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THE HANFORD NUCLEAR ENERGY CENTER
A PRELIMINARY CONCEPTUAL STUDY

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Battelle

Pacific Northwest Laboratories
Richland, Washington 99352

JANUARY 25, 1974

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Under Contract AT(45-1)-1830

THE HANFORD NUCLEAR ENERGY CENTER
A PRELIMINARY CONCEPTUAL STUDY

by

The Staff of Battelle,
Pacific Northwest Laboratories

January 1974

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SECTION I

EXECUTIVE SUMMARY

I. EXECUTIVE SUMMARY

A. THE CONCEPT

A scenario was developed for a Hanford Nuclear Energy Center (HNEC) concept to evaluate potential benefits and problems of nuclear energy centers (NEC) which might be built on Federal properties. The study was made in response to the Atomic Energy Commission's request to determine whether NEC's offer potential for meeting the nation's energy requirements faster, cheaper, or more effectively than present reactor siting methods. The concept was examined in the context of two hypothetical cases: 1) the operation of up to two 1300 MWe reactors each year starting in 1979, termed the accelerated case, and 2) the operation of two 1300 MWe reactors each year starting in 1982, termed the normal case. Both of these cases are in addition to presently planned thermal power plants at Hanford.

By 1985 these hypothetical cases would result in a generating capability of about 20,000 MWe for the accelerated case, and about 13,000 MWe for the normal case. By 1990 these figures would be approximately 34,000 and 26,000 respectively; it is assumed that additional capacity could be added beyond that date. The scenario for the HNEC includes an enrichment plant added in 1982 and capable of supplying the needs for over 60,000 MWe of installed nuclear capacity and in 1986, a spent fuel reprocessing plant would be added. A privately owned fuel fabrication plant is already located adjacent to the Hanford site. This plant would be enlarged, or additional plants would be built onsite to supply the fuel requirements of the HNEC (including the needs for plutonium recycle) and other markets. All plutonium produced by HNEC reactors would remain on the HNEC and would be used as enrichment material for the HNEC reactors along with plutonium that has been separated from the incoming fuels of other nuclear plants. Onsite radioactive waste treatment and storage facilities (Federal Repository) would be available as required. Reactor generating capacity would be owned and operated by both public and investor-owned utilities in the Pacific Northwest (PNW). Fuel reprocessing, fabrication, and waste management plants would be operated by investor-owned energy firms. Ownership

of the enrichment plant(s) would depend on future national decisions. Several or more large electricity-consuming industries would locate on or adjacent to the HNEC and some waste heat would be used in special food-related industries.

This study has been limited, in large part, to an examination of the potential benefits and problems of an NEC located at Hanford. A similar study of other alternatives for the PNW (e.g., dispersed siting of reactor facilities) is needed before it can be concluded that the potential benefits and problems of the HNEC are compelling or unique.

The practicality of bringing two large reactors on-line in 1979 (the accelerated case) has not been established. A Federal statement of need, probably supported by priority actions in areas of siting and licensing, and perhaps in materials procurement would be needed as a minimum. Achieving two reactors on-line by 1982 (the normal case) is probably feasible without the above priority actions in these areas.

The need for such massive amounts of electrical power as projected in the two cases has not been established. The PNW utilities are constructing or planning generating facilities to meet load forecasts through the mid-1980's.

The potential impact and problems and benefits of an HNEC, and the practicality of realizing the preceding scenario are described in the following sections.

B. POTENTIAL IMPACT OF HNEC ON REGIONAL ENERGY NEEDS

The HNEC could supply the PNW region's additional electrical base-load needs through 1990 (estimated at about 18,000 MWe). Alternatively, a portion of the region's electrical needs could be supplied by the HNEC with the remainder supplied by presently planned or future plants located elsewhere in the region. The HNEC's remaining power could be used for 1) fuel cycle facility needs at the HNEC, 2) electricity-intensive industry development adjacent to the HNEC, 3) substitution of electrical energy for petroleum use, and 4) energy export to the other regions.

For the accelerated case one allocation of electrical energy in 1990 might be approximately as follows:

- Regional growth - 6000 MWe
- HNEC fuel cycle facilities - 4000 MWe
- Industrial facilities - 5000 MWe
- Petroleum substitution - 6000 MWe
- Regional export - 5000 MWe

The 6000 MWe for petroleum substitution, if realized, could lessen petroleum requirements in the PNW by about 175,000 barrels of oil equivalent per day.

Development of nuclear electrical generation capability beyond forecasted needs appears to require a statement of national policy (and perhaps Federal implementation assistance) promoting the substitution of electrical energy for petroleum.

C. MAJOR INSTITUTIONAL CHANGES REQUIRED FOR AN HNEC

There appear to be no significant institutional problems for utilities who choose to locate their reactors in an HNEC; public utilities now are locating reactor plants at Hanford. However, if utilities are required to provide additional power beyond their projected needs (e.g., resulting from a national policy of encouraging change from petroleum use to electrical use) some institutional arrangements are needed which relieve the financial burden that excess capacity (to utility needs) places on them.

The extremely large capital investment that the HNEC would create in several counties in Washington requires examination of existing methods of taxing such facilities and/or sharing of such revenues with other governmental entities throughout the PNW. The influx of population to these counties might require support for community facilities during the period of impact. For private ownership of enrichment plants laws would have to be amended.

D. ATOMIC ENERGY COMMISSION RESTRICTIONS ON USE OF THE HANFORD RESERVATION

The AEC has (for a number of years) encouraged the establishment of an NEC on the Hanford Reservation as being generally compatible with the AEC's programmatic activities. The AEC reserves the right to examine on a case-by-case basis the siting of nuclear power plants or support activities (such as fuel cycle facilities) to determine that proposed facilities or operations are compatible with current operations and foreseeable programs.

Currently, the primary AEC use of the Hanford Reservation is related to the LMFBR Program, production of nuclear materials, waste management activities, and life sciences and environmental R&D programs.

E. ENVIRONMENTAL IMPACTS OF HNEC

It appears environmentally acceptable to site at least 24 reactor plants in the HNEC in the period to 1990. The reactors could be cooled with Columbia River water by evaporative cooling towers, and by cooling ponds. No discernible damage to Columbia River biota was caused by heat from the old plutonium production reactors, and direct cooling of several of the proposed power reactors likewise should have no significant effect. Should future environmental standards not permit once-through cooled plants, the other two methods could assume the heat dissipation load. It should be noted that the Hanford environment has been well studied. The ability exists to predict environmental impacts by using existing models for assessing environmental impacts.

The Hanford site may be almost unique (in size, water availability and other characteristics) among sites available in the U.S. for a major buildup of nuclear facilities. Thus, care should be taken in extrapolating conclusions in this report to other, less well endowed sites.

F. COSTS AND SAVINGS

An estimated cost savings of 5 to 10% of the capital cost of the reactor plants appears likely from the continuity of construction activities, standardization, and modularization possibilities at the HNEC compared to

single and multi-unit dispersed plants. Modest operational savings appear possible, though larger potential savings, which might accrue from fuel cycle optimization and innovation, have not been evaluated. Transmission costs are higher than for dispersed plants nearer to load centers in the PNW by an estimated 0.3 to 0.4 mill/kW-hr. Transmission costs for inter-region energy transfer have not been estimated.

The following major nuclear related costs would be incurred for the HNEC for the scenario described:

	Accelerated Case \$ Billion	Normal Case \$ Billion
Reactor Plants	14.6	11.7
Fuel Cycle Facilities	1.67	1.14
Transmission Facilities	0.7	0.7

G. RISKS FROM THE HNEC

Centralizing in one location (albeit spread over ~600 miles) a major electrical generation facility potentially comprising a large portion of the region's loads constitutes a risk of major load reduction from common-mode failures (e.g., natural occurrences such as earthquakes). A preliminary, qualitative study suggests that the risks can be made acceptably low. The large peaking capacity of the PNW hydro system which could be used for emergency short-term backup generation in case of a major HNEC outage, and the highly capable and flexible transmission grid system in the PNW tend to reduce the risk. However, the PNW load shedding policy might need to be re-examined to handle any sustained, major generating loss from the HNEC.

All plants are proposed to be located above the maximum credible flood level. In case it is deemed necessary to protect against failure of Grand Coulee Dam, options exist to control floods to acceptable levels.

H. REQUIRED RESEARCH AND DEVELOPMENT

The HNEC does not appear to depend on the development of new equipment, technology, or analytical techniques, though a large number of engineering and environmental studies and investigations would be needed to support the development of the HNEC. Some R&D may be identified as a result of the studies and investigations (e.g., to reduce risks of major outages in plants or transmission systems). The principal technical uncertainties relate to the environmental impact of heat releases accompanying massive electrical generation. These would probably have to be quantified before environmental clearance could be sought for the entire HNEC concept.

I. OTHER CONSIDERATIONS

1. Sufficient skilled manpower (e.g., pipefitters) does not exist in the PNW to man the HNEC at peak construction employment periods for the two-reactor a year cases. A special training program would have to be initiated to provide the necessary skills in a timely manner. Further, it would be critically important that the HNEC not deprive other reactor construction projects in the PNW of needed craftsmen.
2. It is questionable whether domestic manufacturing capacity exists for the steel reactor pressure vessels (for LWR's) to meet HNEC needs in the accelerated case.
3. A peak construction work force of about 21,000 is projected for the two reactor per year case for HNEC. Assistance to local communities in the areas of housing, public facilities, and transportation, may be required. A further impact may occur after construction declines unless adequate industry locates in the region.

J. NEXT ACTIONS REQUIRED

If it is decided to proceed with the implementation of the HNEC to bring plants on-line in 1979:

1. Formal arrangements must be made with PNW utilities and related organizations to continue the HNEC development effort.
2. More detailed studies are required in facility layout, transmission design, environmental studies, contractual arrangements for use of Hanford land, acceptable arrangements for provision of fuel cycle services, community development, and other areas.
3. Environmental and institutional clearances must be initiated to permit construction activities to commence in mid-1975 and engineering activities in late 1974.
4. Discussions should be initiated with commercial energy firms to ensure the availability of adequate fuel cycle services at the HNEC.

SECTION II

INTRODUCTION

II. INTRODUCTION

The proposed Federal energy research and development program contained several areas of energy development which might produce immediate impacts on the energy shortage and could be wholly or partly financed by private industry. One of these relates to the construction of a nuclear energy center (NEC). Two potential NEC sites are being studied: one believed typical of Federal sites which might be available and one believed typical of potential utility sites which might be acquired. This report considers the former by examining the Hanford Reservation in detail.

An NEC is conceived as a site which contains many nuclear power plants (in the range of 10,000 to 40,000 MWe) plus supporting fuel cycle facilities. One underlying incentive for the NEC is the possibility of electric generating capacity increasing substantially faster than conventional siting approaches. In addition to meeting a region's electrical growth requirements, extra energy could be used as a substitute for petroleum use and for export to other regions with pressing electrical energy shortages.

The capability of an NEC to permit greater increases in electric generating capacity might result from one or more of the following possible advantages:

1. Major reduction in time required to site reactors and bring them on-line. At present, substantial time is required for site selection, environmental studies, licensing of site facilities, and satisfying public concerns about nuclear power plants. The NEC would involve an initial site selection for a large number of plants followed by in-depth site evaluation studies to license the overall site and its contained specific reactor sites. Having gone through the preconstruction and licensing activities related to siting, this time segment would be essentially eliminated from the subsequent licensing of the reactor plants on the NEC. Overall schedule savings from this and likely attendant plant standardization could well be measured in years and amount to one-third or more of the present lead time for bringing a nuclear plant on-line.

2. Reduced construction costs resulting from a relatively stable and technically sophisticated construction force responsive to special requirements of nuclear reactors. Construction forces, craftsmen, startup technicians, etc., would not have to be moved in and out of the site. The time and effort to marshal forces would be largely eliminated and a more efficient staff would be available leading, for example, to improved quality assurance.
3. More efficient operations resulting from added flexibility and ability to share costs for certain operating staff and facilities. This includes such things as sophisticated tritium removal systems, environmental surveillance programs, shutdown maintenance crews, and roads and buildings.

In addition, one can project the possibility of less overall environmental impact from an NEC. Possible sources of environmental impact would be confined to a few carefully selected and planned sites. Sharing of the environmental surveillance and control costs by many facilities on the NEC would provide relatively massive resources to monitor side effects, and employ the latest and best technology to minimize the effects on the environment.

4. The confinement to a single site of fission products, plutonium, transuranium isotopes, and wastes would add an extra degree of assurance in the handling of these materials. The risk and consequences of transportation accidents with such materials would be minimized. Fewer sites would need safeguards control and security measures to protect against potential acts of sabotage or theft of fissionable material.

Potential disadvantages of an NEC approach might relate to problems such as the following:

- Very large thermal discharges from a limited geographical area.
- Combined radiological discharges from reactor facilities and fuel reprocessing facilities.

- Common-mode failures, acts of war and sabotage, and unusual natural occurrences.
- The cost and reliability of power transmission to and from the NEC.

The objective of the study as defined by the AEC was:

" . . . to perform an analysis of nuclear energy centers to determine whether they offer any potential for meeting the Nation's energy requirements faster, cheaper or more effectively. Included in this overall objective is the need to assess the problems involved and weigh these against the potential advantages. This involves a critical evaluation of the need for nuclear energy centers, the desirability of the Federal government's involvement, and what its role should be if it does become involved."

The AEC requested the Pacific Northwest Laboratory to provide a concept of a nuclear power center at Hanford, including how it might be conceptionally organized and built, an assessment of costs, and initial investigations into the validity of the claimed advantages and the potential disadvantages. This report is in response to the above request. The ground rules for the study as set by the AEC were:

- Size of Center. At least 10,000 to 15,000 MWe in the 1985 to 1990 period and up to 40,000 MWe by Year 2000.
- Size of Individual Units. Maximum size of individual nuclear reactors should be held to 1300 MWe.
- Scope of Facilities. The NEC should include power plants, reprocessing plants, fuel fabrication plants, enrichment plants, waste handling and storage plants. The extent of industrial activity on the site should be estimated based on economic factors and regional needs.
- Limitations on Ultimate Size of Center. The ultimate size will be determined by one or more of the following: ability to use the power, heat disposal, radioactive and chemical releases, transmission, effective common-mode failure.
- Construction Schedule. Construction schedule will be influenced by the availability of craft forces, the ability to provide the necessary

facilities and accommodations, and the desirability of maintaining a stabilized construction force, which can be shifted to successive plants.

How The HNEC Study Was Conducted

A cursory examination was made of the potential electrical demand in the region, construction limitations, and technical problems (e.g., heat and radiological releases). Accelerated and normal reactor construction schedules for two 1300-MWe plants each year starting in 1979 and 1982, respectively, were then assumed. These cases resulted in an installed capacity of about 13,000 to 20,000 MWe by 1985 and about 26,000 to 34,000 MWe by 1990. Auxiliary nuclear facilities, such as enrichment plants, fuel reprocessing plants, fuel preparation plants, were added as required. The impact of these many facilities at the Hanford site was then evaluated. In selected areas the concept was examined for one 1300-MWe plant/yr to round out an envelope of possibilities.

The concept of the NEC was discussed with some of the private and public utilities, and governmental agencies in the northwest. Their comments were considered in producing this preliminary conceptual study of the HNEC.

The study has necessarily been completed in a very short time. As a result not all topics have been treated to the same degree of depth. In particular, projected costs are presented only as rough estimates. Except when stated otherwise, they should be taken as 1973 dollars with no factor added for inflation.

SECTION III

CONCLUSIONS AND RECOMMENDATIONS

III. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. Data available on the Hanford site indicate that a HNEC is practical from the following standpoints:

- site availability and suitability
- cooling water availability
- radiological releases
- chemical releases
- population density
- access to a large electrical transmission system
- environmental impacts.

The necessary baseline environmental studies have already been completed and productive models developed. As much as 2 yr can probably be saved in certifying the sites as acceptable relative to nuclear safety and environmental impacts.

Special attention would have to be given to the following items to ensure adequacy for HNEC:

- atmospheric studies (especially as related to the number and spacing of wet cooling towers to minimize impacts during the winter or during adverse atmospheric conditions)
 - location of cooling ponds to minimize impact on groundwater resources
 - community services, including housing.
2. To obtain up to two 1300 MWe reactors coming on-line each year starting in 1979 (the most restrictive part of the envelope of possibilities examined) would probably require the following:
 - A Federal government statement of need supported by priority actions in areas of siting and licensing, and probably in materials procurement.
 - Initiation of construction by mid-1975, which would require initiation of site engineering studies by late 1974 and site environmental clearance by early 1975.

- Field fabrication of steel reactor vessels for LWR's until present fabricators are able to assume the load, or until other fabricators are qualified to provide suitable vessels.
- A training program to ensure adequate numbers of construction craftsmen.

Construction of two plants per year appears to be a practical limit for the HNEC.

3. The PNW utilities appear to have the necessary plants under construction or planned to meet regional electrical growth to the mid-1980's. Projected reserve shortage which may exist in the late 1970's could be increased in severity with plant construction slippage, water shortages, or major outages of large plants, but it is unlikely that a HNEC could provide significant power for this period.
4. Utilities are restricted from installing substantial generating overcapacity. Overcapacity in itself would not necessarily lead to electricity substitution for petroleum. It appears that incentives would have to be provided to accelerate the substitution of electrical power for petroleum use.
5. Cost savings for reactor construction at a HNEC are estimated at 5 to 10%. Transmission costs from a HNEC are estimated at 0.3 to 0.4 mill per kW-hr higher than for dispersed reactor plants.
6. The HNEC is a feasible method (though not the only method) of accelerating the generation of electrical power to help offset other energy shortages. Accelerated construction of dispersed plants might be feasible.
7. Based on shipping distances for irradiated fuel and the restricted public access to shipping routes at HNEC, it is concluded that the HNEC represents a significant lessening of risk to the public due to possible transportation accidents. There would be a similar lessening of risk in plutonium handling and shipping.
8. Electrical transmission from the HNEC with generating capacities up to 35,000 MWe appears practical with 500 kV or 765 kV systems, or 1100 kV systems if developed by the mid-80's.

B. RECOMMENDATIONS

1. An adequate comparison of an HNEC, dispersed plants, and an HNEC with satellites has not been made with respect to the following questions:
 - a. What is possible in energy growth from dispersed plants in the PNW?
 - b. What are the comparative risks to the public of a HNEC, dispersed plants or HNEC-satellite siting in the PNW?A study of these topics is recommended.
2. Should it become a national policy to encourage rapid substitution of electrical energy for petroleum, the following is recommended:
 - a. A study of the likely growth of electrical power arising from this policy.
 - b. A regional study of the most optimum locations for siting nuclear plants to meet the increased growth.
3. It is recommended that the electrical utilities organizations of the PNW be contacted to determine if it would be prudent to clear and reserve a number of sites on the Hanford Reservation, in conjunction with PNW utilities, for potential plant siting. This could provide them backup in case: a) present sites fail to materialize, b) irradiated fuel and plutonium shipments are severely restricted from isolated plant sites, c) an unusually large growth in electrical power demand occurs because of petroleum unavailability or price, or d) it becomes a national policy to encourage rapid change from petroleum use to electricity.
4. Should a major program be undertaken similar to the accelerated case, it is recommended that:
 - a. A limited number of sites be licensed on the Hanford Reservation to accommodate early construction activities.
 - b. A HNEC concept be cleared in parallel (though on a longer time schedule) to license massive siting of nuclear facilities on the Hanford Reservation.

- c. A thorough study of the heat island effect be undertaken for the Hanford site.
- d. The issues relative to the HNEC be presented to the public.

SECTION IV

PROJECTED ENERGY NEEDS POTENTIALLY SERVED
BY HANFORD NUCLEAR ENERGY CENTER

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IV. PROJECTED ENERGY NEEDS POTENTIALLY SERVED BY HANFORD NUCLEAR ENERGY CENTER

As previously stated, the groundrules for the study of a Hanford Nuclear Energy Center (HNEC) were that it should have at least 10,000 to 15,000 MWe by 1985 to 1990 and up to 40,000 MWe by 2000. This section of the report is an analysis of how this large energy resource might be used by the region. In addition to being used to meet presently projected regional needs (especially those in the mid and late 1980's), it was assumed that the electrical energy would be used for (1) the HNEC energy requirements, particularly for projected enrichment facilities, (2) industrial activities attracted to the HNEC, (3) encouragement of substitution of electric energy for petroleum use, and (4) export to other regions in order to reduce their petroleum use. It is realized that these factors result in a much larger electrical energy projection for the Pacific Northwest (PNW) than that presently projected.⁽⁵⁾ The intention, however, is simply to indicate what might be the bounds for electrical energy growth in the HNEC. As a result two cases have been developed: an accelerated case with the introduction of two 1300 MWe reactors per year starting in 1979 and a normal case which assumes introduction to begin in 1982 (described in Section V.B).

A. ENERGY USE IN THE PNW

The PNW region consumed 2217×10^{12} Btu (British thermal units) of energy in 1970. The consumption of energy has been increasing at an annual rate of about 3.6% which represents a doubling time of 20 years; this is greater than the annual U.S. rate of 3.1%/yr.⁽¹⁾ Two factors account for the greater than average use of energy in the PNW: (1) very low electric rates, which have encouraged the location of energy intensive industries and also encouraged residential and commercial electric consumption, and (2) high per capita use of the automobile. Table IV-1 lists the breakdown of energy consumption for 1970.

TABLE IV-1. Energy Consumption by Source in the PNW Region in 1970⁽¹⁾

	<u>10¹² Btu</u>
Coal	
Nonelectric Use	24.6
Electric Generation (includes nuclear)	90.6
Natural Gas	311.5
Liquified Petroleum Gases	11.0
Gasoline	380.6
Fuel Oil	333.6
Other Petroleum Products	157.3
Hydropower	<u>907.5</u>
	2,216.6

The region's natural energy resource is hydropower, which provides 41% of the energy used. A modest amount of coal does exist in Southwest Washington and this is primarily used at the Centralia thermal plant. Since very large deposits of coal exist in Montana and Wyoming adjacent to the PNW (Section VII.J), it is being proposed to ship quantities of these resources into Washington and Oregon to fuel fossil steam electric plants in these states. This region contains no known petroleum or natural gas resources, but it does contain a potentially significant geothermal resource.

The present status of electrical generation of the Pacific Northwest Power System is almost entirely dependent on the area's hydroelectric potential which is about 50% of this power comes from the Federal Columbia River Project (FCRP); Table IV-2 lists the current electrical generating capability in the PNW.

The available thermal generating capacity is not sufficient to meet energy demands under critical water conditions. Much of the hydroelectric potential can only be used during high flow periods or for load factoring. Thus, the forecast is that resources, other than hydroelectric, must be

TABLE IV-2. PNW Installed Electrical Generating Capacity (January 1, 1974)^(2,3)

	<u>MWe</u>
Hydroelectric	21,042 ^(a)
Thermal	<u>2,639</u>
	23,671

(a) FCRP = 11,000

developed to meet the PNW's electrical needs. Appendix IV provides additional data on hydroelectric generation and use by State and sector as well as the currently planned additional electrical generating facilities.

B. REGIONAL GROWTH PROJECTIONS AND ASSUMPTIONS FOR HNEC

Projections of growth are generally based on some extension of historical trends. Experience indicates that for energy usage these projections are generally low. However, deviations from these historical trends (to make a higher or lower projection) can be justified only if exceptional situations can be proven. In the present case, the increased cost and limited availability of natural gas and petroleum appears to be an exceptional situation. Past projections have not taken this into account and present studies are only now attempting to examine the likely impact on electrical energy use. For this study previous projections were evaluated to determine where substitutions for oil and gas may be necessary if PNW energy requirements are to continue to grow. The areas of potential substitution are discussed in Appendix IV-B.

All projections of energy growth in the PNW region indicate that electrical energy will play an increasingly predominant role in the total energy usage. One projection indicates an increase from 41% in 1970 to 52% in 1985 to 69% in 2010.⁽¹⁾ Another projection,⁽⁴⁾ using a lower growth model, shows a similar trend for the PNW and the U.S. as a whole. Table IV-3⁽¹⁾ shows projected total energy consumption in the PNW for a projected demand (consumption) level for the period from 1965 to 2010.

TABLE IV-3. Energy Consumption by Energy Source in the PNW^(a)
1965-2010⁽¹⁾

Energy Source	Trillions of Btu/yr					
	1965	1970	1975	1980	1985	2010
Coal						
Nonelectric use ^(b)	30.0	24.6	22.8	21.2	19.0	25.8
Electric generation ^(c)	0.2	90.6	100.5	304.1	726.0	5092.6
Natural gas ^(d)	227.7	311.5	386.7	447.7	510.8	892.0
Liquefied petroleum gases ^(e)	9.6	11.0	12.1	12.9	13.6	16.9
Gasoline ^(f)	327.5	380.6	449.0	516.9	602.3	1069.0
Fuel oil ^(g)	309.6	333.6	353.2	366.1	371.7	408.4
Other petroleum products ^(h)	111.2	157.3	177.8	227.1	252.8	470.5
Hydropower ⁽ⁱ⁾	744.1	907.5	1143.9	1242.5	1210.8	1135.5
Total PNW energy consumption	1759.9	2216.7	2645.6	3138.5	3707.0	9110.7

- (a) PNW includes Idaho, Oregon, Washington and Western Montana.
- (b) Mid-point between a maximum and minimum forecast of PNW coal requirements, excluding electric generation and exports. Assumes coal with an average heat content of 10,000 Btu/lb.⁽⁶⁾
- (c) Loads were based on References 7 and 8. Heat rate used (Btu/kW-hr): 1970--9000; 1975--8666; 1980--8333; 1985--8000; 2010--7500 (Ref. 9, pp. 167 and 192). Division of electrical loads between nuclear and coal fuels is left indeterminate.
- (d) Assumes heat value of 1000 Btu/ft³⁽⁹⁾
- (e) Assumes heat value of 95,500 Btu/gal⁽¹⁰⁾
- (f) Assumes heat value of 5,248,000 Btu/barrel.⁽¹⁰⁾
- (g) Includes heating oils and non-heating oils (distillate and residual). Assumes heat values of 5,825,000 Btu/barrel of distillate and 6,287,000 Btu/barrel of residual.⁽¹⁰⁾
- (h) Includes kerosine, aviation gasoline, jet fuel, and naptha. Excludes non-energy products such as lubricants, wax, asphalt, road oil, and other finished products.⁽¹⁰⁾
- (i) Hydropower converted to Btu at the prevailing thermal heat rates assumed for the region.⁽¹⁰⁾

This table was prepared before the shortage in hydrocarbon fuels; however the energy requirements supplied by the hydrocarbon fuels indicates potential levels of substitution for additional electricity. Figure IV-1 plots the projected electrical demands by sectors. It is important to realize that this projection is based on extrapolation of current trends. It is quite possible that with the current energy "crisis" this projection may represent a lower limit.

A lower projection is obtained where an econometrics model, which takes into account various elasticity factors, is used. This projected electrical demand is given in Table IV-4 and is compared with the high projection.⁽⁴⁾ Appendix IV details this projection by State and sector for the 1970-2000 period.

Figure IV-2^(a,b) plots the most recent Bonneville Power Administration (BPA) estimates of projected electrical loads and generating capacity for the PNW region.⁽⁵⁾ The projected loads are lower than in Figure IV-1 and probably reflect more recent data. It is observed that even with no reserve capacity the system is anticipated to have a deficit for any year in the future. The deficit increases significantly if reserve resources are included.

Tables IV-5 and IV-6 summarize the PNW's regional growth in electric supply and demand for the two cases of the HNEC concept considered. The first three rows list projected average loads, resources, and energy deficit. These data are taken from Reference 5 and reflect the fact that present plans do not go beyond 1982 in adding to resources. This can be also seen in Figure IV-2. Also plotted on this figure are the average deficits in MW generating capacity.^(b) Each 1000 MW of deficit can be thought of as one 1300 MWe nuclear reactor operating at 77% plant factor and this number has been used for planning purposes in this study. The next five rows in Tables IV-5 and IV-6 list these deficits and the effects of the proposed siting schedule of the HNEC. The next six rows of

(a) Data were converted to kW-hr by multiplying average generating capacity by 8760 hr/yr for comparison purposes.

(b) The 1977 drop of 880 MW in generating capacity indicates the Hanford No. 1 shutdown to increase its capacity to about 1200 MW in 1982.

FIGURE IV-1. Growth in Total PNW Electric Power Requirements (1965-1985)(1)

TABLE IV-4. PNW Electrical Demand Projections for Electrical Intensive Industries

Source	Millions of kW-hr			
	1970	1975	1980	1985
Tyrrell (4)(a)	102,170 ^(b)	114,072	139,826	165,625
BPA (1)	110,000 ^(b)	143,549	185,600	242,100

(a) Does not contain losses

(b) The difference between these numbers may be due to transmission losses.

FIGURE IV-2. Projected PNW Region Electric Situation 1974-1994

TABLE IV-5. Summary of PNW Projected Electrical Loads and Resources, Accelerated Growth

	74 - 75	75 - 76	76 - 77	77 - 78	78 - 79	79 - 80	80 - 81	81 - 82	82 - 83	83 - 84	84 - 85	85 - 86	86 - 87	87 - 88	88 - 89	89 - 90	90 - 91	91 - 92	92 - 93	93 - 94
Average Electric Load (MW)	13,951	14,712	15,306	16,798	17,720	18,622	19,557	20,559	21,572	22,632	23,745	24,925	26,119	27,467	28,852	30,326	31,867	33,493	35,240	37,089
Average Net Resources (MW)	12,800	14,332	15,150	15,124	16,066	16,666	17,353	19,051	19,809	19,804	19,757	19,770	19,711	19,696	19,652	19,620	19,585	19,583	19,532	19,480
Resource Net (MW)	(1,151) ^(a)	(440)	(756)	(1,674)	(1,654)	(1,956)	(2,204)	(1,508)	(1,763)	(2,828)	(3,988)	(5,155)	(6,428)	(7,765)	(9,200)	(10,706)	(12,282)	(13,910)	(15,708)	(17,609)
Number 1300 MW Nuclear Plants Required, 77% Plant Factor	1.1	0.4	0.8	1.7	1.7	2.3	2.2	1.5	1.3	2.8	4.0	5.2	6.4	7.8	9.2	10.7	12.3	13.9	15.7	17.6
Estimated Other Regional Growth 10 ³ MW					0.7	0.3	0.5	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.0	0.0	
Yearly Addition Total					0.7	1.3	1.5	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	5.5	5.5		
Net Resource Expressed As 1300 MW Plants	(1.5)	(0.4)	(0.8)	(1.7)	(1.0)	(1.3)	(0.7)	(3.0)	+0.2	(0.3)	(1.0)	(1.7)	(2.4)	(3.3)	(4.2)	(5.2)	(6.8)	(8.4)	(10.2)	(12.1)
Proposed Growth of Nuclear Center, No. 1300 MW Plants					1.0	3.3	5.0	7.0	9.0	11.0	13.0	15.0	17.0	19.0	21.0	23.0	25.0	27.0		
Effect of Hanford Nuclear Energy Center on Resource, 10 ³ MW	(1.5)	(0.4)	(0.8)	(1.7)	0.0	+2.3	+4.3	+7.0	+9.2	+10.7	+12.0	+13.3	+14.6	+15.7	+16.8	+17.8	+18.2	+18.6		
Enrichment Plant (MW)																				
1 Plant Total									1,820	1,945	2,065	2,190	2,320	2,445	2,570	2,695	2,820	2,945	3,070	3,195
2 Plants Total									1,820	1,945	2,065	2,190	2,320	2,445	2,570	2,695	2,820	2,945	3,070	3,195
Industrial Facilities (MW)							450	450	450	450	450	450	450	450	450	450	450	450	450	450
Yearly Addition Total							450	900	1,350	1,800	2,250	2,700	3,150	3,600	4,050	4,500	4,950	5,400	5,850	6,300
Site Demands (MW)					10	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Yearly Addition Total					10	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Petroleum Substitution (MW)				40	40	80	230	540	540	540	540	540	540	540	540	540	540	540	540	540
Yearly Addition Total				40	80	160	390	930	1,470	2,010	2,550	3,090	3,630	4,170	4,710	5,250	5,790	6,330	6,870	7,410
TOTAL OF ABOVE (1 Plant for Enrichment)				40	50	100	700	1,010	2,830	1,035	1,130	1,135	1,140	635	1,105	1,105	1,110	1,110	1,110	1,110
Yearly Additions Total				40	90	150	890	1,900	4,730	5,765	6,895	8,030	9,170	9,805	10,510	12,015	13,125	14,235	15,345	16,455
Net Power Available for Export	(1,151)	(440)	(750)	(1,714)	(90)	1,850	3,400	5,100	4,470	4,935	5,105	5,270	5,435	5,895	6,350	6,785	7,215	7,645	8,075	8,505
Net Regional Electric Power, 10 ³ MW	12.8	14.3	15.2	15.1	17.8	20.7	23.9	27.6	30.8	33.3	35.8	38.3	40.7	43.2	45.7	48.1	50.1	52.1		

(a) parenthesis indicate power deficiency

TABLE IV.6. Summary of PNW Projected Electrical Loads and Resources,
Normal Growth

	74 - 75	75 - 76	76 - 77	77 - 78	78 - 79	79 - 80	80 - 81	81 - 82	82 - 83	83 - 84	84 - 85	85 - 86	86 - 87	87 - 88	88 - 89	89 - 90	90 - 91	91 - 92	92 - 93	93 - 94
Average Electric Load (MW)	13,951	14,772	15,906	16,798	17,720	18,622	19,557	20,559	21,572	22,632	23,745	24,925	26,169	27,467	28,852	30,326	31,867	33,493	35,240	37,089
Average Net Resources (MW)	12,800	14,332	15,150	15,124	16,066	16,666	17,353	19,051	19,809	19,804	19,757	19,770	19,741	19,698	19,652	19,620	19,585	19,583	19,532	19,480
Resource Net (MW)	(1,151) ^(a)	(440)	(756)	(1,674)	(1,654)	(1,956)	(2,204)	(1,508)	(1,763)	(2,828)	(3,988)	(5,155)	(6,428)	(7,769)	(9,200)	(10,706)	(12,282)	(13,910)	(15,708)	(17,609)
Number 1300 MW Nuclear Plants Required, 77% Plant Factor	1.1	0.4	0.8	1.7	1.7	2.0	2.2	1.5	1.8	2.8	4.0	5.2	6.4	7.8	9.2	10.7	12.3	13.9	15.7	17.6
Estimated Other Regional Growth 10 ³ MW	Yearly Addition Total				0.7	0.3	0.5	1.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.0	0.0	0.0	
					0.7	1.0	1.5	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	5.5	5.5	5.5	
Net Resource Expressed As 1300 MW Plants	(1.5) ^(a)	(0.4)	(0.8)	(1.7)	(1.0)	(1.0)	(0.7)	0.0	+0.2	(0.3)	(1.0)	(1.7)	(2.4)	(3.3)	(4.2)	(5.2)	(6.8)	(8.4)	(10.2)	(12.1)
Proposed Growth of Nuclear Center, No. 1300 MW Plants									1.0	3.0	5.0	7.0	9.0	11.0	13.0	15.0	17.0	19.0	21.0	23.0
Effect of Hanford Nuclear Center on Resource, 10 ³ MW									+1.0	+3.2	+4.7	+6.0	+7.3	+8.6	+9.7	+10.8	+11.8	+12.2	+12.6	+12.8
Enrichment Plant (MW)	Plant Total ± Plants Total									1,820	1,945	2,065	2,190	2,320	1,945	2,040	2,135	2,235	2,333	2,333
															2,816	3,423	4,080	4,470	4,666	4,666
Industrial Facilities (MW)	Yearly Addition Total									450	450	450	450	450	450	450	450	450	0	0
										450	900	1,350	1,800	2,250	2,700	3,150	3,600	3,600	3,600	3,600
Site Demands (MW)	Yearly Addition Total									10	20	20	20	20	20	20	20	20	20	20
										10	30	50	70	90	110	130	150	170	190	230
Petroleum Substitution (MW)	Yearly Addition Total				40	40	80	230	540	540	540	540	540	540	540	540	540	540	540	540
					40	80	160	390	930	1,470	2,010	2,550	3,090	3,630	4,170	4,710	5,250	5,790	6,330	6,330
TOTAL OF ABOVE (+ Plant for Enrichment)	Yearly Additions Total				40	40	80	240	2,380	1,135	1,130	1,135	1,140	935	1,105	1,105	1,110	560	560	560
					40	80	160	400	2,780	3,915	5,045	6,180	7,320	8,255	9,360	10,465	11,575	11,933	12,493	12,493
Net Power Available for Export (MW)	(1,151) ^(a)	(440)	(750)	(1,674)	(994)	(1,036)	(864)	592	457	757	967	1,165	1,252	1,476	1,440	1,329	643	757	299	
Average Regional Electric Power 10 ³ MW	12.8	14.3	15.2	15.1	16.8	17.7	18.9	21.6	24.8	27.3	29.8	32.3	34.7	37.2	39.7	42.1	44.1	46.1	48.0	

^(a) parentheses indicate power deficiency

Tables IV-5 and IV-6 tabulate some of the uses of the power generated by the HNEC. The last line lists the average regional electric generating power. The data for these rows was obtained by the means described below.

1. Enrichment Plants

The proposed enrichment plant (assumed to be a gaseous diffusion type) is estimated to come on stream in 1982, about the time when the country needs a fourth $8.75 (10^3)$ SWU facility. It is further assumed that the enrichment requirements would be split equally among the four plants (for example all facilities would operate at $3/4$ of the total capacity). The projected growth in reactors is such that 4 to 5 years later, another enrichment facility will be required (a growth rate of about 7%/yr). The second plant may or may not be located at HNEC. However, if it does locate at HNEC, it would grow in stages so that all plants would continuously operate at 90 to 95% capacity. If it locates elsewhere, all five plants would initially operate at 80% capacity. These growths are reflected in Tables IV-5 and IV-6 for both the first and second enrichment plants.

2. Industrial Facilities

It is assumed that industrial facilities will be attracted to the HNEC because of the available power (see Section V.D). The most likely to locate at the HNEC will be the energy intensive industries (aluminum reduction plants). Tables IV-5 and IV-6 list the amounts of additional yearly industry electrical load that might be needed for industries attracted to the HNEC if the power was available. This load requirement is estimated at approximately 450 MW/yr. The industrial activities would start operating 1 year after the first reactor comes on line. In the normal development case (Table IV-6) projected regional growth limits HNEC industrial load to 3600 MW unless the normal regional growth relocates there.

3. Site Demands

Site demands are expected to be nominal apart from the enrichment plant. Loads are estimated to be 10 MW-yr/reactor. During operation each reactor supplies its own electrical needs. It is assumed that the effect of population and other local growth on electrical demand are covered in regional forecasts.

4. Petroleum Substitution

Petroleum and natural gas availability as well as price changes will impact on electrical demands. Where and when substitutions will be made and in what magnitude, are difficult to assess. Federal policy on petroleum and natural gas use could have a major impact as well. Preliminary studies (Appendix IV-B) suggest that petroleum substitution will occur in areas of transportation and heating. For the purposes of this study, it was assumed that half the energy requirement of the additional use of gasoline, between now and 1990-1991, would be assumed by electric power. This amounts to the output of about two reactors by 1990 to 1991. The accelerated growth case of HNEC assumes early introduction of electric driven transportation (on a test basis) and 1/2 the growth by 1990. The normal growth case delays this by 1 year.

Currently about 120 (10^{12}) Btu of heating oil or natural gas are used for houses in the PNW. It was assumed that about 1/2 of these users will be converted to electricity by 1990 with energy from the HNEC. It was assumed that the growth is linear starting in 1980 and by 1990 this would require the output from about two reactors. Other projected fuel oil demand growth to 1990 (Table IV-3) is about 35 (10^{12}) Btu. This amounts to about one reactor's output. Tables IV-5 and IV-6 list all these useages. In terms of petroleum substitution the output of five reactors is equal to about 150,000 barrels/day oil equivalent.

5. Projected Regional Deficit

Tables IV-5 and IV-6 project the regional deficit at about 11,000 MW in 1990. It has been assumed that 1/2 of the projected deficit will be provided by the HNEC and the other 1/2 will be provided by other generating sites in the region. These points are reflected in the middle section of Tables IV-5 and IV-6.

6. Inter-Region Transfer

Excess energy generation from the HNEC is assumed available for export from the region. These amounts are shown on the last line of Tables IV-5 and IV-6. Figures IV-3 and IV-4 summarize the data of Tables IV-5 and IV-6, respectively, and illustrate the potential uses of electric power produced in a HNEC. Under a normal growth case (i.e., introduction of two plants/yr in 1982) little excess generating capacity is available for export of power. In fact, a second enrichment plant would start to cause a deficit by 1990. The accelerated growth case provides large amounts of power for export all during the time period under study. The amount decreases slightly at the end of the 1980's; a second enrichment plant could make significant demands on this excess of accelerated growth.

FIGURE IV-3. Effect of HNEC on Regional Electric Production Accelerated Growth (from Table IV-5)

FIGURE IV-4. Effect of HNEC on Regional Electric Production Situation 2 (from Table IV-6)

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SECTION V

DESCRIPTION OF THE HANFORD NUCLEAR ENERGY CENTER

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V. DESCRIPTION OF THE HANFORD NUCLEAR ENERGY CENTER

The purpose of this section is to describe the present Hanford Reservation and to indicate, in a conceptual way, the new facilities which would be constructed as the various parts of the Hanford Nuclear Energy Center (HNEC). Accordingly, the present site is described first. This is followed by discussions of the reactor plants and projected schedule, supporting fuel cycle facilities, industrial activities which might be attracted to the HNEC and, lastly, potential on-site industrial and food-industry uses of process heat and waste heat from the center. The industries which might be attracted to the HNEC are only conceptual at this early stage, but the discussion at the end of this section presents some possibilities to help round out the overall visualization of the center.

