7	3.2	11,990
Muhlenberg-McLean	7.9	8.6	3.7	12,120
Ohio	9.6	9.3	3.7	11,640

The bituminous coal reserves in Kentucky are similar to other coals of equal rank in weathering and slacking characteristics and present no particular storage problems. These coals usually slack readily but do not ignite spontaneously when exposed to air. Such coals present no particular storage problem. Kentucky coals are similar in grindability and friability to comparable industrial coals.

Most of the coal beds in eastern Kentucky contain thin partings of bone or shale ranging from less than 1/8 inch to as much as 6 inches in thickness. The principal beds of western Kentucky coals usually contain one or more bedded impurities or partings.
Ky These partings range from less than 1/4 inch to 3 inches or more in thickness.

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3a The greater Btu input requirements for coal synthine
10 plants result in larger quantities, and thus higher total costs,
0021 for the coal supply. Capital costs to provide coal mining facil-
ities in the 16 General Areas are shown below:

Tonnages of Coal Required and Initial Capital Cost of Coal Supply for 10,000-barrel-per-day Unit Plants
(As of March 31, 1950)

General Area	Underground Mining: Daily Production (Tons) (240 Days per Yr)	Underground Mining: Initial Capital Cost ($1,000's)	Strip Mining: Daily Production (Tons) (240 Days per Yr)	Strip Mining: Initial Capital Cost ($1,000's)
Hydrogenation				
Johnson-Magoffin	5,428	$7,818	-	-
Pike	5,289	6,345	-	-
Floyd-Magoffin	5,550	6,660	-	-
Knott-Breathitt	5,420	6,505	-	-
Perry-Breathitt	5,524	6,630	-	-
Leslie-Harlan	5,448	6,535	-	-
Northern Letcher	5,335	6,400	-	-
Harlan-Letcher	5,331	6,395	-	-
Bell	5,400	7,128	-	-
Daviess	6,906	7,457	6,906	$6,214
Henderson	6,800	7,344	-	-
Union	6,039	6,521	-	-
Webster	6,010	6,489	6,019	5,058
Hopkins-Christian	6,216	5,968	6,252	5,254
Muhlenberg-McLean	6,149	5,904	6,144	5,163
Ohio	6,363	6,872	6,468	5,044
Coal Synthine Process				
Johnson-Magoffin	6,978	$10,050	-	-
Pike	6,800	8,160	-	-
Floyd-Magoffin	7,134	8,560	-	-
Knott-Breathitt	6,968	8,360	-	-
Perry-Breathitt	7,102	8,525	-	-
Leslie-Harlan	7,003	8,405	-	-
Northern Letcher	6,859	8,230	-	-
Harlan-Letcher	6,853	8,225	-	-
Bell	6,943	9,163	-	-
Daviess (A)	8,880	9,590	8,880	7,991
Henderson	8,742	9,441	-	-
Union	7,764	8,384	-	-
Webster	7,727	8,348	7,740	6,500
Hopkins-Christian	7,990	7,672	8,038	6,752
Muhlenberg-McLean	7,905	7,588	7,899	6,636
Ohio	8,182	8,838	8,317	6,487

Note: (A) Coal reserves insufficient for one coal synthine unit plant.

Factors influencing capital costs include depth and character of the coal beds and associated strata, also the quantity and quality of the coal. The costs provide for all necessary mine structures and operating equipment, facilities for transporting the output from two or more adjacent mining operations to a joint preparation plant, as well as for mechanical cleaning to produce a merchantable coal, waste disposal, surge storage at the mine, engineering, development, and contingencies.

The estimated unit costs of coal per ton, per million Btu, and per barrel of synthetic liquid fuels are shown below for each General Area:

Estimated Coal Production Costs in Kentucky General Areas
To Supply 10,000-barrel-per-day Synthetic Liquid Fuels Plants
(As of March 31, 1950)

General Area	Btu per Pound	Dollars per Ton	Cents per Million Btu	Dollars per Barrel	
				Hydro-genation	Coal Synthine
Johnson-Magoffin	13,730	$5.11	18.61¢	$1.82	$2.34
Pike	14,090	4.76	16.89	1.66	2.13
Floyd-Magoffin	13,430	4.66	17.35	1.70	2.19
Knott-Breathitt	13,750	4.66	16.95	1.66	2.14
Perry-Breathitt	13,490	4.66	17.27	1.69	2.18
Leslie-Harlan	13,680	4.66	17.03	1.67	2.15
Northern Letcher	13,970	4.66	16.68	1.63	2.10
Harlan-Letcher	13,980	4.76	17.02	1.67	2.14
Bell	13,800	4.71	17.07	1.67	2.15
Daviess:					
Hydrogenation	10,790	3.76	17.42	1.71	
Coal Synthine	10,790	3.79	17.56		2.21
Henderson	10,960	4.16	18.98	1.86	2.39
Union	12,340	3.65	14.79	1.45	1.86
Webster:					
Hydrogenation	12,400	3.39	13.67	1.34	
Coal Synthine	12,400	3.44	13.87		1.75
Hopkins-Christian	11,920	2.81	11.79	1.16	1.49
Muhlenberg-McLean:					
Hydrogenation	12,130	2.81	11.58	1.13	
Coal Synthine	12,130	2.89	11.91		1.50
Ohio	11,520	2.79	12.11	1.19	1.53

The estimates of costs presented in this survey are based upon available information and on generalized present-day methods of mining and preparation.

General Areas of Coal and Water Availability

Investigation of potential sources of water for the large quantities required for synthetic liquid fuels processing shows that there is enough available water in the Ohio River and its tributaries to supply all of the plant capacity for which coal is available. Water required for full development would vary from 18 cubic feet per second (cfs), or 12 million gallons per day (mgd), in the Daviess General Area to 794 cfs, or 513 mgd in the Pike General Area. The total water required for complete development of the coal resources in all 16 General Areas would be 3,434 cfs or 2,219 mgd.

Water quantities and costs are based on the use of the synthine process, which requires the greater amount of water. Most of the process water is needed for cooling and, for the figures used, it is assumed that water would be recirculated through cooling towers.

Water for initial plants in eastern Kentucky could be supplied from the following tributaries of the Ohio River: Johns Creek, Mud Creek, and Caney Fork Reservoir. Another group of General Areas in the southeast could be supplied from sources such as Lotts Creek Reservoir, Middle Fork, Kentucky River Reservoir, and Cranks Creek Reservoir. In western Kentucky, the sources of water supply for initial unit plants would be the Ohio River, Green River, and the Lick Creek Reservoir.

Since each of the 16 General Areas has sufficient water
for at least one 10,000-barrel-per-day plant for 40 years, they are K
all designated as General Areas of Coal and Water Availability.

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Capital costs to supply water for process and domestic
purposes for a unit project in each General Area are shown in the 1
following table: 7002

Initial Capital Cost To Supply Process
and Domestic Water for One Unit Project
in Each General Area
(As of March 31, 1950)

General Area	Capital Costs: Process Water	Capital Costs: Domestic Water	Capital Costs: Total Cost
Johnson-Magoffin	$ 891,000	$ 369,000	$1,260,000
Pike	2,846,000	708,000	3,554,000
Floyd-Magoffin	3,170,000	766,000	3,936,000
Knott-Breathitt	6,750,000	1,387,000	8,137,000
Perry-Breathitt	3,957,000	902,000	4,859,000
Leslie-Harlan	4,175,000	939,000	5,114,000
Northern Letcher	5,754,000	1,214,000	6,968,000
Harlan-Letcher	4,619,000	1,017,000	5,636,000
Bell	4,246,000	952,000	5,198,000
Daviess	495,000	300,000	795,000
Henderson	721,000	340,000	1,061,000
Union	628,000	324,000	952,000
Webster	3,231,000	776,000	4,007,000
Hopkins-Christian	6,766,000	1,389,000	8,155,000
Muhlenberg-McLean	1,209,000	425,000	1,634,000
Ohio	898,000	370,000	1,268,000

These costs are based on an adequate water supply system consisting of storage reservoirs, pumping stations, power lines, aqueducts, and storage at plant sites.

The estimated operating costs, as of March 31, 1950, for process water supplies for unit plants range from a minimum of $0.017 per barrel of products in the Daviess General Area to a maximum of $0.083 per barrel of products in Northern Letcher General Area.

There is sufficient water in the nearby creeks and rivers to supply ultimate development of all coal resources by the use of these water supplies.

Suitability of General Areas

Power requirements for a hydrogenation unit plant amount
Ky to a total load of about 65,000 kw plus 3,000 kw for mine opera-
tion, of which 40,000 kw can be supplied either by purchased power,
16 or from a system integral with the plant proper. For the coal syn-
17a thine process, waste heat can supply the steam necessary to generate
15 the required power. The most economical source of power for hydro-
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genation plants in the 16 General Areas might be in steam generating stations built as integral parts of the plants where power could be generated at an average cost of about 6.64 mills per kilowatthour (100 percent load factor) without allowance for return on the investment or for income taxes. Existing utilities could supply some power for construction purposes in each of the General Areas. In the nine eastern General Areas of Kentucky, the West Virginia Power Company has an ample supply of available power at an unusually low rate per kilowatthour. In the seven General Areas of western Kentucky, the cost of utility power appears higher. Further detailed studies may show that hydroelectric power obtained from the Corps of Engineers' proposed hydroelectric developments could be delivered at a synthetic liquid fuels plant at a cost comparable with or lower than thermal generation at the plant.

Construction and operation of synthetic liquid fuels plants will in general require direct water or rail facilities and a highway connection. The very rough and mountainous eastern portion of Kentucky has made railroad transportation generally difficult. In spite of these problems of terrain, the greater part of eastern Kentucky is within reach of one or the other of the major railroad facilities crossing this region. The western part of the State lies in the Highland Rim Plateau, which generally slopes toward the Mississippi and is not as rugged as the eastern part of the State. This section is generally served by the Louisville & Nashville or the Illinois Central Railroad and, except for river crossings, railroad branches do not present important engineering problems.

It is estimated that no capital costs are required to provide access transportation in three General Areas in the southeastern portion of the State, namely, Northern Letcher, Harlan-Letcher and Bell General Areas. The maximum estimated capital investment for access transportation is $2,576,000 in the Leslie-Harlan General Area in southeastern Kentucky.

The average straight-time hourly wage rate, as of March 31, 1950, payable to wage earners (exclusive of supervisors) in synthetic liquid fuels plants in Kentucky is estimated at $1.64. In the coal counties of Kentucky, requirements of an average unit plant for total personnel could be satisfied by the numbers of unemployed in an area of about 17.5 miles radius in the eastern counties and about 20 miles radius in the western counties. Such conditions indicate an ample supply of labor to meet the requirements of an average unit plant as to total personnel in an area convenient to the plant. However, there are few workers in industries comparable with synthetic liquid fuels as to skills and training required in any of the coal counties of Kentucky and it is considered that the requirements of a synthetic liquid fuels plant would have to be met by inducing workers to relocate from areas beyond the immediate vicinity of the plant. Accordingly, two differentials have been allowed in developing the rate payable in synthetic liquid fuels plants: (a) 8 cents per hour as an inducement for sufficient workers to relocate in the vicinity of the plant to completely satisfy personnel requirements, and (b) 3 cents per hour for average premium pay for working second and third shifts.

The net initial investment required for rental housing and community development in the average General Area, exclusive of one-half of the residential property (assumed as sold) and exclusive of property used for commercial enterprises (assumed as self-supporting), is estimated, as of March 31, 1950, at $4,388,136 in eastern Kentucky and $6,201,267 in the west for a hydrogenation unit plant, and $4,165,384 in eastern Kentucky and $6,569,401 in the west for a coal synthine unit plant. It is assumed that rental housing will pay for operating and maintenance costs plus a return on the investment.

The potential marketing territory for synthetic liquid fuels plants in Kentucky is defined as including the entire market in the States of Kentucky, Virginia, West Virginia, North Carolina, South Carolina, Georgia, and Florida. Since the General Areas in eastern Kentucky are a part of a large region of coal and water availability located in southern West Virginia, western Virginia, and eastern Kentucky, it is assumed that the region would be developed as a whole to supply large quantities of synthetic liquid fuels to the markets in the South Atlantic States mentioned.

Motor fuel consumption in the marketing territory, excluding aviation and military uses, in 1948 amounted to 84.8 million barrels. This is equivalent to the gasoline output of 31 synthetic liquid fuels unit plants. It is estimated that by 1975 motor fuel requirements will reach an annual volume of 175.7 million barrels, the equivalent of the output of 64 synthetic liquid fuels unit plants.

While the major product of hydrogenation and coal synthine
Ky plants is motor gasoline, minor quantities of other fuels are specified to be produced, including Diesel fuel, heavy fuel oil, and
18b liquefied petroleum gases. The proportions of these fuels in re-
19a lation to gasoline are considerably different from the present de-
10 mand pattern in the marketing territory. There is, however, some
70021 leeway in the processes, particularly the hydrogenation process, for varying the proportions of the various products. Consequently, it would appear that any large-scale development in the future would require synthetic liquid fuels plants to be designed so as to produce the products then in demand.

There is some production of crude oil in Kentucky, but in most of the marketing territory, the demand for liquid fuels is economically supplied principally by petroleum products from refineries in Louisiana and Texas and to some extent from refineries near Baltimore and Philadelphia. Wholesale prices of petroleum products fob. refineries in Kentucky, as of June 1, 1950, amount to $4.21 per barrel when weighted in the same proportions as the liquid fuel products specified to be produced by hydrogenation plants and to $4.53 when weighted in the same proportions as for coal synthine plants. The estimates of future demand for liquid fuels in the marketing territory may be substantially reduced by a major increase in liquid fuel prices, altering the basic competitive positions of fuels. The prospective future supply of petroleum appears adequate to satisfy at least the major portion of future requirements for liquid fuels for a long period of years.

Synthetic liquid fuels plants situated in Kentucky would be well located for the distribution of products. A single unit plant in any one of the General Areas probably could market its output within reasonable trucking distance of the plant. If a substantial part of the requirements for motor fuel in the entire marketing territory were to be supplied by synthetic liquid fuels plants situated in the General Areas in eastern Kentucky, southern West Virginia, and western Virginia, economical transportation of products throughout the marketing territory could be obtained by the construction of a large-capacity pipe line extending to the Atlantic seaboard and connecting with the petroleum products pipe lines now serving the marketing territory.

The operation of synthetic liquid fuels plants and of the coal mines to supply them with raw material involves the production of wastes, for the disposal of which provision has been made. Liquid wastes may require skimming and sedimentation and, in some cases chemical treatment, before return to the streams; solid wastes (principally ash from the plant and refuse from coal cleaning at the mine) must be transported to the disposal areas and there piled up or compacted.

From a strategic standpoint, all 16 General Areas appear favorably located, especially due to the absence of nearby large cities. It is believed that the development of all General Areas could be planned to conform to all strategic considerations outlined in publications of the National Security Resources Board.

Comparison of Suitable General Areas

All of the foregoing economic features are reflected in the total capital costs and operating costs for synthetic liquid fuels plants in Kentucky. Both cost estimates utilized the Bureau of Mines method for estimating typical unit plant costs as adjusted to existing conditions in the 16 General Areas.

Initial capital costs for hydrogenation unit projects, as shown in Exhibit No. 85, range from a maximum of $118,561,000 in the Knott-Breathitt General Area to a minimum of $111,669,000 in the Ohio General Area. Similar capital costs for coal synthine unit projects, shown on Exhibit No. 86, range from a maximum of $110,278,000 in the Knott-Breathitt General Area to a minimum of $103,609,000 in the Ohio General Area. These estimates, as of March 31, 1950, provide for adequate coal and water supply, plant facilities, and access transportation, and include capital amounts for housing. In addition, there is provision for adequate waste disposal. Coal production costs include provision for cost of disposal of waste from mining operations and coal cleaning to provide a merchantable coal.

The estimated costs of synthetic liquid fuels and the potential plant capacities which can be provided by the available recoverable coal reserves over a 40-year period of time in all 16 Suitable General Areas in Kentucky are shown in a table which follows:

Order of Relative Desirability of
Suitable General Areas in Kentucky
(As of March 31, 1950)

Suitable General Area	Unit Plants 10,000-barrel-per-day	Cost per Barrel of Products of Initial Plant (A)
Hydrogenation		
Muhlenberg-McLean	17.6	$5.189
Ohio	8.2	5.238
Hopkins-Christian	23.5	5.265
Webster	13.6	5.412
Union	10.3	5.497
Northern Letcher	7.4	5.736
Pike	50.4	5.744
Harlan-Letcher	21.3	5.747
Bell	4.3	5.752
Perry-Breathitt	9.5	5.765
Floyd-Magoffin	19.9	5.767
Daviess	1.2	5.770
Leslie-Harlan	6.8	5.774
Knott-Breathitt	12.7	5.776
Johnson-Magoffin	4.1	5.862
Henderson	7.0	5.915
Coal Synthine		
Muhlenberg-McLean	13.7	$5.243
Ohio	6.4	5.267
Hopkins-Christian	18.3	5.283
Webster	10.6	5.508
Union	8.0	5.599
Northern Letcher	5.8	5.885
Pike	39.2	5.898
Harlan-Letcher	16.6	5.906
Bell	3.3	5.913
Knott-Breathitt	9.9	5.933
Perry-Breathitt	7.4	5.933
Leslie-Harlan	5.3	5.934
Floyd-Magoffin	15.5	5.938
Daviess (B)	0.9	5.968
Johnson-Magoffin	3.2	6.065
Henderson	5.5	6.139

Note: (A) Using strippable coal to the full extent available; exclusive of return on investment.
(B) Coal reserves insufficient for the support for 40 years of one coal synthine unit plant.

The costs per barrel of products for one unit plant in each Area (from Exhibit No. 85 for the hydrogenation process and Exhibit No. 86 for the coal synthine process) assume use of strippable coal to the full extent available in Daviess, Webster, Hopkins-Christian, Muhlenberg-McLean, and Ohio General Areas. The operation of more than one unit plant in these Areas or continuation in operation of initial plants beyond the 40-year period would necessitate use of more expensive underground-mined coals at correspondingly increased capital and operating costs.

When less costly coal is depleted, the costs per barrel of products, as of March 31, 1950, in the five Suitable General Areas which initially contain some strippable coal, are estimated to be:

Cost of Products Using Underground-mined Coal
(As of March 31, 1950)

Suitable General Area	Cost per Barrel of Products: Hydrogenation	Cost per Barrel of Products: Coal Synthine
Daviess	$5.828	(A)
Webster	5.513	$5.614
Hopkins-Christian	5.667	5.800
Muhlenberg-McLean	5.594	5.722
Ohio	5.721	5.888

Note: (A) Insufficient coal reserves in Daviess General Area to warrant consideration of more than one unit plant for 40 years.

Operating costs for a hydrogenation unit plant (excluding return on investment) range from a maximum of $5.915 per barrel (14.08 cents per gallon) in the Henderson General Area to a minimum of $5.189 per barrel (12.35 cents per gallon) in the Muhlenberg-McLean General Area. For synthine unit plants, similar figures range from a maximum of $6.139 per barrel (14.62 cents per gallon) in the Henderson General Area to a minimum of $5.243 per barrel (12.48 cents per gallon) in the Muhlenberg-McLean General Area. Costs as stated herein, as directed by the Contracting Officer, are based on operating costs of the process rather than a "cost of service" or selling price basis. Such costs are based on the Bureau of Mines formula and include a basic allowance for plant maintenance of approximately 3 percent of plant investment. They also include an allowance equal to 10 percent of direct labor, plant maintenance and operating supplies for general administration and general office overhead (which includes the salaries and wages of a General Manager or a Plant Manager and his immediate staff reporting directly to management); 6-2/3 percent of plant investment for depreciation; and 1 percent of plant investment for insurance and local, county, and State real estate taxes; but they include no allowance for head office or top management costs, selling expenses, return on investment, or sales and corporate (including income) taxes. Costs of coal used in the process have been computed without including selling cost or return on investment. The cost of water has been estimated on the same basis. Return on total initial capital investment, including coal and water as indicated herein, would require on an average about 29.3 cents for the coal synthine process and 31.5 cents for hydrogenation per barrel of products for each 1 percent gross return before the deduction of income taxes.

The costs herein are reported as per barrel of total products. Estimates of the equivalent costs of gasoline and credits for sale of by-products were not considered necessary for the determination of the most desirable General Areas. Because the product grades and quantities are different for each process, the raw material and process selected in each General Area would be the one whose products most satisfactorily meet the particular market demand. Therefore, comparison of General Areas has been made separately for each process.

Synthetic Liquid Fuels Potential of Suitable General Areas

The potential synthetic liquid fuels capacity of the Suitable General Areas in Kentucky, in total and as a daily average over a 40-year period of time, would be: Ky

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Synthetic Liquid Fuels Potential in the
Suitable General Areas in Kentucky in Total
and as a Daily Average over 40 Years,
Using Coal as Raw Material
in 1,000 Barrels
(As of January 1, 1949)

Suitable General Area	Total Potential		Equivalent Average Daily Plant Capacity for 40-Year Period	
	Hydro-genation	Coal Synthine	Hydrogenation	Coal Synthine
Johnson-Magoffin	596,000	463,000	41	32
Pike	7,363,000	5,727,000	504	392
Floyd-Magoffin	2,908,000	2,261,000	199	155
Knott-Breathitt	1,854,000	1,442,000	127	99
Perry-Breathitt	1,382,000	1,075,000	95	74
Leslie-Harlan	987,000	768,000	68	53
Northern Letcher	1,080,000	840,000	74	58
Harlan Letcher	3,107,000	2,417,000	213	166
Bell	624,000	485,000	43	33
Daviess	169,000	131,000	12	9(A)
Henderson	1,029,000	800,000	70	55
Union	1,510,000	1,174,000	103	80
Webster	1,986,000	1,545,000	136	106
Hopkins-Christian	3,428,000	2,666,000	235	183
Muhlenberg-McLean	2,571,000	2,000,000	176	137
Ohio	1,209,000	940,000	82	64
Total	31,803,000	24,734,000	2,178	1,696

Note: (A) Coal reserves in the Daviess General Area are insufficient for a 40-year supply of one coal synthine unit plant.

Bituminous coals are the only raw materials available in Kentucky for the manufacture of synthetic liquid fuels. Although deposits of oil-impregnated strippable deposits exist in quantity and quality meeting the survey requirements, unavailability of plant requirement data and of specific processing specifications preclude establishment of Suitable General Areas for the production of synthetic liquid fuels from oil-impregnated strippable deposits.

PART I - INTRODUCTION

INTRODUCTION

Authorization

At the request of the Secretary of the Interior, the Department of the Army directed the Corps of Engineers to make a survey of the United States and Alaska to determine areas suitable for synthetic liquid fuels manufacture. In order to accomplish this survey, a contract (W 49-129 eng-137) was made between the United States of America and Ford, Bacon & Davis, Inc., (sometimes hereinafter referred to as the Contractor). This investigation and report have been made as a part of that required by the contract. By approval of the Corps of Engineers, Department of the Army, portions of the contract obligations were subcontracted to other firms engaged as experts in their particular fields of operation, as follows:

Subcontract No. 1 to Paul Weir Company, Inc., Chicago, Ill., for coal investigations.

Subcontract No. 2 to DeGolyer and MacNaughton (a corporation), Dallas, Texas, for natural gas investigations.

Subcontract No. 3 to DeGolyer and MacNaughton (a corporation), Dallas, Texas, for oil shale investigations.

Subcontract No. 4 to Malcolm Pirnie Engineers (a partnership), New York City, for water supply investigations.

Subcontract No. 5 to Max W. Ball (an individual), Washington, D.C., for investigations of oil-impregnated strippable deposits.

Purpose

This study was undertaken to determine the potential synthetic liquid fuels production capacity of the State of Kentucky. To make such a determination, three categories of study are usually required; in order, they are:

1. Investigate the reserves of coal, natural gas, oil shale, and oil-impregnated strippable deposits available for the manufacture of synthetic liquid fuels.

2. Select General Areas of Raw Material and Water Availability.

3. Determine the suitability of each General Area so selected for the production of synthetic liquid fuels.

Scope of Survey

In the selection of General Areas suitable for the location of synthetic liquid fuels plants, where all plant requirements can be met, the survey does not select or establish specific sites for the construction of a plant. The studies are based primarily on available information and data obtained from various authoritative sources. No detailed field surveys were carried out, but a brief reconnaissance was made of a number of the General Areas.

The raw materials considered in this survey are:

(a) Coal
(b) Natural gas
(c) Oil shale
(d) Oil-impregnated strippable deposits (Limited to the determination of raw material reserves).

Because of the known deposits of coal in Kentucky and their economic importance, a complete detailed survey for that raw material was authorized by the Corps of Engineers. This comprised, in addition to the determination of available coal reserves, a determination of water availability and a critical examination of the suitability of other conditions affecting plant location for the manufacture of synthetic liquid fuels.

The report authorized on oil-impregnated strippable deposits is confined to determination of the nature and extent of available deposits; no consideration is given to other factors influencing plant location for the production of synthetic liquid fuels nor to processing facilities or costs.

As available information indicated that deposits of
natural gas and oil shale do not exist in Kentucky in sufficient Ky
quantities to constitute reserves, as defined herein, for the
production of synthetic liquid fuels (although of possible 27b
economic importance), the Corps of Engineers directed that the 28a
investigation in respect of those materials be limited to a 3
general determination of the nature and extent of such deposits 70021

and their suitability or unsuitability for the manufacture of synthetic liquid fuels. The scope of the required report, as well as the conclusions contained in this report that available information indicated insufficient deposits of these materials to constitute reserves for the manufacture of synthetic liquid fuels, obviate the necessity for making an investigation in respect of these materials as to General Areas suitable for the location of synthetic liquid fuels plants.

To facilitate further study, those coal reserves found to be of satisfactory quality and quantity were grouped into areas not larger than a county or 1,000 square miles. Where such areas contained reserves adequate for 40 years' operation of at least one 10,000-barrel-per-day synthetic liquid fuels plant, they were designated as General Areas of Coal Availability. Those areas found also to have adequate supply of water for at least one 10,000-barrel-per-day plant were designated as General Areas of Coal and Water Availability.

General Areas of Coal and Water Availability were then critically examined with reference to the following factors to determine their suitability for the production of synthetic liquid fuels.

1. Raw materials
2. Water supply
3. Power
4. Access transportation
5. Labor
6. Housing
7. Marketing and products transportation
8. Waste disposal
9. Plant investment
10. Processing costs
11. Strategic considerations.

The total comparative costs per barrel of products determined from a study of the several factors listed above, together with consideration of other factors incapable of evaluation in dollars and cents, made possible the listing of the several Suitable General Areas in their order of desirability, considering separately each applicable manufacturing process.

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PART II - GENERAL

GENERAL

The terminology used in this report is that in general use and acceptance. Such terms, together with those idiomatic to this survey, are defined in the following paragraphs:

Definition of General Terms

General terms used in this report are defined as follows:

A General Area as used herein is not larger than a county or 1,000 square miles, depending on local conditions. General Areas are used to facilitate the detailed study of parts of the state and are designated by name.

A General Area of Coal Availability is one where adequate coal reserves are available for 40 years' operation of at least one 10,000-barrel-per-day synthetic liquid fuels plant, in conformity with raw material requirements for such plants.

A General Area of Coal and Water Availability is one where both adequate coal reserves and water supply are available for 40 years' operation of at least one 10,000-barrel-per-day synthetic liquid fuels plant, in conformity with raw material and water requirements.

A Suitable General Area is one which meets all requirements for 40 years' operation of at least one 10,000-barrel-per-day synthetic liquid fuels plant using coal in conformity with plant requirements as to raw materials, water supply, power, transportation, labor, housing, marketing, transportation of plant products, waste disposal, and strategic considerations.

A Unit Plant is the amount of production capacity adopted in the survey for purposes of comparison and for estimation of investment, operating costs, etc. It is not necessarily the most efficient size for an independent plant. The sizes adopted in the survey as unit plants are:

Sizes of Unit Plants

Process	Barrels per Day
Hydrogenation of coal	10,000
Synthine process using coal	10,000

Definition of Coal

Bituminous Coal - Coal having less than 86 percent fixed carbon (dry, mineral-matter-free basis) and, if fixed carbon is less than 69 percent, having a heating value of 11,000 or more Btu (moist, mineral-matter-free basis) and either agglomerating or nonweathering.

Types of Coal Mining and Related Terms

Strip Mining - The method of first removing the overburden so as to expose the coal seam, usually by power shovels or drag lines, and then "loading" the coal.

Underground Mining - The method of coal extraction through underground operations, usually by driving a tunnel or drift, or by sinking a slope or shaft.

Overburden - In strip operations, the soil or surface material, or the geological formation, overlying the coal seam.

Stripping Ratio - The ratio between the thickness of the overburden and the thickness of the underlying coal seam.

Overburden Ratio - The ratio between the cubic yards of overburden and the tons of recoverable coal.

Geological Terms

Geological terms in common use include the following:

Horizon (Geological) - Strata formed at the same geological time at different locations.

Stratigraphic Section - A vertical cross section showing the relative position and thickness of geological formations in a particular area.

Coal Bed or Seam - A well-marked or homogeneous division of a stratified series, characterized by a more or less well-defined divisional plane from its neighbors above and below.

Dip - The angle which the plane of a bed makes with the horizontal plane.

Outcrop - The occurrence of any geologic strata of rock or coal at or immediately below the surface of the ground.

Parting - Extraneous material in a coal seam, in a relatively thin layer, separating parts of the seam. When parallel to the plane of the coal, partings usually consist of sedimentary material, such as clay, shale, or sandstone. Partings which cross the plane of the coal seam commonly may contain calcite, kaolinite, or pyrite.

Bench - A stratum of coal forming part of the seam.

Bone (or Bony Coal) - Slaty coal or carbonaceous shale found in coal seams.

Terms Relating to Classification and Analysis of Coal

Among the terms in general use relating to analysis, classification, and mining of coal are the following:

Raw Coal - Coal as it comes out of the mine, not having been subjected to cleaning or any other preparation.

Merchantable Coal - Processed or cleaned coal of a quality acceptable for commercial use, and generally equivalent (or in some cases superior) in analysis to that of a channel sample, i.e., secured from coal in place. (See definition of mine sample, face sample, etc.)

Recoverable Coal - That portion of the total estimated coal in place that can be delivered as merchantable coal, after being mined and (where necessary) washed or otherwise cleaned, primarily to remove ash.

Proximate Analysis - An analysis made of coal for the determination of moisture, volatile matter, fixed carbon, and ash.

Ultimate Analysis - An analysis made of coal for the determination of constituent elements, as sulfur, hydrogen, carbon, nitrogen, oxygen (by difference) and ash.

As Received - The condition representing the sample as received at the laboratory which for mine samples approximates closely the condition of the coal in the mine.

Moisture-free - A condition, actual or assumed, permitting the determination or calculation of the analysis of a coal sample excluding its moisture content.

Moisture- and ash-free (Maf) - An assumed condition permitting calculation of the analysis of a coal sample excluding its moisture content and its ash content.

Rank - The stage of coalification in a series in which bituminous coal is subdivided, in order of decreasing completeness, as follows:

Rank of Coal

Class	Group	Abbreviation
Bituminous	Low-volatile bituminous	Lvb
	Medium-volatile bituminous	Mvb
	High-volatile A bituminous	Hvab
	High-volatile B bituminous	Hvbb
	High-volatile C bituminous	Hvcb

Btu (British Thermal Unit) - Quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit. Btu determination of coal may be made or reported on one or more bases, as:

(1) As-received
(2) Moisture-free (i.e. dry)
(3) Moisture- and ash-free (Maf)

Heating Value - Heat (gross) resulting from combustion of one pound of coal, expressed as Btu per pound with specification of sample condition, as "as received", "moist, mineral-matter-free", "moisture- and ash-free" or "dry".

Mine Sample, Face Sample, or Channel Sample - A sample secured from coal in place in the ground in accordance with procedure specified by the U. S. Bureau of Mines, which requires that such sample be obtained by collecting material in a uniform channel extending from roof to floor of bed, except that partings of shale, bone, and pyrite 3/8 inch or thicker and lenses or concretions of pyrite or other impurities, more than 2 inches in maximum diameter or 1/2 inch in thickness, are excluded. Such analyses are representative of merchantable coals obtainable from a mine. Ky

"Tipple" Samples - Samples collected in accordance with the Bureau of Mines procedure after the coal has received final treatment at the tipple or cleaning plant, or as it is loaded into railroad cars or trucks.

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Delivered Samples - Samples taken in accordance with the Bureau of Mines procedure from coal delivered for use as unloaded from railroad cars or trucks.

Inorganic Sulfur - That portion of the total sulfur content (in coal) which exists in the form of sulfides and sulfates, the former commonly being iron pyrites, marcasite, chalcopyrite, arsenopyrite, and stibnite, with calcium sulfate (gypsum) the more usual sulfate.

Organic Sulfur - That portion of the total sulfur content other than the mineral sulfides and sulfates, which is combined in organic compounds.

Hydrogenation Yield - The relative quantity of liquid hydrocarbon products obtained by hydrogenation of a unit quantity of a particular coal.

Washability of Coal - The extent to which extraneous objectionable impurities (such as mineral matter, bone, and/or inorganic sulfur) can be reduced by treatment in commercial coal cleaning plants with due consideration to the loss of coal which accompanies such treatment and the size limits of the coal before and after treatment.

Survey Specifications as to Minimum Requirements for Coal

The minimum requirements for bituminous coal deposits considered in this survey are as follows:

1. Thickness

   A. For coal to be mined by underground methods - At least 24 inches.
   B. For strip-mined coal - Minimum thickness 12 inches.

2. Depth

   A. Underground-mined Coal - Not more than 1,500 feet below drainage level.

   B. Strip-mined Coal - Not more than 200 feet of overburden.
      (1) Stripping Ratio (for coal mined by stripping) - Not more than 40 to 1 up to 75 feet of overburden, and 8 to 1 for overburden in excess of 75 feet.

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The classification of coal deposits as "strippable" shall be governed by the experience and good judgment of the coal subcontractor as to the economy of that operation.

3. Minimum Recoverable Tonnage (in an area of 3 miles radius) - 30,000,000 tons for underground mining or 5,000,000 tons for stripping.

Survey Classification of Coal Reserves

Coal reserves have been classified into three groups, and the tonnages of each have been computed, on the basis of the following definitions:

Measured Coal - Coal for which tonnage is computed from dimensions revealed in outcrops, trenches, mine workings, and drill holes, with the points of observation, in general, on the order of 1/2 mile apart.

Indicated Coal - Coal for which tonnage is computed partly from specific measurements, and partly from projection of visible data for a reasonable distance on geologic evidence; the points of observation, in general, are of the order of 1 mile apart but may be as much as 1-1/2 miles for beds of known geologic continuity.

Inferred Coal - Coal for which quantitative estimates are based largely on broad knowledge of the geologic character of the bed or region, and for which there are few, if any, measurements. The estimates are based on an assumed continuity, for which there is geologic evidence. Where there are only outcrop data on which to base estimates, such inferred coal is that lying more than 2 miles in from the outcrop and within limited areas (established as described by Paul Averitt, of the U.S. Geological Survey, in a paper published in the magazine "Mining Engineering" of June 1949).

Classification of Coal Reserves in Respect of Plant Requirements

Available Coal Reserves - The amount of estimated recoverable coal remaining after deduction of estimated commercial and industrial requirements. Available coal reserves include primary and secondary reserves.

The classification of bituminous coal reserves as primary or secondary is based upon thickness of seam and class of reserve as measured, indicated, or inferred. Thus, primary reserves for underground mining include only beds 28 inches or more in thickness which are classed as either measured or indicated. The complete classification is as follows:

Primary Reserves ("Measured" and "Indicated" only)

a. Underground - At least 28 inches in thickness.

b. Strip - Minimum thickness of 12 inches. Not more than an average depth of 75 feet of overburden; stripping ratio not to exceed 15 to 1.

Secondary Reserves ("Measured", "Indicated", and "Inferred" not included in Primary Reserves)

a. Underground - At least 24 inches in thickness.

b. Strip - Minimum thickness of 12 inches. Not more than an average depth of 200 feet of overburden; stripping ratio not to exceed 40 to 1 up to 75 feet of overburden and 8 to 1 for overburden in excess of 75 feet.

Definitions of Oil-impregnated Strippable Deposits

Oil-impregnated Strippable Deposits. - Deposits of sedimentary rocks impregnated or intimately intermixed with mineral oils, asphalts, or other liquid or solid hydrocarbons soluble in organic solvents. Such rocks are commonly known as oil sands, tar sands, bituminous sands, or rock asphalt. As used herein, the term also includes deposits of pure hydrocarbon such as gilsonite, occurring in sedimentary rocks.

Reserves (Minimum Requirements) - Oil-impregnated strippable deposits are not considered reserves for the purpose of this report unless they contain at least 10,000,000 tons in an area of not more than 5 square miles, occur in a vertically continuous series of beds not less than 15 feet thick, are amenable to opencut mining by removing a cover not thicker than the beds themselves, and have an oil content of at least 10 gallons per ton.

Primary Reserves - Deposits meeting the minimum requirements
Ky and with an average yield of not less than 25 gallons per ton.

Secondary Reserves - Deposits, in addition to those in primary reserves, meeting minimum requirements and with an average yield of
36b not less than 15 gallons per ton.

37a

3 Tertiary Reserves - Deposits, in addition to those in primary
70021 and secondary reserves, meeting minimum requirements and with an average yield of not less than 10 gallons per ton.

A General Area of Oil-impregnated Strippable Deposits - An area in which adequate deposits are available to meet the minimum reserve requirements as a potential supply for synthetic liquid fuels manufacture.

Terms Relating to Water Supply

Surface Water - Water in a natural open channel or a natural lake.

Ground Water - Water existing below the surface of the ground in a porous material. It may be either stationary or moving.

Firm Water - A quantity of water that is available for use at all times - year in and year out.

Acre-Foot (AF) - A quantity of water necessary to cover an area of one acre with water one foot deep.

Collection of Data

In the course of the investigation, all available data pertaining to Kentucky were obtained from various sources, especially the U. S. Geological Survey, U. S. Bureau of Mines, the Federal Power Commission, and various Kentucky State agencies and private organizations. In addition, certain unpublished and classified reports were made available for study. Considerable supplementary data were obtained in the course of interviews and correspondence with individuals in industry, colleges, chambers of commerce, and State agencies.

Much of the published coal data was obtained from U. S. Bureau of Mines bulletins and technical papers and from reports and maps published by both State and Federal organizations. Information of value was secured from railroad companies serving the coal-bearing parts of the State, as well as from local chambers of commerce and individuals.

Basic water supply data were obtained from publications of the Tennessee Valley Authority and from papers of the U. S. Geological Survey as well as from files of the Corps of Engineers, particularly relating to water storage. The Kentucky Water Pollution Control Commission and related agencies were consulted in matters pertaining to water pollution.

Data on natural gas were secured from published material and from files of the Subcontractor, from public records of the Federal Power Commission, and from geologists and natural gas companies operating in Kentucky.

A brief reconnaissance was made of the selected General Areas of Coal and Water Availability.

PROCESSES AND PLANT REQUIREMENTS

Processes Considered for Kentucky

The term "synthetic liquid fuels" as used in this report is applied to liquid fuels made by the hydrogenation or synthine processes using high-volatile bituminous coal as a raw material.

Unit Plant

As a basis for estimates for purposes of comparison in this survey, a unit plant (unit of plant capacity or unit capacity) has been adopted which is not necessarily the most efficient size for an independent plant. The production capacity to be understood for both the hydrogenation and coal synthine processes, when the term "unit plant" is used, is 10,000 barrels per calendar day.

Basis of Estimates

The prime purpose of the estimates of construction and manufacturing cost presented in this report is for use in determining the relative desirability of individual Areas as potential locations for synthetic liquid fuels plants. Since it is probable that some years would be required to construct any significant number of plants of this magnitude, it was decided for comparative purposes to base estimates of plant requirements and plant and product costs upon the assumed use of certain improvements in process (including the direct pressure gasification of coal) which are still under development here or abroad but which appear reasonably likely to be applicable by the time any synthetic liquid fuels program could be well under way. If synthetic liquid fuels plants were constructed today, basic requirements and costs might be appreciably higher than estimates given, due to the necessity for the use of equipment and processes now commercially available. In drawing other than relative conclusions from these estimates, therefore, this qualification must be clearly recognized.

Detailed data as to plant requirements, products, and process wastes, for typical plants operating on both the hydrogenation and synthine processes, as furnished for use in this report, are shown in Exhibit No. 1.

Hydrogenation Process

History. Hydrogenation of coal to yield synthetic liquid fuels was the original concept of Franz Bergius, for which German Patent No. 301,231 was granted in 1913. The process, after intensive development and modification, was used to produce about 85 percent of German aviation gasoline in World War II. Germany then had available a total daily nominal liquid fuels producing capacity of about 90,000 barrels in 12 plants.

In the United States, hydrogenation of coal has been studied intensively by the Bureau of Mines at Bruceton, Pa., and at Louisiana, Mo. At the latter location a hydrogenation plant has been erected and operated experimentally and for demonstration purposes with a capacity of about 200 barrels per stream day. Commercially, hydrogenation has been limited in the United States to the occasional upgrading of various petroleum fractions in four or five separate commercial units.

Nature of Process. The conversion of coal into liquid fuels by hydrogenation consists of combining hydrogen with the coal substance at elevated temperatures (about 700 to 900 deg F) and pressures (ranging from 3,000 to 10,000 psi) in the presence of catalysts. The process is extremely flexible with respect to the nature and proportions of products. As an example, by varying plant equipment, operating conditions, nature of catalyst, and/or plant design, gasoline output may be varied from less than 20 to over 90 percent, or fuel oils from zero to about 80 percent.

In condensed summary, the hydrogenation of coal consists in preparation of the raw material by careful washing, drying, and grinding and formation of a paste by mixing part of the heavy oils from the first stage of hydrogenation with the prepared coal and a suitable solid catalyst. This paste, under high temperature and pressure, reacts with hydrogen in the first or liquid phase hydrogenation. Phenols may be separated from the products at this point or may be carried on with the rest of the products to the second or vapor phase hydrogenation. This step consists in passing a gaseous mixture of hydrogen and the vaporized products from the first stage through beds of appropriate granular solid catalysts. The output of the second stage of hydrogenation is separated ~~into~~ the various final products, mainly by distillation employing equipment and methods not varying greatly from those commonly used in the petroleum industry.

Hydrogen for the first stage (liquid phase) and second stage (vapor phase) hydrogenation is obtained in part from water gas produced by reaction between steam, oxygen, and coal and in part by cracking with steam the light hydrocarbon gases which are by-products of the main hydrogenation. Provision is also made for recovery and reuse of the portion of hydrogen not consumed in the reaction vessels. Pressure operation of coal gasification and hydrocarbon cracking equipment is assumed.

Cooling water is injected into the hot gas streams leaving the hydrogenation converters. This water, together with additional water formed in the reaction, condenses out and is separated from the product oil streams before distillation, carrying with it some dissolved hydrogen sulfide and phenols and constituting the major contaminated liquid process waste. Ky

The appended block flow diagram, Exhibit No. 2, indicates a typical arrangement for such a plant, consistent with the above description and with the specific unit plant design for which estimated construction and operating costs are given in this report. It should be remembered, however, that the principle of hydrogenation is extremely flexible in application, and that variations in methods of hydrogen production, ash elimination, product processing, and number and balance of hydrogenation steps may be used in individual plants designed to meet different local conditions.

Plant Requirements. The principal materials required for the hydrogenation process are coal and water. Other materials include catalysts used in hydrogenation and hydrogen production and chemicals used in gas scrubbing. Remaining other materials are relatively insignificant in both value and volume.

Coal. Coal is used in the hydrogenation process for conversion to liquid fuels, for the manufacture of hydrogen and fuel gas, and as fuel, both for steam power generation and in certain direct-fired operations. That portion of the coal to be hydrogenated to liquid fuels should be of good quality; the balance may be of inferior grade. Roughly one-half of the total coal used in the plant is converted into liquid fuels, the other half being consumed to supply energy and hydrogen for the process. A unit plant of 10,000 barrels daily capacity would require daily about 3,800 tons of Kentucky coals, the exact amount dependent upon the heating value.

Coals readily washed to low-ash content are preferable to less easily washed coals of the same type.

Coal is a complex and variable material. Actual trial of an adequate sample in a pilot plant is the only sure criterion of the practicality and ease of hydrogenation. The following properties of coal are, however, indicative of its amenability to the process:

1. The following factors should be high -

   (a) Net hydrogen content
   Hydrogen in excess of that theoretically required to combine with all oxygen, nitrogen, and sulfur of the coal.

   (b) Volatile matter
   Not less than 31 percent (maf).

   (c) Tar and bitumen yields on carbonization.

   (d) Iron and chlorine
   Of the inorganic constituents of coal, iron and chlorine usually affect the catalysts favorably.

2. The following factors should be low -

(a) Fixed carbon content
Not over 69 percent (maf).

(b) Oxygen
Oxygen of the coal appears in part in the form of phenols, the balance combining with hydrogen to form water and with carbon to form oxides. Phenols may be converted in the second stage hydrogenation to hydrocarbons and additional water.

(c) Ash
Low-ash content is desirable as reducing both the total amount of coal to be handled, and loss of oil (carried out of the system with rejected ash). Ash content should be minimized by washing. Fusion point of the ash is not of major importance. Maximum permissible ash content (dry basis) is 15 percent for process coal and 20 percent for other uses.

(d) Calcium and alkali
These constituents may cause operating difficulties by their effect on the catalysts.

(e) Fusain and opaque attritus
These constituents of coal (determined by petrographic analysis) are difficult to convert but may be in part hydrogenated to liquid fuels. Fusain is normally largely removable by proper preparation.

(f) Nitrogen
Largely converted to ammonia by hydrogenation.

(g) Sulfur
Largely converted to hydrogen sulfide and other sulfur compounds.

Water. The hydrogenation of coal and the production of the energy required by the process developed large amounts of heat which must be removed. The availability of an adequate supply of cooling water is therefore of great importance. Although more
than 120 mgd must pass through a unit plant with a 33 deg F rise in Ky
temperature, the total water requirements can be reduced to 7.3 mgd
by recirculation through cooling towers. Two-thirds of the make-up 41
water is lost by evaporation when recirculation is used. The bal- 4
ance is returned to the source as wastes from coal preparation, as
blowdown from cooling towers and boilers, and as sewage. 70021

Power. The hydrogenation of coal requires installed generating capacity to supply 68,000 kw at 100 percent load factor for the operation of a unit plant which includes an allowance of 3,000 kw for mine operation. Of the total, approximately 25,000 kw can be supplied in connection with the production of process steam. Purchase of the excess prime power requirements of about 40,000 kw from outside sources could decrease the total coal requirement of the process by approximately 12 percent, water requirement by about 17 percent, and would also effect reductions in manpower requirements and in investment in power generating facilities. However, the magnitude of the installation required for handling process coal alone, together with the desirability of an outlet for the higher-ash fractions of the washed coal, would usually make purchase of outside power disadvantageous. Outside power sources are desirable as stand-by capacity. The possible mutual advantage of integrating the electric generation of the plant into an existing power network should be considered.

Personnel. Plant operating personnel must be high-grade semitechnical labor as in the chemical and petroleum refining industries. Highly qualified machinists and mechanics are required for the effective and safe maintenance of high-pressure equipment. Indirect labor includes such classifications as material handlers, stock clerks, guards, watchmen, and janitors. Technical workers will require a certain amount of training in specialized plant operations and maintenance. The Bureau of Mines has estimated that 80 percent of the manpower required for a hydrogenation plant can be trained in the plant, and would require no specialized skill prior to employment.

The number of employes of a unit plant, including labor and supervision, will vary slightly according to the proportion of the total output represented by the various final products but may be stated for a typical example in continental United States as follows:

Personnel Required for
a Typical Hydrogenation Process Unit Plant
in Continental United States

	Number of Personnel		
Classification	Operational	Administrative	Total
Operations:			
Labor	365	-	365
Supervision	37	-	37
Maintenance:			
Labor	430	-	430
Supervision	43	-	43
Indirect Labor	50	53	103
Indirect Salaried Personnel	-	197	197
Total	925	250	1,175

Plant Products and By-products. The hydrogenation process can produce, from coal as raw material, liquid fuels covering the entire range from heavy fuel oil, through Diesel fuel, jet fuel, and motor gasoline, to 100-octane aviation gasoline. By varying operating conditions, number of hydrogenation steps, and choice of catalyst any one of these grades may be made the principal product, as local markets may require.

The gasoline produced by hydrogenation of coal contains a high proportion of aromatics (benzene, toluene, and xylene), which may be separated if required, making the hydrogenation process an important potential source of those products.

Liquefiable petroleum gases (propane and butane) form an appreciable percentage of total plant products. A considerable amount of phenolic compounds, including phenol, cresol, and xylenols, may also be separated as optional by-products. If left in the main product stream, they are ultimately converted to additional gasoline.

Wastes. The hydrogenation of coal produces gaseous, solid, and liquid wastes. Gaseous wastes result in part from the combustion of coal in the power plant and at other points. Sulfur in the coal fed to the hydrogenation converters is separated from the process stream as hydrogen sulfide. This may be converted to sulfuric acid or elemental sulfur and sold or burned in the power plant and dissipated from the stack with the other flue gases, according to local conditions. Small amounts of ammonia which might be discharged could be rendered inoffensive by passage through a combustion zone.

Solid wastes of the process are comparable to and would be disposed of in the same manner as solid wastes from any large coal-burning industrial plant. Although hydrogenation ash will contain about 8 pounds of spent catalyst per barrel of plant products, its volume and nature will present no disposal problems not adequately met by usual methods employed to prevent the carrying off of excessive suspended solids by rainfall.

Various liquid wastes of the hydrogenation plant may carry small amounts of oil, removable by separators such as are commonly used by petroleum refineries. Of the total amount of liquids to be discharged, a relatively small and segregable portion will consist of so-called "foul water" containing dissolved gases (such as hydrogen sulfide) and solids, principally phenolic in nature.

A variety of methods is available for removing phenolic compounds. They may be applied in a series of consecutive steps, the number of steps depending on the degree of purification required by local conditions. These would be arranged in the following order: Ky

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1. Preliminary removal of remaining oil by solvent extraction, followed by removal of the bulk of the dissolved gases by pressure release and heating or aeration.

2. Removal and recovery of phenols by ion exchange on highly alkaline exchange resins; or alternatively, destruction of phenols by biochemical action.

3. Oxidation of remaining traces of phenols by ozone.

A more detailed discussion will be found in the section on "Waste Disposal" in a later part of this report.

Choices between methods will be largely determined by economic factors at specific locations. Treated water can be rendered suitable for return to streams without harm to aquatic life and may be rendered potable by standard treatments.

Typical Hydrogenation Plant for Continental United States. In selecting a form of hydrogenation plant suited to the conditions imposed in the continental United States by the types of coal available and the required types and proportions of products, the Bureau of Mines has prepared estimates in its publication, R.I. 4564 (August 1949), for several typical plants, each of 30,000-barrel-per-day capacity. These data for a plant to use Wyoming bituminous coal, a specific case, have been adopted for this survey for estimating construction and operating costs of a unit plant. More generalized data may be summarized as follows for a typical unit plant.

Basic Data and Estimates
for Typical Hydrogenation Unit Plant
in Continental United States
(Based on U.S. Bureau of Mines Data)

Plant area - Acres (Minimum)	70
Estimated approximate total steel requirements - tons	60,000
Estimated personnel:	
Operations and maintenance	925
Administrative, clerical, and engineering	250
Total daily coal requirements - Billions of Btu	98
Power required at 100 percent load factor - Kw	65,000
Daily water requirement - Gallons	7,286,000
Total production - Barrels per calendar day:	
Gasoline	7,220
Liquefied petroleum gas (L.P.G.)	2,367
Phenols	413(A)

Note: (A) Convertible, without additional equipment, to 463 barrels additional gasoline.

The current stage of development of a synthetic liquid fuels program does not permit the statement that any specific plant represents average conditions for those which may be constructed. Variations from the mean, however, will not seriously affect the utility of such a plant as a basis for the purpose of this survey, i.e., the determination of the relative desirability of General Areas.

Synthine Process Using Coal

History. Early work in Germany by F. Fischer and H. Tropsch developed a process to combine carbon monoxide and hydrogen, producing a mixture of alcohols which was called synthol. In 1926, the same men announced a modification of their process to produce, from the same gases, a mixture of hydrocarbons. To indicate the close similarity, this product was termed synthine and has given its name to the process itself. The more general names "Fischer-Tropsch synthesis" and "gas synthesis" are also applied to this process. Ky

Intensive development after 1926 resulted in the construction of a commercial plant in 1936 by Ruhrchemie, A.G. Following this installation, the number of synthine plants in Germany in- 45/4 creased to a total of ten by the end of World War II. Required carbon monoxide and hydrogen were produced by conventional water gas equipment.

Development of the process by others has been followed for many years by the U.S. Bureau of Mines, which since 1945 has itself carried on active work at Bruceton, Pa. Simultaneously, research on the continuous production of synthesis gas (a carefully proportioned mixture of carbon monoxide and hydrogen) has been under way at Morgantown, W. Va. A 50 to 100-barrel-per-day demonstration plant for the Bureau of Mines is nearing completion at Louisiana, Mo.

Private capital has nearly completed a 7,000-barrel-per day synthine plant to use natural gas near Brownsville, Tex.

<u>Nature of Process.</u> Except for obvious necessary differences in the production of synthesis gas, and in disposal of waste products, the synthine process is the same whether coal or natural gas is used as the primary raw material.

The synthine process consists essentailly of the combination, over a suitable catalyst at pressures of from 200 to 400 psi and at temperatures of from 550 deg to 650 deg F, of carbon monoxide and hydrogen to form a condensable mixture of hydrocarbon vapors. The reaction releases large amounts of heat and, since the temperature may be allowed to vary only within narrow limits, adequate provision for cooling is important. The liquid products are recovered and, for the most part, separated by methods and equipment well known in petroleum technology. Subsequent catalytic cracking or hydrogenation of the heavier oil fractions may be used according to the desired products distribution.

In the reaction, most of the oxygen of the carbon monoxide is converted to water but a part reacts to form carbon dioxide and a series of both water- and oil-soluble oxygenated organic compounds consisting of alcohols, aldehydes, ketones, and acids.

The nature and quality of products of the synthine process depend entirely upon the type of catalyst used and the operating conditions regardless of the raw material used to produce the synthesis gas. This gas can be produced from any material containing combustible carbon, the hydrogen being obtainable by reaction of steam and carbon monoxide.

The principal raw materials suitable for the synthine process are coal of all ranks and natural gas. Of these, the former is available in much larger quantities. Although the latter is commonly less expensive, it is also usually less available when existing commercial demands are satisfied.

The appended block flow diagram, Exhibit No. 3, indicates a typical arrangement for such a plant, consistent with the above description and with the specific unit plant design, for which estimated construction and operating costs are given in this report. However, the synthine process is more or less flexible in application, and variations in method of synthesis gas production, type of synthesis reactors, number of reaction stages, steps in product processing, and manner of separation or reuse of oxygenated chemical by-products may be used in individual plants designed to meet different local conditions.

Plant Requirements. The synthine process uses major quantities of coal and of water. Other necessary materials, including chemicals for catalyst manufacture, for the treatment of intermediate liquid products, and for imparting anti-knock properties to finished gasoline, are of relatively small amount.

Coal. Coal for the synthine process may be of any rank and of almost any quality although low quality (heating value) will obviously increase the quantity required for a given plant capacity. A unit plant of 10,000 barrels daily capacity would require daily about 4,900 tons of Kentucky coal, the exact amount dependent upon the heating value. Ash content is not inherently objectionable but should preferably be as low as possible. To this end, good washability is desirable. The maximum permissible ash content is 20 percent (dry basis). High sulfur content in the coal is to be avoided because of the necessity for nearly complete sulfur removal from the synthesis gas, in order to maintain catalyst activity.

Water. Water is required in a synthine plant mainly for cooling purposes. Too high a solids content will somewhat increase the requirement for solids control in cooling towers and boilers. From one-eighth to one-fourth of the water used must be capable of treatment to provide satisfactory boiler feed. Less than 1 percent need be of potable quality or fit to be made so by chlorination and other treatment. For a unit plant, the total daily requirement is about 11,150,000 gallons per day.

Power. The basic chemical reactions of the synthine process liberate quantities of waste heat sufficient for the generation of all required electric power and no additional fuel for power would be required. Outside power is required for starting up and in the event of temporary failure of plant generating facilities. Integration, where possible of plant facilities with an existing power network merits consideration.

Personnel. Operating personnel for a synthine process plant must be largely of a high class of semitechnical labor as in the petroleum refining and chemical industries. Because of the use of pressure equipment, the same is true of a substantial portion of maintenance labor. Indirect personnel includes such classifications as material handlers, stock clerks, guards, watchmen, janitors, and laborers. Technical workers will require a certain amount of training in specialized plant operations and maintenance. The Bureau of Mines has estimated that 80 percent of the technical workers can be trained from an inexperienced labor supply.

The number of employes of a unit plant will vary slightly according to the proportions of the total output represented by the various final products, but may be stated for a typical example as follows:

Personnel Required for
a Typical Coal Synthine Unit Plant
in Continental United States

Classification	Number of Personnel
Operations:	
Wage Earners	338
Supervision	34
Maintenance:	
Wage Earners	420
Supervision	42
Indirect Labor (Wage Earners)	103
Indirect Salaried Personnel	198
Total	1,135

Plant Products and By-products. The synthine process can produce a series of hydrocarbon liquid products comparable to petroleum fractions and meeting similar commercial specifications. Although it is expected that normally a preponderant part of the output will be gasoline, a certain limited flexibility is possible in design and operation through variations in the catalyst used and in operating conditions.

Gasoline quality from a synthine plant varies widely with the type of catalyst used. The German practice of using cobalt produced gasoline of markedly low octane number. Use of iron catalysts and of higher operating pressures as contemplated by the Bureau of Mines is expected to result in entirely satisfactory motor gasolines.

Diesel oil by the synthine process is expected to be of good quality with a cetane number of about 55. The typical fuel oil product is expected to meet specifications for a higher grade than No. 6 (Bunker C), possibly as high as No. 3.

A small amount of liquefiable petroleum gases (L.P.G.) principally propane, may be produced as final product (as assumed in the basic data for a typical coal synthine plant; see following table) or may be recycled or burned as plant fuel. The same is true with respect to a series of oxygenated organic compounds formed by part of the oxygen content of the synthesis gas. Most of these products, including alcohols, aldehydes, ketones, and acids, have a definite though limited market which probably could not absorb the output of such chemicals from any large production capacity of synthetic liquid fuels by the synthine process. Recycling of any of these materials is entirely possible and would result not only in solving a disposal problem but also in somewhat increased liquid fuel output or alternatively decreased raw material consumption. Recycling of only the oxygenated compounds is assumed in the specific plant design for which cost estimates are given in this report.

Waste. Solid wastes of a typical coal synthine plant will consist principally of ash from the coal processed or burned as fuel. The small amounts of spent catalyst (mainly iron oxide) included will be no more obnoxious than the ash. Disposal of this waste offers no problem, except perhaps in quantity, that is not readily met in the case of any large coal-burning industrial plant.

Gaseous wastes will be principally those removed in the purification of the synthesis gas, especially hydrogen sulfide resulting from sulfur in the coal. In order to avoid atmospheric pollution, the hydrogen sulfide may be converted to sulfuric acid or elemental sulfur, the sale of which would provide a credit against cost of sulfur removal.

Liquid wastes of the plant can be handled so as to skim those carrying oils and to segregate those containing dissolved organic compounds from the process. Such segregated water, before discharge, may be treated for recovery of these compounds, either for sale or for recycling. Alternatively, it may be fed to special boilers to produce a contaminated steam replacing part of the normal process water requirement. Relatively small quantities of sanitary and storm sewage can be handled by well-known methods. Some water from cooling tower operation and boiler blowdown will be discharged with an increased content of dissolved solids. Ky

Typical Coal Synthine Plant for Continental United States. 49a
Based on the results of extensive research and development work of its own, as well as upon available data of other investigators in the 4

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United States and in Germany, the Bureau of Mines has in the course of preparation estimates of construction and operating costs of a synthine plant of commercial scale. Preliminary data from this study, for a plant producing 10,000 barrels of synthetic liquid fuels per day from western Kentucky bituminous coal, a specific case have been adopted for this survey for estimating construction and operating costs of a unit plant, to be used as a basis of comparison for determining relative desirability of General Areas. In drawing other than relative conclusions from these cost estimates, however, the preliminary nature of the data so far available must be remembered. The final estimates determined by the Bureau at the completion of its work may differ appreciably from the present figures.

More generalized data may be summarized as follows for a typical unit plant:

Basic Data and Estimates
for Typical Coal Synthine Unit Plant
in Continental United States
(Based on Preliminary Data from U.S. Bureau of Mines)

Plant area - Acres (minimum)	77
Estimated personnel:	
Operations and maintenance (including all indirect labor)	937
Administrative, clerical, and engineering (salaried personnel only)	198
Total daily coal requirements - Billions of Btu	126
Power required at 100% load factor - Kw (produced from waste heat)	114,500
Daily water requirements - Gallons	11,150,000
Total production - Barrels per calendar day:	
Propane	470
Gasoline	7,280
Diesel oil	1,900
Fuel oil	350

The current stage of development of the synthetic liquid fuels program does not permit the statement that any specific plant represents average conditions for those which may be constructed. Variations from the mean, however, will not seriously affect the utility of such a plant as a basis for the purpose of the survey; i.e., the determination of the relative desirability of General Areas.

PART III -SUMMARY OF STATE CHARACTERISTICS

SUMMARY OF STATE CHARACTERISTICS

Surface Features

The area of Kentucky is 40,109 square miles. The State extends more than 400 miles from east to west and a maximum of 175 miles from north to south. Its surface gradually rises eastward from the Mississippi River to the western slope of the Appalachian Mountain province. West of the Tennessee River, the surface is low; rolling terrain marks the central part of the State; and the entire eastern part, being part of the Allegheny Mountain region, is both elevated and much dissected by water courses.

Kentucky has many rivers, the principal of which are the Mississippi, Ohio, Cumberland, Tennessee, Kentucky, Green, Barren, Licking, Dix, and Big Sandy. Drainage from the State is generally to the west and northwest, eventually finding its way to the Ohio and Mississippi Rivers. Forty-six percent of the State is forested.

Climate

Kentucky enjoys a temperate climate. Exhibit No. 4 shows the mean monthly temperature and precipitation at Ashland Dam, Boyd County, and at Greenville, Muhlenberg County, which points are assumed to be representative, respectively, of the eastern and western coal-bearing sections. In degrees Fahrenheit, annual high, mean, and low temperatures at these stations are 76.7, 56.6, and 35.8 at Ashland Dam and 77.8, 57.5, and 36.1 at Greenville. Annual mean precipitations at the two locations are, respectively, 42.46 and 46.88 inches. In the western part of the State, the mean temperature is only slightly higher than in the east, but precipitation is considerably greater.

Population

Kentucky's 1940 population totaled (U.S. census) 2,845,627; the 1950 census preliminary count indicated that the population in 1950 was 2,921,708. Using the latter figure, the population density averages 72.8 persons per square mile over the State's 40,109 square miles.

The population in 1940 of the 11 principal eastern coal-bearing counties was 433,810 and remained almost stationary in the 10 years until the 1950 census, from which the corresponding figure is 433,315. In the nine coal-bearing counties in the western part of the State, between the 1940 and 1950 censuses, population decreased at a slightly greater rate, dropping from 263,303 to 261,977. As of the 1950 census, population densities were 95.7 and 62.3 persons per square mile in the eastern and western groups, respectively.

Industry and Agriculture

The major industries in Kentucky include coal mining, chemical and allied products, tobacco manufacture, food and kindred products, fabricated metal products, and machinery (except electrical). The 1947 Census of Manufactures reported a total of 2,244 establishments with 577 establishments manufacturing food and kindred products. In the eastern coal-bearing section of the State, the principal economic activities are agriculture and coal mining. In the west, considerable manufacturing is done in the two counties immediately south of Evansville, Indiana. In the balance of the western coal-bearing counties, agriculture and coal mining predominate.

The table which follows shows the size of manufacturing establishments in Kentucky as compared to the United States total. These figures for establishments are from the 1947 Census of Manufactures and indicate that the relative proportions of large and small establishments in the State of Kentucky are generally similar to the United States total. Population figures are from the 1950 census.

Manufacturing Establishments in Kentucky
and the United States Total by Size Groups

	Kentucky		United States		Kentucky
Employes per Establishment	Number of Establishments	Percent of Total	Number of Establishments	Percent of Total	Percent of the U.S.
1 - 19	1,453	64.7%	157,651	65.4%	
20 - 99	508	22.6	58,688	24.4	
100 - 499	239	10.7	19,878	8.3	
Over 500	44	2.0	4,664	1.9	
Total	2,244	100.0%	240,881	100.0%	0.93%
Population	2,921,708		150,697,361		1.94%

Transportation

The State has an adequate transportation system of railroads, highways, and waterways. The coal-producing regions of eastern Kentucky are served by the Louisville & Nashville, Chesapeake & Ohio, and Norfolk & Western Railroads. The coal-producing regions of western Kentucky are served by the Illinois Central and Louisville & Nashville Railroads and Ohio River barge lines.

Other Features

The largest cities in the State are Louisville, Covington, and Lexington, none of which is in either of the coal-producing sections. The population of those areas is, to a very great degree, rural. Huntington and Williamson, West Virginia, are local trade centers near the eastern coal-producing section; the western coal counties are served in this respect by Owensboro, Paducah, and Bowling Green. The nearest large city to the eastern group of counties is Knoxville, Tenn.; Evansville, Ind., fills that position in the west.

PART IV - RAW MATERIALS

COAL

General Geology of Coal Deposits
(See Exhibit No. 5 for references below)

The coal-bearing formations of Kentucky are in two distinct areas, the larger in eastern Kentucky, where it is an important part of the Appalachian region of the Eastern province. The western coal-bearing area is the southeastern extension of the Eastern region of the Interior province, which also includes the coal fields of Illinois and Indiana. The areas in central Kentucky between the two coal fields, as well as those south and southwest of the western field, are largely underlain by geological formations stratigraphically older than the coal-bearing strata. These older formations are not known to contain coal deposits and the areas immediately underlain by such bedrock strata have not been further considered. Discussion of the general geology of the coal deposits of Kentucky is separately presented for each of the two principal coal-bearing areas.

Eastern Kentucky Coal-bearing Area. The coal-bearing formations of eastern Kentucky are Pennsylvanian in age and occupy an area of approximately 10,450 square miles in all or parts of 37 counties. These strata are co-extensive with those of southern Ohio and southwestern West Virginia along the northeastern border of the Eastern Kentucky coal field, with those of southwestern Virginia along the southeastern border, and with those of eastern Tennessee along the southern border.

As elsewhere in the Appalachian region, the coal measures of eastern Kentucky occur in a broad, shallow syncline, the axis of which extends northeast-southwest near the center of the coal-bearing area. The major part of the Eastern Kentucky field, except a relatively narrow strip adjacent to the Virginia State line in portions of Bell, Harlan, and Letcher Counties, is the southern extension of the main Appalachian region syncline although partially separated therefrom by a low cross-fold running in a northwest-southeast direction across the northeastern portion of the eastern Kentucky coal-bearing area. This major basin is separated from the narrow strip across southern Letcher and southeastern Harlan and Bell Counties by the Pine Mountain overthrust block which forms the Kentucky-Virginia State line along portions of the southeastern border of northeastern Letcher and Pike counties. The coal measures southeast of the narrow, coal-barren belt, which marks the northwestern "front" of the overthrust, are geologically more closely related to the coal measures of southwestern Virginia than to the principal eastern Kentucky basin.

(References: 28, 34, 39, 40, 47, 56, 61, 64)

In accordance with regional structure, the coal beds northwest of the Pine Mountain overthrust largely dip inwardly from the northwestern and southeastern margins of the broad basin, although regional dips are frequently modified along the axes of numerous local patternless folds. Coal beds southeast of the Pine Mountain overthrust dip sharply toward the southeast for relatively short distances before rising slowly in the same direction into contiguous fields of southwestern Virginia. The northwestern border of the Eastern Kentucky field is represented by an irregular erosional escarpment overlooking the topographically and stratigraphically lower formations comprising the gently-dipping southeastern flank of the Cincinnati arch, which occupies central Kentucky.

The coal beds of the Eastern Kentucky field are largely in the Pottsville, or basal, formation of the Pennsylvanian series; there are also some higher beds in overlying formations of lower Alleghany age in the deepest portions of the basin. The Pennsylvanian strata thin rapidly from their areas of maximum thickness along the southeastern border of the field toward the northwestern boundary with resulting decrease in number of coal beds from the southeast toward the northwest. In general, the coal-bearing formations northwest of the Pine Mountain overthrust are correlated with those of southern Ohio and southwestern West Virginia, while the formations southeast of the Pine Mountain overthrust are correlated with those of southwestern West Virginia. With relatively large areas in the Eastern Kentucky field not having been mapped in detail, the exact number and correlations of coal beds in eastern Kentucky are not known. Even the coal-bearing formations bear different names at various locations within the field, as applied in early days by individual investigators with little subsequent clarification or correlation.

The principal coal beds and horizons in eastern Kentucky, together with approximate correlations in adjoining states, as based on comparatively recent correlations in Appalachian stratigraphic studies, are listed in descending order as follows:

Principal Coal Beds in Eastern Kentucky and Approximate Correlations in Adjoining States

Eastern Kentucky	Correlations
High Splint (Richardson, Hindman, No. 9)	Lower Kittanning No. 5 (West Va., Ohio)
Hignite (Frances, No. 8)	Stockton (West Va.)
Flag (Cornett, No. 7)	Lower Mercer (Ohio)
Hazard (Peach Orchard, No. 6)	Coalburg (West Va.)
Haddix (Limestone, No. 5)	Winifrede (West Va.), Pardee (Va.)
Fire Clay Rider	
Flatwoods (Wallins Creek)	Chilton (West Va.)
Taylor	
Fire Clay (Hazard No. 4)	
Whitesburg	Hernshaw (West Va.)
Mills	
Williamson (Amburgy)	Williamson (West Va.), Low Splint (Va.)
Upper Elkhorn No. 3 (Kellioka, "C")	Cedar Grove (West Va.), Taggart (Va.)
Upper Elkhorn No. 2 ("B")	
Upper Elkhorn No. 1 (Millers Creek, "A")	Alma (West Va.), Jellico (Tenn.)
Harlan	Standiford (Va.)
Lower Elkhorn (Pond Creek, Warfield, Shelby Gap)	Logan-Eagle, Campbell Creek No.2 Gas (West Va.), Imboden (Va.) Blue Gem (Tenn.)
Pucketts Creek	
Bingham (Feds Creek)	Clintwood (Va.)
Millard	Eagle (West Va., Va.)
Blair	Little Eagle (West Va.)
Cedar	Dorchester (Va.)
Auxier (Hagy)	Splash Dam (Va.)
Banner (Elswick)	Upper, Lower Banner (Va.)
Kennedy	Kennedy (Va.)
Raven	Raven, Red Ash (Va.)
Jawbone	Jawbone (Va.)

The Eastern Kentucky field is topographically highly dissected; the crests of the major ridges and divides range from 1,000 to 3,800 feet in elevation. The Massive sandstones and conglomerates
Ky of the Pottsville formation have produced rugged cliffs and escarpments in many portions of the area, especially along the southeastern
57b boundary of the field. The Eastern Kentucky field is largely drained
58 toward the northwest by the Big Sandy, Little Sandy, and Licking Rivers and their tributaries, and toward the west by the Cumberland
15 River and its tributaries.
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<u>Western Kentucky Coal-bearing Area.</u> The coal-bearing formations of western Kentucky, also Pennsylvanian in age, occupy an area of approximately 4,680 square miles comprising all or portions of 21 counties. This area is the southeasternmost extension of the Eastern region of the Interior province, which includes the larger coal-bearing areas of southwestern Indiana and Illinois. In western Kentucky, the coal-bearing strata are connected to the coal-bearing formations of Indiana and Illinois under the Ohio River from near the northwestern corner of Breckenridge County to a point near the northern corner of Crittenden County.

The coal measures of western Kentucky lie in a broad, shallow basin which dip gently toward the northwest and is surrounded on its eastern, southern, and southwestern margins by inward-facing escarpments of topographically higher but stratigraphically lower formations than the coal-bearing series. In conformance with this regional pattern, the coal beds around the margins of the basin dip gently toward the central axis of the syncline at rates which rarely exceed 3 degrees. Approximately the southern one-half of the Western Kentucky field, however, is structurally distorted by two separate fault belts in which the coal measures are transected by numerous individual faults of varying direction and degree. The northern fault belt is comprised of a predominantly east-west line of compressive faulting and overthrusting, which nearly bisects the coal-bearing area as it extends from the center of the west line of Union County across northern Webster and McLean Counties to and beyond the center of the eastern line of Ohio County. This belt is geologically termed the Rough Creek uplift.

The southern fault block extending across most of the southwestern and southern margins of the Western Kentucky field is a direct eastward continuation of a similar belt of faulting in southern Illinois, largely south of the coal measures in that State. The structure is further complicated by the presence of numerous additional faults radiating outward from highly complicated flexures in the area immediately southwest of the coal measures in Livingston and Crittenden Counties. Coal-bearing strata adjacent to the numerous individual faults and within the individual fault blocks may depart widely in direction and amount of dip from the regional, basin-like structure.

As in Indiana and Illinois, the principal coals of the Western Kentucky field are in coal-bearing formations corresponding roughly to the Conemaugh, Allegheny, and Pottsville formations of the Appalachian region. In western Kentucky, the highest coal-bearing strata of Conemaugh correlation are of the McLeansboro formation, the upper portions of the Allegheny strata are known as the Carbondale formation and the underlying lower Allegheny and Pottsville strata as the Tradewater and Caseyville formations. The principal coal beds and horizons, together with their stratigraphic equivalents in Illinois and Indiana, are listed, in descending order, as follows:

Principal Coal Beds in Western Kentucky and Their Correlations in Illinois and Indiana

		Correlations	
Formation	Coal Bed	Illinois	Indiana
McLeansboro	No. 14	-	-
Carbondale	No. 12	-	-
	No. 11	No. 6	-
	No. 9	No. 5	No. 5
Pottsville (Tradewater)	No. 6 (Mannington)	No. 1 (?)	Minshall(?)
	Elmlick and other scattered coals, locally named Bell		

The western Kentucky coal field is topographically characterized by relatively moderate relief, with but few surface indications of the fault blocks in the southern part of the field. While the coal-bearing area is largely drained toward the northwest by the Green River and its tributaries, the southwestern portion of the area is drained, also to the northwest, by the Tradewater River. Both of these rivers empty into the Ohio River, which forms the entire northern border of the coal field.

Sources of Information

The coal resources of Kentucky have been the subject of numerous, although sporadic, investigations commencing approximately in 1876. The Kentucky Geological Survey has published a number of bulletins and chapters in geologic reports on many scattered portions of both the eastern and western coal fields. The U.S. Geological Survey has published the results of geological investigations, largely in the Eastern Kentucky field, in the form of geologic folios, professional papers, and bulletins. A series of areal geologic maps were prepared by the Kentucky Geological Survey for most of the coal-bearing counties in the Western Kentucky field during the period 1923 to 1931. These maps indicate the structure of the coal measures, the areas underlain by the various coal-bearing formations, and the outcrops of some of the more important coal beds. A volume on the "Geology and Mineral Resources of Kentucky", published in 1928 by the Kentucky Geological Survey, contains short descriptions of the principal coals and coal-bearing formations in most of the coal-bearing counties in the entire State. The records and results of such publications provide varying scopes of information on coal bed occurrences in a number of areas, but are insufficient in coverage to permit studies of a comprehensive and uniform nature throughout the entire coal-bearing area.

The Kentucky Department of Mines and Minerals publishes annual production statistics, which afford material information on locations, depths, and thicknesses of beds at mines in areas for which no other specific information is available. Substantial information on quality, physical and chemical characteristics of coal beds in Kentucky has been obtained from various publications of the U.S. Bureau of Mines.

While the above references generally supply the major amount of available information on the coal resources of Kentucky, other available publications and reports were examined throughout the survey. The footnote annotations included in this report in sections dealing with coal refer to publications listed in the bibliography shown as Exhibit No. 5, Coal Bibliography.

Survey Methods and Procedure

In estimating the coal reserves of Kentucky, all pertinent information available from the literature and other sources was posted on previously prepared base maps with sources of information being appropriately indicated. Each base map covered an area consisting of one degree of longitude (east-west) and one-half degree of latitude (north-south) on a scale of 1:62,500. Such an area comprises eight 15-minute topographic quadrangle maps as ordinarily prepared by the U.S. Geological Survey. A separate print of each base map was generally used for each coal bed within the area having sufficient information to permit an evaluation of reserves. In some cases, information on two or more beds was posted on the same base map where the areas occupied by reserves of different seams were sufficiently separated to avoid overlapping. Where available, the extents of mined-out areas as shown by mine maps or other information were shown on the appropriate base map. In other areas where it was evident that mining activities had been in progress for many years in certain beds, the extent of depletion was estimated and indicated on the corresponding base maps by limiting lines.

All available information on outcrop, depth, and thick- Ky
ness of each bed, including the known or estimated extent of under-
ground and/or strip-mine depletion was posted on each base map 61
area. The areas underlain by coal in each 5-minute quadrangle 62
were carefully analyzed and evaluated prior to delineation of
classified areas of reserves. Individual areas depleted by under- 15
ground or strip operations were then demarcated and eliminated 70021

from further measurement by enclosure within a limiting line located sufficiently far outside the outermost extents of the mined-out area to represent the limit of the probable barrier pillars which would be left between the depleted area and subsequent mining operations. Where individual depleted areas approached other depleted areas to such an extent that subsequent mining operations in the intervening areas would not be practical, as by groups of mines located relatively close together in many areas of major depletion, the entire area was demarcated and eliminated from further measurement by a similar limiting line. Since the property lines toward which mining operations in active mines may be expected to proceed were not determined in this survey, it is probable that some portions of such intervening areas thus eliminated may be undergoing current depletion. The amounts of such reserves, which are considered relatively minor in extent, would thus not be included in the total amount of estimated reserves.

The delineation of measured, indicated, and inferred strippable reserves, whenever the presence of such reserves might be indicated, was based on detailed and individual examination of areas adjacent to the coal bed outcrop. Factors taken into account in estimating the presence and extent of strippable reserves included the distribution, frequency and reliability of available information; the accuracy of location of the line of outcrop; the character of the slope immediately adjacent to the outcrop, and the thickness of cover and width of the potential strippable area as shown by topographic maps, if available; the character of the overburden, if known, and the size, shape, and extent of areas already depleted by stripping or shallow underground operations, if present. In estimating strippable reserves, the amount and character of the available information are relatively much more important than in estimating underground reserves because of the determinative interdependence of factors such as the thickness and continuity of coal bed and the thickness and character of overburden in a relatively small portion of the general coal-bearing area. The available information in the Eastern Kentucky field is insufficient to permit the delineation of strippable areas, and, accordingly no estimates of strippable reserves have been made for that field. Sufficient information was available in the Western Kentucky field, however, to permit estimates of strippable reserves in that area.

An additional factor in estimating areas of strippable reserves is the economic relationship between the costs of recovery of reserves under relatively heavy cover by the stripping method and by underground mining. While the determination of reserves available for the manufacture of synthetic liquid fuels properly precedes any consideration of costs in this survey, it is considered relevant and proper to classify such areas of reserves as primary reserves for underground operation rather than as secondary reserves for strip-mine operation when it is estimated that underground mining will result in more economic recovery than strip mining. The inclusion of this factor in the several determinative criteria enumerated above has been adopted as a portion of the procedure followed in this survey.

Having demarcated and eliminated from further measurement all depleted areas and having delineated any areas of strippable reserves as described above, the remaining areas of reserves adjacent to such depleted and strippable areas and to outcrops, including any portions of the bed disclosed by drill hole or isolated shaft records, were classified by lines defining the various areas of measured, indicated, and inferred underground reserves as warranted by the available information and according to the definitions established in Part II of this report. Distinctions between primary and secondary underground reserves were based on average thicknesses of bed.

Each classified area of reserves was measured by planimeter to determine acreage, this figure then being multiplied by average thickness of bed as developed from the data and by a constant of 1,800 tons per acre-foot, following U.S. Geological Survey procedure, to estimate the number of tons in place. Since the counties in Kentucky are not subdivided into civil townships, the data on thickness of coal and cover and on acreage and quantity of reserves were averaged, measured and then tabulated by 5-minute quadrangles on basic Coal Data Sheets (A), with the information and estimated quantities of reserves in each such quadrangle being grouped by individual beds in each county.

Preliminary analysis of available data on Kentucky coal reserves indicated that consideration of these reserves as raw material for synthetic liquid fuels plant supply could best be conducted on the individual coal beds occurring in each county. While the coal production of Kentucky is commonly segregated into five or more commercial mining districts, these districts do not cover all the areas of potential reserves. Reserves in coal beds not now being commercially mined within such districts would not commonly be recognized as parts of these districts.

Strip mining is a recent factor in Kentucky, representing only a nominal proportion (approximately 3 percent) of total production in the Eastern Kentucky field in 1948, but accounting for
a major proportion (approximately 46 percent) of total production Ky
in the Western Kentucky field in the same year. Many areas adjacent
to the outcrops of the principal coal beds in western Kentucky have 64b
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Note: (A) Complete sets of the basic Coal Data Sheets are available 15
at the specific depositories listed in Exhibit No. 6. 70021

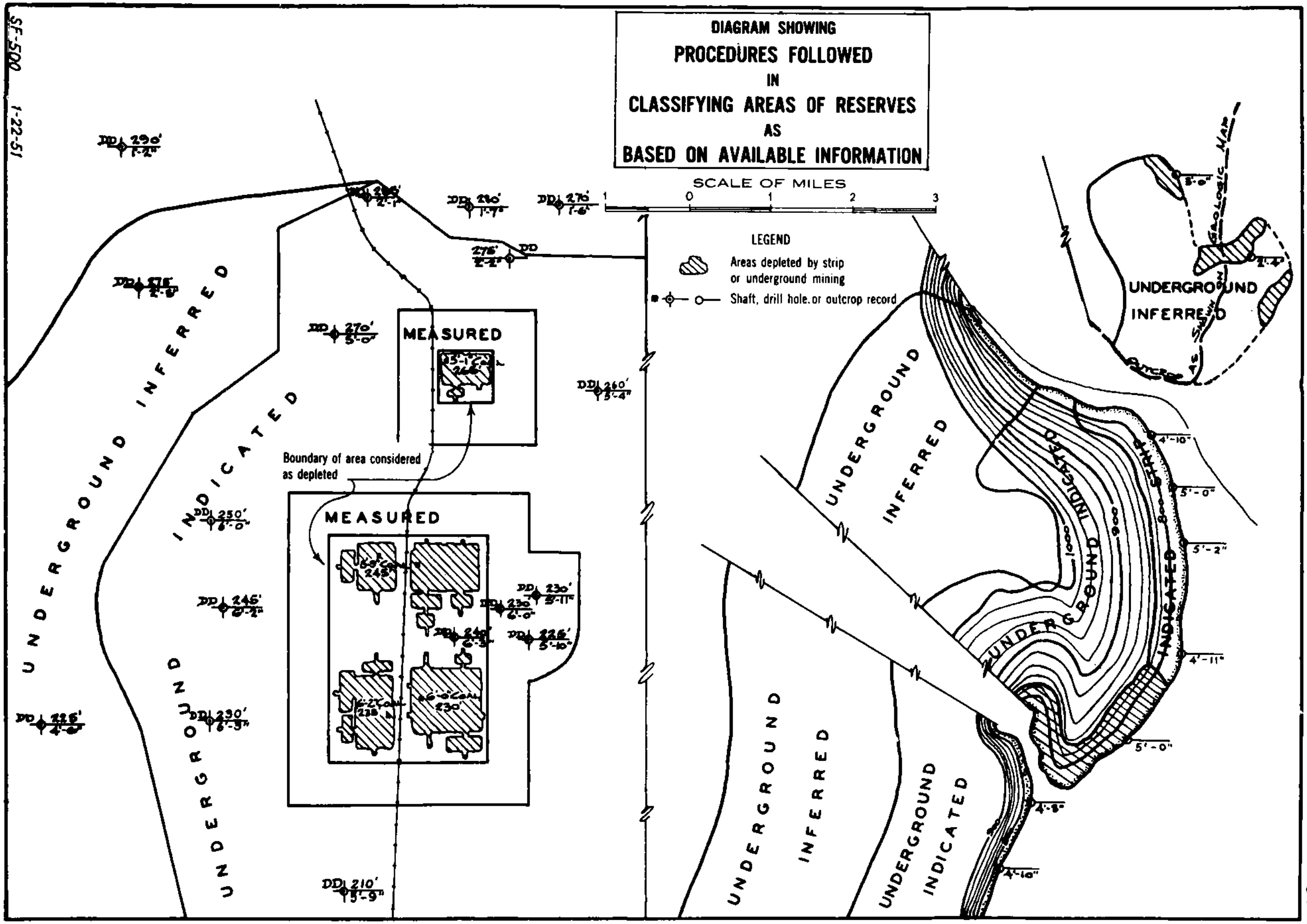
been extensively stripped and even more extensively prospected for potential strip-mine operation. The result has been that substantial portions of the strippable reserves in the Western Kentucky field, in sizes adequate for consideration as synthetic liquid fuels plant supply under the definitions followed in this survey, are now either in active operation or are held by present mining companies for future operation.

Under the definitions employed in this survey for delineating areas of measured, indicated, and inferred coal reserves, estimates of measured and indicated classes of reserves are largely based upon positive points of observation at maximum intervals as provided by the respective definitions. Estimates of inferred reserves, however, are based largely upon assumptions of extent, continuity, and thickness for which there is geologic evidence. While available evidence of continuity and persistence of individual coal beds has thus been taken into account in projecting areas of inferred reserves beyond areas of measured and indicated reserves, the resultant estimates are regarded as only provisional until further evidence from new or hitherto undisclosed exploration becomes available.

The information used in this survey was generally based on data from major sources such as Federal and State publications, annual production statistics, etc. Neither time nor funds were available to this project for complete collection of all potential information in the hands of private interests. Since information from these sources would probably increase the usable information on extent of demonstrated coal reserves above that available from most publications, the estimated primary reserves in this survey would probably tend to increase as and when such additional information may become available in the future.

The diagram following has been prepared to indicate graphically the results of the previously described "Survey Methods and Procedure" as these may appear on the individual base maps on which the various coal data are shown in detail.

DIAGRAM SHOWING
PROCEDURES FOLLOWED
IN
CLASSIFYING AREAS OF RESERVES
AS
BASED ON AVAILABLE INFORMATION



Elimination of Counties Not Meeting Requirements of Survey

The table following indicates that there are 37 counties in eastern Kentucky and 21 counties in western Kentucky, which are entirely or in part underlain by coal-bearing strata. Preliminary examination revealed that five of these counties in eastern Kentucky and six in western Kentucky (second column of the table) were too close to the outermost edge of the coal-bearing formations to contain appreciable minable areas of any of the coal beds. These counties were accordingly eliminated from further consideration in this report.

Available information on each of the remaining 32 counties in eastern Kentucky and 15 counties in western Kentucky was then compiled by coal beds and examined in detail. After detailed study 18 additional counties in eastern Kentucky and 5 additional counties in western Kentucky (third column of the table) were found in which either isolated reserves were insufficient in amount to warrant consideration as synthetic liquid fuels plant supply or for which available information on depth, continuity, thickness and number of coal beds was insufficient to permit estimates of reserves. These 23 counties were also eliminated from further consideration in this report, although detailed descriptions are given in Appendix A.

The elimination of the 23 counties, as described above, left 14 of the original 37 counties in eastern Kentucky and 10 of the original 21 counties in western Kentucky in which the coal reserves appear to qualify as suitable for synthetic liquid fuels production. These counties are enumerated in the last column of the preceding table, and a summary of their recoverable coal reserves is shown in Exhibit No. 7. The following section of the report describes the nature and extent of the principal coal beds for which information was available in these counties and presents some data relating to recent production.

Description of Coal Beds in Selected Counties - Eastern Kentucky Field

Bell County. (See Exhibit No. 5 for references below). Bell County, at the southeastern corner of the Eastern Kentucky field, adjoins Claiborne and Campbell Counties of Tennessee on the south and Lee County of Virginia on the southeast. The Bell-Lee County line, located along the crest of Cumberland Mountain, is the southeastern border of the Appalachian coal field in this area.

(References: 5, 7, 19, 37, 39, 40, 62, 63)

Selection of Counties In Kentucky, by Coal Fields, Containing Coal Reserves Suitable for Production of Synthetic Liquid Fuels

All Counties Containing Coal-bearing Strata	Counties Eliminated Because of: Fringe Position near Outermost Limit	Counties Eliminated Because of: Insufficient Information or Isolated and Insufficient Reserves (A)	Counties Selected for Consideration
Eastern Kentucky Coal Field			
Bell			Bell
Boyd		Boyd	
Breathitt			Breathitt
Carter		Carter	
Clay			Clay
Clinton		Clinton	
Elliott		Elliott	
Estill	Estill		
Floyd			Floyd
Greenup		Greenup	
Harlan			Harlan
Jackson		Jackson	
Johnson			Johnson
Knott			Knott
Knox			Knox
Laurel		Laurel	
Lawrence		Lawrence	
Lee		Lee	
Leslie			Leslie
Letcher			Letcher
Lewis	Lewis		
McCreary		McCreary	
Madison	Madison		
Magoffin			Magoffin
Martin			Martin
Menifee		Menifee	
Morgan		Morgan	
Owsley		Owsley	
Perry			Perry
Pike			Pike
Powell	Powell		
Pulaski		Pulaski	
Rockcastle		Rockcastle	
Rowan	Rowan		
Wayne		Wayne	
Whitley		Whitley	
Wolfe		Wolfe	

Selection of Counties in Kentucky, by Coal Fields, Containing Coal Reserves Suitable for Production of Synthetic Liquid Fuels

All Counties Containing Coal-bearing Strata	Counties Eliminated Because of: Fringe Position near Outermost Limit	Counties Eliminated Because of: Insufficient Information or Isolated and Insufficient Reserves (A)	Counties Selected for Consideration
Western Kentucky Coal Field			
Breckinridge	Breckinridge		
Butler			Butler
Caldwell	Caldwell		
Christian			Christian
Crittenden		Crittenden	
Daviess			Daviess
Edmonson		Edmonson	
Grayson		Grayson	
Hancock		Hancock	
Hart	Hart		
Henderson			Henderson
Hopkins			Hopkins
Livingston	Livingston		
Logan	Logan		
McLean			McLean
Muhlenberg			Muhlenberg
Ohio			Ohio
Todd	Todd		
Union			Union
Warren		Warren	
Webster			Webster

Note: (A) Descriptions of these 23 counties, eliminated from further consideration for synthetic liquid fuels plant coal supply on account of insufficient information or isolated and insufficient reserves, are in Appendix A.

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Coal measures of Bell County are divided into two separate areas by the coal-barren front of the Pine Mountain overthrust. Those southeast of Pine Mountain occupy the relatively shallow Middlesboro syncline, the axis of which crosses the county in a northwest-southeast direction, parallel to the northwestern edge of the Pine Mountain overthrust. The coal beds dip southeast from Pine Mountain at rates ranging up to 5 degrees or more but flattening rapidly within short distances, thence dipping at gentle rates toward the synclinal axis from which they rise at gentle rates toward Cumberland Mountain. The Middlesboro syncline, southeast of Pine Mountain in Bell County, is broken by two transverse faults which extend in a nearly north-south direction through the center of the area. The relatively small part of Bell County northwest of the Pine Mountain overthrust is monoclinal in structure with a slight increase in northwestward dip from the northwest toward the southeast, and with a few minor flexures without particular pattern locally modifying the regional dip at some locations.

U.S. Bureau of Mines Publication "Bituminous Coal and Lignite in 1948" (M.M.S. No. 1807) indicates that approximately 3,005,000 tons were produced in Bell County during that year, with 84,000 tons being obtained from 3 stripping operations. The Kentucky Department of Mines and Minerals reports for 1948 a production of approximately 2,350,000 tons from 21 railroad mines and an additional 735,000 tons from 101 truck mines. These mines operated in coals variously designated as Apex, Barner, Blue Jim, Buckeye, Collier, Creech, Crockett, Dean, Dixie Gem, Harlan, Hignite, Jack Rock, Jellico, Lower Dean, Lower Hignite, Mason, Nugym, Popular Lick, Red Bird, Red Springs, Rim Splint, Sterling, Straight Creek, Turkey Pen, Turner and "stray" beds. Since the designations of these beds are largely limited to areas of small extent, with no county-wide correlations available, it is probable that the number of beds actually being worked is substantially less than indicated by the number of names.

Bell County northwest of Pine Mountain has not been mapped or investigated in sufficient detail to provide adequate data on location or extent of coal occurrences. Although numerous mines have operated along the principal drainage channels in this part of Bell County, information available is not sufficient to permit descriptions of the number, occurrences, or extents of coal beds nor to justify estimates of reserves.

Six coal beds southeast of Pine Mountain in Bell County contain reserves sufficient to warrant further consideration as synthetic liquid fuels plant supply. These beds, in descending order, are the High Splint, Hignite, Fire Clay, Williamson, Harlan, and Puckett Creek beds.

The High Splint bed, also known as the Red Springs coal, occurs in only two limited areas in the southwestern portion of the county, where it ranges from 4 ft 2 in. to 6 ft 4 in. in total thickness. The thicker cocurrences are generally characterized by inclusion of from one to three partings ranging up to 5 inches in thickness. In the areas of estimated reserves, the thickness of this bed ranges from 4 ft 7 in. to 4 ft 9 in.

The Hignite bed likewise is found only in southwestern Bell County, where it is extremely variable in thickness, from less than 3 ft 0 in. to as much as 9 ft 11 in. In areas of thicker coal occurrence, the bed is generally separated into individual benches by intervening partings 1 ft or more thick; the workable coal usually is less than 4 ft 0 in. in thickness.

The Fire Clay bed, or the Dean bed, occurs in workable thickness in southwestern Bell County and in small scattered areas along the Bell-Harlan and Bell-Leslie County lines. Thickness of this bed ranges up to 6 ft 3 in. in total; there are two or more relatively thin benches separated by partings as much as 1 ft 3 in. thick. Portions of the Fire Clay bed have been extensively worked in areas of superior quality and physical conditions in the central part of southeastern Bell County. Thicknesses of workable benches in areas of estimated reserves in Bell County range from 2 ft 3 in. to 4 ft 4 in.

The Williamson bed, or the Mason bed, occurs persistently across the southwestern and northeastern portions of the area in Bell County southeast of Pine Mountain. This bed ranges from 2 ft 4 in. to as much as 6 ft 0 in. in thickness but generally occurs in an average thickness of approximately 3 ft 6 in.; gradually increasing to 4 ft 6 in. near the Bell-Harlan County line. The Williamson bed in the areas of estimated reserves in Bell County is from 2 ft 9 in. to 4 ft 6 in. thick.

The Harlan bed extends southwestward into southeastern Bell County from its greatest development in Harlan County. While persistent, it is variable in thickness and in content of shale partings within short distances, so that it may range from 3 ft 2 in. of clean coal on one flank of a narrow ridge to 9 ft 1 in. on the opposite flank; this latter thickness contains five shale partings, totaling 2 ft 10 in. in thickness, which divide the bed into six coal benches ranging from 0 ft 3 in. to 1 ft 5 in. in individual thickness. There are relatively substantial areas, however, in which the bed persists in thicknesses from 3 ft 3 in. to 4 ft 2 in.; without adverse thicknesses of included partings.

The Puckett Creek bed is locally developed only in southeastern Bell County near the Bell-Harlan County line; it generally consists of two or more benches separated by thick intervening partings. There are two relatively small areas of reserves in which the workable coal thickness without adverse partings ranges from 2 ft 8 in. to 4 ft 7 in.

Breathitt County. (See Exhibit No. 5 for references below). In Breathitt County, in the north-central portion of the Eastern Kentucky field, the coal measures occur over the deeper portion of the general structural syncline. In conformance with this regional position, the coal beds and their associated strata in the northwestern and western portions of the county dip toward the southeast and east, while the beds in the eastern portion of the county dip gently toward the west. The predominant synclinal structure is locally affected by scattered and irregular anticlines, which do not greatly modify the directions or rates of dip.

Bureau of Mines data on bituminous coal production in 1948 show approximately 159,000 tons as produced in Breathitt County during that year, all from underground operations. The Kentucky Department of Mines and Minerals reports for 1948 that approximately 46,000 tons were loaded from two railroad mines in Breathitt County; an additional 128,000 tons was obtained from 66 truck mines. This production was from the Elkhorn No. 3, Hazard No. 4, No. 4, and No. 4 Ryder beds.

Of the 11 coal beds in Breathitt County 6 were found suitable for further consideration for the production of synthetic liquid fuels. The following classification, arranged in descending stratigraphic order, indicates the suitability or non-suitability of each bed examined in this survey. It is followed by brief descriptions of all of the coal beds for which information was available.

Breathitt County Coal Beds

Coal Bed	Suitable	Non-Suitable
High Splint		x
Flag	x	
Hazard	x	
Leatherwood		x
Haddix	x	
Fire Clay	x	
Wilson Fork		x
Whitesburg	x	
Big Branch		x
Round Bar		x
Upper Elkhorn No. 3	x	

(References: 15, 32, 39, 40, 48, 62, 63)

The High Splint bed occurs only near the summits of the highest ridges and divides in southeastern Breathitt County. The areas of coal occurrence are too limited to warrant further consideration.

The Flag bed likewise occurs near the summits of the higher ridges and divides in southern Breathitt County. It ranges from 2 ft 0 in. to 4 ft 9 in. in thickness and is usually composed of splint or cannel coal with two or more partings ranging up to 0 ft 5 in. in thickness. Thicknesses of this bed in scattered areas of estimated reserves range from 2 ft 3 in. to 4 ft 2 in.

The Hazard bed underlies the higher ridges and divides in southern Breathitt County and also extends into Breathitt County along the Breathitt-Magoffin County line from outcrops in southern Magoffin County. Within these areas, the Hazard bed ranges widely in thickness from 1 ft 1 in. to as much as 7 ft 5 in. Areas of thicker coal are commonly characterized by two or more shale partings sometimes as thick as 3 ft 3 in. One or two benches near the middle of the bed commonly consist of cannel coal. The thicknesses of the Hazard bed in the areas of estimated reserves range from 3 ft 1 in. to 5 ft 2 in.

The Leatherwood bed is only a horizon marker in southern and eastern Breathitt County; it rarely exceeds 1 ft 0 in. in thickness.

The Haddix bed, also sometimes called the No. 4 bed, outcrops widely across central and eastern Breathitt County in a total thickness of as much as 7 ft 6 in. It generally contains two or more partings ranging from 0 ft 1 in. to as much as 2 ft 0 in.; two or more of the coal benches generally consist of cannel or splint coal. In areas containing thicker or more numerous partings, only portions of the full bed can be considered minable; thicknesses of the workable benches in numerous scattered areas of estimated reserves range from 2 ft 3 in. to 4 ft 4 in.

The Fire Clay bed, usually merely a horizon marker in northern and eastern Breathitt County, extends northward into southern Breathitt County from areas of thicker coal in Perry County to the south. There are a few small areas of reserves in northern Breathitt County slightly over 2 ft 0 in. thick. Reserves along the Breathitt-Perry County line range in thickness up to 3 ft 6 in. The bed throughout Breathitt County contains highly variable proportions of coal and shale material.

The Wilson Fork bed is confined to eastern Breathitt County, where it occurs in widely varying thicknesses ranging locally up to 6 ft 2 in. Moderate reserves of this bed, in areas where thicknesses exceed 2 ft 0 in., may be present but available information is too limited to permit estimates of reserves.

The Whitesburg bed is largely confined in occurrence to northeastern Breathitt County where its thickness ranges from less than 2 ft 0 in. to approximately 3 ft 6 in. Although persistent, it varies widely both in thickness and number of contained partings. Workable thicknesses range from 2 ft 9 in. to 3 ft 6 in. in the relatively limited areas of estimated reserves.

The Big Branch bed is a lenticular coal which thickens locally to as much as 3 ft 4 in. in east-central Breathitt County. Estimates of reserves are not justified by available information; the Big Branch coal is too limited in extent to warrant further consideration.

The Round Bar bed is another lenticular coal of limited extent in east-central Breathitt County. At one location, it is reported to occur as 0 ft 10 in. of coal immediately underlain by 2 ft 0 in. of cannel coal.

The Upper Elkhorn No. 3 bed has not been widely mined or prospected in Breathitt County; it appears to be limited in occurrence to the easternmost portions where it approximates 3 ft 0 in. in workable thickness. The bed is reported to decrease in thickness toward the west, even within its more persistent areas.

Clay County. (See Exhibit No. 5 for references below). Clay County, in the south-central portion of the Eastern Kentucky field, is near the central axis of the principal synclinal basin but minor undulations in structure occur in irregular pattern over the entire county. The coal beds and their associated strata generally dip at low rates from the northwest toward the southeast.

According to Bureau of Mines data on bituminous coal production in 1948 approximately 813,000 tons were produced in Clay County during that year, of which 103,000 tons were from 10 stripping operations. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates no production from railroad mines in Clay County during that year, although approximately 576,000 tons came from 32 truck mines, from beds variously designated as the "B", Hazard No. 4, Horse Creek, and No. 4 beds. Nevertheless, estimates of moderate amounts of reserves are confined to but two beds, the Fire Clay and the Upper Elkhorn No. 3
(Horse Creek). Ky

The Fire Clay coal horizon should underlie a strip 77b
along the eastern border of Clay County closely adjacent to occur- 78
rences of this same bed throughout Leslie County to the east. In 79a
Clay County, however, the Fire Clay bed is reported to range from
0 ft 6 in. to 4 ft 7 in. in thickness at scattered locations. 15
Available measurements on this bed in Clay County indicate greater 70021

(References: 15, 29, 39, 40, 62, 63)

variations in thickness and in number of contained partings than elsewhere in the Eastern Kentucky field. Broad areas cannot be estimated as underlain by a persistent bed. The thicknesses of the Fire Clay bed in the scattered areas of estimated reserves in eastern Clay County range from 2 ft 8 in. to 3 ft 10 in.

The Upper Elkhorn No. 3 bed, designated at truck mine operations in 1948 as the Horse Creek bed, persistently underlies several areas of moderate extent in west-central Clay County. It generally occurs as a relatively clean bed ranging up to 3 ft 7 in. in thickness and approximates 3 ft 3 in. in thickness within the areas of estimated reserves in Clay County.

Floyd County. (See Exhibit No. 5 for references below). Floyd County is located in the east-central portion of the Eastern Kentucky field and, in its northwestern portion, is crossed by the principal axis of the eastern Kentucky syncline. The coal measures in other portions of the county dip toward the synclinal axis at low angles somewhat modified by areas of irregular dips.

Bureau of Mines data on bituminous coal production for 1948 indicate that approximately 6,698,000 tons were produced from Floyd County in that year, all from underground operations; this production was the fourth largest production from an individual county within the field. The Kentucky Department of Mines and Minerals for 1948 reported a production of approximately 5,076,000 tons from 31 railroad mines and an additional 1,659,000 tons at 579 truck mines. The producing coal beds are variously designated as the Elkhorn Nos. 1, 2, and 3, the Millers Creek, the No. 4, the No. 4 Whitesburg, and the Whitesburg beds.

The nomenclature and correlations of coal beds in Floyd County are uncertain; local names are applied to the principal beds at many locations and the numbered Elkhorn beds occasionally are referenced to an immediate locality rather than on a county-wide basis. The presence of reserves suitable for further consideration is indicated in the Hazard, Flatwoods, Williamson, Upper Elkhorn Nos. 3, 2, and 1 and Lower Elkhorn beds (listed in descending order).

The Hazard bed outcrops near the center of the western and southwestern border line of Floyd County; reserves also extend into northwestern Floyd County from outcrops in southern Magoffin County to the west. The Hazard bed may also underlie the topographically higher portions of southern Floyd County although not reported in that area. The thickness of the Hazard bed in the relatively small area of estimated reserves along the Magoffin-Floyd County line ranges from 3 ft 9 in. to 4 ft 6 in.

(References: 6, 21, 39, 40, 62, 63)

The Flatwoods bed, or the Hazard No. 4 bed, occurs only near the summits of the highest ridges along the Floyd-Pike County line, the eastern boundary of Floyd County. Its thickness ranges from 3 ft 4 in. to 5 ft 3 in. at scattered points in small areas. Available information indicates the presence in Floyd County of only very limited reserves, which approximate 3 ft 4 in. in thickness.

The Williamson bed has been prospected only in the southern portion of Floyd County, where the total bed thickness ranges from 4 ft 10 in. to 6 ft 6 in.; the bed usually includes at least one parting which may range up to 1 ft 9 in. in thickness. There is a small area of estimated reserves in southern Floyd County, in which the thickness of the minable bench ranges from 2 ft 11 in. to 3 ft 11 in.

The Upper Elkhorn No. 3 bed outcrops widely in eastern, southern, and western Floyd County but is highly variable in total thickness, in number and thickness of clean coal benches, and in composition and thickness of contained partings. Individual coal benches and partings may thicken, thin, or disappear within short distances and without apparent pattern. Substantial reserves are present in which the thicknesses of workable coal benches range from 2 ft 6 in. to 4 ft 1 in.

The Upper Elkhorn No. 2 bed, or the Ivel bed, outcrops widely along the Floyd-Pike County line. Relatively substantial reserves extend westward from Pike County into southeastern Floyd County. Although frequently occurring in two benches separated by as much as 1 ft 0 in. of shale, the Upper Elkhorn No. 2 bed is relatively persistent in minable coal of thicknesses ranging from 2 ft 11 in. to 3 ft 6 in.

The Upper Elkhorn No. 1 bed, also widely called the Van Lear, Millers Creek, or Middle Creek bed, underlies extensive portions of Floyd County, where it commonly persists in thicknesses between 2 ft 6 in. and 5 ft 0 in. Reports of thicker coal occurrences range up to 8 ft 0 in. or more, although the bed generally contains one or more thick partings at such locations. There are substantial reserves in which the thickness of the minable bench or benches ranges between 2 ft 7 in. and 4 ft 4 in.

The Lower Elkhorn bed, also widely termed the Dwale, Syck, Warfield, or Freeburn bed, occurs persistently across the southern half of Floyd County. This bed, normally outcropping near the base of the deeper drainage channels, ranges from 2 ft 0 in. to approximately 4 ft 6 in. in thickness, with but one or two thin partings which only locally thicken to as much as 1 ft 0 in. Substantial areas exist in which the Lower Elkhorn bed ranges from 2 ft 9 in. to 3 ft 7 in. in thickness.

Harlan County. (See Exhibit No. 5 for references below). The southeastern boundary of Harlan County in the southeastern portion of the Eastern Kentucky field forms a part of the Kentucky-Virginia State line. The coal measures of Harlan County are divided into two distinct fields by the coal-barren front of the Pine Mountain overthrust extending in a northeast-southwest direction near the northwestern boundaries of Harlan County. The larger part of Harlan County, southeast of Pine Mountain, is synclinal in structure; coal beds dip toward the synclinal axis from both Pine Mountain and from Cumberland Mountain, which forms part of the southeastern boundary of the County. The smaller coal-bearing area northwest of the Pine Mountain fault is relatively flat in structure with a slight regional dip toward the northwest.

Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 11,710,000 tons were produced in Harlan County during that year, including 17,000 tons from two stripping operations. This was the second highest production from any individual county of Kentucky in 1948. The Kentucky Department of Mines and Minerals reported for 1948 production of approximately 11,025,000 tons in 55 railroad mines and an additional 362,000 tons from 60 truck mines. The producing coal beds are variously designated as the "A", "B", "C", Blue Gem, Bulldog, Creech, Darby, Dean, Harlan, High Cliff, High Splint, Imperial, Kellioka, Low Splint, Marker, Mason, No. 1, No. 2, No. 10, Splint, and Wallins beds. It is highly probable that many of these names result from local usage and actually represent a smaller number of principal beds. Available information indicates the presence of substantial reserves in beds herein designated, in descending order, as the High Splint, Hazard, Fire Clay Rider, Fire Clay, Williamson, Upper Elkhorn No. 3, Upper Elkhorn No. 2, and Harlan.

The High Splint bed, also known as the Hindman or
No. 9 bed, occurs in the higher ridges in the northeastern portion
of the Harlan County area southeast of Pine Mountain. The bed ranges
up to 7 ft 7 in. in total thickness, although the lower portion at
points of maximum thickness is usually unminable because of numerous
thin partings. Thicknesses of workable benches in the relatively
Ky large areas of estimated reserves range from 3 ft 5 in. to 6 ft 9 in.

The Hazard bed, sometimes also the No. 6 coal, is
82b limited to areas along the Harlan-Leslie County line northwest of
83 Pine Mountain, where it underlies a relatively limited area with an
84a average thickness of 3 ft 2 in.

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70021 (References: 1, 2, 5, 7, 37, 39, 40, 44, 62, 63)

The Fire Clay Rider bed likewise occurs only in a small area near the center of the Harlan-Leslie County line. It approximates 2 ft 6 in. in thickness.

The Fire Clay bed, also called the Wallins Creek bed, occurs in limited extent near the center of the Harlan-Leslie County line and also in small scattered areas southeast of Pine Mountain. While ranging up to as much as 9 ft 5 in. in total thickness, the bed is highly variable in thickness in southeastern Harlan County and usually contains two or more partings, ranging up to a maximum of 1 ft 11 in. in thickness, which may be sufficient in number to preclude the mining of either the upper or lower portions of the bed. Thicknesses of workable benches of the Fire Clay bed in the small, scattered areas of estimated reserves range from 2 ft 5 in. to 6 ft 2 in.

The Williamson bed, or the Low Splint or Mason bed, occurs in Harlan County only in small, scattered areas southeast of Pine Mountain, where it ranges from 2 ft 2 in. to 5 ft 4 in. in thickness and usually contains one or two thin partings. The largest individual area of estimated reserves occurs in northeastern Harlan County along the Kentucky-Virginia State line.

The Upper Elkhorn No. 3 bed, also widely known as the Kellioka, Taggart, or Darby bed, occurs throughout Harlan County southeast of Pine Mountain. As elsewhere in eastern Kentucky, this bed varies rapidly in thickness and composition; individual coal benches and intervening partings thicken, thin or disappear in relatively short distances without particular pattern ranging up to 10 ft 7 in. in maximum total bed thickness. The thicknesses of the minable portions of this bed in the substantial areas of estimated reserves range from 2 ft 10 in. to 4 ft 10 in.

The Upper Elkhorn No. 2 bed, otherwise also the Leonard or "B" bed, occurs at scattered locations in the northeastern portion of Harlan County southeast of Pine Mountain where it ranges up to a maximum thickness of approximately 8 ft 0 in. and generally contains two or more thin partings, of which one may occasionally thicken to as much as 1 ft 2 in. The thickness and frequency of the thin partings sometimes preclude the mining
of upper or lower portions of the thicker coal occurrences. The Ky
thicknesses of the Upper Elkhorn No. 2 bed in the scattered areas
of estimated reserves range from 2 ft 5 in. to 4 ft 1 in. 84b
85
The Harlan bed appears to occur at approximately 86a
the same stratigraphic position as the Upper Elkhorn No. 1 bed of
Floyd, Johnson, and Pike Counties but is separately designated as 15
the Harlan coal in Harlan and Bell Counties, where it has been 70021

widely mined. Occurring only southeast of Pine Mountain in Harlan County, the Harlan bed persistently underlies large areas in thicknesses ranging up to a maximum of 12 ft 4 in. At some locations, substantial thicknesses or portions of the bed are considered unminable because of the frequency and combined thickness of contained partings, although these are generally less than 6 in. in individual thickness. Thicknesses of workable benches of the Harlan bed in the substantial areas of estimated reserves in Harlan County range from 3 ft 1 in. to 4 ft 2 in.

Johnson County. (See Exhibit No. 5 for references below). Johnson County, in the northeastern portion of the Eastern Kentucky field, is in approximately the center of the eastern Kentucky syncline. A persistent upfold crossing the center of Johnson County in an east-west direction, however, somewhat modifies the regional structure of the Eastern Kentucky field in this area, resulting in variations in direction of dip of the coal beds but not in sufficient degree to interfere with mining operations. Structure of the coal beds is further modified at the northwestern corner of Johnson County by additional minor reversals of the general synclinal structure.

The Bureau of Mines data on bituminous coal production in 1948 report approximately 956,000 tons produced in Johnson County during that year, all from underground operations. The Kentucky Department of Mines and Minerals for 1948 reports approximately 326,000 tons produced from three railroad mines and an additional 502,000 tons from 225 truck mines. Such production was principally from the Millers Creek bed; minor amounts were from the Millers Creek No. 1, No. 3, and the Lower Elkhorn beds. Although there are one or two beds above and below the Upper Elkhorn No. 1 bed, available information is sufficient to establish estimates of reserves for only the latter bed.

The Upper Elkhorn No. 3 bed, also tentatively designated the Kellioka "C" bed, has been locally mined at scattered locations in southern Lawrence County near the Johnson Lawrence County line but is reported to become highly irregular in thickness and content of partings within Johnson County.

One or two coal horizons sometimes designated as the No. 4 or No. 2 beds are also present in northeastern Johnson and southern Lawrence County, where they frequently occur as cannel coals. While known to be present at widely scattered points, estimates of reserves are not warranted; these beds vary too widely in thickness and continuity to merit further consideration.

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86b
87a
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70Q21

(References: 6, 21, 39, 40 62, 63)

The Upper Elkhorn No. 1 bed, also widely known as the Millers Creek bed, underlies nearly the entire southern half of Johnson County with an average thickness of approximately 3 ft 6 in. In Johnson County, this bed is highly persistent in thickness and in quality; only one or two thin partings occur in relatively limited areas. The thickness of the Upper Elkhorn No. 1 bed in the substantial areas of estimated reserves in Johnson County ranges from 2 ft 10 in. to 3 ft 11 in.

A coal horizon stratigraphically lower than the Upper Elkhorn No. 1 bed occurs in limited extent near the north western corner of Johnson County with a reported average thickness of 1 ft 8 in., too thin to warrant further consideration.

Knott County. (See Exhibit No. 5 for references below). In Knott County, near the center of the southeastern limb of the principal eastern Kentucky syncline, the coal beds and their associated strata in the main dip toward the northwest at low angles. The regional dip is slightly modified in the northwestern part of the county by minor local folding.

As shown in Bureau of Mines data on bituminous coal production in 1948 approximately 1,175,000 tons were produced in Knott County during that year, of which 7,000 tons were from two stripping operations. The Kentucky Department of Mines and Minerals reported for 1948 that approximately 928,000 tons were produced from 6 railroad mines in Knott County and an additional 335,000 tons from 144 truck mines. Such production was from coal beds variously designated as the Elkhorn Nos. 1, 2, and 3 beds, the Nos. 3, 4, 7, and 9 beds, and the Hazard No. 4, Hindman, Hindman No. 4, Whitesburg, and Whitesburg No. 9 beds. It is highly probable that there is duplication of beds in the above separate designations which may actually represent only a limited number of principal beds. There are relatively substantial reserves in what are herein designated, in descending order, as the Flag, Hazard, Fire Clay, Whitesburg, Williamson, Upper Elkhorn No. 3, Upper Elkhorn No. 1, and Lower Elkhorn beds.

The Flag bed occurs in southwestern Knott County, where it generally persists as a clean coal ranging up to 5 ft 0 in. in thickness with but a few areas containing lenticular partings of a maximum thickness of 1 ft 0 in. Thicknesses of the Flag bed in the relatively small, scattered areas of estimated reserves range from 2 ft 3 in. to 4 ft 6 in.

(References: 6, 15, 21, 39, 40, 62, 63)

The Hazard bed, also sometimes designated as the No. 6 bed, outcrops along the western border of Knott County. It occurs usually only as a horizon marker with thicknesses of but a few inches. The bed thickens locally, however, to a maximum of nearly 7 ft 0 in. in relatively limited scattered areas. The thicknesses of the Hazard bed in three such areas of estimated reserves in Knott County range from 3 ft 3 in. to 3 ft 8 in.

The Fire Clay bed, or the Dean bed, persistently underlies southern Knott County and is also present in the central and northern parts. Only limited information is available on occurrences of this bed in the central and northern portions of the county; larger reserves might be found by further investigation. In southern Knott County, the Fire Clay bed generally persists in workable thicknesses although in some areas it contains too many thin partings to permit mining activities. Over large portions of its total known area, however, the bed commonly contains up to 4 ft 0 in. of workable coal benches although additional upper or lower thicknesses may contain sufficiently frequent thin partings to preclude mining of such portions. The thicknesses of persistent and workable benches of the Fire Clay bed in the substantial areas of estimated reserves in southern Knott County range from 2 ft 5 in. to 3 ft 9 in.

The Whitesburg bed occurs only in limited scattered areas in southern Knott County where it ranges from less than 1 ft 0 in. to 3 ft 8 in. in thickness. There is sufficient information to indicate limited reserves of inferred classification, in which the bed thicknesses range from 2 ft 7 in. to 3 ft 3 in.

The Williamson bed, also called the Amburgy bed, is generally limited in occurrence to the southern portion of Knott County near the Knott-Letcher County line. There it consists of a principal bench about 3 ft 0 in. thick, underlain or overlain by irregular thicknesses of laminated coal and shale. The principal bench occasionally thins to as little as 0 ft 10 in. There is only a limited area of reserves in the Williamson bed in southern Knott County.

The Upper Elkhorn No. 3 bed outcrops extensively and has been widely mined across eastern Knott County where it ranges between 1 ft 7 in. and 7 ft 0 in. in thickness but more commonly persistently averages 4 ft 1 in. in thickness. Estimates of substantial reserves of the Upper Elkhorn No. 3 bed are warranted, both along outcrops within Knott County and as extensions of reserves from outcrops in the adjoining portion of Floyd County. These reserves range from 2 ft 7 in. to 5 ft 0 in. in thickness.

The Upper Elkhorn No. 1 bed outcrops persistently along the Knott-Floyd County line. Relatively substantial reserves are present in eastern Knott County, ranging in thickness from 3 ft 6 in. to 4 ft 4 in.

The Lower Elkhorn bed underlies substantial areas in eastern Knott County adjacent to the Knott-Floyd County line. Although apparently thinning to the west and south, this bed is persistent within its area of principal occurrence, where it ranges from 2 ft 4 in. to 3 ft 7 in. in thickness. While generally reported to contain one or two shale partings, these do not appear to exceed 0 ft 3 in. in individual thickness.

Knox County. (See Exhibit No. 5 for references below). In Knox County, in the southern portion of the Eastern Kentucky field, the principal axis of the eastern Kentucky syncline extends in a northeast-southwest direction across the approximate center of the county. The breadth of the Eastern Kentucky field diminishes from the northeast toward the southwest, so that the northwestern and southeastern borders of the field in Knox County are closer to the central axis of the syncline than in areas to the north. The extreme southern corner of Knox County, in fact, is bounded by the coal-barren front of the Pine Mountain overthrust. In conformance with this regional position, the coal beds of Knox County dip inward from the northwestern and southeastern parts of the county, although the regional dips are somewhat modified by additional moderate folding of limited extent and degree.

Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 1,008,000 tons were produced in Knox County during that year, of which 178,000 tons were from two stripping operations. The Kentucky Department of Mines and Minerals reported for 1948 approximately 411,000 tons produced at 5 railroad mines in Knox County in that year and an additional 609,000 tons at 123 truck mines. The producing coal beds are the Blue Jim, Dean, Fisher, Jellico, Straight Creek, and a stray bed.

The available information on coal bed occurrences in Knox County is highly limited; scattered data from records of mining operations, which indicate the probable presence of coal beds, are sufficient only to show the presence of moderate reserves in the Fire Clay bed in Knox County. Ky

The Fire Clay bed, or the Dean coal, underlies a 90b
moderate area at the extreme southern corner of Knox County, 91
where it approximates 3 ft 6 in. in thickness. 92a

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(References: 15, 19, 30, 39, 40, 62, 63) 70021

The Jellico bed, considered as correlated with the Upper Elkhorn No. 1 bed and also sometimes called the Straight Creek bed, provides both underground and strip production in the westernmost corner of Knox County. Available information is too limited to permit estimates of reserves.

The Blue Gem bed, correlated with the Lower Elkhorn bed and also called the Dean or Blue Jim, is mined by trucking operations at a number of scattered points in Knox County. Available information is too limited to permit estimates of reserves.

Leslie County. (See Exhibit No. 5 for references below). The coal beds of Leslie County, near the center of the southeastern flank of the principal eastern Kentucky syncline, generally dip toward the northwest at moderate rates, locally modified in direction by additional local folding. A few dips of up to 6 degrees close to the axes of such additional folds are minor and local in extent.

Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 1,073,000 tons were produced in Leslie County during that year, all from underground operations. The Kentucky Department of Mines and Minerals reported for 1948 that there was no production in that year from railroad mines but that there was a production of approximately 929,000 tons from 47 truck mines working in coal beds variously designated as the Hazard No. 4, Hazard No. 7, and No. 4 beds.

Of the 10 coal beds for which information is available in Leslie County, 5 were found to be suitable for further consideration for the production of synthetic liquid fuels. The following classification, in descending stratigraphic order, indicates the suitability or non-suitability of each bed examined in this survey.

Suitability of Leslie County Coal Beds for Synthetic Liquid Fuels Plant Supply

Coal Bed	Suitable	Non-Suitable
Helton		x
Hindman		x
Flag		x
Hazard	x	
Haddix		x
Hamlin		x
Fire Clay Rider	x	
Fire Clay	x	
Whitesburg	x	
Williamson	x	

Ky
92b
93
94a
15
70021

(References: 39, 40, 62, 63)

The Helton bed, of uncertain stratigraphic correlation, occurs near the summits of the highest hills and divides at scattered locations in southern Leslie County. At such locations, the bed ranges up to 6 ft 2 in. in total thickness but is generally divided into two or more benches by numerous shale partings so that the thickness of the minable bench or benches rarely exceeds 4 ft 0 in. Information available is too limited to permit estimates of reserves and the areas underlain by the Helton bed are too limited to require further consideration.

The Hindman bed occurs at high topographic elevations in the northern part of the county where individual areas of occurrence are too limited to warrant further consideration. The bed is reported to range from 3 ft 7 in. to as much as 9 ft 2 in. in total thickness but usually contains one or more shale partings of varying thicknesses which reduce the minable thickness to 4 ft 6 in. or less. The middle bench of this bed is occasionally reported as a splint coal.

The Flag bed has been found by limited prospecting at scattered locations in central Leslie County. Scattered measurements indicate a range of from 3 ft 0 in. to 5 ft 10 in. in thickness. At all such points of measurements, the coal contains two or more partings individually ranging up to 0 ft 9 in. in thickness. A single measurement in southern Leslie County indicates that the Flag bed there splits into two thin benches measuring but 0 ft 7 in. and 0 ft 10 in., separated by 14 ft 0 in. of shale and sandstone.

The Hazard bed, or the No. 6 coal, has been widely reported across southeastern Leslie county but at points of observation generally too far apart to permit estimates of substantial reserves. Thicknesses of the Hazard bed in the small scattered areas of estimated reserves in eastern Leslie County range from 2 ft 3 in. to 3 ft 8 in.; such measurements indicate frequent occurrence of one or more partings, which range up to 0 ft 8 in. in individual thickness.

The Haddix bed occurs in Leslie County mainly as a horizon marker; thicknesses are generally less than 1 ft 8 in. A reported measurement of 5 ft 11 in. total thickness at one location in southeastern Leslie County is probably of a local pocket too limited in extent to warrant further consideration. At this
location, an upper bench 1 ft 3 in. thick is separated by a 1 ft Ky
8 in. shale parting from a lower bench 3 ft 0 in. thick.

94b

The Hamlin bed, of uncertain stratigraphic correla- 95a
tion, has been reported at a few scattered locations in southern
Leslie County. This bed is largely composed of thin benches, 15
separated by numerous partings of irregular and varying thickness. 70021

The Fire Clay Rider bed underlies a moderate area in east-central Leslie County in workable thickness; there are indications of numerous other minor occurrences in other parts of the county. This bed is characterized by numerous partings; the workable coal thickness rarely exceeds 3 ft 6 in. and frequently is less than 2 ft 3 in. Thicknesses in the numerous and scattered areas of estimated reserves in Leslie County range from 2 ft 1 in. to 3 ft 10 in.

The Fire Clay bed, or the No. 4 coal, outcrops widely in a general east-west direction across the center of Leslie County and also appears in a number of scattered locations in the southern part of the county. While persistent in occurrence, its thickness decreases to less than 2 ft 0 in. at a number of locations; numerous local mining operations in this coal are largely confined to lenticular areas in which the bed may range up to 4 ft 0 in. in thickness. Occasional measured sections of coal, ranging up to 5 ft 7 in. in thickness, usually show the presence of numerous thin shale partings which preclude the mining of at least portions of the bed.

The Whitesburg bed is found only in deeper portions of the drainage channels at a few scattered locations in Leslie County; it ranges from 1 ft 6 in. to as much as 4 ft 0 in. in thickness. It is characterized in its southern occurrences by the presence of numerous thin shale partings, sufficient in number and frequency at some locations to prevent mining operations. The thicknesses of the Whitesburg bed in the relatively limited areas of estimated reserves in Leslie County range from 2 ft 4 in. to 3 ft 10 in.

The Williamson bed, or the Amburgy bed, appears above drainage at only one moderate area in north-central Leslie County. There, the bed ranges from 2 ft 2 in. to as much as 4 ft 10 in. in thickness, and commonly contains one or two shale partings ranging from 1 to 4 inches in thickness. The bed decreases in average thickness toward the south.

Letcher County. (See Exhibit No. 5 for references below). Letcher County, along the southeastern border of the Eastern Kentucky field, contains coal measures divided by the Pine Mountain overthrust into two, greatly unequal portions. Approximately the northeastern half of the southeastern boundary of Letcher County is formed by Pine Mountain. This boundary, however, thence swings
Ky southward from Pine Mountain to enclose a small coal basin to the southeast in the south-central part of the county. This area is some-
95b times called Poor Fork basin and represents the northeastward exten-
96 sion of the Middlesboro syncline of southeastern Bell and Harlan
97a Counties. The coal beds and their associated strata northwest of

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70021 (References: 1,2,6,9,10,20,21,27,35,37,39,40,62,63)

Pine Mountain dip at gentle rates toward the northwest interrupted by a few minor modifications due to local folding extending northwestwards from Pine Mountain.

According to Bureau of Mines data on bituminous coal production in 1948 approximately 10,385,000 tons were produced in Letcher County during that year, including 207,000 tons from three stripping operations. This is the third highest production from an individual county in eastern Kentucky. The Kentucky Department of Mines and Minerals reports for 1948 that approximately 3,364,000 tons were produced from 17 railroad mines in Letcher County during that year and an additional 7,476,000 tons from 801 truck mines. The coal beds worked for such production are variously designated as the "A", "B", "C", Amburgy, Darby "B", Elkhorn, Elkhorn No. 3, Elkhorn No. 4, Fire Clay, Hazard No. 4, Mizpah, Shelby Gap, and Whitesburg beds.

There are substantial reserves in one or both portions of the areas northwest and southeast of Pine Mountain in beds designated, in descending order, as the Fire Clay, Whitesburg, Williamson, Upper Elkhorn No. 3, Upper Elkhorn No. 2, Upper Elkhorn No. 1, and Lower Elkhorn beds. Other coal horizons, also present in Letcher County, are included in the following descriptions of all of the coal beds for which information is available.

The Flag bed occurs only in northwestern Letcher County where minor areas underlie a few high divides.

The Haddix bed, also commonly called the Pardee or Limestone coal, occurs in the highest portions of the hills southeast of Pine Mountain in southern Letcher County. There are generally two thin benches varying up to 30 feet in vertical separation. The limited available information suggests that reserves of this bed are too limited to warrant further consideration.

The Fire Clay bed, also known as the No. 4 or Dean coal, outcrops widely along the northwestern borders of Letcher County. It is persistent in continuity, ranging from 2 ft 6 in. to as much as 6 ft 3 in. in thickness. Although there are commonly one or two partings ranging up to 4 in. in individual thickness, the Fire Clay bed contains substantial reserves. The Fire Clay horizon is also present in southern Letcher County southeast of Pine Mountain but there it is too thin and contains too many thin Ky
partings to warrant further consideration.

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The Whitesburg bed occurs only in the area northwest 98
of Pine Mountain where it is persistent in stratigraphic position

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but varies widely in thickness from only a few inches to as much as 5 ft 0 in. It frequently carries numerous partings which reduce the workable thicknesses of the coal benches and the extent of apparent reserves. Thicknesses of the Whitesburg bed in the relatively small and scattered areas of estimated reserves in Letcher County range from 2 ft 11 in. to 4 ft 4 in.

The Williamson bed, sometimes also termed the Amburgy bed and frequently the Low Splint bed in the area southeast of Pine Mountain, occurs in moderate areas in both sections of Letcher County. In both, the bed contains numerous thin partings, one or more of which occasionally thicken to as much as 1 ft 2 in. The number and frequency of the partings are sufficient to prevent consideration as synthetic liquid fuels plant supply over substantial areas. Thicknesses of this bed in the scattered areas of estimated reserves in both portions of Letcher County range from 2 ft 8 in. to 4 ft 4 in.

The Upper Elkhorn No. 3 bed, or the Taggart bed in the area southeast of Pine Mountain, underlies substantial areas in both sections of Letcher County. In northern Letcher County, it characteristically occurs as two persistent benches separated by a vertical interval of as much as 30 feet, which in some areas so decreases in thickness that both benches can be mined as a single bed. The more persistent lower bench also contains a thin parting which may in places range up to as much as 3 ft 0 in. in thickness. A similar multiple-bench occurrence is found in the area southeast of Pine Mountain, where the upper and lower benches are also sometimes designated as the "D" and "C" beds, respectively. The thicknesses of the Upper Elkhorn No. 3 bed in the substantial areas of estimated reserves in both portions of Letcher County range from 2 ft 5 in. to 5 ft 0 in.

The Upper Elkhorn No. 2 bed, sometimes designated as the Collier bed in southern Letcher County, is not as widespread in occurrence as the No. 3 bed and appears in minable thickness only in the northeastern part of the county and at the extreme southern corner, south of Pine Mountain, where it represents a northeastward extension of the same bed from northeastern Harlan County. Limited information indicates the presence of moderate reserves in these two areas in which the bed thickness ranges from 3 ft 3 in. to 5 ft 5 in.

The Upper Elkhorn No. 1 bed occurs in Letcher County in minable thickness only in small areas southeast of Pine Mountain where the thickness in the limited areas of estimated reserves ranges from 3 ft 0 in. to 4 ft 3 in. The horizon of the Upper Elkhorn No. 1 bed in northern Letcher County contains thin coal benches and shale partings which may attain a total thickness of as much as 4 ft 2 in. but in which the thickness of the minable coal benches is generally less than 2 ft 0 in.

The Harlan bed of southeastern Harlan County probably extends into Letcher County southeast of Pine Mountain; available information is too limited to permit estimates of reserves.

The Lower Elkhorn bed, or, in southern Letcher County, Imboden coal, occurs only southeast of Pine Mountain and in the extreme northeastern corner of Letcher County, where it is adjacent to substantial reserves of the same bed in southeastern Pike County. Its widespread occurrence southeast of Pine Mountain is characterized by two principal benches separated by a shale parting, which ranges up to 30 feet in vertical thickness. One or both of the coal benches are generally persistent in an average thickness of approximately 3 ft 6 in. In northeastern Letcher County, the Lower Elkhorn bed, occurring only near drainage level, ranges from 2 ft 9 in. to 3 ft 0 in. in thickness.

Magoffin County. (See Exhibit No. 5 for references below). Magoffin County, in the northeast-central portion of the Eastern Kentucky field, is crossed in its southeastern corner by the principal synclinal axis of the basin extending approximately northeast-southwest. The coal beds over most of the county consequently dip toward the southeast at moderate rates with local modifications in direction and degree of dip due to irregular and minor associated folding. In the northwestern portion of the county, the coal beds have been gently uplifted along a broad anticline, with which are associated two nearly east-west faults with vertical displacements ranging from 40 to 140 feet. The principal coal occurrences of Magoffin County are southeast of the faulted area.

Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 165,000 tons were produced in Magoffin County during that year, including 43,000 tons from one stripping operation. The Kentucky Department of Mines and Minerals reported for 1948 production of approximately 62,000 tons from 1 railroad mine and an additional 109,000 tons from 66 truck mines. The coal beds worked are variously designated as the Elkhorn No. 3, Hazard No. 4, Hindman, Millers Creek, No. 7, and "Cannel" beds. Moderate amounts of reserves exist in beds designated, in descending order, as the Hazard, Haddix, Fire Clay, Whitesburg, Upper Elkhorn No. 3, and Upper Elkhorn No. 1. Available information on Magoffin County coal beds does not indicate the presence of the Hindman coal, reported to have been mined in 1948.

The Hazard bed outcrops widely in and underlies substantial portions of southeastern Magoffin County where it has been opened in numerous mining operations. The bed appears to become thin and inferior in quality toward the north and west. In southeastern Magoffin County, however, it ranges from 2 ft 6 in.

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(References: 14, 31, 39, 40, 62, 63) 70021

to 6 ft 2 in. in normal thickness, with scattered measurements of as much as 9 ft 7 in. at a few locations where there are numerous thin partings. In normal development, the bed has at least one parting and more frequently contains unminable upper or lower benches due to numerous thin partings. The thicknesses of the minable coal benches in the relatively substantial areas of estimated reserves in Magoffin County range from 2 ft 9 in. to 4 ft 6 in.

The Haddix bed occurs largely as a horizon marker less than 2 ft 0 in. in thickness in southeastern Magoffin County, but thickens to a maximum of 3 ft 3 in. in a few scattered and relatively limited areas, usually containing benches of splint or cannel coal.

The Fire Clay bed, or the Hazard No. 4 bed, occurs in only a few scattered areas in the south-central portion of Magoffin County where it approximates 3 ft 0 in. in thickness. It usually contains at least one shale parting, which may range up to 5 inches in thickness.

The Whitesburg bed appears, from a few scattered points of observation, to underlie limited areas in central Magoffin County and near the center of the Magoffin-Breathitt County line, ranging from 2 ft 4 in. to 3 ft 6 in. in thickness. At some locations, the bed is reported to contain a single parting ranging up to 1 ft 0 in. in thickness.

The Upper Elkhorn No. 3 bed, possibly confused at some points with the overlying Whitesburg bed, is reported at only a few scattered and limited areas in southeastern Magoffin County, where it ranges from 2 ft 8 in. to 3 ft 0 in. in thickness.

The Upper Elkhorn No. 1 bed outcrops east of Magoffin County in southwestern Johnson and western Floyd Counties. It is persistent in thickness and continuity a short distance east of the eastern boundary of Magoffin County; relatively substantial areas of estimated reserves extend westward from their outcrops into eastern Magoffin County. The thicknesses of the Upper Elkhorn No. 1 bed within the two areas of estimated reserves in Magoffin County range from 2 ft 6 in. to 3 ft 8 in.

Martin County. (See Exhibit No. 5 for references below). Martin County, near the center of the northeastern boundary of the Eastern Kentucky field, has a northeastern boundary which forms a part of the Kentucky-West Virginia State line along Tug Fork of Big Sandy River. The coal beds and their associated strata are relatively flat-lying, conforming in direction and amount of dip with irregular arches and basins which extend across the county in varying patterns.

(References: 6, 21, 38, 39, 40, 62, 63)

Bureau of Mines data on bituminous coal production in 1948 show that approximately 430,000 tons were produced in Martin County during that year, all from underground operations. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates that approximately 372,000 tons were produced from 2 railroad mines in Martin County during that year and an additional 60,000 tons came from 19 truck mines. The producing coal beds are the Coalburg, Warfield, and Winford. Three or four poorly correlated coal horizons appear in Martin County, in two of which estimates of relatively small amounts of reserves have been established. In this report, these beds are termed, in descending order, the Flatwoods and Lower Elkhorn beds.

A series of five beds, present in western Martin County, are locally designated, in descending order, as beds "F" to "B", inclusive. Correlations have not been made either within the area of their occurrence, or with the principal coals of the Eastern Kentucky field. Each of the five beds has been reported in thicknesses ranging up to 4 ft 0 in. or more, but available information suggests them to be lenticular in occurrence and usually to contain a number of shale partings of varying thicknesses. Reported measurements are too widely scattered to permit estimates of reserves.

<u>The Flatwoods bed</u> of northern Pike County extends northward a short distance into the extreme southeastern corner of Martin County, with an average thickness of 3 ft 10 in. It is not known whether this bed may be equivalent to one of the lettered beds described above.

One of the lower lettered beds is sometimes also called the Warfield bed, in which case it could be correlated as the <u>Lower Elkhorn coal.</u> At a few scattered locations in southeastern Martin County, this bed ranges up to 5 ft 0 in. in total thickness and usually contains one or more partings of irregular thickness. The thicknesses of the Lower Elkhorn bed in the scattered areas of estimated reserves in Martin County range from 2 ft 8 in. to 5 ft 0 in.

<u>Perry County.</u> (See Exhibit No. 5 for references below).
Perry County, near the center of the southeastern limb of the
principal Eastern Kentucky field syncline, has its northern bound-
ary approximately along the axis of the syncline. In this regional Ky
position, the coal beds of Perry County dip gently toward the
northwest, being slightly modified in direction of dip along a 1031
local uplift which extends in a northwest-southeast direction along 104
the eastern line of the county. 105

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(References: 15, 32, 39, 40, 62, 63) 70021

Bureau of Mines bituminous coal production data for 1948 show production of approximately 6,685,000 tons in Perry County, including 139,000 tons from one stripping operation. The Kentucky Department of Mines and Minerals reported for 1948 production of approximately 5,548,000 tons from 28 railroad mines in Perry County and an additional 698,000 tons from 140 truck mines. This coal was from beds variously designated as the Hazard Nos. 4, 5A, 6, 7, 9, and the Leatherwood. In this report, the Hazard Nos. 9, 7, 6, 5A, and 4 beds are correlated in descending order as the Hindman, Flag, Hazard, Haddix, and Fire Clay beds. There are relatively substantial reserves in all except the Hindman bed, and additional limited reserves in the underlying Whitesburg bed. The Leatherwood bed, from which some 1948 production was reported, appears to occur between the Hazard and Haddix beds.

The Hindman (Hazard No. 9) bed, also called the High Splint bed, is reported mined in two small areas in western and northwestern Perry County, in a thickness of 5 ft 6 in. Stratigraphically, the Hindman bed probably occurs only near the summits of the higher ridges and divides. Available information is insufficient to permit estimates of reserves.

The Flag (Hazard No. 7) bed outcrops persistently across the center of Perry County and ranges up to 7 ft 3 in. in thickness. Over much of the area, the Flag bed persists in thicknesses between 4 ft 0 in. and 5 ft 0 in., with rarely more than one or two thin partings. The stratigraphic position of the Flag bed is such that it occurs generally near the summits of the higher ridges and divides, which topographic distribution results in separation of the bed into individual areas formed by the drainage pattern of the county. The thicknesses of the Flag bed in the scattered, but relatively large areas of estimated reserves in Perry County, range from 2 ft 3 in. to 5 ft 0 in.

The Hazard (Hazard No. 6) bed is widespread in occurrence throughout Perry County but varies widely in total thickness and in number and individual thickness of contained partings. In general, the bed is thicker, more persistent, and contains fewer partings in the northern than in the southern part of the county.
Ky Separated into numerous areas of varying extent by the drainage
pattern of the county, substantial reserves of the Hazard bed
105b exist in thicknesses ranging from 3 ft 2 in. to 5 ft 3 in.

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107a The Haddix (Hazard No. 5) bed is reported at a number
of scattered locations in northern Perry County to be from less than
15 2 ft 0 in. to as much as 5 ft 5 in. thick. The bed commonly contains
70021 at least one parting which ranges up to 6 inches in thickness.
Southward from these reported areas, available information is limited

but indicates that the principal parting thickens to at least 1 ft 0 in., separating the bed into two thin, unworkable benches. Measurements of the Haddix bed in the scattered areas of estimated reserves in Perry County range from 2 ft 8 in. to 4 ft 6 in.

The Fire Clay (Hazard No. 4) bed outcrops widely throughout Perry County except in the northeastern corner, where it thins as it passes below drainage level. Elsewhere, the bed is persistent in general continuity and thickness, ranging from 1 ft 10 in. to as much as 5 ft 8 in. The Fire Clay bed frequently contains at least one parting which, although generally less than 6 inches thick, may increase to as much as 11 inches within relatively limited areas. Thicknesses of the Fire Clay bed in the substantial areas of estimated reserves in Perry County range from 2 ft 5 in. to 3 ft 11 in.

The Whitesburg bed is generally below drainage level in southern Perry County and occurs usually only as a horizon marker with thicknesses rarely exceeding 1 ft 10 in. in the north. The bed appears to range from 1 ft 10 in. to 2 ft 9 in. in thickness within a limited area in northwestern Perry County, which it is estimated contains a small amount of inferred reserves approximating 2 ft 5 in. in thickness.

Pike County. (See Exhibit No. 5 for references below). Pike County, at the easternmost corner of the Eastern Kentucky field, has a northeastern boundary forming a part of the West Virginia-Kentucky State line; on the southeast, the county adjoins Buchanan and Dickenson Counties of Virginia. The regional geological structure of the Pike County coal beds exhibits a gentle northwestern dip toward the principal axis of the Eastern Kentucky syncline. This prevailing dip is modified in both direction and degree, however, by several irregular folds, one of which crosses the approximate center of the county in a generally southwest-northeast direction. Deformation resulting from such accessory folding is in no place sufficient to interfere with mining operations.

Bureau of Mines data on bituminous coal production in 1948 indicate production of approximately 11,955,000 tons in Pike County during that year, the largest production of any individual county in eastern Kentucky, exceeded in western Kentucky only by production from Hopkins County. Approximately 258,000 tons were reported by the Bureau of Mines to have been produced in five strip
mines in Pike County during 1948. The Kentucky Department of Mines Ky
and Minerals reported for 1948 that approximately 8,371,000 tons
came from 43 railroad mines in Pike County during that year and an 107
additional 3,798,000 tons from 918 truck mines. The coal beds from 108

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(References: 6,9,10,13,20,21,35,39,40,46,62,63) 7002 which the above productions were obtained are:

Producing Coal Beds of Pike County, Kentucky

Alma	Flatwoods
Alma No. 12	Freeburn
Cedar Grove	Gem, Lower
Clintwood	Millers Creek
Elkhorn No. 1	Pond Creek
" No. 2	Shelby Gap
" No. 3	Splash Dam
" No. 3-1/2	Thacker
" No. 4	Warfield
" No. 5	Whitesburg
Elkhorn, Lower	Winford
Ellswick	Winifrede
Feds Creek, Upper	

Pike County is reported to contain at least 12 principal coal beds and as many as 48 other coal horizons, any of which may become minably thick in local areas. They are contained in a vertical section approximately 2,500 feet thick, of which about 1,000 feet lie below drainage level over portions of the county. The nomenclature and correlations of the numerous coals in Pike County are highly uncertain, partly because of the area involved (Pike County being the largest county in the entire State) and partly because of the lack of over-all correlations between the areas studied by various investigators. The Bureau of Mines is currently engaged in preparing a comprehensive survey of coal occurrences in Pike County but results are not yet available. Many of the bed names reported by the local operators have been carried over into Pike County from adjoining portions of West Virginia and Virginia. Substantial coal reserves exist in beds designated, in descending order, as Flatwoods, Taylor, Fire Clay, Williamson, Upper Elkhorn Nos. 3, 2, 1, Lower Elkhorn, Bingham, and Millard.

The Flatwoods bed occurs only near the summits of the highest ridges and divides in northern and western Pike County where it ranges from 3 ft 0 in. to 6 ft 0 in. in thickness. Although thus divided into many separate areas of varying sizes according to the drainage pattern, available information indicates relatively substantial reserves of this coal in Pike County.

The Taylor bed, not elsewhere recognized in Eastern Kentucky, occurs in the upper portions of the highest ridges in northern and southeastern Pike County, where it ranges up to 4 ft 2 in. in thickness. While commonly containing but one or two thin partings, the bed is locally separated into two benches by a lenticular shale parting which may attain a maximum thickness of 2 ft 0 in. Measurements of the Taylor bed in the scattered areas of estimated reserves in Pike County range from 2 ft 5 in. to 4 ft 2 in.

The Fire Clay bed, of occasionally doubtful relationships with the overlying Taylor and the underlying Williamson beds, appears to occur across an extensive area in northwestern Pike County, in which total bed thicknesses range up to 6 ft 0 in. or more. As elsewhere in eastern Kentucky, the Fire Clay bed commonly contains numerous thin partings which, in places, are sufficiently close together to preclude mining of all or portions of the total bed. Measurements of workable benches of the Fire Clay bed in the substantial areas of estimated reserves in Pike County range from 2 ft 6 in. to 4 ft 1 in.

The Williamson bed approximates 4 ft 0 in. in thickness over substantial portions of northern Pike County, thinning southwards toward an area in central Pike County for which little information is available. The bed also decreases markedly in thickness toward the southwest, where it thins to less than 2 ft 0 in. or contains numerous thin partings sufficient in number and frequency to preclude mining operations. The Williamson bed is relatively persistent within its principal areas of occurrence, normally containing but a single shale parting which ranges up to 4 inches in thickness. Thicknesses of the Williamson bed in the relatively substantial areas of estimated reserves in Pike County range from 2 ft 0 in. to 4 ft 9 in.

The Upper Elkhorn No. 3 bed, correlated with the Cedar Grove bed of West Virginia, occurs at numerous scattered locations in north-central and western Pike County. While persistent in occurrence, this bed varies widely in number and thickness of individual coal benches and partings which may thicken, thin, or disappear within relatively short distances and without particular pattern. A large proportion of the reported measurements indicate the presence of two or more partings, one of which may range up to as much as 4 ft 4 in. in thickness; only one bench is of minable thickness at locations of such thick partings. The thicknesses of the minable benches of the Upper Elkhorn No. 3 bed in the many scattered areas of estimated reserves in Pike County range from 2 ft 3 in. to 6 ft 1 in.

The Upper Elkhorn No. 2 bed occurs widely throughout most of Pike County; the larger individual areas of coal occurrence become more numerous toward the northwest and west in conformance with the structure and topography of the area. The stratigraphic horizon of this bed is too high to appear in any but the highest ridges and divides in the eastern part of the county. The Upper Elkhorn No. 2 bed is highly irregular in total thickness and in number and thickness of individual coal benches and partings. These components of the total bed may thicken, thin, or disappear within relatively short distances and without apparent pattern. The bed has been widely opened by both railroad and truck mines, each of such operations being located in the better portions of the bed within the areas of such activities. There are substantial reserves of the Upper Elkhorn No. 2 bed in Pike County in which the thicknesses of the minable benches range from 2 ft 2 in. to 6 ft 1 in.

The Upper Elkhorn No. 1 bed, or the Millers Creek bed correlated with the Alma bed of West Virginia, outcrops widely in and underlies substantial portions of eastern and southeastern Pike County. The bed dips gently under drainage levels toward the north and northwest. Although persistent in thickness and character over substantial areas, the bed varies somewhat in thickness and in content of partings on a regional basis. In some areas, for example, the bed ranges up to 6 ft 0 in. in thickness without significant partings. In other areas, the upper or lower portions of the bed consist of laminated bone or shale and coal which reduce the thickness of the workable coal. In still other areas, the bed may consist of three benches ranging in individual thickness from 1 ft 0 in. to 1 ft 8 in., with two intervening partings ranging up to 2 ft 6 in. in thickness. The thicknesses of the workable coal benches in the substantial areas of estimated reserves of the Upper Elkhorn No. 1 bed in Pike County range from 2 ft 4 in. to 5 ft 1 in.

The Lower Elkhorn bed, also called the Pond Creek, Freeburn, Warfield, or Shelby Gap bed, correlated with the Campbells Creek No. 2 Gas bed of West Virginia and the Imboden bed of Virginia, outcrops widely throughout the central and eastern portions of Pike County, where it underlies very substantial areas. The bed slowly disappears under drainage levels toward the western and northwestern boundaries of the county, where it also becomes somewhat thinner in occurrence. It ranges up to as much as 8 ft 8 in. thick in the easternmost corner of Pike County, slowly decreasing in average thickness to around 4 ft 0 in. in the south-central portion of the county. While frequently containing one or two thin partings, the bed is generally continuous in occurrence and quality within its principal areas of occurrence. The thicknesses of the Lower Elkhorn
Ky bed in the substantial areas of estimated reserves range from 3 ft 0 in. to 5 ft 9 in.

111b

112 Several thin coal beds occur below the Lower Elkhorn
113a bed, with a lenticular coal occurrence below the latter bed in the
central portion of southeastern Pike County being designated as the
15• Upper Feds Creek bed. Information on this coal is too limited to
70021 permit estimates of reserves.

The Bingham bed, or the Feds Creek bed, correlated with the Clintwood bed of Virginia, next underlies the Lower Elkhorn bed over substantial portions of southern Pike County. Although thinning northward and westward information available indicates that there are relatively substantial reserves of the Bingham bed in southern Pike County in which thicknesses range from 2 ft 6 in. to 4 ft 10 in.

The Millard bed, correlated with the Eagle bed of West Virginia, appears at scattered locations in the deeper drainage portions of southeastern Pike County. Although characteristically occurring as a horizon marker less than 2 ft 0 in. thick, the bed thickens to as much as 4 ft 1 in. in sufficient areas to warrant estimates of moderate amounts of reserves.

The Auxier bed, correlated with the Splash Dam bed of Virginia, occurs at scattered intervals in the lower drainage levels of southeastern Pike County. Although mined to some extent by local operations, the bed is too limited in thickness, quality, and extent to warrant further consideration.

The Ellswick bed, correlated with the Banner bed of Virginia, appears only in the lowest drainage channels in eastern Pike County, where it is reported in a thickness of 3 ft 4 in. Available information is too limited to permit estimates of reserves.

Description of Coal Beds in Selected Counties - Western Kentucky Field

Butler County. (See Exhibit No. 5 for references below). Butler County is in the southeastern portion of the Western Kentucky field, with the southeastern boundary of the coal measures roughly coinciding with the Butler-Warren County line in eastern Butler County and extending across the southern portion of western Butler County to approximately the southwestern corner of the county. The coal beds and their associated strata dip at low rates toward the southwest in the northeastern part of the county and toward the northwest in the western section. Two short faults with vertical displacements of up to 160 feet, extending in an approximate east-west direction, displace the coal measures in the southwest-central portion of the county. A major fault extends eastward from Muhlenburg County for approximately 5 miles east of the northwest corner of Butler County; the vertical displacement along this fault ranges up to 300 feet. Ky

Bureau of Mines data on bituminous coal production in 113
1948 show production of approximately 117,000 tons in Butler County 114

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(References: 24, 39, 40, 43, 62, 63) 70021

during that year, including 29,000 tons in three stripping operations. The Kentucky Department of Mines and Minerals for 1948 reports that approximately 126,000 tons were produced from No. 6 bed in Butler County from 12 truck mines and none from railroad mines.

While areas underlain by various coal-bearing formations have been geologically mapped in Butler County, the outcrops of the various coal beds are not shown; available information, accordingly, is insufficient to permit estimates of reserves. Areas underlain by the No. 6 bed, from which the reported productions in 1948 were obtained, are limited in extent and confined to the northwestern portion of the county along the banks of Green River.

With the principal producing coal beds of western Kentucky stratigraphically higher than the No. 6 coal horizon outcropping northwest of Butler County, the scattered coal occurrences reported over most of the county are stratigraphically lower in horizon than the No. 6 bed. A geologic section reported in the southern portion of eastern Butler County includes the following designated coal beds, listed, in descending order, as follows:

Butler County Coal Beds

Designation	Reported Thickness
Mining City	3' to 4'
Unnamed coal	2'
Topmiller coal	3' 6"
Aberdeen (Elmlick)	3' 0"
Foster	2' 6"
Amos	2' 6"
Gidcomb	4' 0"
Nolan	3' 0"

The No. 6 bed, already indicated as occurring only in the northwestern portion of Butler County, is not reported in sufficient detail to permit descriptions or estimates of reserves. This bed is characteristically lenticular in occurrence in other western Kentucky counties and probably exhibits the same characteristics in Butler County. Local mining activities are usually con-
Ky fined to relatively limited areas in which the bed may range up to perhaps 4 ft 0 in. in thickness.

114b
115 The Mining City bed occurs in minable thickness
116a mainly in an area of limited extent in central Butler County. Thicknesses are commonly of 1 ft 6 in. or less, but occasional scat-
15 tered measurements indicate lenticular areas in which the bed at-
70021 tains a maximum thickness of 3 ft 6 in.

The Topmiller bed has been mined locally in the east-central portion of the county, but available information is insufficient to indicate areas of workable thickness sufficient to warrant further consideration.

The Aberdeen bed, correlated with the Elmlick bed of Ohio County to the north, occurs for the most part only in the northern portion of the county. Two small areas of reserves are in north-central Butler County, with thicknesses ranging from 2 ft 5 in. to 3 ft 8 in.

The Foster bed has been opened for local use at a number of locations in the southern portion of eastern Butler County, where it is reported to approximate 2 ft 6 in. in thickness.

The Amos bed is reported as occurring at only a few scattered locations in the southern portion of eastern Butler County, with maximum thicknesses of 2 ft 2 in.

Coal horizons in Butler County below the Amos bed are too thin and too limited in extent to warrant further consideration.

Christian County. (See Exhibit No. 5 for references below). Approximately the southern four-fifths of Christian County, the southern boundary of which is part of the Kentucky-Tennessee State line, is located south of the southern boundary of the coal measures and is underlain by formations geologically older than the coal-bearing strata. The coal measures, confined to a strip approximately 6 miles in average width along the northern boundary of the county, form a central portion of the southern rim of the Western Kentucky field. The coal beds and their associated strata generally dip toward the north at rates which seldom exceed 2 degrees. The approximate line of the southernmost outcrop of the coal measures is highly distorted by an east-west belt of deformation, marked by from two to four principal faults, with numerous cross faults connecting such principal faults at varying angles. Vertical displacements along the more pronounced of these faults range up to 460 feet. Individual fault blocks, bounded by the intersecting faults, contain coal measures with varying directions and rates of dip, conforming largely to the regional trend but departing therefrom in varying modifications.

Bureau of Mines data on bituminous coal production in 1948 show approximately 11,000 tons produced in Christian County during that year, all from underground operations. The Kentucky

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(References: 23, 24, 39, 40, 43, 62, 63)

Department of Mines and Minerals reported for 1948 approximately 11,000 tons produced from three truck mines in Christian County during that year; no production was reported from railroad mines. This production was reported as from the No. 6 or No. 6 "Stray" beds.

Horizons of coal No. 9 and higher beds, representing the principal producing coals of the Western Kentucky field, outcrop only to the north of Christian County. The single workable coal in northern Christian County is variously designated as the Mannington or Empire bed and is correlated with the Dawson Springs bed to the east. While there is a tendency in the Western Kentucky field to identify any important coal below the No. 9 bed as the No. 6 coal, it is probable that additional investigation would show that the various beds as named above are actually one, which on a regional basis could properly be considered as the No. 6 coal. There are moderate reserves of the No. 6 bed in the central portion of the area underlain by coal measures in northern Christian County, and a small portion of the reserves is recoverable by stripping. With detailed mapping of the basal portion of the coal measures not having been attempted in northern Christian County, largely because of difficulties in correlation of strata in the various fault blocks, no other coals except the No. 6 coal are reported within the county.

The No. 6 bed has been mined by both underground and stripping operations at various locations in northern Christian County, largely near the center of the coal-bearing area. Apparent thicknesses at the locations thus mined range up to as much as 6 ft 0 in., but the bed varies widely in thickness and continuity in the reported areas. The thickness of the bed within the areas of estimated reserves ranges from 3 ft 0 in. to 3 ft 7 in.

Daviess County. (See Exhibit No. 5 for references below). Daviess County is located in the north-central portion of the Western Kentucky field, with its northern boundary formed by the Ohio River facing Spencer County of Indiana. Although the coal measures extend east of the east line of Daviess County, underlying approximately the entire area of Hancock County the eastern one-half of Daviess County is underlain by coal measures stratigraphically lower than the No. 9 bed; only scattered and isolated coal occurrences indicate the presence of the horizons of the No. 6 and older beds. Occurrences of coal in eastern Daviess County are too irregular and limited to permit estimates of reserves.

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Substantial portions of western Daviess County are covered
17b by flood plains of the Green and Ohio River drainage systems. The
18 areas, topographically higher than the elevations of the flood plains,
19a represent more or less isolated remnants of coal measures which once

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0021 (References: 17, 22, 25, 39, 40, 43, 62, 63)

extended across the entire area, but which suffered removal by erosion, followed by deposition of river outwash. The coal-bearing strata exposed in such topographic hills are relatively uniform in structure with a gentle dip rarely exceeding 1 degree toward the southwest or west. Two northeast-southwest trending fault zones thought to occur at and near the western boundary of the county, are projected from known lines of faulting in adjoining counties rather than as proved by actual geologic mapping. A third fault of minor character within Daviess County extends in an east-west direction near the center of the county's irregular south boundary. Maximum displacements along the three mapped faults are not known, but do not appear to be of major importance.

According to Bureau of Mines data on bituminous coal production in 1948, approximately 634,000 tons were produced in Daviess County during that year, including 337,000 tons from two stripping operations. The Kentucky Department of Mines and Minerals reported for 1948 that approximately 337,000 tons were produced from 2 railroad mines and an additional 310,000 tons from 31 truck mines. The great majority of the production is reported from the No. 9 bed; relatively minor amounts were from the No. 6 "Stray" bed. Moderate reserves of No. 9 coal are estimated in western Daviess County; a relatively small proportion is recoverable by stripping.

The No. 9 bed, stratigraphically the highest coal horizon in Daviess County, outcrops widely along the eastern flanks of the hilly areas in southwestern and northwestern Daviess County. The line of outcrop of this bed also completely encircles relatively small areas in the southern portion of the county which are eastward outliers of the southwestern area of principal coal occurrence. The No. 9 coal is persistent and present in thicknesses ranging from approximately 3 ft 8 in. to as much as 5 ft 0 in. wherever the stratigraphic position of the bed permits its appearance above the flood plains. As a result of such relatively widespread occurrence at accessible locations, the areas along large portions of the lines of outcrop have been developed by numerous underground and stripping operations, usually of limited size.

Records of production indicate one or more coals,
stratigraphically of lower horizons than the No. 9 bed, at scat- Ky
tered locations in eastern Daviess County; the most recently re-
corded production has been near the center of this area. The 119b
available information is insufficient to permit further description 120
or estimates of reserves for such coal occurrences. 121a

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Henderson County. (See Exhibit No. 5 for references below). Henderson County, in the northwestern portion of the West Kentucky field, has a northern boundary, formed by the Ohio River, opposite southeastern Posey, Vanderburgh, and southwestern Warrick Counties of Indiana. Henderson County is located along the deepest portion of the Western Kentucky basin; the slight regional dip of the coal measures toward the northwest rarely exceeds 1 degree. The only known faulting is at the eastern boundary of the county, where a northeast-southwest fault extends along the Henderson-Daviess County line. The essentially horizontal structure of the coal beds over most of the county is slightly modified in some locations by the presence of broad, low arches or basins without definite pattern.

As shown in Bureau of Mines data on bituminous coal production in 1948, approximately 253,000 tons were produced in Henderson County during that year, all from underground operations. The Kentucky Department of Mines and Minerals as of 1948 indicates production of approximately 264,000 tons from 15 truck mines in Henderson County; no production was reported from railroad mines. With the exception of 37,000 tons from one mine in the No. 14 coal, all production was from the No. 9 bed. There are moderate reserves in the No. 14 bed, minor inferred reserves in the No. 11 coal, and substantial reserves of the No. 9 coal in Henderson County, all recoverable only by underground operations.

The No. 14 bed presumably outcrops in eastern Henderson County, with the unmapped line of outcrop extending in a generally north-south direction. The No. 14 coal bed is thin throughout eastern Henderson County, occurring largely as a horizon marker in thicknesses limited to but a few inches. Limited and scattered drilling operations and records of local shaft operations indicate that the No. 14 bed underlies portions of western Henderson County at depths of approximately 185 feet and in thicknesses approximating 4 ft 9 in.

The No. 11 bed occurs only sporadically over most of Henderson County; it is usually less than 1 ft 6 in. thick, but is known in limited areas in thicknesses ranging up to 6 ft 2 in. Such areas of thicker coal are commonly of too limited area to warrant further consideration, except along the center of the south line of Henderson County, where a small area of inferred reserves projects northward into Henderson County from a similarly small area of reserves in northeastern Webster County. The average thickness within the area of reserves in the Henderson County portion of this small area is 4 ft 6 in.

21b The No. 9 bed is known to outcrop in western Daviess
22a County, just east of Henderson County, and may outcrop under the

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0021 (References: 17, 25, 39, 40, 62, 63)

gravel-covered plains in the northeastern corner of Henderson County. It has been mined by generally limited shaft operations at a number of scattered locations within the county. These operations and information from scattered drilling programs, indicate that the No. 9 coal underlies the major portion of the county. The presence of reserves is not indicated in the extreme western portion of the county; the depth or occurrence of the bed under the wide flood plains of the Ohio River is not known. The northern limit of the No. 9 coal is usually drawn at the foot of the bluff line facing the Ohio River valley gravels. Within the broad area of known occurrence, No. 9 coal ranges between 3 ft 6 in. and 4 ft 2 in. in thickness at depths of as much as 250 feet below the surface. Substantial reserves of the No. 9 coal are present in Henderson County but this coal is thinner and inferior in quality than in the widespread occurrences of the same bed along the southern margin of the Western Kentucky field.

Hopkins County. (See Exhibit No. 5 for references below). In Hopkins County, along the southwestern flank of the Western Kentucky field, the coal measures dip regionally toward the northeast at low rates. The northern half of the county is of relatively simple structure; one or possibly two minor synclines extend in an east-west direction, where the rates and amounts of dip are locally modified. In the southern half of the county, however, the structure is greatly modified by a number of approximately parallel faults extending in a generally east-west direction and separating the coal-bearing formations into parallel steps ranging in north-south width from less than one-half mile to as much as four miles. Only a few cross-faults are known to connect the predominantly east-west fault system. While the downthrow sides of the faults are predominantly on the north, the coal measures along a few of the principal faults have been downthrown to the south; the net effect of such varying directions of displacements is the preservation of higher coal measures south of their principal outcrop and the exposure of lower coal measures, from which upper measures have been eroded, in substantial areas north of the southernmost occurrences of the higher beds. Reported displacements along the many lines of faulting range from only a few to as much as 350 feet; their occurrence has greatly modified and affected the numerous mining activities in southern Hopkins County.

Bureau of Mines data on bituminous coal production in 1948 show production of approximately 12,692,000 tons in Hopkins County during that year, including approximately 6,817,000 tons in 28 strip mines. This is the highest individual county production in the Western Kentucky field, as well as in the entire State. As shown in the annual report of the Kentucky Department of Mines and Minerals for 1948, approximately 11,828,000 tons were produced

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(References: 17,23,24,25,39,40,43,62,63) in 45 railroad mines in Hopkins County during that year and an additional 1,116,000 tons from 58 truck mines. The coal beds worked are variously designated as the No. 6, No. 9, No. 11, No. 12, and No. 14 beds. There are moderate underground reserves in the No. 14 bed, and relatively small reserves in the No. 12 bed, which are considered recoverable by stripping. The No. 11 and No. 9 beds contain very substantial reserves, of which moderate amounts are recoverable by stripping. There are also moderate reserves of both underground and strippable coal in the No. 6 bed.

The No. 14 bed occurs in unusual thicknesses ranging up to 12 ft 0 in. in an elongated area extending from a point somewhat west of the center of the county to the Webster-Hopkins County line. Although this area has been extensively stripped, moderate amounts of underground reserves remain in the west-central portion of the county in thicknesses ranging from 4 ft 9 in. to 6 ft 0 in. These reserves are adjacent to and contiguous with similar reserves of the same bed, which extend across southwestern Webster County.

The No. 12 bed attains its best continuity and thickness along the southern flank of the West Kentucky field in southern Hopkins and northwestern Muhlenburg Counties. In these areas, the No. 12 bed averages approximately 4 ft 0 in. at a vertical interval of around 6 ft 0 in. above the No. 11 bed. The No. 12 coal is notably inferior in quality to the underlying No. 11 bed, which is much more uniform in occurrence, thickness, and physical characteristics. With this relationship, it is improbable that the No. 12 coal would be mined by underground operations. Since it is a part of the overburden of the No. 11 coal in stripping operations, however, it could be and is being recovered at some of the extensive stripping operations scattered along the No. 11 coal outcrops in these two counties. With reported irregularities and occurrences, the No. 12 coal cannot be considered as uniformly overlying the No. 11 coal; the areas of estimated reserves are somewhat restricted by the lack of comprehensive information. It is estimated, however, that moderate amounts of strippable reserves ranging in thickness from 2 ft 6 in. to 5 ft 6 in. remain in a number of small scattered areas in southern Hopkins County. They can probably be recovered during the stripping of the underlying No. 11 bed.

The No. 11 bed outcrops widely across southern Hopkins County and underlies very substantial areas north of its line of
y outcrop throughout the county. Production from this bed, which is of relatively high quality after mechanical cleaning, has increased
24b materially from both underground and stripping operations during
25 recent years. The notable uniformity in continuity, thickness,
26a and accompanying physical conditions, permits high-capacity mining. Although large areas along the outcrops of this bed, both within
5 fault blocks in the southern portion of the county and in areas of
0021 relatively undisturbed coal occurrence, have been and are being

depleted, there are substantial remaining reserves between such operations and in the relatively undepleted northern portions of the county. The thicknesses of the reserves in the estimated areas of occurrence range from 4 ft 0 in. to 6 ft 7 in.

The No. 9 bed has been extensively worked for many years along and near its outcrops, both within the faulted areas south of the relatively undisturbed portion of the county and along the principal outcrop which extends across southern Hopkins County in a generally northwest-southeast direction. Partly because of the numerous underground operations at relatively shallow depths which were conducted before modern stripping methods were developed, the proportion of No. 9 coal mined by stripping is smaller than for the overlying No. 11 bed. There are substantial reserves of the No. 9 coal, north of the areas of principal mining activities, in the northern half of Hopkins County, with additional scattered reserves in some of the areas still unmined between the east-west faults south of the principal outcrop of the bed. Thicknesses of reserves in the estimated areas in Hopkins County range from 3 ft 11 in. to 5 ft 5 in.; a relatively small proportion of reserves at a few locations is considered recoverable by stripping.

The No. 6 bed, while not definitely correlated as such across the entire county, is generally considered the principal coal horizon in which there have been mining acitivities south of the No. 9 bed outcrops. The coals worked at many such areas of scattered mining acitivities have been variously designated by local names such as the Empire, Dawson Springs, and Mannington beds. The coals in or relatively near the No. 6 bed horizon are characteristically lenticular in occurrence and continuity; areas of widely varying extent contain coal ranging from less than 2 ft 0 in. to as much as 4 ft 6 in. in thickness. Such areas have been mined at varying rates by both underground and stripping operations. Moderate amounts of reserves remain in several scattered areas of various sizes along the southern boundary of Hopkins County in the No. 6 bed; thicknesses range from 3 ft 0 in. to 4 ft 3 in. Portions of these reserves, usually adjacent to present stripping operations, are considered recoverable by stripping.

A single bed, definitely occurring at a substantially lower stratigraphic horizon than the No. 6 coal, is reported to occur across the southwestern portion of the county in thicknesses ranging up to 3 ft 0 in. Information is too limited to permit estimates of reserves; this bed appears generally too limited in thickness and extent to warrant further consideration. K

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McLean County. (See Exhibit No. 5 for references below). 127
McLean County, in the central part of the Western Kentucky field, 128

(References: 17, 25, 39, 40, 43, 62, 63)

occupies a position along approximately the deepest portion of the axis of the coal-bearing basin; the coal beds and their associated strata should normally dip at low rates toward the north or nothwest. The coal measures of McLean County, however, are highly distorted by varying fault systems and local folds, which separate the coal-bearing areas into a number of individual blocks.

The principal fault system extends across the northern portion of the county in a generally northwest-southeast direction and forms a central portion of the persistent Rough Creek disturbance which crosses the entire Western Kentucky field. It is not connected with the intricate fault system along the southwestern and southern flanks of the basin. In McLean County, this uplift is characterized by a series of numerous intersecting faults which divide the belt into individual fault blocks of varying shape and size. The directions and rates of dip of the coal-bearing strata within the individual blocks are not well-known, although there are some extremely high rates of dip. This fault block in northern McLean County is terminated at the west near the Henderson-McLean County line by a major northeast-southwest fault with a maximum displacement of 180 feet.

A major fault extending in a roughly northwest-southeast direction across the center of McLean County marks the southern limit of the Rough Creek uplift. The coal measures north of this fault are displaced vertically downward as much as 200 feet below the comparable coal measures to the south.

The southeastern corner of the county, south of the Rough Creek uplift, is separated from the larger southwestern part of the county by a major north-south fault at which the coal measures have been downdropped approximately 300 feet on the west. The broad, southwestern section of the county, south of the Rough Creek uplift and west of the north-south fault just described, is anticlinal in structure, although the rates of dip on the flanks of the anticline do not exceed 2 or 3 degrees. The axis of this anticline extends across southwestern McLean County in a northwest-southeast direction.

Bureau of Mines data on bituminous coal production for 1948 show that approximately 126,000 tons were produced in McLean County during that year, including 26,000 tons from one stripping operation. In its annual report for 1948, the Kentucky Department of Mines and Minerals stated that approximately 125,000 tons were produced at 13 truck mines in McLean County during that year; no production was reported from railroad mines. With the exception of 26,000 tons produced by stripping at one operation in the No. 11 bed, all production in McLean County was in the No. 9 bed. There are moderate reserves in coals No. 14, No. 11, and No. 9 in McLean County.

The No. 14 bed has been developed by largely local operations at scattered locations in southwestern McLean County in thicknesses reported to range from 2 ft 0 in. to 6 ft 6 in. Such scattered operations and a few drill holes indicate relatively limited reserves in the No. 14 bed in two separate areas in which the bed ranges from 4 ft 6 in. to 5 ft 4 in. in thickness.

The No. 11 bed is not known to have been mined in McLean County; a few scattered drill holes in the northern portion of the county indicate that it is largely a horizon marker in that area. A relatively small amount of reserves, largely inferred in classification, is estimated to extend northward from northeastern Webster and northern Muhlenburg Counties into southwestern McLean County in thicknesses ranging from 3 ft 6 in. to 4 ft 9 in.

The No. 9 bed has been mined at scattered locations within the county where it has been brought near the surface within individual fault blocks. Such locations are in the southeastern corner of the county and in the western portion of northern McLean County, north of the principal faulting in the Rough Creek uplift and within the southernmost fault block within that area. Reported thicknesses in such scattered areas and in drill holes at similarly scattered locations range from 3 ft 8 in. to 5 ft 4 in. Moderate reserves are indicated in three separate areas in McLean County, one along the McLean-Daviess County line. Another of the areas is along the Webster-McLean County line in the western part of northern McLean County. The third contains reserves largely inferred to be present along the southern line of McLean County from the more extensive and better known areas of reserves in southwestern Ohio, northern Muhlenberg, and northeastern Hopkins Counties.

Muhlenberg County. (See Exhibit No. 5 for references below). Muhlenberg County, near the center of the southern flank of the Western Kentucky field, is essentially solidly underlain by coal measures except for a relatively small area at its southwestern corner. The southern portion of the area underlain by the principal coal beds in central Muhlenberg County is highly fractured by the fault belt along the southern flank of the coal-bearing basin. This fault belt is characterized in Muhlenberg County by a series of approximately east-west faults which divide the coal measures into steps of varying north-south width. The intersection of a few such faults, together with minor cross-faulting, separates the central portion of Muhlenberg County into individual blocks of varying extent and size. In the regional position occupied by Muhlenberg County, the coal beds and their associated strata largely dip toward the north and northwest at relatively low rates. The faulting has not greatly affected the regional

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(References: 17, 24, 25, 39, 40, 43, 62, 63)

dip of the strata except in close proximity to some of the major faults which range in vertical displacement up to as much as 350 feet. The presence of the faults results in appearances of outcrops of upper beds south of their main outcrops and likewise in the elevation and consequent removal by erosion of the same beds in areas in which they would normally occur. As a result of the belt of faulting through central Muhlenberg County, mining activities, usually located along or near the various coal bed outcrops, have been highly modified.

In Bureau of Mines data on bituminous coal production in 1948, approximately 5,276,000 tons were shown to have been produced in Muhlenberg County during that year, of which 1,539,000 tons were from 10 stripping operations. This is the second highest production from an individual county in the Western Kentucky field. The Kentucky Department of Mines and Minerals reported for 1948 that approximately 5,296,000 tons were produced from 23 railroad mines and an additional 304,000 tons from 44 truck mines. Such productions were obtained from coal beds designated as the No. 6, No. 9, No. 11, and No. 12. Moderate reserves in the No. 14 bed are recoverable only by underground operations. There are also moderate reserves of the No. 12 bed which are strippable. There are substantial reserves in the No. 11 and No. 9 beds, portions of which are recoverable by stripping, and additional reserves of minor extent in the No. 6 bed, some also recoverable by stripping.

The No. 14 bed occurs only in northeastern Muhlenberg County adjacent to Green River, where it ranges widely in thickness from less than 2 ft 0 in. to as much as 8 ft 11 in. As in Hopkins County to the west, the No. 14 bed is irregular in continuity; it is not always present in workable thickness at its proper stratigraphic horizon. Information is sufficient to permit estimates of moderate underground reserves of the No. 14 bed in Muhlenberg County, ranging from 2 ft 6 in. to 6 ft 7 in. in thickness within the several scattered areas.

The No. 12 bed attains its greatest thickness and continuity in Hopkins and Muhlenberg Counties along the southern flank of the Western Kentucky field. In this area, the bed approximates 4 ft 0 in. in thickness and occurs vertically around 6 ft 0 in. above the underlying No. 11 coal. The No. 12 bed is more irregular in thickness and inferior in quality to the underlying No. 11 bed, so that it is extremely doubtful that it would be recovered by underground operations. Since in stripping operations it forms a portion of the overburden above the No. 11 coal, the No. 12 bed can be and is being recovered at some of the high-capacity stripping operations primarily installed to mine the No. 11 bed. There are moderate strippable reserves at a number of scattered locations along the principal outcrop of the No. 12 bed in northwestern Muhlenberg County.

The No. 11 bed outcrops widely and underlies substantial areas in the northern half of Muhlenberg County, both in areas protected in fault blocks south of the principal area and in the relatively unfaulted area north of its principal outcrop. Production of No. 11 coal, which is of superior quality after mechanical cleaning, has steadily increased in recent years at both underground and stripping operations in Hopkins and Muhlenberg Counties. There are relatively substantial reserves remaining, some strippable, between abandoned and present operations along the principal outcrops and north of the principal areas of mining in the northern portion of the county. Thicknesses of No. 11 coal in the widespread areas of estimated coal reserves range from 4 ft 3 in. to 6 ft 3 in.

The No. 9 bed has been worked extensively along areas adjacent to the outcrops of the bed for a long period preceding the advent of modern, high-capacity stripping operations. In consequence, areas originally available for stripping along the lines of outcrop have largely been mined by shallow underground operations, so that the proportion of remaining strippable reserves to total reserves is substantially less in the No. 9 bed than in the No. 11 bed. Coal No. 9 is highly persistent in thickness and continuity throughout its area of occurrence in Muhlenberg County, with thicknesses ranging from around 4 ft 0 in. to as much as 5 ft 6 in. There are substantial remaining reserves, largely north of the faulted belt through central Muhlenberg County, in which the coal thicknesses range from 3 ft 11 in. to 5 ft 6 in.

The No. 6 bed appears to occur in several scattered areas of individually limited extent in southern Muhlenberg County where it has been mined by both underground and stripping operations in thicknesses ranging up to a maximum of 4 ft 0 in. There are moderate remaining reserves in two separate areas in which thicknesses of the bed range from 3 ft 1 in. to 4 ft 0 in. A portion of these reserves is considered to be recoverable by stripping generally in areas adjacent to past and present stripping operations.

Ohio County. (See Exhibit No. 5 for references below). Ohio County, in the eastern portion of the Western Kentucky field, is divided into two separate areas by the approximately east-west Rough Creek uplift which passes through the middle of the entire Western Kentucky field. The northern area approximates one-third of the county in size and the southern area the remaining two-thirds of the county. In Ohio County, the belt of the Rough Creek uplift is relatively narrow from north to south and consists of a complex system of interfingering faults and fault blocks. In some places along the Ohio County portion of the uplift, the upthrusting between two or more faults has been sufficient to bring to the surface Mississippian strata stratigraphically older than the coal

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(References: 17, 25, 39, 40, 43, 62, 63)

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measures. The coal measures in both parts of Ohio County, other than in the Rough Creek fault belt, are relatively undisturbed in structure; those in the northern portion dip at low rates to the northwest and those in the south of the county toward the west and southwest.

Bureau of Mines data on bituminous coal production in 1948 shows production of approximately 1,761,000 tons in Ohio County during that year, of which 1,471,000 tons were from 13 stripping operations. The Kentucky Department of Mines and Minerals reported for 1948 that approximately 1,706,000 tons were produced in 15 railroad mines in Ohio County during that year and that an additional 232,000 tons were obtained from 27 truck mines. The producing coal beds were the No. 6, No. 9, No. 11, No. 14, and "Stray" beds. Moderate underground reserves remain in the No. 14, No. 11 and Elmlick beds; substantial additional reserves of the No. 14 coal are recoverable by stripping. Substantial remaining reserves of the No. 9 bed are also indicated, of which some are recoverable by stripping.

The No. 14 bed occurs as a relatively large lens of unusual thickening south of the Rough Creek uplift near the center of the western border of Ohio County. The bed ranges up to 11 ft 0 in. in maximum thickness and is divided by a thin parting into two benches in areas of such maximum thickness. Although widely mined by relatively small underground and stripping operations around the margins of the thick coal occurrence, there are substantial remaining reserves of the No. 14 bed, of which approximately 75 percent are considered strippable.

The No. 11 bed attains its maximum thickness near the southernmost tip of Ohio County, where it ranges up to 8 ft 2 in. Although the stratigraphic horizon of the No. 11 bed underlies most of the southwestern portion of the county, the bed decreases irregularly in thickness toward the north, ranging from less than 1 ft 6 in. to no more than 3 ft 3 in. in the northern portion of its area of principal occurrence. Information is limited, but indicates the presence of relatively small reserves in two separate areas in southwestern Ohio County, with thicknesses of estimated reserves ranging from 2 ft 7 in. to 7 ft 1 in.

The No. 9 bed persistently underlies the broad, southwestern portion of Ohio County and is notably regular in thickness and uniform in occurrence within this area. Ranging in thickness from 4 ft 0 in. to 5 ft 8 in., the bed has been widely mined by both underground and stripping operations for the most part confined to areas relatively close to the outcrops. Remaining reserves are substantial; some can be recovered by stripping, with bed thicknesses ranging from 4 ft 0 in. to 5 ft 1 in.

The No. 6 bed occurs irregularly at its stratigraphic horizon in the areas east of the outcrop of No. 9 coal in southern Ohio County and in portions of northern Ohio County. It has been mined by relatively small operations at two principal locations within the county, one near the center of the southern portion of the county and one near the northernmost county limits. Reported thicknesses at such workings range up to a maximum of 3 ft 6 in. Information is too limited to permit estimates of reserves and suggests that the No. 6 coal is too irregular in continuity and thickness to warrant further consideration.

The Elmlick bed in southern Ohio County represents one of the several coal horizons occurring stratigraphically below the No. 6 bed in the marginal areas surrounding the principal portion of the western Kentucky coal basin underlain by coal No. 9 and higher beds. The Elmlick bed outcrops widely from the center of the county toward the common corner of Grayson, Butler, and Ohio Counties. Ranging to a maximum thickness of 4 ft 2 in., the Elmlick coal more generally varies between 1 ft 6 in. and 3 ft 6 in. in thickness. There are relatively limited reserves of Elmlick coal in possibly six scattered areas in southeastern Ohio in which the bed thicknesses range from 2 ft 8 in. to 3 ft 6 in.

Union County. (See Exhibit No. 5 for references below). Union County is located in the westernmost portion of the Western Kentucky field with its western boundary, formed by the Ohio River, facing the southernmost boundary of Posey County in Indiana and the eastern boundary of Gallatin County in Illinois. In this regional position, the coal beds and their associated strata dip at low rates toward the north. The direction and rate of dip, however, are greatly modified by two belts of folding and faulting, which cross the county in an approximately east-west direction. The northernmost belt of disturbance is a western portion of the Rough Creek uplift which crosses the approximate center of the entire Western Kentucky field. In Union County, this belt is characterized by interfingering fault blocks formed by an intricate fault system of relatively narrow, north-south width, along which the otherwise horizontal strata are highly displaced. In at least one area, the displacement has been such as to bring Mississippian formations to the surface. The southern belt of faulting extends along the southern boundary of the county and is the northeasternmost extension of the intricate fault patterns of Crittenden, Livingston, and Caldwell Counties, in which the Kentucky fluorite deposits are located. Individual faults in the southern fault system are highly irregular in direction and in amount of displacement.

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Bureau of Mines data on bituminous coal production in 1948 show production of approximately 623,000 tons in Union County during that year, all from underground operations. The Kentucky Department of Mines and Minerals reported for 1948 production of approximately 577,000 tons from one railroad mine and an additional 41,000 tons from four truck mines. The outputs of two of the local mines were obtained from the No. 6 bed, the outputs of the railroad mine and one local mine from the No. 9 bed, and the output of the fourth local mine from the No. 11 bed. There are relatively substantial underground reserves in the No. 11 and No. 9 beds and additional moderate reserves in the underlying No. 6 bed.

The No. 14 bed is not known to occur in Union County, although there is sufficient information from scattered operations and drill holes to warrant moderate estimates of reserves of this bed in western Henderson and northwestern Webster Counties within short distances of the eastern line of Union County.

The No. 11 bed underlies substantial portions of Union County on both sides of the Rough Creek uplift. While less regular in occurrence and inferior in quality to the No. 11 bed along the southwestern and southern flanks of the Western Kentucky field, the bed has been mined by scattered underground operations at widely separated points within Union County. Scattered outcrop and drill hole measurements indicate that the No. 11 bed is too thin or irregular to warrant consideration in the southernmost portion of Union County and along the eastern county lines between Union, Webster, and Henderson Counties. Although somewhat scattered throughout the central portion of Union County, points of observation are sufficiently close to permit the estimates of relatively substantial reserves in central Union County, ranging from 3 ft 9 in. to 5 ft 0 in. in thickness.

The No. 9 bed is persistent at its proper stratigraphic position in Union County except possibly along the easternmost boundary of the county where there is insufficient information. This coal has been worked by scattered underground operations in the areas both north and south of the Rough Creek uplift, in thicknesses ranging between 4 ft 0 in. and 5 ft 2 in. A few records of greater thickness along the fault lines across central Union County are considered to represent distortion or squeezing as a result of compressive forces. The measurements of the No. 9 bed within the substantial area of estimated reserves range from 4 ft 0 in. to 5 ft 0 in.

The No. 6 bed is known at depth in central and northern Union County at scattered drill hole locations within which areas it ranges from 3 ft 9 in. to as much as 5 ft 10 in. in thickness. Small areas of reserves are estimated, as reflected by the number and frequency of drill hole points of observation. The bed outcrops near the Ohio River and along the Union-Crittenden County line in southern Union County, where it has been mined in areas of relatively limited extent and thickening. Information is too limited in this latter area to permit estimates of reserves but suggests that the bed is too irregular in continuity and thickness to warrant further consideration.

Several thin coal beds, stratigraphically lower than the No. 6 coal, outcrop and have been mined along the Ohio River in southernmost Union County. While sometimes persistent within relatively limited areas of known occurrence and frequently high in quality, these beds are too thin to be considered as suitable raw material for synthetic liquid fuels plant supply.

Webster County. (See Exhibit No. 5 for references below). Webster County, near the center of the general southwestern flank of the Western Kentucky field, is essentially solidly underlain by coal-bearing strata, whose regional dip is toward the northeast. A portion of the Rough Creek uplift, which crosses the center of the western Kentucky coal basin in an approximately east-west direction, crosses the northern portion of Webster County in an irregular east-west line. In Webster County, it is characterized by a relatively narrow north-south belt of intersecting faults, along which compressive forces have resulted in substantial overthrusts which, in places, have brought to the surface Mississippian strata normally below the coal measures. Aside from this belt of deformation, Webster County is relatively free from dislocations caused by faulting.

Bureau of Mines data on bituminous coal production in 1948 show that approximately 647,000 tons were produced in Webster County during that year, including 390,000 tons from five stripping operations. The Kentucky Department of Mines and Minerals reported for 1948 that approximately 497,000 tons were obtained from 5 railroad mines in Webster County during that year, and an additional 100,000 tons from 15 truck mines. The coal beds involved are the No. 6, No. 8, No. 9, and No. 11. There are relatively substantial underground reserves in the No. 14, No. 11, and No. 9 beds and minor reserves in the No. 6 bed. There are also small amounts of strippable reserves in the No. 12, No. 11, and No. 9 beds in Webster County.

The geological section has been worked out in Webster
County in greater detail than in many of the other counties con- Ky
taining portions of the Western Kentucky field. This section in-
dicates the presence of as many as 11 coal horizons above the No. 140
14 bed, the maximum thickness of such horizons, however, being 141

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(References: 17, 22, 25, 33, 39, 40, 43, 62, 63) 70Q21

1 ft 3 in. There are many additional horizons between the principal coals of the other Western Kentucky counties and below the horizon of coal No. 6, but such horizons rarely exceed 2 ft 0 in. in thickness.

The No. 14 bed is also locally designated in Webster County as the Baker coal. As elsewhere in the Western Kentucky field, its occurrences in Webster County are lenticular; the coal ranges from but a few inches to as much as 7 ft 0 in. in areas of relatively limited extent. The coal has been opened by but a few operations of relatively small size. Such openings and scattered drill hole measurements indicate the occurrence of possibly three separate areas of reserves in cental and western Webster County in which the No. 14 bed ranges from 4 ft 9 in. to 7 ft 2 in. in thickness.

The No. 12 bed, which attains its maximum continuity and thickness in Hopkins and Muhlenburg Counties southeast of Webster County, occurs in but limited extent at a few small areas in the southwestern corner of Webster County, where it approximates 5 ft 0 in. in thickness. The bed also appears in small pocket-like areas in the northeastern section of the county, but available information is insufficient to permit estimates of reserves. The estimated reserves in southwestern Webster County, considered recoverable by stripping, are only limited.

The No. 11 bed outcrops across southwestern Webster County, where it ranges up to 6 ft 0 in. or more in thickness although in some areas the bed is less than 2 ft 0 in. in total thickness. This latter characteristic is relatively rare in Hopkins and Muhlenburg Counties and indicates the gradual deterioration of the bed northwest and north of its principal area of occurrence. Numerous underground and stripping operations relatively near the outcrop in southwestern Webster County justify estimates of relatively substantial reserves, a small proportion of which is considered to be recoverable by stripping. Lack of information, together with the indications in some drill holes that the No. 11 coal is less than 2 ft 0 in. thick, prevents extending the areas of estimated reserves to most of central and northern Webster County. Outcrops and shallow drill holes in the northeasternmost corner of the county indicate a small area of reserves contiguous with and adjacent to similar
y • reserves of the same bed in southern Henderson County; in this area the bed approximates 4 ft 4 in. in thickness.

141b

142 The No. 9 bed outcrops widely across southwestern
143a Webster County and has been extensively mined by both underground and stripping operations in areas adjacent to the outcrops. As else-
15 where in the southwestern and southern portions of the Western
70021 Kentucky basin, coal No. 9 in Webster County is persistent in con-

tinuity and thickness, ranging only between 4 ft 6 in. and 5 ft 1 in. within the areas developed by mining operations. Information from scattered drill holes indicates that it thins somewhat toward the north to a minimum of approximately 4 ft 0 in. There are substantial reserves in the entire area northeast of the principal outcrop of the bed, except for small areas near the common corner of Union, Henderson, and Webster Counties, and in the northeastern corner of the county near western McLean and northern Hopkins Counties; there, information is insufficient to permit estimates of reserves.

The coal designated as the No. 8 bed in the Kentucky Department of Mines and Minerals report of output for 1948 is not clearly correlated with known coal occurrences, as indicated by other available information. The post office addresses of the three or four mines working in the No. 8 bed are in areas northeast of the principal outcrop of the No. 9 bed, suggesting that such operations are in that bed. It is possible, however, that the operations are in a lower bed than the No. 9, in which case the proper correlation would probably be as coal No. 6.

The No. 6 bed outcrops in a northwest-southeast direction near the Webster-Crittenden County line and has been mined at scattered locations by operations of limited capacity. Available measurements indicate that this bed ranges up to 4 ft 8 in. in thickness. While information available is scattered and incomplete, it is sufficient to support estimates of relatively limited reserves in a belt along the outcrop of the bed at the southwestern line of Webster County in which the bed averages 4 ft 0 in. in thickness.

Estimated Percentage of Recovery of Coal in Place

Broad over-all records of percentage of recovery from coal reserves in place in existing underground and strip mine operations in Kentucky are not available. In 1923, the U.S. Bureau of Mines prepared a summary report on "Amount and Nature of Losses in Mining Bituminous Coal in Eastern United States", which was published in 1925 as a portion of the report of the United States Coal Commission established in accordance with Public Act No. 347 by Congress on September 22, 1922. This report, which covered only the underground mining which prevailed at that time, found that in 1921 the average amount of coal lost in individual mining operations in eastern Kentucky was 27.5 percent and in western Kentucky 37.0 percent indicating recoveries of 72.5 and 63.0 percent, respectively.

In estimating percentage of recovery from reserves in place across broad areas, such as those established in this report, the amount of over-all bed losses entailed in future mining operations would normally be considered as exceeding the average percentages of losses involved in present individual operations, assuming that methods of mining were not essentially changed. The causes of such decreases in over-all recovery in broad areas include coal left in barrier pillars between mines, coal left in mined-over areas when individual active operations are abandoned, coal unmined because of undetected local decreases in thickness, quality, or continuity, coal left in place under towns, cemeteries, railroads, schools, or other reservations, and coal left in pillars around oil and gas wells, etc.

An additional difficulty in establishing the percentage of recovery that may be expected from the estimated total reserves in place in Kentucky is caused by the lack of available information on extents of depletion in many areas of long-established or abandoned mining activity. Although estimated areas of depletion in specific beds, based on all available information, were eliminated from mapping and tabulating as reserves, it is probable that additional areas of depletion of some extent are present, both in the specific beds thus treated and in other beds which were included in the estimated reserves but for which no indications of depletion were found.

The recovery from coal reserves in place by underground mining in Kentucky, based upon available data and upon providing for the possible contingencies cited above, and including a nominal reject loss by mechanical cleaning, is estimated for this report as 60 percent in eastern Kentucky and 50 percent in western Kentucky.

Although individual stripping operations recover a materially higher percentage of the original coal in place than underground operations, the estimating of over-all recovery of strippable reserves over substantial areas requires consideration of the bearing of a number of economic factors on final percentage of recovery. These factors include allowances for areas which probably will not be stripped because of the presence of town developments, improved highways, existing facilities of all kinds, and because of possible excessive costs of acquisition, local decreases in thickness, quality, or continuity of the coal bed, etc. In order to provide for possible contingencies thus indicated, the recovery by stripping operations in western Kentucky is estimated in this report as 60 percent.

Summary Description of Estimated Recoverable Coal Reserves

The total tonnage of coal considered for synthetic liquid fuels production in Kentucky, as of January 1, 1949, based on available information and within the limits of reserves specified for this survey as described in Part II of this report under "Survey Specifications" and in Part IV under "Survey Methods and Procedure" is estimated at 22,932,403,000 tons in place, of which 12,826,094,000 tons are estimated as recoverable. Because of the limitations imposed by this survey, the estimates presented herein are not comparable with other coal estimates which generally include the total coal reserves in Kentucky. For example, in Circular 94 of the U.S. Geological Survey, the total recoverable reserves in Kentucky as of January 1, 1950, (assuming 50 percent recovery) are reported as 59,711,697,000 tons. This estimate of the U.S. Geological Survey, in the absence of a new appraisal, is based upon the estimates of original reserves prepared by M.R. Campbell in the years prior to 1928.

The detailed data on coal reserves estimated in the synthetic liquid fuels survey are presented in a volume of Coal Data Sheets which are available at certain depositories listed in Exhibit No. 6. The recoverable coal reserves are also indicated on the Coal Data Sheets and summarized by counties and beds in Exhibit No. 7. The estimated total recoverable reserves (12,826,094,000 tons) considered for synthetic liquid fuels manufacture are recapitulated, by counties and beds, in the table following. Diagrammatic outlines of the areas underlain by coal reserves are indicated on Exhibit No. 8.

As shown in the table, 19 coal beds in eastern Kentucky and 6 in western Kentucky were found to contain suitable reserves for production of synthetic liquid fuels according to the definitions and procedures established for this survey.

In eastern Kentucky, the Upper Elkhorn No. 1 bed contains the greatest amount of estimated reserves of any individual bed, with over 1,300,000,000 tons in 6 of the 14 counties found to contain suitable reserves. Other coals containing over 1 billion tons of estimated reserves are the Lower Elkhorn bed with reserves in 5 counties, the Upper Elkhorn No. 3 bed with reserves in 8 counties, and the Fire Clay bed with reserves in 11 counties. The reserves in the remaining 15 beds range from 708,000,000 tons in the Upper Elkhorn No. 2 bed to approximately 26,000,000 tons in the Hignite bed.

With estimated reserves in 10 beds (of the 19 beds found to contain suitable reserves in eastern Kentucky), the largest amount of reserves in a single county is in Pike County, where such reserves total nearly 2,800,000,000 tons. Harlan and Floyd Counties each contain also over 1 billion tons of reserves, these being established in eight different beds in Harlan and seven in Floyd County. The reserves in the remaining counties range from about 749,000,000 tons in Knott County to approximately 21,000,000 tons in Martin County.

**Estimated Total Recoverable Coal Reserves (Strip and Underground)
Considered for Synthetic Liquid Fuels Manufacture in Kentucky
By Counties and Beds in Thousands of Tons (A)
(As of January 1, 1949)**

Coal Bed	Bell	Breathitt	Clay	Floyd	Johnson	Harlan	Knott	Knox	Leslie	Letcher	Magoffin	Martin	Perry	Pike	Total
Eastern Kentucky Field:															
High Splint	6,922					113,053									119,975
Hignite	26,626														26,626
Flag		4,649					49,196						88,531		142,376
Hazard		25,292		12,114		13,393	9,929		30,890		54,525		126,094		272,237
Haddix		26,143									10,376	.	36,609		73,128
Fire Clay Rider						2,851			61,482						64,333
Flatwoods				881								3,125		70,007	74,013
Taylor														40,357	40,357
Fire Clay	46,332	20,651	12,583			41,230	173,951	41,950	216,025	134,712	10,978		276,268	110,761	1,085,441
Whitesburg		20,164					9,524		21,747	35,359	6,998		1,553		95,345
Williamson	66,079			16,076		106,744	28,330		31,889	51,401				190,041	490,560
Upper Elkhorn No. 3		10,788	37,136	131,197		350,297	286,884			189,961	4,721			250,425	1,261,409
Upper Elkhorn No. 2				106,889		74,690				52,496				473,976	708,051
Upper Elkhorn No. 1				477,847	189,621		73,347			26,007	42,020			529,517	1,338,359
Harlan	52,520					330,906									383,426
Lower Elkhorn				259,164			117,896			61,009		17,548		809,951	1,265,568
Pucketts Creek	30,065														30,065
Bingham														195,908	195,908
Millard														111,452	111,452
Total Eastern Ky.	228,544	107,687	49,719	1,004,168	189,621	1,033,164	749,057	41,950	362,033	550,945	129,618	20,673	529,055	2,782,395	7,778,629
	Butler	Christian	Daviess	Henderson	Hopkins	McLean	Muhlenberg	Ohio	Union	Webster					
Western Kentucky Field:															
No. 14				72,453	64,310	12,725	32,093	207,489		137,907					526,977
No. 12					15,619		18,182			2,522					36,323
No. 11				18,197	606,546	65,438	353,355	27,759	245,727	122,467					1,439,489
No. 9			76,567	407,621	594,265	59,457	531,607	273,695	311,299	555,093					2,809,604
No. 6		23,232			97,044		22,595		42,465	16,682					202,018
Elmlick	12,862							20,192							33,054
Total Western Ky.	12,862	23,232	76,567	498,271	1,377,784	137,620	957,832	529,135	599,491	834,671					5,047,465
Total Recoverable Reserves															12,826,094

Note: (A) Estimated in accordance with specifications and procedures established for this survey.

In western Kentucky, the No. 9 bed contains the greatest amount of estimated reserves, with over 2,800,000,000 tons being present in 8 of the 10 counties found to contain suitable reserves. The No. 11 bed contains over 1,400,000,000 tons of reserves in seven counties. The reserves in the remaining four beds range from 527,000,000 tons in the No. 14 bed to 33,000,000 tons in the Elmlick bed.

With estimated reserves of nearly 1,400,000,000 tons in five of the six beds found to contain suitable reserves in western Kentucky, the largest amount of reserves in a single county is in Hopkins County. The reserves in the remaining nine counties range from approximately 958,000,000 tons in Muhlenburg County to nearly 13,000,000 tons in Butler County.

Commercial Coal Production

Trends in Production. (See Exhibit No. 5 for references below). The earliest record by the U.S. Geological Survey of coal production in Kentucky was of 328 tons in 1828. U.S. Bureau of Mines data indicate that, since that time, to the end of 1948, a total of 1,893,191,000 tons of coal has been produced. Achieving its maximum annual production of 84,241,000 tons in 1947, the annual production in Kentucky has followed the general rise and fall of industrial activity for the entire country. Coal production in 1932, a year of serious depression, was only 35,300,000 tons. Since 1939, production has steadily increased from 42 to over 80 million tons annually; in 1948, the last year of record, the total was 82,084,000 tons. Although annual production in the Western Kentucky field surpassed that of the Eastern Kentucky field until 1911, the latter field has produced far greater annual tonnages in subsequent years. The total production from eastern Kentucky in 1948 was 59,687,000 tons; western Kentucky production totaled 22,397,000 tons.

Prior to 1917, all of Kentucky's recorded coal production was from underground operations. Production by stripping in subsequent years did not exceed 3 percent of total State production until 1943. Since that year, the amount of coal produced by stripping has increased steadily until, in 1948, the proportion of strip mine production to total State production was 15.1 percent. Strip mining has only recently become a factor in eastern Kentucky, representing approximately 3 percent of total production in 1948. It is a major factor in western Kentucky where it accounted for approximately 46 percent of total production in that year.

Beginning in 1923, the mechanical loading of underground coal, commonly used as an index of underground coal mechanization was not an important factor until 1937, when it began to increase

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(References: 34, 56, 62, 63, 64)

rapidly from 2.8 percent of underground production until in 1948 approximately 45 percent of the total underground production was mechanically loaded. While detailed figures are not available, the proportion of underground mechanical loading to total underground production is known to be substantially higher in western Kentucky than in the eastern fields.

With increases in production, the number of active mines in Kentucky has increased from 409 in 1933 to 2,516 in 1948; 2,387 were underground operations and 129 were strip mines. The average number of employes has also increased in approximately the same period from 42,000 in 1932 to 69,000 in 1948.

With increases in strip mining and in mechanization of underground operations as described above, the average productivity in tons per man per day in the Kentucky coal fields has increased from 3.50 in 1918 to 6.11 in 1948. The average productivity in the Eastern Kentucky field, with but a nominal amount of strip mining, was 5.16 tons in 1948, while that of the Western Kentucky field, in which stripping is an important factor, was 12.03 tons. Data for 1948 indicate that productivity for all underground mines in Kentucky was 5.46 tons, while that of all strip mines was 18.57 tons per man per day.

Thickness of Coal Beds. The thicknesses of coal beds being mined by commercial operations in Kentucky vary from less than 2 to over 8 feet. The weighted average thickness is approximately 4 ft 5 in. A special study of underground and strip mining in the United States, classified by thickness of beds mined in each state, was conducted in 1945 by the Bureau of Mines. The following table shows the percentages of total production produced by underground and strip operations in beds of varying thickness. These figures are available for the State as a whole and for the Western Kentucky field, but not separately for the Eastern Kentucky field.

Percentage of Total Production Produced by Underground and Strip Operations in Beds of Varying Thickness

	Percent of Total Production			
	State of Kentucky		Western Kentucky	
Bed Thickness	Underground	Strip	Underground	Strip
Less than 2 feet	0.1%	1.2%	-	-
2 to 3 feet	4.9	3.5	-	(A)
3 to 4 feet	39.4	14.7	3.7%	14.1%
4 to 5 feet	39.7	8.6	48.7	10.0
5 to 6 feet	9.5	20.4	27.8	20.4
6 to 7 feet	5.6	30.6	19.6	30.0
7 to 8 feet	0.8	(A)	0.2	(A)
8 feet and over	(B)	(A)	-	(A)
Undistributed	-	21.0	-	25.5
	100.0%	100.0%	100.0%	100.0%
Weighted average thickness - Feet	4.2	5.8	5.1	5.9

Note: (A) Included in "Undistributed".
(B) Less than 0.05%.

Quality of Coal. (See Exhibit No. 5 for references below). The coal beds of eastern Kentucky are predominantly high-volatile A bituminous (Hvab) in rank, while those of western Kentucky range from high-volatile A to high-volatile C bituminous (Hvcb). Cannel coal is widespread in the Eastern Kentucky field and was formerly mined to a limited extent in the northeastern portion of the Western Kentucky field. Where present in the principal productive beds of eastern Kentucky, cannel coal is commonly produced as a portion of the bituminous coal operations, although relatively limited outputs of cannel coal as such are produced from one or two cannel-coal beds in Bell, Carter, Floyd, Greenup, and Morgan Counties. The general quality of the bituminous coals increases from northwest to southeast in the Eastern Kentucky field and from north to south in the Western Kentucky field.

In general, eastern Kentucky coals are similar in quality to coals of southern West Virginia, southwestern Virginia, and northern Tennessee; they are relatively low in moisture, ash, and sulfur as compared with the average coals of the Appalachian region.

(References: 34, 56, 62, 63, 64)

Western Kentucky coals are generally comparable with or slightly superior in quality to the average coals of Illinois and Indiana.

The table following summarizes the general ranges and averages in quality of the individual beds considered in this survey for which information was available. In large part, the available analyses of coals in Kentucky have been obtained from operating mines, which are primarily located in the higher-quality beds. For this reason, the analyses may not be fully representative of the entire reserves in any specific county. But few analyses are available from beds of inferior quality, inasmuch as these have not been developed and operated for commercial industrial competition.

General Quality of Kentucky Coal Beds, as Indicated by Selected Items of Typical Analyses for Available Representative Samples
(Mostly Mine Samples, As-received Basis)

Coal Bed	Rank	Moisture (Percent)	Ash (Percent)	Sulfur (Percent)	Btu per Pound
Eastern Kentucky Field					
High Splint	Hvab	4.4%	4.7%	0.7%	13,490
Hignite	Hvab	3.6	4.3	0.8	13,800
Flag	Hvab	4.5	7.2	0.7-0.9	13,180-13,410
Hazard	Hvab	5.1	5.8- 8.4	0.6-1.3	12,780-13,910
Haddix	Hvab	5.1	5.8- 8.4	0.6-1.3	12,780-13,910
Fire Clay Rider		Not Available			
Flatwoods		Not Available			
Taylor		Not Available			
Fire Clay	Hvab	3.3- 5.6	4.0- 7.9	0.7-1.9	12,960-13,790
Whitesburg	Hvab	4.6	6.9	2.2	13,590
Williamson	Hvab	2.6- 3.7	4.2- 6.0	0.7-2.9	13,660-14,000
Upper Elkhorn No. 3	Hvab	2.8- 3.8	3.4- 4.9	0.5-1.0	13,440-14,170
Upper Elkhorn No. 2	Hvab	2.9- 4.2	3.6- 5.8	0.7-0.9	13,440-14,280
Upper Elkhorn No. 1	Hvab	3.2- 4.8	2.7- 6.0	0.6-1.6	13,450-14,290
Harlan	Hvab	2.1- 3.1	3.7- 3.8	0.8	14,050
Lower Elkhorn	Hvab	3.2- 3.5	3.0- 8.5	0.6-2.3	13,090-14,290
Pucketts Creek		Not Available			
Bingham	Hvab	1.1	7.6	1.9	14,130
Millard		Not Available			
Western Kentucky Field					
No. 14	Hvcb-Hvab	5.9-11.8	6.8- 9.6	1.5-4.7	11,300-12,930
No. 12	Hvcb-Hvbb	5.4-12.2	9.3-14.3	1.1-3.8	11,040-12,500
No. 11	Hvbb-Hvab	5.2- 8.7	7.7- 9.8	3.2-4.1	11,710-12,570
No. 9	Hvcb-Hvab	3.9-12.1	9.2-13.5	2.9-3.7	10,790-12,740
No. 6	Hvbb-Hvab	4.5-10.7	3.9- 8.5	1.9-3.4	12,200-13,020

Distribution and Use. Approximately 86 percent of present commercial production in eastern Kentucky and 88 percent in western Kentucky is loaded directly at the mines into railroad cars or trucked to railroads or waterways for shipment to destination. Except for coal used at the mines (less than 1 percent) the remaining production is loaded into trucks. Principal railroad carriers in Kentucky, in the approximate order of tonnages loaded for shipment as reported by mine operators, are as follows:

Louisville & Nashville
Chesapeake and Ohio
Illinois Central
Norfolk & Western
Southern
Kentucky & Tennessee
Artemus-dellico
Interstate

Available information on distribution of coal does not permit a precise analysis of the distribution of eastern Kentucky coal by destination and uses inasmuch as production from eastern Kentucky was, statistically, included with that of District 8 (southwestern West Virginia-high volatile, southwestern Virginia and northern Tennessee) in compiling such information during the years when these data were available. With comparatively little coal from District 8 being consumed in Kentucky, coal from District 8 in 1945 was shipped in varying quantities to nearly every state east of the Mississippi River and as far west as South Dakota and Nebraska. Substantial amounts of coal from District 8 were likewise used as railroad fuel; additional substantial amounts were shipped to tidewater or to Lake Erie for further transhipment by water. Of shipments other than for locomotive fuel and water-borne transportation, approximately 45 percent went to industrial users, 37 percent to retail yards and 18 percent for by-product or water-gas manufacture.

Over 50 percent of the production of western Kentucky in 1945 was consumed within the States of Kentucky and Tennessee. Substantial tonnages, however, were shipped to destinations in such states as Illinois, Indiana, Mississippi, Iowa, California, Alabama, Wisconsin, Arkansas, Virginia and Minnesota. Over 7,000,000 tons were used for railroad fuel in 1945; minor amounts were shipped to tidewater or lake ports for transfer into vessels. Of shipments other than for locomotive fuel and by trucks, approximately 55 percent was distributed to industrial users and 45 percent to retail yards.

In 1945 the percentages of production of western Kentucky and District 8 coal, by consolidated size groups, were as follows:

Percentage of Production by Size Groups in 1945 for Western Kentucky and Coal District 8

	Western Kentucky	Coal District 8
Modified mine run with top size over 2 in.	44.5%	34.9%
Lump coal and double-screened coal with top size over 2 in.	27.4	28.4
Resultant and dedusted screenings with top size over 3/4 in. and not exceeding 2 in.	19.2	22.9
Double-screened coal with top size not exceeding 2 in.	6.6	8.3
Resultant and dedusted screenings with top size not exceeding 3/4 in.	2.3	5.5

Future Coal Requirements. As one of the principal coal-producing states, the annual productions from Kentucky coal fields have responded closely to the fluctuating rates of demand determined by the national economy. That production from Kentucky has maintained at least a proportionate position with respect to total United States coal demand is illustrated by an increase in production of from 42,500,000 tons in 1939 to 82,000,000 tons in 1948. Both the Eastern and Western Kentucky fields have participated in this growth.

In general, coals from eastern Kentucky are suitable for a wide variety of purposes. According to Information Circular No. 7559 of the U.S. Bureau of Mines in 1950, over 13,700,000 tons of high-volatile Kentucky coal were received at slot-type ovens in the United States for coke production in 1947, together with 174,000 tons of medium-volatile coal. With a grand total of over 97,000,000 tons being received from various states for coke production at slot-type ovens, the total Kentucky coal received for such use represented 14.3 percent of the total for the country.

Western Kentucky coal, used principally for industrial power generation, railroad, and domestic fuel, is not adapted for special uses, such as production of coke, except in minor amounts. The coal reported as received at slot-type ovens above is considered as probably having been obtained exclusively from the Eastern Kentucky field.

It is possible that increasing demand for high-grade coking coals and improvements in utilization of somewhat lower-grade coals will increase the rate of demand for coking coal from those beds in eastern Kentucky best adapted to this method of utilization. It is not possible, however, to forecast the amount or extent of such possible rate of increase on the basis of available information. It appears that the future demand for eastern Kentucky coal may approximate the rate which has prevailed in recent years. Except for possible increases in demand for midwest coal for future coke production, the future major requirements for western Kentucky coal appear to be confined to the generally industrial uses for which it is now employed.

At the 1948 production rate of approximately 59,687,000 tons, the total demand for eastern Kentucky coal in the next 50 years would approximate 2,984,000,000 tons. At the 1948 production rate of approximately 22,397,000 tons, the total demand for Western Kentucky coal in the next 50 years would approximate 1,120,000,000 tons. These figures are used solely as a means of estimating future requirements other than for the development of a synthetic liquid fuels industry.

Selection of General Areas of Coal Availability

Elimination of Unsatisfactory Areas. Upon completion of basic mapping and tabulation, each area of reserves was then examined as to location, extent, amount of recoverable reserves, and relationship to other adjacent or nearby reserve areas. Isolated areas, with insufficient reserves to provide at least one synthetic liquid fuels unit plant for a 40-year life, were eliminated from further consideration. Where large reserves of two or more principal beds were overlain or underlain by one or more coal beds of relatively limited extent or of inferior quality, which would probably not be mined concurrently with mining of the more extensive beds, these intermediate beds were likewise eliminated. The locations, coal bed designations, and amounts of estimated recoverable reserves of such eliminated areas are shown in the table following.

Deduction of Coal Reserves for Future Commercial Requirements. The total recoverable reserves in eastern Kentucky considered available for synthetic liquid fuels manufacture, as previously shown, are estimated at approximately 7,778,600,000 tons, and those of western Kentucky at approximately 5,047,500,000 tons. It is
Ky estimated that the future commercial requirements for eastern
Kentucky coal in the next 50 years, based upon the 1948 production
155b rate of 59,687,000 tons, would be approximately 2,984,000,000 tons,
156 and those of western Kentucky, based on their 1948 production rate,
157a about 1,120,000,000 tons. On these bases, there are about
4,794,600,000 tons in eastern Kentucky and 3,927,500,000 tons in
15 western Kentucky available for the production of synthetic liquid
70021 fuels.

Eliminated Areas of Unsatisfactory Reserves

County	Coal Bed	Location in County	Estimated Recoverable Reserves (Thousands of Tons) Primary	Secondary	Total
Eastern Kentucky Field:					
Bell	High Splint	SW.	1,283	5,639	6,922
Breathitt	Flag	SE.	-	4,649	4,649
	Hazard	NE., Central	3,793	21,499	25,292
	Haddix	SE.	-	26,143	26,143
	Fire Clay	NE.	-	9,643	9,643
	Whitesburg	NE.	3,032	17,132	20,164
Clay	Fire Clay	E.	-	12,583	12,583
	Upper Elkhorn No.3	Central	20,758	16,378	37,136
Floyd	Flatwoods	SE.	-	881	881
	Williamson	SE.	8,710	7,366	16,076
Harlan	Fire Clay Rider	Central	2,851	-	2,851
	Fire Clay	NE.	19,031	22,199	41,230
Knott	Hazard	W.	6,014	3,915	9,929
	Whitesburg	S.	-	9,524	9,524
	Williamson	S.	24,412	3,918	28,330
Knox	Fire Clay	S.	21,773	20,177	41,950
Leslie	Whitesburg	Central	2,956	18,791	21,747
Letcher	Williamson	W., Central	6,245	45,156	51,401
	Upper Elkhorn No. 2	SE.	3,257	4,089	7,346
Magoffin	Haddix	SW.	9,253	1,123	10,376
	Fire Clay	Central	-	10,978	10,978
	Whitesburg	Central	3,636	3,362	6,998
	Upper Elkhorn No.3	SE.	2,158	2,563	4,721
Martin	Flatwoods	SE.	3,125	-	3,125
	Lower Elkhorn	NE., S.	2,835	14,713	17,548
Perry	Haddix	N.	26,051	10,558	36,609
	Whitesburg	NW.	-	1,553	1,553
Pike	Flatwoods	W.	55,595	14,412	70,007
	Taylor	N., Central	21,745	18,612	40,357
	Millard	S.	34,969	76,483	111,452
Total			283,482	404,039	687,521
Western Kentucky Field:					
Butler	Elmlick	N.	12,862	-	12,862
Henderson	No. 11	SE.	-	18,197	18,197
McLean	No. 14	S.	12,725	-	12,725
	No. 9	NW.	11,158	-	11,158
Muhlenberg	No. 14	NE.	29,398	2,695	32,093
Ohio	Elmlick	SE.	20,192	-	20,192
Webster	No. 11	NE.	10,575	13,167	23,742
	No. 6	SW.	16,682	-	16,682
Total			113,592	34,059	147,651
Total Eliminated Reserves			397,074	438,098	835,172

Substantial areas of underground reserves of coals of superior quality, continuity, or thickness in eastern Kentucky and of both underground and strip reserves of similar characteristics in western Kentucky are in the hands of operating companies. While no attempt was made in this survey to confine estimates of reserves to areas not owned or controlled by operating or holding companies, some allowances for present ownership of both underground and strippable coal were probably unavoidably effected by excluding from the mapping and tabulation of reserves certain relatively minor areas not yet depleted but lying within major areas of depletion as previously described under "Survey Methods and Procedure". It is considered that such eliminated reserves, at least some of which are probably being depleted by active mines, will supply some portion of the estimated future commercial requirements for Kentucky coals. The total amount of potential supply thus provided, however, is considered relatively minor in extent.

Delineation of General Areas of Coal Availability. After elimination of the unsatisfactory areas of reserves listed in the previous table, the remaining areas of reserves were grouped into nine General Areas of Coal Availability in eastern Kentucky and seven such General Areas in western Kentucky, in accordance with definitions and procedures established for this survey. The locations, boundaries, and areas underlain by included coal reserves for each General Area as listed below are diagrammatically shown on Exhibit No. 9.

General Areas of Coal Availability

Eastern Kentucky	Western Kentucky
Johnson-Magoffin	Daviess
Pike	Henderson
Floyd-Magoffin	Union
Knott-Breathitt	Webster
Perry-Breathitt	Hopkins-Christian
Leslie-Harlan	Muhlenberg-McLean
Northern Letcher	Ohio
Harlan-Letcher	
Bell	

Detailed data pertaining to each General Area are presented in Exhibit No. 10, which indicates that in the Daviess General Area there are insufficient recoverable coal reserves available for the 40-year supply of one unit plant using the coal synthine process. Therefore, subsequently in this report, when the coal synthine process is considered, the Daviess General Area of Coal Availability has been eliminated.

The data of Exhibit No. 10 include information on thicknesses of beds, depths of cover, rank and quality of coal, areas underlain by coal reserves, estimated recoverable reserves (by classes), and the daily capacity of synthetic liquid fuels plants, in thousands of barrels, which could be supported through a 40-year life by the estimated reserves.

Each General Area is less than 1,000 square miles in size and is of the approximate size of a single county, or less. County lines are crossed, however, when areas of adjoining, continuous reserves in one county properly belong with larger areas of reserves in another county. Where areas of continuous reserves in two or more adjoining counties each contain substantially greater reserves than the amount required to supply one synthetic liquid fuels unit plant, such areas are separated into individual General Areas by counties.

The table following (summarized from Exhibit No. 10) shows the estimated primary, secondary, and total reserves in each General Area, together with the daily synthetic liquid fuels capacity, in thousands of barrels, which could be supported for a 40-year life by such reserves, using either the hydrogenation or coal synthine processes, where applicable.

Summary of General Areas of Coal Availability (A)
(As of January 1, 1949)

General Area	Estimated Reserves (B) (Thousands of Tons) Primary	Secondary	Total	Daily Plant Capacity (Thousands of Barrels) Hydro-genation Process	Coal Synthine Process
Eastern Kentucky Field					
Johnson-Magoffin	106,306	106,176	212,552	41	32
Pike	1,491,652	1,068,927	2,560,579	504	392
Floyd-Magoffin	620,892	439,933	1,060,825	199	155
Knott-Breathitt	330,407	381,655	660,814(C)	127	99
Perry-Breathitt	280,710	221,191	501,901	95	74
Leslie-Harlan	194,498	159,181	353,679	68	53
Northern Letcher	248,960	129,874	378,834	74	58
Harlan-Letcher	628,401	460,653	1,089,054	213	166
Bell	119,847	101,775	221,622	43	33
Subtotal	4,021,743	3,069,365	7,039,860(C)	1,364	1,062
Western Kentucky Field					
Daviess	52,690	23,877	76,567	12	9
Henderson	229,933	250,141	459,866(C)	70	55
Union	343,296	256,195	599,891	103	80
Webster	392,493	401,754	784,986(C)	136	106
Hopkins-Christian	887,681	513,335	1,401,016	235	183
Muhlenberg-McLean	663,870	375,606	1,039,476	176	137
Ohio	435,503	73,440	508,943	82	64
Subtotal	3,005,466	1,894,348	4,870,345(C)	814	634
Total Kentucky	7,027,209	4,963,713	11,910,205(C)	2,178	1,696

Note: (A) Detailed data on General Areas are presented in Exhibit No. 10.
(B) Recoverable by strip and by underground mining.
(C) Total primary and secondary reserves for synthetic liquid fuels plant supply are limited by definition to twice the primary reserves in any General Area.

In connection with this table and with the detailed data, it should be noted that the total reserves estimated as available for synthetic liquid fuels production do not equal the sum of the estimated primary and secondary reserves in one General Area in eastern Kentucky and two General Areas in western Kentucky. This reduction in total reserves conforms to the definition of availability of raw materials reserves which states that "---the quantity considered sufficient for one or more plants is based upon a recoverable amount sufficient to supply such plant for a period of 40 years of which 20 years' supply is from primary reserves and the additional 20 years' supply is from either primary or secondary reserves".

The amounts of secondary reserves thus eliminated from the actual total of recoverable reserves are shown by the following tabulation, with quantities listed in thousands of tons:

Secondary Reserves Eliminated as Excess
(1,000 Tons)

General Area	Actual Totals Primary and Secondary	Totals Used	Amounts Eliminated
Eastern Kentucky Field:			
Knott-Breathitt	712,062	660,814	51,248
Western Kentucky Field:			
Henderson	480,074	459,866	20,208
Webster	794,247	784,986	9,261
Total	1,986,383	1,905,666	80,717
Total Usable Reserves, All General Areas			11,910,205
Total Estimated Reserves in General Areas			11,990,922

The total reserves of 7,039,860,000 tons estimated for the nine General Areas of Coal Availability in eastern Kentucky exceed the 4,794,600,000 tons determined to be available for the production of synthetic liquid fuels by deducting the estimated future commercial requirements (2,984,000,000 tons) from the total recoverable K
reserves in eastern Kentucky (7,778,600,000 tons) by 2,245,260,000 tons. The total reserves of approximately 4,870,345,000 tons esti- 16
mated for the seven General Areas of Coal Availability in western 16
Kentucky exceed the 3,927,500,000 tons determined to be available for the production of synthetic liquid fuels by deducting the esti- 1
mated future commercial requirements (1,120,000,000 tons) from the 700

total recoverable reserves in western Kentucky (5,047,500,000 tons) by 942,845,000 tons. Deduction of these amounts as unavailable for synthetic liquid fuel production decreases the total daily plant capacities in eastern Kentucky from 1,364,000 to 929,000 barrels by the hydrogenation process and from 1,062,000 to 723,000 barrels by the synthine process. The similar decreases in total daily plant capacity in western Kentucky are from 814,000 to 656,000 barrels by the hydrogenation process and from 634,000 to 511,000 barrels by the synthine process.

The above reductions in daily synthetic liquid fuels plant capacity are considered as maximum possibilities. While it is not considered that the total amounts of estimated reserves in the areas eliminated as unsatisfactory (687,521,000 tons in eastern Kentucky and 147,651,000 tons in western Kentucky) would be necessarily used for future commercial requirements, it is possible that a portion of either synthetic liquid fuels supply or future commercial requirements will be obtained from such reserves or from the 51,248,000 tons in eastern Kentucky or from the 29,469,000 tons in western Kentucky, which represent excess secondary reserves eliminated from one General Area in eastern Kentucky and two General Areas in western Kentucky as stated above. It is likewise possible that present operating companies either own or control relatively minor amounts of reserves for future commercial production which were not included in the total amounts of reserves estimated herein as available for synthetic liquid fuels plant supply as previously described under the heading "Survey Methods and Procedure". There is also the probability of additional reserves being developed in areas for which there is not now sufficient information to warrant the estimation of reserves for the purpose of this report.

Under the definitions and procedures employed in this survey, and with the allowances specified for future commercial production, it is concluded that sufficient coal reserves are available in nine General Areas of Coal Availability in eastern Kentucky and in seven General Areas of Coal Availability in western Kentucky to supply synthetic liquid fuels plants having a minimum capacity of 1,585,000 barrels per day for a period of 40 years using the hydrogenation process and 1,233,000 barrels per day for a period of 40 years using the coal synthine process. All information available at the time of this survey indicates that sufficient coal reserves are available to supply a maximum synthetic liquid fuels capacity
y of 2,178,000 barrels per day by the hydrogenation process or 1,696,000 barrels per day by the coal synthine process. It is prob-
62b able that continued exploration and development of coal reserves
63a in both eastern and western Kentucky will result in the discovery of additional reserves for both synthetic liquid fuels plant supply and
5 future commercial requirements in areas for which there is not now
0021 sufficient information to permit the present estimation of reserves.

Synthetic Liquid Fuels Potential in General Areas of Coal Availability

Based on the recoverable coal reserves in the 16 General Areas of Coal Availability, the potential synthetic liquid fuels capacity for each of said General Areas of Kentucky, in total and as a daily average over a 40-year period, would be as follows:

Available Underground and Strip Coal Reserves (A) and Equivalent Synthetic Liquid Fuels Potential General Areas of Coal Availability and Process in Total and as a Daily Average over 40 Years (As of January 1, 1949)

General Areas of Coal Availability	Recoverable Coal Reserves (1,000 Tons)	Average Btu per Pound (As Received)	Equivalent Potential: Total (1,000,000 Barrels)		Equivalent Potential: Average Daily Plant Capacity 40-Year Period (1,000 Barrels)	
			Hydrogenation	Coal Synthine	Hydrogenation	Coal Synthine
Johnson-Magoffin	212,552	13,730	596	463	41	32
Pike	2,560,579	14,090	7,363	5,727	504	392
Floyd-Magoffin	1,060,825	13,430	2,908	2,261	199	155
Knott-Breathitt	660,814	13,750	1,854	1,442	127	99
Perry-Breathitt	501,901	13,490	1,382	1,075	95	74
Leslie-Harlan	353,679	13,680	987	768	68	53
Northern Letcher	378,834	13,970	1,080	840	74	58
Harlan-Letcher	1,089,054	13,980	3,107	2,417	213	166
Bell	221,622	13,800	624	485	43	33
Daviess	76,567	10,790	169	131	12	9
Henderson	459,866	10,960	1,029	800	70	55
Union	599,491	12,340	1,510	1,174	103	80
Webster	784,986	12,400	1,986	1,545	136	106
Hopkins-Christian	1,401,016	11,990	3,428	2,666	235	183
Muhlenberg-McLean	1,039,476	12,120	2,571	2,000	176	137
Ohio	508,943	11,640	1,209	940	82	64
Total	11,910,205		31,803	24,734	2,178	1,696

Note: (A) Considered for synthetic liquid fuels manufacture in accordance with specifications and procedures for this survey.

Logan County on the south to Breckenridge County on the north. Minor extensions of these outcrops lie in bordering Butler, Hart, and Hancock Counties.

The beds within which the bituminous deposits are found, and their associated beds, are as follows:

Beds of Bituminous Deposits

System	Formation	Bed
Pennsylvanian	Pottsville	Bee Spring Sandstone
		Main Nolin Coal
		Basal Conglomerate
Mississippian	Chester	
	Upper Chester	Litchfield
	Middle Chester	Glen Dean Limestone
		Hardensburg Sandstone
		Golconda Limestone
		Cypress Sandstone
	Lower Chester	Renault-Paint Creek Limestone

The rocks in this region form part of the eastern upslope of the Western geosyncline and the western flank of the Cincinnati Arch, about midway between the Cincinnati and Nashville domes. The strata, in general, dip 30 feet to the mile to the north and northwest, although the regional dip is interrupted by local irregularities, mainly small faults. Westward, the beds pass under capping sandstones; eastward, older formations outcrop.

The Cypress sandstone contains most of the oil-impregnated deposits of the Chester series. It is generally crossbedded, fine-grained in Logan County, medium-grained in Grayson County, and uniformly fine-grained (0.006 in.) in Hardin County. Individual layers range from 2 inches to 2 feet in thickness. It is relatively competent and resistant to erosion and forms gently rolling, nearly level, cliff-bounded terrain.

Pennsylvanian rocks of the Pottsville series overlie the Chester beds. The basal conglomerate of the Pottsville is composed of two massive medium- to coarse-grained sandstones, conspicuously crossbedded in places.

Above the basal conglomerate lies a shale containing the main Nolin coal and above this the Bee Spring sandstone. The latter is a massive member, similar in many ways to the lowermost sandstone member. It is brown, coarse-grained, crossbedded, and a conspicuous cliff former in some areas.

Source of Bitumen
(See Exhibit No. 13 for references A below)

The origin of the bitumen in the sand formations is not known. Weller (Ref. 12) holds that it was derived from underlying formations. No source beds are known, either in the Pottsville of this region or the underlying Upper Mississippian formations, which seem likely to have produced the amount of petroleum contained in the impregnated horizons, but oil may have migrated upward from much lower beds. The location of the thickest Pottsville deposits along the deeper part of a pre-Pottsville channel in the northcentral part of Edmonson County suggests that the presence of this channel may have been a factor in the accumulation, and possibly in the upward migration, of petroleum in this vicinity. McCormack (Ref. 8) says the beds may be erosional remnants of a once large, oil-filled anticline.

Description of Deposits in Eastern Kentucky
(See Exhibit No. 13 for references B below)

Oil-impregnated deposits occur in the Pottsville formation in Johnson, Morgan, Magoffin, Carter, and Rowan Counties in eastern Kentucky.

Johnson, Morgan, and Magoffin Counties. Asphalt-impregnated sandstones occur in the cliffs of Big Paint Creek gorge near Low Gap Branch and in other places in the gorge and its tributaries in Johnson and the adjacent portions of Morgan and Magoffin Counties. The asphaltic sands are Pottsville basal conglomeratic sediments. Jillson states (Ref. 4) that they are not sufficiently thick nor so situated as to be commercial.

Ky

The following Kentucky Agricultural Experimental Station
analyses of samples from Little Paint and Big Paint Creeks show 16
lean bitumen content: 17

700

(References A: 8, 12)
(References B: 1, 4)

OIL-IMPREGNATED STRIPPABLE DEPOSITS IN KENTUCKY

Eighteen Kentucky counties are known to contain oil-impregnated deposits, as shown in Exhibit No. 11 and described in Exhibit No. 12. The largest and most important are in the Pottsville (Pennsylvanian) and Cypress (Mississippian) sandstones in central Kentucky.

Edmonson and Logan Counties appear to have 434 million tons of oil-impregnated material in place or 347 million tons recoverable, containing 10 to 15 gallons of oil per ton, in beds 15 to 35 feet thick, with less than an equal footage of overburden. Of the total recoverable, 196 million tons are in 4,220 acres in Edmonson County; the remaining 151 million are in 2,253 acres in Logan County. These estimates are as of January 1, 1950.

Available information reveals no deposit outside Edmonson and Logan Counties that contains 10 million tons of oil-impregnated material within a 5-square-mile area, that is 15 feet or more thick, that is overlain by no more than its own thickness of overburden, and that will yield 10 gallons of oil per ton of raw material.

Footnote references included in this section refer to publications listed in the bibliography, Exhibit No. 13. Acknowledgments for technical information are listed in Exhibit No. 14.

Character of Deposits

(See Exhibit No. 13 for reference below)

The oil-impregnated sands of Kentucky are used chiefly for paving. They are composed of fine- to course-grained quartz sandstone, impregnated with bitumen of about the consistency of warm tar. The bitumen content varies from a trace, barely sufficient to color the rock gray, to saturation; it averages 3 to 7 percent by weight, although some samples have shown more than 10 percent.

Top and bottom contacts with noncommercial rock are well defined, as a rule, and are described by Tyler (Ref. 15) as "sharp breaks".

Test results on uncrushed samples show marked differences in bitumen content and hardness of recovered asphalt from different horizons and faces of the same quarry. A rich ledge lying on lean rock in one place may lie under what appears to be the same lean streak a short distance away. There is no apparent textural differ-

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(References: 15)

ence to cause this variation, but complex crossbedding is evident, with cementation along the bedding planes tending to check the flow of bitumen. Thin shaly layers, in places interbedded with the sandstone, also confine the bitumen and cause local variations in the amount present.

The deposits seem to decrease in thickness and bitumen content beneath heavy overburden.

Outcrops weather dark gray or white on exposure, but a fresh sample reveals the black liquid bitumen coating sand grains and filling interstices.

Mining

The bituminous sandstone is mined by conventional quarrying methods. The overburden consists of soil and alluvium, barren sandstone, and sometimes a thin layer of leached bituminous sandstone. The sandstone overburden is well cemented and must be drilled and blasted to remove it. Hydraulic methods have been used to remove loose overburden.

History of Development

In 1891, the American Bituminous Rock Company built a plant to extract bitumen from the bituminous sandstone near Grayson Springs in Grayson County, but shut down after about 80 barrels had been separated.

In 1894, the Logan County Asphalt Company, later renamed the Standard Asphalt Company, mined the first natural rock asphalt for road-paving material. In the early 1900's, several companies followed suit in Breckenridge, Warren, Edmonson, and Logan Counties.

The Kentucky Rock Asphalt Company has been mining in Edmonson County since 1917 and is the only surviving large producer of natural rock asphalt. Exhibit No. 15 lists the names and locations of most of the Kentucky rock asphalt companies.

Ky

Stratigraphy and General Occurrence

166b

Small bituminous outcrops are exposed in stream valleys 167a
in eastern Kentucky, but the chief outcrops lie in a broad arcuate 10
belt of Pennsylvanian and Mississippian rocks across the midwest- 70021
ern part of the State. The rocks (see table below) are impregnated more or less continuously throughout portions of six counties from

Analyses of Samples from Little Paint and Big Paint Creeks

	Location		
	Pleasant Run Branch Big Paint Creek	Shack Branch Little Paint Creek	McKenzie Tracey Farm Big Paint Creek
Moisture 105°C	4.6% (wt)	3.0% (wt)	3.1% (wt)
Combustible Matter Insoluble CS_2	1.0	.6	.5
Bit. Sol. CS_2	.6	.6	.4
Sand	93.8	95.8	96.0
Total	100.0%	100.0%	100.0%

According to available information, no deposit in this area constitutes a reserve as defined herein.

Carter and Rowan Counties. A portion of the Pottsville basal sandstone contains bitumen in Carter and Rowan Counties near Soldier. The deposit lies on the eastern side of the divide between Tygart and Triplet Creeks in a north-south ridge above the forks of Soldier and Main Tygart Creeks. The area is about three miles long and three-quarters of a mile wide. According to Hagan (Ref. 1) and Jillson (Ref. 4) exposures on Soldier and Mocabee Creeks have been examined where 5- to 10-foot outcrops are found on the following farms: J. P. Danner, J. D. Patent, L. S. Vincent, J. F. Gilbert, W. C. Underwood, and S. M. Bradley. On the J. P. Danner farm, a quarry was developed in 1917 but did not operate commercially.

The bituminous sandstone is underlain by 5 or 6 feet of fire clay and overlain by 15 to 20 feet of soft, coarse-grained sandstone. The dip is 1 to 2 degrees to the southeast. The richest portion is a middle zone about 3 feet thick, grading into moderately rich zones above and below. The deposit is irregular and bitumen content varies, but the average is less than 10 gallons per ton.

Jillson (Ref. 4) gives the following analyses from the deposit:

Analyses of Samples from Carter and Rowan Counties

	Location			
	S. M. Bradley Farm Mocabee Creek	J. P. Danner Quarry Soldier Fork	Danner Farm Soldier Fork	Danner Farm Soldier Fork
Moisture 105°C	0.11% (wt)	0.07% (wt)	0.06% (wt)	0.04% (wt)
Volatile Combust. Matter	6.53	3.52	3.45	3.43
Sand	93.36	96.41	96.49	96.53
Total	100.00%	100.00%	100.00%	100.00%
Sol. CS_2	7.13%	3.55%	3.39%	4.06%

Available information reveals no reserve in this area.

Description of Deposits in West-central Kentucky
(See Exhibit No. 13 for references below)

Bituminous sandstone deposits of both Pottsville and Chester age are more or less continuous throughout portions of Logan, Edmonson, Warren, Grayson, Hardin, and Breckenridge Counties, with minor extensions in Butler, Hart, and Hancock Counties. Only in Edmonson and Logan Counties are the deposits sufficiently rich and thick and of the proper extent to be classified as reserves.

Logan and Edmonson Counties. The reserves in Logan and Edmonson Counties are described later under "General Areas of Raw Material Availability".

Warren County. Bitumen-impregnated Pottsville basal sandstone is known in the northeastern part of Warren County. Several small deposits in the area bordering Green River, in the vicinity of Youngs Ferry, are of high quality and have been worked commercially in the past. However, there is no indication that any of the deposits in the area constitutes a reserve as herein defined.

Ky

Grayson County. The Kentucky Geological Survey (Ref.
10) shows that the bituminous Pottsville beds extend continuously 171
172
10
(References: 10, 11) 7002

from Edmonson County into the southern part of Grayson County, where the Bee Spring sandstone is thickest. Bituminous sandstone is present throughout the entire southern portion of the county, south of a line from Caneyville on the west through Leitchfield to Millerstown on the east, near the junction of Grayson, Hardin, and Hart Counties. The terrain in the eastern portion of this section is highly dissected and the beds are either small, isolated units or are under considerable overburden. To the west, and especially in the vicinity of the Church-Shrewsbury area, the deposits occur at or near the surface over rather large continuous areas. In this portion of the county, however, available information gives no indication that any of these deposits constitutes a reserve.

Farther in the north, near the county line, bituminous Cypress beds outcrop. Here again there is no available information that these deposits are either thick enough or rich enough to qualify as a reserve.

Hardin County. The bituminous sandstone deposits in Hardin County are an extension of the impregnated portion of the Cypress formation in northern Grayson County (Ref. 10). Outcrops are known in the vicinity of Meeting Creek. From available information, there is no indication that these deposits contain the requisite tonnage of the thickness and yield that would constitute a reserve.

Breckenridge County. The bituminous beds of the Chester formations extend in a broad belt from Hardin and Grayson Counties through the towns of Cloverport and Garfield into Breckenridge County. In the northwestern part of Breckenridge County, they occur in the Tar Springs member, a little above the Cypress sandstone. The deposits are small. Jillson (Ref. 11) states that the Tar Springs sandstone is a thinner and higher member in the Chester series than the Cypress sandstone and that it covers a smaller area.

The Cypress sandstone, although bituminous in the middle part of Breckenridge County, is not continuously so, and there are large areas where it is completely barren. Bituminous Cypress outcrops occur in the vicinity of Garfield and Cloverport, and some deposits have been mined but are not considered as important as those to the south.

Available information fails to show that these deposits meet the requirements for a reserve.

Hart, Butler, and Hancock Counties. Pottsville bituminous sandstone extends from a short distance within the southeastern border of Butler County, east of Reedyville, to westcentral Hart County between Pine Grove church and Cherry Spring school. Some Cypress bituminous sandstone outcrops as far north as Hancock County east of Patesville. There seem to be no reports of detailed field examinations to indicate the extent of these deposits; they are probably of a minor nature. In Butler and Hancock Counties, the beds dip below capping sandstones. East of the center of Hart County, they have been eroded away. There are no areas adjacent to these counties that contain deposits which qualify as reserves and which would attach importance to these deposits. Also, there has been little commercial interest in the development of rock asphalt mining in these counties. The deposits in Hart, Butler, and Hancock Counties probably do not qualify as reserves.

Description of Miscellaneous Deposits

Kentucky has several other bituminous accumulations at or near the ground surface. Among these are small deposits of asphalt-impregnated limestone outcropping in Nelson, Madison, Marion, and Bell Counties. These deposits are small and of academic importance only.

General Areas of Raw Material Availability

Both Edmonson and Logan Counties are General Areas of Raw Material Availability as previously defined.

Edmonson County. (See Exhibit No. 13 for reference below).

Geography and Geology. Edmonson County is the site of the largest known tar sands deposits in Kentucky and of the greatest commercial development. The terrain is hilly and in places precipitous; surface elevations range from 400 to 900 feet. Streams have dissected asphalt beds that were once continuous. The Kentucky Geological Survey (Ref. 9) shows numerous outcrops of asphalt in the county.

Bituminous Cypress sandstone, as exposed in the beds of First, Second, and Bylew Creeks, and bituminous Hardensburg sandstone in the valley of Crooked Creek, are known but are not of interest for this report because they lie under excessive overburden.

Pottsville rock asphalt occurs chiefly in two different Ky
horizons, the upper sandstone of the basal conglomerate and the Bee
Spring sandstone. 173b
to
The basal conglomerate is over 200 feet thick in a pre- 175a
Pottsville river channel exposed along Pine and Pigeon Creeks. It 10
thins to the southern border of the area of Pennsylvanian outcrop. 70021

(Reference: 9)

Northward from the channel it thins and loses continuity.

The Bee Spring sandstone is at its maximum thickness, about 50 feet, in the northern part of the county. It becomes increasingly shaly and discontinuous to the south.

The chief bituminous sandstone exposures are in the Pottsville and lie in the valleys between Bear Creek and Green River and between the northern boundary of the Mammoth Cave National Park and the Dog Creek Fault. Several deposits are scattered west of Bear Creek to the Grayson County line and south of Green River on both sides of Little Beaver Dam Creek, but core drilling has not proved these to be of more than limited extent.

The reserves areas lie in the northern part of the county, north of an east-west line through Brownsville, where the Pottsville beds are thickest. Available information fails to disclose any reserves south of this line.

Reserves. (See Exhibit No. 13 for references below.) Exhibit No. 16 summarizes and assigns letter designations to the Edmonson County reserves and lists their locations. The only reserve considered measured contains less than 10 million tons and is included in a larger indicated deposit. Assuming recovery of 80 percent, a total of 2,705 acres is estimated to contain 125,885,000 recoverable tons classified as indicated tertiary reserves. A total of 1,517 acres is estimated to contain 69,666,000 recoverable tons classified as inferred secondary and tertiary reserves.

On the 2,705 acres of indicated reserves, 104 holes have been drilled, an average of 1 hole per 26 acres or approximately 1,000 feet between holes. Area I has been explored with the highest exploration density, 21 core holes on 380 acres. This spacing averages approximately 900 feet between holes.

Core drill and outcrop measurements and geologic and topographic maps have been used to determine reserves.

The density of the bituminous sand or rock asphalt is taken as 148 pounds per cubic foot and that of the bitumen as 83 pounds per cubic foot. Area A (see Exhibit No. 16) contains an indicated tertiary reserve of 30.93 million tons on about 800 acres, as shown by 22 core holes. The essentially horizontal deposit averages 15 feet thick under about 15 feet of overburden and contains 10 gallons per ton or an estimated 309.3 million gallons. The reserve area
75b pinches out or has been faulted off on the north side by the Dog
to Creek Fault, the Straw Fault, and others. It is bounded on the
77a southwest by its outcrop, on the east by similar beds under excessive
10 overburden, and on the north and south by areas on which no informa-
0021 tion is available.

(References: 2, 12)

Within Area JK, 61 core holes on 1,523 acres indicate a tertiary reserve of 77.33 million recoverable tons of bituminous sandstone averaging 20 feet thick, with a bitumen content of 10 gallons per ton, under an average of 23 feet of overburden. The deposit outcrops on the east and west. It terminates abruptly on the north near Ridgedale. Cores have failed to show important rock asphalt across the Bee Spring Road to the south.

Area B comprises 416 acres underlain with an estimated 16.1 million tons of 10-gallon-per-ton bituminous sandstone 15 feet in thickness with an average overburden of 20 feet. Seven core holes averaging about 1,600 feet apart and a map of the outcrop infer an indicated tertiary reserve.

Within Area G, an estimated tertiary reserve of 31.9 million tons of bituminous sandstone is inferred from cores about 2,400 feet apart on 283 acres and from other geological evidence. The bitumen content averages 12 gallons per ton. The deposit averages 30 feet thick and lies under about 30 feet of overburden.

The traces of rock asphalt which Bryant (Ref. 2) reports in this area suggest a continuous deposit throughout the area. The deposit occurs in the region of Bee Spring development, but the good exposures within this member are less widely distributed than those of the basal conglomerate. Weller (Ref. 12) states this is probably the result of differences in stratigraphy rather than an indication of a less continuous asphalt-bearing horizon. Where weathering has drawn out the bitumen or covered exposures with talus, the true character of the deposit cannot always be ascertained at the outcrop. The possibility of continuity is supported by the revelation of rock asphalt by core holes in the area.

Within Area N, 258 acres are estimated to contain 10 million tons of bituminous sandstone, averaging 15 feet thick, and under no greater thickness of overburden. The bitumen content is estimated at 10 gallons per ton. The tonnage is estimated chiefly from the persistence of the bed, from outcrop evidence, and from a few specific measurements.

In Area E'F', 560 acres are estimated to contain 21.6 million tons of bituminous sandstone of an average thickness of 15 feet and under less than 15 feet of overburden. The bitumen content is estimated at 15 gallons per ton.

The northern portion of this deposit has been measured closely by core drilling. The estimate is also based on outcrop measurements and assumption of continuity of the deposit throughout the area confined by the outcrop line. The larger portion of the tonnage has been computed, however, from measurements farther apart than 1,200 feet, and the reserve is therefore classified as inferred.

Analyses. (See Exhibit No. 13 for reference 15). The chart below lists abridged results of four analyses of samples taken by the Kentucky Agricultural Experimental Station from Pottsville bituminous sandstone in Edmonson County.

Analyses of Samples from Edmonson County

Sample No.	Composition of Sample: Moisture (Percent)	Solubility CS_2 (Percent)	Residue Insol. (Percent)	Residue After Ignition (Percent)	Combust. Matter Insol. CS_2 (Percent)	Screen Analysis of Mineral Matter, Percent of Total Retained on Mesh: 50 Mesh	60 Mesh
1	0.2%	6.8%	93.0%	92.09%	0.9%	11.5%	51.3%
2	.2	6.5	93.3	92.4	.9	6.3	57.2
3	.5	7.0	92.5	91.1	1.09	1.7	42.0
4	.4	5.6	94.1	93.3	.75	0.0	56.0

An unusually coarse-grained sample from the R. Willis farm on the east side of Bear Creek, containing 7.9 percent bitumen soluble in carbon disulfide, showed 78 percent of the separated sand held by the 50 mesh screen and 99 percent held by the 80 mesh screen.

The following complete sieve analysis of six samples of sand from rock asphalt of Edmonson County shows distribution of grain size similar to that of the abridged analyses above.

Composite of Sieve Analyses - 6 Edmonson County Samples

Size of Sieve	Total Percent Retained (Extremes)	Total Percent Retained (Average)
1/4 in.	0.1 - 1.6%	0.7%
No. 4	.2 - 2.6	1.5
8	.6 - 6.0	3.7
40	3.2 - 11.9	8.7
80	52.6 - 66.8	59.5
200	91.2 - 94.1	92.7

The analyses tabulated in Exhibits Nos. 17 and 18, reported by Tyler (Ref. 15), show the physical properties of Edmonson County asphaltic sandstone (Pottsville) as mined and under various conditions of stockpiling. The lack of uniformity in bitumen content and hardness is notable.

The results of tests on four other bitumen samples are shown in Exhibit No. 19.

Logan County

Geography and Geology. Logan County deposits are considerably thicker although not as extensive as the Edmonson Pottsville sandstone deposits. They have not been as widely commercialized, although they were the first to be developed.

In the central portion of the county, about 4 to 5 miles northeast of Russellville, near Homer, the Cypress sandstone lies at the surface to form the southeastern fringe of the Chester formation. The area comprises part of a dissected plateau tilted slightly to the northwest. The terrain is one of gentle ridges and meandering valleys with a physical relief of 100 to 150 feet. The Cypress rests on limestone which is exposed at or near the bottoms of the valleys. Karst topography is present and some of the streams disappear into sink holes.

Six known rock asphalt deposits, two of which are probably extensions of two others, have been studied. These occur in the Cypress sandstone within an area of 3 square miles. The bituminous formation is probably larger, but information is lacking outside this area. The deposits appear to lie in four isolated pockets of enrichment.

Reserves. Exhibit No. 20 summarizes and assigns Roman numeral designations to the Logan County reserves.

The highest exploration density is in Area II, with 10 core holes on 205 acres, an average spacing of 900 feet. Of these core holes, 21 are spaced on 555 acres of indicated reserves, an average of 1 per 23 acres, or approximately 1,000 feet between holes.

Assuming recovery of 80 percent of the rock asphalt, indicated tertiary recoverable reserves are 27.8 million tons in 555 acres; inferred tertiary recoverable reserves are 123.5 million tons on 1,698 acres. The deposit is considerably thicker than its overburden.

Adequate topographic coverage and outcrop data are lacking; the estimates rely chiefly on available core drill records.

Bitumen content is estimated rather arbitrarily but conservatively. Allowance has been made for mined-out areas.

As in Edmonson County, density in pounds per cubic foot has been taken as 148 for the rock asphalt and 83 for the bitumen.

Within Area II, 10 core holes averaging about 900 feet apart indicate that 205 acres contain a tertiary recoverable reserve of 10.6 million tons of bituminous sandstone averaging 20 feet in thickness under an average of 17 feet of overburden. Bitumen content is about 14.4 gallons per ton.

The outcrop is well marked on the west and thinner but still plain to the south. The deposit probably extends farther to the north than shown.

In Area III, 11 core holes in the 350 acres indicate a tertiary reserve of 17.2 million tons of bituminous sandstone averaging 20 feet in thickness under an equal thickness of overburden and containing about 10 gallons of bitumen per ton.

The deposit outcrops on the south. It probably extends considerably farther than assumed in the other three directions and may constitute a continuation of Area II.

Within Area IV, five core holes about 1,300 feet apart on 191 acres infer a tertiary reserve of 17.3 million tons of 10-gallon-per-ton bituminous sandstone averaging 35 feet in thickness under an equal thickness of overburden.

This deposit and the deposit contained in Area V (below) are the thickest known in Kentucky. Area IV has been limited in outline by core drill locations. It may extend further to the north and east but probably does not join other deposits in these directions. It may be cut off to the northwest from Area V by the valley of Mud River.

In Area V, six core holes about 1,800 feet apart on 406 acres infer a tertiary reserve of 36.6 million tons of 10-gallon-per-ton bituminous sandstone averaging 35 feet in thickness under an average thickness of 27 feet of overburden. The deposit appears to exist as an isolated pocket of enrichment.

Within Area VI, nine core holes about 1,900 feet apart on 715 acres infer a tertiary reserve of 38.8 million tons of 10-gallon-per-ton bituminous sandstone averaging 20 feet in thickness under an average thickness of 15 feet of overburden.

The area joins Area VII on the north by a thin neck. It appears to thin out to the west.

In Area VII, six core holes about 1,700 feet apart on 386 acres infer a tertiary reserve of 30.9 million tons of 10-gallon-per-ton bituminous sandstone averaging 30 feet in thickness under 16 feet of overburden.

Analyses. Samples Nos. 1 to 7 below are from the southern part and Sample No. 8 is from the northern part (near Homer), of the Logan County Cypress bituminous sandstone region:

Analyses of Samples from Logan County

Sample No.	Moisture (Percent)	Composition of Sample: Solubility CS_2 (Percent)	Residue Insol. (Percent)	Combust. Matter Insol. CS_2	Screen Analysis of Mineral Matter, Percent of Total: Retained on Mesh 20	50	100	200	Passed 200
1	0.1%	6.0%	93.1%	0.8%	0	0	53%	32%	15%
2	.5	8.2	90.8	.5	0	0	56	35	9
3	.3	7.4	91.8	.5	0	0	49	33	18
4	.1	8.2	90.7	1.0	0	0	55	34	11
5	.2	6.1	93.1	.6	0	0	60	28	12
6	.1	6.5	92.8	.6	0	0	46	35	19
7	.4	7.9	91.3	.4	0	0	44	35	21
8	.5	6.4	92.3	.8	0	0	51	33	16

Detailed analyses of the physical properties of the Logan County bituminous sandstone are not available.

NATURAL GAS

The natural gas phase of the investigation included a study of the geology of the gas-bearing formations and of data on natural gas in the State.

The principal oil and gas producing formation areas in Kentucky are of Lower Ordovician age. Formations of Pennsylvanian and Mississippian age make up a large percentage of the area of the State.

The study of the availability and extent of natural gas reserves in Kentucky, as of January 1, 1949, indicated the total remaining recoverable proved gas reserves to be 1,684,300,000 Mcf under standard conditions. However, all gas reserves in Kentucky are under contract for commercial use or will be used in the field.

Based on the foregoing, it appears that none of the natural gas deposits in Kentucky could be considered available reserves for synthetic liquid fuels purposes, as of January 1, 1949, since an adequate reserve must contain at least 225 trillion Btu (225,000,000 Mcf of 1,000 Btu gas) producible within a radius of 40 miles and with a heating value of 400 Btu per cubic foot at standard conditions.

It is therefore concluded that there are no reserves of natural gas in Kentucky available for use as a source of raw materials for synthetic liquid fuels manufacture. New fields and expansion of known fields between January 1, 1949 and the date of this report warrant no change in this conclusion.

Detailed information pertaining to the natural gas survey, and the bases for the conclusions expressed herein, are contained in the report prepared by DeGolyer and MacNaughton, which accompanies this report as Appendix B.

OIL SHALE

The oil shale phase of the investigation included a study of the geology of the oil-shale-bearing formations and of assay data on oil shale samples from various localities in Kentucky.

In Kentucky, oil shales occur in the New Albany shale and in shales associated with Pennsylvanian coal-bearing formations.

The study of the nature and extent of oil shale deposits in Kentucky, as of September, 1950, indicated that none of the shales is of sufficient richness and thickness to meet the minimum reserve requirements, which specify an average oil content of at least 15 gallons per ton of oil shale in vertically continuous beds with a minimum thickness of 25 feet and totaling not less than 100,000,000 tons of oil shale within an area not greater than 5 square miles. Also, there is no indication that additional sampling and assaying would reveal the presence of shales of sufficient richness and thickness to meet the minimum reserves requirements.

It is therefore concluded that there are no reserves of oil shale in Kentucky suitable for use as a source of raw materials for synthetic liquid fuels manufacture. No new information nor discovery of additional deposits between September, 1950, and the date of this report warrant any change in this conclusion.

Detailed information pertaining to the oil shale survey, and the bases for the conclusions expressed herein, are contained in the report prepared by DeGolyer and MacNaughton, which accompanies this report as Appendix C.

WATER SUPPLY

Hydrological Features

Coal reserves in sufficient quantity for producing 1,696,000 barrels of synthetic liquid fuels daily by the coal synthine process over a 40-year period are found in 16 General Areas of Coal Availability in Kentucky. The greatest concentrations of coal reserves are in nine General Areas in the extreme southeast section of the State; the remaining seven General Areas are in the west. Locations of the General Areas and their relation to available water resources are shown on Exhibit No. 21. The 16 General Areas are listed as follows:

General Areas of Coal Availability in Kentucky

Eastern Kentucky	Western Kentucky
Johnson-Magoffin	Daviess
Pike	Henderson
Floyd-Magoffin	Union
Knott-Breathitt	Webster
Perry-Breathitt	Hopkins-Christian
Leslie-Harlan	Muhlenberg-McLean
Northern Letcher	Ohio
Harlan-Letcher	
Bell	

The average annual rainfall in Kentucky is 45 inches, ranging from 40 inches in the northern tip of the State to more 50 inches in the south-central section. The lowest annual rainfall of record, amounting to 28 inches, was in 1930; the year of greatest rainfall was 1890 with a precipitation of 58 inches. The occurrence of rainfall, however, is fairly regular with relatively higher precipitation during the winter and spring months.

Most of the State of Kentucky drains to the northwest through tributaries of the Ohio River. The south-central part of the State is drained by the Cumberland River into Tennessee and thence northwest into the Ohio River near Paducah. Annual runoff averages about 18 inches and varies from less than 14 inches or 1 cfs per square mile of drainage area in the western portion of the State, to more than 21 inches or 1.6 cfs per square mile of drainage area in the mountainous eastern regions. The coal-bearing areas in the western part of the State lie in gently rolling country, rural in nature, with very few large cities. The eastern coal fields are in the sparsely populated mountainous sections, where there is little activity other than coal mining.

Water Requirements for Synthetic Liquid Fuels Plants

Quantity of Water Needed. The total quantities of water required, both for plant use and for domestic supply in the plant-city serving a synthetic liquid fuels unit project, have been estimated to be:

Water Requirements for Unit Projects

	Make-up		Consumed		Returned	
	Mgd	Cfs	Mgd	Cfs	Mgd	Cfs
Hydrogenation:						
Plant Use	7.29	11.28	5.36	8.29	1.93	2.99
Domestic Supply	1,73	2.68	0.43	0.67	1.30	2.01
Total	9.02	13.96	5.79	8.96	3.23	5.00
Coal Synthine:						
Plant Use	11.15	17.25	7.71	11.93	3.44	5.32
Domestic Supply	1.94	3.00	0.49	0.76	1.45	2,24
Total	13.09	20.25	8.20	12.69	4.89	7.56

Process Supply. It is obvious that the water requirements for any specific project would depend upon the choice of manufacturing process, being 45 percent greater for the coal synthine process. However, water costs represent in the neighborhood of only 1 percent of the total cost of products, exclusive of return on investment. Therefore, it appears desirable to adopt the coal synthine process requirements as the basis for estimates of water quantities and costs.

A detailed statement of the coal synthine process water requirement is given in Exhibit No. 22. This shows most of the plant use of water to be for cooling purposes. The estimates assume recirculation of cooling water through cooling towers, which practice would reduce the quantity taken from the water source to about one-eighteenth of the amount otherwise necessary.

Once-through cooling, without recirculation, might be feasible for a relatively small development located on the bank of a large river. Elsewhere in Kentucky, the stream flows are in-
adequate and the cost of delivering large quantities of water to a Ky
remote site would be prohibitive. In general, the cost of hauling
coal is relatively so great that the plants would be located near 186
the coal mines rather than along the rivers. In the State, most of 187

the assumed plant sites are at considerable distances from the large rivers; only two sites are within 2 miles of such streams. At these locations, in Henderson and Hopkins-Christian General Areas, on the Ohio River, detailed comparison of once-through and recirculated water cooling systems, with allowances for different process costs, might prove once-through cooling more economical. Since the cost differential, in any event, would not be large, cost estimates in this report are based upon use of recirculated water.

Water requirements for mining are small and nonconsumptive; they are not included in the foregoing tabulation.

In estimating water supplies for the General Areas of coal Availability and in making provisions for other water demands, total plant requirements have been used without allowance for water returned to the stream as possible waste or sewage. Such waste water might be returned at a considerable distance from the point of withdrawal and might be less satisfactory for some purposes than natural water from the stream.

Water consumption data and cost estimates are based upon average annual values. During summer months, cooling requirements might increase because of higher water intake temperatures but probably would have only slight effect in a plant recirculating its water through cooling towers. In preparing cost estimates, works large enough to take care of estimated peak summer demands have been assumed.

The amount of water required for complete development of the fuel resources of each of the General Areas of Coal Availability in Kentucky varies with the coal reserves available. It ranges from 18 cfs in the Daviess General Area to 794 cfs in the Pike General Area. The total quantity required for concurrent full development in all 16 General Areas within the State would be 3,434 cfs or 2,219 mgd, which amount of water is considered available.

Domestic Supply. The water necessary for domestic supply is affected not only by the total number of workers (determined by the choice of process) but also by the portion of those workers for which housing would be required in the project's plant-city. Again, in view of the very small relative cost of water as compared with other items contributing to total products cost, variations in conditions affecting domestic water supply requirements
Ky* are relatively unimportant. In Kentucky, a per capita allowance of
150 gallons per day has been made uniformly for the population of the
187b plant-city. For the purpose of the water supply study, such popula-
188a tion is taken to be five times the number of plant workers and mine
4 personnel. For the coal synthine process, this amounts to 12,955
persons.

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Quality of Water Needed. Process water must be relatively clear and free from turbidity and substances that would clog condenser tubes, cooling towers, and other equipment. The dissolved solids content is not of major importance, except that a high concentration would require frequent blowdown of cooling towers and boilers and would increase the amount of make-up water. Boiler feed waters must be free or organic matter and insoluble solids, and suitable for softening.

Water for drinking and sanitary purposes at the mines and plants, and in the communities serving the developments, would have to be potable and of quality satisfactory to the public health authority of the State. Water softening might be justified for domestic use.

Water Resources

The water resources of Kentucky consist principally of the Ohio River and its many tributaries, which as a group drain 97 percent of the State. Over a length of 664 miles, the Ohio River forms Kentucky's northern boundary and it is estimated that more than one-third of the total population of the State lives within a few miles of the river.

Water supplies for synthetic liquid fuels projects could be developed from the Ohio River and tributary streams. There is very little coal along the river itself and, therefore, much of the development would naturally be at some distance, principally in the eastern part of the State. Although large ground water supplies have been developed in the alluvial deposits along the Ohio River, suitable aquifers are not available in most of the mountain tributaries and practically all of the large cities and industries away from the Ohio River use surface water supplies.

The principal references consulted in the course of the survey for statistical and technical information in conjunction with the water supply section of this report are listed in the Water Resources Bibliography, Exhibit No. 23. Acknowledgments to individuals and agencies who cooperated in furnishing technical information and assistance are presented in Exhibit No. 24.

Surface Water. The potential sources of water supply in Ohio for synthetic liquid fuels production are treated in the following order; main stem of the Ohio River, Ohio River tributaries, and ground water.

Ohio River, Main Stem. The Ohio River, draining approximately 203,900 square miles, is one of the largest rivers in the country. Characteristic flows in Kentucky are summarized in the following table:

Characteristic Flows of the Ohio River in Kentucky

	Gaging Station	
	Huntington, West Virginia	Louisville, Kentucky
Drainage Area, Sq Mi	55,900	91,170
Period of Record	1935 - 1947	1929 - 1947 (A)
Mean Flow, Cfs	76,450	110,300
Minimum Annual Flow, Cfs	53,060	60,458
Year of Occurrence	1941	1931
Minimum Monthly Flow, Cfs	7,343	4,400
Month of Occurrence	Sept. 1946	Oct. 1930
Minimum Daily Flow, Cfs	3,200	2,100
Date of Occurrence	Sept. 6, 1934 (B)	Oct. 12, 1930

Note: (A) 1929-1935 data from Corps of Engineers
(B) Also 9/13/34, 11/2/34, 10/3/35, 10/1/37

The minimum monthly flows of record in the Ohio River occurred in 1930. Regulating reservoirs have been constructed since 1930; and it is estimated that under existing conditions, the minimum monthly flow at Evansville would be approximately 6,800 cfs. The regulating reservoirs have also reduced the severity of the minimum monthly flows. The critical flow conditions of the Ohio River at several gaging stations along its course, are shown on Exhibit No. 25.

The Ohio River is an important link in the transportation system of the country. Locks and dams maintain a 9-foot navigation channel throughout the length of the river. Most of the larger cities along its course obtain their public water supplies from the Ohio River. Of these, only Henderson, Ky., and Evansville, Ind., are near the western coal field in Kentucky. At Henderson, a population of 20,000 persons uses approximately 4.5 mgd. At Evansville, a population of 116,000 uses 18 mgd. Ohio River water is used extensively for industrial plants. Such water uses are largely nonconsumptive and the water finds its way back into the streams either as sewage or as industrial waste. Therefore, the existing uses would

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have no serious effect on the availability of water for synthetic liquid fuels plants.

Daviess, Henderson, and Union General Areas in the western part of Kentucky border on the Ohio River. It is expected, however, that a water supply for a synthetic liquid fuels plant in Daviess General Area could be developed from the Green River at less cost than from the Ohio River. Water for the other two Areas would be pumped directly from the river. Webster General Area is at some distance from the Ohio River, and it would be necessary to pump water from there to this area for concurrent full development of the coal reserves.

Adequate water supplies are available locally in most of the Areas to take care of unit plants or moderately larger production. However, if all of the coal resources in the Hopkins-Christian General Area were developed, local sources would be inadequate and an additional supply from the Ohio River would be necessary. Similarly, full development of the coal resources in Pike General Area in the eastern part of Kentucky would require so much water that it would be necessary to build a long pipe line to the Ohio River.

Full development of the coal resources in the General Areas of western Kentucky to be served from the Ohio River would require a total water supply of 859 cfs, or approximately 12 percent of the monthly low flow of the Ohio River with present regulation. During periods of low flow, diversion of this quantity would have no effect upon navigation and little on the concentration of wastes. At other times, more than enough water would be available in the river. Therefore, it is assumed that for all practical purposes, the four western General Areas could be supplied without the construction of storage reservoirs. Similarly, a total potential demand of 794 cfs in Pike General Area could be met from the Ohio River, but if water were required for both eastern and western Kentucky General Areas at the same time, additional storage would be needed. Other water supply systems drawing from the tributaries of the Ohio River for synthetic liquid fuels plants would include storage reservoirs and would have no effect upon the low flows of the main stem. The relation of large-scale water needs to the water available in the Ohio River basin are discussed further under the heading "Relation of Water Needs for a Major Synthetic Liquid Fuels Development to Water Available in the Ohio River Basin".

<u>Tributaries of the Ohio River.</u> The principal tributaries of the Ohio River beginning with the Big Sandy River in the eastern part of the State, are noted below with their total drainage areas:

Principal Tributaries of the Ohio River in Kentucky

River	Drainage Area (Square Miles)
Big Sandy River	4,281
Licking River	3,655
Kentucky River	6,949
Green River	9,222
Tradewater River	1,008
Cumberland River	18,080

Water supplies for the nine eastern General Areas would logically be obtained from Levisa Fork of the Big Sandy River, Licking River, Kentucky River, or Cumberland River. Water supplies for the western General Areas, not pumped from the Ohio River, probably would be obtained from tributaries of the Green River or Tradewater River. The stream flow characteristics of these rivers are shown by the summary of stream gaging data for representative stations in the following table:

Runoff Characteristics of Principal Kentucky Rivers

	Gaging Station			
	Levisa Fork at Paints-ville	Kentucky River at Heidelberg (at Lock 14)	Kentucky River near Winchester	Green River at Livermore
Drainage Area, Sq Mi	2,143	2,648	3,960	7,580
Period of Record	1930-48	1926-31 1939-47	1910-48	1931-48
Mean Flow, Cfs (A)	2,176	3,293	5,044	9,824
Mean Flow, Cfs per Sq Mi	1.02	1.24	1.27	1.30
Minimum Annual Flow, Cfs	720	1,494	1,983	3,390
Year of Occurrence	1941	1941	1941	1931
Minimum Monthly Flow, Cfs	11	9	15	318
Month of Occurrence	Oct.1930	Sept. 1930	Oct. 1930	Oct.1930
Minimum Daily Flow, Cfs	8.4	6	9	280
Date of Occurrence	July 25, 1930	Oct.16.-31 1930	Sept.20-24 1930	Frequent

	Tradewater River at Olney	Cumberland River near Harlan	Cumberland River at Cumberland Falls
Drainage Area, Sq Mi	255	374	1,997
Period of Record	1941-47(B)	1941-47	1908-11 1916-31 (C) 1933-48
Mean Flow, Cfs (A)	250	594	3,098
Mean Flow, Cfs per Sq Mi	0.98	1.59	1.55
Minimum Annual Flow, Cfs	61.6	293	1,423
Year of Occurrence	1941	1941	1941
Minimum Monthly Flow, Cfs	0	19.6	23
Month of Occurrence	Oct. 1940	Oct. 1940	Sept. 1925
Minimum Daily Flow, Cfs	0	6.7	9
Date of Occurrence	Frequent	July 31, 1945	Sept.18-20, 1932

Note: (A) Flow records obtained from U.S. Geological Survey Water Supply Papers, except as noted.

(B) Flow for 1930 of Tradewater River near Dalton (gage located 1-1/2 miles upstream from Donaldson Creek Drainage area = 284 sq mi) was used for mass diagram but is not in records shown here.

(C) Flow of water, year 1932, was estimated and included in the record.

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It will be noted from the preceding table, that, while the average flows of many of the rivers are large, the annual flows during dry years are comparatively small and that the minimum daily or monthly flows are extremely small, except in the case of the Green River. From this table, it is evident that very few of the rivers or their tributaries would furnish a year-round supply of water adequate for one or more synthetic liquid fuels unit plants, unless storage reservoirs were provided to furnish the water needed during periods of low flow. Therefore, in determining water supply systems required for synthetic liquid fuels plants in Kentucky, it has been necessary to consider possible reservoir locations and the safe yield that could be obtained by developing several of the tributary streams.

The capacity of reservoirs needed for development of the tributary streams has been estimated from the stream flow records during the driest period of record. Mass diagrams and storage yield curves were prepared for the streams studied. Those for the Levisa Fork River at Paintsville, Kentucky, and for the Green River at Livermore, Kentucky, are shown on Exhibits Nos. 26 and 27, respectively. Ten-day hydrographs of the Levisa Fork at Paintsville and the Green River at Livermore are shown on Exhibits Nos. 28 and 29, respectively.

The economic development of drainage areas in Kentucky would range between 0.6 and 0.8 cfs per square mile of drainage area, and between 330 and 720 AF of storage would be required for each square mile of drainage area impounded. These estimates are based on the assumption that it would not be economical to develop a stream to the point that the reservoir would be drawn down for a period exceeding 2 years.

It would not be possible, in general, to divert or store the full flow of a river or stream. Although there may be no substantial existing downstream water uses, some minimum flow would certainly be required to satisfy the lower riparian owners. In estimating storage requirements, the minimum flow below which water would not be withdrawn for synthetic liquid fuels plants is taken as that flow which has been exceeded 90 percent of the time. This flow is defined as the control flow and its application may be illustrated by an example:

The average flow of the Cumberland River at Cumberland Falls, Kentucky, is 3,098 cfs, or 1.55 cfs per square mile of drainage area. The duration curve of the flows at this station shows that during 90 percent of the time, the flow has exceeded 100 cfs, or 0.05 cfs per square mile of drainage area. Therefore, it is assumed that no water from the river would be diverted into storage or used at a synthetic liquid fuels plant water works whenever the natural stream flow fell below 0.05 cfs per square mile of drainage area. At such times, the synthetic liquid fuels demand would be met from a reservoir and the natural flow of the stream would be permitted to pass through unchanged. However, in estimating reservoir capacity, no allowance has been made for increasing the natural flow in excess of water supply requirements. The mass diagrams of monthly runoff have been adjusted by deducting the control flow in each case.

Available water supplies and required storage have been estimated from stream flow records of the U.S. Geological Survey in the general vicinity of the coal areas in Kentucky. The flows at seven gaging stations in the State with records of at least 7 years duration and some as long as 39 years were studied. These stations are listed in the preceding table. The studies showed that the most severe dry spell occurred during the 1930-32 drought, and it is reasonable to assume that runoff upon which storage requirements are based is as critical as any likely to be experienced in a 50-year period; see Exhibit No. 30 for stream flow information in the state. On streams for which there are no adequate runoff data, storage estimates were based on data for the most comparable of adjacent streams. In these analyses, it is assumed that the runoff per square mile of drainage area at any given time is constant throughout the basin, and equals the runoff per square mile at the gaging station used. This assumption is not entirely correct inasmuch as there are variations in runoff within basins, and from one basin to another, but it is sufficiently accurate for purposes of this report. Sites for the proposed reservoirs were selected to provide drainage areas sufficient to provide water for at least one synthetic liquid fuels unit plant. A drainage area of at least 25 square miles with a yield of 0.8 cfs per square mile is needed to furnish water for a single 10,000-barrel-per-day plant. Smaller drainage areas could be combined to furnish water for one unit plant, but normally this would not be economical. The drainage areas and reservoir sites were sketched out on U.S. Geological Survey topographic maps and the areas determined by planimeter.

The reservoir capacities determined from the mass diagram were increased by allowances for evaporation and for siltation. The evaporation during a 2 year period of depletion has been calculated as 24 inches times the surface area of the reservoir when two-thirds full. The allowance for silt deposition has been estimated over a period of 40 years at the rate of 0.2 AF per square mile of tributary drainage area. Siltation is not serious in this part of the country, and the capacity required for silt deposition from a drainage area of 25 square miles would be only 200 AF. It is recognized that the quantity of silt carried varies with different streams, and that in general, the silt deposition per square mile of drainage area is less for large drainage areas than for small. However, for the drainage areas considered, the uniform allowance is believed sufficiently accurate. The total storage, including allowances for evaporation and silting, for a 10,000-barrel-per-day plant ranges from 9,300 to 25,000 AF.

Existing water uses and the possible development of each of the tributary streams for synthetic liquid fuels purposes are summarized in the following paragraphs:

Levisa Fork of the Big Sandy River. Levisa Fork drains the four General Areas in eastern Kentucky having the largest coal resources in the State, Johnson-Magoffin, Pike, Floyd-Magoffin, and Knott-Breathitt General Areas. Levisa Fork joins Tug Fork at Louisa, Kentucky, where together they form the Big Sandy River, only 27 miles from the Ohio River. Levisa Fork rises in southwestern Virginia and flows through the eastern Kentucky coal areas. The drainage basin is generally rugged, the terrain mountainous, and the streams flow through narrow steep valleys. The basin is sparsely settled; principal towns are Pikesville, Prestonsburg, and Paintsville.

The lower section of the Big Sandy River is improved for navigation with three locks and dams between Louisa and the mouth of the river; there is one lock each on Levisa Fork and Tug Fork a few miles upstream from Louisa. Levisa Fork is used as the source of public water supply by approximately 12,000 persons, including the two largest communities of the region, Paintsville and Pikesville.

The Corps of Engineers has studied five reservoir sites for flood control and power generation on Levisa Fork. Dewey Reservoir, already built on Johns Creek, and the proposed Fishtrap Reservoir are in Kentucky; the other sites are in Virginia. Dewey Reservoir controls a drainage area of 207 square miles and has a total storage capacity of 88,000 AF, equivalent to 8 inches of runoff from the drainage area. The reservoir is formed by an earthfill dam 118 feet high. The Fishtrap Reservoir project on Levisa Fork has been authorized, but work has not been started. This dam is planned as a concrete gravity dam 161 feet high, impounding a reservoir with a capacity of 126,000 AF, equivalent to 6 inches of runoff from a drainage area of 395 square miles.

Water supplies for Johnson-Magoffin, Pike, Floyd-Magoffin, and Knott-Breathitt General Areas could be obtained by constructing reservoirs on the tributaries of Levisa Fork, by increasing the capacity of Dewey Reservoir, or by utilizing storage that might be made available from the conservation pools of the other proposed reservoirs. The coal resources of the four General Areas would support, for 40 years, the production of 678,000 barrels per day of synthetic liquid fuels which would require a total water supply of 1,373 cfs. Of this total requirement, approximately 375
Ky cfs could be obtained from the tributaries of Levisa Fork. The
remainder would have to be either from the North Fork of the
197b Kentucky River or from the Ohio River. In these calculations,
198 sufficient water is reserved for a unit plant development further
4 upstream on Levisa Fork in Virginia.

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Licking River. The Licking River lies to the southwest of Big Sandy River and flows northwest into the Ohio River. It rises near Salyersville, in Magoffin County and empties into the Ohio River at Covington, Ky., opposite Cincinnati, Ohio. The Licking River has a total drainage area of 3,655 square miles and meanders through a narrow drainage basin about 140 miles long. The terrain ranges from rolling to mountainous; short steep tributary streams produce a rapid runoff and low flows during dry periods. The basin is devoted predominantly to agriculture except for some mining operations in the upper portion. The principal towns in the upper basin are Salyersville and West Liberty. The Licking River has not been improved for navigation or any other purposes except for municipal water supplies serving approximately 36,000 persons.

The Licking River is at some distance from the assumed plant sites in Johnson-Magoffin, Pike, and Floyd-Magoffin General Areas, and probably would not be used as a source of water supply, except perhaps in the event of large scale development of the coal resources in eastern Kentucky.

Kentucky River. The Kentucky River is formed by the junction near Beattyville, Kentucky, of North Fork, Middle Fork, and South Fork, of which the North Fork is much the largest. The total drainage area of the Kentucky River is 6,949 square miles. Its basin ranges from the mountainous area in the headwaters to the relatively flat tableland of the Blue Grass region, where the river flows through a deep gorge with limestone cliffs rising to as much as 300 feet. The economy of the basin is predominantly agricultural, except in the mountainous sections where mining and lumbering are important. Principal cities and towns in the upper watershed are Whitesburg, Hazard, Jackson, and Beattyville.

The Kentucky River is improved for navigation with 14 locks and dams from near the mouth almost to Beattyville. These provide a minimum channel depth of 6 feet for a distance of 280 miles upstream from the mouth. The only two existing hydroelectric projects on the Kentucky River system are in the lower basin, considerably removed from any General Areas of Coal Availability. They are on the Dix River and on the main Kentucky River at Lock and Dam No. 7. The Dix River installation consists of a rock-fill dam 270 feet high, storing 30,000 AF of water and having an installed capacity of 22,500 kw. The development is owned by the Kentucky Utilities Co. of Louisville. The installation at Dam No. 7 is a run-of-river plant automatically controlled from the Dix River station with a total capacity of 2,040 kw.

Two flood control reservoirs have been considered for construction on the Kentucky River. The Jessamine Reservoir, controlling a drainage area of 4,440 square miles, is authorized as a flood control reservoir and a 13,900-kw hydroelectric power installation has been considered for the site. The total storage proposed is 1,135,000 AF, which would provide a pool extending upstream to navigation Dam No. 14, 6 miles below Beattyville.

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The Booneville Reservoir, impounding a drainage area of 697 square miles is proposed for construction at a site less than 1 mile above the town of Booneville on the South Fork of the Kentucky

River. The reservoir would have a total capacity of 485,000 AF, part of which would be used for maintaining a dry weather flow of 410 cfs for power purposes. The installed capacity of the proposed power plant would be approximately 7,300 kw. Construction of either reservoir is not anticipated in the immediate future. None of the tributaries of the Kentucky River has sufficient natural flow during periods of drought to furnish water supplies for synthetic liquid fuels production; storage reservoirs would be required. These reservoirs would either supply water directly to the plant or would be used for supplementing low flows of the river further downstream. On the basis of storage studies, it is estimated that a yield of 0.8 cfs per square mile could be obtained economically in the upper Kentucky River basin by building approximately 570 AF of storage per square mile of tributary drainage area.

Water supplies for Perry-Breathitt, Leslie-Harlan, and Northern Letcher General Areas would logically be developed on the Kentucky River or its tributaries. If the coal reserves in all three General Areas should be fully developed, a total water supply of 375 cfs would be required. Development of a water supply of this size would require reservoirs on the Middle and North Forks of the Kentucky River with a total storage capacity of 251,000 AF.