A. SITE DESCRIPTION

The Hanford site is in a semiarid region of southeastern Washington State (Figure V-1) where the annual average rainfall is about 16 cm (6 in.). This section of the state has a sparse covering of natural vegetation primarily suited for grazing, although large areas near the site have gradually been put under irrigation during the past few years. The plant site (Figure V-2) covers an area of about 1300 km² (500 mi²). The Columbia River flows through the northern edge of the Hanford site and forms part of the eastern boundary. As indicated by the wind roses shown in this figure, prevailing winds near the fuel reprocessing area at the center of the site are from the northwest with strong drainage and cross winds causing distorted flow patterns in localized areas. The meteorology of the region is typical of desert areas with frequent strong inversions occurring at night, but breaking during the day to provide unstable and turbulent conditions.

The nearest population center is the Tri-Cities area (Richland, Pasco, and Kennewick) situated on the Columbia River directly downstream from the plant. Smaller communities in the vicinity include Benton City, West Richland, Mesa and Othello. The population, within a 50-mile radius of existing major plant facilities, varies from 160,000 to 260,000 people.

FIGURE V-1. The Hanford Site

FIGURE V-2. The Plant Site

The farming area closest to Hanford is on the Wahluke Slope, about 11 km (7 miles) from Hanford No. 1, but much of the land east and south of the project boundary is under cultivation and could be in the path of airborne releases. Most irrigated farms near the Hanford site obtain water from the Yakima River or from the Columbia Basin Project which brings water from Grand Coulee Dam. However, two small irrigated areas using Columbia River water taken downstream from the reactor are the Ringold farms and the Riverview district west of Pasco. These are about 40 km (25 miles) and 70 km (45 miles), respectively, downstream from the Hanford No. 1 site. The principal products from the larger farm plots are hay, alfalfa, sugar beets, potatoes, beef, and dairy products. Figure V-3 is an aerial photograph of the site; the darker regular patterns outside the site boundary indicate areas currently under cultivation.

Production of plutonium has been the primary objective of the Atomic Energy Commission at the Hanford site. Activities have included nuclear fuel fabrication (300 Area), plutonium production (100 Areas) and test reactor (300 Area) operation, chemical separations (200 Areas) for irradiated fuels, laboratory support and research (300 Area), waste storage and disposal (all areas). High-level waste storage and processing is confined to the 200 Areas in the elevated (near 700 ft above MSL) central plateau of the plant site. In recent years, non-Federally-owned facilities have been located within the Hanford site boundaries, including a power generating station and office buildings (at 100-N Area), and a radioactive waste burial site (near 200-East Area). Figure V-2 shows the operating areas. Figure V-4 shows the site highway and railroad systems and the main electrical supply grid.

The most significant Hanford contributions to off-plant radioactivity and population doses have in recent years usually originated with reactor once-through cooling water released to the Columbia River. At one time, nine production reactors, eight with once-through cooling, were in operation at Hanford. Between December 1964 and January 1971, all reactors with once-through cooling were deactivated. The only production reactor remaining in operation at Hanford is N-Reactor which has a closed primary

FIGURE V-3. Aerial Photograph of the Hanford Site

cooling loop and releases only minor quantities of radioactivity to the river. As a result, the amount of radioactivity released to the Hanford environment, other than to soil, within the plant reservation decreased to relative insignificance.

Construction of a new test reactor, the Fast Flux Test Facility and associated engineering facilities began in 1971 and is scheduled for operation in 1977. Construction of the first utility-owned power reactor at the Hanford site, WPPSS Hanford No. 2, began in 1972. These reactor locations are shown on Figure V-4. Both reactors will use cooling towers for heat dissipation rather than the Columbia River. Hanford No. 1 power reactor is scheduled as a replacement for N-Reactor and is in an early licensing stage.^(a)

The Hanford railroad system (Figure V-4), owned by the Atomic Energy Commission, is tied to the Burlington Northern and Union Pacific railroads at the City of Richland. The electrical power grid (Figures V-5 and V-6) is tied to the Bonneville Power Administration (BPA) grid and the Pacific Northwest Power Pool primarily through the Midway Substation and the N-Reactor Substation. Although barge traffic on the Columbia River, through the project, is available but is intermittent. There is an existing Port of Benton barge docking facility in North Richland just south of the southern Hanford site boundary.

The many environmental and site studies conducted in past years for the Atomic Energy Commission have provided voluminous information on the local ecosystems, climatology, geology, and surface and groundwater hydrology. Selected material of this kind has been added as Appendix V-A and will be available in much more detail in the Hanford Environmental Statement for Waste Management Operations to be published in 1974.

(a) At the time this report is being written, consideration is being given to resiting the Hanford No. 1 reactor adjacent to Hanford No. 2, complete with a new electrical generating system.

FIGURE V-5. 230 kV High Voltage Transmission Line on the Hanford Reservation

FIGURE V-6. 500 kV, 115 kV and 13.8 kV High Voltage Transmission Lines on the Hanford Reservation

B. POWER REACTOR REQUIREMENTS

The reactor construction and operation schedules have been based on two premises:

- Sufficient national priority to permit initiation of reactor construction in mid-1975, resulting in operation in 1979.
- Present planning and review schedules which would result in initial reactor operation in 1982. Further, analysis of load growth and construction work force limitations suggest that a two reactor/yr construction program is about a practical limit for the HNEC. Thus, two reactors/yr coming on-line in 1979 represents an upper limit of the envelope of what appears practical at Hanford. The number probably could be increased in later years if the need developed.

The accelerated and normal schedules are presented in Table V-1.

There are several methods in which the reactors at the HNEC could be constructed (for example, one at a time or several or more in sequence). The method would be influenced by a number of factors, including institutional arrangements (see Section VII-I Utility Relationships), load growth, savings from multiple unit ordering, and public acceptance. The reactors could be ordered as individual reactor plants by one utility, several at a time by one utility, several at a time by a consortium of utilities, and in other ways. Since there are significant economies in ordering several standardized units at one time, this was the mode assumed for evaluation. The plants in each order could be built at the same general site or at scattered sites on the Hanford reservation. However, the former would probably result in the greatest economies.

At present, the Hanford Reservation contains one power reactor, Hanford No. 1 (N-Reactor), which produces 860 MWe (Figure V-7). Hanford No. 2, an 1100-MWe net LWR, is currently under construction with a projected commercial operating date of 1978. Hanford No. 1 is scheduled to 1220 MWe in 1981 (at this writing an alternative to convert about 1980 to a fossil-fuel fired plant with a capacity of about 2000 MWe is under

TABLE V-1. Projected Installation of Reactor Facilities^(d) at HNEC - Accelerated and Normal Cases

Year	Accelerated			Normal Case		
	Number of Reactors Added	Incremental Addition of Electrical Power, MW	Cumulative Electrical Power, MW	Number of Reactors Added	Incremental Addition of Electrical Power, MW	Cumulative Electrical Power MW
1974	1 (Existing) ^(a)	860	860	1	860	860
1975	-	-	860	-	-	860
1976	-	-	860	-	-	860
1977	-	-	860	-	-	0
1978	1	1,100 ^(b)	1,100	1	1,100	1,100
1979	2	2,600	3,700	-	-	1,100
1980	2	2,600	6,300	-	-	1,100
1981	3	3,720 ^(c)	10,120	1	1,220	2,320
1982	2	2,600	12,720	2	2,600	4,920
1983	2	2,600	15,320	2	2,600	7,520
1984	2	2,600	17,920	2	2,600	10,120
1985	2	2,600	20,520	2	2,600	12,720
1986	2	2,600	23,120	2	2,600	15,320
1987	2	2,600	25,720	2	2,600	17,920
1988	2	2,600	28,320	2	2,600	20,520
1989	2	2,600	30,920	2	2,600	23,120
1990	2	2,600	33,520	2	2,600	25,720

(a) Hanford No. 1 plus N-Reactor.

(b) Hanford No. 1 shutdown for conversion to Hanford No. 1 replacement reactor; Hanford No. 2 comes on-line with 1100 MWe.

(c) Includes 1220 MWe from conversion of Hanford No. 1.

(d) Reactors may be LWRs and HTGRs.

FIGURE V-7.

consideration). Should the latter occur the Hanford No. 1 reactor would be built next to Hanford No. 2 and add about 1200 MWe to the PNW generation pool.

Approximately 16 nuclear plant sites have been tentatively identified on the Hanford Reservation; there are probably many more. Most of these sites could receive up to several or more reactor plants. It is assumed that each reactor would be standard steam supply units of 1300 MWe net output and the remainder of the plants will also be standard plants. Greater outputs may be practical in later years.

Since any reactor site identified on Figure V-7⁽⁵⁾ could presumably be used by any northwest utility or power producing group no attempt has been made to indicate the order in which sites would be occupied. Should the HNEC be initiated it is likely that cooling tower and pond installations would be developed first.

It is assumed that some of the reactor plants could be cooled by once-through cooling when environmental clearances have been obtained. It appears environmentally sound to divide the reactor heat dump equally between towers, ponds and once-through cooling. It is clear that all plants could not use the once-through cooling capability of the Columbia River. It is less clear whether all could use evaporative cooling towers due to cloud cover and other effects in the region. The limits of pond cooling (including spray ponds) have not been defined for Hanford. It is possible that some dry cooling towers might be required late in the time period 1990-2000. These might be used in conjunction with gas-cooled reactors.

C. SUPPORTING FUEL CYCLE FACILITIES

1. Fuel Fabrication Facilities

Fuel fabrication facility requirements for the proposed HNEC were based on the assumptions that two 1300-MWe Light Water Reactors (LWR's) (one Pressurized Water Reactor PWR and one Boiling Water Reactor BWR) would be started up each year starting in 1979 and continuing until 1990, and that all plutonium generated in the reactors would be recycled through

the reactors in the center. Information from an AEC staff report⁽¹⁾ was used to calculate annual fuel requirements and plutonium production, which formed the basis for determining fuel fabrication facility requirements.

Calculated annual fuel requirements and plutonium available for recycling for each year are shown in Table V-2 and Figure V-8. These fuel requirements include the initial loadings for new reactors and the reloads for operating reactors. Table V-2 and Figure V-8 also show the combined fuel requirements expressed as a percentage of the total projected fuel requirements for commercial LWR's in the United States. It is significant that the UO_2 fuel fabrication requirements for the HNEC at no time exceed 7.4% of the projected national fuel requirements.

A UO_2 fuels fabrication plant, sized to meet the requirements of the HNEC, would have an initial capacity in 1978 of 2 metric tons of fuel/day. This capacity would have to be expanded to 3 tons/day by 1982 and 4 tons/day by 1986 in order to meet fuel requirements through 1990. A fuels plant of this size is considerably smaller than the plants which will be supplying fuel for the balance of the light water power reactors in the United States during this time period.

The Hanford UO_2 fuels might be provided by an existing commercial fuel plant located adjacent to the Hanford site. This plant, or a new one, could be expanded to meet the growing Hanford needs.

It is assumed that by 1986 the UO_2 fuels plant would be expanded to a capacity of 4 tonnes/day, and ultimately to the order of 5 to 10 tons/day. The excess capacity of the plant could be used to provide fuel for reactors outside of the HNEC. AEC projections of total U.S. LWR UO_2 fuels requirements through 1990 correspond to full utilization of installed fabrication capacities of approximately 18, 34, and 56 metric tons of fuel/day for 1980, 1985, and 1990, respectively. Approximately 15% of this requirement is for reactors located or to be located in the western states.

Adequate fuel management schemes for recycling plutonium have been developed for both BWRs and PWRs. Recently it has been reported⁽²⁾ that optimum plutonium fuel management in a Westinghouse 1300-MWe PWR can be

TABLE V-2. UO_2 Fuel Requirements and Plutonium Utilization in Hanford Reactors

	Metric Tons of Oxide Fuel											
	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
<u>Initial Loading</u>												
BWR	168	168	168	168	168	168	168	168	168	168	168	168
PWR	<u>118</u>	<u>118</u>	<u>118</u>	<u>118</u>	<u>118</u>	<u>118</u>	<u>118</u>	<u>118</u>	<u>118</u>	<u>118</u>	<u>118</u>	<u>118</u>
Total	286	286	286	286	286	286	286	286	286	286	286	286
<u>Reloads (a)</u>												
UO_2 BWR		37	74	111	148	185	222	259	296	333	370	407
PWR		<u>34</u>	<u>55</u>	<u>76</u>	<u>97</u>	<u>117</u>	<u>134</u>	<u>151</u>	<u>168</u>	<u>184</u>	<u>201</u>	<u>217</u>
Total Mixed Oxide (b)		71	129	187	245	302	356	410	464	517	571	624
<u>Total UO_2 Fuel</u>			13	26	39	53	70	87	104	122	139	157
<u>Total Fuel</u>	286	357	415	473	531	588	642	696	750	803	857	910
<u>Total Pu Discharged (a)</u>												
Kg fissile Pu	286	357	428	499	570	641	712	783	854	925	996	1067
HEC LWR UO_2 Fuel (a)		330	660	990	1379	1823	2268	2712	3163	3623	4085	4546
Requirements as % of National Requirements	5.9	7.2	7.3	7.4	7.2	7.4	7.1	6.8	6.8	6.6	6.3	6.1

(a) Based on assumptions used in WASH-1139 (72).

(b) It is assumed that Pu will be recycled using the most efficient fuel management scheme available. This may involve Pu recycling in both BWRs and PWRs, or in only one reactor type. For convenience in calculating requirements for this study, PWR data only was used.

FIGURE V-8. Annual UO₂ and Mixed Oxide Fuel Charged in Hanford Reactors and Relation of UO₂ Fuel Charged to Total National Requirements

designed to minimize the additional control requirement associated with Pu recycle operation and assure the capability of recycling 1300 to 1400 kg of Pu in the first reactor cycle. For any subsequent cycle, 2000 to 2500 kg of Pu can be in the Pu assemblies in the core.

This loading limit is equivalent to loading at each refueling the Pu discharged from 2-1/2 U-fueled reactors. This performance is achieved using fuel assemblies in which each rod contains mixed-oxide fuel pellets. Graded enrichments throughout the assembly are used to control local power peaking.

This type of Pu recycling fuel management at the HNEC would permit the recycling of all the Pu generated at the Center in a relatively few of the reactors.

Pu recycling fuel management schemes have also been developed for BWRs.⁽³⁾ In this case an "island" design is used in the fuel assemblies, with the Pu rods located in the central regions of the fuel assembly away from the control blade, resulting in complete interchangeability of enriched UO_2 and Pu recycle assemblies. This design makes it possible to intermix any relative quantity of U and Pu recycle assemblies in a reload batch.

It can be reasonably assumed that in the proposed HNEC, where the fuel (Pu) supply can be so well identified, many of the reactors would be designed with performance characteristics optimized for Pu recycle. Since all of the Hanford reactors would not be required for recycling the Pu generated at Hanford, a significant amount of excess Pu recycling capacity would be available to accommodate the Pu recovered from offsite irradiated fuel reprocessed in the HNEC reprocessing plant.

A 1/4 ton/day mixed-oxide fuels plant would be required for initial Pu recycle by 1980. If storage capacity for approximately 2000 kg of Pu is available, operation of the mixed-oxide fuels plant could be delayed until 1982. By expanding the plant capacity to 1/2 ton/day by 1985, and 3/4 ton/day by 1989, all of the Pu recycle requirements for the HNEC's reactors through 1990 and beyond could be accommodated. However, as

discussed in the next section, it is assumed that the HNEC reprocessing plant would initially be at least 5 metric tons/day (tonnes/day) capacity and process fuel from up to 20 off-site reactors as well as the on-site reactors. All of the Pu recovered from 24 Hanford reactors plus 20 additional (1250 MWe equivalent) reactors located elsewhere could be accommodated in 14 of the Hanford reactors. For this recycle fuel rate, a mixed-oxide fuels fabrication plant of 1 ton/day capacity would be required by 1980. This would have to be doubled by 1985.

Construction costs for the mixed-oxide fuels plant are estimated to be approximately \$10 million (1974 dollars) for the initial 1/4 ton/day plant, \$20 million for 3/4 tons/day, \$24 million at 1 ton/day, and \$36 million for 2 tons/day. Sometime in the 1980's, fast breeder reactors may need most of the available Pu, decreasing the amount available for recycling in the HNEC LWR's. The UO_2 fuels plant would cost approximately \$30 million (1974 dollars) in its initial 2 tons/day stage, and would increase to a total of about \$50 million at its final size of 4 tons/day.

If a larger UO_2 fuels plant of 5 to 10 tons/day capacity is built initially, construction costs are estimated to be between \$50 and \$90 million (1974 dollars).

2. Fuel Reprocessing Facilities

a. Reprocessing Plant Characteristics

The reprocessing plant is an integral part of the nuclear fuel cycle. At discharge the LWR uranium fuel contains about 0.8 wt% ^{235}U and 0.5 wt% fissile Pu, both of which have sufficient value to justify recovery and recycle. The spent fuel assembly is allowed to cool for about 180 days to eliminate the short-lived radioactive fission products and is then ready for reprocessing. At the reprocessing plant the U and Pu are separated from the fission products and actinides, and then separated from each other and purified. The U is returned to the diffusion plant for reenrichment and the Pu is sent to an intermediate storage repository or to the fuel fabricator for eventual incorporation in recycle fuel. The concentrated waste is either stored for an interim period as a liquid

and then solidified or is solidified immediately. The solid waste is stored in sealed capsules which may be cooled by air or water.

Chemical reprocessing systems exist for the processing of the specialized fuels to be discharged from other types of reactors such as High Temperature Gas-cooled Reactors (HTGRs) and Liquid Metal Fast Breeder Reactors (LMFBRs). Because it is uncertain when such plants might be needed at the HNEC, none have been included in the current HNEC schedule. However, such plants could be added when needed and justified.

Table V-3 presents information summarizing the characteristics of a representative LWR fuel reprocessing plant. Data for this table were taken from the Barnwell Fuel Recovery Plant Environmental Report where possible. For some of the data estimates were made on the basis of engineering judgment.

TABLE V-3. Characteristics of a Representative LWR Fuel Reprocessing Plant (1973 Costs)

<u>Fuel Type</u>	<u>LWR (4)</u>
Plant Capacity	1500 tonne/yr
Number of 1250 MWe plants serviced	47
Capital Investment	\$130 million
Heat Dissipation	67 MW
Operating Force	300
Total Operating Cost	\$12 million ^(a)
On-Stream Efficiency	82%
Water Requirements (cooling)	3000 gpm
Land Requirement	1700 acres
Construction Period	4 yr
Peak Construction Force	1150 persons
Construction Labor	2500 man-yr ^(a)

(a) Estimated values

b. Radioactive Materials Inventory

The inventory of radioactive material at the reprocessing plant consists of in-process and purified material, fuel waiting to be processed and the wastes from fuel processed from as long as 10 years prior to that time. The data in Table V-4 were constructed assuming the fission products were stored on site for 10 years prior to shipment to the Federal repository that is associated with the HNEC.

TABLE V-4. Inventory of Material Stored at the
LWR Fuel Reprocessing Plant

Plant Throughput	1500 tonnes/yr
Amount of Radioactive Material Stored on Site	1.7×10^{10} Ci

c. Reprocessing Facilities in the NEC

Because of the favorable economics of scale as the capacity increases, reprocessing plants generally will be built as large as can be justified in order to favor low reprocessing unit costs. It is expected that the reprocessing plant built in the HNEC would be large enough to service most of the power reactors built in the western part of the country because of the lower shipping distance to that plant in comparison to plants in the east. The relative unit costs for reprocessing plants of various capacities are shown in Table V-5.

TABLE V-5. LWR Fuel Reprocessing Plant Characteristics
Capacity versus Relative Unit Capital Cost

<u>Capacity</u>		<u>Relative Unit Cost</u>	<u>Number of Reactors Served/yr</u>
<u>tonnes/day</u>	<u>tonnes/yr</u>		
1	260	1.00	8
5	1300	0.35	40
10	2600	0.23	80
20	5200	0.15	160

Forecasts of nuclear plant construction in the western states indicate that by 1985 there will be enough irradiated fuel available to support a 3 tonne/day reprocessing plant. By 1990 the amount of irradiated fuel would be about 5 tonnes/day.

In order to compete most advantageously, it is assumed that the HNEC reprocessing plant would have a capacity of 5 to 10 tonnes/day and ability to expand.

Table V-3 indicates the characteristics of such a plant. It also indicates that such a plant will have capability of serving 47 plants, each of 1250 MWe power capacity. This is equivalent to 58,750 MWe total. As indicated in Section V-B the total reactor additions in the NEC will be about 34,000 MWe by 1990. Thus, a reprocessing plant as characterized in Table V-3 could serve twenty more reactors, each of 1250 MWe capacity.

d. Onsite Plutonium Recycle

With an integrated and essentially closed-fuel cycle within the NEC, the attractive potential exists for complete retention and productive utilization within the center of not only all of the Pu produced in the local reactors, but also from all off-site reactors serviced by the reprocessing plant. An LWR can accept for recycle loads all of the Pu produced in at least 2-1/2 other LWRs. Putting the situation in other terms: for every 10,000 MWe of LWR capacity in the NEC 25,000 MWe of other LWRs could also furnish Pu for recycle in the NEC reactors. Under the projection indicated in the previous section the reactors contemplated for the complex by 1990 could consume all of the Pu from all LWR's projected to be operating in the western states in 1990. However, since Pu is most valuable when fueling breeder reactors, demand for Pu fast breeders should eventually reduce the amount available for recycle in the HNEC LWR's.

3. Enrichment Facilities

The LWR and HTGR obtain most of their power from fissioning the uranium isotope U-235 which has a natural assay in uranium of 0.71 wt%; the balance is predominately U-238. The HTGR and LWR rely on enrichment plants to increase the amount of U-235 in uranium. A LWR is typically

charged with 2 to 4 wt% U-235 and an HTGR utilizes 93.5 wt% U-235. The LMFBR obtains most of its power by fissioning Pu thereby eliminating the uranium enrichment requirement.

In the United States the U-235 content is currently enriched in gaseous diffusion plants (GDF's). Uranium hexafluoride gas UF₆ containing U-235 diffuses through a membrane faster than a UF₆ molecule containing the uranium isotope U-238. In each pass through the barrier (a stage) the maximum increase in the U-235/U-238 ratio is approximately 1.004. This means that many stages are required to obtain significant enrichments of U-235. One alternate method, which is used or being investigated, is the gas centrifuge. In these machines, the stage separation is not as severely limited by theory, but by design. Centrifuge technology may become competitive with gaseous diffusion in the 1980's.

In both centrifuge and diffusion processes there is one feed stream and two discharge streams, one enriched in U-235 (the product stream) and the other depleted in U-235 (the tails stream). The optimum composition of the tails stream is dependent on the uranium price and the cost of separation. It ranges from 0.2 to 0.4 wt% U-235 and is currently about 0.25 wt% U-235.

Enrichment plant capacity is conventionally expressed in terms of kilogram separative work units (SWU) rather than kilograms of product uranium because a plant with a given number of stages can be operated at a variety of tails and product compositions. For example, it takes 3.811 SWU's to make 1 kg of 3% enriched uranium or 2 kg of 2% enriched uranium. To obtain these numbers, the feed stream was natural uranium and the tails composition was fixed at 0.25 wt% U-235.

The comparison between gaseous diffusion and centrifuge plants is difficult because the centrifuge technology is not fully developed and many of the details remain classified. In general, the most significant difference will be the power cost. It is estimated to take 1/10 the power of a diffusion plant to run a centrifuge plant of the same capacity. There appears to be no capital cost advantage but preliminary estimates

indicate that the lower power requirements of the centrifuge process could result in an SWU cost 20-30% lower.

The characteristics of the smallest economically competitive GDP are shown in Table V-6. Based on published data referred to above, the centrifuge plant would probably have similar characteristics with perhaps the additional annual operating cost (excluding power) being higher to partially offset the reduced power requirements. The higher operating cost would be mainly associated with maintaining and/or replacing centrifuge components.

TABLE V-6. Characteristics of Gaseous Diffusion Plants

Plant capacity	8,750,000 SWU/yr
Capital investment (1971 dollars)	\$1,050,000,000 ^(a)
Electricity consumption	2,050 MW
Heat dissipation to the environment	~2,050 MW
Operating force	960
Annual operating cost (excluding power)	\$15,000,000
On-stream efficiency	99.5%
Water requirements (with cooling tower operation)	15,000 gpm
Tonnes uranium feed/yr ^(b)	13,628
Tonnes product/yr (3% U-235) ^(b)	2,285
Tonnes tails (waste uranium)/yr ^(b)	11,343
Land requirement	300 acres
Construction period	6 yr
Peak construction force	4,000 persons
Construction labor	12,000 man-yr

(a) Enrichment plant only; does not include cost of power plants.

(b) Assumes 0.25 wt% U-235 tails composition.

If government facilities are brought to full operating power and are upgraded by proposed improvements, they will meet the needs of the LWR industry through about 1982. There will be a need for about 8.75×10^6 SWU of additional capacity each year after that date. This requirement will continue until the LMFBR takes over as the major reactor concept being constructed. From then on the existing enrichment plants will support the existing LWR power plants and no additional enrichment facilities will be required.

After 1982 these new plants may be government, privately or jointly owned. Laws would have to be amended to allow any private ownership. It is frequently cited that a \$1 billion investment is a very large risk for any large corporation to assume. This is one reason for suggesting private ownership of centrifuge plants which could conceivably be built in smaller sizes and thus with smaller capital cost. However, an 8.75×10^6 SWU enrichment plant operating with natural uranium fuel and 0.25% U-235 tails can only produce 6 tonnes/day of 3% product uranium. This is not a large throughput in comparison to other fuel cycle components such as fabrication and reprocessing plants. Thus, there really seems to be little incentive to build enrichment plants with capacities smaller than 8.75×10^6 SWU even if the plant cost were relatively insensitive to size.

Enrichment plants do not require isolation. The only radioactive waste material is uranium, which is released in very low quantities and which has a very low potential for biological damage. If the plant is being operated to produce 2-4% enriched uranium, this low enrichment reduces the probability of creating criticality conditions to essentially zero.

a. Enrichment Facilities in the NEC

Table V-7 shows published enrichment unit cost estimates for two plant sizes.

TABLE V-7. Illustrative Unit Enrichment Costs^(a)

Plant Capacity (10^6 SWU/yr)	8.75	17.5
Capital Investment (\$ x 10^6)	1200	1900
Power Usage (MW)	2430 ^(b)	4730
Annual Power Cost (\$ x 10^6 /yr)	106	207
Annual Operating Cost (\$ x 10^6)	14	16
Annual Return on Capital (\$ x 10^6 /yr)	240	380
Annual Enrichment Cost (\$ x 10^6)	360	603
Enrichment Unit Cost (\$/SWU)	41.2	34.5
Relative Enrichment Unit Cost	1.00	0.84

-
- (a) Assumptions: 1. Electricity cost of 5 mills/kW-hr
 2. 100% plant factor
 3. 1971 dollars
 4. 20% annual return on capital.

- (b) Based on 1970 technology. The lower value of 2050 MW in Table V-6 is for a projected advanced plant.

These data illustrate that increasing the size above 8.75×10^6 SWU/yr gradually decreases the unit cost, but the rate of decrease is not rapid enough to have a significant effect on the sales price.

It is assumed that an 8.75×10^6 SWU plant would be completed on the HNEC in 1982, with the possibility of expansion at a later date. The AEC now has three plants of that size, and it would be logical for private industry to build three to four plants of similar size while developing a competitive private industry. Because the feasibility and economics for centrifuge plants currently are uncertain, it is not possible at present to say which type plant will be built on the HNEC.

It is expected that a plant built on the HNEC would provide enrichment for reactors at both the center and other locations. The relatively low cost for shipping enriched uranium in comparison to the enrichment cost favors construction of a few large plants and resulting lower total costs than for construction of many small plants scattered throughout the

country. Since it is possible that larger enrichment plants may ultimately be desirable, the extra costs for building an 8.75×10^6 SWU plant which could be readily expanded to larger sizes should be determined.

4. Waste Management Facilities

It is expected that a Waste Treatment and Storage Facility (WTSF) will be built on the HNEC for long-term interim storage (up to 100 years) or ultimate storage of solidified high-level waste and for the processing and storage of low-level waste. These facilities, and the nuclear waste management procedures are summarized in Section VII F. Appendix V-B presents a more detailed generic description of high- and low-level radioactive waste storage facilities as now visualized.

D. HNEC INDUSTRIAL ACTIVITIES

Projections of electric energy requirements of heavy energy using industries in the PNW are presented in Table V-8. Many other industries will be selecting new sites throughout the region and could choose to locate at a HNEC, but their electric energy requirements will not be large enough to make the availability of electrical power a major locational determinant.

Even though energy availability may be one of the principal criteria in plant location, many industries identified in Table V-8 are not logical candidates for a NEC because other locational determinants would be more important. Some industries require deep water transportation, for example, which the available Columbia River Barge potential might not be able to satisfy. Others would prefer to be located in close proximity to major customers. In some cases, the balance between processing stocks and final markets would be detrimental to a NEC location.

Forecasting industrial development in the vicinity of a NEC is speculative. To obtain some approximation of industrial energy uses the following approach was used. Industrial growth is based primarily upon some previous work of the BPA plus a general review of economic developments in the PNW. In most cases, the estimates for the PNW are spinoffs from

TABLE V-8. Estimate of Annual Electric Requirements of Heavy Energy Using Industries Operating in the PNW

Industry Category	Millions of kW-hr				
	1962-1965	1970	1975	1980	1985
Abrasives					
Silicon Carbide	220.8		287.0	348.8	434.1
Aluminum Oxide	0.0		0.0	0.0	0.0
Ferro Alloys	1,440.0	1,640.0	2,000.0	2,390.0	2,810.0
Magnesium	0.0	270.0	720.0	960.0	1,600.0
Steel (by Area)	363.7	513.1	715.5	932.4	1,208.5
Ingot	326.3	398.8	485.8	587.3	710.5
Castings	37.4	39.3	42.2	45.1	48.0
Pig Iron	0.0	75.0	75.0	300.0	450.0
Titanium	0.0	8.0	78.0	155.0	310.0
Smelting	0.0	0.0	70.0	140.0	280.0
TiO ₂	0.0	8.0	8.0	15.0	30.0
Sulphur	22.91	25.25	27.92	30.61	34.08
Acid	17.9	20.0	22.4	24.7	27.9
Sulphur	5.01	5.25	5.52	5.91	6.18
Copper		926.6	995.4	1,056.1	1,108.0
Zinc		960.7	1,031.3	1,113.8	1,214.3
Lead Mining Concentrating					
Smelting and Refining		135.8	137.6	139.0	141.2
Phosphate Fertilizer Manufacturing		90.0	90.0	115.0	145.0
Chlorine and Caustic Soda Industry					
(Without a Magnesium Plant)	772.0	1,081.0	1,163.0	1,458.0	1,848.0
(With a Magnesium Industry)	772.0	1,081.0	1,081.0	1,081.0	1,081.0
Aluminum Metal	12,045.0		31,500.0	42,000.0	57,000.0
Paper and Pulp		14.2	16.6	19.5	22.5

national assessments and a share calculated for the PNW as based on factors such as historical trends, resource base, transportation facilities, etc. Since the development of an HNEC could provide volumes of electrical energy, which would far exceed foreseeable residential and commercial requirements, there would be an incentive for industries listed in Table V-9 to locate at a NEC if such location resulted in lower power costs. This table contains estimates of the volumes of electrical energy, which could be required by industries likely to locate at a NEC between now and 1985. The kilowatt hours shown in the table are roughly half of that which is estimated for the PNW as a whole. It has been assumed that with the availability of such power resources, about that proportion of industries would consider locating at an HNEC site. The balance would choose to locate elsewhere. This estimate is reflected in power demand projections (Section IV) and economic analyses of the HNEC (Section VI).

TABLE V-9. Estimate of Annual Additional Power Requirements of Industries Potentially Locatable at HNEC by 1985

<u>Industry Category</u>	<u>Additional (Millions kW-hr)</u>
Abrasives	107
Ferro Alloys	585
Steel	348
Phosphate Fertilizer	38
Magnesium	665
Chlorine (with a magnesium plant)	NA
Aluminum	2,248
Pulp ^(b)	<u>61</u>
TOTAL	4,052

(a) Assumed to be half that estimated for the PNW as a whole.

(b) Assuming one pulp mill of 500 ton daily capacity is located at the Hanford Center

It should be noted that most of these PNW estimates of industrial growth and electrical energy needs were made prior to the period of energy shortage. Some of the factors which were applicable at that time may no longer be operative today, and review should be made when the effects of the energy shortage on these industries' plans can be determined.

While there could be some satellite industry activity brought about by these bulk material processors, it is industry practice for most of the fabrication to take place at the final market point. There also would be many service and trade related industries springing up throughout the area to serve the growing population, but these would not likely become a part of a NEC.

E. PROCESS HEAT INDUSTRIAL USES

1. Excess Heat Utilization

In the concept of a major energy production center consideration should be given to the utilization on a large scale of available excess heat in the form of low, intermediate and high quality steam as well as the availability of high temperature heat from a reactor specifically designed for such production. A detailed study of the potential users of such forms of heat should be made with the objective of identifying those having the greatest probability of being attracted to a NEC. Some potential examples follow. No major impact on the HNEC can be seen at this time in the area of process heat industrial uses.

2. Low Quality Steam or Hot Water

The disposition of the enormous quantities of low quality heat in the form of low pressure steam or hot (or warm) water from conventional steam-electric power plants is a common problem. The use of district heating and cooling in the United States has grown very little since mid 1900 due to low cost fossil fuels for space heating. The energy crisis with attendant shortages and higher costs of fossil fuels will require that systems be developed that more efficiently utilize available energy

sources. Low quality steam and/or hot water from an energy center could be used for district heating and cooling of residential and commercial buildings. Development of the HNEC would cause an increase in population in the area and develop an increased demand for housing. Sufficient land is available around the Hanford site for development of a model city or a housing project to utilize alternate district heating and cooling concepts. Demonstrations of both steam and hot water systems for heating and cooling of residential and commercial buildings could be conducted in connection with the NEC. Distribution systems and equipment for use of hot water and/or steam heating could be evaluated from both the technical and economic standpoints.

It is also likely that under anticipated conditions of more intensified energy conservation, additional power may be recovered from low quality steam by incorporation of a binary fluid cycle based on low-boiling hydrocarbons, fluorocarbons or gases.

Industrial uses for such low quality steam or hot water may also be appreciable. In industry, generally the use of process steam accounts for at least 40% of the total energy requirements. For commercial uses the fraction is closer to 50% for space heating alone. In the industrial sector the ratio would vary widely, particularly when specific industries such as pulp and paper and other chemical process industries are considered. A specific comment relative to pulp may be made as follows.

The PNW is a major producer of pulp and paper and this industry can be expected to increase its capacity during the period that the HNEC is developed. Pulp and paper manufacturing facilities require large quantities of process steam, water, and electricity in addition to wood chips. Wood chips could be transported to Hanford as they are presently transported by truck and rail to the Boise Cascade plant which is approximately 20 miles from the Hanford site. The Hanford Reservation is located in the center of a large forest products industry and could be the site of a pulp and paper products industry using low-cost process steam and water from the nuclear center. Identification of those specific industries of greatest likelihood for integration with an energy center should be studied further.

3. High Temperature Process Heat

The large-scale availability and application of high temperature heat for process uses is another area for study. It is concluded that such heat would come from a nuclear reactor of specific design.

Although a wide range of conventional process industries may be shown to be potential users of such heat such as metallurgical processing, steel, copper, zinc, lead, aluminum and ferroalloys as well as nonmetallurgical processing such as phosphorus and chlorine, the more advanced technologies employing nonconventional processes for these essential materials may also be considered. Among them would be aluminum production by nonelectrolytic methods and the same for phosphorus and chlorine as examples.

Although it is unlikely that thermodynamic considerations would suggest that less energy would be required by nonelectrolytic methods, the effective use of a "lower form" of energy may be possible. The magnitude of the thermal demand in shifting from an electrolytic process to thermal processes in aluminum production, for example, would be substantial. In the PNW it has been estimated that electrolytic aluminum production in 1980 will require in the range of 17 to 24 billion kW-hr (60 to 80 trillion BTU). Similar equivalents can be shown for the other presently entirely electro-chemical based processes such as phosphorus, magnesium, and chlorine.

4. Hydrogen Production

Very large-scale production of hydrogen via successive chemical and thermal cycles rather than electrolysis for the decomposition of water is an extremely attractive possibility for employing large quantities of very low cost process heat. The specific combination of chemical reactions to be selected for such a thermal cycle has yet to be identified. A number of such cycles are being studied world-wide by a number of investigators at the present time. Their objectives include the utilization of a combination of chemical process steps none of which require temperatures in excess of about 750°C and which consume no scarce nonrenewable resources. Thus, these processes all involve regeneration of intermediate compounds.

Without suggesting its actual suitability or practicality the following is an example of one of such processes which has received considerable attention particularly in Europe:

If it is assumed that a means will be developed for the large-scale production of very low cost hydrogen, a very attractive possibility exists for the production of low cost methanol. The only other raw material needed would be carbon dioxide which could be recovered from the waste flue gases from a variety of combustion processes such as Kraft furnaces, cement and lime kilns, fossil fuel burning power plants and metallurgical processes. Although carbon monoxide would appear to be a preferred raw material, carbon dioxide could be used under conditions of sufficiently low cost hydrogen. One of the earliest commercial processes for the production of methanol in the U.S. utilized the carbon dioxide-hydrogen process.

Methanol is produced today in the U.S. at a level of about 5,000,000 ton/yr. Its use is growing. Low cost methanol is now being considered for use as a general purpose liquid fuel in place of fuel oil and gasoline. Its principal use today (about half of it) is in the production of formaldehyde (for plastics and plywood adhesives). It also has many other current uses as a chemical intermediate and as a solvent.

F. REJECT HEAT UTILIZATION IN THE FOOD AND AGRICULTURE INDUSTRY

The enormous quantities of warm condenser cooling water that would be discharged from a nuclear energy center containing a number of large, water-cooled nuclear power plants might be beneficially used on a large scale in the local food and agriculture industry. These benefits would be realized both in terms of increased production of basic foodstuff commodities, and on the net profitability of food processing plants built to utilize these commodities. The beneficial effects would be proportionately larger for a nuclear energy center located in northern regions, such as Hanford, than in more southerly locations because of the greater need for heat during the winter season. The ready availability of higher temperature fluids (steam and water) and electricity at such an installation would provide flexibility in utilizing the condenser cooling water in the most beneficial manner if suitable provisions are included in the design to facilitate use of these resources when needed. Two possible examples of using waste heat from the HNEC for food production and processing are discussed below.

1. Aquaculture

In the United States, consumption of edible fish products has risen from 4.3 to 6.2 billion lb/yr over the past decade. Domestic seafood production, however, has remained approximately constant at 2.0 to 2.5 billion lb, while the imported supply has increased from 1.8 to 3.7 billion lb. Less than one percent of the total consumption is supplied by aquaculture at the present time. An increase in the Nation's production of fish products through aquaculture offers not only a steady supply of high protein foods, but could contribute toward the reduction of the trade deficit.

The feasibility of using coolant discharged from a power plant for aquaculture recently was demonstrated by growing the Eastern oyster, Crassostrea virginica, in the discharge canal of the Long Island Lighting Company in Northport, Long Island, New York. Normal growing periods of 4 years were reduced to 2.5 years by selective breeding, artificial

spawning, and growing the oysters in the temperature controlled water. Catfish are cultured in cages in the thermal discharge canal of a fossil-fueled plant of the Texas Electric Service Company at Lake Colorado City, Texas. Yield during the winter of 1969-70 was 100 tons/acre-yr.

Within the Hanford Reservation there is land available for the installation of a 200 to 400 acre aquaculture facility. It would be sufficiently isolated from the population centers of the Tri-Cities that the environmental impact should be of no concern. (The use of heated effluent from the HNEC for aquaculture purposes would not significantly reduce the thermal energy to be dissipated, because considerably more water is needed to cool reactors than is needed for intensive aquaculture).

Heated effluent discharged from the center can be utilized to maintain the water temperature at the optimum growth level (approximately 60°F for the cold water species such as rainbow trout (Salmo gairdneri), especially during the cold winter months. The fingerlings of anadromous species, such as salmon (Oncorhynchus spp.) and steelhead (Salmo gairdneri) can also be maintained in the water at 60°F. They will grow larger than the natural population of comparable age and consequently have a higher ocean survival rate.

In addition, the heated effluent can be used for a year around cultivation of warm water species, such as catfish (Ictalurus punctatus), tilapia (Tilapia spp.), freshwater shrimp (Macrobrachium rosenbergi and M. carcinus). These species will not survive or attain marketable size in a short time in a temperate climate. By maintaining them in the optimum temperature range of 75 to 85°F, they can be marketed in less than 10 months from the egg, larvae, or fingerling stages. Growth rates of these species of fish and invertebrates have been increased by a factor of 2 to 3 over the wild stock at these temperatures.

Temperature control alone, however, is not sufficient for optimum production of aquatic species. Dissolved oxygen level, biological oxygen demand of culture systems, fish waste control, and nutritional adequacy of the feed are the other important parameters that also influence the

production of aquatic species. The low-level biological productivity of the Columbia River water make it unnecessary, under certain selected conditions, to add chlorine or other chemicals before it is passed through a condenser. This is a decided advantage because heated effluent water can be pumped directly into the aquaculture facility.