Cumberland River. The Cumberland River rises in Letcher County on the Kentucky-Virginia boundary. It follows a winding course, swinging south into Tennessee and then back north to cross Kentucky parallel to the Tennessee River and not very far from it. The topography of the upper part of the Basin in eastern Kentucky is extremely rugged with tributary streams running through the deep narrow, crooked valleys of a mountainous region. The principal tributaries in the eastern part of Kentucky are Laurel and Rock Castle Rivers, and the South Fork of the Cumberland River. The principal towns and cities in this part of the basin are Harlan, Middlesboro, Barbourville, and Williamsburg. Coal mining is the only industry of consequence in the upper part of the basin.

The lower Cumberland River has been improved for navigation with a minimum channel depth of 6 feet from its mouth to some distance beyond Nashville, Tennessee. Cumberland River water is used for water supply purposes at Williamsburg and Harlan, serving a total population of 9,500 persons. A comprehensive program of flood control, navigation, and hydroelectric power generation has been developed by the Corps of Engineers for the lower Cumberland River basin. Construction of some of the dams and power houses has been completed, and work on some of the others is underway. No comparable program has been initiated for the upper basin.

Water supply for Harlan-Letcher and Bell General Areas would logically be obtained from the Cumberland River basin. Supplies adequate for unit plants in each General Area would have no appreciable effect upon the flows of the river. The maximum potential water requirements for synthetic liquid fuels plants in
Ky these two General Areas estimated at 403 cfs, which quantity of water could be provided from impoundments on tributary streams pro-
201b viding reservoir capacity of 282,200 AF. The most economical water
to supply system for synthetic liquid fuels plants at the locations
203a selected in Harlan-Letcher and Bell General Areas would include
4 small reservoirs on local tributary streams; there would be no depletion of the natural stream flow during periods of extreme

drought. On the whole, these small reservoirs would be beneficial to the lower basin and water supplies for synthetic liquid fuels plants, therefore, would have no detrimental effect upon power generation or other present water uses in the valley.

<u>Green River</u>. The Green River, rising in central Kentucky, flows west for 200 miles before turning northwest to empty into the Ohio River. Its principal tributaries are the Barren, Nolin, Rough, Mud, and Pond Rivers. The Green River basin comprises about one-quarter of the total area of Kentucky. The topography is rolling and uneven, and many of its river channels are deeply cut. Characteristic of the basin are the limestone caverns and solution channels in the underground formations. There are many large subsurface streams such as the Lost River near Bowling Green. Springs are numerous in the area and are important in sustaining the low flows of the Green River.

Farming is the principal occupation in this area although there is some mining and manufacturing. The principal towns and cities are Leitchfield, Brownsville, Bowling Green, Central City, Greenville, Madisonville, Calhoun, and Livermore. The Green River and its tributaries are used as a source of municipal water supply by more than 50,000 persons in several communities, the largest of which is Bowling Green. The river has been improved for navigation with six locks and dams providing slackwater pools with a minimum channel depth of 5 feet from the mouth to Mammoth Cave near Brownsville. One lock and dam on Barren River provides navigation with a 5-foot channel depth as far as Bowling Green; another on Rough River provides navigation up to Hartford. There has been no development of hydroelectric power in the Green River basin.

Navigation requirements for leakage and lockages in the river are estimated at about 25 cfs, or 16 mgd. Municipal water requirements average approximately 3 mgd. Reduction of river flows below present minimums might cause some nuisance by interfering with the dilution of sewage. In a 1943 report entitled, "Ohio River Pollution Control", the U.S. Public Health Service stated that primary treatment combined with dilution should be sufficient to maintain satisfactory stream conditions along the Green River. Stream flow records of the Corps of Engineers show that the minimum monthly average rate of flow at Green River, Kentucky, about 9 river miles upstream from Rockport was 385 cfs during the period 1900-1943 inclusive. Instantaneous discharges as low as 30 cfs have been recorded at Lock No. 4, Green River. The District Office of the Corps of Engineers has indicated that the ordinary low flow is ample to sustain navigation and that the 20 cfs demand for a single 10,000-barrel-per-day synthetic liquid fuels plant in each of the three General Areas below Rockport could be met from the river without difficulty.

The Green River would be the logical source of water Ky
supply for unit plant developments in Daviess, Muhlenberg-McLean,
Ohio General Areas. If the coal resources in the General Areas 203b
should be developed fully, a total of 426 cfs would be required. This to
represents a substantial part of the total flow in the river during 205a
extreme low flow periods and it would be necessary to provide stor- 4
age reservoirs for any such large-scale development. From storage
studies of the Green River and its tributaries, it is estimated that 70021

water developments up to 0.8 cfs per square mile of tributary drainage area with storage of 615 AF per square mile would be economically feasible, and that sufficient water could be obtained. In making these estimates, it has been assumed that the control flow of 0.09 cfs per square mile, or 680 cfs at Livermore, Kentucky, would be provided for downstream water users. This is many times the present requirements for navigation and pollution abatement needs.

Several sites for the construction of impounding reservoirs are available in the upper Green River watershed. Representative sites are listed in Exhibit No. 31 and shown on Exhibit No. 21. Detailed surveys and investigations of foundation conditions would be particularly necessary in the eastern part of the drainage basin where leakage through the underlying limestone might require costly cutoff works or might altogether preclude construction.

Tradewater River. The Tradewater River is a relatively small stream lying immediately north of the Cumberland River with a total drainage area of 1,008 square miles. Only short records of its stream flow are available but in 1940, the flow fell to zero during the entire month of October. From the mass diagram studies, it has been determined that the economical limit for development of the Tradewater River is approximately 0.6 cfs per square mile, requiring a storage of 510 AF per square mile of tributary drainage area.

There has been no development of the Tradewater River other than for municipal water supply purposes in two communities serving less than 10,000 persons. The Tradewater River would be the logical source of supply for unit plants or relatively small developments in Webster and Hopkins-Christian General Areas. Full development of the coal resources in Hopkins-Christian General Area would require more water than is available in the Tradewater River and it would be necessary to extend a pipeline from the Ohio River.

Ground Water. Kentucky can be divided into seven distinct physiographic regions, as indicated by the diagram shown on Exhibit No. 32.

The western coal field region, embracing most of Daviess, Henderson, Union, Webster, Hopkins-Christian, Muhlenberg-McLean, and Ohio General Areas, is underlain by sandstones, coals, shales, and some limestones, the latter usually not more than 5 feet in thickness. Most of the shales and the masses of sandstone have large quantities of ground water, but since the joint system of the areas is the controlling factor in the location of ground water supplies, the finding of large quantities is a matter of chance. Many oil and gas wells have been drilled in the region, and the logs of these wells often show the presence of large quantities of ground water. However, the ready availability of surface supplies and the element of chance in obtaining ground water eliminated it from consideration in these General Areas.

The Eastern Kentucky coal field, or the Cumberland Plateau, is similar, geologically speaking to the Western Kentucky coal field, as is shown in the cross section of the State on Exhibit No. 32. This portion of the State is underlain by sandstones, conglomerates, coals, shales, and some localized thin layers of limestones. Joints and bedding plains have undergone no solutional development, but they do traverse each formation in many directions. Since good well development depends upon the size and number of fractures encountered as well as the interconnections between interstices, although there is sufficient supply of ground water for small communities and individuals, conditions are not suitable for the development of large municipal or industrial supplies.

The Ohio River valley extends for 664 miles along the entire northern boundary of the State. At the close of the last glacial age, a 100-foot deep valley cut in the bedrock was filled with gravel and sand, and it is over this material that the Ohio River flows today. Immense quantities of ground water are available in these unconsolidated materials. Most of the recharge of this underground reservoir comes from the ground water in the formations making up the sides of the valley, although under flood conditions, the direction of flow might be reversed. In areas of heavy pumping, such as Louisville, where large quantities are drawn from wells for industrial purposes, this is the case, and the well water is a mixture of water from the river and from the ground.

Because of this and because at best the production of multi-million-gallon ground water supplies contains grave elements of chance, estimates for water supplies for the General Areas near the Ohio River are based on surface water intakes.

The region lying between the Tennessee and Mississippi Rivers is known as the Jackson Purchase. The artesian supplies available there and in the large subterranean streams of the Pennyroyal Plateau provide the most abundant ground water in the interior of Kentucky. The outer Blue Grass and Lexington Plains regions have poor potential ground water supplies.

Water Quality. Typical analyses of surface waters from the several rivers in or near the General Areas of Coal Availability are shown on Exhibit No. 33. It will be noted from these analyses that the water is quite clear with low turbidities, and that the dissolved solids concentration generally does not exceed 250 ppm. The water is well-suited for industrial and domestic water supply purposes. Some of the small streams in the coal-bearing areas become quite acid
during periods of low flow, and the presence of iron would require Ky
treatment in some cases. Increased coal mining for synthetic liquid
fuels production would aggravate the acid mine drainage problem, un- 207
less steps were taken to control it. The river waters could be used 208a

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for cooling without treatment. It is expected that filtration would be required for the domestic water supplies and for some minor industrial purposes in all Areas. Boiler feed waters would have to be softened.

Where ground waters might be available in the General Areas, they are normally quite hard and more highly mineralized than the surface waters. Analyses of ground water typical of the Ohio River valley are included on Exhibit No. 34 but no other areas are included, since in general, they are relatively unimportant and the variable quality cannot be indicated by representative analyses.

Water Rights

The common law doctrine of water rights is applicable to surface and ground waters in Kentucky. The common law doctrine for surface waters, also termed the riparian rights doctrine, accords to each owner of land contiguous to a stream the right to make whatever use of the water he requires for domestic purposes and the watering of livestock, and to make such use of the water for irrigation or other purposes (such as manufacturing) as is reasonable with regard to like reasonable uses by all other owners of land riparian to the same stream.

The common law, or old English law, for ground waters, is based upon the principle that the owner of land is also the owner of all water underlying his realty. The land owner is, therefore, entitled to withdraw such subsurface waters without hindrance and regardless of the effect such withdrawal would have on surrounding territory.

Kentucky, at present, has no regulations concerning the utilization of surface or ground waters. The Game and Fish Commission does require that fish ladders be erected and maintained during April, May, and June of each year in order that fish be permitted to pass over dams.

The State Department of Health maintains supervision over public water supplies and industrial supplies used for drinking. Plans and specifications must be submitted to and approved by the Department for such works.

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Water Available for Synthetic Liquid Fuels Manufacture

The sources of water that might be developed for synthetic liquid fuels plants for each of the 16 General Areas of Coal Availability in Kentucky are shown in Exhibit No. 35. Sufficient water for at least one 10,000-barrel-per-day plant in each General Area,

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20 cfs, can be obtained locally or within reasonable distance from the assumed plant site, and each General Area may therefore be classified as a General Area of Coal and Water Availability.

In 2 of the 16 General Areas, water could be obtained for a synthetic liquid fuels unit plant directly from the Ohio River. In an additional 3 of the 16 General Areas, water could be obtained for a synthetic liquid fuels unit plant directly from the Green River. In all other instances, storage to impound wet weather runoffs would be required.

The sources of water for a representative water supply development for one 10,000-barrel-per-day plant in each of the 16 General Areas are summarized below:

Sources of Water for One 10,000-Barrel-per-day Synthetic Liquid Fuels Plant in Each of 16 General Areas in Kentucky

Source	Water Supply: No. of General Areas	Cfs	Mgd	Percent of Total
Ohio River	2	40	26	12.5%
Cumberland River and Tributaries	2	40	26	12.5
Tradewater River and Tributaries	2	41	27	13.0
Green River (A)	3	59	38	18.3
Kentucky River and Tributaries	3	61	39	18.7
Levisa Fork and Tributaries	4	81	52	25.0
Total	16	322	208	100.0%

Note: (A) Only 29,000 Barrels capacity in 3 initial plants.

If the coal resources in Kentucky were fully developed, 1,696,000 barrels of synthetic liquid fuels could be produced daily and 3,434 cfs of water would be required. As summarized from Exhibit No. 35, the water might be obtained from the following sources:

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Sources of Water Required for Full Development of Synthetic Liquid Fuels Resources in Kentucky

Source	Water Supply Cfs	Mgd	Percent of Total
Ohio River	1,653	1,068	48.1%
Cumberland River and Tributaries	403	260	11.7
Green River	425	275	12.4
Kentucky River and Tributaries	574	371	16.7
Levisa Fork and Tributaries	379	245	11.1
Total	3,434	2,219	100.0%

It must be recognized that the extremely large quantity of water indicated above as being obtained from the Ohio River would require reservoirs on its tributaries to augment the flow of the river during dry periods.

Relation of Water Needs for a Major Synthetic Liquid Fuels Development to Water Available in the Ohio River Basin

There are eight states having sufficient coal reserves in the Ohio River basin for a synthetic liquid fuels development. While it is unlikely that a large-scale development using all of the coal resources would take place throughout the Ohio Valley, it is important to consider the effect of large drafts of water upon the flow of the river. The Ohio River basin states and the principal rivers are shown on Exhibit No. 36.

Inventories of coal resources prepared for this report indicate that, if all coal were devoted to the production of synthetic liquid fuels, the maximum water demand in the Ohio River basin states would be about 15,000 cfs. It is estimated that of this 15,000 cfs about 10,000 cfs would be obtained from water supply systems involving storage reservoirs built either for the development of low stream flow or for the regulation of low flows in the major tributaries. Reservoirs proposed for synthetic liquid fuels development would not reduce the low flows in the Ohio River, as they would not store water during the critical low flow period. The total amount of water to be pumped directly from the Ohio River or its major tributaries would be approximately 5,000 cfs. This would be taken throughout the length of the river. Withdrawal of this amount of water would affect the flow of the Ohio River, which is shown in the following table, only to a small degree.

Average Flow of Ohio River at Three Points

Gaging Station	Drainage Area (Square Miles)	Average Flow (Cfs)	Years of Record
Sewickley, Pa.	19,500	31,900	1934-48
Huntington, W. Va	55,900	76,450	1935-47
Louisville, Ky.	91,170	110,300	1929-47

The low flow of the Ohio River below Huntington would not be affected seriously by the withdrawal of this water, but in the area above Huntington, where an estimated 3,000 cfs would be diverted, the low flow could be seriously affected.

The lowest flows of record occurred during the 1930 drought period. Unfortunately, the U.S. Geological Survey stream flows for this period are meager. However, it is possible to prepare from the records of tributary streams and from Corps of Engineers data regarding flows at Louisville an estimate of the flow that occurred during October 1930, the lowest month of record. This runoff is plotted on the bottom line of Exhibit No. 25. Since the drought period of 1930 several reservoirs have been built in the Ohio River basin to conserve runoff and aid regulation. The more important of these reservoirs are Tygart in West Virginia, Youghiogheny and Pymatuning Reservoirs in Pennsylvania and Berlin and Mosquito Creek Reservoirs in Ohio; and a large number of reservoirs on the Tennessee and Cumberland Rivers. It is estimated that low flows of the Ohio River during 1930, in the critical section between Pittsburgh, Pa., and Huntington, W. Va., would have been increased by at least 1,000 cfs, and the flow in the Lower Ohio would have been increased 2,000 cfs, if these reservoirs had been built at that time. The middle line on Exhibit No. 25 indicates what the 1930 flow would have been with regulation of these reservoirs.

Additional storage reservoirs for the regulation of the Ohio River flows are being considered. Some of these would be for flood control and river regulation and some for hydroelectric power production. The largest of these are the Allegheny in Pennsylvania, Mill Creek on the Clarion River, Cave Run on the Licking River in Kentucky, and several reservoirs on the Green River in Kentucky. Some of these have been authorized for construction by Congress but no funds have been appropriated. If all the proposed reservoirs should be built, together with those already constructed, it is estimated that the minimum flow of the Ohio River in a period like
1930 would have been increased 5,000 cfs in the section above Ky
Huntington and 11,000 cfs near the mouth. The top line on Exhibit
No. 25 indicates this increased runoff. 213b

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The Ohio River is not only an important waterway for freight haulage but it is also the source of water supply for some 30 communities drawing 300 cfs for domestic use and for many industries. Therefore, the quality of Ohio River water is of great economic importance. Many of the industrial uses are for cooling only and the water is returned to the river without much change except for a rise in temperature. Most of the water used for municipal purposes is returned as sewage. This stream pollution is most severe, and the low flows most critical, immediately below Pittsburgh. Serious pollution occurs also at Cincinnati, Louisville, and Evansville and it is important that the low flows be controlled at levels sufficient to prevent further degradation in quality.

It cannot be predicted now how many of these reservoirs will be built nor how much of the storage water will be available for the production of synthetic liquid fuels. However, the low-flow regulation program is primarily for the benefit of municipal and industrial water supplies in the Ohio River valley and it is reasonable to believe that a large-scale synthetic liquid fuels development would have such economic importance that it would participate in any such program. Up to the present time, flood control and regulating reservoirs have been built with Federal funds and the municipalities and industries benefiting have not been asked to contribute.

If none of the reservoirs proposed for regulating storage capacity on the Ohio River were available to the synthetic liquid fuels industry, it would then have to provide its own reservoirs. The additional storage requirements needed to regulate the river above Huntington for maximum synthetic liquid fuels development would be that storage required to maintain a draft of 3,000 cfs and has been estimated at 1,200,000 AF. These estimates are based upon gross water requirements for the synthetic liquid fuels plants and do not take into consideration the return water from the plants, amounting to more than 30 percent of the total demand. This return water would have a relatively high mineral concentration but none the less would add very substantially to the minimum flows.

The cost of providing this storage for over-all regulation of the Ohio River for full synthetic liquid fuels production has not been estimated. In any event, the cost of this storage would be spread out over so many plants that it would increase by only a very small amount the unit cost of water.

Since it is almost certain that the proposed storage development will take place in the Ohio River basin and a considerable portion of the conserved water would be available for synthetic liquid fuels production, and since it is also likely that the full development of synthetic liquid fuels possibilities in the Ohio River basin will not take place, the determination of the cost does not seem to be warranted.

Synthetic Liquid Fuels Potential of General Areas of Raw Material and Water Availability

In summary, the synthetic liquid fuels potential of the 16 General Areas of Raw Materials and Water Availability in Kentucky, in total and as an equivalent daily average over a 40-year period would be as follows:

Synthetic Liquid Fuels Potential (in Thousand Barrels) of General Areas of Raw Material and Water Availability in Kentucky, in Total and as a Daily Average for 40 years (As of January 1, 1949)

General Area	Total Potential		Equivalent Average Daily Plant Capacity 40-year Period	
	Hydro-genation	Coal Synthine	Hydro-genation	Coal Synthine
Johnson-Magoffin	596,000	463,000	41	32
Pike	7,363,000	5,727,000	504	392
Floyd-Magoffin	2,908,000	2,261,000	199	155
Knott-Breathitt	1,854,000	1,442,000	127	99
Perry-Breathitt	1,382,000	1,075,000	95	74
Leslie-Harlan	987,000	768,000	68	53
Northern Letcher	1,080,000	840,000	74	58
Harlan-Letcher	3,107,000	2,417,000	213	166
Bell	624,000	485,000	43	33
Daviess	169,000	131,000	12	9
Henderson	1,029,000	800,000	70	55
Union	1,510,000	1,174,000	103	80
Webster	1,986,000	1,545,000	136	106
Hopkins-Christian	3,428,000	2,666,000	235	183
Muhlenberg-McLean	2,571,000	2,000,000	176	137
Ohio	1,209,000	940,000	82	64
Total	31,803,000	24,734,000	2,178	1,696

PART V

SUITABILITY OF THE GENERAL AREAS

COAL

The 16 areas in Kentucky determined to be General Areas of Coal and Water Availability, grouped according to location in the coal fields of the State, are:

Kentucky General Areas
of Coal and Water Availability

Eastern Kentucky Field	Western Kentucky Field
Johnson-Magoffin	Daviess (A)
Pike	Henderson
Floyd-Magoffin	Union
Knott-Breathitt	Webster (A)
Perry-Breathitt	Hopkins-Christian (A) (B)
Leslie-Harlan	Muhlenberg-McLean (A) (B)
Northern Letcher	Ohio (A) (B)
Harlan-Letcher	
Bell	

Note: (A) Part of estimated coal reserves are strippable.
(B) Strippable reserves are adequate for 40-year supply of at least one unit plant using either process, except that such reserves of Muhlenberg-McLean General Area would not support a coal synthine unit plant.

These General Areas were next studied in detail from an economic standpoint to ascertain their further suitability for the production of synthetic liquid fuels. The locations of the 16 General Areas have been previously indicated on Exhibit No. 9. Detailed estimates of coal production costs are shown in Exhibit No. 37. Basic data on coal bed characteristics, estimates of recoverable reserves, estimated capital cost requirements, and estimated costs of coal supply per barrel of synthetic liquid fuel products are presented in Exhibit No. 38. The bibliography is appended as Exhibit No. 5.

Coal Characteristics and Properties

Rank and Chemical Analysis. (See Exhibit No. 5 for references below.) Descriptions and evaluations of the chemical and physical characteristics of the coal reserves in the 16 General Areas are generally available. These reserves, located in from

(References: 42, 49, 52, 56, 60)

one to seven principal coal beds in each General Area, range from high-volatile A bituminous (Hvab) to high-volatile C bituminous (Hvcb). The high-volatile A bituminous coals occur in the eastern counties of the State and the high-volatile B and C bituminous coals occur in the western counties. Average values of selected items of representative analyses of the beds containing coal reserves in the 16 General Areas are as follows (mine samples, as-received basis):

Representative Analyses of Coal Reserves
in the 16 General Areas
(Mine Samples, As-received Basis)

General Area	Moisture (Percent)	Ash (Percent)	Sulfur (Percent)	Btu Per Pound
Eastern Kentucky Field:				
Johnson-Magoffin	4.7%	3.0%	1.2%	13,730
Pike	3.1	4.3	1.0	14,090
Floyd-Magoffin	3.9	6.1	1.5	13,430
Knott-Breathitt	3.7	4.9	1.0	13,750
Perry-Breathitt	4.3	5.3	0.7	13,490
Leslie-Harlan	3.9	4.4	0.7	13,680
Northern Letcher	3.5	4.0	0.9	13,970
Harlan-Letcher	3.3	4.2	0.7	13,980
Bell	2.8	5.0	1.2	13,800
Western Kentucky Field:				
Daviess	12.1%	11.7%	3.0%	10,790
Henderson	10.7	12.8	3.4	10,960
Union	5.9	10.0	3.7	12,340
Webster	6.1	9.3	3.3	12,400
Hopkins-Christian	8.5	8.7	3.2	11,990
Muhlenberg-McLean	7.9	8.6	3.7	12,120
Ohio	9.6	9.3	3.7	11,640

Detailed analyses and other characteristics of the coals in each General Area are presented in Exhibit No. 38 of this report.

<u>Type and Petrographic Analysis.</u> (See Exhibit No. 5 for references below.) The Bureau of Mines has published the results of petrographic assays on representative Kentucky coals which show the following percentages of constitutents:

(References: 42, 45, 68)

Petrographic Analyses of Kentucky Coals

County	Bed	Anthraxylon	Translucent Attritus	Opaque Attritus	Fusain
Eastern Kentucky	Field:				
Bell	Lower Hignite	51%	32%	15%	2%
	Straight Creek	50	35	13	2
Floyd	Upper Elkhorn No. 3	51	35	8	6
Harlan	High Splint	31	41	26	2
	Taggart	51	32	14	3
Johnson	Millers Creek	49	27	21	3
Letcher	Elkhorn	37	35	24	4
Perry	Hazard No. 4	55	31	11	3
Pike	Pond Creek	43	37	16	4
Western Kentucky	Field:				
Hopkins	No. 6	55%	37%	5%	3%
	No. 11	64	30	3	3
	No. 12	64	31	3	2
	No. 14	63	29	5	3
Muhlenberg	No. 9	65	27	5	3

The above analyses indicate that the eastern Kentucky coals range from the "bright" petrographic type, wherein anthraxylon and translucent attritus predominate, with opaque attritus and fusain being present in minor amounts, to predominantly attrital types with the moderately high percentage of opaque attritus indicating compositions approaching that of semisplint coal. The western Kentucky coals are largely of the "bright" petrographic type. Since most of the coals in the 16 General Areas are similar in rank, appearance, and chemical composition to the coals for which petrographic analyses are available, there is no reason to expect any substantial differences in the degree of heterogeneity or adaptability to hydrogenation.

The value of petrography in predicting hydrogenation yield lies in the fact that the degree of heterogeneity of lithologic components is readily indicated and the approximate proportion of high-carbon opaque constituents (difficult to liquefy) are revealed, whereas chemical analysis determines only the average content of simple components.

<u>Organic and Inorganic Sulfur Content.</u> (See Exhibit No. 5 for references below.) Publications of the U.S. Bureau of Mines contain relatively comprehensive information on the organic and inorganic sulfur contents of representative Kentucky coals. Percentages of organic
19b and inorganic sulfur have been determined for various beds in 14 coal-
20a bearing counties as follows (as-received basis):

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(References: 42, 49, 52, 56, 60)

Analyses for Sulfur Content

County	Sulfur (Percent in Raw Coal) Inorganic	Organic	Total	Organic Sulfur, Percent of Total Sulfur
Eastern Kentucky Field:				
Bell	0.298%	0.734%	1.032%	71%
Harlan	0.188	0.631	0.819	77
Knott	0.478	0.934	1.412	66
Knox	1.054	0.537	1.591	34
Letcher	0.310	0.701	1.011	69
Perry	0.129	0.600	0.729	82
Western Kentucky Field:				
Daviess	2.313%	1.437%	3.750%	38%
Henderson	2.142	1.485	3.627	41
Hopkins	1.923	1.431	3.354	43
McLean	1.689	1.578	3.267	48
Muhlenberg	2.012	1.535	3.547	43
Ohio	2.081	1.464	3.545	41
Union	1.766	1.635	3.401	48
Webster	1.605	1.721	3.326	52

The above analyses indicate that organic sulfur, which is not considered amenable to reduction by mechanical cleaning, may range from 34 to 82 percent, averaging approximately 66 percent, of the total sulfur in eastern Kentucky coal beds, and from 38 to 52 percent, averaging approximately 43 percent, in western Kentucky coals. The complete removal of pyritic (inorganic) sulfur by mechanical cleaning of the coal, if possible, would thus result in decreasing the total sulfur content in eastern Kentucky coals by an average amount of approximately 34 percent to minimum sulfur contents of from 0.5 to 1.0 percent in the cleaned coal and would result in decreasing the total sulfur content by an average of approximately 57 percent to minimum sulfur contents of from 1.4 to 2.0 percent in cleaned coal in the western Kentucky area. The actual extent of reduction depends upon the amounts, sizes, and types of occurrences of the pyritic sulfur-bearing ingredients in the raw coal. Specific washability tests are required, however, to determine the reduction in total sulfur which might result from mechanical cleaning.

Storage, Weathering, and Slacking Characteristics. (See Exhibit No. 5 for references below.) The high-volatile A, B, and C bituminous rank coal reserves in the Kentucky General Areas are similar to other coals of equal rank in weathering and slacking characteristics and present no particular problems when stored

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(References: 54, 58)

properly. These coals usually slack readily but do not ignite spontaneously when exposed to air, thus reducing the problems of coal storage necessary in synthetic liquid fuels manufacture. Surge storage at the mine would provide for a uniform daily flow of coal to the process plant from the mines probably operating only two shifts per day for 5 days each week. The synthetic liquid fuels plant is assumed to operate continuously for three shifts per day throughout the year. It is probable that substantial additional storage facilities will be necessary at the plant to protect it from interruptions or decreases in production at the coal mines and from possible transportation stoppages between mine and plant. At the process plant, provision is made for sufficient storage to provide a 30 days' reserve supply. As only cleaned coal will be stored in volume, no especial hazards are expected, and the coal may be stored in necessary quantities for indefinite periods. Costs of surge storage at the mine, together with those of handling the coal into and out of storage, are provided for in the estimates of capital investment for the mine and coal producing costs. Estimates of required working capital for the process plant allow for a reserve storage of a 30-day coal supply. Facilities for coal storage and its operation at the process plant are included in the process costs.

Grindability and Friability. (See Exhibit No. 5 for reference below.) Information on grindability of the coals in the 16 General Areas in Kentucky indicates that they are similar in grindability to comparable industrial coals and will respond without undue difficulty to fine grinding. The degree of ease with which a coal may be pulverized depends not only on its relative grindability index, but also upon the fineness of grinding desired and on its moisture content. The standard of grindability (Hardgrove index 100) is arbitrarily selected, according to American Society for Testing Materials, as represented by low-volatile, run-of-mine bituminous coal from the Jerome Mine, Upper Kittanning bed, Somerset County, Pennsylvania. Coals of low surface-moisture content, such as those in eastern Kentucky, accelerate pulverization by their lack of tendency toward coherence and formation in cakes, while coals of medium surface-moisture content, as in western Kentucky, are average in nature and neither retard nor accelerate pulverization.

The relative grindability indices of representative coals in eight eastern Kentucky counties range between 31 and 73, with an average of approximately 53. Grindability indices of representative coals in seven western Kentucky counties range from 51 to 75, with an average of about 63. The ranges and averages in the individual counties are shown in the following table:

(Reference: 59)

Determination of Grindability Indices

County	Grindability Index Low	High	Average
Eastern Kentucky Field:			
Bell	42	73	56
Floyd	43	64	50
Harlan	31	68	50
Johnson	57	58	57
Leslie (one test)	50	50	50
Letcher	46	62	53
Perry	43	63	51
Pike	44	68	54
Western Kentucky Field:			
Christian	51	69	58
Daviess	60	65	63
Hopkins	54	68	60
Muhlenberg	53	75	64
Ohio (one test)	64	64	64
Union	61	72	66
Webster	62	67	64

The lower index numbers in eastern Kentucky probably reflect the greater proportion of coal of semisplint nature in comparison with the "bright" coals of western Kentucky. The relatively low index numbers in both fields indicate that coals in the Kentucky General Areas resist pulverization to a greater extent than the standard coal, thus requiring an increase in pulverizer capacities. This results in an increase in cost of pulverization over that of a coal with an index of 100.

Nature of Partings. The available information indicates that the majority of the coal beds in eastern Kentucky frequently contain one or more thin partings of bone or shale ranging from less than one-eighth inch to as much as six inches in thickness. Many of the beds are characterized in some areas by the occurrence of top or bottom benches of irregular thickness composed of alternating bands of coal and partings to the extent that the entire bench is relatively worthless. Such beds, however, commonly contain one or two principal benches which represent a minable thickness. In such cases, attempts may be made to leave these top or bottom benches in the mine although, if unsuccessful, such impurities may be removed in mechanical cleaning plants.

The principal beds of western Kentucky coals commonly contain one or more bedded impurities or partings. These partings, ranging from less than one-quarter inch to three inches or more in thickness, normally consist of shale or underclay, with varying admixtures of carbonaceous material. The partings are frequently pyritized in areas of irregular extent.

The No. 14 bed, of widely varying thickness, is highly irregular in occurrence and content of impurities, which range from specific shale partings to high-ash coal benches containing large proportions of disseminated impurities.

The No. 12 bed characteristically contains high amounts of impurities disseminated throughout the coal as well as additional bands or lenses of shale or pyrite.

The No. 11 bed is characteristically composed of three low-ash coal benches separated by two persistent shale partings ranging from one-half inch to two inches in thickness.

The No. 9 bed is relatively high in ash derived from shaly material deposited in disseminated form through the coal bed; it rarely contains persistent shale or pyrite partings.

The No. 6 bed is characteristically composed of clean coal, with but a few thin partings or lenses of shale occurring infrequently in local areas.

The roof materials overlying Kentucky coal beds range from shale or limestone in western Kentucky to shale, sandy shale, or sandstone in eastern Kentucky. Where composed of relatively weak material, fragments of the roof may become mixed with the raw coal during mining in either Kentucky coal field.

Mechanical Cleaning. In considering washability characteristics, the character, number, and thickness of contained partings serve as a partial guide to the relative ease with which a specific coal may be mechanically cleaned. While the presence of partings in Kentucky coals is generally not such as to seriously interfere with mining operations, they do affect the type and capacity of the necessary cleaning facilities and the amount of refuse which must be handled during the cleaning process. These factors were taken into consideration in estimating mine investment and operating costs in each of the General Areas as hereinafter established.

No specific data are available on washability tests of eastern Kentucky coals, although examination of washability studies on similar coals in adjacent portions of Tennessee, Virginia, and West Virginia indicate that the ratios of refuse to raw coal in eastern Kentucky may range between 6.5 and 20.9 percent, with an average of approximately 12.6 percent.

Data on washability of western Kentucky coals are available from tests by the U.S. Bureau of Mines. The following table shows the results on a moisture-free basis of washability tests on several representative coal beds in Hopkins and Muhlenberg Counties:

Results of Washability Tests - West Kentucky Coals
(Moisture-free Basis)

	Ash (Percent)		Sulfur (Percent)		
Coal Bed	Raw	Washed	Raw	Washed	Percent of Refuse
No. 6	4.83%	2.55%	2.74%	1.44%	21.1%
	4.77	2.31	2.60	1.38	21.9
	6.60	4.10	3.80	2.30	17.8
No. 9	11.00	6.80	4.20	2.90	20.0
No. 11	9.80	5.50	4.40	3.10	20.0
No. 12	18.80	12.20	4.10	3.10	20.0
	18.50	11.00	4.60	3.40	20.0

Ky
These data indicate that Kentucky coals are generally amenable to
improvement in qualify by commercial-type mechanical cleaning. 225b
With installation of relatively simple facilities for removal of 226a
solid impurities and other high-ash refuse, the cleaned mine 10
products from the General Areas in Kentucky should contain the 70021
following average ash and sulfur contents (as-received basis):

Approximate Average Ash
and Sulfur Contents (As Received)
Cleaned Coals from Kentucky General Areas

General Area	Ash (Percent)	Sulfur (Percent)
Eastern Kentucky Field:		
Johnson-Magoffin	2.5%	1.0%
Pike	3.8	0.8
Floyd-Magoffin	5.4	1.2
Knott-Breathitt	4.3	0.8
Perry-Breathitt	4.8	0.5
Leslie-Harlan	3.9	0.5
Northern Letcher	3.5	0.7
Harlan-Letcher	3.7	0.5
Bell	4.4	1.0
Western Kentucky Field:		
Daviess	7.0%	2.0%
Henderson	7.7	2.2
Union	6.5	2.5
Webster	6.0	2.2
Hopkins-Christian	6.0	2.1
Muhlenberg-McLean	6.0	2.5
Ohio	6.5	2.5

Available information indicates that mechanical cleaning of Kentucky coals, in addition to reduction of ash and sulfur, also reduces the proportion of opaque lithologic constituents in the raw coal, thus improving amenability to hydrogenation. Information on the specific quality of the cleaned coal resulting from mechanical preparation in each General Area, however, requires further washability investigations of typical samples of the available coal reserves.

The foregoing discussion of washability of Kentucky coals applies only to the preparation of raw coal from the available reserves to a merchantable quality, as would be done in ordinary commercial practice. The possibilities of further reduction of ash, sulfur, and opaque constituents for purposes of hydrogenation require additional study beyond the scope of this phase of the synthetic liquid fuels survey and are not herein considered.

Modern mechanical mining, because of its lack of selectivity at the working face, requires mechanical cleaning facilities to obtain economic production costs. Mechanical cleaning also insures the removal of solid impurities which might otherwise severely damage pulverizers or other plant equipment. Provision is made in the estimates of capital and producing costs for a mechanical cleaning plant designed to remove solid and high-ash impurities from the mine-run coal in each of the General Areas. Such estimates are relatively higher for western Kentucky coals than for coals of eastern Kentucky and some other states, largely because of the presence of the numerous partings.

Mine Waste Disposal. The refuse from the coal preparation plant at the mine is expected to consist largely of shale partings and contaminating material from roof or floor, together with some bone and fusain from the coal bed. According to the Bureau of Mines report on bituminous coal for 1948, the ratio of refuse to raw coal which was cleaned was 17.2 percent in Kentucky. On this basis the percentage of refuse to clean marketable coal would be about 20.8 percent. The estimated range of percentage of waste to marketable coal in the various General Areas would be approximately from 14 percent in eastern to 25 percent in western Kentucky. At 14 percent of daily production of marketable coal in eastern Kentucky, the refuse would total approximately 760 tons per working day, or 182,400 tons per year, equivalent to 121,600 cubic yards, based on supplying marketable coal to a hydrogenation plant; and 970 tons per working day, or 232,800 tons per year, equivalent to 155,200 cubic yards, based on supplying marketable coal to a synthine plant. The corresponding figures for western Kentucky at 25 percent of daily production of marketable coal would be approximately 1,590 tons of refuse per working day, or 381,600 tons per year, equivalent to 254,400 cubic yards, based on supplying marketable coal to a hydrogenation plant, and 2,050 tons per working day, or 492,000 tons per year, equivalent to 328,000 cubic yards, based on supplying marketable coal to a synthine plant.

The disposal of these types and quantities of refuse presents no particular problems. It could be transported by tramway or by trucks from the preparation plant to nearby mine property or to selected areas of rugged land or other land unfit for farm use, of which there are many acres in each of the General Areas. With proper precautions, the possibilities of contamination of water supply should be negligible. The estimated capital and operating costs hereinafter established in this report provide for waste disposal from the coal preparation plant, assuming that the waste-disposal tract is within 3 miles of the coal preparation plant.

Hydrogenation Yield. (See Exhibit No. 5 for references Ky
below.) The degree of liquefaction of coals by hydrogenation is,
roughly, inversely proportional to their moisture- and ash-free 227
carbon content, as determined by ultimate analysis. Coals with 228
high carbon content are generally low in liquefaction yield. 229
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7002

(References: 50, 51, 53, 55)

Normal carbon contents (maf) range from approximately 55 percent in peat to 95 percent in anthracite. The coals in the nine General Areas of eastern Kentucky range between 83.0 and 86.5 percent in carbon content (maf) with an average of 84.2 percent. The coals in the seven General Areas of western Kentucky range from 77.6 to 83.2 percent in carbon content (maf) with an average of 80.5 percent.

These averages are comparable to a carbon content of 86.6 percent (maf) for an assay on Upper Freeport coal from Monongalia County, West Virginia, from which an oil yield of 61 percent of the coal as received was obtained, and to a carbon content of 84.2 percent (maf) for an assay on Pittsburgh coal from Allegheny County, Pennsylvania, from which an oil yield of 66 percent of the coal as received was obtained. These yields compare with a high of 69 percent from a high-volatile A bituminous coal from the Black Creek bed in Walker County, Alabama, and with a low of 31 percent from lignites from the Fort Union and Coteau beds in Mercer and Ward Counties, respectively, in North Dakota. The coals in all Kentucky General Areas are reasonably comparable in rank and quality to similar coals assayed by the Bureau of Mines, and it is reasonable to expect a similar hydrogenation yield from them, although the suitability of a particular coal for hydrogenation purposes can be determined only by actual tests.

Land Ownership, Coal Rights, and Surface Valuation

Private Ownership and Purchase Costs. (See Exhibit No. 5 for reference 16.) Essentially all coal-bearing lands in Kentucky are privately owned. Underground coal, without surface rights, may be leased at amounts ranging from 5 to 30 cents or more per ton and may be purchased at amounts ranging from less than $25 to more than $150 per acre depending on thickness, quality, and location of the coal bed. Strippable coal, including necessary surface lands, may be leased at amounts ranging from 15 to 50 cents or more per ton and may be purchased at amounts ranging from less than $100 to $300 or more per acre depending on thickness, depth, quality, and location of the coal bed. Surface land values without coal rights range from $20 to $200 or more per acre depending on the agricultural value and geographic location of the specific property.

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Legislation Affecting Production of Coal

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Taxes. Kentucky mines are in a favorable position in the matter of taxation. Real estate and property taxes average 2.5 percent on assessed valuation, generally based on 100 percent of fair market value. Other taxes, such as corporate organization fee and corporation franchise tax would not apply separately to coal mining conducted as an associated operation with all production going to a synthetic liquid fuels plant.

Restitution of Surface Damaged by Mining. There is no specific legislation in Kentucky which requires restoration of surface damaged by strip mining or payment of damages resulting from subsidence caused by underground mining.

Production Costs

(See Exhibit No. 5 for references below)

The data on coal bed occurrences in the 16 General Areas are in no-wise sufficient in scope or in detail to permit the preparation of actual mining layouts and of specific estimates of mining costs based thereon. Extensive drilling programs will be necessary before precise location and extent of reserves available for mining operations can be determined. Comprehensive engineering studies, based on the results of the drilling programs, will then be necessary to determine the equipment and methods of mining best adapted to the efficient and economic production of fuel for synthetic liquid fuels plant supply. The estimates of coal production costs presented are necessarily generalized in nature and are based on the assumption that thorough drilling and engineering will precede any development of mining operations in connection with coal supply for synthetic liquid fuels manufacture, thereby permitting more precise estimates of costs.

In estimating over-all mining costs for each of the 16 General Areas in Kentucky, as of March 31, 1950, the total estimated investment costs are considered to include erection of all necessary mine structures, together with purchase and installation of all necessary operating equipment. They also include investment costs of facilities for transporting the output from two or more adjacent mining operations to a joint preparation plant, a mechanical cleaning plant designed largely to remove solid and high-ash impurities from the raw fuel, waste disposal from the preparation plant, sufficient coal surge storage at the mine to provide uniform daily shipments to the synthetic liquid fuels plant, engineering, development, and contingencies. While the estimated investment costs do not include purchase price of surface or coal lands, a royalty charge of from \$0.10 to \$0.30 per ton of cleaned coal for underground mining and of from \$0.15 to \$0.35 per ton of cleaned coal for strip mining, as included in producing costs, is considered to represent the cost of acquisition of coal reserves. In the case of strip mining, the royalty figure is also considered to provide for the return of a portion of the cost of necessary surface acquisition, or its equivalent, through reclamation and reuse after strippable reserves are depleted.

In estimating producing costs for each of the 16 General Areas in Kentucky, as shown in Exhibit No. 37, separate consideration was given to each of the following principal items of cost, their total being taken as the total producing cost per ton of cleaned coal:

(References: 57, 63, 65, 69)

(1) All labor. This item includes all labor costs paid in the form of wages for mining (pieceworkers and dayworkers) and for yardage and dead work and in the form of salaries paid to supervisory, technical, and clerical employes at the mines. Weighted average wage rates were calculated from the schedules of wages established by the National Bituminous Coal Wage Agreement of 1950 for the various mining districts, with suitable adjustment for the concentration of high-wage workers in a fully mechanized underground or stripping operation. The labor cost per ton was calculated by dividing the estimated weighted average daily wage rate by the estimated productivity in tons of cleaned coal per man-shift.

(2) Vacation payments. This item represents the vacation allowance of $100 per year to each employe, where applicable, and is computed by dividing $100 by the estimated annual production per man (240 days times productivity per man-shift). In actual practice, this may be increased slightly due to injured men or others carried on the payroll but not actually engaged in production.

(3) Welfare fund. This item represents a flat payment of $0.30 per ton which is paid into the U.M.W.A. welfare fund for each ton of coal produced for use or sale in accordance with the National Bituminous Coal Wage Agreement of 1950.

(4) All supplies. This item includes the cost of all materials and supplies used in mining and in operating the mine equipment and facilities, including the maintenance and repair of mine structures and equipment. Additional included costs consist of freight, drayage, expressage, and storage of supplies, mine office supplies, fuels other than coal, and rentals of equipment. The costs of such supplies per ton, as estimated in this survey, average approximately $0.72 for underground operations and $0.75 for stripping operations, the actual estimated amounts to some extent varying inversely with the estimated productivity per man-shift, but being modified in accordance with consideration of the anticipated natural mining conditions.

(5) Power. This item includes the cost of all power requirements at the mining operations, whether purchased from outside sources or produced by a mine-operated central power station. It also includes the cost of any coal required to produce heat at the mine. While small variations in cost of power may be expected to exist among the General Areas considered in this survey, an assumed cost of $0.15 per ton is herein employed for estimating purposes.

(6) Payroll taxes. This item includes the costs of social security (old-age benefits), unemployment taxes, and any other Federal or State taxes levied upon the amount of the payroll. These taxes average approximately 4 percent of the labor cost.

(7) Other taxes, insurance, miscellaneous. This item includes the following types of costs:

a. Real estate, personal property, and other taxes on mine property and equipment, including reserves. These taxes may range from 1 to 6 percent of the fair cash value of the property as established by the local assessors, depending on locality.

b. Corporate, privilege, and severance taxes, which average approximately $0.02 per ton.

c. Workmen's compensation and vocational disease insurance, including the sums paid to an insurance company or to a State fund for protection of the employes, which aggregate approximately 5 percent of the payroll.

d. Other insurance such as fire, tornado, and other classes of insurance applicable to the mine property, which is estimated to average approximately $0.01 per ton.

e. Costs arising from unforeseeable and unpredictable conditions of all kinds, which are herein estimated at a flat rate of $0.10 per ton. This item is added to the producing costs as estimated in this survey because of the limited available information on mining conditions in many of the General Areas.

(8) Depreciation. This item represents the cost of providing
for replacement of the mining facilities and equipment Ky
at the end of their useful life. In determining pro-
duction costs, the weighted average useful life of all 233b
items of mine property and equipment, exclusive of coal 234a
reserves, is estimated to be 15 years. The rate of de- 10
preciation, accordingly, is taken at 6.67 percent of 7002
the initial investment.

(9) Royalty or depletion. As discussed in a preceding paragraph, the estimated investment costs do not include the purchase costs of surface and coal properties. A royalty charge of $0.10 to $0.30 per ton of cleaned coal for underground mining and of from $0.15 to $0.35 per ton for strip mining is considered to represent the cost of acquisition of coal reserves.

(10) Engineering, management, administration. This item includes the cost represented by salaries and expenses of administrative, management, and engineering personnel, together with salaries of associated assistants, bookkeepers, clerks, and stenographers. It also includes legal expenses and office expenses, or rent, including depreciation on office equipment. The cost of this item is estimated at $0.10 per ton.

Detailed consideration of all factors pertinent to estimating the potential mine investment costs for each of the 16 General Areas indicated that the General Areas could be classified into four groups of relative mine plant and equipment capital costs, arranged in order of increasing investment costs as follows:

Classification of General Areas by Capital Costs for Initial Unit Project Mines

Below Average:	Hopkins-Christian, Muhlenberg-McLean.
Average:	Pike, Floyd-Magoffin, Knott-Breathitt, Perry-Breathitt, Leslie-Harlan, Northern Letcher, Harlan-Letcher, Union, Webster, Ohio
Above Average:	Bell, Daviess, Henderson
Highest Cost:	Johnson-Magoffin.

The maximum ranges in daily and annual synthetic liquid fuels plant and mine requirements for the production of 10,000 barrels of synthetic liquid fuel final products per calendar day in the several General Areas, based on 98 billion Btu per calendar day for the hydrogenation process and 126 billion Btu per calendar day for the coal synthine process, may be summarized as follows:

Range in Daily and Annual Coal Requirements of a Unit Plant

	Minimum Btu Value		Maximum Btu Value	
	Hydro-genation	Coal Synthine	Hydro-genation	Coal Synthine
Average Btu content of coal (as received)	14,090	14,090	10,790	10,790
Tons per day:				
Plant (365 working days)	3,478	4,471	4,541	5,839
Mine (240 working days)	5,289	6,800	6,906	8,880
Annual Requirements (thousand tons)	1,269	1,632	1,657	2,131

Although estimated aggregate recoverable reserves in the 16 General Areas are sufficient to supply synthetic liquid fuels plants having a combined capacity of from 1,696,000 to 2,178,000 barrels a day for 40 years, depending on whether the synthine or hydrogenation process is used, the following estimates of coal production costs are based on the capacity of mine operations necessary to supply one 10,000-barrel-per-day synthetic liquid fuels unit plant in each of the General Areas.

<u>Strip Mining Costs.</u> The Hopkins-Christian, Muhlenberg-McLean, and Ohio General Areas in western Kentucky contain sufficient estimated strippable coal reserves to indicate extensive stripping operations. Because of inherent limitations in uncovering capacity of single-stripping units, and to minimize the effects of such hazards as failure of excavating, loading, or transporting equipment, it is assumed that mining in these three General Areas would be conducted in two or more separate pits from which coal would be handled through joint facilities, including a central preparation plant, to the transportation system by which the coal would be delivered to the synthetic liquid fuels plant. Surge storage facilities at the mines would be provided to assure continuous supply for year-round three-shift-per-day operation of the synthetic liquid fuels plant from mines operating on a 5-day-per-week, two-shift-per-day basis. In the other General Areas containing strippable reserves, strip mining would probably be combined with underground mining for the most economic results.

Ky

Approximate capital investments required for 40 years'
production of synthetic liquid fuels plant supply by strip mining 235b
in quantities cited hereinbefore are estimated as of March 31, 236a
1950 at from $5,044,000 to supply a hydrogenation unit plant in 10
the Ohio General Area, to $7,991,000 to supply a coal synthine 70021
unit plant in the Daviess General Area. Factors affecting strip
mine investment costs are depth and character of the overburden

and quantity and quality of the coal. The quantity to be mined is governed by the Btu content and by the specific synthetic liquid fuels process in which the coal is to be used. The quality affects the type and capacity of preparation facilities necessary to produce a merchantable coal.

Actual producing costs for strip mines in Kentucky have been relatively less than the average costs for the United States, these figures having been $2.10 per ton for the United States and $1.73 per ton for western Kentucky in 1945, according to Economic Data, Office of Price Administration, for that year. It may be assumed that the Kentucky stripping cost closely represents that in the Western Kentucky field, there having been but minor strip production in eastern Kentucky in 1945.

An estimated over-all labor productivity in new operations, measured by the average tons produced per shift per man employed in the stripping operation and in necessary auxiliary facilities, may be partially based upon experience at present stripping operations because of their relatively high degree of mechanization and their relatively comparable capacity of output.

Bureau of Mines statistics on bituminous coal production in 1948 indicated that average productivity in stripping operations by counties in western Kentucky ranged from 12.24 to 23.65 tons per man-shift, averaging approximately 21 tons for the entire Western Kentucky field. Assuming that the installation of modern high-capacity operations, including the purchase and use of large stripping shovels, draglines, trucks, and other modern equipment, would result in an estimated productivity of 25 tons per man-shift in average mining conditions, the estimated costs of strip-mine production in the five General Areas containing strippable reserves, after making allowances for variations in preparation costs, range as follows:

Estimated Costs of Strip Mine Production in Five General Areas in Kentucky (As of March 31, 1950)

General Area	Btu per Pound (As Received)	Tons per Man-shift	Cost per Ton	Cost in Cents per Million Btu
Daviess	10,790	25	$2.63	12.19¢
Webster	12,380	25	2.61	10.54
Hopkins-Christian	11,920	25	2.81	11.79
Muhlenberg-McLean	12,130	25	2.81	11.58
Ohio	11,520	25	2.79	12.11

Details of the above estimated costs for each General Area are shown in Exhibit No. 37. They are based on retirement of the property in 15 years and exclude selling expense. Estimates of labor cost are based on weighted average wage rates resulting from the 1950 wage agreement.

These costs reflect the concept of most efficient application of present-day strip mining methods and equipment. Opportunities for possible future improvements of mining methods or equipment in areas similar to those in western Kentucky probably best await potential development of high-speed, high-capacity excavating, loading, and hauling equipment. It is not possible at this time, however, to predict successful development and application of such equipment to western Kentucky coal reserves, or to estimate possible future saving in production costs which might accrue through their use.

Underground Mining Cost. Because of inherent limitations on transporting coal to the surface, and to minimize the effects of such hazards as mine fires, roof falls, floods, etc., it is assumed that the annual requirements in each General Area would not be obtained through a single opening. From two to three underground mining operations would probably be opened at appropriate intervals in each Area for concurrent operation. Although obtained from separate underground operations, it is assumed that the coal as produced from the mines would be handled through joint surface facilities, including a central preparation plant, to the transportation system by which the coal would be delivered to the synthetic liquid fuels plant. Surge storage facilities at the mine would be supplied to provide for year-round, three-shift-per-day operation of the synthetic liquid fuels plant from mines operating on a 5-day-per-week, two-shift-per-day basis.

Approximate capital investments, as of March 31, 1950, required for underground production of synthetic liquid fuels plant coal supply in the quantities previously cited are estimated at from $5,904,000 to supply a hydrogenation plant in the Muhlenberg-McLean General Area to $10,050,000 to supply a synthine plant in the Johnson-Magoffin General Area. Factors affecting mine investment costs are depth and character of the bed and its associated strata, together with quantity and quality of the coal. The quantity to be mined is governed by the Btu content and by the specific synthetic liquid fuels process in which the coal is to be used. The quality affects the type and capacity of preparation facilities
necessary to produce a merchantable coal. Ky

Actual producing costs for mechanical underground mining 238
in eastern Kentucky have been relatively higher and in western 239
Kentucky relatively lower than average costs for the United States, 10
having been $2.64 per ton for the United States, $2.83 per ton for 7002
District No. 8 (A), and $1.77 per ton for western Kentucky in 1945, according to Economic Data, Office of Price Administration, for that year.

Note: (A) District No. 8 includes eastern Kentucky, southwestern West Virginia (high-volatile), southwestern Virginia, and northern Tennessee.

An estimated over-all labor productivity in new operations, measured by the average tons produced per shift by each man employed in the underground operation and in necessary surface facilities, can be based upon experience at present underground operations in Kentucky because of their relatively high degree of mechanization. Bureau of Mines statistics on bituminous coal production indicate that eastern Kentucky underground mines had an average productivity of 5.09 tons per man-shift in 1948, while underground mines in western Kentucky averaged 8.64 tons per man-shift and the average for the entire State was 5.46 tons per man-shift.

An estimate of future productivity per man-shift in new underground mines necessarily should take into account past records of production, but must recognize that older mines usually involve relatively long and costly haulage, and that the character of a particular seam, the mining conditions, and the type of equipment are all important factors affecting the productivity; likewise, if proposed mining operations involve new coal beds not now producing, estimates of productivity may be noticeably affected. The estimates herein for new underground mining operations are dependent on judgment, based on consideration of all known factors, including Bureau of Mines data on average productivities in going operations.

Assuming that the installation of modern high-capacity operations, including the purchase and use of all necessary mechanical equipment, would result in an estimated productivity of 8 tons per man-shift for average mining conditions, 6 to 7 tons for more difficult conditions, and 9 to 10 tons for more favorable conditions, the estimated costs of production by underground operations would be as follows:

Ky
239b
20a
240a
10
70021

Estimated Cost of New Underground Operation
in the Sixteen General Areas of Kentucky
(As of March 31, 1950)

General Area	Btu Per Pound	Tons per Man-shift	Cost per Ton	Cost in Cents per Million Btu
Eastern Kentucky Field:				
Johnson-Magoffin	13,730	6	$5.11	18.61¢
Pike	14,090	7	4.76	16.89
Floyd-Magoffin	13,430	7	4.66	17.35
Knott-Breathitt	13,750	7	4.66	16.95
Perry-Breathitt	13,490	7	4.66	17.27
Leslie-Harlan	13,680	7	4.66	17.03
Northern Letcher	13,970	7	4.66	16.68
Harlan-Letcher	13,980	7	4.76	17.02
Bell	13,800	7	4.71	17.07
Western Kentucky Field:				
Daviess	10,790	9	$3.89	18.03¢
Henderson	10,960	8	4.16	18.98
Union	12,340	10	3.65	14.79
Webster	12,400	10	3.65	14.72
Hopkins-Christian	11,990	10	3.81	15.89
Muhlenberg-McLean	12,120	10	3.81	15.72
Ohio	11,710	9	3.99	17.04

Details of these estimated costs for each General Area are shown in Exhibit No. 37. They are based on retirement of the property in 15 years and exclude selling expense. Estimates of labor cost are based on weighted average wage rates resulting from the 1950 agreement.

These costs reflect the concept of most efficient application of present-day underground mining methods and equipment. Opportunities for possible future improvements of mining methods or equipment in areas similar to Kentucky probably best await potential development of continuous mining machines which combine Ky
cutting, drilling, blasting, and loading operations, now under scrutiny and development at a number of points in the United 240b
States. This type of equipment is being actively tested and, when 241a
perfected, could result in changes in mining methods which would 10
reduce the estimated producing costs in Kentucky. It is not pos- 7002
sible at this time, however, to predict the successful application of such equipment to Kentucky coal reserves or to estimate possible future savings which might accrue through their use.

In considering possible revolutionary techniques in utilizing areas of coal reserves, the underground gasification of coal in place offers considerable potential promise since it would eliminate the relatively costly processes of mining the coal and gasifying the mined output in gas generators to produce synthesis gas. This method of utilization would also provide a low-cost fuel for power generation and would permit utilization of coal from beds which would otherwise be costly or uneconomic of operation. The results of experiments in underground gasification now in progress by the Bureau of Mines and the Alabama Power Company indicate that the process has distinct possibilities and is worthy of continued experimentation. It is not possible at this time, however, to predict the successful application of this method of utilization to the coal reserves in the General Areas in Kentucky.

<u>Coal Transportation.</u> Provision has been made, in estimating capital and operating costs, for transportation of coal from the several mine openings to a joint distribution point in each General Area for handling onto the transportation system by which the coal is delivered to the synthetic liquid fuels plant. As elsewhere indicated, it has been assumed for the purpose of this survey that the site of the synthetic liquid fuels plant would be located within a 3-mile radius of the mining operations. Under this assumption, no additional facilities or costs for transportation, other than those included in the estimates of costs already established, are contemplated.

<u>Coal Supply from Present Operations.</u> (See Exhibit No. 5 for reference 63.) Bureau of Mines data on bituminous coal production in 1948 indicate that synthetic liquid fuels plants in six eastern Kentucky and three western Kentucky General Areas could have been supplied with sufficient coal in that year to have produced synthetic liquid fuel final products at the rate of 10,000 barrels per day. Such consumption, however, would have required from approximately 8 to 56 percent of the total production of the respective counties in which or near which the nine General Areas are located. For a 10,000-barrel-per-day synthine unit plant in each of the 16 General Areas, a total of approximately 28,803,000 tons of
Ky coal would have been required. This amount represents 35 percent of the total State production in that year.

241b

242 In Kentucky, the 1948 total production of 82,083,939 tons
243a was produced in 194 working days, an average of 423,113 tons per
10 day. At such a daily rate, the additional coal which could have
C021 been produced during a 240-day work-year would have amounted to
19,463,198 tons, sufficient for approximately 108,000 barrels of
synthetic liquid fuel final products per day using the synthine
process.

Accurate information on current costs of production at present operations in Kentucky is not available. Consideration of all known factors of increased wage rates, costs of supplies, contributions to welfare funds, etc., since the last year of available cost data (1945) indicates that current costs in Kentucky may exceed the estimated average costs of mine operations as herein presented ($2.79 to $5.11) by as much as $0.75 per ton. Mine-run coal could probably be purchased from current operations at such costs, plus freight, plus $0.30 to $0.50 per ton for profit and income taxes. Selected sizes would probably run slightly higher in price, while it is possible that lower-priced sizes such as screenings could be purchased from current operations for production of synthetic liquid fuels, on a contract basis, at fob. mine prices comparable with the costs estimated herein. In general, such sizes would contain higher ash and sulfur contents than the cleaned mine-run products estimated as obtainable from reserves of the General Areas.

Based on operating costs data for the first quarter of 1946 (Office of Price Administration) for large, mechanized mines, the Corps of Engineers, Department of the Army, has estimated the present cost of producing coal in western Kentucky as follows:

Estimated Cost of Producing Coal
in the Western Kentucky Field as of April 1, 1950

Bed Name	No. 11	No. 11	No. 9
Thickness, inches	65-85	70-80	50-60
Type of Mining	Strip	Underground	Underground
Productivity (A)	25	9	10
Estimated Costs per Ton: (B)			
First quarter 1946	$1.15	$1.65	$1.50
Increase to April 1, 1950	.75	1.10	1.00
Total during March 1950	$1.90	$2.75	$2.50

Note: (A) Average output per man-day (tons).
(B) Producing and administrative.

The increases in costs per ton since the first quarter of 1946 reflect the 1950 U.M.W.A. wage agreement and are based on $4.75 per day increase in wages; $25.00 per year increase in vacation pay; 30 cents per ton welfare payment; 35 and 45 percent increase in supply costs for strip and underground mining, respectively; and 25 percent increase in all other costs. These costs are fob. tipple, excluding selling expense, and represent large, modern, highly efficient and mechanized mines producing merchantable coal in sufficient quantities to meet the requirements of synthetic liquid fuels unit plants. However, they do not reflect improvements in coal mining techniques since 1946, including the continuous coal mining machines now being tested. The costs do not necessarily represent either the average production costs for the entire area or the average production costs which might be obtained in new operations in the area, but probably represent optimum mining operations.

An additional cost of purchasing coal from present operations would be transportation charges, or freight rates, from existing mines to the synthetic liquid fuels plant. Unless located in the heart of a group of substantial commercial operations, such additional costs for delivered coal would probably range from $0.60 to $2.00 per ton, depending on the selection of location of a synthetic liquid fuels plant.

Total Costs. Detailed studies leading to estimated capital and operating costs as of March 31, 1950, based on information as to coal characteristics and available reserves, have indicated that considerable variations in costs exist among the several General Areas, partly because of differences in proportions of strippable reserves, where present, in the General Areas. Differences in varying degrees of amenability to mechanical cleaning because of the nature, thickness, and number of included partings, and in the inherent calorific value of the various coal beds at the locations in which reserves are available, also affect the extent of variations in costs between General Areas. Details of these estimates and of the coal data upon which they are based are provided in Exhibits Nos. 37 and 38.

Estimated capital costs in the Eastern Kentucky field range from $6,345,000 to supply a hydrogenation unit plant in the Pike General Area to $10,050,000 to supply a coal synthine unit plant in the Johnson-Magoffin General Area, with similar costs in western Kentucky ranging from $5,044,000 to supply a hydrogenation unit plant in the Ohio General Area to $9,590,000 to supply a coal synthine unit plant in the Daviess General Area. These costs are based on complete facilities for strip or underground mining, conveying of raw coal to surface, transportation to central preparation plant, mechanical cleaning including refuse disposal, and loading for shipment or into surge storage at the mine with subsequent reloading. In those General Areas where some of the coal may be produced by strip mining,
Ky the initial investment would be somewhat less, but the ultimate total investment during the 40-year period would be about the same as for
244b all-underground mining, since the underground facilities would have
to to be ready for capacity production before the strippable reserves
246a were fully depleted. In some General Areas, strip and underground
10 operations would start simultaneously and operate concurrently. The
0021 salvage values of the stripping and coal-loading equipment for the strip operations should be approximately sufficient to offset the required added investment for equivalent underground facilities; this would tend to bring the total up to, but not more than, the figures used in this report for estimated mine capital costs. The estimated capital costs are summarized as follows:

Initial Capital Cost for Unit Plant Coal Supply in Thousands of Dollars (As of March 31, 1950)

General Area	Hydrogenation Under-ground	Hydrogenation Strip	Hydrogenation Ultimately (Combined)	Coal Synthine Under-ground	Coal Synthine Strip	Coal Synthine Ultimately (Combined)
Eastern Kentucky Field:						
Johnson-Magoffin	$7,818	-	$7,818	$10,050	-	$10,050
Pike	6,345	-	6,345	8,160	-	8,160
Floyd-Magoffin	6,660	-	6,660	8,560	-	8,560
Knott-Breathitt	6,505	-	6,505	8,360	-	8,360
Perry-Breathitt	6,630	-	6,630	8,525	-	8,525
Leslie-Harlan	6,535	-	6,535	8,405	-	8,405
Northern Letcher	6,400	-	6,400	8,230	-	8,230
Harlan-Letcher	6,395	-	6,395	8,225	-	8,225
Bell	7,128	-	7,128	9,163	-	9,163
Western Kentucky Field:						
Daviess	$7,457	$6,214	$7,457	$ 9,590	$7,991	$ 9,590
Henderson	7,344	-	7,344	9,441	-	9,441
Union	6,521	-	6,521	8,384	-	8,384
Webster	6,489	5,058	6,489	8,348	6,500	8,348
Hopkins-Christian	-	5,254	5,254	-	6,752	6,752
Muhlenberg-McLean	-	5,163	5,163	7,588	6,636	7,588
Ohio	-	5,044	5,044	-	6,487	6,487

Estimated coal producing costs, including depreciation but excluding selling costs, range in the Eastern Kentucky field from $4.66 per ton of merchantable coal in the Floyd-Magoffin, Knott-Breathitt, Perry-Breathitt, Leslie-Harlan, and Northern Letcher General Areas to $5.11 in the Johnson-Magoffin General Area. In the Western Kentucky field, the range is between $2.79 in Ohio General Area and $4.16 in the Henderson General Area. All of the above figures apply regardless of whether the hydrogenation or the coal synthine process is used.

The Hopkins-Christian General Area contains sufficient strippable coal reserves to supply a hydrogenation unit plant for 64 years or a synthine unit plant for 50 years. Similar figures for the Muhlenberg-McLean General Area are 47 and 37 years. The strippable coal reserves of the Ohio General Area are sufficient for 124 Ky
years of operation of a hydrogenation unit plant or 97 years of operation of a coal synthine unit plant. Estimated strippable reserves 24€
in the remaining General Areas, where strippable reserves exist, are 247
sufficient to supply unit plants for periods ranging from 3 to 10]
years. It is contemplated that reserves recoverable by strip mining 7002
in these latter General Areas will be combined with those from underground operations until depleted, and that the balance of the

coal required to operate a unit plant for 40 years will be recovered from the same General Area by underground mining. Estimated coal costs per ton are summarized as follows:

Coal Costs per Ton for the Initial
Synthetic Liquid Fuels Unit Plants
(As of March 31, 1950)

General Area	Hydrogenation			Coal Synthine		
	Underground	Strip	Combined	Underground	Strip	Combined
Eastern Kentucky Field:						
Johnson-Magoffin	$5.11	-	$5.11	$5.11	-	$5.11
Pike	4.76	-	4.76	4.76	-	4.76
Floyd-Magoffin	4.66	-	4.66	4.66	-	4.66
Knott-Breathitt	4.66	-	4.66	4.66	-	4.66
Perry-Breathitt	4.66	-	4.66	4.66	-	4.66
Leslie-Harlan	4.66	-	4.66	4.66	-	4.66
Northern Letcher	4.66	-	4.66	4.66	-	4.66
Harlan-Letcher	4.76	-	4.76	4.76	-	4.76
Bell	4.71	-	4.71	4.71	-	4.71
Western Kentucky Field:						
Daviess	$3.89	$2.63	$3.76	$3.89	$2.63	$3.79
Henderson	4.16	-	4.16	4.16	-	4.16
Union	3.65	-	3.65	3.65	-	3.65
Webster	3.65	2.61	3.39	3.65	2.61	3.44
Hopkins-Christian	-	2.81	2.81	-	2.81	2.81
Muhlenberg-McLean	-	2.81	2.81	3.81	2.81	2.89
Ohio	-	2.79	2.79	-	2.79	2.79

The cost per ton for combined underground and strip mining is weighted according to reserves of strip and underground mined coal for 40 years' production during which period all of the strippable coal is assumed to have been mined out and the balance of the supply produced by underground mining. In some Areas, the combined cost for coal synthine unit plant supply is higher than for hydrogenation unit plant supply because of the larger percentage of underground coal required to meet the demand of the synthine plant.

The unit cost of coal supply per barrel of synthetic liquid fuel final products ranges from $1.63 in the Northern Letcher General Area to $1.82 in the Johnson-Magoffin General Area for the hydrogenation process and from $2.10 to $2.34 in the same General Areas for the coal synthine process in the Eastern Kentucky field. In the Western Kentucky field, for the hydrogenation process, the range is from $1.13 in the Muhlenberg-McLean General Area to $1.86 in the Henderson General Area. For the coal synthine process, the cost of coal per barrel of synthetic liquid fuel final products ranges from $1.49 in the Hopkins-Christian General Area to $2.39 in the Henderson General Area. These costs are summarized as follows:

Total Cost Costs for the Initial
Synthetic Liquid Fuels Unit Plants
(As of March 31, 1950)

General Area	Btu per Pound (As-received) (A)	Cost for Hydrogenation (A) Per Ton	Cost for Hydrogenation (A) Per Million Btu	Cost for Hydrogenation (A) Per Barrel	Cost for Coal Synthine (A) Per Ton	Cost for Coal Synthine (A) Per Million Btu	Cost for Coal Synthine (A) Per Barrel
Eastern Kentucky Field:							
Johnson-Magoffin	13,730	$5.11	18.61¢	$1.82	$5.11	18.61¢	$2.34
Pike	14,090	4.76	16.89	1.66	4.76	16.89	2.13
Floyd-Magoffin	13,430	4.66	17.35	1.70	4.66	17.35	2.19
Knott-Breathitt	13,750	4.66	16.95	1.66	4.66	16.95	2.14
Perry-Breathitt	13,490	4.66	17.27	1.69	4.66	17.27	2.18
Leslie-Harlan	13,680	4.66	17.03	1.67	4.66	17.03	2.15
Northern Letcher	13,970	4.66	16.68	1.63	4.66	16.68	2.10
Harlan-Letcher	13,980	4.76	17.02	1.67	4.76	17.02	2.14
Bell	13,800	4.71	17.07	1.67	4.71	17.07	2.15
Western Kentucky Field:							
Daviess	10,790	$3.76	17.42¢	$1.71	$3.79	17.56¢	$2.21
Henderson	10,960	4.16	18.98	1.86	4.16	18.98	2.39
Union	12,340	3.65	14.79	1.45	3.65	14.79	1.86
Webster	12,400	3.39	13.67	1.34	3.44	13.87	1.75
Hopkins-Christian	11,920	2.81	11.79	1.16	2.81	11.79	1.49
Muhlenberg-McLean	12,130	2.81	11.58	1.13	2.89	11.91	1.50
Ohio	11,520	2.79	12.11	1.19	2.79	12.11	1.53

Note: (A) Based on average Btu of strip and underground mined coal (as required) for the initial plant.

Ky

The estimates of costs presented in this survey are based
on available information and on generalized, present-day methods of 247c
mining and preparation. The installation of mining operations to 248a
provide coal supply for a specific synthetic liquid fuels plant 10
should be preceded by detailed engineering studies, including 7002

drilling programs, before final methods of operation and firm estimates of costs can be established.

Incremental Cost of Coal for Ultimate Unit Plants. The foregoing estimates represent weighted average costs assuming that strip coal will be used to the fullest extent in Daviess, Webster, Hopkins-Christian, Muhlenberg-McLean, and Ohio General Areas. In these General Areas continued operation of the initial unit plant or of additional plant capacity would eventually necessitate exclusive dependence upon underground-mined coal. Under such circumstances, the total costs of coal in those General Areas would be:

Total Cost of Coal for Ultimate
Synthetic Liquid Fuels Unit Plants
Using Underground-Mined Coal Exclusively
(As of March 31, 1950)

General Area	Btu per Pound (As-received) (A)	Cost for Hydrogenation (A)			Cost for Coal Synthine (A)		
		Per Ton	Per Million Btu	Per Barrel	Per Ton	Per Million Btu	Per Barrel
Daviess	10,790	$3.89	18.03¢	$1.77	-	(B)	-
Webster	12,400	3.65	14.72	1.44	$3.65	14.72¢	$1.85
Hopkins-Christian	11,990	3.81	15.89	1.56	3.81	15.89	2.00
Muhlenberg-McLean	12,120	3.81	15.72	1.54	3.81	15.72	1.98
Ohio	11,710	3.99	17.04	1.67	3.99	17.04	2.15

Note: (A) Based on weighted average Btu of underground reserves.

(B) Insufficient coal reserves in Daviess General Area to warrant consideration of more than one unit plant for 40 years.

WATER SUPPLY PLAN AND ESTIMATES OF COST FOR GENERAL AREAS

In order to permit more detailed studies for water supply developments for each General Area, and to prepare cost estimates, a representative plant size or terminal point for the water works system has been arbitrarily selected. While proposed receiving points for coal and topographic and geographic features of the Area are considered in the selection of such a point, it is, in the final analysis, arbitrary and is in no way intended to represent a recommended plant location.

Similarly, the source of water for the unit plant in each Area is chosen as being representative in development cost for the Area. Most of the projects chosen for making cost estimates have been checked by field surveys, but detailed investigations are beyond the scope of this report. It may be expected therefore that, in some instances, the storage reservoir projects could not be built as described. In some instances, detailed investigations might indicate the need for modifications, but the over-all unit costs should not be materially changed thereby.

Facilities Required. The water supply projects are made up of the facilities required for conserving stream runoff and transporting water from the selected source to the arbitrary plant location and for temporaty storage and treatment works at this terminal point. The projects are based upon a water supply system adequate for a single 10,000-barrel-per-day synthetic liquid fuels plant and its supporting population. The principal elements of the water supply system, which are discussed in the following paragraphs, are assumed to be representative of the requirements for each of the General Areas in Kentucky.

Impounding Reservoir. Impounding reservoirs would be required on the smaller streams to furnish water during dry-weather periods of low flow. The method for determining the size of the reservoir required is discussed earlier in this report. The impounding reservoirs generally would be less than 90 feet in depth and, in most cases, the dams would be of concrete, gravity type in the western part of the State. In eastern Kentucky, they would consist of earthen embankments with concrete spillways. In general, where other agencies have proposed or built dams in Kentucky, these types have been recommended or used. In general, no site has been considered where it would be necessary to move the main line of a railroad system, but in some instances the relocation of branch lines might be necessary.

Pumping Station. It would be necessary to provide pumping stations for each of the 16 General Areas. For a synthetic liquid fuels unit project, requiring 13.1 mgd or 20.3 cfs, the pumping station would consist of three electrically driven pumps of approximately 8 mgd or 12.4 cfs capacity each, with auxiliary stand-by gasoline engines for two of the pumps. The total pumping head would vary for each of the several General Areas and would depend upon the difference in elevation between the intake and the assumed plant location and the head loss due to friction in the pipe line. In the estimates, an additional allowance of 50 feet has been made for hydraulic losses in the treatment plant and for the distribution of water in the synthetic liquid fuels plant.

Aqueduct. A 30-inch diameter pressure pipe line, extending along the most probable route from the water works intake to the assumed plant site, has been used for cost estimates.

Electric Power Transmission Lines and Substations. It is assumed that electric power for operating the pumps would be generated at the synthetic liquid fuels plant and would be transmitted to the pumping station by means of a power transmission line extending along the pipe line right-of-way. The cost of power delivered to the pumping station, estimated in this manner, would be substantially the same as the cost of power available from the several utility companies in Kentucky. There are no existing Federal hydroelectric power projects in Kentucky from which low-cost power might be obtained.

Storage Basin at Assumed Plant Site. A 13.1 million gallon storage basin, equal to one day's supply, is included to provide a reserve source of water in the event of pump failures, or a break in the pipe line, and also to serve as a settling basin for the removal of turbidity during periods of high water. It is expected that the settled water from the basin would be of suitable quality for cooling purposes and for coal preparation. In the Pike and Leslie-Harlan General Areas, no storage basin has been provided because of the proximity of the storage reservoir to the plant site.

Filter Plant. Filtered water would be required in all instances for the domestic water supply, for the sanitary water in plant and mine, for boiler make-up, and for other minor process uses. It is estimated that 3.5 mgd, or 27 percent of the total supply, would require filtration. Of this, 1.94 mgd is estimated for domestic use and 1.56 mgd for process. A filter plant of 5 mgd capacity is included in order to take care of peak demands, particularly during the summer months when domestic requirements might be unusually high. The cost of filtered water storage is included in the treatment plant estimates. No allowance is made for softening of boiler water, since this is considered a process cost.

Costs of Water Supply Projects for Suitable General Areas

Total construction costs and annual costs have been estimated on the basis of prices prevailing as of March 1950. Since it is assumed that water supply for a synthetic liquid fuels plant's supporting population would be paid for by the consumers, these costs have been allocated between domestic and process supply on the basis of use. It is to be noted that about 55.4 percent of the filter plant costs is chargeable to domestic supply, whereas only about 14.8 percent of the other water supply components is allocated to domestic consumers.

Capital Costs. Construction cost estimates are based on works necessary for a single synthetic liquid fuels unit project. The indicated cost trends for large water supplies for full development of the fuel resources are approximate, since they assume full development at one time. Step-by-step construction over a period of years is more likely, and the unit savings in water costs, indicated for an immediate full-scale development, would not be realized in many instances.

The reservoir and pipe line cost estimates include allowances for the purchase of land and rights-of-way and for the relocation of existing roads and other structures where necessary. All construction cost estimates include an allowance of about 20 percent for engineering and contingencies.

Annual Operating Costs. The principal elements of annual cost have been estimated as follows:

Power. Electric power required for pumping the water from the source to the assumed plant site is based upon a wire-to-water efficiency of 75 percent and a unit cost of 7 mills per kilowatthour. An allowance for transmission and transformer losses is included in the estimated power requirements.

Labor and Superintendence. This has been estimated at $20,000 per year in all Areas.

Miscellaneous Supplies and Repairs. These have been estimated at $5,000 per year in all Areas.

Filtration. It is recognized that chemical costs would vary substantially in the several Areas. However, a total unit operating cost of $15 per million gallons is assumed to be representative of filter plant costs in the region. This figure includes all operating costs, such as labor, chemicals, supervision, repairs, and maintenance.

Fixed Charges. Property taxes and insurance have been taken as 1 percent of the total depreciable capital costs. Depreciation is estimated on a straight-line basis, with a 40-year life assumed for major structures, such as dams, buildings, and pipe lines; and a 20-year life for equipment, such as motors, pumps, and transformers. Return on the investment, or interest, is not included in the fixed charges for water supply, so the estimates show the cost of water without this item. There is shown, however, the additional cost of water supply which would be incurred if interest at 1 percent were included.

Cost of Water by General Areas of Coal and Water Availability

The paragraphs following include a brief description of the water supply developments for each General Area, with a summary statement of the estimated construction costs and annual costs, allocated between domestic and process water supply. A unit water cost per barrel of products is shown, which includes that water properly chargeable to process and mining. The cost trends for complete development of all the fuel resources are also indicated. A more detailed summary of the water supply costs for each General Area is shown on Exhibit No. 39. The General Areas and arbitrarily chosen plant sites are shown on Exhibit No. 40.

Johnson-Magoffin General Area. Cost estimates for this Area are based upon a pumping station on Levisa Fork near Paintsville, 0.25 mile of 30-inch pipe line and power transmission line, storage basin, and treatment works. The estimates also include an allowance for increasing the capacity of the existing Dewey Reservoir on Johns Creek by 8,000 AF in order to increase the low flows on Levisa Fork during periods of drought. The estimated costs for a 10,000-barrel-per-day synthetic liquid fuels unit project, as shown on Exhibit No. 39 are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$ 891,000	$ 76,050
Domestic	369,000	32,550
Total	$1,260,000	$108,600

Cost of water for process use: 2.1 cents per barrel of products.
Additional cost for each 1 percent interest on capital investment: 0.2 cents per barrel of products.

If all of the coal resources in the Area should be developed for a daily production of 32,000 barrels of synthetic liquid fuels, a water supply of 65 cfs would be needed. This quantity of water could be made available by a 30,000 AF increase in the capacity of Dewey Reservoir. The estimated unit capital cost for a development of this size would be approximately the same as the unit capital cost of water for a single 10,000-barrel-per-day project.

Pike General Area. Cost estimates for this Area are based upon a 12,900 AF storage reservoir on Johns Creek, a low-head booster pumping station immediately below the dam, 0.25 miles of 30-inch pipe line and power transmission line, and treatment works. The estimated costs for a 10,000-barrel-per-day synthetic liquid fuels unit project, as shown on Exhibit No. 39, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$2,846,000	$136,070
Domestic	708,000	42,970
Total	$3,554,000	$179,040

Cost of water for process use: 3.7 cents per barrel of products.
Additional cost for each 1 percent interest on capital investment: 0.8 cent per barrel of products.

If all of the coal resources in the Area should be developed for a daily production of 392,000 barrels of synthetic liquid fuels, a water supply of 794 cfs would be needed. Development of local tributary streams might yield as much as 375 cfs, or less than half of the total water required for full concurrent utilization of the coal resources. If full development should ever take place, it would be necessary to extend a pipe line from the Ohio River more than 85 miles away. A large-scale development of this kind would permit the use of large pipe lines, pumping stations, etc., and some savings could be realized. It is therefore estimated that the unit capital cost for a development of this size would be approximately 90 percent of the unit capital cost of water for a single 10,000-barrel-per-day project.

Floyd-Magoffin General Area. Cost estimates for this Area are based upon a 10,900-AF regulating reservoir on Mud Creek, a pumping station downstream on Levisa Fork opposite the synthetic liquid fuels plant assumed location, a 2-mile pipe line and power transmission line, storage basin, and treatment works. The estimated costs for a 10,000-barrel-per-day synthetic liquid fuels unit project, as shown on Exhibit No. 39, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$3,170,000	$153,710
Domestic	766,000	46,050
Total	$3,936,000	$199,760

Cost of water for process use: 4.2 cents per barrel of products.
Additional cost for each 1 percent interest on capital investment: 0.9 cent per barrel of products.

If all of the coal resources in the Area should be developed for a daily production of 155,000 barrels of synthetic liquid fuels a water supply of 314 cfs would be needed. This quantity of water could be made available by construction of four reservoirs on the headwaters of Levisa Fork with a total storage capacity of approximately 207,000 AF. The four sites that might be used are the Fishtrap site on Levisa Fork proposed by the Corps of Engineers and sites on Mud Creek, Long Fork, and Elkhorn Creek. The estimated unit capital cost for a development of this size would be approximately 60 percent of the unit capital cost of water for a single 10,000-barrel-per-day project. However, if the Fishtrap site were not available for synthetic liquid fuels purposes, other reservoirs could be built on the Licking River, Mud Creek, and Elkhorn Creek, although at a substantially greater cost.

Knott-Breathitt General Area. Cost estimates for this Area are based upon a 24,600-AF reservoir on Caney Fork, a pumping station immediately below the dam, 4-1/2 miles of pipe line and power transmission line, storage basin, and treatment works. The estimated costs for a 10,000-barrel-per-day synthetic liquid fuels project, as shown on Exhibit No. 39, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$6,750,000	$288,860
Domestic	1,387,000	69,510
Total	$8,137,000	$358,370

Cost of water for process use: 7.9 cents per barrel of products.
Additional cost for each 1 percent interest on capital investment: 1.8 cents per barrel of products.

If all of the coal resources in the Area should be developed for the daily production of 99,000 barrels of synthetic liquid fuels, a water supply of 200 cfs would be needed. This larger quantity of water could be obtained by the construction of a 144,000-AF reservoir on Troublesome Creek, some distance west of the General Area. The estimated unit capital cost for a development of this size would be approximately 50 percent of the unit capital cost of water for a single 10,000-barrel-per-day project.

Perry-Breathitt General Area. Cost estimates for this Area are based upon a pumping station on the North Fork of the Kentucky River near the plant site, 1/2 mile of 30-inch pipe line and power transmission line, storage basin, and treatment works. Stream flows in the North Fork would be supplemented by discharges from a 9,300-AF reservoir constructed on Lotts Creek. The estimated costs for a 10,000-barrel-per-day synthetic liquid fuels unit project, as shown on Exhibit No. 39, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$3,957,000	$181,260
Domestic	902,000	50,830
Total	$4,859,000	$232,090

Cost of water for process use: 5.0 cents per barrel of products.
Additional cost for each 1 percent interest on capital investment: 1.1 cents per barrel of products.

If all of the coal resources in the Area should be developed for the daily production of 74,000 barrels of synthetic liquid fuels, a water supply of 150 cfs would be needed. This quantity of water could be obtained from the North Fork of the Kentucky River by increasing the capacity of the Lotts Creek reservoir to 110,600 AF. The drainage area tributary to that reservoir, however, would be inadequate to assure refilling such a large reservoir during years of low flow; it would be necessary to pump water from the North Fork into the reservoir during flood season. The estimated unit capital cost for a development of this size would be approximately 60 percent of the unit capital cost of water for a single 10,000-barrel-per-day project.

Leslie-Harlan General Area. Cost estimates for this Area are based upon a 10,800-AF storage reservoir near the assumed plant site on the Middle Fork of the Kentucky River, a low-head booster pumping station, 1/2 mile of 30-inch pipe line and power transmission line, and treatment works. The estimated costs for a 10,000-barrel-per-day synthetic liquid fuels unit project, as shown on Exhibit No. 39, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$4,175,000	$185,480
Domestic	939,000	51,560
Total	$5,114,000	$237,040

Cost of water for process use: 5.1 cents per barrel of products.
Additional cost for each 1 percent interest on capital investment: 1.1 cents per barrel of products.

If all of the coal resources in the Area should be developed for the daily production of 53,000 barrels of synthetic liquid fuels, a water supply of 107 cfs would be needed. This quantity of water could be obtained from the Middle Fork of the Kentucky River if the reservoir capacity were increased to 54,100 AF. The estimated unit capital cost for a development of this size would be approximately 50 percent of the unit capital cost of water for a single 10,000-barrel-per-day project.

Northern Letcher General Area. Cost estimates for this Area are based upon a 11,500-AF storage reservoir on Carr Fork a pumping station immediately below the dam, 8 miles of 30-inch pipe line and power transmission line, storage basin, and treatment works. The estimated costs for a 10,000-barrel-per-day synthetic liquid fuels unit project, as shown on Exhibit No. 39, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$5,754,000	$301,130
Domestic	1,214,000	71,650
Total	$6,968,000	$372,780

Cost of water for process use: 8.3 cents per barrel of products.
Additional cost for each 1 percent interest on capital investment: 1.6 cents per barrel of products.

If all of the coal resources in the Area should be developed for the daily production of 58,000 barrels of synthetic liquid fuels, a water supply of 117 cfs would be needed. This quantity of water could be obtained by the construction of an 86,500-AF storage reservoir on Right Fork. The drainage area tributary to such a reservoir would not be sufficient to refill it during periods of low flow, and it would be necessary to pump water into the reservoir from the North Fork of the Kentucky River during periods of high flow. The estimated unit capital cost for a development of this size would be approximately 65 percent of the unit capital cost of water for a single 10,000-barrel-per-day project.

Harlan-Letcher General Area. Cost estimates for this Area are based upon a 11,200-AF regulating reservoir on Cranks Creek, an intake and pumping station on Martins Fork several miles downstream from the reservoir, about 1 mile of 30-inch pipe line and power transmission line, storage basin, and treatment works. The estimated costs for a 10,000-barrel-per-day synthetic liquid fuels unit project, as shown on Exhibit No. 39, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$4,619,000	$214,810
Domestic	1,017,000	56,650
Total	$5,636,000	$217,460

Cost of water for process use: 5.9 cents per barrel of products.
Additional cost for each 1 percent interest on capital investment: 1.3 cents per barrel of products.

If all of the coal resources in the Area should be developed for a daily production of 166,000 barrels of synthetic liquid fuels, a water supply of 336 cfs would be needed. This quantity of water could be obtained, but only by building a 250,000-AF reservoir on Straight Creek some distance away. The Straight Creek drainage area, furthermore, is too small to assure refilling of the reservoir during dry years, and water would have to be pumped to the reservoir from the Cumberland River during its periods of high water. The estimated unit capital cost of a development of this size would be 75 percent of the unit capital cost of water for a single 10,000-barrel-per-day project.

Bell General Area. Cost estimates for this Area are based upon a pumping station on the Cumberland River near the plant site, 1 mile of 30-inch pipe line and power transmission line, storage basin, and treatment works. The estimated costs for a 10,000-barrel-per-day synthetic liquid fuels unit project, as shown on Exhibit No. 39, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$4,246,000	$216,870
Domestic	952,000	57,010
Total	$5,198,000	$273,880

Ky
4

Cost of water for process use: 5.9 cents per barrel of products. 257b
Additional cost for each 1 percent interest on capital investment: 1.2 cents per barrel of products. 258a
4

If all of the coal resources in the Area should be developed for the daily production of 33,000 barrels of synthetic liquid fuels, a water supply of 67 cfs would be needed. This larger quantity of water could be obtained by building a 33,000-AF reservoir on Stinking Creek and an intake farther down on the Cumberland River. Under this plan, water would have to be pumped back up the Cumberland valley for a distance of 10 or 15 miles and operating costs would be correspondingly high. The estimated unit capital cost of a development of this size would be approximately 80 percent of the unit capital cost of water for a single 10,000-barrel-per-day project.

Daviess General Area. Cost estimates for this Area are based upon a pumping station on the Green River near the assumed plant location, 1/4 mile of pipe line and power transmission line, storage basin, and treatment works. The estimated costs for a 10,000-barrel-per-day synthetic liquid fuels unit project, as shown on Exhibit No. 39, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$495,000	$62,980
Domestic	300,000	30,270
Total	$795,000	$93,250

Cost of water for process use: 1.7 cents per barrel of products.
Additional cost for each 1 percent interest on capital investment: 0.1 cent per barrel of products.

If all of the coal resources in the Area should be developed for the daily production of slightly more than 10,000-barrels-per-day of synthetic liquid fuels by the hydrogenation process, the water supply already estimated would be adequate. The coal resources of the area are, in fact, not quite adequate for even one coal synthine unit plant.

Ky Henderson General Area. Cost estimates for this Area are
based upon an intake and pumping station on the Ohio River about
5 miles below Henderson, Kentucky, a 30-inch pipe line and power
58b transmission line each 2 miles long, storage basin, and treatment
59a works. The estimated costs for a 10,000-barrel-per-day synthetic
4 liquid fuels unit project, as shown on Exhibit No. 39, are:

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Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$ 721,000	$ 75,720
Domestic	340,000	32,490
Total	$1,061,000	$108,210

Cost of water for process use: 2.1 cents per barrel of products.
Additional cost for each 1 percent interest on capital investment: 0.2 cent per barrel of products.

If all of the coal resources in the Area should be developed for the daily production of 55,000 barrels of synthetic liquid fuels, a water supply of 111 cfs would be needed. This greater quantity of water is obtainable directly from the Ohio River. The estimated unit capital cost for a development of this size would be approximately 60 percent of the unit capital cost of water for a single 10,000-barrel-per-day project.

Union General Area. Cost estimates for this Area are based upon intake works and a pumping station on the Ohio River just above its junction with the Wabash River, 1.5 miles of 30-inch pipe line and power transmission line, storage basin, and treatment works. The estimated costs for a 10,000-barrel-per-day synthetic liquid fuels unit project, as shown on Exhibit No. 39, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$628,000	$66,690
Domestic	324,000	30,930
Total	$952,000	$97,620

Cost of water for process use: 1.8 cents per barrel of products.
Additional cost for each 1 percent interest on capital investment: 0.2 cent per barrel of products. Ky

If all of the coal resources in the Area should be developed for the daily production of 80,000 barrels of synthetic liquid 259c/4 fuels, a water supply of 162 cfs would be needed. This quantity of water could be obtained directly from the Ohio River. The estimated unit capital cost for a development of this size would be about 50 percent of the unit capital cost for a single 10,000-barrel-per-day project.

Webster General Area. Cost estimates for this Area are based upon an intake works and pumping station on the Tradewater River near the assumed plant location, 2 miles of 30-inch pipe line and power transmission line, storage basin, and treatment works. The estimated costs for a 10,000-barrel-per-day synthetic liquid fuels unit project, as shown on Exhibit No. 39, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$3,231,000	$156,480
Domestic	776,000	46,540
Total	$4,007,000	$203,020

Cost of water for process use: 4.3 cents per barrel of products.
Additional cost for each 1 percent interest on capital investment: 0.9 cent per barrel of products.

If all of the coal resources in the Area should be developed for the daily production of 106,000 barrels of synthetic liquid fuels, a water supply of 215 cfs would be needed. This could be obtained from the Ohio River. The estimated unit capital cost for a development of this size would be approximately 50 percent of the unit capital cost of water for a single 10,000-barrel-per-day project.

Hopkins-Christian General Area. Cost estimates for this Area are based upon a 20,200-AF storage reservoir on Lick Creek, a pumping station immediately below the dam, 9 miles of 30-inch pipe line and power transmission line, storage basin, and treatment works. The estimated costs for a 10,000-barrel-per-day synthetic liquid fuels unit project, as shown on Exhibit No. 39, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$6,766,000	$289,360
Domestic	1,389,000	69,590
Total	$8,155,000	$358,950

Cost of water for process use: 7.9 cents per barrel of products.
Additional cost for each 1 percent interest on capital investment: 1.9 cents per barrel of products.

If all of the coal resources in the Area should be developed for the daily production of 183,000 barrels of synthetic liquid fuels, a water supply of 371 cfs would be needed. This very much larger quantity of water would have to be obtained from the Ohio River. The estimated unit capital cost for a development of this size would be approximately 25 percent of the unit capital cost of water for a single 10,000-barrel-per-day project.

Muhlenberg-McLean General Area. Cost estimates for this Area are based upon intake works and a pumping station on the Green River near Central City, 6 miles of 30-inch pipe line and power transmission line, storage basin, and treatment works. The estimated costs for a 10,000-barrel-per-day synthetic liquid fuels unit project, as shown on Exhibit No. 39, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$1,209,000	$ 93,030
Domestic	425,000	35,510
Total	$1,634,000	$128,540

Ky

Cost of water for process use: 2.5 cents per barrel of products.
Additional cost for each 1 percent interest on capital investment: 0.3 cent per barrel of products. 260b 261a

4

If all of the coal resources in the Area should be developed for the daily production of 137,000 barrels of synthetic liquid fuels, a water supply of 277 cfs would be needed. This large quantity of water is available in the Green River, but regulating storage of 124,000-AF would be necessary. Such storage might be built at dam sites on Welch Creek, Reedy Creek, and Bear Creek. The estimated unit capital cost for a development of this size would be approximately 45 percent more than the unit capital cost of water for a single 10,000-barrel-per-day project.

Ohio General Area. Cost estimates for this Area are based upon an intake and pumping station on the Green River, 3-1/2 miles of 30-inch pipe line and power transmission line, storage basin, and treatment works. The estimated costs for a 10,000-barrel-per-day synthetic liquid fuels unit project, as shown on Exhibit No. 39, are:

Water-supply Costs
(As of March 31, 1950)

	Construction Costs	Annual Costs
Process	$ 898,000	$ 79,530
Domestic	370,000	33,150
Total	$1,268,000	$112,680

Cost of water for process use: 2.2 cents per barrel of products.
Additional cost for each 1 percent interest on capital investment: 0.2 cent per barrel of products.

If all of the coal resources in the Area should be developed for the daily production of 64,000 barrels of synthetic liquid fuels, a water supply of 130 cfs would be needed. This quantity of water could be obtained from the Green River by providing 55,100-AF of storage for low-flow control purposes on Muddy Creek. The estimated unit capital cost for a development of this size would be approximately twice the unit capital cost of water for a single 10,000-barrel-per-day project.

Hydroelectric Possibilities

Water could not be supplied to unit synthetic liquid fuels projects in any of the 16 General Areas of Kentucky without pumping. In most cases, the full capacity of the contemplated reservoirs and drainage areas would be needed to furnish necessary water during dry periods. Therefore, the generation of hydroelectric power in connection with synthetic liquid fuels unit projects would be neither feasible nor economical. Even where water was released from a reservoir to an intake farther downstream, generation of power would not be economical because such discharges would be relatively small and discontinuous; only low heads would be available. Increasing the size of reservoirs for unit projects to provide sufficient head for power production would not be warranted.

Where full development of the coal resources of an Area would require large reservoirs, such as the Fishtrap Reservoir proposed by the Corps of Engineers, hydroelectric units might be installed at the dam to use the water released for synthetic liquid fuels purposes. Detailed investigations in specific cases would be required to determine the costs and prospective benefits of any such program. In general, it appears that hydroelectric developments in conjunction with water supply systems for synthetic liquid fuels plants would not be warranted.

POWER

Requirements

For a 10,000-barrel-per-day plant using the coal synthine process, it is estimated that the power requirements will amount to 114,500 kw. However, waste heat recovery arrangements will have sufficient output to supply the steam needed to generate this amount of electricity plus 3,500 kw for the mine. Outside power would be required only for construction purposes, for starting up the process plant, and as emergency stand-by.

For a 10,000-barrel-per-day plant using the hydrogenation process, it is estimated that the total power load will be 65,000 kw at 100 percent load factor. Only 40,000 kw of this can be classed as prime power, because the remaining 25,000 kw will be by-product power produced in conjunction with process steam. The 40,000 kw of prime power plus 3,000 kw of mine load would be supplied from the most economical source of power, whether it be a generating station constructed as an integral part of the synthetic liquid fuels plant, a hydroelectric development, or a public utility.

Existing Facilities

On Exhibit No. 41, there are indicated the power plant facilities now available to the coal-producing areas of Kentucky. On page 1 of this exhibit are tabulated the identification, ownership, and capacity of each such power plant.

In the State of Kentucky, there are 16 General Areas each with reserves of coal and water sufficient for the operation of at least one synthetic liquid fuels unit plant. Nine of the General Areas are in the eastern part of the State and seven in the west. All nine of the eastern Areas either are on or in close proximity to the transmission lines of the Kentucky and West Virginia Power Company, Inc. All seven Areas in the western part of the State either are on or in close proximity to the transmission lines of the Kentucky Utilities Company.

Kentucky and West Virginia Power Company is a unit in the integrated system of the American Gas & Electric Company which extends from South Bend, Ind., through Indiana, Ohio, Kentucky, West Virginia, and Virginia to Roanoke, Va As of the end of 1949, the system had a maximum demand of 2,041,145 kw, with a system generating capability of 2,136,000 kw. The system reserve, therefore, was 94,855 kw and was scheduled to be increased to 426,000 kw in 1951 and to 601,000 kw in 1952.

Kentucky Utilities Company is an independent utility serving 72 counties in Kentucky from eight steam stations and two hydro stations, which had a combined capacity of 151,040 kw as of the end of 1949. This was scheduled to be increased to 213,040 kw in 1951. In addition to its own generating facilities, Kentucky Utilities Company has interconnections with Central Illinois Public Service Company, Kentucky Electric Power Company, Louisville Gas & Electric Company, and Tennessee Valley Authority. However, since Kentucky Utilities Company purchases from other utilities a large part of the power it sells, it is apparent that there would be no reserve capacity available in its existing or proposed generating stations for a supply of power to synthetic liquid fuels plants in Kentucky.

Proposed Hydroelectric Developments

The Corps of Engineers prepared a report entitled "Potential Water Power Sites - As Summarized from Reports by the Corps of Engineers to the Congress - Edition of March 1935". The following sites, which are either within or reasonably close to the General Areas in Kentucky, have been designated in the report as potential sources of hydroelectric energy.

Potential Water Power Sites
Selected by the Corps of Engineers
(Costs as of March 1935 or earlier)

Project No.	Name of Project	Head in Feet	Capacity in Megawatts	Cost per Installed Kw	Annual Output (Million Kwhr)	Cost per Kwhr (Mills)
1128	Wolf Creek	160	221	$139	455.0	3.55
1132	System No. 5	143	60	451	1,450.0	3.06
1133	System No. 6	51	121	146	1,740.0	2.98
1135	System No. 8	170	30.7	155	2,280.0	3.20
1139	Rockcastle Narrows	132	19.2	327	3.5	8.30
1140	Laurel	245	27.8	270	48.2	10.50
1141	Aurora Landing	50	334.0	126		-
1400	Chestnut	39	12.5	72	53.0	2.00
1401	Prestonburg	39	8.8	86	38.0	2.20
1402	State Line	143	24.7	94	61.0	3.60
1403	Towers	384	70.5	161	165.0	6.00
1404	Pound	156	7.6	244	17.0	7.50
1405	Cranes Nest	154	5.3	317	12.0	12.00
1406	Fishtrap	157	23.0	60	51.0	2.80
1407	Dewey	101	6.7	83	17.0	3.30
1452	Lock 13	28	8.7	256	22.0	9.70
1454	Booneville	128	71.2	125	41.0	21.50
1455	Buckhorn	89	16.1	179	9.0	29.7
1456	Fincastle	63	14.4	203	8.0	32.4
1457	Laurel Branch	63	14.4	203	8.0	32.4
1477	Golconda Reservoir	39.5	175.0	165	767.0	2.9

Power Cost

It is estimated that the average cost for producing power from steam at a synthetic liquid fuels plant, assuming 100 percent load factor, will be about 6.64 mills per kilowatthour, depending on the Area under consideration. This estimate includes an allowance for depreciation on a 15-year life basis but excludes any allowance for return on the investment or for income taxes. The application of a rational depreciation allowance even with allowances for return and profit should not materially increase the estimated cost of power. On the other hand, use of the higher-ash fractions from process coal washing, which might not have a ready market, might effect substantial savings in power costs.

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Conclusions

Sufficient power for plant construction, for starting up the process plant, and as emergency stand-by would be available from the local utility in each of the 16 General Areas.

Since, in the coal synthine process, steam from waste heat would be available from the process in sufficient quantity to supply all the operating power needs, it would be necessary to furnish additional power facilities only for construction purposes, for starting up the process plant, and as emergency stand-by. In the hydrogenation process, the magnitude of the installation required for handling process coal alone, together with the desirability of an outlet for the higher-ash fractions of the washed coal would usually make purchase of outside power disadvantageous.

However, in the nine eastern General Areas, served by the Kentucky and West Virginia Power Company, the availability of an ample supply of outside power at an unusually low rate per kilowatthour makes it advisable, in the final consideration of a possible synthetic liquid fuels plant site in eastern Kentucky, to survey carefully the exact quality and costs of coals available and to design a power plant with equipment to handle such coal economically. The possible new plant should estimate the cost of producing its own power on a basis comparable to that used by the utility. Outside power sources are desirable as stand-by capacity. The possible mutual advantage of integrating the electric generation of the plant into an existing power network should be given careful consideration.

For the seven General Areas in western Kentucky, the higher cost of outside utility power would probably eliminate it in the final analysis of a synthetic liquid fuels plant site.

ACCESS TRANSPORTATION

The construction and operation of a synthetic liquid fuels plant and its auxiliary coal mine facilities will, in general, require a direct rail or water connection and a highway connection. Such services would be essential during the construction period to move in the large volume of construction materials and plant equipment and later to transport plant and community supplies and plant products, other than the primary product of synthetic liquid fuels. The latter may be handled either by rail, highway, or pipe line as described in the section of this report pertaining to "Marketing".

The coal areas in the State of Kentucky are in two distinct regions, the larger field being the Eastern Kentucky field in the Appalachian region; the other is the Western Kentucky field.

The eastern Kentucky region is very rough and broken and dominated by the Cumberland and Pine Mountains, which run in a generally northeast-southwesterly direction. The river valleys of the Cumberland, Kentucky, and Big Sandy River systems in this part of the State are deep and narrow between the mountain folds. This has made provision of railroad transportation generally difficult and fraught with many engineering problems. However, the extensive areas of high-grade coal, steam and coking and the proximity of active, large markets has resulted in an intensive railroad construction program during the past 35 to 40 years, bringing the major portion of this Eastern Kentucky field within reach of one or another of the major railroad systems tapping this region.

The western part of the State lies in the Highland Rim Plateau generally sloping toward the Mississippi River, and is not as rugged as the eastern part of the State. It has been generally covered by the Louisville and Nashville or Illinois Central Railroads in serving needs in and out of the Louisville area, south and west, and by numerous branch lines reaching into the developed coal fields in this region. Being less rugged than the eastern region of the State, extensions of railroad branches do not present comparable engineering difficulty, except in avoiding the need for or in crossing some of the several rivers flowing into the Ohio.

Railroad access is essential but it is also important that highway access be assured for truck movement in and out of the plant and for transportation of personnel to and from the Area. The Eastern Kentucky field has been generally supplied with a complete network of highways following the development of this region from a coal-mining standpoint. Major Federal highways, however, are few due to the past backwardness of the region and the difficulty of traversing the broken mountainous terrain. However, no General Area is far remote from a paved road system; they generally are reachable by a road that can readily be improved to provide a hard-surfaced connection. The Western Kentucky field, offers less obstacles to highway construction and is contiguous to a more completely developed industrial area, north and south beyond the State confines. With a terrain that has resulted in much more advanced general development within the State, it is quite well criss-crossed with a hard-surfaced highway system.

While water transportation is available on the Tennessee and Ohio Rivers, and to a limited extent on the Green River, the location of the General Areas is such that water transportation cannot be considered available, except for very limited usage for which intermediate rehandling would be required.

The estimated cost of access facilities for each of the 16 General Areas in Kentucky is given in the following table. Under the column heading, General Area, the first item describes the required railroad facilities and the second item the required access highway facilities from the public paved highway system. In order to prepare cost estimates, a representative plant site, consistent with topographic and geographic features of each General Area, has been arbitrarily selected. The selection of such a point, in the final analyses, is arbitrary and is in no way intended to represent a recommended plant location.

The amounts shown for railroad facilities under construction and operating costs are based on the assumption that the plants will bear full construction and maintenance costs of the required facility. Operating costs are to provide for maintenance at an annual rate of 5 percent of the capital costs for such facilities.

In the case of access highway facilities, costs represent one-half the construction costs with no direct maintenance charges. It has been assumed that local governments would bear one-half the construction costs and maintain the highways after their completion. Under operating costs, the amounts charged against highway facilities are to provide for 40-year depreciation at an annual rate of 2.5 percent of the capital costs shown. Highway costs are based on a 20-foot highway of rough aggregate, bituminous-bound surface, 3 inches thick on a 9 to 12-inch base course.

Estimated Cost of Access Facilities by General Areas (As of March 31, 1950)

General Area	Capital Cost	Annual Operating Cost	Daily Operating Cost
Johnson-Magoffin			
Approximately 0.7 mile from Chesapeake and Ohio, southeast of Paintsville, Kentucky, near Thelma, along the bank of Levisa Fork; moderate grading.	$ 75,000	$ 3,750	$ 10
Metal-surfaced road, from Paintsville through Thealka to plant site, may possibly require resurfacing.	0	0	0
Total	$ 75,000	$ 3,750	$ 10
Pike			
Approximately 7.0 miles from the Norfolk and Western branch up Pinson Fork from Williamson, with approximately 0.5 mile tunnel required through the mountains to Rockhouse Fork, following it, Meathouse Fork, and Johns Creek to plant site; moderately heavy grading with some possible bridging.	$2,250,000	$112,500	$308
Improve approximately 4.0 miles of existing road from U.S. Highway 19 near Meta, along Johns Creek.	50,000	1,250	4
Total	$2,300,000	$113,750	$312
Floyd-Magoffin			
Approximately 0.3 mile from Chesapeake and Ohio up Beaver Creek, including a bridge crossing of the creek; moderately easy grading.	$ 180,000	$ 9,000	$ 25
Adjacent to improved Highway 80, plant facility road only.	0	0	0
Total	$ 180,000	$ 9,000	$ 25

General Area	Capital Cost	Annual Operating Cost	Daily Operating Cost
Knott-Breathitt			
Approximately 3.0 miles, with possibly 0.25 mile tunnel, from the new Wayland-Deane extension of the Chesapeake and Ohio, Elkhorn and Beaver Valley subdivision; moderately heavy grading.	$1,060,000	$53,000	$ 145
Improve approximately 3.8 miles of existing road up Terry Fork to Beaver Creek from junction with Highway 80; may require some widening.	67,500	1,688	5
Total	$1,127,500	$54,688	$ 150
Perry-Breathitt			
Approximately 1.0 mile from Louisville and Nashville branch near Darfolk; moderately heavy sidehill grading.	$ 125,000	$ 6,250	$ 17
Adjacent to Highway 80, plant facility road only	0	0	0
Total	$ 125,000	$ 6,250	$ 17
Leslie-Harlan			
Approximately 15.5 miles from the Louisville and Nashville on the North Fork of the Kentucky River near Busy, up Willard Creek, crossing by heavy cut - approximately 1,000-foot tunnel to Peavine Branch, down it to MacIntosh Creek, up Outshine Creek to Flackey Branch, across to Davis Branch and Hurricane Creek to the Mioch Branch of the Kentucky River; moderate to heavy grading, possibly some bridge construction.	$2,550,000	$127,500	$349

General Area	Capital Cost	Annual Operating Cost	Daily Operating Cost
Leslie-Harlan (Concluded)			
Improve approximately 0.9 mile of existing unimproved road from Hurricane Creek along the Middle Fork of the Kentucky River; 1.0 mile of connecting road to junction with Highway 257 at Windover may need resurfacing.	$ 26,000	$ 650	$ 2
Total	$2,576,000	$128,150	$351
Northern Letcher			
Adjacent to recently completed Louisville and Nashville Duo, Kentucky to Deane, Kentucky branch extension up Rockhouse Creek; access by plant facility siding.	0	0	0
Adjacent to Highway 7, plant facility road only	0	0	0
Total	0	0	0
Harlan-Letcher			
Adjacent to Louisville and Nashville branch from Harlan, access by plant facility siding.	0	0	0
Adjacent to Highway 66, plant facility road only.	0	0	0
Total	0	0	0
Bell			
Adjacent to Louisville and Nashville branch to Colmar, access by plant facility siding.	0	0	0
Adjacent to Highway 88, plant facility road only.	0	0	0
Total	0	0	0

General Area	Capital Cost	Annual Operating Cost	Daily Operating Cost
Daviess			
Approximately 10.0 miles from the Louisville and Nashville, Evansville branch, near Stanley along the east side of the Green River; moderately easy grading.	$900,000	$45,000	$123
Improve approximately 0.25 mile of present unimproved road from Curdsville.	4,000	100	0
Total	$904,000	$45,100	$123
Henderson			
Adjacent to Illinois Central southwest of Henderson; access by plant facility siding.	0	0	0
Improve approximately 0.8 mile of present road from U.S. Highway 41 and construct approximately 0.2 mile of plant access road.	$ 14,000	$ 350	$ 1
Total	$ 14,000	$ 350	$ 1
Union			
Adjacent to Illinois Central, Uniontown branch, access by plant facility siding.	0	0	0
Construct approximately 0.3 mile of plant access road from Highway 131 south of Uniontown, including railroad crossing.	$ 8,000	$ 200	$ 1
Total	$ 8,000	$ 200	$ 1
Webster			
Adjacent to Illinois Central, Blackford-Providence branch, access by plant facility siding.	0	0	0

General Area	Capital Cost	Annual Operating Cost	Daily Operating Cost
Webster (Concluded)			
Improve approximately 0.5 mile of existing road from junction with Highway 85.	$ 8,500	$ 213	$ 1
Total	$ 8,500	$ 213	$ 1
Hopkins-Christian			
Restore approximately 1.75 miles of former Coiltown branch from Louisville and Nashville, Morganfield branch, and construct approximately 0.25 mile of road; easy grading.	$155,000	$7,750	$ 21
Improve approximately 2.8 miles of present secondary road from junction with Highway 41 at Nebo and approximately 1.0 mile of unimproved road from Coiltown	53,000	1,325	4
Total	$208,000	$9,075	$ 25
Muhlenberg-McLean			
Adjacent to Illinois Central, access by plant facility siding.	0	0	0
Improve approximately 0.5 mile of present secondary road from junction at Midland with Highway 70.	$ 6,000	$ 150	0
Total	$ 6,000	$ 150	0
Ohio			
Adjacent to Louisville and Nashville, Morganfield branch, access by plant facility siding.	0	0	0
Resurface Highway 85 from junction with U.S. Highway 62 to Centertown, approximately 5.25 miles, and improve approximately 1.75 miles of present unimproved road, southwest from junction with Highway 85.	$ 83,000	$2,075	$ 6
Total	$ 83,000	$2,075	$ 6

LABOR

General

Determination of the labor force available to a proposed new synthetic liquid fuels unit plant involves a detailed study of the number of workers existing in and around the proposed location together with their characteristics, the nature of their present employment, the extent of unemployment, and the extent to which the proposed new plant would divert existing employment from present industry to itself. Personnel requirements of the proposed plant would then be compared with results of the detailed study to determine the size of the area containing sufficient available labor to satisfy the needs of the plant. Determination of the level of wages to be paid in a unit plant involves consideration of the wage level in such an area prevailing among existing industries comparable to synthetic liquid fuels as regards the skills and experience required of workers.

In this report, such studies by particular locations were not made. Instead, data on the number and composition of the labor force in the State and in the coal counties, data on unemployment in the State, and data on average wages prevailing in selected industries in the State were developed. Conclusions were drawn from such data as to the availability of labor, and as to the prevailing level of wages in an average location in the coal counties, which were applied uniformly to the General Areas within the State.

Population and Employment Characteristics

The State of Kentucky had a population density of 70.9 persons per square mile in 1940. The 1940 census showed a total population of 2,845,627, of which 849,327, or 29.8 percent, lived in urban areas.

The 1950 census preliminary count shows the population of the State as of April 1, 1950 to be 2,921,708 and the density of population at that time was 72.8 persons per square mile.

The 16 General Areas of Coal and Water Availability in Kentucky occupy part or all of 20 counties, as listed below:

Coal Counties of Kentucky

Eastern		Western	
Bell	Leslie	Christian	Muhlenberg
Breathitt	Letcher	Daviess	Ohio
Floyd	Magoffin	Henderson	Union
Harlan	Perry	Hopkins	Webster
Johnson	Pike	McLean	
Knott			

In these coal counties, the 1940 population was 697,113, of which 126,371 or 18.1 percent lived in urban areas. The 1950 census preliminary count indicates that while the population of the State as a whole increased by 2.7 percent over 1940, the population in the 20 coal counties decreased by 0.3 percent. Considering eastern and western groups of counties separately, the 11 eastern coal counties had a 1940 population of 433,810, of which 45,940, or 10.6 percent, lived in urban areas. As compared with an over-all increase of 2.7 percent in the population of the State from 1940 to 1950, the population of the 11 eastern coal counties decreased in the same period by 0.1 percent. The 9 western coal counties had a 1940 population of 263,303, of which 80,431, or 30.5 percent, lived in urban areas. The population of these western 11 counties decreased from 1940 to 1950 by 0.5 percent.

Data on population and employment characteristics in Kentucky are shown by Exhibit No. 42 and a summary of these data is shown below as a comparison of population, labor force, and employment, between the State as a whole and the two groups of coal counties.

Comparison of Population, Labor Force, and Employment in Kentucky and in the 2 Groups of Coal Counties

	Whole State, 120 Counties	Eastern Kentucky: 11 Counties	Eastern Kentucky: Percent of State	Western Kentucky: 9 Counties	Western Kentucky: Percent of State
Preliminary U.S. Census Data - 1950					
Area (Square Miles)	40,109	4,530	11.3%	4,204	10.5%
Population	2,921,708	433,315	14.8	261,977	9.0
Population Density - Persons per Sq Mi	72.8	95.7		62.3	
U.S. Census Data - 1940					
Population	2,845,627	433,810	15.2	263,303	9.3
Residing in Urban Areas:					
Number	849,327	45,940	5.4	80,431	9.5
Percent	29.8%	10.6%		30.5%	
Labor Force:	998,700	121,709	12.2	92,889	9.3
Employed Number	847,563	97,118	11.5	73,952	8.7
Percent of Labor Force	84.9%	79.8%		79.6%	
Occupations of Employed Labor, Percentage of Total:					
Agriculture	36.5%	28.6%	9.0%	36.3%	8.7%
Mining	7.1	40.1	64.3	13.1	16.0
Construction	4.2	2.1	5.7	3.8	7.9
Manufacturing	11.9	4.3	4.1	10.0	7.3
Service	40.3	24.9	7.1	36.8	8.0

The above tabulation shows marked differences between the eastern and western coal counties and between them and the State as a whole. Eastern coal counties had a population density in 1950 of 95.7 persons per square mile; western coal counties had a density of 62.3, while the State as a whole averaged 72.8 persons per square mile. In eastern coal counties the percentage of population (as of 1940) living in urban areas was 10.6; in western coal counties 30.5 and in the entire State 29.8. The percent of the labor force employed was 79.8 and 79.6 in the eastern and western coal counties, respectively, while in the State as a whole this percentage was 84.9. In eastern coal counties the major occupation of employed labor was mining, with 40.1 percent so engaged, while in western coal counties the major occupation (aside from service) was agriculture, with 36.3 percent so engaged.

Estimated Labor Force. In Kentucky, the total labor force, based on the 1940 census, has previously been stated as 998,700. If the labor force has increased proportionately to that of population, the 1950 labor force would be 1,025,401. The labor force of the eastern coal counties on the same basis would be 121,570 or an average of 26,837 per 1,000 square miles, and in the western coal counties 92,421, or an average of 21,984 per 1,000 square miles.

The occupations of almost one-half of the labor force in the State (workers covered by Federal Old-Age and Survivors Insurance), are indicated by the following tabulation. These workers include employes of an employer with as few as one employe.

Number of Workers Covered by Federal Old-Age and Survivors Insurance as of Mid-March 1948

Industry Group Mid-March 1948	Total State		11 Eastern Coal Counties		9 Western Coal Counties	
	Total	Percent	Total	Percent	Total	Percent
Agriculture, Forestry, and Fishing	708	0.2%	-	-	30	0.1%
Mining	71,278	16.4	50,243	74.8%	10,285	27.3
Contract Construction	23,448	5.4	811	1.2	1,083	2.9
Manufacturing	140,421	32.3	3,515	5.2	11,220	29.8
Public Utilities	27,399	6.3	1,758	2.6	1,976	5.2
Wholesale Trade	34,093	7.8	1,460	2.2	2,491	6.6
Retail Trade	80,602	18.6	5,353	8.0	6,628	17.6
Finance, Insurance and Real Estate	15,686	3.6	463	0.7	830	2.2
Service Industries	39,007	9.0	3,020	4.5	2,994	8.0
Other (A)	1,762	0.4	525	0.8	147	0.3
Total	434,404	100.0%	67,148	100.0%	37,684	100.0%

Note: (A) Includes groups not elsewhere classified and unclassified.

The balance of the total labor force (disregarding the increase from mid-March 1948 to April 1, 1950) was not covered and consisted of employes of government, railroads, and certain non-profit organizations, agricultural, domestic, and unpaid family workers, those self-employed, and those unemployed. These workers generally, except some of the unemployed, are of types that do not now have the training or skills required for operation of synthetic liquid fuels plants.

From the above tabulation, it may be seen that in the eastern coal counties mining is by far the predominant occupation of covered workers, 74.8 percent being so engaged. In the western coal counties, mining, while important and engaging 27.3 percent of covered workers, is exceeded by manufacturing, which employs 29.8 percent. In the State as a whole, manufacturing is the predominant occupation, engaging 32.3 percent of covered workers.

The number of workers engaged in manufacturing in the entire State of Kentucky, as shown in the above tabulation, is further broken down by industry groups as shown in Exhibit No. 43. While group totals are available for all counties in the State, individual industry figures are not available for the coal counties.

Seasonal Trends in Employment. Employment of workers covered by the Kentucky Unemployment Compensation Law, as shown in the following table for a recent typical 13-month period, is generally steady, showing little seasonal variation, but rather an irregular decline.

Workers Covered by Kentucky
Unemployment Compensation Law

Month	Monthly Employment	Percent of Average
1948		
June	400,000	103.4%
July	395,000	102.1
August	398,000	102.8
September	393,000	101.6
October	391,000	101.0
November	389,000	100.5
December	397,000	102.6
1949		
January	386,000	99.7
February	379,000	97.9
March	374,000	96.6
April	378,000	97.7
May	375,000	96.9
June	376,000	97.2
Average	387,000	100.0%

Workers covered by this law exclude employes of government, railroads, and certain non-profit organizations, agricultural, domestic, and unpaid family workers, and those self-employed. Employes of an employer with less than four employes in any three quarters are also excluded, but the number of such employes is small.

Technical Training. While Kentucky is primarily an agricultural State, bituminous coal mining dominates the economy in the southeastern counties, and is important in mid-western counties. There are several industrial areas where technically trained workers may be found, principal among them being centered in Louisville, Ashland (including Huntington, W. Va.), and Lexington. Cincinnati, Ohio, and Evansville, Ind., lie just across the Ohio River from Kentucky, and workers in these cities may be considered as adding to the number of technically trained workers available to a new industry in Kentucky.

The number of workers who are engaged (as of mid-March 1948) in industries employing workers of skills comparable to those required in operating and maintaining synthetic liquid fuels plants is indicated by the following table (selected from the industry groups shown on Exhibit No. 43), which table also includes workers in electric and gas utilities.

Industries Employing Workers of Skills Comparable to Those Required by Synthetic Liquid Fuels Plants

	Workers Covered by Old-Age and Survivors Insurance
Manufacturing:	
Chemicals and Allied Products	5,141
Products of Petroleum and Coal	1,888
Rubber Products	27
Primary Metal Industries	10,037
Fabricated Metal Products	9,502
Machinery (except Electrical)	13,007
Electrical Machinery, etc.	4,730
Transportation Equipment	2,254
Total Manufacturing	46,586
Electric and Gas Utilities	6,746
Total in All Selected Industries	53,332

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Unemployment

Unemployment varies from one area to another dependent on local conditions. For a particular area, a survey of conditions prevailing in the area would have to be made to determine its extent. In this report, however, studies by particular areas were not made. Instead, as a measure of the extent of unemployment, the percentage of unemployed workers covered by State Unemployment Insurance to average covered employment in the State were tabulated by months for the years 1947 to 1949 inclusive, and the first 2 months in 1950. These percentages were taken from Bulletins of the Bureau of Employment Security of the U.S. Department of Labor and plotted in the form of a graph as shown in Exhibit No. 44.

Unemployment varied between 2 and 4 percent in the years 1947 and 1948, with an average during those years of 3.1 and 2.9 percent, respectively. During 1949, however, unemployment rose as high as 7.6 percent, with an average for the year of 6.7 percent. This rise continued in the first 2 months of 1950 reaching a peak of 8 percent in February 1950. The average percentage for the 12-month period ended February 1950, was 7.0 percent and this percentage has been adopted in this report as representing the degree of unemployment prevailing in the coal counties of the State as of March 31, 1950.

Estimated Total Unemployment. Application of the 7.0 percent of unemployment to the total estimated labor force in 1950 of 1,025,401 would indicate a total number of unemployed in the entire State of Kentucky of 71,778. On the same basis, the unemployed in the eastern coal counties would be 8,510 or 1,879 per 1,000 square miles and in the western coal counties would be 6,469 or 1,539 per 1,000 square miles.

Unemployed Skilled Labor. Assuming that the 7.0 percentage of unemployment in Kentucky applies equally to the 53,332 workers in the industries employing skilled labor (as well as to the total labor force), then the unemployed skilled labor force in the entire State would be 3,733.

Workers in all manufacturing industries in the eastern coal counties have been shown to number 3,515. By application of the same 7.0 percentage of unemployment, the unemployed manufacturing workers in these counties would be 246 or an average of 54 per 1,000 square miles. Similar data for western coal counties indicate unemployed manufacturing workers to number 785 or 187 per 1,000 square miles. The types of manufacture in these coal counties is not available from data of the Old-Age and Survivors Insurance program, but it is improbable that any appreciable number of workers are in industries comparable to the synthetic liquid
1b fuels industry, as such industries tend to be located in the larger
2a industrial cities of the State.

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Personnel Requirements of a Typical Synthetic Liquid Fuels Unit Plant in Kentucky

Total Personnel Requirements. The total requirements of personnel to operate and maintain a typical synthetic liquid fuels plant in Kentucky, to produce all the coal necessary as a raw material for the plant from mines owned or associated directly with the synthetic liquid fuels plant, and to supply the service requirements of such workers and their families, are shown in the following tabulation for the two processes using coal:

Total Personnel Requirements of a Unit Plant

	Hydrogenation		Coal Synthine	
	Eastern	Western	Eastern	Western
Unit Plant Employes	1,175	1,175	1,135	1,135
Coal Mine Employes	907	438	1,167	574
Total Production Employes	2,082	1,613	2,302	1,709
Service Workers	1,208	936	1,335	991
Total Personnel	3,290	2,549	3,637	2,700

The numbers of unit plant employes shown above are those estimated by the U.S. Bureau of Mines for plants using the two proeesses as shown on the Plant Requirements Sheet, Exhibit No. 1.

The numbers of coal mine employes shown above are those required to produce sufficient coal per annum to meet the fuel requirements of an average unit plant, using heating values and productivities per man-day at the average of those shown for the General Areas in Kentucky in the section of this report entitled "Coal". Development of such numbers of employes is shown in the following tabulation:

Total Number of Coal Mine Employes Necessary
To Produce Fuel Requirement of a Unit Plant in Kentucky

	Hydrogenation		Coal Synthine	
	Eastern	Western	Eastern	Western
Daily fuel requirement of a unit plant in billions of Btu	98	98	126	126
Heating value of coal in Btu per pound, average General Area	13,770	11,720	13,770	11,720
Annual fuel requirement of a unit plant in tons of coal, average General Area	1,298,838	1,526,024	1,669,935	1,962,031
Number of working days per annum in coal mines (assumed)	240	240	240	240
Productivity in tons per man-shift of operational coal mine employes in an average General Area, each General Area weighted by number of years of operation using strip and underground coal	6.89	16.78	6.89	16.44
Number of operational coal mine employes working daily	785	379	1,010	497
Number of operational coal mine employes absent due to accident, illness, etc., 10%	79	38	101	50
Total number of operational employes	864	417	1,111	547
Administrative employes, 5% of operational	43	21	56	27
Total coal mine employes	907	438	1,167	574

The number of service workers shown is 58 percent of total production employes. Such workers and the relation between them and production employes are defined in a succeeding section of this report entitled "Housing and Community Development".

Skilled Plant Personnel Required. The U.S. Bureau of Mines estimates that 80 percent of the technical workers in synthetic liquid fuels plants can be trained from inexperienced local labor. A maximum of 20 percent must then consist of workers already possessed of skills or experience required in such plants. The requirements of skilled personnel are tabulated below for the two processes using coal:

Skilled Personnel Requirements of a Unit Plant

	Hydrogenation	Coal Synthine
Unit Plant Employes	235	227

It was considered that no particular difficulty would be encountered in obtaining the necessary skilled labor for mining operations.

Diversion of Presently Employed Labor. If a unit plant consuming large amounts of coal were to be introduced into an area already containing a large coal mining industry, its requirements of coal may be presumed to have a profound effect on the economy of the industry at least within the county or General Area in which the plant is to be located. It may be reasonably presumed that existing coal mines in the area will be able and willing to divert a portion of their present capacity (at least all of their marginal business) to supplying the unit plant. Thus, a portion of the total personnel requirements of a unit plant may be satisfied by diversion of the productivity of existing coal miners in the area surrounding the plant, to the use of the plant.

The diversion of as much as the total annual requirement of one average unit plant in eastern Kentucky (a maximum of 1,669,935 tons in the case of an average synthine unit plant) would represent a diversion of only 3.1 percent of the 1948 coal production of the eleven eastern coal counties containing General Areas of Coal and Water Availability (53,966,920 tons). Such a diversion could easily be made up without additional manpower by working mines in these counties only 6 days more per year over the average of 198 days worked in 1948. Similarly, diversion of the annual requirement of one average unit plant in western Kentucky (1,962,031 tons in the case of the synthine process) would represent a diversion of 8.9 percent of the 1948 coal production of the 9 western coal counties containing General Areas of Coal and Water Availability (22,025,231 tons). This diversion could be made up in 16 more working days per year over the average of 181 days worked in 1948.

New Personnel Requirements. When a new industry is introduced in a community its requirement for workers, in excess of that portion met by the diversion of existing production to the new industry, must be satisfied either directly or indirectly by recruiting of new workers; directly from workers who are not now employed, or indirectly from workers who will leave their present employment to work in the new industry and whose places must in turn be filled by recruiting from the ranks of the unemployed. An estimate of the number of new workers required by an average unit plant is shown in the following tabulation:

Total Requirements of New Personnel for an
Average Unit Plant in General Areas of Kentucky

	Hydrogenation		Coal Synthine	
	Eastern	Western	Eastern	Western
Unit Plant Employes	1,175	1,175	1,135	1,135
Coal Mine Employes	0	0	0	93
Total Production Employes	1,175	1,175	1,135	1,228
Service Workers	682	682	658	712
Total Personnel	1,857	1,857	1,793	1,940

The numbers of new plant employes are the same as those previously indicated under "Total Personnel Requirements". Since no such plant as the unit plant exists in the General Area, the total personnel requirements, including skilled workers, are new and must be filled either directly or indirectly by unemployed workers.

The numbers of new coal mine employes are estimated to be those required to supply the fuel requirements of an average unit plant on the same basis as used in developing the total personnel requirements but with the following assumptions regarding diversion of production of existing mines in an average General Area:

(a) That production of existing mines be brought to the capacity possible by working 240 days per annum (the same as that assumed in an associated mine) with the added production diverted to the unit plant.

(b) That one-fifth of the present (1948) production in an average General Area be diverted from its existing market to the unit plant.

(c) That the balance of production required by a unit plant will be produced in an associated mine working 240 days per annum.

The estimated number of coal miners required is developed in Exhibit No. 45.

Service workers are estimated at 58 percent (service to production worker ratio previously explained) of the new production workers required. It is logical to assume that service workers would be reduced in proportion to the reduction in production workers made possible by diversion of marginal coal production to the plant and the use of more working days per year.

Comparison of Personnel Requirements of a Unit Plant and Unemployment

The extent to which the new personnel requirements of a unit plant are met by the unemployed labor in the area surrounding the plant in an average location in the coal counties of Kentucky is indicated by the following tabulation:

Comparison of New Personnel Requirements of a Unit Plant and Unemployed per 1,000 Square Miles in Coal Counties of Kentucky and Size of Area Containing Sufficient Unemployed To Satisfy Requirements

Description and Process	New Personnel Requirement of a Unit Plant	Unemployed per 1,000 Square Miles	Size of Area Containing Sufficient Unemployed To Satisfy Requirement: Sq Miles	Size of Area Containing Sufficient Unemployed To Satisfy Requirement: Radius-Miles
Eastern Coal Counties				
Total Personnel:				
Hydrogenation	1,857	1,879	988	17.7
Coal Synthine	1,793	1,879	954	17.4
Skilled Personnel:				
Hydrogenation	235	(A)		
Coal Synthine	227	(A)		
Western Coal Counties				
Total Personnel:				
Hydrogenation	1,857	1,539	1,207	19.6
Coal Synthine	1,940	1,539	1,261	20.0
Skilled Personnel:				
Hydrogenation	235	(A)		
Coal Synthine	227	(A)		

Note: (A) Not estimated but assumed to be negligible.

The above comparison indicates that, in the coal counties of Kentucky, the personnel requirements of an average unit plant for total personnel could be satisfied by the numbers of unemployed in an area of about 17.5 miles radius from the plant in eastern counties and of about 20 miles radius in western counties. Such conditions indicate an ample supply of labor to meet the requirements of an average unit plant as to total personnel within an area convenient to the plants.

However, there are few workers in industries comparable to synthetic liquid fuels with respect to skills and experience required in either the eastern or western coal counties of Kentucky. It is considered that the requirements of a unit plant for such workers would have to be met by inducing workers to relocate from the industrial centers of the State to the area surrounding the plants.

Operating Labor Costs

The average straight-time hourly rate as of March 31, 1950, payable to wage earners (exclusive of supervisors) in synthetic liquid fuels unit plants in both the eastern and western coal counties in Kentucky is estimated at $1.64. Development of this hourly rate is shown in the following tabulation:

Estimated Average Straight-time Hourly Rate Payable in Synthetic Liquid Fuels Plants

Average straight-time hourly rate (exclusive of premium pay) prevailing in Kentucky in industries comparable with synthetic liquid fuels plants as to skills and experience required of workers	$1.53
Differential of 5 percent as inducement to relocate	.08
Total straight-time rate exclusive of premium pay	$1.61
Average differential (premium) paid because of working second and third shift	.03
Total average straight-time hourly rate payable in synthetic liquid fuels plants	$1.64

The average straight-time hourly rate (exclusive of premium) prevailing in Kentucky as of March 31, 1950, of wage earners (exclusive of supervisors) in industries competitive with synthetic liquid fuels plants for workers of the skills and experience required has been estimated at $1.53 as described in succeeding paragraphs.

Basis of Estimated Wage Rates. Wage rates of workers of the higher skills to be employed in synthetic liquid fuels plants would be governed by the rates paid in the chemical, petroleum refining, and coal mining industries, as such workers would have to be recruited from or paid in competition with them. Wages of workers of lesser skills, however, are not dependent to the same extent on wages paid in the above industries, but are determined by wages paid in the manufacturing industries presently existing in the Areas in which the proposed plants might be located.

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In estimating wage rates in the synthetic liquid fuels industry, wage rates in the chemical, petroleum refining, and coal mining industries in relation to other widespread industries have been taken at a ratio of two to one. By dividing the number of workers (exclusive of supervisors), shown by the U.S. Bureau of Mines personnel classification for a 30,000-barrel-per-day hydrogenation plant, into two groups as to relative skills (above or below a wage rate of $1.70 per hour) a ratio of approximately two to one is shown as follows:

Ratio of Wage Earners of Higher Skills to Those of Lower Skills

	Number of Wage Earners			
Department	Higher Skilled	Lower Skilled		Total
Operating	955	139		1,094
Maintenance	807	484		1,291
Indirect	22	288		310
Total	1,784	911		2,695
Ratio of wage earners of higher skills to those of lower skills	1,784 ÷	911	=	1.96

Wage Rates by Regional Areas. Wage Survey Bulletins prepared by the Bureau of Labor Statistics of the U.S. Department of Labor, as of various dates, were used as a basis for development, by regional areas, of wages paid in industries similar to synthetic liquid fuels plants. After adjustment to a uniform date, March 31, 1950, the average straight-time hourly rate, exclusive of premium, for the Border States (which includes Kentucky) has been developed for selected industries.

The industries selected as representative in each group of required labor skills are those for which there are available Wage Survey Bulletins covering all areas in the United States. Development of average straight-time hourly wage rates, exclusive of premium, paid in the Border States is shown in the following tabulation.

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Average Straight-time Hourly Wage Rates, Exclusive of Premium, Paid in Selected Industries in Border States (As of March 31, 1950)

Industry	Hourly Wage Rate
Industries employing workers of higher skills:	
Chemical	$1.61
Petroleum Refining	1.80
Bituminous Coal Mining	1.84
Average straight-time hourly earnings, weighted by reported total number of workers	$1.81
Industries employing workers of lesser skills:	
Fabricated Structural Steel	$1.30
Paints and Varnishes	1.10
Ferrous Foundries	1.25
Machinery	1.39
Fertilizers	1.02
Electric and Gas Utilities	1.36
Average straight-time hourly earnings, weighted by reported total number of workers	$1.29
Average straight-time hourly earnings combined by means of a weighting ratio of two to one of wages paid by industries using workers of higher skills to those using workers of lesser skills	$1.64

Wage Rates in Kentucky. Straight-time average hourly wage rates, exclusive of premium, as developed for the regional area, were then broken down to individual states by assuming that the ratio of the state rates to the area rates would be the same as that indicated by other wage studies such as: (a) that made by the Army-Air Force Wage Board in 1948; (b) the Old-Age and Survivors Insurance (OASI) Program during the first quarters of 1948 and 1947; and (c) the State Unemployment Insurance Program for the year 1946. This determination for the State of Kentucky, is shown in the following tabulation:

Straight-time Average Hourly Wage Rates,
Exclusive of Premium, Paid in Selected Industries in Kentucky
(As of March 31, 1950)

	Hourly Rates as per Source of Information		Hourly Rates Adjusted to Level of Synthetic Liquid Fuels Industry	
	Regional Area	Kentucky	Regional Area	Kentucky
Army-Air Force Survey	$1.21	$1.22	$1.64	$1.65
OASI Program:				
1st Quarter 1948	1.48	1.32	1.64	1.46
1st Quarter 1947	1.39	1.25	1.64	1.47
Unemployment Insurance Program:				
Year 1946	1.27	1.20	1.64	1.55
Average Straight-time Hourly Earnings - Kentucky				$1.53

Relocation Differential. In order to induce workers to relocate in the vicinity of a unit plant, it is considered that it will be necessary to offer an increase of 5 percent over the hourly rate prevailing in the State in industries comparable to synthetic liquid fuels plants. Such an increase amounts to 8 cents per hour or $166.40 per annum (of 2,080 working hours). Such an increase would probably pay relocation costs in 1 year, and, when coupled with the prospect of steady year-round work and of new housing in a model village, should constitute inducement to sufficient workers to completely staff the plant.

Shift Differential. It is the practice in manufacturing industries operating on round-the-clock basis to pay a differential (or premium) to workers on the second and third shifts over hourly wages paid workers on the first shift. The differentials most prevalent in petroleum refining and bituminous coal mining are 4 cents per hour on the second shift and 6 cents per hour on the third. Assuming an equal number of workers on the 3 shifts in synthetic liquid fuels plants, the average amount of shift differentials would be 3 cents per hour.

HOUSING AND COMMUNITY DEVELOPMENT

Population Characteristics

The State of Kentucky has a 1950 population density of 72.8 persons per square mile. Of the entire State population in 1940, 29.8 percent lived in urban areas. There are two large cities, part or all of whose metropolitan areas lie in Kentucky; as tabulated below:

Estimated Metropolitan Area
Population as of January 1, 1950

City	Population
Ashland, Ky. Huntington, W.Va.	200,000
Louisville	575,500

Source: Sales Management "Survey of Buying Power" - further reproduction not licensed.

In 11 eastern counties of the State, where General Areas for the location of synthetic liquid fuels plants are being considered, the 1950 density of population is 95.7. In nine similar western counties, the 1950 density is 62.3. There are eight cities of over 5,000 population in all of these counties as shown in the following tabulation:

Cities of 5,000 or Greater Population in
Kentucky Counties Containing Available Raw Material

City	1950 Census Preliminary Count
Eastern Coal Counties	
Hazard	6,850
Jenkins	6,933
Middlesborough	14,419
Pikeville	5,162
Western Coal Counties	
Henderson	16,760
Hopkinsville	12,531
Owensboro	33,983
Madisonville	11,136

In the 11 eastern coal counties as of 1940, 10.6 percent of the population lived in urban areas, 45.3 percent in rural non-farm and 44.1 percent in rural farm areas. In the nine western coal counties, similar percentages as of 1940 were 30.5, 28.9 and 40.6 percent, respectively.

Community Requirements and Population Determination

When a new manufacturing establishment is set up, unless it is located in an already established large community, it may be presumed necessary to develop an entire new community to house plant and associated workers conveniently near their place of employment to the extent that experience has shown it to be required.

Housing facilities alone, however, are not the only requisite of a new community. Residents of a new housing development require civic and commercial facilities reasonably convenient to their homes. It has been considered that such facilities must be provided as an integral part of a planned community rather than allowing them to develop without plan on the outskirts of the development.

An estimate follows of the population of the plant-city associated with average unit plants in Kentucky based on numbers of plant and mine employes, together with associated service workers, for whom housing would be required. This estimate is based on average conditions in the eastern and western coal counties of Kentucky. It is subject to variation from one location to another according to conditions existent in each individual location.

Population of 10,000-barrel-per-day Synthetic Liquid Fuels Plant-city

	Hydrogenation		Coal Synthine	
	Eastern	Western	Eastern	Western
Plant and Mine Employes	670	858	636	909
Service Workers	389	498	369	527
Total Workers	1,059	1,356	1,005	1,436
Number of Households or Dwelling Units	868	1,111	824	1,177
Total Population To Be Housed	3,559	4,555	3,378	4,826

Number of Plant and Mine Employes To Be Housed. The percentage of plant and mine employes for whom housing would be required in a plant-city is based on a chart, Exhibit No. 46, which shows the "Ratio of Employes Housed in a Plant-city to the Relative Personnel Demand". This chart was developed from a study of the effect of density of population in the area surrounding existing communities, in which the predominant source of employment is one plant or factory.

The number of plant and mine employes estimated to be housed in the plant-city is shown in the following tabulation:

Number of Plant and Mine Employes Estimated To Be Housed

	Coal Hydrogenation		Coal Synthine	
	Eastern	Western	Eastern	Western
Population Density in Persons per Square Mile in Kentucky Coal Counties	95.7	62.3	95.7	62.3
Population within 1,000 Square Miles (17.8 miles radius from plant)	95,700	62,300	95,700	62,300
Requirements of New Plant and Mine Personnel (from "Labor" section)	1,175	1,175	1,135	1,228
Above Requirements in Percentage of Population within 1,000 Square Miles	1.23%	1.89%	1.19%	1.97%
Plant and Mine Employes To Be Housed in the Plant-city:				
Percent of Total (from Exhibit No. 46)	57%	73%	56%	74%
Number	670	858	636	909

y
Number of Service Workers To Be Housed. In every com-
94b munity, there must be service workers to minister to the needs of
95a production workers. Such workers consist of proprietors and employes
of wholesale and retail trade establishments, finance, insurance,
5 and real estate agencies, and a great variety of miscellaneous ser-
0021 vice establishments, such as laundries, dry cleaners, barbers, shoe

and hat cleaners and repairers, automobile repair shops, garages, motion picture houses, etc., as well as professional personnel such as doctors, lawyers, teachers, and governmental workers. Transportation and public utility workers are also considered as service workers for the purpose of this report. In sparsely settled rural counties, only the minimum services are provided in nearby centers and the more specialized services must be secured in more distant trade centers. As mining or manufacturing expands in a community, trade and service establishments spring up within it over a period of time and the number of workers in the service industries tends to equal the number in the production group, unless the community is a satellite of a large urban center. In estimating the service requirements of a plant-city in Kentucky, it is considered that production workers living in the plant-city will receive the same degree of service as that prevalent in the coal counties. The percentage of service workers in terms of production workers was developed for the eastern and western coal counties in Kentucky as of 1940 and found to be, respectively, 33 and 58 percent. A similar percentage of 67 was developed for the State as a whole. Computations were based upon data from Exhibit No. 42.

Percentage of Service Workers to Production Workers in Kentucky as of 1940

Class of Worker	Number Entire State	Eastern Coal Counties	Western Coal Counties
Production			
Agricultural	309,146	27,835	26,843
Mining	60,552	38,913	9,683
Construction	35,607	2,023	2,828
Manufacturing	100,804	4,144	7,398
Total Production Workers	506,109	72,915	46,752
Service			
Total Service Workers	341,454	24,203	27,200
Percentage of Service Workers in terms of Production Workers	67%	33%	58%

Ky

The percentage of service to production workers of 33 as
existing in the industrially undeveloped eastern coal counties was 29
considered to represent too low a grade of service for the proposed 29
plant-city in Kentucky. Injection of the proposed plant-city would
create a new and modern community of size exceeded by few now ex- 1
isting in these counties. Such a city would tend to attract to it- 7002

self service industries serving not only its own inhabitants, but also those surrounding it.

On the other hand, the percentage of 67 for the State as a whole was considered in excess of that which might be required of a plant-city, as the more specialized service requirements may be obtained in the existing larger cities of the State. It was considered that the percentage of 58 as prevalent in the western coal counties would represent an adequate degree of service in a plant-city in both eastern and western Kentucky.

Applying this percentage to the number of plant and mine employes estimated to be housed in the plant-city, the number of service workers to be so housed would be:

Estimated Number of Service Workers
To Be Housed

	Hydrogenation		Coal Synthine	
	Eastern	Western	Eastern	Western
Plant and Mine Employes	670	858	636	909
Service Workers - 58% of Plant and Mine Workers	389	498	369	527

Population of Plant-city. The number of employed persons per household may be determined for the State of Kentucky, according to the 1940 census, as shown below:

Estimated Number of Employed Persons
per Household as per 1940 Census

Employed Persons	847,563
Households	693,960
Employed Persons per Household	1.22

y The Bureau of the Census shows, for Kentucky for 1940, a population per household of 4.1.

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97a
5
0021

Assuming these ratios to apply to the plant-city, the total population is determined as below:

Estimated Total Population of Plant-city

	Hydrogenation		Coal Synthine	
	Eastern	Western	Eastern	Western
Employed persons in plant-city	1,059	1,356	1,005	1,436
Households or dwelling units (Employed persons divided by 1.22)	868	1,111	824	1,177
Total population (households multiplied by 4.1)	3,559	4,555	3,378	4,826

Estimates for this report have been based on the assumption of only one unit plant per 1,000 square miles. Simultaneous operation of two or more unit plants within such an area would require housing a substantially larger proportion of workers. This would entail increased investment in housing per plant with corresponding changes in operating costs.

Family Housing Requirements. In the past, common practice in construction of "company towns" has been to limit dwellings to those accommodating a single family. There is now, however, an increasing demand for multi-family or apartment dwellings. In this report, it has been assumed that 20 percent of all dwellings will be of this type, the balance being single homes. Analysis of single homes in existence in Oak Ridge, Tenn., in 1947 shows that about 75 percent had two bedrooms and 25 percent had three. For the purpose of estimating costs of the plant-city, the distribution by types of dwellings is assumed to be as follows:

Distribution by Types of Dwellings

		Number of Dwellings for Plant-city of a Unit Plant			
		Hydrogenation		Coal Synthine	
Type of Dwelling	Percent of Total	Eastern	Western	Eastern	Western
2-Bedroom single-family	60%	521	667	494	706
3-Bedroom single-family	20	174	222	165	235
Multi-family units	20	173	222	165	236
Total	100%	868	1,111	824	1,177

Cost of Housing and Community Development for a Unit Plant

Investment in Plant city. Based on the Contractor's experience in similar installations, a plan of a model city for employes of a synthetic liquid fuels plant was designed. This city plan provided housing, utilities, and civic and commercial facilities adequate for a population of 5,000 inhabitants. Cost estimates for such a model city were made at levels prevailing at December 1949, in the Pittsburgh, Pa., area.

From this estimate, unit costs were developed for application to plant-cities of populations estimated to be required in connection with unit plants in Kentucky. An index of building construction costs applicable to the average location in General Areas of Kentucky, as of March 31, 1950, as compared to similar costs in Pittsburgh, Pa., as of December 1949, was developed based on data on construction costs as reported by The Dow Service, Inc. This index, for Kentucky, is 86 in eastern counties and 95 in western counties.

The estimated investment required to construct a plant-city in connection with unit plants in Kentucky is shown in the following tabulations for the two processes:

Cost of Housing and Community Development Required for an Average Hydrogenation Unit Plant in Eastern Coal Counties of Kentucky
(As of March 31, 1950)

Type of Facility	Investment
Land	
For 3,559 population at $9 per person	$ 32,031
Grading and Landscaping Site	
For 3,559 population at $130 per person	462,670
Dwelling Units	
521 - 2-Bedroom single-family at 806 sq ft at $7.89 per sq ft	3,313,039
174 - 3-Bedroom single-family at 988 sq ft at $7.89 per sq ft	1,356,330
173 - Multi-family at 850 sq ft at $7.20 per sq ft	1,058,760
477 - Garages (55% of Dwelling Units) at $697 each	332,469
Total Dwelling Units	$ 6,060,598
Utilities	
Lighting, water distribution, sewage disposal, streets, roadways, sidewalks, curbs, and gutters	$ 1,132,740
Civic Facilities	
Municipal building, comfort station, schools, hospital, sanitation	1,024,992
Commercial Facilities	
Bus station, theatre, bank and professional building, shopping buildings	1,519,693
Total Investment for Complete Plant-city, exclusive of Water Supply	$10,232,724

Cost of Housing and Community Development Required for an Average Hydrogenation Unit Plant in Western Coal Counties of Kentucky
(As of March 31, 1950)

Type of Facility	Investment
Land	
For 4,555 population at $9 per person	$ 40,995
Grading and Landscaping Site	
For 4,555 population at $143 per person	651,365
Dwelling Units	
667 - 2-Bedroom single-family at 806 sq ft at $8.72 per sq ft	4,687,676
222 - 3-Bedroom single-family at 988 sq ft at $8.72 per sq ft	1,912,530
222 - Multi-family at 850 sq ft at $7.95 per sq ft	1,500,276
611 - Garages (55% of Dwelling Units) at $770 each	470,470
Total Dwelling Units	$ 8,570,952
Utilities	
Lighting, water distribution, sewage disposal, streets, roadways, sidewalks, curbs, and gutters	$ 1,602,062
Civic Facilities	
Municipal building, comfort station, schools, hospital, sanitation	1,448,490
Commercial Facilities	
Bus station, theatre, bank and professional building, shopping buildings	2,149,960
Total Investment for Complete Plant-city, exclusive of Water Supply	$14,463,824

Cost of Housing and Community Development Required for an Average Coal Synthine Unit Plant in Eastern Coal Counties of Kentucky
(As of March 31, 1950)

Type of Facility	Investment
Land	
For 3,378 population at $9 per person	$ 30,402
Grading and Landscaping Site	
For 3,378 population at $130 per person	439,140
Dwelling Units	
494 - 2-Bedroom single-family at 806 sq ft at $7.89 per sq ft	3,141,346
165 - 3-Bedroom single-family at 988 sq ft at $7.89 per sq ft	1,286,175
165 - Multi-family at 850 sq ft at $7.20 per sq ft	1,009,800
453 - Garages (55% of Dwelling Units) at $697 each	315,741
Total Dwelling Units	$5,753,062
Utilities	
Lighting, water distribution, sewage disposal, streets, roadways, sidewalks, curbs, and gutters	$1,075,320
Civic Facilities	
Municipal building, comfort station, schools, hospital, sanitation	972,864
Commercial Facilities	
Bus station, theatre, bank and professional building, shopping buildings	1,442,406
Total Investment for Complete Plant-city, exclusive of Water Supply	$9,713,194

Cost of Housing and Community Development Required for an Average Coal Synthine Unit Plant in Western Coal Counties of Kentucky
(As of March 31, 1950)

Type of Facility	Investment
Land	
For 4,826 population at $9 per person	$ 43,434
Grading and Landscaping Site	
For 4,826 population at $143 per person	690,118
Dwelling Units	
706 - 2-Bedroom single-family at 806 sq ft at $8.72 per sq ft	4,961,768
235 - 3-Bedroom single-family at 988 sq ft at $8.72 per sq ft	2,024,525
236 - Multi-family at 850 sq ft at $7.95 per sq ft	1,594,888
647 - Garages (55% of Dwelling Units) at $770 each	498,190
Total Dwelling Units	$ 9,079,371
Utilities	
Lighting, water distribution, sewage disposal, streets, roadways, sidewalks, curbs, and gutters	$ 1,697,234
Civic Facilities	
Municipal building, comfort station, schools, hospital, sanitation	1,534,668
Commercial Facilities	
Bus station, theatre, bank and professional building, shopping buildings	2,277,872
Total Investment for Complete Plant-city, exclusive of Water Supply	$15,322,697

Commercial Facilities. It is recognized that, insofar as possible, an industrial plant-city such as would be required by a synthetic liquid fuels plant should be self-supporting. Commercial establishments and services, as an integral part of a community, are profit-making entities resulting from community development. Therefore, it has been considered that rental from commercial facilities would be ample to cover the charges on the investment in those facilities, including a proportionate share of the utilities and civic facilities and land. Such investment has been estimated as follows:

Allocation of Total Investment in Plant-city between Residential and Commercial Facilities with Estimation of Appreciated Land Values for Hydrogenation Unit Plant

	Commercial	Residential	Total
Eastern Coal Counties			
Capital Investment	$ 1,519,693	$ 6,060,598	$ 7,580,291
Percent of Total	20%	80%	100%
Allocation (based on percent of total) of:			
Utilities	$ 226,548	$ 906,192	$ 1,132,740
Civic Facilities	204,998	819,994	1,024,992
Investment in land improvements	$1,951,239		
Appreciated value of land, 1/6 of improvements	325,207		
Total Commercial Investment	$2,276,446		
Western Coal Counties			
Capital Investment	$2,149,960	$ 8,570,952	$10,720,912
Percent of Total	20%	80%	100%
Allocation (based on percent of total) of:			
Utilities	$ 320,412	$ 1,281,650	$ 1,602,062
Civic Facilities	289,698	1,158,792	1,448,490
Investment in land improvements	$2,760,070		
Appreciated value of land, 1/6 of improvements	460,012		
Total Commercial Investment	$3,220,082		

Allocation of Total Investment in Plant-city between Residential and Commercial Facilities with Estimation of Appreciated Land Values for Coal Synthine Unit Plant

	Commercial	Residential	Total
Eastern Coal Counties			
Capital Investment	$1,442,406	$5,753,062	$ 7,195,468
Percent of Total	20%	80%	100%
Allocation (based on percent of total) of:			
Utilities	$ 215,064	$ 860,256	$ 1,075,320
Civic Facilities	194,573	778,291	972,864
Investment in land improvements	$1,852,043		
Appreciated value of land, 1/6 of improvements	308,674		
Total Commercial Investment	$2,160,717		
Western Coal Counties			
Capital Investment	$2,277,872	$9,079,371	$11,357,243
Percent of Total	20%	80%	100%
Allocation (based on percent of total) of:			
Utilities	$ 339,447	$1,357,787	$ 1,697,234
Civic Facilities	306,934	1,227,734	1,534,668
Investment in land improvements	$2,924,253		
Appreciated value of land, 1/6 of improvements	487,375		
Total Commercial Investment	$3,411,628		

The advantages to management in the construction, operation, and control of its own city are recognized. Among them are:

(1) A more dependable and stable labor supply
(2) More desirable living conditions
(3) Better civic administration
(4) A cleaner and more orderly community
(5) Lower plant and community taxes.

Against these advantages, management will have the responsibility and expense of construction and administration of the plant-city. It is felt, however, that savings to the plant in municipal taxes will be sufficient to compensate for such expense.

Employe Home Ownership. The advantages of home ownership, both to the employes as individuals and to the company, are well recognized, and it is believed that some arrangement should be encouraged whereby at least one-half the housing could be offered to employes on liberal terms, either directly by management or by reputable builders approved by management. The cost of the several types of housing including its share of land and utilities (but excluding civic facilities) and the bare cost of a garage are estimated for unit plants as follows:

Estimation of Residential Housing Costs
Hydrogenation Unit Plants

	Eastern Coal Counties	Western Coal Counties
Cost of land, grading, and landscaping	$ 494,701	$ 692,360
Less allocation to commercial facilities	325,207	460,012
	$ 169,494	$ 232,348
Cost of utilities allocated to residential	906,192	1,281,650
Residential share of land and utilities	$1,075,686	$1,513,998

	No. of Units	Total Cost of Dwelling Units	Allocated Cost of Share of Land and Utilities	Residential Cost Total	Residential Cost Per Unit
Eastern Coal Counties:					
Dwelling Units-					
2-Bedroom single-family	521	$3,313,039	$ 622,156	$ 3,935,195	$7,553
3-Bedroom single-family	174	1,356,330	254,705	1,611,035	9,259
Multi-family	173	1,058,760	198,825	1,257,585	7,269
	868	$5,728,129	$1,075,686	$ 6,803,815	$7,838
Garages	477	332,469	-	332,469	697
Total Residential		$6,060,598	$1,075,686	$ 7,136,284	
Western Coal Counties:					
Dwelling Units-					
2-Bedroom single-family	667	$4,687,676	$ 876,137	$ 5,563,813	$8,342
3-Bedroom single-family	222	1,912,530	357,456	2,269,986	10,225
Multi-family	222	1,500,276	280,405	1,780,681	8,021
	1,111	$8,100,482	$1,513,998	$ 9,614,480	$8,654
Garages	611	470,470	-	470,470	770
Total Residential		$8,570,952	$1,513,998	$10,084,950	

Estimation of Residential Housing Costs
Coal Synthine Unit Plants

	Eastern Coal Counties	Western Coal Counties
Cost of land, grading, and landscaping	$ 469,542	$ 733,552
Less allocation to commercial facilities	308,674	487,375
	$ 160,868	$ 246,177
Cost of utilities allocated to residential	860,256	1,357,787
Residential share of land and utilities	$1,021,124	$1,603,964

	No. of Units	Total Cost of Dwelling Units	Allocated Cost of Share of Land and Utilities	Residential Cost Total	Residential Cost Per Unit
Eastern Coal Counties:					
Dwelling Units-					
2-Bedroom single-family	494	$3,141,346	$ 589,942	$ 3,731,288	$7,553
3-Bedroom single-family	165	1,286,175	241,542	1,527,717	9,259
Multi-family	165	1,009,800	189,640	1,199,440	7,269
	824	$5,437,321	$1,021,124	$ 6,458,445	$7,838
Garages	453	315,741	-	315,741	697
Total Residential		$5,753,062	$1,021,124	$ 6,774,186	
Western Coal Counties:					
Dwelling Units-					
2-Bedroom single-family	706	$4,961,768	$ 927,436	$ 5,889,204	$8,342
3-Bedroom single-family	235	2,024,525	378,417	2,402,942	10,225
Multi-family	236	1,594,888	298,111	1,892,999	8,021
	1,177	$8,581,181	$1,603,964	$10,185,145	$8,653
Garages	647	498,190	-	498,190	770
Total Residential		$9,079,371	$1,603,964	$10,683,335	

If one-half the dwellings of each type were sold at cost to their occupants, then the remaining investment in dwellings and civic development would be:

Estimated Remaining Investment in Dwellings and Civic Development for Unit Plant

	Hydrogenation		Coal Synthine	
	Eastern	Western	Eastern	Western
Total Investment for Complete Plant-city	$10,232,724	$14,463,824	$9,713,194	$15,322,697
Less:				
Commercial Facilities and Related Costs	$ 2,276,446	$ 3,220,082	$2,160,717	$ 3,411,628
One-half Cost of Housing Sold to Occupants	3,568,142	5,042,475	3,387,093	5,341,668
Total	$ 5,844,588	$ 8,262,557	$5,547,810	$ 8,753,296
Balance of Investment in Land, Dwelling Units, Garages, Utilities, and Civic Development	$ 4,388,136	$ 6,201,267	$4,165,384	$ 6,569,401

This balance of investment consists of dwellings not sold to employes, together with the investment in land, grading, utilities, and civic facilities not recovered by rental of commercial facilities or sold. This investment would be operated by the plant.

Operating Costs

The annual costs of operation of investment not recovered by rental of commercial facilities or by sale are estimated below:

Annual Operating Costs

	Hydrogenation		Coal Synthine	
	Eastern	Western	Eastern	Western
Net Total Investment	$4,388,136	$6,201,267	$4,165,384	$6,569,401
Operating Costs @ 6%	263,288	372,076	249,923	394,164

Annual costs of operation are estimated to comprise, in terms of annual percentages on investment:

Annual Costs of Operation in
Terms of Annual Percentage on Investment

	Percent
Depreciation (40-year life)	2.5%
Maintenance Costs	2.0
State and County Taxes, Insurance, and Operation of Municipal Facilities	1.5
Total Annual Percentage	6.0%

It is considered that costs of operation of housing and community development may be recovered by rents of dwelling units without the necessity of any charge to plant operations.

The average amount per month required to offset operating costs would be $50.58 in the eastern coal counties and $55.83 in the western coal counties, as shown below:

Monthly Amount Required To Offset Operating Costs

	Hydrogenation		Coal Synthine	
	Eastern	Western	Eastern	Western
Annual Operating Costs	$263,288	$372,076	$249,923	$394,164
Number of Rental Units	434	555	412	588
Average per Unit:				
Annual	$ 607	$ 670	$ 607	$ 670
Monthly	50.58	55.83	50.58	55.83

Such an amount would be 14.6 percent in the eastern coal counties and 16.1 percent in the western coal counties of the average income per household of $4,162. The average annual wage of plant workers in Kentucky has been estimated at $1.64 per hour or $3,411.20 per annum (of 2,080 hours). The average income per household on this basis would be $4,162 ($3,411.20 times 1.22 wage earners).

Return on Investment

Recognizing that different investors may require different rates of return upon their capital, these estimates include no allowance for return. However, as a guide, the following tabulation indicates the amounts per day and per barrel of products which would be required for each increment of 1 percent (before income taxes) on the estimated net total investment in housing and community development associated with unit plants in Kentucky:

Incremental Costs for Each 1 Percent Gross Return on Net Total Investment in Housing and Community Development

	Hydrogenation		Coal Synthine	
	Eastern	Western	Eastern	Western
Net Total Investment entitled to Return	$4,388,136	$6,201,267	$4,165,384	$6,569,401
1 Percent Return on Above:				
Per Annum	$ 43,881	$ 62,013	$ 41,654	$ 65,694
Per Dwelling Unit:				
Per Annum	101	112	101	112
Per Month	8.42	9.33	8.42	9.33
Per Calendar Day	120	170	114	180
Per Barrel of Products	0.012	0.017	0.011	0.018

The monthly rental to be paid by the occupant would be the average monthly operating cost plus the required return on the investment.

MARKETING

Introduction

The agreement under which this report was prepared requires the General Areas suitable for the location of synthetic liquid fuels plants to be arranged in groups of relative desirability, with at least 2,000,000 barrels of daily production in the most desirable group for the total United States. This is equal to 730,000,000 barrels annually, or approximately 36.3 percent of the total demand for liquid fuels in the United States for the year 1949.

Motor Fuel - Major Plant Product. If a substantial part of the demand for liquid fuels in the United States were supplied by synthetic liquid fuels plants, the principal product would be motor gasoline.

Plants Using Coal or Natural Gas. For plants using coal or natural gas as raw materials, motor gasoline would be the major plant product. The amounts of motor gasoline specified to be produced from these raw materials by the various processes are as follows:

Percentage of Motor Gasoline
Specified To Be Produced by the Various Processes

Process	Percent
Hydrogenation	72.2%
Synthine Using Coal	72.8
Synthine Using Natural Gas	91.5

Plants Using Oil Shale. In the case of shale-oil plants for the purpose of this report, motor gasoline is not specified as one of the products to be produced although such plants, if so designed, could produce motor gasoline. For a 10,000-barrel shale-oil unit plant, the principal products specified are 5,150 barrels of jet fuel and 3,350 barrels of Diesel fuel daily. The annual production of Diesel fuel of such a plant would be 1,220,000 barrels. In the year 1948, total sales of Diesel fuel in all of the Mountain States amounted to only 5,209,000 barrels. In other words, about five shale-oil unit plants would have been sufficient to satisfy the total demand for Diesel fuel in the Mountain States in that year. In the case of jet fuel, the annual output of a single 10,000-barrel-per-day shale-oil plant would be 1,880,000 barrels. This is approximately equal to the total sales of jet propulsion fuel in the year 1948 of 1,891,000 barrels in the total United States. Consequently, it appears that if a relatively large number of synthetic liquid fuels unit plants should be established, the principal product would be motor gasoline. Furthermore, since it appears that only enough natural gas will be available for relatively few synthetic liquid fuels unit plants, motor gasoline would amount to approximately 75 percent of the total productive capacity, based upon the plant product specifications.

From the foregoing, it is evident that of the total 2,000,000 barrels of daily productive capacity (which is equivalent to the capacity of 200 10,000-barrel synthetic liquid fuels plants) required to be included in the most desirable group of General Areas, gasoline would amount to approximately 1,500,000 barrels daily, or 547,500,000 barrels annually. This would be 62.3 percent of the total United States demand for motor gasoline in 1949, which amounted to 878,887,000 barrels. If the total demand for motor gasoline in 1949 had been supplied by synthetic liquid fuels plants a total of 321 such unit plants would have been required. This is a relatively small number in contrast to the several thousands of plants potentially possible based on raw materials available.

Estimated Future Liquid Fuel Requirements. While the hazards of a long-range forecast of liquid fuel consumption are well recognized, it has been considered necessary in this present study to attempt to estimate probable liquid fuels requirements over the next 25 years because the usual short-term forecasts of a few years' duration would have little significance in appraising the economic factors that may have a bearing on the bringing into existence of a long-range program, such as the development of a synthetic liquid fuels industry. On the basis of present-day factors affecting motor gasoline consumption, the future demand has been projected by states and from this the total demand for the United States has been estimated, as shown in Exhibit No. 47, which demand in 1975 amounts to approximately 59 billion gallons, or 1.4 billion barrels annually. If this demand were met entirely with synthetic motor gasoline, the equivalent of 511 plants, each of 10,000 barrels daily capacity, would be required.

In recent years, the proportion of motor gasoline to the total demand for liquid fuels in the United States has averaged approximately 40 percent. At the present time, there are several factors which indicate that the motor gasoline percentage may rise in the next few years. There is a tendency for the percentage of residual fuel oils to decline as refining operations are altered. Furthermore, it is expected that the expansion of the natural gas industry may reduce relatively the consumption of fuel oil and kerosene. On the other hand, there may be some counterbalancing factors, such as the increasing use of jet propulsion fuel and Diesel fuel. However, on the basis of motor gasoline consumption of 40 percent, the total United States demand for liquid fuels in 1975 would be of the order of 3.5 billion barrels annually.

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In order to provide a check upon the reasonableness of
this estimate, the total annual energy supply for the United States
was studied and projected to 1975. This is shown on the chart, 321
Exhibit No. 48, which indicates estimated total energy requirements 312
in 1975 of 50 thousand trillions of Btu. In a recent study, "Energy
Uses and Supplies, 1939, 1947, 1965," by the U.S. Bureau of Mines,
Information Circular 7582, energy supplies in the United States are 7002
projected at approximately 48 thousand trillions of Btu in 1965.

This is in close agreement with the 47 thousand trillions of Btu for 1965 shown on the chart, Exhibit No. 48. Of the estimated total energy supply in 1975 of 50 thousand trillions of Btu, the 3.5 billion barrels of liquid fuels would constitute 42 percent as contrasted with 35 percent in 1948, as shown on the chart, Exhibit No. 49. The relative proportions of energy supplied by coal, natural gas, and petroleum, which are also shown on that chart, indicate the reasonableness of the estimate. Some studies of liquid fuel demand have estimated that consumption in 1975 may be of the order of 5 or 6 billion barrels. If these quantities are related to the estimated 1975 total energy requirements, they would amount to 60 percent and 72 percent respectively. Such high percentages would appear to assume an unreasonable limitation on the use of other fuels such as coal and natural gas.

Crude Oil Reserves and Production. As of December 31, 1949, the estimated proved reserves of crude oil in the United States stood at 24,649,489,000 barrels, which is an all-time record high. This amount is 13.6 times the crude oil production of 1,818,800,000 barrels in 1949. If the proved reserves of natural gas liquids are added to the crude oil reserves, the estimated proved reserves of liquid hydrocarbons as of December 31, 1949 amounted to 28,378,501,000 barrels. In the past, new discoveries and extensions of old fields have added to the known supply. The following tabulation shows the amount of crude oil added to the supply by 5-year periods from 1925 to 1949:

Amounts of Crude Oil Added to the Supply

Period	Billions of Barrels
1925-29	10.044
1930-34	3.325
1935-39	12.161
1940-44	9.296
1945-49	13.336
Total	48.162

The above tabulation shows that, when the incentive has been strong, substantial quantities of crude oil have been discovered. It must be anticipated that further substantial quantities of oil will be discovered in the future. Recent important oil discoveries in Scurry County, Tex., and in California have increased appreciably the optimism with respect to future oil discoveries. Furthermore, the major oil discoveries made in Alberta, Canada, in recent years indicate that vast oil resources may exist in western Canada. This has led to the belief that important oil resources also may be found in North Dakota. In fact, the oil companies have under lease in the United States more than 200 million acres of untested lands, having geological formations considered favorable to the discovery of oil.

Based upon the estimate of future requirements of liquid fuels in 1975, as previously developed, crude oil production during the next 25 years would be required in the amount of approximately 62 billion barrels. This may be compared to the 48.2 billion barrels added to the supply in the 25-year period 1925 to 1949. Stated in other terms, the estimated crude oil requirements during the next 25 years are at about the rate of additions to the supply developed in the 5-year period 1945 to 1949. Through 1949 the total amount of crude oil produced in the United States amounted to approximately 39 billion barrels. This, together with the estimated requirements to 1975, would indicate a total cumulative production by that time of approximately 100 billion barrels. In recent years it has been variously estimated that the total amount of oil ultimately recoverable from primary onshore operations amounts to approximately 110 billion barrels. In addition, it is estimated that approximately 40 billion barrels more might be obtained from offshore operations and from secondary recovery. In the petroleum industry, it is generally estimated at present that less than half of the oil originally in place is produced. Important changes in methods of production, therefore, might add considerably to the recoverable supply.

Order of Desirability Influenced by Markets. Since there are some 25 states having Suitable General Areas, it is not possible in these separate state reports, which are being prepared seriatim, and not simultaneously, to contemplate all of the factors to be developed in subsequent state reports, which might tend to vitiate some of the material presented herein. It might be shown subsequently, for example, that markets allocated to nearby General Areas could be supplied more economically from synthetic liquid fuels plants located in other distant states. In any case, the determination of the order of desirability of the General Areas must take into consideration the cost of transporting products to a designated market that could absorb the assumed output and not be based solely on estimated fob. plant costs. In these state reports, markets are defined and allocated to the General Areas under consideration with the full realization that information subsequently developed may show that the markets could be served more economically by other potential synthetic liquid fuels plants.

Definition of the Marketing Territory

As shown on Exhibit No. 9, there are 16 General Areas of Coal and Water Availability in Kentucky divided into 2 distinct groups. One group of nine General Areas is located in the eastern part of the State. The other group, consisting of seven General Areas, is situated in western Kentucky. The neighboring States of Illinois, Indiana, Ohio, West Virginia, Virginia, Tennessee, and Missouri also contain General Areas suitable for the production of synthetic liquid fuels. A determination of the potential markets for the major products of synthetic liquid fuels plants in Kentucky must, therefore, give consideration to the limiting factors placed upon the market by the existence of potential plant sites in neighboring states.

The estimated cost of producting synthetic liquid fuels in each of the neighboring states have not been determined precisely, at this time. It appears from available factors, however, that such costs in Illinois, Indiana, Ohio, West Virginia, and Tennessee will not differ sufficiently from those in Kentucky for synthetic liquid fuels to move into those five States from potential plants in the Kentucky General Areas. It appears desirable, therefore, to establish limits to the marketing territory to be served from synthetic liquid fuels plants in Kentucky on the assumption that there will be no crosshaul of products between synthetic liquid fuels plants in Kentucky and those in Illinois, Indiana, Ohio, West Virginia, and Tennessee.

The estimated costs of producing synthetic liquid fuels in Missouri and Iowa are so high that markets in those States might be served more economically from potential synthetic liquid fuels plants in western Kentucky or Illinois. While Iowa does not border on Kentucky, the Mississippi River could afford excellent means of transporting synthetic liquid fuels to important markets in that State. Nevertheless, in order to avoid allocating markets to the Synthetic liquid fuels plants of more than one state, neither Missouri nor Iowa is included, at this time, in the potential marketing territory for synthetic liquid fuels plants in Kentucky. Similarly, the markets which lie along the Mississippi River in the States of Tennessee, Arkansas, and Mississippi might also be supplied more economically from synthetic liquid fuels plants in western Kentucky or Illinois, although those states have not been included in the potential marketing territory for plants in Kentucky.

The General Areas in eastern Kentucky are actually only a part of a large region of coal and water availability located in southern West virginia, western Virginia, and eastern Kentucky. This region possesses a large synthetic liquid fuels potential. A major demand on this potential, brought about by widespread dependence on synthetic liquid fuels, would probably result in the development of the region as a whole. The flow of products from synthetic liquid fuels plants in this region would probably be to the northeast, east, and southeast into the important markets of Virginia, North Carolina, South Carolina, Georgia, and Florida. None of the four last named States is now known to have General Areas suitable for the production of synthetic liquid fuels. Consequently, it is assumed that the southern West Virginia, western Virginia, and eastern Kentucky region would be developed as a whole to supply the demand for synthetic liquid fuels in the South Atlantic States mentioned. Therefore the marketing territory for synthetic liquid fuels plants in Kentucky is defined as including the State of Kentucky itself and the States of Virginia, North Carolina, South Carolina, Georgia, and Florida, the markets in which latter states would be shared by plants in southern West Virginia and western Virginia.

Consumption of Motor Fuel in The Marketing Territory

The major product specified to be produced from coal by both hydrogenation and synthine plants, as shown in a previous section of this report, is motor gasoline. For both processes, motor gasoline constitutes approximately 75 percent of the total productive capacity. Since this product constitutes such a high percentage of the total proposed output, extensive consideration has been given to the factors bearing upon the present and predicted future demand and the present and predicted future supply of motor gasoline.

Motor Fuel Consumption in Kentucky. In this analysis, data on motor fuel consumption published by the Public Roads Administration have been used. In these figures, motor fuel consumption is reported for on-highway and off-highway uses excluding sales to the Federal Government for military purposes. Consequently, military requirements are eliminated from consideration in this report.

Although it is recognized there is some leeway in the processes, particularly the hydrogenation process for producing some higher-grade gasolines, the quality of gasoline proposed to be produced by both the hydrogenation and coal synthine plants is specified to be about 78 to 80 octane motor method rating. Since this gasoline would be of lower standard than commonly used for aviation, aviation gasoline consumption has been eliminated from the total off-highway consumption of motor fuel as published by the Public Roads Administration. Therefore, motor fuel consumption figures given in this analysis do not include aviation use or purchases by the Federal Government for military purposes.

Motor gasoline consumption for the State of Kentucky in the year 1948 amounted to 11,577,000 barrels. The annual production of motor gasoline from coal by a synthine or hydrogenation plant of 10,000-barrel-per-day capacity, would be approximately 2,737,500 barrels. Consequently, if the entire motor gasoline consumption in the State of Kentucky in 1948 had been supplied by synthetic liquid fuels plants, approximately four such unit plants would have been sufficient to satisfy the total demand.

Since the motor fuel requirements of Kentucky are well satisfied at the present time by petroleum products and since it appears that it may be many years before large quantities of synthetic liquid fuels will be required, it is desirable to estimate the future demand for motor fuel in Kentucky. While ordinarily five or ten years might be considered the limit to which an estimate of
future demand might be extended with a reasonable degree of ac- Ky
curacy, it was believed desirable in the present instance to attempt
to estimate motor fuel consumption in the marketing territory to 1975. 317
Even though the hazards of such long-range prediction are realized, 318
the main purpose of the estimate is to indicate the probable maximum number of synthetic liquid fuels unit plants which would be needed
were no petroleum liquid fuels available. 7002

<u>Future Consumption of Motor Fuel in Kentucky.</u> To make an estimate of the future demand in the State of Kentucky, motor fuel consumption was divided into on-highway and off-highway uses. The estimate of future on-highway use of motor fuel was based primarily on the growth trends of population, motor vehicle registrations, and consumption per vehicle. The off-highway use was determined principally from the on-farm consumption.

<u>Population.</u> In general, the future population estimates were based on an estimate published in November 1949, by the Bureau of Agricultural Economics of the U.S. Department of Agriculture. In the report, the population of the United States was projected to 1975 by major geographic divisions and the basis for these projections was past population figures of the Bureau of the Census.

The projections of future population by geographic divisions of the United States were based upon two estimates of future population by the Bureau of the Census. One of these, termed the high projection, was described as high fertility, low mortality, 200,000 net immigration per year, and high internal migration. The other, termed the low projection, was based upon medium fertility, medium mortality, no net immigration after 1950, and low internal migration. In this report, the high projection has been used since that forecast appears to be more reasonable, considering present population trends. On this basis, the population of the United States in 1975 is estimated by the Bureau of Agricultural Economics as 188,585,000.

Exhibit No. 50 shows the population by major geographic divisions of the United States from 1870 to 1950, with estimates to 1975. The extensions to 1975 on the chart correspond to the high projections made by the Bureau of Agricultural Economics, adjusted in the Pacific, Mountain, and South Atlantic States to reflect more recent conditions as indicated by the results of 1950 Census. It should be noted that these extensions carry out the trends in the past and may provide a fairly accurate gage of the population growth in the years to come.

Since the State of Kentucky is in the East South Central geographic division and the States of Virginia North Carolina, South Carolina, Georgia and Florida are in the South Atlantic geographic division, the population of each state in these two divisions was studied, both in absolute numbers and as percentages of the total population of the respective geographic divisions. From the percentage figures, projections of past trends were extended to 1975. The percentages so derived were then applied to the total estimated population of the geographic division in order to determine the population estimates of the various states. The figures so derived for the East South Central geographic division are presented in chart form in Exhibit No. 51 and for the South Atlantic geographic division in Exhibit No. 52. These exhibits show the population of each of the states in those two geographic divisions from 1900 to 1950 with estimates to 1975. The total estimated population in 1975 of the four states in the East South Central geographic division and of the eight states and the District of Columbia in the South Atlantic geographic division is equal to 14,182,000 and 27,345,000, respectively, which are the estimates for those geographic divisions, adjusted in light of the 1950 Census in the case of the South Atlantic geographic division. The population of Kentucky as of April 1, 1950 was 2,944,806 and the estimate for 1975 is approximately 3,546,000 which is an increase of approximately 20 percent.

Motor Vehicles. To obtain an approximation of the number of automobiles likely to be in use during the next 25 years, data of past automobile registrations published by the Public Roads Administration were studied. The number of persons per private and commercial automobile registration in each state was calculated and projected to 1975. In making these projections, attention was given to effects of present and possible future population density, income per capita, and other economic factors which would influence the number of persons per automobile.

Exhibit No. 53 shows the number of persons per private and commercial automobile plotted against income payments per capita, for each of the states of the United States in 1948. It will be noted that on this chart the number of persons per private and commercial automobile decreases as the income payments per capita increase, except in the most densely populated states. The lower limit appears to be about three persons per vehicle and this limit seems to be approached only in those states where the income payments per capita are high and where the population density is not high. These data were used as guides in projecting the future number of persons per private and commercial automobile in each of the states. Exhibit No. 54 shows the number of persons per private and commercial automobile in each state of the East South Central States for the years 1930 to 1949, with projections to 1975.

The number of persons per private and commercial automobile in the State of Kentucky in 1948 was approximately 6.09. The estimate for 1975 is approximately 3.50 persons per private and commercial automobile. Using the future population estimates mentioned previously and this number of persons per automobile, the number of private and commercial automobiles in the State of Kentucky in 1975 is estimated to be approximately 1,013,000, while the number
in 1949 was approximately 505,000 an increase of about 101 percent. Ky
Exhibit No. 55 shows private and commercial automobile registrations
in Kentucky for the years 1927 to 1949 with estimates to 1975. The 319
number of publicly owned automobiles in 1975 was assumed to bear the 320
same relationship to private and commercial automobiles in that year as existed in 1948. On this basis, the total number of automobiles estimated for the State of Kentucky in 1975, including both publicly
owned and private and commercial vehicles, is 1,016,000. 70021

The number of motor trucks likely to be in use in the State of Kentucky by the year 1975 was estimated in much the same manner as that employed in calculating the number of automobiles. Consideration having been given to the main economic factors which would influence the growth in number of motor trucks, the number of persons per private and commercial truck was projected to 1975. The present and possible future conditions with respect to population density and income per capita were considered. Special attention was given to the number of farm motor trucks now in use in the various states, since farm motor trucks comprise approximately 29 percent of the total number of private and commercial trucks in the United States. A study was made of the size and number of farms in each state, and the potential number of farm trucks which could be supported was taken into consideration. With this and the other guides mentioned, the number of persons per private and commercial motor truck in each of the states was projected to 1975. Exhibit No. 56 is a chart which shows the number of persons per private and commercial motor truck in the East South Central States for the years 1930 to 1948 and estimates to the year 1975. From the future projection on this chart for the State of Kentucky, the number of persons per private and commercial truck in 1975 is shown to be 15.0. Using the population estimates developed previously and the same proportion of publicly owned motor trucks as existed in 1948, the total number of motor trucks expected to be in use was projected to 1975. For that year the estimate is 246,000 motor trucks as compared with 1948 registrations of 142,295, as reported by the Public Roads Administration. This is an increase of about 73 percent.

To estimate the growth in bus registrations, Public Roads Administration figures were used in conjunction with more recent figures obtained from the bus census of "Bus Transportation". From these data the number of persons per common carrier bus and per school bus were computed and projected to 1975. Using the population figures, previously developed, the total number of buses for the State of Kentucky was projected to 1975 with the number in that year amounting to approximately 4,720 buses.

<u>On-Highway Consumption of Motor Fuel in Kentucky.</u> To arrive at an estimate of future on-highway use of motor fuel, the weighted average annual use of motor fuel per vehicle by type of vehicle was calculated from information of on-highway consumption for the State of Kentucky published by the Public Roads Administration for 1948. The estimated future on-highway use of motor fuel was then calculated from the number of motor vehicles previously estimated, multiplied by the weighted average annual consumption per vehicle. In other words, the estimates of future consumption are predicated on the average annual consumption per vehicle obtained in 1948. It is realized that motor vehicle efficiencies may increase somewhat in the future but data published by the Public Roads Administration covering vehicle travel per gallon of fuel consumed over the past 15 years would not indicate the likelihood of any striking changes in over-all efficiency. It may be that eventually

motor vehicles will consume less fuel per vehicle-mile but it was believed preferable in this study to run the risk of overstating the future consumption rather than understating it by taking into consideration statements concerning future motor vehicle efficiencies that may not be achieved. If motor vehicle fuel efficiencies are increased appreciably in the future, the estimates of future on-highway consumption here developed will be proportionately too large. Based on the estimated number of vehicles and weighted average annual fuel consumption per vehicle, the on-highway motor fuel consumption in Kentucky in 1975 is estimated at 923,419,000 gallons. This is an increase of approximately 99 percent over 1948 on-highway consumption of 465,125,000 gallons.

Off-Highway Use of Motor Fuel in Kentucky. Since the consumption of motor fuel in agriculture constitutes the largest single item of off-highway use, special attention was given to the consumption of motor fuel by tractors on farms. To estimate the number of farm tractors that will be required in 1975, the amount of crop land harvested per tractor was studied. Exhibit No. 57 shows in chart form the average crop land harvested in acres per tractor for the United States from 1940 to 1949 with estimates to 1975.

To estimate the future number of tractors on farms for individual states, analyses were made of the number of farms by size groups, trends in the number of tractors on farms, the amount of crop land harvested in acres per tractor, per capita income payments, and the average amount of crop land harvested per farm. The chart, Exhibit No. 58, shows for each of the states in the United States for the year 1949 the average crop land harvested per tractor plotted against the average harvested crop land per farm. From the analysis of the number of farms by size groups, estimates were made of the maximum number of tractors which could be economically supported in each state. These numbers were then adjusted in view of the other factors mentioned above to arrive at an estimate of the number of tractors in each state. Using the estimated number of tractors in each state for 1975, the average crop land harvested per tractor was calculated and plotted against the average crop land harvested per farm, as shown in the chart, Exhibit No. 59.

The number of tractors on farms in the United States
obtained for the year 1975 by totaling the individual state esti-
mates developed as above amounts to 5,264,000 tractors. The reason- Ky
ableness of the estimate of the number of tractors in each state in
1975 is indicated by the fact that the total for the United States 321
(obtained in this manner) agrees quite well with the total estimated 322
by the U.S. Department of Agriculture. In a study of food and
harvested crop land required in 1975, the Department of Agriculture
estimated that there would be 5,000,000 tractors on farms in the
United States. That Department's estimate of the harvested crop 2
land required, however, was based upon a lower estimate of future 7002
population than now appears reasonable. These estimates for tractors
in 1975 may be compared to 3,365,000 tractors (excluding garden
tractors) on United States farms as of July 1, 1949.

For the State of Kentucky the number of farm tractors in 1975 is estimated at 86,000. This is an increase of approximately 126 percent over the 38,015 tractors estimated on Kentucky farms as of July 1, 1949. The amount of motor fuel consumed per tractor in each state in 1948 was obtained from information published by the Bureau of Agricultural Economics. These amounts were then multiplied by the estimated number of tractors in each state to arrive at estimates of future consumption of motor fuel by tractors in each state. For Kentucky, motor fuel consumption by tractors in 1975 is calculated at 50,912,000 gallons.

Other off-highway uses of motor fuel in Kentucky in 1948 represent only a small percentage of the total consumption and for purposes of this estimate are assumed to bear the same relationship in the future as in the past. The total motor fuel consumption in Kentucky for the years 1927 to 1948 is shown on the chart, Exhibit No. 60, which also presents the estimate of future motor fuel consumption to 1975. It will be noted from the chart that the total motor fuel consumption (excluding aviation and military uses) for 1975 is approximately 976,280,000 gallons or about 23.2 million barrels. This represents an increase of approximately 101 percent over 1948 consumption.

<u>Number of Synthetic Liquid Fuels Unit Plants Equivalent to Estimated Motor Fuel Consumption in Kentucky in 1975.</u> If there were no supplies of petroleum products available in 1975 in Kentucky to satisfy the motor fuel requirements, and if all the estimated future demand were supplied from hydrogenation or coal synthine unit plants, approximately eight plants, each with a daily capacity of 10,000 barrels, would be required. This represents an increase of four synthetic liquid fuels unit plants over the number which would have been needed to supply the motor gasoline requirements for the State in 1948. It should be emphasized that the number of unit plants as given represents merely the maximum number, the output of which would be equivalent to the requirements for motor gasoline and makes no implication that that number of plants would be needed.

<u>Motor Fuel Consumption in Virginia.</u> Since the marketing territory has been defined for the present, as including Virginia, it is necessary to analyze that market and to estimate its future magnitude. In this analysis the same methods and sources of information have been used as were employed in the study of motor fuel consumption in Kentucky.

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The population of the State of Virginia from 1900 to 1950,
22b with estimates to 1975, is shown on the chart, Exhibit No. 52. As
23 of April 1, 1950, the population of Virginia was 3,318,680 and the
24a estimate for 1975 is 4,362,000, an increase of about 31 percent.
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The number of persons per private and commercial automobile in Virginia is shown on the chart, Exhibit No. 61, with projections to 1975. In 1948, the number stood at 5.0 persons per private and commercial automobile and the 1975 estimate is 3.25 persons. Based on the two factors of population and persons per automobile, future private and commercial registrations are estimated as shown on the chart, Exhibit No. 62, which gives registrations from 1927 to 1949 and estimates to 1975. Total registrations for 1975, including publicly owned automobiles as well as private and commercial, are estimated at 1,352,300 as compared with approximately 669,600 vehicles in 1949, an increase of about 102 percent.

On the chart, Exhibit No. 63, persons per private and commercial motor truck for the State of Virginia are shown from 1930 to 1948, with projections to 1975. As of 1975, the total number of motor trucks estimated to be in use, including public, private, and commercial, is 294,700 as compared with the total 1948 registrations of 149,406. Motor bus registrations in Virginia are expected to increase to approximately 5,600 in 1975. From the estimates of the number of motor vehicles developed above and the weighted average annual consumption of motor fuel per vehicle by type of vehicle in 1948 for the State of Virginia, the total on-highway motor fuel consumption in Virginia in 1975 is estimated at 1,302,195,000 gallons. This represents an increase of about 110 percent over the 1948 on-highway motor fuel consumption.

By the methods previously employed, the number of tractors on farms in the State of Virginia is projected to 1975 and in that year is estimated at 74,200 as compared with 34,230 as of July 1, 1949. Based upon the motor fuel consumption per tractor, as given by the Bureau of Agricultural Economics in 1948, motor fuel consumption by tractors in Virginia in 1975 is estimated at 58,173,000 gallons.

The total motor fuel consumption, including both on-highway and off-highway uses, but excluding aviation and military use, is estimated for the State of Virginia in 1975 at 1,396,418,000 gallons or approximately 33.2 million barrels. This is an increase of approximately 111 percent over the total motor fuel consumption of 15,755,000 barrels in 1948. Exhibit No. 64 is a chart of total motor fuel consumption in Virginia for the years 1927 to 1948, with estimates to 1975.

Motor Fuel Consumption in North Carolina. Since the marketing territory has been defined for the present, as including North Carolina, it is necessary to analyze that market and to estimate its future magnitude. In this analysis, the same methods and sources of information have been used as were employed in the study of motor fuel consumption in Kentucky.

The population of the State of North Carolina from 1900 to 1950, with estimates to 1975, is shown on the chart, Exhibit No. 59. As of April 1, 1950, the population of North Carolina was 4,061,929 and the estimate for 1975 is 4,895,000, an increase of about 21 percent.

The number of persons per private and commercial automobile in North Carolina is shown on the chart, Exhibit No. 61, with projections to 1975. In 1948, the number stood at 5.76 persons per private and commercial automobile and the 1975 estimate is 3.65 persons. Based on the two factors of population and persons per automobile, future private and commercial registrations are estimated as shown on the chart, Exhibit No. 65, which gives registrations from 1927 to 1949 and estimates to 1975. Total registrations for 1975, including publicly owned automobiles as well as private and commercial, are estimated at 1,346,100 as compared with approximately 704,500 vehicles in 1949, an increase of about 91 percent.

On the chart, Exhibit No. 63, persons per private and commercial motor truck for the State of North Carolina are shown from 1930 to 1948, with projections to 1975. As of 1975, the total number of motor trucks estimated to be in use, including public, private, and commercial, is 336,400 as compared with the total 1948 registrations of 177,139. Motor bus registrations in North Carolina are expected to increase to approximately 7,600 in 1975. From the estimates of the number of motor vehicles developed above and the weighted average annual consumption of motor fuel per vehicle by type of vehicle in 1948 for the State of North Carolina, the total on-highway motor fuel consumption in North Carolina in 1975 is estimated at 1,393,241,000 gallons. This represents an increase of about 96 percent over the 1948 on-highway motor fuel consumption.

By the methods previously employed, the number of tractors on farms in the State of North Carolina is projected to 1975 and in that year is estimated at 102,000 as compared with 47,730 as of July 1, 1949. Based upon the motor fuel consumption per tractor, as given by the Bureau of Agricultural Economics in 1948, motor fuel consumption by tractors in North Carolina in 1975 is estimated at 69,564,000 gallons.

The total motor fuel consumption, including both on-highway and off-highway uses, but excluding aviation and military use, is estimated for the State of North Carolina in 1975 at 1,502,740,000 gallons or approximately 35.8 million barrels. This is an increase of approximately 98 percent over the total motor fuel consumption of 18,088,000 barrels in 1948. Exhibit No. 66 is a chart of total motor fuel consumption in North Carolina for the years 1927 to 1948, with estimates to 1975.

Motor Fuel Consumption in South Carolina. Since the marketing territory has been defined for the present, as including South Carolina, it is necessary to analyze that market and to estimate its future magnitude. In this analysis, the same methods and sources of information have been used as were employed in the study of motor fuel consumption in Kentucky.

The population of the State of South Carolina from 1900 to 1950, with estimates to 1975, is shown on the chart, Exhibit No. 52. As of April 1, 1950, the population of South Carolina was 2,117,027 and the estimate for 1975 is 2,529,000, an increase of about 19 percent.

The number of persons per private and commercial automobile in South Carolina is shown on the chart, Exhibit No. 61, with projections to 1975. In 1948, the number stood at 5.20 persons per private and commercial automobile and the 1975 estimate is 3.45 persons. Based on the two factors of population and persons per automobile, future private and commercial registrations are estimated as shown on the chart, Exhibit No. 67, which gives registrations from 1927 to 1949 and estimates to 1975. Total registrations for 1975, including publicly owned automobiles as well as private and commercial, are estimated at 735,000 as compared with approximately 409,000 vehicles in 1949, an increase of about 80 percent.

On the chart, Exhibit No. 63, persons per private and commercial motor truck for the State of South Carolina are shown from 1930 to 1948, with projections to 1975. As of 1975, the total number of motor trucks estimated to be in use, including public, private, and commercial, is 181,400 as compared with the total 1948 registrations of 98,377. Motor bus registrations in South Carolina are expected to increase to approximately 3,700 in 1975. From the estimates of the number of motor vehicles developed above and the weighted average annual consumption of motor fuel per vehicle by type of vehicle in 1948 for the State of South Carolina, the total on-highway motor fuel consumption in South Carolina in 1975 is estimated at 657,587,000 gallons. This represents an increase of about 88 percent over the 1948 on-highway motor fuel consumption.

By the methods previously employed the number of tractors
on farms in the State of South Carolina is projected to 1975 and
in that year is estimated at 61,000 as compared with 24,960 as of
July 1, 1949. Based upon the motor fuel consumption per tractor, Ky
as given by the Bureau of Agricultural Economics in 1948, motor fuel
consumption by tractors in South Carolina in 1975 is estimated at 326
44,896,000 gallons.

The total motor fuel consumption, including both on-high-
way and off-highway uses, but excluding aviation and military use,
is estimated for the State of South Carolina in 1975 at 720,045,000
gallons or approximately 17.1 million barrels. This is an increase 2
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of approximately 92 percent over the total motor fuel consumption of 8,927,000 barrels in 1948. Exhibit No. 68 is a chart of total motor fuel consumption in South Carolina for the years 1927 to 1948, with estimates to 1975.

Motor Fuel Consumption in Georgia. Since the marketing territory has been defined for the present, as including Georgia, it is necessary to analyze that market and to estimate its future magnitude. In this analysis, the same methods and sources of information have been used as were employed in the study of motor fuel consumption in Kentucky.

The population of the State of Georgia from 1900 to 1950, with estimates to 1975, is shown on the chart, Exhibit No. 52. As of April 1, 1950, the population of Georgia was 3,444,578 and the estimate for 1975 is 4,115,000, an increase of about 19 percent.

The number of persons per private and commercial automobile in Georgia is shown on the chart, Exhibit No. 61, with projections to 1975. In 1948, the number stood at 5.85 persons per private and commercial automobile and the 1975 estimate is 3.64 persons. Based on the two factors of population and persons per automobile, future private and commercial registrations are estimated as shown on the chart, Exhibit No. 69, which gives registrations from 1927 to 1949 and estimates to 1975. Total registrations for 1975, including publicly owned automobiles as well as private and commercial, are estimated at 1,134,000 as compared with approximately 586,000 vehicles in 1949, an increase of about 94 percent.

On the chart, Exhibit No. 63, persons per private and commercial motor truck for the State of Georgia are shown from 1930 to 1948, with projections to 1975. As of 1975, the total number of motor trucks estimated to be in use, including public, private, and commercial, is 299,700 as compared with the total 1948 registrations of 168,755. Motor bus registrations in Georgia are expected to increase to approximately 5,300 in 1975. From the estimates of the number of motor vehicles developed above and the weighted average annual consumption of motor fuel per vehicle by type of vehicle in 1948 for the State of Georgia, the total on-highway motor fuel consumption in Georgia in 1975 is estimated at 1,130,133,000 gallons. This represents an increase of about 95 percent over the 1948 on-
y. highway motor fuel consumption.

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27a By the methods previously employed, the number of tractors on farms in the State of Georgia is projected to 1975 and in that year is estimated at 108,000 as compared with 44,020 as of July 1, 1949. Based upon the motor fuel consumption per tractor, as given by the Bureau of Agricultural Economics in 1948, motor fuel consumption by tractors in Georgia in 1975 is estimated at 88,884,000
0021 gallons.

The total motor fuel consumption, including both on-highway and off-highway uses, but exclusing aviation and military use, is estimated for the State of Georgia in 1975 at 1,250,468,000 gallons or approximately 29.8 million barrels. This is an increase of approximately 99 percent over the total motor fuel consumption of 14,931,000 barrels in 1948. Exhibit No. 70 is a chart of total motor fuel consumption in Georgia for the years 1927 to 1948, with estimates to 1975.

Motor Fuel Consumption in Florida. Since the marketing territory ~~has been defined for the present,~~ as including Florida, it is necessary to analyze that market and to estimate its future magnitude. In this analysis, the same method and sources of information have been used as were employed in the study of motor fuel consumption in Kentucky.

The population of the State of Florida from 1900 to 1950, with estimates to 1975, is shown on the chart, Exhibit No. 52. As of April 1, 1950, the population of Florida was 2,771,305 and the estimate for 1975 is 4,334,000, an increase of about 56 percent.

The number of persons per private and commercial automobile in Florida is shown on the chart, Exhibit No. 61, with projections to 1975. In 1948, the number stood at 3.94 persons per private and commercial automobile and the 1975 estimate is 3.00 persons. Based on the two factors of population and persons per automobile, future private and commercial registrations are estimated as shown on the chart, Exhibit No. 71, which gives registrations from 1927 to 1949 and estimates to 1975. Total registrations for 1975 including publicly owned automobiles as well as private and commercial, are estimated at 1,451,000 as compared with approximately 673,000 vehicles in 1949, an increase of about 116 percent.

On the chart, Exhibit No. 63, persons per private and commercial motor truck for the State of Florida are shown from 1930 to 1948, with projections to 1975. As of 1975, the total number of motor trucks estimated to be in use, including public, private, and commercial, is 394,700 as compared with the total 1948 registrations of 158,821. Motor bus registrations in Florida are expected to increase to approximately 6,100 in 1975. From the estimates of the number of motor vehicles developed above and the weighted average annual consumption of motor fuel per vehicle by type of vehicle in 1948 for the State of Florida, the total on-highway motor fuel consumption in Florida in 1975 is estimated at 1,396,577,000 gallons. This represents an increase of about 137 percent over the 1948 on-highway motor fuel consumption.

By the methods previously employed, the number of tractors on farms in the State of Florida is projected to 1975 and in that year is estimated at 33,000 as compared with 18,130 as of July 1, 1949. Based upon the motor fuel consumption per tractor, as given by the Bureau of Agricultural Economics in 1948, motor fuel consumption by tractors in Florida in 1975 is estimated at 22,438,000 gallons.

The total motor fuel consumption, including both on-highway and off-highway uses, but excluding aviation and military use, is estimated for the State of Florida in 1975 at 1,534,665,000 gallons or approximately 36.5 million barrels. This is an increase of approximately 136 percent over the total motor fuel consumption of 15,490,000 barrels in 1948. Exhibit No. 72 is a chart of total motor fuel consumption in Florida for the years 1927 to 1948, with estimates to 1975.

Number of Synthetic Liquid Fuels Unit Plants Equivalent to Motor Fuel Consumption in the Marketing Territory

The following tabulation shows a summary of total motor fuel consumption, less aviation and military use, in the States of Kentucky, Virginia, North Carolina, South Carolina, Georgia, and Florida for the year 1948 and the estimates for 1975. The tabulation also presents the total motor fuel consumption for the marketing territory and the number of hydrogenation or coal synthine plants, the motor fuel productive capacity of which would be equivalent to the total motor fuel consumption in the marketing territory.

Motor Fuel Consumption and Equivalent Number of Synthetic Liquid Fuels Unit Plants

	Annual Consumption (Millions of Barrels)		Equivalent Number of Synthetic Liquid Fuels Unit Plants	
	1948	1975	1948	1975
Kentucky	11.58	23.24		
Virginia	15.76	33.25		
North Carolina	18.09	35.78		
South Carolina	8.93	17.14		
Georgia	14.93	29.77		
Florida	15.49	36.54		
Total Marketing Territory	84.78	175.72	31	64

While it is indicated by the above tabulation that the motor fuel output of 64 hydrogenation or coal synthine plants each of 10,000 barrels daily capacity would be the equivalent of the estimated consumption in the marketing territory in 1975, it must be emphasized that it is not implied that this number of synthetic liquid fuels unit plants would be required. The calculation is made to show the maximum number of such plants that would be needed if no supplies of petroleum products were available and for purposes of comparison with the number of synthetic liquid fuels unit plants potentially possible, based upon the coal and water availability. In the State of Kentucky, as shown previously, these are sufficient to support approximately 218 hydrogenation plants or approximately 170 synthine plants.

Consumption of Liquid Fuel Products other than Motor Fuel in the Marketing Territory

Although motor gasoline is specified as the major plant product of both hydrogenation and synthine plants using coal as a raw material, other liquid fuel products and phenols are also specified to be produced. These are listed in the following tabulation, which shows the plant product distribution for both hydrogenation and coal synthine plants and also shows the other products as percentages of the proposed motor gasoline production.

Unit Plant Product Distribution

	Barrels per Day		Percent of Gasoline	
	Hydrogenation	Coal Synthine	Hydrogenation	Coal Synthine
Gasoline	7,220(A)	7,280	100%	100%
Diesel Fuel	-	1,900	-	26.1
Fuel Oil	-	350	-	4.8
Liquefied Petroleum Gases	2,367	470	32.8	6.5
Phenols	413	-	5.7	-
Total	10,000	10,000		

Note: (A) May be increased to 7,684 barrels per day of gasoline by conversion of phenols.

The actual consumption of liquid fuels in the States of Kentucky, Virginia, North Carolina, South Carolina, Georgia, and Florida by principal product classifications is presented in the following tabulation: Ky 330b

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Liquid Fuel Consumption
in the States of Kentucky, Virginia, North Carolina,
South Carolina, Georgia and Florida
in the Year 1948 by Principal Product Classifications
(1,000 Barrels)

Product Classification	Kentucky	Virginia	North Carolina	South Carolina	Georgia	Florida
Motor Fuel	11,577	15,755	18,088	8,927	14,931	15,490
Kerosene	1,383	2,008	3,787	2,064	2,181	2,687
Diesel Fuel	1,093	1,432	1,221	728	1,225	2,118
Other Distillates	887	3,443	1,999	869	1,368	1,715
Residual Fuel	1,303	7,503	461	2,445	3,375	16,132
Total	16,243	30,141	25,556	15,033	23,080	38,142

In the above tabulation, the figures for motor fuel consumption are exclusive of aviation and military uses. The data given for the other product classifications are sales figures as published by the Bureau of Mines. Consumption or sales figures for liquefied petroleum gases are not published by states but are available by Petroleum Administration for War Districts. The figures for District No. 2, which includes the State of Kentucky, and 14 other states, and the figures for District No. 1 which includes the States of Virginia, North Carolina, South Carolina, Georgia and Florida, and 12 other states and the District of Columbia, show that sales of liquefied petroleum gases in the year 1948 amounted to approximately 5.9 and 4.0 percent of the motor fuel consumption in those two districts respectively.

The following tabulation shows, for petroleum products similar to the products specified to be produced by synthetic liquid fuels plants, consumption in Kentucky, Virginia, North Carolina, South Carolina, Georgia, and Florida in 1948 as percentages of motor fuel consumption.

Consumption of Other Liquid Fuel Products
as Percentages of Motor Fuel Consumption

Item	Kentucky	Virginia	North Carolina	South Carolina	Georgia	Florida
Motor Fuel	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Diesel Fuel	9.4	9.1	6.8	8.2	8.2	13.7
Residual Fuel Oil	11.3	47.6	2.5	27.4	22.6	104.1

The distribution of actual product consumption evident in the above tabulation differs materially from the proposed distribution of plant products specified to be produced by the hydrogenation and coal synthine plants. In the case of Diesel fuel, the actual consumption in the marketing territory amounts to 9 percent of the motor fuel consumption, whereas for synthine plants the estimated production is 26.1 percent. The output of liquefied petroleum gases by hydrogenation plants at 32.8 percent of the gasoline produced, is unusually high as compared with consumption in 1948 in P.A.W. District Nos. 1 and 2, which amounted to approximately 4.0 and 5.9 percent respectively.

It is apparent from the above analysis that the plant product distribution for both hydrogenation and coal synthine plants does not correspond to actual product consumption in the marketing territory. In the case of the hydrogenation type of plant, according to the proposed plant product distribution, too high a percentage of liquefied petroleum gases is specified, and in the case of the coal synthine plants the percentage of Diesel fuel specified is too high. Of course, if only a few synthetic liquid fuels unit plants were in operation, the differences would be immaterial, but if the entire amount of motor fuel requirements were to be supplied by either one or the other type of synthetic liquid fuels plants, the plants would have to be redesigned to approach more nearly the required product distribution. It appears, however, that complete reliance upon synthetic liquid fuels plants as a source of supply is so far in the future that the product demand pattern may change considerably in the intervening years. At such time as synthetic liquid fuels plants are economically feasible, it is probable that they would be so designed as to produce the products then in demand.

Sources of Liquid Fuels Supply for the Marketing Territory

Sources of Crude Oil. Crude oil production in the marketing territory is relatively small and the bulk of the crude oil produced originates in Kentucky. In 1949, approximately 9.5 million barrels of crude oil were produced in Kentucky while proved reserves of crude oil as estimated by the American Petroleum Institute stood at 56.2 million barrels as of December 31 of that year. Of the five other states in the marketing territory, Virginia and Florida are the only ones which produced crude oil in 1948. In that year, approximately 33,000 barrels of crude oil were produced in Virginia and approximately 290,000 barrels in Florida. Proved reserves of crude oil, as estimated by the American Petroleum Institute, are not shown separately for Virginia and Florida, but total proved reserves of crude oil in the States of Virginia, Florida, Tennessee and Missouri were estimated as of December 31, 1949, at 3.6 million barrels, a great part of which was in Florida.

Although Kentucky is the largest crude oil producing State in the marketing territory, production is small as compared to the total crude oil requirements of the State. Consequently, part of the Kentucky crude oil requirements are obtained from other producing states. In the year 1948, a large part of the crude oil received at refineries in Kentucky originated in Illinois and Indiana and in the Gulf Coast region. Similarly, the local production of crude oil in the other states in the marketing territory is not adequate to supply total crude oil requirements of refineries located within those states, even though the refining capacity is very small in relation to the demand for liquid fuels. As a result, some crude oil is shipped in and the Monthly Crude Refinery Reports, published by the Bureau of Mines, indicate that in 1948 the major portion of the crude oil received at refineries in those states originated in foreign countries.

Crude Oil Refining Capacity. As of January 1, 1950 there were nine oil refineries located in the marketing territory, seven of which were in Kentucky. The total annual crude oil capacity of the nine refineries amounted to approximately 33 million barrels. This is equivalent to only a small part of the total demand for liquid fuels in the marketing territory, which in 1948 amounted to approximately 148 million barrels. Information regarding locations, daily crude oil capacities, and companies operating the refineries is given below.

Oil Refineries in the Marketing Territory
as of January 1, 1950

Location	Crude Oil Capacity (Barrels per day)	Company
Kentucky:		
Betsey Layne	300	Gilley Oil & Refining Co.
Catlettsburg	45,000	Ashland Oil & Refining Co.
Latonia	16,500	Standard Oil Co. (Ohio)
Louisville	8,000	Aetna Oil Co. (Ashland Oil & Refining Co.)
Louisville	6,000	Louisville Refining, Inc.
Louisville	1,800	Stoll Oil Refining Co.,Inc.
Somerset	1,500	South Kentucky Refinery
Total	79,100	
Georgia:		
Savannah	5,500	Mexican Petroleum Corporation of Georgia
South Carolina:		
Charleston	6,500	Esso Standard Oil Co.

Sources of Refined Products. The refining capacity in Kentucky is more than adequate to care for the liquid fuels requirements in the State. Nevertheless, there is a substantial movement of products by barge up the Mississippi and Ohio Rivers into Kentucky from refineries located in Texas and Louisiana.

In the rest of the marketing territory, the demand for liquid fuels is now met principally by the movement of products from refineries in Texas and Louisiana. Ocean-going tank ships provide for the transportation of products from the refineries to the Gulf Coast regions of Florida and along the eastern seaboard of the marketing territory. In addition, the Plantation and Southeastern products pipe lines afford a movement of liquid fuels to the important inland markets. There is also some movement of petroleum products from refineries in the Baltimore and Philadelphia areas to the markets in northern Virginia.

Prices of Petroleum Products.

Transportation of crude oil and products by barge to Kentucky from the Southwest is accomplished quite economically. Nevertheless, this movement requires a rather long haul and transportation costs are sufficient to provide some competitive advantage to synthetic liquid fuels plants in Kentucky due to being located in a market relatively distant from the major sources of supply of petroleum.

In this study, consideration has necessarily been given to the prices of petroleum products as being one of the important factors affecting present and future demand for liquid fuels in the marketing territory. Weighted average composite prices of petroleum products have been computed based upon the same liquid fuel products and proportions as those specified to be produced by hydrogenation and coal synthine plants. These composite prices were constructed from quotations obtained on the various petroleum products in wholesale quantities fob. refineries in Kentucky, excluding taxes. While the cost calculations for synthetic liquid fuels plants and products contained in other sections of this report are based upon prices and quotations prevailing as of March 31, 1950, it was deemed preferable to use, in these calculations, quotations for petroleum products as of June 1, 1950 because refinery margins as of that date, appear to have been more nearly normal. In the tabulation on the following page, prices of the various petroleum products in Kentucky, as of June 1, 1950, are weighted according to the plant product distributions specified for hydrogenation and coal synthine plants.

In the tabulation, the price shown for gasoline is that of regular grade house brand containing tetraethyl lead with an octane rating of 82 or better. This product is evidently superior as a motor fuel to the gasoline specified to be produced by the hydrogenation and synthine processes using coal. The gasoline produced by these processes is stated to have an octane rating of 78 to 80 motor method and no provision has been made in the calculations for the addition of tetraethyl lead, although it is understood that such additions could be made at nominal cost above the base cost of the required tetraethyl lead. The quotation on Diesel fuel is for a product with a rating of 55 cetane. In the tabulation, the price used for fuel oil for the synthine process is that of No. 6 (residual fuel oil).

Propane is specified to be produced by the synthine process using coal and both propane and butane by the hydrogenation process in the proportions of about 72 percent propane and 28 percent butane. The price differential between propane and butane is subject to wide seasonal fluctuation. In the summertime, prices of the two products may be equal, but in the wintertime, when there is a demand for butane for mixing with motor fuel, the price may rise considerably above that for propane. In the calculations above, the price for propane alone is used since that product constitutes such a high percentage of the total.

Composit Prices of Petroleum Products Fob. Refineries in Kentucky as of June 1, 1950
Weighted According to the Plant Fuel Product Distributions
Specified for Hydrogenation and Synthine Plants Using Coal

		Prices of Petroleum Products				Prices of Petroleum Products		
Product	Hydrogenation Plant Fuel Product Distribution (Percent)	Cents per Gallon	Dollars per Barrel	Weighted Composite Dollars per Barrel	Synthine Plant Product Distribution (Percent)	Cents per Gallon	Dollars per Barrel	Weighted Composite Dollars per Barrel
Gasoline	75.31%	12.00¢	$5.040	$3.796	72.80%	12.00¢	$5.040	$3.669
Diesel	-	-	-	-	19.00	8.75	3.675	.698
Fuel Oil	-	-	-	-	3.50	6.00	2.520	.088
Propane and Butane	24.69(A)	4.00	1.680	.415	4.70	4.00	1.680	.079
Total	100.00%			$4.211	100.00%			$4.534

Note: (A) 72 percent propane and 28 percent butane.

In the foregoing tabulation the composite wholesale price fob. refinery of petroleum products as of June 1, 1950 weighted in the same proportions as the liquid fuel productions specified to be produced by hydrogenation synthetic liquid fuels plants is shown to be $4.21 per barrel and for products weighted in the same proportions as those specified to be produced by coal synthine plants the composite wholesale price is shown to be $4.53 per barrel. It should be pointed out that the estimates of future demand for petroleum products have been based on projections of present-day factors affecting consumption. It is not known how or when synthetic liquid fuel products will become competitive with petroleum products in the marketing territory. If, due to difficulties in developing supplies, costs of crude petroleum rise to such an extent in the future as to cause petroleum product prices to rise substantially relative to the general price level and to alter the competitive price positions of fuels, the projected future demand may be considerably less than the amounts estimated previously for the marketing territory.

Transportation of Plant Products

When synthetic liquid fuels plants become economically feasible, they will occur first obviously in those General Areas where the over-all conditions appear most favorable for financial success. An important advantage of synthetic liquid fuels plants in certain areas would be their proximity to markets, made possible by raw material resources located in or near regions of high population density. In such cases, the resultant lower costs of distributing plant products to the points of consumption within the marketing territory would give an important economic advantage to the local plants.

Synthetic liquid fuels plants situated in the Suitable General Areas in Kentucky would be well located for the distribution of plant products. A single plant in any one of the General Areas in Kentucky could probably dispose of its output within reasonable trucking distance of the plant, while a number of plants situated in the General Areas in eastern Kentucky, southern West Virginia and western Virginia could obtain economical transportation of products throughout the marketing territory.

The estimated population of the counties in Kentucky by size groups, as of January 1, 1949, is shown on the map, Exhibit No. 73. This exhibit also shows the approximate center of each General Area. During 1948, the average annual per capita consumption of motor fuel in Kentucky was about four barrels. At that rate, approximately 684,000 persons would consume the motor gasoline production of a single hydrogenation or coal synthine unit plant. It is clear from a study of the map, Exhibit No. 73, that sufficiently large populations live within reasonable trucking distance of the General Areas in Kentucky for all or a major part of the output of a single plant located in any one of the General Areas to be disposed of locally if the products were distributed by one of the important marketers or if there was an exchange of products between companies. If it is assumed that single plants exist simultaneously in each of the General Areas, all of their production could not be marketed locally.

If a substantial part or all of the motor fuel requirements in the marketing territory were to be supplied by synthetic liquid fuels plants, it would appear desirable to develop the eastern Kentucky, southern West Virginia and western Virginia region as a whole and to construct a large-capacity pipe line in order to obtain economical transportation of products throughout the marketing territory. Such a pipe line extending from the General Areas to the Atlantic seaboard, for example to the port of Norfolk, would provide for the economical movement of products by tank ship to the important markets in the territory lying along the eastern seaboard and the Gulf of Mexico. The petroleum products pipe lines in existence in the marketing territory, as of August 1, 1949 are shown on the map, Exhibit No. 74. Furthermore, if a pipe line from the General Areas in the eastern Kentucky, southern West Virginia and western Virginia region to the Atlantic seaboard were also connected to the Plantation pipe line at its terminus near Greensboro, N.C., and that system operated in the reverse direction to its present flow, products could also be distributed economically to the major inland markets lying along the Piedmont. An interchange of products between the Plantation and Southeastern pipe lines would provide for effective distribution to the important inland markets in Georgia. Given such a system of distribution, potential synthetic liquid fuels plants in the region under consideration would appear favorably located for the economical distribution of products throughout the marketing territory.

Synthetic liquid fuels plants located in the General Areas in western Kentucky, while not as well situated as those in the eastern part of the State in regard to supplying the marketing territory as a whole, would be conveniently located for the distribution of products to a large part of the market in Kentucky itself. Short product pipe lines could be constructed from plants in the several General Areas in western Kentucky to bulk terminals on the Ohio River. Barge movement on the Ohio River would provide access to the major markets in Kentucky. The Tennessee, Cumberland, and Kentucky Rivers might also be utilized for the movement of products to some markets in the interior of the State. As mentioned previously, the Mississippi River would afford economical transportation of products to important markets lying along the River in other states not included, at this time, in the potential marketing territory for synthetic liquid fuels plants in Kentucky.

In this report no consideration is given to the possibility of using the presently existing crude oil pipe lines for the transportation of synthetic liquid fuel products. At such time as synthetic liquid fuels become commercially feasible, it might be possible to convert such crude oil pipe lines as are then in operating condition and conveniently located for the transportation of synthetic liquid fuel products.

The cost of transportation of plant products to the marketing territory is one of the factors that must be taken into consideration in determining the relative desirability of the General Areas suitable for synthetic liquid fuels plants. It has been shown that a single 10,000-barrel-per-day hydrogenation or coal synthine plant located in any one of the General Areas in Kentucky could probably dispose of all or a major part of its output locally. Products from each of the General Areas could probably be moved to bulk stations or to dealers by transport truck or tank truck. In this study, it is not considered feasible or necessary to measure the cost of transporting products to local distribution points or to dealers' premises.

In the case of a substantial number of synthetic liquid fuels plants operating simultaneously, delivery of products to the points of consumption would be by pipe lines, tank ships, barges, and trucks. A large part of the cost of distributing products throughout the marketing territory would be incurred jointly and might not be segregable by plants. While the cost of transportation is one of the factors that must be considered in determining the relative desirability of General Areas, in this study this requirement has been construed not to include the cost of moving products within the marketing territory. By definition, the marketing territory for plants located in the Suitable General Areas in eastern Kentucky, southern West Virginia, and western Virginia was limited to the area in which it was assumed the local plants would have transportation cost advantages over synthetic liquid fuels plants located in states outside of the marketing territory. In other words, the transportation costs with which this study is concerned are those covering the movement of products to distant marketing territories and not those incurred in distributing products to points of consumption within the defined marketing territory. It is assumed that the cost of distribution within a given marketing territory would be about the same for plants located outside as for those within the territory but that outside plants would incur additional costs of transporting products to the market under consideration. Consequently, in determining the relative desirability of General Areas, costs of transportation need not be taken into consideration for those General Areas which lie wholly within a local marketing territory.

Summary and Conclusions

For the purpose of analyzing potential markets for syn-
41b thetic liquid fuels plants in Kentucky, the marketing territory
542a has been defined to include the entire market in the States of
Kentucky, Virginia, North Carolina, South Carolina, Georgia and
Florida. It has been assumed that plants in eastern Kentucky
0021 would be developed in conjunction with plants in southern West
Virginia and western Virginia to supply the demand for synthetic

liquid fuels in Virginia, North Carolina, South Carolina, Georgia and Florida. Motor fuel consumption in this marketing territory, exclusive of aviation and military uses, in 1948 amounted to 84.8 million barrels and is estimated to reach an annual volume of 175.7 million barrels by 1975. These amounts of motor fuel consumption would be equivalent respectively to the gasoline output of about 31 and 64 synthetic liquid fuels plants of 10,000 barrels daily capacity using coal as raw material.

The plant product distributions specified for both the hydrogenation and synthine plants using coal do not correspond to the present actual product consumption in the marketing territory. If only a few synthetic liquid fuels unit plants were in operation, the differences would be inconsequential. If a substantial part of the motor fuel requirements, however, were to be supplied by one or the other of these processes, it is probable that the plants would be so designed as to produce the products then in demand.

The demand for liquid fuels in the marketing territory is economically supplied. Wholesale prices of petroleum products fob. refineries in Kentucky, as of June 1, 1950, amount to $4.21 per barrel when weighted in the same proportions as the liquid fuel products specified to be produced by hydrogenation plants and to $4.53 when weighted according to the plant products specified for coal synthine plants. A major increase in liquid fuel prices altering basically the competitive positions of fuels could have the effect of reducing substantially the estimates of demand within the marketing territory.

In the United States, during the 5-year period 1945-1949, the amount of crude oil added to the known supply was larger than in any similar period; furthermore, proved reserves as of December 31, 1949 stood at an all-time record high of about 25,000,000,000 barrels. During this 5-year period, proved reserves increased 4,864,959,000 barrels. From the analysis, the prospective supply of petroleum appears adequate to satisfy the demand for liquid fuels for the present and at least a major portion of future requirements for a long period of years.

When synthetic liquid fuels plants, using coal as a raw material, become commercially feasible, it appears likely that they will be constructed first in those General Areas where there is a combination of unusually favorable factors. An important advantage for synthetic liquid fuels plants in certain parts of the United States would be their proximity to relatively large centers of consumption, where plant products doubtless would be largely distributed locally. Such plants, if situated in the Suitable General Areas in Kentucky, would be well located for the distribution of plant products. A single unit plant, located in any one of the General Areas in Kentucky could dispose of all or a major part of its output locally within trucking distance of the plant. If a substantial part or all of the requirements for motor gasoline in the marketing territory were to be supplied by synthetic liquid fuels plants situated in the Suitable General Areas in eastern Kentucky, southern West Virginia and western Virginia, it would appear desirable to construct a large capacity pipe line extending to the Atlantic seaboard and connecting with the petroleum products pipe lines now serving the marketing territory. Within the marketing territory defined, plants in these General Areas would have minimum costs for distribution of synthetic liquid fuels. For the purpose of determining the relative desirability of General Areas in the United States, cost of transportation of plant products need not be taken into consideration for those General Areas which lie wholly within a local marketing territory.

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WASTE DISPOSAL

General

The manufacture of synthetic liquid fuels from coal, by either hydrogenation or synthine process, produces gaseous, liquid, and solid wastes, all of them constituting potential nuisances. Any or all of these may require special treatment or disposal, in degree depending upon the location of the plant with respect to settled communities, public water supply, farming areas, etc. The principal gaseous wastes are sulfur compounds, resulting from combustion or removal of sulfur present in the coal. Liquid wastes consist of waste water from process, carrying oil and chemical contamination; blowdown from cooling towers and boilers, which may carry excessive concentrations of dissolved solids; and plant sanitary sewage. Solid waste consists of ash originally present in the coal, any unburned coal, and spent catalysts, principally iron oxide.

Gaseous Wastes

In the hydrogenation process, about one-fifth of the coal consumption of the plant is burned in the boiler house. Sulfur dioxide is present in the flue gases to the same extent as in those from any other power plant of equivalent size (about 90,000 to 100,000 kw) in respect of boiler capacity. The sulfur present in the balance of the coal is removed at various points in the process, appearing as hydrogen sulfide. This may be burned in the power plant, producing additional sulfur dioxide in the stack gases; burned to sulfur dioxide and converted to by-product sulfuric acid; or converted directly to elemental sulfur, using current by established commercial processes. If burned in the power plant the total sulfur dioxide resulting will be about equivalent to that from a very large steam power plant - say 500,000 kw. Choice of alternative disposal methods would depend on local markets for the respective by-products.

In the coal synthine process, the steam and power required are generated from waste heat. The coal received at the plant goes direct to synthesis gas manufacture, the sulfur in the coal appearing principally as hydrogen sulfide, which is removed in concentrated form in the course of gas purification. If necessary, hydrogen sulfide may be burned in flares, producing sulfur dioxide. In the case of high-sulfur coals, however, the quantity of hydrogen sulfide produced may be too great for such disposition. In such case, hydrogen sulfide may be converted to sulfuric acid or to elemental sulfur, the choice depending upon local markets for these by-products. In any event, it appears practicable to reduce the sulfur nuisance to any reasonable extent required.

Liquid Wastes

The principal contaminated liquid process waste discharged from a hydrogenation unit plant will be a relatively small amount - about 50,000 gallons per day - of foul process water, separated from the oil stream in the cold traps and pressure letdown tanks, and carrying relatively high concentrations (in the tenths of a percent) of dissolved phenols, ammonia, and hydrogen sulfide, as well as oil and tar in suspension. Preliminary studies indicate that it will be possible to remove all of these contaminants to any extent which may be required by local health or other authorities, as a total cost well within the allowance already made for this purpose in the overall plant construction and operating cost estimates. Subject to necessary further development work, it now appears that this removal can be accomplished by a series of operations consisting of:

(a) A skimming pond for gross removal of oil and tar;

(b) Liquid-to-liquid solvent extraction of remaining oil and tar, using hydrocarbon solvent cuts obtained in the main process and recycled;

(c) Pressure release, accompanied by heating, to remove hydrogen sulfide and ammonia;

(d) Treatment with recently developed highly basic ion-exchange resin, to effect phenol removal down to perhaps 0.005 ppm; followed by

(e) Final treatment with ozone to oxidize any remaining phenol below possible taste level, if necessary.

Periodic regeneration of the ion-exchange resin with concentrated caustic soda will produce a strong solution of sodium phenolate from which crude phenol may be separated by treatment with waste carbon dioxide from the main plant and returned to process. The small quantity of sodium carbonate solution remaining could be evaporated to dryness for ultimate disposal, if necessary. A rough preliminary estimate indicates that a total sum of $500,000 to $600,000 should be adequate to cover the cost of such a disposal system, including the oil-skimming pond.

It is also possible to destroy phenols by biochemical oxidation, as for example on a trickling filter. This method, which is practiced on a commercial scale in the United States, requires preliminary reduction of phenol concentration, either by solvent extraction ("pheno-solvan" process) or by dilution, to about 200 ppm. The combined operation would be substituted for step (d), above. However, the possible presence, in the foul process water, of cyanides which may cause serious interference with bacterial action, has led to the consideration of ion-exchange as an alternative method.

In the case of synthine, side-reactions in the process together with scrubbing operations, result in a water stream containing large quantities of organic compounds, principally aliphatic alcohols, acids, aldehydes, and ketones. Information from the U.S. Bureau of Mines, together with preliminary studies by other engineers in the petroleum industry who have worked on this problem, indicates that scrubbing may be limited to the point where the total quantity of process and scrubbing water combined amounts to about 450,000-500,000 gallons per day in a unit plant. To the extent that a market can be found for the chemical by-products, they may be recovered and sold. However, after a few synthine unit plants have been established, it is anticipated that the existing market for such products in refined state would be saturated, with the result that their recovery would no longer be profitable. In such case, it is assumed that a crude mixture of the more volatile alcohols and ketones will be removed by a simple distillation, and either sold at fuel value or returned to process for gasification to provide additional synthesis gas. The contaminated water remaining would be used as boiler feed to provide make-up steam for synthesis gas production.

Plant sanitary sewage from either hydrogenation or synthine plants would be of the order of 100,000 gallons per day in a unit plant. If local authorities require treatment before this effluent is run into the streams, the necessary sewage disposal plant should not involve an investment of more than $100,000 to $150,000.

Engineers of the U.S. Bureau of Mines have stated that the plant cost estimates, in the case of each process, include an allowance of approximately $1,000,000 to cover waste disposal from a unit plant. This should be sufficient to cover maximum requirements for complete treatment of contaminated liquid process wastes and plant sanitary sewage. Since over-all plant operating cost estimates are based primarily upon factors proportionate to construction cost, the inclusion of adequate construction cost provision for liquid waste disposal in the general estimates also implies inclusion of proportionate allowance for disposal system operating costs. The probable adequacy of this allowance is indicated by preliminary estimates. In respect of coal synthine, some dissenting opinion exists as to whether the scrubbing water may be limited within the amount which can be reabsorbed in process. Any excess would require treatment before disposal. Further development work is necessary before the question may be resolved. At the worst, a disposal cost of $0.10 to $0.20 per barrel of products might be required, over and above the allowance already included in general process cost estimates.

The remaining liquid plant waste to be considered is that resulting from boiler and cooling tower blowdown. Since the principal water consumption in both hydrogenation and synthine processes is by evaporation loss, the water rejected from the plant, other than the process and sanitary wastes mentioned, will consist largely of these blowdowns and may contain the major part of the daily tonnage of dissolved solids in the gross water make-up drawn by the plant. As a result, the concentration of dissolved mineral salts in the blowdown water may be several times as great as that in the original make-up. For plant locations where the make-up water is not already abnormally high in dissolved salts and where the wastes can be discharged into streams of which the minimum flow is large in proportion to the waste volume, dilution of the blowdown with other plant effluents should serve to keep the whole within acceptable limits. Where large quantities of blowdown are to be discharged into small streams having a low minimum flow, the increase in solids might affect the suitability of the water for other uses. Such uses are minor, and, in general, no difficulty should be encountered in the discharge of blowdown from cooling towers. In extreme cases, however, it is possible that State authorities may require a reduction in the concentration of dissolved solids before approval is granted. This may involve added costs, over and above those included in the general allowance for waste disposal. Actual determination of these added costs (if any) for any specific plant location would require detailed information, such as individual standards applying to the particular stream which would receive the wastes, complete analysis of the water available for cooling tower make-up and for possible dilution purposes, and similar data not available in the current general survey.

<u>Stream Pollution.</u> In regard to possible stream pollution and the necessity for treatment of liquid wastes for plants in Kentucky the following conditions have been developed in the course of the investigation:

If synthetic liquid fuels plants were built in Kentucky so that sewage or wastes would be discharged into the streams of the State, sewage or industrial waste treatment may be required. The degree of treatment would depend upon the particular receiving stream. Phenols and other organic compounds in the process wastes would have to be reduced to harmless concentration.

Domestic sewage could be treated by conventional methods to whatever degree is necessary. In any event, the cost of such treatment would be only a small part of the total cost for providing community facilities.

Waste treatment would not remove the high concentration of mineral salts from the blowdown water from the cooling towers. In larger streams, the low concentration of solids in the natural waters and the dilution of the return process water would be such as to prevent serious difficulty. However, in the case of small tributary streams where summer flows would be about equal to or even less than the quantities of synthetic liquid fuels plant wastes, the increase in solids might affect the suitability of such waters for other purposes.

The effect of discharges from synthetic liquid fuels plants upon public water supplies would depend upon the exact location of the plant and the distance from the point of discharge to the water works intake or intakes. There are a few public water supplies in the coal regions in Kentucky; namely, Pikeville, Prestonsburg, Hazard, and Harlan, which are taken from streams that might receive synthetic liquid fuels wastes and which might be affected by such wastes.

Water supplies taken from streams many miles below plant sites ordinarily would not be harmed because of natural purification and oxidation in the streams. However, in some areas, natural purification is inhibited by acid mine drainage and organic compounds such as phenols, might be noticed many miles from the plant site. In some instances, it might be cheaper to replace small water supply systems, rather than change the site of a synthetic liquid fuels plant.

The effect of synthetic liquid fuels plant wastes upon neighboring water supplies would depend upon the exact stream into which the wastes were discharged, the distance between the point of discharge and the water works intake, and other factors. In determining actual plant sites, this aspect should be considered. Otherwise, serious operating difficulties might develop.

Legal Aspect. Stream pollution control is an essential part of the over-all development of water resources and the State regulatory activities pertaining to water use and pollution are closely related.

Kentucky, through the Water Pollution Control Commission created in 1950, is engaged in the control and abatement of stream pollution. Pollution is defined as the discharge of sewage or industrial wastes in such manner as may contaminate the waters of the Commonwealth and render them detrimental to the public health or welfare, to animal or aquatic life, to the use of such waters as present or future sources of public water supply, or to their use for recreational, commercial, agricultural, or other legitimate purpose.

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The Commission has the power to enforce all pollution control laws and regulations, to develop a program for pollution control, to establish water quality standards, and to issue after hearings, orders abating discharges or requiring adoption of remedial measures. The Commission may institute court action to compel compliance with its orders.

Plans and specifications of all new waste disposal works, or industrial plants that may cause pollution, must be submitted to the Commission and a permit obtained. The Commission is an agency of the Department of Health, and the Director of the Division of Sanitary Engineering of the Department of Health serves as Technical Secretary and administrative agent of the Commission.

No regulations with regard to minimum treatment requirements for sewage or industrial wastes have yet been promulgated.

The Kentucky legislature has approved and enacted into law the Ohio River Valley Water Sanitation Compact for the control of stream pollution in the Ohio River Basin. The Ohio River Valley Water Sanitation Commission created by the Compact is composed of three members from each of the participating states and three from the Federal Government. It is authorized to prescribe regulations and standards for administering and enforcing the Compact, although it is the policy of the Commission to leave the enforcement of pollution control measures primarily with the state regulatory agencies. The Commission is authorized, however, to hold hearings and issue orders against pollution offenders when this action is desired by the signatory state in which the particular pollution occurs.

The Compact prescribes that sewage shall be treated to remove all settleable solids and 45 percent of the total suspended solids with a higher degree of treatment to be provided where deemed necessary by the Commission. The Compact also requires that all industrial wastes shall be treated to protect the public health or to preserve the surface waters for other legitimate purposes to such degree as may be determined to be necessary by the Commission. The Commission first met in 1948, and its requirements for industrial waste treatment have not been fully established. The Commission's policies will, however, influence the degree of treatment to be required of wastes from synthetic liquid fuels plants in Kentucky.

Solid Wastes

Solid wastes of the order of 270 to 880 tons per day, Ky
consisting of coal ash, unburned coal, and spent catalysts, would
be produced by a 10,000-barrel-per-day synthine plant operating on 350
Kentucky coal as raw material. A hydrogenation plant would produce to
in total about three-fifths of this amount, but in normal, isolated [illegible]
plant locations, about 45 percent of the ash may be dissipated from 352
the power plant stack as fly-ash, leaving net ash quantity sent to 10
disposal only about one-third of that from a coal synthine plant. 7002

Cost of Solid Waste Disposal. The quantity requiring disposal is sufficient to justify fairly elaborate mechanical handling and stacking in order to minimize labor cost. In the case of the coal synthine process, estimates prepared for this purpose indicate that from approximately 110 to 360 acres of land will be required to provide space for the ash dumps resulting from 40 years of plant operation. The ash transport and disposal system considered assumes hydraulic and pneumatic conveying of ash and spent catalyst from the various sources to separating and holding tanks located at the disposal area. Decanted water would be recycled. Moist ash accumulated in the tanks would be carried, after drainage, by belt conveyor to an unloader-stacker which would distribute it onto dump piles, with the assistance of a bulldozer to compact the piles and maintain formation. Total cost of ash disposal area equipment of the capacity required for a coal synthine unit plant operating on Kentucky coal, (from 270 to 880 tons of ash per day) is estimated at approximately \$490,000 to \$980,000. This does not include ash collection equipment, which is normally covered in process plant costs. Total operating cost and fixed charges are estimated at approximately \$300 to \$580 per day, or \$0.030 to \$0.058 per barrel of products. Each percent of the total investment allowed as gross return would amount to about \$13 to \$27 per day, or to approximately \$0.0013 to \$0.0027 per barrel of products.

In the coal synthine process practically all ash appears in the gasifier (synthesis gas producer) and must be completely removed from the synthesis gas before it passes to the reactors. In hydrogenation, fuel consumed in the power plant consists of coal, amounting to about 20 percent of total plant requirements, plus the coke from delayed coking of heavy oil from the hydrogenation process. The coke contains all the ash in the coal fed to hydrogenation (about 50 percent of plant requirements). Assuming pulverized fuel firing of the power plant boilers and normal distribution of ash size between fine and coarse particles, about 45 percent of total solid waste will appear in the form of fly-ash in the stack gases from the power plant. Assuming that the plant is in a fairly isolated location, where fly-ash nuisance can be tolerated, it should be unnecessary to install collection and removal equipment. In this case the net tonnage of ash actually requiring disposal will be about three-fifths as great as for the coal synthine process, resulting in capital and operating costs of solid waste disposal only about three-fifths as great as those stated above. However, if local authorities should require fly-ash removal, total ash disposal costs would be about three-fourths of those for coal synthine.

The estimated solid waste disposal plant investment and daily operating costs (exclusive of return on investment) for the various General Areas in Kentucky, for both hydrogenation and (coal) synthine unit plants, are shown in the following tabulations:

Solid Waste Disposal - Kentucky
Estimated Disposal Plant Investment
(As of March 31, 1950)

General Area	Hydrogenation (A)	Coal Synthine
Johnson-Magoffin	$322,000	$493,000
Pike	370,000	527,000
Floyd-Magoffin	406,000	594,000
Knott-Breathitt	388,000	551,000
Perry-Breathitt	388,000	567,000
Leslie-Harlan	365,000	536,000
Northern Letcher	362,000	519,000
Harlan-Letcher	368,000	525,000
Bell	378,000	553,000
Daviess	518,000	932,000(B)
Henderson	534,000	980,000
Union	474,000	777,000
Webster	466,000	749,000
Hopkins-Christian	461,000	744,000
Muhlenberg-McLean	467,000	750,000
Ohio	474,000	787,000

Note: (A) Assuming that removal of fly-ash from stack gases is not required.
(B) Coal reserves in the Daviess General Area are insufficient for a 40-year supply of one coal synthine unit plant.

Solid Waste Disposal - Kentucky
Estimated Disposal Plant Operating and Fixed Costs
(As of March 31, 1950)

General Area	Hydrogenation (A) Per Day	Hydrogenation (A) Per Barrel	Coal Synthine Per Day	Coal Synthine Per Barrel
Johnson-Magoffin	$156	$0.016	$298	$0.030
Pike	186	0.019	327	0.033
Floyd-Magoffin	213	0.021	378	0.038
Knott-Breathitt	200	0.020	346	0.035
Perry-Breathitt	200	0.020	359	0.036
Leslie-Harlan	183	0.018	335	0.034
Northern Letcher	182	0.018	322	0.032
Harlan-Letcher	186	0.019	327	0.033
Bell	193	0.019	349	0.035
Daviess	321	0.032	561	0.056
Henderson	333	0.033	584	0.058
Union	280	0.028	484	0.048
Webster	274	0.027	470	0.047
Hopkins-Christian	266	0.027	467	0.047
Muhlenberg-McLean	273	0.027	470	0.047
Ohio	280	0.028	490	0.049

Note: (A) Assuming that removal of fly-ash from stack gases is not required.

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The operation of such a disposal installation may require a total of about 13 to 26 employes, including direct operating and maintenance wage earners and supervisors, with a proportionate allocation of indirect personnel.

Over-all Costs of Waste Disposal

The preceding discussion indicates that treatment of liquid process wastes may absorb practically all of the allowance for waste disposal included in the general cost estimates for the process plant. In such event, costs of solid waste disposal developed above are in addition to and above any general processing costs and must be added separately to the total cost of product.

At certain locations, however, the study of stream pollution indicates that considerably less than maximum waste treatment may be acceptable. In such case, the saving in cost of liquid waste disposal presumably could be applied as a credit against the cost of handling solid wastes.

PROCESS COSTS

Basis of Estimates

Estimates of plant capital investment and operating costs follow for two synthetic liquid fuels processes both using coal as the raw material, i.e., the hydrogenation process and the synthine process. These estimates are based on estimates prepared by the Bureau of Mines. Plant capital investments, as so prepared, have been adjusted by the Contractor, as explained later in the text, to changes and differences in basic costs of labor and material between the time of such estimates and the time of this report.

As noted in a preceding section, under "Processes and Plant Requirements", the estimated plant construction costs and process costs developed in the following pages are intended primarily for use in comparing the relative desirability of different Areas as potential plant locations. For this reason, they were based on the assumed use of certain improvements in process and equipment which are still in the development stage but which appear reasonably likely to be applicable by the time significant number of synthetic liquid fuels plants could be constructed. For plants constructed as of today, using only equipment and processes now commercially available in this country, basic requirements and costs might be appreciably higher than the estimates given.

Process costs estimated herein, as of March 31, 1950, as directed by the Contracting Officer, have been limited to operating costs included in U.S. Bureau of Mines cost estimating procedure, rather than costs comprising "cost of service" or selling prices. The Bureau of Mines procedure includes an allowance of approximately 3 percent of plant investment for plant maintenance; 6-2/3 percent for depreciation; 1 percent for insurance and local, county, and State real estate taxes; and an allowance equivalent to 10 percent of direct labor, plant maintenance and operating supplies for general administrative and general office overhead (which includes the salaries and wages of the General Manager or Plant Manager and his immediate staff reporting directly to management); but they include no allowance for head office or top management costs, selling expenses, return on investment or sales and corporate (including income) taxes. Cost of coal used in the process has been computed on a "captive mine" basis and as such does not include selling expenses or return on the initial investment. The cost of water has been estimated on the same basis. To show the effect of return on investment, estimates are included herein to show the total investment required by its component parts, and the amount per barrel required for each 1 percent gross return (before income taxes) on initial capital investment.

Operating costs shown herein are reported, as directed by the Contracting Officer, in dollars per barrel of total products. Estimates of the equivalent cost of gasoline and credits for sale of by-products were not considered necessary for the determination of the most desirable General Areas. Because the product grades and quantities are different for each process, the raw material and process selected in each General Area would be the one whose products most satisfactorily meet the particular market demand. Therefore, comparison of General Areas has been made on the basis of one raw material at a time, for each applicable process.

Hydrogenation Process

Plant Capital Investment. Based on an estimate by the Bureau of Mines of a typical unit plant hereinafter described the required plant capital investment has been estimated for a 10,000-barrel-per-day unit plant in Kentucky using the hydrogenation process. The table below compares the Bureau of Mines estimate with the estimate for a unit plant in Kentucky Johnson-Magoffin General Area (as an example).

Estimates of Plant Capital Investment
for a 10,000-barrel-per-day Unit Plant
Using Hydrogenation Process

Item	Bureau of Mines Estimate of Typical Unit Plant (A) as of 1st Quarter 1948	Adjusted Estimate of Unit Plant in Kentucky Johnson-Magoffin General Area as of March 31, 1950
Plant Construction Cost	$80,974,000	$91,096,000
Interest during Construction	3,037,000	3,416,000
Depreciable Investment	$84,011,000	$94,512,000
Operating Capital	4,608,000	4,961,000
Total Investment	$88,619,000	$99,473,000

Note: (A) Taken at one-third of the Bureau of Mines estimate (R.I. 4564) for a 30,000-barrel-per-day plant.

The Contractor's estimates for all General Areas in Kentucky are tabulated in Exhibit No. 75 by General Areas of Coal and Water Availability.

Bureau of Mines Estimate. For a 10,000-barrel-per-day hydrogenation unit, this survey has adopted a cost equal to one-third of the plant cost estimated as of the first quarter of 1948 by the Bureau of Mines (and reported in its publication R.I. 4564) for a 30,000-barrel-per-day plant at Rock Springs, Wyo., designed to convert Wyoming bituminous coal to synthetic liquid fuels in the proportions stated in the section of this report entitled "Processes and Plant Requirements."

Such a plant includes complete power generation facilities. Bureau of Mines estimates for a 30,000-barrel-per-day plant represent the cost of an arbitrary production unit of substantially maximum efficiency; the actual cost of a plant of only 10,000 barrels daily capacity might be considerably greater per barrel of product. Construction costs and required total investment for a typical unit plant, as previously defined - i.e., one-third of the cost of a 30,000-barrel plant are shown in Exhibit No. 76.

Adjusted Estimate for Kentucky. Since estimates in this report of processing costs in Kentucky are as of March 31, 1950, it is necessary to apply factors to the Bureau of Mines costs to convert them to cost levels prevailing at that date.

Adjustment to cost levels of March 31, 1950 is shown in the following tabulation.

Conversion of Costs of 10,000-barrel-per-day
Hydrogenation Plant at Rock Springs, Wyo.,
From First Quarter 1948 to March 31, 1950 Price Basis

	Cost as of 1st Quarter 1948	Estimated Costs As of March 31, 1950 Factor (%)	Estimated Costs As of March 31, 1950 Cost
Process Units			
Material:			
Major Equipment	$19,498,000	114.4%	$22,306,000
Other Materials and Equipment	9,410,000	109.1	10,266,000
Subtotal	$28,908,000		$32,572,000
Field Construction Labor	7,863,000	112.2	8,822,000
Field Indirect Costs	3,960,000	112.2	4,443,000
Total Construction Costs	$40,731,000	112.5	$45,837,000
Overheads	9,950,000		11,179,000
Total Process Units Costs	$50,681,000	112.5%	$57,016,000
Auxiliary Units			
Tankage	$ 1,670,000	112.5%	$ 1,879,000
Power Plant	12,083,000	112.5	13,593,000
Plant Utilities Distribution	8,573,000	112.5	9,645,000
General Plant Facilities	7,967,000	112.5	8,963,000
Total Auxiliary Units	$30,293,000	112.5%	$34,080,000
Total Plant	$80,974,000	112.5%	$91,096,000
Factor	100.0%		112.5%

Factors for conversion of cost levels from the first quarter of 1948 to March 31, 1950 have been derived as follows:

Major Equipment (Material):

Bureau of Labor Statistics index of wholesale prices of iron and steel:

As of March 1948	As of March 1950	Factor of Change
147.7	169.0	114.4%

Other Materials and Equipment:

Other Materials and Equipment may be grouped in three general classifications with costs reported in R.I. 4564 (for a 30,000-barrel-per-day plant) as below:

Building Materials	Thousands of Dollars	
Foundations	$1,815	
Structures and Supports	2,930	
Buildings	3,220	
Painting	178	
Total		$ 8,143
Piping		11,924
Other Materials		
Instruments	$1,985	
Electrical	3,326	
Insulation	764	
Other Miscellaneous	2,088	
Total		8,163
Total Other Materials and Equipment		$28,230

The factor of conversion used for Other Materials and Equipment is a weighted average of the indices of wholesale prices of Building Materials (Bureau of Labor Statistics) and of the cost of Piping from the Contractor's Cost Bureau. The first index was weighted by the cost of Building Materials above and the second by the cost of Piping. Other Materials were considered to follow the weighted index of Building Materials and Piping. Computation of the factor used is shown below:

Basis	As of March 1948	As of March 1950	Factor of Change	Weighting (Cost in $1,000's) Amount	Product
BLS Index, Wholesale Price of Building Materials	193.1	194.2	100.6%	$ 8,143	$ 8,192
Wholesale Price of Seamless Pipe:					
8 in.	$1.445	$1.664			
10 in.	1.775	2.041			
12 in.	2.321	2.662			
Total Pipe	$5.541	$6.367	114.9%	$11,924	$13,701
Total and Average			109.1%	$20,067	$21,893

Labor:

Average of Bureau of Labor Statistics on union wage scales for selected building trades (giving building laborers a weight of three and skilled crafts a weight of one):

City	As of 4/1/48	As of 4/3/50	Factor of Change
Butte	$1.872	$2.067	110.4%
Denver	1.832	2.073	113.2
Salt Lake City	1.667	1.886	113.1
Average			112.2%

Field Indirect Costs:

This item, estimated as a percentage of labor costs, uses the conversion factor for labor.

Total Plant Costs:

The weighted average factor of total construction costs
is obtained by dividing costs of March 31, 1950 by costs as of the Ky
first quarter of 1948. This factor is used for total process units
and for all auxiliary units. Overheads for Kentucky are the differ- 362
ence between total process units and total construction cost. 10
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No adjustment of costs for change in location from Rock Springs, Wyo., to the General Areas in Kentucky has been made as such an adjustment is considered to be within the range of accuracy of the original estimates.

Interest during construction (shown in Exhibit No. 75) was estimated according to the Bureau of Mines practice described as follows in R.I. 4564:

"It is estimated that 4 years will be required to construct such a plant. The interest on capital expenditures during construction is calculated at 2-1/2 percent. Expenditures are estimated at 10 percent of the total cost of the plant the first year, 20 percent the second, 30 percent the third, and 40 percent the fourth. It may be expected that some units will be completed and production begun by the end of the third year of construction. Under this financing schedule, interest amounts to approximately 3.75 percent of the plant cost".

Operating capital was estimated for one plant in each General Area as shown in Exhibit Nos. 75 and 77. The method used was that of the Bureau of Mines as described in its R.I. 4564:

"In determining the amount of operating capital required, it is assumed that the plant will reach designed production within its first year of operation. It is expected that limited plant operation will begin at the end of 3 years' construction, and that construction and operation will be carried on simultaneously during the fourth year. It is expected that the average production rate during this period will be approximately 50 percent of full normal production. Similarly, it is assumed that consumption of raw material will be 25 percent of normal for the first 6 months and 100 percent for the last 6 months. The raw materials include coal, catalysts, and water. Operating capital must cover the cost of the initial 30-day supply of coal, raw materials consumed during the first 6 months of operation, labor, maintenance, and all other operating costs except fixed charges. Fixed charges are not assessed until construction is completed; interest during construction is treated as a part of total plant cost. Operating expenses during the second 6 months will be financed from the sale of products made during previous operations".

In estimation of operating capital, the Contractor has in-
Ky cluded in the inventory prices of coal and water, an allowance for return on investment in coal mines and water works.

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364a It has been considered, in estimation of the average oper-
10 ating capital over a 40-year period required for a unit plant in
70021 each General Area, that cheaper strip coal would be used to the
extent of its availability before using the more expensive underground coal. Depletion of strip coal and the necessary inventory

replacement by more expensive underground coal would ultimately, in the case of certain General Areas, increase the operating capital requirement. The following tabulation shows, by General Areas, the number of years for which strip coal is available for supply of a unit plant, and the increase in the operating capital requirement occasioned by the ultimate exclusive use of underground coal over the operating capital requirement of the initial plant:

Increase in Operating Capital Requirement for Ultimate Hydrogenation Unit Plants Using All Underground Coal over Such Requirement for Initial Plant in Same Area

General Area	Strip Coal Available for Unit Plant (Years)	Increase in Operating Capital (Using All Underground Coal)
Daviess	4	$ 45,677
Webster	10	80,238
Hopkins-Christian	64	309,836
Muhlenberg-McLean	47	312,558
Ohio	124	380,243

Operating Costs. Estimates of manufacturing costs based on estimates by the Bureau of Mines for the specific hydrogenation unit plant for which estimated construction costs have been stated (considered as a typical unit plant) are summarized in the first column of the following table:

Estimated Processing Costs Using Bureau of Mines Method
10,000-barrel-per-day Hydrogenation Plant

Manufacturing Costs	Bureau of Mines Estimate of Typical Plant per Calendar Day	Bureau of Mines Estimate Adjusted to General Areas in Kentucky as of March 31, 1950: Per Calendar Day	Bureau of Mines Estimate Adjusted to General Areas in Kentucky as of March 31, 1950: Per Barrel of Products
Direct Costs			
Direct Materials:			
Coal	$14,037	$18,238	$1.82
Catalysts and Chemicals	1,293	1,293	.13
Total Direct Materials	$15,330	$19,531	$1.95
Direct Labor:			
Wage Earners	$ 3,402	$ 3,282	$ .33
Supervision	510	492	.05
Total Direct Labor	$ 3,912	$ 3,774	$0.38
Plant Maintenance:			
Wage Earners	$ 3,858	$ 3,722	$0.37
Supervision	579	558	.06
Total Maintenance Labor	$ 4,437	$ 4,280	$0.43
Materials	2,218	2,496	.25
Total Plant Maintenance	$ 6,655	$ 6,776	$0.68
Payroll Overhead	$ 1,044	$ 1,007	$0.10
Operating Supplies	1,331	1,355	.14
Make-up Water	876	208	.02
Total Direct Costs	$29,148	$32,651	$3.27
Indirect Costs			
Indirect Labor	$ 927	$ 894	$0.09
Indirect Salaried Personnel	1,943	1,943	.19
Other Indirect Costs	3,079	3,116	.31
Total Indirect Costs	$ 5,949	$ 5,953	$0.59
Total Direct and Indirect Costs	$35,097	$38,604	$3.86
Fixed Costs			
Local, County, and State Taxes and Insurance	$ 2,302	$ 2,589	$0.26
Depreciation	15,344	17,262	1.73
Total Fixed Costs	$17,646	$19,851	$1.99
Total Manufacturing Costs	$52,743	$58,455	$5.85
Less Coal and Make-up Water	14,913	18,446	1.85
Other Processing Costs (A)	$37,830	$40,009	$4.00

Note: (A) Other than coal and make-up water.

The figures in the first column of the above table, adopted for this survey, are one-third of the manufacturing costs (as of the first quarter of 1948) estimated by the U.S. Bureau of Mines and reported in its publication R.I. 4564 for a 30,000-barrel-per-day plant (with complete power generation facilities) designed to convert Wyoming bituminous coal to products in proportions already stated. Coal and water quantities used in these estimates differ somewhat from those shown in the tabulation of basic data in the "Processes and Plant Requirements" section which, as stated, were based on the use of an average rather than a specific plant.

Preparation of the estimate based on that of the Bureau of Mines of daily operating costs of a typical unit plant used methods tabulated in Exhibit No. 78.

Operating costs estimated to apply as of March 31, 1950, in the General Areas of Coal and Water Availability in Kentucky are summarized in the second column of the table. Costs of coal and make-up water are those for Johnson-Magoffin General Area, which Area was used as an example.

The bases of the adjusted estimate of daily operating costs of a unit plant in the General Areas of Coal and Water Availability in Kentucky as of March 31, 1950 are tabulated in Exhibit No. 79.

The items of plant maintenance materials, operating supplies, and other indirect costs might have been taken at the same cost in Kentucky as at Rock Springs, Wyo. (i.e., treated similarly to catalysts and chemicals, and indirect salaried personnel) but have been computed according to methods adopted by the Bureau of Mines.

Return on Investment. Recognizing that different investors may require different rates of return upon their capital, these estimates include no allowance for return. However, as a guide, the following tabulation indicates the amounts per day and per barrel of products which would be required for each increment of 1 percent on the estimated plant capital in the case of Johnson-Magoffin General Area, used as an example:

Incremental Costs for Each 1 Percent Gross Return on Initial Investment in Process Plant Johnson-Magoffin General Area, Kentucky

Total Initial Capital Investment	$99,473,000
1 Percent Return on Above:	
Per Annum	$ 994,730
Per Calendar Day	$ 2,725
Per Barrel of Product	0.273

Similar incremental costs for each 1 percent gross return on initial investment in Process Plant for all General Areas in Kentucky are shown in Exhibit No. 75.

Additional plants in certain Areas previously mentioned would require increased operating capital in the different General Areas, the maximum increase being $380,000 in Ohio General Area.

The incremental cost for each 1 percent gross return on this amount would be equivalent to $10 per day or $0.0010 per barrel of products which would not materially change the rates indicated in the foregoing table and Exhibit No. 75.

Effect of Coal Characteristics. In preparing estimates of coal quantity required, plant cost, and processing cost in each General Area, the calculations have been based on an (average) total daily raw material requirement of 98,000,000,000 Btu, for a typical coal hydrogenation unit plant, as specified in the plant requirements data furnished for use in this report.

Actually, for a plant of given capacity in terms of daily production of synthetic liquid fuels, the over-all efficiency of conversion, which in turn affects both daily Btu requirements and physical size of the plant (and hence construction and operating costs) varies with certain characteristics of the coal used as raw material, particularly with ash and moisture content and coal chemical reactivity.

A study of the effect of these factors was made to determine the maximum range of possible variation within the limits of the coals considered in this survey. The results of this study showed that in no case did the probable variation in coal quantity (as Btu), plant cost, or processing cost, due to individual coal characteristics, exceed plus or minus 10 percent of the mean. Only in the case of coals at the extreme upper and lower limits of the range designated as suitable for hydrogenation would indicated coal quantity and plant cost exceed by more than 10 percent the actual base figures used in the cost calculations above. In the large majority of cases, the variation should be a few percent only.

As the maximum error is within the probable limits of accuracy of the base figures themselves, in the interest of simplicity no adjustment has been made to reflect the effect of coal characteristics on Btu requirements and physical size of plant.

Coal Synthine Process

Basis of Estimates. Based on the results of extensive research and development work of its own, as well as upon available data of other investigators in the United States and in Germany, The Bureau of Mines has in the course of preparation estimates of construction and operating costs of a coal synthine plant of commercial scale. Preliminary data from this study, for a plant producing 10,000 barrels of synthetic liquid fuels per day from western Kentucky bituminous coal, a specific case, have been adopted for this survey for estimating construction and operating costs of a unit plant, to be used as a basis of comparison for determining relative desirability of General Areas. In drawing other than relative conclusions from these cost estimates, however, the preliminary nature of the data so far available must be remembered. The final estimates determined by the Bureau at the completion of its work may differ appreciably from the present figures.

Plant Capital Investment. Based on the preliminary estimates of the Bureau of Mines for a typical unit plant, the required plant capital investment has been estimated for a 10,000-barrel-per-day unit plant in Kentucky using the coal synthine process. The table below shows figures as estimated by the Bureau of Mines and as adjusted for a coal synthine unit plant in Kentucky Johnson-Magoffin General Area.

Estimates of Plant Capital Investment
for a Unit Plant
Using Coal Synthine Process

Item	Bureau of Mines Preliminary Estimate of Typical Unit Plant as of March 1, 1950	Adjusted Estimate of Unit Plant in Kentucky Johnson-Magoffin General Area as of March 31, 1950
Plant Erection Cost	$81,805,000	$81,805,000
Interest during Construction	2,455,000	2,455,000
Depreciable Investment	$84,260,000	$84,260,000
Operating Capital	4,000,000	5,173,000
Total Investment	$88,260,000	$89,433,000

The Contractor's estimates for all General Areas in Kentucky are tabulated in Exhibit No. 80 by General Areas of Coal and Water Availability. Ky 369b 370a

Construction costs and required total investment for a coal synthine unit plant are shown in Exhibit No. 81, as estimated by the Bureau of Mines. 70 70021

Adjusted Estimate for Kentucky. For this survey, estimates of processing costs in Kentucky are as of March 31, 1950. It is considered that any difference in cost levels prevailing between that date and the date of the Bureau of Mines estimate, March 1, 1950, is within the range of accuracy of the original estimate. No adjustment of costs for change in location from Caseyville, Ky. to the General Areas in Kentucky has been made as such an adjustment is considered to be within the range of accuracy of the original estimate. Consequently, the Bureau of Mines estimate of plant erection cost has been adopted as directly applicable to such a cost in the General Areas in Kentucky.

Interest during construction was estimated, as by the Bureau of Mines at 3 percent of plant construction costs and is shown in Exhibit No. 80.

Operating capital was estimated for one plant in each General Area as shown in Exhibits Nos. 80 and 82. In the absence of information as to the method employed in the Bureau of Mines estimate of costs of a typical plant using the coal synthine process the method followed for the hydrogenation process was used.

It has been considered, in estimation of the average operating capital over a 40-year period required for a unit plant in each General Area, that cheaper strip coal would be used to the extent of its availability before using the more expensive underground coal. Depletion of strip coal and the necessary inventory replacement by the more expensive underground coal would ultimately, in the case of certain General Areas, increase the operating capital requirement. The following tabulation shows, by General Areas, the number of years for which strip coal is available for supply of a unit plant, and the increase in the operating capital requirement occasioned by the ultimate exclusive use of underground coal over the operating capital requirement of the initial plant:

Increase in Operating Capital Requirement for
Ultimate Coal Synthine Unit Plants
Using All Underground Coal over Such
Requirement for Initial Plant in Same Area

	General Area	Strip Coal Available for Unit Plant (Years)	Increase in Operating Capital (Using All Underground Coal)
Ky	Webster	8	$ 83,187
	Hopkins-Christian	50	398,393
370b	Muhlenberg-McLean	37	369,807
371	Ohio	97	488,916
10	Daviess	3	(A)

70021 Note: (A) Insufficient coal reserves in Daviess General Area to warrant consideration of more than one unit plant for 40 years.

<u>Operating Costs.</u> Estimates of manufacturing costs, based on estimates by the Bureau of Mines for the typical coal synthine unit plant for which estimated construction costs have been stated, are summarized in the first column of the following table:

Estimated Processing Costs Using Bureau of Mines Method
10,000-barrel-per-day Coal Synthine Plant

Manufacturing Costs	Bureau of Mines Preliminary Estimate of Typical Plant per Calendar Day	Bureau of Mines Estimate Adjusted to General Areas in Kentucky as of March 31, 1950: Per Calendar Day	Bureau of Mines Estimate Adjusted to General Areas in Kentucky as of March 31, 1950: Per Barrel of Products
Direct Costs			
Direct Materials:			
Coal	$14,383	$23,445	$2.34
Catalysts and Chemicals	1,200	1,200	.12
Total Direct Materials	$15,583	$24,645	$2.46
Direct Labor:			
Wage Earners	$ 3,150	$ 2,986	$0.30
Supervision	473	448	.04
Total Direct Labor	$ 3,623	$ 3,434	$0.34
Plant Maintenance:			
Wage Earners	$ 3,897	$ 3,694	$0.37
Supervision	585	554	.06
Total Maintenance Labor	$ 4,482	$ 4,248	$0.43
Materials	2,241	2,241	.22
Total Plant Maintenance	$ 6,723	$ 6,489	$0.65
Payroll Overhead	$ 1,013	$ 960	$0.10
Operating Supplies	1,345	1,298	.13
Make-up Water	1,115	208	.02
Total Direct Costs	$29,402	$37,034	$3.70
Indirect Costs			
Indirect Labor	$ 963	$ 913	$0.09
Indirect Salaried Personnel	1,953	1,953	.20
Other Indirect Costs	2,930	2,745	.27
Total Indirect Costs	$ 5,846	$ 5,611	$0.56
Total Direct and Indirect Costs	$35,248	$42,645	$4.26
Fixed Costs			
Local, County, and State Taxes and Insurance	$ 2,308	$ 2,308	$0.23
Depreciation	15,390	15,390	1.54
Total Fixed Costs	$17,698	$17,698	$1.77
Total Manufacturing Costs	$52,946	$60,343	$6.03
Less Coal and Make-up Water	15,498	23,653	2.36
Balance Other Processing Costs (A)	$37,448	$36,690	$3.67

Note: (A) Other than coal and make-up water.

The estimate, based on that of the Bureau of Mines of daily operating costs of a typical coal synthine unit plant, is developed by methods summarized in Exhibit No. 83.

Operating costs estimated to apply in the General Areas of Coal and Water Availability in Kentucky as of March 31, 1950 are summarized in the second column of the table. Costs of coal and make-up water are those for Johnson-Magoffin General Area, which Area was used as an example.

The bases of the adjusted estimate of daily operating costs of a unit plant in the General Areas of Coal and Water Availability in Kentucky as of March 31, 1950 are tabulated in Exhibit No. 84.

The items of plant maintenance materials, operating supplies, and other indirect costs might have been taken at the same cost in Kentucky as at Caseyville, Ky., (i.e. treated similarly to catalysts and chemicals and indirect salaried personnel) but have been computed according to methods adopted by the Bureau of Mines.

Return on Investment. Recognizing that different investors may require different rates of return upon their capital, these estimates include no allowance for return. However, as a guide, the following tabulation indicates the amounts per day and per barrel of products which would be required for each increment of 1 percent on the estimated plant capital in the case of Kentucky Johnson-Magoffin General Area, used as an example:

Incremental Costs for each 1 Percent Gross
Return on Initial Investment in Process Plant
Kentucky Johnson-Magoffin General Area

Total Initial Capital Investment	$89,433,000
1 Percent Return on Above:	
Per Annum	$ 894,330
Per Calendar Day	2,450
Per Barrel of Products	0.245

Incremental costs for each 1 percent gross return on initial investment in process plant for all General Areas in Kentucky are shown in Exhibit No. 80.

Additional plants in certain General Areas previously mentioned would require increased operating capital for such plants, the maximum increase being about $489,000 in Ohio General Area.

The incremental cost for each 1 percent gross return on this amount would be equivalent to $13 per day, or $0.0013 per barrel of products which would not materially change the rates indicated in the foregoing table and Exhibit No. 80.

Effect of Coal Characteristics. In preparing estimates of coal quantity required, plant cost, and processing cost in each General Area, the calculations have been based on an average total daily raw material requirement of 126,000,000 Btu for a typical coal synthine unit plant, as specified in the plant requirements data furnished for use in this report.

Actually, for a plant of given capacity in terms of daily production of synthetic liquid fuels, the daily Btu requirements and physical size of the plant (and hence construction and operating costs) vary with certain characteristics of the coal used as raw material. The over-all Btu consumption increases with increasing moisture content of the coal as received at the process plant, since additional Btu, over and above basic process requirements, must be consumed in evaporating surplus moisture to produce a coal of the requisite dryness for gasification. Furthermore, construction costs (dependent on physical size) of a coal synthine plant of given production capacity may vary through a maximum range of 20 percent, according to the rank of the coal available.

A study of the effect of these factors was made to determine the maximum range of possible variation within the limits of the coals considered in this survey. The results of this study showed that in the case of Btu requirements the maximum probable variation, over the entire range of coals included in the survey, from anthracite to the lowest grades of brown coal, is approximately plus or minus 10 percent of the mean. As stated above, there may be a variation in plant cost because of rank of coal of not more than plus or minus 10 percent of the mean. The base cost and Btu requirements for the typical plants used in the foregoing calculations differ somewhat from the actual mean. However, only the lower grades of lignites and brown coal give rise to Btu requirements and plant costs more than 10 percent greater than the base figures used. In the large majority of cases, the variation should be only a few percent.

As the maximum error is within the probable limits of accuracy of the base figures themselves, in the interest of simplicity no adjustment has been made to reflect the effect of coal characteristics on Btu requirements and physical size of plant.

STRATEGIC CONSIDERATIONS

Based on studies made by the National Security Resources Board, it is believed that areas of industrial concentration of less than 5 square miles, or urban concentrations of less than 50,000 people separated by about 10 miles of relatively open country, will be reasonably secure from atomic bomb attack under all circumstances expected to prevail.

The 9 General Areas in the eastern part of Kentucky are located in 11 counties, namely, Johnson, Magoffin, Pike, Floyd, Knott, Breathitt, Perry, Leslie, Harlan, Letcher, and Bell. The largest towns are Middlesboro, Jenkins, and Hazard, each of which has less than 15,000 population. The four nearest cities which might be considered as possible targets, from a strategic standpoint, are Huntington, W. Va., about 50 miles to the north, Charleston, W. Va., about 80 miles to the northeast, Knoxville, Tenn., about 125 miles to the south, and Louisville, Ky., about 160 miles to the northwest.

The seven General Areas in the western part of Kentucky are located in nine counties, namely, Daviess, Henderson, Union, Webster, Hopkins, Christian, Muhlenberg, McLean, and Ohio. The largest towns are Owensboro, Henderson, Hopkinsville, and Madisonville, each of which has less than 35,000 population. The three nearest cities which might be considered as possible targets, from a strategic standpoint are Evansville, Indiana, about 25 miles to the north, Nashville, Tenn., about 100 miles to the southeast, and Louisville, Ky., about 100 miles to the northeast.

Possible targets, other than the cities indicated above, are the dams of the Tennessee Valley Authority and the several coal-hauling railroads, all of which are some distance from the Kentucky General Areas.

Giving due consideration to the factors indicated above, especially the absence of nearby large cities, it seems evident that the development of a new synthetic liquid fuels industry in the General Areas of Kentucky could be so planned as to conform to the presently published policy of the NSRB with regard to strategic considerations.

PART VI

COMPARISON OF SUITABLE GENERAL AREAS

COMPARISON OF SUITABLE GENERAL AREAS

The relative merits of the 16 Suitable General Areas within the State of Kentucky may be judged by a number of more or less independent criteria. Data therefor have been presented throughout this report and are in large part summarized in Exhibits Nos. 10, 85, 86, 87, and 88. As affecting the size of an industry which a General Area could support, the amount of available coal reserves is important, but it has little weight in comparison of the relative desirability of Areas for an initial unit plant in each.

The Suitable General Areas may be ranked according to estimated over-all construction costs of the initial unit plant and associated development in each General Area. Such systems include the capital investment required for coal mining and process water supply facilities, the process plant itself, access transportation, products transportation (beyond the local marketing territory to the extent required), disposal of solid wastes from process, plant-city development, and rental housing. The amounts, as tabulated in Exhibits Nos. 85 and 86, are exclusive of capital required for one-half of the dwelling units in the plant-city (assumed to be sold) and of the commercial facilities and domestic water supply (assumed to be self-supporting).

Another basis for relative ranking of the Suitable General Areas is by the estimated costs of products of the initial unit plant in each Area which, as shown in Exhibits Nos. 85 and 86 are exclusive of return on investment. Furthermore, the costs as shown make no allowance for that portion of the plant-city assumed ultimately to be sold, nor do they include operating costs of domestic water supply which are to be offset by water rents. The costs as shown are exclusive of operating costs of one-half of the dwelling units in the plant-city (assumed to be sold) and of the commercial facilities (assumed to be self-supporting). They also are exclusive of the costs of operation of rental housing and domestic water supply as these costs are estimated to be offset by a portion of the rentals paid by occupants of rental dwelling units and by water rents paid by consumers.

The relative ranking of the 16 Suitable General Areas on each of the foregoing bases is shown in the tabulation following for the hydrogenation and coal synthine processes, separately. The same table indicates also the orders of relative desirability with respect to various components of the project construction costs and the over-all cost per barrel of products.

It can be noted that, although the relative orders of desirability of the General Areas as regards total cost of products (exclusive of return on investment) are essentially the same for initial plants for both types of processes, use of the coal synthine process as compared with hydrogenation slightly betters the relative position of the Knott-Breathitt, and Leslie-Harlan General Areas and harms that of Perry-Breathitt, Floyd-Magoffin, and Daviess General Areas.

Relative Orders of Desirability of Suitable General Areas in Kentucky on Various Bases
Hydrogenation Process

Suitable General Area	Total Cost per Barrel of Products	Cost per Barrel of Products for: Coal	Water (Process)	Access Transportation	Waste Disposal	Total Capital Required	Capital Required for: Coal Mining	Water (Process)	Process Plant	Access Transportation	Waste Disposal	Available Coal Reserves
Muhlenberg-McLean	1	1	6	4	10	2	2	6	1	4	12	5
Ohio	2	3	5	8	13	1	1	5	2	9	13	9
Hopkins-Christian	3	2	14	11	11	15	3	16	3	12	10	2
Webster	4	4	9	5	12	9	4	9	4	6	11	6
Union	5	5	2	6	14	4	9	2	5	5	14	8
Northern Letcher	6	6	16	1	2	13	7	14	7	1	2	12
Pike	7	7	7	15	4	12	5	7	6	15	5	1
Harlan-Letcher	8	9	12	2	5	10	6	13	10	2	4	3
Bell	9	11	13	3	6	11	13	12	11	3	6	14
Perry-Breathitt	10	12	10	10	7	8	11	10	13	10	7	10
Floyd-Magoffin	11	13	8	12	9	5	12	8	12	11	9	4
Daviess	12	14	1	13	15	7	14	1	8	13	15	16
Leslie-Harlan	13	10	11	16	3	14	10	11	9	16	3	13
Knott-Breathitt	14	8	15	14	8	16	8	15	14	14	8	7
Johnson-Magoffin	15	15	3	9	1	3	16	4	15	8	1	15
Henderson	16	16	4	7	16	6	15	3	16	7	16	11

Relative Orders of Desirability of Suitable General Areas in Kentucky on Various Bases
Coal Synthine Process

Suitable General Area	Total Cost Per Barrel of Products	Cost per Barrel of Products for:				Total Capital Required	Capital Required for:					Available Coal Reserves
		Coal	Water (Process)	Access Transportation	Waste Disposal		Coal Mining	Water (Process)	Process Plant	Access Transportation	Waste Disposal	
Muhlenberg-McLean	1	2	6	1	10	2	2	6	1	4	12	5
Ohio	2	3	5	8	13	1	1	5	2	9	14	9
Hopkins-Christian	3	1	14	11	11	15	3	16	3	12	10	2
Webster	4	4	9	5	12	11	4	9	4	6	11	6
Union	5	5	1	6	14	4	9	2	5	5	13	8
Northern Letcher	6	6	16	2	2	13	7	14	7	1	2	12
Pike	7	7	7	15	3	9	5	7	6	15	4	1
Harlan-Letcher	8	9	12	3	4	7	6	13	9	2	3	3
Bell	9	11	13	4	6	10	13	12	10	3	7	14
Knott-Breathitt	10	8	15	14	7	16	8	15	11	14	6	7
Perry-Breathitt	11	12	10	10	8	6	11	10	14	10	8	10
Leslie-Harlan	12	10	11	16	5	14	10	11	8	16	5	13
Floyd-Magoffin	13	13	8	12	9	5	12	8	12	11	9	4
Daviess	14	14	2	13	15	12	15	1	13	13	15	16
Johnson-Magoffin	15	15	3	9	1	3	16	4	15	8	1	15
Henderson	16	16	4	7	16	8	14	3	16	7	16	11

The effect of exhaustion of the limited reserves of cheaper strip-minable coal in five General Areas and the consequent necessity in the case of later plants of recourse to higher-cost underground coal is shown by Exhibit Nos. 87 and 88. These exhibits show separately for the hydrogenation and coal synthine processes, respectively, total costs for an ultimate unit plant in such General Areas using underground coal only. Should only underground coal be used in all General Areas the order of relative desirability would change from that already determined on the basis of the use of strip and underground coal (first plant) as follows:

Change in Relative Desirability for Ultimate
(All Underground Coal)
as Compared with Initial Unit Plants

Suitable General Area	Hydrogenation Process	Coal Synthine Process
Basis: Estimated Capital Required		
Ohio	1st place to 4th	1st place to 5th
Muhlenberg-McLean	2nd place to 3rd	No change
Daviess	7th place to 8th	(A)
Webster	9th place to 11th	11th place to 13th
Hopkins-Christian	15th place to 16th	15th place to 16th
Basis: Estimated Cost of Products		
Muhlenberg-McLean	1st place to 3rd	1st place to 3rd
Ohio	2nd place to 5th	2nd place to 6th
Hopkins-Christian	3rd place to 4th	3rd place to 4th
Webster	4th place to 2nd	4th place to 2nd
Daviess	12th place to 14th	(A)

Note: (A) Insufficient coal reserves in Daviess General Area to warrant consideration of more than one unit plant for 40 years.

The relative orders of desirability of the 16 Suitable General Areas for initial and for ultimate unit plants using underground coal only are compared in the following tabulation:

Relative Orders of Desirability of Suitable General Areas in Kentucky for Initial and Ultimate (Using Underground Coal Only) Unit Plants

Suitable General Area	Estimated Cost of Products		Estimated Capital Required	
	Initial	Ultimate	Initial	Ultimate
Hydrogenation Process				
Muhlenberg-McLean	1	3	2	3
Ohio	2	5	1	4
Hopkins-Christian	3	4	15	16
Webster	4	2	9	11
Union	5	1	4	2
Northern Letcher	6	6	13	13
Pike	7	7	12	12
Harlan-Letcher	8	8	10	9
Bell	9	9	11	10
Perry-Breathitt	10	10	8	7
Floyd-Magoffin	11	11	5	5
Daviess	12	14	7	8
Leslie-Harlan	13	12	14	14
Knott-Breathitt	14	13	16	15
Johnson-Magoffin	15	15	3	1
Henderson	16	16	6	6
Coal Synthine Process				
Muhlenberg-McLean	1	3	2	2
Ohio	2	6	1	5
Hopkins-Christian	3	4	15	16
Webster	4	2	11	13
Union	5	1	4	3
Northern Letcher	6	5	13	12
Pike	7	7	9	9
Harlan-Letcher	8	8	7	7
Bell	9	9	10	10
Knott-Breathitt	10	10	16	15
Perry-Breathitt	11	11	6	6
Leslie-Harlan	12	12	14	14
Floyd-Magoffin	13	13	5	4
Daviess	14	14	12	11
Johnson-Magoffin	15	15	3	1
Henderson	16	16	8	8

Although unit costs for process water supply for full development of potential capacity in any General Area would, in the various General Areas, range from approximately 40 percent to slightly more than the unit costs for water for a single unit plant, the differences are insignificant as compared to total operating costs as stated (exclusive of return on investment). Such total costs include costs of coal, water processing, transportation, housing, and waste disposal, subject to qualifications already discussed.

The figures presented are to be considered as indicative of average conditions within the respective General Areas. Depending upon actual plant locations, there will be some variation from the indicated orders of desirability. It is also possible that some plant locations, although satisfying most conditions, may be relatively less desirably situated with respect to other factors.

In evaluating the relative importance of the several bases of ranking relative order of desirability, the importance of the various criteria may be judged by average data for all Suitable General Areas of Kentucky. The average estimated cost of construction and cost per barrel of products may be tabulated:

Average Estimated Cost of Products per Barrel
and of Construction and Processes
(As of March 31, 1950)

	Hydrogenation Process		Coal Synthine Process	
	Amount	Percent	Amount	Percent
Estimated Cost of Products				
Coal	$1.563	27.72%	$2.015	34.89%
Water (Process)	.044	.78	.044	.76
Processing	4.001	70.97	3.669	63.52
Access Transportation	.007	.12	.007	.12
Product Transportation	-	-	-	-
Waste Disposal	.023	.41	.041	.71
Total	$5.638	100.00%	$5.776	100.00%
Estimated Capital Required				
	(x $1,000)		(x $1,000)	
Coal Mining	$ 6,450	5.61%	$ 8,306	7.76%
Water (Process)	3,147	2.74	3,147	2.94
Process Plant	99,290	86.36	89,194	83.36
Access Transportation	476	.41	476	.44
Product Transportation	-	-	-	-
Waste Disposal	421	.37	662	.62
Housing	5,181	4.51	5,217	4.88
Total	$114,965	100.00%	$107,002	100.00%

The order of desirability from the standpoint of estimated required capital differs somewhat from a ranking in terms of estimated cost of products, exclusive of return on investment. However, the range of variation in capital investment is slightly less than the range in cost of products and, moreover, probably is less susceptible to significant improvement as the industry may develop. It appears, therefore, in determining the over-all relative order of desirability, cost of products would be of greater importance than required capital investment and this is the basis which has been adopted.

Although, exclusive of return on investment, the cost per barrel of products is higher in every General Area for initial unit plants using the synthine process (see Exhibits Nos. 85 and 86), the cost spread between hydrogenation and coal synthine, which averages 13.8 cents per barrel, does not exceed 2.4 percent of the average cost of hydrogenation. Based on stated costs per barrel of products for initial unit plants, preceding tables show no significant differences in the order of relative desirability between the hydrogenation and coal synthine processes, although there are several minor changes in the order of Areas.

The Suitable General Areas of Kentucky may also be listed in terms of daily production capacity which could be supported by available raw material reserves. Such a listing however, as in the following tabulation, has no bearing upon the relative desirability of the Areas for initial unit plants.

Daily Production Capacity of Synthetic Liquid Fuels
Supportable over a 40-Year Period from Available Coal Reserves
(Based upon alternative use of the two processes.
Capacities as estimated are not additive.)

Suitable General Area	Thousands of Barrels per Day: Hydrogenation	Thousands of Barrels per Day: Coal Synthine
Pike	504	392
Hopkins-Christian	235	183
Harlan-Letcher	213	166
Floyd-Magoffin	199	155
Muhlenberg-McLean	176	137
Webster	136	106
Knott-Breathitt	127	99
Union	103	80
Perry-Breathitt	95	74
Ohio	82	64
Northern-Letcher	74	58
Henderson	70	55
Leslie-Harlan	68	53
Bell	43	33
Johnson-Magoffin	41	32
Daviess	12	9(A)
Total	2,178	1,696

Note: (A) Coal reserves insufficient for one coal synthine unit plant.