Food requirements would be met by shipping to the facility fish meal, soy bean products, slaughterhouse waste, and similar material. (Carp and tilapia are herbivores, requiring no import of food. These species would find a foreign market demand).

It is envisioned that it would be feasible to construct 400 aquaculture ponds, each 1/4 to 1/2 acre in size, with a total water surface area of about 150 acres.

For an average annual production of 50 tons/acre-yr the facility would yield 300,000 lb of fish/week. At an average, wholesale price of \$0.50/lb (which may be conservative), the annual wholesale value would be \$7.5 million. This would constitute a large aquaculture facility, but the above production represents only 0.24% of the U.S. annual consumption of edible fish products.

With technical innovations, a significant reduction in production cost comparable to that already achieved by the chicken fryer and broiler industries could take place in aquaculture utilizing the heated effluent from the energy center.

2. Agro-Industrial Complex

It is visualized that an agro-industrial complex might be built on or adjacent to the HNEC to utilize waste heat in the form of warm water and steam. It would also use some of the electricity generated by the energy center.

The major ingredients in the diets of most people in the U.S. are beef, pork, poultry, potatoes, other vegetables, dairy products, and grains (as cereals and bread). Accordingly, the integrated agro-industrial complex is visualized as producing several major products:

- Fresh-pack potatoes
- Dehydrated potato flakes
- Beef, milk, and cattle production by-products
- Pork and swine production by-products
- Fresh vegetables, flowers, etc., and
- Protein-rich feed supplement materials for livestock and poultry.

Supplemental inputs required to this complex would include the following:

- Irrigation water (warmed, when appropriate, with HNEC waste heat).
- Water for process operations (warmed by HNEC waste heat),
- Hay, grain, and feed supplements for livestock feeding, and
- Waste heat and electrical energy from the HNEC.

The agro-industrial complex would be designed to use all internal waste products in the most advantageous manner. The complex would be modular in nature; that is, expansion of any segment of the complex could be accomplished by construction of additional production and/or processing capacity.

Figure V-9 illustrates schematically an integrated production system for the complex visualized on or adjacent to the HNEC. The controlling factors for the size of the complex are the potato production and processing operations. All other activities derive from these considerations. It is assumed that a dehydrated potato flake processing capacity of 50×10^6 lb/yr would be installed. Associated criteria for the agro-industrial complex are as follows:

1. Potato flake production rate: 50×10^6 lb/yr.
2. Fresh-pack potato production rate: 300×10^6 lb/yr.
3. Acreage required for potato production: 15,000 acres.
4. Beef production rate (dressed carcass): 8,000 lb/day.
5. Pork production rate (dressed carcass): 3,200 lb/day.
6. Hay requirements for livestock: 12,000 tons/yr.

FIGURE 5.9. A Portion of an Integrated Agro-Industrial Complex to Beneficially Utilize HNEC Waste Heat

7. Grain requirement for livestock: 15,000 tons/yr.
8. Feed supplements requirements for livestock: 2,000 tons/yr.
9. Acreage required for hay production: 2,500 acres.
10. Acreage required for grain production: 15,000 acres.
11. Feed supplements for livestock: Produce virtually the entire supplement requirements from the fermentation complex.
12. Fresh produce from greenhouse complex: Not estimated; will depend on decisions as to crop mix, and economics involved.

The expected meat production from this complex should approximate the needs of about 25,000 people. This is less than the anticipated incremental increase in population due to construction and operation of the HNEC. The potato product production rates are larger than could be utilized within the local region, and would, therefore, provide for some export elsewhere. The same situation is assumed for vegetables from the greenhouse operation and for specialty items such as flowers, shrubs, etc. from the greenhouses.

No quantitative evaluation has been made in connection with this study of the beneficial effects of warm water irrigation in increasing productivity of open-land farming operations, or of increasing livestock productivity by environmental temperature control. There is evidence that some benefits would result in these areas. Figure V-10 illustrates results obtained during research at Purdue University to establish the effect of temperature control on the rate of weight gain by swine. Note that the optimum temperature range is 65 to 75°F depending on swine weight. Thus, both winter heating and summer cooling would be required to achieve totally optimum weight gain conditions. Climate control in the optimum range should increase swine production within the complex by about 20% (from 1.7 lb/day/pig to 2.0 lb/day/pig). Similar data are available to illustrate the beneficial effects of temperature control for beef cattle and poultry production.

FIGURE V-10. Effect of Temperature on Pig Growth

Figure V-9 shows the utilization of HNEC warm water in a number of operations in the agro-industrial complex. These include:

- a. Potato processing
- b. Swine production
- c. Cattle production
- d. Greenhouse complex (includes hydroponics)
- e. Fermentation complex

Land Requirements

The integrated agro-industrial complex is envisioned to consist of about 30-35,000 cultivated acres for potato, hay, and grain production each year. Fallow land and crop rotation requirements will be in addition to the above. Probably less than 1,000 acres would be required

for livestock management activities. The greenhouse complex may occupy 1000 to 4000 acres. Land requirements for the fermentation complex are estimated at roughly 500 to 1000 acres.

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SECTION VI

ECONOMICS OF THE HANFORD NUCLEAR ENERGY CENTER

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VI. ECONOMICS OF THE HANFORD NUCLEAR ENERGY CENTER

A. SUMMARY

The purpose of the economic analysis of the Hanford Nuclear Energy Center (HNEC) is twofold: (1) to identify areas of potential cost benefits or penalties compared to more dispersed siting of nuclear power plants, and (2) to indicate the magnitude of investments that may be required in initiating and implementing the NEC concept. The analysis is performed in a general way. A more detailed analysis would be desirable if the concept is to hinge on economics alone.

The electricity production cost for an HNEC is estimated to be from 5 to 10% lower than for dispersed plants. Factors tending to lower the cost include land costs, continuity of construction, operating efficiencies, and benefits from increased standardization and modernization in plant construction. Factors tending to increase the cost include transmission costs (both initial and operating), potential employment of marginal construction workers, and financial assistance to local communities to help provide required services. However, the 5 to 10% figure is a preliminary estimate, and additional studies would need to be made to determine it more accurately. Other potential economic benefits are described in Appendix VI; these too require further analysis before quantification.

The capital investment savings at the NEC for the accelerated construction program might be over \$1.0 billion by 1990, and operating cost savings might reach at least \$9 million/yr by 1990. Capital investments would total about \$18.5 billion; Table VI-1 details the investment by year. Similar figures for the normal case might total 0.75, 7, and 15, respectively. Table VI-2 details the investment by year.

B. LAND INVESTMENT AND STARTUP EXPENSES FOR THE HNEC

The major investment needed for initiating a nuclear energy center is that necessary for acquiring the required land. Some administrative and coordinating

functions and some preliminary studies could incur significant costs. The land cost investments will depend on the size of the properties selected for the various components of the HNEC.

The Hanford Project contains about 600 miles². It is estimated that about 10% of the entire project area would be required for the plant sites, construction areas, cooling ponds, and related facilities. At the current price of about \$100/acre for arid lands, this would require an investment of about \$4 million if the land was purchased outright. The remaining land (e.g., the AEC lands and the ALE reserve) could be retained in its current state. Some of the land for the HNEC could also be leased. The annual leasing cost would be about \$400,000/yr if all the land was leased. It is difficult to estimate potential land cost savings from use of the Hanford Reservation without analyzing alternative sites. Further, the large expanses of land potentially available at Hanford permit greater flexibility of site selection, heat disposal methods, construction methods, and other activities, than would be possible with smaller sites. On the other hand, other sites would probably optimize at less land areas than the estimated 60 miles² for the HNEC. If one assumes one-third of the area and land costs of \$1000/acre (this compares with an average cost of industrial land in the PNW of \$5000 to \$10000/acre), the savings in land cost could amount to about \$10,000,000 or more. Costs for more expensive systems (because of smaller sites) would increase this difference. A study is necessary to determine costs of administering and coordinating land use, construction, and operating activities at the HNEC. There is no reason to believe that the costs of administering the land (e.g. security, radiation monitoring, etc.) would be greater than for separated plant sites. The cost of such an activity is expected to be relatively low -- less than \$1 million/yr.

Should there be a need for coordinating the efforts of the HNEC participants, it probably would cost less than \$1 million/yr since this would probably consist primarily of assuring that there are no land or water use conflicts and that all waste releases are in accordance with

applicable laws and regulations. Normally, participants would manage such evaluations, but a coordinating function might be desirable to be sure that there are no detrimental synergistic effects. Another coordination activity could relate to the use of common facilities (railroads, etc.) to assure the most effective use.

To summarize, a HNEC might require an initial investment for land of up to \$4 million (1/10 of the project area), and annual operating expenses of about \$2.0 million. If the land was leased, there would be no initial capital investment, but the annual expenses would increase to about \$2.4 million. For assumed 50% investor-owned/50% public utility owned facilities, the initial investment would be about \$2 million and annual expenses would be about \$2.2 million.

C. POTENTIAL INVESTMENTS FOR FACILITIES AT THE HNEC

The potential investments by all participants in the NEC could reach \$18.5 billion by 1990 for the accelerated case, and \$15 billion for the normal case (Table VI-1 and VI-2). Of this, \$15 billion and \$12 billions, respectively would be for nuclear power plants. The investments by industrial participants (utilities, manufacturers, etc.) probably will be equal to the investments that they would make for the same facilities at other locations. The expenses to the Federal Government (assuming that it does not build any of the facilities) would relate to the development of the HNEC. Expenses to the Federal Government would probably be offset by the sale or lease of the land.

The largest potential savings to industrial participants would be connected with economies derived from the construction and operation of a multiple reactor site. Savings of up to 7% were estimated in other studies^(1,2) for the construction of multiple reactors. This might be over \$1,000 million for the \$14.6 billion (accelerated) reactor center in 1990, and about 3/4 over that for the normal case. Savings on standardization of reactor design and component fabrication might achieve another 5 to 10% savings. Although standardization is also possible at dispersed sites with similar savings the potential to standardize would

be greater at a single site. If partial standardization resulted in a 2% savings, the normal savings by 1990 could reach \$300 million for the accelerated case and 3/4 of that for the normal case.

A detailed analysis has not been made of operating cost differences between a NEC and dispersed plants, except in this area of operating manpower, which apart from the fuel cycle, is expected to be the major cost item. At a multiple reactor site, the operating crew would be reduced by at least 20 men/reactor. Since labor related costs (salaries, benefits, and other costs related to employment) would be \$20,000/man-yr, the annual savings in reactor operating costs would reach \$9 million in 1990 in the accelerated case and 3/4 of that for the normal case. Cost savings appear possible from optimization of the fuel cycle within a NEC, but these have not been examined.

Costs of transmission systems are discussed in Section VII D. It is assumed that costs for inter-region transfers of electrical power will be borne by the regions receiving the power.

REFERENCES

1. J. R. Young, et al., Cost Analysis of Multiple Power Reactor Siting at Hanford, November 1970.
2. General Electric Company Modular Design and Construction Concept, unpublished information, January 1974.

TABLE VI-1. Capital Investments for the HNEC

Accelerated Case

<u>YEAR</u>		<u>FACILITY</u> ^(a)	<u>\$</u> <u>MILLION</u>	<u>SOURCE OF</u> <u>FUNDING</u> ^(b)
1978	1	2 tonne/day UO ₂ Fuel Fabrication Plant	30	NF
		Transmission Facilities	100	BPA
1979	2	1300 MWe Reactors at \$500/kW	1,300	Utilities
		Transmission Facilities	100	BPA
1980	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
	1	600 ft ³ /day Low-level Waste Treatment Plant	40	NF
1981	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
		Transmission Facilities	100	BPA
	1	500 T/D Aluminum Plant	140	Industry
1982	2	1300 MWe Reactors	1,300	Utilities
	1	8.75 x 10 ⁶ MT SWU/Yr Enrichment Plant	1,200	NF
	1	Low-level Waste Storage Warehouse	3	NF
		Transmission Facilities	100	BPA
		UO ₂ FAB Expansion 2 to 3 tonnes/day	10	NF
	1	500 T/D Aluminum Plant	140	Industry
1983	2	1300 MWe Reactors	1,300	Utilities
	1	1500 tonnes/yr Reprocessing Plant	130	NF
	1	Low-level Waste Storage Warehouse	3	NF
		Transmission Facilities	100	BPA
	1	Ferro Alloy Plant	20	Industry
	1	500 T/D Aluminum Plant	140	Industry
1984	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
		Transmission Facilities	100	BPA
	1	500 T/D Aluminum Plant	140	Industry
	1	500 T/D Pulp Mill	40	Industry

(a) A second enrichment plant might be added in 1988. Its cost are not included in the totals.

(b) NF = Nuclear Fuel Cycle Services; BPA = Bonneville Power Administration.

TABLE VI 1. (continued)

<u>YEAR</u>		<u>FACILITY</u> ^(a)	<u>\$</u> <u>MILLION</u>	<u>SOURCE OF</u> <u>FUNDING</u> ^(b)
1985	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
		Transmission Facilities	100	BPA
		Expansion UO ₂ -PuO ₂ Plant 1/4 to 1/2 T/D	5	NF
	1	500 T/D Aluminum Plant	140	Industry
1986	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
		Expansion UO ₂ Fuel FAB Plant		
		3 MT→4 tonne/day	10	NF
	1	Magnesium Plant	100	Industry
	1	500 T/D Aluminum Plant	140	Industry
1987	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
	1	500 T/D Aluminum Plant	140	Industry
1988	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
	1	500 T/D Aluminum Plant	140	Industry
1989	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
	1	500 tonne/yr Reprocessing Plant	130	NF
		Expansion UO ₂ -PuO ₂ Plant 1/2→3/4 T/D	5	NF
	1	500 T/D Aluminum Plant	140	Industry
1990	2	1300 MWe Reactors	1,300	Utilities
	1	High-level Waste Disposal Facility	40	NF
	1	600 ft ³ /day Low-level Waste Treatment Plant	40	NF
	1	Low-level Waste Storage Warehouse	3	NF
	1	500 T/D Aluminum Plant	140	Industry

SUMMARY - TOTAL INVESTMENT THROUGH 1990

Reactor Investment	\$14.60 Billion
Industry Investment	1.56
Transmission Investment	0.70
Nuclear Fuel Cycle Service	1.67
TOTAL	<u>\$18.53</u>

(a) A second enrichment plant might be added in 1988. Its cost are not included in the totals.

(b) NF = Nuclear Fuel Cycle Services; BPA = Bonneville Power Administration.

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TABLE VI 2. Capital Investments for the HNEC.

Normal Case

<u>YEAR</u>		<u>FACILITY</u> (a)	<u>\$</u> <u>MILLION</u>	<u>SOURCE OF</u> <u>FUNDING</u> (b)
1981	1	2 tonne/day UO ₂ Fuel Fabrication Plant	30	NF
		Transmission Facilities	100	BPA
1982		Transmission Facilities	100	BPA
	2	1300 MWe Reactors	1,300	Utilities
	1	8.75 x 10 ⁶ MT SWU/yr Enrichment Plant	1,200	NF
1983	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
	1	600 ft ³ /day Low-level Waste Treatment Plant	40	NF
1984	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
		Transmission Facilities	100	BPA
	1	500 T/D Aluminum Plant	140	Industry
1985	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
		Transmission Facilities	100	BPA
		UO ₂ FAB Expansion 2 to 3 tonnes/day	10	NF
	1	500 T/D Aluminum Plant	140	Industry
1986	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
		Transmission Facilities	100	BPA
	1	Ferro Alloy Plant	20	Industry
	1	500 T/D Aluminum Plant	140	Industry
1987	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
		Transmission Facilities	100	BPA
		Transmission Facilities	100	BPA
	1	500 T/D Aluminum Plant	140	Industry
	1	500 T/D Pulp Mill	40	Industry

(a) A second enrichment plant might be added in 1988. Its cost are not included in the totals.

(b) NF = Nuclear Fuel Cycle Services; BPA = Bonneville Power Administration.

TABLE VI 2. (continued)

<u>YEAR</u>		<u>FACILITY</u> ^(a)	<u>\$</u> <u>MILLION</u>	<u>SOURCE OF</u> <u>FUNDING</u> ^(b)
1988	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
		Transmission Facilities	100	BPA
		Expansion UO ₂ -PuO ₂ Plant 1/4 to 1/2 T/D	5	NF
	1	500 T/D Aluminum Plant	140	Industry
1989	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
		Expansion UO ₂ Fuel FAB Plant		
		3 to 4 tonnes/day	10	NF
	1	Magnesium Plant	100	Industry
	1	500 T/D Aluminum Plant	140	Industry
1990	2	1300 MWe Reactors	1,300	Utilities
	1	Low-level Waste Storage Warehouse	3	NF
	1	500 T/D Aluminum Plant	140	Industry

SUMMARY - TOTAL INVESTMENT THROUGH 1990

Reactor Investment	\$11.70 Billion
Industry Investment	1.14
Transmission Investment	0.70
Nuclear Fuel Cycle Services	<u>1.45</u>
TOTAL	\$14.99

SECTION VII

BENEFITS AND PROBLEMS ASSOCIATED WITH THE CONSTRUCTION
AND OPERATION OF THE HANFORD NUCLEAR ENERGY CENTER

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VII. BENEFITS AND PROBLEMS ASSOCIATED WITH THE CONSTRUCTION AND OPERATION OF THE HANFORD NUCLEAR ENERGY CENTER

A. INTRODUCTION

The primary benefits and problems associated with the HNEC are identified in Sections I, II, and III of this report. The Center's purposes, conceptual description and economics are discussed in Sections IV, V and VI.

Section VII goes into more detailed discussions of the benefits and problems. Much of the discussion would apply for almost any Nuclear Energy Center (NEC), but the focus in this section is on the Hanford NEC.

The topics generally relate to:

- Impacts of the energy center on the environment, on man, and on man's institutions.
- Adequacy of applicable laws and regulations.
- Public safety considerations, and
- Cost/benefit trade-offs in the use of energy resources, including timeliness to relieve shortages.

Benefits and problems are discussed together because they are frequently interrelated. A problem at one site may be a benefit at another site. Or centralizing facilities at an energy center may facilitate transporting fuel and radioactive materials but tend to complicate electrical transmission and system reliability.

Such considerations are discussed in the paragraphs which follow. Some topics are treated in greater depth than others. Those not fully definitive will need further effort if the HNEC concept is to be developed further.

B. ENVIRONMENTAL CONSIDERATIONS

1. Ecological Effects

a. Meteorological

The meteorological data that has been acquired at the Hanford site for the past 29 years can be helpful in assessing the impact of the development of the HNEC. Because the area to be considered is large, it is anticipated that additional information on the spatial and temporal variations in meteorology will be required to fully evaluate the effects of potential effluent releases, including heat, moisture, air pollutants and radionuclides. Nevertheless, data already in hand, and programs now in progress, provide a source of information for an initial evaluation of the feasibility for this concept. If the program is pursued, these data will be used in determining where additional measurements should be made, significantly reducing the time required to achieve multiple siting in the area.

The major source of data is the Hanford Meteorological Station (HMS) which has been in continual operation obtaining basic information related to plant siting for 29 years. The meteorological tower extends 400 ft high and is instrumented to measure and record wind and temperature data at intervals of 50 ft. Summaries of these data are contained in two comprehensive climatological documents. In addition, basic data can be readily retrieved in those cases where special summaries are needed.

In addition to the HMS tower, there have been numerous other measurements that were obtained periodically over the years that permit a partial assessment of the variability of meteorology at the site. Because variations of this kind can be expected at any location of similar size in the country, these tentative data are considered a major advantage for defining the air flow characteristics on a regional basis. Data include wind measurements at the Fast Flux Test Facility (FFTF) site, and wind, temperature, and humidity measurements at the WPPSS Nuclear Project No. 2 site. A 245-ft instrumented meteorological tower is presently being erected at the WPPSS No. 2 site and will provide continuous data to be correlated with that from HMS. A third meteorological tower (300-ft) is at the N-Reactor site and

can be made part of the system. Data from these three towers and wind measurements obtained from selected ground-based stations will constitute a comprehensive weather measurement grid.

The effect of dissipating heat into the atmosphere through wet cooling towers and spray ponds will, in addition to heating the air, add moisture in the form of a visible plume. The extent to which the effect is felt in turn depends on meteorological conditions. Cooling towers and spray ponds dissipate energy as sensible and latent heat in varying proportions depending, primarily, on the season. The high temperatures and low humidities of the Columbia Basin in mid-summer result in most of the energy being dissipated as the latent heat of water vapor. The colder temperatures of the ambient air during winter tend to equalize the division between sensible and latent heat fluxes, and sensible heat can predominate during extremely cold conditions. The lowered capacity of the ambient air for additional moisture in winter assures that it will be the season of frequently visible plumes. Further, by virtue of increased stability of the atmosphere, they will tend to persist for greater distances than during the summer.

Assuming that two-thirds of the proposed 70,000 Mwt of heat is dissipated through cooling towers and cooling ponds and that half of that heat is dissipated as latent heat, the water vapor input to the atmosphere from the NEC would represent about 3% of the water evaporated from irrigation projects of eastern Washington during July. Although the input would be more concentrated from the HNEC than from the irrigated lands, the effects in mid-summer would be expected to be insignificant at distances for which the HNEC can be considered a homogeneous areal source. It is not possible to draw similar conclusions for winter, when relatively small additions of moisture to the atmosphere may be significant. The Hanford No. 2 plant will provide some direct experience with one wet cooling tower onsite, after startup in about 1978.

The total heat dissipation of 70,000 Mwt should also be considered since it represents a quantity on the order of that from the city of Chicago which has been attributed with measurable weather modification effects at

downwind points. In order that the effects of the energy release be minimized, it is important that the power plants be distributed over Hanford to take advantage of the large area which is available to dilute the emissions.

Using available models, it is possible to make estimates of the downwind behavior of vapor plumes for use in the presently qualitative evaluation. Such estimates show that significant increases in water vapor will occur to distances of several kilometers and point out the necessity to provide separation of the reactor sites within Hanford to minimize interaction of their cooling tower and cooling pond plumes. Such interaction would increase their visibility and the potential for inadvertent weather modification. Preliminary evaluation suggests that separation on the order of 10 km along the river corridor would be advisable if dual reactor sites (e.g., 2600 MWe) are contemplated. This would limit the number of dual evaporative cooling sites along the river to, perhaps, six with an additional dual site on a pond near the Yakima River approach to Hanford and another dual cooling pond site remote from the rivers. A full assessment of the meteorological implications of a NEC at Hanford will require a more extensive modelling effort utilizing the data described above and a proposed distribution of the cooling-tower and spray-pond facilities.

Some specific development areas needing further work are listed below.

- The development of a new generation regional multisource computer model for describing the diffusion, transport, depletion and interaction of multiple plumes. This model would be a major and necessary improvement over the Year 2000 Model, but would be based basically on state-of-the-art information.
- The development and/or verification of cooling tower plume models for single and multiple sources.
- Investigate the potential for cooling tower drift buildup on vegetation and in soils.
- The development and/or verification of improved cooling pond and spray pond performance models.
- The verification of heat island models.

- The investigation of the potential for beneficial as well as detrimental weather and climate modification due to the heat island effect and the added moisture and pollutants that would be generated.
- Investigate the rates of plume depletion that can be expected, i.e., the rate at which precipitation, aerosol interactions, and pollutant uptake (or attachment) by surfaces will affect the downwind air and surface concentrations.
- Investigate the feasibility of releasing nuclear park effluents into cooling tower exhausts to gain increased lofting and reduce surface concentrations.

b. Terrestrial

Shrub-Steppe Ecosystem. The most apparent impact of a NEC on the terrestrial environment is the amount of land required for buildings, parking lots, roadways, railroads and ancillary structures with a subsequent loss of biological productivity. Biological productivity in the unmodified shrub-steppe ecosystem at Hanford is low on the scale of ecosystem productivity; only the more arid southwestern deserts of the United States are less productive. Species diversity of the shrub-steppe ecosystem at Hanford is poor as compared to southwestern desert areas. Most of the plant and animal species in the shrub-steppe ecosystem have broad geographic ranges. There are no rare or endangered plant or animal species that would become wiped out, assuming the careful construction and operation of a NEC on the Hanford Reservation.

Vegetative Rehabilitation of Disturbed Soil. Construction activities invariably result in the destruction of existing vegetation cover and the mixing and stirring of surface soil. Through the careful selection of plants adapted to the rigorous climate of the shrub-steppe region and by designed preparation of seed beds, it is possible to rehabilitate self-sustaining vegetative cover on most sites. Restoration of pristine (climax) vegetation is not practical within a reasonable time span, if at all.

Transfer of Radionuclides to Man Through Food Chains. Historically, the unmodified shrub-steppe ecosystem has provided little plant or animal food

to man. With the exclusion of livestock grazing and the absence of irrigated agriculture, the potential for transfer of radionuclides and other kinds of potential environmental contaminants to man through shrub-steppe food chains is very low.

Transfer of Materials Beyond the Boundaries of the NEC. Natural draft and mechanical draft wet cooling towers will deposit variable amounts of dissolved solids at unknown distances from the NEC. The dissolved material will include minerals inherent in the coolant water, corrosion retardent chemical additives, corrosion products and chemical biocides. Some of this material will be carried offsite and deposited over range and farm land. Most of this material is believed to be non-deleterious to plant and animal growth. However, the ecological effect of long-term accumulation of cooling tower drift is uncertain and would have to be monitored.

Project ALE. Project ALE (Arid Land Ecology Reserve) is a 120 mi² (77,000 acres) portion of land located on the northeast slope of Rattlesnake Mountain and abutts the northwest boundary of the Hanford Reservation. It was set aside in perpetuity 6 years ago for the preservation of relatively undisturbed shrub-steppe ecosystems. Extensive ecological research has been in progress on it since its establishment, and on parts of it dating back to the late 1950's.

This ecology reserve is the largest contiguous area of shrub-steppe landscape in North America devoted to the preservation and study of shrub-steppe soils, plants, and animals. Over the past 10 years, data have been gathered concerning species composition, rare and endangered species, abundance of important plants and animals, primary productivity, mineral cycling, food chain dynamics, and the impact of environmental stresses such as fire, grazing by livestock, soil disturbance, fertilization, and ionizing radiation on its flora and fauna. The overall purpose of the Reserve is to provide for continuing ecological research and education. It serves also as a baseline (control) area to evaluate ecological changes as they occur in nearby areas.

Although some construction and operating facilities of a NEC may be adjacent to the eastern boundaries of the ALE Reserve, most facilities will

be separated by an unoccupied buffer zone several miles in width. Some airborne effluents from construction and operations will be carried over the ALE Reserve and some will be deposited on vegetation and soil surfaces. Impacts on the ALE Reserve will likely be small and not detectable by ecological methodology in use today. Development of an HNEC, including ground and surface water use, is not expected to interfere with ALE's ecological program.

Monitoring and surveillance activities on Project ALE, currently in progress, can be expanded as required both on the ALE Reserve and within the HNEC to serve mutual needs for environmental surveillance.

c. Aquatic

The Columbia River supports approximately 40 species of resident and anadromous fish. The river's only remaining free-flowing stretch runs through the Hanford Reservation, provides spawning grounds for chinook salmon and steelhead trout, and serves as a migration route for these and other salmonids to upstream spawning areas. Although this region of the Columbia River appears to be the most vulnerable to perturbation by an HNEC, it has already demonstrated an impressive tolerance to reactor operations in the past. Based on 28 years of extensive ecological research over the period from 1944 to 1971, there were no demonstrable adverse effects on river biota caused by the Hanford reactors.

Phytoplankton, zooplankton, and drifting organisms (including small fishes) could be affected by once-through reactor cooling in two ways. Organisms passing through the reactor cooling systems would be subjected to sudden increases in temperature which, in some cases, would be lethal. For larger drift organisms and small fish, condenser passage would likely be fatal, but studies of the passage of phytoplankton at the Hanford No. 1 plant have shown that short-term exposure to increased temperature produces no measurable effect on these organisms. Furthermore, long-term reproduction capabilities of phytoplankton are not impaired by either thermal or mechanical stress experienced during passage. Biotic effects in the thermal mixing zones of the river would not likely be significant. For

20,000 MW of heat dumped into the river, during periods of low flow the water pumped could involve about one-quarter of the organisms floating in the river. Annually, an average of about one-tenth of suspended organisms in the river would pass through condenser cooling systems. Losses of plankton and drift organisms of this magnitude could, theoretically, disrupt the balance of production in the river and possibly alter the structure of the river ecosystem. (Again, it is worth noting that past experiences have shown that this is not necessarily true.) Upstream replacement (i.e., recruitment) and natural responses to population reductions may be sufficient to negate the effect of mortalities caused by condenser passage.

For a limited number of plants using once-through cooling, chemical effects on river biota probably would be negligible. Ordinary releases of process materials would be insufficient to cause concern. Past experiences have shown that Columbia River water under certain specific conditions does not cause fouling in the condenser cooling systems so the use of anti-foulants is not routinely necessary.

Wet cooling towers and ponds would involve removal of certain quantities of water which would not be returned to the Columbia River. All organisms in the diverted cooling water would be lost. However, these losses would not be nearly as great as those incurred by single passes through once-through cooling systems.

In the case of cooling towers, the major aquatic impact would come from the release of salts, biocides and other chemicals as a result of blow-down. Such releases into the Columbia River should not endanger the biota by creating toxic conditions or alerting the natural chemistry if, say, ten cooling towers are used. Substantially higher numbers may require waste ponds to receive blow-down effluents.

Cooling ponds (lakes, lagoons) would not require a release of potentially harmful chemicals into the Columbia River, but this cooling technique introduces a new problem. Cooling ponds of substantial size would constitute a new and different aquatic habitat which would itself be impacted by nuclear plant operation. Possible locations of these ponds

are shown in Figure V-5 in Section V. It would be advisable for these ponds to be managed to achieve some level of acceptable ecological condition. Most of the Columbia River organisms would not survive in these ponds, and a major concern would be an over-production and accumulation of undesirable plant life (mainly noxious algae). If such ponds were established, it would be necessary to plan or control thermal and chemical releases so that these aquatic habitats would be allowed satisfactory ecological balance and stability. Several small ponds could be used without concern for their ecological well being, but the size of the water bodies created by a nuclear center, as envisioned on Figure V-5, would necessitate a special aquatic maintenance program. The use of these ponds would also have an impact on the terrestrial environment and groundwater movement. On a long-term basis, water removed from the Columbia River to create these ponds should not be of sufficient volume to cause a concern over water depletion in the river.

d. Water Use

Columbia River. THE HNEC will require water of adequate quantity and quality for numerous uses including, but not limited to, cooling, processing, sanitary, waste discharge, and construction. Water resources in the immediate vicinity of the Hanford Reservation include the Columbia and Yakima Rivers and the groundwater flowing under the Reservation itself. Since the Yakima River flow is very small in comparison to the Columbia and not as readily accessible, for all practical purposes the available surface water resource can be considered to be the Columbia River, one of the nation's major water systems.

In 1942 the subject area was selected as the ideal site for a nuclear reactor complex because of the presence of the river, which was successfully utilized as a heat sink for the Hanford production reactors.

In 1965, 1966, and 1967, river temperatures showed that the river typically absorbed from 19,000 to 23,000 MW of heat from all sources between Priest Rapids and Richland.⁽¹⁾ In 1965 when this heat input was 23,000 MW the river temperature at Richland was 1.5°C higher than at Priest Rapids at

a mean river flow of 129,000 cfs. This temperature rise is about 65% dissipated at the Washington-Oregon border, and the remaining increment at Bonneville Dam is on the order of 20 to 30% of the energy increment added to the river in the Hanford reach.⁽¹⁾

During Hanford's history as a nuclear center, extensive hydrologic data have been collected and effects of thermal loading estimated. Figure VII-1 outlines the river system, showing dam sites and monitoring stations. As a result of the Columbia Treaty with Canada, the water supply in the Hanford reach is now even better able to accept discharge heat. Basically, with the completion of the treaty dams the flow will be more regulated throughout the year. Consequently, in the Hanford reach, the maximum river temperature will be 1 to 2° cooler than in previous years; the maximum river temperature occurs in August. Following implementation of the Columbia Treaty, the average year-to-year peak is predicted not to exceed about 63°F, with the high extreme (maximum for any year) predicted not to exceed about 65 to 66°F. However, during times of low power needs, the discharge flow from the Priest Rapids Dam can be reduced to an allowable minimum of 36,000 cfs, which could occur during the peak river temperature period of August and September, even though the average August flow is projected to be 89,000 cfs.

The 36,000 cfs flow along with the provisions of PL92-500 (the Federal Water Quality Act, as amended) and State of Washington Water Quality Standards currently limit the number of once-through cooled reactors which could be sited at Hanford. When the river is at 66°F, the maximum permitted temperature rise is 2°F. At the minimum river flow of 36,000 cfs, the 2°F rise would permit once-through cooling of only two large (1250 to 1300 MWe) reactors. At 100,000 cfs and 150,000 cfs the 2°F rise would handle about five and eight reactors, respectively. Since the ability to regulate minimum flow below Priest Rapids Dam at substantially above the present 36,000 cfs exists, a strong technical case can be made that a significant capacity exists in the Columbia for dissipation of heat from once-through cooled reactors. However, raising the minimum flow would be a trade-off at the expense of some hydro-peaking capacity, and hence involves regional

FIGURE VII-1. The Columbia River System

power optimization considerations. Basic to obtaining variances from institutional constraints will be the ability to predict the effects of any action in advance to permit realistic regulating agency decisions.

Detailed evaluations of thermal loading will be aided by Battelle's collection of approximately 30 years of hydrologic and meteorologic records for the Columbia River. These data were collected from a network of stations spanning the Columbia River from the Canadian source to the Pacific Ocean. Most of them are available in permanent card files and magnetic tape data libraries. Tributary inflows are well gauged and data reported by the U.S. Geological Survey.

This information has been used extensively in the development and application of computer codes for simulating the thermal and hydraulic regime of the river.^(1,2) The code most commonly used for these purposes is termed COLHEAT as developed by Jaske. This program is fully operational and verified such that specific case studies could be initiated immediately to evaluate specific siting options.

Groundwater. Since the initiation of activities at the Hanford Project in the mid-1940's geological and hydrological investigations have been conducted to establish and evaluate management alternatives with respect to groundwater resources. Initially, these investigations consisted mainly of analyzing (1) well logs and driller's samples for stratigraphic information, and (2) groundwater potentials for groundwater movement patterns and rates. The efforts concentrated on defining and understanding the water table aquifer because of its direct relationship to waste management activities.

Since then, the aquifer has been classified into textural types and pump tests have been conducted to determine the permeabilities of each textural type; geophysical logging tools have been used to aid in defining the stratigraphy. Substantial resources have also been directed to development of methods for utilizing these data to produce the answers required for managing the Hanford groundwater basin, and a system of models was developed for simulating groundwater and waste movement in the Hanford complex as functions of time and space.

Since utilization of groundwater for the NEC may be extensive, its effect on groundwater resources already being used needs to be analyzed. Groundwater transmissibility varies over 5 orders of magnitude on the Hanford Reservation, making the impact of proposed action highly site specific. The operational modelling system could be used to help evaluate alternate siting schemes and agriculture and aquaculture uses of waste heat in the form of warm water.

e. Land Use

The Hanford Reservation has a long history of use in support of the nuclear industry which continues with new applications including the FFTF, Hanford No. 2 and Hanford No. 1 nuclear power reactors. In addition to these newer activities, portions of reservation lands are dedicated to waste management and storage (200 Areas). In the southwest portion of the reservation, 120 mi² are set aside for long-term ecological studies (Project ALE) (see Figure VII-2). The smaller ecology reserve areas within the site are temporary study areas which will eventually be available for other uses. The reactor areas along the northern edge of the reservation (100 Areas), with the exception of 100-N Area, have a low intensity of current use and many of the facilities have been declared abandoned. Islands in the upper portion of the Columbia River adjacent to the Hanford Reservation are restricted for several species of wildlife and related use. Some land north and east of the river adjacent to the reservation is designated for recreational uses.

Land uses within a 30-mile radius of the Hanford Reservation include residential, commercial, industrial, agricultural, scenic, and recreational among others, but are dominated by agricultural uses. Population density data for land surrounding the reservation are included in Appendix V-A. Although the population density is relatively low, Hanford has the advantage of an existing technical and cultural base necessary to attract and hold the professional and skilled workers required for an NEC.

With the exception of Rattlesnake Mountain, forming the west boundary of the reservation, and the much smaller Gable Mountain and Gable Butte in

FIGURE VII-2. Hanford Reservation Land Uses

the north central portion of the reservation, major portions of the reservation display little relief and are suitable for industrial construction. The internal part of the reservation is a plateau some 300 feet above the Columbia River.

Even to the casual observer touring the Hanford Reservation, the percentage of presently uncommitted land in the 600 mi² is substantial. From a strictly land-availability standpoint, siting of the proposed HNEC should offer little difficulty. The total available land is well distributed across the reservation, which should permit near-optimum separation of the various HNEC components. The HNEC is believed to be in harmony with AEC plans for diversification of the Hanford Reservation by incorporating nuclear activities compatible with continuing AEC programs on the site.

Environmental studies have been carried out on the Hanford Reservation for over 30 years. These studies encompass essentially every environmental factor of significance in siting. Environmental effects of nuclear facilities on the reservation have been separately studied by over five independent firms.⁽³⁻⁸⁾ Numerous potential reactor sites have been identified in the area.^(8,9) (See Figure V-7 in Section V of this report.)

A final in-depth analysis will be needed to plan the best overall use of the reservation land for the AEC's continuing programs plus all of the HNEC activities, including various combinations of industries. The zoning, planning, and potential interaction effects must be known. The number of potential sites and their relationship to one another and other industrial sites must be evaluated and the potential of agriculture and its compatibility with the HNEC needs more thorough evaluation. Terrestrial ecology and other environmental studies now being conducted will provide a significant data base of direct application to land use siting considerations.

Such in-depth analysis of HNEC components and their interrelationships would be integrated with long-term AEC planning. A product of the study would be an identification of alternative physical arrangements for an HNEC to permit selection of individual sites in a time sequence consistent with a comprehensive long-range plan.

2. Radiological Impact

The feasibility and ultimate size of an NEC will depend, among other things, upon the capacity of the environment to accept the radioactive effluents released to the atmosphere and to the ground or surface waters. A generic discussion of the radioactive materials in and released from the types of nuclear facilities expected to be part of the NEC is presented in Appendix VII-A. The following discussion assesses the impact of the combined releases of radioactive effluents from the proposed HNEC facilities.

a. Environmental Studies at Hanford

Because of the availability of measurable quantities of radioactivity, the Hanford environs have been the locus of several scientific studies, sponsored by the AEC and others, of the movement of radioactive materials through the biosphere and of the resultant radiation doses received by the local population. These studies are in addition to the extensive environmental sampling and analysis programs, and the studies of meteorology, hydrology, reactor safety and management of radioactive wastes carried on as part of the AEC activities onsite.

An environmental survey program was initiated at the beginning of the Hanford project. As more sophisticated analytical methods were developed, specific radionuclides were identified and traced through the environs in minute amounts.

In early 1958, the staff of the Hanford environmental surveillance group compiled the first in a continuing series of comprehensive annual reports on the status of environmental radiation in the Hanford environs. (10) This report, presented to the 2nd Geneva Conference on Peaceful Uses of Atomic Energy, demonstrated the feasibility of estimating the total radiation dose potentially received by local residents from external exposure and from consumption of food, air and water, provided certain diet, recreational, and residency factors were known. Each year's annual report estimated such radiation doses with increasing accuracy as a result of the environmental research carried on at Hanford. (11,12)

An appreciation of the detail covered in these dose evaluations can be gained from the report for 1969,⁽¹²⁾ when three of the original nine plutonium production reactors were operating at Hanford. Figure VII-3 illustrates the radiation doses received by a hypothetical maximum individual, whose diet and recreational habits have been assembled from the highest values found in local studies. The doses received by such a hypothetical person represent a conservative upper limit to the potential dose likely to be received by any local resident.

Figure VII-4 illustrates the estimated radiation doses received by an average member of the general population. Both figures indicate the approximate contribution of various nuclides and pathways to the total dose. Considerable knowledge about the contributions of radionuclides in the several environmental pathways and of the population habits are necessary to construct such a composite dose with a reasonable degree of accuracy.

Some of the environmental studies carried out at Hanford are listed in Table VII-1.⁽¹¹⁾ Many of these studies involved the use of whole-body counters, for direct measurement of the small amounts of radionuclides contained within the bodies of local residents.

Several studies of the habits and success of fishermen have been made of the Columbia River immediately below the Hanford project. The most detailed was a year-long statistical study designed to determine the kinds and quantities of various species of fish being caught and the hours spent by fishermen on the shoreline harvesting these fish.⁽¹³⁾ For this study, a game biologist actually visited various portions of the river shoreline and observed the catch.