In determining the order of relative desirability of the Suitable General Areas of Kentucky, the qualifications of each Area are to be judged not only by factors which may be numerically evaluated but also on other bases not directly reflected in costs. Examples of such factors include power availability, strategic considerations, climate, and the like. Preceding discussion has, however, indicated in the case of Kentucky that differences of such nature between the several Areas are minor and relatively insignificant.

Consideration of all the foregoing comparisons has resulted in the determination of orders of relative desirability of the 16 Suitable General Areas in Kentucky, separately for each synthetic liquid fuels process, as follows:

Relative Desirability of Kentucky Suitable General Areas

Hydrogenation Process

Order	Area Name
1	Muhlenberg-McLean
2	Ohio
3	Hopkins-Christian
4	Webster
5	Union
6	Northern-Letcher
7	Pike
8	Harlan-Letcher
9	Bell
10	Perry-Breathitt
11	Floyd-Magoffin
12	Daviess
13	Leslie-Harlan
14	Knott-Breathitt
15	Johnson-Magoffin
16	Henderson

Coal Synthine Process

Order	Area Name
1	Muhlenberg-McLean
2	Ohio
3	Hopkins-Christian
4	Webster
5	Union
6	Northern-Letcher
7	Pike
8	Harlan-Letcher
9	Bell
10	Knott-Breathitt
11	Perry-Breathitt
12	Leslie-Harlan
13	Floyd-Magoffin
14	Daviess
15	Johnson-Magoffin
16	Henderson

CONCLUSIONS

The following major conclusions are developed from this investigation and report. These conclusions and the determination of Suitable General Areas in Kentucky for production of synthetic liquid fuels are based upon presently available information. It should also be noted that the determination of relative order of desirability for Suitable General Areas within a state such as Kentucky does not at this stage:

(a) Constitute or propose a program of development;

(b) Imply any relationship to Suitable General Areas in other states; nor

(c) Reflect any allowance for new developments and future information which can neither be foreseen nor predicted.

1. Coal is the most important raw material in Kentucky meeting the requirements of the survey. A second raw material, oil-impregnated strippable deposits, also meets the survey's requirements. The scope of the investigation with respect to this raw material is limited to a general determination of the nature and extent of the deposits. Available information indicated no reserves of natural gas or oil shale in Kentucky adequate for synthetic liquid fuels production.

2. Oil-impregnated strippable deposits occur in 18 counties of Kentucky. The largest deposits, in Edmonson and Logan Counties, comprise 434 million tons of oil-impregnated strippable material in place or 347 million tons recoverable. Of the recoverable deposits, 196 million tons are within an area of 4,220 acres in Edmonson County and 151 million tons in 2,253 acres of Logan County. These deposits contain from 10 to 15 gallons of oil per ton.

3. The 16 Suitable General Areas in Kentucky have the following orders of relative desirability for initial unit plants, based mainly on total cost per barrel of products, exclusive of return, for the hydrogenation and coal synthine processes, respectively:

Hydrogenation	Coal Synthine
1. Muhlenberg-McLean	1. Muhlenberg-McLean
2. Ohio	2. Ohio
3. Hopkins-Christian	3. Hopkins-Christian
4. Webster	4. Webster
5. Union	5. Union
6. Northern-Letcher	6. Northern-Letcher
7. Pike	7. Pike
8. Harlan-Letcher	8. Harlan-Letcher
9. Bell	9. Bell
10. Perry-Breathitt	10. Knott-Breathitt
11. Floyd-Magoffin	11. Perry-Breathitt
12. Daviess	12. Leslie-Harlan
13. Leslie-Harlan	13. Floyd-Magoffin
14. Knott-Breathitt	14. Daviess
15. Johnson-Magoffin	15. Johnson-Magoffin
16. Henderson	16. Henderson

4. Estimation of coal reserves contained in this report is based on available information and the requirements established for this survey as described in Part II of this report under "Survey Specifications" and "Survey Classifications" and as further described in Part IV under "Survey Methods and Procedure". Coal deposits occur in 37 counties in eastern Kentucky and 21 counties in the western portion of the State. They underlie an area in eastern Kentucky of 10,450 square miles while in the western portion of the State they occupy approximately 4,680 square miles. The total coal reserves in place considered for synthetic liquid fuels manufacture have been estimated at 22,932,403,000 tons according to the specifications and procedures established for this survey. Of this tonnage, 12,826,094,000 tons were estimated as being recoverable. In eastern Kentucky three counties, namely, Floyd, Harlan, and Pike have estimated reserves in excess of 1,000,000,000 tons. The recoverable reserves in Pike County are estimated at 2,782,395,000 tons, and the total recoverable reserves in eastern Kentucky are estimated at 7,778,629,000 tons. In western Kentucky, Hopkins County has an estimated reserve in excess of 1,000,000,000 tons and the total for that portion of the State is estimated at 5,047,465,000 tons.

5. Of the total recoverable coal reserves considered, 380,726,000 tons, or 3.0 percent, are estimated to be suitable for strip mining.

6. The recoverable coal reserves in Kentucky are distributed by counties as follows: in total and as contained within General Areas of Coal Availability:

Estimated Recoverable Coal Reserves
Considered for Synthetic Liquid Fuels Manufacture
by Counties (A)
(As of January 1, 1949)

County	Total Reserves (B)		Satisfactory Reserves within The General Areas	
	Thousands of Tons	Percent of Total	Thousands of Tons	Percent of Total
Eastern Kentucky				
Bell	228,544	1.78%	221,622	1.85%
Breathitt	107,687	.84	21,796	.18
Clay	49,719	.39	-	-
Floyd	1,004,168	7.83	987,211	8.23
Johnson	189,621	1.48	189,621	1.58
Harlan	1,033,164	8.06	989,083	8.25
Knott	749,057	5.84	701,274	5.85
Knox	41,950	.33	-	-
Leslie	362,033	2.82	340,286	2.84
Letcher	550,945	4.30	492,198	4.11
Magoffin	129,618	1.01	96,545	.81
Martin	20,673	.16	-	-
Perry	529,055	4.12	490,893	4.09
Pike	2,782,395	21.69	2,560,579	21.35
Total	7,778,629	60.65%	7,091,108	59.14%
Western Kentucky				
Butler	12,862	.10%	-	-
Christian	23,232	.18	23,232	.19%
Daviess	76,567	.60	76,567	.64
Henderson	498,271	3.88	480,074	4.00
Hopkins	1,377,784	10.74	1,377,784	11.49
McLean	137,620	1.07	113,737	.95
Muhlenberg	957,832	7.47	925,739	7.72
Ohio	529,135	4.13	508,943	4.25
Union	599,491	4.67	599,491	5.00
Webster	834,671	6.51	794,247	6.62
Total	5,047,465	39.35%	4,899,814	40.86%
Total State	12,826,094	100.00%	11,990,922	100.00%

Note: (A) Based on the Specifications and procedures established for this survey.
(B) Before elimination of tonnage in unsatisfactory areas.

7. These recoverable coal reserves of Kentucky are classified by beds as follows; in total and as contained within General Areas of Coal Availability.

Estimated Recoverable Coal Reserves Considered for Synthetic Liquid Fuels Manufacture, by Coal Beds (As of January 1, 1949)

Coal Bed	Total Reserves (A) Thousands of Tons	Total Reserves (A) Percent of Total	Satisfactory Reserves within The General Areas Thousands of Tons	Satisfactory Reserves within The General Areas Percent of Total
Eastern Kentucky				
High Splint	119,975	0.94%	113,053	0.94%
Hignite	26,626	.21	26,626	.22
Flag	142,376	1.11	137,727	1.15
Hazard	272,237	2.12	237,016	1.98
Haddix	73,128	.57	-	-
Fire Clay Rider	64,333	.50	61,482	.51
Flatwoods	74,013	.58	-	-
Taylor	40,357	.32	-	-
Fire Clay	1,085,441	8.46	969,057	8.08
Whitesburg	95,345	.74	35,359	.30
Williamson	490,560	3.82	394,753	3.29
Upper Elkhorn No. 3	1,261,409	9.84	1,219,552	10.17
Upper Eklhorn No. 2	708,051	5.52	700,705	5.84
Upper Elkhorn No. 1	1,338,359	10.43	1,338,359	11.16
Harlan	383,426	2.99	383,426	3.20
Lower Elkhorn	1,265,568	9.87	1,248,020	10.41
Puckette Creek	30,065	.23	30,065	.25
Bingham	195,908	1.53	195,908	1.64
Millard	111,452	.87	-	-
Total	7,778,629	60.65%	7,091,108	59.14%
Western Kentucky				
No. 14	526,977	4.11%	482,159	4.02%
No. 12	36,323	.28	36,323	.30
No. 11	1,439,489	11.22	1,397,550	11.65
No. 9	2,809,604	21.91	2,798,446	23.34
No. 6	202,018	1.57	185,336	1.55
Elmlick	33,054	.26	-	-
Total	5,047,465	39.35%	4,899,814	40.86%
Total State	12,826,094	100.00%	11,990,922	100.00%

Note: (A) Before elimination of tonnage in Unsatisfactory Areas.

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8. The total coal reserves within the 16 Suitable General Areas of Kentucky and the amounts available after elimination of secondary reserves in excess of primary reserves are estimated to be:

Estimated Coal Reserves Available for
Synthetic Liquid Fuels Manufacture in the
16 General Areas after Elimination of Excess Secondary Reserves (A)
(As of January 1, 1949)

Suitable General Area	Satisfactory Reserves within The General Areas (B) Thousands of Tons	Satisfactory Reserves within The General Areas (B) Percent of Total	Available Reserves Thousands of Tons	Available Reserves Percent of Total
Eastern Kentucky				
Pike	2,560,579	21.35%	2,560,579	21.50%
Harlan-Letcher	1,089,054	9.08	1,089,054	9.14
Floyd-Magoffin	1,060,825	8.85	1,060,825	8.91
Knott-Breathitt	712,062	5.94	660,814	5.55
Perry-Breathitt	501,901	4.19	501,901	4.21
Northern Letcher	378,834	3.16	378,834	3.18
Leslie-Harlan	353,679	2.95	353,679	2.97
Bell	221,622	1.85	221,622	1.86
Johnson-Magoffin	212,552	1.77	212,552	1.79
Total	7,091,108	59.14%	7,039,860	59.11%
Western Kentucky				
Hopkins-Christian	1,401,016	11.68%	1,401,016	11.76%
Muhlenberg-McLean	1,039,476	8.67	1,039,476	8.73
Webster	794,247	6.62	784,986	6.59
Union	599,491	5.00	599,491	5.03
Ohio	508,943	4.25	508,943	4.28
Henderson	480,074	4.00	459,866	3.86
Daviess	76,567	.64	76,567	.64
Total	4,899,814	40.86%	4,870,345	40.89%
Total State	11,990,922	100.00%	11,910,205	100.00%

Note: (A) Based on the specifications and procedures established for this survey.

(B) After elimination of coal in unsatisfactory areas.

9. The 16 Suitable General Areas are estimated to contain available recoverable coal in the amount of 11,910,205,000 tons after elimination of excess secondary reserves, which quantity, dependent upon the conversion process used, is equivalent to a total of from 24,734,000,000 to 31,803,000,000 barrels of synthetic liquid fuels.

10. It is probable that continued exploration and development of Kentucky's coal resources will result in the discovery of additional reserves in Areas for which there is not now sufficient information to permit the present estimation of the reserves for this survey. Information available at the time of this survey indicates that after allowances of 2,984,000,000 tons of coal in eastern Kentucky and 1,120,000,000 tons in western Kentucky for future commercial requirements (50 years' production at the 1948 rate of production of 59,687,000 tons annually in eastern Kentucky and 22,397,000 tons annually in western Kentucky) sufficient recoverable coal reserves are available to support, for a 40-year period, the following daily production capacities (by alternative processes) in the 16 Suitable General Areas:

Synthetic Liquid Fuels Potential of Kentucky
in Thousands of Barrels
in Total and as a Daily Average over 40 Years
(As of January 1, 1949)

Suitable General Area	Potential Capacity: Total Potential: Hydro-genation	Total Potential: Coal Synthine	Equivalent Average Daily Plant Capacity for 40-year Period: Hydro-genation	Equivalent Average Daily Plant Capacity for 40-year Period: Coal Synthine
Johnson-Magoffin	596,000	463,000	41	32
Pike	7,363,000	5,727,000	504	392
Floyd-Magoffin	2,908,000	2,261,000	199	155
Knott-Breathitt	1,854,000	1,442,000	127	99
Perry-Breathitt	1,382,000	1,075,000	95	74
Leslie-Harlan	987,000	768,000	68	53
Northern-Letcher	1,080,000	840,000	74	58
Harlan-Letcher	3,107,000	2,417,000	213	166
Bell	624,000	485,000	43	33
Daviess	169,000	131,000	12	9(A)
Henderson	1,029,000	800,000	70	55
Union	1,510,000	1,174,000	103	80
Webster	1,986,000	1,545,000	136	106
Hopkins-Christian	3,428,000	2,666,000	235	183
Muhlenberg-McLean	2,571,000	2,000,000	176	137
Ohio	1,209,000	940,000	82	64
Total	31,803,000	24,734,000	2,178	1,696

Note: (A) Insufficient coal reserves for a unit plant using the coal synthine process.

11. No coals in Kentucky are classified as not amenable to hydrogenation, since reported analyses uniformly show fixed carbon contents of less than 69 percent (Maf basis).

12. Cleaning of eastern Kentucky coals, as necessary to supply merchantable coal to the synthetic liquid fuels plant would produce, per unit plant, approximately 760 tons of mine refuse per working day for a hydrogenation plant and approximately 970 tons for a coal synthine plant. Cleaning of western Kentucky coals would produce, per unit plant approximately 1,590 tons and 2,050 tons of refuse per working day for a hydrogenation plant and a coal synthine plant respectively. Equivalent annual quantities of

refuse from eastern Kentucky coals would amount to about 121,600 cubic yards for a hydrogenation plant and 155,200 cubic yards for a coal synthine plant. Equivalent annual quantities of refuse from western Kentucky coals would amount to about 254,400 and 328,000 cubic yards, respectively. No particular disposal problem would be presented.

13. Coals of the Kentucky General Areas range from a high-volatile A bituminous to high-volatile C bituminous, in rank, with heating values, as received, ranging from 10,790 to 14,290 Btu per pound. Moisture, ash, and sulfur contents are:

Content of Selected Components of Kentucky Coals
(Mine Sample, As received basis)

	Maximum	Minimum
Moisture	12.1%	2.8%
Ash	12.8	3.0
Sulfur	3.7	0.7

14. A limited number of petrographic assays of coal in Kentucky indicate that the eastern Kentucky coals range from the "bright" petrographic type, wherein anthraxylon and translucent attritus predominate, with opaque attritus and fusain being present in minor amounts, to predominately attrital types with moderately high percentages of opaque attritus indicating a composition approaching that of semi-splint coal. The western Kentucky coals are largely of the "bright" petrographic type. Since most of the coals of the 16 Suitable General Areas are similar in rank, appearance, and chemical composition to the coals on which petrographic assays were made, no substantial differences are expected in their adaptability to hydrogenation.

15. Estimated capital required in Kentucky for coal mines, each to supply a single synthetic liquid fuels unit plant, is as follows:

Initial Capital Required in Kentucky for a Coal Mine to Supply One Synthetic Liquid Fuels Unit Plant in Thousands of Dollars (As of March 31, 1950)

Suitable General Area	Hydrogenation		Coal Synthine	
	Underground	Strip	Underground	Strip
Johnson-Magoffin	$7,818	-	$10,050	-
Pike	6,345	-	8,160	-
Floyd-Magoffin	6,660	-	8,560	-
Knott-Breathitt	6,505	-	8,360	-
Perry-Breathitt	6,630	-	8,525	-
Leslie-Harlan	6,535	-	8,405	-
Northern Letcher	6,400	-	8,230	-
Harlan-Letcher	6,395	-	8,225	-
Bell	7,128	-	9,163	
Daviess	7,457	$6,214	9,590	$7,991
Henderson	7,344	-	9,441	-
Union	6,521	-	8,384	-
Webster	6,489	5,058	8,348	6,500
Hopkins-Christian	-	5,254	-	6,752
Muhlenberg-McLean	-	5,163	7,588	6,636
Ohio	-	5,044	-	6,487

16. Coal production costs, exclusive of selling expenses and return on investment in the several General Areas of Kentucky are estimated to be:

Coal Production Costs in Underground and Strip Mines (As of March 31, 1950)

General Area	Coal Costs per Ton	
	Underground	Strip
Johnson-Magoffin	$5.11	-
Pike	4.76	-
Floyd-Magoffin	4.66	-
Knott-Breathitt	4.66	-
Perry-Breathitt	4.66	-
Leslie-Harlan	4.66	-
Northern-Letcher	4.66	-
Harlan-Letcher	4.76	-
Bell	4.71	-
Daviess	3.89	$2.63
Henderson	4.16	-
Union	3.65	-
Webster	3.65	2.61
Hopkins-Christian	-	2.81
Muhlenberg-McLean	-	2.81
Ohio	-	2.79

17. The production costs of coal per barrel of products in synthetic liquid fuels unit plant in Kentucky are estimated to be:

Production Cost of Coal per Barrel of Products
(As of March 31, 1950)

Suitable General Areas	Hydrogenation	Synthine
One Unit Plant (A)		
Muhlenberg-McLean	$1.13	$1.50
Hopkins-Christian	1.16	1.49
Ohio	1.19	1.53
Webster	1.34	1.75
Union	1.45	1.86
Northern Letcher	1.63	2.10
Pike	1.66	2.13
Knott-Breathitt	1.66	2.14
Harlan-Letcher	1.67	2.14
Leslie-Harlan	1.67	2.15
Bell	1.67	2.15
Perry-Breathitt	1.69	2.18
Floyd-Magoffin	1.70	2.19
Daviess	1.71	2.21
Johnson-Magoffin	1.82	2.34
Henderson	1.86	2.39
Ultimate Unit Plants (B)		
Webster	$1.44	$1.85
Muhlenberg-McLean	1.54	1.98
Hopkins-Christian	1.56	2.00
Ohio	1.67	2.15
Daviess	1.77	(C)

Note: (A) One Unit plant in each Area, based on use of Underground and Strip Coal.

(B) Based on underground-mined coal. Costs in the other Areas not listed would be the same as for the first unit plant.

(C) Insufficient coal reserves in Daviess General Area to warrant consideration of more than one unit plant for 40 years.

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18. Ample water resources exist for the supply of sufficient synthetic liquid fuels plant capacity to furnish all available coal in a period of 40 years. The maximum water requirement is estimated at 3,434 cfs.

19. Initial capital investment and annual costs as of March 31, 1950, exclusive of return on investment, required for process water supply works, each to serve a complete unit plant for synthetic liquid fuels, are estimated to be as follows in the 16 Suitable General Areas of Kentucky.

Initial Capital Investment and Annual Costs for Process Water Supply Works for Suitable General Areas (As of March 31, 1950)

Suitable General Area	Investment	Annual Cost
Daviess	$ 495,000	$ 62,980
Union	628,000	66,690
Henderson	721,000	75,720
Johnson-Magoffin	891,000	76,050
Ohio	898,000	79,530
Muhlenberg-McLean	1,209,000	93,030
Pike	2,846,000	136,070
Floyd-Magoffin	3,170,000	153,710
Webster	3,231,000	156,480
Perry-Breathitt	3,957,000	181,260
Leslie-Harlan	4,175,000	185,480
Bell	4,246,000	216,870
Harlan-Letcher	4,619,000	214,810
Northern Letcher	5,754,000	301,130
Knott-Breathitt	6,750,000	288,860
Hopkins-Christian	6,766,000	289,360

20. Initial capital investment and annual costs as of March 31, 1950, of the domestic water supply, exclusive of return on investment, required for each of the 16 Suitable General Areas in Kentucky, as shown in the following table, are not chargeable to plant operations as it has been assumed that these costs would be paid for by the consumers living in the plant-city:

Initial Capital Investment and Annual Operating Costs for Domestic Water Supply for Initial Unit Projects
(As of March 31, 1950)

Suitable General Area	Investment	Annual Operating Costs, Exclusive of Return on Investment
Daviess	$ 300,000	$30,270
Union	324,000	30,930
Henderson	340,000	32,490
Johnson-Magoffin	369,000	32,550
Ohio	370,000	33,150
Muhlenberg-McLean	425,000	35,510
Pike	708,000	42,970
Floyd-Magoffin	766,000	46,050
Webster	776,000	46,540
Perry-Breathitt	902,000	50,830
Leslie-Harlan	939,000	51,560
Bell	952,000	57,010
Harlan-Letcher	1,017,000	56,650
Northern Letcher	1,214,000	71,650
Knott-Breathitt	1,387,000	69,510
Hopkins-Christian	1,389,000	69,590

21. Local utilities could be expected to have adequate power available for plant construction purposes. Plant operating power requirements might be more economically provided by generating facilities provided as part of the project but in the nine General Areas in eastern Kentucky, there is an ample supply of outside power at an unusually low rate per kilowatthour. In the seven General Areas in the western part of Kentucky the cost of utility power appears higher. Ky

22. The costs of installing and operating, exclusive of 40
return on investment, the necessary supplementary 40
access transportation facilities for an initial 1
synthetic liquid fuels unit plant in each Suitable 2002
General Area in Kentucky are estimated: 7002

Cost of Access Transportation Facilities
(As of March 31, 1950)

Suitable General Area	Investment	Annual Cost
Northern Letcher	0	0
Harlan-Letcher	0	0
Bell	0	0
Muhlenberg-McLean	$ 6,000	$ 150
Union	8,000	200
Webster	8,500	213
Henderson	14,000	350
Johnson-Magoffin	75,000	3,750
Ohio	83,000	2,075
Perry-Breathitt	125,000	6,250
Floyd-Magoffin	180,000	9,000
Hopkins-Christian	208,000	9,075
Daviess	904,000	45,100
Knott-Breathitt	1,127,500	54,688
Pike	2,300,000	113,750
Lester-Harlan	2,576,000	128,150

23. In Kentucky an ample supply of labor to meet the requirements of an average unit plant as to total personnel is available in an area convenient to the plant. However, there are few workers in industries comparable with synthetic liquid fuels as to skills and training required, in any of the eastern or the western coal counties of Kentucky, and it is considered that the requirements of a synthetic liquid fuels plant would have to be met by inducing the workers to relocate from areas beyond the immediate vicinity of the plant. Including a relocation allowance, the average straight-time hourly wage rate, as of March 31, 1950, payable in a synthetic liquid fuels unit plant in Kentucky, is estimated at $1.64.

24. On an average for the 16 Suitable General Areas in Kentucky, the necessary plant-city for an initial synthetic liquid fuels unit plant would be expected to accommodate 3,559 persons in eastern Kentucky and 4,555 in western Kentucky for a hydrogenation project and for a coal synthine project 3,378 and 4,826 persons, respectively. Corresponding required initial investments estimated as of March 31, 1950 would be $10,232,724 in eastern or $14,463,824 in western Kentucky, using the hydrogenation process and $9,713,194 or $15,322,697, respectively, using the synthine process, exclusive of domestic water supply.

25. The value of the commercial facilities (assumed to be self-supporting) and of one-half of the dwelling units in the plant-city (assumed to be sold), plus a proportionate share of the cost of land and utilities, is estimated at $5,844,588 in eastern Kentucky and $8,262,557 in western Kentucky for a hydrogenation unit plant and $5,547,810 and $8,753,296, respectively, for a coal synthine unit plant. The remaining net investments in rental housing and plant-city development would be $4,388,136 in eastern and $6,201,267 in western Kentucky for hydrogenation and $4,165,384 and $6,569,401, respectively, for the coal synthine process.

26. From the standpoint of motor fuel, the average daily consumption (exclusive of aviation and military use) in Kentucky, Virginia, North and South Carolina, Georgia, and Florida amounted to about 232,000 barrels in 1948, and it is estimated to increase to approximately 481,000 barrels in 1975. Such demands would be equivalent, respectively, to the gasoline output of about 31 and 64 synthetic liquid fuels unit plants processing coal.

27. The proportions of the various synthetic liquid fuel products specified for plants considered in this survey differ importantly from the distribution of actual product consumption in Kentucky, Virginia, North and South Carolina, Georgia, and Florida. At such time as large-scale development would be required, synthetic liquid fuels plants undoubtedly would be designed, since the processes are variable, to conform to the then existing demand pattern.

28. Liquid fuel requirements in Kentucky are economically supplied by petroleum products at refinery prices as of June 1, 1950, of $4.21 and $4.53 per barrel, respectively, for the fuel product distributions specified for hydrogenation and coal synthine plants.

29. When synthetic liquid fuels are required, plants in the eastern Kentucky, southern West Virginia, and western Virginia region would be well located for the distribution of products within the defined marketing territory.

30. No unusual methods would be required in Kentucky for the inoffensive disposal of solid and gaseous wastes of synthetic liquid fuels plants.

31. The treatment of liquid wastes, before disposal, to meet any anticipated requirements is feasible at costs within allowances made in the general estimates for the process plants.

32. Disposal of solid wastes for synthetic liquid fuels plants in Kentucky is estimated to involve the following capital investment in operating costs before return on investment:

Estimated Costs of Solid Waste Disposal
(As of March 31, 1950)

Suitable General Area	Hydrogenation Capital	Hydrogenation Daily Cost	Coal Synthine Capital	Coal Synthine Daily Cost
Johnson-Magoffin	$322,000	$156	$493,000	$298
Pike	370,000	186	527,000	327
Floyd-Magoffin	406,000	213	594,000	378
Knott-Breathitt	388,000	200	551,000	346
Perry-Breathitt	388,000	200	567,000	359
Leslie-Harlan	365,000	183	536,000	335
Northern Letcher	362,000	182	519,000	322
Harlan-Letcher	368,000	186	525,000	327
Bell	378,000	193	553,000	349
Daviess	518,000	321	932,000	561
Henderson	534,000	333	980,000	584
Union	474,000	280	777,000	484
Webster	466,000	274	749,000	470
Hopkins-Christian	461,000	266	744,000	467
Muhlenberg-McLean	467,000	273	750,000	470
Ohio	474,000	280	787,000	490

33. Typical synthetic liquid fuels unit plants in Kentucky (represented by Johnson-Magoffin General Area) would involve investments as follows:

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Typical Plant Investment
(As of March 31, 1950)

	Hydrogenation	Coal Synthine
Plant Construction Cost	$91,096,000	$81,805,000
Interest during Construction	3,416,000	2,455,000
Depreciable Investment	$94,512,000	$84,260,000
Operating Capital	4,961,000	5,173,000
Total Investment	$99,473,000	$89,433,000

34. Typical synthetic liquid fuels unit plants in Kentucky (represented by Johnson-Magoffin General Area) would incur daily processing costs, exclusive of return on investment, as follows:

Typical Daily Processing Costs Exclusive of Return on Investment
(As of March 31, 1950)

Processing Costs	Hydrogenation	Coal Synthine
Direct Materials	$19,531	$24,645
Water	208	208
Other Direct Costs	12,912	12,181
Direct Costs	$32,651	$37,034
Indirect Wages and Salaries	$ 2,837	$ 2,866
Other Indirect Costs	3,116	2,745
Indirect Costs	$ 5,953	$ 5,611
Taxes and Insurance	$ 2,589	$ 2,308
Depreciation	17,262	15,390
Fixed Costs	$19,851	$17,698
Total Manufacturing Costs	$58,455	$60,343
Less Coal and Make-up water	$18,446	$23,653
Other Processing Costs	$40,009	$36,690

35. Development of a synthetic liquid fuels industry in Kentucky could be planned to conform with presently published requirements of strategic considerations.

36. In the 16 Suitable General Areas of Kentucky the initial net capital required for the complete installation of a synthetic liquid fuels unit plant (shown on Exhibit Nos. 85 and 86) including the manufacturing plant, process water supply, rental housing, mine, and other incidental facilities but exclusive of commercial facilities and domestic water supply for the plant-city (assumed as self-supporting) and of one-half of the dwelling units (assumed as sold to employes), is estimated as follows:

Estimated Initial Net Capital Required for Synthetic Liquid Fuels Unit Projects in Kentucky (A)
(As of March 31, 1950)

Suitable General Area	Initial Net Capital (A) Hydro-genation	Coal Synthine
One Unit Plant (B)		
Ohio	$111,669,000	$103,609,000
Muhlenberg-McLean	111,980,000	104,017,000
Johnson-Magoffin	112,967,000	105,107,000
Union	113,008,000	105,419,000
Floyd-Magoffin	114,198,000	105,994,000
Henderson	114,309,000	107,187,000
Daviess	114,822,000	107,685,000
Perry-Breathitt	114,884,000	106,665,000
Webster	115,150,000	107,530,000
Harlan-Letcher	115,154,000	106,842,000
Bell	115,531,000	107,444,000
Pike	115,602,000	107,272,000
Northern Letcher	116,281,000	107,961,000
Leslie-Harlan	117,419,000	109,161,000
Hopkins-Christian	117,900,000	109,858,000
Knott-Breathitt	118,561,000	110,278,000
Ultimate Unit Plant (C)		
Muhlenberg-McLean	$113,034,000	$105,264,000
Ohio	113,877,000	106,449,000
Daviess	114,998,000	(D)
Webster	115,594,000	107,979,000
Hopkins-Christian	118,924,000	111,176,000

Note: (A) Exclusive of Commercial facilities and domestic water supply for the plant-city (assumed as self-supporting) and of one-half of the dwelling units (assumed as sold to employes).

(B) Based on one unit plant in each General Area using strip coal as far as available and underground-mined coal to complete the 40-year fuel requirement. Ky

(C) Based on all Underground-mined coal.

(D) Insufficient coal reserves in Daviess General Area to warrant consideration of more than one unit plant for 40 years. 409 3

37. Operating costs of synthetic liquid fuels unit projects in Kentucky (See Exhibit Nos. 85 and 86), in dollars per barrel of products by type of process, exclusive of return on investment, are estimated as follows:

Estimated Operating Costs in Dollars per Barrel of All Products, by Type of Process, Exclusive of Return on Investment
(As of March 31, 1950)

Suitable General Area	Hydrogenation	Coal Synthine
One Unit Plant (A)		
Muhlenberg-McLean	$5.189	$5.243
Ohio	5.238	5.267
Hopkins-Christian	5.265	5.283
Webster	5.412	5.508
Union	5.497	5.599
Northern Letcher	5.736	5.885
Pike	5.744	5.898
Harlan-Letcher	5.747	5.906
Bell	5.752	5.913
Perry-Breathitt	5.765	5.933
Floyd-Magoffin	5.767	5.938
Daviess	5.770	5.968
Leslie-Harlan	5.774	5.934
Knott-Breathitt	5.776	5.933
Johnson-Magoffin	5.862	6.065
Henderson	5.915	6.139
Ultimate Unit Plant (B)		
Webster	$5.513	$5.614
Muhlenberg-McLean	5.594	5.722
Hopkins-Christian	5.667	5.800
Ohio	5.721	5.888
Daviess	5.828	(C)

Note: (A) Based on one unit plant in each General Area using strip coal as far as available and underground-mined coal to complete the 40-year fuel requirement.
(B) Based on all underground coal.
(C) Insufficient coal reserves in Daviess General Area to warrant consideration of more than one unit plant for 40 years.

38. The amounts required to yield 1 percent gross return (before the deduction of income taxes) on net initial investment (See Exhibit Nos. 85 and 86) are estimated as follows:

Amount of Each 1 Percent Gross Return on Net Initial Investment in Plant and Facilities in Dollars per Barrel of All Products
(As of March 31, 1950)

Suitable General Area	Hydrogenation	Coal Synthine
First Unit Plant (A)		
Ohio	$0.306	$0.284
Muhlenberg-McLean	0.307	0.285
Johnson-Magoffin	0.309	0.288
Union	0.310	0.289
Floyd Magoffin	0.313	0.290
Henderson	0.313	0.294
Daviess	0.314	0.295
Perry-Breathitt	0.315	0.292
Harlan-Letcher	0.315	0.293
Webster	0.315	0.295
Pike	0.317	0.294
Bell	0.317	0.294
Northern Letcher	0.319	0.296
Leslie-Harlan	0.322	0.299
Hopkins-Christian	0.323	0.301
Knott-Breathitt	0.325	0.302
Ultimate Unit Plant (B)		
Muhlenberg-McLean	$0.310	$0.288
Ohio	0.312	0.292
Daviess	0.315	(C)
Webster	0.317	0.296
Hopkins-Christian	0.326	0.305

Note: (A) Based on one unit plant in each General Area using strip coal as far as available and underground-mined coal to complete the 40-year fuel requirement.
(B) Based on all underground coal. Ky
(C) Insufficient coal reserves in Daviess General Area to warrant consideration of more than one unit plant for 40 years. 412 413 3

70021

EXHIBITS

Ky

70021

Synthetic Liquid Fuels Plant Requirements
Coal Processes
(Approved by Corps of Engineers)
As of May 15, 1950

	Hydrogenation Requirements for a 10,000-barrel-per-calendar-day Unit (in Continental United States) Based on a 30,000-barrel-per-day Plant	Coal Synthine Requirements for a 10,000-barrel-per-calendar-day Unit Based on a 10,000-barrel-per-day Plant
A. DESCRIPTION OF PROCESSES (Brief Description of Flow Sheet, Names of Equipment or Units Proposed for Use, Significant Temperatures and Pressures, Over-all Efficiency (A) for Average Rank of Coal)	Coal, which is made into paste by mixing with oil, is hydrogenated at 10,000 psi and 900° F in two consecutive stages, Liquid and Vapor Phase. Vapor phase products are distilled into finished gasoline and L.P.G. With slight modification, alternate products such as jet fuel, Diesel fuel, furnace oil, etc., can be produced if desired. Fuel gas needed is generated from coal. Hydrogen is produced at 350 psi pressure by gasification of coal with oxygen and conversion of hydrogenation off-gas with steam Steam and power production facilities are provided with the plant. A coal cleaning plant is included The process data below are based on the following efficiency: Over-all 50.6% (A)	Raw coal is pulverized and gasified with oxygen and steam at 450 psi pressure. The resulting synthesis gas, composed of mainly carbon monoxide and hydrogen is purified by the removal of hydrogen sulfide and organic sulfur compounds and then fed to a single stage synthesis reaction. The synthesis reaction takes place at 300 psi pressure and about 600° F. An internally cooled reactor using liquid-suspended iron catalyst has been assumed in this estimate. Alternate types of reactors are solid bed catalyst internally cooled reactor, or iron catalyst slurry process. The liquid products are separated by distillation into motor gasoline, Diesel fuel, and heavier fractions which are refined and upgraded by conventional petroleum and refinery processes to finished products. Steam and power facilities are provided within the plant. The data below are based on the following efficiency: Over-all 41.2% (A)
B. RAW MATERIALS		
Quantity		
Coal Requirements in Btu x 10^9 per Calendar Day	Process 50 Hydrogen Manufacturing and Fuel Gas 21 Direct-fired (Distillation, etc.) 8 Power and Steam 19 Total 98	Process 126 Total 126
Quality		
Ash		
Maximum Allowable Ash Content to Equipment (Dry Basis)	Process 15% Hydrogen Manufacturing and Fuel Gas 20% Direct-fired (Distillation, etc.) 20% Power and Steam 20%	Process 20%
Other Characteristics (Chemical Analysis, etc.)	(1) Good washability is desirable. (a) Low calcium in process coal is preferable. (2) Chemical analysis and physical properties should be known.	(1) Good washability is desirable. (2) Chemical analysis and physical properties should be known.
Sulfur		
Cost of Desulfurization	Cost of desulfurization does not change materially with percent of sulfur in coal when credit of 1/5 of market price is taken for recovered sulfur.	Cost of desulfurization does not change materially with percent of sulfur in coal when credit of 1/5 of market price is taken for recovered sulfur.
Other Characteristics	High organic sulfur content in raw coal is undesirable since it is not easily removed by cleaning (of only minor importance).	High organic sulfur content in raw coal is undesirable since it is not easily removed by cleaning.
Other Characteristics (Effect of Rank, Opaque Attritus, Fusain, etc.)	Fusain and opaque attritus should be low in process coal. Fusain normally can be removed by cleaning. Fixed Carbon (maf) Not to exceed 69% Volatile Matter (maf) 31% Minimum Sulfur No limit Moisture No limit Rank of coal has little effect on total plant required. For coals of equal rank, higher net hydrogen is desirable. Information Required for Evaluation: 1. Proximate analysis - dry basis - include moisture as lb per lb of dry coal (face sample). 2. Fischer Assay (dry basis). 3. Ultimate analysis (maf basis). 4. Btu content.	Fixed Carbon No limit Volatile Matter No limit Sulfur No limit Moisture No limit Decrease in rank increases amount of plant required. (Range of plant cost 20% between extremes of rank). Information Required for Evaluation: 1. Ultimate analysis (maf basis) Btu content. 2. Proximate analysis - dry basis - include moisture as lb per lb of dry coal (face sample).
C. WATER		
Quantity		
Heat Capacity of Coolant Required in Btu x 10^9 per Calendar Day (includes Coolant for Power Requirements)	35 Average for All Ranks of Coal	54 Average for All Ranks of Coal

Water Requirements in Thousands of Gallons per Calendar Day

	Hydrogenation Make-up	Hydrogenation Consumed	Hydrogenation Returned	Coal Synthine Make-up	Coal Synthine Consumed	Coal Synthine Returned
Evaporated (Cooling Towers)	4,180	4,180		6,410	6,410	
Blowdown from Cooling Towers	1,255	627	628	1,920	960	960
Boiler Make-up for Hydrogen Manufacturing	483	338	145			
Boiler Make-up for Boiler Blowdown	245	49	196	737	147	590
Boiler Make-up for Synthesis Gas Mfg.				578	51	527
High-pressure Injection Water (Process Water)	50	50				
Sanitary Water for Plant	72		72	60		60
Sanitary Water for Mines	37		37	48		48
Water for Coal Preparation	233	63	170	300	80	220
Water for Mines	Information not available. (Assumed to be self-sufficient)			Information not available. (Assumed to be self-sufficient)		
Water for Mine Power	69	55	14	81	65	16
Miscellaneous, 10%	662		662	1,016		1,016
Total	7,286	5,362	1,924	11,150	7,713	3,437

	Hydrogenation	Coal Synthine
Quality	1. Boiler water suitable for treatment. 2. Sanitary water suitable for chlorination and potable. 3. Cooling water is based on soft water. Water of high solids content increases water requirements or necessitates a water treatment plant.	1. Boiler water suitable for treatment. 2. Sanitary water suitable for chlorination and potable. 3. Cooling water is based on soft water. Water of high solids content increases water requirements or necessitates a water treatment plant.
D. POWER		
Total Power Required for Mine (Kw)	3,000 (based on 2 shifts per day - 5-day week - 5 Kwhr per ton)	3,500 (based on 2 shifts per day - 5-day week - 5 Kwhr per ton)
Total Power Required for Plant (Kw)	65,000	114,500
By-product Power (Kw)	25,000 (Back-pressure power)	114,500 (Produced from waste heat)
Prime Power (Kw)	40,000 (May be procured from outside sources. Fuel requirements would be reduced in proportion) (B)	
E. PERSONNEL		
Total Operating Personnel Required for Year-Round Operation		
Plant (3 shifts), 365 days (year)	Operational 925 Administrative 250	Operational 937 Administrative 198
Underground Mines (2 shifts, 240 days per year operation) (C)		
Operational	Bituminous (13,100 Btu) 782 Subbituminous (9,500 Btu) 1,079 Lignite (7,000 Btu) 1,464	Bituminous (13,100 Btu) 1,005 Subbituminous (9,500 Btu) 1,387 Lignite (7,000 Btu) 1,882
Administrative	Bituminous (13,100 Btu) 39 Subbituminous (9,500 Btu) 54 Lignite (7,000 Btu) 73	Bituminous (13,100 Btu) 50 Subbituminous (9,500 Btu) 69 Lignite (7,000 Btu) 94
Strip Mine (2 shifts, 240 days per year operation) (D)		
Operational	Bituminous (13,100 Btu) 312 Subbituminous (9,500 Btu) 431 Lignite (7,000 Btu) 585	Anthracite Culm (11,500 Btu) 366 Bituminous (13,100 Btu) 403 Subbituminous (9,500 Btu) 554 Lignite (7,000 Btu) 752
Administrative	Bituminous (13,100 Btu) 16 Subbituminous (9,500 Btu) 22 Lignite (7,000 Btu) 29	Anthracite Culm (11,500 Btu) 18 Bituminous (13,100 Btu) 20 Subbituminous (9,500 Btu) 28 Lignite (7,000 Btu) 38

F. PRODUCTS

Estimated Quantity of Products per Calendar Day (Ranges or Specific Quantities)

	Hydrogenation Barrels per Day	Hydrogenation Btu per Pound	Hydrogenation Btu x 10^9 per Day	Coal Synthine Barrels per Day	Coal Synthine Btu per Pound	Coal Synthine Btu x 10^9 per Day
Liquefied Petroleum Gases:						
Propane	1,709	21,700	6.52	470	21,700	1.833
Butane	658	21,300	2.96			
Motor Gasoline	7,220	19,450	37.76	7,280	20,310	37.26
Diesel Oil				1,900	19,990	10.72
Residual Fuel Oil				350	19,775	2.151
By-products:						
Phenols (E)	413	15,730	2.38			
Total	10,000		49.62	10,000		51.964

G. WASTES

Nature and Amount of Wastes

	Hydrogenation Solid Wastes	Hydrogenation Liquid Wastes	Hydrogenation Gaseous Wastes	Coal Synthine Solid Wastes	Coal Synthine Liquid Wastes	Coal Synthine Gaseous Wastes
	Reject from cleaning plant Spent Catalyst - 40 tons per day Ash (total ash in coal) Unburned Coal	Total - 53,000 gal per day (Composition of this waste is: Hydrogen Sulfide = 0.5% Carbon Dioxide = 2.0% Ammonia = 2.0% Phenols = 0.3%)	Total - 6,100,000 cu ft per day (Based on 1% Sulfur in coal. Composition: Hydrogen Sulfide = 1% Carbon Dioxide = 10% Air = 89%)	Reject from cleaning plant Spent Catalyst Dry Box Mass - 0.5 tons per day Ash (Total ash in coal) Unburned Coal		Hydrogen Sulfide from Girbotol 240 cu ft per 1% sulfur per ton of coal (as received). Can be converted to sulfur or burned as Sulfur Dioxide. The amount of wastes varies with sulfur in coal.

	Hydrogenation	Coal Synthine
H. AREA		
Area Required in Acres (Minimum)	70	77

Note: (A) Over-all Efficiency is defined as - $\frac{\text{Btu in products}}{\text{Btu in coal}} \times 100$

(B) Water requirements would be 17.2% less total water for hydrogenation if prime power were purchased from some outside source.
(C) Assuming 8 tons of coal per man and shift; administrative personnel 5% of operational; 10% allowance for absenteeism.
(D) Assuming 20 tons of coal (25 tons of anthracite culm) per man and shift; administrative personnel 5% of operational; 10% allowance for absenteeism.
(E) Convertible in proportion 1,240 bbl phenols equivalent to 1,391 bbl gasoline; no additional equipment.

Exhibit No. 1

SF-50 7-25-50

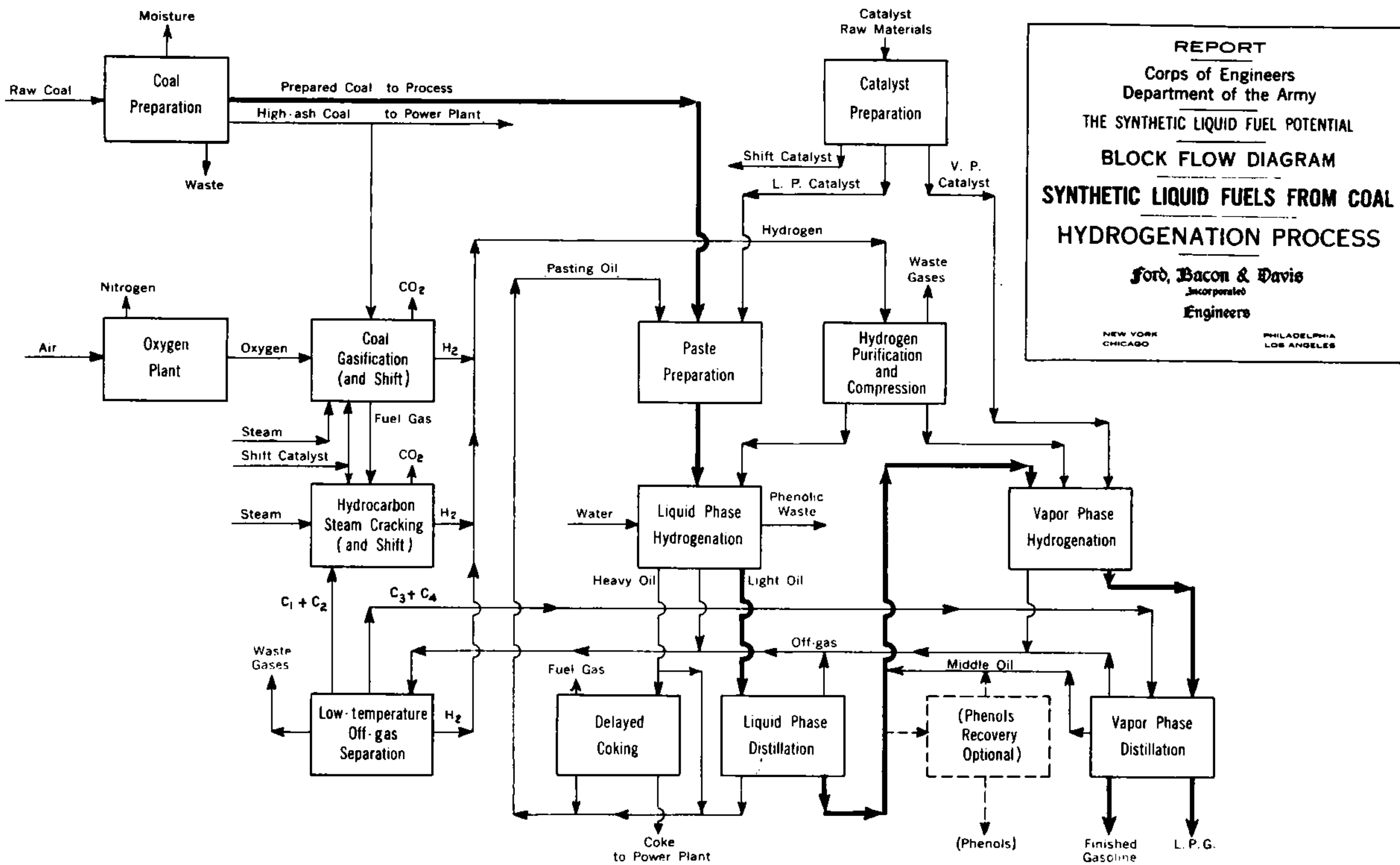
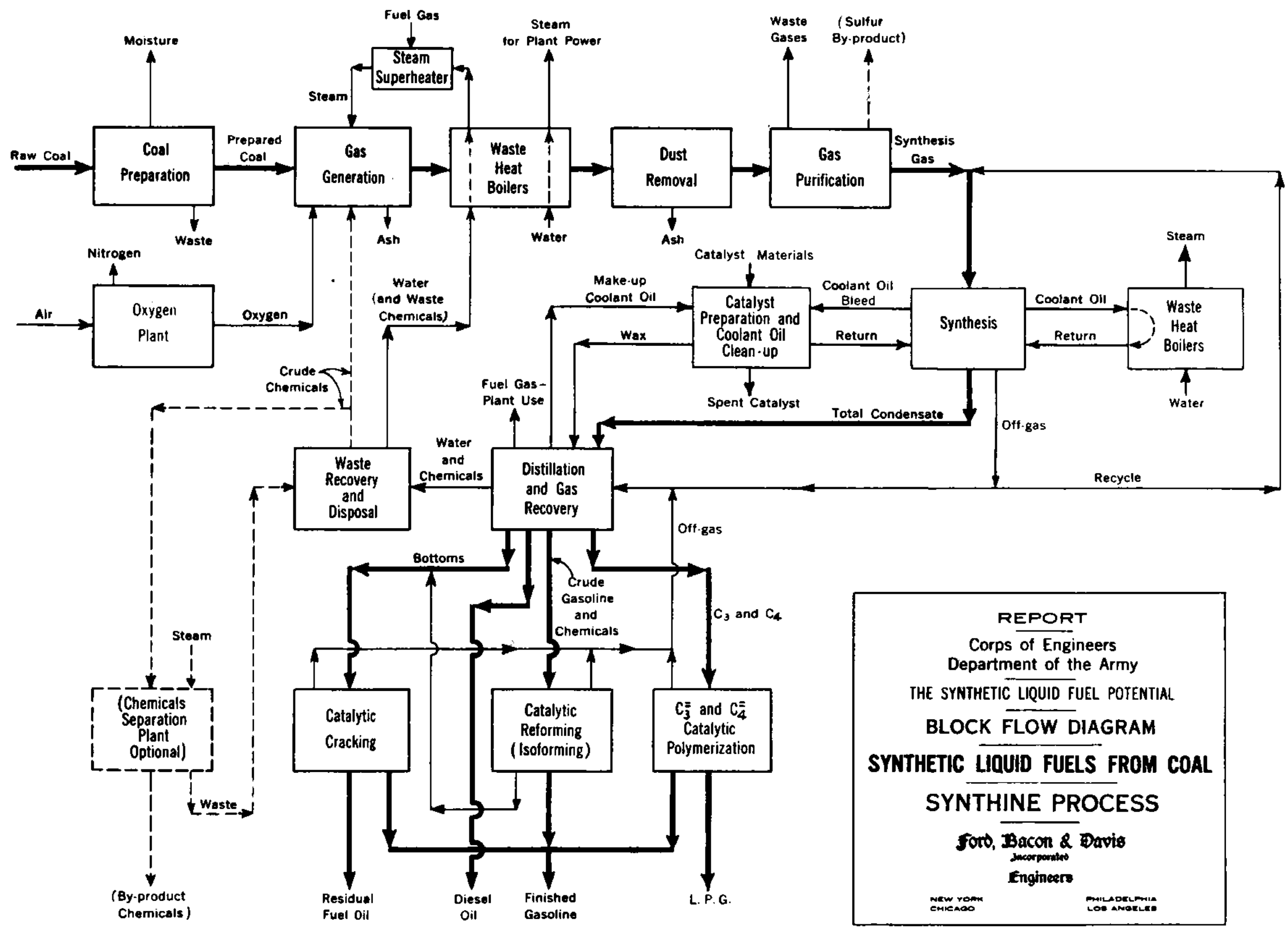


EXHIBIT NO. 2

SF-51 7-25-50



REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL

BLOCK FLOW DIAGRAM

SYNTHETIC LIQUID FUELS FROM COAL

SYNTHINE PROCESS

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES

EXHIBIT NO. 3

EXHIBIT NO 4

REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY

WEATHER DATA

AVERAGE PRECIPITATION AND TEMPERATURE

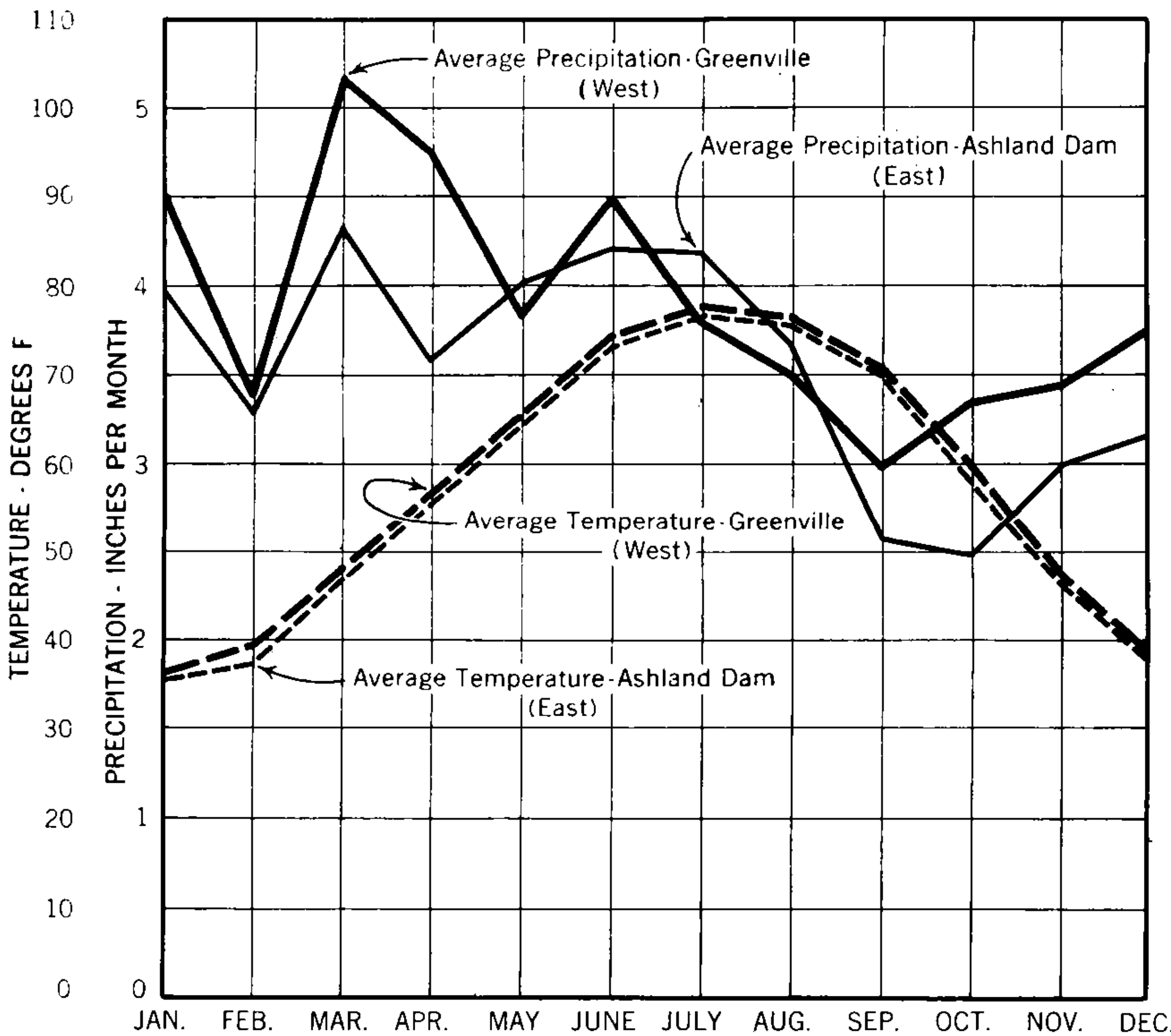
BY MONTHS

AT ASHLAND DAM AND GREENVILLE, KENTUCKY

(SELECTED AS REPRESENTATIVE OF THE COAL-BEARING AREAS OF KENTUCKY)

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES



SF-1569 8-17-51

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Depositories of Coal Data Sheets

The Bureau of Mines has informed the Office of Chief of Engineers, Department of the Army, that it will furnish the following depository libraries with bound copies of coal data sheets where they will be available for public inspection:

Bureau of Mines Library
4800 Forbes Street
Pittsburgh, Pennsylvania

Bureau of Mines Library
University Campus
Grand Forks, North Dakota

Bureau of Mines Library
Coal Branch
Denver Federal Center, Bldg. 2A
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SYNTHETIC LIQUID FUEL SURVEY

SUMMARY OF RECOVERABLE COAL RESERVES IN KENTUCKY *

CONSIDERED FOR SYNTHETIC LIQUID FUELS MANUFACTURE

BY COUNTIES AND BEDS

AS OF JANUARY 1, 1949

Line	County	Bed	Thickness of Coal (Inches) Max	Min	Ave	Dip of Bed (Degrees) Max	Min	Ave	Thickness of Cover (Feet) Underground Mining Max	Min	Ave	Strip Mining Max	Ave	Rank of Coal	● Analysis (As Received) Proximate: Moisture	Volatile Matter	Fixed Carbon	Ash	Ultimate: Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen
1	MARTIN	FLATWOODS			46						120			†Hvab	5.5	35.3	50.8	8.4	0.8				
2		L. ELKHORN	60	32					175	100				Hvab	3.5	38.7	49.3	8.5	2.3				
3		TOTAL				2	0																
4																							
5	JOHNSON	U. ELKHORN #1	47	34		2	0		245	160				Hvab	4.8	36.7	55.8	2.7	1.2	5.7	76.8	1.6	12.0
6																							
7	MAGOFFIN	HAZARD	54	33					140	100				†Hvab	5.1	35.5	52.9	6.5	0.7	5.5	73.7	1.6	12.0
8		HADDIX	32	29					90	80				Hvab	4.7	38.5	51.0	5.8	1.3				
9		FIRECLAY	37	36					170	160				†Hvab	5.6	34.0	53.3	7.1	1.0				
10		WHITESBURG	34	29					200	125				Hvab	4.6	34.7	53.8	6.9	2.2				
11		U. ELKHORN #3	36	32					300	130				†Hvab	3.4	35.8	57.4	3.4	0.5				
12		U. ELKHORN #1	44	30					245	200				†Hvab	4.1	37.0	53.4	5.5	1.6				
13		TOTAL				2	0																
14																							
15	PIKE	FLATWOODS	72	36					400	45				†Hvab	5.5	35.3	50.8	8.4	0.8				
16		TAYLOR	50	29					240	50					NO ANALYSIS AVAILABLE								
17		FIRECLAY	49	30					275	70				Hvab	4.5	36.4	53.6	5.5	0.8	5.6	75.0	1.5	11.6
18		WILLIAMSON	57	24					310	30				Hvab	2.9	39.2	51.9	6.0	2.9	5.5	75.6	1.3	8.7
19																							
20		U. ELKHORN #3	73	27					275	40				Hvab	3.8	37.0	55.0	4.2	1.0	5.5	77.0	1.5	10.8
21																							
22		U. ELKHORN #2	73	26					340	50				Hvab	2.9	35.7	57.8	3.6	0.9	5.6	79.6	1.5	8.8
23		U. ELKHORN #1	61	28					400	100				Hvab	3.2	34.8	58.1	3.9	0.7	5.4	79.3	1.5	9.2
24		L. ELKHORN	69	36					450	100				Hvab	3.2	32.7	60.3	3.8	0.6	5.4	79.7	1.4	9.1
25																							
26		BINGHAM	58	30					350	80				Hvab	1.1	34.4	56.9	7.6	1.9				
27		MILLARD	38	24					525	200					NO ANALYSIS AVAILABLE								
28		TOTAL				2	0																
29																							
30	FLOYD	HAZARD	54	45					140	105				†Hvab	5.1	35.5	52.9	6.5	0.7	5.5	73.7	1.6	12.0
31		FLATWOODS			51						150			†Hvab	5.5	35.3	50.8	8.4	0.8				
32		WILLIAMSON	47	35					310	300				†Hvab	2.9	39.2	51.9	6.0	2.9	5.5	75.6	1.3	8.7
33		U. ELKHORN #3	49	30					260	80				Hvab	3.4	35.8	57.4	3.4	0.5				
34		U. ELKHORN #2	42	35					310	190				Hvab	4.2	36.2	53.8	5.8	0.7				
35		U. ELKHORN #1	52	31					375	200				Hvab	4.1	37.0	53.4	5.5	1.6				
36		L. ELKHORN	43	33					400	250				†Hvab	3.5	38.7	49.3	8.5	2.3				
37		TOTAL				2	0																
38																							
39	BREATHITT	FLAG	50	27					90	60				†Hvab	4.5	35.4	52.9	7.2	0.7	5.4	73.9	1.6	11.2
40		HAZARD	62	37					110	60				†Hvab	5.1	35.5	52.9	6.5	0.7	5.5	73.7	1.6	12.0
41		HADDIX	52	27					140	60				†Hvab	4.7	38.5	51.0	5.8	1.3				
42		FIRECLAY	42	24					180	120				Hvab	5.6	34.0	53.3	7.1	1.0				
43		WHITESBURG	42	33					200	130				†Hvab	4.6	34.7	53.8	6.9	2.2				
44		U. ELKHORN #3	37	36					305	300				†Hvab	3.4	35.8	57.4	3.4	0.5				
45		TOTAL				2	0																
46																							
47	KNOTT	FLAG	54	27					180	60				†Hvab	4.5	35.4	52.9	7.2	0.7	5.4	73.9	1.6	11.2
48		HAZARD	44	39					215	105				†Hvab	5.1	35.5	52.9	6.5	0.7	5.5	73.7	1.6	12.0
49		FIRECLAY	45	29					275	160				†Hvab	3.9	37.0	55.1	4.0	0.7	5.6	77.4	1.7	10.6
50		WHITESBURG	39	31					175	155				†Hvab	4.6	34.7	53.8	6.9	2.2				
51		WILLIAMSON	40	29					325	260				†Hvab	2.9	39.2	51.9	6.0	2.9	5.5	75.6	1.3	8.7
52		U. ELKHORN #3	60	31					305	190				†Hvab	3.4	35.8	57.4	3.4	0.5				
53		U. ELKHORN #1	52	42					375	210				†Hvab	4.1	37.0	53.4	5.5	1.6				
54		L. ELKHORN	43	28					350	300				†Hvab	3.5	38.7	49.3	8.5	2.3				
55		TOTAL				2	0																
56																							
57	PERRY	FLAG	60	27					180	40				†Hvab	4.5	35.4	52.9	7.2	0.7	5.4	73.9	1.6	11.2
58		HAZARD	63	38					215	50				†Hvab	5.1	35.5	52.9	6.5	0.7	5.5	73.7	1.6	12.0
59		HADDIX	54	32					150	80				Hvab	6.1	35.0	53.0	5.9	0.6				
60		FIRECLAY	47	29					280	120				Hvab	3.9	37.0	55.1	4.0	0.7	5.6	77.4	1.7	10.6
61		WHITESBURG			29						190			†Hvab	4.6	34.7	53.8	6.9	2.2				
62		TOTAL				2	0																
63																							
64																							
65																							
66																							
67																							
68																							
69																							

Line	B.T.U. As Received	B.T.U. Moisture and Ash Free	Area of Unmined Coal (Acres)	Primary Reserves (Thousands of Tons) Underground Mining Measured Acres	Tons	Indicated Acres	Tons	Strip Mining Measured Acres	Tons	Indicated Acres	Tons
1	12,780	14,840	755			755	3,125	NONE		NONE	
2	13,090	14,870	3,469			525	2,835	"		"	
3			4,224			1,280	5,960	"		"	
4											
5	13,760	14,880	58,786	4,289	13,836	25,991	83,474	"		"	
6											
7	13,110	14,830	16,045	973	4,101	7,065	23,930	"		"	
8	13,910	15,540	3,872			3,456	9,253	"		"	
9	12,960	14,840	3,335					"		"	
10	13,590	15,360	2,432			1,312	3,636	"		"	
11	14,160	15,190	1,556			666	2,158	"		"	
12	13,450	14,880	14,272	211	646	4,608	15,459	"		"	
13			41,512	1,184	4,747	17,107	54,431	"		"	
14											
15	12,780	14,840	14,944	1,536	6,497	10,185	49,098	"		"	
16			11,186	768	3,202	4,774	18,543	"		"	
17	13,380	14,870	33,156	2,732	10,160	11,347	38,838	"		"	
18	13,660	15,000	49,714	4,365	18,843	15,559	66,104	"		"	
19											
20	13,710	14,900	74,485	16,027	58,898	25,845	87,231	"		"	
21											
22	14,280	15,270	134,701	18,036	71,766	62,943	237,236	"		"	
23	14,080	15,160	139,495	6,330	23,629	53,981	209,805	"		"	
24	14,290	15,370	179,719	23,327	102,955	104,990	481,227	"		"	
25											
26	14,130	15,480	53,946	3,500	11,553	19,552	73,407	"		"	
27			37,791			12,179	39,969	"		"	
28			729,137	76,621	307,503	321,235	1,296,458	"		"	
29											
30	13,110	14,830	2,816	90	437	2,201	9,551	"		"	
31	12,780	14,840	192					"		"	
32	13,660	15,000	4,219			2,087	8,710	"		"	
33	14,160	15,190	39,593	2,957	10,344	19,496	63,375	"		"	
34	13,440	14,930	30,581	935	3,197	10,208	35,324	"		"	
35	13,450	14,880	123,526	13,985	56,036	63,174	250,722	"		"	
36	13,090	14,870	76,474	9,036	33,169	36,468	123,672	"		"	
37			277,401	27,003	103,183	133,634	491,354	"		"	
38											
39	13,180	14,930	1,087					"		"	
40	13,110	14,830	6,368			1,139	3,793	"		"	
41	13,910	15,540	8,050					"		"	
42	12,960	14,840	7,002			1,344	4,234	"		"	
43	13,590	15,360	6,552			1,017	3,032	"		"	
44	14,160	15,190	3,277			3,277	10,788	"		"	
45			32,336			6,777	21,847	"		"	
46											
47	13,180	14,930	11,315	550	2,468	6,688	29,638	"		"	
48	13,110	14,830	2,648			1,644	6,014	"		"	
49	13,790	14,970	53,753	3,385	11,170	25,164	81,584	"		"	
50	13,590	15,360	3,175					"		"	
51	13,660	15,000	8,435	2,080	6,845	5,600	17,567	"		"	
52	14,160	15,190	82,457	1,369	6,563	36,788	128,653	"		"	
53	13,450	14,880	18,336	282	1,226	3,002	12,212	"		"	
54	13,090	14,870	32,493	1,690	6,540	10,451	39,565	"		"	
55			212,612	9,356	34,812	89,337	315,233	"		"	
56											
57	13,180	14,930	19,214	2,900	13,532	8,884	40,939	"		"	
58	13,110	14,830	28,264	2,605	11,722	14,245	63,715	"		"	
59	13,060	14,840	9,083			6,593	26,051	"		"	
60	13,790	14,970	81,682	9,600	32,961	33,293	113,607	"		"	
61	13,590	15,360	595					"		"	
62			138,838	15,105	59,215	63,015	244,312	"		"	
63											
64											
65											
66											
67											
68											
69											

Line	Secondary Reserves (Thousands of Tons) Underground Mining Measured Acres	Tons	Indicated Acres	Tons	Inferred Acres	Tons	Strip Mining Measured Acres	Tons	Indicated Acres	Tons	Inferred Acres	Tons	Co-ordinates
1	NONE						NONE		NONE		NONE		37°45' 82°20'
2	"				2,944	14,713	"		"		"		37°45,50' 82°25'; 37°40' 82°25,30'
3	"				2,944	14,713	"		"		"		
4													
5	"				28,506	92,311	"		"		"		37°50' 82°35-50'; 37°40,45' 82°40-55'
6													
7	"				8,007	26,494	"		"		"		37°30,35' 82°50,55'; 37°35' 83°00,05'
8	"				416	1,123	"		"		"		37°40' 83°00'; 37°35' 82°55'; 37°35' 83°00,10'
9	"				3,335	10,978	"		"		"		37°35,40' 83°00'
10	"				1,120	3,362	"		"		"		37°40' 82°55,83°00'; 37°35' 83°05,10'
11	"				890	2,563	"		"		"		37°30,40' 82°55'
12	"				9,453	25,920	"		"		"		37°40,45' 82°55'; 37°35,30' 82°50,55'
13	"				29,221	70,440	"		"		"		
14													
15	"				3,283	14,412	"		"		"		37°40' 82°15,20'; 37°35' 82°15-35'; 37°30' 82°10,15,25'; 37°25' 82°25'; 37°20' 82°30,35'; 37°15' 82°30'
16	"				5,644	18,612	"		"		"		37°35,40' 82°15,20'; 37°25' 82°05-25'
17	"				19,077	61,763	"		"		"		37°35,40' 82°20-30'; 37°30' 82°20-35'; 37°10,15' 82°40'
18	"		1,229	2,986	28,561	102,108	"		"		"		37°40' 82°15,20,30,35'; 37°35' 82°10-35'; 37°30' 82°05-25'; 37°25' 82°10'; 37°20' 82°35'
19													37°15' 82°25'
20	"				32,613	104,296	"		"		"		37°40' 82°15,20'; 37°35' 82°05-35'; 37°30' 82°05,10,20-35'; 37°25' 82°05,10,20-35'
21													37°20' 82°25-35'; 37°10,15' 82°30-40'
22	"		1,113	2,653	52,609	162,321	"		"		"		37°15' 82°10-35'; 37°25,30' 82°05-35'; 37°20' 82°15-35'; 37°15' 82°15-40'; 37°10' 82°30,35'
23	"				79,184	296,083	"		"		"		37°35' 82°05-30'; 37°30' 82°05-35'; 37°25' 82°00-35'; 37°20' 82°10-35'; 37°15' 82°15,25-40'
24	"				51,462	225,769	"		"		"		37°40' 82°15-20'; 37°35' 82°05-20'; 37°30' 82°00-30'; 37°25' 82°05-25'; 37°20' 82°10-30'
25													37°15' 82°20-30'; 37°10' 82°30,35'
26	"				30,894	110,948	"		"		"		37°25' 82°05-30'; 37°20' 82°05-25'; 37°15' 82°15,20'
27	"				25,612	76,483	"		"		"		37°25' 82°05-25'; 37°20' 82°10-25'; 37°15' 82°15-25'
28	"		2,342	5,639	328,939	1,172,795	"		"		"		
29													
30	"				535	2,126	"		"		"		37°30,35' 82°50'
31	"				192	881	"		"		"		37°20' 82°35'
32	"				2,132	7,366	"		"		"		37°20' 82°35,40'
33	"				17,140	57,478	"		"		"		37°40' 82°50,55'; 37°35' 82°35,45,50'; 37°30' 82°35,45'; 37°20,25' 82°35-45'; 37°15' 82°40'
34	"				19,438	68,368	"		"		"		37°30' 82°35'; 37°30' 82°35,40'; 37°25' 82°35'; 37°15,20' 82°35,40'
35	"				46,367	171,089	"		"		"		37°40' 82°40-55'; 37°35' 82°40-50'; 37°30,25' 82°35-50'; 37°20' 82°35-50'; 37°15' 82°40'
36	"				30,970	102,323	"		"		"		37°35' 82°40'; 37°30' 82°35-50'; 37°25' 82°35-55'; 37°20' 82°35-45'; 37°15' 82°40'
37	"				116,764	409,631	"		"		"		
38													
39	"				1,087	4,649	"		"		"		37°25' 83°05-20'; 37°20' 83°05'
40	"				5,229	21,499	"		"		"		37°35' 83°00,05'; 37°25-83°05-15'
41	"				8,050	26,143	"		"		"		37°35' 83°00-10'; 37°30' 83°00-15'; 37°25' 83°05,10,20'; 37°20' 83°20'
42	"				5,658	16,417	"		"		"		37°35' 83°05-15'; 37°30' 83°10,15'; 37°20' 83°20,25'
43	"				5,535	17,132	"		"		"		37°35,30' 83°05-15'
44	"						"		"		"		37°30' 82°55,83°00'
45	"				25,539	85,840	"		"		"		
46													
47	"				4,077	17,090	"		"		"		37°20,25' 83°05'; 37°15' 82°55-83°05'; 37°10' 82°55-83°05'
48	"				1,004	3,915	"		"		"		37°15-25' 83°05'
49	"				25,204	81,187	"		"		"		37°30' 83°00'; 37°25,20' 82°55'; 37°15-82°45-50'; 37°10' 82°50,55'; 37°15,10' 83°00,05'
50	"				3,125	9,524	"		"		"		37°15,10' 82°50,55'
51	"				755	3,918	"		"		"		37°15,10' 82°50,55'
52	"				44,300	151,668	"		"		"		37°30' 83°00'; 37°25,20' 82°45-55'; 37°15' 82°40-55'; 37°10' 82°50'; 37°20,25' 83°00'
53	"				15,052	59,909	"		"		"		37°25,20' 82°45,50'; 37°15' 82°40,45'
54	"				20,352	71,791	"		"		"		37°25' 82°45-55'; 37°20,15' 82°45,50'
55	"				113,919	399,012	"		"		"		
56													
57	"				7,490	34,060	"		"		"		37°20' 83°05-15'; 37°15' 83°05,10'; 37°10' 83°00-10'; 37°05' 83°05'
58	"				11,419	50,657	"		"		"		37°20' 83°05-25'; 37°15' 83°05-30'; 37°10' 83°05-15'; 37°00' 83°05,10'
59	"				2,490	10,558	"		"		"		37°20' 83°05-20'; 37°15' 83°05-15'
60	"				38,789	129,700	"		"		"		37°20,15' 83°05-25'; 37°10' 83°00-15'; 37°05' 83°00-10'; 37°00' 83°00,05'
61	"				595	1,553	"		"		"		37°20' 83°25'
62	"				60,718	226,528	"		"		"		
63													
64													
65													
66													
67													
68													
69													

SOURCES OF INFORMATION AND OTHER FOOTNOTES: * BASED ON AN ESTIMATED RECOVERY FACTOR OF 60 PER CENT FOR UNDERGROUND RESERVES IN PLACE

† NO ANALYSIS AVAILABLE - ESTIMATED FROM ADJOINING COUNTY

● AVERAGE ANALYSIS OF MINE SAMPLES OBTAINED BY STANDARD U. S. BUREAU OF MINES PROCEDURE.

SF-1266 7-3-51

SYNTHETIC LIQUID FUEL SURVEY

SUMMARY OF RECOVERABLE COAL RESERVES IN KENTUCKY*

CONSIDERED FOR SYNTHETIC LIQUID FUELS MANUFACTURE

BY COUNTIES AND BEDS

AS OF JANUARY 1, 1949

	COUNTY	BED	THICKNESS OF COAL (INCHES) MAX	MIN	AVE	DIP OF BED (DEGREES) MAX	MIN	AVE	THICKNESS OF COVER (FEET) UNDERGROUND MINING MAX	MIN	AVE	STRIP MINING MAX	AVE	RANK OF COAL
1	LETCHER	FIRECLAY	75	31					275	290				†Hvab
2		WHITESBURG	52	35					175	80				†Hvab
3		WILLIAMSON	52	32					575	230				†Hvab
4		U. ELKHORN #3	60	29					610	140				Hvab
5		U. ELKHORN #2	65	39					660	320				†Hvab
6		U. ELKHORN #1	51	36					525	500				†Hvab
7		L. ELKHORN	47	34					550	400				†Hvab
8		TOTAL				4	0							
9														
10	LESLIE	HAZARD	44	27					210	105				†Hvab
11		FIRECLAY RIDER	46	25					240	130				
12		FIRECLAY	47	28					300	100				†Hvab
13		WHITESBURG	46	28					240	160				†Hvab
14		WILLIAMSON	43	30					350	340				†Hvab
15		TOTAL				3	0							
16														
17	CLAY	FIRECLAY	46	32					275	120				†Hvab
18		U. ELKHORN #3			39				180	90				†Hvab
19		TOTAL				2	0							
20														
21	HARLAN	HIGH SPLINT	81	41					660	130				Hvab
22		HAZARD			38						200			†Hvab
23		FIRECLAY RIDER			30						225			
24		FIRECLAY	74	29					310	115				Hvab
25		WILLIAMSON	60	33					850	100				Hvab
26		U. ELKHORN #3	58	34					700	185				Hvab
27		U. ELKHORN #2	49	29					700	180				†Hvab
28		HARLAN	50	37					800	370				Hvab
29		TOTAL				5	0							
30														
31	BELL	HIGH SPLINT	57	55					125	110				Hvab
32		HIGNITE	46	44							300			Hvab
33		FIRECLAY	52	27					350	175				Hvab
34		WILLIAMSON	54	33					510	245				Hvab
35		HARLAN	50	39					400	100				Hvab
36		PUCKETT CREEK	55	32					150	100				
37		TOTAL				4	0							
38														
39	KNOX	FIRECLAY			42	3	0				300			Hvab
40														
41														
42														
43														
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	● ANALYSIS (AS RECEIVED) PROXIMATE: MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH	ULTIMATE: SULPHUR	HYDROGEN	CARBON	NITROGEN	OXYGEN	B.T.U. AS RECEIVED	B.T.U. MOISTURE AND ASH FREE	AREA OF UNMINED COAL (ACRES)
1	3.7	38.0	54.3	4.0	0.7					13,780	14,930	39,935
2	4.6	34.7	53.8	6.9	2.2					13,590	15,360	9638
3	3.7	37.8	54.3	4.2	0.7	5.6	76.9	1.4	11.2	13,830	15,020	14,617
4	3.3	36.4	56.3	3.5	0.7	5.6	79.2	1.6	9.4	14,100	15,130	48,170
5	2.9	35.7	57.8	3.6	0.9	5.6	79.6	1.5	8.8	14,280	15,270	9811
6	3.2	34.8	58.1	3.9	0.7	5.4	79.3	1.5	9.2	14,080	15,150	6,362
7	3.2	32.7	60.3	3.8	0.6	5.4	79.7	1.4	9.1	14,290	15,370	18,426
8												146,959
10	5.1	35.5	52.9	6.5	0.7	5.5	73.7	1.6	12.0	13,110	14,830	9,683
11	NO ANALYSIS AVAILABLE											18,848
12	3.7	38.0	54.3	4.0	0.7					13,780	14,930	69,676
13	4.6	34.7	53.8	6.9	2.2					13,590	15,360	7,142
14	3.7	37.8	54.3	4.2	0.7	5.6	76.9	1.4	11.2	13830	15,020	9,337
15												114,686
17	3.3	36.6	52.2	7.9	1.9	5.4	73.4	1.8	9.6	13,210	14,880	3641
18	2.8	36.2	56.8	4.2	0.7	5.5	79.2	1.5	8.9	14,170	15,240	10,580
19												14,221
21	4.4	37.1	53.8	4.7	0.7	5.5	76.0	1.4	11.7	13,490	14,840	19,883
22	5.1	35.5	52.9	6.5	0.7	5.5	73.7	1.6	12.0	13,110	14,830	3,898
23	NO ANALYSIS AVAILABLE											1,056
24	3.7	38.0	54.3	4.0	0.7					13,780	14,930	9,966
25	3.7	37.8	54.3	4.2	0.7	5.6	76.9	1.4	11.2	13,830	15,020	26,509
26	2.8	36.2	56.8	4.2	0.7	5.5	79.2	1.5	8.9	14,170	15,240	85,779
27	4.2	36.2	53.8	5.8	0.7					13,440	14,930	20,174
28	3.1	37.0	56.1	3.8	0.8	5.5	78.6	1.7	9.6	14050	15090	85,111
29												252,376
31	3.3	37.0	55.9	3.8	1.1	5.7	77.8	2.0	9.6	13,980	15,050	1,358
32	3.6	36.7	55.4	4.3	0.8	5.6	77.1	1.6	10.6	13,800	14,980	6,624
33	3.3	36.6	52.2	7.9	1.9	5.4	73.4	1.8	9.6	13,210	14,880	12,536
34	2.6	37.2	55.8	4.4	1.1	5.6	78.4	1.8	8.7	14,000	15,050	18,297
35	2.1	38.3	55.9	3.7	0.8	5.6	78.6	2.0	9.3	14,070	14,940	12,651
36	NO ANALYSIS AVAILABLE											9089
37												60,555
39	4.2	36.4	53.3	6.1	0.8	5.6	74.8	1.7	11.0	13,410	14,950	11,098

QUANTITY OF PRIMARY RESERVES (THOUSANDS OF TONS)

	UNDERGROUND MINING MEASURED ACRES	TONS	INDICATED ACRES	TONS	STRIP MINING MEASURED ACRES	TONS	INDICATED ACRES	TONS
1	2,201	7,599	18,265	61,466	NONE		NONE	
2	486	1,874	6,419	23,580	"		"	
3			1,715	6,245	"		"	
4	3,715	14,362	34,836	142,604	"		"	
5			4,134	22,012	"		"	
6			6,362	26,007	"		"	
7	429	1,951	7,962	27,335	"		"	
8	6,831	25,121	79,693	309,249	"		"	
10			3,750	13,898	"		"	
11	1,235	4,370	7,322	25,394	"		"	
12	5,907	22,111	29,254	98,075	"		"	
13			966	2,956	"		"	
14	1017	3,487	5,349	18,849	"		"	
15	8,159	29,968	46,636	159,172	"		"	
17					"		"	
18	1,165	4089	4,749	16,669	"		"	
19	1,165	4089	4,749	16,669	"		"	
21	3014	15,128	11,763	68,728	"		"	
22			2,413	8,314	"		"	
23			1,056	2,851	"		"	
24	224	1,169	4,109	17,862	"		"	
25	940	3,888	11,450	44,108	"		"	
26	4,275	20,186	32,443	135,224	"		"	
27			8,340	30,666	"		"	
28	15,544	63,184	43,832	171,381	"		"	
29	23,997	103,555	115,406	479,134	"		"	
31			250	1,283	"		"	
32			4083	16,418	"		"	
33			6,841	25,718	"		"	
34	2,893	11,542	6,304	22,861	"		"	
35	454	1,921	5,228	21,773	"		"	
36			5,460	19,614	"		"	
37	3,347	13,463	29,166	107,667	"		"	
39	1,005	3,799	4,755	17,974	"		"	

QUANTITY OF SECONDARY RESERVES (THOUSANDS OF TONS)

	UNDERGROUND MINING MEASURED ACRES	TONS	INDICATED ACRES	TONS	INFERRED ACRES	TONS	STRIP MINING MEASURED ACRES	TONS	INDICATED ACRES	TONS	INFERRED ACRES	TONS
1	NONE				19,469	65,712	NONE		NONE		NONE	
2	"				2,733	9,905	"		"		"	
3	"				12,902	45,156	"		"		"	
4	"				9,619	32,995	"		"		"	
5	"				5,677	30,484	"		"		"	
6	"						"		"		"	
7	"				10,035	32,323	"		"		"	
8	"				60,435	216,575	"		"		"	
10	"				5,933	16,992	"		"		"	
11	"				10,291	31,718	"		"		"	
12	"				34,515	95,839	"		"		"	
13	"				6,176	18,791	"		"		"	
14	"				2976	9,553	"		"		"	
15	"				59,891	172,893	"		"		"	
17	"				3,641	12,583	"		"		"	
18	"				4666	16,378	"		"		"	
19	"				8,307	28,961	"		"		"	
21	"				5,106	29,197	"		"		"	
22	"				1,485	5,079	"		"		"	
23	"						"		"		"	
24	"				5633	22,199	"		"		"	
25	"				14,119	58,748	"		"		"	
26	"				49,061	194,887	"		"		"	
27	"				11,834	44,029	"		"		"	
28	"				25,735	96,341	"		"		"	
29	"				112,973	450,475	"		"		"	
31	"				1,108	5,639	"		"		"	
32	"				2,541	10,208	"		"		"	
33	"				5695	20,614	"		"		"	
34	"				9,100	31,676	"		"		"	
35	"				6,969	28,826	"		"		"	
36	"				3629	10,451	"		"		"	
37	"				29,042	107,414	"		"		"	
39	"				5,338	20,177	"		"		"	

	CO-ORDINATES
1	37°55' 83°00'; 37°15' 82°40'-50'; 37°10' 82°40'-55'; 37°05' 82°45'-55'; 37°00' 82°55'; 37°00',10' 83°00'
2	37°10' 82°40'-50'; 37°05' 82°45'-55'
3	37°10' 82°35'-50'; 37°05' 82°45'-55'; 37°00' 82°45',50'; 36°55' 82°50'
4	37°15' 82°40'-50'; 37°10' 82°35'-50'; 37°05' 82°45',50'; 37°00' 82°40'-50'; 36°55' 82°50'
5	37°10' 82°35',40'; 36°55' 82°50'
6	37°00' 82°40'-50'; 37°55' 82°50'
7	37°10' 82°35'; 37°00' 82°45',50'
10	37°10' 83°10',15'; 37°05' 83°10'-20'; 37°00' 83°10'-15'; 36°55' 83°10'-20'
11	37°10' 83°10'-20'; 37°05' 83°10'-25'; 37°00' 83°10',15',25'; 36°55' 83°15',20'
12	37°55' 83°15'-30'; 37°50' 83°25'; 37°15' 83°20',25'; 37°10'-00' 83°10'-30'
13	37°10' 83°15',20'; 37°00' 83°20',25'
14	37°10',05' 83°15',20'
17	37°55' 83°30',35'; 37°05',10' 82°30'; 37°00' 82°30',35'
18	37°05',10' 83°45'; 37°05' 83°50'
21	36°55',50' 82°50',55'; 36°55' 83°00',05'; 36°50' 83°00',10'
22	36°55' 83°10'
23	36°55' 83°15'
24	37°55' 83°10',15'; 37°50' 83°00',05',15'; 37°45' 83°15'-25'; 37°40' 83°15',20'
25	36°55',50' 82°50',55'; 36°55' 83°00',05'; 36°50' 83°00'-15'; 36°45' 83°10',15'; 36°40' 83°25'
26	36°55',50' 82°50',55'; 36°55' 83°00',05'; 36°50' 83°00'-15'; 36°45' 83°05'-25'; 36°40' 83°15'-25'
27	36°55' 82°50',55'; 36°50' 82°55'; 36°55',50' 83°00',05'
28	36°55' 82°55',83°00',05'; 36°50' 83°00'-20'; 36°45' 83°05'-25'; 36°40' 83°15'-25'
31	36°35' 83°45',50'
32	36°35' 83°45',50'
33	37°55' 83°30'; 37°45' 83°25'; 37°40' 83°40'-50'; 37°35' 83°45',50'
34	36°45' 83°30'; 36°40' 83°25',30',45'; 36°35' 83°40',45'; 36°45' 83°50'
35	36°45' 83°25',30'; 36°40' 83°25'-35'; 36°35' 83°35',45'
36	36°45' 83°25',30'; 36°40' 83°30',35'; 36°35' 83°30',35'
39	37°45' 83°50'; 37°40' 83°50',55'

SOURCES OF INFORMATION AND OTHER FOOTNOTES: * BASED ON AN ESTIMATED RECOVERY FACTOR OF 60 PER CENT FOR UNDERGROUND RESERVES IN PLACE.
† NO ANALYSIS AVAILABLE - ESTIMATED FROM ADJOINING COUNTY
● AVERAGE ANALYSIS OF MINE SAMPLES OBTAINED BY STANDARD U. S. BUREAU OF MINES PROCEDURE

SYNTHETIC LIQUID FUEL SURVEY

SUMMARY OF RECOVERABLE COAL RESERVES IN KENTUCKY*

CONSIDERED FOR SYNTHETIC LIQUID FUELS MANUFACTURE

BY COUNTIES AND BEDS

AS OF JANUARY 1, 1949

	COUNTY	BED	THICKNESS OF COAL (INCHES) MAX	MIN	AVE	DIP OF BED (DEGREES) MAX	MIN	AVE	THICKNESS OF COVER (FEET) UNDERGROUND MINING MAX	MIN	AVE	STRIP MINING MAX	AVE	RANK OF COAL	● ANALYSIS (AS RECEIVED) PROXIMATE: MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH	SULPHUR	ULTIMATE: HYDROGEN	CARBON	NITROGEN	OXYGEN	B.T.U. AS RECEIVED	B.T.U. MOISTURE AND ASH FREE	AREA OF UNMINED COAL (ACRES)
1	DAVIESS	#9	53	46		2	0		95	30		65	45	Hvcb	12.1	36.1	40.1	11.7	3.0	5.5	60.5	1.2	18.1	10,790	14,160	19,500
2																										
3	HENDERSON	#14			57				185	180				Hvcb	11.8	32.9	46.1	9.2	2.0	5.5	63.8	1.4	18.1	11,300	14,300	16,948
4		#11			54				100	55				†Hvbb	8.7	38.1	43.4	9.8	3.9	5.4	64.6	1.3	15.0	11,710	14,370	4493
5		#9	54	42					310	50				Hvcb	10.5	35.0	41.0	13.5	3.6					10900	14,340	112,075
6		TOTAL				2	0																			133,516
7																										
8	UNION	#11	60	45					225	80				Hvbb	8.7	38.1	43.4	9.8	3.9	5.4	64.6	1.3	15.0	11,710	14,370	62,701
9		#9	60	48					450	300				Hvab	3.9	36.8	49.0	10.3	3.7	5.2	70.4	1.5	8.9	12,740	14,850	73,736
10		#6	66	45					545	50				Hvab	4.5	36.6	50.7	8.2	2.6	5.4	72.3	1.6	9.9	13020	14910	9,644
11		TOTAL				3	0																			146,081
12																										
13	OHIO	#14	108	39					70	40		75	40	Hvcb	9.9	37.5	43.0	9.6	4.7	5.5	63.1	1.4	15.7	11,490	14,270	5638
14		#11	85	31					80	30				†Hvbb	6.1	41.0	45.2	7.7	4.1	5.6	69.3	1.3	12.0	12,570	14,580	6,271
15		#9	61	48					290	40		75	40	Hvbb	9.8	36.4	44.6	9.2	2.9	5.6	65.2	1.4	15.7	11,660	14,390	67,117
16		ELMLICK	42	32					100	35					No Analysis Available											7079
17		TOTAL				2	0																			86,105
18	Mc LEAN	#14	64	54					70	45				†Hvcb	10.9	34.6	47.5	7.0	2.4	5.9	65.2	1.5	18.0	11,790	14,360	2,701
19		#11	57	42					300	265				†Hvbb	6.1	41.0	45.2	7.7	4.1	5.6	69.3	1.3	12.0	12,570	14,580	17,415
20		#9	61	46					410	30				Hvbb	9.7	36.9	43.8	9.6	3.3	5.6	64.2	1.3	16.0	11,690	14,480	14,772
21		TOTAL				3	0																			34,888
22																										
23	WEBSTER	#14	86	57					465	125				Hvab	5.9	35.3	52.0	6.8	1.5	5.7	72.7	1.6	11.7	12,930	14,810	25,280
24		#12			60							75	40	Hvbb	5.4	34.9	50.4	9.3	1.1	5.1	70.4	1.6	12.5	12,500	14,650	467
25		#11	72	48					300	50		90	50	Hvbb	5.2	38.0	47.1	9.7	4.0	5.3	68.8	1.4	10.8	12,480	14,660	25,676
26		#9	64	46					450	85		75	45	Hvbb	6.3	36.7	47.2	9.8	3.6	5.4	67.8	1.4	12.0	12,260	14,610	139,866
27		#6			48				115	80				Hvab	5.4	35.9	50.2	8.5	3.2	5.4	70.8	1.4	10.7	12,750	14,810	4634
28		TOTAL				3	0																			195,923
29																										
30	BUTLER	ELMLICK	44	29		3	0		45	35					No Analysis Available											5466
31																										
32	MUHLENBERG	#14	79	30					65	30				Hvcb	10.9	34.6	47.5	7.0	2.4	5.9	65.2	1.5	18.0	11,790	14,360	5855
33		#12	66	30								75	20	Hvbb	8.4	34.9	42.4	14.3	3.8					11,040	14,280	4,173
34		#11	75	51					285	45		80	35	Hvbb	6.1	41.0	45.2	7.7	4.1	5.6	69.3	1.3	12.0	12,570	14,580	77,417
35		#9	66	47					395	30		75	40	Hvbb	9.1	36.7	45.0	9.2	3.4	5.6	65.3	1.4	15.1	11,810	14,450	118,787
36		#6	48	37					50	40		60	25	Hvbb	7.6	39.1	48.2	5.1	3.4	5.8	70.7	1.6	13.4	12,800	14,660	7,199
37		TOTAL				3	0																			213,431
38	HOPKINS	#14	72	57					360	50				Hvbb	8.9	35.3	47.4	8.4	2.8	5.4	67.2	1.5	14.7	11,920	14,410	12,627
39		#12	78	30								75	20	†Hvbb	8.4	34.9	42.4	14.3	3.8					11,040	14,280	3162
40		#11	79	48					315	40		90	20	Hvbb	8.2	38.4	45.7	7.7	3.2	5.7	67.6	1.3	14.5	12,170	14,470	121,631
41		#9	65	47					410	50		80	40	Hvbb	8.4	36.6	44.9	10.1	3.3	5.5	65.6	1.3	14.2	11,780	14,450	139,345
42		#6	51	36					80	30		60	20	Hvbb	9.7	36.3	47.2	6.8	2.7	5.8	67.5	1.6	15.6	12,200	14,610	30,183
43		TOTAL				3	0																			306,951
44																										
45	CHRISTIAN	#6	43	36		3	0		70	30		50	30	Hubb	10.7	35.6	49.8	3.9	1.9	5.9	69.8	1.7	16.8	12,440	14,570	7,263
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	QUANTITY OF PRIMARY RESERVES (THOUSANDS OF TONS) UNDERGROUND MINING MEASURED ACRES	TONS	INDICATED ACRES	TONS	STRIP MINING MEASURED ACRES	TONS	INDICATED ACRES	TONS	QUANTITY OF SECONDARY RESERVES (THOUSANDS OF TONS) UNDERGROUND MINING MEASURED ACRES	TONS	INDICATED ACRES	TONS	INFERRED ACRES	TONS	STRIP MINING MEASURED ACRES	TONS	INDICATED ACRES	TONS	INFERRED ACRES	TONS	QUANTITY DEPLETED BY PREVIOUS MINING ACRES	TONS	ANNUAL PRODUCTION (TONS)	CO-ORDINATES	
1	3,136	12,194	8902	33580	1,485	6,916			NONE		NONE		5977	23877	NONE		NONE		NONE					37°45'-87°10',15'; 37°40'-87°15'-20'; 37°35'-87°05'-10'	1
3			16,948	72,453					"		"				"		"		"					37°45'-87°35'-45'; 37°40'-87°35',40'	3
4									"		"		4493	18,197	"		"		"					37°35',40'-87°30'	4
5			43,378	157,480					"		"		68,697	250,141	"		"		"					37°50'-87°20'-30'; 37°45'-87°15'-40'; 37°40'-87°15'-40'; 37°35'-87°30'-40'	5
6			60,326	229,933					"		"		73,190	268,338	"		"		"						6
8			36,959	145,089					"		"		25,742	100,638	"		"		"					37°45'-87°50',55'; 37°40'-87°50',55',88°00'; 37°35'-87°50',55',88°00'	8
9	5,401	23016	31,088	132,726					"		"		37,247	155,537	"		"		"					37°45'-87°45',55'; 37°40'-87°45',50',55',88°00'; 37°35'-87°45'-55',88°00'; 37°30'-87°45'-55',88°00'	9
10			9644	42465					"		"				"		"		"					37°45'-87°50'-55'; 37°40'-87°50',55'; 37°30'-88°00'	10
11	5,401	23016	77691	320280					"		"		62989	256,195	"		"		"						11
13			1,279	19068			4359	158,421	"		"				"		"		"					37°25'-87°00',05'; 37°20'-87°00',15'	13
14			6,271	27,759					"		"				"		"		"					37°20',25'-86°55'; 37°15'-86°50',55'	14
15	4,946	19,153	37,388	146,525			7,291	34577	"		"		17,492	73440	"		"		"					37°25'-87°00',05',86°55'; 37°20'-87°00',05',86°50',55'; 37°15'-87°05',86°50',55',87°10'	15
16			7079	20,192					"		"				"		"		"					37°25'-86°40'-50'; 37°20'-86°40',50' [86°50',55']	16
17	4,946	19,153	52017	243544			11,650	192998	"		"		17,492	73440	"		"		"						17
18			2701	12,725					"		"				"		"		"					37°25'-87°15'; 37°20'-87°10'	18
19			4,115	16,590					"		"		13,300	48,848	"		"		"					37°20',25'-87°10',15'	19
20	2,298	9,135	7,513	30,510					"		"		4,961	19,812	"		"		"					37°35'-87°15'; 37°30'-87°15',20'; 37°25'-87°05'-20'; 37°20'-87°05'-15'	20
21	2,298	9,135	14329	59825					"		"		18,261	68660	"		"		"						21
23			25,280	137,907					"		"				"		"		"					37°35'-87°40'; 37°30'-87°45',50'; 37°25'-87°40'-50'; 37°20'-87°40',45'	23
24							467	2,522	"		"				"		"		"					37°20',25'-87°45'	24
25	4,313	21,752	14010	67008			787	5,035	"		"		6,566	28,672	"		"		"					37°35'-87°30'; 37°30'-87°45',50'; 37°25'-87°30'-50'; 37°20'-87°40',45'	25
26	6,567	28,880	32,441	132,819			1,383	7,144	"		"		99,475	386,249	"		"		"					37°35'-87°30'-40'; 37°25',30'-87°30'-50'; 37°20'-87°40'-45'	26
27			4634	16682					"		"				"		"		"					37°25'-87°35',50'; 37°20'-87°45'	27
28	10,880	50,633	76,365	354,416			2,637	14,701	"		"		106,041	414,921	"		"		"						28
30			5466	12,862					"		"				"		"		"					37°10',15'-86°45',40'	30
32			5030	29,598					"		"		825	2,685	"		"		"					37°15'20'-87°45'; 37°15'-87°10'	32
33							4,173	18,182	"		"				"		"		"					37°15'-87°05'-20'; 37°10'-87°00',05',15',20'	33
34	3,123	15,566	35016	159314			6,964	40,557	"		"		32,314	137,918	"		"		"					37°10',15'-86°55'; 37°00'-87°00'-20'; 37°15'-87°00'-20'; 37°20'-87°00'-20'; 37°10'-87°00',05',15',20'	34
35	21,248	96,980	57982	260,198			985	5,401	"		"		38,572	169,028	"		"		"					37°10',15'-86°55'; 37°10'-87°00'-20'; 37°05'-87°00',05'	35
36			5580	16,862			1619	5,233	"		"				"		"		"					37°10'-87°00',10',86°55'	36
37	24,371	112,546	103,608	465,772			13,741	69,873	"		"		71,711	309,641	"		"		"						37
38			12,627	64,310					"		"				"		"		"					37°25'-87°40'; 37°20'-87°35',40'	38
39							3,162	15,619	"		"				"		"		"					37°20'-87°35',40'; 37°15'-87°20'-35'; 37°10'-87°05'-35'	39
40	5848	32,940	60,690	313,579			5260	32,722	"		"		49,836	227,305	"		"		"					37°25'-87°30'-40'; 37°20'-87°25'-40'; 37°15'-87°20'-35'	40
41	12,979	50,644	53,694	231,081			3962	20,510	"		"		68,710	286,030	"		"		"					37°25'-87°00',25',35'-40'; 37°20'-87°15'-45'; 37°15'-87°20'-45'; 37°10'-87°20'-35'	41
42			23,294	72,874			6,899	24,170	"		"				"		"		"					37°15'-87°35',40'; 37°10'-87°20',30'-40'; 37°05'-87°20'-35'	42
43	18,827	83,584	150,295	681,844			19,263	93,021	"		"		118,546	513,335	"		"		"						43
45			6,412	29,015			851	3,217	"		"				"		"		"					37°05'-87°25'-35'; 37°00'-87°25',30'	45

SOURCES OF INFORMATION AND OTHER FOOTNOTES: * BASED ON ESTIMATED RECOVERY FACTORS OF 50 PER CENT FOR UNDERGROUND RESERVES IN PLACE; 60 PER CENT FOR STRIPPABLE RESERVES IN PLACE

† NO ANALYSIS AVAILABLE - ESTIMATED FROM ADJOINING COUNTY

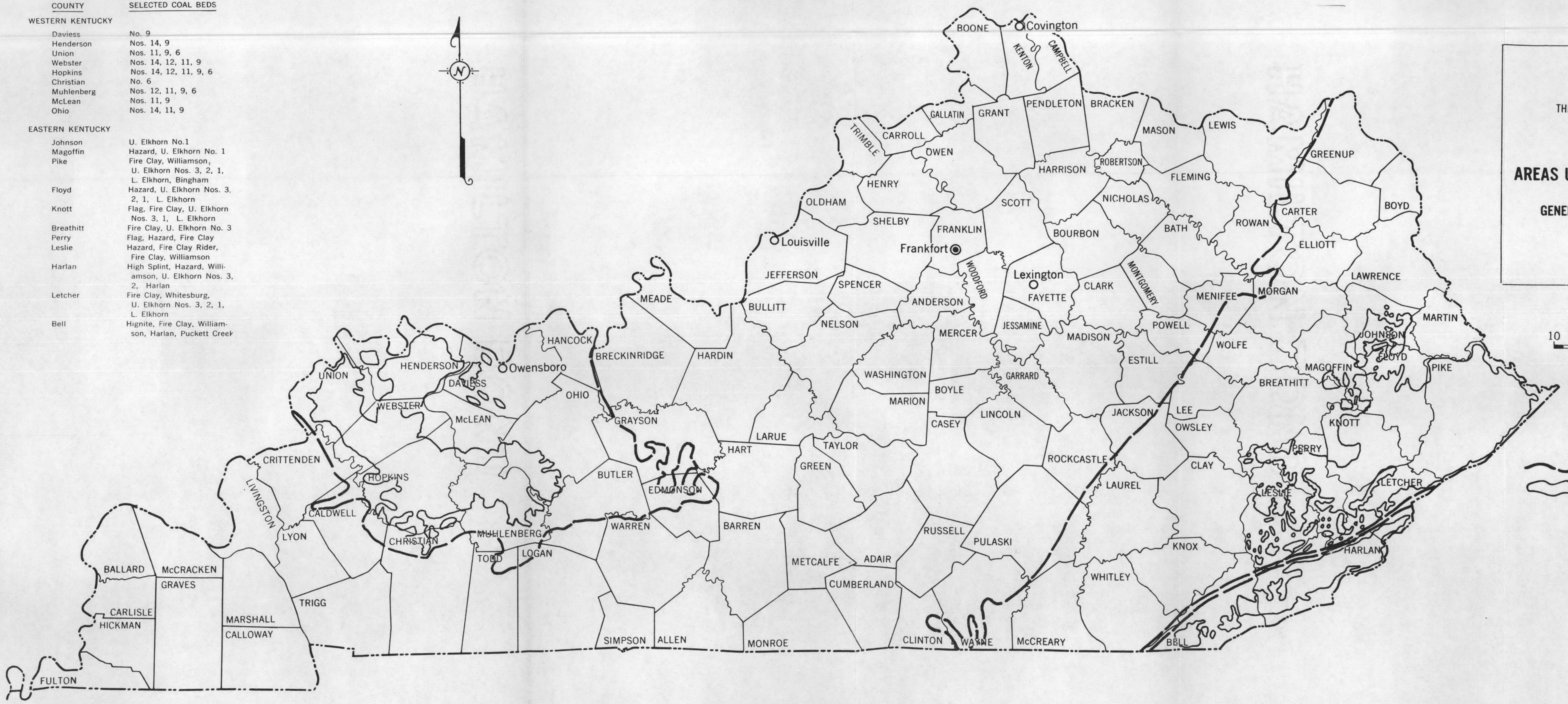
● AVERAGE ANALYSIS OF MINE SAMPLES OBTAINED BY STANDARD U. S. BUREAU OF MINES PROCEDURE

EXHIBIT NO. 8

REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY
AREAS UNDERLAIN BY COAL RESERVES
SELECTED FOR INCLUSION IN GENERAL AREAS OF COAL AVAILABILITY

Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK CHICAGO PHILADELPHIA LOS ANGELES

COUNTY	SELECTED COAL BEDS
WESTERN KENTUCKY	
Daviess	No. 9
Henderson	Nos. 14, 9
Union	Nos. 11, 9, 6
Webster	Nos. 14, 12, 11, 9
Hopkins	Nos. 14, 12, 11, 9, 6
Christian	No. 6
Muhlenberg	Nos. 12, 11, 9, 6
McLean	Nos. 11, 9
Ohio	Nos. 14, 11, 9
EASTERN KENTUCKY	
Johnson	U. Elkhorn No.1
Magoffin	Hazard, U. Elkhorn No. 1
Pike	Fire Clay, Williamson, U. Elkhorn Nos. 3, 2, 1, L. Elkhorn, Bingham
Floyd	Hazard, U. Elkhorn Nos. 3, 2, 1, L. Elkhorn
Knott	Flag, Fire Clay, U. Elkhorn Nos. 3, 1, L. Elkhorn
Breathitt	Fire Clay, U. Elkhorn No. 3
Perry	Flag, Hazard, Fire Clay
Leslie	Hazard, Fire Clay Rider, Fire Clay, Williamson
Harlan	High Splint, Hazard, Williamson, U. Elkhorn Nos. 3, 2, Harlan
Letcher	Fire Clay, Whitesburg, U. Elkhorn Nos. 3, 2, 1, L. Elkhorn
Bell	Hignite, Fire Clay, Williamson, Harlan, Puckett Creek



SCALE OF MILES
10 0 10 20 30 40

LEGEND
Boundary of Kentucky Coal Measures
Area Underlain by Coal Reserves

SF-1567 8-16-51

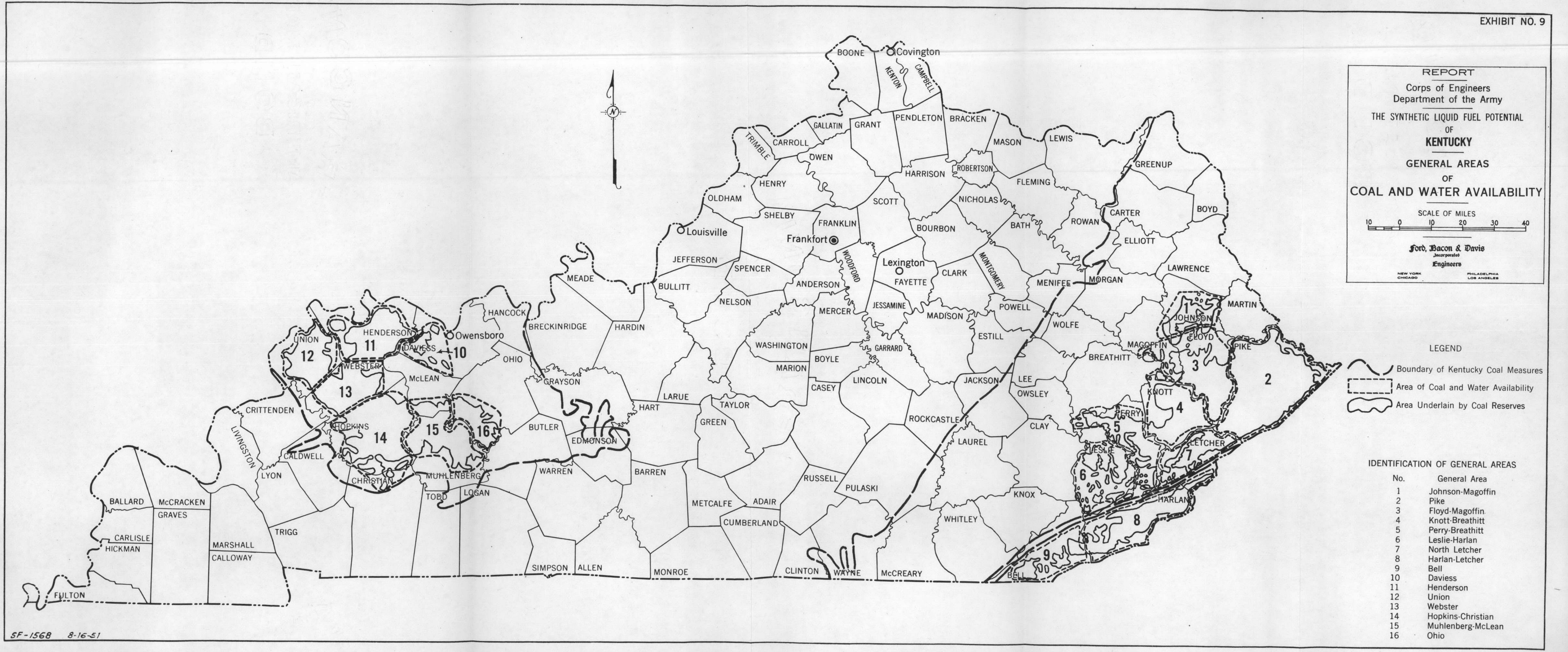


EXHIBIT NO. 9
REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY
GENERAL AREAS
OF
COAL AND WATER AVAILABILITY
SCALE OF MILES
10 0 10 20 30 40
Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK CHICAGO PHILADELPHIA LOS ANGELES
LEGEND
Boundary of Kentucky Coal Measures
Area of Coal and Water Availability
Area Underlain by Coal Reserves
IDENTIFICATION OF GENERAL AREAS
No. General Area
1 Johnson-Magoffin
2 Pike
3 Floyd-Magoffin
4 Knott-Breathitt
5 Perry-Breathitt
6 Leslie-Harlan
7 North Letcher
8 Harlan-Letcher
9 Bell
10 Daviess
11 Henderson
12 Union
13 Webster
14 Hopkins-Christian
15 Muhlenberg-McLean
16 Ohio
Covington
Louisville
Frankfort
Lexington
Owensboro
BOONE
KENTON
CAMPBELL
GALLATIN
GRANT
PENDLETON
BRACKEN
MASON
LEWIS
TRIMBLE
CARROLL
OWEN
ROBERTSON
HARRISON
FLEMING
GREENUP
HENRY
OLDHAM
SCOTT
NICHOLAS
BOYD
CARTER
SHELBY
FRANKLIN
BOURBON
BATH
ROWAN
ELLIOTT
JEFFERSON
SPENCER
WOODFORD
FAYETTE
CLARK
MONTGOMERY
LAWRENCE
MEADE
BULLITT
ANDERSON
MENIFEE
MORGAN
NELSON
MERCER
JESSAMINE
MADISON
POWELL
MARTIN
HANCOCK
BRECKINRIDGE
HARDIN
WOLFE
JOHNSON
HENDERSON
DAVIESS
UNION
WASHINGTON
GARRARD
ESTILL
MAGOFFIN
FLOYD
PIKE
WEBSTER
OHIO
MARION
BOYLE
BREATHITT
McLEAN
GRAYSON
CASEY
LINCOLN
JACKSON
LEE
KNOTT
OWSLEY
CRITTENDEN
LARUE
HART
TAYLOR
ROCKCASTLE
PERRY
HOPKINS
BUTLER
GREEN
LAUREL
CLAY
LIVINGSTON
EDMONSON
LESLIE
LETCHER
CALDWELL
LYON
WARREN
BARREN
RUSSELL
MUHLENBERG
CHRISTIAN
PULASKI
KNOX
BALLARD
McCRACKEN
TODD
LOGAN
METCALFE
ADAIR
HARLAN
GRAVES
CUMBERLAND
WHITLEY
TRIGG
CARLISLE
HICKMAN
MARSHALL
CALLOWAY
SIMPSON
ALLEN
MONROE
CLINTON
WAYNE
McCREARY
BELL
FULTON
SF-1568 8-16-51

General Areas of Coal Availability

Johnson-Magoffin General Area
(As of January 1, 1949)

	Coal Bed: Upper Elkhorn No. 1		
County	Johnson	Magoffin	Totals and/or Weighted Averages
Portion of County	Southern	East-central	
Maximum Thickness of Coal Bed (inches)	47	-	
Minimum " " " " "	34	-	
Average " " " " "		34	
Maximum Dip of Bed (degrees)	2	2	
Minimum " " " "	0	0	
Maximum Overburden Thickness (feet)	245	245	
Minimum " " "	160	200	
Rank (A)	Hvab	Hvab	
Analysis: (B)			
Moisture	4.8%	4.1%	4.7%
Volatile Matter	36.7	37.0	36.7
Fixed Carbon	55.8	53.4	55.6
Ash	2.7	5.5	3.0
Sulfur	1.2%	1.6%	1.2%
Btu, as received	13,760	13,450	13,730
Btu, moisture- and ash-free	14,880	14,830	14,880
Area Underlain by Reserves (acres)	58,786	7,494	65,000
Estimated Recoverable Reserves (1,000 tons):			
Primary Underground	97,310	9,066	106,376
Primary Strip	-	-	-
Primary Total	97,310	9,066	106,376
Secondary Underground	92,311	13,865	106,176
Secondary Strip	-	-	-
Secondary Total	92,311	13,865	106,176
Total Underground	189,621	22,931	212,552
Total Strip	-	-	-
Total Underground and Strip	189,621	22,931	212,552

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	41	-	41
Coal Synthine Process " " "	32	-	32

Note: (A) High-volatile A bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.

General Areas of Coal Availability

Pike General Area
(As of January 1, 1949)

	Coal Bed							
	Fire Clay	William-son	Upper Elkhorn No. 3	Upper Elkhorn No. 2	Upper Elkhorn No. 1	Lower Elkhorn	Bingham	Totals and/or Weighted Averages
County	Pike	Pike	Pike	Pike	Pike	Pike	Pike	
Portion of County	Northern	NE.	Total	Total	Total	SE.	Southern	
Maximum Thickness of Coal Bed (inches)	49	57	73	73	61	69	58	
Minimum " " " " "	30	24	27	26	28	36	30	
Maximum Dip of Bed (degrees)	2	2	2	2	2	2	2	
Minimum " " " "	0	0	0	0	0	0	0	
Maximum Overburden Thickness (feet)	275	310	275	340	400	450	350	
Minimum " " "	70	30	40	50	100	100	80	
Rank (A)	Hvab	Hvab	Hvab	Hvab	Hvab	Hvab	Hvab	
Analysis: (B)								
Moisture	4.5%	2.9%	3.8%	2.9%	3.2%	3.2%	1.1%	3.1%
Volatile Matter	36.4	39.2	37.0	35.7	34.8	32.7	34.4	34.9
Fixed Carbon	53.6	51.9	55.0	57.8	58.1	60.3	56.9	57.7
Ash	5.5	6.0	4.2	3.6	3.9	3.8	7.6	4.3
Sulfur	0.8%	2.9%	1.0%	0.9%	0.7%	0.6%	1.9%	1.0%
Btu, as received	13,380	13,660	13,710	14,280	14,080	14,290	14,130	14,090
Btu, moisture- and ash-free	14,870	15,000	14,900	15,270	15,160	15,370	15,480	15,220
Area Underlain by Reserves (acres)	33,156	49,714	74,485	134,701	139,495	179,719	53,946	325,000
Estimated Recoverable Reserves (1,000 tons):								
Primary Underground	48,998	84,947	146,129	309,002	233,434	584,182	84,960	1,491,652
Primary Strip	-	-	-	-	-	-	-	-
Primary Total	48,998	84,947	146,129	309,002	233,434	584,182	84,960	1,491,652
Secondary Underground	61,763	105,094	104,296	164,974	296,083	225,769	110,948	1,068,927
Secondary Strip	-	-	-	-	-	-	-	-
Secondary Total	61,763	105,094	104,296	164,974	296,083	225,769	110,948	1,068,927
Total Underground	110,761	190,041	250,425	473,976	529,517	809,951	195,908	2,560,579
Total Strip	-	-	-	-	-	-	-	-
Total Underground and Strip	110,761	190,041	250,425	473,976	529,517	809,951	195,908	2,560,579

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	504	-	504
Coal Synthine Process " " "	392	-	392

Note: (A) High-volatile A bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.

Ky

70021

General Areas of Coal Availability

Floyd-Magoffin General Area
(As of January 1, 1949)

	Coal Bed							
	Hazard		Upper Elkhorn No. 3	Upper Elkhorn No. 2	Upper Elkhorn No. 1		Lower Elkhorn	
County	Magoffin	Floyd	Floyd	Floyd	Magoffin	Floyd	Floyd	Totals and/or Weighted Averages
Portion of County	Southern	Western	Southern	SE.	SE.	Total	Southern	
Maximum Thickness of Coal Bed (inches)	54	54	49	42	44	52	43	
Minimum " " " " "	33	45	30	35	30	31	33	
Maximum Dip of Bed (degrees)	2	2	2	2	2	2	2	
Minimum " " " "	0	0	0	0	0	0	0	
Maximum Overburden Thickness (feet)	140	140	260	310	225	375	400	
Minimum " " "	100	105	80	190	200	200	250	
Rank (A)	Hvab	Hvab	Hvab	Hvab	Hvab	Hvab	Hvab	
Analysis: (B)								
Moisture	5.1%	5.1%	3.4%	4.2%	4.1%	4.1%	3.5%	3.9%
Volatile Matter	35.5	35.5	35.8	36.2	37.0	37.0	38.7	37.1
Fixed Carbon	52.9	52.9	57.4	53.8	53.4	53.4	49.3	52.9
Ash	6.5	6.5	3.4	5.8	5.5	5.5	8.5	6.1
Sulfur	0.7%	0.7%	0.5%	0.7%	1.6%	1.6%	2.3%	1.5%
Btu, as received	13,110	13,110	14,160	13,440	13,450	13,450	13,090	13,430
Btu, moisure- and ash-free	14,830	14,830	15,190	14,930	14,880	14,880	14,870	14,920
Area Underlain by Reserves (acres)	16,045	2,816	39,593	30,581	6,778	123,526	76,474	150,000
Estimated Recoverable Reserves (1,000 tons):								
Primary Underground	28,031	9,988	73,719	38,521	7,034	306,758	156,841	620,892
Primary Strip	-	-	-	-	-	-	-	-
Primary Total	28,031	9,988	73,719	38,521	7,034	306,758	156,841	620,892
Secondary Underground	26,494	2,126	57,478	68,368	12,055	171,089	102,323	439,933
Secondary Strip	-	-	-	-	-	-	-	-
Secondary Total	26,494	2,126	57,478	68,368	12,055	171,089	102,323	439,933
Total Underground	54,525	12,114	131,197	106,889	19,089	477,847	259,164	1,060,825
Total Strip	-	-	-	-	-	-	-	-
Total Underground and Strip	54,525	12,114	131,197	106,889	19,089	477,847	259,164	1,060,825

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	199	-	199
Coal Synthine Process " " "	155	-	155

Note: (A) High-volatile A bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.

Ky

70021

General Areas of Coal Availability

Knott-Breathitt General Area
(As of January 1, 1949)

	Coal Bed: Flag	Coal Bed: Fire Clay	Coal Bed: Upper Elkhorn No. 3		Coal Bed: Upper Elkhorn No. 1	Coal Bed: Lower Elkhorn	Totals and/or Weighted Averages
County	Knott	Knott	Breathitt	Knott	Knott	Knott	
Portion of County	SW.	Southern	Eastern	NE.	NE.	NE.	
Maximum Thickness of Coal Bed (inches)	54	45	37	60	52	43	
Minimum " " " " "	27	29	36	31	42	28	
Maximum Dip of Bed (degrees)	2	2	2	2	2	2	
Minimum " " " "	0	0	0	0	0	0	
Maximum Overburden Thickness (feet)	180	275	305	305	375	350	
Minimum " " "	60	160	300	190	210	300	
Rank (A)	Hvab	Hvab	Hvab	Hvab	Hvab	Hvab	
Analysis: (B)							
Moisture	4.5%	3.9%	3.4%	3.4%	4.1%	3.5%	3.7%
Volatile Matter	35.4	37.0	35.8	35.8	37.0	38.7	36.6
Fixed Carbon	52.9	55.1	57.4	57.4	53.4	49.3	54.8
Ash	7.2	4.0	3.4	3.4	5.5	8.5	4.9
Sulfur	0.7%	0.7%	0.5%	0.5%	1.6%	2.3%	1.0%
Btu, as received	13,180	13,790	14,160	14,160	13,450	13,090	13,750
Btu, moisture- and and ash-free	14,930	14,970	15,190	15,190	14,880	14,870	15,030
Area Underlain by Reserves (acres)	11,315	53,753	3,277	82,457	18,336	32,493	135,000
Estimated Recoverable Reserves (1,000 tons):							
Primary Underground	32,106	92,754	10,788	135,216	13,438	46,105	330,407
Primary Strip	-	-	-	-	-	-	-
Primary Total	32,106	92,754	10,788	135,216	13,438	46,105	330,407
Secondary Underground	17,090	81,197	-	151,668	59,909	71,791	381,655
Secondary Strip	-	-	-	-	-	-	-
Secondary Total	17,090	81,197	-	151,668	59,909	71,791	381,655
Total Underground	49,196	173,951	10,788	286,884	73,347	117,896	712,062(E)
Total Strip	-	-	-	-	-	-	-
Total Underground and Strip	49,196	173,951	10,788	286,884	73,347	117,896	660,814(D)

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	127	-	127
Coal Synthine Process " " "	99	-	99

Note: (A) High-volatile A bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.
(D) Total primary and secondary coal reserves for synthetic liquid fuels plant supply limited by definition to twice the primary reserves.
(E) Usable coal will be only 660,814 tons due to above limitations in (D).

General Areas of Coal Availability

Perry-Breathitt General Area
(As of January 1, 1949)

	Coal Bed				
	Flag	Hazard	Fire Clay		
County	Perry	Perry	Breathitt	Perry	Totals and/or Weighted Averages
Portion of County	Central	North-central	SW.	Total	
Maximum Thickness of Coal Bed (inches)	60	63	35	47	
Minimum " " " "	27	38	29	29	
Maximum Dip of Bed (degrees)	2	2	2	2	
Minimum " " " "	0	0	0	0	
Maximum Overburden Thickness (feet)	180	215	180	280	
Minimum " " "	40	50	120	120	
Rank (A)	Hvab	Hvab	Hvab	Hvab	
Analysis: (B)					
Moisture	4.5%	5.1%	5.6%	3.9%	4.3%
Volatile Matter	35.4	35.5	34.0	37.0	36.3
Fixed Carbon	52.9	52.9	53.3	55.1	54.1
Ash	7.2	6.5	7.1	4.0	5.3
Sulfur	0.7%	0.7%	1.0%	0.7%	0.7%
Btu, as received	13,180	13,110	12,960	13,790	13,490
Btu, moisture- and ash-free	14,930	14,830	14,840	14,970	14,920
Area Underlain by Reserves (acres)	19,214	28,264	3,648	81,682	110,000
Estimated Recoverable Reserves (1,000 tons):					
Primary Underground	54,471	75,437	4,234	146,568	280,710
Primary Strip	-	-	-	-	-
Primary Total	54,471	75,437	4,234	146,568	280,710
Secondary Underground	34,060	50,657	6,774	129,700	221,191
Secondary Strip	-	-	-	-	-
Secondary Total	34,060	50,657	6,774	129,700	221,191
Total Underground	88,531	126,094	11,008	276,268	501,901
Total Strip	-	-	-	-	-
Total Underground and Strip	88,531	126,094	11,008	276,268	501,901

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	95	-	95
Coal Synthine Process " " "	74	-	74

Note: (A) High-volatile A bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.

General Areas of Coal Availability

Leslie-Harlan General Area
(As of January 1, 1949)

	Coal Bed: Hazard		Coal Bed: Fire Clay Rider	Coal Bed: Fire Clay	Coal Bed: Williamson	
County	Leslie	Harlan	Leslie	Leslie	Leslie	Totals and/or Weighted Averages
Portion of County	SE.	NE.	Central	S.-central	Central	
Maximum Thickness of Coal Bed (inches)	44	-	46	47	43	
Minimum " " " " "	27	-	25	28	30	
Average " " " " "		38				
Maximum Dip of Bed (degrees)	3	3	3	3	3	
Minimum " " " "	0	0	0	0	0	
Maximum Overburden Thickness (feet)	210	-	240	300	350	
Minimum " " "	105	-	130	100	340	
Average " " "		200				
Rank (A)	Hvab	Hvab		Hvab	Hvab	
Analysis: (B)						
Moisture	5.1%	5.1%		3.7%	3.7%	3.9%
Volatile Matter	35.5	35.5	Not	38.0	37.8	37.6
Fixed Carbon	52.9	52.9	Available	54.3	54.3	54.1
Ash	6.5	6.5		4.0	4.2	4.4
Sulfur	0.7%	0.7%		0.7%	0.7%	0.7%
Btu, as received	13,110	13,110		13,780	13,830	13,680
Btu, moisture- and ash-free	14,830	14,830		14,930	15,020	14,920
Area Underlain by Reserves (acres)	9,683	3,898	18,848	69,676	9,337	75,000
Estimated Recoverable Reserves (1,000 tons):						
Primary Underground	13,898	8,314	29,764	120,186	22,336	194,498
Primary Strip	-	-	-	-	-	-
Primary Total	13,898	8,314	29,764	120,186	22,336	194,498
Secondary Underground	16,992	5,079	31,718	95,839	9,553	159,181
Secondary Strip	-	-	-	-	-	-
Secondary Total	16,992	5,079	31,718	95,839	9,553	159,181
Total Underground	30,890	13,393	61,482	216,025	31,889	353,679
Total Strip	-	-	-	-	-	-
Total Underground and Strip	30,890	13,393	61,482	216,025	31,889	353,679

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	68	-	68
Coal Synthine Process " " "	53	-	53

Note: (A) High-volatile A bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.

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General Areas of Coal Availability

Northern Letcher General Area
(As of January 1, 1949)

	Coal Bed: Fire Clay	Whitesburg	Upper Elkhorn No. 3	Upper Elkhorn No. 2	Lower Elkhorn	Totals and/or Weighted Averages
County	Letcher	Letcher	Letcher	Letcher	Letcher	
Portion of County	NW.	N.-central	Northern	NE.	NE.	
Maximum Thickness of Coal Bed (inches)	75	52	60	-	-	
Minimum " " " " "	31	35	33	-	-	
Average " " " " "				65	35	
Maximum Dip of Bed (degrees)	4	4	4	4	4	
Minimum " " " "	0	0	0	0	0	
Maximum Overburden Thickness (feet)	275	175	275	-	-	
Minimum " " "	90	80	140	-	-	
Average " " "				320	400	
Rank (A)	Hvab	Hvab	Hvab	Hvab	Hvab	
Analysis: (B)						
Moisture	3.7%	4.6%	3.3%	2.9%	3.2%	3.5%
Volatile Matter	38.0	34.7	36.4	35.7	32.7	36.5
Fixed Carbon	54.3	53.8	56.8	57.8	60.3	56.0
Ash	4.0	6.9	3.5	3.6	3.8	4.0
Sulfur	0.7%	2.2%	0.7%	0.9%	0.6%	0.9%
Btu, as received	13,780	13,590	14,100	14,280	14,290	13,970
Btu, moisture- and ash-free	14,930	15,360	15,130	15,270	15,370	15,110
Area Underlain by Reserves (acres)	39,935	9,638	33,489	7,718	7,226	65,000
Estimated Recoverable Reserves (1,000 tons):						
Primary Underground	69,000	25,454	124,742	18,755	11,009	248,960
Primary Strip	-	-	-	-	-	-
Primary Total	69,000	25,454	124,742	18,755	11,009	248,960
Secondary Underground	65,712	9,905	16,109	26,395	11,753	129,874
Secondary Strip	-	-	-	-	-	-
Secondary Total	65,712	9,905	16,109	26,395	11,753	129,874
Total Underground	134,712	35,359	140,851	45,150	22,762	378,834
Total Strip	-	-	-	-	-	-
Total Underground and Strip	134,712	35,359	140,851	45,150	22,762	378,834

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	74	-	74
Coal Synthine Process " " "	58	-	58

Note: (A) High-volatile A bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.

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General Areas of Coal Availability

Harlan-Letcher General Area
(As of January 1, 1949)

	Coal Bed								
	Upper Splint	William-son	Upper Elkhorn No.3		Upper Elk-horn No. 2	Upper Elk-horn No. 1	Harlan	Lower Elkhorn	
County	Harlan	Harlan	Harlan	Letcher	Harlan	Letcher	Harlan	Letcher	Totals and/or Weighted Averages
Portion of County	Eastern	Southern	Southern	Southern	Eastern	Southern	Southern	Southern	
Maximum Thickness of Coal Bed (inches)	81	60	58	52	49	51	50	47	
Minimum " " " " "	41	33	34	29	29	36	37	34	
Maximum Dip of Bed (degrees)	5	5	5	4	5	4	5	4	
Minimum " " " "	0	0	0	0	0	0	0	0	
Maximum Overburden Thickness (feet)	660	850	700	610	700	525	800	550	
Minimum " " "	130	100	125	170	180	500	370	500	
Rank (A)	Hvab	Hvab	Hvab	Hvab	Hvab	Hvab	Hvab	Hvab	
Analysis: (B)									
Moisture	4.4%	3.7%	2.8%	3.3%	4.2%	3.2%	3.1%	3.2%	3.3%
Volatile Matter	37.1	37.8	36.2	36.4	36.2	34.8	37.0	32.7	36.5
Fixed Carbon	53.8	54.3	56.8	56.8	53.8	58.1	56.1	60.3	56.0
Ash	4.7	4.2	4.2	3.5	5.8	3.9	3.8	3.8	4.2
Sulfur	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.8%	0.6%	0.7%
Btu, as received	13,490	13,830	14,170	14,100	13,440	14,080	14,050	14,290	13,980
Btu, moisture- and ash-free	14,840	15,020	15,240	15,130	14,930	15,150	15,090	15,370	15,110
Area Underlain by Reserves (acres)	19,883	26,509	85,779	14,681	20,174	6,362	85,111	11,200	140,000
Estimated Recoverable Reserves (1,000 tons):									
Primary Underground	83,856	47,996	155,410	32,224	30,666	26,007	234,565	17,677	628,401
Primary Strip	-	-	-	-	-	-	-	-	-
Primary Total	83,856	47,996	155,410	32,224	30,666	26,007	234,565	17,677	628,401
Secondary Underground	29,197	58,748	194,887	16,886	44,024	-	96,341	20,570	460,653
Secondary Strip	-	-	-	-	-		-	-	-
Secondary Total	29,197	58,748	194,887	16,886	44,024	-	96,341	20,570	460,653
Total Underground	113,053	106,744	350,297	49,110	74,690	26,007	330,906	38,247	1,089,054
Total Strip	-	-	-	-	-	-	-	-	-
Total Underground and Strip	113,053	106,744	350,297	49,110	74,690	26,007	330,906	38,247	1,089,054

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	213	-	213
Coal Synthine Process " " "	166	-	166

Note: (A) High-volatile A bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.

General Areas of Coal Availability

Bell General Area
(As of January 1, 1949)

	Coal Bed: Hig-nite	Fire Clay	William-son	Harlan	Puckett Creek	Totals and/or Weighted Averages
County	Bell	Bell	Bell	Bell	Bell	
Portion of County	SW.	SW.	Southern	Southern	SE.	
Maximum Thickness of Coal Bed (inches)	46	52	54	50	55	
Minimum " " " " "	44	27	33	39	32	
Maximum Dip of Bed (degrees)	4	4	4	4	4	
Minimum " " " "	0	0	0	0	0	
Maximum Overburden Thickness (feet)	-	350	510	400	150	
Minimum " " "	-	175	245	100	100	
Average " " "	300					
Rank (A)	Hvab	Hvab	Hvab	Hvab		
Analysis: (B)						
Moisture	3.6%	3.3%	2.6%	2.1%		2.8%
Volatile Matter	36.7	36.6	37.2	38.3		37.3
Fixed Carbon	55.4	52.2	55.8	55.9	Not	54.9
Ash	4.3	7.9	4.4	3.7	Available	5.0
Sulfur	0.8%	1.9%	1.1%	0.8%		1.2%
Btu, as received	13,800	13,210	14,000	14,070		13,800
Btu, moisture- and ash-free	14,980	14,880	15,050	14,940		14,970
Area Underlain by Reserves (acres)	6,624	12,536	18,297	12,651	9,089	30,000
Estimated Recoverable Reserves (1,000 tons):						
Primary Underground	16,418	25,718	34,403	23,694	19,614	119,847
Primary Strip	-	-	-	-	-	-
Primary Total	16,418	25,718	34,403	23,694	19,614	119,847
Secondary Underground	10,208	20,614	31,676	28,826	10,451	101,775
Secondary Strip	-	-	-	-	-	-
Secondary Total	10,208	20,614	31,676	28,826	10,451	101,775
Total Underground	26,626	46,332	66,079	52,520	30,065	221,622
Total Strip	-	-	-	-	-	-
Total Underground and Strip	26,626	46,332	66,079	52,520	30,065	221,622

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	43	-	43
Coal Synthine Process " " "	33	-	33

Note: (A) High-volatile A bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.

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General Areas of Coal Availability

Daviess General Area
(As of January 1, 1949)

	Coal Bed No. 9
County	Daviess
Portion of County	Western
Maximum Thickness of Coal Bed (inches)	53
Minimum " " " " "	46
Maximum Dip of Bed (degrees)	2
Minimum " " " "	0
Maximum Overburden Thickness - Underground (feet)	95
Minimum " " " "	30
Maximum Overburden Thickness - Strip (feet)	65
Average " " " "	45
Rank (A)	Hvcb
Analysis: (B)	
Moisture	12.1%
Volatile Matter	36.1
Fixed Carbon	40.1
Ash	11.7
Sulfur	3.0%
Btu, as received	10,790
Btu, moisture- and ash-free	14,160
Area Underlain by Reserves (acres)	19,500
Estimated Recoverable Reserves (1,000 tons):	
Primary Underground	45,774
Primary Strip	6,916
Primary Total	52,690
Secondary Underground	23,877
Secondary Strip	-
Secondary Total	23,877
Total Underground	69,651
Total Strip	6,916
Total Underground and Strip	76,567

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	11	1	12
Coal Synthine Process (1,000 " ")	8	1	9(D)

Note: (A) High-volatile C bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.
(D) Coal reserves are insufficient for a unit coal synthine plant for 40 years' operation.

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General Areas of Coal Availability

Henderson General Area
(As of January 1, 1949)

	Coal Bed		
	No. 14	No. 9	
County	Henderson	Henderson	Totals and/or
Portion of County	Western	Central	Weighted Averages
Maximum Thickness of Coal Bed (inches)	-	54	
Minimum " " " " "	-	42	
Average " " " " "	57		
Maximum Dip of Bed (degrees)	2	2	
Minimum " " " "	0	0	
Maximum Overburden Thickness (feet)	185	310	
Minimum " " "	180	50	
Rank (A)	Hvcb	Hvcb	
Analysis: (B)			
Moisture	11.8%	10.5%	10.7%
Volatile Matter	32.9	35.0	34.7
Fixed Carbon	46.1	41.0	41.8
Ash	9.2	13.5	12.8
Sulfur	2.0%	3.6%	3.4%
Btu, as received	11,300	10,900	10,960
Btu, moisture- and ash-free	14,300	14,340	14,330
Area Underlain by Reserves (acres)	16,948	112,075	125,000
Estimated Recoverable Reserves (1,000 tons):			
Primary Underground	72,453	157,480	229,933
Primary Strip	-	-	-
Primary Total	72,453	157,480	229,933
Secondary Underground	-	250,141	250,141
Secondary Strip	-	-	-
Secondary Total	-	250,141	250,141
Total Underground	72,453	407,621	480,074(E)
Total Strip	-	-	-
Total Underground and Strip	72,453	407,621	459,866(D)

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	70	-	70
Coal Synthine Process " " "	55	-	55

Note: (A) High-volatile C bituminous.
(B) Average or representative analyses of mine samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.
(D) Total primary and secondary coal reserves for synthetic liquid fuels plant supply limited by definition to twice the primary reserves.
(E) Usable coal will be only 459,866 tons due to above limitations in (D).

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General Areas of Coal Availability

Union General Area
(As of January 1, 1949)

	Coal Bed			
	No. 11	No. 9	No. 6	
County	Union	Union	Union	Totals and/or Weighted Averages
Portion of County	North-central	SE.	NW.	
Maximum Thickness of Coal Bed (inches)	60	60	66	
Minimum " " " " "	45	48	45	
Maximum Dip of Bed (degrees)	3	3	3	
Minimum " " "	0	0	0	
Maximum Overburden Thickness (feet)	225	450	545	
Minimum " " "	80	300	50	
Rank (A)	Hvbb	Hvab	Hvab	
Analysis: (B)				
Moisture	8.7%	3.9%	4.5%	5.9%
Volatile Matter	38.1	36.8	36.6	37.3
Fixed Carbon	43.4	49.0	50.7	46.8
Ash	9.8	10.3	8.2	10.0
Sulfur	3.9%	3.7%	2.6%	3.7%
Btu, as received	11,710	12,740	13,020	12,340
Btu, moisture- and ash-free	14,370	14,850	14,920	14,660
Area Underlain by Reserves (acres)	62,701	73,736	9,644	95,000
Estimated Recoverable Reserves (1,000 tons):				
Primary Underground	145,089	155,742	42,465	343,296
Primary Strip	-	-	-	-
Primary Total	145,089	155,742	42,465	343,296
Secondary Underground	100,638	155,557	-	256,195
Secondary Strip	-	-	-	-
Secondary Total	100,638	155,557	-	256,195
Total Underground	245,727	311,299	42,465	599,491
Total Strip	-	-	-	-
Total Underground and Strip	245,727	311,299	42,465	599,491

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	103	-	103
Coal Synthine Process " " "	80	-	80

Note: (A) High-volatile A bituminous and high-volatile B bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.

General Areas of Coal Availability

Webster General Area
(As of January 1, 1949)

	Coal Bed				
	No. 14	No. 12	No. 11	No. 9	Totals and/or Weighted Averages
County	Webster	Webster	Webster	Webster	
Portion of County	Western	SW.	Southern	Central	
Maximum Thickness of Coal Bed (inches)	86	-	72	64	
Minimum " " " " "	57	-	48	46	
Average " " " " "		60			
Maximum Dip of Bed (degrees)	3	3	3	3	
Minimum " " " "	0	0	0	0	
Maximum Overburden Thickness - Underground (feet)	465	-	300	450	
Minimum " " " "	125	-	50	85	
Maximum Overburden Thickness - Strip (feet)	-	75	90	75	
Average " " " "	-	40	50	45	
Rank (A)	Hvab	Hvbb	Hvbb	Hvbb	
Analysis: (B)					
Moisture	5.9%	5.4%	5.2%	6.3%	6.1%
Volatile Matter	35.3	34.9	38.0	36.7	36.6
Fixed Carbon	52.0	50.4	47.1	47.2	48.0
Ash	6.8	9.3	9.7	9.8	9.3
Sulfur	1.5%	1.1%	4.0%	3.6%	3.3%
Btu, as received	12,930	12,500	12,480	12,260	12,400
Btu, moisture- and ash-free	14,810	14,650	14,660	14,610	14,650
Area Underlain by Reserves (acres)	25,280	467	19,814	139,866	140,000
Estimated Recoverable Reserves (1,000 tons):					
Primary Underground	137,907	-	78,185	161,700	377,792
Primary Strip	-	2,522	5,035	7,144	14,701
Primary Total	137,907	2,522	83,220	168,844	392,493
Secondary Underground	-	-	15,505	386,249	401,754
Secondary Strip	-	-	-	-	-
Secondary Total	-	-	15,505	386,249	401,754
Total Underground	137,907	-	93,690	547,949	779,546(E)
Total Strip	-	2,522	5,035	7,144	14,701
Total Underground and Strip	137,907	2,522	98,725	555,093	784,986(D)

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	133	3	136
Coal Synthine Process " " "	104	2	106

Note: (A) Hvab: High-volatile A bituminous; Hvbb: High-volatile B bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.
(D) Total primary and secondary coal reserves for synthetic liquid fuels plant supply limited by definition to twice the primary reserves.
(E) Usable coal will be only 784,986 tons due to above limitations in (D).

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General Areas of Coal Availability

Hopkins-Christian General Area
(As of January 1, 1949)

	Coal Bed: No. 14	No. 12	No. 11	No. 9	No. 6	No. 6	Totals and/or Weighted Averages
County	Hopkins	Hopkins	Hopkins	Hopkins	Hopkins	Christian	
Portion of County	Western	S.-central	Central	Central	Southern	Northern	
Maximum Thickness of Coal Bed (inches)	72	78	79	65	51	43	
Minimum " " " " "	57	30	48	47	36	36	
Maximum Dip of Bed (degrees)	3	3	3	3	3	3	
Minimum " " " "	0	0	0	0	0	0	
Maximum Overburden Thickness - Underground (feet)	360	-	315	410	80	70	
Minimum " " " "	50	-	40	50	30	30	
Maximum Overburden Thickness - Strip (feet)	-	75	90	80	60	50	
Average " " " "	-	20	20	40	20	30	
Rank (A)	Hvbb	Hvbb	Hvbb	Hvbb	Hvbb	Hvbb	
Analysis: (B)							
Moisture	8.9%	8.4%	8.2%	8.4%	9.7%	10.7%	8.5%
Volatile Matter	35.3	34.9	38.4	36.6	36.3	35.6	37.2
Fixed Carbon	47.4	42.4	45.7	44.9	47.2	49.8	45.6
Ash	8.4	14.3	7.7	10.1	6.8	3.9	8.7
Sulfur	2.8%	3.8%	3.2%	3.3%	2.7%	1.9%	3.2%
Btu, as received	11,920	11,040	12,170	11,780	12,200	12,440	11,990
Btu, moisture- and ash-free	14,410	14,280	14,470	14,450	14,610	14,570	14,470
Area Underlain by Reserves (acres)	12,627	3,162	121,634	139,345	39,183	7,263	165,000
Estimated Recoverable Reserves (1,000 tons):							
Primary Underground	64,310	-	346,519	287,725	72,874	20,015	791,443
Primary Strip	-	15,619	32,722	20,510	24,170	3,217	96,238
Primary Total	64,310	15,619	379,241	308,235	97,044	23,232	887,681
Secondary Underground	-	-	227,305	286,030	-	-	513,335
Secondary Strip	-	-	-	-	-	-	-
Secondary Total	-	-	227,305	286,030	-	-	513,335
Total Underground	64,310	-	573,824	573,755	72,874	20,015	1,304,778
Total Strip	-	15,619	32,722	20,510	24,170	3,217	96,238
Total Underground and Strip	64,310	15,619	606,546	594,265	97,044	23,232	1,401,016

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	219	16	235
Coal Synthine Process " " "	170	13	183

Note: (A) Hvbb: High-volatile B bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.

General Areas of Coal Availability

Muhlenberg-McLean
(As of January 1, 1949)

	Coal Bed						
	No. 12	No. 11		No. 9		No. 6	
County	Muhlenberg	McLean	Muhlenberg	McLean	Muhlenberg	Muhlenberg	Totals and/or Weighted Averages
Portion of County	NW.	Southern	Northern	Southern	Northern	Central	
Maximum Thickness of Coal Bed (inches)	66	57	75	61	66	48	
Minimum " " " " "	30	42	51	47	47	37	
Maximum Dip of Bed (degrees)	3	3	3	3	3	3	
Minimum " " " "	0	0	0	0	0	0	
Maximum Overburden Thickness - Underground (feet)	-	300	285	410	395	50	
Minimum " " " "	-	265	45	110	30	40	
Maximum Overburden Thickness - Strip (feet)	75	-	80	-	75	60	
Average " " " "	20	-	35	-	40	25	
Rank (A)	Hvbb	Hvbb	Hvbb	Hvbb	Hvbb	Hvbb	
Analysis: (B)							
Moisture	8.4%	6.1%	6.1%	9.7%	9.1%	7.6%	7.9%
Volatile Matter	34.9	41.0	41.0	36.9	36.7	39.1	38.5
Fixed Carbon	42.4	45.2	45.2	43.8	45.0	48.2	45.0
Ash	14.3	7.7	7.7	9.6	9.2	5.1	8.6
Sulfur	3.8%	4.1%	4.1%	3.3%	3.4%	3.4%	3.7%
Btu, as received	11,040	12,570	12,570	11,690	11,810	12,800	12,120
Btu, moisture- and ash-free	14,280	14,580	14,580	14,480	14,450	14,660	14,510
Area Underlain by Reserves (acres)	4,173	17,415	77,417	12,052	118,787	7,199	130,000
Estimated Recoverable Reserves (1,000 tons):							
Primary Underground	-	16,590	174,880	28,487	357,178	16,862	593,997
Primary Strip	18,182	-	40,557	-	5,401	5,733	69,873
Primary Total	18,182	16,590	215,437	28,487	362,579	22,595	663,870
Secondary Underground	-	48,848	137,918	19,812	169,028	-	375,606
Secondary Strip	-	-	-	-	-	-	-
Secondary Total	-	48,848	137,918	19,812	169,028	-	375,606
Total Underground	-	65,438	312,798	48,299	526,206	16,862	969,603
Total Strip	18,182	-	40,557	-	5,401	5,733	69,873
Total Underground and Strip	18,182	65,438	353,355	48,299	531,607	22,595	1,039,476

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	164	12	176
Coal Synthine Process " " "	128	9	137

Note: (A) High-volatile B bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.

General Areas of Coal Availability

Ohio General Area
(As of January 1, 1949)

	Coal Bed No. 14	Coal Bed No. 11	Coal Bed No. 9	Totals and/or Weighted Averages
County	Ohio	Ohio	Ohio	
Portion of County	Western	SW.	SW.	
Maximum Thickness of Coal Bed (inches)	108	85	61	
Minimum " " " " "	39	31	48	
Maximum Dip of Bed (degrees)	2	2	2	
Minimum " " " "	0	0	0	
Maximum Overburden Thickness - Underground (feet)	70	80	290	
Minimum " " " "	40	30	40	
Maximum Overburden Thickness - Strip (feet)	75	-	75	
Average " " " "	40	-	40	
Rank (A)	Hvcb	Hvbb	Hvbb	
Analysis: (B)				
Moisture	9.9%	6.1%	9.8%	9.6%
Volatile Matter	37.5	41.0	36.4	37.1
Fixed Carbon	43.0	45.2	44.6	44.0
Ash	9.6	7.7	9.2	9.3
Sulfur	4.7%	4.1%	2.9%	3.7%
Btu, as received	11,490	12,570	11,660	11,640
Btu, moisture- and ash-free	14,270	14,580	14,390	14,350
Area Underlain by Reserves (acres)	5,638	6,271	67,117	69,000
Estimated Recoverable Reserves (1,000 tons):				
Primary Underground	49,068	27,759	165,678	242,505
Primary Strip	158,421	-	34,577	192,998
Primary Total	207,489	27,759	200,255	435,503
Secondary Underground	-	-	73,440	73,440
Secondary Strip	-	-	-	-
Secondary Total	-	-	73,440	73,440
Total Underground	49,068	27,759	239,118	315,945
Total Strip	158,421	-	34,577	192,998
Total Underground and Strip	207,489	27,759	273,695	508,943

Capacity of Synthetic Liquid Fuels Plant: (C)

	Underground	Strip	Total
Hydrogenation Process (1,000 bbl/day)	51	31	82
Coal Synthine Process " " "	40	24	64

Note: (A) High-volatile B bituminous or High-volatile C bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and of 126 billion for coal synthine unit plant.
(D) Total primary and secondary coal reserves for synthetic liquid fuels plant supply limited by definition to twice the primary reserves.

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EXHIBIT NO. 11

REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY

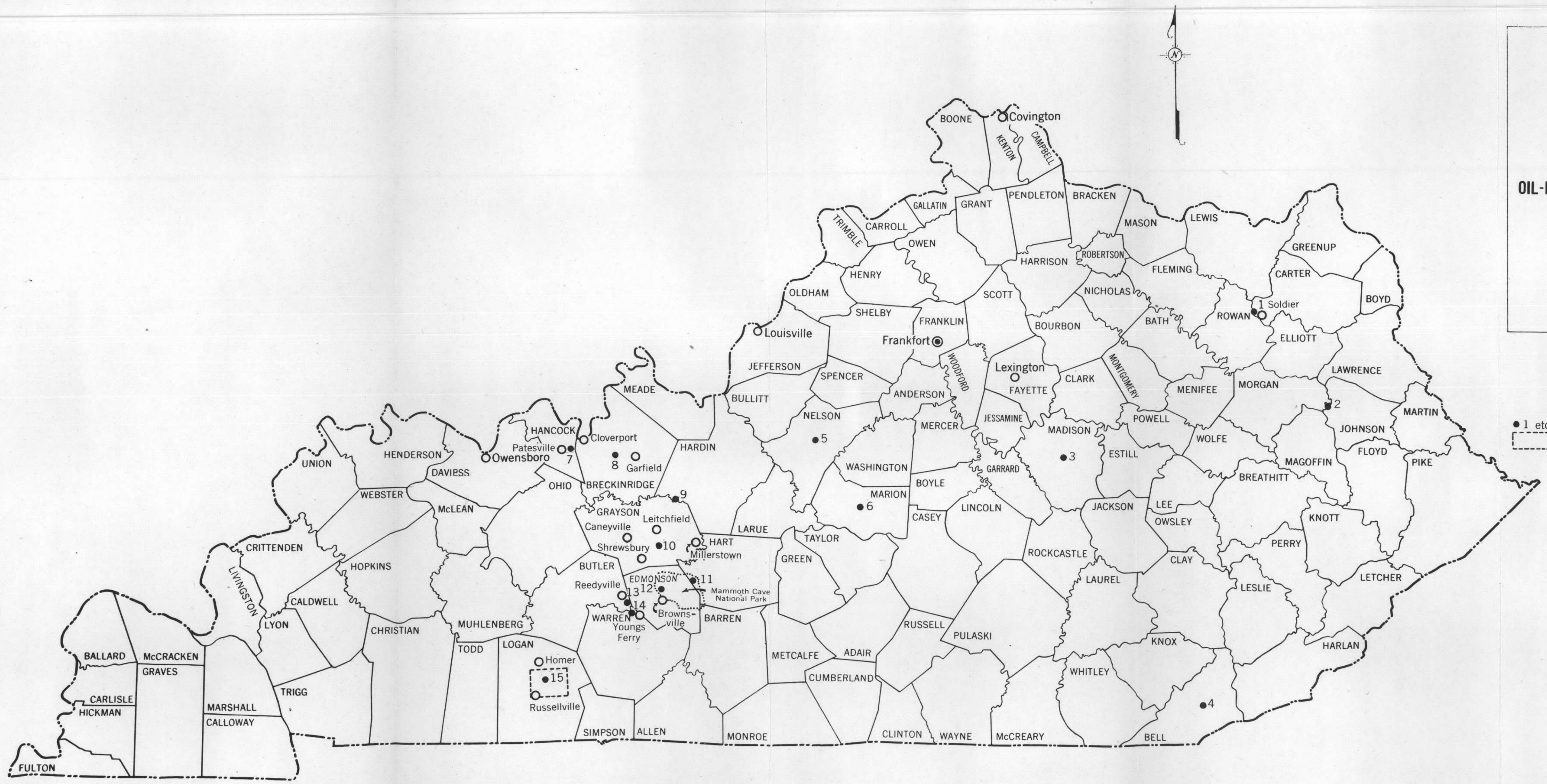
LOCATION OF
OIL-IMPREGNATED STRIPPABLE DEPOSITS

MAY 1950

SCALE OF MILES
10 0 10 20 30 40

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES



LEGEND
● 1 etc. Deposit or group of deposits
[ ] General Area of O. I. S. D. Availability

SF-249 11-24-50

Oil-impregnated Strippable Deposits in Kentucky

Key to Map

Location Number	County	Type Bituminous Deposit	System	Series	Reference (Exhibit No.13)	Remarks
1	Carter and Rowan	Sandstone	Pennsylvanian	Pottsville	1, 4, 7, 17, 18	Irregular deposit with variable bitumen content averaging less than 10 gallons per ton.
2	Johnson, Morgan, and Magoffin	Sandstone	Pennsylvanian	Pottsville	4	Reported to be not thick enough and so situated as not to be commercial
3 4 5 6	Madison) Bell) Nelson) Marion)	Limestone			13	Miscellaneous small outcropping deposits.
7	Hancock	Sandstone	Mississippian	Chester	9, 13	Beds dip below capping sandstones.
8	Breckenridge	Sandstone	Mississippian	Chester	1, 11, 17	Available information fails to show deposits meet requirements.
9	Harden	Sandstone	Mississippian	Chester	7, 15, 16, 18	Extention of Grayson County Chester deposits.
10	Grayson	Sandstone	Pennsylvanian Mississippian	Pottsville Chester	1, 2, 7, 10, 13, 16, 17	Pottsville deposits in south are small, isolated, or under considerable overburden. Chester deposits in north; no information that deposits are thick or rich enough.
11	Hart	Sandstone	Pennsylvanian	Pottsville	9, 13	Deposits appear to be of minor nature
12	Edmonson	Sandstone	Pennsylvanian	Pottsville	1, 2, 3, 4, 5, 7, 8, 12, 13, 14, 15, 17, 18	General Area of O.I.S.D. Availability.
13	Butler	Sandstone	Pennsylvanian	Pottsville	9, 13	Beds dip below capping sandstones.
14	Warren	Sandstone	Pennsylvanian	Pottsville	1, 13, 17, 18	Several small deposits of high quality.
15	Logan	Sandstone	Mississippian	Chester	1, 4, 13, 15, 17, 18	General Area of O.I.S.D. Availability.

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Hagan, W.W., Owensboro, Kentucky

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Kentucky Rock Asphalt Company, Brownsville, Kentucky

Mason, R.S., President, Pioneer Asphalt Company, Eddyville, Kentucky

Puckett, Alton, Progress Printing Company, Owensboro, Kentucky

Reconstruction Finance Corporation, Louisville, Kentucky

Scoggin, J.C., Treasurer, Louisville Credit Men's Services, Louisville, Kentucky

Taneyhill, C.P., Bowling Green, Kentucky

Asphalt Companies in Kentucky with Approximate Last Dates of Operation

Last Date of Operation	Name of Company	Town Nearest Operation	
1891	American Bituminous Rock Co.	Grayson Springs, Grayson	County
1894	Logan County Asphalt Co.	Russellville, Logan	"
1899	Federal Asphalt Co.	Big Clifty, Grayson	"
1901	Breckenridge Asphalt Co.	Garfield, Breckenridge	"
1901	Green River Asphalt Co.	Young's Ferry, Warren	"
1901	Sicilian Asphalt Co.	Young's Ferry, Warren	"
1917	Wadsworth Stone & Paving Co.	Davis Ferry, Edmonson	"
1922	Standard Asphalt Co.	Russellville, Logan	"
1924	Black Rock Asphalt Co.	Church, Grayson	"
1927	Continental Rock Asphalt Co.	Big Clifty, Grayson	"
1927	Silica Asphalt Co.	Leitchfield, Grayson	"
1930	Natural Rock Asphalt Co.	Lower Bear Creek, Edmonson	"
1930	United Rock Asphalt Co.	Big Clifty, Grayson	"
1930	Garfield Rock Asphalt Co.	Garfield, Breckenridge	"
1930	Crown Rock Asphalt Co.	Big Clifty, Grayson	"
1930	American Rock Asphalt Co.	Pittsburgh Ferry, Edmonson	"
1946	Ohio Valley Rock Asphalt Co.	(Summit, Hardin (Segal, Edmonson	" "
(A)	Kentucky Rock Asphalt Co.	Brownsville, Edmonson	"

Note: (A) The Company was in operation as of January 1, 1950 at the time of the field work.

Classification of
Reserves of Oil-impregnated Strippable Deposits in Edmonson County, Kentucky (A)
(As of January 1, 1950)

Area	Approximate Location	Average Thickness of Deposit (Feet)	Area (Acres)	Average Thickness of Overburden (Feet)	Average Bitumen Content (Gallons per ton)	Altitude of Deposit	Quantity Recoverable in Thousands of Tons: Indicated, Secondary	Indicated, Tertiary	Inferred, Secondary	Inferred, Tertiary
A	Lat. 37°16', Long. 86°11' (6 mi NE. Brownsville, near Ollie)	15	800	15	10	Horizontal		30,928		
I	Lat. 37°16', Long. 86°20' (N. of Beaverdam Creek, E. of Green Hill School)	18	380	18	10	Horizontal		17,629		
JK	Lat. 37°17'-37°13', Long. 86°18' (Along Bee Spring Rd., near Sweden)	20	1,523	23	10	Horizontal		77,328		
B	Lat. 37°15', Long. 86°13' (2 mi E. of Woodside)	15	416	20	10	Horizontal				16,099
G	Lat. 37°17', Long. 86°19' (Bet. Nappers and Sycamore Branches E. of Bear Creek)	30	283	30	12	Horizontal				21,923
N	Lat. 37°18', Long. 86°18' (N. of Nappers Branch and E. of Bear Creek)	15	258	15	10	Horizontal				9,996
E'F'	Lat. 37°18', Long. 86°15' (Bet. Dismal Creek and Nolin River, 7 mi N. of Brownsville)	15	560	15	15	Horizontal			21,648	
	Total		4,220					125,885	21,648	48,018

Note: (A) All reserves in Pottsville Formation.

Exhibit No. 17

Physical Properties of Crude Samples of Edmonson County (Pottsville) Asphaltic Sandstone

Sample No.	Moisture (Wet Weight Percent)	Ign. Loss (Dry Weight Percent)	Penetration (25° C, 5 Sec.) 100 Grams	50 Grams
1	0.55%	6.02%	454	318
2	.41	8.73	483	338
3	.50	7.98	402	282
4	.45	8.27	429	300
5	.33	8.40	459	321
6	.53	8.42	267	187

Effects of Stockpile Curing on Physical Properties of Edmonson County (Pottsville) Asphaltic Sandstone

Curing Period (Days)	Moisture (Wet Weight Percent)		Ign. Loss (Dry Weight Percent)		Penetration (25 deg C 100 Grams, 5 Sec.)	
	Crust	Interior	Crust	Interior	Crust	Interior
0	0.29%	0.29%	7.55%	7.55%	166	166
30	.17	.42	7.38	7.34	86	155
60	.16	.30	7.49	7.43	61	125
90	.29	.29	7.29	7.51	47	128
140	.08	.22	7.31	7.58	46	131
202	.18	.29	7.28	7.52	39	137
242	.17	.44	7.45	7.57	44	139
278	.17	.32	7.41	7.76	42	135
300	.05	.17	7.67	7.65	33	130
333	.20	.39	7.57	7.56	45	138

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Effect of 360 Days Curing on the Physical Properties of Edmonson County (Pottsville) Asphaltic Sandstones at Different Levels in Stockpile

Depth (Inches)	Moisture (Wet Weight Percent)	Ign. Loss (Dry Weight Percent)	Penetration (25° C, 100 grams, 5 Sec.)
0- 2	0.20%	7.62%	110
2- 4	.26	7.79	120
4- 6	.29	7.72	137
6- 8	.21	7.71	138
8-10	.24	7.70	144
10-12	.29	7.61	130
12-14	.40	7.81	129
14-16	.27	7.62	119
16-18	.28	7.82	105

Characteristics of Separated Bitumen from Edmonson County (Pottsville) Deposit of Asphaltic Sandstone (A)

	Samples Nos. 1	2	3	4
Softening Point	52.3°C	50.9°C	43.2°C	45.7°C
Penetration at 25° C, 50 Grams, 5 Sec.	55	62	100	84
Penetration at 0° C, 100 Grams, 60 Sec.	37	40	60	51
Ductility at 25° C	83.5 cm	89 cm	110 cm	102 cm
Ductility at 0° C	32.3 cm	34.6 cm	61 cm	53.5 cm
Loss on Heating, 5 hr at 163° C	1.88%	1.97%	2.34%	2.08%
Penetration at 25° C after Heating	50	54	56	55
Penetration at 0° C after Heating	33	34	34	34
Solubility in Carbon Tetrachloride	99.53%	99.57%	99.57%	99.57%
Solubility in Carbon Disulfide	99.97%	99.98%	99.93%	99.95%
True Colloidal Percent	.44%	.41%	.36%	.38%
Temperature Susceptibility Index	.00732	.00760	.00771	.00771
Percent Bitumen by Ignition (Weight)	5.75%	8.66%	8.29%	8.35%

Note: (A) Samples taken from the Pottsville sandstone in the southern portion of the Edmonson County deposits.

Exhibit No. 20

Classification of Reserves of
Oil-impregnated Strippable Deposits in Logan County, Kentucky
(As of January 1, 1950)

							Quantity Recoverable in Thousands of Tons			
							Indicated		Inferred	
Area	Approximate Location	Average Thickness of Deposit (Feet)	Area (Acres)	Average Thickness of Overburden (Feet)	Average Bitumen Content (Gallons per ton)	Altitude of Deposit	Secondary	Tertiary	Secondary	Tertiary
II	Lat. 36°54' Long. 86°51' (4 mi NE. Russellville)	20	205	17	14.4	Horizontal		10,584		
III	Lat. 36°54' Long. 86°51' (4 mi NE. Russellville)	20	350	20	10	"		17,168		
IV	Lat. 36°55' Long. 86°52' (5 mi N. Russellville)	35	191	35	10	"				17,258
V	Lat. 36°56' Long. 86°52' (5 mi N. Russellville)	35	406	27	10	"				36,640
VI	Lat. 36°57' Long. 86°51' (vic. Homer, 7 mi NE. Russellville)	20	715	15	10	"				38,752
VII	Lat. 36°58' Long. 86°51' (vic. Homer, 7 mi NE Russellville)	30	386	16	10	"				30,858
	Total		2,253					27,752		123,508

Note: All Reserves in Chester Formation.

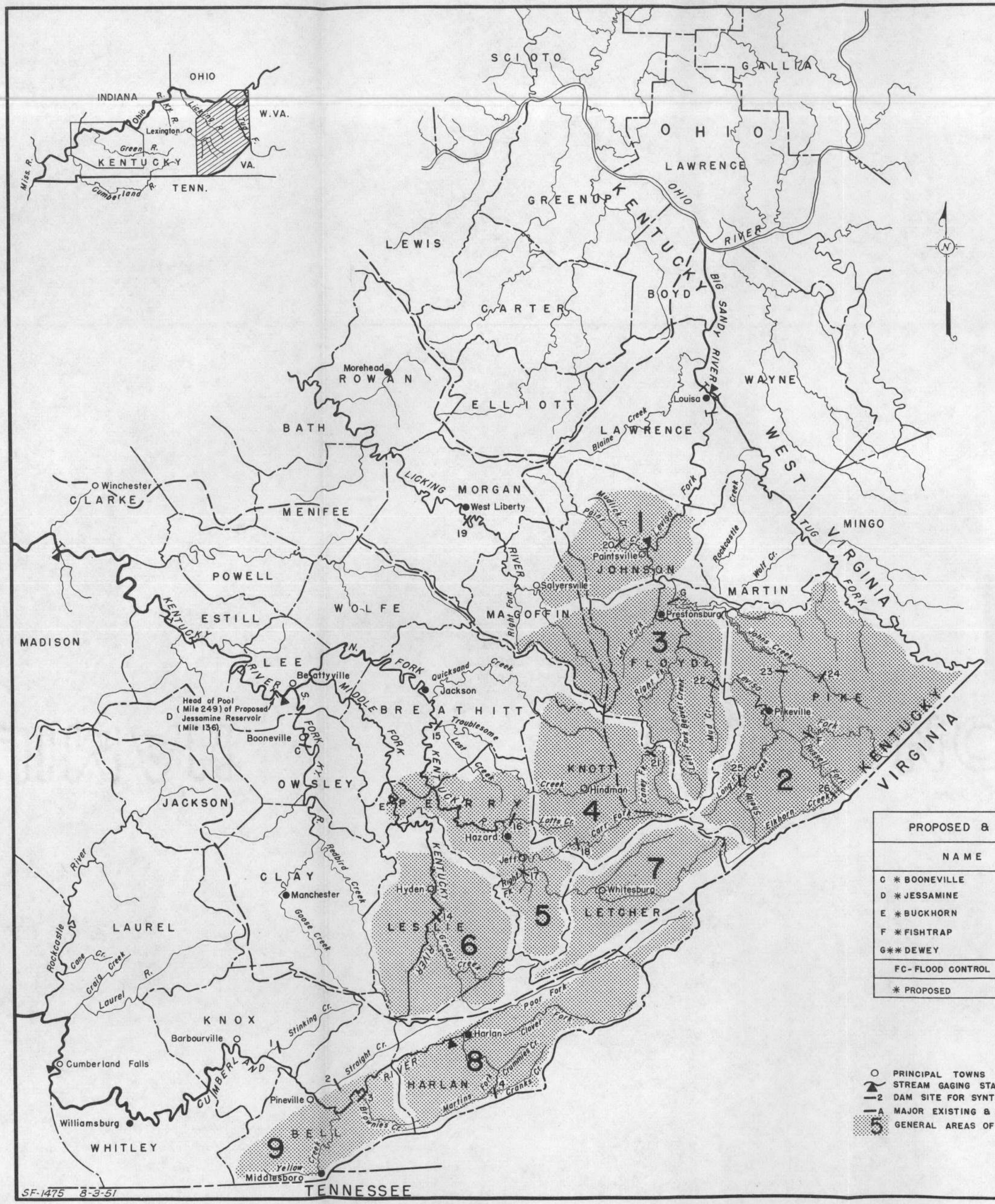
REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY

WATER RESOURCES
IN
EASTERN KENTUCKY

Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK CHICAGO PHILADELPHIA LOS ANGELES



IDENTIFICATION OF GENERAL AREAS

NO.	GENERAL AREA
1	JOHNSON-MAGOFFIN
2	PIKE
3	FLOYD-MAGOFFIN
4	KNOTT-BREATHITT
5	PERRY-BREATHITT
6	LESLIE-HARLAN
7	NORTH LETCHER
8	HARLAN-LETCHER
9	BELL

PROPOSED & EXISTING MAJOR DAMS & RESERVOIRS

NAME	RIVER	TOTAL STORAGE CAP. AF	USE
C * BOONEVILLE	S. FORK KENTUCKY R.	485,000	FC - P
D * JESSAMINE	KENTUCKY RIVER	1,135,000	FC - P
E * BUCKHORN	MIDDLE FK. KY. R.	153,000	FC
F * FISHTRAP	LEVISA FORK	126,000	FC - C
G ** DEWEY	JOHNS CREEK	88,000	FC - C

FC- FLOOD CONTROL P - POWER C-CONSERVATION

* PROPOSED ** EXISTING

LEGEND

- O PRINCIPAL TOWNS
- ● WITH SURFACE WATER SUPPLY
- STREAM GAGING STATION
- WATERSHED BOUNDARY
- —2 DAM SITE FOR SYNTHETIC LIQUID FUEL WATER SUPPLY
- —A MAJOR EXISTING & PROPOSED DAM FOR OTHER PURPOSES
- 5 GENERAL AREAS OF COAL AND WATER AVAILABILITY

REPORT

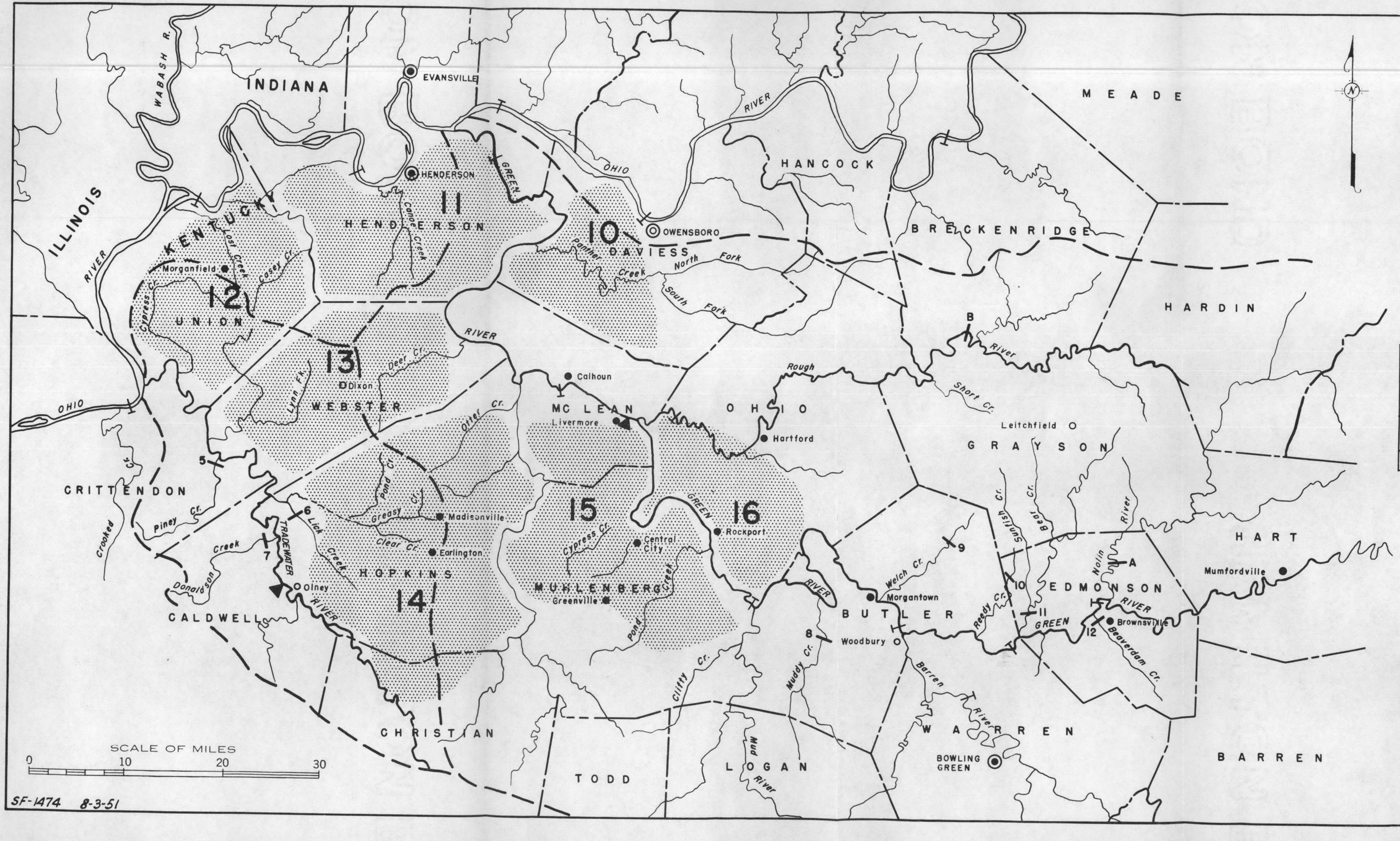
Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL OF **KENTUCKY**

WATER RESOURCES IN WESTERN KENTUCKY

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES



IDENTIFICATION OF GENERAL AREAS

NO.	GENERAL AREA
10	DAVIESS
11	HENDERSON
12	UNION
13	WEBSTER
14	HOPKINS-CHRISTIAN
15	MUHLENBERG-McLEAN
16	OHIO

PROPOSED MAJOR DAMS & RESERVOIRS

	NAME	RIVER	TOTAL STORAGE CAP. AF	USE
A	NOLIN RIVER	NOLIN RIVER	474,000	FC-C
B	ROUGH RIVER	ROUGH RIVER	312,700	FC-C

FC - FLOOD CONTROL C - CONSERVATION

LEGEND

- CITIES OVER 10,000 — WITH SURFACE SUPPLY
- OTHER PRINCIPAL TOWNS — WITH SURFACE SUPPLY
- STREAM GAGING STATION
- WATERSHED BOUNDARY
- 2 DAM SITE FOR SYNTHETIC LIQUID FUEL WATER SUPPLY
- 13 GENERAL AREA OF COAL AND WATER AVAILABILITY
- B PROPOSED MAJOR DAMS & RESERVOIRS

Daily Process Water Requirements with Recirculation
of Cooling Water for 10,000-barrel-per-day Plant Using Coal Synthine Process

Item	Use	Make-up (A) Gallons (1,000's)	Make-up (A) AF	Make-up (A) Cfs	Consumed (B) Gallons (1,000's)	Consumed (B) AF	Consumed (B) Cfs	Returned (C) Gallons (1,000's)	Returned (C) AF	Returned (C) Cfs
1	Evaporated (Cooling Towers)	6,410	19.67	9.92	6,410	19.67	9.92	-	-	-
2	Blowdown for Cooling Towers	1,920	5.89	2.97	960	2.95	1.48	960	2.94	1.49
3	Boiler Make-up for H_2 Manufacturing	-	-	-	-	-	-	-	-	-
4	Boiler Make-up for Synthesis Gas	578	1.77	0.89	51	0.15	0.08	527	1.62	0.81
5	Boiler Make-up for Boiler Blowdown	737	2.26	1.14	147	0.45	0.23	590	1.81	0.91
6	High Pressure Injection H_2O (Process H_2O)	-	-	-	-	-	-	-	-	-
7	Sanitary H_2O for Plant	60	0.19	0.09	-	-	-	60	0.19	0.09
8	Sanitary H_2O for Mines	48	0.15	0.08	-	-	-	48	0.15	0.08
9	Water for Coal Preparation	300	0.92	0.46	80	0.25	0.12	220	0.67	0.34
10	Water for Mines	-	-	-	-	-	-	-	-	-
11	Water for Mine Power	81	0.25	0.13	65	0.20	0.10	16	0.05	0.03
12	Miscellaneous, 10 percent	1,016	3.12	1.57	-	-	-	1,016	3.12	1.57
13	Total	11,150	34.22	17.25	7,713	23.67	11.93	3,437	10.55	5.32

Note: For "once-through" cooling with 33° F rise in water temperature through the plant, approximately 197 mgd, or 304 cfs of water are required in place of Items 1 and 2 above.

(A) Make-up - The total amount of water required to be delivered from the source to the plant.

(B) Consumed - The amount of water evaporated or used in the coal synthine process.

(C) Returned - The amount of water returned to a stream as waste and sewage.

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A Review of the Cost of Water Works Structures, Charles B. Burdick, vol. 36, pages 821-831 (1944)

Transactions of American Society of Civil Engineers

Evaporation from Water Surfaces, A Symposium, vol. 99, pages 671-747 (1934)

Acknowledgments for Technical Information

Agencies and Persons who Rendered Assistance in Preparation of Water Supply Report

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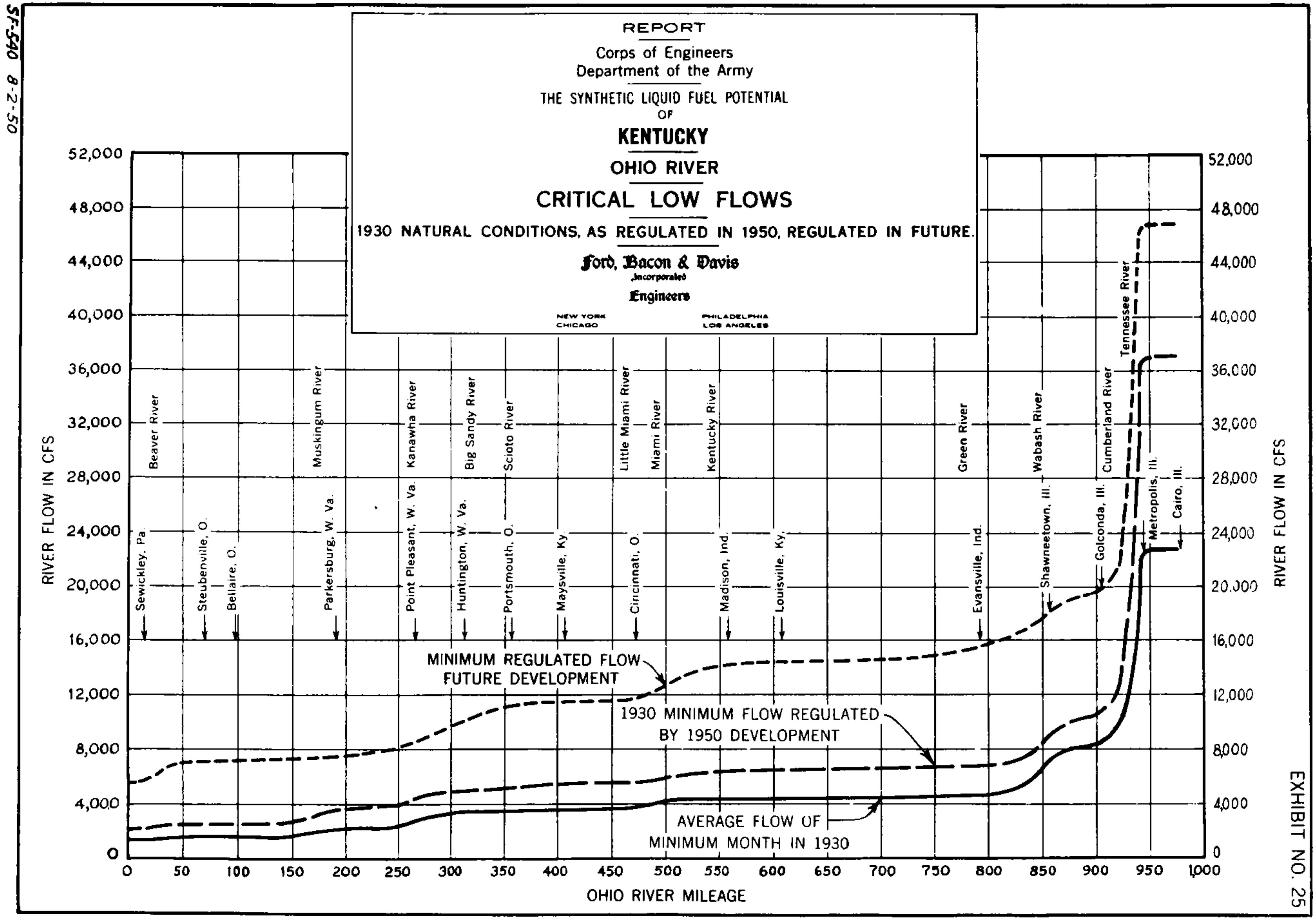
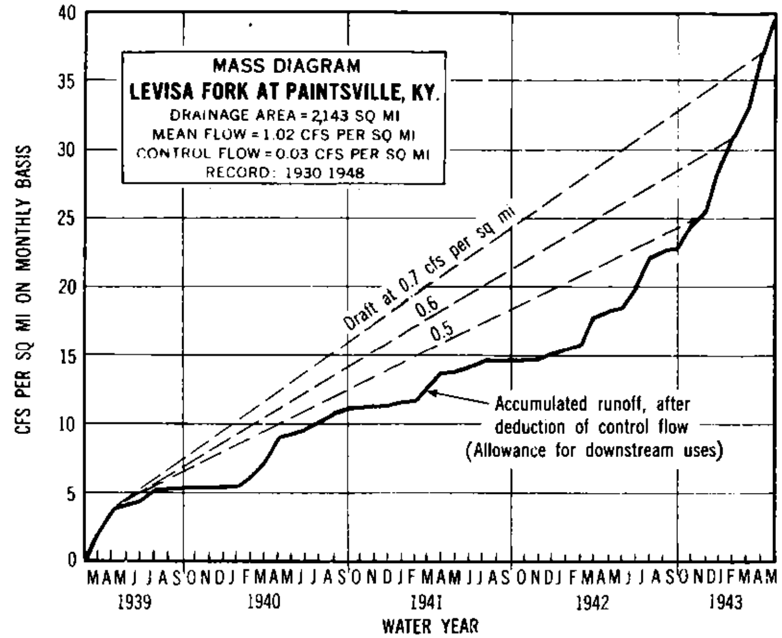
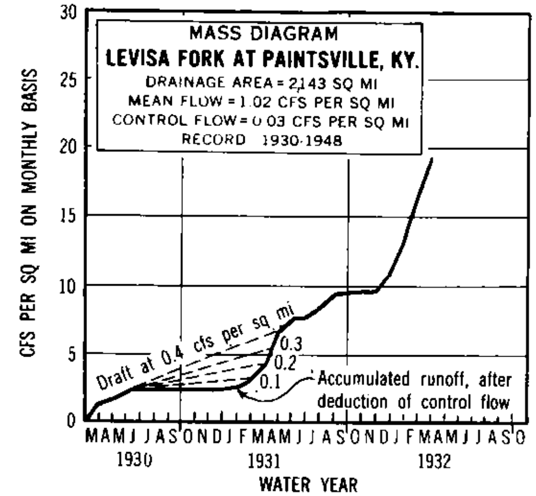
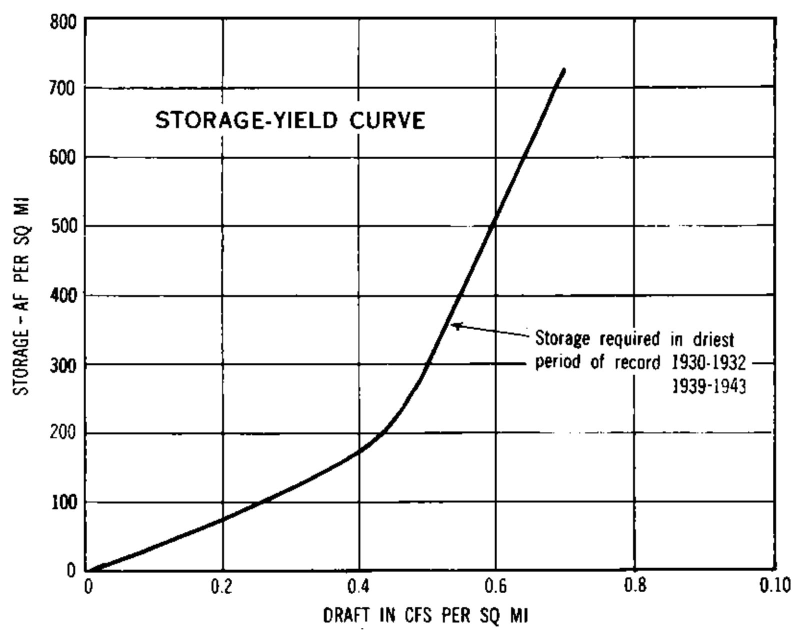

SF-540 8-2-50
REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY
OHIO RIVER
CRITICAL LOW FLOWS
1930 NATURAL CONDITIONS, AS REGULATED IN 1950, REGULATED IN FUTURE.
Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK
CHICAGO
PHILADELPHIA
LOS ANGELES
RIVER FLOW IN CFS
52,000
48,000
44,000
40,000
36,000
32,000
28,000
24,000
20,000
16,000
12,000
8,000
4,000
0
Beaver River
Muskingum River
Kanawha River
Big Sandy River
Scioto River
Little Miami River
Miami River
Kentucky River
Green River
Wabash River
Cumberland River
Tennessee River
Sewickley, Pa.
Steubenville, O.
Bellaire, O.
Parkersburg, W. Va.
Point Pleasant, W. Va.
Huntington, W. Va.
Portsmouth, O.
Maysville, Ky.
Cincinnati, O.
Madison, Ind.
Louisville, Ky.
Evansville, Ind.
Shawneetown, Ill.
Golconda, Ill.
Metropolis, Ill.
Cairo, Ill.
MINIMUM REGULATED FLOW
FUTURE DEVELOPMENT
1930 MINIMUM FLOW REGULATED
BY 1950 DEVELOPMENT
AVERAGE FLOW OF
MINIMUM MONTH IN 1930
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1,000
OHIO RIVER MILEAGE
EXHIBIT NO. 25

SF-1073 5-2-51







REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY

CURVES USED TO ESTIMATE
WATER STORAGE REQUIREMENTS

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES

EXHIBIT NO. 26

EXHIBIT NO. 27

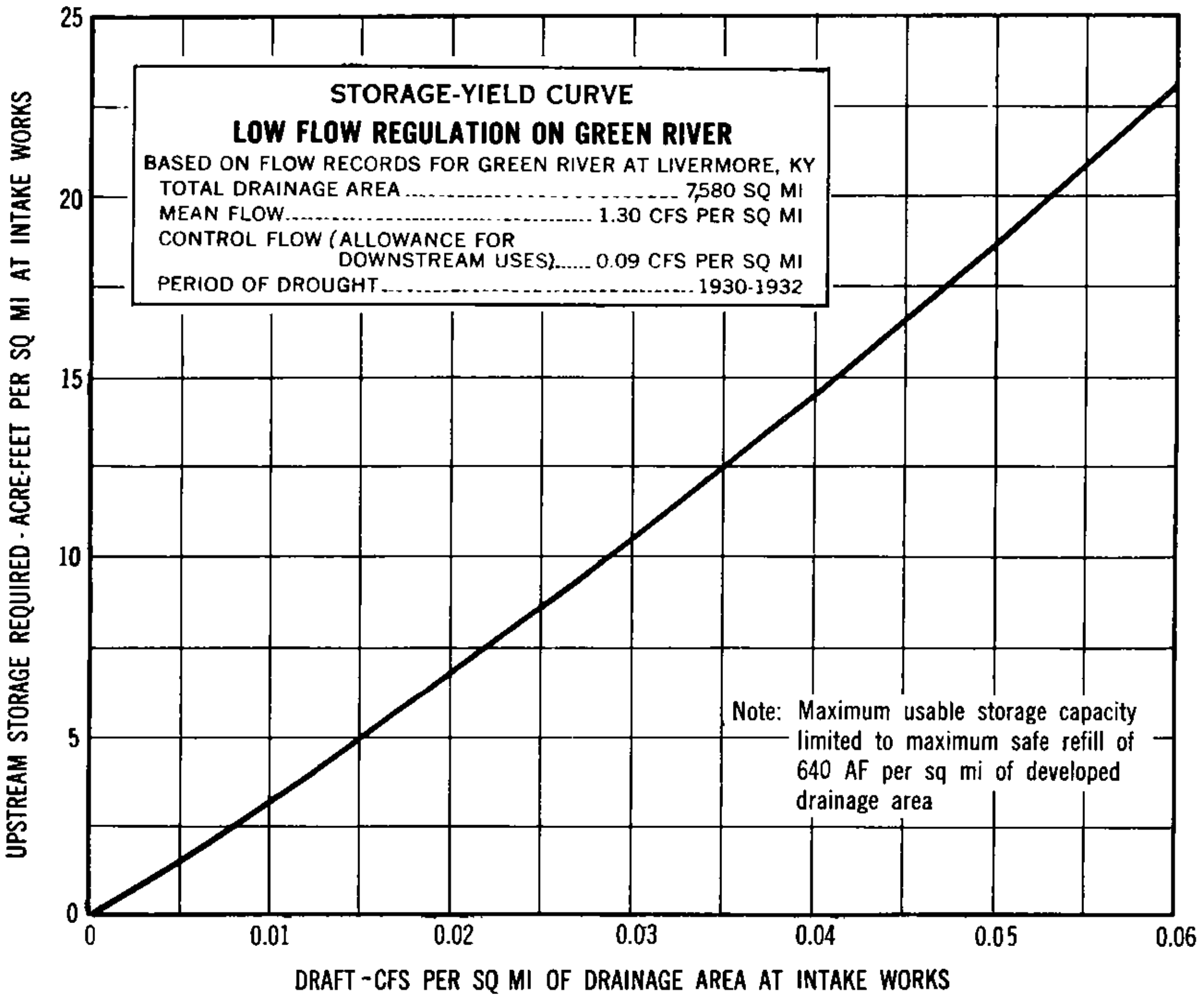
REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY

CURVE USED TO ESTIMATE
WATER STORAGE REQUIREMENTS

Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK CHICAGO PHILADELPHIA LOS ANGELES



Example:

Drainage area at waterworks intake .... 1,000 sq mi
Drainage area impounded .... 50 sq mi
Assumed draft (including 10% allowance for river losses) .... 22.5 cfs
Draft per sq mi of total drainage area .... 0.0225 cfs
Upstream storage required (from curve) ... 7.75 AF per sq mi or 7,750 AF

SF-1060A 12-18-51

EXHIBIT NO. 28

REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY

TEN-DAY HYDROGRAPH

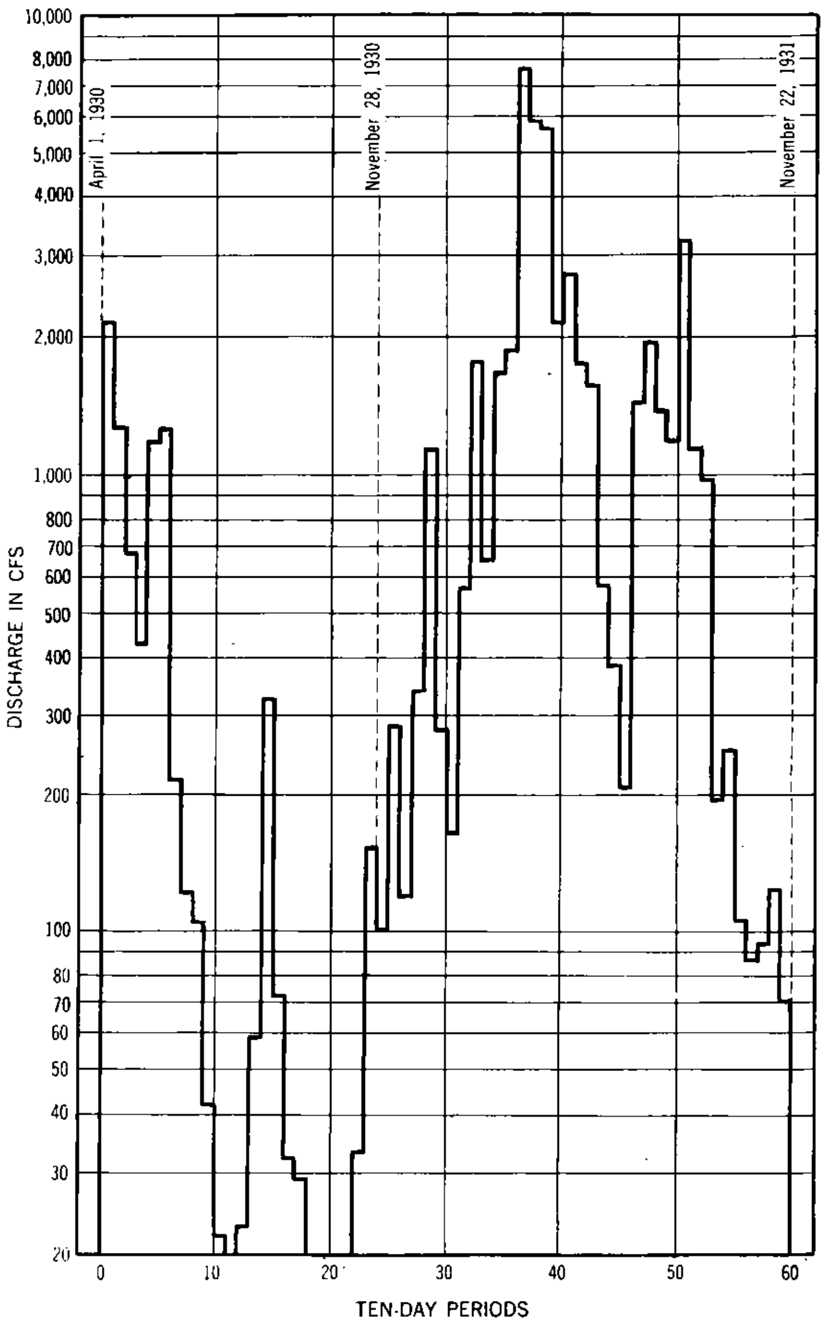
LEVISA FORK AT PAINTSVILLE, KY

FOR PERIOD APRIL 1, 1930 TO NOV. 22, 1931

DRAINAGE AREA = 2,143 SQ MI

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES



SF-1072 5-1-51

EXHIBIT NO. 29

REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY

TEN-DAY HYDROGRAPH

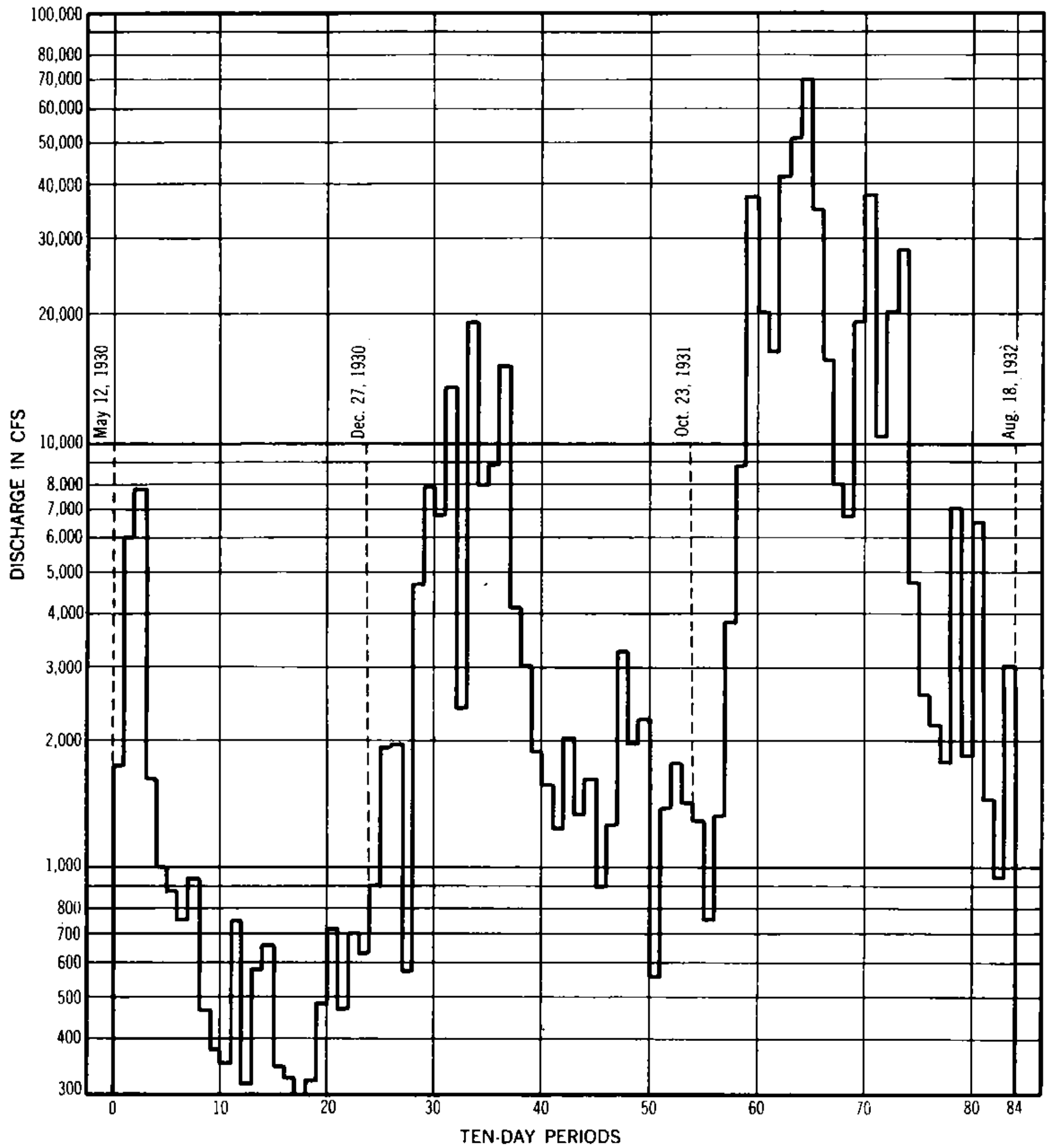
GREEN RIVER AT LIVERMORE, KY.

FOR PERIOD MAY 12, 1930 TO AUG. 18, 1932

DRAINAGE AREA = 7,580 SQ MI

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES



SF-1485 8-7-51

Kentucky Stream Flow Records and Estimates

Stream and Gaging Station	Drainage Area (Sq Mi)	Mean Annual Flow Cfs	Mean Annual Flow Cfs per Sq Mi	Minimum Flow (Cfs) Monthly	Minimum Flow (Cfs) Daily	Records Used in Preparing Estimates
Cumberland River Basin:						
Stinking Creek at Site No. 1	85	132	1.55	*	*	Cumberland River at Cumberland Falls
Straight Creek at Site No. 2	40	62	1.55	*	*	Cumberland River at Cumberland Falls
Brownies Creek at Site No. 3	30	47	1.57	*	*	Cumberland River at Cumberland Falls
Poor Fork	149	231	1.55	1.7	*	Cumberland River at Cumberland Falls
Clover Fork	223	346	1.55	2.6	*	Cumberland River at Cumberland Falls
Cranks Creek at Site No. 4	27	42	1.56	*	*	Cumberland River at Cumberland Falls
Tradewater River Basin	1,008	988	0.98	0	0	Tradewater River at Olney
Crab Orchard Creek	170	167	0.98	0	0	Tradewater River at Olney
Piney Creek at Site No. 5	60	59	0.98	0	0	Tradewater River at Olney
Clear Creek	208	204	0.98	0	0	Tradewater River at Olney
Lick Creek at Site No. 6	32	31	0.97	0	0	Tradewater River at Olney
Donaldson Creek at Site No. 7	72	71	0.99	0	0	Tradewater River at Olney
Green River Basin	9,222	11,989	1.30	387	341	Green River at Livermore
Pond River	795	1,034	1.30	33	29	Green River at Livermore
Rough River	1,077	1,400	1.30	452	398	Green River at Livermore
Mud River	381	495	1.30	16	14	Green River at Livermore
Muddy Creek at Site No. 8	82	107	1.30	3.4	3	Green River at Livermore
Welch Creek at Site No. 9	22	29	1.32	*	*	Green River at Livermore
Barren River	2,142	2,785	1.30	90	79	Green River at Livermore
Reedy Creek at Site No. 10	20	26	1.30	*	*	Green River at Livermore
Bear Creek at Site No. 11	127	165	1.30	5.3	4.7	Green River at Livermore
Beaver Dam Creek at Site No. 12	23	30	1.30	*	*	Green River at Livermore
Nolin River	728	946	1.30	31	27	Green River at Livermore
Kentucky River Basin:						
South Fork Kentucky River	744	945	1.27	2.8	1.9	Kentucky River near Winchester
Middle Fork Kentucky River	553	702	1.27	2.1	1.4	Kentucky River near Winchester
North Fork Kentucky River	1,321	1,678	1.27	5.0	3.3	Kentucky River near Winchester
Middle Fork Kentucky River at Site No. 13	191	243	1.27	*	*	Kentucky River near Winchester
Middle Fork Kentucky River at Site No. 14	192	244	1.27	*	*	Kentucky River near Winchester
Troublesome Creek at Site No. 15	257	326	1.27	*	*	Kentucky River near Winchester
Lotts Creek at Site No. 16	21	27	1.29	*	*	Kentucky River near Winchester
Right Fork at Site No. 17	27	34	1.26	*	*	Kentucky River near Winchester
Carr Fork at Site No. 18	31	39	1.26	*	*	Kentucky River near Winchester
Licking River Basin:						
Grassy Creek	128	163	1.27	*	*	Kentucky River near Winchester
Licking River at Site No. 19	326	414	1.27	1.2	*	Kentucky River near Winchester

Kentucky Stream Flow Records and Estimates

Stream and Gaging Station	Drainage Area (Sq Mi)	Mean Annual Flow Cfs	Mean Annual Flow Cfs per Sq Mi	Minimum Flow (Cfs) Monthly	Minimum Flow (Cfs) Daily	Records Used in Preparing Estimates
Big Sandy River Basin:						
Levisa Fork	2,314	2,360	1.02	11.8	9.0	Levisa Fork at Paintsville
Paint Creek at Site No. 20	120	122	1.02	*	*	Levisa Fork at Paintsville
Caney Fork at Site No. 21	25	26	1.04	*	*	Levisa Fork at Paintsville
Mud Creek at Site No. 22	53	54	1.02	*	*	Levisa Fork at Paintsville
Raccoon Creek at Site No. 23	26	27	1.04	*	*	Levisa Fork at Paintsville
Johns Creek at Site No. 24	40	41	1.03	*	*	Levisa Fork at Paintsville
Beaver Creek	250	255	1.02	1.3	*	Levisa Fork at Paintsville
Shelby Creek	115	117	1.02	*	*	Levisa Fork at Paintsville
Long Fork at Site No. 25	33	34	1.03	*	*	Levisa Fork at Paintsville
Russell Fork	678	692	1.02	3.5	2.6	Levisa Fork at Paintsville
Elkhorn Creek at Site No. 26	52	53	1.02	*	*	Levisa Fork at Paintsville

Note: Flow records obtained from U.S.G.S. Water Supply Papers, except as noted.

* Less than 1 Cfs.

Summary of Data of
Representative Water Storage Projects in Kentucky

Reservoir Number	Stream	Gaging Station Used and Years of Record	Reservoir Data: Drainage Area (Sq Mi)	Storage - Acre-feet: Net	Evaporation	Silting	Total	Depth of Water (Feet)	County	Remarks
	Cumberland River Basin:									
1	Stinking Creek		85	30,000	2,000	1,000	33,000	23	Knox	
2	Straight Creek	Cumberland River (A)	40	242,000	6,000	2,000	250,000	200	Bell	Used as storage reservoir
3	Brownies Creek	at Cumberland Falls	30	9,300	500	200	10,000	81	Bell	for water, pump
		1908-1911								from Cumberland River
4	Cranks Creek	1916-1931	27	10,500	500	200	11,200	102	Harlan	
		1933-1948								
	Tradewater River Basin:									
5	Piney Creek	Tradewater River at	60	30,600	4,800	500	35,900	34	Crittendon	
6	Lick Creek	Olney, Kentucky	32	17,300	2,600	300	20,200	18	Hopkins	
7	Donaldson Creek	1941-1947	72	36,700	6,000	600	43,300	25	Caldwell	
	Green River Basin:									
8	Muddy Creek		82	46,600	7,800	700	55,100	35	Butler	Low flow control
9	Welch Creek	Green River at	22	14,500	1,800	200	16,500	39	Butler	Low flow control
10	Reedy Creek	Livermore, Kentucky	20	13,000	2,000	200	15,200	30	Edmonson	Low flow control
11	Bear Creek	1931-1948	127	83,500	7,400	1,000	91,900	57	Edmonson	Low flow control
12	Beaver Dam Creek		23	7,800	700	200	8,700	55	Edmonson	Low flow control
	Kentucky River Basin:									
13	Middle Fork Kentucky River		191	102,000	6,400	1,500	109,900	100	Leslie	
14	Middle Fork Kentucky River		192	51,000	1,600	1,500	54,100	118	Leslie	
15	Troublesome Creek	Kentucky River near	257	135,000	6,600	2,100	143,700	100	Breathitt	
16	Lotts Creek	Winchester, Kentucky	21	107,000	2,500	1,100	110,600	210	Perry	Used as storage reservoir
17	Right Fork	1910-1948	27	83,500	2,100	900	86,500	228	Perry	for water, pump
										from Kentucky River
18	Carr Fork		31	10,500	800	200	11,500	58	Knott	
	Licking River Basin:									
19	Licking River	Kentucky River near	326	174,000	13,000	3,000	190,000	60	Morgan	
		Winchester, Kentucky								
		1910-1948								
	Big Sandy River Basin:									
20	Paint Creek		120	42,000	2,000	1,000	45,000	82	Johnson	
21	Caney Fork		25	23,300	1,100	200	24,600	100	Knott	
22	Mud Creek	Levisa Fork at	53	21,100	1,300	400	22,800	51	Floyd	
23	Raccoon Creek	Paintsville, Kentucky	26	8,600	700	200	9,500	55	Pike	Low flow control
24	Johns Creek	1930-1948	40	12,000	600	300	12,900	76	Pike	
25	Long Fork		33	13,100	500	300	13,900	84	Pike	Low flow control
26	Elkhorn Creek		52	20,700	500	400	21,600	54	Pike	Low flow control

Ky Note: (A) Flow for water year 1932 was estimated and included in record.

70021

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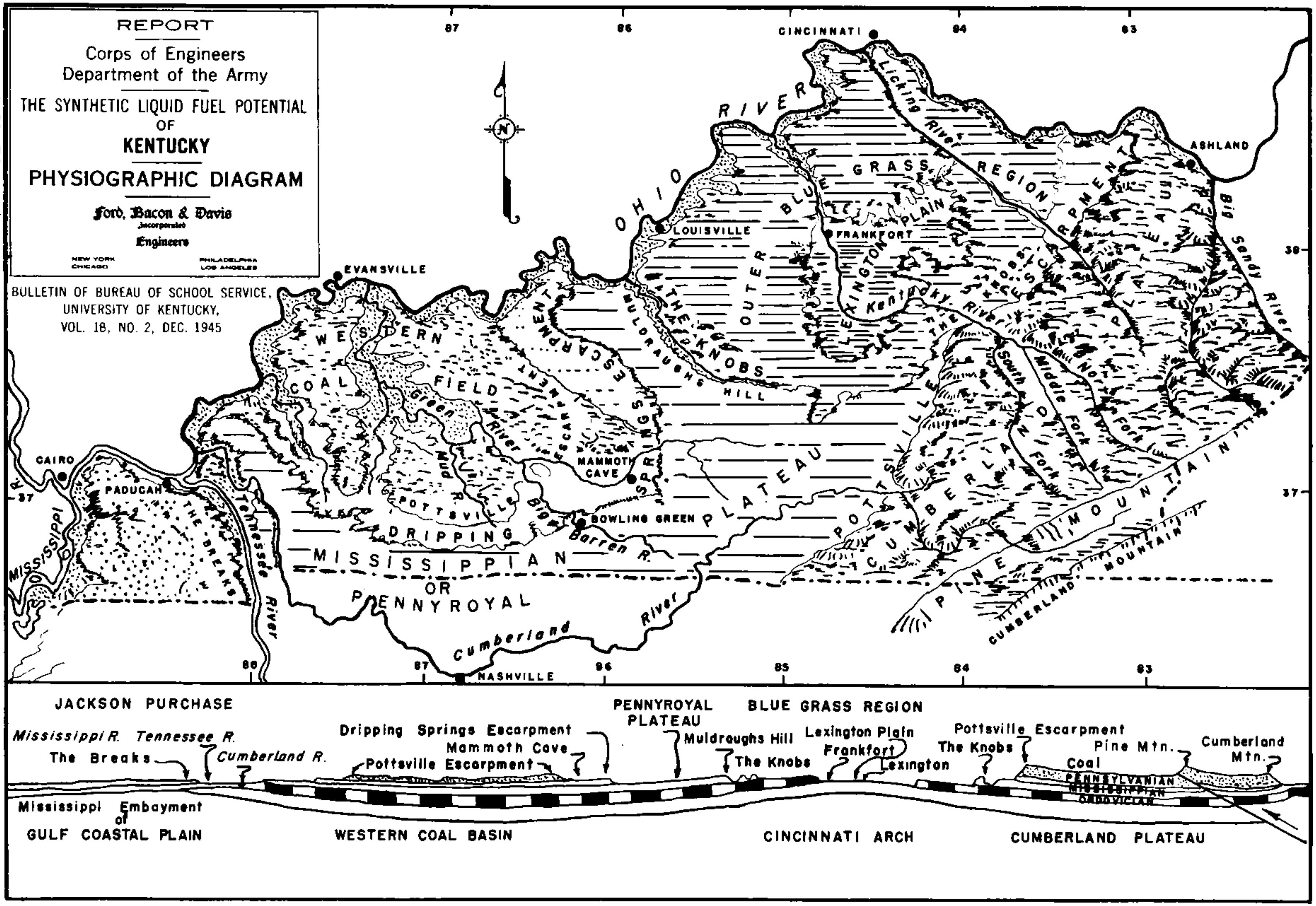


EXHIBIT NO. 32

Chemical and Physical Analysis of Surface Waters of Kentucky at Selected Sampling Stations

	Tradewater River at mouth Crittendon Co.	Green River above Central City Muhlenberg Co.	Green River below Morgantown Butler Co.	Bear Creek at mouth Edmonson Co.	Middle Fork Kentucky River below Hyden Leslie Co.	Carr Fork mouth at Jeff Perry Co.	Licking River 1/4 mile below West Liberty Morgan Co.	Paint Creek 100 yds above mouth at Paintsville Johnson Co.	Long Fork at mouth - Virgie Pike Co.	Clover Fork below Evarts Harlan Co.	Elkhorn Creek at mouth above Elkhorn City Pike Co.	Ohio River at Henderson, Ky. Henderson Co.	Tradewater River at Olney, Ky. Hopkins Co.	Pond River at Jewel City Hopkins Co.	Green River near Sebree, Webster Co.	Johns Creek near Van Lear Johnson Co.	Levisa Fork at Paintsville Johnson Co.	Levisa Fork at Pikeville Pike Co.
Source of Data	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(B)(T)	(C)	(C)	(C)	(C)	(C)	(C)
Date of Collection	9/12/40	10/30/40	10/9/40	10/8/40	10/16/39	11/2/39	11/20/39	11/20/39	11/14/39	9/5/40	11/13/39	7/6/31	3/6/50	7/12/50	4/25/50	10/26/49	11/1-10/50	10/16/49
River Discharge - Cfs	1	320	360	1-			27			33								
Temperature ° F.	73	62	50	65	51	41	47	48	35	69	39							
Color													1	2	3	10	7	7
pH	7.8	7.7	7.7	7.7	7.3	7.3	7.0	7.0	7.0	7.4	7.9		7.7	3.9	7.8	7.4	7.6	7.4
Sp. Cond. (K x 10^5) - Ppm																		
Silica (SiO_2) - Ppm												4	9.4	9.6	4.8	6.7	9.5	3.8
Iron (Fe) - Ppm												.03	.02	1.0	.04	.03	.14	.06
Manganese (Mn) - Ppm														3.9				
Calcium (Ca) - Ppm												39	25	54	38	12	16	16
Magnesium (Mg) - Ppm												9.1	11	33	6.9	5.1	7.1	8.2
Sod. & Pot. (Na + K) - Ppm												14.5	6.4	24.4	5.2	14	16	19
Bicarbonate (HCO_3) - Ppm												56	20	0	110	43	43	58
Sulfate (SO_4) - Ppm												85	97	324	36	17	50	53
Chloride (Cl) - Ppm												18	2.0	3.0	3.0	19	10	7.8
Fluoride (F) - Ppm													.3	.4	.3	.2	.1	.1
Nitrate (NO_3) - Ppm												1.6	.7	.4	2.3	1.6	1.6	.1
Hardness as $CaCO_3$, Total - Ppm	85	102	96	114			97	254	82	62	204	135	108	270	123	51	69	74
Non-Carbonate - Ppm													91	270	33	16	34	26
M.O. Alkalinity as $CaCO_3$ - Ppm	68	102	100	114	37	17	48	102	42	38	139							
Dissolved Solids - Ppm												221	173	491	153	102	131	138
Turbidity - Ppm	23	8	10	5	11	4	22	37	4	5	5							
Aluminum (Al) - Ppm														4.4				
Total Acidity as H_2SO_4 - Ppm														41				

Note: (A) Data from Ohio River Pollution Control Report, 1944

(B) Water Supply Paper 658, U.S.G.S.

(T) Average tap sample of filtered water

(C) Data from Agricultural and Industrial Development Board in Kentucky

Exhibit No. 34

Chemical and Physical Analysis of Ground Waters of the Ohio River Valley at Selected Stations in West Virginia

	Well			
	Parkersburg	Parkersburg	Parkersburg	Point Pleasant
Depth in Feet	55	50-65	50-65	96
Date of Collection	2/14/27	8/30/29	5/27/42	8/13/42
Yield - Gpm	150	50-300	50-300	250
Temperature - ° F			53	55
Silica (SiO_2) - Ppm	21	18	13	
Iron (Fe) - Ppm	1.6		0.11	
Manganese (Mn) - Ppm			0.8	
Calcium (Ca) - Ppm	26	48	47	
Magnesium (Mg) - Ppm	3.7	8.4	8.4	
Sod. & Pot. (Na + K) - Ppm	14	7.3	17	
Bicarbonate (HCO_3) - Ppm	78*	83	72	236
Sulfate (SO_4) - Ppm	21	58	93	36*
Chloride (Cl) - Ppm	17	28	19	8.0
Fluoride (F) - Ppm			0.2	0.2
Nitrate (NO_3) - Ppm		0.25	1.8	4.1
Total Hardness as $CaCO_3$ - Ppm	80	152	152	213
Non-Carbonate - Ppm	16	84	93	19
Dissolved Solids - Ppm		230	240	

Ky Source: "Ground Water Conditions Along the Ohio Valley at Parkersburg, W. Va.," W. Va. Geological Survey, Bull. 1945

7

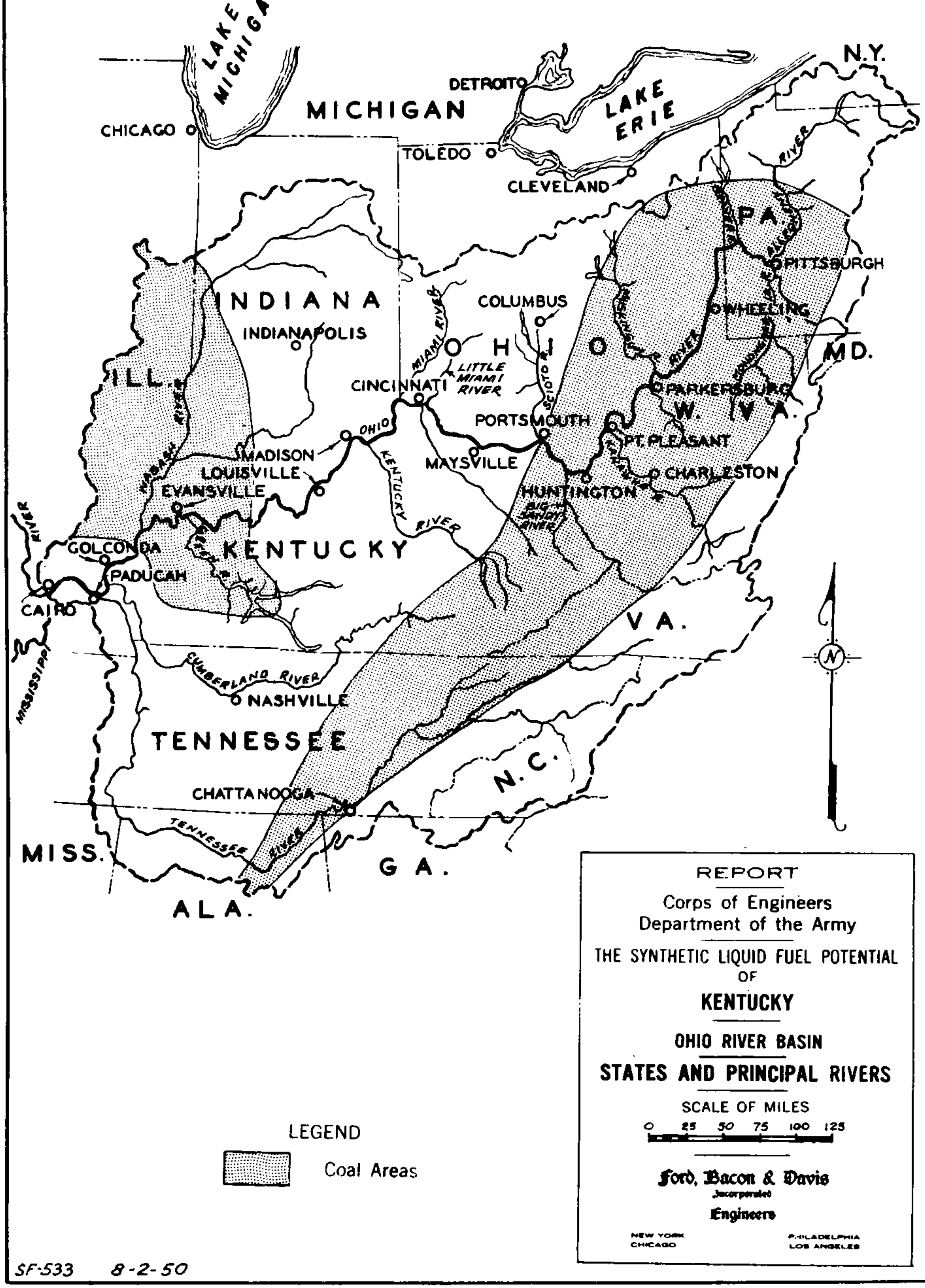
70021 * By turbidity, approximate

Sources and Quantities of Water Available for Complete Development of Synthetic Liquid Fuel Resources
(Coal Synthine Process)

General Area	Source of Water Supply for Initial Unit Plant (20 Cfs)	Daily Production Capacity Supportable by Coal Resources (1,000 Bbl)	Potential Total Water Requirement (Cfs)	Available Sources for Additional Water Supply	Total Water Available (Cfs)
Johnson-Magoffin	Dewey Reservoir (Johns Creek)	32	65	Dewey Reservoir (Johns Creek)	65
Pike	Johns Creek Reservoir (No. 24)	392	794	Ohio River	794
Floyd-Magoffin	Mud Creek Reservoir (No. 22)	155	314	Levisa Fork augmented by -	
				Proposed Fishtrap Reservoir	226
				Mud Creek Reservoir (No. 22)	34
				Long Fork Reservoir (No. 25)	21
				Elkhorn Creek Reservoir (No. 26)	33
				Total	314
Knott-Breathitt	Caney Fork Reservoir (No. 21)	99	200	Troublesome Creek Reservoir (No. 15)	200
Perry-Breathitt	North Fork Kentucky River augmented by Lotts Creek Reservoir (No. 16)	74	150	North Fork Kentucky River augmented by Lotts Creek Reservoir (No. 16)	150
Leslie-Harlan	Middle Fork Kentucky River Reservoir (No. 14)	53	107	Middle Fork Kentucky River Reservoir (No. 14)	107
Northern Letcher	Carr Fork Reservoir (No. 18)	58	117	North Fork Kentucky River augmented by Right Fork Reservoir (No. 17)	117
Harlan-Letcher	Cranks Creek Reservoir (No. 4)	166	336	Cumberland River augmented by Straight Creek Reservoir (No. 2)	336
Bell	Brownies Creek Reservoir (No. 3)	33	67	Stinking Creek Reservoir (No. 1)	67
Daviess	Green River	9	18	Green River	18
Henderson	Ohio River	55	111	Ohio River	111
Union	Ohio River	80	162	Ohio River	162
Webster	Tradewater River	106	215	Ohio River	215
Hopkins-Christian	Lick Creek Reservoir (No. 6)	183	371	Ohio River	371
Muhlenberg-McLean	Green River	137	277	Green River augmented by -	
				Welch Creek Reservoir (No. 9)	36
				Reedy Creek Reservoir (No. 10)	32
				Bear Creek Reservoir (No. 11)	209
				Total	277
Ohio	Green River	64	130	Green River augmented by Muddy Creek Reservoir (No. 8)	130
	Total	1,696	3,434		

Note: Numbers in parenthesis refer to Reservoirs shown on Exhibit No. 31.

EXHIBIT NO. 36



REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL OF

KENTUCKY

OHIO RIVER BASIN

STATES AND PRINCIPAL RIVERS

SCALE OF MILES

0 25 50 75 100 125

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES

Estimates of Coal Production Costs
(As of March 31, 1950)

	General Area									
	Johnson-Magoffin		Pike		Floyd-Magoffin		Knott-Breathitt		Perry-Breathitt	
Type of Mining	Underground		Underground		Underground		Underground		Underground	
Productivity (tons per man-shift)	6		7		7		7		7	
Hydrogenation (H) or Synthine (S) Process	H	S	H	S	H	S	H	S	H	S
Daily Production - tons (240 days per year)	5,428	6,978	5,289	6,800	5,550	7,134	5,420	6,968	5,524	7,102
Annual Production (thousands of tons)	1,303	1,675	1,269	1,632	1,332	1,712	1,301	1,672	1,326	1,705
Daily Plant Consumption - tons (365 days per year)	3,569	4,588	3,478	4,471	3,649	4,691	3,564	4,582	3,632	4,670
Life of Reserves (years) (as of January 1, 1949)	163	127	2,017	1,569	796	620	508	395	379	294
Plant Investment (thousands of dollars)	$ 7,818	$10,050	$ 6,345	$8,160	$ 6,660	$8,560	$ 6,505	$8,360	$ 6,630	$8,525
Items of Cost per ton:										
All Labor	$2.67		$2.29		$2.29		$2.29		$2.29	
Vacation Payments	.07		.06		.06		.06		.06	
Welfare Fund	.30		.30		.30		.30		.30	
Total Labor	$3.04		$2.65		$2.65		$2.65		$2.65	
All Supplies	.78		.75		.75		.75		.75	
Power	.15		.15		.15		.15		.15	
Payroll Taxes	.11		.09		.09		.09		.09	
Other Taxes, Insurance, Miscellaneous	.43		.39		.39		.39		.39	
Depreciation	.40		.33		.33		.33		.33	
Royalty or Depletion	.10		.30		.20		.20		.20	
Engineering, Management, Administration	.10		.10		.10		.10		.10	
Net Production Cost per Ton	$5.11		$4.76		$4.66		$4.66		$4.66	
Btu per pound of coal (as received)	13,730		14,090		13,430		13,750		13,490	
Cost per million Btu (cents)	18.61¢		16.89¢		17.35¢		16.95¢		17.27¢	

Estimates of Coal Production Costs
(As of March 31, 1950)

General Area

	Leslie-Harlan		Northern Letcher		Harlan-Letcher		Bell		Daviess			
Type of Mining	Underground		Underground		Underground		Underground		Underground		Strip	
Productivity (tons per man-shift)	7		7		7		7		9		25	
Hydrogenation (H) or Synthine (S) Process	H	S	H	S	H	S	H	S	H	S	H	S
Daily Production - tons (240 days per year)	5,448	7,003	5,335	6,859	5,331	6,853	5,400	6,943	6,906	8,880	6,906	8,880
Annual Production (thousands of tons)	1,307	1,681	1,280	1,646	1,279	1,645	1,296	1,666	1,657	2,131	1,657	2,131
Daily Plant Consumption - tons (365 days per year)	3,582	4,605	3,508	4,510	3,505	4,506	3,551	4,565	4,541	5,839	4,541	5,839
Life of Reserves (years) (as of January 1, 1949)	271	210	296	230	851	662	171	133	42	33	4	3
Plant Investment (thousands of dollars)	$6,535	$8,405	$6,400	$8,230	$6,395	$8,225	$7,128	$9,163	$7,457	$9,590	$6,214	$7,991

Items of Cost per ton:	Leslie-Harlan	Northern Letcher	Harlan-Letcher	Bell	Daviess Underground	Daviess Strip
All Labor	$2.29	$2.29	$2.29	$2.29	$1.78	$0.66
Vacation Payments	.06	.06	.06	.06	.05	.02
Welfare Fund	.30	.30	.30	.30	.30	.30
Total Labor	$2.65	$2.65	$2.65	$2.65	$2.13	$0.98
All Supplies	.75	.75	.75	.75	.69	.70
Power	.15	.15	.15	.15	.15	.15
Payroll Taxes	.09	.09	.09	.09	.07	.03
Other Taxes, Insurance, Miscellaneous	.39	.39	.39	.40	.35	.27
Depreciation	.33	.33	.33	.37	.30	.25
Royalty or Depletion	.20	.20	.30	.20	.10	.15
Engineering, Management, Administration	.10	.10	.10	.10	.10	.10
Net Production Cost per Ton	$4.66	$4.66	$4.76	$4.71	$3.89	$2.63
Btu per pound of coal (as received)	13,680	13,970	13,980	13,800	10,790	10,790
Cost per million Btu (cents)	17.03¢	16.68¢	17.02¢	17.07¢	18.03¢	12.19¢

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Estimates of Coal Production Costs
(As of March 31, 1950)

	General Area							
	Henderson		Union		Webster			
Type of Mining	Underground		Underground		Underground		Strip	
Productivity (tons per man-shift)	8		10		10		25	
Hydrogenation (H) or Synthine (S) Process	H	S	H	S	H	S	H	S
Daily Production - tons (240 days per year)	6,800	8,742	6,039	7,764	6,010	7,727	6,019	7,740
Annual Production (thousands of tons)	1,632	2,098	1,449	1,863	1,442	1,855	1,445	1,857
Daily Plant Consumption - tons (365 days per year)	4,471	5,748	3,971	5,105	3,952	5,081	3,958	5,089
Life of Reserves (years) (as of January 1, 1949)	282	219	414	322	534	415	10	8
Plant Investment (thousands of dollars)	$7,344	$9,441	$6,521	$8,384	$6,489	$8,348	$5,058	$6,500
Items of Cost per ton:								
All Labor	$2.00		$1.60		$1.60		$0.66	
Vacation Payments	.05		.04		.04		.02	
Welfare Fund	.30		.30		.30		.30	
Total Labor	$2.35		$1.94		$1.94		$0.98	
All Supplies	.72		.66		.66		.70	
Power	.15		.15		.15		.15	
Payroll Taxes	.08		.06		.06		.03	
Other Taxes, Insurance, Miscellaneous	.36		.34		.34		.27	
Depreciation	.30		.30		.30		.23	
Royalty or Depletion	.10		.10		.10		.15	
Engineering, Management, Administration	.10		.10		.10		.10	
Net Production Cost per Ton	$4.16		$3.65		$3.65		$2.61	
Btu per pound of coal (as received)	10,960		12,340		12,400		12,380	
Cost per million Btu (cents)	18.98¢		14.79¢		14.72¢		10.54¢	

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Estimates of Coal Production Costs
(As of March 31, 1950)

General Area

	Hopkins-Christian				Muhlenberg-McLean				Ohio			
Type of Mining	Underground		Strip		Underground		Strip		Underground		Strip	
Hydrogenation (H) or Synthine (S) Process	H	S	H	S	H	S	H	S	H	S	H	S
Daily Production - tons (240 days per year)	6,216	7,990	6,252	8,038	6,149	7,905	6,144	7,899	6,363	8,182	6,468	8,317
Annual Production (thousands of tons)	1,492	1,918	1,501	1,929	1,476	1,897	1,475	1,896	1,527	1,964	1,552	1,996
Daily Plant Consumption - tons (365 days per year)	4,087	5,254	4,111	5,285	4,043	5,198	4,040	5,194	4,184	5,380	4,253	5,469
Life of Reserves (years) (as of January 1, 1949)	875	680	64	50	657	511	47	37	207	161	124	97
Plant Investment (thousands of dollars)	$5,968	$7,672	$5,254	$6,752	$5,904	$7,588	$5,163	$6,636	$6,872	$8,838	$5,044	$6,487

	Hopkins-Christian Underground	Hopkins-Christian Strip	Muhlenberg-McLean Underground	Muhlenberg-McLean Strip	Ohio Underground	Ohio Strip
Productivity (tons per man-shift)	10	25	10	25	9	25
Items of Cost per ton:						
All Labor	$1.60	$0.66	$1.60	$0.66	$1.78	$0.66
Vacation Payments	.04	.02	.04	.02	.05	.02
Welfare Fund	.30	.30	.30	.30	.30	.30
Total Labor	$1.94	$0.98	$1.94	$0.98	$2.13	$0.98
All Supplies	.66	.70	.66	.70	.69	.70
Power	.15	.15	.15	.15	.15	.15
Payroll Taxes	.06	.03	.06	.03	.07	.03
Other Taxes, Insurance, Miscellaneous	.33	.27	.33	.27	.35	.26
Depreciation	.27	.23	.27	.23	.30	.22
Royalty or Depletion	.30	.35	.30	.35	.20	.35
Engineering, Management, Administration	.10	.10	.10	.10	.10	.10
Net Production Cost per Ton	$3.81	$2.81	$3.81	$2.81	$3.99	$2.79
Btu per pound of coal (as received)	11,990	11,920	12,120	12,130	11,710	11,520
Cost per million Btu (cents)	15.89¢	11.79¢	15.72¢	11.58¢	17.04¢	12.11¢

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Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation		Johnson-Magoffin	
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		Underground	
Coal Bed Designations		Upper Elkhorn No. 1	
Maximum Thickness of Bed (inches)		47	
Minimum " " "		34	
Maximum Dip of Bed (degrees)		2	
Minimum " " "		0	
Maximum Overburden Thickness (feet)		245	
Minimum " " "		160	
Rank of Coal (A)		Hvab	
Proximate Analysis: (B)			
Moisture		4.7%	
Volatile Matter		36.7	
Fixed Carbon		55.6	
Ash		3.0	
Sulfur		1.2%	
Btu, as received		13,730	
Btu, moisture- and ash-free		14,880	
Estimated Recoverable Reserves (1,000 tons):			
Primary		106,376	
Secondary		106,176	
Total		212,552	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	41		32
Estimated Mine Capital Cost ($1,000's)	$7,818		$10,050
Estimated Cost per ton of coal produced:			
Available by stripping	None		None
Balance from underground	$5.11		$5.11
Combined (weighted average) Cost	$5.11		$5.11
Estimated Cost per million Btu (cents)	18.61¢		18.61¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.82		$2.34
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.82		$2.34

Note: (A) High-volatile A bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.

Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation		Pike	
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		Underground	
Coal Bed Designations		Fire Clay; Williamson; U. Elkhorn No. 3; U. Elkhorn No. 2; U. Elkhorn No. 1; Lower Elkhorn; Bingham	
Maximum Thickness of Bed (inches)		73	
Minimum " " " "		24	
Maximum Dip of Bed (degrees)		2	
Minimum " " " "		0	
Maximum Overburden Thickness (feet)		450	
Minimum " " "		30	
Rank of Coal (A)		Hvab	
Proximate Analysis: (B)			
Moisture		3.1%	
Volatile Matter		34.9	
Fixed Carbon		57.7	
Ash		4.3	
Sulfur		1.0%	
Btu, as received		14,090	
Btu, moisture- and ash-free		15,220	
Estimated Recoverable Reserves (1,000 tons):			
Primary		1,491,652	
Secondary		1,068,927	
Total		2,560,579	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	504		392
Estimated Mine Capital Cost ($1,000's)	$6,345		$ 8,160
Estimated Cost per ton of coal produced:			
Available by stripping	None		None
Balance from underground	$4.76		$4.76
Combined (weighted average) Cost	$4.76		$4.76
Estimated Cost per Million Btu (cents)	16.89¢		16.89¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.66		$2.13
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.66		$2.13

Note: (A) High-volatile A bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.

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Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation	Floyd-Magoffin		
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		Underground	
Coal Bed Designations		Hazard, U. Elkhorn No. 3, 2 and 1, Lower Elkhorn	
Maximum Thickness of Bed (inches)		54	
Minimum " " " "		30	
Maximum Dip of Bed (degrees)		2	
Minimum " " " "		0	
Maximum Overburden Thickness (feet)		400	
Minimum " " "		80	
Rank of Coal (A)		Hvab	
Proximate Analysis: (B)			
Moisture		3.9%	
Volatile Matter		37.1	
Fixed Carbon		52.9	
Ash		6.1	
Sulfur		1.5%	
Btu, as received		13,430	
Btu, moisture- and ash-free		14,920	
Estimated Recoverable Reserves (1,000 tons):			
Primary		620,892	
Secondary		439,933	
Total		1,060,825	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	199		155
Estimated Mine Capital Cost ($1,000's)	$ 6,660		$ 8,560
Estimated Cost per ton of coal produced:			
Available by stripping	None		None
Balance from underground	$4.66		$4.66
Combined (weighted average) Cost	$4.66		$4.66
Estimated Cost per million Btu (cents)	17.35¢		17.35¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.70		$2.19
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.70		$2.19

Note: (A) High-volatile A bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.

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Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation		Knott-Breathitt	
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		Underground	
Coal Bed Designations		Flag, Fire Clay, U. Elkhorn Nos. 3 and 1, L. Elkhorn	
Maximum Thickness of Bed (inches)		60	
Minimum " " "		27	
Maximum Dip of Bed (degrees)		2	
Minimum " " " "		0	
Maximum Overburden Thickness (feet)		375	
Minimum " " "		60	
Rank of Coal (A)		Hvab	
Proximate Analysis: (B)			
Moisture		3.7%	
Volatile Matter		36.6	
Fixed Carbon		54.8	
Ash		4.9	
Sulfur		1.0%	
Btu, as received		13,750	
Btu, moisture- and ash-free		15,030	
Estimated Recoverable Reserves (1,000 tons):			
Primary		330,407	
Secondary		381,655	
Total		660,814(D)	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	127		99
Estimated Mine Capital Cost ($1,000's)	$ 6,505		$ 8,360
Estimated Cost per ton of coal produced:			
Available by stripping	None		None
Balance from underground	$4.66		$4.66
Combined (weighted average) Cost	$4.66		$4.66
Estimated Cost per million Btu (cents)	16.95¢		16.95¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.66		$2.14
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.66		$2.14

Note: (A) High-volatile A bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.
(D) Total primary and secondary coal reserves limited by definition to twice the primary reserves.

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Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation	Perry-Breathitt		
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		Underground	
Coal Bed Designations		Flag, Hazard, Fire Clay	
Maximum Thickness of Bed (inches		63	
Minimum " " " "		27	
Maximum Dip of Bed (degrees)		2	
Minimum " " " "		0	
Maximum Overburden Thickness (feet)		280	
Minimum " " "		40	
Rank of Coal (A)		Hvab	
Proximate Analysis: (B)			
Moisture		4.3%	
Volatile Matter		36.3	
Fixed Carbon		54.1	
Ash		5.3	
Sulfur		0.7%	
Btu, as received		13,490	
Btu, moisture- and ash-free		14,920	
Estimated Recoverable Reserves (1,000 tons):			
Primary		280,710	
Secondary		221,191	
Total		501,901	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	95		74
Estimated Mine Capital Cost ($1,000's)	$ 6,630		$ 8,525
Estimated Cost per ton of coal produced:			
Available by stripping	None		None
Balance from underground	$4.66		$4.66
Combined (weighted average) Cost	$4.66		$4.66
Estimated Cost per million Btu (cents)	17.27¢		17.27¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.69		$2.18
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.69		$2.18

Note: (A) High-volatile A bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.

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Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation	Leslie-Harlan		
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		Underground	
Coal Bed Designations		Hazard, Fire Clay Rider, Fire Clay, Williamson	
Maximum Thickness of Bed (inches)		47	
Minimum " " " "		25	
Maximum Dip of Bed (degrees)		3	
Minimum " " " "		0	
Maximum Overburden Thickness (feet)		350	
Minimum " " "		100	
Rank of Coal (A)		Hvab	
Proximate Analysis: (B)			
Moisture		3.9%	
Volatile Matter		37.6	
Fixed Carbon		54.1	
Ash		4.4	
Sulfur		0.7%	
Btu, as received		13,680	
Btu, moisture- and ash-free		14,920	
Estimated Recoverable Reserves (1,000 tons):			
Primary		194,498	
Secondary		159,181	
Total		353,679	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	68		53
Estimated Mine Capital Cost ($1,000's)	$6,535		$8,405
Estimated Cost per ton of coal produced:			
Available by stripping	None		None
Balance from underground	$4.66		$4.66
Combined (weighted average) Cost	$4.66		$4.66
Estimated Cost per million Btu (cents)	17.03¢		17.03¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.67		$2.15
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.67		$2.15

Note: (A) High-volatile A bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.

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Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation	Northern Letcher		
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		Underground	
Coal Bed Designations		Fire Clay, Whitesburg*, U. Elkhorn No. 3 and No. 2, Lower Elkhorn	
Maximum Thickness of Bed (inches)		75	
Minimum " " " "		31	
Maximum Dip of Bed (degrees)		4	
Minimum " " " "		0	
Maximum Overburden Thickness (feet)		400	
Minimum " " "		80	
Rank of Coal (A)		Hvab	
Proximate Analysis: (B)			
Moisture		3.5%	
Volatile Matter		36.5	
Fixed Carbon		56.0	
Ash		4.0	
Sulfur		0.9%	
Btu, as received		13,970	
Btu, moisture- and ash-free		15,110	
Estimated Recoverable Reserves (1,000 tons):			
Primary		248,960	
Secondary		129,874	
Total		378,834	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	74		58
Estimated Mine Capital Cost ($1,000's)	$6,400		$8,230
Estimated Cost per ton of coal produced:			
Available by stripping	None		None
Balance from underground	$4.66		$4.66
Combined (weighted average) Cost	$4.66		$4.66
Estimated Cost per million Btu (cents)	16.68¢		16.68¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.63		$2.10
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.63		$2.10

Note: (A) High-volatile A bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.

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Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation		Harlan-Letcher	
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		Underground	
Coal Bed Designations		High Splint, Williamson, U. Elkhorn Nos. 3, 2, and 1, Harlan, L. Elkhorn	
Maximum Thickness of Bed (inches)		81	
Minimum " " " "		29	
Maximum Dip of Bed (degrees)		5	
Minimum " " " "		0	
Maximum Overburden Thickness (feet)		850	
Minimum " " "		100	
Rank of Coal (A)		Hvab	
Proximate Analysis: (B)			
Moisture		3.3%	
Volatile Matter		36.5	
Fixed Carbon		56.0	
Ash		4.2	
Sulfur		0.7%	
Btu, as received		13,980	
Btu, moisture- and ash-free		15,110	
Estimated Recoverable Reserves (1,000 tons):			
Primary		628,401	
Secondary		460,653	
Total		1,089,054	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	213		166
Estimated Mine Capital Cost ($1,000's)	$6,395		$8,225
Estimated Cost per ton of coal produced:			
Available by stripping	None		None
Balance from underground	$4.76		$4.76
Combined (weighted average) Cost	$4.76		$4.76
Estimated Cost per million Btu (cents)	17.02¢		17.02¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.67		$2.14
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.67		$2.14

Note: (A) High-volatile A bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.

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Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation		Bell	
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		Underground	
Coal Bed Designations		Hignite, Fire Clay, Williamson, Harlan, Puckett Creek	
Maximum Thickness of Bed (inches)		55	
Minimum " " " "		27	
Maximum Dip of Bed (degrees)		4	
Minimum " " " "		0	
Maximum Overburden Thickness (feet)		510	
Minimum " " "		100	
Rank of Coal (A)		Hvab	
Proximate Analysis: (B)			
Moisture		2.8%	
Volatile Matter		37.3	
Fixed Carbon		54.9	
Ash		5.0	
Sulfur		1.2%	
Btu, as received		13,800	
Btu, moisture- and ash-free		14,970	
Estimated Recoverable Reserves (1,000 tons):			
Primary		119,847	
Secondary		101,775	
Total		221,622	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	43		33
Estimated Mine Capital Cost ($1,000's)	$7,128		$9,163
Estimated Cost per ton of coal produced:			
Available by stripping	None		None
Balance from underground	$4.71		$4.71
Combined (weighted average) Cost	$4.71		$4.71
Estimated Cost per million Btu (cents)	17.07¢		17.07¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.67		$2.15
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.67		$2.15

Note: (A) High-volatile A bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.

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Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation		Daviess	
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		U & S	
Coal Bed Designations		No. 9	
Maximum Thickness of Bed (inches)		53	
Minimum " " " "		46	
Maximum Dip of Bed (degrees)		2	
Minimum " " " "		0	
Maximum Overburden Thickness Underground (feet)		95	
Minimum " " " "		30	
Average Maximum Overburden Thickness Strip (feet)		65	
" Minimum " " " "		45	
Rank of Coal (A)		Hvcb	
Proximate Analysis: (B)			
Moisture		12.1%	
Volatile Matter		36.1	
Fixed Carbon		40.1	
Ash		11.7	
Sulfur		3.0%	
Btu, as recived		10,790	
Btu, moisture- and ash-free		14,160	
Estimated Recoverable Reserves (1,000 tons):			
Primary		52,690	
Secondary		23,877	
Total		76,567	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	12		9
Estimated Mine Capital Cost ($1,000's)	$7,457		$9,590
Estimated Cost per ton of coal produced:			
Available by stripping	$2.63		$2.63
Balance from underground	3.89		3.89
Combined (weighted average) Cost	$3.76		$3.79
Estimated Cost per million Btu (cents)	17.42¢		17.56¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.71		$2.21
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.71		$2.21

Note: (A) High-volatile C bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.

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Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation		Henderson	
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		Underground	
Coal Bed Designations		No. 14, No. 9	
Maximum Thickness of Bed (inches)		57	
Minimum " " " "		42	
Maximum Dip of Bed (degrees)		2	
Minimum " " " "		0	
Maximum Overburden Thickness (feet)		310	
Minimum " " "		50	
Rank of Coal (A)		Hvcb	
Proximate Analysis: (B)			
Moisture		10.7%	
Volatile Matter		34.7	
Fixed Carbon		41.8	
Ash		12.8	
Sulfur		3.4%	
Btu, as received		10,960	
Btu, moisture- and ash-free		14,330	
Estimated Recoverable Reserves (1,000 tons):			
Primary		229,933	
Secondary		250,141	
Total		459,866(D)	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	70		55
Estimated Mine Capital Cost ($1,000's)	$7,344		$9,441
Estimated Cost per ton of coal produced:			
Available by stripping	None		None
Balance from underground	$4.16		$4.16
Combined (weighted average) Cost	$4.16		$4.16
Estimated Cost per million Btu (cents)	18.98¢		18.98¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.86		$2.39
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.86		$2.39

Note: (A) High-volatile C bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.
(D) Total primary and secondary coal reserves limited by definition to twice the primary reserves.

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Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation		Union	
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		Underground	
Coal Bed Designations		No. 11, No. 9, No. 6	
Maximum Thickness of Bed (inches)		66	
Minimum " " "		45	
Maximum Dip of Bed (degrees)		3	
Minimum " " " "		0	
Maximum Overburden Thickness (feet)		545	
Minimum " " "		50	
Rank of Coal (A)		Hvab-Hvbb	
Proximate Analysis: (B)			
Moisture		5.9%	
Volatile Matter		37.3	
Fixed Carbon		46.8	
Ash		10.0	
Sulfur		3.7%	
Btu, as received		12,340	
Btu, moisture- and ash-free		14,660	
Estimated Recoverable Reserves (1,000 tons):			
Primary		343,296	
Secondary		256,195	
Total		599,491	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	103		80
Estimated Mine Capital Cost ($1,000's)	$6,521		$8,384
Estimated Cost per ton of coal produced:			
Available by stripping	None		None
Balance from underground	$3.65		$3.65
Combined (weighted average) Cost	$3.65		$3.65
Estimated Cost per million Btu (cents)	14.79¢		14.79¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.45		$1.86
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.45		$1.86

Note: (A) High-volatile A bituminous or high-volatile B bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.

Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation		Webster	
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		U & S	
Coal Bed Designations		No. 14, No. 12, No. 11, No.9	
Maximum Thickness of Bed (inches)		86	
Minimum " " " "		46	
Maximum Dip of Bed (degrees)		3	
Minimum " " " "		0	
Maximum Overburden Thickness Underground (feet)		465	
Minimum " " " "		50	
Average Maximum Overburden Thickness Strip (feet)		90	
" Minimum " " " "		40	
Rank of Coal (A)		Hvab-Hvbb	
Proximate Analysis: (B)			
Moisture		6.1%	
Volatile Matter		36.6	
Fixed Carbon		48.0	
Ash		9.3	
Sulfur		3.3%	
Btu, as received		12,400	
Btu, moisture- and ash-free		14,650	
Estimated Recoverable Reserves (1,000 tons):			
Primary		392,493	
Secondary		401,754	
Total		784,986(D)	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	136		106
Estimated Mine Capital Cost ($1,000's)	$6,489		$8,348
Estimated Cost per ton of coal produced:			
Available by stripping	$2.61		$2.61
Balance from underground	3.65		3.65
Combined (weighted average) Cost	$3.39(F)		$3.44(F)
Estimated Cost per million Btu (cents)	13.67¢		13.87¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.34		$1.75
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.34		$1.75

Note: (A) High-volatile A bituminous or high volatile B bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.
(D) Total primary and secondary coal reserves limited by definition to twice the primary reserves.
(F) Based on weighted average Btu of strip and underground-mined coal used in 1st plant, 12,400 for hydrogenation and synthine.

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Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation		Hopkins-Christian	
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		U & S	
Coal Bed Designations		No. 14, No. 12, No. 11 No. 9, No. 6	
Maximum Thickness of Bed (inches)		79	
Minimum " " " "		30	
Maximum Dip of Bed (degrees)		3	
Minimum " " " "		0	
Maximum Overburden Thickness Underground (feet)		410	
Minimum " " " "		30	
Average Maximum Overburden Thickness Strip (feet)		90	
" Minimum " " " "		20	
Rank of Coal (A)		Hvbb	
Proximate Analysis: (B)			
Moisture		8.5%	
Volatile Matter		37.2	
Fixed Carbon		45.6	
Ash		8.7	
Sulfur		3.2%	
Btu, as received		11,990	
Btu, moisture- and ash-free		14,470	
Estimated Recoverable Reserves (1,000 tons):			
Primary		887,681	
Secondary		513,335	
Total		1,401,016	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	235		183
Estimated Mine Capital Cost ($1,000's)	$5,254		$6,752
Estimated Cost per ton of coal produced:			
Available by stripping	$2.81		$2.81
Balance from underground	None		None
Combined (weighted average) Cost	$2.81		$2.81
Estimated Cost per million Btu (cents)	11.79¢		11.79¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.16		$1.49
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.16		$1.49

Note: (A) High-volatile B bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.

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Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation		Muhlenberg-McLean	
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		U & S	
Coal Bed Designations		No. 12, No. 11, No. 9, No. 6	
Maximum Thickness of Bed (inches)		75	
Minimum " " " "		30	
Maximum Dip of Bed (degrees)		3	
Minimum " " " "		0	
Maximum Overburden Thickness Underground (feet)		410	
Minimum " " " "		30	
Average Maximum Overburden Thickness Strip (feet)		80	
" Minimum " " " "		20	
Rank of Coal (A)		Hvbb	
Proximate Analysis: (B)			
Moisture		7.9%	
Volatile Matter		38.5	
Fixed Carbon		45.0	
Ash		8.6	
Sulfur		3.7%	
Btu, as received		12,120	
Btu, moisture- and ash-free		14,510	
Estimated Recoverable Reserves (1,000 tons):			
Primary		663,870	
Secondary		375,606	
Total		1,039,476	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	176		137
Estimated Mine Capital Cost ($1,000's)	$5,163		$7,588
Estimated Cost per ton of coal produced:			
Available by stripping	$2.81		$2.81
Balance from underground	None		3.81
Combined (weighted average) Cost	$2.81		$2.89(F)
Estimated Cost per million Btu (cents)	11.58¢		11.91¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.13		$1.50
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.13		$1.50

Note: (A) High-volatile B bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.
(F) Based on weighted average Btu of strip and underground-mined coal used for 1st plant, 12,130 for synthine.

Coal Characteristics and Cost Summaries
General Areas of Coal and Water Availability
(Costs as of March 31, 1950; Reserves as of January 1, 1949)

General Area Designation		Ohio	
Hydrogenation (H) or Synthine (S) Process	H	H & S	S
Type of Mining (Underground or Strip)		U & S	
Coal Bed Designations	No. 14,	No. 11,	No. 9
Maximum Thickness of Bed (inches)		108	
Minimum " " " "		31	
Maximum Dip of Bed (degrees)		2	
Minimum " " " "		0	
Maximum Overburden Thickness Underground (feet)		290	
Minimum " " " "		30	
Average Maximum Overburden Thickness Strip (feet)		75	
" Minimum " " " "		40	
Rank of Coal (A)		Hvcb-Hvbb	
Proximate Analysis: (B)			
Moisture		9.6%	
Volatile Matter		37.1	
Fixed Carbon		44.0	
Ash		9.3	
Sulfur		3.7%	
Btu, as received		11,640	
Btu, moisture- and ash-free		14,350	
Estimated Recoverable Reserves (1,000 tons):			
Primary		435,503	
Secondary		73,440	
Total		508,943	
Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	82		64
Estimated Mine Capital Cost ($1,000's)	$5,044		$6,487
Estimated Cost per ton of coal produced:			
Available by stripping	$2.79		$2.79
Balance from underground	None		None
Combined (weighted average) Cost	$2.79		$2.79
Estimated Cost per million Btu (cents)	12.11¢		12.11¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:			
Coal, cost to produce	$1.19		$1.53
Transportation to Process Plant	-		-
Total Cost per Barrel	$1.19		$1.53

Note: (A) High-volatile B bituminous or high-volatile C bituminous.
(B) Average or representative analyses of mine samples obtained by standard U.S. Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation unit plant and 126 billion Btu per calendar day for coal synthine unit plant.

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Summary of Estimated Water Costs for Unit Coal Synthine Plant in Kentucky

General Area and Source of Water	Water Use	Construction Costs of Water Works To Provide 11.15 Mgd for Process Use and 1.94 Mgd for Domestic Use					Annual Costs To Provide 11.15 Mgd for Process Use and 1.94 Mgd for Domestic Use					Unit Costs of Process Water		
		Storage Reservoir	Pumping Station and Transmission	Storage Basin at Plant Site	Filter Plant	Total	Taxes and Insurance at 1 Percent	Depreciation	Power for Pumping	Supervision, Labor, Repair, Filtration etc. (A)	Total (Less Interest)	Per Mg (Less Interest)	Per Barrel of Products (Less Interest)	Additional Cost per Barrel of Products for each 1 percent on Investment
Johnson-Magoffin														
Dewey Reservoir	Process	$ 423,000	$ 97,000	$170,000	$201,000	$ 891,000	$ 8,910	$ 25,610	$11,670	$29,860	$ 76,050	$18.69	$0.021	$0.002
	Domestic	73,000	17,000	30,000	249,000	369,000	3,690	12,490	2,030	14,340	32,550			
	Total	$ 496,000	$ 114,000	$200,000	$450,000	$1,260,000	$12,600	$ 38,100	$13,700	$44,200	$108,600			
Pike														
Johns Creek Reservoir No. 24	Process	$2,573,000	$ 72,000	-	$201,000	$2,846,000	$28,460	$ 74,090	$ 3,660	$29,860	$136,070	33.43	0.037	0.008
	Domestic	447,000	12,000	-	249,000	708,000	7,080	20,910	640	14,340	42,970			
	Total	$3,020,000	$ 84,000	-	$450,000	$3,554,000	$35,540	$ 95,000	$ 4,300	$44,200	$179,040			
Floyd-Magoffin														
Mud Creek Reservoir No. 22	Process	$2,496,000	$ 303,000	$170,000	$201,000	$3,170,000	$31,700	$ 82,440	$ 9,710	$29,860	$153,710	37.77	0.042	0.009
	Domestic	434,000	53,000	30,000	249,000	766,000	7,660	22,360	1,690	14,340	46,050			
	Total	$2,930,000	$ 356,000	$200,000	$450,000	$3,936,000	$39,360	$104,800	$11,400	$44,200	$199,760			
Knott-Breathitt														
Caney Fork Reservoir No. 21	Process	$5,666,000	$ 713,000	$170,000	$201,000	$6,750,000	$67,500	$173,180	$18,320	$29,860	$288,860	70.98	0.079	0.018
	Domestic	984,000	124,000	30,000	249,000	1,387,000	13,870	38,120	3,180	14,340	69,510			
	Total	$6,650,000	$ 837,000	$200,000	$450,000	$8,137,000	$81,370	$211,300	$21,500	$44,200	$358,370			
Perry-Breathitt														
Lotts Creek Reservoir No. 16	Process	$3,459,000	$ 127,000	$170,000	$201,000	$3,957,000	$39,570	$102,120	$ 9,710	$29,860	$181,260	44,54	0.050	0.011
	Domestic	601,000	22,000	30,000	249,000	902,000	9,020	25,780	1,690	14,340	50,830			
	Total	$4,060,000	$ 149,000	$200,000	$450,000	$4,859,000	$48,590	$127,900	$11,400	$44,200	$232,090			
Leslie-Harlan														
Middle Fork Kentucky River Reservoir No. 14	Process	$3,851,000	$ 123,000	-	$201,000	$4,175,000	$41,750	$107,570	$ 6,300	$29,860	$185,480	45,58	0.051	0.011
	Domestic	669,000	21,000	-	249,000	939,000	9,390	26,730	1,100	14,340	51,560			
	Total	$4,520,000	$ 144,000	-	$450,000	$5,114,000	$51,140	$134,300	$ 7,400	$44,200	$237,040			

Summary of Estimated Water Costs for Unit Coal Synthine Plant in Kentucky

General Area and Source of Water	Water Use	Construction Costs of Water Works To Provide 11.15 Mgd for Process Use and 1.94 Mgd for Domestic Use					Annual Costs To Provide 11.15 Mgd for Process Use and 1.94 Mgd for Domestic Use					Unit Costs of Process Water		
		Storage Reservoir	Pumping Station and Transmission	Storage Basin at Plant Site	Filter Plant	Total	Taxes and Insurance at 1 Percent	Depreciation	Power for Pumping	Supervision, Labor, Repair, Filtration etc. (A)	Total (Less Interest)	Per Mg (Less Interest)	Per Barrel of Products (Less Interest)	Additional Cost per Barrel of Products for each 1 percent on Investment
Northern Letcher														
Carr Fork Reservoir No. 18	Process	$4,030,000	$1,353,000	$170,000	$201,000	$5,754,000	$57,540	$150,680	$ 63,050	$29,860	$301,130	$73.99	$0.083	$0.016
	Domestic	700,000	235,000	30,000	249,000	1,214,000	12,140	34,220	10,950	14,340	71,650			
	Total	$4,730,000	$1,588,000	$200,000	$450,000	$6,968,000	$69,680	$184,900	$ 74,000	$44,200	$372,780			
Harlan-Letcher														
Cranks Creek Reservoir No. 4	Process	$3,877,000	$ 371,000	$170,000	$201,000	$4,619,000	$46,190	$119,500	$ 19,260	$29,860	$214,810	52,78	0.059	0.013
	Domestic	673,000	65,000	30,000	249,000	1,017,000	10,170	28,800	3,340	14,340	56,650			
	Total	$4,550,000	$ 436,000	$200,000	$450,000	$5,636,000	$56,360	$148,300	$ 22,600	$44,200	$271,460			
Bell														
Brownies Creek Reservoir No. 3	Process	$3,544,000	$ 331,000	$170,000	$201,000	$4,246,000	$42,460	$111,070	$ 33,480	$29,860	$216,870	53.29	0.059	0.012
	Domestic	616,000	57,000	30,000	249,000	952,000	9,520	27,330	5,820	14,340	57,010			
	Total	$4,160,000	$ 388,000	$200,000	$450,000	$5,198,000	$51,980	$138,400	$ 39,300	$44,200	$273,880			
Daviess														
Green River	Process	-	$ 124,000	$170,000	$201,000	$ 495,000	$ 4,950	$ 15,900	$ 12,270	$29,860	$ 62,980	15.48	0.017	0.001
	Domestic	-	21,000	30,000	249,000	300,000	3,000	10,800	2,130	14,340	30,270			
	Total	-	145,000	$200,000	$450,000	$ 795,000	$ 7,950	$ 26,700	$ 14,400	$44,200	$ 93,250			
Henderson														
Ohio River	Process	-	$ 350,000	$170,000	$201,000	$ 721,000	$ 7,210	$ 21,780	$ 16,870	$29,860	$ 75,720	18.61	0.021	0.002
	Domestic	-	61,000	30,000	249,000	340,000	3,400	11,820	2,930	14,340	32,490			
	Total	-	$ 411,000	$200,000	$450,000	$1,061,000	$10,610	$ 33,600	$ 19,800	$44,200	$108,210			
Union														
Ohio River	Process	-	$ 257,000	$170,000	$201,000	$ 628,000	$ 6,280	$ 19,050	$ 11,500	$29,860	$ 66,690	16.39	0.018	0.002
	Domestic	-	45,000	30,000	249,000	324,000	3,240	11,350	2,000	14,340	30,930			
	Total	-	$ 302,000	$200,000	$450,000	$ 952,000	$ 9,520	$ 30,400	$ 13,500	$44,200	$ 97,620			

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Summary of Estimated Water Costs for Unit Coal Synthine Plant in Kentucky

		Construction Costs of Water Works To Provide 11.15 Mgd for Process Use and 1.94 Mgd for Domestic Use					Annual Costs To Provide 11.15 Mgd for Process Use and 1.94 Mgd for Domestic Use					Unit Costs of Process Water		
General Area and Source of Water	Water Use	Storage Reservoir	Pumping Station and Transmission	Storage Basin at Plant Site	Filter Plant	Total	Taxes and Insurance at 1 Percent	Depre- ciation	Power for Pumping	Super- vision, Labor, Repair, Filtration etc. (A)	Total (Less Interest)	Per Mg (Less Interest)	Per Barrel of Products (Less Interest)	Additional Cost per Barrel of Products for each 1 percent on Investment
Webster														
Tradewater River	Process	$2,471,000	$ 389,000	$170,000	$201,000	$3,231,000	$32,310	$ 83,750	$ 10,560	$29,860	$156,480	$38,45	$0.043	$0.009
	Domestic	429,000	68,000	30,000	249,000	776,000	7,760	22,600	1,840	14,340	46,540			
	Total	$2,900,000	$ 457,000	$200,000	$450,000	$4,007,000	$40,070	$106,350	$ 12,400	$44,200	$203,020			
Hopkins-Christian														
Lick Creek Reservoir No. 6	Process	$5,172,000	$1,223,000	$170,000	$201,000	$6,766,000	$67,660	$173,180	$ 18,660	$29,860	$289,360	71.10	0.079	0.019
	Domestic	898,000	212,000	30,000	249,000	1,389,000	13,890	38,120	3,240	14,340	69,590			
	Total	$6,070,000	$1,435,000	$200,000	$450,000	$8,155,000	$81,550	$211,300	$ 21,900	$44,200	$358,950			
Muhlenberg-McLean														
Green River	Process	-	$ 838,000	$170,000	$201,000	$1,209,000	$12,090	$ 34,040	$ 17,040	$29,860	$ 93,030	22.86	0.025	0.003
	Domestic	-	146,000	30,000	249,000	425,000	4,250	13,960	2,960	14,340	35,510			
	Total	-	$ 984,000	$200,000	$450,000	$1,634,000	$16,340	$ 48,000	$ 20,000	$44,200	$128,540			
Ohio														
Green River	Process	-	$ 527,000	$170,000	$201,000	$ 898,000	$ 8,980	$ 26,120	$ 14,570	$29,860	$ 79,530	19.54	0.022	0.002
	Domestic	-	91,000	30,000	249,000	370,000	3,700	12,580	2,530	14,340	33,150			
	Total	-	$ 618,000	$200,000	$450,000	$1,268,000	$12,680	$ 38,700	$ 17,100	$44,200	$112,680			

Note: (A) These items are considered constant for 10,000-barrel-per-day plants in all General Areas, and include the following:

	Chargeable to Process Water	Chargeable to Domestic Water	Total
Supervision and Labor	$17,040	$2,960	$20,000
Materials and Repairs	4,260	740	5,000
Filtration (1,280 mg per yr)	8,560	10,640	19,200
Total	$29,860	$14,340	$44,200

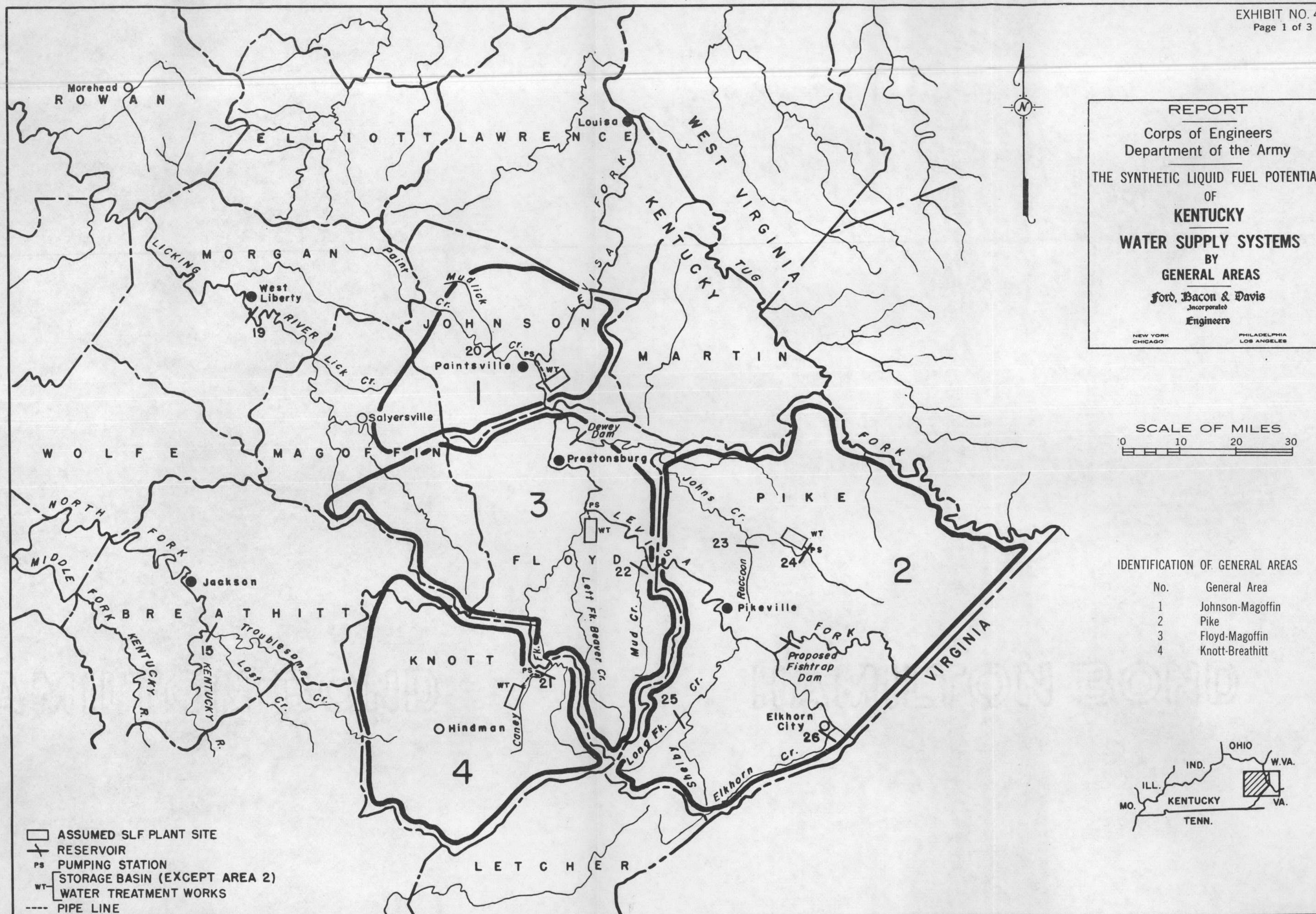


EXHIBIT NO. 40
Page 1 of 3
REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY
WATER SUPPLY SYSTEMS
BY
GENERAL AREAS
Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK
CHICAGO
PHILADELPHIA
LOS ANGELES
SCALE OF MILES
0
10
20
30
IDENTIFICATION OF GENERAL AREAS
No. General Area
1 Johnson-Magoffin
2 Pike
3 Floyd-Magoffin
4 Knott-Breathitt
ASSUMED SLF PLANT SITE
RESERVOIR
PS PUMPING STATION
STORAGE BASIN (EXCEPT AREA 2)
WATER TREATMENT WORKS
PIPE LINE
ROWAN
Morehead
ELLIOTT
LAWRENCE
Louisa
WEST VIRGINIA
KENTUCKY
TUG
FORK
LEVISA
MORGAN
LICKING
RIVER
West Liberty
19
Paint
Mudlick
Cr.
JOHNSON
20
Paintsville
MARTIN
Lick Cr.
Salyersville
Dewey Dam
WOLFE
MAGOFFIN
Prestonsburg
Johns Cr.
PIKE
NORTH
FORK
MIDDLE
FORK
Jackson
FLOYD
23
24
22
Raccoon
2
3
1
BREATHITT
Left Fk. Beaver Cr.
Mud Cr.
Pikeville
15
KENTUCKY
R.
Troublesome
Lost
Cr.
KNOTT
21
Proposed Fishtrap Dam
VIRGINIA
25
Elkhorn City
26
Hindman
Caney
Long Fk.
Shelby
Elkhorn
4
LETCHER
OHIO
IND.
W.VA.
ILL.
KENTUCKY
MO.
VA.
TENN.
SF-1471 8-3-51

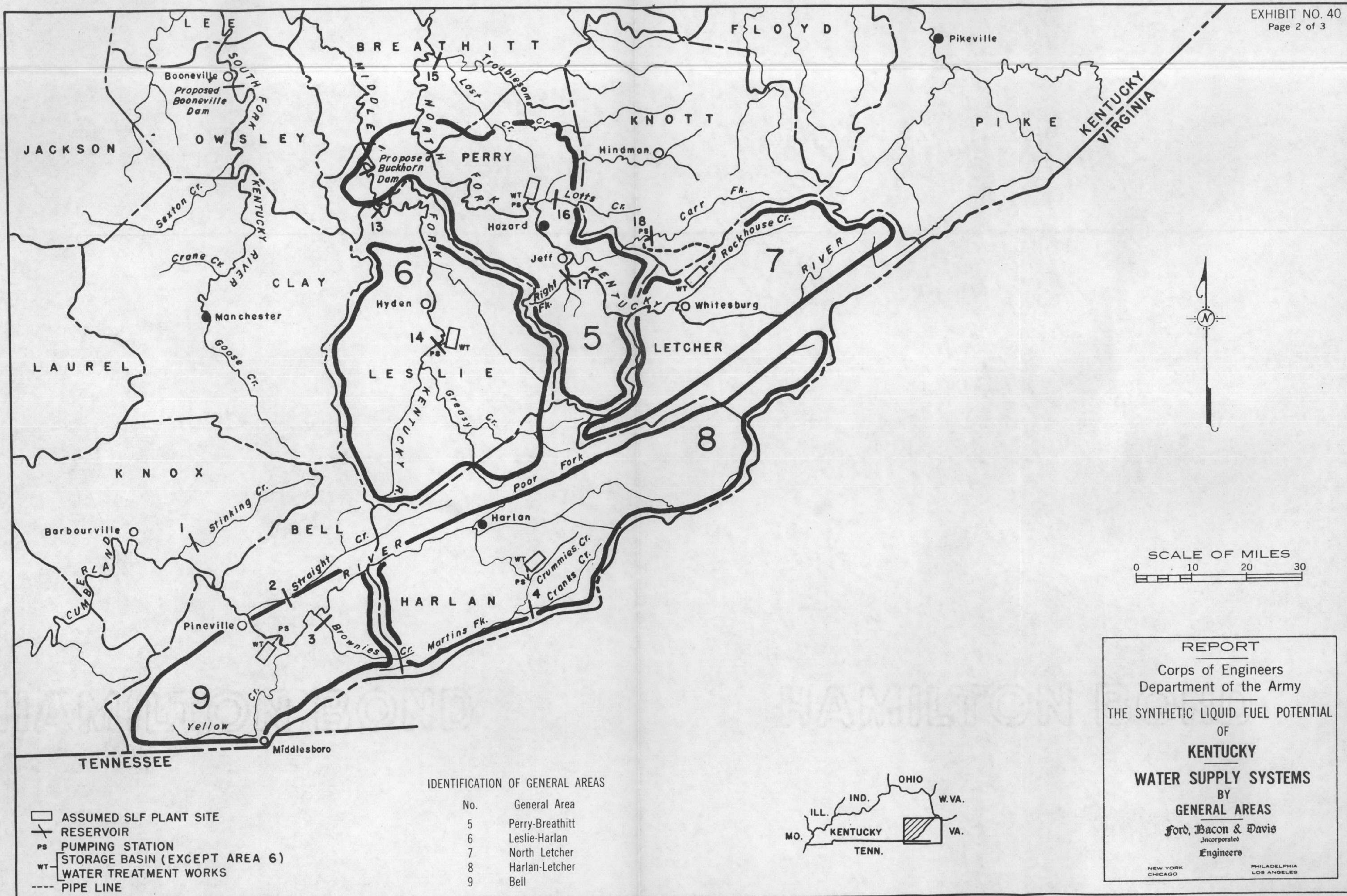
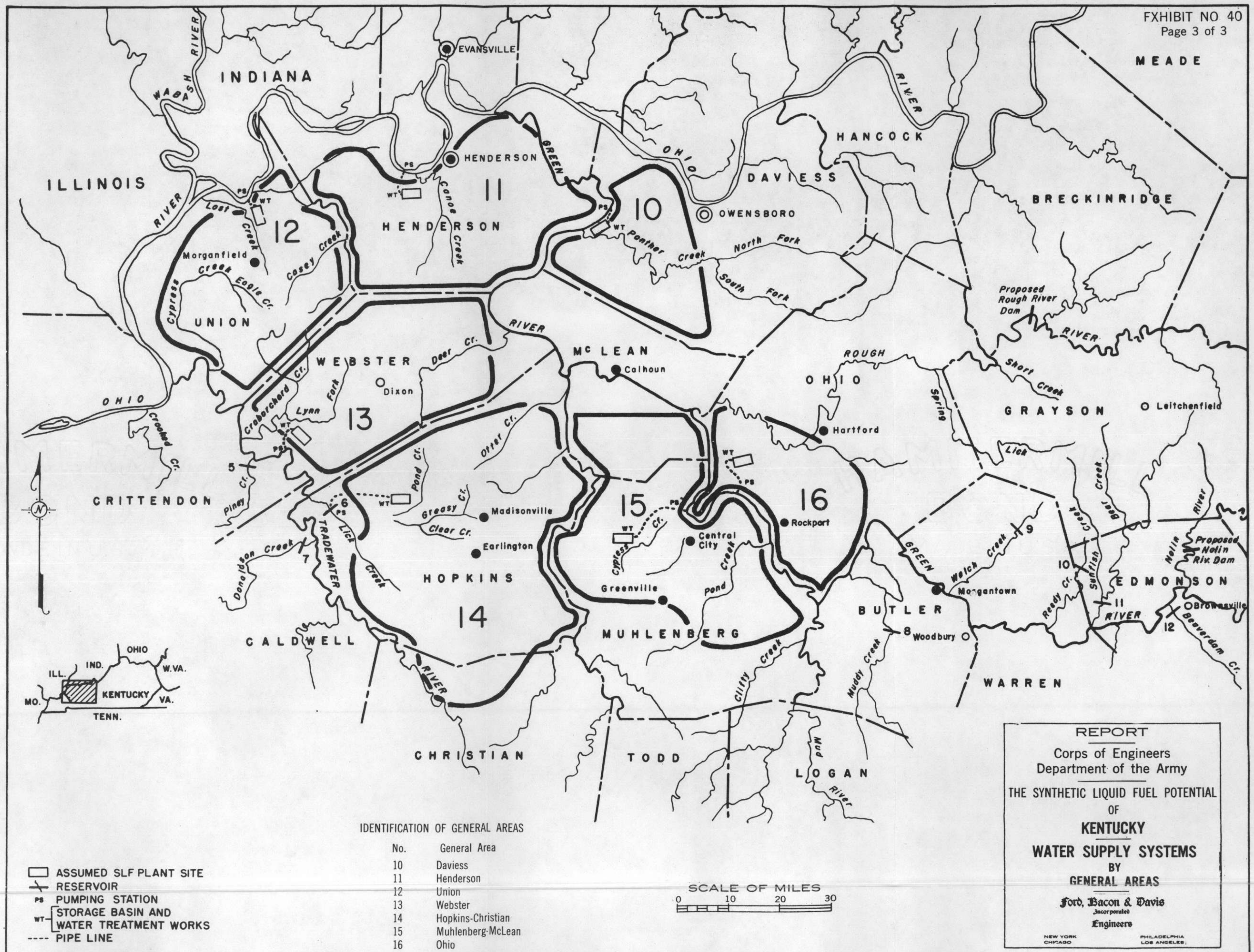


EXHIBIT NO. 40
Page 2 of 3
LEE
BREATHITT
FLOYD
Pikeville
Booneville
Proposed Booneville Dam
SOUTH FORK
Troublesome Cr.
Lost Cr.
15
MIDDLE FORK
NORTH FORK
KNOTT
PIKE
KENTUCKY
VIRGINIA
JACKSON
OWSLEY
Proposed Buckhorn Dam
PERRY
Hindman
KENTUCKY RIVER
Sexton Cr.
Lotts Cr.
Carr Fk.
13
16
18
Hazard
Rockhouse Cr.
7
RIVER
Crane Cr.
6
Jeff
17
Right Fk.
KENTUCKY
Whitesburg
CLAY
Hyden
Manchester
5
LETCHER
14
LAUREL
Goose Cr.
LESLIE
Greasy Cr.
KENTUCKY R.
8
KNOX
Poor Fork
Stinking Cr.
Harlan
Barbourville
1
BELL
Cr.
CUMBERLAND
2
Straight
RIVER
Crummies Cr.
Cranks Cr.
HARLAN
4
3
Pineville
Brownies Cr.
Martins Fk.
9
Yellow Cr.
Middlesboro
TENNESSEE
SCALE OF MILES
0 10 20 30
IDENTIFICATION OF GENERAL AREAS
No. General Area
5 Perry-Breathitt
6 Leslie-Harlan
7 North Letcher
8 Harlan-Letcher
9 Bell
OHIO
IND.
ILL.
W.VA.
MO.
KENTUCKY
VA.
TENN.
ASSUMED SLF PLANT SITE
RESERVOIR
PS PUMPING STATION
WT STORAGE BASIN (EXCEPT AREA 6)
WATER TREATMENT WORKS
---- PIPE LINE
REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL OF
KENTUCKY
WATER SUPPLY SYSTEMS BY GENERAL AREAS
Ford, Bacon & Davis Incorporated
Engineers
NEW YORK
CHICAGO
PHILADELPHIA
LOS ANGELES

SF-1472 8-3-51



SF-1473A 12-18-51

Exhibit No. 41

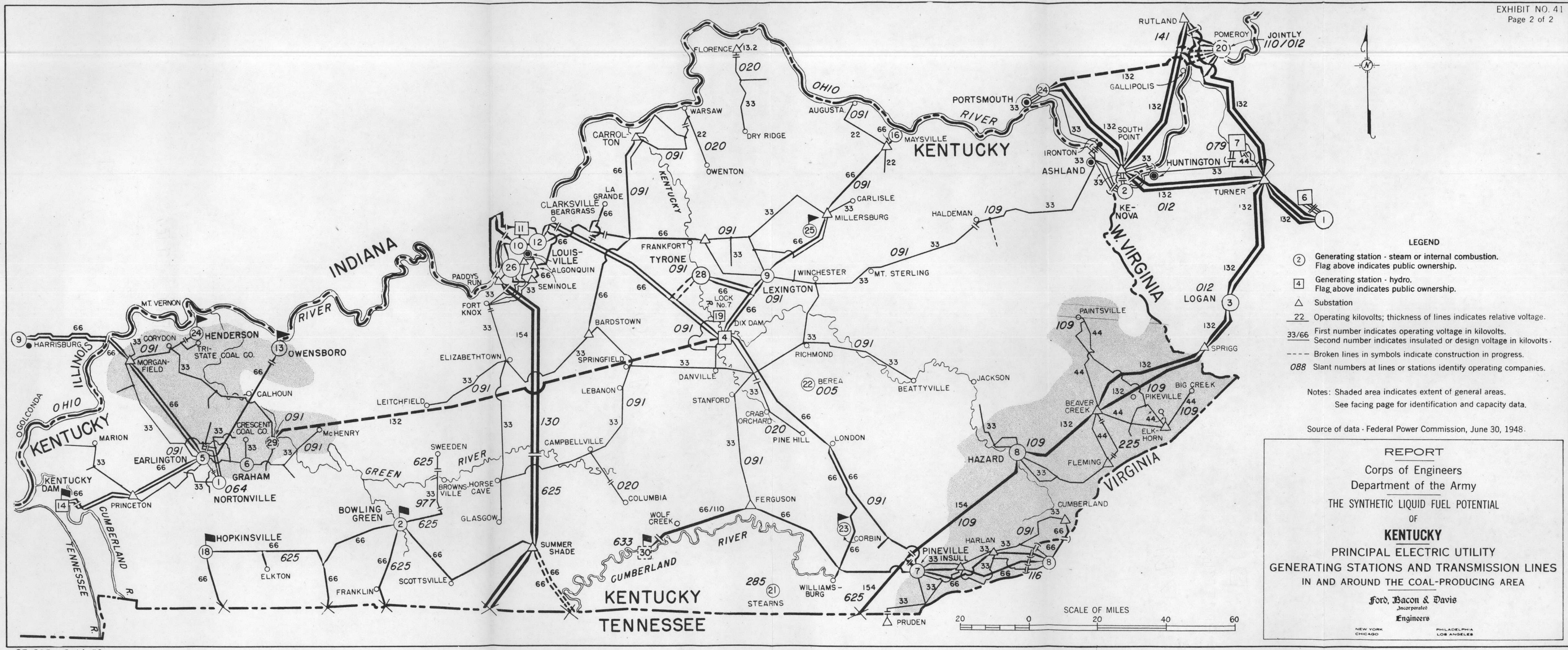
Principal Electric Utility
Operating Companies and Generating Stations

Key to Map

FPC No.		Generating Stations No.	Name	Type	Installed Capacity (Kilowatts)
Kentucky:					
064	Kentucky Electric Power Co.	1	Nortonville	Steam	5,000
625	Tennessee Valley Authority	2	Bowling Green	"	7,250
091	Kentucky Utilities Co.	4	Dix Dam	Hydro	28,500
091	" " "	5	Earlington	Steam	6,000
091	" " "	6	Graham	"	6,500
091	" " "	7	Pineville	"	30,000
109	Kentucky & West Virginia Power Co., Inc.	8	Hazard	"	19,500
091	Kentucky Utilities Co.	9	Lexington	"	9,000
127	Louisville Gas & Electric Co.	10	Canal	"	(12,500(25C) (50,000
127	" " " " "	11	Ohio Falls	Hydro	80,320
127	" " " " "	12	Waterside	Steam	92,500
595	Municipal Plant	13	Owensboro	"	15,000
625	Tennessee Valley Authority	14	Kentucky Dam	Hydro	160,000
091	Kentucky Utilities Co.	16	Maysville	Steam	1,750
625	Tennessee Valley Authority	18	Hopkinsville	"	4,300
091	Kentucky Utilities Co.	19	Lock No. 7	Hydro	4,040
285	Stearns Coal & Lumber Co., Inc.	21	Stearns	Steam	3,500
005	Berea College Heat & Power Plant	22	Berea	"	1,500
523	Municipal Plant	23	Corbin	"	2,600
547	" "	24	Henderson	"	6,375
607	" "	25	Paris	Int.Comb.	2,426
127	Louisville Gas & Electric Co.	26	Paddy's Run	Steam	110,000
091	Kentucky Utilities Co.	28	Tyrone	"	50,000
091	" " "	29	Green River	"	60,000
633	U.S. Army Corps of Engineers	30	Wolf Creek	Hydro	135,000
130	Louisville Transmission Corp. (Ky)	-	-	-	-
225	Consolidation Coal Co. Inc.	-	-	-	-
977	Warren Rural Elec. Coop. Corp.	-	-	-	-
020	Community Public Service Co.	-	-	-	-
West Virginia:					
012	Appalachian Electric Power Co.	1	Cabin Creek	Steam	281,740
012	" " " "	2	Kenova	"	40,000
012	" " " "	3	Logan	"	90,400
079	Kanawha Valley Power Co.	6	Marmet	Hydro	14,400
079	" " " "	7	Winfield	"	14,760
012	Appalachian Electric Power Co.	20	Philip Sporn	Steam	250,000
110	The Ohio Power Co.	-	-	-	-
Ohio:					
141	The Ohio Power Co.	24	New Boston	Steam	9,500
Virginia:					
116	Old Dominion Power Co.	8	Pocket	Steam	12,500
Illinois:					
032	Central Illinois Public Service Co.	9	Muddy	Steam	25,000

Population Labor Force, and Employment in Kentucky in 1940 and Preliminary 1950 Census

	Area (Square Miles)	1950 Census Preliminary Count	Population (1940) Total	Urban	Rural Nonfarm	Rural Farm	Labor Force (1940)	Numbers Employed (1940) Total	Agriculture	Mining	Construction	Manufacturing	Service
Percentages showing Composition of Population and Numbers Employed in Coal Counties and in Entire State:													
Eastern Coal Counties -													
Total Population			100.0%	10.6%	45.3%	44.1%							
Total Employed								100.0%	28.6%	40.1%	2.1%	4.3%	24 9%
Western Coal Counties -													
Total Population			100.0%	30.5%	28.9%	40.6%							
Total Employed								100.0%	36.3%	13.1%	3.8%	10.0%	36 8%
Entire State -													
Total Population			100.0%	29.8%	26.0%	44.2%							
Total Employed								100.0%	36.5%	7.1%	4.2%	11.9%	40.3%
Percentages of Classified Populations in Coal Counties in Relation to Entire State:													
Eastern Coal Counties		14.8%	15.2%	5.4%	26.6%	15.2%	12.2%	11.5%	9.0%	64.3%	5.7%	4.1%	7.1%
Western Coal Counties		9.0	9.3	9.5	10.3	8.5	9.3	8.7	8.7	16.0	7.9	7.3	8.0
Other Counties		76.2	75.5	85.1	63.1	76.3	78.5	79.8	82.3	19.7	86.4	88.6	84.9
Entire State		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%



SF-205 9-14-50

KY.