Information and methodology developed at Hanford has been utilized in constructing generalized mathematical models of the behavior of radionuclides in the environment and for assessing radiation doses to man and animals.⁽¹⁴⁻¹⁸⁾ Applications of these data and models include:

- Estimation of the doses to man from a nuclear power industry in a large region of the United States in the Year 2000.^(14,15,19)

FIGURE VII-3. Estimated Doses to the Maximum Individual in the Hanford Environs - 1969(3)

FIGURE VII-4. Estimated Doses to the Average Richland Resident⁽³⁾

TABLE VII-1. Population Surveys at Hanford ⁽¹¹⁾

Date	Population Group and Survey	Group Size
1960-1968	Plant employees measured with a Hanford Whole-body Counter were asked to complete a diet survey form; a computer file of diet and whole-body counting data was prepared.	~~7000 persons
1965-1968	Elementary school children (5 to 12) in 17 local schools were surveyed with a whole-body counter and a 7-day diet record card; about 75% of the students voluntarily participated in the survey.	~ 5500 children
1969	Teen-aged students (12 to 17) in a high school and a junior high school were surveyed with whole-body counter and oral diet and river recreation questions; about 50% of the students responded.	427 Teen-agers
1967-1968	A statistically derived sampling program was used to obtain information on Columbia River fishing. Stretches of the river were visited for 4-hr periods according to a schedule derived from random selection, and the fishermen interviewed.(13)	2,132 Fishermen interviewed
1966-1969	Whole-body counter and diet surveys were made of fishermen located at popular fishing spots on four occasions.	85 Fishermen
1969	A survey using the mobile whole-body counter and oral diet questions was conducted in a local rural area using Columbia River water for irrigation. Scheduling families to visit the whole-body counter became a community service project for seven 4-H clubs in the area.	343 Persons
1969	Students in Home Economics classes in two local schools assisted in a survey of eating habits of family members. They estimated the size of servings taken by family members during the course of 11 meals during a 1-week survey period using handbooks containing pictures of five weighed serving sizes for 25 different varieties of foods.	250 Persons
1970	A survey was conducted in two coastal communities located near enough to the mouth of the Columbia River that Zn-65 from Hanford could be detected in local marine organisms; both communities were centers for commercial seafood production.(19)	462 Persons

- Estimation of the radiological impact of nuclear reactors for inclusion in Environmental Impact Statements as required by NEPA. (17)
- Estimation of doses to man from various concepts for ultimate disposal of high-level wastes from commercial nuclear power production. (18,20)
- Evaluation of various rad-waste treatment systems versus resulting radiation doses for the AEC's proposed Appendix I to CFR Title 10 Part 50. (20,21)

b. Impact of an NEC at Hanford

The numerous studies of the Hanford environment discussed above indicated that it is possible to establish all of the facilities required for an NEC at Hanford without a significant radiological impact on man or biota and without the need for prohibitively expensive rad-waste systems. Preliminary estimates of the radiation doses expected from liquid and gaseous effluents are discussed below.

Because of the isolation provided by the Hanford project, no measurable radiation doses to offsite residents are postulated to occur from routine handling of solid wastes or from transportation of liquid or solid materials within the complex.

Liquid Effluents. The doses to the maximum individual and general public from liquid effluents were estimated using the following assumptions:

- Twelve PWR's and thirteen BWR's (including Hanford No. 2) were sited on the Columbia River.
- The PWR's utilized rad-waste Case 3 from Reference 13 and the BWR used rad-waste Case 2 treatment systems for liquid effluents.
- Eight of the reactors utilized spray ponds and only tritium reached the Columbia River via pond seepage.
- Eight of the reactors utilized once-through cooling and nine (including Hanford No. 2) utilized cooling towers.
- No other nuclear facilities discharged radioactive liquid effluents to the Columbia River.

- There are a maximum of two reactors per site and initial mixing in the river is the same as that given in Reference 22.
- The maximum individual is allowed access to within 500 meters of the most downstream reactor where he fishes, swims, boats and withdraws irrigation water for home-grown produce. He drinks water drawn from the Columbia River containing the completely mixed effluents from all 25 reactors.
- The annual average flow rate of the Columbia River is 10^{14} liters/yr.
- The effect of the effluent from the 23 upstream reactors at the downstream site is to increase the radiation doses received by the maximum individual by about 50%.
- The general population exposed downstream of the project includes 120,000 people swimming, boating, fishing, etc., in locations where the effluents from all 25 reactors have been uniformly mixed in the river.
- Forty-eight thousand people consume water derived from the Columbia River. No credit was taken for cleanup in the municipal water plants.
- Annual consumption and recreation habits were those derived from local studies as used previously for the Hanford No. 2 Environmental Report.⁽²³⁾

The doses to the maximum individual and general population within 50 miles of the Hanford site were estimated from the above assumptions and are summarized in Table VII-2 below:

TABLE VII-2. Estimated Annual Radiation Dose Received from Liquid Effluents Released to the Columbia River from an HNEC

<u>Organ</u>	<u>Maximum Individual, mrem</u>	<u>General Population, person-rem</u>
Skin	0.4	0.09
Total Body	8	0.8
GI-LLI	0.7	0.4
Thyroid	0.9	5
Bone	5	0.6

Since these doses were calculated assuming relatively simple rad-waste treatment systems, it should be possible to reduce the maximum individual doses to less than 5 mrem. The principal contributors to the total-body and bone doses listed in the table are Cs-134 and Cs-137. Reduction of the cesium release rates by factors of 2 to 3 would result in corresponding reductions in the doses to these two organs.

The population doses are certainly low in comparison to those from natural background radiation which amounts to about 25,000 person-rem/yr to the ~200,000 persons living within 50 miles of the project (in 1970).⁽²³⁾

Gaseous Effluents. Calculations of the radiological impact of releasing radioiodine from a 200-ft (60-meter) stack on the Hanford Project have been performed in the past utilizing the comprehensive set of meteorological data available at the Hanford Tower. Table VII-3 summarizes the results of these calculations in terms of air concentrations and resulting infant thyroid doses per Ci/yr released, assuming a 7-month grazing season and a 5-month vegetable consumption period.

TABLE VII-3. Estimated Infant Thyroid Doses from Release of 1 Ci/yr of I-131 at the HNEC

Distance (miles)	Maximum Air Concentration pCi/m ³ (a,b)	Maximum Milk(c)	Infant Thyroid Dose, mrem/yr Vegetables(d)	Total
0.5	1.6×10^{-2}	34	7.9	42
1.5	5.0×10^{-3}	11	2.5	13
2.5	2.6×10^{-3}	5.5	1.3	6.8
3.5	1.7×10^{-3}	3.7	0.86	4.6
4.5	1.3×10^{-3}	2.8	0.66	3.5
5.0	1.2×10^{-3}	2.5	0.60	3.1
7.5	8.9×10^{-4}	1.8	0.42	2.2
15	5.1×10^{-4}	1.1	0.25	1.3
21	4.0×10^{-4}	0.85	0.20	1.0
25	3.5×10^{-4}	0.74	0.17	0.91
35	2.7×10^{-4}	0.56	0.13	0.69
45	2.1×10^{-4}	0.45	0.11	0.56

(a) The maximum direction is towards the SE from the release point.

(b) Release height - 200 ft (60 meters)

(c) Grazing season - 7 months

(d) Vegetable consumption period - 5 months

A fuels reprocessing plant with a rad-waste system similar to that for the Barnwell plant would release about 0.4 Ci I-131/yr to the atmosphere (see Appendix VII-A). If such a plant was operated where the existing Hanford Redox or Purex plants are located, the closest potential farmlands would be 6 miles NNW, 13 miles east, and 17 miles SE. A release of 0.4 Ci/yr of I-131 would lead to infant thyroid doses at these locations of about 1, 1.5 and 1 mrem/yr, respectively. However, experience with actual releases of I-131 from the separations plants at Hanford indicate that such a release would actually yield doses about 10% of those calculated by the environmental model.

Data in Appendix VII-A indicate that the release rates of I-131 from power reactors could be maintained as low as 10^{-2} Ci/yr with sophisticated rad-waste systems. If such low release rates could be maintained for all of the 25 reactors to be located in the HNEC, then the maximum individual thyroid dose at the boundary of the site furthest downwind would not be unacceptably high. For example, if the effective average distance from reactor release points to the location of the grazing area were only ~5 miles (actual range would be about 2 to 20 miles) then the combination of 23 reactors, each releasing 10^{-2} Ci I-131/yr would lead to an infant thyroid dose of ≤ 1 mrem/yr. This dose would be in addition to the dose received from releases from the nearest two-reactor site. The latter dose could be ~1 mrem/yr at ~0.5 mile from an elevated source. (This dose would increase to ~50 to 100 mrem/yr for a ground-level release point of 0.5 mile distance.) Therefore, if all of the releases were from a tall stack, the maximum infant thyroid dose from 25 reactors and a fuels reprocessing plant combined would still be ≤ 5 mrem/yr from all airborne radionuclides and atmospheric pathways.

The population exposure resulting from the release of noble gases to the atmosphere from 25 reactors and a fuels reprocessing plant can be estimated from the population dose estimates given in Reference 22 versus rad-waste systems. The population exposure principally resulting from the release of noble gases from all of the facilities at the HNEC would probably be acceptable because of the low population density and the remoteness

of most of the sources. Using the data given in Reference 22 on release rates and population doses versus rad-waste systems for LWR's and the data in Appendix VII-A concerning the release of Kr-85 from the Barnwell Plant, it is possible to estimate the potential population exposure. Assuming that the rad-waste systems employed at the power reactors were at least equivalent in noble gas removal efficiency to Cases BWR-5 and PWR-2 in Reference 22, then the total population dose to the 2×10^5 persons in the Hanford vicinity would certainly be below 100 person-rem/yr and could be as low as 25 to 50 person-rem/yr. Such a value is very small compared to the dose currently received by the same persons from natural background radiation (25,000 person-rem/yr).

3. Chemical Effects

Operation of the HNEC will require the use of a wide variety of chemicals, some of which will be released to the environment under controlled conditions. A significant fraction of the chemicals used will be associated with radioactive substances and will be converted to solid wastes for storage and/or appropriate disposal to prevent dispersal of radioactivity and associated waste chemicals. Remaining chemicals will either be consumed during use or disposed of following their use. Following is a discussion of types of chemical waste normally discharged by nuclear facilities. These are summarized on Table VII-4.

a. Water Treatment Waste

Production of purified water for reactors, fuels fabrication, and fuels reprocessing facilities requires chemicals to remove suspended matter and/or dissolved salts from the water. Filter backwashes normally discharged to receiving waters contain suspended matter removed from raw water plus alum, iron, or lime sludges used to coagulate suspended matter. To avoid increasing suspended solids in receiving waters, regulatory agencies favor land disposal of sludges.

A major chemical discharge from the complex will be spent chemicals used to regenerate ion exchange beds utilized for demineralizing water. Most frequently used are sulfuric acid and sodium hydroxide which are

normally blended to neutrality before discharge into receiving waters. Wastes are sodium sulfate with smaller quantities of magnesium, calcium, and chloride salts, which are relatively innocuous but can contribute significantly to water quality degradation by increasing dissolved solids in receiving waters if sufficient dilution is not available. An alternative disposal scheme is the use of solar evaporation ponds to produce solids for burial or road salts for deicing.

b. Chemical Wastes Associated with Cooling Water

Heat exchange surfaces in recirculating cooling systems sometimes require the use of biocides to control slime which adversely affects heat transfer. Chlorine is currently the most favored biocide used by power generating facilities; however, care must be exercised in its use because of its toxicity to aquatic life. Wastewater discharges to the Columbia River must not exceed 0.04 mg Cl/liter for periods not more than 2 hr/day or 0.002 mg Cl/liter for continuous discharge.

Proper design of the chlorination system will minimize discharges of chlorine in spent cooling water. Sequential chlorination of the various cooling systems within the complex can be accomplished in a manner that will allow sufficient blending of chlorinated water with unchlorinated water to dilute and reduce the chlorine to innocuous levels.

c. Chemical Process Wastes

Chemical waste from fuels fabrication and reprocessing plants include fluorides, nitrates, and ammonia as the principal pollutants. Recovery and reuse of some chemicals is often feasible. Storage of ammonia and fluoride bearing wastes in lagoons is currently practiced by some fuels fabrication plants, although recovery of high grade ammonium fluoride is possible. Treatment of fluoride wastes with lime to form insoluble calcium fluoride is an alternative. This would allow recovery of ammonia by steam stripping.

Nitric acid is readily recovered from many acidic wastes by evaporation and/or calcination. Wet scrubbers may be required to reduce residual NO_x in the offgas from the recovery system to acceptable levels for discharge.

Relatively low levels of ammonia and fluoride in waste discharges are required to avoid toxicity problems with aquatic life. Excessive ammonia and nitrate in wastewater discharges can also cause undesirable acceleration of algal growths.

d. Miscellaneous Chemical Wastes

Relatively small quantities of chemical wastes will be discharged from HNEC facilities which may or may not require treatment. They include substances such as cleaning agents, hydrazine, boric acid, lithium hydroxide, polyphosphates, chromates, laboratory reagents, corrosion or erosion products (e.g., copper), oil, and laundry detergents. Water conditioning chemicals such as hydrazine and lithium hydroxide and reactor shim control agents such as boric acid are generally very dilute in the wastes and do not ordinarily require removal prior to discharge. Excessive leakage or replacement of the closed loop water requires treatment of these wastes on an infrequent basis.

The Hanford area offers a unique advantage for an NEC in that solar evaporation can be used for those wastes which cannot be readily reduced to innocuous forms. A solar evaporation pond can be constructed at a reasonable cost using plastic or rubber liners to prevent soil percolation. A relatively few ponds could be constructed to serve the entire center. Evaporation to salt cakes would take place over a period of years following which the cake could be removed for burial in a landfill specially constructed to prevent leaching of the salt cake. Leaching of salts from a landfill with a suitable cover of coarse sand topped with fine sediments is insignificant in areas of low rainfall.

TABLE VII-4(a). Reactor Plant Chemical Process Wastes/1000 MWe Reactor-yr

Process	Chemical	Tons Discharged	Fate
Water Treatment	Alum lime sludges	50	Landfill
Demineralization	Na ₂ SO ₄ plus other salts	200-500	River, landfill, or road deicing
Once-Through Cooling		None	River
Wet Tower Cooling Blowdown	Residual chlorine	0.05	River via waste storage basin
Sanitary Wastes	Residual chlorine	Negligible (0.005 tons)	Sewage treatment system

NOTE: Once-through cooling with Columbia River water requires no Cl₂

TABLE VII-4(b). Enrichment Plant Process Chemical Wastes/8,750,000 SWU/yr
(Product contains 3% U-235, Tails contain 0.25% U-235)

Process	Chemical	Tons Discharged	Fate
Once-Through Cooling	None	--	River
Wet Tower Cooling	Chlorine	Negligible	River
Sanitary Wastes	Residual chlorine	0.06	River via sewage treatment system

NOTES: Once-through cooling using Columbia River water will not require chlorination.

Wet tower cooling - 15,000 gpm water (BNW report to Tri-City Nuclear Industrial Council) - assume continuous chlorination with a 0.002 mg/liter Cl concentration - Blowdown (at three concentrations) would be approximately 2.6 MGD, therefore, lb of Cl discharge per year = ~16.

Based on 3,811 SWU/kg of 3% ²³⁵U.

Decontamination acids, etc., waste to barrels.

TABLE VII-4(c). Fuel Fabrication Plant Chemical Process
Wastes/100 Tons U Fuel Fabricated

<u>Process</u>	<u>Chemical</u>	<u>Tons Discharged</u>	<u>Fate</u>
Chemical Processing	Ammonium Hydroxide	942	Waste treatment system
	Ammonium Fluoride	834	Waste treatment system
	Ammonium Nitrate	150	Waste treatment system
Etching	Aluminum Nitrate	0.07	Waste treatment system
	Nitric Acid	250	Waste treatment system
	Hydrofluoric Acid	33	Waste treatment system
	Zirconium Sulfate	15	Waste treatment system
Water Treatment	Sodium Sulfate	0.03	Waste treatment system

C. ENGINEERING, CONSTRUCTION, AND OPERATIONAL MANPOWER CONSIDERATIONS^(a)

The Hanford Nuclear Energy Center (HNEC) will generate considerable schedule and cost economies in the areas of construction, engineering and operations. The impact on construction will be an overall reduction in the construction time and manpower requirement for each facility. Obtaining the work force required to support construction of the Nuclear Energy Center (NEC) poses some difficult though solvable problems. A significant reduction in the engineering support required for construction of each facility is anticipated due to similarities in design and environmental conditions between reactors.

1. Construction Schedule

For construction planning purposes the HNEC is assumed to consist of twenty 1300-MWe power reactors to be used for commercial purposes, two 1300-MWe reactors to be used to power a gaseous-diffusion enrichment plant, and supporting fuel fabrication, reprocessing, and waste management facilities. Two alternates have been considered. In the primary alternative, reactors following Hanford No. 2 and No. 1 are scheduled to be started at a rate of one every 6 months starting in July 1975 and having a 5-yr construction duration, as shown on Figure VII-5. A peak work force of approximately 21,000 is required to support this schedule, with the peak occurring in 1979 and 1980 (see Figure VII-6). Manpower requirements for each facility are shown on Figure VII-7.

The secondary alternative is based on the premise that reactors following Hanford No. 2 and No. 1 will be started at a rate of one every 12 months beginning in July 1975; each reactor will have a 5-yr construction duration (see Figure VII-8). The peak work force required to support the secondary alternative is nearly 13,000 and occurs in 1979 and 1980 (see Figure VII-9).

As centrifuge enrichment technology has not yet progressed to the stage where it is commercially available, construction of this type of

(a) Section VII-C is based on a study and report prepared for PNL by the Olympic Engineering Corp., Seattle, WA.

FIGURE VII-5. Construction Schedule for the HNEC - Primary Plan
(Based on Start of Construction of One Reactor
Every 6 Months)

FIGURE VII-6. HNEC Total Onsite Manpower Requirements - Primary Plan
(Based on Start of Construction of One Reactor Every
6 Months, Completing Two per Year Through 1989)

EXHIBIT III - CONSTRUCTION MANPOWER REQUIREMENT BY FACILITY - PRIMARY PLAN
(BASED ON STARTING CONSTRUCTION OF TWO REACTORS EACH YEAR)

FIGURE VII-7. Construction Manpower Requirements by Facility - Primary Plan
(Based on Starting Construction of Two Reactors Each Year)

FIGURE VII-8. Construction Schedule of HNEC - Secondary Plan
(Based on Starting Construction of One Reactor
Each Year)

FIGURE VII-9. HNEC Total Onsite Manpower Requirements - Secondary Plan
(Based on Starting Construction of One Reactor Each Year)

facility has not been examined in depth. Preliminary estimates indicate that there is no significant capital cost advantage in construction of a centrifuge enrichment facility over a normal gaseous diffusion plant. However, since a centrifuge enrichment plant requires only approximately 10% of the power required to operate a gaseous diffusion plant, the two reactors required to power the gaseous diffusion plant could be eliminated if the enrichment plant were the centrifuge type. Elimination of these two reactors would result in a reduction of the peak manpower requirement from 21,000 to 18,000 and, for the secondary alternative from about 13,000 to 10,000.

The manpower peak in 1978, 1979 and 1980 is due to the construction of the enrichment plant and its two reactors (plus the other fuel cycle facilities) at the beginning of the time period. This is on top of the continuing reactor construction activity which is also building up to its sustaining maximum. A 5-yr construction period is assumed for each reactor, with each 1300-MWe reactor requiring 1700 onsite construction personnel in the peak (4th) year. This includes 1600 craft personnel plus 100 onsite engineering personnel. As discussed below, the total man-years of construction labor to build one reactor should decrease for reactors later in the series due to the learning curve. No such reduction was estimated or built into the construction manpower projections, partly because the 21,000 manpower peak comes early in the time period--perhaps too soon to benefit significantly from the learning curve.

2. Construction Review

Construction of these facilities in an NEC should reduce the overall construction time and manpower requirements for each facility. This forecast reduction is based on increased construction and operational efficiencies in the areas discussed below.

a. Minimization of Work Force Mobilization and Qualification

Construction of these facilities in the same locality will create a stable requirement for craftsmen over an extended period as compared with a 2- to 4-year peak period for construction of a single reactor. This

will allow the labor force to permanently locate near the job site. This constant trained labor force pool will reduce the time and cost otherwise incurred by multiple mobilizations of the work force that is normally required for construction of individual reactors. Additionally, many mechanical and electrical crafts are required to take extensive qualification tests if they have not done nuclear grade work in the last 60 or 90 days. As the NEC approach will provide continuous employment to these crafts, the time and cost required for qualification testing can be minimized.

b. Increased Capital Intensive Fabrication and Construction

Construction of a multi-reactor power plant complex will make it economically feasible to create onsite fabrication centers to prefabricate assemblies normally constructed piece by piece at each site. Concrete forms, pipe spools and pipe subassemblies are typical of the materials which can be prefabricated near the site. This will result in a significant reduction in the required work force. Additionally, it will be economically feasible to bring automatic machinery such as automatic welding machines, etc. to the construction site, thereby further reducing the construction time and number of craftsmen required.

c. Reduction of Construction Support Facilities

The Nuclear Energy Center approach would make it possible for all projects to be serviced by common construction support facilities; consequently, some construction time and labor force savings could be realized by eliminating redundant construction facilities. For example, the construction and operation of one large concrete batch plant to service all projects will require far less manpower than the alternative of constructing 20 batch plants to service individual reactors at separate job sites. These support facilities will service many projects over an extended period of time and will operate at sustained peak efficiency throughout the construction of the NEC.

d. Elimination of Redundant Reactor Operation Support Facilities

A sizable construction time savings will be realized through elimination of redundant reactor operation support facilities. By placing the reactors in close proximity, common maintenance, fuel storage and other service facilities can be constructed to service several reactors. The elimination of the redundant facilities will result in a significant reduction in the amount of construction required.

3. Manpower Requirement

The peak construction force requirement for the primary alternative is estimated to be approximately 21,000 workers in 1979 (see Figure VII-6). Of these, 15,000 will be certified construction craftsmen. This represents one-fifth of the construction tradeworkers forecast to be in the State of Washington by 1979. Construction craft figures for the five western states (Washington, Oregon, Alaska, California, and Hawaii) indicate that with the exception of pipefitters there will be sufficient manpower available for construction of the HNEC. With the forecast increase in reactor and other mechanical intensive construction, a nationwide shortage of pipefitters is anticipated by 1979.

At peak construction in 1979, 4,600 pipefitters are required for the primary alternative (see Figure VII-10) whereas 3,000 pipefitters are required for the secondary alternative. Occupational trend data indicates that 3,300 pipefitters will reside in Washington by 1979 and 23,500 will reside in the five western state region. It is feasible that up to 2,500 pipefitters could be drawn from the western region to support construction work at Hanford. Difficulties are anticipated in recruiting the remainder of the pipefitters required for this project. However, the NEC concept provides two distinct advantages in coping with potential shortages of craftsmen. The number of craftsmen required in this case will be slightly less than the number of craftsmen required if the reactors are constructed separately due to efficiencies previously discussed. With the number of craftsmen involved it would be feasible to develop a large-scale accelerated training program for nuclear work near the site. This program would

FIGURE VII-10. Required Construction Manpower by Craft - Primary Plan
(Based on Starting Construction of Two Reactors Each Year)

serve a dual purpose of encouraging apprenticeships in the pipefitter trade in addition to providing re-education for journeymen in related fields, such as plumbers. Fortunately the peak requirement for pipefitters is not until 1979 to 1980 so if an accelerated program were started in 1975, it is feasible to meet the peak requirement for both alternatives.

4. Procurement

The NEC concept will provide several benefits in the procurement of materials needed to construct the required reactors. The use of existing designs and specifications, and the building of nearly identical units should provide both reliable sources of supply and dollar savings on repetitive orders. Additionally, the tremendous volume of material and equipment required over a 12- to 16-yr period will create a competitive pricing and supply situation from both the standpoint of multiple ordering and the incentive for new vendors to enter the nuclear market. The forecast construction of new reactor plants exceeds the current ability of suppliers or vendors to produce necessary materials. However, given the high priority of this project and the well-defined and scheduled requirement for materials, it is felt that vendors can react in time to meet the schedule requirements of the HNEC.

The difficulties encountered in the procurement of materials and equipment for the construction of reactors within an NEC are not unlike those encountered in building reactors at various sites throughout the western states. The nuclear power plants currently under construction are experiencing difficulties with procurement even to a point of halting construction due to the nonavailability of essential materials and/or components. These procurement problems are related not only to the limited number of nuclear qualified suppliers, but also to shortages of raw materials. The problems encountered in procurement for an NEC are somewhat alleviated in that the material requirements are well defined over a 15- to 20-yr period.

Procurement of the reactor vessel is a typical procurement problem facing construction of nuclear reactors throughout the nation. Combustion

Engineering, Babcock & Wilcox, and Chicago Bridge and Iron are the only organizations in the U.S. with the capability of producing reactor vessels. Their best delivery time in recent years is 41 months and they are presently operating at near peak capacity. Current estimates are that it will take new vendors in excess of three years to install the necessary equipment to start reactor vessel fabrication. In other words, the forecast national requirement for reactor vessels exceeds the existing capability of the U.S. manufacturers. It will take new vendors a minimum of 6 1/2 years to make delivery on their first reactor vessel. Reactor vessels are currently being made in Europe, Japan and the USSR; however, competition is becoming increasingly keen for those on the international market. To resolve this and other procurement problems, considerable effort must be expended to qualify additional vendors and expand the capacity of existing vendors. The vendors must be encouraged to produce the components required to construct the reactors within the scheduled time frame of the NEC. The incentive required to encourage vendors to manufacture to the Nuclear Code may have to take the form of tax incentives, guaranteed procurement schedules, premium pricing or governmental priorities.

The primary alternative requires the most pressing procurement schedule of the two alternatives. However, even the scheduled construction of reactors in the primary schedule should provide sufficient lead time to develop the necessary suppliers and resources required to support construction of the NEC.

An aid to procurement is the fact that design packages would exist with approved specifications for the necessary materials and equipment to build a number of successive identical units. Procurement of long lead items could begin almost immediately once the decision to build the HNEC is made.

5. Hanford Site

Hanford is located in an area with direct access to rail, road, water and air transportation. The climate is considered to be excellent for construction purposes; however, due to the dryness of the area, dust is a

problem. It has been demonstrated on recent projects at Hanford that with proven dust control techniques the dust problem will not affect construction progress.

6. Engineering Review

The design benefits of an NEC involving several near-identical reactors on a common site could be substantial. Of all the commercial nuclear power plants now operating or under construction, no two are identical. Although the basic reactors which provide the energy for these power plants have been standardized and are available as packages, the support systems, auxiliary systems, and containment structures are individually designed for each power plant.

There are two major savings peculiar to the NEC approach. The first is the standardization of design related to using a common site for construction (seismic studies, foundation engineering, tornado hardening, insulation requirements, etc.). Individual location of nuclear power plants would result in a redundancy of many design functions. If physical conditions involving various construction sites remain constant, the bulk of the design analysis becomes non-recurring. Approximately 50,000 man-hr and \$1,000,000 associated with these recurring design functions can be eliminated.

The most significant savings can be realized if the actual design of reactors is standardized. Preliminary estimates have put this potential savings at \$20 million per reactor. Though the majority of this savings can be achieved without adopting the NEC concept, the likelihood of accomplishing this is much greater in an NEC.

To take advantage of the standardization potential available in design, a cooperative atmosphere should exist among individual firms involved in the design of various reactors on the site. If several design teams are involved simultaneously, each in preparing plans for some of the reactors, provisions should be made to permit an exchange of information needed to achieve savings due to standardization.

7. Cost Savings

A cost reduction on the order of \$100 million for construction of each \$600 million reactor should be possible. However, only 30% of this reduction is due to savings peculiar to construction of an NEC. Approximately 70% of the savings should be realizable as a result of standardizing design and constructing reactors in groups of two or more. A breakdown of the estimated \$100 million savings is shown below:

ESTIMATED COST SAVINGS	
	<u>\$ Millions</u>
Facility Cost	20
Construction Support Services	10
Common Facilities	15
Spare Parts and Fuel Sharing	5
Engineering and Design	20
Overhead and Indirect Costs	<u>30</u>
Total Estimated Savings	\$100 Million/reactor

D. TRANSMISSION CONSIDERATIONS

1. NEC Requirements

The electric generating capacity at the HNEC, and the growth of loads (1) in or near the HNEC and (2) at distant load centers, postulated for the purpose of examining transmission requirements, are given below for the Year 1990:

	<u>Peak MW</u>
Generating capacity at HNEC	35,000
<u>Load</u>	
Onsite	8,500
Transmitted to western load centers	16,000
Transmitted to interregional points to the south	<u>10,500</u>
Total load	35,000

Peak power transmitted across the Cascade Mountain Range to load centers in Seattle, Portland, and the Willamette Valley would include the 16,000-MW component from HNEC, and 19,500-MW hydroelectric generation in excess of loads east of the range. The combined flow is that which must be accommodated in the mountain pass corridors, where bottlenecks are more likely to occur than in corridors carrying only HNEC power. The total 35,000 MW would flow through various corridors in the amounts:

	<u>Peak MW</u>
To Puget Sound load center area	16,000
To Portland load center area	14,000
To the Willamette Valley	<u>5,500</u>
	35,500

Transmission facilities for these loads would be determined by the above capacity requirements, by stability and spare capacity requirements of the system under normal types of generating plant and transmission line

failures, and by any special requirements imposed because of the concentration of power generation at HNEC.

A transmission plant that is added to provide the necessary capacity and degree of reliability must build upon, and be compatible with, a transmission plant in existence or authorized.

2. Status of Transmission Capability in the PNW

Major lines in the BPA system are overhead AC lines at 230, 345, and 400 kV, and a DC tie-line with the Southwest, which is ± 400 kV. The network of major lines to be in place by 1975 in the vicinity of Hanford and to the west is shown on Figure VII-11.

Peak transmission in 1973 in the east-west corridors was:

	<u>MW</u>
Puget Sound Area	4900
Portland and the Willamette Valley	4250

3. Transmission Installation Required by the HNEC

To accommodate the anticipated increase in power flow, the capacity in the east-west corridors must be increased about fourfold. The new capacity must be built in corridors radiating from Hanford to major tie points in the system. Some additions may be necessary in other parts of the system to accommodate the concentration of generation in the HNEC. Capacity of the Pacific Northwest-Southwest intertie would be increased by a factor of about 2.

A major objective in expanding the capacity of the system would be to confine new transmission facilities to existing corridors. Advance studies made by the BPA for analogous situations indicate that the necessary capacity can be provided in existing corridors with high-capacity overhead AC lines at 500 to 1100 kV. To obtain the necessary degree of system reliability, multiple circuits may be needed in certain corridors; reportedly, space is available for them. Lines and equipment of 500 kV are currently in use in the BPA system. By the time the capacity would be needed, adequate

FIGURE VII-11. Major Electrical Transmission Lines as of 1975

transmission plant equipment at voltages above 500 kV should be available, provided that development programs now underway are successfully completed. The use of single 1100 kV lines, or two double-circuit 500 kV lines, could be considered. Each of these alternates has a capacity of about 10,000 MW and comparable economy. Expansion of system capacity by the use of either of these two alternates, or by the use of intermediate voltages, could be compatible with the existing transmission system in the PNW. For example, a superimposed 1100 kV system of six lines from HNEC to the western load centers, and one north-south line interconnecting these centers may provide ample capacity, stability, and spare transmission capability for the development of HNEC to the 1990-1995 period under the assumptions adopted for the report (see Section V.B and Table V-1). The estimate discussed below is based on such a system.

Modes of transmission other than those discussed above are not presently feasible for transmitting HNEC power to the West Coast load centers, for technical or economic reasons. Presently, DC is economically competitive with AC transmission only for distances much greater than 200 miles, untapped. For this reason it is not suitable for east-west transmission, but may be competitive with AC for long transmission lines to California. The most optimistic estimates of cost of long-distance underground transmission lines are many times that of overhead transmission of equal capacity. Underground cable systems are, or will be available for short runs to avoid congestion, improve reliability or penetrate urban areas. By 1990 work on cryogenic and other advanced types of transmission may have progressed to a point at which their technical and economic feasibility can be determined for applicability in later years.

4. Transmission Cost Penalty

A rough preliminary estimate has been made of the added transmission costs associated with the 16,000 MW component of HNEC generation (in 1990) sent to western load centers, relative to those that would be incurred if equal generating capacity were distributed in twin-unit stations in the general vicinity of the Puget Sound, Portland, and Willamette Valley load centers. The comparative estimates are in terms of 1973 costs. The major assumptions are:

For the HNEC Case

- The character of the 1100 kV system would be as described above, with an average transmission distance of 196 miles.
- An allowance for unamortized cost of lower voltage lines removed to make room for new lines is included.
- An allowance for cost of intermediate substations required because of replacement of lower-voltage lines is included.
- Losses are included in the unit cost estimate for transmission.
- Transmission costs for the hydro component of power flow will neither increase nor decrease because of the transition to higher-capacity lines.
- Normal peak loading on transmission lines will average 60% of nominal capacity.

For the Case of Distributed Generating Plants

- It is assumed that dual 500 kV single circuit lines from each twin-unit station would be 50 miles in length.
- Additional right-of-way for all lines would be acquired.
- Normal peak loading on transmission lines would average 70% of nominal capacity.

The difference in estimates of transmission costs for generation concentrated at HNEC, or distributed near the load centers, was from \$30 to \$40 million/year, or from 0.3 to 0.4 mill/kW-hr of energy transmitted, assuming that HNEC plants would operate at an average plant capacity factor of 70%.

There would be a transmission cost penalty against HNEC for power sent to interregional points to the south, assuming that the alternate locations for generating plants would be in the general vicinity of The Dalles. The cost difference would be less than the 0.3 to 0.4 mill/kW-hr cited above because the incremental distance is less.

5. Risk of Service Interruptions

The occurrence of an earthquake or tornado at the center, or accidental release of radioactivity from one reactor, or a storm that could cause simultaneous failure of many east-west transmission lines could have serious consequences such as shedding of all but the most essential loads at the western load centers for a substantial period of time. However, the probability of occurrence of such events would be extremely low. The incidence and severity of earthquakes and tornados in this area are very low and no storm has ever caused transmission line outages in more than one corridor at a time. Whether or not the possible consequences could be accepted would be a matter of public policy influenced by the benefits that would derive from the existence of the NEC. The risk to service interruptions at western load centers caused by multiple transmission line failures would be no greater than it is today, but would be greater than it would if more new thermal plants were sited west of the Cascade Range. It is believed that the transmission arrangements described above could provide ample protection against complete failure of all lines in any one corridor. Further study will be needed to determine system design that can reduce the risk associated with the HNEC to an acceptable level.

6. Alternatives to Electrical Transmission

Hydrogen is an attractive fuel, environmentally, and can be liquified, transported, stored, and later used when needed. Possibilities are discussed in Appendix VII-B.

E. LICENSING AND REGULATION CONSIDERATIONS

A large body of Federal and State statutes and regulations, which affect location and operation of nuclear industries, would apply at the NEC. Some of the applicable laws include the Atomic Energy Act of 1954 as amended, the National Environmental Policy Act of 1969, the Federal Water Pollution Control Act and the Clean Air Act. The statutes and regulations which have developed from these basic laws cover several factors, including (1) Environmental Impact Analysis, (2) Siting, (3) Pollution Control, and (4) Waste Management.

1. Applicable Statutes and Regulations

a. Environmental Impact Analysis

The establishment of a demonstration power center by the AEC constitutes a major Federal action within the meaning of the National Environmental Policy Act of 1969 (NEPA), and therefore would require that a generic Environmental (Impact) Statement be prepared for power centers. Although this statement would not be site-specific, additional information would be required for each specific site. CFR Title 10 Part 11, "Environmental Statements-Operations," describes how this is to be done. In response to Federal Acts, several states including Washington have established compatible requirements. The following Washington State statutes appear to be applicable:

- Environmental Quality Reorganization Act of 1970 RCW 43.21 (a)(b)
- Environmental Policy Act of 1971 RCW 43.21 (c)

Much of the information which must be provided for a Nuclear Center Impact Statement exists for the Hanford site. This information includes that which has been prepared in the licensing of existing nuclear facilities on or near the site, the Hanford Waste Management Environmental Impact Statement, information obtained specifically for this study, and published Hanford reports.

b. Siting

Siting of nuclear facilities is covered on the Federal level by CFR Title 10, Chapters 50 and 100 and associated appendices. Additionally, several states, including Washington, have established requirements for siting of thermal power facilities, including nuclear.

The siting of thermal power plants in Washington State is controlled by the Washington State Thermal Power Plant Site Evaluation Council established by RCW 80.50. It is intended that this council provide a "one-step" certification by all involved state agencies, within 1 year, of

" . . . any stationary or floating thermal power plant with generating capacity of 50 thousand kilowatts or more"

" . . . new transmission lines of 48 kV or more installed anywhere within the State of Washington."

The law specifies that "the council be composed of the directors or their designees, of the following departments, agencies and commissions or the statutory successors of such directors:

- Water Pollution Control Commission
- Department of Water Resources
- Department of Fisheries
- Department of Game
- State Air Pollution Control Board
- Department of Parks and Recreation
- Department of Health
- Interagency Committee for Outdoor Recreation
- Department of Commerce and Economic Development
- Utilities and Transportation Commission
- Office of Program Planning and Fiscal Management
- Department of Natural Resources
- Planning and Community Affairs Agency
- Department of Civil Defense

Presumably, certification by the Site Evaluation Council would indicate that the requirements of these state agencies or their successors had been met.

The Hanford site has been approved by the AEC for the WPPSS Hanford No. 2 reactor currently under construction and, therefore, the site appears to meet current siting requirements for nuclear facilities.

c. Pollution Control

The Clean Air and Water Pollution Control Acts provide basic guidance on the Federal level as to requirements for protecting the environment. Regulations issued by the Environmental Protection Agency (CFR Title 40, Chapter 1) provide specific guidance as to limits on chemical and thermal releases to the environment. The following Washington State statutes appear to be applicable to the proposed power center:

- Clean Air Act of 1972-1973 RCW 70.94
- Water Pollution Control RCW 90.48

The following regulations have been promulgated under the authority of the above statutes:

- Washington General Air Pollution Regulations WAC 18-04
- Reporting by Thermal Power Plants, Aluminum Plants and Chemical Wood Pulp Mills WAC 18-28
- Washington Carbon Monoxide Standards WAC 18-32
- Washington Suspended Particulate Standards WAC 18-40
- Washington Particle Fallout Regulations WAC 18-44
- Washington Photo Chemicals, Hydrocarbons, Nitrogen Dioxide Regulations WAC 18-46
- Washington Sulfur Oxide Standards WAC 18-56
- Washington Procedures Regulations WAC 18-60
- Washington Ecological Commission Regulations WAC 132-12
- Shoreline Development Permit Regulations WAC 173-14
- Washington Water Quality Standards WAC 173-201
- Washington General Occupational Health Standards WAS 296-62
- Water Pollution Control WAC 372-68

In accordance with the enabling legislation (RCW 70.94) a Tri-County Air Pollution Authority has been established for Benton, Franklin and

Walla Walla counties. The Authority has issued regulations which, if met by the nuclear center participants, should satisfy the requirements of both the State and Federal regulations.

CFR Title 10 Part 20 "Standards for Protection Against Radiation" establishes limits on air and water effluent concentrations. A recently proposed Appendix I would supplement Title 10 Part 50 to maintain radioactivity in the effluents of light-water-cooled nuclear power reactors as low as practicable. While final values to provide definitive guidance to "as low as practicable" have not been established, it is believed that Appendix I is indicative of future regulations, even for nuclear facilities other than light-water-cooled reactors. Therefore, allowable effluent releases for the nuclear center will probably be based on values proposed in Appendix I of Part 50.

d. Thermal Pollution and Other State Water Quality Criteria

The State of Washington has, in compliance with earlier Federal water quality legislation, established water quality standards for all inter- and intra-state waters within its boundaries and controls industrial waste discharges through a waste discharge permit system. Specific numerical criteria are included in the Standards (attached as Appendix VII-A) for coliform organisms, dissolved oxygen, dissolved gases, pH, turbidity, and temperature, with generalized criteria for toxic, radioactive or deleterious material concentrations and aesthetic values. A special temperature provision has been included, covering the Columbia River within and adjacent to the Hanford site boundaries, which states that: "Water temperature shall not exceed 68°F due in part to measurable (0.5°F) increases resulting from human activities; nor shall such temperature increases, at any time, exceed $t = 110/(T-15)$; for purposes hereof, "t" represents the permissive increase and "T" represents the water temperature due to all causes combined." T is the water temperature after mixing, and includes t.

The EPA has been reluctant to accept this concept of a variable permissible river temperature increase, preferring instead a fixed maximum temperature differential from waste discharge; the issue has not at this time been resolved. Some possibility exists of conflicting State of

Washington/EPA requirements. The point has been raised that some interpretations of the Federal Water Quality Act of 1972 could negate any thermal additions to the river from industrial waste discharges by 1983. This is the date when the best available technology practically achievable is to be employed to minimize or eliminate waste discharges to rivers and groundwater.

e. Waste Management

There appear to be no Federal laws dealing with waste management, although there are administrative regulations. Applicable laws have been developed in several states including Washington. The appropriate Washington State statute is the "Solid Waste Management Act" RCW 70.95. As for individually-sited reactor plants, radioactive waste management at the nuclear center will be controlled by regulations of the Atomic Energy Commission (AEC). Sections 20.301 to 20.305 of CFR Title 10 Part 20 apply specifically to waste disposal and burial considerations.

CFR Title 10 Part 50 "Licensing of Production and Utilization Facilities" contains the bulk of the AEC's regulations concerning the licensing of nuclear power reactors and other nuclear facilities. However, appendices to Part 50 provide guidance on important aspects of waste management. Specifically, Appendix F limits the high-level liquid waste inventory of the fuel reprocessing plant of the center to that processed in the prior 5 years. Furthermore, the Appendix notes that liquid waste must then be converted to an approved solid form within an additional 5 years and transported to a Federal repository. Since the waste management facility of the HNEC is considered to be a Federal repository, transportation of high-level solids and waste from the complex after 10 years will not be required. The primary requirement is to provide storage for high-level solid wastes for at least 100 years and to make it possible to retrieve failed or weak canisters and repackage the contained waste for continued storage or for shipment for ultimate disposal. The latter might not be required if the center were also uniquely sited for ultimate disposal of the high-level solids.

Other portions of Federal regulations potentially associated with waste management practices and facilities for the nuclear center include

CFR Title 10 Part 30 (Licensing of byproduct material), CFR Title 10 Part 71 (Packaging of radioactive material for transport), and CFR Title 10 Part 100 (Reactor site criteria).

2. Institutional Action Which May Be Required

Existing laws, regulations and enabling legislation as well as the agreements entered into by the participants should be oriented to take full advantage of such things as common strengths, pooling of efforts, and collective approvals for the site. While none of the existing laws or regulations prohibit this development, it appears that revision and interpretation of the regulations, and some legislative action should be considered if the potential advantages of a nuclear energy center are to be realized. These would appear to fall in three categories:

- Establishment of a Central State Agency for Site Approval
- Interpretation of Existing Regulations Relative to "Site" and "Plant" Boundaries
- Coordination of Onsite Activities
 - a. Central State Agency for Site Approval

As currently established, the Washington State Thermal Power Plant Site Evaluation Council has jurisdiction only over the thermal power plants and transmission line facilities associated with the power center. Many of the advantages of the center can be realized only if other nuclear fuel cycle facilities are included within the same site. It seems certain that the eventual presence of these facilities must necessarily be taken into account by the State agencies represented by the Siting Council in approving the site for the thermal power plants in view of the interaction, both additive and synergistic, of the impact of the various kinds of plants upon the same environment. It would be very desirable to broaden the authority of the Site Evaluation Council to encompass all nuclear fuel cycle facilities envisioned for the site.

b. Interpretation of Existing Regulations on Site and Plant Boundaries

Various parts of the AEC's regulations (e.g., CFR Title 10 Parts 20, 50, 70, 71 and 100) use a variety of terms to describe boundaries of the areas contained within these boundaries, in establishing requirements relative to siting reactors, access control, pollution control, plant security, material control, accident analysis, transportation controls, etc. Some examples:

<u>Term</u>	<u>As Used in, for example</u>
Site	Part 100; Part 50, paragraph 50.34, and Appendix E, part IV
Restricted Area	Part 20; Part 50, paragraph 50.34(a) and Appendix I
Environment	Part 50, Appendix A, criteria 60 and 64
Plant Site	Part 70, paragraph 70.22 f
Confines of His Plant	Part 71, paragraph 71.2
Place	Part 70, paragraph 70.22(a) (7) and 70.23(a) (3)
Locations	Part 70, paragraph 41(a)
Plants or Other Place of Use	Part 71, paragraph 71.5(a)

In the normal licensing situation where a single facility is involved, the intended meaning of these terms is generally clear. In the case of an NEC, consisting of a large site (with a site boundary) within which many separate privately-owned plant areas (with plant boundaries) are imbedded, the terms are in many cases ambiguous.

Which of these terms may be taken as the area within the center boundaries and which may be taken as the individual licensee's property boundaries is not clear. Many of the potential advantages of a power center can be realized only if the entire nuclear center (e.g., entire Hanford Reservation) is identified as a common site for all facilities within the center and the uncontrolled area outside the center is considered the plant environs for all environmental impact purposes.

c. Coordination of Onsite Activities

The various onsite facility operators might realize economies by arranging for a central organization to provide some commonly needed services and coordinating landlord functions. If desired, this could also include such activities as land use planning, emergency plans and supporting activities, meteorology, and environmental dose evaluation and environmental surveillance for the center and environs.

d. Immediate Actions

If construction on the HNEC is to start in 1975, some of the above institutional actions need almost immediate consideration and appropriate decisions and actions. Most importantly, the charter of the Washington State Thermal Plant Siting Council should be broadened to include considerations of all nuclear fuel cycle and related facilities to assure uniformity in requirements or conditions and eliminate duplicate effort.

The NEC operator should be identified and the details of his relationship and the interface of responsibilities with the center participants should be clearly defined. Effort should then be made to obtain a practical interpretation of AEC regulations governing the definitions of site boundary.

F. NUCLEAR WASTE MANAGEMENT

Radioactive wastes that cannot be released to the air or water will be managed within the NEC in the Waste Treatment and Storage Facility (WTSF), a Federal repository. Waste generation rates, summarized below, were based on an installed electrical generating capacity that increases from 10,000 to 15,000 MWe in 1985 to 40,000 MWe in the year 2000, and a total accumulated fuel processing load (to the year 2000) of 30,000 tonnes. The processing load, 72, 20, and 8% of which is associated with LWR, LMFBR, and HTGR plants, respectively, reflects a market area extending outside of the NEC. Additional details are presented in Appendix V-B.

1. High-Level Waste

For the purposes of this study it was assumed that the high-level solid waste arising from the chemical reprocessing of "spent" or irradiated fuel will be stored, in the form of 12 in. I.D. x 10-ft long canisters, in modular concrete-walled water-filled basins; the water provides both shielding and cooling. The high-level portion of the WTSF will also be sized to store compacted cladding hulls.

Each storage module is capable of storing about 400 canisters or about 6,000 ft³ of compacted hulls. Eight storage modules, requiring about 15,000 ft² of floor area, will be required by about 1990 along with a receiving and handling facility of similar size. Using current dollars, a preliminary estimate of the total capital cost associated with this first stage of construction is \$40 million. Additional storage capacity for 3,000 canisters and 12,000 ft³ of cladding hulls would then be constructed every 5 years at an estimated cost of \$12 million. Costs for operation of the facility, estimated for 1990, are \$3 million/yr.

Facilities will be designed for the retrievable, long-term (100-yr) storage of high-level waste. After long-term storage, offsite shipment may be required in conjunction with yet to be defined ultimate disposal concepts. The need for shipment would, of course, be negated if it is determined that the Hanford site is suitable for ultimate disposal.

2. Low-Level Waste

Total low-level waste arising from operations within the HNEC by the year 2000 is estimated to be 3.8 million ft^3 of solid after compaction and incineration, plus 1,000 canisters of compressed noble gas. This volume of waste is estimated to contain 13 million Ci. The maximum throughput is estimated at 1,200 ft^3/day .

The treatment of solid low-level waste consists of sorting, compaction, incineration and packaging. It was assumed that low-level liquid and gaseous wastes are treated at the point of origin. Liquids are evaporated to a solid residue and gases are compressed and stored in cylinders. The packaged waste will be stored in shielded and unshielded warehouses until a permanent disposal method becomes available. Ultimate storage may be onsite or the waste may be shipped to an offsite repository. In order to contain the low-level waste that will accumulate by the year 2000, 1.7 million ft^2 of storage space will be required.

The estimated cost of a low-level waste treatment facility designed for an output rate of 1200 ft^3/day is \$60 million, while the cost of the 1.7 million ft^2 waste storage facility is about \$100 million.

3. Benefits and Problems

The primary benefit derived from siting the WTSF within the HNEC is that transportation of high-level solids through non-Federal land is not required, at least for 100 years. The detailed environmental data, necessary for a reliable safety analysis of waste management, has already been gathered for the AEC over the many years of operation of the Hanford site. A potential problem is that siting considerations for waste management facilities and power reactors are not always compatible, e.g., a river can be viewed not only as a heat sink but also as a potential driving force for dispersion of stored radionuclides; however, at Hanford, wastes can be stored on a plateau above the maximum flood level of the Columbia River. A potentially serious problem is that acts of war and sabotage and natural catastrophies can be related to a stored source of nuclides, now concentrated in one location. This consideration applies to a greater or lesser degree wherever the WTSF, Federal repository, is located.

G. TRANSPORTATION

An essential part of the nuclear fuel cycle is the transportation of nuclear products between plants, as follows:

- Uranium and plutonium fuel elements are transported from the fabrication plant to the reactor.
- Spent fuel is transported from the reactor to the separations facility.
- Plutonium product is transported from the separations facility to the fuel fabrication plant.
- High-level waste and other waste products are transported from the separations and fuel fabrication plants and reactors to waste storage facilities.

The transportation of these products carries a certain risk to the public. This risk is now undergoing close evaluation by USAEC and other interested groups. Already there is indication that the shipment of plutonium in solution form may be prohibited in 3 years. Moreover, mention has been made that depending on the outcome of current studies, plutonium shipment in any form in the near future may be questioned.

The risk to the public of transporting radioactive materials depends on many factors such as packaging integrity, mode of transport, number of miles transported, population density, accident frequency and accident severity. Design verification studies subject packages to a 30-ft drop followed by exposure to a 1-hr fire at 1500°F to verify the design. Trucks have been slammed into barriers to test hold-down devices. In many instances design deficiencies have been detected and changes made to the final design before exposure to the general transportation environment. Such tests demonstrate the package integrity and thus serve to insure the health and safety of the general public.

However, such analyses may leave some questions of general public concern unanswered. Who is bearing the greatest risk? How does this risk compare to the hazards from other material shipments? What is the effect of container design, physical or chemical form, quantity, transport mode, and

route on the overall risk? Until these questions are adequately answered, the nuclear industry cannot assure itself or the general public that everything has been done to sufficiently minimize the risk of shipping radioactive material.

To estimate the degree of reduced risk under the NEC concept is beyond the scope of the present study. However, the important variables that go into this assessment can be identified. These variables could be reviewed in detail at a later time.

An estimate of the average annual distance that new fuel and irradiated fuel must be transported under the two concepts is given below.

	<u>Reactors Located Throughout Northwest, miles</u>	<u>Reactors Located on NEC Site, miles</u>
1. Average Distance Between Fuels and Separations Plants and Reactors	150	10
2. Distance Traveled/yr to Deliver New Fuel to Reactor	33,750	2,250
3. Average Distance Traveled/ yr to Deliver Spent Fuel to Separations Plant		
By truck	334,000	22,000
By rail	42,000	2,800

-
- Basis:
- a. 25 reactors of 1300 MW each
 - b. Fuel fabrication and waste storage is at Hanford
 - c. Truck capacity for new fuel: 16 assemblies
 - d. Truck capacity for spent fuel: 2 BWR/1 PWR assembly
 - e. Rail car capacity for spent fuel: 18 BWR/7 PWR assemblies

To estimate difference in risk, one must consider the differences in the relative hazards of the fuel forms. Uranium fuel elements would involve a low risk, because uranium is least toxic. Fuel elements that contain plutonium would be of more concern, because of the toxicity of plutonium. In fuel elements, however, the plutonium is bound tightly in the form of sintered $\text{PuO}_2\text{-UO}_2$ pellets and, thus not likely to be released in the event of a containment breach.

Of most concern, perhaps, is the shipment of spent, irradiated fuel. This fuel form is thermally hot, emits radiation, contains toxic gases, and the fuel pellets may be pulverized within the rods. The containment vessel must therefore be cooled and shielded, and have a high level of structural integrity. Therefore, from the standpoint of risk to the public, there is a high incentive to reduce the number of miles traveled by the various fuel forms. The lower the miles traveled, the lower the exposure of the packages or casks to a serious accident. One must also take into consideration that outside of the center, waterways must be crossed, which adds to the risk of the public. This factor either does exist or the hazard is greatly minimized for transportation on a NEC.

The NEC concept nearly eliminates risk to the public from transportation of radioactive materials. Casks and packages will be transported within the confines of the center. The probability of a severe transportation accident becomes nearly negligible. Exposure to the public (high population densities enroute) too is essentially eliminated. On the other hand packaging integrity and closure will continue to be of great importance.

One problem of the concept to be contended with is complacency. Because shipments are limited to the confines of a nuclear center should not be reason to significantly relax packaging integrity or transportation requirements. Some packaging benefits, however, should be realized because of the less severe transportation environment.

H. SOCIOLOGICAL IMPACTS

The sociological impacts of energy centers versus scattered siting relate primarily to tax sharing, community effects, and nuclear plant acceptance.

1. Tax Sharing

The high investment in nuclear facilities results in very large tax payments to local taxing districts such as schools, port districts and counties. This causes wide variation in tax payments between tax districts because of the large variation in tax base per capita. This wide variation would become even wider if a NEC were built. One possible solution is tax distribution laws which would require distribution of tax revenues to more than the local tax districts. This possibility should be studied to determine the possible solutions and the most favorable ones.

2. Community Effects*

a. Introduction

The purpose of this section is to establish the effects on the surrounding communities of the construction of the HNEC and to determine the potential of these communities and related areas to absorb the anticipated growth. In order to do this within established time limits for this preliminary study, it was necessary to rely on secondary sources of information and to verify conclusions through applicable local, state and national standards and trends.

This section discusses first the existing conditions which will impact potential development around the Hanford Reservation; second, the capability to absorb growth; third, the community requirements based on the projected work force; and finally, conclusions regarding the effects.

The communities around Hanford were divided into primary and secondary impact areas for purposes of data collection and studies. The study areas (illustrated on Figure VII-12) are based on a review of other reports

* Based on studies and a report prepared for PNL by Naramore, Bain, Brady and Johanson, Architects/Engineers, Seattle, WA.

FIGURE VII-12. Study Areas

related to the impact of Hanford and discussions with local officials. It was determined that the areas of greatest impact would be Benton and Franklin Counties, and the closest portions of Yakima County. Within these, prime emphasis would be on the already established population centers of Yakima-Sunnyside to the west and the Tri-Cities (Kennewick-Pasco-Richland) to the south. Areas of secondary impact include Kittitas, Grant, Adams, and Walla Walla Counties and the remaining portion of Yakima County. The Vernita Bridge provides a gateway to Adams, Grant and Kittitas Counties. These areas appear logical due to their accessibility, proximity, and current role and relationship to Hanford.

b. Existing Community Factors

This section briefly analyzes the factors related to the existing communities in order to determine their ability to absorb the impact of growth resulting from the proposed HNEC. The general constraints in the region are noted. The physical and environmental characteristics of the primary impact areas are discussed. Discussions with the planners in the counties and cities in the Primary Impact Area were held to determine the potential to accept growth. In addition analysis of New Town development in England and the U.S. was made to verify cost and development standards as well as possible construction schedules.

General Constraints. In evaluating the potential areas for development related to the HNEC, a number of factors were reviewed: accessibility, available sources of services, natural barriers and present commitments of land resources. Figure VII-13 indicates the major elements: The Columbia River, the Hanford Reservation itself, and the Yakima Firing Range. Accessibility to Hanford is limited at the present time to State Highways 24 and 240.

The major sources of services are the existing population centers in the Yakima-Sunnyside area and the Tri-Cities area. Further discussion is centered on these two areas.

Physical Characteristics. This section briefly discusses the physical characteristics of the southeastern Washington area which includes Yakima and Tri-Cities-Benton and Franklin County areas.

FIGURE VII-13. Development Constraints

Yakima Area:

The Yakima Valley, with Yakima as its major urban area, is oriented primarily to an agricultural economy and related food processing industries. The impact of the Hanford Reservation has been a secondary one with Yakima, Sunnyside and related areas serving as a bedroom community for Hanford personnel; about 35 miles from the Hanford Reservation. Yakima has two major land holdings related to it: The Yakima Firing Range between Hanford and Yakima, and the Yakima Indian Reservation to the west.

Yakima is centrally located in the state and is tied into major east-west and north-south expressway routes. It is linked to Hanford by Route 24 and to the Tri-Cities by State Highway 22 and Route 12, and is served by a commercial airport near Yakima and transcontinental railroad facilities.

The Yakima area has sustained a continuous, relatively slow rate of growth. It is estimated that about 15 to 20% of the employment generated by Hanford presently lives in the Yakima-Sunnyside-Yakima County area. This lower percentage of total population coupled with the distance and lack of direct involvement has produced less identification with Hanford.

Tri-Cities, Benton and Franklin Counties:

The Tri Cities, Kennewick-Pasco-Richland, are the primary center of Benton and Franklin Counties, and the focus of the AEC Hanford Reservation. This area is well served by a variety of transportation modes: highway, rail, air and water. It is served by U.S. Highway 12 and State Highway 240 while U.S. Highway 395 serves Franklin County and connects to Spokane. A link of the Interstate System is planned which will connect the Tri-Cities more directly to Seattle and Portland. In addition, three transcontinental railroads serve the area, and over 1,000,000 carloads of freight are handled annually. Commercial air travel is supplied by the airport located in Pasco, while local airfields are located in both Kennewick and Richland. More than 1.5 million tons of cargo are shipped annually by barge to and from the Tri-Cities.

The most prominent geographic features of the Tri-Cities area are the Columbia, Yakima and Snake Rivers. These provide a resource for farming,

energy, shipping and recreation. Topographically, the region's borders enclose an expanse of desert land moderately elevated along the southern, eastern and western fringes, but generally flat in the inner portions.

The arid climate is a continental type with dry, hot summers and cool, damp conditions prevailing during the winter months. Due to the land terrain, variations in temperature and precipitation are minimal. The rain-free summer months average in the 80's with a low relative humidity; rain is light and occurs during the late fall and winter months. Winter temperatures range between 30 to 40 degrees during the daylight hours and snowfall seldom lasts more than 2 to 4 weeks or exceeds 4 to 6 in. General climatological factors produce an area with clean air and little susceptibility to inversions and other factors related to air pollution.

Initially, the dry climate and unlimited availability of land dictated a restricted economy tied closely to agriculture. In 1943 the Hanford Project introduced a permanent and solid industrial base. This base has become increasingly broadened as a nationally recognized complex for scientific research and development of nuclear technology. In addition the agriculture sector has expanded steadily as irrigated cultivation has been added and numerous production facilities have been added. A report developed by the State of Washington's Department of Commerce and Economic Development summarized this area as follows:

"Together, an abundance of land for agriculture-industrial-commercial uses; a unique location enabling the region to serve as a strategic transportation center; a limitless supply of water for power and irrigation purposes; plus the accumulation of a highly educated and technically trained labor force have propagated a region of unique potential. These factors, coupled with conducive livability features--moderate climate, advanced educational facilities, and countless recreation opportunities--guarantee a future of disciplined development . . ."

Potential Growth. This section deals with the potential growth of the various jurisdictions. This is defined as the "design" population which is able to be accommodated with present jurisdiction rather than the growth which is projected to occur due to current trends. A detailed discussion of the projections is included in Section c, below.

Discussions were held with the planners in Yakima, Yakima County, Benton-Franklin Council of Governments, Richland, Pasco, Kennewick and Franklin County. Most of them did not have an official "design" figure for their community. Estimates for the City of Yakima indicated the ability to take 600 persons/yr, which was beyond the normal growth allocated. It was felt that additional growth beyond that could also be accommodated. Yakima County has only recently adopted zoning and has not yet evaluated the related holding capacities. The urbanizing fringe around a fairly large established city such as Yakima should, however, have considerable potential for growth. The recent trends have had a majority of the growth in this area west of Yakima.

Significant growth in the area of smaller cities such as Sunnyside could prove to be more difficult to handle. Although relatively small compared to the total, it is very major for a city of 3 to 6 thousand.

Within the Tri-Cities area, the cities of Pasco, Kennewick and Richland estimate a potential of holding 37,500 beyond the projected 1980 growth. The developing fringe areas around Pasco in Franklin County and between Kennewick and Richland in Benton County obviously hold a great deal of vacant land which could be developed. Much of it is presently developing.

The Benton-Franklin Sewer and Water Plan for the year 2000 is based on a design year population of about 113,000. This anticipates a population in excess of the 1980 projection by some 17,000 to 18,000.

Although it is difficult to establish the precise ability of the various primary communities, it appears reasonable to assume that the Yakima-Sunnyside area could absorb limited increased growth. The Tri-Cities area seems able to absorb a significantly larger amount.

Two factors which affect the ability of the Tri-Cities area to accommodate the HNEC and the anticipated growth are attitudinal in nature. The local citizens have developed a knowledgeable acceptance toward nuclear energy. The safety record built up over the past 25 years has demonstrated to them that safe operation is possible and reasonably assured. In addition, the Tri-Cities region has a history of large construction projects in

the construction of the USAEC facilities on the Hanford Project, nearby Columbia River dams and the current WPPSS Nuclear Projects No. 1 and No. 2. This illustrates the regional capability to accommodate such projects.

Development Schedule. In order to test the feasibility to develop facilities within the anticipated short development schedule, a review of current new town construction was made. The new town at Columbia, Maryland, has one of the fastest development schedules. It provides for the development of units to support 110,000 within a 15-yr production schedule. At the halfway point approximately 25% has been accomplished and the annual production rate is about two-thirds that required to reach the goal (1850± units/yr).

The majority of the time in that initial period was spent in land acquisition, planning and preparing the site with streets, utilities and initial community facilities. The area started with no basic population. However, it does indicate a considerable lag time spent in this initial phase which is not available under the proposed time schedule.

It should be recognized that this is being developed by a private company without the impetus of meeting a national crisis. The population which is planned for is a permanent population where the initial peak period in this project would have a considerable number of temporary housing units. The Tri-Cities and Yakima-Sunnyside areas also have an existing development potential which can absorb the initial population with limited disruption.

c. Projected Community Requirements

General. This part of the report describes and analyzes the requirements likely to be imposed on the surrounding communities by the proposed NEC. The most detailed analysis is made on the faster (2 reactors/yr) construction schedule to 1990 since it will have the most significant impact. The impact of the alternate development schedule (one instead of two reactors/yr) is briefly discussed in each section as applicable. Components of this analysis include:

- Population Forecasts (1970-1990): These projections consist of base or natural-growth population forecasts; the estimated incremental

population growth attributable to the proposed HNEC, and resultant forecast total population including the HNEC.

- Indicated Community Requirements: These requirements consist of projected residential land use and amounts and construction costs of required community road, utility, school, recreation, community facilities and medical support. They have been developed based upon sustained maximum population and work force projections.

As a result of the limited time available for this analysis, extensive reliance has been placed on forecast data and relationships contained in existing reports.⁽²⁴⁻²⁷⁾ While these data have been reviewed, checked and compared for general validity and modified where appropriate based on subsequent experience and anticipated trends, the conclusions reached on the following pages are dependent in large part on the completeness and accuracy of this secondary information. Data contained in these reports were supplemented by information contained in other newly completed environmental reports, state and national population, economic and labor force data and conversations with area government and planning officials.

There are other major assumptions critical to the performance of this analysis.

1. The proposed HNEC facilities will be distributed along the Columbia River, with some emphasis on the northern sector of the reservation.
2. The gravity flow basis,⁽²⁸⁾ emphasizing travel distances, is an appropriate basis for distribution of estimated incremental population increases attributable to the proposed HNEC.
3. The potential centralizing impacts upon population distribution imposed by reduced gasoline availability will be offset by improved arterial transportation, increased accessibility, via additional bridges, of lands across the Columbia River and improved mass transit access to the outlying areas.
4. The declining labor force requirements resulting from completion of construction activities in the HNEC will be offset by a combination of

natural growth and the requirements related to supplementary industries attracted to the area by increased availability of non-interruptible electrical power.

5. The natural growth-related population increases will use up existing excess community support capacity so that all HNEC-related population increases will generate incremental support requirements. A general review of existing reports indicates this to be a reasonable assumption. To the extent that some support capabilities in excess of those required for natural growth may exist in some areas, these effects may be logically assumed to be offset by the inability of these areas to provide other support requirements related to natural growth increases.

The basic methodology employed in this analysis consisted of developing a natural growth forecast for areas likely to be affected by the HNEC. To this forecast was added an estimated increment based upon the work force projections developed in Section VII-C of this report and application of secondary employment, household and total population multipliers. Finally, general planning and other standards were applied to determine projected impact upon the affected communities. Projected results are shown for 1970 (the last year for which actual census data are available), 1976 (the first full year of construction activity), 1980 (the year of peak construction activity), 1985 (the approximate mid-point of the "declining shoulder" period of construction activity), and 1990 (the first year after completion of all construction activity). Results are also shown for the following general geographic areas:

- Tri-Cities - Consisting of the cities of Kennewick, Pasco and Richland and related suburban fringe areas.
- Yakima/Sunnyside - Consisting of the cities of Yakima and Sunnyside.
- Other Primary Areas - Consisting of the remainder of Benton and Franklin Counties and other close-in Yakima County areas.
- Secondary Areas - Consisting of the remainder of Yakima County and portions of Grant, Adams, Kittitas, Walla Walla and Klickitat Counties.

Population Forecasts (1970-1990). The following pages contain exhibits and discussions of natural growth, incremental and total population results for the study area. All exhibits contain actual data for 1970 and projections as at January 1 for the years 1976, 1980, 1985 and 1990.

As can be seen on Figure VII-14, natural growth of the area population, exclusive of the effects of the NEC, is projected to be relatively slow and steady, with an increase of slightly over 13% estimated for the 20-yr period. Over half the increase is forecast to occur in the Tri-Cities, whose proportion of the total study area population is projected to increase from slightly over 25% in 1970 to just under 30% by 1990 as the result of natural growth.

Figure VII-15 shows the estimated increased population attributable to the HNEC for the case involving construction of two reactor plants per year. This was the primary case evaluated since it represents the greatest probable community impact likely to be caused by the HNEC. An alternate case of constructing one reactor plant per year with its attendant reduction and stabilizing of peak primary employment needs has also been examined with results noted as applicable. "Primary workers," as shown on Figure VII-15, are those construction and operating personnel projected to be employed at the HNEC. These estimates are developed and explained in Section VII.C of this report. A multiplier of 1.5 times estimated primary workers was employed to determine the forecast secondary employment levels, resulting from expansion of the area's economic base.

As the peak increase achieved in 1980 is assumed to be maintained throughout the remainder of the study period, as mentioned earlier, no adjustment was made to the multiplier to reflect effects of short-term work force peaking.

In determining dependents attributable to the project-increased work force, it was assumed that 90% of these requirements will be satisfied from outside the existing study area population, with the remaining 10% satisfied from the existing labor supply. (An existing unemployment rate of 8 to 10% and a programmed peaking of present Hanford labor requirements in 1974 to 1975, as estimated in the Richland Planning Commission's employment forecast, provide evidence of potential slack in area employment.)

	ACTUAL	FORECAST			
	1970	1976	1980	1985	1990
TRI-CITIES	73.9	80.6	83.8	89.2	94.9
SUNNYSIDE/YAKIMA	52.3	52.7	52.9	53.2	53.5
OTHER PRIMARY	57.3	59.3	60.5	62.1	63.7
SUB-TOTAL	183.5	192.6	197.2	204.5	212.1
SECONDARY	101.8	104.4	106.2	108.5	110.8
TOTAL	285.3	297.0	303.4	313.0	322.9

FIGURE VII-14. Population Projections - Natural Growth Forecast - by Area
(Does Not Include Population Growth Due to the HNEC)

	ACTUAL	FORECAST			
	1970	1976	1980	1985	1990
PRIMARY WORKERS	0	1.350	18.900	11.700	3.600
SECONDARY WORKERS	0	2.025	28.350	17.550	5.400
DEPENDENTS	0	4.125	57.750	35.750	11.000
SUB-TOTAL	0	7.500	105.000	65.000	20.000
DEVELOPMENT GAP	0	0	0	30.400	65.500
TOTAL	0	7.500	105.000	95.400	85.500

FIGURE VII-15. HNEC Population Projections - by Components
(For Construction of Two Reactors per Year
Plus Fuel Cycle Facilities)

The number of additional dependents introduced to the area population by the required additional primary and secondary workers was developed based upon an assumed family size of 3.0 that is generally prevailing in the area today and the previously noted assumption that 10% of the new positions would be filled from the existing population. In addition, based on natural census data, it was assumed that half the remaining secondary positions would be filled by other members of primary and secondary worker's families, reducing the number of additional families and, therefore, dependents likely to be brought into the area.

As shown on Figure VII-15, the overall population increase due to the HNEC peaks in 1980 at 105,000. The "development gap" estimates in 1985 and 1990 (see Figure VII-15) refer to the additional population required to be introduced by the attraction of industries to the area based upon the energy resources offered by the HNEC in order to maintain total population at the estimated 1980 peak.

The projected 14,500 1980 to 1990 increase in natural growth-related population enables a decline in the 1985 and 1990 HNEC-related population. In any case, however, a significant amount of supplementary industry employment (some 5,500 additional primary jobs in 1985 and nearly 12,000 additional primary jobs in 1990) will be required in order to maintain total area population at 1980 levels throughout the remainder of the forecast period.

The estimated population impact for the alternate case of constructing 1 reactor/yr is an increase of 62,500, rather than 105,000. The peak year is still 1980, but the estimated employment development gap is less than 2,500 jobs required to maintain a stable total population through 1990.

After allocation to geographic area, the estimated additional HNEC-related population which is shown on Figure VII-16 is added to the natural growth forecast shown on Figure VII-14, resulting in projected total population numbers for the study area including effects of the proposed NEC as shown on Figure VII-15. The development gap numbers are repeated near the bottom of Figure VII-16. The last sub-total line on this figure shows

	ACTUAL	FORECAST			
	1970	1976	1980	1985	1990
TRI-CITIES	73.9	84.7	141.8	125.0	105.9
SUNNYSIDE/YAKIMA	52.3	53.9	68.6	63.7	56.7
OTHER PRIMARY	57.3	60.5	77.0	72.3	66.8
SUB-TOTAL	183.5	199.1	287.4	261.0	229.4
SECONDARY	101.8	105.4	121.0	117.0	113.5
SUB-TOTAL	285.3	304.5	408.4	378.0	342.9
DEVELOPMENT GAP	0	0	0	30.4	65.5
TOTAL	285.3	304.5	408.4	408.4	408.4

FIGURE VII-16. Population Projections - by Area (Natural Growth Plus Growth Due to the HNEC)

that the area population could decline in 1985 and 1990 if the development gap jobs are not available. Figure VII-16 is based on the 2 reactors/yr construction case. For the case of constructing only 1 reactor/yr, the total area population, exclusive of potential supplemental industry effects, is projected to increase to a maximum of 365,900 by 1980, decreasing to 347,500 by 1985 and actually increasing to 360,900 by 1990 due to an estimated increased operating labor force for the HNEC.

As can be seen in Figure VII-16, the major impact of the HNEC is projected to occur in the Tri-Cities area, which is forecast to show a 1980 total population increase of some 92% above 1970 levels and 69% above the forecast natural growth level for 1980. It is the latter increase which is of primary importance in determining the potential community impact of the proposed HNEC. The potential 1980 NEC impact on 1980 population in the Yakima/Sunnyside and Other Primary Areas is seen to be an increase of from 27 to 30% above 1980 natural growth levels, while the potential 1980 impact in Secondary Areas is projected to be an increase of only about 15% above 1980 natural growth levels.

The alternate case (1 reactor/yr) is forecast to result in a 1980 total population increase in the Tri-Cities area of less than 47% above 1970 levels and about 41% above the forecast natural growth level of 1980. The impact of this alternate case would be considerably less in the other areas analyzed.

Community Impact. Tables VII-5 and VII-6, respectively, show the bases for calculation of community impact and support requirements and the results of those calculations. Allocation of the requirements to the geographic areas is on the same basis as previously employed.

The significance of the potential impact on the Tri-Cities area is summarized on Table VII-6: about \$72.7 million in street and utility construction costs, \$62.7 million in school construction costs, \$8.4 million in hospital costs, \$31.2 million for parks and recreation facilities and \$4.6 million for libraries and fire stations (in 1974 dollars) could be required to accommodate 1980 forecast requirements. For the alternative 1 reactor/yr case, the likely related impact on the Tri-Cities is:

TABLE VII-5. Indicated Requirements to Support Population Increase - Unit Relationships

<u>Dependent Variable</u>	<u>Independent Variable</u>	<u>Relationship</u>	<u>Source</u>
1. Households (Primary)	Primary Workers	0.9	1. Previous analysis of impact of enrichment complex
2. Secondary Workers	Primary Workers	1.5	2. Richland Planning Commission, Battelle analyses
3. Households (Secondary)	Secondary Workers	0.5	3. Previous analysis of impact of enrichment complex
4. Population	Total Households	3.0	4. Current area family sizes
5. Trailers, Apartments	Total Households	35%	5. Previous analysis of impact of enrichment complex
6. Single Dwellings	Total Households	30%	6. Previous analysis of impact of enrichment complex
7. Trailer Acreage	Trailers	14.5/acre	7. Tri-Cities building code allowable maximum
8. Apartment Acreage	Apartments	20.0/acre	8. Current planning standards
9. Single Dwelling Acreage	Single Dwellings	4.0/acre	9. Current planning standards
10. Streets, lineal feet	a. Total Acreage	.20	10. a. Previous analysis of impact of enrichment complex
	b. Step (a) results	43,560	
	c. Step (b) results	60-ft width	b. Current Tri-Cities planning standards for residential street widths
11. Streets, cost	Streets, lineal feet	\$50	11. Estimate provided by Richland Department of Public Works
12. Water, average requirement	Population	470 MGD	12. Current Richland use patterns
13. Water, peak requirement	Population	1,200 MGD	13. Current Richland use patterns
14. Water, cost	Population	\$630	14. Cost estimates prepared by R. W. Beck, in \$ 1974
15. Sewer, average requirement	Population	120 MGD	15. Current Richland use patterns
16. Sewer, cost	Population	\$345	16. Cost estimates prepared by R. W. Beck, in \$ 1974
17. Students	Households	0.64	17. Analysis of census data
18. Teachers	Students	24/Teacher	18. Existing student/teacher ratios
19. Schools, cost	Students	\$5,100	19. Current construction cost experience
20. Hospital Beds	Population	0.0021	20. State recommendations
21. Hospital Cost	Beds	\$70,000	21. Current construction cost experience
22. Parks, Playground, Playfields	1 acre/100 population	\$50,000	22. Local and National Standards & Costs
23. Recreation centers w/9 Pools	1/25,000 population	\$1,000,000	23. Local and National Standards & Costs
24. Libraries w/equipment	1/25,000 population	\$750,000	24. Local and National Standards & Costs
25. Fire Stations w/equipment	1/15,000 population	\$750,000	25. Local and National Standards & Costs

NOTE: Other community facilities may be required; however, these are felt to be the primary ones required to meet the 1980 peak year development.

**TABLE VII-6. Indicated Requirements to Support
Population Increase - Summary**

	<u>Tri-Cities</u>	<u>Yakima/ Sunnyside</u>	<u>Other Primary</u>	<u>Secondary</u>	<u>Total</u>
<u>Population</u>	57,855	16,905	16,485	13,755	105,000
<u>Labor Force</u>					
Primary	11,570	3,380	3,300	2,750	21,000
Secondary	17,355	5,070	4,950	4,125	31,500
Total	28,925	8,450	8,250	6,875	52,500
<u>Households</u>	19,285	5,635	5,495	4,585	35,000
Trailers	6,750	1,970	1,925	1,605	12,250
Apartments	6,750	1,970	1,925	1,605	12,250
Single Family	5,785	1,695	1,645	1,375	10,500
<u>Housing Acreage</u>	2,249	659	640	535	4,083
Trailers	465	136	133	111	845
Apartments	338	99	96	80	613
Single Family	1,446	424	411	344	2,625
<u>Community Support</u>					
<u>Streets</u>					
lineal feet (000)	326	96	93	78	593
cost (000)	\$ 16,300	\$ 4,800	\$ 4,650	\$ 3,900	\$ 29,650
<u>Water</u>					
average (MGD)	27,200,000	7,940,000	7,750,000	6,460,000	49,350,000
peak (MGD)	69,425,000	20,285,000	19,785,000	16,505,000	126,000,000
construction cost(000)	\$ 36,450	\$ 10,650	\$ 10,385	\$ 8,665	\$ 66,150
<u>Sewer</u>					
average (MGD)	6,940,000	2,030,000	1,980,000	1,650,000	12,600,000
construction cost(000)	\$ 19,960	\$ 5,830	\$ 5,690	\$ 4,745	\$ 36,225
<u>Schools</u>					
students	12,290	3,590	3,500	2,920	22,300
teachers	512	150	146	122	930
construction cost(000)	\$ 62,680	\$ 18,310	\$ 17,850	\$ 14,890	\$ 113,730
<u>Hospitals</u>					
beds	120	36	35	29	220
construction cost(000)	\$ 8,400	\$ 2,520	\$ 2,450	\$ 2,030	\$ 15,400
<u>Parks</u>					
acre/population	578	169	165	138	1,050
construction (000)	\$ 28,930	\$ 8,450	\$ 8,240	\$ 6,880	\$ 52,500
<u>Recreation Facilities</u>					
units	2.31	.60	.66	.55	4.2
construction (000)	\$ 2,310	\$ 680	\$ 660	\$ 550	\$ 4,200
<u>Libraries</u>					
units	2.31	.68	.66	.55	4.2
construction (000)	\$ 1,735	\$ 507	\$ 495	\$ 413	\$ 3,150
<u>Fire Stations</u>					
units	3.85	1.13	1.10	.92	7
construction (000)	\$ 2,893	\$ 845	\$ 824	\$ 688	\$ 5,250

\$43.1 million in street and utility construction costs, \$37.1 million for schools, \$5.1 million for hospitals, \$18.6 million for park and recreation facilities, and \$2.8 million for libraries and fire stations. In either case, these costs are of a magnitude to indicate the need for complete new basic facilities, as well as expansion of existing capabilities.

In all other areas, the projected impact is either relatively small or will probably be sufficiently dispersed to permit satisfaction of requirements primarily by adding to existing facilities.

In all cases, the indicated additional residential acreage needs are relatively slight, in comparison to the potential space available.

Summary. The following general conclusions result from the foregoing analysis of potential community impact of the proposed HNEC.

- The impact of the HNEC on the Tri-Cities area population and related community support requirements could be significant. A population increase of nearly 70% above currently forecast levels could occur by 1980, with an indicated basic construction cost impact of \$180 million, in 1974 dollars, for roads, utilities, schools, hospital, recreation and community facilities. The population and community support impact of the NEC on other portions of the study area does not appear likely to be nearly as significant.
- Significant amounts of supplemental industry employment will be required to offset projected post-1980 declines in HNEC-related employment and population. The previous analysis indicates a potential requirement of 5,500 and 12,000 jobs in 1985 and 1990, respectively, in industries attracted to the area by available electric power in order to maintain area population at forecast 1980 levels.
- Implementation of a slower construction schedule (viz, 1 reactor/yr instead of 2) would significantly alter the above potential impact on the area. The Tri-Cities population increase could be reduced to about 40% above current forecast levels for 1980, with a lower indicated basic construction impact of slightly over \$100 million for community

support facilities in the Tri-Cities area. Finally, the lower peak and more gradual decline of the primary labor force requirements attributable to this alternative approach are projected to result in supplemental industry employment of less than 2,500 to fill the development gap necessary to maintain stable area population after the 1980 peak year.

d. Conclusions

From this evaluation it is concluded, first, that the logical areas to accommodate the anticipated growth due to building 2 reactors/yr plus other fuel cycle facilities are the present population centers, the Tri-Cities area and the Yakima-Sunnyside area. Within this context, it is further concluded that the growth in the Yakima-Sunnyside area could be accommodated without significant disruption if a definitive program is developed and adequate funding is available. The growth in the non-urban portions of the Primary Impact Area and the Secondary Areas is sufficiently small and is spread over a large enough area that the impact is considered of low significance. Communities here, however, will require assistance in accommodating the growth.

In order to be able to provide for the peak growth projected by 1980, to minimize disruptions to existing communities which will be affected, and to insure a quality of development beyond that previously accomplished, it will be necessary to develop a planned program with an administrative mechanism which has adequate authority and funding to make the necessary decisions and allocate the funds with a minimum of delay. As previously indicated, the major impact will be on the Tri-Cities area. It is felt that the area can absorb the growth if a carefully planned program is established and funded. The program must have two major thrusts:

- (1) Immediate action programs for the existing communities (particularly Yakima, Sunnyside, Yakima County, Richland, Kennewick, Pasco, Benton County and Franklin County) to plan, coordinate and expedite local programs to absorb the 1975 to 1977 population. This will include such things as the acceleration of housing, school, utility and street

construction within the presently developed areas. This would also include state programs to insure adequate roads and bridges in the area and would require priority funding for certain planned Federal programs.

- (2) Planning and implementation for that substantial population increment beyond the indicated potential held by the present community plans. The emphasis in this stage will be on the Tri-Cities area where over half of the growth is projected to occur. This would include the development of the unified structure which can plan, program and insure the completion of required facilities by the peak year. The development schedule of this increment must parallel the immediate action program and may function within the established governmental units or separately. It must, however, provide for the major growth in 1978, 1979 and 1980; therefore, it has a limited development schedule. During this phase, planning should begin for the supplementary industrial development which will start in the early 1980's.

There are a number of opportunities with a development of this scale which must not be lost due to the limited time table. The fact that the project is expected to draw additional industry and jobs and, in essence, stabilize population at the peak level is extremely positive and requires that the development which is produced be aimed at a permanent population.

The ability of the present communities to absorb a great deal of the initial impact provides a short, but extremely important, lead time to ensure that detailed plans can be made to insure development in a logical manner.

The increased population in this southeastern Washington area will provide an opportunity to develop some major community facilities currently beyond the scope of any one city, such as a cultural center including convention, sports, music and art facilities. In the long run, zoos, aquariums and other community-wide facilities can also be added to provide additional amenity to what will be the third largest area in the State of Washington. It would be expected that increased higher education facilities would also be developed. Care must be taken, however, to retain the present community identity.

Housing. Although it has been assumed that the housing would be developed by the private sector, it is contemplated that some governmental cost would be incurred to subsidize the establishment of manufacturing plants for housing systems such as those developed in Operation Break-through. This type of increase will be required to meet the peak year demand of 12,250 apartments and 10,500 single family units by 1980 in addition to the normal growth. Provision for some 12,250 trailers will also have to be made.