Population, Labor Force, and Employment in Kentucky in 1940 and Preliminary 1950 Census

	Area (Square Miles)	1950 Census Preliminary Count	Population (1940)				Labor Force (1940)	Numbers Employed (1940)					
			Total	Urban	Rural Nonfarm	Rural Farm		Total	Agriculture	Mining	Construction	Manufacturing	Service
Coal Counties:													
Eastern -													
Bell	370	47,535	43,812	15,659	20,374	7,779	12,527	9,594	684	4,001	363	897	3,649
Breathitt	486	19,924	23,946	-	3,470	20,476	6,827	4,887	3,435	326	128	83	915
Floyd	402	53,473	52,986	-	29,854	23,132	14,238	11,110	3,037	5,096	210	171	2,596
Harlan	469	71,753	75,275	9,271	55,201	10,803	22,813	19,809	1,044	12,621	317	780	5,047
Johnson	264	23,823	25,771	-	11,705	14,066	7,832	5,694	2,395	1,219	150	137	1,793
Knott	356	20,336	20,007	-	4,680	15,327	5,204	3,701	1,778	963	70	229	661
Leslie	412	15,520	14,981	-	1,367	13,614	3,877	2,537	1,876	77	47	95	442
Letcher	339	39,497	40,592	9,428	15,780	15,384	10,815	8,797	2,019	4,415	144	426	1,793
Magoffin	303	13,829	17,490	-	3,185	14,305	5,001	3,878	3,031	190	56	89	512
Perry	343	46,439	47,828	7,397	21,984	18,447	13,137	10,686	2,404	4,828	175	539	2,740
Pike	786	81,186	71,122	4,185	29,003	37,934	19,438	16,425	6,132	5,177	363	698	4,055
Total Eastern Coal Counties	4,530	433,315	433,810	45,940	196,603	191,267	121,709	97,118	27,835	38,913	2,023	4,144	24,203
Western -													
Christian	726	42,378	36,129	11,724	6,997	17,408	13,234	11,268	4,631	254	377	1,080	4,926
Daviess	466	57,680	52,335	30,245	5,391	16,699	20,399	17,546	4,459	801	1,066	3,766	7,454
Henderson	440	30,278	27,020	13,160	3,982	9,878	10,041	8,215	2,904	332	292	1,223	3,464
Hopkins	555	38,329	37,789	13,627	11,778	12,384	13,042	10,025	2,771	2,738	349	390	3,777
McLean	257	10,012	11,446	-	4,488	6,958	3,803	3,012	1,824	130	113	267	678
Muhlenberg	482	32,216	37,554	4,199	19,510	13,845	12,074	8,471	2,730	2,781	235	265	2,460
Ohio	596	20,718	24,421	-	8,767	15,654	8,022	5,974	3,718	573	156	169	1,358
Union	343	14,860	17,411	3,079	7,511	6,821	5,800	4,474	1,863	770	132	112	1,597
Webster	339	15,506	19,198	4,397	7,682	7,119	6,474	4,967	1,943	1,304	108	126	1,486
Total Western Coal Counties	4,204	261,977	263,303	80,431	76,106	106,766	92,889	73,952	26,843	9,683	2,828	7,398	27,200
Total All Coal Counties	8,734	695,292	697,113	126,371	272,709	298,033	214,598	171,070	54,678	48,596	4,851	11,542	51,403
Other Counties	31,375	2,226,416	2,148,514	722,956	465,692	959,866	784,102	676,493	254,468	11,956	30,756	89,262	290,051
Total State	40,109	2,921,708	2,845,627	849,327	738,401	1,257,899	998,700	847,563	309,146	60,552	35,607	100,804	341,454

Manufacturing Workers Covered by Old-age and Survivors Insurance, by Industry Groups

Industry Group Mid-March 1948	Number of Employes	Percent of Total
Food and Kindred Products	23,395	16.6%
Tobacco Manufactures	10,904	7.8
Textile Mill Products	4,526	3.2
Apparel, Fabric Products, etc.	14,123	10.1
Lumber and Wood Products	13,239	9.4
Furniture and Fixtures	8,512	6.1
Paper and Allied Products	1,083	.8
Printing, Publishing, etc.	6,097	4.3
Chemicals and Allied Products	5,141	3.7
Products of Petroleum and Coal	1,888	1.3
Rubber Products	27	-
Leather and Leather Products	3,303	2.3
Stone, Clay and Glass Products	4,214	3.0
Primary Metal Industries:		
Blast Furnace, Steel Works, etc.	5,478	3.9
Iron and Steel Foundries	529	.4
Rolling, etc., nonferrous metals	3,694	2.6
Nonferrous Foundries	94	.1
Misc. Primary Metal Industries	242	.2
Total Primary Metal Industries	10,037	7.2%
Fabricated Metal Products:		
Cutlery, Hand Tools, Hardware	87	.1%
Heaters, Plumbers' Supplies, etc.	5,799	4.1
Fabricated Structural Metal Products	2,347	1.7
Metal Stamping, Coating Engraving	640	.5
Fabricated Wire Products	293	.2
Miscellaneous Fabricated Metal Products	336	.2
Total Fabricated Metal Products	9,502	6.8%
Machinery (except electrical)	13,007	9.2%
Electrical Machinery, etc.	4,750	3.4
Transportation Equipment:		
Motor Vehicles and Equipment	2,254	1.6%
Total Transportation Equipment	2,254	1.6%
Instruments, etc.	1,076	.8%
Miscellaneous Manufacturing Industries	2,195	1.6
Unaccounted-for and Added to balance total	1,168	.8
Total Manufacturing	140,421	100.0%

EXHIBIT NO. 44

REPORT

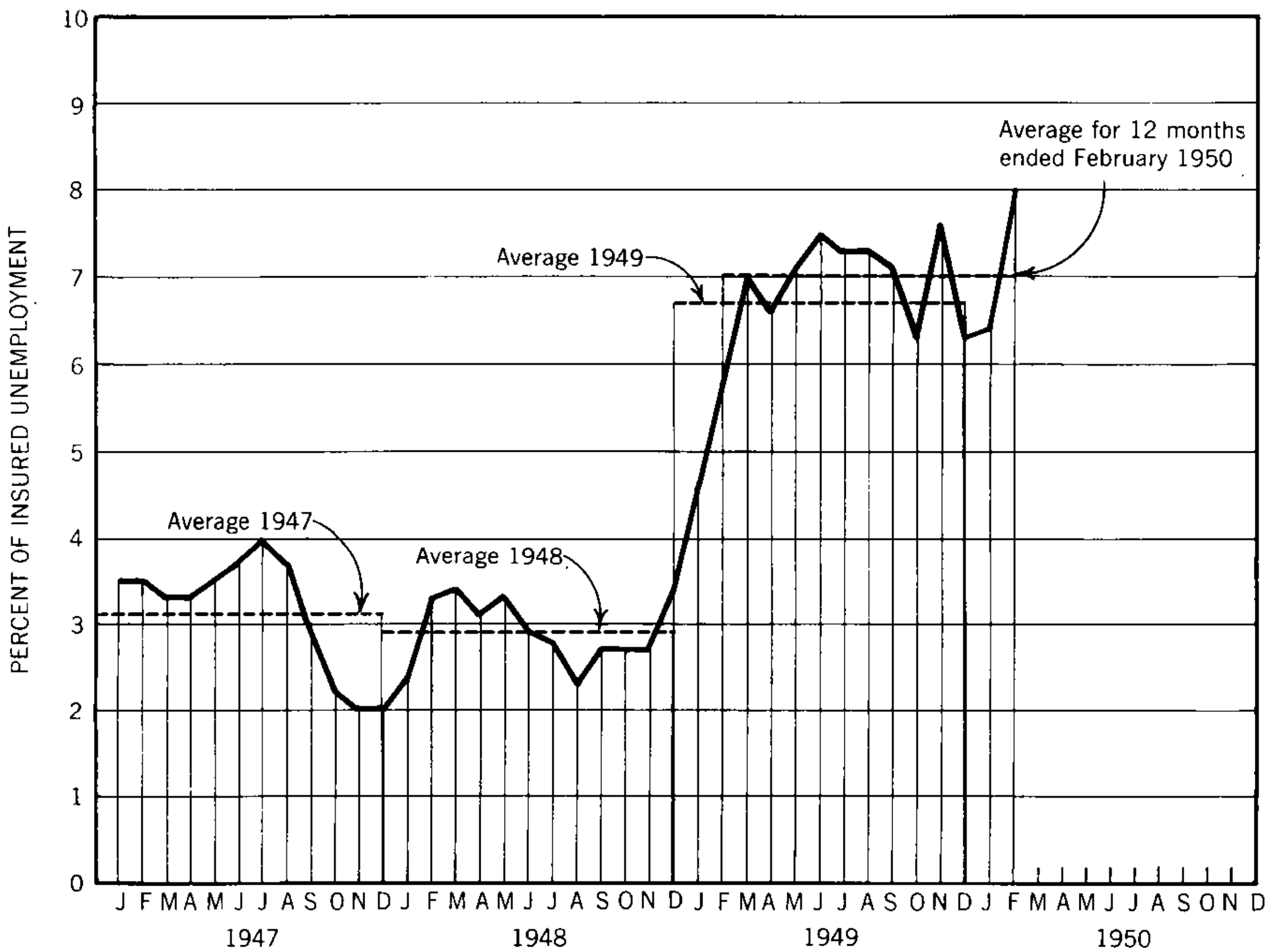
Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY

PERCENT OF
INSURED UNEMPLOYMENT
OF
AVERAGE MONTHLY COVERED EMPLOYMENT

1947-1950

Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK CHICAGO PHILADELPHIA LOS ANGELES



SF-1328 6-28-51

Number of New Coal Mine Employes Necessary to Produce Fuel Requirement of a Unit Plant after Diversion of a Portion of Present Production Capacity in an Average General Area - EASTERN KENTUCKY

	Coal Production (Tons)	Number of Working Days	Productivity per Man-day (Tons)	Number of Men Working Daily
Before Introduction of Unit Plant (1948)				
Total 11 Counties	53,966,920	198	5.21	52,394
Average for 9 General Areas:				
At present conditions	5,996,324	198	5.21	5,822
Production capacity at 240 working days per year	7,279,829	240	5.21	5,822
Increase in capacity at 240 days over present	1,283,505			
After Introduction of Coal Hydrogenation Unit Plant in an Average General Area				
Fuel Requirement of Unit Plant	1,298,838			
Less Increase in Present capacity 240-day basis	1,283,505			
Less Diversion of 20% of present production	1,199,265			
Balance production required of associated mine	0			
After Introduction of Coal Synthine Unit Plant in an Average General Area				
Fuel Requirement of Unit Plant	1,669,935			
Less Increase in present capacity, 240-day basis	1,283,505			
Less Diversion of 20% of present production	1,199,265			
Balance, production required of associated mine	0			

Ky

4

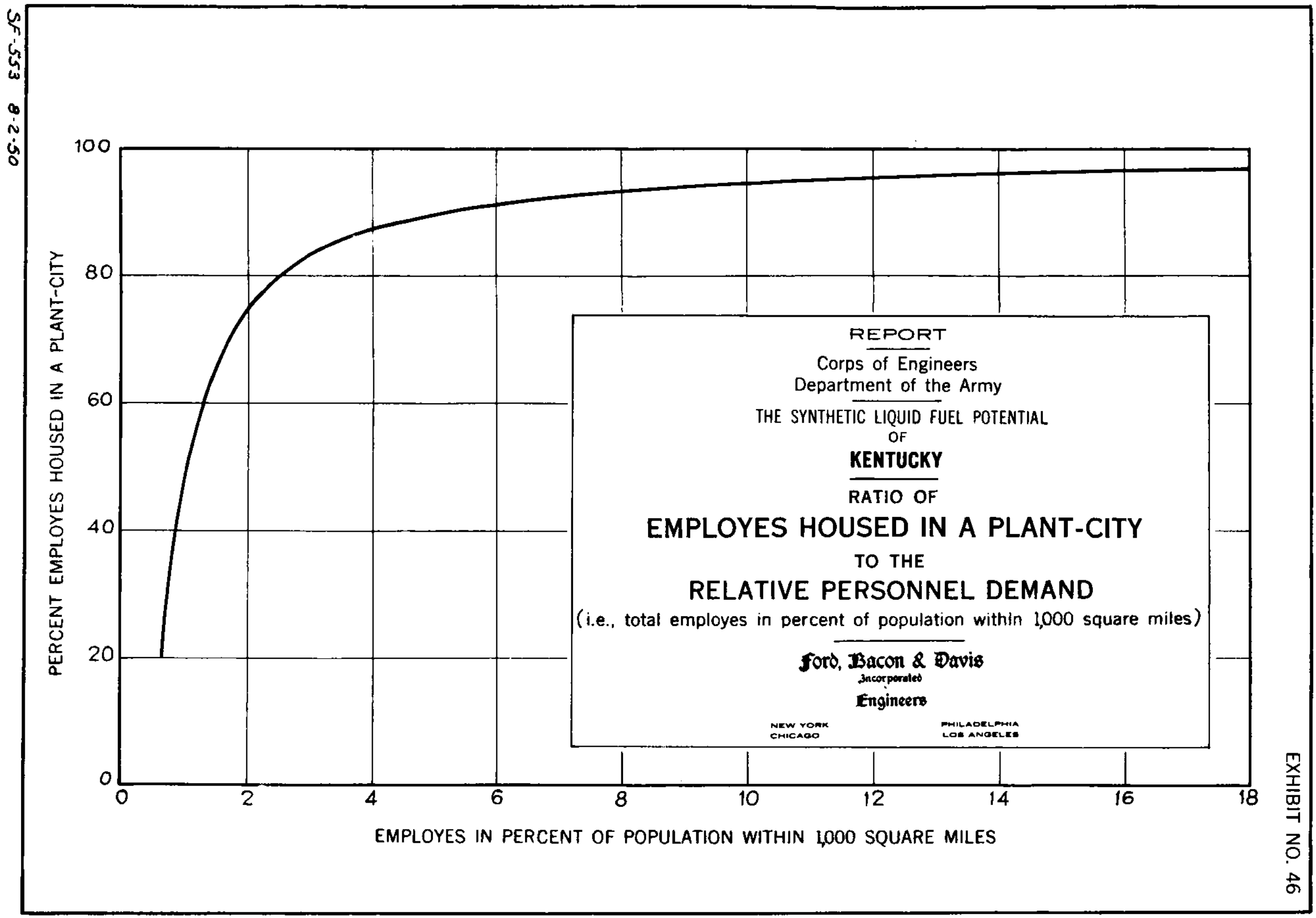
70021

Number of New Coal Mine Employes Necessary to Produce Fuel Requirement of a Unit Plant after Diversion of a Portion of Present Production Capacity in an Average General Area - WESTERN KENTUCKY

	Coal Production (Tons)	Number of Working Days	Productivity per Man-day (Tons)	Number of Men Working Daily
Before Introduction of Unit Plant (1948)				
Total 9 Counties	22,025,231	181	12.09	10,041
Average for 7 General Areas:				
At present conditions	3,146,462	181	12.09	1,434
Production capacity at 240 working days per year	4,160,894	240	12.09	1,434
Increase in capacity at 240 days over present	1,014,432			
After Introduction of Coal Hydrogenation Unit Plant in an Average General Area				
Fuel Requirement of Unit Plant	1,526,024			
Less Increase in present capacity, 240-day basis	1,014,432			
Less Diversion of 20% of present production	629,292			
Balance, production required of associated mine	0			
After Introduction of Coal Synthine Unit Plant in an Average General Area				
Fuel Requirement of Unit Plant	1,962,031			
Less Increase in present capacity, 240-day basis	1,014,432			
Less Diversion of 20% of present production	629,292			
Balance, production required of associated mine	318,307			
Number of new operational workers		240	16.44	81
Vacations, Illness, etc. 10%				8
Total Operational Employes				89
Administrative Employes 5%				4
New Coal Mine Employes Required				93

Ky

4


SF-553 8-2-50
PERCENT EMPLOYES HOUSED IN A PLANT-CITY
100
80
60
40
20
0
0
2
4
6
8
10
12
14
16
18
EMPLOYES IN PERCENT OF POPULATION WITHIN 1,000 SQUARE MILES
REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY
RATIO OF
EMPLOYES HOUSED IN A PLANT-CITY
TO THE
RELATIVE PERSONNEL DEMAND
(i.e., total employes in percent of population within 1,000 square miles)
Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK
CHICAGO
PHILADELPHIA
LOS ANGELES
EXHIBIT NO. 46

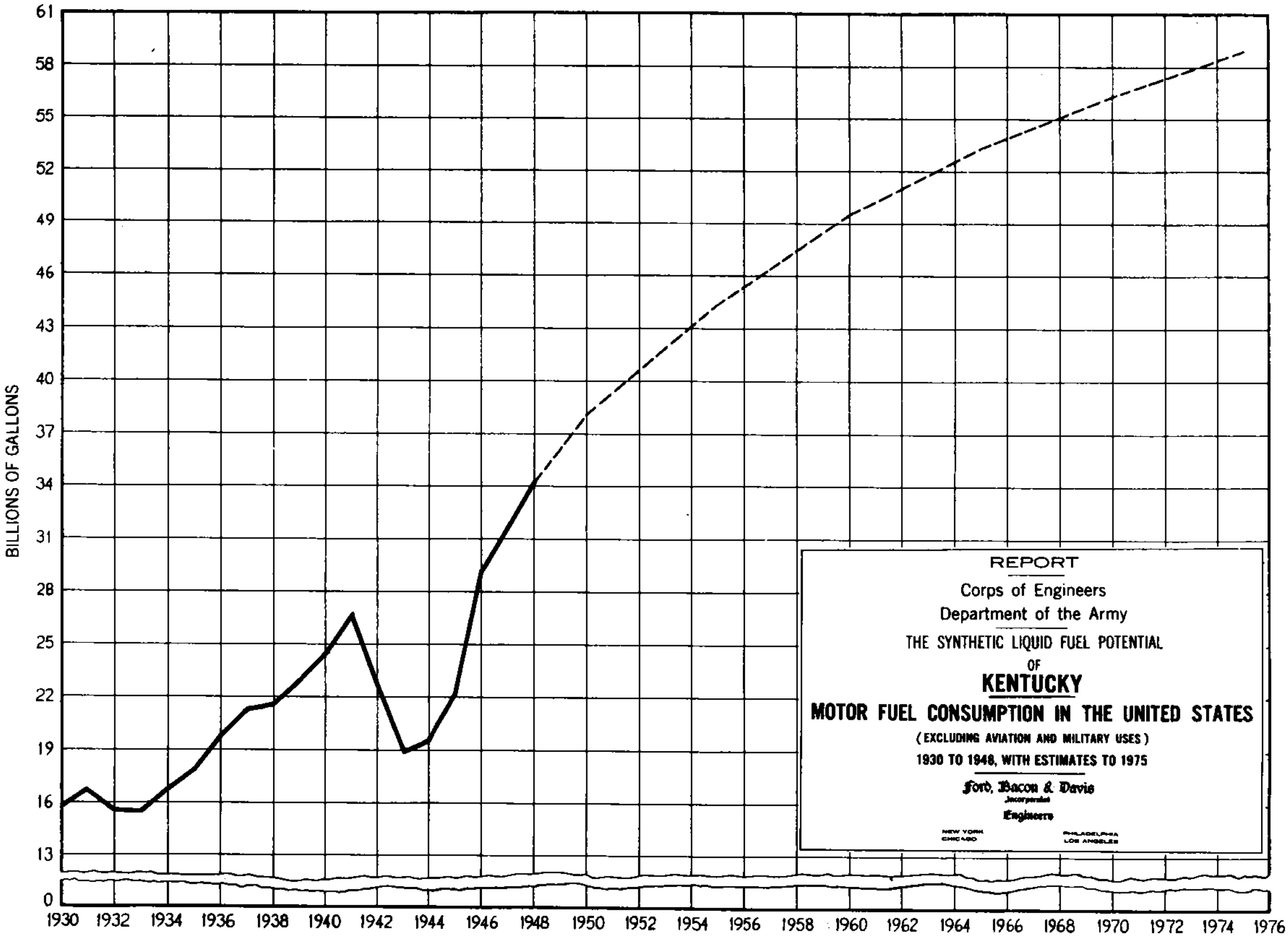


EXHIBIT NO. 47

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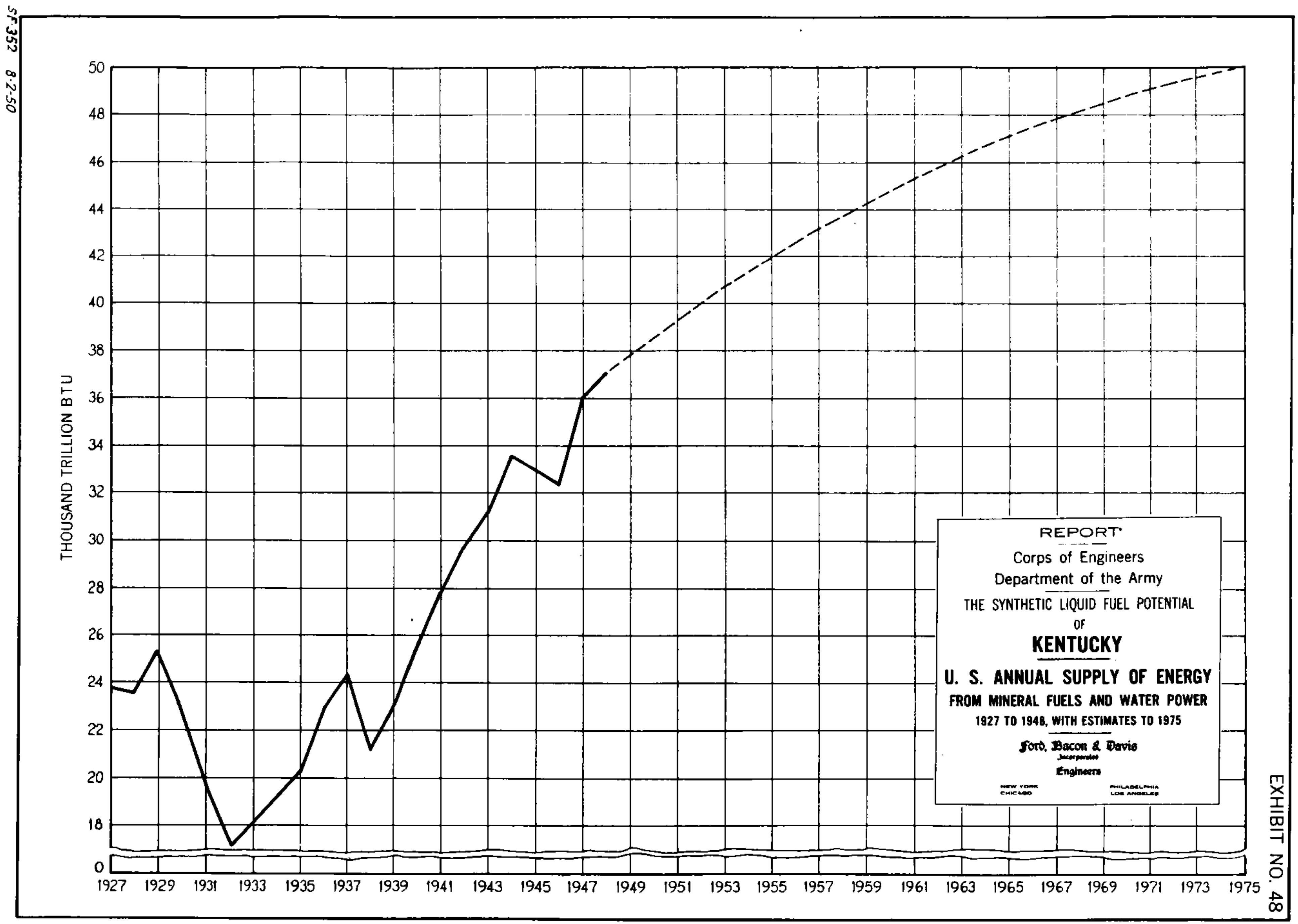
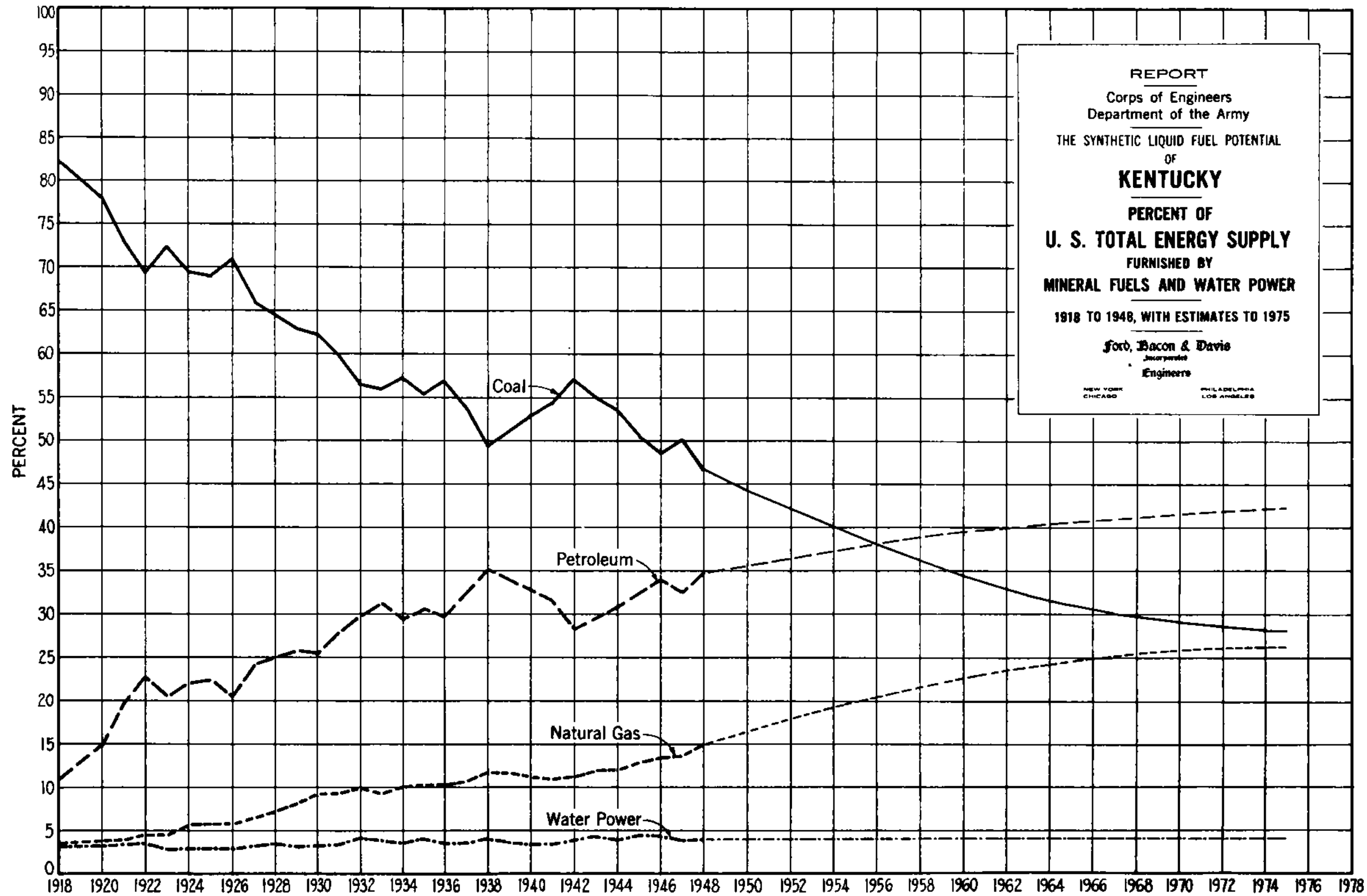
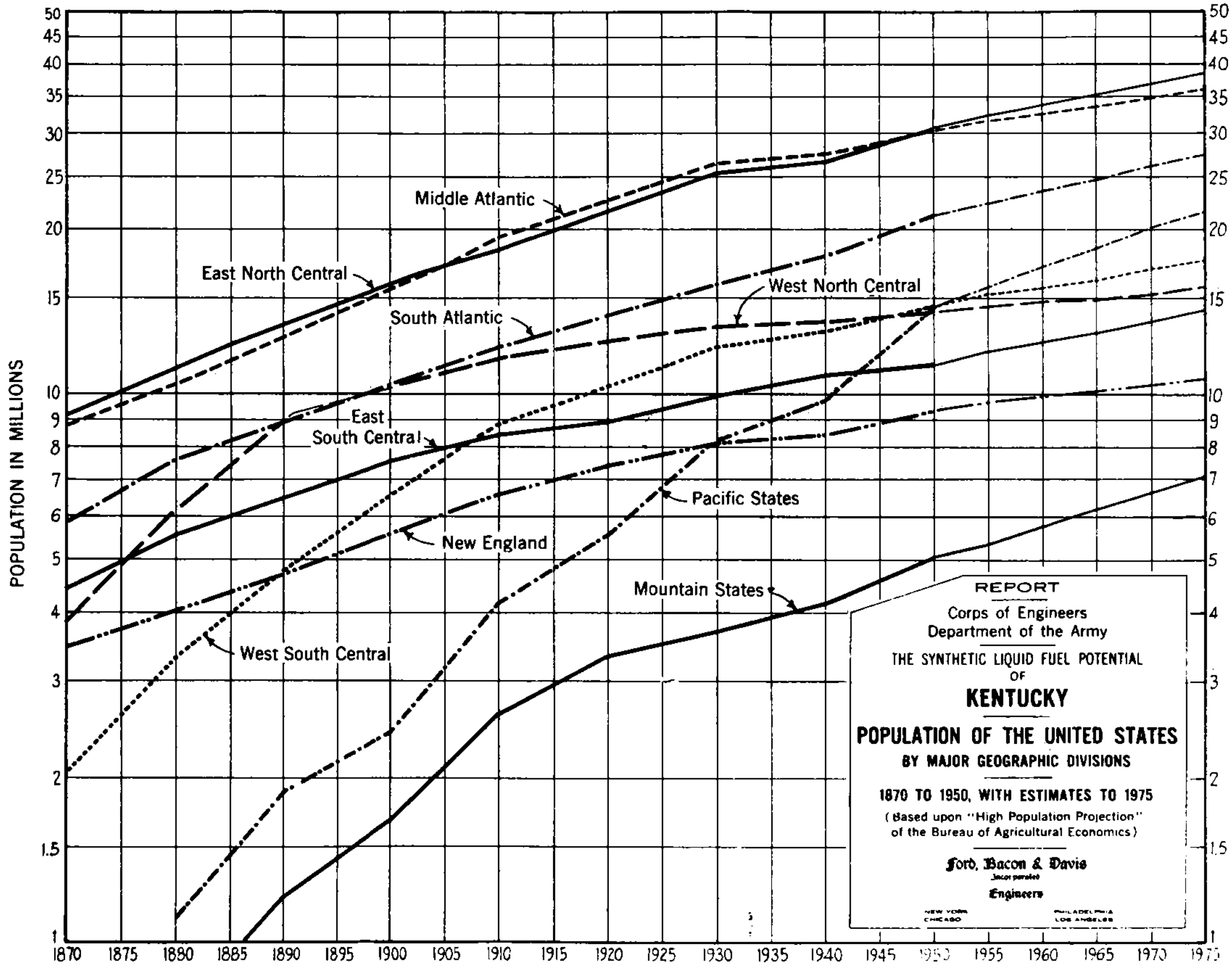

SF-352 8-2-50
THOUSAND TRILLION BTU
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
0
1927 1929 1931 1933 1935 1937 1939 1941 1943 1945 1947 1949 1951 1953 1955 1957 1959 1961 1963 1965 1967 1969 1971 1973 1975
REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY
U. S. ANNUAL SUPPLY OF ENERGY
FROM MINERAL FUELS AND WATER POWER
1927 TO 1948, WITH ESTIMATES TO 1975
Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK
CHICAGO
PHILADELPHIA
LOS ANGELES
EXHIBIT NO. 48



SF-374 8-2-50

EXHIBIT NO. 49

SF-398 11-16-50



REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY

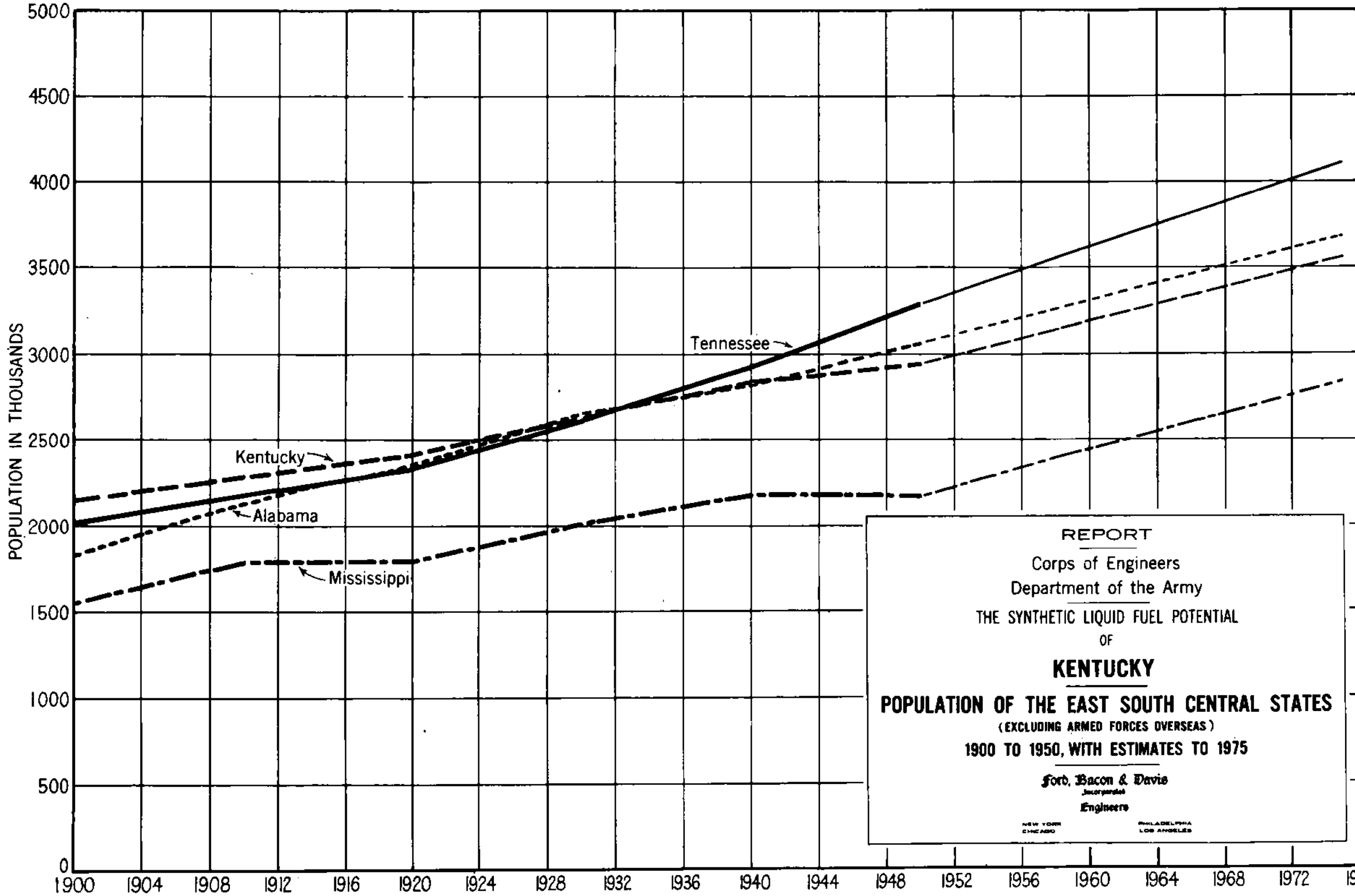
POPULATION OF THE UNITED STATES
BY MAJOR GEOGRAPHIC DIVISIONS

1870 TO 1950, WITH ESTIMATES TO 1975
(Based upon "High Population Projection" of the Bureau of Agricultural Economics)

Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK PHILADELPHIA
CHICAGO LOS ANGELES

EXHIBIT NO. 50

SF-692 12-14-50



REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF

KENTUCKY

POPULATION OF THE EAST SOUTH CENTRAL STATES
(EXCLUDING ARMED FORCES OVERSEAS)
1900 TO 1950, WITH ESTIMATES TO 1975

Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK CHICAGO PHILADELPHIA LOS ANGELES

EXHIBIT NO. 51

SF-1343 7-9-51

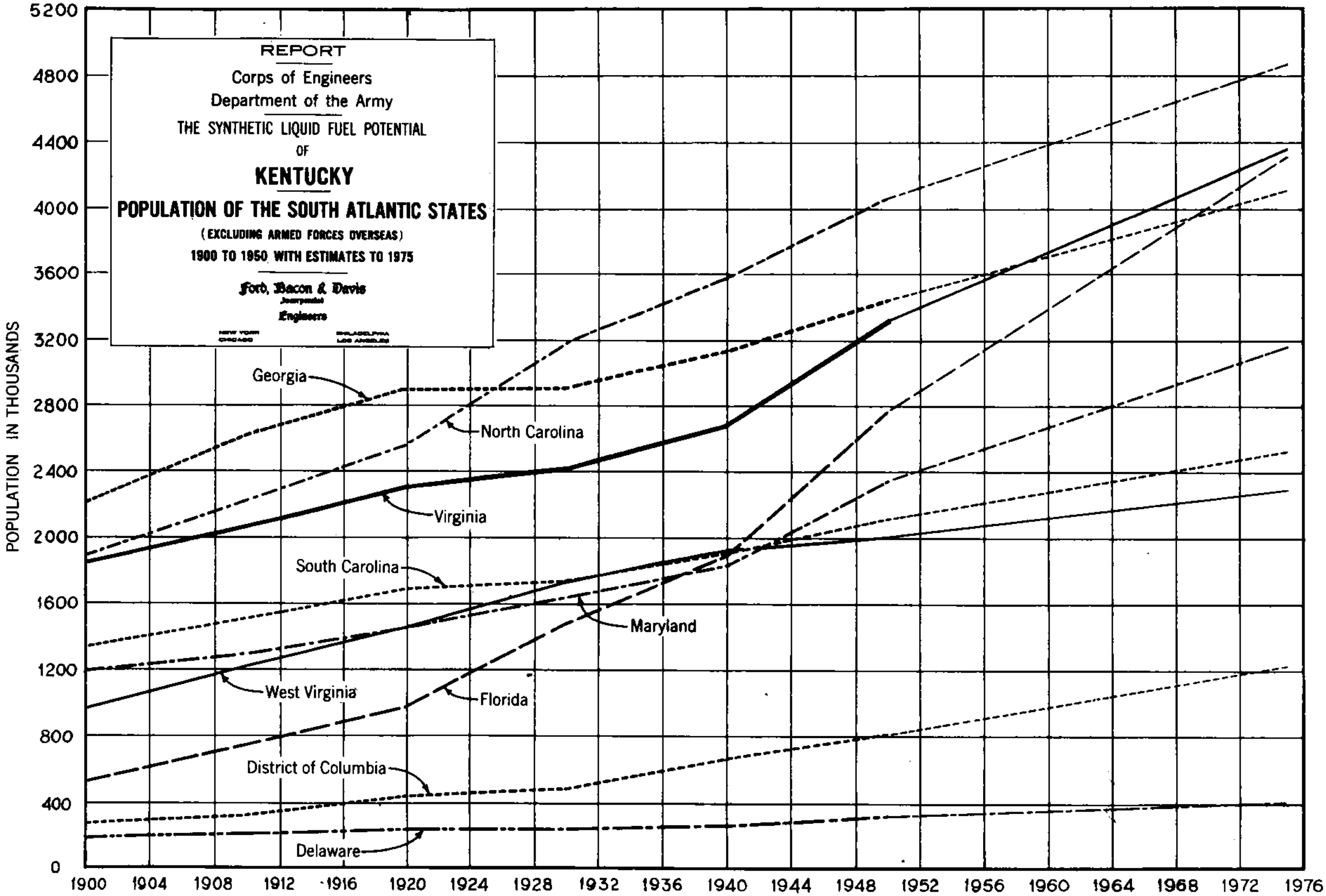
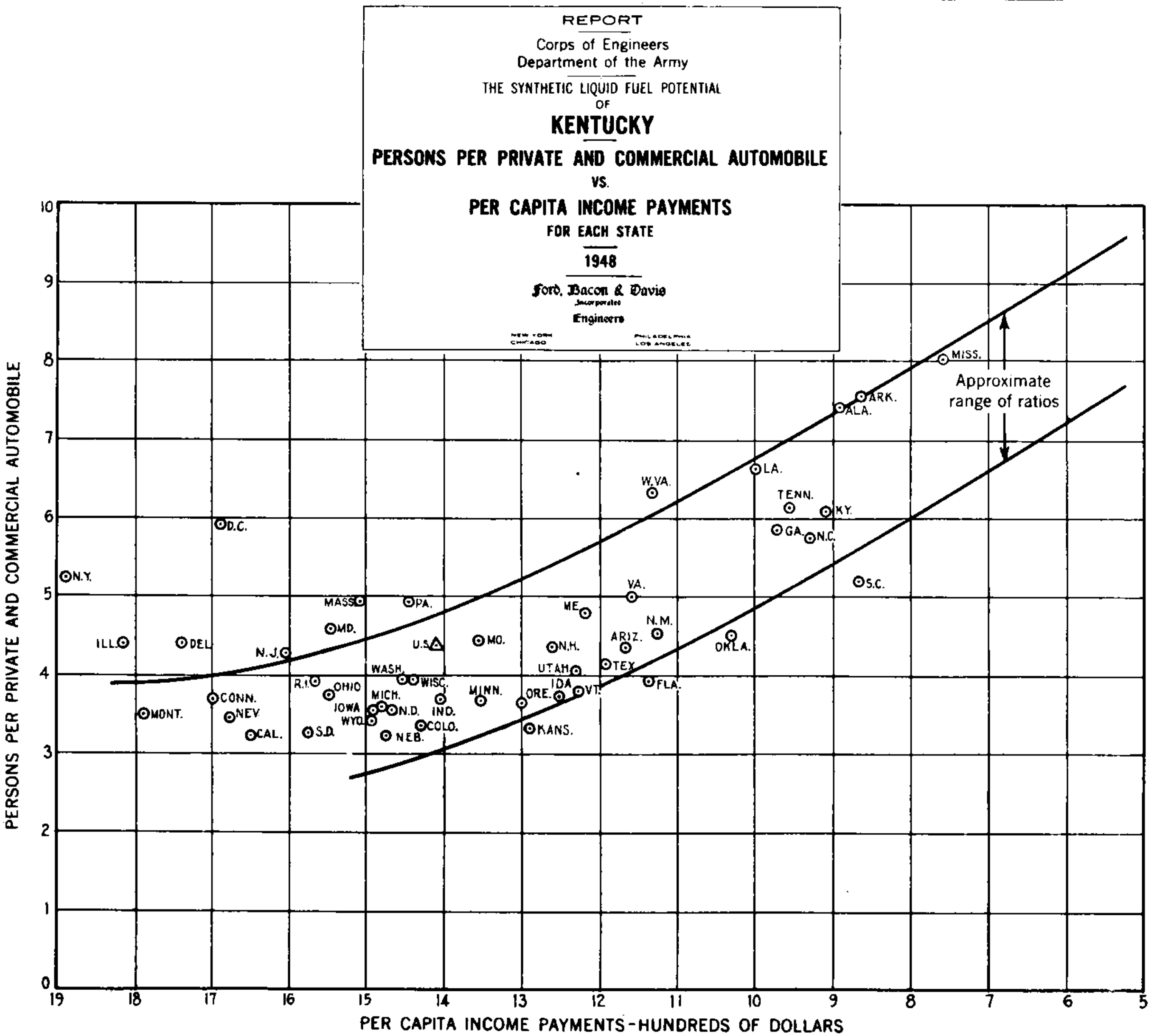
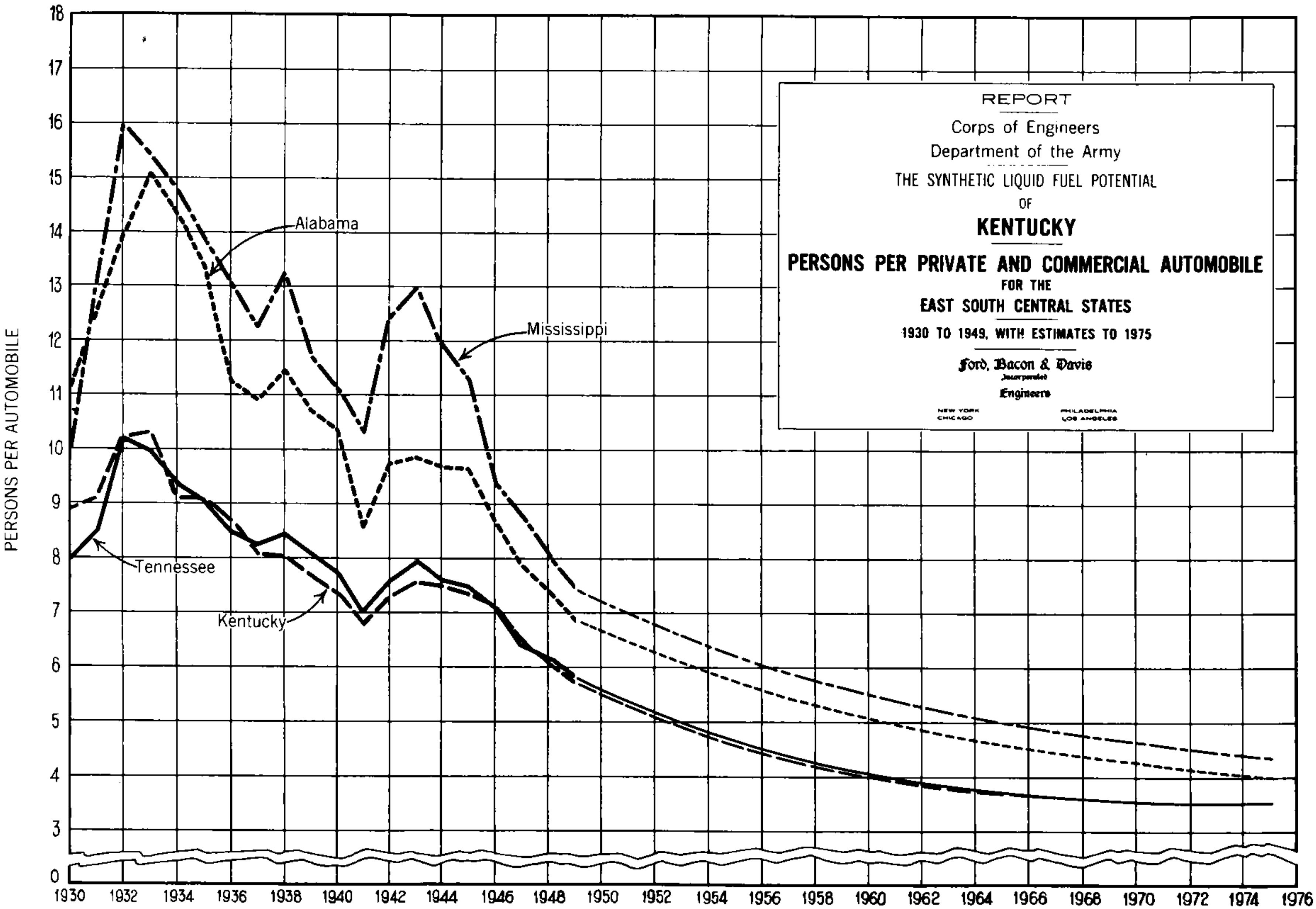


EXHIBIT NO. 52


REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL OF
KENTUCKY
PERSONS PER PRIVATE AND COMMERCIAL AUTOMOBILE
VS.
PER CAPITA INCOME PAYMENTS
FOR EACH STATE
1948
Ford, Bacon & Davis Incorporated Engineers
NEW YORK CHICAGO
PHILADELPHIA LOS ANGELES
PERSONS PER PRIVATE AND COMMERCIAL AUTOMOBILE
PER CAPITA INCOME PAYMENTS-HUNDREDS OF DOLLARS
Approximate range of ratios
N.Y.
ILL.
DEL.
D.C.
MONT.
CONN.
NEV.
CAL.
N.J.
S.D.
R.I.
OHIO
MD.
MASS.
PA.
IOWA
WYO.
MICH.
N.D.
NEB.
WASH.
WISC.
U.S.
IND.
COLO.
MO.
MINN.
ORE.
KANS.
N.H.
UTAH
IDA.
VT.
ME.
VA.
ARIZ.
TEX.
N.M.
FLA.
W.VA.
OKLA.
LA.
TENN.
GA.
N.C.
KY.
S.C.
ALA.
ARK.
MISS.

SF-695 12-14-50



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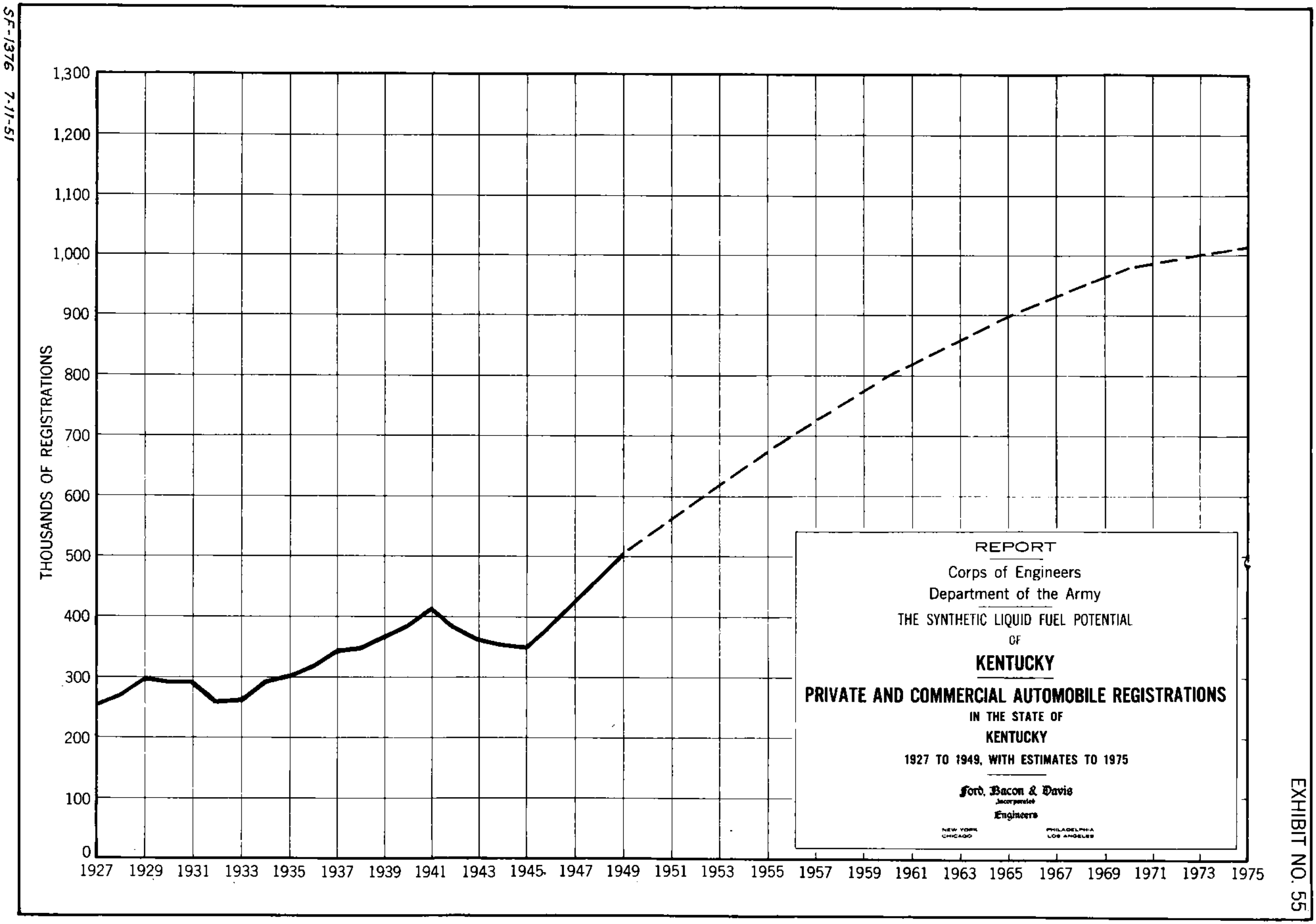
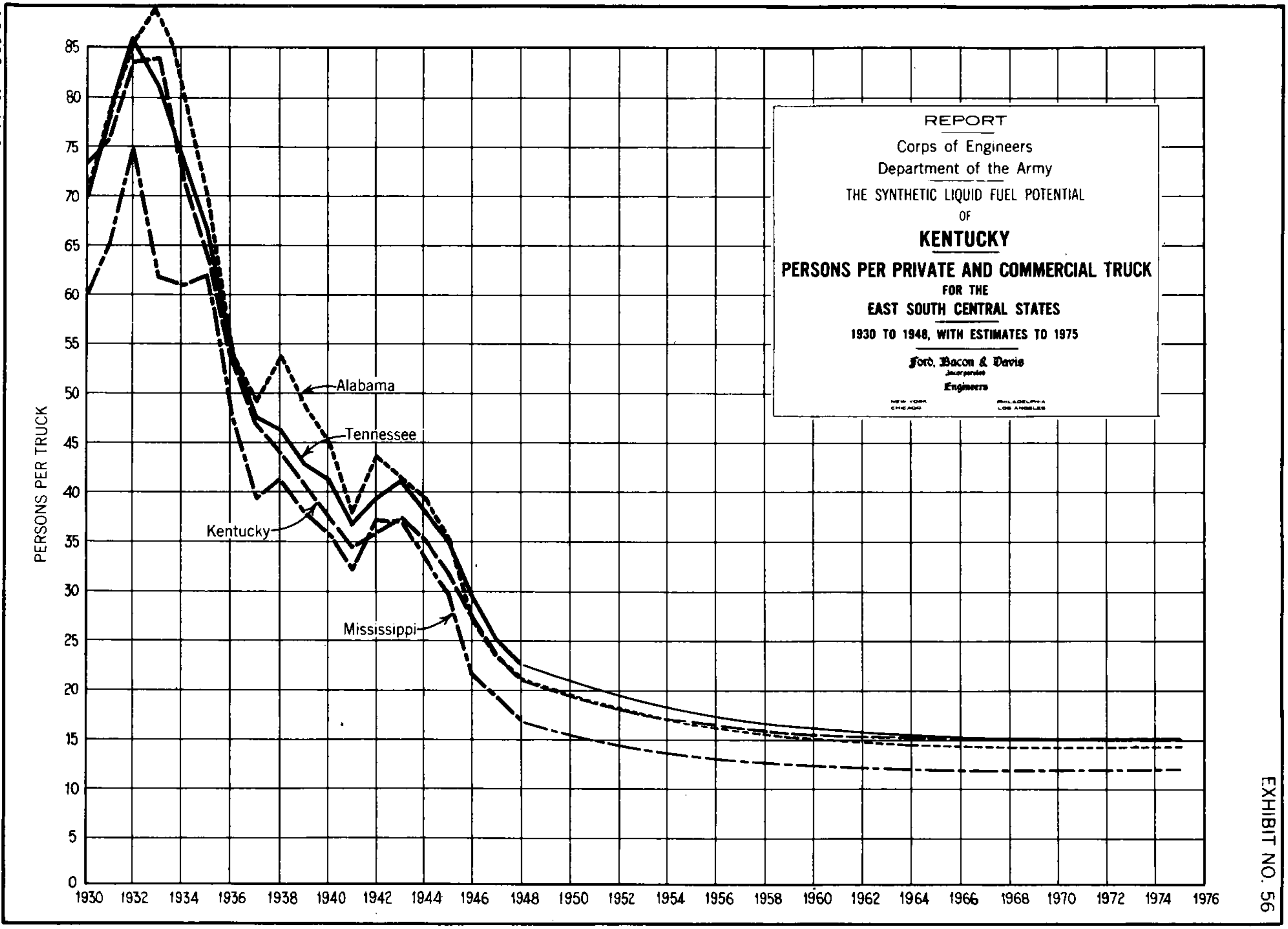

SF-1376 7-11-51
THOUSANDS OF REGISTRATIONS
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
1927 1929 1931 1933 1935 1937 1939 1941 1943 1945 1947 1949 1951 1953 1955 1957 1959 1961 1963 1965 1967 1969 1971 1973 1975
REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY
PRIVATE AND COMMERCIAL AUTOMOBILE REGISTRATIONS
IN THE STATE OF
KENTUCKY
1927 TO 1949, WITH ESTIMATES TO 1975
Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK
CHICAGO
PHILADELPHIA
LOS ANGELES
EXHIBIT NO. 55


REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY
PERSONS PER PRIVATE AND COMMERCIAL TRUCK
FOR THE
EAST SOUTH CENTRAL STATES
1930 TO 1948, WITH ESTIMATES TO 1975
Ford, Bacon & Davis
Incorporated
Engineers
PERSONS PER TRUCK
Alabama
Tennessee
Kentucky
Mississippi
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
1930
1932
1934
1936
1938
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976

SF-441 8-2-50

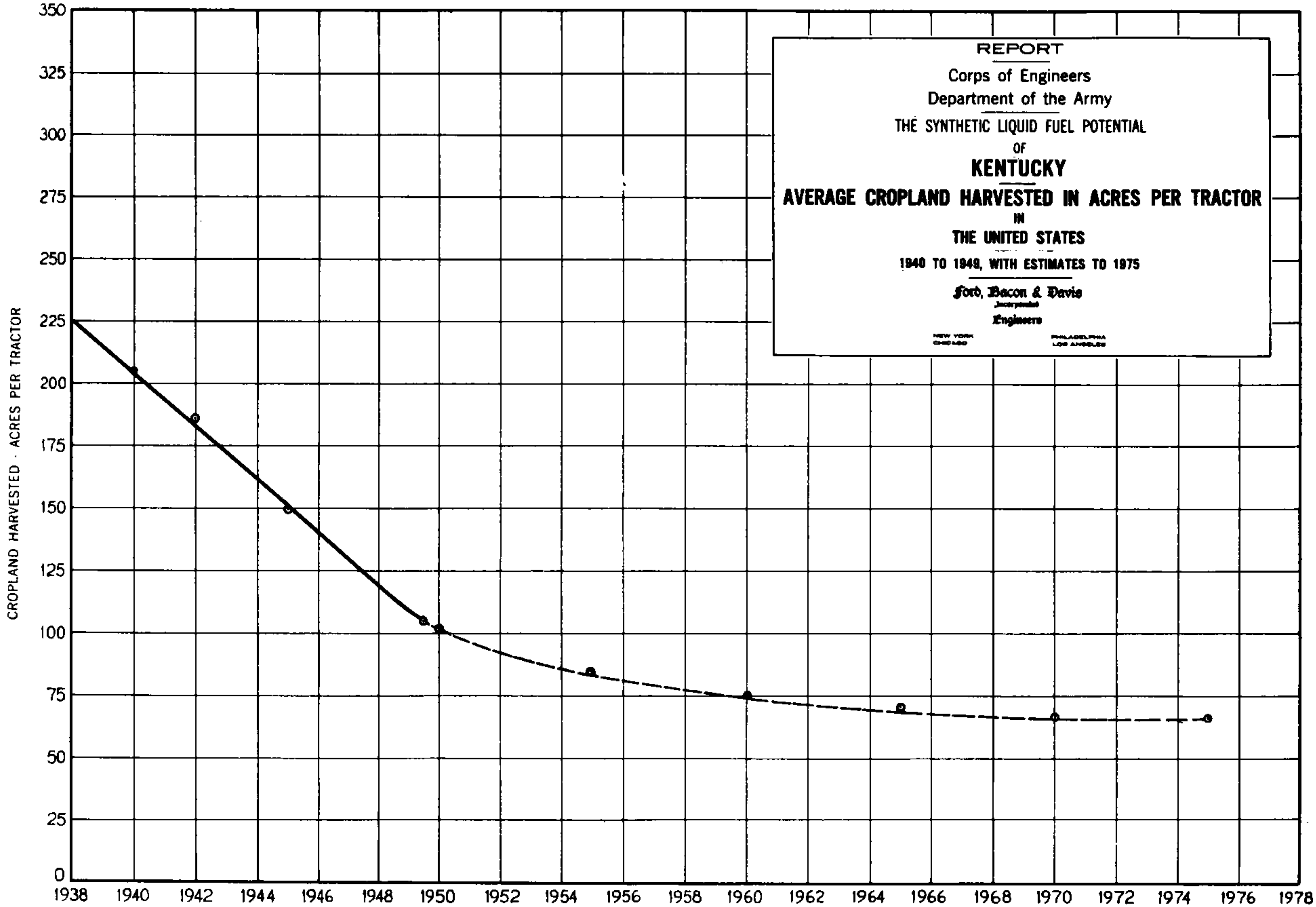
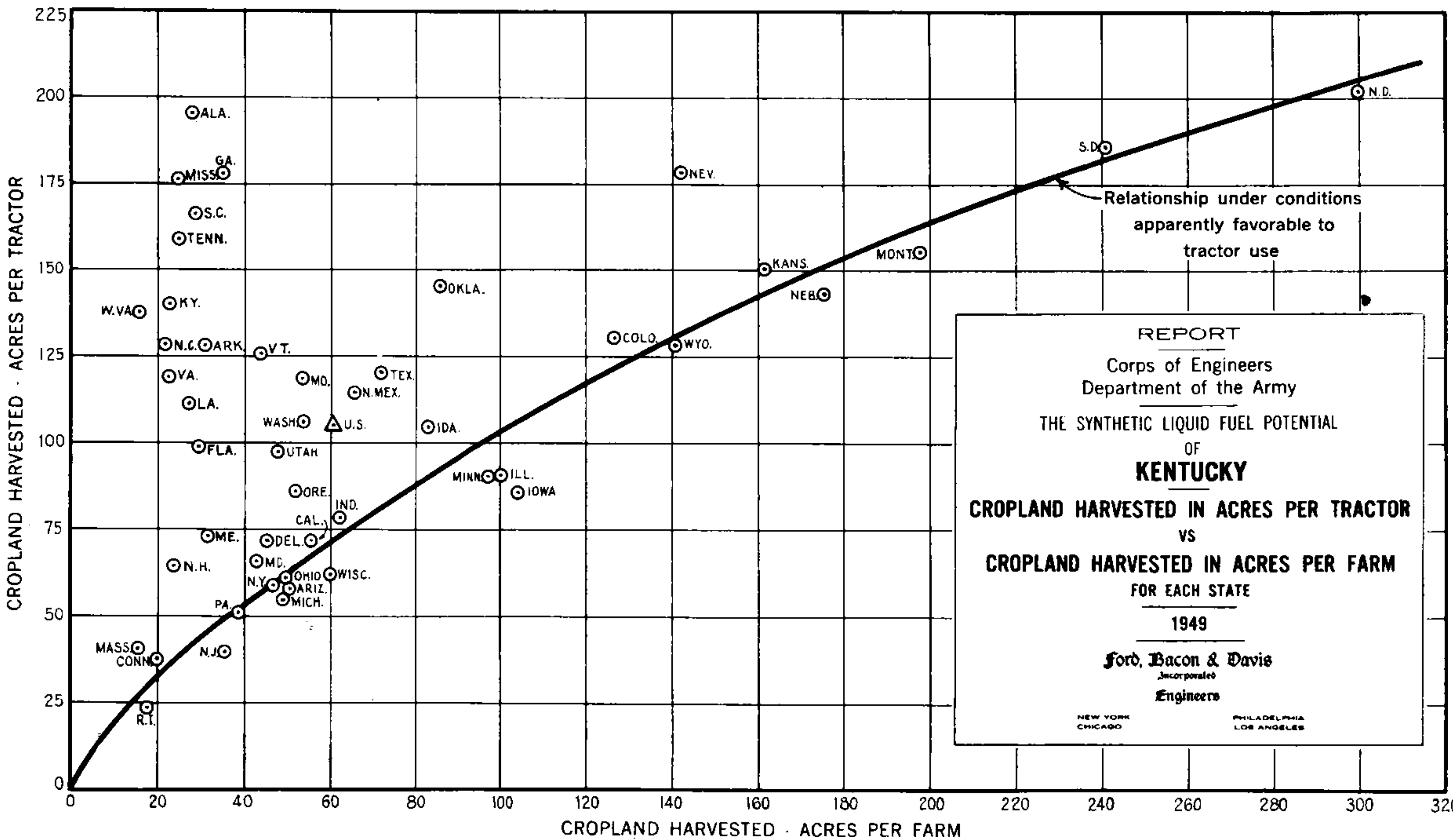


EXHIBIT NO. 57

SF-464 8-2-50



REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY

CROPLAND HARVESTED IN ACRES PER TRACTOR
VS
CROPLAND HARVESTED IN ACRES PER FARM
FOR EACH STATE

1949

Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK CHICAGO PHILADELPHIA LOS ANGELES

EXHIBIT NO. 58

SF-486 8-2-50

REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY

ESTIMATED CROPLAND HARVESTED IN ACRES PER TRACTOR
VS.
CROPLAND HARVESTED IN ACRES PER FARM
FOR EACH STATE

1975

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES

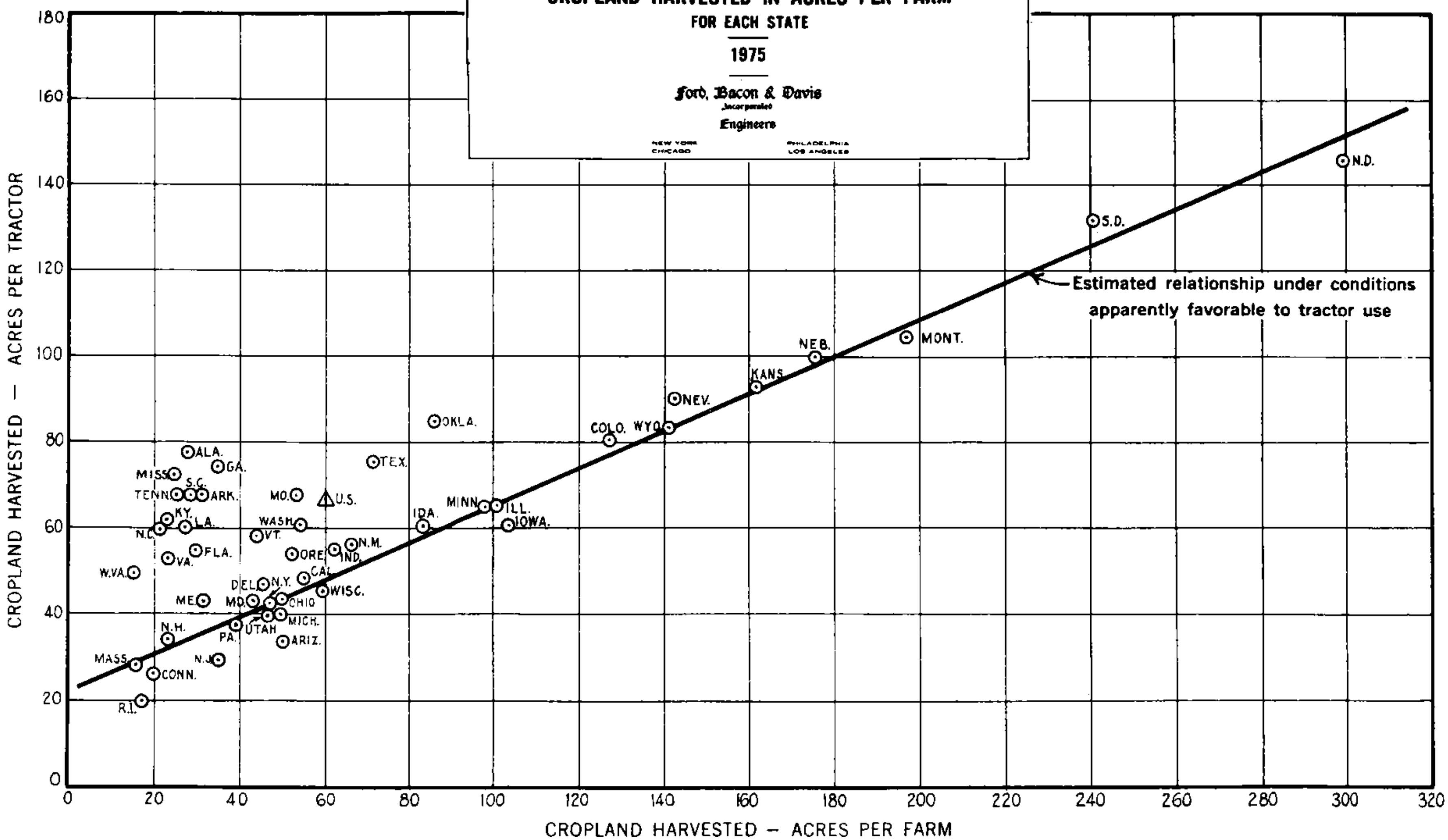


EXHIBIT NO. 59

SF-1375 7-11-51

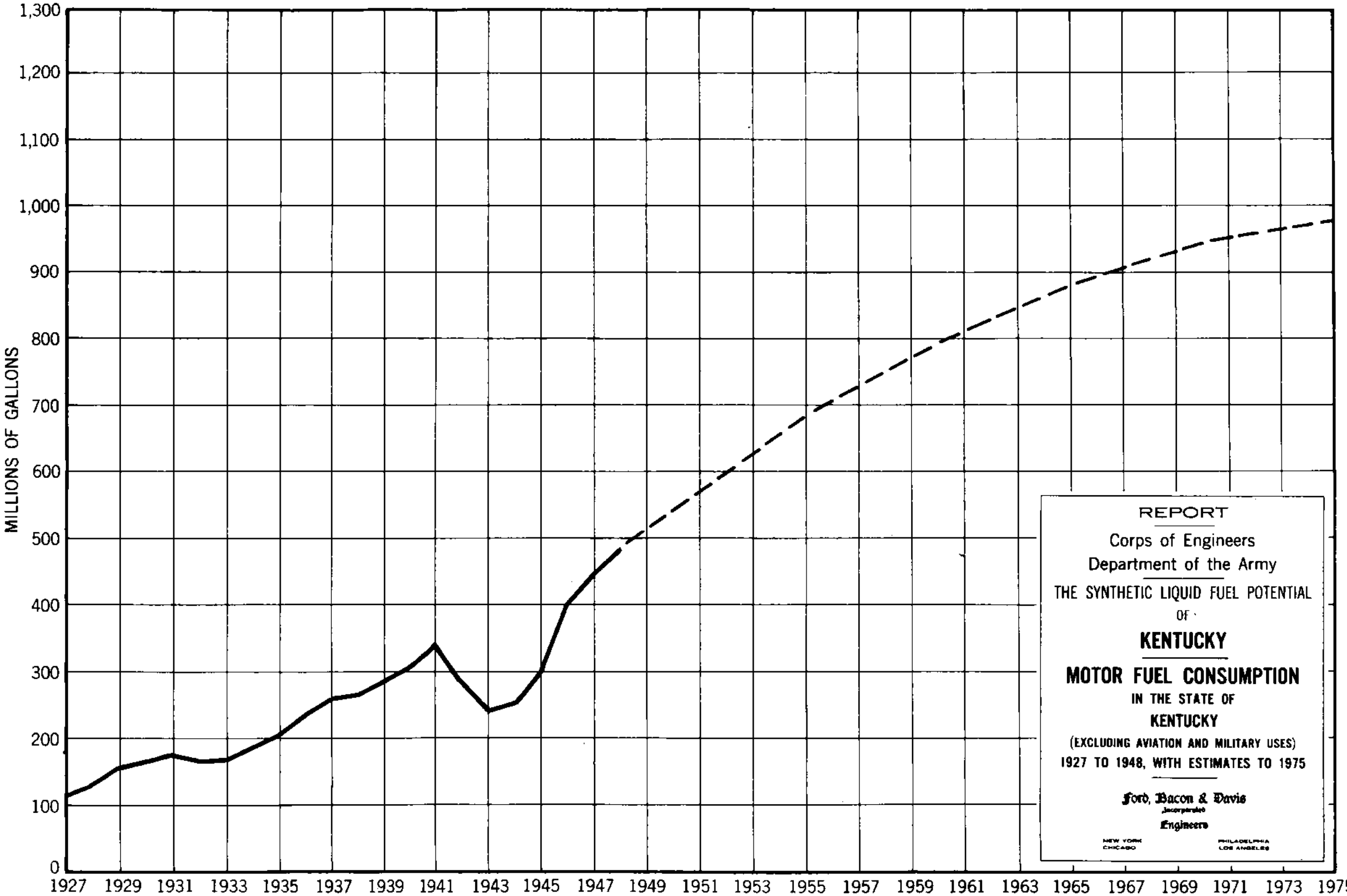


EXHIBIT NO. 60

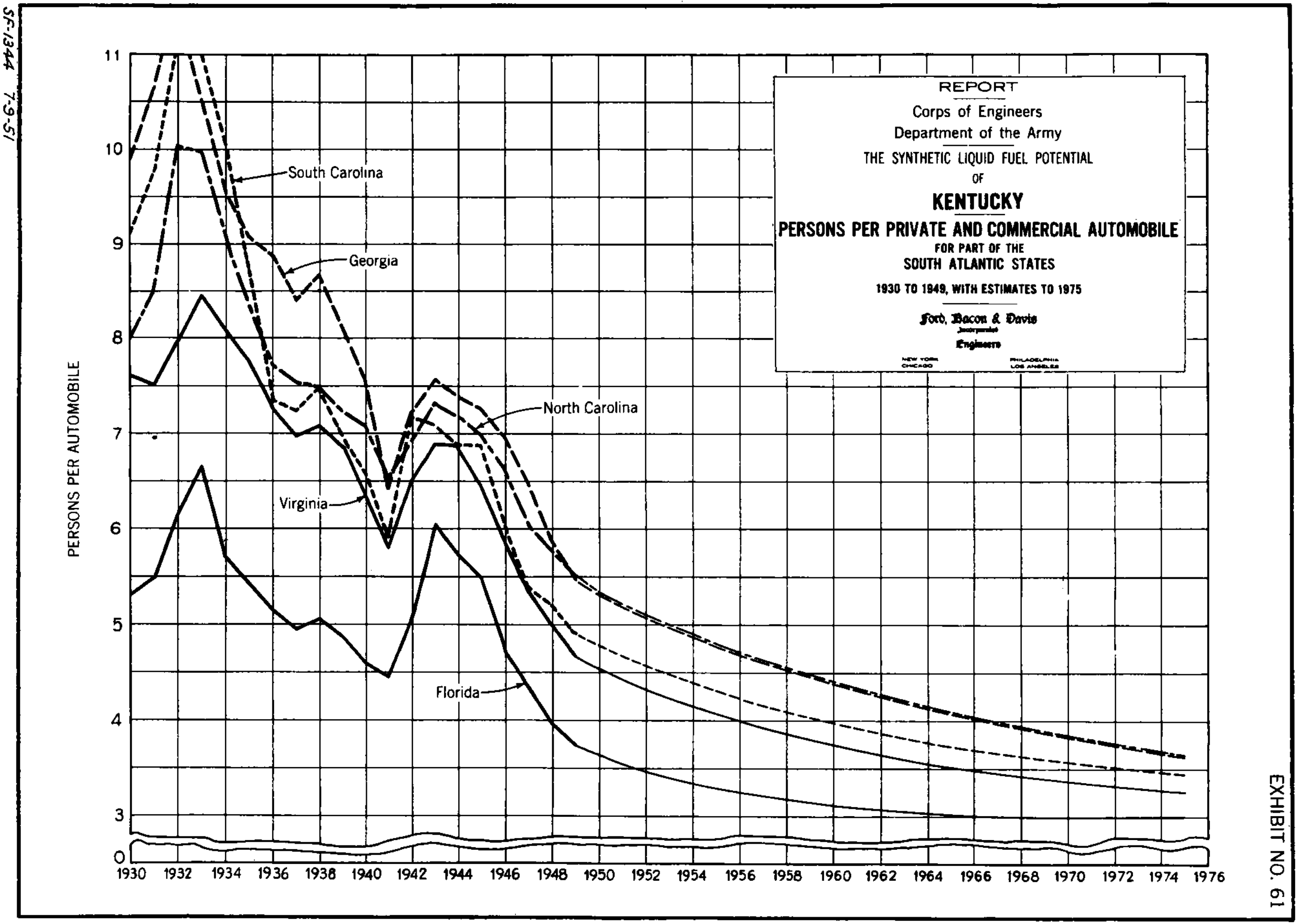
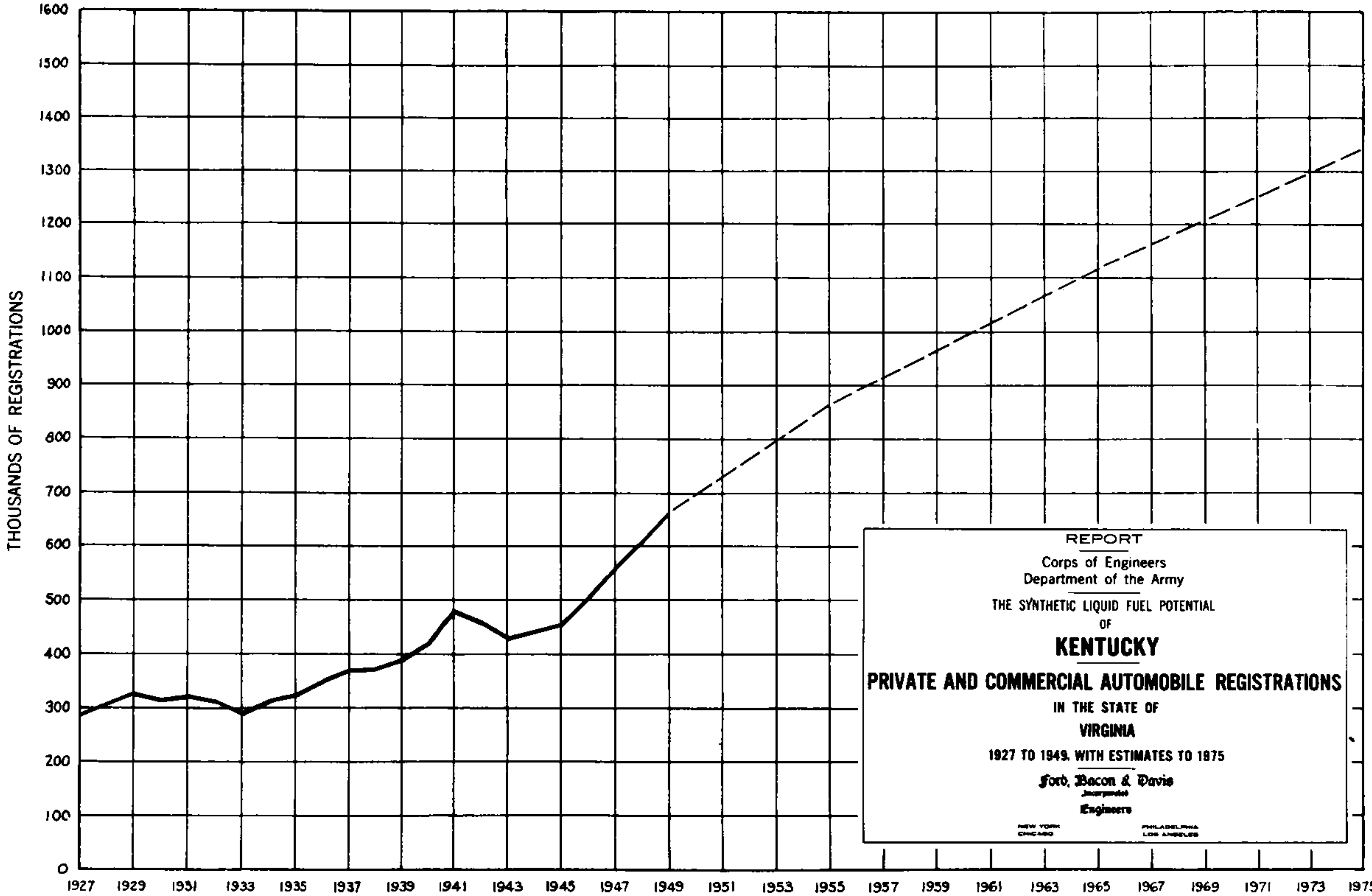


EXHIBIT NO. 61

SF-1345 7-9-51



REPORT

Corps of Engineers
Department of the Army

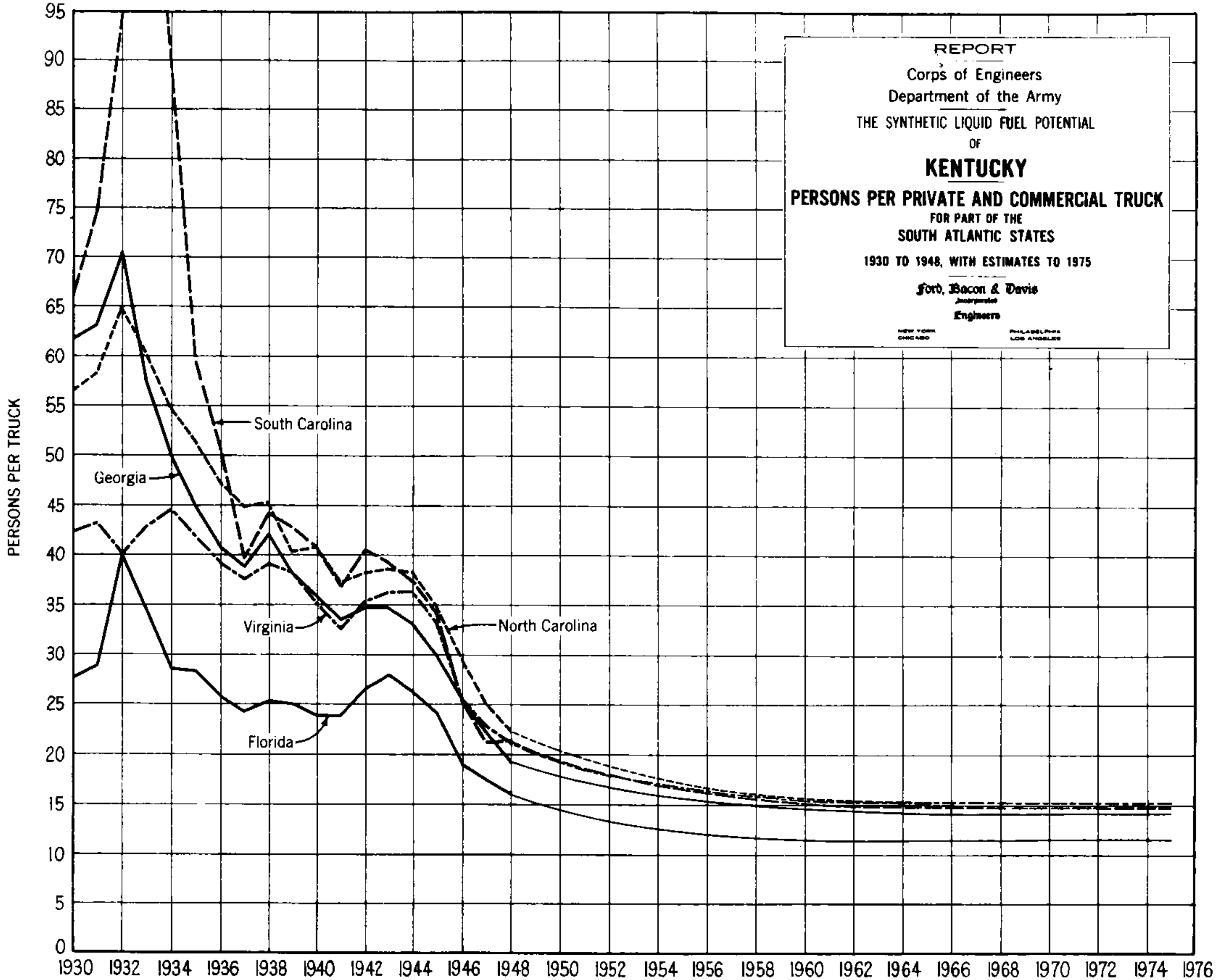
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY

PRIVATE AND COMMERCIAL AUTOMOBILE REGISTRATIONS
IN THE STATE OF
VIRGINIA
1927 TO 1949, WITH ESTIMATES TO 1975

Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK CHICAGO PHILADELPHIA LOS ANGELES

EXHIBIT NO. 62

SF-1346 7-9-51



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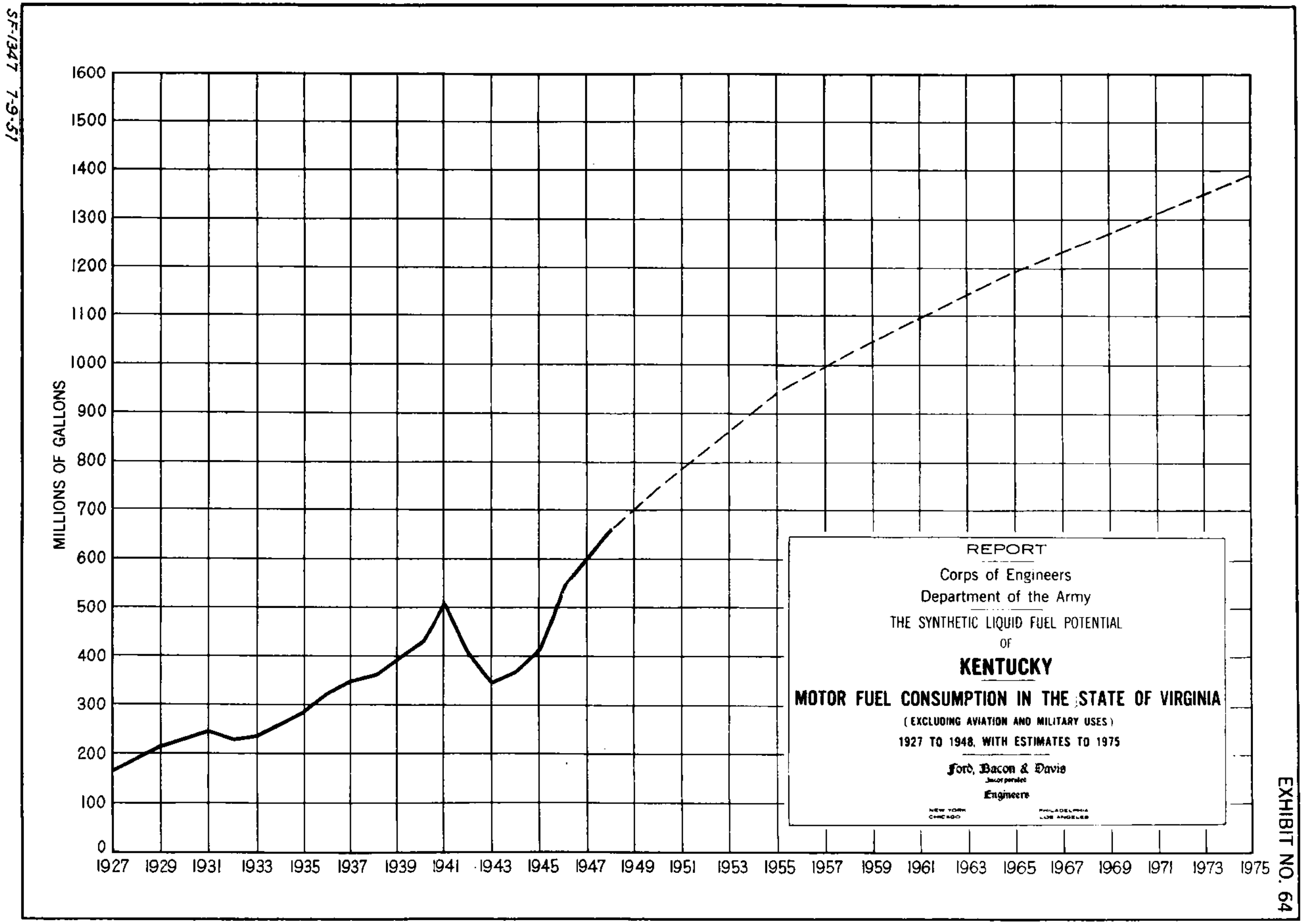


EXHIBIT NO. 64

SF-1348 7-9-51

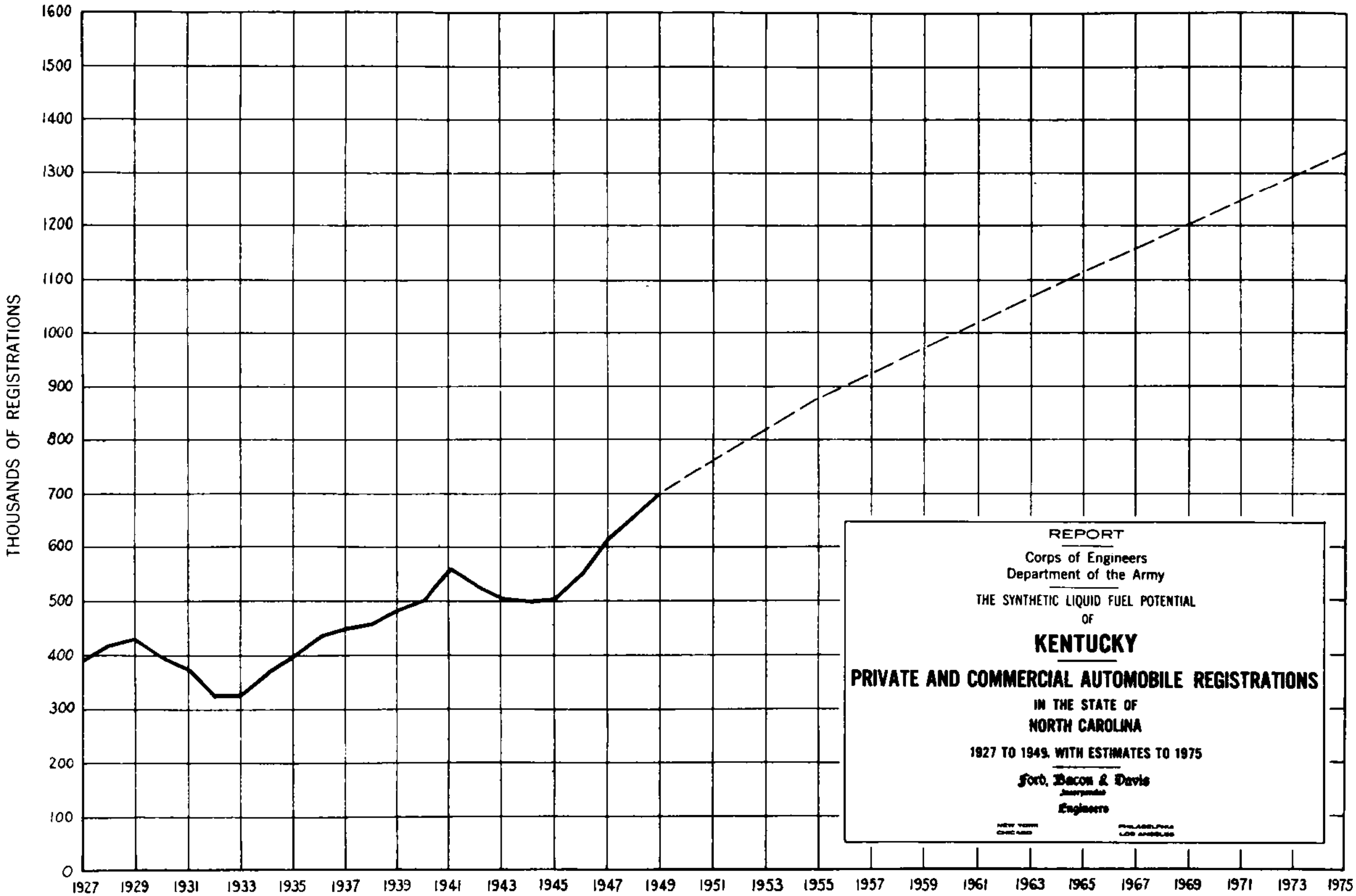
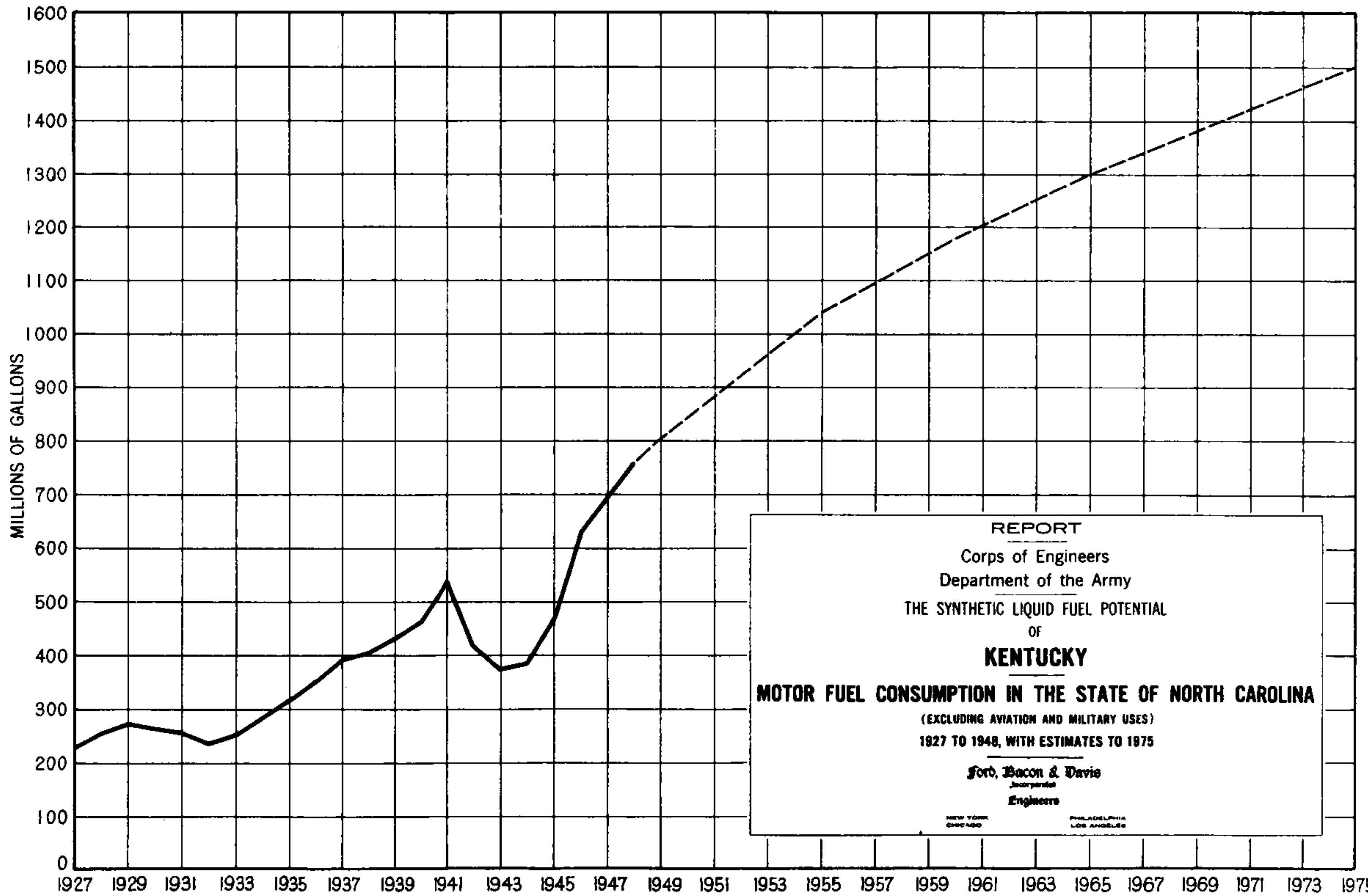


EXHIBIT NO. 65



REPORT

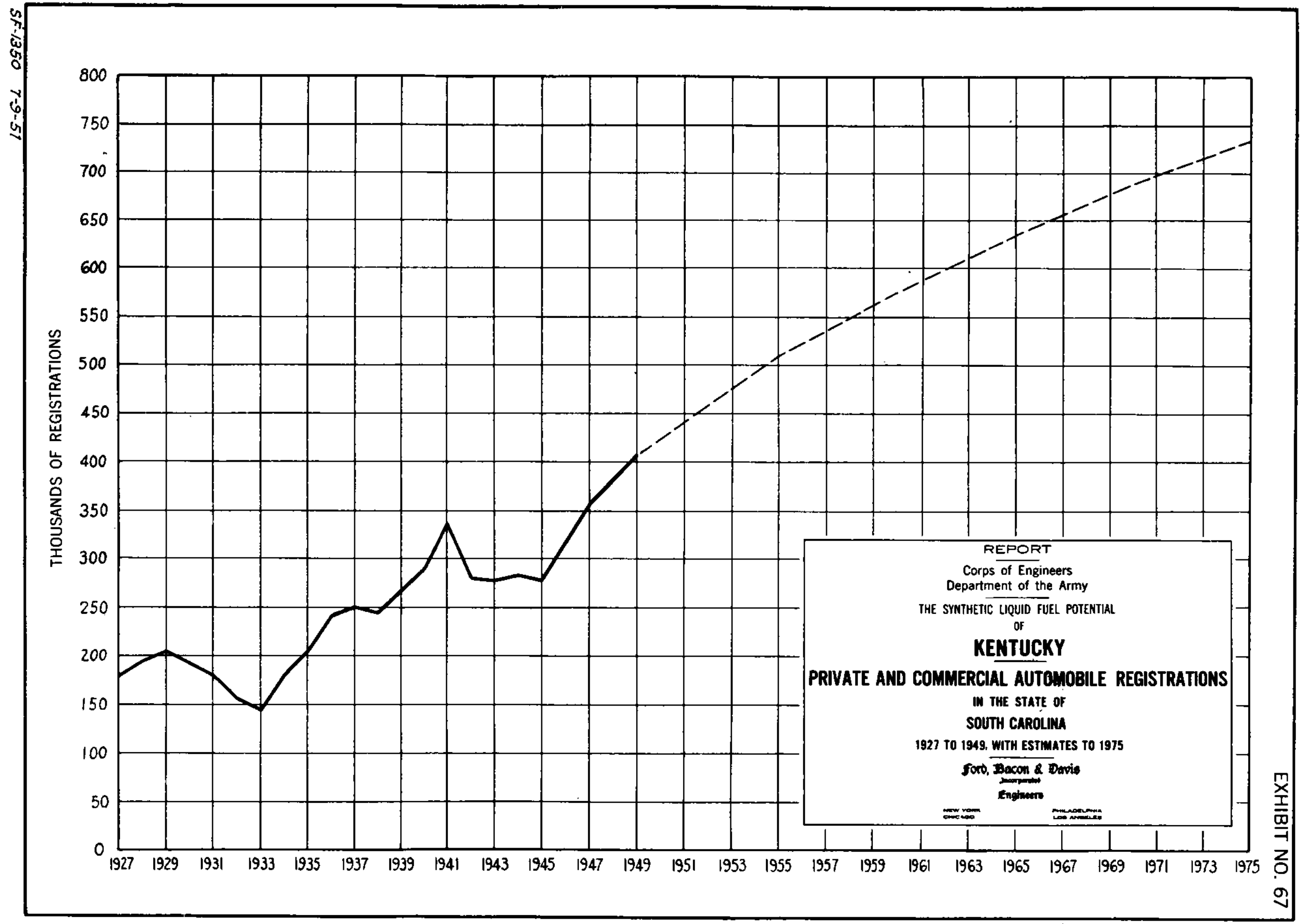
Corps of Engineers
Department of the Army

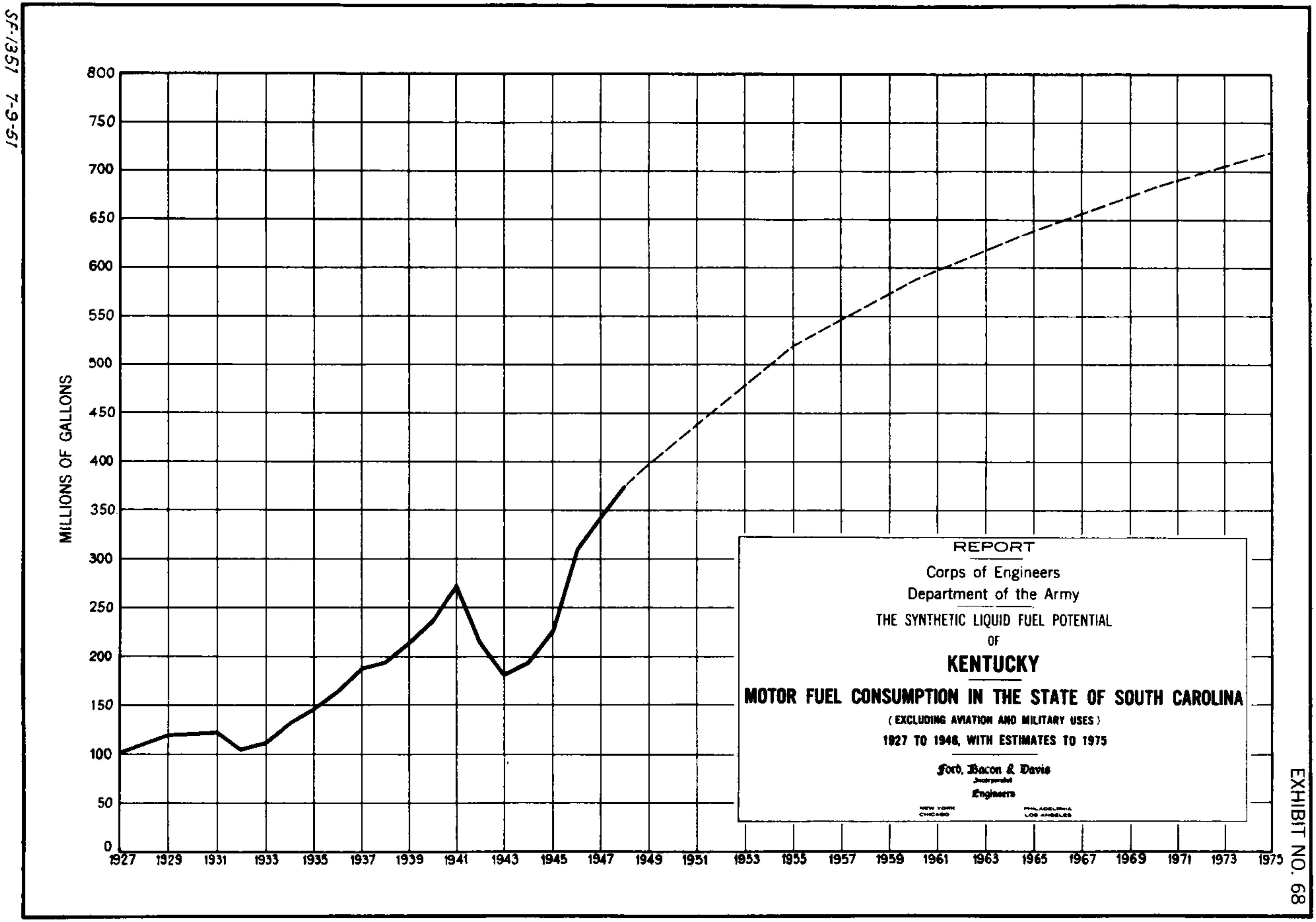
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY

MOTOR FUEL CONSUMPTION IN THE STATE OF NORTH CAROLINA
(EXCLUDING AVIATION AND MILITARY USES)
1927 TO 1948, WITH ESTIMATES TO 1975

Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK CHICAGO PHILADELPHIA LOS ANGELES

EXHIBIT NO. 66


SF-1350 7-9-51
THOUSANDS OF REGISTRATIONS
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
1927 1929 1931 1933 1935 1937 1939 1941 1943 1945 1947 1949 1951 1953 1955 1957 1959 1961 1963 1965 1967 1969 1971 1973 1975
REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY
PRIVATE AND COMMERCIAL AUTOMOBILE REGISTRATIONS
IN THE STATE OF
SOUTH CAROLINA
1927 TO 1949, WITH ESTIMATES TO 1975
Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK
CHICAGO
PHILADELPHIA
LOS ANGELES
EXHIBIT NO. 67



SF-1351 7-9-51
MILLIONS OF GALLONS
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
1927 1929 1931 1933 1935 1937 1939 1941 1943 1945 1947 1949 1951 1953 1955 1957 1959 1961 1963 1965 1967 1969 1971 1973 1975
REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY
MOTOR FUEL CONSUMPTION IN THE STATE OF SOUTH CAROLINA
(EXCLUDING AVIATION AND MILITARY USES)
1927 TO 1948, WITH ESTIMATES TO 1975
Ford, Bacon & Davis
Engineers
EXHIBIT NO. 68

SF-1352 7-9-51

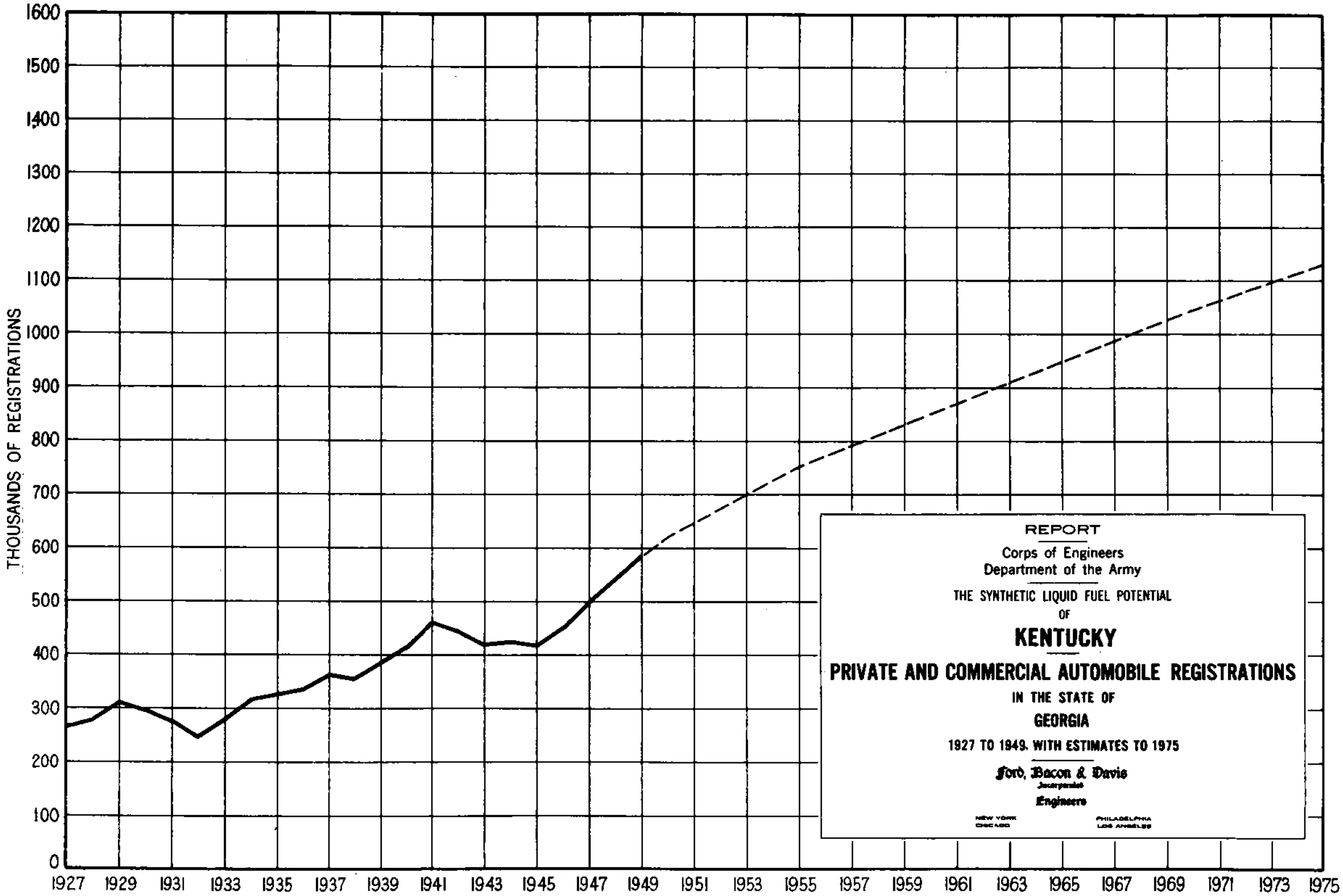
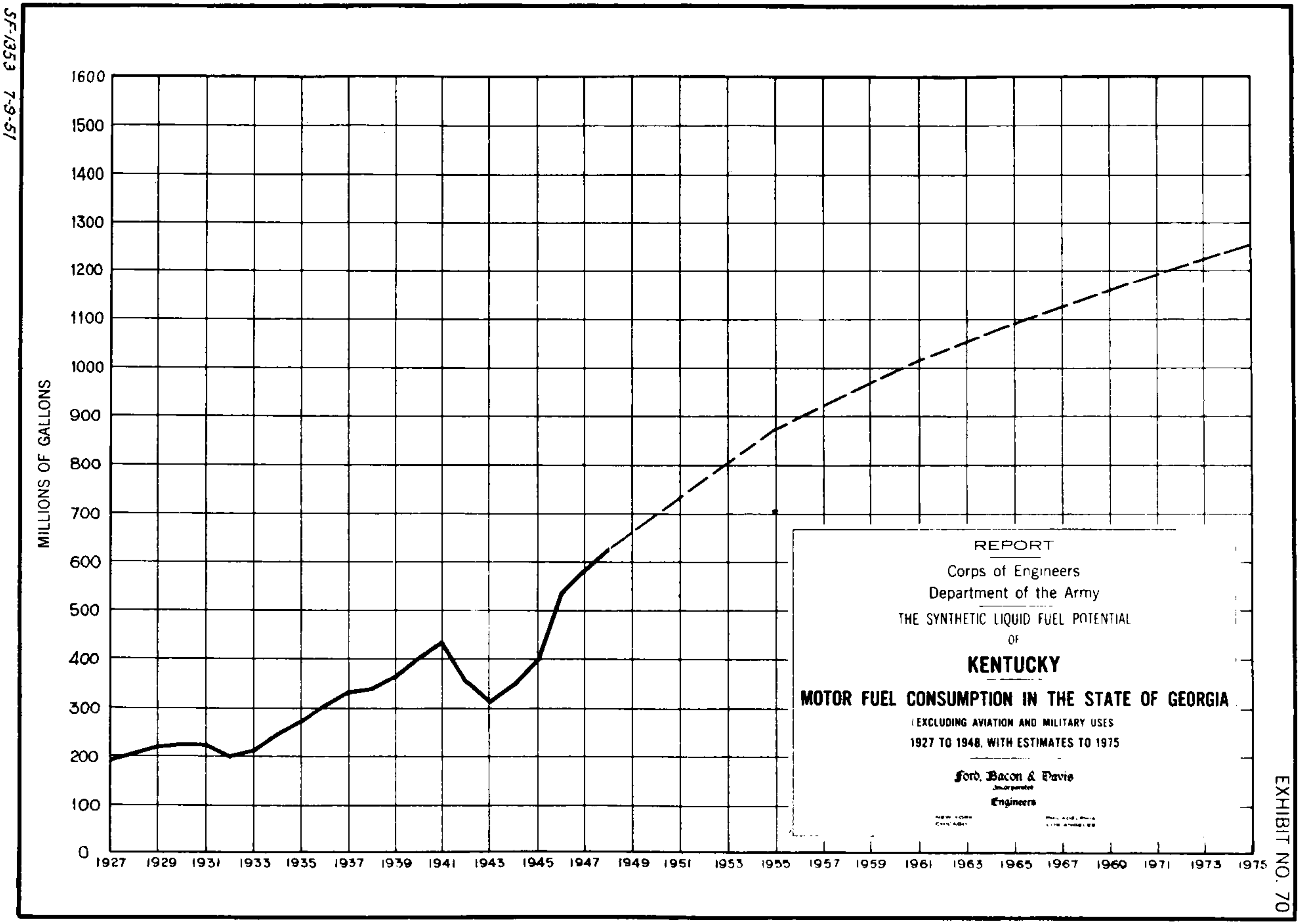
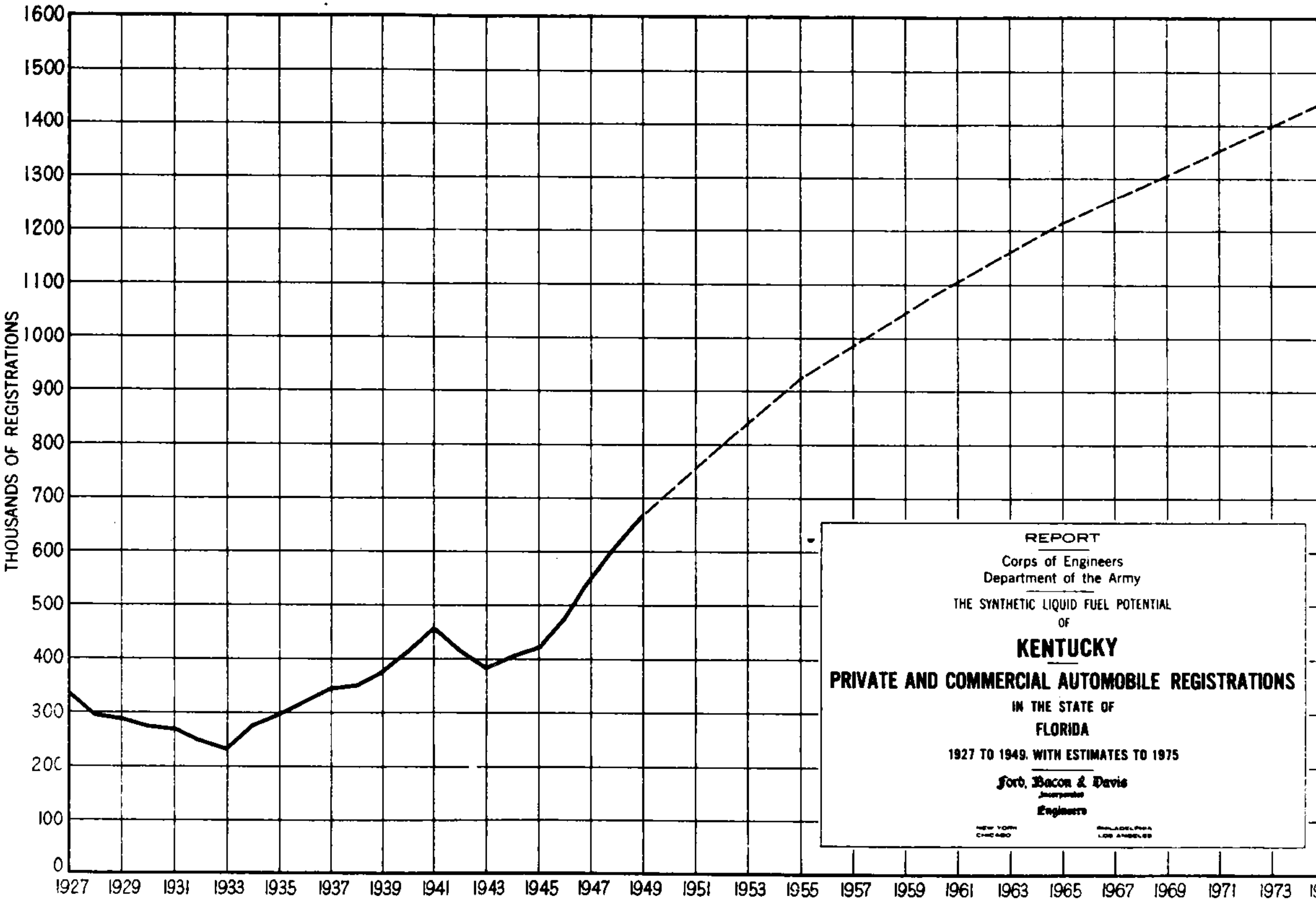


EXHIBIT NO. 69


SF-1353 7-9-51
MILLIONS OF GALLONS
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1927
1929
1931
1933
1935
1937
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY
MOTOR FUEL CONSUMPTION IN THE STATE OF GEORGIA
(EXCLUDING AVIATION AND MILITARY USES
1927 TO 1948, WITH ESTIMATES TO 1975
Ford, Bacon & Davis
Incorporated
Engineers
EXHIBIT NO. 70

SF-1354 7-9-51



REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF

KENTUCKY

PRIVATE AND COMMERCIAL AUTOMOBILE REGISTRATIONS

IN THE STATE OF

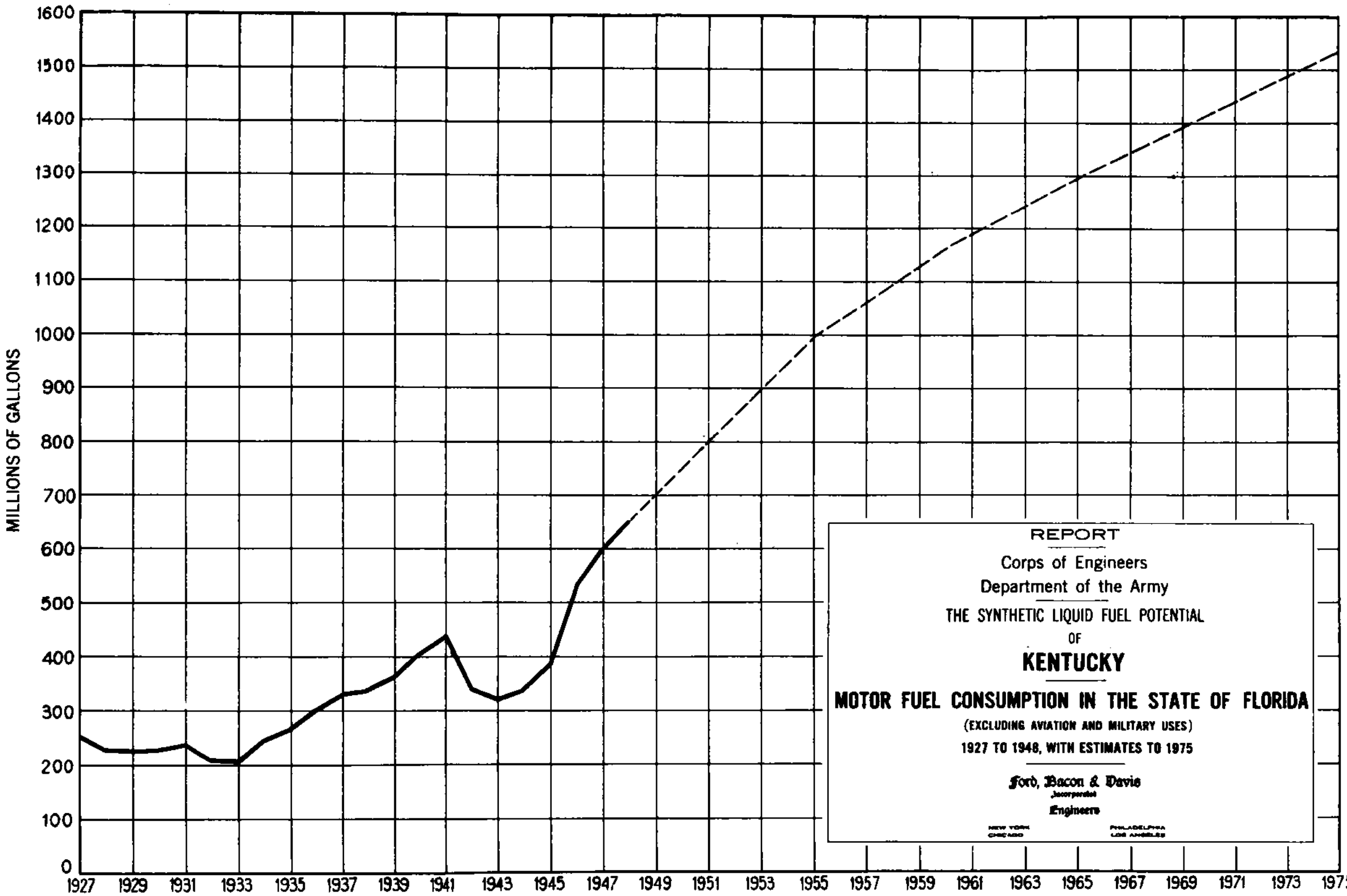
FLORIDA

1927 TO 1949, WITH ESTIMATES TO 1975

Ford, Bacon & Davis
Incorporated
Engineers

EXHIBIT NO. 71

SF-1355 7-9-51



REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY

MOTOR FUEL CONSUMPTION IN THE STATE OF FLORIDA
(EXCLUDING AVIATION AND MILITARY USES)
1927 TO 1948, WITH ESTIMATES TO 1975

Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK CHICAGO PHILADELPHIA LOS ANGELES

EXHIBIT NO. 72

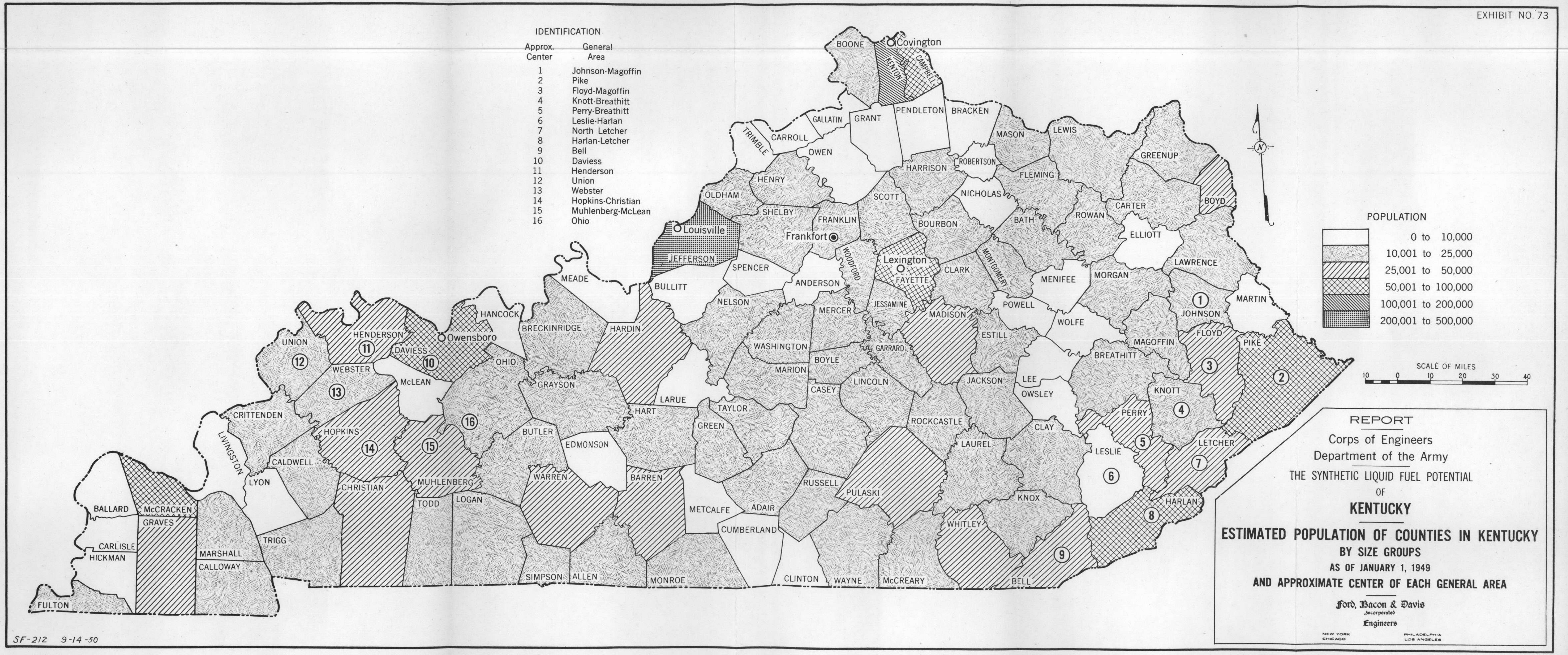
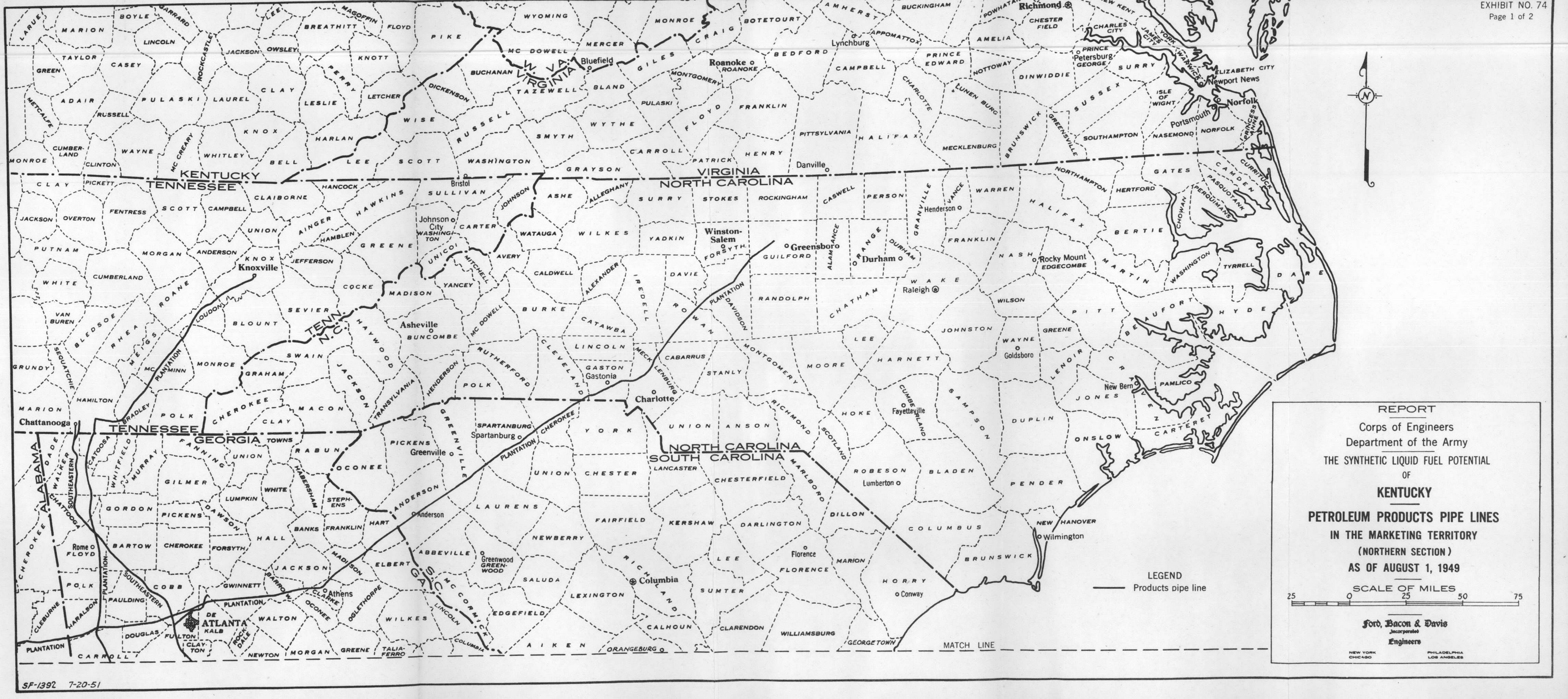


EXHIBIT NO. 73
IDENTIFICATION
Approx. Center | General Area
1 Johnson-Magoffin
2 Pike
3 Floyd-Magoffin
4 Knott-Breathitt
5 Perry-Breathitt
6 Leslie-Harlan
7 North Letcher
8 Harlan-Letcher
9 Bell
10 Daviess
11 Henderson
12 Union
13 Webster
14 Hopkins-Christian
15 Muhlenberg-McLean
16 Ohio
POPULATION
0 to 10,000
10,001 to 25,000
25,001 to 50,000
50,001 to 100,000
100,001 to 200,000
200,001 to 500,000
SCALE OF MILES
10 0 10 20 30 40
N
Covington
Louisville
Frankfort
Lexington
Owensboro
BOONE
KENTON
CAMPBELL
GALLATIN
GRANT
PENDLETON
BRACKEN
TRIMBLE
CARROLL
OWEN
MASON
LEWIS
GREENUP
HARRISON
ROBERTSON
FLEMING
BOYD
HENRY
OLDHAM
SCOTT
NICHOLAS
CARTER
SHELBY
FRANKLIN
BOURBON
BATH
ROWAN
ELLIOTT
JEFFERSON
SPENCER
WOODFORD
FAYETTE
MONTGOMERY
CLARK
LAWRENCE
MEADE
BULLITT
ANDERSON
MENIFEE
MORGAN
NELSON
MERCER
JESSAMINE
POWELL
MARTIN
JOHNSON
HANCOCK
BRECKINRIDGE
HARDIN
MADISON
ESTILL
WOLFE
UNION
HENDERSON
DAVIESS
WASHINGTON
GARRARD
FLOYD
MAGOFFIN
PIKE
OHIO
WEBSTER
MARION
BOYLE
BREATHITT
McLEAN
GRAYSON
CASEY
LINCOLN
JACKSON
LEE
OWSLEY
KNOTT
LARUE
CRITTENDEN
HART
TAYLOR
ROCKCASTLE
PERRY
HOPKINS
BUTLER
GREEN
CLAY
LETCHER
LIVINGSTON
EDMONSON
LAUREL
LESLIE
CALDWELL
LYON
CHRISTIAN
WARREN
BARREN
RUSSELL
PULASKI
MUHLENBERG
KNOX
HARLAN
BALLARD
McCRACKEN
TODD
LOGAN
METCALFE
ADAIR
GRAVES
CUMBERLAND
WHITLEY
CARLISLE
HICKMAN
TRIGG
MARSHALL
CALLOWAY
SIMPSON
ALLEN
MONROE
CLINTON
WAYNE
McCREARY
BELL
FULTON
REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY
ESTIMATED POPULATION OF COUNTIES IN KENTUCKY
BY SIZE GROUPS
AS OF JANUARY 1, 1949
AND APPROXIMATE CENTER OF EACH GENERAL AREA
Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK
CHICAGO
PHILADELPHIA
LOS ANGELES
SF-212 9-14-50

KY

EXHIBIT NO. 74
Page 1 of 2



REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY

PETROLEUM PRODUCTS PIPE LINES
IN THE MARKETING TERRITORY
(NORTHERN SECTION)
AS OF AUGUST 1, 1949

Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK CHICAGO PHILADELPHIA LOS ANGELES

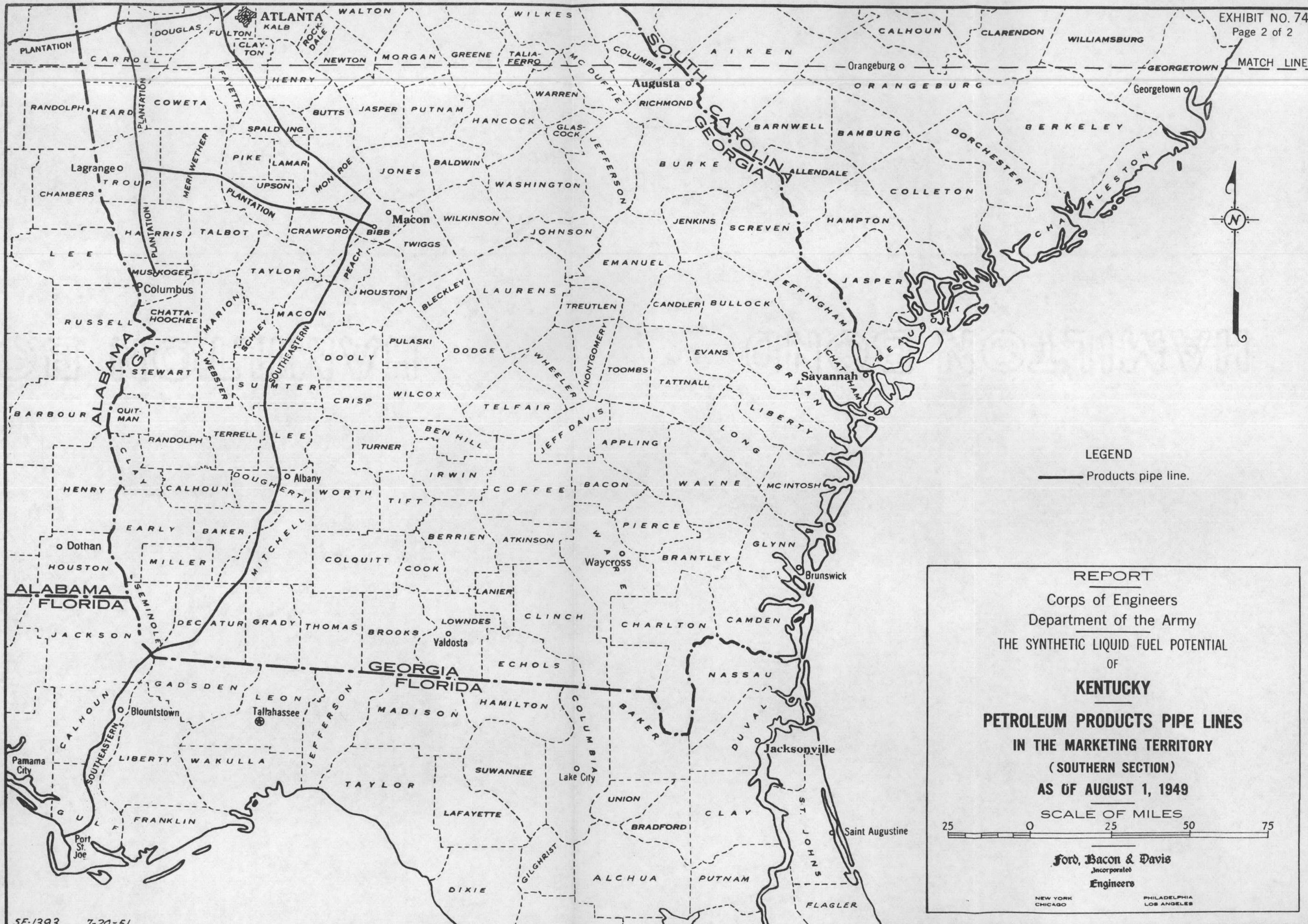


EXHIBIT NO. 74
Page 2 of 2
MATCH LINE
ATLANTA
Augusta
Macon
Columbus
Lagrange
Albany
Dothan
Waycross
Brunswick
Savannah
Orangeburg
Georgetown
Valdosta
Tallahassee
Blountstown
Pamama City
Port St. Joe
Lake City
Jacksonville
Saint Augustine
SOUTH CAROLINA
GEORGIA
ALABAMA
GA.
ALABAMA
FLORIDA
GEORGIA
FLORIDA
PLANTATION
SOUTHEASTERN
LEGEND
Products pipe line.
REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KENTUCKY
PETROLEUM PRODUCTS PIPE LINES
IN THE MARKETING TERRITORY
(SOUTHERN SECTION)
AS OF AUGUST 1, 1949
SCALE OF MILES
25 0 25 50 75
Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK
CHICAGO
PHILADELPHIA
LOS ANGELES
5F-1393 7-20-51

Exhibit No. 75

Initial Capital Investment in Process Plant
by General Areas of Coal and Water Availability
10,000-barrel-per-day Hydrogenation Plants in Kentucky
(As of March 31, 1950)

Item	Eastern Kentucky General Areas of Coal and Water Availability									Western Kentucky General Areas of Coal and Water Availability						
	Johnson-Magoffin	Pike	Floyd-Magoffin	Knott-Breathitt	Perry-Breathitt	Leslie-Harlan	Northern Letcher	Harlan-Letcher	Bell	Daviess	Henderson	Union	Webster	Hopkins-Christian	Muhlenberg-McLean	Ohio
Plant Construction Cost (A)	$ 91,096	$ 91,096	$ 91,096	$ 91,096	$ 91,096	$ 91,096	$ 91,096	$ 91,096	$ 91,096	$ 91,096	$ 91,096	$ 91,096	$ 91,096	$ 91,096	$ 91,096	$ 91,096
Interest during Construction (A)	3,416	3,416	3,416	3,416	3,416	3,416	3,416	3,416	3,416	3,416	3,416	3,416	3,416	3,416	3,416	3,416
Depreciable Investment (A)	$ 94,512	$ 94,512	$ 94,512	$ 94,512	$ 94,512	$ 94,512	$ 94,512	$ 94,512	$ 94 512	$ 94,512	$ 94,512	$ 94,512	$ 94,512	$ 94,512	$ 94,512	$ 94 512
Operating Capital (A)	4,961	4,841	4,882	4,890	4,884	4,868	4,865	4,872	4,879	4,865	4,983	4,664	4,606	4,498	4,422	4,457
Total Capital Investment (A)	$ 99,473	$ 99,353	$ 99,394	$ 99,402	$ 99,396	$ 99,380	$ 99,377	$ 99,384	$ 99,391	$ 99,377	$ 99,495	$ 99,176	$ 99,118	$ 99,010	$ 98,934	$ 98,969
1 Percent Return on Above Investment:																
Per Annum	$994,730	$993,530	$993,940	$994,020	$993,960	$993,800	$993,770	$993,840	$993,910	$993,770	$994,950	$991,760	$991,180	$990,100	$989,340	$989,690
Per Calendar Day	2,725	2,722	2,723	2,723	2,723	2,723	2,723	2,723	2,723	2,723	2,726	2,717	2,716	2,713	2,711	2,711
Per Barrel of Products	0.273	0.272	0.272	0.272	0.272	0.272	0.272	0.272	0.272	0.272	0.273	0.272	0.272	0.271	0.271	0.271

Note: (A) In thousands of dollars.