The mixture of housing will provide an opportunity after the 1980 peak and during the development of supplementary industries to slowly replace temporary units with permanent housing responding to the population trend at that time.

Transportation. It is assumed that the present expressway plans for I-82 and I-182 will provide adequate linkages to the Interstate System. It is further assumed that they will be completed to match the proposed development schedule. Additions to major State routes and a third bridge across the river may be required depending on the specific location of the additional population in the Tri-Cities.

Some forms of mass transportation within the Tri-Cities and Yakima areas and to Hanford may be required, but have not been costed in the figures on Table VII-6.

Environment. It is felt that the contemplated community development can be accommodated in all areas with limited negative impact on the environment. The planning which is done will have this as a major criterion for site, and development decisions and strict adherence to environmental standards should be maintained.

Conclusions Concerning the Alternate Schedule. If the HNEC is developed at the rate of 1 reactor/yr rather than 2, the impact of the construction will be considerably less on the existing communities. The effect of the growth from the NEC and subsequent industrial development would be more easily accommodated. The analysis of potential growth indicates that the existing communities have the ability to utilize the forecast growth within

their current jurisdiction and immediate fringe areas. However, immediate action programs, expanded plans and implementation programs with adequate funding must be developed to assist the communities to accommodate the anticipated growth.

3. Nuclear Plant Acceptance

Severe opposition to nuclear plants often exists because of worries about radiation and its effects. Often this opposition diminishes as more information and knowledge are gathered about the safe use and control of radiation processes. Also, construction of a large number of nuclear power plants on one isolated NEC locates these reactors and radiation activities sufficiently remote that they are a less visible reminder of potential concern. In the case of the Hanford site, the local residents have lived safely with nuclear reactors and other nuclear fuel cycle activities for up to 30 years. As a result there is very little alarm evident among residents of the Tri-Cities and other surrounding towns when plans are announced for new reactors or radiochemical and fuel cycle activities.

I. UTILITY RELATIONSHIPS AND GOVERNMENTAL CONSIDERATIONS

The utility structure in the PNW includes the Bonneville Power Administration, public utilities, investor-owned utilities, and other entities. BPA markets the power from about 30 Federal dams in the region and operates the nation's largest network of transmission lines.

For the public power sector the major electrical power comes from federally operated dams on the Columbia River system. Public utility districts also generate substantial amounts of hydropower. Thermal power plants are being built by the Washington Public Power Supply System, who presently have the steam plant associated with Hanford-N reactor. As previously stated, WPPSS is currently constructing several large reactor plants in the PNW.

The investor-owned utilities comprise Puget Sound Power and Light Company, Portland General Electric Company, Pacific Power and Light Company, Washington Water Power Company, Montana Power Company and Idaho Power Company. The investor-owned utilities have hydropower, coal-fired steam electric plants, and are planning and building several large nuclear plants. The first nuclear plant to come on line will be the Trojan Plant in 1975.

Various councils have been established in the PNW to ensure that the sequence and timing of new projects will meet load requirements. The Pacific Northwest Utility Conference Committee provides such a coordinating function.

Many of the newer thermal plants in the PNW are owned jointly by both public and investor-owned utilities. It is expected that this practice would continue with nuclear plants built in an NEC. No new legislative requirements or regulation changes have been identified as required for construction of investor-owned plants on the Hanford Reservation. Land ownership requirements might be necessary though investor-owned utilities apparently can construct plants on suitably leased lands. Public utility nuclear plants are currently being constructed on leased land on the Hanford Reservation. Presumably fuel cycle service firms could make appropriate arrangements for land also.

1. AEC Restrictions on the Hanford Site. The AEC has (for a number of years) encouraged the establishment of a Nuclear Power Center on the Hanford Project as being generally compatible with the Commission's programmatic activities.

AEC has previously indicated it reserved the right to examine on a case-by-case basis the siting of nuclear power plants or support activities (such as fuel cycle facilities) to determine that proposed facilities or operations are compatible with current operations and foreseeable programs.

Currently, primary use of the Hanford Project by AEC is related to the LMFBR Program, production of nuclear materials, waste management activities, and life sciences and environmental work.

2. Supergenerating Capacity. There is no provision in financial bonding services or rate structures to provide for installing capacity for which loads have not been identified by the utility. For supergenerating capacity to be installed (e.g., to encourage petroleum saving, to provide power to energy-short regions, etc.) some governmental provisions or assistance appear necessary.

3. The extremely large capital investment that the HNEC would create in several counties in Washington would necessitate modification to existing methods of taxing such facilities and/or sharing such revenues with others in the entire PNW.

4. For there to be direct cooling of reactor plants using Columbia River water, control agencies such as EPA and some State of Washington departments will have to modify policies of no direct cooling on inland waters.

J. COAL, HYDRO, AND NUCLEAR SYNERGISMS

Most PNW electricity is generated in hydroelectric plants and a small fraction is generated in coal and nuclear plants. Nuclear plants, which are expected to be more economical than coal plants, will provide most of the new base generating capacity. The hydroelectric plants are expected to gradually convert to primarily peaking operation because of their more favorable characteristics which permit storage of energy and rapid response to load changes. Nuclear plants operate more economically as base load plants. Coal-fired power plants may play an increasingly important role as short-term load plants to support the system during periods of very high loads and during periods of low or insufficient water flow. This function can be filled by either remotely sited plants (in Montana or Wyoming) or by transporting coal to nearer the load centers. An analysis is needed of the optimum mix of hydro, nuclear, and fossil plants to minimize engineering and construction demands for power stations, and for most economical power costs.

1. Coal in the PNW

The coal resources of Washington, Oregon, and Idaho are modest, but nevertheless support the 20th largest coal mine in the United States at Centralia, Washington. Reserves of these states are limited to Washington, the resources in Oregon and Idaho being negligible. However, the surrounding states of Montana, Wyoming, and Utah and the adjoining Canadian provinces of British Columbia and Alberta have large resources of coal potentially available. The estimated total coal resources of these states and provinces to a depth of 3000 feet are listed in Table VII-7.

The use of unit trains has made it possible for western strip-mined coal to be marketed at great distances. Montana coal is hauled to Indiana at a cost of 0.7¢/ton-mile. At this rate Colstrip coal valued at \$2.00/ton could be delivered to Hanford (926 miles) at a cost of \$8.44/ton or about 48¢/million Btu. On the same basis Centralia coal valued at \$6.51/ton would cost \$8.26/ton delivered to Hanford (252 miles) or 51¢/million Btu.

TABLE VII-7. Estimated Coal Resources⁽²⁹⁻³²⁾

	<u>Millions of Short Tons</u>	
	<u>Resource</u>	<u>Reserve^(a)</u>
Washington	36,181	6,183
Oregon	432	332
Idaho	600	9
Montana	378,701	221,701
Wyoming	445,710	120,710
Utah	80,250	32,250
British Columbia	59,457	7,329
Alberta	47,240	2,204

(a) Reserves, the measured portion of the resource, are much smaller than the total resource which estimated from the geological extent of the deposit.

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SECTION VIII

RISK ANALYSIS OF THE HANFORD NUCLEAR ENERGY CENTER

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VIII. RISK ANALYSIS OF THE HANFORD NUCLEAR ENERGY CENTER

This preliminary risk analysis study of the Hanford Nuclear Energy Center (HNEC) is intended to identify areas of risk and describe them in a qualitative way. Much additional work is needed in the risk analysis area, in part because there is little or no experience with concentrating such large amounts of energy in a relatively small geographical area, and it is uncertain whether NEC's create new risks that have not been identified. This preliminary study suggests that the risks identified may be acceptably low, and/or that there are ways to make the risks acceptable, at least in the context of the Pacific Northwest (PNW). A more detailed analysis of risks associated with dispersed plants is needed for comparative purposes. The analysis considers common-mode failure of either generation or transmission capability and nuclear materials shipping and storage risks. In this discussion, a risk is defined as the probable consequence or cost per unit time of a given outcome. It is the product of the probability of an event and its consequences.

A. COMMON-MODE FAILURES

Common-mode failures are the most likely failure mode in oysters when multiple identical components are installed to perform a function which can be successfully completed by a single component. In the above definition the most important word is identical. All components, when exposed to the same condition or environment, must behave similarly.

Since nuclear reactors are designed with multiple components performing the same operation, they are susceptible to common-mode failures within a given facility. However, when reactors are distributed at several sites, the potential for common-mode failure between sites is reduced.

An exception to the above generalization is the electrical distribution and generation systems which are directly interrelated through the transmission grid. Thus, in looking at the common-mode failure aspects of nuclear

energy centers, a detailed study of transmission stability and the load shedding characteristics of the system is required.

A design defect present in all reactors is another example of a common-mode failure, which could potentially require shutdown or derating of every class of reactor built by a common vendor. This type of failure could occur even if the reactors were scattered throughout the region. It can be avoided by having several reactor designs in the system. At the present time competitive economics generally results in an appropriate mix of reactor types to minimize common-mode failures from design problems. This should be the case in a NEC, however, economic considerations that would lead to ordering several standardized plants at one time would need to be balanced against the risk of all plants having a common design defect.

1. Risks of Loss of Generating Capacity

The following factors could potentially cause a loss of generating capacity.

a. Labor Strife

Whenever a large multibillion dollar facility, such as a NEC, is constructed and operated, there is always the concern that a general labor walkout could completely shutdown the facility. Such a concern assumes irresponsibility on the part of labor unions. There is increasing evidence that labor and management believe there are better ways to reach agreement than through strikes which could cause a general shutdown of a segment of a region's economy. The long-term, no-strike compulsory arbitration agreement in the steel industry is an example of this, and is an arrangement that might be negotiated for NEC employees. Similar agreements have been drawn up for the construction of the Alaska pipeline. Agreements between management and labor can be drawn up so labor strife should not cause a loss of generating capacity. Should that occur this factor could cease to be of significant concern in the nuclear energy center.

b. Earthquakes (also see Section V-A)

Severe earthquakes can effect a large region. Thus, the separation between reactors, even if scattered sites are utilized, may not be much different than the case where all reactors are located at one site. In the case of Hanford, since it is located in an area of low seismicity the likelihood of damaging the whole power generation facility may be an acceptable risk.

If a reactor experiences an earthquake a shutdown for an operability review is required if a seismic signal exceeds 0.05 g at the site. That would result in a down time of at least a few days to a week or two. This is not unlike the recovery time for a region struck by an earthquake.

c. General Electrical Failure

Each reactor receives operating power from two independent supply lines. Loss of electricity to operate pumps and reactor instruments is guarded against by having internal, emergency power sources in each unit. Failure of several or all of these systems in any one reactor is feasible, but shutdown of several reactors at once would be highly unlikely.

d. Fire

Grass fires can occur on the Hanford site. Such fires are nearly always confined to a few square miles and are not of sufficient intensity to damage steel and concrete structures. In addition, fire breaks are maintained around all structures. The only possible mode of interference with power plant operations is to cause temporary evacuation of the workers because of smoke. This could result in shutdown of two to four reactors for a short period. If necessary, counter measures can be taken.

e. Severe Storm

Severe windstorms, tornadoes, and ice storms would not interfere with a nuclear power plant operation except through damage to substations and transmission lines, as discussed in Part 2 which follows.

f. Sabotage

A large concentration of nuclear power at one site could be an attractive target for saboteurs. The probability that a sabotage effort could shutdown more than a few reactors in one effort is extremely small.

Reasons are:

- Each station of two to four reactors would be separately secured and located several miles from another station. It is unlikely that several stations could be penetrated at the same time without detection of at least one of the efforts, thereby raising a general alarm.
- Security throughout the HNEC will be coordinated and consequently probably better trained, equipped and organized than at dispersed single stations.
- Since the site is remote from population centers and the Hanford area is primarily level, undeveloped desert terrain, an unobserved intrusion by people is very unlikely.

g. War

A well placed, multiple-warhead nuclear weapon could put all of the HNEC out of operation for a long period. The question is, "Would the HNEC be a military target of that importance?" If it were, would not the major cities of the region be targets of similar importance?

A HNEC is more likely to be a military target in a conventional war. Disabling the plant with conventional weapons might be much more difficult because the plants would be dispersed over a relatively large area - about 660 miles², located about 250 miles inside the U.S. borders (excluding the Canadian border).

h. Flood

The only possible cause of a flood in the Hanford site would be a catastrophic failure of Grand Coulee Dam, releasing the waters of Lake Roosevelt. The reactors at HNEC will be constructed above the flood plain.

However, operability of some pumping stations might be impaired for a week or more and some of the reactors might therefore not be operated, or operated at reduced efficiency, during the period.

2. Transmission Considerations

The development of a HNEC would centralize the switching and transformer stations for transmission of up to 50% of the PNW electrical power at one source point covering an area of about 650 miles² (see Table VIII-1). This section addresses the issue of the risks associated with such a concentration of the electrical power sources.

TABLE VIII.1. Projected Fraction of HNEC Power in the PNW Total (Accelerated Case)

	Projected Nuclear Power from HNEC, MWe	PNW Total Electrical Capacity, (a) MWe	HNEC, %
1974	860	23,671	4
1980	6,300	36,000	18
1985	20,520	53,000	39
1990	33,520	70,000	48

(a) Projected capacity from other sources plus the HNEC capacity (see Table IV-5, Section IV).

Essentially all of the transmission load would be through the three major existing corridors to Western Washington and Oregon; the transmission plans are described in Section VII-D. From the standpoint of risk, the key design feature is that all power generated and transmitted from the many nuclear stations, several substations (design considerations might suggest a single 1100-kV switchyard if that voltage becomes available) located within the Hanford reservation. These yards would transmit the power via the three corridors through the Cascade Mountain range.

The kinds of events that could cause accidental interruption of the transmission of power to the load centers are earthquake, fire, flood, windstorm, tornado, icestorm, airplane crash, sabotage and vandalism. The possibility that electrical-mechanical failure of switchgear or transformers could cut off power transmission is very remote because the system would be built to eliminate such a common mode failure mechanism by duplication of systems and by isolation of transmission sections.

The transmission lines could be less vulnerable to total loss risk than switchyards because they would be routed through three corridors via multiple lines. This risk exists at the present time in the transmission of power from the many hydroplants of the Columbia and Snake River Basin. Duplication of routings within corridors as well as between corridors provides alternative pathways. Some credible events could disable all lines in one corridor at once, but the other two corridors could carry about 85% of the power, even at the peak load (see Part D of Chapter VII). The remainder of this discussion will center on the primary risk area, the main HNEC switchyards and the three transmission lines immediately adjacent to it.

a. Sources of Risk

(1) Earthquake. The Hanford site is in an area of moderately low earthquake frequency and only 16 of at least Mercalli magnitude V (considerably below the level that can crack weak masonry or plaster) have occurred within a radius of 100 miles of the site during the past 100 yr. Only two of magnitude VII or greater have been recorded. Only a very severe earthquake centered at Hanford could disable the switchyard equipment or one or more of the main transmission line towers. An earthquake of such a magnitude has not been recorded in the PNW.

(2) Fire. Desert grass and sagebrush fires of low intensity can and do occur. Transmission towers and switchyards are protected from such fires by firebreaks. Switchgear and transformer fires in such stations are guarded against by protective design.

(3) Floods. The only possible cause of a major flood in the area would be the failure of a major dam such as Grand Coulee. The switchyard and many of the transmission lines can be located well above the potential flood zone.

(4) Windstorms. Wind velocities above 70 mph and gusts of over 100 mph are common in the Hanford area. Industrial structures are built to withstand these velocities with an adequate safety margin. A transmission line in the Hanford area has been knocked down by a large "dust-devil" but never by a straight wind. Loss of all three transmission lines at one time is a highly unlikely event.

A direct hit by a tornado could readily destroy towers and transmission lines or temporarily damage a switchyard. Only 14 tornadoes have occurred within 100 miles of the Hanford site since 1916. Jaeck⁽¹⁾ estimated that the probability of a tornado striking a particular Hanford site is about six chances in a million during any given year.

(5) Icestorm. Transmission lines and switchyards are designed to withstand all probable icing conditions. Redundancy of transmission lines and corridors provides considerable protection against more than a 15 to 20% loss of transmission capability, even should such a storm occur. Occurrence of conditions of such severity in more than one transmission corridor at the same time is less likely and an occurrence at the site of the Hanford switchyard is much less likely than in the Cascade Mountains.

(6) Airplane Crash. The crash impact of a large airplane could disable a switchyard, possibly for several months. Air traffic density is low for several reasons (low population density, long distance from any military and commercial airports, restricted air space over the Hanford Reservation, etc.) and the probability of a crash at the vulnerable location is believed to be very small. A crash into a transmission line is more probable because of the mileage of target available. However, the consequences would be much less, as discussed above.

(7) Sabotage. A major switchyard could be a sabotage target. However, it would be well secured, would be manned 24 hr a day and would be located in a rather remote area that could be easily protected.

Sabotage against transmission lines in the main corridors would be much easier to accomplish. A well-organized effort would be required to disable 50% or more of the transmission capability in one event but it is feasible. There is no way to estimate the probability of such an event but a similar risk exists even now.

(8) Vandalism. Vandalism against transmission lines is a constant maintenance problem for the BPA (up to 300 incidents/yr for 12,500 miles of lines in Washington, Oregon, and Idaho-Montana)⁽²⁾ Most vandalism is insulator-conductor damage by rifle fire. The probability of major loss of transmission in even one corridor is very low because, unlike a sabotage event, the incidents are limited to one or two lines per event. Vandalism against a switchyard is very unlikely because of its remoteness and security provisions.

(9) Consequences. The risk to transmission facilities of the HNEC is that one of the causes discussed above would result in an unplanned loss of a large block of power in the PNW. Table VIII-1 shows the possible size of the power block involved. The consequences of such an event could be:

- A brownout or blackout over an extended area, particularly affecting Western Washington and Oregon.
- Possible shutdown of many industrial plants for hours or days.
- Cost of transmission system repairs.

Most of the probable events discussed above would risk only a partial loss of power, usually no more than 15%. Such a loss, even if extended, would be relatively easily absorbed.

If the probability of a major loss (up to 50% of PNW power) is judged to be higher than desired several countermeasures can be taken. Most of these would relate to either the security and protection of the switchyards

or the ability of the PNW power users to respond to a sudden large reduction in available power. The latter point was discussed above in Part A of this chapter.

B. NUCLEAR MATERIALS SHIPPING AND STORAGE

The principal events resulting in public risk in nuclear materials shipping and storage are (1) accidents during transport that result in release of nuclear material, (2) theft and diversion of strategic nuclear material to nonpeaceful uses, and (3) accidents at a storage facility that result in release of nuclear material. Natural accidents and sabotage are the two causes of a risk event considered. The consequences of an accident or sabotage that results in public cost is either a release of radioactive material or loss of a barrier to the environment, resulting in radiation doses to people and other costs such as temporary restriction of traffic movement and decontamination and recovery expenses.

1. Transportation

The number of shipments of nuclear material to and from PNW nuclear power plants would be the same if the plants were located at the HNEC as if they were dispersed. However, the shipping distance and average population densities along shipping routes could be different.

Studies pertaining to transportation safety for nuclear materials are currently being made at several laboratories including Sandia, the Pacific Northwest Laboratory and Oak Ridge. Model developments and assessment of plutonium shipment risks at PNL show that the annual risk is a function of the number of shipments made, the distance per shipment, the accident rate along the route, the fraction of accidents that result in a release of nuclear material, the population density along the route and constants that quantify the consequences of an incident.⁽³⁾ For risk comparison purposes, a useful unit is the product of shipment, miles per shipment, and people per mile².

Significant differences in risk between the central and dispersed reactor siting can occur. The lowest risk case would be for a HNEC that includes the support facilities as well as the reactors. In that case both the shipment distances and the population density along the routes are essentially zero, resulting in no shipment risk.

Under conditions of a partially developed HNEC the greatest step in risk reduction will be when an irradiated fuel processing plant, fuel material conversion-fabrication facilities for plutonium fuels and high level waste storage facilities are operational in the center. These will eliminate transportation risks for plutonium intermediates and fuels and irradiated fuel, the most hazardous materials to be handled in the nuclear fuel cycle.

2. Theft or Diversion

It is generally agreed that the opportunities for theft of nuclear material are greater during transport than during processing and storage. At a given level of security effort, safeguards risks are primarily function of transport mileage and secondarily a function of population density along the route (since crime rates are higher in highly urbanized areas than rural areas). Since this is the case, safeguards risks would be lowest for the shortest transportation routes through the least populated areas. The HNEC plan therefore favors safeguards in the same manner as accident risks.

The biggest advantage of HNEC in this respect would be in consolidating plutonium fuels fabrication, immediate fuel processing and uranium enrichment at one site because safeguards risk is related to the strategic value of the material.^(a) If these supporting facilities were located elsewhere, nuclear power plant clustering would have little advantage over disperse siting.

(a) Plutonium and Uranium-233 in purified forms and high enrichment Uranium-235 are most important.

3. Storage

A fire, explosion or flood in a nuclear material storage facility could result in release of radioactive material. For any given incident, the public cost would be primarily proportional to the population density near the facility. One would expect the risk associated with nuclear material storage facilities to be lower for the HNEC than for dispersed nuclear power and processing facilities because the center can more economically centralize storage (hence fewer facilities) and provide tighter security systems. On the other hand, the risk associated with large storage facilities increases with inventory. The HNEC would also provide a lower risk because of its remoteness and the low population in the general area. The point of the closest approach of future residential or commercial development (barring major zoning changes) would be more than 3 miles from any of the proposed nuclear power plants and most plants would be at much greater distances.

Nuclear materials storage facilities may be targets of sabotage. The potential results of sabotage from a public risk standpoint would be nuclear material releases similar to accidental events as discussed above. The comparative level of risk would follow the same pattern as discussed above for accidents.

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SECTION IX

ALTERNATIVES TO THE HANFORD NUCLEAR ENERGY CENTER SITE

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IX. ALTERNATIVES TO THE HANFORD NUCLEAR ENERGY CENTER SITE

There are other potential sites in the Pacific Northwest (PNW) which might be developed as nuclear energy centers (NEC). Further, there appear to be alternatives to siting most of the reactors at a NEC which might retain many of the benefits of a center without potential difficulties, e.g., transmission problems, uncertainties of common-mode failures, and institutional problems of tax distribution. These alternatives should be examined in more detail than has been done in this study. Since one aspect of the objective of this study is to determine whether NEC's offer potential for meeting the Nation's energy requirements faster; the discussion that follows is largely predicated on that consideration.

A. PACIFIC NORTHWEST SITES

Numerous constraints are recognized in comparing alternative nuclear energy center sites, among which four are identified as being of probable critical importance: (1) water supply, (2) transmission, (3) safety, and (4) environmental values. It is possible to argue that transmission facilities could be provided to most PNW sites, although at varying cost differentials and time schedules. The other three constraints cannot be ignored or relegated to a level of secondary importance in an initial screening.

As a practical matter, the main stem Columbia and potentially the lower main stem Snake Rivers and Banks Lake are probably the only Northwest fresh water sources which could provide an adequate water supply. Intense agriculture and restrictive local ordinances do not appear to make the Willamette River an attractive alternate. Safety considerations would eliminate large areas of both Western Washington and Oregon and the more heavily populated areas to the east.

Adequate saltwater for consumptive use in cooling is, of course, available on the ocean coasts of Washington and Oregon and in Puget Sound and it has been suggested that salt water could be pumped considerable

distances inland. Environmental values, however, strongly suggest most coastal areas of both Oregon and Washington as well as the Puget Sound shoreline would not be available for NEC siting.

Thus, the lesser populated areas of Eastern Washington and Oregon along the Columbia and lower Snake Rivers and Banks Lake would initially appear to be the most promising for alternative siting of NEC's. It is likely that sufficient real estate could be located at various points along these sources which is large enough to support a NEC. However, when the need for rapid approval and construction of a center is considered, it is difficult to visualize a location which has the mass of supporting data available for Hanford, and collecting it would require a substantial time.

B. OTHER SITES OUTSIDE THE PACIFIC NORTHWEST

No in-depth studies are known to have been made of potential NEC's in other areas of the U.S. The magnitude of land requirements and water volume needed for NEC's, coupled with safety and environmental restrictions will limit the number of potential sites available. A major study would be required to identify and evaluate these potential sites.

C. SATELLITE CONCEPT

An alternative to the NEC is one termed the satellite concept. This is conceived of as a centralization of the fuel cycle processes plus some reactors at one site. Many of the region's reactor plants would be grouped at several sites (satellites). This reduces the total land and water requirements for any given location. However, with time as a primary factor, it may take a considerable time to study and get approval for the satellite sites. Thus, the NEC may need to contain the initial facilities. Although numerous sites have already been studied in the PNW,¹⁻⁴ many of these studies were cursory. It does, therefore, appear that this alternative to the present methods should receive serious consideration and further study.

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APPENDIX IV-A

HYDROELECTRIC RESOURCES AND USES IN THE PNW

APPENDIX IV-A

HYDROELECTRIC RESOURCES AND USES IN THE PNW

TABLE 1. Developed Hydroelectric Power Resources
of the Pacific Northwest 1972(3)

	Installed Capacity, MW	Average Annual Generation, MW-hr
Idaho	1,255	7,093,500
Washington	12,363	79,075,200
Oregon	5,457	30,250,000
Western Montana	<u>779</u>	<u>4,125,000</u>
Total	19,854	120,544,000

TABLE 2. State and PNW Electrical Demand in 1970
(millions of kW-hr)(4)

Western Montana (a)

Residential	437
Commercial	380
Industrial	1,960

Idaho

Residential	2,406
Commercial	2,311
Industrial	4,950

Washington

Residential	16,266
Commercial	7,753
Industrial	25,255

Oregon

Residential	9,389
Commercial	5,406
Industrial	10,995

PNW Region

Residential	28,458
Commercial	15,850
Industrial	43,160

(a) Uses 0.32 population factor for Western Montana
and whole state data

TABLE 3. Installation Schedule for Thermal Power Projects
Period 1973-1974 through 1983-1984

	<u>Status^(a)</u>	<u>Type of Fuel</u>	<u>Nameplate Rating, MW</u>	<u>Commercial Operation Date</u>	<u>Principal Sponsor^(b)</u>
<u>Combustion Turbines</u>					
Salem, OR - No. 1 & 2	UC	Oil/Gas	65/ea ^(c)	Sept. 1973	PGE
Portland, OR - No. 3-6	UC	Oil/Gas	65/ea ^(c)	Sept. 1973	PGE
Puget Sound Area	UC	Oil	27	Sept. 1973	PSP&L
Othello (Moses Lake)	UC	Oil	33	Sept. 1973	WWP
Northwest Oregon	UC	Oil/Gas	460	Aug. 1974	PGE
Near Seattle, WA	UC	Oil	60	Sept. 1974	Seattle
Trojan	UC	Nuclear	1130	July 1975	PGE
Colstrip - No. 1	UC	Coal	175 ^(d)	July 1975	PSP&L
Colstrip - No. 2	UC	Coal	175 ^(d)	July 1976	
Jim Bridger - No. 2	UC	Coal	500	Sept. 1975	PP&L
Jim Bridger - No. 3			500	Sept. 1976	
<u>WPPSS Nuclear Project</u>					
Hanford - No. 2	UC	Nuclear	1100	Sept. 1978	WPPSS
Colstrip - No. 3	T	Coal	490 ^(d)	Sept. 1978	PSP&L
Colstrip - No. 4			490 ^(d)	Sept. 1979	
Boardman	C	Nuclear	1260	Sept. 1980	PGE
<u>WPPSS Nuclear Project</u>					
Hanford - No. 1	C	Nuclear	1220	Sept. 1981	WPPSS
Hanford - No. 3	C	Nuclear	1300	Sept. 1981	WPPSS

(a) Status on 9-20-73; UC--Under Construction; C--Committed; T--Tentatively Scheduled.

(b) Abbreviations are: PP&L--Pacific Power & Light Co.; PGE--Portland General Electric Co.; PSP&L--Puget Sound Power & Light Co.; WPPSS--Washington Public Power Supply System; WWP--Washington Water Power Co.

(c) Nominal rating 65 MW at 25°F, 50 MW at 80°F.

(d) Colstrip Units No. 1 and 2 are rated 350 MW each; one-half of each unit will be used by West Group (PNW) Area. Colstrip Units No. 3 and 4 are rated 700 MW each; 70% of each unit will be used by West Group Area.

Source: BPA - Branch of Power Resources
September 20, 1973
Revised: December 3, 1973

TABLE 4. Federal Columbia River Power System Installation Schedule
for Hydro Projects (a) 1972-1973 through 1982-1983

<u>Project</u>	<u>Unit No.</u>	<u>Nameplate, MW (b)</u>	<u>Current Schedule</u>
The Dalles	15	86	January 1973
	16	86	February 1973
	17	86	February 1973
	18	86	March 1973
	19	86	May 1973
	20	86	June 1973
	21	86	August 1973
	22	86	September 1973
Dworshak	1	90	March 1973
	2	90	March 1973
	3	220	April 1973
Grand Coulee Pump Generators	P/G-7	50	April 1973
	P/G-8	50	June 1973
3rd Powerplant	G-19	600	June 1975
	G-20	600	January 1976
	G-21	600	May 1976
	G-22	600	July 1978
	G-23	600	January 1979
	G-24	600	July 1979
Ice Harbor Addition	4	111	February 1975
	5	111	March 1975
	6	111	April 1975
Lower Granite Addition	1	135	April 1975
	2	135	April 1975
	3	135	April 1975
	4	135	February 1979
	5	135	March 1979
	6	135	April 1979
Libby	1	105	July 1975
	2	105	October 1975
	3	105	January 1976
	4	105	April 1976

(a) Includes projects under construction and authorized.

(b) Manufacturer's rating and does not necessarily represent maximum capability.

TABLE 4. (contd)

<u>Project</u>	<u>Unit No.</u>	<u>Nameplate, MW (b)</u>	<u>Current Schedule</u>
Lost Creek	1	24.5	October 1975
	2	24.5	December 1975
Teton	1	10	June 1976
	2	10	September 1976
	3	10	July 1979
Chief Joseph	17	95	March 1977
	18	95	June 1977
	19	95	September 1977
	20	95	December 1977
	21	95	March 1978
	22	95	May 1978
	23	95	July 1978
	24	95	September 1978
	25	95	November 1978
	26	95	January 1979
	27	95	March 1979
Little Goose Addition	4	135	February 1979
	5	135	March 1979
	6	135	April 1979
Lower Monumental Addition	4	135	February 1980
	5	135	March 1980
	6	135	April 1980
Bonneville 2nd Powerplant	11	68	May 1982
	12	68	July 1982
	13	68	September 1982
	14	68	November 1982
	15	68	January 1983
	16	68	March 1983
	17	68	May 1983
	18	68	July 1983
Libby Reregulating	Dam	-	July 1982
Total		8829	

Source:
BPA - Branch of Power Resources
February 13, 1973

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APPENDIX IV-B

PETROLEUM SUBSTITUTION

APPENDIX IV-B

PETROLEUM SUBSTITUTION

The existing and projected shortages of petroleum and petroleum products and projected price increases make the possibility of substituting electricity for the petroleum products usage increasingly attractive. There has been a tendency toward an all-electric economy in the country and some of the possibilities have been examined in the past.⁽¹⁾ Mostly, the studies have been rather generalized and did not examine the possibilities in an explicit fashion, that is, use-by-use. A number of petroleum uses should be examined to give additional confidence to petroleum substitution projections. Rail transportation, special purpose vehicles, process heating needs are among those which might be examined. For this report two cases are examined for the Pacific Northwest (PNW): automobile transportation and building heating.

A. TRANSPORTATION - ELECTRIC AUTOMOBILE

In an effort to estimate how much petroleum or gasoline will be displaced by nuclear-electric propulsion of automobiles the petroleum supply and demand must be considered along with some policy rules. For this study it has been assumed that:

- The PNW will get no more and no less of its share of the available gasoline.
- Domestic production of petroleum has or will shortly peak and even with the Alaskan oil, the consumption after 1973-1974 will hold roughly constant for awhile and then decline after perhaps 1975 to about 15% below current levels. The addition of Alaskan oil will probably hold the supply constant with minor variation until 1990.
- Synthetic crudes (from shale and coal) will not produce appreciable supplies until after 1980, peaking perhaps by 1990 or 2000.

- These incremental supplies (Alaska and synthetic crude) will only come at higher prices (relatively, in constant dollar comparisons).

One may therefore surmise that the domestic supply situation (which may vary from this estimate) at a constant or slowly increasing price will be roughly constant after 1974. Thus, the PNW supply would remain approximately constant at 3.5×10^9 gal/yr. If it is to be a policy that the U.S. should be self-sufficient after 1980 or 1985, conclusions which follow would have added validity since the difference between supply and demand would have to be met in some other way. The currently feasible methods of meeting this shortfall between supply and demand will have to come from sources other than petroleum, e.g. electric-nuclear or electric-coal. Figure 1 shows a forecast of the oil situation until 2000 by Rose⁽²⁾ and the above remarks are based upon those estimates.

Given the situation in petroleum supply, what then of demand? It surely won't go away simply because the supply is short; people will still demand ever increasing "miles of mobility" as populations, incomes, industrialization, and other driving factors increase. Two rather widely disparate estimates are possible; these are shown in Figure 4-B-2. The upper curve is a simple extrapolation of gasoline consumption in the PNW which has been increasing at approximately 5.1%/yr (or doubling about every 14 yr). The Bonneville Power Administration in its estimates "Economic Base Study" the rate increase at about 2.3%/yr.⁽³⁾ The difference is appreciable, but is representative perhaps of the uncertainty in such estimates. We can consider one as being the upper limit and the other the lower.

For the time being, perhaps, oil will continue to be imported and the available oil will fall somewhere between the upper limit and the domestic supply line. If it is assumed that imports are terminated (except for Canada) the available oil will fall back to the domestic plus Canada curve. During the period from 1980 on, it may be assumed that the electric car may be introduced to fill the gap in "miles". The shortfall is seen to be between 2 and 5 billion gal of gasoline/yr. We estimate the shortfall to be 3.5 billion gal by 1990; this is approximately equal to the 1972 consumption.

U.S. DEPENDENCE ON OVERSEAS OIL cannot be eliminated in the foreseeable future except at what would seem to be prohibitive cost. It is estimated that the U.S. will have to import some 16 million bbl/day of oil from overseas in 1990, of which at least 14 million bbl will originate in the Eastern Hemisphere, chiefly the Middle East and Africa. Just to reduce this figure to 8 million bbl/day the U.S. would have to build plants capable of producing 6 million bbl/day of synthetic crude oil from coal or shale, at an estimated cost exceeding \$50 billion. This would be virtually as much oil as the U.S. is expected to pump from all its domestic wells in 1990. The broken lines in the projections for the U.S. and the Alaskan North Slope indicate how even their oil output will fall if there are no further discoveries. The curve for total supply is made of of barrels of varying Btu content, depending on source, hence the total corresponds in Btu content, but not exactly to barrels.

FIGURE 1

FIGURE 2. Supply and Demand Estimates for Gasoline in the PNW (billions of gallons)

The incentives to encourage the development of electric vehicles goes beyond the alleviation of fuel shortages since the costs of such a vehicle becomes increasingly favorable with the rising price of fuel. Additional advantages include a significant reduction of pollutant emissions such as sulfur oxide and particulates and the reduction of local noise levels in urban areas.

In order for an electric vehicle to be competitive with gasoline powered vehicles, it is assumed that the electric vehicle must be capable of traveling 60 miles and achieving a top speed of 60 mph. To obtain this performance standard it has been calculated that the electricity requirement is 37.5 kW-hr. Given present technology, this figure requires a battery weight of approximately 2500 lb. In order to make a reasonable comparison between gas and electric cars, it was assumed that they weigh approximately 4000 lb. There exists a positive correlation between the weight and the price of domestically produced automobiles. This relationship is expressed by the equation:

$$\begin{aligned} P &= 9238.24 - 4.96W + 0.0009W^2 \\ R^2 &= 0.83 \end{aligned} \tag{1}$$

where,

P = the price of the automobile

W = the weight of the automobile and,

R² = the coefficient of determinative

Eighty-three percent of the variations in price may be explained on the basis of weight. Equation (1) is plotted in Figure 3. The price of a 4000-lb car is then \$3800. The price of an electric car is presumed to be approximately \$1000 greater than that of a gas-powered car. Since the cost of batteries is amortized separately for calculational purposes, the price of the electric car is assumed to be \$4000 (plus \$800 for battery pack). Table 1 shows a cost comparison for a gas and an electric car. The figures in Table 1 are based on the following additional assumptions.

FIGURE 3. Price versus Weight

1. Both cars are driven an average of 12,000 miles/yr for 8 years.
2. The cost of gasoline is \$0.40/gal with a consumption rate of 15 mile/gal.
3. Electricity cost is \$0.05/mile plus a tax of \$0.44/mile corresponding to the gasoline tax.
4. The battery pack costs \$800 and will be replaced every 2 years.

TABLE 1. Cost Comparison of Gas and Electric Automobiles
(c/mile)(a)

<u>Cost</u>	<u>Gas</u>	<u>Electric</u>
Capital expense amortization ^(b)	3.96	4.17
Maintenance ^(c)	1.78	1.08
Fuel (gasoline) ^(d)	2.67	
Electricity (including tax similar to gas) ^(e)		0.94
License and Insurance ^(c)	0.85	0.85
Battery amortization ^(f)		<u>3.34</u>
Total	9.26	10.38

(a) Assumes both cars driven 12,000 miles/yr for 8 yr.

(b) Gasoline powered, cost of \$3800.

Electric powered, cost of \$4000 less batteries.

(c) Reference 3.

(d) Assumes fuel cost of \$0.40/gal and consumption of 15 miles/gal.

(e) Cost of electricity: \$0.05/mile plus \$0.44/mile tax.

(f) Battery cost of \$800; pack to be replaced every 2 yr.

The cost/mile is greater for the electric car due to its increased capital cost and battery costs. This difference, however, decreases as the price of gasoline increases, as shown in Table 2. The break-even price of gasoline is slightly less than \$0.57/gal. At this price the difference in cost/mile driven is zero. There are several other factors which influence the break-even point. The first factor is the increasing cost of electricity which tends to raise the break-even point. The

TABLE 2. Break-even Costs of Gasoline and Electric Powered Cars (a)

<u>Gasoline Price</u> <u>\$/gal</u>	<u>Gas</u> <u>¢/mile</u>	<u>Electric</u> <u>¢/mile</u>
0.40	9.26	10.38
0.45	9.59	10.38
0.50	9.92	10.38
0.55	10.25	10.38
0.56	10.32	10.38
0.57	10.39	10.38
0.60	10.59	10.38

(a) Based on costs from Table 1.

second is battery use patterns. Battery costs are calculated on the basis of 400 discharges reducing battery capacity to 80%. Shorter trips and increased frequency of charging would tend to increase battery life and therefore, lower the replacement frequency and cost. The effect would be to lower the break-even point. The third factor is the different types of batteries. Longer life batteries with high energy densities and adequate power (Na-S, Li-S, Ni-H⁺, etc.) are currently in the laboratory stage and given adequate impetus could be brought into large-scale production in perhaps 10 years. This would tend to make electric vehicles even more competitive.

With the shortage of gasoline relative to population pressures forecast to continue, the substitution of electricity for petroleum in privately owned vehicles could become a reality in the near future. The amount of electric energy needed to supply the entire estimated shortfall in gasoline by 1990 for private vehicles would be the base load output of 3000 MWe.

B. BUILDING HEATING

For heating purposes in 1971 the PNW consumed 30 million barrels (bbl) of oil (of all grades). With the average energy being about 6.1 million Btu/bbl, this oil corresponds to 183×10^{12} Btu for heat. As a rough estimate, taking an overall performance for a heat pump as being equivalent to 67% efficiency (approximately the same as oil and gas burners), the same amount of Btu's would be required, but at an effective heat rate of approximately 6800 Btu/kW-hr. The total required electrical energy would then be:

$$\frac{183 \times 10^{12}}{6800} = 27 \times 10^9 \text{ kW-hr} .$$

Thus, the total replacement of the PNW heating requirements (for 1971) with heat pumps with an average coefficient of performance of 2.0 would require 4000 MWe.

It is understood that the foregoing statements are just estimates and that it would require a reasonable amount of research to establish the numbers. Total substitution is very unlikely but the magnitudes of the numbers indicate that the potential is large and as the incentives increase (price increases for fossil fuels, pollution abatement requirements, etc.) so also increases desirability of achieving a substantial substitution of electricity for petroleum. There are other substitutions possible, for instance the substitution for natural gas as space heat fuel; this would require another reactor or two for residential heating alone. Since new supply of petroleum fuels and natural gas are not likely to increase as rapidly as the demand, the substitution would be effective in even the incremental additions to demand to be expected in the coming years.

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APPENDIX V-A

DESCRIPTION OF THE HANFORD NUCLEAR ENERGY CENTER

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APPENDIX V-A

DESCRIPTION OF THE HANFORD NUCLEAR ENERGY CENTER

A. SITE DESCRIPTION

1. Plant Location

The Hanford Reservation is comprised of an area of approximately 559 miles² located in southeastern Washington state. The boundaries lie between 46° 18' and 46° 48' north latitude and 119° 17' and 119° 52' west longitude.⁽¹⁾ Although most of the project area is within Benton County, portions of Franklin and Grant Counties are also included. The western most boundary is approximately 30 miles due east of Yakima, Washington, with the closest population center, Richland, Washington, located about 3 miles from the southern most portion of the boundary; Figure 1 shows the site and the larger nearby communities.

2. Regional Demography

Estimates of the population distribution within a 50-mile radius of three separate points within the Reservation boundaries have been made for the years 1973 and 2000, see Figure 1 for the 50-mile radius circles.⁽²⁻⁷⁾ The three separate points are:

- the 100 N-Reactor Area,
- the Meteorological Tower, located between the 200 East and 200 West Fuel Reprocessing and Waste Management Areas, and
- the 300 Laboratory and Fuel Fabrication Area.

The population projections were based upon 1970 census information, current birth rate trends, and an estimate of net migration into or out of the state as the economic and employment opportunities change over the forecast period. The forecast does not reflect the population expansion, which would result from the creation of a Nuclear Energy Center (NEC)

FIGURE 1. Hanford Reservation Site and the Larger Nearby Communities

or a more intensive utilization of nuclear energy for power generating and other purposes. It was assumed that the Hanford Reservation will remain under the control of the U.S. Atomic Energy Commission and that no persons will reside within the Reservation boundaries.

It is estimated that there were 226,600 people living within a 50-mile radius of the 100-N Area in 1973 and that 248,700 people lived within a 50-mile radius of the Hanford Meteorological Tower in 1973. The geographic distribution of this population is shown in Figure 2. In 1973, an estimated population of 163,300 people lived within a 50-mile radius of the 300 Area. The year 2000 projections indicate about a 20% growth in these populations.

3. Land and Water Use

The nature and extent of present land and water use will be explained on the basis of arcs described from the Meteorological Tower. This tower is part of the Meteorology Facility shown on Figure 3 near the Air Strip slightly northwest of the center of the map. Land areas included in the 50-mile radii from other points discussed earlier will also be included here.⁽⁸⁻¹⁰⁾ Each of five zones is described in a clockwise fashion, starting from the north. Zone A is the area between the 0 and 10-mile radii. Zones B, C, and D define 10-mile bands while Zone E generally described the area between the 40- and 50-mile radii, but in some cases extends to 70 miles.

Starting from a line directly north of the Meteorological Tower, Zone A consists of land within the Reservation boundaries. The area south of the Columbia River is under AEC control and is a limited access area. Land north of the river is controlled by the Bureau of Sport Fisheries and Wildlife and is a game refuge. All of Zone A, between the 12 and 150° radials, is limited access area under control of the AEC. Most of Zone A, between the 150 and 270° radials, consists of the Arid Lands Ecology Reserve. This is limited access AEC land under the control of Battelle,

FIGURE 2. Estimated Geographic Distribution of the 1973 Population Within a 50-Mile Radius of the Meteorological Tower

Pacific Northwest Laboratories. Between the 270° radial, land south of the Columbia River is limited access Reservation and north of the river the game refuge is again encountered.

Again starting from the 0° radial, Zone B is a continuation of the game refuge with some areas open for fishing, shotgun and bow hunting during daylight hours. Further north, Zone B includes the eastern most portion of the Wahluke Slope and the Saddle Mountains. Between the Wahluke Branch Canal and the Columbia River, Zone B consists of lands in the Columbia Basin Project which are irrigated or are being developed for irrigation. The area west of the river is limited access Hanford Reservation. Leaving the Reservation, the land is mainly unirrigated land used for grazing cattle and sheep. South and west of the Columbia River, in the vicinity of the Priest Rapids Dam, is the Yakima Firing Range and is undeveloped, unpopulated land. Northwest of Priest Rapids Dam and Reservoir is the Wahluke Slope. This area is partially irrigated with the rest expected to be irrigated in the next 5 years.

Zone C, on the 0° radial, is north of the Saddle Mountains. This is irrigated farm land and part of the Columbia Basin Project. The largest crop acreages in the irrigated area within the 50-mile radius are in alfalfa and wheat, but sugar beets, potatoes, and many other crops are grown, as well as some dairying activity. The area between Lower Crab Creek and northwest of Othello is generally undeveloped. From Othello south to the Columbia River, the land is irrigated farm land. On the west side of the river is the city of Richland. West from Richland, Zone C includes the Yakima River and towns of Prosser, Sunnyside, Grandview and Mabton; land along the Yakima River is primarily in orchard use. Higher land away from the valley floor is used primarily for grazing livestock with some land used for grain crops. At approximately the 270° radial is the Yakima Firing Range again. At 320° is the Ginko Petrified Forest, which is a national landmark.

At the 0° radial, Zone D consists of an undeveloped area of sagebrush and sand dunes. At 20° is located the Potholes Reservoir which is surrounded by sand dunes and is a recreation area south of Moses Lake. Between 30 and 150°, Zone D encompasses a major portion of the Columbia Basin Irrigation Project. At approximately the 150° radial, the Columbia River is encountered with the city of Pasco on the north side and the city of Kennewick on the south side. South and west of Kennewick, Zone D consists of land south of the Horse Heaven Hills. This is farm land primarily used for dry-land wheat. There are, however, about 88 sections (56,320 acres) where permits have been granted for private irrigation development. Crossing the Horse Heaven Hills, Zone D consists of that part of the Yakima Valley containing the town of Granger, Toppenish, Zilla and Wapato. This is again orchard land with livestock grazing at the higher elevations. Northeast of Yakima is the Yakima Firing Range, east of which lies irrigated farm land of the Columbia Basin Project.

At the 0° radial, Zone E extends from the 40- to 60-mile radii and includes the towns of Ephrata and Soap Lake. Also included here is the southern end of Grand Coulee, which is a national landmark. The land is primarily range land with some irrigated farm land around Soap Lake. The town of Moses Lake is in Zone E at approximately the 20° radial. Between the 20 and 90° radials is a large portion of land planned for irrigation development as a part of the Columbia Basin Project. At approximately 70° between the 45-and 60-mile radii, the land is used for non-irrigated wheat production. Between the 90 and 120° radials and extending to the 75-mile radius, the land is used for non-irrigated wheat production. The exception to this is the area at the confluence of the Snake and Columbia Rivers where private irrigation projects are underway. Zone E also includes the town of College Place and part of Walla Walla. Moving west and south, the land is irrigated along the Walla Walla River and produces alfalfa and sugar beets. Land on both sides of the Columbia River, below McNary Dam, hold private irrigation projects totaling approximately 345 sections (220,800 acres). Between the 200 and 260° radials, the land is very rugged

and, for the most part, undeveloped. At the 260° radial is the Yakima Valley with the City of Yakima at 270°. Across the Umtanum Ridge and the Manastash Ridge is the Kittitas Valley which is an area of both irrigated and dry-land farming and cattle production. A portion of the Wenatchee National Forest is found at 330°.

Farming areas in Figure 4 adjacent to the Hanford site boundaries can be recognized by color and regular shape. The circular areas were under irrigation by radial sprinkling systems.

In order to determine points of water usage from the Columbia River and riverbank wells, data were taken from records located at the Department of Ecology, State of Washington, Spokane, Washington. It is estimated that about 200,000 acre-ft of water are annually taken from the Columbia River within 50 miles of the 100 N Area, about a third of this by the City of Richland. This estimate is from the best available data for wells and surface water pumpage, but it is important to note that these are "paper water rights" and are, therefore, estimated to be twice what is actually being pumped. On the other hand, water rights received after 1969 are not reflected, and not all of the people who have been pumping ground and surface water have applied to the state for water rights.

In the next 65 miles of downstream flow, the Columbia River forms the border between Washington and Oregon. There is extensive private irrigation development on both sides of the river. Land, which is now irrigated or expected to be irrigated in the next 5 to 10 years, totals approximately 277,000 acres. Assuming that all of this land were put into a high water use crop such as alfalfa, it is estimated that 1,154,666 acre-ft of water would be required between April and October.^(11,12) Converting this to gallons, 372,199,872,000 gallons of water would be required during the normal irrigation period (April to October).⁽¹³⁾

4. Historic and Archeological Sites and Natural Landmarks

No historical or archeological sites of national importance exist within the Reservation boundaries. The National Register of Historic

FIGURE 4. Aerial Photograph of the Hanford Site

Places⁽¹⁴⁾ lists only three historic sites within approximately 50 miles of the Hanford Reservation. These are:

- (1) Marmes Rockshelter, located 1 mile north of Lyons Ferry on the west side of the Palouse River in Franklin County,
- (2) Olmstead Place State Park, which is 4 miles east of Ellensburg, near the Kittitas highway in Kittitas County, and,
- (3) Whitman Mission National Historic Site, located 6 miles west of Walla Walla, off U.S. 410 in Walla Walla County.

While further archeological sites are not of national significance, there are many less unique sites in the area.^(15,16) The Columbia River shoreline from Vantage at the upstream site boundary downstream to Umatilla is rich with Indian artifacts. There are several campsites and fishing grounds along the Reservation boundary which were traditionally used as wintering areas from prehistoric times until the area was evacuated in 1943.

The National Registry of Natural Landmarks⁽¹⁷⁾ lists two sites within a 50-mile radius of the Reservation. These are:

- (1) Ginkgo Petrified Forest, located in Kittitas County, and
- (2) Grand Coulee, located in Grant County between the towns of Grand Coulee and Soap Lake.

Other natural landmarks in the area which are not of national significance include the Saddle Mountains immediately to the north of the Reservation. This range of hills running east-west include Sentinel Mountain (2,625 ft) and Wahatis Peak (2,969 ft). The Columbia River, which flows through the northern portion of the Reservation and then along the eastern boundary, provides another natural landmark as do the bluffs rising 200 to 300 ft along the eastern shoreline. The south-western edge of the Reservation is marked by the Rattlesnake Hills and Rattlesnake Mountain (approximately 3,400 ft). Figure 5 shows the dominating terrain features surrounding the site.

FIGURE 5. Features of Hanford Project and Vicinity

5. Hydrology

Figure 6 shows plots of the Columbia River flow for an average year and for 1948; the flood of 1948 was the largest of record in the past 75 yr. During the past 15 yr, the flow of the Columbia River at Hanford has varied from a minimum of 34,000 to a maximum of 659,000 ft³/sec. The estimated 100 yr maximum flood stage of 1,440,000 ft³/sec would give a river level of 386 ft and the estimated average flood stage of 400,000 ft³ per sec would give a level of 351 ft at the southeast corner of the Hanford site. Facility elevations throughout the project are such that currently operating facilities would in general not be affected directly by such flood elevations, although some flooding would occur in retired reactor areas, and some plant transportation routes would be under water by the 100 yr flood.

Construction of new dams along the Columbia River and its sources will affect the hydrology to some extent. The Canadian dam projects especially are expected to have a major influence on the normal river flows as well as on the estimated 100 yr maximum flood stage.

Richland, Kennewick and Pasco all take their municipal water supplies from the Columbia River. The intake of the new Richland Filtration plant is about 4 miles south of the 300 Area.

6. Meteorology and Climatology

Meteorological and climatological data have been collected and compiled from appropriate sources by the Atmospheric Sciences Department, Battelle-Northwest. The principal sources of meteorological and climatological data at Hanford are observations made at the 622 Meteorology Tower. This is a 410-ft tower instrumented at 8 levels with sensors recording humidity, temperature, and wind velocity. Standard weather observations are also recorded at the tower location. Over 26 yr of observational data have been compiled and summarized. A network of remote ground stations recording wind velocity at about 15 ft above the ground provides supplemental data for determining certain meteorological characteristics of the Hanford Reservation.

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FIGURE 6. Columbia River Flow at Hanford

(a) Climatic Characteristics

The climate of the Hanford site is a relatively mild continental steppe. It has a small amount of precipitation that falls in the colder half of the year with little snowfall and large annual, daily and day-to-day ranges of temperature. The winds are of a local character much of the time and the humidity extremely low in the summer, but high in the winter with frontal passages primarily during the winter.

(b) Precipitation

Precipitation averages 6.4 in./yr occurring mainly during the winter months with a secondary maximum in June. Table 1 is a tabulation of record amounts of rainfall for various time intervals.

TABLE 1. Record Greatest Amounts of Precipitation During Specified Period of Time (from 5 Minutes to 12 Months, 1912 to 1969)^(a)

<u>Period</u>	<u>Amount, in.</u>	<u>When Occurred</u>
5 min	0.14	April 28, 1951
10 min	0.20	April 28, 1951
15 min	0.30	June 12, 1969
20 min	0.55	June 12, 1969
30 min	0.55	June 12, 1969
1 hr	0.55	June 12, 1969
2 hr	0.88	October 1, 1957
24 hr	1.91	October 1-2, 1957
1 mo	3.08	February 1940
2 mo	4.05	December-January 1931-1932
3 mo	5.61	December-February 1939-1940
4 mo	6.82	October-January 1940-1941
6 mo	7.47	September-February 1940-1941
12 mo	12.74	July-June 1947-1948

(a) For the period 1 mo and over, the period of record is from 1912 to 1969. For periods less than 1 mo but greater than 30 min, the period of record is 1944-1969. For periods of 30 min or less the period of record is 1947-1969 (this reflects refinements in measurement techniques).

(c) Wind

The surface wind velocity distributions, as measured at the Hanford Reservation for the period 1951 to 1956, are summarized in Figure 7. The wind roses indicate the direction toward which the wind was blowing to facilitate visualizing the direction trajectories and show the frequency distributions during all hours for the 5 yr of record. The difference in flow patterns between the 200 Area plateau and the river are evident by comparison of wind roses for Station 8 (the Meteorology Tower in the 200 Area) and Stations 5, 9, and 17 (300 Area). The changes in wind direction at Stations 5, 9 and 17 are caused by topographic influences along the river. The nocturnal drainage wind usually observed at Hanford is evident from the high frequency of downslope (northwest) winds along the major axis of the valley and general convergence of flow along the river. During the daytime hours, 0700 to 1900 PST, the wind is generally more variable because of a higher frequency of upslope movement that is observed.

(d) Thunderstorms

Thunderstorms occur on an average of 11 days/yr with about 80% of the total occurring during May through August. About 20% of the storms have high winds (gusts to 40 mph or more) and a lesser percentage are accompanied by blowing dust, heavy rain, or hail. However, hurricanes are unknown in this locality.

(e) Tornadoes

The PNW is one of the geographical areas in the contiguous United States with the lowest frequency of tornadoes. Thirteen tornadoes have been confirmed within 100 miles of the Hanford area between 1916 and the present. Observers at the Hanford Meteorology Station have observed three tornadoes during the period 1944 to 1970, although none of these occurred on the Hanford Reservation.

The probability of a tornado occurring within a 1° square, which includes the Hanford Reservation, has been calculated using the method

FIGURE 7. Wind Rose for the Hanford Reservation

of H. C. S. Thom.⁽⁹⁾ Calculated by this method, the probability of a tornado striking any point on the Hanford site in any year is estimated to be about 6 in 1,000,000.

(f) Vertical Temperature Structure

The vertical temperature profile at Hanford is measured at the 622 Meteorology Tower located on the 200 Area plateau. The difference in temperature between the 200-ft and 3-ft level is used as one measure of atmospheric stability. A very stable (VS) condition is defined as a temperature difference ($T_{200} - T_{31}$) of greater than or equal to 3.5°F. A moderately stable (MS) condition is defined by a difference less than 3.5°F, but greater than or equal to -0.5°F. An unstable (U) condition is defined by a difference equal to or less than -1.5°F. The intermediate range is considered as neutral (N). Table 2 presents the frequency of occurrence of these conditions during light wind speeds during the period January 1955 through July 1961.

TABLE 2. Percentage Frequency of Occurrence of VS, MS, N, AND U Lapse Rates at the Hanford Meteorology Tower for a Wind Speed of 0 to 3 mph

Lapse Rate Classification	Season				
	Winter	Spring	Summer	Fall	Annual
VS ($\Delta T \geq 3.5$)	7.59	3.93	1.67	8.77	5.37
MS ($3.5 > \Delta T \geq -0.5$)	11.23	2.33	1.54	5.93	5.17
V ($-0.5 > \Delta T \geq -1.5$)	11.92	2.53	2.14	5.56	5.47
U ($\Delta T \leq -1.5$)	1.82	6.23	7.0	6.50	5.38

(g) Stagnation

Stagnation is an important climatological feature of the Hanford Area during the winter season. Low wind speed and fog or low stratus are commonly associated with this condition. Fog and low stratus are, in turn, indicative of an inversion lid which traps atmospheric contaminants within the confines of nearby valley walls. Usually there are several periods of stagnation each season. An annual series of maximum persistence shows a variation from 5 to 20 days during a 15-yr period.

(h) Seismology

Hanford facilities are exposed to the possibility of earthquake damage from two sources: 1) the active seismic zones of western Washington, and 2) closer shocks originating in the seismic zone that includes Walla Walla. However, the underlying sands and gravels in the Hanford Reservation provide excellent protection against damage. As far as can be determined, earthquake intensities greater than three on the Modified Mercalli Scale (MM-III) have not occurred in the immediate Hanford area, although intensities as high as MM-V or MM-VI have been observed at surrounding towns.

The strongest shock to occur in western Washington of historic record was the 1949 earthquake originating in the Puget Sound channel just off Steilacoom, 150 miles from Hanford. Neumann reports that intensities from MM-IV to MM-VII were experienced at distances of 150 miles.⁽¹⁸⁾ Four shocks in western Washington between 1932 and 1946 had maximum intensities of MM-VII.

The eastern Washington earthquakes occurring in historic times have not been as intense as those in western Washington, nor have they been as frequent. In 1936, the Walla Walla area experienced an MM-VI shock. In 1934 at Ellensburg and in 1957 near Othello, "Seismic Swarms" of small shocks occurred. A magnitude of MM-VI was reached in some of these, but the shocks were highly localized. The closest recorded shock has occurred at Corfu, 31 miles north of the 300 Area. In 1918, the most severe shock at Corfu shook articles from shelves and caused landslides.

The great Alaska earthquake of 1964 and the most recent shock in western Washington (1956) were not felt as strongly at Hanford as in surrounding localities. In addition, Hanford is not located in a historically active seismic zone. These considerations make the area one of the safest in the state.

Figure 8 shows a map summarizing the seismic history of Washington State although the numerous shocks of northeastern and north central Washington are omitted; their general locations are shown by lines

FIGURE 8. Earthquake Zones of Washington

indicating active fault zones. For building purposes, the Hanford area has been included in Zone 2 in the seismic probability map adopted as part of the Uniform Building Code by the International Conference of Building Officials.

(i) Geology

Eastern Washington is dominated by the Columbia Basin geologic province, the northernmost extension of the Columbia River Basalt Plateau. The Basin encompasses about 50,000 miles² of southeastern Washington and adjacent parts of Idaho and Oregon. It is underlain by the vast field of flood lavas of the Columbia River Basalt Group. Today, those lavas and the ground surface dip radically inward toward the Pasco Basin, the physiographic and structural low of the larger Columbia Basin.

The Columbia, Snake, Yakima and Walla Walla Rivers reflect the regional gradients, drain centripetally and join within a few miles of each other within the Pasco Basin, the slightly off-centered low point of the Columbia Basin. To the south the Columbia River exits from the Pasco Basin through Wallula Gap at an altitude of about 340 ft, then flows westward through an ever-deepening gorge until it exits from the region through the Cascade Range.

The Hanford Reservation overlies the structural low point of Pasco Basin. the Reservation is bounded to the southwest, west and north by large anticlinal ridges that trend eastward from the Cascade Range, enter the Pasco Basin and die out within its confines. The eastern boundary in the southern portion is the Columbia River and the steep west-facing White Bluffs of the Ringold Formation. Beyond them the gently rising basaltic lava flows lead into the Palouse country of eastern Washington. To the southeast the Reservation is bounded by the confluence of the Yakima and Columbia Rivers and by the City of Richland.

The Hanford Reservation lies on the low-lying alluvial plain of the Columbia River within the central part of the Pasco Basin. Altitudes on the plain range from a low of about 345 ft in the southeastern part of the

Reservation to a high of about 800 ft in the northwest corner. Beyond the plain, the bordering White Bluffs rise to a maximum altitude of 980 ft above sea level and the anticlinal ridges to a maximum altitude of 3,586 ft at the crest of the Rattlesnake Hills.

The Hanford alluvial plain reflects the complex geological history and development of the Pasco Basin, especially during the Holocene epoch (the last about 12,000 yr ago). The discontinuous plain, as originally formed about 12,000 yr ago, sloped down from a high of perhaps 700 ft above sea level in the northwest, to about 100 ft lower to the southeast.

Subsequent to the deposition of the basin fill sediments, the Columbia River cut its way across the reservation, shifting generally northeastward as it lowered its base level and its grade. Estimates of its lateral rates of shift range up to 1 ft/yr. Today, residual channels cross the northeast part of the reservation and attest to that shift. In addition, the shifting helped to etch out Gable Butte and Gable Mountain, two basaltic anticlinal ridges. In the process of eastward shifting and concomitant with downcutting, several benches or terraces were cut. They are best displayed in the southern part of the reservation south of the Hanford Wye road junction. There, the uppermost terrace lies at an altitude of 500 to 540 ft, the lower terrace at 400 to 440 ft, with the escarpment or boundary between the two paralleling the Columbia River and about 4 to 5 miles from the river.

Subsequent to the river shift, wind action established two sets of dunes that now cross both terraces indiscriminately. The first set forms a belt that extends from the junction of Cold and Dry Creek Valleys to a point halfway to the Yakima Horn, then east-northeastward immediately north of the Hanford Wye road junction to the Columbia River. There they form a belt 4 miles wide immediately south of the Hanford townsite to a point opposite Ringold on the east bank of the Columbia River. They evidently originated in Cold Creek Valley by deflation of the valley and wind transport of the sands to the east-northeast.

The second group of dunes focuses on the area between the Yakima Horn and North Richland, with the dunes dying out to the northwest and southeast. The dunes trend northeastward reflecting the strong prevailing winds and wind gaps to the southwest.

Both sets of dunes evidently developed 4000 to 8000 yr ago in the Altithermal geological period and have, in part, stabilized as a result of climatic changes. They also attest to the continued eastward migration of the Columbia River and to the lack of its presence on the Hanford Reservation in the time since dune emplacement. Otherwise, the dunes would have been breached.

The eastward shift of the Columbia River evidently is continuing in the northern reaches of the reservation. Thus, the northern reaches of the White Bluffs (north of the Hanford townsite) are being actively undercut. Landslides into the Columbia River have occurred and will occur as the bluffs are oversteepened.

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APPENDIX V-B

RADIOACTIVE WASTE MANAGEMENT
FOR NUCLEAR ENERGY CENTER

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APPENDIX V-B

RADIOACTIVE WASTE MANAGEMENT FOR NUCLEAR ENERGY CENTER

A. HIGH-LEVEL WASTE

In the production of electrical power from nuclear energy, the nuclear processes that take place in the reactors result in the formation of radioactive fission products and heavy isotope build-up within the nuclear fuel. The irradiated or "spent" fuel will be discharged from the reactors of the NEC and then chemically processed at the fuel reprocessing plant to recover the significant amount of valuable "unspent" fissile and fertile materials for recycle. As an example, irradiated enriched uranium LWR fuels will typically contain about 30% of the original fissionable uranium and the fissionable plutonium produced by reactor irradiation. Chemical reprocessing will be used to separate and recover these useful products from the fission products and the higher waste actinides. Existing or planned reprocessing flowsheets are based on a solvent extraction process. Aqueous acidic "feed" solutions, arising from the dissolution of irradiated fuels in nitric acid, will be fed to the initial (first-cycle) solvent extraction contact. Here, most of the nuclear fuel products will be retained in an organic phase, while the fission products, along with a small quantity of uranium, plutonium or thorium (product loss) and generally all other actinide elements will be discarded as aqueous acidic high-level waste.

For this study it was assumed that this aqueous acidic high-level waste stream will be solidified, at the reprocessing plant, almost immediately after generation of the waste. The resulting solid waste will be transferred to the WTSF after about 5 yr of interim storage at the reprocessing plant. The transfer will take place in sealed metallic canisters, typically 12-in. inside diameter by 10-ft long, each containing

6.3 ft³ of solid waste, probably in the form of borosilicate glass. The interim storage period prior to transfer will result in individual canister heat generation rates of 5 kW or less.

About 7000 canisters of waste will be stored at the WTSF by the year 2000. The number of canisters that will accumulate was determined by assuming a fuel reprocessing plant load that increases almost linearly, from 1 tonne/day of fuel (300 tonnes/yr) in 1982 to 10 tonnes/day (3000 tonnes/yr) in 2000 (it is estimated that about half of the load arises from reactor plants not associated with the center). Furthermore, it was assumed that 72, 20, and 8% of the load is associated with LWR, LMFBFR, and HTGR plants, respectively, and that final volumes of solidified high-level waste from the three reactor types are 2, 3, and 6 ft³/tonnes, respectively.⁽¹⁾

The WTSF high-level waste facility will also be sized to store waste cladding hulls from spent LWR and LMFBFR fuels. Estimated volume of this material accumulated to the year 2000, based on a compacted product of 2 ft³/tonne, is 60,000 ft³. It was assumed that the compacted hulls are in the form of coated "bales" and that compaction facilities are available at the WTSF. Storage space for cladding hulls at the reprocessing plant will be minimal.

1. High-Level Waste Facility^(a)

a. Characteristics

Review of the concepts for high-level radioactive waste management indicates that the system should have the following characteristics:

(a) Characteristics, description and estimated costs for the facility were developed from information prepared for EPA and by BNW staff (Contract No. 68-01-0762) and presented in Program for the Management of Hazardous Wastes, Final Report, July 1973.

- Capability to accept sealed metallic canisters of previously solidified high-level radioactive wastes to a form which is chemically, thermally, and radiolytically stable.
- Capability to compact and store packages of waste cladding hulls.
- Assurance of the health and safety of the public and the protection of the environment.
- Safety of operation, including the ability to remove heat and maintain canister integrity and retrievability following extended periods of time.
- Controllability of effluent emissions to those in proposed Appendix I to 10 CFR 50 for nuclear reactors, which are generally 1.0 to 0.001% of those now in 10 CFR 20.
- Retrievability under all conditions.
- Ability to withstand all credible natural forces.
- Reasonable capital investment consistent with the objectives of safe waste storage for 100 yr or more, and safe recovery from unplanned events.
- Modular construction to provide waste storage space on a schedule consistent with future commercial reprocessing waste deliveries.
- Contamination-free operations.

Until a concept for ultimate disposal of high-level radioactive waste becomes available, it is planned that the WTSF will be used to store radioactive waste. The primary requirement is to provide safe storage for encapsulated solidified high-level waste for at least 100 yr and to make it possible to retrieve failed or weak canisters from storage areas and repack the contained waste for continued storage or for shipment.

b. Description of Facility⁽²⁾

In the preliminary concept of the WTSF described here, the high-level waste will be stored in water basins built in modules. New modules will be constructed as required to handle the increasing waste inventory.

The water in the basins provides shielding and cooling for the canisters and shielding for the waste cladding hulls. Surveillance will be necessary to assure that the canisters remain in satisfactory condition. Extensive monitoring will be used to detect any evidence of canister overheating, leakage or deterioration so that necessary corrective action can be taken if the need arises.

Before proceeding it should be noted that there are alternative management systems that conceivably could be used instead of the water basin concept. Both air-cooled vaults and a system where canisters of solids are stored out-of-doors in heavy-walled steel casks are being evaluated in conjunction with the conceptual design of the Retrievable Surface Storage Facility (RSSF).⁽³⁾

Storage buildings will be designed for a service lifetime of at least 100 years and built to withstand all natural forces which might be expected at the facility such as severe storms, earthquakes, and floods, as well as all credible adverse accident conditions. It is expected that even with nominal maintenance the structures can be maintained in serviceable condition well beyond the design lifetime. The facility will be designed in accordance with nationally accepted codes and standards. A quality assurance program will be applied to the design, fabrication, construction, and testing of structures, systems and components of the facility, to assure that each component of the facility will perform its required function.

In addition to the storage basin, the WTSF also will have facilities to receive, inspect, and decontaminate high-level waste canisters and their transfer casks. The WTSF will be sized to receive up to 10 canisters per day. Facilities will also be provided to repackage failed canisters. Transfer casks containing canisters will be brought into the receiving area within the building and immersed in a stainless steel-lined receiving basin filled with water. The canisters will then be removed from the cask and inspected under water before they are moved into the storage basin.

Facilities will be provided to compact the cladding hulls at a maximum rate of 4 tons/day. It is estimated that the receiving and handling facility will require about 15,000 ft² of building floor area.

The initial storage area will consist of eight concrete-walled water basin storage modules requiring about 15,000 ft² of floor area. Each storage module is capable of storing about 500 high-level waste canisters or about 6000 ft³ of compacted hulls. The modules are lined with stainless steel and filled with water before any waste is emplaced. The height of water above the top of the canisters is sufficient to protect operating personnel from radiation. Above the modules is an enclosed working area from which an overhead crane is used to handle canisters and the optional cover blocks for each module. Storage modules will be connected to a water-filled transfer canal.

One central water treatment loop consisting of a filter, cooler, ion-exchanger, and auxiliary equipment will process the storage basin water in all modules. The temperature of the water in each module will be maintained at about 120°F by circulation through the tube side of a heat exchanger. Cooling water on the shell side will be pumped through externally located evaporative coolers. Maximum heat generation per module is 2.5 MW (500 5-kW canisters).

c. Estimated Costs

Preliminary cost estimates have been made for the WTSF waste repository to provide an initial economic appraisal of the conceptual design. The facility would be constructed in stages to handle the high-level waste canisters resulting from the continually increasing fuel reprocessing load. By 1990, the first stage of construction would be completed and the facility would be in operation. This first stage includes the cladding hull compaction, and receiving and handling facility as well as storage modules for storing a total of 3000 waste canisters and about 12,000 ft³ of compacted hulls. Using 1974 dollars a preliminary estimate of the total capital cost for this first stage of construction is about \$40 million. Direct and

indirect costs associated with the buildings, equipment, and auxiliaries for the receiving and storage facilities amount to \$23 million. An allowance of 75% of the direct and indirect costs, amounting to \$17 million, was estimated for the design of the facility, engineering, quality assurance, and contingencies.

Additional storage capacity for 3000 waste canisters and 12,000 ft³ of cladding hulls would be constructed approximately every 5 years to meet projected storage requirements. Estimated capital cost for these additions is about \$12 million of 1974 dollars.

Costs (in 1974 dollars) for operation of the facility, estimated for 1990, are about \$3 million/yr and result primarily from operating manpower, utilities, materials consumption, and equipment replacement.

B. LOW-LEVEL WASTE

1. Low-Level Wastes Generation Rates

Low-level waste generation rates for the various processing steps in the nuclear fuel cycle which are assumed to take place within the NEC were estimated from a previous study carried out for the Office of Environmental Affairs (USAEC).⁽⁴⁾

Gross waste generation rates were estimated from these data using the following assumptions in addition to the assumptions listed in the foregoing section:

- The total maximum full throughput rate for all types of fuels will be 10 tonnes/day.
- The solid low-level waste volume is reduced 50% by compaction and incineration.
- PuO₂-UO₂ fuels make up 5% of total fuel throughput.
- For the want of published information, the low-level solid waste generation rate for the U₃O₈ to UF₆ conversion process was assumed to be 10 ft³/MTU.

- Low-level aqueous wastes are decontaminated to releasable levels at the originating process facilities. The concentrated residues are handled as solid wastes.
- Low-level wastes are defined here as wastes with heat generation rates less than 0.1 W/ft^3 from radioactive decay.

The estimated low-level waste generated by operations of the NEC is shown in Table 1. The volumes shown in the table represent waste volumes after incineration, compaction and packaging.

2. Criteria and General Description for Retrievable Low-Level Radioactive Storage System

The overall criteria used for the conceptual design of the treatment and storage of low-level radioactive wastes in this report are derived from those previously cited for high-level wastes. The basic premise is that the system should not permit the release of biologically significant amounts of radioactivity into the environment.

The system for storage of low-level radioactive wastes was designed to meet the following requirements:

- It should accept sealed canisters of chemically, thermally, and radiolytically stable, solid low-level radioactive wastes.
- The facility will provide for sorting, volume reduction and incineration of combustible solid wastes, and encapsulation of wastes which require treatment.
- It should provide instantaneous processing capacity at the rate of $1200 \text{ ft}^3/\text{day}$ output.
- The health and safety of the public and the protection of the environment should be assured.
- Storage capacity for all treated and packaged low-level radioactive wastes accumulated between 1982 and 2000 should be provided.

TABLE 1. Output Low-Level Waste from Low-Level Waste Processing Facility

Waste Source	Maximum Daily Rate ft ³ /day (a)	Cumulative Amount by Year 2000, ft ³ (a)	Cumulative Activity by Year 2000, Ci
Yellowcake Conversion and Enrichment	50	150,000	25,000
U-Th Fuel Fab for HGTR	2.5	7,000	7,400
PuO ₂ -UO ₂ Fuel Fab for LMFBR and LWR	45	136,000	3,900,000
UO ₂ Fuels	50	76,000	<0.1
Total Fuels Fabrication (Rounded)	<u>100</u>	<u>220,000</u>	<u>3,900,000</u>
Power Reactor Operations	100	360,000	4,000,000
LMFBR Fuels Reprocessing	60	180,000	2,000,000
LWR Fuels Reprocessing	860	2,600,000	3,100,000
HGTR Fuels Reprocessing	85	250,000	160,000
Total Reprocessing Low-Level Waste (Rounded)	<u>1,000</u>	<u>3,000,000</u>	<u>9,300,000</u>
Total Low-Level Waste (Rounded)	<u>1,200</u>	<u>3,800,000</u>	<u>13,000,000</u>

(a) Volumes are those after incineration, compaction, and processing.

- Operation should be safe and should include the ability to maintain canister integrity and retrievability after extended periods of time.
- Effluent emissions should be controlled at least to those in proposed Appendix 1 to 10 CFR 50 for nuclear reactors, which are generally 1.0 to 0.001% of those now in CFR 20.
- The stored wastes should be retrievable under all conditions.
- The facility should be able to withstand all credible natural forces.
- Reasonable capital investment should be made consistent with the objectives of safe waste storage with retrievability for 100 yr or more and safe recovery from planned events.
- Construction should be modular to provide space on a schedule consistent with the objectives of safe waste storage with retrievability for 100 yr or more and safe recovery from planned events.
- Contamination-free operation should be provided.

Until a concept for permanent disposal of low-level radioactive wastes becomes available, a retrievable surface storage facility should be used to store low-level radioactive wastes. Other design considerations, such as surveillance, design lifetime, and integrity should be similar to those for high-level wastes.

The use of man-made retrievable surface storage facilities assures that there is a safe solution to the low-level waste problem for many tens of years and possibly several centuries. During this period development of an integrated waste management program should be completed to provide for optimal ultimate disposal.

3. Description of Retrievable Surface Storage Facility for Low-Level Radioactive Wastes

The scheme selected for disposal of low-level radioactive waste consists of a processing facility for volume reduction plus a facility for storage of the packaged residue for up to 100 yr. A flow diagram for the operations in the facility is shown in Figure 1.

FIGURE 1. Low-Level Radioactive Waste Processing and Storage Facility

The head-end materials-handling portion of the facility will provide systems for receiving and storing liquid and solid wastes, segregation of solid wastes into combustible and noncombustible fractions, and decontamination facilities for transportation, materials handling, and process equipment. Material will flow from the head-end materials handling facility to the processing systems or to storage. The receiving section will have access to the decontamination facility so that transportation equipment can be decontaminated as required. The receiving facility will be housed in the processing building to assure that all radioactive materials are contained during transfer operations.

Sufficient storage will be provided for one week's production capacity of both liquid and solid wastes prior to processing or final placement for storage. Several storage tanks will be provided so that the liquids can be segregated, neutralized, mixed with other wastes, and prepared as feed for the evaporation or incineration processes. Multiple glove boxes equipped with sorting equipment will allow segregation of the solid waste into noncombustible fractions for transfer to storage or to the packing area for final packaging prior to storage. Feed preparation of combustibles for incineration will also be performed in glove boxes. The decontamination facility to be located in the head-end materials handling and processing facility will be designed to handle the transportation equipment as well as equipment used in the processing facility.

Both combustible liquids and solids will be fed into a remotely controlled incinerator in a shielded area or into an alternative processing scheme for oxidation and volume reduction. Use of controlled air incineration to minimize the generation of fly ash and to provide complete oxidation of the offgases is anticipated. The offgases will be routed through a gas cleaning system to assure that the releases are within standards. The same offgas cleaning equipment will be used to process noncondensable gas from the evaporation and condenser system. The gas cleaning system will consist of wet and dry mist eliminating systems, a wet scrubber, and a final stage of High Efficiency Particulate (HEPA) filters. Solids from the incinerator and the gas cleaning systems will be transferred to the solids processing system for final packaging.

Noncombustible liquids will be processed through a remotely operated evaporator located in a shielded area. Special modifications of evaporation equipment may have to be designed to handle these radioactive liquids. Solids from the evaporation step will be transferred to the solids processing system for final treatment and packaging. Overheads from the evaporation system will be condensed to remove condensables while noncondensables will be routed through the gas cleaning system for particulate removal before discharge to the atmosphere. Condensate and all other process water will be routed to a retention basin for chemical and radioactive analysis before final discharge. Wastewaters that do not meet effluent standards will be recycled through the evaporation system.

The processing systems will be housed in a building with two or three ventilation zones to assure that air is always flowing from the zones of lower-level contamination to the zones of higher-level contamination. Building ventilation will be a major design consideration for this facility since personnel and the environment must be protected from the escape of contamination. All processing and operations must be done in enclosed hood-type facilities having detailed design which must be carried out with extreme care to assure confinement of radioactive contamination. All waste products (solid and liquid) generated within the facility, primarily from decontamination operations, are processed internally and handled as waste received from outside sources.

The receiving, handling and processing facility will be connected to two central corridors, which in turn, connect with the several warehouse structures. For the year 2000 a total of 34 warehouses, each 100-ft wide by 500-ft long, will be arranged side by side and will connect at right angles to the central corridors. Each warehouse can accommodate 4000 waste containers in layers three high. Future expansion of the storage facility will be achieved by building additional warehouses and extending the central corridors; the overall layout is shown in Figure 2.

FIGURE 2. Overall Layout of Low-Level Radioactive Waste Storage Facility

Two types of warehouses are used, one of which will be for wastes requiring shielding (up to about 3 ft of ordinary concrete). Waste canisters, which require shielding, are transferred by remotely operated crane down through the access corridor to the entrance of the appropriate warehouse. There the waste canister is transferred to the remotely-operated warehouse crane for transfer through the air lock and into its storage position. Wastes which do not require shielding, are transported by forklift. Gaseous wastes are stored in cylinders; these cylinders are kept in a separate shielded warehouse equipped with special adsorbent ventilation systems.

Each warehouse is provided with its independent supply of treated and prefiltered ventilation air. The compartmented ventilation exhaust from each warehouse is separately filtered and monitored prior to joining the exhaust air from the remaining warehouses. This compartmentation facilitates identification of canisters which have developed leaks during storage. All exhaust air from each warehouse is combined and passed through a bank of high efficiency filters and is monitored before being exhausted through the central facility stack.

4. Unit Operations for Storage of Low-Level Radioactive Waste

Unit operations at the disposal site for low-level radioactive wastes will involve 1) receiving, sorting, and handling; 2) decontamination of transportation devices, work areas, and equipment; 3) concentration, conversion to solid, and canning (e.g., incineration of solid wastes and evaporation of liquid wastes); and 4) storage for an extended period.

Safety Provisions

Provision will be made for possible spills and accidents in the receiving area. Unloading will be done within an enclosed area with controlled ventilation to prevent direct release of contamination to the environment which might result from surface contamination of containers or rupture of containers during handling. Spills will be isolated and cleaned up using established radioactive decontamination procedures. High radiation levels in wastes will be contained by special shielding. All other material with low radiation doses will be treated in hoods or glove boxes in the same way

plutonium is handled in nuclear fuel plants. Direct monitoring of personnel for radioactive contamination and indirect monitoring of radiation doses with badges, pencils, and rings will be conducted. Because of the definition of low-level wastes, no significant heat generation problem is anticipated.

Evaporator operation results in the entrainment of some radioactive aerosols, which are controlled with close-coupled offgas equipment, and is by far the process step with the most potential for contamination spread by incidents such as temperature and pressure excursions. Combustion of organic liquids and cellulose in materials could result in temperature excursions and possible explosions if operating conditions become abnormal. Design for automatic pressure relief (to another enclosed vent system) and equipment shutdown would be an integral part of equipment design, particularly in view of the potential hazard of the radioactivity in the processed material. Release of radioactivity outside of the processing facility would be avoided by backup ventilation decontamination (filter) systems in case the primary offgas treatments fail. Spills resulting from the canning operation would be handled with routine isolation and cleanup procedures. Sampling of the retention pond should prevent aqueous releases. Environmental surveillance should include the placement of nearby wells for sampling purposes.

Safety problems associated with the storage facility are 1) container rupture followed by contamination spread, 2) criticality, 3) overheating, and 4) natural disasters. Canister rupture will be detected by ventilation gas sampling and criticality detection equipment will be located in the storage array. Similarly, temperature recording will detect unusual radioactive or chemical heating which will be supplemented with automatic fire alarms and automatic fire fighting equipment. Fire should be unlikely in the storage areas because combustible wastes will have been previously incinerated. The facility will be constructed to survive tornadoes and earthquakes, and located to avoid floods and ground subsidence.

Procedures to prevent sabotage or theft are not yet well developed beyond the usual military-type guard system; a factor which must be considered in detail during the final design phase. In any event, a high,

unclimbable fence will surround the total property of the disposal site, and another fence should probably be installed around the processing and warehouse area. The total site should have appropriate audio/visual surveillance.