Estimated Plant Construction Cost and Capital Investment
Required for a 10,000-barrel-per-day Hydrogenation Unit Plant
at Rock Springs, Wyoming,
(Based on Estimates by U.S. Bureau of Mines
for a 30,000-barrel Plant as of First Quarter of 1948)

Subdivisions of Total Plant		Estimated Initial Capital Investment (As of First Quarter of 1948)
Gas Production Section (including recovery and compression):		
Low-temperature Off-gas Separation	$ 1,922,000	
Hydrocarbon Steam Cracking	2,389,000	
Coal Gasification	3,066,000	
Oxygen Plant	3,673,000	
Hydrogen Purification and Compression	7,200,000	
Total Gas Production		$18,250,000
Hydrogenation Section (including product distillation and separation):		
Coal Preparation	$ 2,327,000	
Paste Preparation	930,000	
Liquid Phase Hydrogenation	14,967,000	
Delayed Coking	2,122,000	
Vapor Phase Hydrogenation	8,400,000	
Product Distillation	3,017,000	
Phenols Recovery	668,000	
Total Hydrogenation		$32,431,000
General and Auxiliary Plants Section:		
Tankage	$ 1,670,000	
Power Plant	12,083,000	
Plant Utilities	8,573,000	
General Plant Facilities	7,967,000	
Total General and Auxiliary Plants		30,293,000
Total Plant Construction Cost		$80,974,000
Interest during Construction		3,037,000
Depreciable Investment		$84,011,000
Operating Capital		4,608,000
Total Investment entitled to Return		$88,619,000

Ky

4

70021

Estimation of Operating Capital
Hydrogenation Unit Plants in Kentucky
(As of March 31, 1950)

Eastern Kentucky General Areas of Coal and Water Availability

	Johnson-Magoffin	Pike	Floyd-Magoffin	Knott-Breathitt	Perry-Breathitt	Leslie-Harlan	Northern Letcher	Harlan-Letcher	Bell
Costs per Calendar Day									
Coal:									
Mine Investment ($1,000's)	$ 7,818	$ 6,345	$ 6,660	$ 6,505	$ 6,630	$ 6,535	$ 6,400	$ 6,395	$ 7,128
Daily Plant Consumption (Tons)	3,569	3,478	3,649	3,564	3,632	3,582	3,508	3,505	3,551
Cost per Ton	$5.11	$4.76	$4.66	$4.66	$4.66	$4.66	$4.66	$4.76	$4.71
Daily Cost excluding return	$18,238	$16,555	$17,004	$16,608	$16,925	$16,692	$ 16,347	$16,684	$16,725
Daily Return on Investment @ 4%	857	695	730	713	727	716	701	701	781
Daily Cost including Return	$19,095	$17,250	$17,734	$17,321	$17,652	$17,408	$ 17,048	$17,385	$17,506
Water:									
Water Investment ($1,000's)	$ 891	$ 2,846	$ 3,170	$ 6,750	$ 3,957	$ 4,175	$ 5,754	$ 4,619	$ 4,246
Annual Cost	76,050	136,070	153,710	288,860	181,260	185,480	301,130	214,810	216,870
Daily Cost excluding return	$ 208	$ $373	$421	791	497	508	825	589	594
Daily Return on Investment @ 5%	122	390	434	925	542	572	788	633	582
Daily Cost including Return	$ 330	$763	$855	$1,716	$1,039	$1,080	$1,613	$1,222	$1,176
Catalysts	1,293	1,293	1,293	1,293	1,293	1,293	1,293	1,293	1,293
Total Raw Material	$20,718	$19,306	$19,882	$20,330	$19,984	$19,781	$19,954	$19,900	$19,975
Total Direct and Indirect Costs, excluding Raw Material (A)	$18,865	$18,865	$18,865	$18,865	$18,865	$18,865	$18,865	$18,865	$18,865
Operating Capital									
Cost of 30 day's Coal Supply at Rated Capacity Operation	$572,850	$517,500	$532,020	$519,630	$529,560	$522,240	$511,440	$521,550	$525,180
Cost of Direct Materials and Water for one-half year operation at average 25 percent capacity	945,259	880,836	907,116	927,556	911,770	902,508	910,401	907,938	911,359
All other operating costs for one-half year (except fixed costs)	3,442,863	3,442,863	3,442,863	3,442,863	3,442,863	3,442,863	3,442,863	3,442,863	3,442,863
Total	$4,960,972	$4,841,199	$4,881,999	$4,890,049	$4,884,193	$4,867,611	$4,864,704	$4,872,351	$4,879,402

Western Kentucky General Areas of Coal and Water Availability

	Daviess	Henderson	Union	Webster	Hopkins-Christian	Muhlenberg-McLean	Ohio
Costs per Calendar Day							
Coal:							
Mine Investment ($1,000's)	$ 7,327	$ 7,344	$ 6,521	$ 6,125	$ 5,254	$ 5,163	$ 5,044
Daily Plant Consumption (Tons)	4,541	4,471	3,971	3,954	4,111	4,040	4,253
Cost per Ton	$3.76	$4.16	$3.65	$3.39	$2.81	$2.81	$2.79
Daily Cost excluding return	$17,074	$18,599	$14,494	$13,404	$11,552	$11,352	$11,866
Daily Return on Investment @ 4%	803	805	715	671	576	566	553
Daily Cost including Return	$17,877	$19,404	$15,209	$14,075	$12,128	$11,918	$12,419
Water:							
Water Investment ($1,000's)	$ 495	$ 721	$ 628	$ 3,231	$ 6,766	$ 1,209	$ 898
Annual Cost	62,980	75,720	66,690	156,480	289,360	93,030	79,530
Daily Cost excluding return	173	207	183	429	793	255	218
Daily Return on Investment @ 5%	68	99	86	443	927	166	123
Daily Cost including Return	$241	$306	$269	$872	$1,720	$421	$341
Catalysts	1,293	1,293	1,293	1,293	1,293	1,293	1,293
Total Raw Material	$19,411	$21,003	$16,771	$16,240	$15,141	$13,632	$14,053
Total Direct and Indirect Costs, excluding Raw Material (A)	$18,865	$18,865	$18,865	$18,865	$18,865	$18,865	$18,865
Operating Capital							
Cost of 30 day's Coal Supply at Rated Capacity Operation	$536,310	$582,120	$456,270	$422,250	$363,840	$357,540	$372,570
Cost of Direct Materials and Water for one-half year operation at average 25 percent capacity	885,627	958,262	765,177	740,950	690,808	621,960	641,168
All other operating costs for one-half year (except fixed costs)	3,442,863	3,442,863	3,442,863	3,442,863	3,442,863	3,442,863	3,442,863
Total	$4,864,800	$4,983,245	$4,664,310	$4,606,063	$4,497,511	$4,422,363	$4,456,601

Note: (A) From Contractor's Estimate of Processing Costs:

Total Direct and Indirect Costs	$38,604
Less Direct Materials (Coal and Catalysts)	19,531
Less Make-up Water	208
Balance, Direct and Indirect Costs excluding Raw Material	$18,865

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Methods Used in Preparation of Estimates of Daily Operating Costs for a Typical Hydrogenation Unit Plant in Continental United States

Direct Labor:

Direct labor 1 man per shift per $1,000,000 of plant cost erected (cost as of first quarter 1948) (A) (B)

Supervisory personnel 10 percent of direct labor personnel (B)

Total labor personnel 4.5 times personnel per shift (B)

Direct labor wage rate (at Rock Springs, Wyo., first quarter 1948) average, all classifications, $1.75 per hour (A)

Cost of supervision 15 percent of labor cost (A)

Plant Maintenance Labor and Supervision:

Total annual cost of maintenance labor and supervision 2 percent of plant cost erected (cost as of first quarter 1948) (A)

Maintenance labor personnel 1.18 times direct labor personnel (B)

Supervisory personnel 10 percent of maintenance labor personnel (B)

Total maintenance labor personnel 4.5 times average personnel per shift (B)

Maintenance labor wage rate (at Rock Springs, Wyo., first quarter 1948) - average, all classifications, $1.68 per hour (B)

Cost of supervision 15 percent of labor cost (A)

Plant Maintenance Materials:

Per year, 1 percent of plant cost erected (A)

Payroll Overhead:

12-1/2 percent of direct labor and supervision and maintenance labor and supervision (A)

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Operating Supplies:

20 percent of maintenance labor, supervision, and materials (A)

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Methods Used in Preparation of Estimates of Daily Operating Costs for a Typical Hydrogenation Unit Plant in Continental United States

Total Indirect Costs (general administrative, office overhead, and indirect operating costs):
50 percent of direct labor and supervision, plant maintenance labor, supervision, and materials, and operating supplies (A)

Indirect Labor:
Total indirect labor personnel (wage earners), as estimated in detail by individual functions (B) - actually amounting to 11-1/2 percent of total wage earners (including indirect labor)

Indirect labor wage rate, (at Rock Springs, Wyo., first quarter 1948) - average, all classifications, $1.58 per hour (B)

Total daily cost of indirect labor, 1/365 of annual cost, at 2,080 hours per year, per man (C)

Cost of supervision, none (supervision provided by salaried personnel) (C)

Indirect Salaried Personnel:
Total indirect salaried personnel, as estimated in detail by individual functions (B)

Average salary $3,600 per year (B)

Other Indirect Costs:
Balance remaining after deducting from total indirect costs (as above) the sum of payments to indirect labor and indirect salaried personnel (also as above)

Local, County, and State Taxes:
Per year, 1 percent (A) of depreciable investment (plant cost erected, plus interest during construction)

Depreciation:
15-year, straight line; per year, 6-2/3 percent (A) of depreciable investment

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Methods Used in Preparation of Estimates of Daily Operating Costs for a Typical Hydrogenation Unit Plant in Continental United States

References:

(A) R.I. 4564, U.S. Bureau of Mines, August 1949:
"Estimated Plant and Operating Costs for Producing Gasoline by Coal Hydrogenation."

(B) Memorandum, U.S. Bureau of Mines Synthetic Oil Plant, Louisiana, Mo., February 3, 1950:
"30,000-barrel-per-day Coal Hydrogenation Plant - Labor Classification and Hourly Rates" (Transmitted to F.B. & D., Inc. by Corps. of Engineers, February 17, 1950)

(C) Memorandum, U.S. Bureau of Mines Synthetic Oil Plant, Louisiana, Mo., March 8, 1950:
"Fischer-Tropsch Commercial Liquid Synthetic Fuel Plant - 10,000-barrels-per-day Estimate."

Methods Used in Preparation of Estimates of Daily Operating Costs for Hydrogenation Unit Plants in Kentucky as of March 31, 1950

Direct Materials:

Coal, from section of report entitled "Coal"; for example, 3,569 tons at $5.11 per ton in General Area No. 1, Johnson-Magoffin

Catalysts and chemicals as estimated by Bureau of Mines.

Direct Labor:

Wage earners, daily cost estimated by Bureau of Mines multiplied by ratio of $1.64 over $1.70. $1.64 represents estimated average straight-time hourly wage rate payable to wage earners (exclusive of supervisors) in synthetic liquid fuels plants in Kentucky as developed in the section of this report entitled "Labor". $1.70 represents the weighted average hourly wage rate of wage earners (exclusive of supervisors) as used in the Bureau of Mines estimate of operating costs in a typical coal hydrogenation unit plant.

Supervisors, 15 percent of daily cost of wage earners

Plant Maintenance Labor and Supervision:

Wage earners, daily cost estimated by Bureau of Mines multiplied by ratio of $1.64 over $1.70, as developed under direct labor.

Supervisors, 15 percent of daily cost of wage earners.

Plant Maintenance Materials:

Per year, 1 percent of plant construction cost.

Payroll Overhead:

12-1/2 percent of direct labor and supervision and maintenance labor and supervision.

Operating Supplies:

20 percent of maintenance labor, supervision, and materials.

Total Indirect Costs (general administrative, office overhead, and indirect operating costs):

50 percent of direct labor and supervision, plant maintenance labor, supervision, and materials, and operating supplies.

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Indirect Labor:

Daily cost estimated by Bureau of Mines multiplied by ratio of $1.64 over $1.70 as developed under direct labor.

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Methods Used in Preparation of Estimates of Daily Operating Costs for Hydrogenation Unit Plants in Kentucky as of March 31, 1950

Indirect Salaried Personnel:
As estimated by Bureau of Mines.

Other Indirect Costs:
Balance remaining after deducting from total indirect costs (as above) the sum of payments to indirect labor and indirect salaried personnel (also as above).

Local, County, and State Taxes:
Per year, 1 percent of depreciable investment (plant construction cost plus interest during construction).

Depreciation:
15-year, straight line; per year, 6-2/3 percent of depreciable investment.

Initial Capital Investment in Process Plant
by General Areas of Coal and Water Availability
10,000-barrel-per-day Coal Synthine Plants in Kentucky
(As of March 31, 1950)

Item	Eastern Kentucky General Areas of Coal and Water Availability								
	Johnson-Magoffin	Pike	Floyd-Magoffin	Knott-Breathitt	Perry-Breathitt	Leslie-Harlan	Northern Letcher	Harlan-Letcher	Bell
Plant Construction Cost (A)	$ 81,805	$ 81,805	$ 81,805	$ 81,805	$ 81,805	$ 81,805	$ 81,805	$ 81,805	$ 81,805
Interest during Construction (A)	2,455	2,455	2,455	2,455	2,455	2,455	2,455	2,455	2,455
Depreciable Investment (A)	$ 84,260	$ 84,260	$ 84,260	$ 84,260	$ 84,260	$ 84,260	$ 84,260	$ 84,260	$ 84,260
Operating Capital (A)	5,173	5,014	5,065	5,064	5,066	5,044	5,033	5,048	5,057
Total Capital Investment (A)	$ 89,433	$ 89,274	$ 89,325	$ 89,324	$ 89,326	$ 89,304	$ 89,293	$ 89,308	$ 89,317
1 Percent Return on above Investment:									
Per Annum	$894,330	$892,740	$893,250	$893,240	$893,260	$893,040	$892,930	$893,080	$893,170
Per Calendar Day	2,450	2,446	2,447	2,447	2,447	2,447	2,446	2,447	2,447
Per Barrel of Products	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245

Item	Western Kentucky General Areas of Coal and Water Availability						
	Daviess	Henderson	Union	Webster	Hopkins-Christian	Muhlenberg-McLean	Ohio
Plant Construction Cost (A)	$ 81,805	$ 81,805	$ 81,805	$ 81,805	$ 81,805	$ 81,805	$ 81,805
Interest during Construction (A)	2,455	2,455	2,455	2,455	2,455	2,455	2,455
Depreciable Investment (A)	$ 84,260	$ 84,260	$ 84,260	$ 84,260	$ 84,260	$ 84,260	$ 84,260
Operating Capital (A)	5,065	5,202	4,793	4,730	4,559	4,512	4,525
Total Capital Investment (A)	$ 89,325	$ 89,462	$ 89,053	$ 88,990	$ 88,819	$ 88,772	$ 88,785
1 Percent Return on above Investment:							
Per Annum	$893,250	$894,620	$890,530	$889,900	$888,190	$887,720	$887,850
Per Calendar Day	2,447	2,451	2,440	2,438	2,433	2,432	2,432
Per Barrel of Products	0 245	0.245	0.244	0.244	0.243	0.243	0.243

Note: (A) In thousands of dollars

Estimated Coal Synthine Unit Plant Construction Costs and Required Total Initial Investment Plant near Caseyville, Ky., using W. Kentucky Bituminous Coal
(Based on Preliminary Estimates by U.S. Bureau of Mines)

Subdivisions of Total Plant	10,000-barrel-per-day Plant Using Coal (As of March 1, 1950)	
Synthesis Gas Production Section:		
Coal Preparation	$ 2,995,000	
Gas Generation	8,330,000	
Gas Purification	3,780,000	
Oxygen Production and Compression	21,700,000	
Total Synthesis Gas Production Section		$36,805,000
Synthesis and Other Processing Section:		
Synthesis	$11,100,000	
Catalyst Preparation and Coolant Oil Clean-up	250,000	
Distillation and Gas Recovery	7,350,000	
Polymerization	875,000	
Catalytic Reforming and Cracking	1,365,000	
Waste Recovery and Disposal	1,000,000	
Total Synthesis and Other Processing		$21,940,000
General and Auxiliary Plants Section:		
Tankage	$ 2,100,000	
Power Plant	3,570,000	
Plant Utilities	9,660,000	
Plant Facilities	7,730,000	
Total General and Auxiliary Plants		$23,060,000
Total Plant Construction Cost		$81,805,000
Interest during Construction		2,455,000
Depreciable Investment		$84,260,000
Operating Capital		4,000,000
Total Investment entitled to Return		$88,260,000

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Estimation of Operating Capital
Coal Synthine Unit Plants in Kentucky
(As of March 31, 1950)

	Eastern Kentucky General Areas of Coal and Water Availability									Western Kentucky General Areas of Coal and Water Availability						
Costs per Calendar Day	Johnson-Magoffin	Pike	Floyd-Magoffin	Knott-Breathitt	Perry-Breathitt	Leslie-Harlan	Northern Letcher	Harlan-Letcher	Bell	Daviess	Henderson	Union	Webster	Hopkins-Christian	Muhlenberg McLean	Ohio
Coal:																
Mine Investment ($1,000's)	$ 10,050	$ 8,160	$ 8,560	$ 8,360	$ 8,525	$ 8,405	$ 8,230	$ 8,225	$ 9,163	$ 9,460	$ 9,441	$ 8,384	$ 7,982	$ 6,752	$ 6,711	$ 6,487
Daily Plant Consumption, Tons	4,588	4,471	4,691	4,582	4,670	4,605	4,510	4,506	4,565	5,839	5,748	5,105	5,083	5,285	5,194	5,469
Cost per Ton	$ 5.11	$ 4.76	$ 4.66	$ 4.66	$ 4.66	$ 4.66	$ 4.66	$ 4.76	$ 4.71	$ 3.79	$ 4.16	$ 3.65	$ 3.44	$ 2.81	$ 2.89	$ 2.79
Daily Cost excluding Return	$ 23,445	$ 21,282	$ 21,860	$ 21,352	$ 21,762	$ 21,459	$ 21,017	$ 21,449	$ 21,501	$ 22,130	$ 23,912	$ 18,633	$ 17,486	$ 14,851	$ 15,011	$ 15,259
Daily Return on Investment @ 4%	1,101	894	938	916	934	921	902	901	1,004	1,037	1,035	919	875	740	735	711
Daily Cost including Return	$ 24,546	$ 22,176	$ 22,798	$ 22,268	$ 22,696	$ 22,380	$ 21,919	$ 22,350	$ 22,505	$ 23,167	$ 24,947	$ 19,552	$ 18,361	$ 15,591	$ 15,746	$ 15,970
Water:																
Water Investment ($1,000's)	$ 891	$ 2,846	$ 3,170	$ 6,750	$ 3,957	$ 4,175	$ 5,754	$ 4,619	$ 4,246	$ 495	$ 721	$ 628	$ 3,231	$ 6,766	$ 1,209	$ 898
Annual Costs	$ 76,050	$ 136,070	$ 153,710	$ 288,860	$ 181,260	$ 185,480	$ 301,130	$ 214,810	$ 216,870	$ 62,980	$ 75,720	$ 66,690	$ 156,480	$ 289,360	$ 93,030	$ 79,530
Daily Cost excluding Return	$ 208	$ 373	$ 421	$ 791	$ 497	$ 508	$ 825	$ 589	$ 594	$ 173	$ 207	$ 183	$ 429	$ 793	$ 255	$ 218
Daily Return on Investment @ 5%	122	390	434	925	542	572	788	633	582	68	99	86	443	927	166	123
Daily Cost including Return	$ 330	$ 763	$ 855	$ 1,716	$ 1,039	$ 1,080	$ 1,613	$ 1,222	$ 1,176	$ 241	$ 306	$ 269	$ 872	$ 1,720	$ 421	$ 341
Catalysts	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Total Raw Material	$ 26,076	$ 24,139	$ 24,853	$ 25,184	$ 24,935	$ 24,660	$ 24,732	$ 24,772	$ 24,881	$ 24,608	$ 26,453	$ 21,021	$ 20,433	$ 18,511	$ 17,367	$ 17,511
Total Direct and Indirect Costs excluding Raw Material (A)	$ 17,792	$ 17,792	$ 17,792	$ 17,792	$ 17,792	$ 17,792	$ 17,792	$ 17,792	$ 17,792	$ 17,792	$ 17,792	$ 17,792	$ 17,792	$ 17,792	$ 17,792	$ 17,792
Operating Capital																
Cost of 30 days' Coal Supply at Rated Capacity Operation	$ 736,380	$ 665,280	$ 683,940	$ 668,040	$ 680,880	$ 671,400	$ 657,570	$ 670,500	$ 675,150	$ 695,010	$ 748,410	$ 586,560	$ 550,830	$ 467,730	$ 472,380	$ 479,100
Cost of Direct Materials and Water for one-half year operation at average 25 percent capacity	$1,189,718	$1,101,342	$1,133,918	$1,149,020	$1,137,659	$1,125,113	$1,128,398	$1,130,223	$1,135,196	$1,122,740	$1,206,918	$ 959,083	$ 932,256	$ 844,564	$ 792,369	$ 798,939
All other operating costs for one-half year (except fixed costs)	3,247,040	3,247,040	3,247,040	3,247,040	3,247,040	3,247,040	3,247,040	3,247,040	3,247,040	3,247,040	3,247,040	3,247,040	3,247,040	3,247,040	3,247,040	3,247,040
Total	$5,173,138	$5,013,662	$5,064,898	$5,064,100	$5,065,579	$5,043,553	$5,033,008	$5,047,763	$5,057,386	$5,064,790	$5,202,368	$4,792,683	$4,730,126	$4,559,334	$4,511,789	$4,525,079

Note: (A) From Contractors Estimate of Processing Costs -

Total Direct and Indirect Costs	$42,645
Less Direct Materials (Coal and Catalysts)	24,645
Less Make-up Water	208
Balance, Direct and Indirect Costs, excluding raw material	$17,792

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Methods Used in Preparation of Estimates of Daily Production Costs for a Typical Coal Synthine Unit Plant in Continental United States

(Based on Preliminary Data from U.S. Bureau of Mines)

Direct Labor:

Direct Labor (75 men per shift), as estimated in detail by individual functions (A)

Supervisory personnel 10 percent of direct labor personnel (A)

Total labor personnel 4.5 times (average) personnel per shift (A)

Direct labor wage rate (at Caseyville, Ky., first quarter 1950) - average, all classifications, $1.75 per hour (A)

Cost of supervision 15 percent of labor cost (A)

Plant Maintenance Labor and Supervision:

Total annual cost of maintenance labor and supervision 2 percent of plant cost, erected (cost as of March 1, 1950) (A)

Maintenance labor personnel 420 men, approximately 5/4 of direct labor personnel (A)

Supervisory personnel 10 percent of maintenance labor personnel (A)

Total maintenance labor personnel 4.5 times (average) personnel per shift

Total maintenance labor cost 100/115 of total daily cost (1/365 of annual cost) of maintenance labor and supervision (as above)

Cost of supervision 15 percent of labor cost (A)

Plant Maintenance Materials:

Per year, 1 percent of plant cost erected (A)

Payroll Overhead:

12-1/2 percent of direct labor and supervision and maintenance labor and supervision (A)

Methods Used in Preparation of Estimates
of Daily Production Costs
for a Typical Coal Synthine Unit Plant
in Continental United States
(Based on Preliminary Data from U.S. Bureau of Mines)

Operating Supplies:
20 percent of maintenance labor, supervision, and materials (A)

Total Indirect Costs (general administrative, office overhead, and indirect operating costs):
50 percent of direct labor and supervision, plant maintenance labor, supervision, and materials, and operating supplies (A)

Indirect Labor:
Total indirect labor personnel (wage earners) 12 percent of total wage earners (including indirect labor) (A)

Indirect labor wage rate (at Caseyville, Ky., first quarter 1950) - average, all classifications, $1.64 per hour (A)

Total daily payments to indirect labor, 1/365 of annual cost at 2,080 hours per year, per man (B)

Cost of supervision, none (supervision provided by salaried personnel)

Indirect Salaried Personnel:
Average salary rate $3,600 per year (A)

Total indirect salaried personnel, number of employes at $3,600 per year payable from a sum equal to 50 percent of total indirect costs less payments to indirect labor (A)

Other Indirect Costs:
Balance remaining after deducting from total indirect costs (as above) the sum of payments to indirect labor and indirect salaried personnel (also as above)

Local County, and State Taxes and Insurance:
Per year 1 percent (A) of depreciable investment (plant cost erected plus interest during construction)

Depreciation:
15-year straight line; per year 6-2/3 percent (A) of depreciable investment

Methods Used in Preparation of Estimates
of Daily Production Costs
for a Typical Coal Synthine Unit Plant
in Continental United States
(Based on Preliminary Data from U.S. Bureau of Mines)

References:
(A) Memorandum, U.S. Bureau of Mines Synthetic Oil Plant, Louisiana, Mo., March 8, 1950:
"Fischer-Tropsch Commercial Liquid Synthetic Fuel Plant - 10,000 Barrels per Day Estimate".

(B) R.I. 4564, U.S. Bureau of Mines, August 1949:
"Estimated Plant and Operating Costs for Producing Gasoline by Coal Hydrogenation".

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Methods Used in Preparation of Estimates of Daily Operating Costs for Coal Synthine Unit Plants in Kentucky as of March 31, 1950

Direct Materials:

Coal, from section of report entitled "Coal"; for example, 4,588 tons at $5.11 per ton in General Area No. 1, Johnson-Magoffin.

Catalysts and Chemicals, same cost as estimated by Bureau of Mines.

Direct Labor:

Wage earners, daily cost estimated by Bureau of Mines multiplied by ratio of $1.64 over $1.73. $1.64 represents estimated average straight-time hourly wage rate payable to wage earners (exclusive of supervisors) in synthetic liquid fuels plants in Kentucky as developed in the section of this report entitled "Labor". $1.73 represents the weighted average hourly wage rate of wage earners (exclusive of supervisors) as used in the Bureau of Mines estimate of operating costs in a typical coal synthine unit plant.

Supervisors, 15 percent of daily cost of wage earners.

Plant Maintenance Labor and Supervision:

Wage earners, daily cost estimated by Bureau of Mines multiplied by ratio of $1.64 over $1.73, as developed under direct labor.

Supervisors, 15 percent of daily cost of wage earners.

Plant Maintenance Materials:

Per Year, 1 percent of plant construction cost.

Payroll Overhead:

12-1/2 percent of direct labor and supervision and maintenance labor and supervision.

Operating Supplies:

20 percent of maintenance labor, supervision, and materials.

Total Indirect Costs (general administrative, office overhead, and indirect operating costs):

50 percent of direct labor and supervision, plant maintenance labor, supervision, and materials, and operating supplies.

Indirect Labor:

Daily cost estimated by Bureau of Mines multiplied by ratio of $1.64 over $1.73 as developed under direct labor.

Methods Used in Preparation of Estimates
of Daily Operating Costs
for Coal Synthine Unit Plants
in Kentucky as of March 31, 1950

Indirect Salaried Personnel:
As estimated by Bureau of Mines.

Other Indirect Costs:
Balance remaining after deducting from total indirect costs (as above) the sum of payments to indirect labor and indirect salaried personnel (also as above).

Local, County, and State Taxes:
Per year, 1 percent of depreciable investment (plant construction cost plus interest during construction).

Depreciation:
15-year, straight-line; per year 6-2/3 percent of depreciable investment.

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Comparison of Suitable General Areas for One 10,000-barrel-per-day Hydrogenation Plant in Each General Area in Kentucky

(As of March 31, 1950)

	Eastern Kentucky Suitable General Areas									Western Kentucky Suitable General Areas						
	Johnson-Magoffin	Pike	Floyd-Magoffin	Knott-Breathitt	Perry-Breathitt	Leslie-Harlan	Northern Letcher	Harlan-Letcher	Bell	Daviess	Henderson	Union	Webster	Hopkins-Christian	Muhlenberg-McLean	Ohio
Capital Investment ($1,000's)																
Raw Material (Coal)	$ 7,818	$ 6,345	$ 6,660	$ 6,505	$ 6,630	$ 6,535	$ 6,400	$ 6,395	$ 7,128	$ 7,327	$ 7,344	$ 6,521	$ 6,125	$ 5,254	$ 5,163	$ 5,044
Water, Process	891	2,846	3,170	6,750	3,957	4,175	5,754	4,619	4,246	495	721	628	3,231	6,766	1,209	898
Other Processing (A)	99,473	99,353	99,394	99,402	99,396	99,380	99,377	99,384	99,391	99,377	99,495	99,176	99,118	99,010	98,934	98,969
Access Transportation	75	2,300	180	1,128	125	2,576	-	-	-	904	14	8	9	208	6	83
Product Transportation	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)
Waste Disposal (Solids)	322	370	406	388	388	365	362	368	378	518	534	474	466	461	467	474
Subtotal	$108,579	$111,214	$109,810	$114,173	$110,496	$113,031	$111,893	$110,766	$111,143	$108,621	$108,108	$106,807	$108,949	$111,699	$105,779	$105,468
Housing	4,388	4,388	4,388	4,388	4,388	4,388	4,388	4,388	4,388	6,201	6,201	6,201	6,201	6,201	6,201	6,201
Total (B)	$112,967	$115,602	$114,198	$118,561	$114,884	$117,419	$116,281	$115,154	$115,531	$114,822	$114,309	$113,008	$115,150	$117,900	$111,980	$111,669
Operating Costs, Exclusive of Return on Investment, in Dollars per Barrel of Products (C)																
Raw Material (Coal)	$ 1.824	$ 1.656	$ 1.700	$ 1.661	$ 1.692	$ 1.669	$ 1.635	$ 1.668	$ 1.673	$ 1.708	$ 1.860	$ 1.450	$ 1.341	$ 1.155	$ 1.135	$ 1.186
Water, Process	.021	.037	.042	.079	.050	.051	.082	.059	.059	.017	.021	.018	.043	.079	.026	.022
Other Processing (D)	4.001	4.001	4.001	4.001	4.001	4.001	4.001	4.001	4.001	4.001	4.001	4.001	4.001	4.001	4.001	4.001
Access Transportation	.001	.031	.003	.015	.002	.035	-	-	-	.012	(H)	(H)	(H)	.003	(H)	.001
Product Transportation	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)
Waste Disposal (Solids)	.015	.019	.021	.020	.020	.018	.018	.019	.019	.032	.033	.028	.027	.027	.027	.028
Subtotal	$5.862	$5.744	$5.767	$5.776	$5.765	$5.774	$5.736	$5.747	$5.752	$5.770	$5.915	$5.497	$5.412	$5.265	$5.189	$5.238
Housing	(G)	(G)	(G)	(G)	(G)	(G)	(G)	(G)	(G)	(G)	(G)	(G)	(G)	(G)	(G)	(G)
Total (E) - per barrel	$5.862	$5.744	$5.767	$5.776	$5.765	$5.774	$5.736	$5.747	$5.752	$5.770	$5.915	$5.497	$5.412	$5.265	$5.189	$5.238
- per gallon	13.96¢	13.68¢	13.73¢	13.75¢	13.73¢	13.75¢	13.66¢	13.68¢	13.70¢	13.74¢	14.08¢	13.09¢	12.89¢	12.54¢	12.35¢	12.47¢
Dollars per Barrel Required for Each Percent of Gross Return on Capital Investment (C)																
Raw Material (Coal)	$0.021	$0.018	$0.018	$0.018	$0.018	$0.018	$0.018	$0.017	$0.020	$0.020	$0.020	$0.018	$0.017	$0.014	$0.014	$0.014
Water, Process	.003	.008	.009	.019	.011	.012	.016	.013	.012	.001	.002	.002	.009	.019	.004	.003
Other Processing	.272	.272	.272	.272	.273	.272	.272	.272	.272	.272	.273	.272	.271	.271	.271	.271
Access Transportation	(H)	.006	.001	.003	(H)	.007	-	-	-	.003	(H)	(H)	(H)	.001	(H)	(H)
Product Transportation	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)
Waste Disposal (Solids)	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
Subtotal	$0.297	$0.305	$0.301	$0.313	$0.303	$0.310	$0.307	$0.303	$0.305	$0.297	$0.296	$0.293	$0.298	$0.306	$0.290	$0.289
Housing	.012	.012	.012	.012	.012	.012	.012	.012	.012	.017	.017	.017	.017	.017	.017	.017
Total per Barrel	$0.309	$0.317	$0.313	$0.325	$0.315	$0.322	$0.319	$0.315	$0.317	$0.314	$0.313	$0.310	$0.315	$0.323	$0.307	$0.306

Notes:
(A) Includes plant construction cost, interest during construction, and operating capital.
(B) Exclusive of capital invested in commercial facilities, one-half of residential housing assumed sold to employes and domestic water supply.
(C) Individual costs sometimes adjusted in last digit to agree with total.
(D) See text of report for details of items included.
(E) Exclusive of domestic water supply and housing, assumed offset by a portion of water rents and residential housing rents.
(F) Product transportation, i.e., the cost of moving products to distant markets has not been considered for those General Areas with adjacent local marketing territory capable of absorbing the output of a unit plant.
(G) Operating costs offset by a portion of rentals paid by occupants of dwelling units.
(H) Less than 0.5 mills.

Comparison of Suitable General Areas For One 10,000-barrel-per-day Coal Synthine Plant in Each General Area in Kentucky (As of March 31, 1950)

Eastern Kentucky Suitable General Areas

	Johnson-Magoffin	Pike	Floyd-Magoffin	Knott-Breathitt	Perry-Breathitt	Leslie-Harlan	Northern Letcher	Harlan-Letcher	Bell
Capital Investment ($1,000's)									
Raw Material (Coal)	$ 10,050	$ 8,160	$ 8,560	$ 8,360	$ 8,525	$ 8,405	$ 8,230	$ 8,225	$ 9,163
Water, Process	891	2,846	3,170	6,750	3,957	4,175	5,754	4,619	4,246
Other Processing (A)	89,433	89,274	89,325	89,324	89,326	89,304	89,293	89,308	89,317
Access Transportation	75	2,300	160	1,128	125	2,576	-	-	-
Product Transportation	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)
Waste Disposal (Solids)	493	527	594	551	567	536	519	525	553
Subtotal	$100,942	$103,107	$101,829	$106,113	$102,500	$104,996	$103,796	$102,677	$103,279
Housing	4,165	4,165	4,165	4,165	4,165	4,165	4,165	4,165	4,165
Total (B)	$105,107	$107,272	$105,994	$110,278	$106,665	$109,161	$107,961	$106,842	$107,444
Operating Costs, Exclusive of Return on Investment, in Dollars per Barrel of Products (C)									
Raw Material (Coal)	$2.344	$2.128	$2.186	$2.135	$2.176	$2.146	$2.102	$2.145	$2.150
Water, Process	.021	.037	.042	.079	.050	.051	.082	.059	.059
Other Processing (D)	3.669	3.669	3.669	3.669	3.669	3.669	3.669	3.669	3.669
Access Transportation	.001	.031	.003	.015	.002	.035	-	-	-
Product Transportation	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)
Waste Disposal (Solids)	.030	.033	.038	.035	.036	.033	.032	.033	.035
Subtotal	$6.065	$5.898	$5.938	$5.933	$5.933	$5.934	$5.885	$5.906	$5.913
Housing	(G)	(G)	(G)	(G)	(G)	(G)	(G)	(G)	(G)
Total (E) - per barrel	$6.065	$5.898	$5.938	$5.933	$5.933	$5.934	$5.885	$5.906	$5.913
- per gallon	14.44¢	14.04¢	14.14¢	14.13¢	14.13¢	14.13¢	14.01¢	14.06¢	14.08¢
Dollars per Barrel Required for Each Percent of Gross Return on Capital Investment (C)									
Raw Material (Coal)	$0.028	$0.022	$0.023	$0.023	$0.023	$0.023	$0.023	$0.023	$0.025
Water, Process	.003	.008	.008	.018	.011	.012	.016	.013	.011
Other Processing	.245	.245	.245	.245	.245	.245	.245	.245	.245
Access Transportation	(H)	.006	.001	.003	(H)	.007	-	-	-
Product Transportation	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)
Waste Disposal (Solids)	.001	.002	.002	.002	.002	.001	.001	.001	.002
Subtotal	$0.277	$0.283	$0.279	$0.291	$0.281	$0.288	$0.285	$0.282	$0.283
Housing	.011	.011	.011	.011	.011	.011	.011	.011	.011
Total per Barrel	$0.288	$0.294	$0.290	$0.302	$0.292	$0.299	$0.296	$0.293	$0.294

Western Kentucky Suitable General Areas

	Daviess	Henderson	Union	Webster	Hopkins-Christian	Muhlenberg-McLean	Ohio
Capital Investment ($1,000's)							
Raw Material (Coal)	$ 9,460	$ 9,441	$ 8,384	$ 7,982	$ 6,752	$ 6,711	$ 6,487
Water, Process	495	721	628	3,231	6,766	1,209	898
Other Processing (A)	89,325	89,462	89,053	88,990	88,819	88,772	88,785
Access Transportation	904	14	8	9	208	6	83
Product Transportation	(F)	(F)	(F)	(F)	(F)	(F)	(F)
Waste Disposal (Solids)	932	980	777	749	744	750	787
Subtotal	$101,116	$100,618	$ 98,850	$100,961	$103,289	$ 97,448	$ 97,040
Housing	6,569	6,569	6,569	6,569	6,569	6,569	6,569
Total (B)	$107,685	$107,187	$105,419	$107,530	$109,858	$104,017	$103,609
Operating Costs, Exclusive of Return on Investment, in Dollars per Barrel of Products (C)							
Raw Material (Coal)	$2.213	$2.391	$1.863	$1.749	$1.485	$1.501	$1.526
Water, Process	.018	.021	.018	.043	.079	.026	.022
Other Processing (D)	3.669	3.669	3.669	3.669	3.669	3.669	3.669
Access Transportation	.012	(H)	(H)	(H)	.003	-	.001
Product Transportation	(F)	(F)	(F)	(F)	(F)	(F)	(F)
Waste Disposal (Solids)	.056	.058	.049	.047	.047	.047	.049
Subtotal	$5.968	$6.139	$5.599	$5.508	$5.283	$5.243	$5.267
Housing	(G)	(G)	(G)	(G)	(G)	(G)	(G)
Total (E) - per barrel	$5.968	$6.139	$5.599	$5.508	$5.283	$5.243	$5.267
- per gallon	14.21¢	14.62¢	13.33¢	13.11¢	12.58¢	12.48¢	12.54¢
Dollars per Barrel Required for Each Percent of Gross Return on Capital Investment (C)							
Raw Material (Coal)	$0.026	$0.026	$0.023	$0.022	$0.018	$0.018	$0.018
Water, Process	.001	.002	.002	.009	.019	.004	.003
Other Processing	.245	.245	.244	.244	.243	.243	.243
Access Transportation	.003	(H)	(H)	(H)	.001	(H)	(H)
Product Transportation	(F)	(F)	(F)	(F)	(F)	(F)	(F)
Waste Disposal (Solids)	.002	.003	.002	.002	.002	.002	.002
Subtotal	$0.277	$0.276	$0.271	$0.277	$0.283	$0.267	$0.266
Housing	.018	.018	.018	.018	.018	.018	.018
Total per Barrel	$0.295	$0.294	$0.289	$0.295	$0.301	$0.285	$0.284

Notes:
(A) Includes plant construction cost, interest during construction, and operating capital.
(B) Exclusive of capital invested in commercial facilities, one-half of residential housing assumed sold to employes and domestic water supply.
(C) Individual costs sometimes adjusted in last digit to agree with total.
(D) See text of report for details of items included.
(E) Exclusive of domestic water supply and housing, assumed offset by a portion of water rents and residential housing rents.
(F) Product transportation, i.e., the cost of moving products to distant markets has not been considered for those General Areas with adjacent local marketing territory capable of absorbing the output of a unit plant.
(G) Operating costs offset by a portion of rentals paid by occupants of dwelling units.
(H) Less than 0.5 mills.

Exhibit No. 87

Costs Reflecting Use of Higher-cost Underground-mined Coal
for Ultimate Hydrogenation Unit Plants in Suitable General Areas in Western Kentucky (A)
(As of March 31, 1950)

	Suitable General Areas				
	Daviess	Webster	Hopkins-Christian	Muhlenberg-McLean	Ohio
Initial Capital Investment ($1,000's)					
Total Capital Investment in Initial Plant	$114,822	$115,150	$117,900	$111,980	$111,669
Coal Mine Investment in Ultimate Plant	7,457	6,489	5,968	5,904	6,872
Coal Mine Investment in Initial Plant	7,327	6,125	5,254	5,163	5,044
Additional Investment in Ultimate Plant	130	364	714	741	1,828
Additional Operating Capital (Processing)	46	80	310	313	380
Total Capital Investment in Ultimate Plant	$114,998	$115,594	$118,924	$113,034	$113,877
Operating Costs, Exclusive of Return on Investment, in Dollars per Barrel of Products					
Total Operating Cost in Initial Plant	$5.770	$5.412	$5.265	$5.189	$5.238
Cost of Coal in Ultimate Plant	$1.766	$1.442	$1.557	$1.540	$1.669
Cost of Coal in First Plant	1.708	1.341	1.155	1.135	1.186
Additional Operating Cost in Ultimate Plant	$0.058	$0.101	$0.402	$0.405	$0.483
Total Operating Cost in Ultimate Plant -					
Per Barrel	$5.828	$5.513	$5.667	$5.594	$5.721
Per Gallon (cents)	13.88¢	13.13¢	13.49¢	13.32¢	13.62¢
Dollars per Barrel Required for Each Percent of Gross Return on Initial Capital Investment					
Total for Initial Plant	$0.315	$0.315	$0.323	$0.307	$0.306
Total for Ultimate Plant	$0.315	$0.317	$0.326	$0.310	$0.312

Note: (A) For those Areas having some strip coal initially available.

Exhibit No. 88

Costs Reflecting Use of Higher-cost Underground-mined Coal
for Ultimate Coal Synthine Unit Plants in Suitable General Areas in Western Kentucky (A)
(As of March 31, 1950)

	Suitable General Areas			
	Webster	Hopkins-Christian	Muhlenberg-McLean	Ohio
Initial Capital Investment ($1,000's)				
Total Capital Investment in Initial Plant	$107,530	$109,858	$104,017	$103,609
Coal Mine Investment in Ultimate Plant	8,348	7,672	7,588	8,838
Coal Mine Investment in Initial Plant	7,982	6,752	6,711	6,487
Additional Investment in Ultimate Plant	366	920	877	2,351
Additional Operating Capital (Processing)	83	398	370	489
Total Capital Investment in Ultimate Plant	$107,979	$111,176	$105,264	$106,449
Operating Costs, Exclusive of Return on Investment, in Dollars per Barrel of Products				
Total Operating Cost in Initial Plant	$5.508	$5.283	$5.243	$5.267
Cost of Coal in Ultimate Plant	$1.855	$2.002	$1.980	$2.147
Cost of Coal in First Plant	1.749	1.485	1.501	1.526
Additional Operating Cost in Ultimate Plant	$0.106	$0.517	$0.479	$0.621
Total Operating Cost in Ultimate Plant -				
Per Barrel	$5.614	$5.800	$5.722	$5.888
Per Gallon (cents)	13.37¢	13.81¢	13.62¢	14.02¢
Dollars per Barrel Required for Each Percent of Gross Return on initial Capital Investment				
Total for Initial Plant	$0.295	$0.301	$0.285	$0.284
Total for Ultimate Plant	$0.296	$0.305	$0.288	$0.292

Note: (A) For those Areas having some strip coal initially available.

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APPENDIX A

REASONS FOR ELIMINATION OF
23 COUNTIES NOT MEETING
SURVEY REQUIREMENTS
AS TO COAL RESERVES

APPENDIX A

REASONS FOR ELIMINATION OF 23 COUNTIES NOT MEETING SURVEY REQUIREMENTS AS TO COAL RESERVES

Counties eliminated from further consideration either because of isolated and insufficient reserves, because of the presence of thin or irregular bids, or both, or because of lack of information concerning the reserves are tabulated below as they occur in eastern and western Kentucky:

Counties Eliminated

Eastern Kentucky:

Boyd	Lawrel	Owsley
Carter	Lawrence	Pulaski
Clinton	Lee	Rockcastle
Elliott	McCreary	Wayne
Greenup	Menifee	Whitley
Jackson	Morgan	Wolfe

Western Kentucky:
Crittenden
Edmonson
Grayson
Hancock
Warren

The details of each of the counties listed with the reasons why each was eliminated for further consideration are contained in this Appendix.

Eastern Kentucky

Boyd County. (See Exhibit No. 5 for references below) Boyd County is located near the northern corner of the Eastern Kentucky field, with the northern half of its eastern boundary formed by the Ohio River fronting southern Lawrence County of Ohio.

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(References: 8, 11, 18, 39, 40, 62, 63)

The southern half of the eastern county boundary comprises a portion of the Kentucky-West Virginia State line which follows the Big Sandy River. The southern margin of Boyd County is close to the axis of the principal synclinal basin forming this portion of the Eastern Kentucky field. The coal beds over most of the county dip toward the south and southeast. The northern portion of the county contains minor folds of varying degree and direction which locally modify the regional directions of dip.

Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 431,000 tons were produced from Boyd County during that year, with 255,000 tons having been obtained from three stripping operations. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates that approximately 183,000 tons were produced by stripping from 2 railroad mines in that year, with an additional 348,000 tons being produced from 21 truck mines. The coal beds from which such productions were obtained are designated as the No. 6 and No. 7 beds.

The coal horizons in the northern portion of the Eastern Kentucky field in and near Boyd County are numerically designated, in descending order, from No. 12 to No. 1. The principal producing beds in this vertical series are probably similar to beds in Ohio ranging from the Upper Freeport No. 7 to the Sharon No. 1 coal horizons in similar descending order. The numbers applied to the Kentucky beds, however, are not the same as the numbers also used in designating the named Ohio beds. The available information on coal bed occurrences in Boyd County is insufficient to permit estimates of reserves. For the most part it is too scattered and too unrepresentative of regional distribution to establish the occurrence and continuity of the several coal horizons. Brief descriptions of the more prominent beds as indicated by preliminary-type investigations are herewith presented.

<u>The No. 7 bed</u>, also designated as the Coalton bed, has been widely mined in northern Boyd County and appears to represent the coal of greatest productivity in this area. Indications are that the bed ranges up to a maximum thickness of 6 ft 3 in. and that there are rapid changes in thickness and composition of bed within relatively short distances from the areas of greater thickness.

<u>The No. 6 bed</u> has likewise been widely mined in the northern portion of Boyd County where it approximates 2 ft 0 in. in thickness with irregular areas of slightly increased thickening.

<u>The No. 5 bed</u> occurs at a few scattered locations in northern Boyd County, where it attains local thicknesses of 3 ft 4 in. The upper portion of such occurrences contain numerous thin partings.

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The coal horizons above the No. 7 bed are mentioned in the available reports in too insufficient detail or scope to permit descriptions. The numbered coal horizons below the No. 5 bed are largely located in areas adjacent to but not within Boyd County in Greenup and Carter Counties to the west and northwest.

Carter County. (See Exhibit No. 5 for references below.) Carter County is located in the northern portion of the Eastern Kentucky field on the northwestern limb of the principal eastern Kentucky syncline. The northwesternmost boundary of the coal-bearing formations of eastern Kentucky closely skirts the northwestern boundary of Carter County. In this regional position, the coal beds of Carter County prevailingly dip toward the southeast, being modified in direction and rate of dip only locally in a few areas of minor cross-folding.

According to Bureau of Mines data on bituminous coal production in 1948 approximately 437,000 tons were mined in Carter County during that year, all of which was obtained from underground operations. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates no production from railroad mines, with approximately 502,000 tons being produced from 15 truck mines. This production is reported to have been obtained from the No. 7 and the Millers Creek beds.

The coal beds of the area in the northern portion of the Eastern Kentucky field in and around Carter County are numerically designated, in descending order, from No. 12 to No. 1. The principal coals within this vertical series are loosely correlated with beds in Ohio, ranging from the Upper Freeport No. 7 to the Sharon No. 1, with the Kentucky numbers, however, having no relation to the numbers also applied to the designations of the Ohio coals.

The No. 7 bed of northern Boyd County extends into eastern Carter County where it appears to represent the most productive coal of the several coal horizons. As reported at widely scattered localities, this bed ranges up to 4 ft 1 in. in thickness within Carter County.

The No. 6 coal appears to be highly erratic in occurrence and thickness in the Carter County portion of the area underlain by this bed.

The No. 5 bed has been locally developed in eastern Carter County, where it is also designated as the Pennington or Cooksie coal. The information available is insufficient to permit descriptions of the regional occurrence of this bed. The underlying No. 4 bed appears to be absent in Carter County.

Ky (References: 8, 11, 18, 39, 40, 62, 63)

The No. 3 bed occurs at scattered locations across central Carter County where it appears to consist of cannel coal approximating 3 ft 0 in. in thickness. The No. 3 bed appears to thicken in Lawrence County, southeast of Carter County to as much as 6 ft 0 in. in the southern part of its area of occurrence, where it is tentatively correlated with the Hazard bed of the main eastern Kentucky series.

The No. 2 bed is reported to attain a thickness of 2 ft 4 in. at one location in central Carter County.

The No. 1 bed considered as the possible equivalent of the basal Sharon bed of Ohio, occurs largely in Greenup County north of Carter County, but has been reported at a few locations in central and southern Carter County in thicknesses approximating 3 ft 0 in.

Clinton County. (See Exhibit No. 5 for references A below.) Located at the extreme southwestern corner of the Eastern Kentucky field, the southern boundary of Clinton County adjoins northwestern Pickett County of Tennessee. Only a relatively small area is underlain by coal-bearing strata in the eastern portion of the county. The remaining portions of the county are underlain by bedrock strata which are geologically older than the coal measures. The coal beds and their associated strata in eastern Clinton County dip gently toward the southeast.

Bureau of Mines data on bituminous coal production in 1948 report that approximately 4,000 tons were produced in Clinton County during that year, all of which was obtained from underground operations. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates that there was no production from railroad mines in Clinton County during that year although approximately 81,000 tons were produced from five truck mines. This production is indicated as being obtained from two coal beds which are designated as the Stearns No. 1 and No. 3 beds. There is insufficient available information to describe coal occurrences in Clinton County.

Elliott County. (See Exhibit No. 5 for references B below.) Elliott County is located in the northern portion of the Eastern Kentucky field along the northwestern flank of the principal eastern Kentucky syncline. The coal beds and their associated strata generally dip at low rates toward the southeast, although this regional dip is somewhat modified in direction along lines of local folding. An east-west fault extends across the approximate center of the county with displacements ranging up to approximately 200 feet.

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(References A: 12, 39, 40, 62, 63)
(References B: 8, 11, 18, 39, 40, 62, 63)

Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 61,000 tons were produced in Elliott County during that year, of which 1,600 tons were produced in one stripping operation. According to the annual report of the Kentucky Department of Mines and Minerals in 1948, there was no production from railroad mines in Elliott County during that year although approximately 60,000 tons were produced from 13 truck mines. This production is indicated to have been obtained largely from the No. 7 coal with minor amounts being obtained from a bed designated only as a "splint" coal. The reported locations of truck mines indicate that such production is limited to the southern portion of the county.

The available information is insufficient to show whether the No. 7 bed indicated as the principal producing coal in Elliott County is the same as the No. 7 bed of Carter, Boyd and Greenup Counties to the north. It is likewise too insufficient to permit estimates or descriptions of reserves.

Greenup County. (See Exhibit No. 5 for references below.) Greenup County is located at the northern corner of the Eastern Kentucky field with the northern line of Greenup County as formed by the Ohio River being opposite portions of Lawrence and Scioto Counties of southern Ohio. The regional dip of the coal beds is toward the southeast although local modifications in direction and amount of dip exist along a few local folds.

As shown by Bureau of Mines data on bituminous coal production in 1948, approximately 88,000 tons were produced in Greenup County during that year, all of which was obtained from underground operations. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates that no production was obtained from railroad mines in Greenup County during that year although approximately 94,000 tons were obtained from 20 truck mines. This production is reported to have been obtained from beds variously designated as the Clod, No. 6, and No. 7 beds.

The coal horizons in the northern portion of the Eastern Kentucky field are designated by numbers in descending order from No. 12 to No. 1. It is considered that the principal coals within this vertical series are correlated with coals ranging in descending order from the Upper Freeport No. 7 to the Sharon No. 1 coals of Ohio. The numbered designations in Kentucky, however, do not conform with the numbers which are also used in designating the named coals of Ohio.

(References: 8, 11, 18, 39, 40, 62, 63)

Coals No. 8 to No. 12 inclusive, appear to outcrop only in areas south of Greenup County.

The No. 7 bed outcrops along the southeastern line of Greenup County and has been mined by a number of local operations in northern Boyd and eastern Carter Counties. This bed, also designated as the Coalton bed, ranges from but a few inches in thickness to as much as 6 ft 3 in. within its area of principal occurrence. The available information is too insufficient to permit estimates of reserves in Greenup County and suggests that the area of occurrence of this bed is too limited to warrant further consideration.

The No. 6 bed is more erratic in occurrence in Greenup County than in Boyd County to the southeast but has furnished some coal for local operations. The information available is insufficient to permit estimates of reserves.

The No. 5 and No. 4 beds occur largely as horizon markers in the northern part of the Eastern Kentucky field, with local thickenings appearing at scattered locations in Boyd, Carter, and Lawrence Counties.

The No. 3 bed is relatively persistent in occurrence in Greenup County but rarely exceeds 2 ft 0 in. in thickness.

The No. 2 bed is known to be of minable thickness only in southern Carter County, although it occurs as a horizon marker in southeastern Greenup County.

The No. 1 bed has been worked at a number of local operations in central and southeastern Greenup County where the thicknesses range from 1 ft 0 in. to a maximum of perhaps 2 ft 6 in. The available information is too limited to permit estimates of reserves and suggests that the coal is generally too thin to warrant further consideration.

Jackson County. (See Exhibit No. 5 for references below.) Located in the western portion of the Eastern Kentucky field, Jackson County occurs near the center of the northwestern flank of the Eastern Kentucky field syncline. The northwestern margin of the coal measures of eastern Kentucky crosses the northwestern corner of Jackson County in a highly irregular pattern along the drainage channels. In this regional position, the coal beds of Jackson County generally dip toward the southeast although the directions and rates of dip are locally modified by the presence of small, irregular cross-folds. Ky

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(References: 3, 4, 12, 39, 40, 62, 63)

Bureau of Mines data on bituminous coal production report that approximately 123,000 tons were produced in Jackson County during 1948, of which 5,500 tons were produced from two stripping operations. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates that there was no production from railroad mines in Jackson County during that year although approximately 130,000 tons were produced in 21 truck mines. The coal beds from which such production was obtained are variously designated as the Beattyville, Bond, Cannel, Horse Creek, Jackson and Middle beds. The correlations of these beds with the principal coals of eastern Kentucky are highly uncertain. The available information is too insufficient to permit descriptions or estimates of reserves for the coal occurrences of Jackson County.

Laurel County. (See Exhibit No. 5 for references A below.) Laurel County is located in the southwestern portion of the Eastern Kentucky field on the northwestern flank of the principal synclinal basin. In this regional position, the coal beds of Laurel County dip at low rates toward the southeast, although the directions and rates of dip are somewhat modified locally in accordance with irregular cross-folding of varying extent. One such fold designated as the Rockcastle River uplift represents a portion of one of the more pronounced folds within the Eastern Kentucky field, crossing the northern portion of Laurel County in a southward facing curve.

As shown by Bureau of Mines data on bituminous coal production in 1948, approximately 242,000 tons were produced in Laurel County during that year, of which 54,000 tons were produced from seven stripping operations. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates that approximately 29,000 tons were produced from 2 railroad mines during that year with an additional 225,000 tons being produced in 30 truck mines. The coal beds from which such production was obtained are variously designated as the Chainey Ridge, Horse Creek No. 1, Lily No. 3, Pittsburg, River and Stearns No. 2 beds. The correlations of these beds with the principal producing beds in the Eastern Kentucky field are highly uncertain, with the available information being insufficient to permit descriptions or estimates of reserves for the coal occurrences of Laurel County.

Lawrence County. (See Exhibit No. 5 for references B below.) Lawrence County is located in the northeastern portion of the
Ky eastern Kentucky field with its eastern border forming a portion of the Kentucky-West Virginia State line along Big Sandy River. The
A-10b to 12a/4 southernmost extension of the principal syncline of the Appalachian

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(References A: 4, 39, 40, 62, 63)
(References B: 6, 8, 11, 18, 21, 39, 40, 62, 63)

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region crosses central Lawrence County in an approximate east-west direction, with the coal beds generally dipping toward this axis from the northern and southern portions of the county. These regional dips, however, are modified by the presence of additional folds which are subparallel to the principal synclinal axis. A major fault, likewise parallel to the synclinal axis, crosses central Lawrence County in an approximate east-west direction, with displacements ranging from 100 to 150 feet.

Bureau of Mines data on bituminous coal production indicate that approximately 112,000 tons were produced in Lawrence County during 1948, with 30,000 tons being obtained from one stripping operation. According to the annual report of the Kentucky Department of Mines and Minerals for 1948 there was no production from railroad mines in Lawrence County during that year, although approximately 118,000 tons were produced in 19 truck mines. The coal beds from which this production was obtained are variously designated as the Blackburn, Hazard No. 4, McHendich, and No. 7 beds. Precise correlations of these beds with the principal producing coals of the eastern Kentucky field are highly uncertain.

The northern portion of Lawrence County contains numbered coal beds of the same series occurring in Boyd, Carter, and Greenup Counties to the north. The coal measures of southern Lawrence County contain four horizons which are roughly more similar to the generalized coal section of the principal eastern Kentucky field. The Kentucky Geological Survey designates the Van Lear or Millers Creek, Peach Orchard, Lower Torch Light, and Upper Torch Light or Richardson coals as being the principal producing beds in Lawrence County. Coal bed Nos. 9 to 12, inclusive, of the northern Kentucky numbered series have not been thoroughly prospected but appear to represent stratigraphic horizon markers rather than specific coal beds.

The No. 8 bed also designated as the Hatcher and Richardson bed, is reported to approximate 4 ft 0 in. in thickness in northwestern Lawrence County and to range up to 6 ft 6 in. in thickness near the southern boundary of Lawrence County. The available information on these widely separated areas is insufficient to permit estimates of reserves.

The No. 7 and No. 6 beds of Boyd, Carter, and Greenup Counties do not appear to occur except as horizon markers in Lawrence County. It is not known whether the production reported from the No. 7 bed in Lawrence County, by the Kentucky Department of Mines and Minerals is correlated with certainty or not. Ky

The No. 5 bed, also known as the Cooksie Fork bed, occurs in scattered locations in eastern Lawrence County, with the possibility that beds otherwise designated as the Torch Light and Watson coals may actually be correlative with the No. 5 bed.

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The No. 4 bed appears to exist only as a horizon marker in Lawrence County.

The No. 3 bed is also designated as the Peach Orchard bed in southern Lawrence County where it ranges up to 6 ft 0 in. in thickness. This bed also outcrops across northern Lawrence County, with reported measurements at widely scattered locations indicating an approximate thickness of 3 ft 0 in.

The available information on all coal occurrences in Lawrence County is too scattered in location and insufficient in scope to permit further descriptions or estimates of reserves.

Lee County (See Exhibit No. 5 for references A below.) Lee County is located in approximately the center of the northwestern flank of the eastern Kentucky syncline, with the coal beds and their associated strata largely dipping at gentle rates toward the southeast.

Bureau of Mines data on bituminous coal production in 1948 report that approximately 97,000 tons were produced in Lee County during that year, all of which was obtained from underground operations. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates that approximately 97,000 tons were produced in seven truck mines during that year with no production being obtained from railroad mines. The single coal listed as providing this production is designated as the Beattyville bed. The local mining operations in Lee County appear to be largely located along the banks of the Kentucky River in the central portion of the county. The available information is insufficient to permit descriptions or estimates of reserves of the coal occurrences in Lee County.

McCreary County. (See Exhibit No. 5 for references B below.) McCreary County is located near the southwestern corner of the Eastern Kentucky field with its southern boundary being contiguous with the northern boundary of Scott County in Tennessee. In this regional position, the coal beds of McCreary County generally dip toward the southeast at moderate rates.

Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 818,000 tons were produced in McCreary County during that year, of which 74,000 tons were produced from four stripping operations. As shown by the annual report of the Kentucky Department of Mines and Minerals for 1948 approximately 643,000 tons were produced from 4 railroad mines, with an additional

(References A: 39, 40, 62, 63)
(References B: 12, 39, 40, 62, 63)

174,000 tons being produced from 14 truck mines. The coal beds from which such productions were obtained are variously designated as the River Jim and Stearns Nos. 1-1/2, 2, 3, and 14-1/2 beds.

The Kentucky Geological Survey designates the principal coals of McCreary County, in descending order, as the Jellico (No. 7), Upper Blue Gem (No. 6), Lower Blue Gem (No. 5), Lily (No. 4), Barren Fork (No. 3), Beaver Creek (No. 2), Hudson Rider (No. 1-1/2), and Hudson (No. 1) beds. The available information is too limited to permit further descriptions or estimates of coal reserves for the coal occurrences of McCreary County. With reported operations of varying extent distributed throughout relatively wide portions of the county, it is probable that additional investigations would both clarify the extents of coal occurrences and warrant estimates of suitable reserves for synthetic liquid fuel plant manufacture.

Menifee County. (See Exhibit No. 5 for references A below.) Located in the northwestern portion of the eastern Kentucky field, Menifee County is slightly northeast of the center of the northwestern limb of the eastern Kentucky syncline. The northwesternmost margin of the coal measures cross central Menifee County in an approximate northeast-southwest direction. In this regional position, the coal beds of Menifee County dip gently toward the southeast with but minor modifications in direction of dip along local folding.

Bureau of Mines data on bituminous coal production in 1948 report a production of approximately 36,000 tons in Menifee County during that year, all of which was obtained from underground operations. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates that approximately 36,000 tons were produced from four truck mines, with no production being reported from railroad mines. The entire production was reported as obtained from a coal designated only as the Cannel bed. The available information is too insufficient to permit descriptions of the coal occurrences in Menifee County.

Morgan County. (See Exhibit No. 5 for references B below.) Morgan County is in the northern portion of the Eastern Kentucky field on the northwestern limb of the eastern Kentucky syncline. While the prevailing dip is toward the southeast, the directions and rates of dip are locally modified by the presence of a number of accessory folds in various portions of the county without particular pattern. An east-west trending fault crosses the southern portion of the county with a vertical displacement of some 70 to 160 feet. The fault is accompanied on the south by a parallel upfold which likewise crosses the entire county.

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(References A: 12, 14, 39, 40, 62, 63)
(References B: 12, 14, 36, 39, 40, 43, 62, 63)

According to Bureau of Mines data on bituminous coal production in 1948, approximately 384,000 tons were produced in Morgan County during that year, of which 47,000 tons were obtained from three stripping operations. As shown by the annual report of the Kentucky Department of Mines and Minerals for 1948, approximately 395,000 tons were obtained from 59 truck mines, with no production being reported from railroad mines. A very large proportion of the above production is reported to have been obtained from cannel beds with minor amounts reported as being produced from the Elkhorn No. 3 bed.

The several coal beds of Morgan County are tentatively correlated with the numbered series of coals underlying the northern portion of the eastern Kentucky field in Elliott and Carter Counties to the north. Exact correlations with the producing beds of the principal eastern Kentucky field are not certain.

The No. 3 bed is reported to be present in eastern Morgan County, largely extending from known occurrences in Elliott and Lawrence Counties to the northeast. There is no available information on the thickness and extent of this bed in Morgan County.

The No. 2 bed appears to represent the principal cannel coal being mined at numerous locations in Morgan County. Where operated in northeastern Morgan County this bed ranges from 2 ft 0 in. to as much as 4 ft 10 in. in thickness. Indications are that the bed becomes thin toward the southeast and south. The available information is insufficient to permit further estimates or descriptions of reserves of this bed in Morgan County.

The No. 1 bed outcrops in central and northern Morgan County but rarely exceeds 3 ft 0 in. in thickness. The scattered reports of occurrences are too insufficient to permit descriptions or estimates of reserves.

A bed stratigraphically below the No. 1 horizon is reported to outcrop in western Morgan County in thicknesses ranging from but a few inches to approximately 2 ft 0 in. at a few widely scattered localities.

Owsley County. (See Exhibit No. 5 for references below.)
Ky Owsley County is located near the center of the northwestern limb of the eastern Kentucky syncline. The county is traversed by a
A-17b to 19a / 4 number of small irregular folds which highly modify the regional southeastward dip within the county.

(References: 39, 40, 62, 63)

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Bureau of Mines data on bituminous coal production in 1948 do not include any production for Owsley County. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates a production of but 3,500 tons in five truck mines, this production reported as being obtained from the Beattyville and the No. 3 coal beds. The Kentucky Geological Survey indicates the presence of the Fire Clay Coal Horizon in the southeastern portion of the county, with no other information being available to indicate the extent or thickness of coal occurrences in Owsley County.

Pulaski County. (See Exhibit No. 5 for references A below.) Pulaski County is in the southwestern portion of the eastern Kentucky field. The irregular northwestern margin of the coal measures cross the center of the county in an approximately northeast-southwest direction. The coal beds dip at low rates toward the southeast with some modifications in direction of dip occurring along the flanks of a few local folds.

According to Bureau of Mines data on bituminous coal production in 1948 approximately 92,000 tons were produced in Pulaski County during that year, with 19,000 tons being obtained from one stripping operation. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates that approximately 72,000 tons were obtained in 24 truck mines, all of which were reported as operating in the No. 3 bed. The Kentucky Geological Survey reports the presence of two coal beds in Pulaski County which occur near the base of the coal measures. No other information is available to indicate the extent or thickness of coal occurrences in Pulaski County.

Rockcastle County. (See Exhibit No. 5 for references B below.) Located in the southwestern portion of the eastern Kentucky field, Rockcastle County is somewhat south of the center of the northwestern flank of the eastern Kentucky syncline. The irregular northwestern boundary of the coal measures of eastern Kentucky extend through the center of the Rockcastle County in an approximate northwest-southeast direction. In this regional position the coal beds of Rockcastle County dip at low rates toward the southeast with a few modifications in direction of dip occurring near the axes of a few local folds.

Bureau of Mines data on bituminous coal production for 1948 indicate that approximately 69,000 tons were produced in Rockcastle County during that year, with 10,000 tons being obtained from five

(References A: 4, 12, 39, 40, 43, 62, 63)
(References B: 3, 4, 12, 39, 40, 43, 62, 63)

stripping operations. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates that approximately 71,000 tons were produced at 18 truck mines, with this production reported as being obtained from the Dean, Horse Creek, Mayflower, and Sand Springs beds.

The Kentucky Geological Survey reports the presence of several coal horizons in Rockcastle County of which two beds near the base of the coal measures appear to be the most important. The available information is insufficient to permit further description or estimates of reserves for the coal occurrences of Rockcastle County.

Wayne County. (See Exhibit No. 5 for references A below.) Wayne County is located at the southwestern corner of the eastern Kentucky field with the areas underlain by coal measures largely occurring as outliers of the main field in southeastern Wayne County. These are separated from the principal areas of coal measures to the east by irregular drainage channels. The coal measures have a prevailing dip toward the southeast, with but few indications of accessory folding.

Bureau of Mines data on bituminous coal production in 1948 report a production of approximately 4,000 tons in Wayne County during that year, all of which was obtained from underground operations. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicate that approximately 65,000 tons were produced in 13 truck mines in Wayne County during that year, all of this production being reported from the Stearns or Stearns No. 3 beds. The information available is insufficient to permit descriptions or estimates of reserves for the coal occurrences in Wayne County.

Whitley County. (See Exhibit No. 5 for references B below.) Whitley County is located at the center of the southern boundary of the eastern Kentucky field, with its southern border forming the northern boundary of Campbell County in Tennessee. The extreme southeastern corner of the county is crossed by the northwestern front of the Pine Mountain overthrust. The principal axis of the eastern Kentucky syncline crosses the southern portion of Whitley County in a direction parallel to the Pine Mountain overthrust, with the coal beds and their associated strata dipping at low rates toward this axis. The directions and rates of such prevailing dips are modified
22 by the presence of additional folding of relatively limited degree on both flanks of the syncline.

(References A: 12, 39, 40, 62, 63)
(References B: 39, 40, 62,63)

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As shown by Bureau of Mines data on bituminous coal production approximately 457,000 tons were produced in Whitley County during 1948, with 49,000 tons being obtained from seven stripping operations. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates that approximately 90,000 tons were produced in 4 railroad mines in Whitley County during that year, with an additional 169,000 tons being produced in 43 truck mines. The coal beds from which these productions were obtained are variously designated as the Blue Heron, Blue Jim, Dean, Jellico, No. 1-1/2, River, River Gem and Vanderpool beds.

The Kentucky Geological Survey reports the occurrence of 30 separate coals, largely very thin, within the county, with the No. 9 and No. 11 beds indicated as being the principal producing coals. The available information is insufficient to permit further descriptions or estimates of reserves for the coal occurrences in Whitley County. It is probable that additional investigations in the southern portion of the northeastern Kentucky field, especially in Whitley and McCreary Counties, would result in sufficient mapping and description of coal bed occurrences to warrant estimates of suitable reserves for synthetic liquid fuels plant supply.

<u>Wolfe County.</u> (See Exhibit No. 5 for references below.) Wolfe County is located near the center of the northwestern flank of the eastern Kentucky syncline. While the prevailing dip of the coal beds and their associated strata in this area is toward the southeast, the directions and rates of dip are modified by the presence of numerous local folds of irregular pattern and extent. An approximate east-west fault crosses the northern portion of Wolfe County with displacements ranging from 50 to 180 feet.

Bureau of Mines data on bituminous coal production in 1948 report that approximately 16,000 tons were produced in Wolfe County during that year, all of which was obtained from underground operations. The annual report of the Kentucky Department of Mines and Minerals indicates that approximately 16,000 tons were obtained from six truck mines, this production being reported as obtained from the Hazard and No. 4 beds. The available information is insufficient to permit descriptions or estimates of reserves for the coal occurrences in Wolfe County. The reported locations of the truck mine production obtained in Wolfe County are all in the eastern portion of the County near the Wolfe-Morgan-Magoffin County line where it is reported by the Geological Survey that numerous coal benches are present.

(References: 39, 40, 62, 63)

Western Kentucky

Crittenden County. (See Exhibit No. 5 for references below.) Crittenden County is located in the extreme southwestern portion of the Western Kentucky field, with approximately the northeastern one-fourth of the county being underlain by coal measures, these measures including only the basal portions of the coal-bearing strata. The coal beds and their associated strata within the coal-bearing portion of Crittenden County regionally dip at low rates toward the northeast, being locally modified in amount and direction of dip at a few locations by the northeasternmost extensions of the highly complex fault system of Livingston and western Crittenden Counties.

Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 4,000 tons were produced in Crittenden County during that year, all of which was obtained from one stripping operation. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates that approximately 4,000 tons were produced from one truck mine operating in what is designated as the Bell bed. The only coal horizons present in northeastern Crittenden County are stratigraphically lower than the horizon of the No. 6 bed. Such coals are notably lenticular in occurrence and thickness and do not appear to possess sufficient continuity or extent to warrant further consideration. The Bell coal in which some mining activities have been reported apparently represents one of the lowest coal horizons in the coal-bearing series, occurring in a relatively limited area at the northern corner of Crittenden County adjacent to the Ohio River. This bed averages less than 2 ft 0 in. in thickness.

Edmonson County. (See Exhibit No. 5 for references below.) Located along the easternmost flank of the western Kentucky coal basin, approximately the northwestern one-third of Edmonson County is underlain by coal measures. The coal-bearing strata of the county are crossed in an approximate east-west direction by the axis of the principal western Kentucky syncline, the coal beds dipping gently toward the center of the syncline from both the northern and southern limbs. A few minor faults effect local displacements at the extreme edges of the coal-bearing area.

As shown by Bureau of Mines data on bituminous coal production in 1948 approximately 11,000 tons were produced in Edmonson County during that year, all of which was obtained from underground operations. The annual report of the Kentucky Department of Mines

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(References: 39, 40, 43, 62, 63)

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and Minerals for 1948 indicates that approximately 11,000 tons were produced from four truck-mines in Edmonson County during that year, all of this production having been reported as from "stray" beds. The available information on coal occurrences in Edmonson County is too scattered in location and limited in scope to permit descriptions or estimates of reserves. The coal horizons in this portion of the western Kentucky field are limited to the basal portion of the coal-bearing series in which such coals are characteristically lenticular in occurrence, continuity, and thickness.

<u>Grayson County.</u> (See Exhibit No. 5 for references below.) Grayson County is located along the easternmost flank of the western Kentucky field, with the coal measures underlying approximately the southwestern one-third of the county. The outer boundary of the coal measures in Grayson County is both delimited and modified by the intricate fault pattern characterizing the Rough Creek uplift which crosses the entire western Kentucky field in an approximately east-west direction. The coal beds south and southwest of this belt of deformation dip regionally toward the southwest at gentle rates.

Bureau of Mines data on bituminous coal production report approximately 9,000 tons production in Grayson County during 1948, all of which was obtained from two stripping operations. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates that approximately 9,000 tons were obtained from two truck mines in Grayson County during that year, this production being reported as obtained from the No. 6 and No. 6 "stray" beds.

The available information on coal occurrences in Grayson County is too limited in extent and frequency to permit descriptions or estimates of reserves. The data on coal occurrences in eastern Ohio and northern Butler Counties, these areas being adjacent to the eastern and southeastern boundaries of Grayson County, suggest that the outcrop of coal bed No. 6 does not extend into Grayson County although production is reported from this bed. It is possible that such production is obtained from coal horizons stratigraphically lower than the No. 6 coal, especially since the coal-bearing strata of Grayson County appear to be restricted to the basal portion of the coal-bearing series. As elsewhere in the western Kentucky field the coal horizons near the base of the coal measures are notably lenticular in thickness and extent.

(References: 39, 40, 62,63)

Hancock County. (See Exhibit No. 5 for references below.) Located at the northeastern corner of the western Kentucky field, the northern boundary of Hancock County formed by the Ohio River, faces southeastern Spencer and southwestern Perry Counties of Indiana. The easternmost outcrop of coal measures of the western Kentucky basin more or less coincide with the eastern boundary of Hancock County so that the entire county is essentially solidly underlain by coal measures. In this regional position, the coal beds and their associated strata dip toward the west at rates ranging up to only 1 or 2 degrees. This regional structure is distorted, however, by two roughly north-south faults which extend across the northeastern portion of the county. These faults have displacements of up to 190 feet at their northernmost points, decreasing in severity toward the south. The coal measures at the lines of both faults have been down-dropped toward the west. The structure of the remaining areas of the county is modified by the presence of a number of relatively small anticlines, synclines and anticlinal noses which locally affect the direction and rate of dip.

Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 230,000 tons were produced in Hancock County during that year, with 180,000 tons being obtained from one stripping operation. The annual report of the Kentucky Department of Mines and Minerals for 1948 indicates that 180,000 tons were produced from one railroad-connected mine in Hancock County during that year, with an additional 50,000 tons being obtained from six truck mines. The output of the railroad mine was reported as obtained from a "stray" bed with the outputs of all the truck mines reported as obtained from the No. 6"stray" bed. It is possible that such reported production has been designated as from the No. 6 coal horizon in accordance with the common practice in Western Kentucky of designating the first principal bed or, almost any bed below the No. 9 coal as the No. 6 bed, regardless of stratigraphic relationships.

The available information on coal occurrences in Hancock County indicates widespread coal occurrences at what are regarded as at least six coal horizons with none of the horizons extending completely across any substantial portion of the county. The geological reports on which the stratigraphic relationships are based indicate further that prospects of discovering even moderate reserves along any of the several coal horizons are highly limited.

The Lewisport bed underlies several ridges in the northwestern portion of the county, in thicknesses ranging from 2 ft 6 in. to 4 ft 0 in., where it has been opened largely for local consumption by numerous operations along the relatively limited lengths

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of outcrop.

The Adair bed is reported to occur at only one location of highly limited extent in the northernmost portion of the county where it locally attains a thickness permitting development of small mining operations.

The Lead Creek bed extends across a limited area in the northern portion of the county in thicknesses ranging from less than 2 ft 0 in. to a maximum of 2 ft 6 in.

The Persimmon Run bed attains sufficient thickness to permit local mining activities at only one location in the northeastern portion of the county where the bed is reported to average 2 ft 6 in. in thickness.

The Hawesville bed, ranging from 2 ft 6 in. to 4 ft 0 in. in thickness, has been widely mined by local operations in an area of moderate extent near the center of the northeastern portion of Hancock County. The bed thins southward from its area of principal occurrence, reappearing in the south-central portion of the county in a few areas of highly limited extent.

The Breckenridge bed, is the designation given to a cannel coal which was once widely mined along the southern portion of the Hancock-Breckenridge County line where it was reported to range from 2 ft 0 in. to 4 ft 0 in. in thickness. The available information is insufficient to permit further description or estimates of reserves for this coal occurrence.

Warren County. (See Exhibit No. 5 for references below.) The coal-bearing portion of Warren County occupies only a narrow strip at the northern line of the county immediately south of Green River. In this regional position the coal-bearing strata of Warren County dip at moderate rates toward the north. The southernmost margin of the coal measures is locally distorted by irregular faults.

No production was reported from Warren County in 1948 by the Bureau of Mines or the Kentucky Department of Mines and Minerals. The available information indicates that a single coal designated as the Nolan bed occurs at three separate areas in northern Warren County in which approximate thicknesses of 2 ft 0 in., 3 ft 6 in. and 2 ft 6 in. have been reported. The available information is sufficient to permit further descriptions or estimates of reserves of coal occurrences in this county.

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(References: 24, 39, 40, 62, 63)

APPENDIX B

REPORT BY DeGOLYER and MacNAUGHTON
ON
NATURAL GAS IN KENTUCKY
AS OF JANUARY 1, 1949

APPENDIX B

REPORT BY DeGOLYER and MacNAUGHTON ON NATURAL GAS IN KENTUCKY AS OF JANUARY 1, 1949

SUMMARY

The investigation included a study of the gas and oil fields in Kentucky with special reference to the quantity of gas to be recovered, the gas available for a synthetic liquid fuels plant, and the cost of gas in the field. The map, Exhibit No. B-1, accompanying this report shows the oil and gas fields and main natural gas pipe lines in Kentucky. The names of the oil and gas fields are listed in Exhibit No. B-2. Data relating to natural gas reserves and gas storage fields in Kentucky are tabulated in Exhibits Nos. B-3 and B-4, respectively. These data are presented and discussed in the report.

Data relating to reserves of natural gas in Kentucky, which have an average heating value in the order of 1,170 Btu under standard conditions, are briefly summarized in the following table:

Summary of Estimated Recoverable Natural Gas Reserves in Kentucky
(In Mcf under Standard Conditions)

As of Jan. 1, 1949	
Total	1,684,300,000
Commercial Requirements: Contract or To Be Used in Field	1,684,300,000
Total Undedicated Reserves as of Jan. 1, 1949	0
Additional Net Gas in Storage	9,488,000

The weighted average field price for gas under contract in Kentucky was in the order of 15 cents per Mcf.

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As shown by the above table, the gas reserves are either under contract for domestic, commercial, and industrial use, or will be used in field operations.

It is, therefore, concluded there are no undedicated reserves of natural gas in Kentucky presently available for synthetic liquid fuels plants. Discoveries of new fields and extensions of known fields between January 1, 1949, and the date of this report warrant no changes in this conclusion.

PART I - INTRODUCTION

Authorization

This investigation and report on natural gas deposits in Kentucky have been made a part of that authorized by a contract, dated June 1, 1949, between Ford, Bacon & Davis, Inc. (called the Contractor) and DeGolyer and MacNaughton (called the Subcontractor). The contract is identified as Subcontract No. 2 of the principal contract No. W 49-129 eng-137, dated May 3, 1949, between the United States of America (called the Government) and Ford, Bacon & Davis, Inc. The subcontract was duly approved by a representative of the Contracting Officer for the Government.

Purpose and Scope of Report

The investigation and report required were confined to a general determination of the nature and extent of natural gas deposits and conclusions as to their suitability or unsuitability for the manufacture of synthetic liquid fuels. Such a report is required for a state in which present information indicates that production of synthetic liquid fuels from existing raw materials is not feasible at the present or near future time (due among other possible causes to excessive raw material costs or existing commercial requirements in excess of possible production) even though such deposits technically may meet the minimum requirements.

The study included the collection of basic data, the preparation of maps, and the determination of factors necessary to estimate the gas reserves in the oil and gas fields in Kentucky; the estimation of the reserves; and the determination of the suitability and availability of the reserves for synthetic liquid fuels manufacture.

PART II - GENERAL

Definitions Relating to Natural Gas and Gas Reserves

Natural Gas - Natural deposits of a combustible gas that occur in porous strata of the earth and consist of a mixture of hydrocarbon gases composed principally of methane, small quantities of ethane, and very often small quantities of other heavier hydrocarbon gases such as propane, butane, pentane, and hexane; usually with a heating value of about 1,000 Btu per cubic foot at standard conditions, which value may vary considerably depending upon the contained percentage of nitrogen and other inert gases.

Heating (or Calorific) Value - Heat (gross) resulting from combustion of fuel, expressed for natural gas as Btu per cubic foot at standard conditions.

Standard Conditions - For natural gas, commonly 14.65 pounds per square inch absolute pressure and 60° F temperature.

Minimum Gas Reserves - Deposits of natural gas are not considered reserves for the purpose of this study unless they contain at least 225 trillion Btu in natural gas producible within a radius of 40 miles and with a heating value of not less than 400 Btu per cubic foot at standard conditions.

Remaining Recoverable Reserves - That portion of the gas reserves not under contract or not required for field use.

Estimates of Natural Gas Reserves - The quantities in each of the categories of "proved drilled", "proved undrilled", and "probable" are calculated assuming standard conditions.

(a) Proved drilled reserves - Those reserves of natural gas which will be produced from existing wells.

(b) Proved undrilled reserves - Those reserves of natural gas proved by existing wells and other data, but which will be produced from new wells as yet undrilled.

(c) Probable Reserves - Those reserves of natural gas indicated to be present by existing wells and other data and which are classified as probable rather than proved due to the nature or scarcity of the data, or the inability to reach definite conclusions from available data.

Non-Associated Gas - Free natural gas not in contact with crude oil.

Associated Gas - Free natural gas in contact with crude oil.

Dissolved Gas - Natural gas in solution in crude oil.

Availability of Natural Gas Reserves - From the viewpoint of availability of natural gas reserves, the quantity remaining after allowance for present commercial and industrial requirements. Available reserves are considered sufficient for one or more plants when there is a recoverable amount sufficient to supply a natural gas synthine plant with a capacity of 5,000 barrels of synthetic liquid fuels per day for a period of 20 years of which 10 years' supply is from primary reserves and the additional 10 years' supply is from either primary or secondary reserves.

(a) Primary Reserves - Deposits containing at least 225 trillion Btu producible from gas wells within a radius of 20 miles, with a minimum heat value of 700 Btu per cubic foot at standard conditions.

(b) Secondary Reserves - Deposits containing at least 225 trillion Btu producible from gas wells within a radius of 40 miles, with a minimum heat value of 400 Btu per cubic foot at standard conditions.

Unit Plant or Unit Capacity - A synthetic liquid fuels plant for processing natural gas by the synthine process with a production capacity of 5,000 barrels of liquid fuel products per day. Such a plant would require 55,000,000,000 Btu daily or 55,000 Mcf of 1,000 Btu gas. It would consume 20,075,000 Mcf of 1,000 Btu gas annually and would require a reserve of such natural gas of 401,500,000 Mcf over a 20-year period. The estimated cost of a 5,000-barrel plant (taken at one-half the amount estimated by the U.S. Bureau of Mines for a 10,000-barrel plant) is $30,000,000. Such a plant size is adopted in the survey for comparative purposes and is not necessarily the most efficient size for an independent plant.

A Suitable General Area - As considered herein, an area not larger than a county or 1,000 square miles, depending on the local conditions, with natural gas reserves and water supply adequate for at least one gas synthine unit plant, and with other satisfactory qualifications as to labor supply, housing, power supply, and transportation.

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Available Sources of Information

Data for this study were obtained from files of the Subcontractor, from public records of the Federal Power Commission, from oil and gas companies operating in the State, and from records of the Kentucky State Geological Survey.

Reference has been made to principal publications on natural gas in Kentucky with particular attention to publications of Federal and State authorities. Important publications consulted are listed in the Bibliography, Exhibit No. B-5.

Personnel of natural gas companies and geologists familiar with gas-bearing formations in Kentucky were interviewed. The cooperation and assistance of individuals listed in Exhibit No. B-6 are gratefully acknowledged.

PART III - STUDY OF SURVEY DATA

History of the Natural Gas Industry in Kentucky

As early as 1856, oil and gas shows were noted in wells being drilled for salt water in eastern Kentucky, but no commercial attempt for production was ever made from these wells. In 1863, natural gas production from a well near Brandenburg, Meade County, Ky., was used as fuel in the distillation of salt from brines which were found associated with the gas in numerous wells in this area. Extensive drilling during the period 1863-1920 resulted in the discovery of small amounts of gas in the oil pools in Wolfe, Estill, Lawrence, and Morgan Counties, but the gas was used only locally in small amounts. Subsequent development led to the discovery of the Rothwell field in Menifee County, and from this field, gas was first produced commercially in central Kentucky.

Increased demand for gas has resulted in a continuous drilling program since 1920, and it is estimated that some 30,000 wells have been drilled in the search for oil and gas and that some 1,200,000,000 Mcf of gas have been produced as of January 1, 1949.

As early as 1917, importation of gas from other states became necessary due to the increased demand. Since that date, the volume of gas imported has continually increased. Annual gas production for the past 10 years has been in the order of 65,000,000 Mcf to 75,000,000 Mcf per year. Reported gas production in Kentucky during 1948 was 74,000,000 Mcf. In addition, about 8,000,000 Mcf of gas was added to net storage.

It is estimated that as of January 1, 1949, there were some 20,000 producing oil and gas wells in Kentucky. During 1948, 1,056 wells were drilled for oil and gas, of which 195 were reported as gas wells, 394 as oil wells, and 467 as dry holes.

General Geology and Natural Gas Reservoirs

The major structural features in Kentucky are the Appalachian geosyncline and the Cincinnati Arch. Most of the State lies on the western flank of the geosyncline and on the eastern flank of the Arch. The regional dip of the formations in the State is eastward from the crest of the Cincinnati Arch toward the axis of the Appalachian geosyncline, with the formations progressively thickening eastward. There are many minor basins within the State, some of which have been found gas productive to date. The deeper basins may be proved to be productive of gas with future development.

Oil and gas production are found in three general areas in the State - the eastern, south-central, and western parts.

The oldest exposed formations of any consequence are near Lexington, Ky., and are of Lower Ordovician age. Formations of Pennsylvanian and Mississippian age make up a large percentage of the surface area within the State.

It is estimated that more than half of the present gas production in Kentucky comes from the Shale Series of Devonian age; most of the remaining production is from sandstones and limestones of Pennsylvanian, Mississippian, Devonian, and Silurian ages.

The formations having the best possibilities for future gas discoveries are those of Silurian and Ordovician ages.

Gas Well and Production Data

It is estimated that as of January 1, 1949, there were some 4,000 producing gas wells in the State of Kentucky, of which 195 were completed during the year 1948. The average initial potential of the gas wells completed during 1948 was in the order of 1,500 Mcf per well. Gas was also produced from about 16,000 oil wells in the State during 1948.

It is estimated that almost 85 percent of the gas production in Kentucky is from the Big Sandy area in eastern Kentucky. About 20 percent of the production from this area is utilized in the State, and the remainder is exported to the eastern markets. Additional gas production is from oil and gas fields in eastern, south-central, and western Kentucky.

The reported daily average gas production during 1948 was about 200,000 Mcf. In addition, about 8,000,000 Mcf of gas was added to net storage. The principal fields being used for storage are the Menifee, Muldraugh, and Doe Run fields. Data concerning these fields are detailed in Exhibit No. A-4.

Gas Purchase Contract Data

Essentially all of the gas produced in commercial quantities in the State of Kentucky is under gas purchase contract. The average price paid for gas at the wellhead is in the order of 15 cents per Mcf at standard conditions.

Estimation of Natural Gas Reserves

Most of the gas reserves in this State exist as non-associated gas. The non-associated gas reserves were estimated by areas and by counties on the basis of pressure-cumulative production decline curves for individual wells. These curves were extrapolated to an assumed abandonment limit of 25 psi closed-in wellhead pressure. To estimate the dissolved gas reserves, it was necessary to first estimate the oil reserves. Data concerning the physical characteristics of the reservoir fluid and of the reservoir were considered in estimating the future quantity of gas that would be produced with the oil.

The estimates were divided into categories of "proved drilled", "proved undrilled" and "probable" reserves, and are calculated assuming standard conditions.

The following table is summarized from Exhibit No. B-3:

Classification of Estimated Recoverable Gas Reserves as of January 1, 1949 in Mcf

	Total	Undedicated and Available for Synthetic Liquid Fuels Manufacture
Reserves		
Proved Drilled	668,900,000	0
Proved Undrilled	516,900,000	0
Probable	498,500,000	0
Total	1,684,300,000	0
Type of Gas		
Non-Associated	1,625,800,000	0
Dissolved	58,500,000	0
Total	1,684,300,000	0

The principal gas reserves are found in Pike, Floyd, Knott, and Martin Counties in the Big Sandy area. Thousands of probable gas producing acres are under lease by the principal gas-producing companies in this area.

Undedicated Natural Gas Reserves

In Kentucky, there are no available undedicated gas reserves as of January 1, 1949, containing at least 225 trillion Btu producible within a radius of 40 miles.

PART IV - CONCLUSIONS

Data relating to remaining available reserves of natural gas in Kentucky, which have an average heating value in the order of 1,170 Btu under standard conditions, are briefly summarized in the following table:

Summary of Estimated Recoverable Natural Gas Reserves in Kentucky
(In Mcf under Standard Conditions)

As of Jan. 1, 1949	
Total	1,684,300,000
Commercial Requirements: Contract or To Be Used in Field	1,684,300,000
Total Undedicated Reserves as of Jan. 1, 1949	0
Additional Net Gas in Storage	9,488,000

The gas reserves are either under contract for domestic, commercial, and industrial use or will be used in field operations. The weighted average field price for gas under contract was in the order of 15 cents per Mcf.

It was concluded that there were no undedicated reserves of natural gas in Kentucky available for synthetic liquid fuels plants as of January 1, 1949, which contained at least 225 trillion Btu (225,000,000 Mcf of 1,000 Btu) gas producible within a radius of 40 miles and having a heating value of not less than 400 Btu per cubic foot at standard conditions. Discoveries of new fields and extension of known fields in the interim between January 1, 1949, and the date of this report warrant no change in this conclusion.

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Oil and Gas Fields of Kentucky

Key to Map

Eastern and Central Kentucky:

1 Big Sandy Gas Field
2 Ashland Gas Field
3 Fallsburg Oil Pool
4 Laurel Creek Oil and Gas Field
5 Elliott County Oil and Gas Fields
6 Frozen Creek Gas Field
7 Grassy Creek Oil Pool
8 Rowan County Gas Field
9 Ragland Oil Pool
10 Menifee County Gas Field
11 Campton Oil Pool
12 Powell County Oil and Gas Fields
13 Irvine Oil Pool
14 Big Sinking Oil Pool
15 Owsley County Oil and Gas Fields
16 Station Camp Creek Oil Pool
17 Jackson County Oil Pools
18 Clay County Gas Fields
19 Knox County Oil and Gas Fields
20 Williamsburg Oil and Gas Fields

South-central Kentucky:

21 Wayne County Oil Pools
22 Clinton County Oil Pools
23 Cumberland County Oil Pools
24 Green River Gas Field
25 Center Gas Field
26 Hart County Oil Pools
27 Barren County Oil and Gas Fields
28 Allen County Oil and Gas Fields
29 Simpson County Oil Pools

Western Kentucky:

30 Warren County Oil and Gas Fields
31 Leitchfield Oil and Gas Fields
32 Jefferson County Gas Field
33 Meade County Gas Fields
34 Cloverport Gas Field
35 Hancock County Oil Pools
36 Ohio County Oil Pools
37 Butler County Oil Pools
38 Logan County Oil and Gas Fields
39 Muhlenberg County Oil and Gas Fields
40 McLean County Oil and Gas Fields
41 Daviess County Oil Pools
42 Henderson County Oil Pools
43 Webster County Oil Pools
44 Union County Oil Pools
45 Hopkins County Oil Pools
46 Caldwell County Oil and Gas Fields

State of Kentucky
Data Concerning Natural Gas Reserves as of January 1, 1949

Location	Name of Producing Geological Series, Groups, and Formations	Depth of Production (Feet)	Kind of Gas	Average Heating Value in Btu per Cu Ft	Analysis of Gas (Percent)			Closed-in Well-head Pressure, (Psi)		Producing Wells as of 1-1-49		Estimated Daily Average Gas Production, 1948 (Mcf)	Estimated Remaining Recoverable Gas Reserves (Million Cu Ft)			
					Methane	Ethane	Other	Original	1-1-49	Gas	Oil		Drilled	Undrilled	Probable	Total
Western Kentucky Counties																
Breckenridge Caldwell Crittenden Daviess Grayson Henderson Hopkins Jefferson Logan McLean Muhlenberg Ohio Union Warren Webster	Pennsylvanian - Pottsville Group Mississippian - Chester and Iowan Groups (Palestine, Waltersburg, Tar Springs, Hardinsburg, Cypress, Bethel, Benoist, Aux Vases and McClosky Sands; St. Genevieve and St. Louis Limes) Devonian - Upper and Hamilton Groups (New Albany Shale and Corniferous Lime)	200-3,000	Non-Associated	923	92.0	1.0	7.0	75-1,000	10-170	125		5,100	10,000	2,000	2,000	14,000
			Dissolved	972	96.0	0.2	3.8	-	-	-	1,320(A) (B)	4,000	38,000	10,000	5,000	53,000
Total Western Kentucky										125	1,320(A) (B)	9,100	48,000	12,000	7,000	67,000
Eastern and Central Kentucky Counties																
Bell Boyd Breathitt Carter Clay Elliott Estill Knox Laurel Owsley Powell Rowan	Pennsylvanian - Pottsville Group (Salt Sand) Mississippian - Chester and Iowan Groups (Maxon, Big Injun, Weir and Berea Sands; St. Genevieve, St. Louis and Ft. Payne Limes; Sunbury Shale) Devonian - Upper and Hamilton Groups (Brown Shale and Corniferous Lime) Silurian - Big Six Sand	200-3,000	Non-Associated	1,019	86.8	7.8	5.4	75-600	100	225	(B)	20,000	35,000	12,000	140,000	187,000
Big Sandy Area:																
Floyd	Pennsylvanian - Pottsville Group (Salt Sand) Mississippian - Chester and Iowan Groups (Maxon, Big Injun, Weir and Berea Sands; St. Genevieve, St. Louis and Ft. Payne Limes; Sunbury Shale	(900-4,000	Non-Associated	1,190	77.4	14.1	8.5	400-650)	(150	1,380	(B)	65,000	246,000	45,000	20,000	311,000
Johnson									(375	80	(B)	4,000	5,000	14,000	40,000	59,000
Knott									(325	580	(B)	28,000	80,000	75,000	51,000	206,000
Lawrence									(200	25	(B)	1,200	3,000	200	5,000	8,200
Letcher									(150	5	(B)	200	200	14,000	90,000	104,200
Magoffin									(350	210	(B)	10,000	15,000	17,000	50,000	82,000

State of Kentucky
Data Concerning Natural Gas Reserves
as of
January 1, 1949

Location	Name of Producing Geological Series, Groups, and Formations	Depth of Production (Feet)	Kind of Gas	Average Heating Value in Btu per Cu Ft	Analysis of Gas (Percent) Methane	Ethane	Other	Closed-in Well-head Pressure, (Psi) Original	1-1-49	Producing Wells as of 1-1-49 Gas	Oil	Estimated Daily Average Gas Production, 1948 (Mcf)	Estimated Remaining Recoverable Gas Reserves (Million Cu Ft) Drilled	Undrilled	Probable	Total
Eastern and Central Kentucky (Concluded)																
Big Sandy Area: (Concluded)																
Martin	Devonian - Upper and Hamilton Groups (Brown Shale and Corniferous Lime) Silurian - Big Six Sand								240	525	(B)	25,000	123,000	45,000	5,000	173,000
Perry									400	5	(B)	200	200	200	63,000	63,400
Pike									350	715	(B)	34,000	104,000	280,000	25,000	409,000
Total Big Sandy Area			Non-Associated							3,525	(B)	167,600	576,400	490,400	349,000	1,415,800
Total Eastern and Central Kentucky			Non-Associated							3,750	(B)	187,600	611,400	502,400	489,000	1,602,800
South-central Kentucky Counties																
Adair, Allen, Barren, Clinton, Hart, Pulaski, Wayne	Mississippian - Iowan Group; Devonian - Upper and Hamilton Groups (Brown Shale and Corniferous Lime); Ordovician - Cincinnatian Champlainian and Canadian Groups (Sunny Brook and Granville Sand, Trenton Lime, and Upper Knox Dolomite); Cambrian - Ozarkian (Lower Knox Dolomite)	200-1,800	Non-Associated	1,183	75.4	23.4	1.2	35-340	110	80	(B)	4,000	5,000	2,000	2,000	9,000
Total South-central Kentucky										80	(B)	4,000	5,000	2,000	2,000	9,000
Other Oil Wells			Dissolved							0	14,500	1,000	4,500	500	500	5,500
Grand Total										3,955	15,820	201,700	668,900	516,900	498,500	1,684,300
Non-Associated										3,955	0	196,700	626,400	506,400	493,000	1,625,800
Dissolved										0	15,820	5,000	42,500	10,500	5,500	58,500

Note: (A) Wells drilled in horizons developed since 1938.
(B) Included in other oil wells.

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State of Kentucky
Data Concerning Gas Storage Fields
as of
January 1, 1949

Field	County	Year Field Initially Used for Storage	Name of Reservoir Used for Storage	Average Depth of Storage Reservoir (Feet)	Cumulative Gas Injected, to 1-1-49, Mcf	Cumulative Gas Withdrawn, to 1-1-49, Mcf	Net Gas in Storage 1-1-49, Mcf
Doe Run	Meade	1946	Limestone-Dolomite	675	1,550,000	962,000	588,000
Menifee	Menifee	1919	Dolomite	600	16,300,000	8,200,000	8,100,000
Muldraugh	Meade	1931	Limestone-Dolomite	500	5,400,000	4,600,000	800,000
		Total			23,250,000	13,762,000	9,488,000

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5. St. Clair, Stuart, "Oil and Gas in Kentucky and Tennessee", Problems of Petroleum Geology, A Symposium, American Association of Petroleum Geologists, Tulsa, Oklahoma, 1934. pp. 515-520.

6. Certain public records of the Federal Power Commission, Washington, D.C.

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Exhibit No. B6

Acknowledgments for Technical Information

1. Deiss, Dr. Charles, State Geologist, Bloomington, Indiana.
2. Esarey, Dr. Ralph, Director, Oil and Gas Division, State Geological Survey, Bloomington, Indiana.
3. Fleger, Philip, President, Kentucky-West Virginia Gas Company, Ashland, Kentucky.
4. Hillman, J. H., Jr., Kentucky Natural Gas Corp., Owensboro, Kentucky.
5. Hubley, G. W., Jr., Director, Agriculture and Industrial Development Board, Frankfort, Kentucky.
6. Jones, Dan, Chief Geologist, Kentucky State Geological Survey, Lexington, Kentucky.
7. Reger, Dr. David B., Consulting Geologist, Morgantown, West Virginia.
8. Thomas, Ralph, Geologist, Inland Gas Company, Ashland, Kentucky.

APPENDIX C

REPORT BY DeGOLYER AND MacNAUGHTON
ON
OIL SHALES IN KENTUCKY
AS OF SEPTEMBER 1950

APPENDIX C

REPORT BY DeGOLYER AND MacNAUGHTON ON OIL SHALES IN KENTUCKY AS OF SEPTEMBER 1950

SUMMARY

This investigation includes a study of the geology of the oil shale-bearing formations and of assay data on oil shale samples from various localities in Kentucky. The map, Exhibit No. C-1, accompanying this report, shows the localities on which assay data were available and presents certain geologic information, pertaining principally to the New Albany shale. The geological information and assay data are presented and discussed in the attached report; the assay data are also shown in tabular form on Exhibit No. C-2.

In Kentucky, oil shales occur in the New Albany shale and shales associated with Pennsylvanian coal-bearing formations.

A review of the limited data available indicates that none of these oil shales is of sufficient richness and thickness to provide a reserve of raw materials for synthetic liquid fuels manufacture, nor does it appear that additional sampling and assaying would reveal the presence of shales of sufficient richness and thickness to meet the minimum requirements. These minimum requirements are an average oil content of at least 15 gallons per ton of oil shale, over a minimum of 25 feet in thickness and existing in a block totaling not less than 100,000,000 tons of oil shale within an area not greater than 5 square miles.

It is concluded, therefore, that there are no oil shale reserves in the State of Kentucky suitable for use as a source of raw materials for synthetic liquid fuels manufacture.

PART I - INTRODUCTION

Authorization

This investigation and report on oil shales in Kentucky have been made as a part of the survey authorized by a contract dated June 1, 1949, between Ford, Bacon & Davis, Inc., and DeGolyer and MacNaughton. The contract is identified as Subcontract No. 3 of the principal Contract No. W 49-129 eng-137 dated May 3, 1949, between the United States of America and Ford, Bacon & Davis, Inc. The subcontract was duly approved by a representative of the Contracting Officer for the Government.

Purpose and Scope

The Purpose of this investigation and report is to present an inventory of oil shale reserves or deposits that meet minimum standards as to quantity, quality, and occurrence, as defined herein, and which might provide a source of raw materials for synthetic liquid fuels manufacture, and to determine General Areas suitable for the location of synthetic liquid fuels plants. An investigation of this type is required for a state in which it was considered that a review of available information might indicate that production of synthetic liquid fuels would be feasible, either at the present time or in the near future.

Since this investigation determined that the oil shales are insufficient to qualify as reserves, this report, "Oil Shales in Kentucky," is confined to a general review of the nature and extent of the oil shale deposits and conclusions as to their suitability or unsuitability for the manufacture of synthetic liquid fuels.

The investigation was confined to a review of available data and no field examination was made.

PART II - GENERAL

Definitions Relating to Oil Shale and Oil Shale Reserves

Oil Shale is a fine-grained sedimentary rock, containing organic matter that yields oil when distilled but not appreciably when extracted with ordinary petroleum solvents. Oil shale is distinguished from certain coals by its content of more than 33 percent ash.

Reserves. Oil shale deposits are not considered as a reserve of raw material for synthetic liquid fuels manufacture and are not reported herein unless they have an oil content averaging at least 15 gallons per ton over a minimum of 25 feet in thickness, and totaling not less than 100,000,000 tons of oil shale within an area not greater than 5 square miles. (In connection with plant requirements, 25 gallons per ton is set as the lower limit to be presently considered, while the limit of 15 gallons per ton is set to include deposits of possible future importance.) Oil shale reserves are classified according to oil content as follows:

Primary Reserves include those deposits of oil shale lying in vertically continuous series of beds not less than 25 feet thick with an average Fischer assay yield of 25 gallons per ton.

Secondary Reserves include those deposits of oil shale, in addition to those in primary reserves, lying in vertically continuous series of beds (or with intervening intervals of primary reserves) not less than 25 feet thick with an average Fischer assay yield of not less than 15 gallons per ton.

Reserve Classifications - Estimates of oil shale tonnages are further classified according to the following definitions of measured, indicated, and inferred reserves. These definitions provide a basis for classifying reserves according to the relative amount of data available for estimating the reserves and serve to indicate the relative dependability of the estimate.

Measured Reserves comprise those oil shale deposits, or portions thereof, on which the available data are adequate to define the thickness, area, and richness so clearly that they are considered proved to a high degree of probability. Such reserves are estimated only for areas where the oil shale beds are continuous and have been completely measured, sampled, and assayed at core holes or surface sections. The data are sufficiently consistent and the geologic evidence so clear that the projection of these data for short distances into the areas lying between and beyond the points of measurement is justified.

Indicated Reserves comprise those oil shale deposits, or portions thereof, on which the thickness and average assay yield are based on assayed well cuttings or must be partially estimated from incomplete assay data, and from visual field estimates, correlations, and comparisons. Although these reserves are not estimated with the accuracy required for measured reserves, they may fairly be considered proved by reason of a more complete knowledge of adjacent deposits of measured reserves. Accordingly, estimates of indicated reserves may be based on projections of data on the better known measured deposits for moderate distances into these indicated areas lying between and beyond the points of measurement, when such projections are consistent with known and inferred geologic conditions.

Inferred Reserves comprise those deposits, or portions thereof, on which assay data are incomplete or lacking and assayed localities are widely separated; they are considered as possible reserves by reason of some knowledge of the deposit and a more thorough knowledge of adjacent or nearby measured and indicated reserves. These estimates depend primarily on estimated data derived from visual field estimates, correlations, and comparisons and on projections of data on better known deposits in the area for such distances as appear consistent with known and inferred geologic conditions. The reserves in this classification are regarded as provisional and are subject to possible revision as a result of further exploration.

Fischer Assay Value is an expression of the yield of oil, in gallons per ton of oil shale, as determined by the retorting of a representative sample, employing certain laboratory procedures presently adopted by the U.S. Bureau of Mines. However, most of the oil yields presented in this report are based on assays by a former "Bureau of Mines method" or methods other than the modified Fischer method.

Average Fischer Assay Value is the average of yields obtained on two or more samples from a vertically continuous series of beds, where the average has been weighted to reflect the relative thickness, but not the specific gravity of samples.

A General Area of Raw Material Availability is an area not larger than a county or 1,000 square miles, containing a sufficient recoverable quantity and quality of oil shale reserve to supply at least one synthetic liquid fuels plant, having a unit capacity of 10,000 barrels per day, for a period of 40 years. Sufficient recoverable primary reserves must be available from which 20 years' supply may be obtained, and the additional 20 years supply may be satisfied either by additional recoverable primary reserves or by recoverable secondary reserves.

Unit Plant or Unit Capacity - A synthetic liquid fuels plant for producing and refining shale oil from oil shale with a productive capacity of 10,000 barrels of liquid fuel products per day.

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Such a plant would require from 13,333 to 14,000 tons of 30-gallon-per-ton shale per day. The higher requirement is equivalent to 5,110,000 tons per year or 204,400,000 tons over a period of 40 years. The cost of such a plant, erected near Rifle, Colo., based on a preliminary estimate by the U.S. Bureau of Mines was about $33,000,000 in November, 1949.

Source of Information

The data and conclusions presented in this report are based on a review of numerous publications describing oil shale-bearing formations and general geologic conditions; particular attention was paid to publications of the United States Geological Survey, the Kentucky Geological Survey, and geological surveys of various other states. Unpublished data have been obtained from the Bureau of Mines and from the files of the Subcontractor. The publications containing specific data presented in this report are listed in the Bibliography forming Exhibit No. C-3, and the reference numbers indicated on this exhibit are referred to in the text of the report by number as (Ref. 1), (Ref. 2), etc.

Survey Area

The area investigated and reported herein comprises the State of Kentucky.

PART III - STUDY OF SURVEY AREA

General Geologic Conditions

The dominant structural feature of Kentucky is the Cincinnati Arch, which traverses central Kentucky in a north-northeasterly direction. In northern Kentucky, the Cincinnati Arch divides into two limbs: the west limb extends northward into Indiana and there forms the Kankakee Arch; the east limb extends northward into Ohio and is there known as the Cincinnati Arch.

Formations on the west flank of the Cincinnati Arch in Kentucky dip westerly into the western Kentucky coal basin, whereas formations on the eastern flank of the Arch dip southeasterly into the Appalachian geosyncline. In the extreme southwestern corner of Kentucky, Cretaceous and Tertiary formations dip southwesterly into the Mississippi Embayment province.

The east-west trending Rough Creek fault zone, comprising numerous faults of varying magnitude, cuts across the western Kentucky coal basin. On the east flank of the Cincinnati Arch, the Kentucky River fault zone, comprising numerous faults which are generally of lesser magnitude than those of the Rough Creek fault zone, cuts across northeastern Kentucky. The Pine Mountain overthrust, comprising an area of extremely deformed rocks, occurs in extreme southeastern Kentucky.

The age of exposed formations ranges from mid-Ordovician to Recent, but formations of Permian, Triassic, and Jurassic age are absent. Pre-Mississippian formations outcrop in a circular area around the crest of the Cincinnati Arch in north-central Kentucky; this area comprises the Blue Grass region of Kentucky, and the New Albany shale, outcropping around the margin of the area, forms the Knobs region. On the east and west flanks of the Cincinnati Arch and throughout the remainder of Kentucky, the principal outcropping formations are of Mississippian and Pennsylvanian age. The outcrop of Cretaceous and Tertiary formations is limited to the Mississippi Embayment area in extreme southwest Kentucky. Pleistocene and recent alluvial deposits occur locally in river and stream valleys, and glacial drift occurs in a small area in the northernmost portion of the State.

New Albany Shales. The New Albany shale is the principal oil shale-bearing formation in Kentucky; minor thicknesses of oil shale are also known to occur in the Sunbury formation, which is often included in the New Albany and in association with Pennsylvanian coal-bearing formations.

Geology. The New Albany shale is the principal oil shale-bearing formation in Kentucky. The formation consists predominantly of black, fissile, somewhat tough and slaty bituminous shales with interbedded softer, gray calcareous shales which are less fissile and bituminous (Ref. 4) (A). A few thin locally persistent beds of phosphate nodules and small cone-in cone structures occur within the formation. In the southeastern outcrop area the basal facies of the formation contain predominantly gray shales, calcareous shales, limestones, or dolomites.

The formation is generally overlain by the Bedford shale, which is a blue clay shale, often silty and containing interbedded siltstone and greenish gray sandstone. Where the Bedford shale and the overlying Sunbury shale are extremely thin and not readily identified, they are often included in the New Albany shale, in which case the New Providence, which is a soft gray to green clay shale, is regarded as the overlying formation. The New Albany shale is generally underlain by limestones of Devonian age.

In Kentucky, the formation is also known as the Ohio shale in much of the area east of the Cincinnati Arch and as the Chattanooga shale in south-central Kentucky. The New Albany of Kentucky is more or less equivalent to the New Albany of Indiana and Illinois, the Ohio shale of Ohio, and the Chattanooga of Tennessee. Although these formations comprise an extensive and more or less continuous series of black shale, they are not of the same age everywhere and may be either Devonian or Mississippian age, or both. Cambell (Ref. 4) (A) and others indicate that the upper portion is of Mississippian age and that the lower portion is of Devonian age.

In Kentucky and adjacent states, the New Albany shale and its equivalents have been the subjects of many detailed lithologic and paleontologic investigations, and some investigators have made detailed subdivisions of the New Albany. These subdivisions will not be discussed here but they indicate that persistent zones of predominantly nonbituminous, lean, gray shales and siltstones occur associated with the black fissile shales of the formation.

The New Albany shale produces gas in many fields in eastern Kentucky and it has been estimated that more than half of the gas produced in Kentucky is from the New Albany shale.

Bedrock Outcrops. Bedrock outcrops of New Albany shale, comprising areas within which the formation is exposed at the surface or is overlain by unconsolidated sediments, form a Y-shaped outcrop pattern, straddling the Cincinnati Arch, as shown on the map, Exhibit No. C-1. The formation is absent in the crestal area of the Cincinnati Arch in north-central Kentucky, and the outcrops occurring along the flanks of the Arch comprise the Knobs region of Kentucky. The formation dips below the surface on the east and west sides of the Arch and underlies the greater portion of the remainder of the State.

Note: (A) For references see Exhibit No. C-3

Structure. The New Albany shale outcropping on the flanks of the Cincinnati Arch dips westward at the rate of approximately 50 feet per mile into the Western Kentucky coal basin and eastward at the rate of approximately 40 feet per mile into the Appalachian geosyncline, as shown by structural contours on Exhibit No. C-1. The formation occurs at a depth of approximately 3,500 feet below sea level in the deeper part of the Western Kentucky coal basin and at about 2,000 feet below sea level in the Appalachian geosyncline.

The Rough Creek fault zone and the Kentucky River fault zone, comprising numerous faults of varying magnitude, have resulted in complicated local structures.

Thickness. The New Albany shale along its outcrop varies in thickness from a feather edge to in excess of 100 feet. On the west flank of the Cincinnati Arch, the New Albany shale is 104 feet thick at the Ohio River near Louisville (Ref. 4)(A) and thins southeastward toward the axis of the Cincinnati Arch, being 60 to 90 feet thick in Marion County and about 45 feet thick in Casey County (Ref. 16) (A). On the east flank of the Cincinnati Arch, the formation is 301.5 feet thick along the Ohio River near Vanceburg (Ref. 4) (A) and likewise thins southeastward toward the axis of the Cincinnati Arch, being about 45 feet thick in Casey County. Outcrops along the axis of the Cincinnati Arch in south-central Kentucky vary between 20 and 50 feet in thickness.

Exploratory wells drilled for oil and gas indicate that the formation thickens basinward, reaching a reported thickness of 400 feet in Caldwell County in the Western Kentucky coal basin (Ref. 13)(A) and reaching a thickness of nearly 1,200 feet in Pike County in the deeper part of the Appalachian geosyncline (Ref.16) (A).

Oil Shale Reserve Estimates

In 1921, Jillson (Ref. 12)(A) stated that the Devonian black shales of Kentucky contained 12.308 billion barrels of recoverable oil. This estimate assumed that minable shales existed in an area of 953 square miles. Although stating that the thickness of the shale varied from 20 to 45 feet, and that the few samples assayed had an average specific gravity of 2.173, the exact figures for thickness and specific gravity used in Jillson's estimate were not given; an average oil yield of 16.08 gallons per ton was assumed in the estimate.

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In 1922, Crouse (Ref. 5)(A) estimated that 90 billion tons of shale amenable to quarry-type mining methods in Kentucky contained 40 billion barrels of oil.

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Note: (A) For references see Exhibit No. C-3.

In 1925, Crouse (Ref. 6) (A) stated that the areas in which the shales outcropped had been estimated to contain 100 billion tons of black shales, and as he estimated these shales would have an average yield of 21 gallons per ton, 50 billion barrels of oil were contained in the black shales of Kentucky.

In 1928, Winchester (Ref. 18) (A) estimated that the Devonian black shales of Kentucky contained 10.979 billion barrels of oil, of which 9.881 billion barrels were recoverable. Winchester's estimate included all shales greater than 1 foot in thickness which would yield more than 10 gallons of oil per ton, at least 2,000 barrels of oil per acre, and considered only those shales amenable to surface mining methods.

The most recent investigations have indicated that the average yield of oil shales in Kentucky will be substantially less than the average yield of 16 to 21 gallons per ton used by Jillson and Crouse in their estimates and that their estimates are untenable. Based on the minimum requirements of this survey, none of the oil shales of Kentucky may be classed as a reserve.

Previous Investigations

Investigations of the oil yield of Kentucky oil shales may be considered in two chronological groups: the work conducted between the years 1917 and 1925; and investigations carried on during the years 1944 and 1948. Most of the early work, reported on by Jillson and Crouse, resulted in conclusions indicating a higher oil yield for the New Albany shale than has been determined by the more thorough sampling reported by Herbert and Gardner in the more recent investigations.

In 1917, George H. Ashley (Ref. 2) (A) reported that a New Albany shale sample representing an 8-foot interval at Locality No. 26 in Jefferson County, yielded 11.2 gallons per ton. The two samples of shales associated with coal-bearing formations had reported yields of a trace and of 14 gallons per ton.

In 1919, Dean E. Winchester (Ref. 17) (A) reported that a hand specimen of New Albany shale from Locality No. 13 in Estill County yielded 7 gallons per ton.

In 1921, Willard R. Jillson (Ref. 12) (A), Kentucky State Geologist presented assay data on 22 random samples of Devonian black shale collected and assayed by C.S. Crouse; only the location and yield of these samples are available. The reported oil yield of these random samples ranged from 5.00 to 27.75 gallons per ton and averaged 15.9 gallons per ton. Assay data were also presented on two samples of shales associated with coal-bearing formations; these two samples had reported yields of 8.25 and 17.25 gallons per ton.

Note: (A) For references see Exhibit No. C-3.

In 1922, Victor C. Alderson (Ref. 1) (A) reported that a random sample of shale from Locality No. 8 in Clay City, Powell County, Ky., assayed 17 gallons per ton when tested at the Colorado School of Mines.

In 1923, Charles R. Fettke (Ref. 8) (A) reported on the yields of five Chattanooga shale samples collected from two localities. Four of these samples were also from Locality No. 8 in Power County and had an average yield of 14.3 gallons per ton, while the fifth sample from Locality No. 6 in Montgomery County had a reported yield of 8.6 gallons per ton.

In 1924, during investigations of the qualities of shale oil, personnel of the United States Bureau of Mines (Ref. 3 and 10) (A) assayed four selected samples of shale from Locality No. 8 in Powell County. The average yield obtained on these four highly selected samples was 16.98 gallons per ton.

In 1925, Charles S. Crouse (Ref. 6) (A) reported that he had assayed many additional shale samples subsequent to those reported by Jillson in 1921, and although he did not report the assay yields obtained, he concluded that the black shales of Kentucky would more likely average 21 gallons per ton rather than 16 gallons per ton as previously reported.

During 1944, Professor C.S. Crouse accompanied Bureau of Mines Engineers (Ref. 11) (A) to several of the localities southeast of the City of Lexington where his earlier work had indicated that the richest shales occurred. Eight channel samples of the New Albany shale at seven of these localities had oil yields ranging from 1.8 to 14.2 gallons per ton; the weighted average yield of the 80 feet of section represented by these samples was 7.2 gallons per ton. These samples, the first Kentucky samples assayed by the modified Fischer method indicated that the oil yield of New Albany shale in Kentucky is quite comparable to yields obtained from the black shales in neighboring states of Indiana, Ohio and Tennessee rather than in the range of 16 to 21 gallons per ton as indicated by Jillson and Crouse.

In 1948, E.D. Gardner (Ref. 9) (A) obtained three samples from a 32.5-foot section of the New Albany shale at Locality No. 14 in Estill County. These samples were assayed by the modified Fischer method, and the oil yields ranged from a trace to 3.5 gallons per ton, with a weighted average yield of 2.1 gallons per ton. The 32.5-foot section sampled by Gardner underlay a 25-foot section from which Herbert had reported that a sample yielded 8.7 gallons per ton.

Note: (A) For references see Exhibit No. C-3.

Classification of Data

While assay data are available on a total of 45 New Albany shale samples from Kentucky, only 12 samples, 1 reported by Ashley, 8 reported by Herbert, and 3 reported by Gardner, present sufficient data to provide a basis for evaluating the thickness and richness of the New Albany shales. These 12 samples are from 8 localities, and only at Locality No. 14 in Estill County has a relatively complete section been sampled. Seven of these localities occur along the outcrop in a limited geographic area lying southeast of the City of Lexington.

The remaining 33 samples assayed prior to 1926 are random samples on which little or no data are available as to the thickness of formation exposed at the locality, the thickness of the interval represented by each sample, the sampling method, nor the portion of the formation from which the sample was obtained. Random samples frequently represent selected portions of rich shale beds which are resistant to weathering and more readily sampled at the outcrop. It must be assumed that the high average yield of 16 to 21 gallons per ton reported by early investigators are the result of sampling selected, thin, rich beds and that the yields obtained cannot be considered representative of an appreciable thickness of the formation. This view is supported by the low yields obtained on recent samples reported on by Herbert and Gardner in areas where early investigators had indicated the presence of rich shales.

The usable data are too limited and so poorly distributed geographically that they do not provide a basis for evaluating the average thickness and richness of the New Albany shales in Kentucky. However, data are available on the results of surface sampling and core drilling of the formation in the adjacent states of Indiana, Ohio, and Tennessee. These more complete data on neighboring states indicate that the yield of the New Albany shale section is in the magnitude of 5 to 10 gallons per ton, which appears to be consistent with yields obtained by Herbert and Gardner.

Assay data are also available on a total of four samples of shales associated with coal-bearing formations of four localities.

All of the available assay data from the foregoing sources are tabulated on Exhibit No. C-2, and the localities at which the samples were obtained are indicated on the map, Exhibit No. C-1. Only the pertinent data on the eight New Albany shale localities sampled by Ashley, Herbert and Gardner and the four localities at which shales associated with coal-bearing formations were sampled are summarized in the text.

New Albany Shale - Assay Data

Summarized below are the results of sampling and assaying at the eight localities in Kentucky on which relatively complete data are available together with comments on the yield of the New Albany shale or its equivalents in adjacent states.

Seven of the localities occur along the eastern outcrop belt in a limited geographic area lying southeast of Lexington in Montgomery, Powell, Estill, and Madison Counties. The New Albany shale in this area ranges from 100 to 200 feet in thickness, of which up to one-third, the basal section, contains predominantly nonbituminous gray shales, calcareous shales, and limestones (Ref. 4)(A).

Herbert (Ref. 11) (A) reported that a sample of a 5-foot section from Locality No. 5 in Montgomery County, taken from the Consolidated Oil Shale Corporation of Pittsburgh's abandoned quarry, yielded 14.2 gallons per ton. Jillson (Ref. 12)(A) had earlier reported that a random sample from this locality yielded 19 gallons per ton, 34 percent higher than a yield obtained on Herbert's sample. Herbert's data indicate that this 5-foot sample was obtained from the basal New Albany shale above a limestone bed, but do not give the thickness of shale section overlying the sampled interval.

Locality No. 8, near Clay City in Powell County, is the location at which the Devon Oil Shale Corporation quarried the New Albany shale for a short period during the 1920's. It is from this locality that 10 random samples were secured for assay by the Colorado School of Mines, the United States Bureau of Mines, and others. These 10 random samples had an average yield of 17.1 gallons per ton but cannot be considered representative of any appreciable interval of the New Albany shale. A sample secured by Herbert (Ref. 11)(A) at the same locality in 1944 and which represented an interval of 5 feet assayed only 4.8 gallons per ton.

Herbert (Ref. 11)(A) reported that a sample of the uppermost 25 feet of New Albany shale at Locality No. 9 in Powell County assayed 8.0 gallons per ton.

Locality No. 10, in Estill County, was sampled at a roadcut in the town of Hargett. Herbert reported that this sample, which represented a 5-foot section of partly weathered shale, assayed 1.8 gallons per ton.

At Locality No. 12 in Estill County, Herbert reported that two samples, each representing a 5-foot section within the total 35-foot New Albany shale section exposed in a quarry, yielded 2.4 and 3.0 gallons per ton.

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Note: (A) For references see Exhibit No. C-3.

Locality No. 14, also in Estill County, and located at a railroad cut along Cow Creek in the town of Ravenna, has been sampled more completely than any other locality in the State. Herbert reported that a sample representative of the uppermost 25 feet of New Albany shale at the locality yielded 8.7 gallons per ton. Gardner (Ref. 9)(A) obtained three samples representative of three successive intervals underlying the section sampled by Herbert; Gardner reported a yield of 3.5, a trace, and 2.9 gallons per ton on these three samples. The weighted average yield of the four samples representing the 57.5 feet of New Albany shale exposed at this locality is 5.0 gallons per ton.

Locality No. 15 in Madison County was sampled at a railroad cut and Herbert reported a yield of 5.4 gallons per ton for this sample which represented the lowermost 5 feet of New Albany shale exposed. A random sample from the Berea College campus, in the same area, was reported by Jillson to have yielded 18.5 gallons per ton.

Locality No. 26 is located on the western outcrop belt within the City of Louisville in Jefferson County. The New Albany shale in this area is 104 feet thick. The middle one-third of the formation, composed of a zone of alternating layers of black and gray shales is leaner than the black shales above and below. Ashley (Ref. 2)(A) reported that a sample representing an 8-foot section of New Albany shale exposed in a canal at this locality yielded 11.2 gallons per ton.

It is concluded from the limited data available that the New Albany shale in Kentucky is of insufficient richness and thickness to meet the minimum requirements of this survey. This view is supported by the results of investigations of oil shales in adjacent states.

The results of core drilling and surface sampling in the adjacent states of Indiana, Ohio, and Tennessee indicated that the yield of the New Albany shale, or its equivalent, ranges from a trace to 16.2 gallons per ton and that the average yield of complete sampled sections of the formation is generally in the range of 5.5 to 8.5 gallons per ton. These data further indicate a general relationship of relatively high yields in the upper and lower sections of the formation with lower yields in the middle.

The Louisville Cement Company corehole, located only 8 miles north of Louisville, Ky., in Clark County, Ind., penetrated a 98.5-foot New Albany shale section. The oil yield varied from 1.9 to 13.4 gallons per ton and the weighted average yield was 8.2 gallons per ton.

On the east side of the Cincinnati Arch, the Chillicothe corehole, located 50 miles north-northeast of Vanceburg, Ky., in Ross County, Ind., penetrated a 376-foot Ohio shale section which yielded from 0.25 to 14 gallons per ton and averaged 5.5 gallons per ton.

Note: (A) For references see Exhibit No. C-3.

About 45 miles south of the Kentucky-Tennessee State line in De Kalb County, Tenn., a corehole and surface section averaging about 32 feet in thickness yielded from a trace to 12.7 gallons per ton and averaged approximately 6.6 gallons per ton.

Shales Associated with Coals - Assay Data

Limited data are available on the oil yield of shales associated with coal-bearing formations of Pennsylvanian age. Four random samples from four different localities have been reported as assayed; two samples were reported by Jillson (Ref. 12)(A) and two samples have been reported by Ashley (Ref. 2)(A).

Locality No. 1 in Elliott County is located in the Appalachian geosyncline in eastern Kentucky and a yield of 17.25 gallons per ton is reported on the random sample from this locality.

Localities Nos. 2, 3, and 4 in Webster, Union, and Crittenden counties are all located in the Western Kentucky coal basin; yields of 8.25, a trace, and 14 gallons per ton, respectively, are reported for the three random samples from these three localities.

The above data on these random samples are too meager to evaluate the shales found associated with the Pennsylvanian coal-bearing formations; however, it is known that these shales are extremely thin, seldom exceeding a very few feet in thickness. It is concluded that none of these shales meets the minimum requirements of an oil shale deposit used in this survey.

Note: (A) For references see Exhibit No. C-3.

PART IV - CONCLUSIONS

The New Albany shale is the principal oil shale-bearing formation in Kentucky. Oil shales also occur in the Sunbury formation and in shales associated with the Pennsylvanian coal-bearing formations.

A review of the limited usable data available, which is poorly distributed geographically, together with data on adjacent states, indicates that none of these shales is of sufficient richness and thickness to provide a source of raw materials for synthetic liquid fuels manufacture. It does not appear that additional sampling and assaying would reveal the presence of shales meeting minimum requirements.

It is concluded, therefore, that there are no oil shale reserves in the State of Kentucky suitable for use as a source of raw materials for synthetic liquid fuels manufacture.


EXHIBIT NO. C-1
STATE OF KENTUCKY
DATA ON OIL SHALES
SCALE OF MILES
10 0 10 20 30 40
DeGOLYER AND MacNAUGHTON DALLAS, TEXAS
SEPTEMBER, 1950
LEGEND
Bedrock Outcrop of New Albany Shale
New Albany Shale Locality
Shales Associated With Coals
Generalized Contours on Top of New Albany Shale Sea Level Datum
Fault
NORTHERN KENTUCKY
MATCH LINE
WEST LIMB OF ARCH
EAST LIMB OF ARCH
ROUGH CREEK FAULT ZONE
KENTUCKY RIVER FAULT ZONE
CINCINNATI ARCH
PINE MOUNTAIN OVERTHRUST
50 Miles From Vanceburg To Chillicothe Corehole
Louisville Cement Co. Corehole Clark Co., Indiana
OHIO
INDIANA
ILLINOIS
MISSOURI
WEST VIRGINIA
VIRGINIA
TENNESSEE
OHIO RIVER
MISSISSIPPI RIVER
Louisville
Frankfort
Lexington
Owensboro
Paducah
Vanceburg
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Data on the Oil Shales of the State of Kentucky, September 1950

Locality Number	County	General Location	Thickness Exposed (Feet)	Thickness Sampled (Feet)	Number of Samples	Average Yield (Gal/Ton)	Bibliography Reference Number	Bibliography Reference Page	Bibliography Reference Sample Number	Remarks
New Albany Shale										
1	Lewis	1-1/2 miles from Vanceburg on the Maysville Road	*	*	1	10.25	12	15	11	
2	Fleming	Near top of first mountain east of Ringo's Mill	*	*	1	21.5	12	14	8	Random sample taken near top of formation.
3	Rowan	Rowan County Freestone Company's Quarry	*	*	1	12.5	12	19	17	
4	Bath	About 1/2-mile from Salt Lock on Caney Road	*	*	1	11.25	12	13	1	Random sample taken about 25 feet above base of formation.
5	Montgomery	Central Oil Shale Corporation of Pittsburgh's abandoned quarry on Town Branch Road, 9 miles east of Mt. Sterling	*	5	1	14.2	11	9	5	Very hard slightly weathered shale which grades downward into a dense gray limestone lying immediately above the Corniferous limestone.
		Ditch alongside Old Town Road, about 8 miles east of Mt. Sterling	*	*	1	19	12	17	15	Random sample taken near base of formation.
6	Montgomery	Outcrop near Means Post Office	*	*	1	8.6	8	91	109	
7	Clark	Old road quarry about 1/2-mile east of Indian Fields on Westchester-Clay City road.	*	*	1	11	12	14	5	
8	Powell	Devon Oil Shale Corporation's abandoned quarry, about 1 mile west of Clay City on the north bank of the Red River	*	5	1	4.8	11	9	4	Well-weathered shale lying 15 to 20 feet above the top of the Corniferous limestone.
			*	*	1	17	1	6	-	
			*	*	4	14.3	8	91	110	
			*	*	1	16.75	12	17	17	
			*	*	2	18.22	10	28	1006	
			*	*	2	15.73	3	16	7	
9	Powell	East end of Turkey Knob at junction of State Highway 15 and Hatten Creek road, about 3 miles southeast of Clay City.	*	25	1	8.0	11	9	3	Uppermost portion of shale exposed beneath Waverly shaly sandstone.

Note: * No data available.

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Data on the Oil Shales of the State of Kentucky, September 1950

Locality Number	County	General Location	Thickness Exposed (Feet)	Thickness Sampled (Feet)	Number of Samples	Average Yield (Gal/Ton)	Bibliography Reference Number	Bibliography Reference Page	Bibliography Reference Sample Number	Remarks
New Albany Shale (Continued)										
10	Estill	Roadside cut near east end of bridge on State Highway 89 over L. & N. R.R. at Hargett	*	5	1	1.8	11	10	6	Section of partly weathered shale 15 feet above Corniferous limestone; contained 1.5 feet interbedded limonitic, gray, and brown shales.
11	Estill	About 2 miles from Irvine on opposite side of Kentucky River from the road to Richmond	*	*	1	22	12	14	7	
12	Estill	Quarry in the City of Irvine, 1/4-mile east of the court house on State Highway 52	15	0	0		11	9		Exposed quarry face; base of section 30 feet above top of Corniferous limestone.
			5	5	1	2.4	11	9	2	
			10	0	0		11	9		
			5	5	1	3.0	11	9	1	
			35	10	2	2.7				Totals and average of section.
13	Estill	Small quarry 1 block southeast of courthouse in Irvine	120	*	1	7	17	52	198	Random sample taken about 25 feet above the base of the formation.
14	Estill	Railroad cut at east end of bridge over Cow Creek, 1/2-mile east of U.S. Lock 12, in City of Ravenna	25	25	1	8.7	11	10	7	Section exposed between overlying Waverly formation and water's edge. Represents most complete sampling in State of Kentucky
			13	13	1	3.5	9	19	1	
			11.5	11.5	1	Trace	9	19	2	
			8	8	1	2.9	9	19	3	
			57.5	57.5	4	5.0				
15	Madison	Railroad cut below viaduct on U.S. Highway 25 at Berea.	*	5	1	5.4	11	10	8	Basal portion of 30-foot roadcut.
		Berea College campus	*	*	1	18.5	12	16	13	
16	Garrard	Copper Creek at Copper Creek Road on Garrard-Rockcastle County line	*	*	1	21	12	15	9	
17	Rockcastle	Roadcut on south side of Gum Sulphur Creek on Boone Highway at Gum Sulphur	*	*	1	8	12	17	18	
18	Boyle	Quarry on north side of road on western edge of Junction City	*	*	1	11	12	13	2	
19	Lincoln	About 1 mile from Milledgeville alongside Black pike	*	*	1	15.5	12	16	12	
20	Casey	About 1/4-mile west of Gap-in-the-Knobs along Huntsville-Bradfordsville pike	*	*	1	18	12	14	4	

Data on the Oil Shales of the State of Kentucky, September 1950

Locality Number	County	General Location	Thickness Exposed (Feet)	Thickness Sampled (Feet)	Number of Samples	Average Yield (Gal/Ton)	Bibliography Reference Number	Bibliography Reference Page	Bibliography Reference Sample Number	Remarks
New Albany Shale (Concluded)										
21	Taylor	Outcrop in Robinson Creek near Mansville	*	*	1	27.75	12	17	20	
22	Marion	Quarry in Ryder's cemetery 1/2-mile east of Lebanon on Danville road	*	*	1	16	12	16	14	
23	Nelson	Quarry on top of a hill, 1 mile from Boston on Bardstown road	*	*	1	19	12	17	16	
24	Bullitt	Railroad cut at gap in the Knobs, where L. & N. R.R. crosses Louisville-Shepherdsville road near Shepherdsville	*	*	1	5	12	13	3	
25	Jefferson	One mile south of Twin Oaks Park on Ash Bottom road	*	*	1	15.5	12	15	10	
26	Jefferson	West end of canal at Louisville	8	*	1	11.2	2	11	314	
-	Estill	Not available	*	*	3	16.5	12	20	1,2, & 3	Data on location of sampling as well as the interval sampled is not given in reference.
Shales Associated with Coals										
1	Elliott	Branch at the head of Corn Hollow of headwaters of Big Sinking Creek	100	*	1	17.25	12	14	6	Sample of bituminous shale section in Lower Pottsville formation.
2	Webster	Near Tilden	*	*	1	8.25	12	18	21	Sample of shale in Pottsville formation.
3	Union	At Caseyville	*	*	1	Trace	2	314	13	Sample of shale 50 feet above Bell coal.
4	Crittenden	Barnaby Mine	*	*	1	14	2	314	12	Sample of "so-called coal rash or mother of coal associated with the coal bed."

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We, the undersigned subcontractors have read and are severally familiar with the over-all contents of this report on The Synthetic Liquid Fuel Potential of Kentucky. Each of us individually approves, by his appended signature, of the report as written, insofar as it relates to conditions, conclusions, and recommendations with respect to the raw material forming his responsibility under his subcontract.

COAL

Paul Weir Company

Paul Weir Company, Incorporated

NATURAL GAS

De Golyer and MacNaughton

DeGolyer and MacNaughton

OIL SHALE

De Golyer and MacNaughton

DeGolyer and MacNaughton

WATER

Malcolm Pirnie Engineers

Malcolm Pirnie Engineers

OIL-IMPREGNATED STRIPPABLE DEPOSITS

Max W. Ball

Max W. Ball