5. Accountability and Monitoring

A major problem in handling low-level radioactive wastes is the determination of the amount of radioactivity in the incoming wastes. Waste producers will be required to inventory radioactivity in the wastes they send in terms of curies or grams of fissile materials and curies or grams of other radioactive materials. The incoming wastes must be monitored for total radiation level, external contamination and the total fissile content (to determine the potential for achieving criticality). It should not be necessary to reopen cans already adequately treated and packaged for storage. The initial monitoring will result in segregation on the basis of radiation level, the need for container decontamination, and the need for treatment. Normal radiation monitoring and isolation techniques should be used in the sorting area with the assumption that all materials contain plutonium.

All effluents of the volume reduction processes will be monitored (stack gases, retention pond effluent) before release. Because of the possibility of accidental releases during processing, environmental monitoring of air, water, land, biota and people around the site should be conducted routinely.

The solid waste materials should be monitored before packaging to provide an estimate of the content of specific nuclides; this will require some sampling. It is hoped that the technology for low-level continuous inventorying of solids will be developed to perform this task, but such technology is not available at this time. A more feasible alternative would be to do "whole body" monitoring of the can after sealing. Improvements in current technology would also be needed for this operation. A check for consistency would then be made between an accumulation of measured can contents and the estimates at the source with a best estimate being assigned forever to the can contents. Inventory controls would be imposed to decrease the likelihood of creating a critical mass during

storage and to segregate temporarily high radiation field materials until decay. A continuous program of air sampling and can monitoring is needed to check for failed cans.

Once the wastes are safely packaged and stored in warehouses, accountability of radioactive materials is largely a matter of restricting unauthorized access to the facility, keeping adequate records of inventories placed in storage, properly labeling each can for identification, and periodically estimating current and projected inventories of radionuclides that build up and decay as time progresses. This last item seriously complicates the inventory record problem, but it is desirable to help define the current and future hazard of the waste and to provide information for decisions that might be necessary regarding future disposition of the waste.

6. Costs for Low-Level Radioactive Waste Disposal Site

The capital and operating costs for facilities with incineration capacities of up to 500 lb/hr have been estimated, but no data on actual operating or capital costs for facilities of the size required to meet the total production rate of 1200 ft³/hr were available. Therefore, a capital and operating cost estimate was made for a facility that could compact, incinerate, and package 3,500 gal of liquid radioactive waste and incinerate an average of 1200 ft³ of solid radioactive waste per hour. The capital and operating costs of remote radioactive processing facilities are highly dependent on the design criteria and operational procedures established for the facility.

7. Capital Costs

The estimated capital cost for the low-level waste processing facility is rounded to \$60 million. Alternatively, an initial facility suitable for the period 1980 to 1990 could be built for about \$40 million, to be augmented by 1990 by additional processing capacity for an additional \$40 million. The approximate capital cost for the storage facility through the year 2000 is \$100 million.

Costs were established on the basis of buildings able to withstand tornadoes and earthquakes, with use of the present state-of-the-art practice for contamination control, shielding, and remote handling. Capital is also dependent on the height to which the canisters are stacked. The standard 4- x 6- x 6-ft high canisters can be stored from one to five high and satisfy technical requirements for storage. If containers are stacked three high, the capital cost for a storage facility is \$8/ft³ of material stored.

C. ENVIRONMENTAL SAFEGUARDS AT THE REPOSITORY SITE FOR RADIOACTIVE WASTE

A detailed survey of the geology of the site with regard to groundwater flow and aquifer characterization, structural and long-term stability characteristics of the underlying strata, and tectonic stability and frequency of earthquakes will be required before the plant is located. Prevailing meteorological conditions (wind velocity and direction versus time, air "dilution" factors, precipitation) and background radioactivity should be monitored and well established before site selection and during site operation.

Because of the long storage time anticipated, population trends should be anticipated and the existence of the storage facility should be considered in long-range local and regional plans. Arid regions of low population density with deep water tables are generally preferred but are not essential. It is assumed that an exclusion distance of at least one mile around the activities within the site, or especially from the ventilation stack location, would allow for good atmospheric dilution.

D. BENEFITS AND PROBLEMS

The primary benefit derived from siting the WTSF within the center is that transportation of high-level solids through non-Federal land is not required, at least for 100 years. A potential problem is that siting considerations for waste management facilities and power reactors are not always compatible, e.g., a river can be viewed not only as a heat sink, but also as a potential driving force for dispersion of stored radionuclides. Another potentially serious problem is that acts of war and sabotage and natural catastrophies can be related to a stored source of nuclides, now concentrated in only a few locations.

E. ADDITIONAL STUDIES

Because of time limitations and the nature of the study, the foregoing information was developed from preliminary data. There is no intent to imply that the waste management schemes are optimum or that water basin storage is the only candidate for potentially meeting the criteria presented earlier for high-level waste. As indicated earlier, in addition to water basin concepts for the management of high-level solid wastes, systems based on air cooling are under consideration in work associated with the conceptual design of a Retrievable Surface Storage Facility (RSSF).⁽³⁾ More specifically, both air-cooled vaults and a system where canisters of solids are stored out-of-doors in individual heavy-walled steel casks are being evaluated. Alternatives to simple compaction of cladding hulls (followed by containerization or coating) include melting or conversion to oxides (glasses) and even storage of uncompacted hulls in underground, shielded vaults.

Additional studies to optimize the WTSF in relation to other facilities of the center are needed. As an alternative, high-level solid waste storage could be essentially integral with the reprocessing plant. Solid geometries other than the typical 12-in. diam x 10-ft long canister may be warranted to facilitate heat removal. Additionally, the center may be sited to permit ultimate disposal in local geologic formations. Finally, additional work is needed to firm the system concepts and the very preliminary cost estimates that are presented.

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APPENDIX VI-A

POTENTIAL ECONOMIC CONSIDERATIONS OF THE HANFORD NUCLEAR
ENERGY COMPLEX

APPENDIX VI-A

POTENTIAL ECONOMIC CONSIDERATIONS OF THE HANFORD NUCLEAR ENERGY CENTER

A Nuclear Energy Center (NEC) should result in the following general types of economic considerations:

1. Lower bus bar electricity costs because of:
 - a. Lower power plant construction costs,
 - b. Lower power plant fuel costs,
 - c. Lower power plant operating costs, and
 - d. Higher power plant innages.
2. Potentially higher electricity transmission costs than for the same number of individual plants scattered throughout the Pacific Northwest (PNW).

Lower power plant construction costs which are typically attributed to:

1. More efficient construction scheduling from assembly line construction of power plants,
2. Lower waste treatment facility costs from sharing of facilities,
3. Construction of duplex power plants instead of single power plants,
4. Reduction of delays due to licensing actions,
5. Use of existing facilities and utilities,
6. Good foundation conditions,
7. Low excavation costs,
8. Satisfactory drainage,
9. Use of common environmental information,
10. Low land costs,
11. Little ecological description,
12. Readily available water supply,
13. High water purity,
14. Extensive meteorological data available,

15. Mild weather conditions,
16. Extensive nuclear construction experience,
17. Low site material costs,
18. Simple site preparation costs,
19. No population displacement, and
20. Large waste disposal capability.

These advantages result partially from the characteristics of NEC's in comparison to construction of scattered plants and partially from the physical characteristics of the Hanford site. It is not expected that a NEC would have all of these advantages when compared to construction of a single facility at another specific site. However, all of these advantages would occur when a comparison is made to all sites for numerous individual plants that would be built in place of the NEC.

The actual reduction in construction cost for a NEC in comparison to construction of scattered plants has not been determined by a detailed study. A preliminary study⁽¹⁾ for the Hanford site indicates about a 5% lower construction cost. A detailed study may be desirable to be more definitive about this cost difference.

A slightly lower fuel cost could be expected for a NEC because of lower transportation costs for both fresh and spent fuel. However, this cost savings is not large enough to have a significant effect on the decision to build a NEC.

Lower operating costs could be expected for a NEC because of more efficient use of personnel, better trained personnel, and the availability of more and better quality support services.

More efficient use of personnel could result from use of larger and common facilities. Larger facilities might be installed for waste treatment, construction support, etc. In many cases, the number of persons required to operate a facility increases at a lower rate than the rate of increase in size of the facility. As an example only about 50% more operating personnel are required for a duplex reactor than for a single plant.

Better trained personnel could result from an increase in the number of similar activities. As an example, if several reactors were built, a well-trained outage crew could result because they could be kept busy during most of the year doing outage work. A common crew could move from reactor to reactor if the outages were scheduled accordingly.

The availability of more and better quality support services could result in a substantial cost savings and increase in plant efficiency. Nuclear facilities require a wide variety of support services which are unique to the nuclear industry. These services in many instances are extremely costly and highly dependent on the capabilities of the technical and other skilled manpower to achieve the desired quality. Many of these services are needed continuously or on short notice, thus, distance to the services is an important factor. One of the economic as well as technical benefits of a NEC would be the availability of complete technical services at the site which are conducted by a staff of highly qualified and experienced professional personnel. One alternative to this would be the development and operation of some of the required services at each nuclear facility. In addition to the economic considerations, the facility would be faced with the justification of their program and procedures to regulatory agencies and the periodic inspection of these services by compliance agencies.

The following are some of the typical benefits that might be realized from services available at a NEC:

1. More sophisticated services for same costs.
 - a. Dose evaluation (dosimeter and bioassay analyses and invivo examination).
 - b. Environmental dose evaluation (sample processing and analysis).
 - c. Occupational medicine.
 - d. Atmospheric physics (measurement and predictive models).
 - e. Radiological instrumentation calibration (test, repair and evaluation).
 - f. Protective equipment supply, decontamination and maintenance (protective clothing and respiratory protection).

- g. Geology, hydrology characterization.
 - h. Waste handling and scrap recovery.
 - i. Centralized training programs (operators, monitors and professionals).
2. More expertise in the general manpower pool (labor, operations and technical).
 3. One plan for all emergencies.
 4. Extensive emergency support (equipment, manpower and communications).
 5. One hospital and one fire department (more training can be accomplished).
 6. Nondestructive testing capabilities.
 7. Compliance office located at the NEC.

With the exception of Item 7 above, the Hanford site currently has all of these. The items listed below, however, are unique services available at the Hanford site which probably would not be duplicated at another site:

1. HEPA filter test facility.
2. Radiosurgery facility with appropriately trained staff.
3. Contact maintenance and minor construction of radiation facilities.
4. Glove box manufacture.
5. Two emergency relocation centers, one hardened, which include complete communication instrumentation and procedure capabilities.
6. AEC Regional Emergency Team located onsite.
7. Approved nuclear pipe fabricator.
8. Large vessel moving and installation technology.

A higher power plant innage probably might be realized at NEC's. This higher innage would result from better personnel training, better preventive maintenance, and more efficient performance of outage work.

Better personnel training could result from the ability to support training schools and the greater experience of employees on each type job. Enough duplicate systems would exist to justify training personnel for specific operating and maintenance jobs. Repetitive performance of jobs (such as opening reactor vessels during outages) would create associated specialists.

Better preventive maintenance could result from accumulation of better statistics concerning types of failures and the effectiveness of maintenance practices. The larger number of facilities would result in a faster accumulation of statistics.

More efficient performance of outage work could result from better planning, better employee training, and availability of better tools and techniques.

Better planning could result from creation of an outage crew with its associated industrial engineers who would be continuously studying outage performance and conceiving more efficient work methods and tools. Better training would result from more experience and ample work to justify training schools. Availability of better tools and techniques would result from increased analysis and from the fact that development and purchase of more sophisticated tools can be justified when they are used more often.

Higher transmission costs could be expected for a NEC than for power plants scattered throughout the region because of the magnitude of transmission line capacity and distance of transmission to load centers.

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APPENDIX VII-A

RADIOLOGICAL IMPACT OF A NUCLEAR
ENERGY CENTER - GENERIC DISCUSSION

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APPENDIX VII-A

RADIOLOGICAL IMPACT OF A NUCLEAR ENERGY CENTER - GENERIC DISCUSSION

A. INTRODUCTION

All industrial plants handling radionuclides have radioactive waste (radwaste) systems that treat the waste streams containing radionuclides. These systems are referred to as the liquid, gas or solid radwaste systems in accordance with the physical form of the waste streams being treated. The purpose of the radwaste systems is to minimize release of radionuclides to the environment and the consequent radiation dose to the general public.

The radwaste systems can be designed for all degrees of treatment from essentially zero up to very sophisticated systems which result in virtually no release of radionuclides to the environment. The costs for operating these systems also have a broad range from a low value for minimal treatment up to high values for sophisticated treatment.

The AEC has a general policy that the radiation dose received by the general public shall be "as low as practicable" which is defined as "as low as is practicably achievable taking into account the state of technology and the economics of improvement in relations to benefits to the public health and safety and in relation to the utilization of atomic energy in the public interest."⁽¹⁾ This has been translated into design guides, in proposed Appendix I to 10 CFR 50, which defines the term "as low as practicable" in relation to radiation doses that the general public might receive as a result of radionuclide releases from nuclear power plants. Such design guides have not been proposed for reprocessing or fabrication plants, but probably will be issued based upon a control philosophy similar to that for LWR power plants.

The radiation dose received by the general public as a result of radionuclide release from a plant depends primarily on the design of the radwaste systems; the distance between the plant and the nearest members of

the general public, and the pathways for radionuclide travel to the public. Of particular importance is the thyroid dose to infants consuming milk containing radioiodine from the air-grass-cow-milk pathway.

In general, the proposed 10 CFR 50 Appendix I guidelines for radiation dose are easily achievable for external exposure to gaseous effluent at a 500 meter (1640 ft) distance between the reactor plant and the site boundary to which the public has unlimited access. The limits are also achievable, but with somewhat more difficulty, for access to that boundary of foraging milk cows which provide milk to infants. As the distance between the plant and the nearest point of public access increases, the radiation dose to the public decreases. As an example, when the releases are from a 100-meter stack, increasing the site boundary distance from 500 to 2000 meters decreases the dose from radioactive gas release to a person at the fenceline by a factor of about 5 to 10 because of greater dilution in the air.

The Appendix I guidelines of 5 mrem/yr for the most highly exposed individual of the public are easily achievable for LWR power stations of 1000-MWe capacity. In addition, AEC Document WASH-1258 describes liquid radwaste systems capable of reducing the maximum individual dose rate to as low as 0.1 mrem/yr from the liquid effluents released from a nominal 2400 MWe, two reactor power station regardless of whether they are Boiling Water Reactors (BWR) or Pressurized Water Reactors (PWR) or whether they are sited on a river, lake or ocean. On this basis it should be possible to place as much as 30,000 to 40,000 MWe total capacity at a nuclear center without exceeding the Appendix I guides for exposure to liquid effluents.

The previous discussion was limited to LWR reactors. At the present time the "as low as practicable" guides for HTGR's, LMFBR's and fuels reprocessing and fabrication plants have not been set; the guides will probably be similar. For reprocessing plants this may be a very severe limitation since the very nature of the process is to release the fission products from the fuel. The reprocessing plant siting Document ORNL-4451,⁽²⁾ states

that LWR plants of capacity of greater than 6 to 10 tons/day will have to have more efficient iodine removal equipment than that demonstrated in present technology. If LMFBF fuels, cooled 30 days are to be processed the iodine removal efficiency must be improved four to six orders of magnitude over present technology.

Each of the several types of nuclear facilities expected to be located within a nuclear energy center (NEC) will routinely release radioactive gases, liquids, and/or solids to the environment under the "low as practicable" philosophy. In a general way, the total impact of the facilities is the sum of the impacts caused by each facility. However, the individuals receiving the highest doses will not necessarily be identical for each geographically-separated facility and the doses to the maximum individual will not necessarily be completely additive, especially in the instance of gaseous effluents.

Several mathematical models developed for calculating radiation doses to man and other biota from radioactive materials released to the environs have been reported in detail in the literature. Some of these models were specifically designed to treat accidental or acute releases^(3,4) although they can be applied with modifications to chronic releases.^(5,6) Other models were designed to calculate radiation doses in a large region of the United States from chronic releases.^(7,8) Applications of these models to the estimation of radiological impact of nuclear facilities for inclusion in the Environmental Reports required by the National Environmental Protection Agency (NEPA) have also been discussed in the literature.^(9,10)

The following discussion addresses, in a generic sense, the routine release rates of radionuclides from fuel fabrication plants, nuclear reactors, reprocessing plants and interim waste storage facilities associated with a nuclear energy center. The radiation doses resulting from such releases are summarized briefly but details of the dose calculations are not presented.

B. FUEL FABRICATION FACILITIES

In an NEC fuel fabrication facilities will be required for both uranium and plutonium LWR fuels as well as for LMFBR fuel. Fuels for any demonstration gas-cooled breeder reactor, which might be sited at the center, could either be fabricated and reprocessed onsite for each of siting or offsite for economic reasons.

In the uranium plant, uranium is received as either the hexafluoride or oxide powder. It is converted to the oxide, formed into pellets, sintered, etc., and then placed in zirconium tubes. The tubes are sealed and then assembled into finished assemblies. The plant ventilation system employs adequate safeguards to prevent the release of significant amounts of particulate matter.

The plutonium fabrication plant has several additional steps in the process. The plutonium may have to be converted to an oxide, blended with uranium oxide and then formed into pellets. The pellets, after further treatment, are then placed in tubes and welded closed. Up to this point all operations have taken place in gloveboxes because of the highly radioactive nature of plutonium. The remainder of the process parallels the uranium assembly line steps. The releases from the plutonium fabrication plant are held to insignificant levels by extensive air filtration equipment, so that both plants do not require significant controlled access or low population zones surrounding them.

The potential environmental impact of a mixed-oxide fuel fabrication plant was addressed in Document BNWL-1697.⁽¹¹⁾ Figures 5 to 8 of that report illustrate the 50-year dose commitment to bone and lung of a Standard Man inhaling plutonium continuously released throughout a 50-year life of the facility. The doses were calculated for the maximum sector (highest air concentrations) versus distance from the facility and for two release heights, ground level and 100 meters, and the results were normalized to a chronic release rate of 1 $\mu\text{g}/\text{yr}$ (i.e., 1 microgram/year). The highest dose commitments were associated with a ground-level release, which would be more typical for a fuel fabrication plant than a 100-meter release.

A typical release rate for the 1000 tonnes/yr fuel plant sited in the nuclear energy center would be about 50 $\mu\text{g}/\text{yr}$.⁽¹²⁾ Assuming a ground level release (Figures 5 and 7 of BNWL-1697) and using the curve for the new ICRP Task Group Lung Model, a release rate of 50 $\mu\text{g}/\text{yr}$ would lead to 50-yr dose commitments of 100 mrem to the bone and 2 mrem to the lung. The dose per year of operation was not calculated and would vary with time since startup, being higher in later years. "Average" doses per year of operation could be taken to be about 2 mrem to bone and 0.05 mrem to lung at a distance of 1000 meters.

At a distance of 2,000 meters, the 50-year dose commitments and "average" doses per year would be reduced to about one-fourth of those above.

The radiological impact of a LMFBR fuel fabrication plant should be similar to that discussed above for the mixed-oxide plant. The radiological impact of a uranium fuel plant, however, would be very much less, so much less that the impact of chemical rather than radioactive releases to the environment would be of more concern.

C. NUCLEAR POWER PLANTS

Each nuclear reactor has a core region containing the fuel elements. In addition, a supply of fresh fuel elements is stored onsite just prior to the annual refueling outage, and spent fuel elements may be stored for about 6 months after removal from the reactor before they are shipped to a reprocessing plant.

Operation of the reactor creates radioisotopes in the reactor structural materials, the coolant and in the fuel element cladding and end supports. Most of these radioisotopes are immobile because they are part of the permanent equipment, but small amounts are created in or enter the coolant and travel throughout the coolant and the associated purification and waste systems. Small amounts also escape into other parts of the reactor building and eventually are transported to the radiation waste systems for appropriate treatment, storage and release to the environment.

The primary radioisotopes of interest are those in the fuel elements. The immobile ones in the structural materials normally present an insignificant hazard. A general estimate of the total quantity of radioisotopes in the fuel elements for typical power reactors is given in Table 1.

Estimated release rates of radionuclides with liquid and gaseous effluents from the current and near-future generation of nuclear power reactors can be found in Environmental Impact Statements prepared by the AEC in response to applications for operating licenses and construction permits. Current AEC practice is to normalize the liquid release rates estimated by an applicant to a total of 5 Ci/yr, exclusive of tritium. Tritium release rates are estimated to be 20 Ci/yr for a BWR and 350 Ci/yr for a PWR. Guidance on the specific radionuclide content of liquid wastes versus radwaste system complexity can be found in WASH-1258.⁽¹⁾

Radiation doses to individuals living at a 500-meter site boundary distance can easily be maintained below the Appendix I guideline of 5 mrem/yr without the need for excessive radwaste treatment. The same radwaste systems which meet this guideline result in total-body, population doses of less than 50 person-rem/yr for a 2400 MWe PWR station situated on a river and less than 10 person-rem/yr for a lake or ocean site. The population dose from a 2400 MWe BWR station is somewhat less at corresponding sites.

Principal pathways of exposure are fish, shoreline exposure and, at freshwater sites, drinking water. The nuclides Cs-134 and Cs-137 are the principal contributors to the total-body population doses from all these pathways, with lesser contributions from Co-58 and Co-60. With the most sophisticated radwaste systems, H-3 made significant contributions in the drinking water pathway for PWR liquid effluents.

Radionuclides released with gaseous effluents from LWRs versus radwaste systems were also defined in WASH-1258.⁽¹⁾ Noble gas releases totaled 10^3 to 5×10^4 Ci/yr for a PWR and 10^3 to 3×10^6 Ci/yr for BWR. Relatively simple radwaste systems were capable of limiting releases to

TABLE 1. Typical Radioisotopes in Power Reactor Fuel^(a)

	Location	Material	Ci
Fresh Fuel	Full reactor load in storage prior to use	Uranium	~200
Irradiated Fuel	In reactor during equilibrium operation	Uranium, Pu Fission Products	1.8×10^{10}
	In reactor--1 week after shutdown	Uranium, Pu Fission Products	3.0×10^9
	In storage--2 months after shutdown	Uranium, Pu Fission Products	6.3×10^8
	In storage--6 months after shutdown	Uranium, Pu Fission Products	4.0×10^8

(a) Basis: 1250 MWe pressurized water reactor with uranium fuel

$\sim 10^3$ Ci/yr from a PWR and $\sim 10^4$ Ci/yr from a BWR and reducing the air submer-sion dose rates at the 500-meter site boundary of a 2400 MWe, two-reactor station to less than the Appendix I guideline of 5 mrem/yr. The population doses associated with these reduced releases of noble gases ranged from 1 to 70 for a 2400 MWe BWR station and from 0.2 to 1 for the PWR station. These population doses are, of course, highly dependent upon population distribution around the site, especially as related to distance and the prevailing wind direction.

Releases of radioiodine listed in WASH-1258 ranged from 10^{-2} to 15 Ci I-131/yr/reactor for a BWR and from 10^{-2} to 1.2 Ci/yr/reactor for a PWR. None of the potential radwaste systems could reduce the potential infant thyroid dose below the originally proposed guideline of 5 mrem/yr without the addition of a tall stack. Since these doses are calculated on the prem-ise that a milk cow forages at the site boundary, the dose versus release

relationship is highly dependent on distance to the site boundary. At a nuclear center the distance to the nearest possible cow pasture might be 10^4 meters rather than the 500 meters assumed in the reference document.

Such an increase in distance could reduce air concentration of radioiodine and hence thyroid dose by a factor of 50 to 100 for ground level releases. This reduction might eliminate the need for a tall stack and still permit multireactor siting of 30,000 to 40,000 MWe at the NEC.

D. FUEL REPROCESSING PLANTS

When the irradiated fuel from the power reactors is dissolved in the reprocessing plants, the radionuclides in the fuel are released and enter either the reprocessing liquid streams or the gas atmospheres in the reprocessing equipment. These gaseous and liquid streams are then treated to remove the radionuclides for storage or reuse. The inventory of radioactive material at a reprocessing plant consists of fuel waiting to be processed and the wastes from fuel previously processed. Table 2 lists the inventory of radioactive material at a reprocessing plant versus the type of fuel being processed assuming the wastes are stored on site for 10 years prior to shipment to a Federal repository.

TABLE 2. Inventory of Materials Stored at Fuel Reprocessing Plants

<u>Plant Type</u>	<u>LWR</u>	<u>HTGR</u>	<u>LMFBR</u>
Plant Throughput	1500 tonnes/yr	260 tonnes/yr	1500 tonnes/yr
Amount of Radioactive Material Stored Onsite	1.7×10^{10} Ci	4.8×10^9 Ci	2.6×10^{10} Ci

Siting of reprocessing plants and associated waste management facilities was discussed in ORNL-4451.⁽²⁾ At the time that document was prepared, the proposed Appendix I guideline and associated philosophy had not yet been prepared. As a result the authors assumed that control of routine releases of radionuclides could be based upon the air concentrations listed in

10 CFR 20. It may be assumed that a significant reduction below these latter air concentrations and resultant radiation doses, will be required by a future definition of "as low as practicable" for fuel reprocessing plants dictating more sophisticated radwaste treatment systems.

The Barnwell fuel reprocessing plant has a minimum site boundary distance of ~2350 meters. The capacity of this plant is 1500 tonnes/yr of LWR fuels. Radionuclides will not normally be released with liquid effluents. Estimated release rates to the atmosphere taken from the Barnwell Environmental Report⁽¹³⁾ are listed below.

<u>Nuclide</u>	<u>Ci/yr</u>
H-3	5.8×10^5
Kr-85	1.4×10^7
I-129	0.047
I-131	0.38
Cs-134	0.6
Cs-137	0.38

At the present time no removal systems for noble gases are commercially available and none appear to be needed at Barnwell. The doses estimated from the releases listed above are summarized in Table 3.⁽¹³⁾

TABLE 3. Annual Radiation Doses Associated with Gaseous Effluents from the Barnwell Plant

<u>Exposure Pathway</u>	<u>Organ</u>	<u>Nuclide</u>	<u>Individual mrem</u>	<u>Population Person-rem</u>
Air Submersion	Total Body	Kr-85	0.07	2
Air Submersion	Skin	KR-85	6.3	180
Inhalation and Transpiration	Total Body	H-3	0.4	13
Milk-Infant	Thyroid	I-131	1.9	100
Milk-Infant	Thyroid	I-129	3.4	70

The doses listed in Table 3 are well within the existing 10 CFR 20 guidelines and should be reasonably compatible with any forthcoming "as low as practicable" guidance for reprocessing plants. As stated before, siting such a plant at a nuclear center would automatically extend the site boundary to perhaps 10^4 meters and reduce the radiation doses even further below the existing and proposed guides.

E. WASTE MANAGEMENT FACILITIES

Waste management facilities were discussed in ORNL-4451 and it was concluded that with proper design and siting any environmental radiological impact of such facilities would be minimal. Interim storage of high-level liquid wastes does not normally result in release of radioactive materials to the surface waters. Acceptably small releases of radionuclides to the atmosphere will occur routinely, and accidental leaks could release liquid material to the ground. For these reasons careful design and judicious siting of a reprocessing plant and associated high-level liquid waste storage facilities must be accomplished. Siting of these facilities within a nuclear center where the distance to the nearest population is relatively large would normally result in lowered radiation doses to the offsite population.

Solidification of liquid wastes after a brief (3 to 5 yr) storage period should also be done at the site of the reprocessing plant for economic and safety reasons. It may be desirable to remove certain fission products and actinides from these wastes prior to solidification. The fission products Sr-90 and Cs-137 may be removed to reduce the heat generation rate within the solids and the actinides may be removed to reduce the extremely long time that the solid product remains highly radiotoxic.

Neither these removal processes nor the solidification itself should impose an unacceptable environmental impact provided that the proper design and siting as mentioned previously have been followed. The separated fission products would need to be encapsulated and placed in a cooled storage facility until such time that their heat rate has decreased significantly or alternately until some beneficial use could be found for them. The

separated actinides could possibly be fabricated into suitable form for charging into an "actinide burner" for transmutation and fission. The radiological problems associated with this latter concept are discussed in more detail later. Properly encapsulated solidified wastes would be stored at an interim Retrievable Surface Storage Facility (RSSF) for several years prior to shipment to an ultimate disposal site.

Evaluation of the several concepts proposed for a Retrievable Surface Storage Facility is currently underway by the AEC and its contractors.^(a) Such a facility would provide interim storage of solidified power reactor wastes until such time as they can be transferred to the ultimate disposal site. Only minor radiological impact is predicted for the RSSF concepts evaluated to date.

F. "ACTINIDE BURNER" NUCLEAR REACTOR

It has been suggested that it may be desirable to remove long-live fission products and actinide elements from high-level wastes prior to solidification for separate disposal via transmutation. It is possible that this could be done without adding appreciably to the total fuel cycle costs.^(16,17) The technical feasibility of transmutation has been established;⁽¹⁶⁾ however, several important problems remain to be addressed. For example, there may be some point in time when further recycling of actinide elements becomes unattractive because the elements are no longer suitable as reactor fuel and additional transmutation cannot be accomplished. At that point, the remaining actinides would again become part of the high-level wastes.

The processes of refabrication of the actinides into reactor fuel have not been established. Some persons believe the fabrication can only be done in heavily shielded facilities and that recycling these wastes could be best accomplished in an LMFBR because "there would be a smaller fuel manufacturing penalty, since the whole system is full of highly toxic gamma-emitting plutonium already;..."⁽¹⁷⁾ Without doubt there are many problems

(a) See, for example, References 14 and 15.

yet to be answered concerning any transmutation program. The facilities and expertise associated with a nuclear center could lend itself to finding solutions to these problems. It is conceivable that close cooperation between reprocessing and refabrication may be absolutely mandatory. Timing between separation and refabrication could be critical because of the in-growth of some radionuclides that might complicate refabrication.

G. OVERALL RADIOLOGICAL IMPACT ON MAN

Primary radiological safety advantages of siting all of the fuel reprocessing, waste management and interim storage facilities at a nuclear power center include elimination of transportation over public highways of highly radioactive materials between the several process stages, and the increased distance between the facilities and the site boundary.

The disadvantages include the larger quantities of radionuclides discharged to air and water at one site compared to isolated facilities. There would not seem to be insurmountable problems with the combined releases to the atmosphere since the facilities would be well separated from each other and from the general public. The discharge of some several thousand Ci/yr of tritium and ~10 Ci/yr each of Cs-134, Cs-136 and Cs-137 to one body of water from the two dozen or so reactors may indeed present environmental impact problems. Special radwaste systems and/or operating procedures may be required to permit siting of 30,000 to 40,000 MWe of nuclear power at one location, unless the aquatic environment has an unusual capacity for safely receiving large quantities of radionuclides.

The radiological impact of releases of radioiodine and noble gases to the atmosphere from 25 power reactors and a fuel reprocessing plant is difficult to estimate without detailed calculations of the contribution from each source to the total dose. The population dose could be approximated by assuming all of the releases occurred at some one point, an effective average distance from the boundary (not necessarily the geographical center of the NEC). On this basis, it was estimated that the total population dose from all sources combined could be restricted to no more than 100 to 200 person-rem/yr.

The maximum individual dose would probably be to an infant consuming milk from a cow pastured at the closest possible point to a facility (probably the reactor nearest the site boundary). This dose would be dependent upon the releases from the nearest facility, with additional contributions from the combined releases of the other facilities probably increasing the total dose by a factor of 2 to 5.

As the distance to the nearest facility increased, the total dose would decrease and the relative contribution of that one facility to the dose would also decrease. It appears that the maximum individual doses calculated for the Proposed Appendix I Environmental Statement⁽¹⁾ could be used with appropriate corrections for multiple sources and increased site boundary distances to estimate the doses at the nuclear energy center. The net result is that the infant thyroid doses would probably be about twice those listed in Reference 1 for each specific rad-waste case. This implies that tall stacks might still be required, at least at the facilities closest to the site boundary, to meet the proposed guidelines.

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APPENDIX VII-B

ALTERNATIVES TO ELECTRICAL TRANSMISSION

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ALTERNATIVES TO ELECTRICAL TRANSMISSION

HYDROGEN

Rising prices for input energy have stimulated a number of studies of alternative ways to deliver energy to the point of use. Rapidly increasing capital charges and the resistance of environmentalists to large new electrical transmission corridors adds to the incentive to find better alternates to electrical transmission.

Another factor which appears to have been under-evaluated in the national context is the continued decrease in the national load factor, both daily and annually. This trend forces a larger investment in stand-by facilities to meet peak loads and reduces the integrated unit energy base upon which transmission costs can be liquidated. Increasing land value in large metropolitan areas reinforces this trend.

In the Pacific Northwest (PNW), these effects will be slower to surface because of the large, low cost peaking capacity in place in the Columbia River hydroelectric system and the relatively higher saturation in the use of electricity in the northwest economy. However, in the long run, some consideration of the integrated economics of transmission may direct attention to means for higher levels of concentration of energy in the delivery system. Such concentrations can be attained by the use of energy storage in the form of chemical energy.

Recently published reports from the Cornell Energy Study sponsored by the National Science Foundation show that the delivery cost of energy per megawatt-mile is from two to as high as four times as high for electrical transmission as it is for gas based on 1971 prices. Deregulation of gas can be expected to shift the numerical values of this differential, but on balance considering the whole picture of land planning, costs, and delivery efficiency it can be expected that consideration of alternative means of transmitting energy from large centers needs serious attention.

New processes have recently been announced for the direct conversion of water to hydrogen and oxygen using catalysis and temperatures under 2000°F. This compares with previous processes announced by Euratom which required very high temperatures in excess of 2500°C. Some utilities have considered the new processes promising enough to support studies of gas distribution systems and fuel cell conversion systems based on hydrogen as the principal energy delivery factor. Local energy distribution would be by means of neighborhood substation systems with electrical distribution to the final point of use. Extensive use of reject heat from the substation could be made including the circulation of hot water for domestic heating where practicable.

Hydrogen is a very attractive fuel from the environmental standpoint, but because of its low specific weight, it is expensive to store as a gas and requires expensive compressors. Therefore, attention to the use of liquified transport or the use of metallic hydrides in fixed energy center systems can be expected to receive serious attention.

In summary, the following situation analysis appears to show promise for the use of chemical transmission of energy, probably in the form of hydrogen.

- Hydrogen can be used in the majority of present day energy systems permitting a phase-in to more suitable, optimized systems in the future.
- The combination of the catalytic production and fuel cell conversion processes indicates practicable efficiencies above those projected for the Rankine cycle.
- Gas as an energy transfer and storage medium is cheaper to move and shows large potential savings in reduction of costs for peaking to meet load factor considerations.
- The combination of nuclear centers with gas production and transmission is a viable technical possibility, and has great promise in the reduction of point source air pollution problems, the minimization of water regulation problems involved in hydro-peaking and the most practicable use of land and land related resources.

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APPENDIX VII-C

EXCERPTS FROM STATE OF WASHINGTON DEPARTMENT OF ECOLOGY
WATER QUALITY STANDARDS, JUNE, 1973

APPENDIX VII-C

EXCERPTS FROM STATE OF WASHINGTON DEPARTMENT OF ECOLOGY WATER QUALITY STANDARDS, JUNE, 1973

WAC 173-201-010 PURPOSE. The purpose of this chapter is to establish water quality standards for waters of the State of Washington pursuant to the provisions of chapter 90.48 RCW and the policies and purposes thereof.

WAC 173-201-020 WATER USE AND QUALITY CRITERIA. The water use and quality criteria set forth in sections 030 through 050 are established in conformance with present and potential water uses of said waters and in consideration of the natural water quality potential and limitations of the same. Nonetheless, the dynamic nature of the process is also recognized. Hence, frequent review of these uses and criteria are anticipated and revisions will be undertaken as additional information is developed.

WAC 173-201-030 -----GENERAL WATER USE AND CRITERIA CLASSES. The following criteria shall be applicable to the various classes of waters in the State of Washington:

-
- (2) Class A (Excellent).
- (a) General characteristic. Water quality of this class shall meet or exceed the requirements for all or substantially all uses.
- (b) Characteristic uses. Characteristic uses shall include, but are not limited to, the following:
- (i) Water supply (domestic, industrial, agricultural).
 - (ii) Wildlife habitat, stock watering.
 - (iii) General recreation and aesthetic enjoyment (picnicking, hiking, fishing, swimming, skiing and boating).
 - (iv) Commerce and navigation.
 - (v) Fish and shellfish reproduction, rearing and harvest.
- (c) Water quality criteria.
- (i) Total coliform organisms shall not exceed median value of 240 (fresh water) with less than 20% of samples exceeding 1,000 when associated with any fecal sources or 70 (marine water) with less than 10% of samples exceeding 230 when associated with any fecal sources.
 - (ii) Dissolved oxygen shall exceed 8.0 mg/liter (fresh water) or 6.0 mg/liter (marine water).
 - (iii) Total dissolved gas - the concentration of total dissolved gas shall not exceed 110% of saturation at any point of sample collection.
 - (iv) Temperature - water temperatures shall not exceed 65° F. (fresh water) or 61° F. (marine water) due in part to measurable (0.5° F.) increases resulting from human activities; nor shall such temperature increases, at any time, exceed $t = 90/(T-19)$ (fresh water) or $t = 40/(T-35)$ (marine water); for purposes hereof "t" represents the permissive increase and "T" represents the water temperature due to all causes combined.
 - (v) pH shall be within the range of 6.5 to 8.5 (fresh water) or 7.0 to 8.5 (marine water) with an induced variation of less than 0.25 units.

- (vi) Turbidity shall not exceed 5 JTU over natural conditions.
- (vii) Toxic, radioactive, or deleterious material concentrations shall be below those of public health significance, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.
- (viii) Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.
-

WAC 173-201-040 -----GENERAL CONSIDERATIONS. The following general guidelines shall be applicable to the water quality criteria and classifications set forth in WAC 173-201-020 through WAC 173-201-080 hereof:

(3) Except for the aesthetic values and acute biological shock conditions the water quality criteria herein established shall not apply:

(a) within immediate mixing zones of a very limited size adjacent to or surrounding a wastewater discharge; (b) in the case of total dissolved gas, when the stream flow exceeds the 10-year, 7-day average flood; or (c) in a manner contrary to the applicable conditions of a valid discharge permit.

(4) The total area and/or volume of a receiving water assigned to a mixing zone shall be as described in a valid discharge permit and limited to that which will: (a) not interfere with biological communities or populations of important species to a degree which is damaging to the ecosystem; (b) not diminish other beneficial uses disproportionately.

(5) The criteria established in WAC 173-201-030 through WAC 173-201-050 for any of the various classifications of this regulation may be modified by the director for limited periods when receiving waters fall below their assigned water quality criteria due to natural causes or if in the opinion of the director the protection of the overall public interest and welfare requires such modification.

(6) Except where the director determines that overriding considerations of the public interest will be served, wherever receiving waters of a classified area are of a higher quality than the criteria assigned for said area, the existing water quality shall constitute water quality criteria.

(7) Whenever the natural conditions are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria.

(8) Due consideration will be given to the precision and accuracy of the sampling and analytical methods used in the application of the criteria.

(9) The analytical testing methods for these criteria shall be in accordance with the most recent editions of Standard Methods for the Examination of Water and Waste Water, and Methods for Chemical Analysis of Water and Wastes (EPA 16020), and other or superseding methods published or approved by the department following consultation with adjacent states and concurrence of the Environmental Protection Agency.

(10) Deleterious concentrations of radioactive materials for all classes shall be as determined by the lowest practicable concentration attainable and in no case exceed: (a) 1/3 of the values listed in WAC 402-24-220 (Column 2, Table II, Appendix A, Rules and Regulations for

Radiation Protection), or (b) the 1962 U.S. Public Health Service Drinking Water Standards as revised, or (c) the Radiation Protection Guides for maximum exposure of critical human organs recommended by the former Federal Radiation Council in the case of foodstuffs harvested from waters for human consumption.

(11) Deleterious concentrations of toxic, or other nonradioactive materials shall be as determined by the department in consideration of the Report of the National Technical Advisory Committee on Water Quality Criteria, 1968, and as revised, and/or other relevant information.

WAC 173-201-050 -----CHARACTERISTIC USES TO BE PROTECTED. The following is a noninclusive list of uses to be protected by the various classifications in fresh and marine waters:

USES	WATERCOURSE CLASSIFICATION
	<u>A</u>
FISHERIES	
Salmonid	
Migration	F M
Rearing	F M
Spawning	F
Warm Water Game Fish	
Rearing	F
Spawning	F
Other Food Fish	F M
Commercial Fishing	F M
Shellfish	M
WILDLIFE	F M
RECREATION	
Water Contact	F M
Boating and Fishing	F M
Environmental Aesthetics	F M
WATER SUPPLY	
Domestic	F
Industrial	F M
Agricultural	F
NAVIGATION	F M
LOG STORAGE & RAFTING	F M
HYDRO-POWER	F

WAC 173-201-080 -----SPECIFIC CLASSIFICATIONS. Various specific waters of the State of Washington are classified as follows:

 (24) Columbia river from Washington-Oregon border (river mile 309) to Grand Coulee Dam (river mile 595). Class A
Special condition from Washington-Oregon border (river mile 309) to Priest Rapids Dam (river mile 397).

Temperature - water temperatures shall not exceed 68° F. due in part to measurable (0.5° F.) increases resulting from human activities; nor shall such temperature increases, at any time, exceed $t = 110/(T-15)$; for purposes hereof, "t" represents the permissive increase and "T" represents the water temperature due to all causes combined.

WAC 173-201-090 ACHIEVEMENT CONSIDERATIONS. To fully achieve and maintain the foregoing water quality in the State of Washington, it is the intent of the department of ecology to apply the various implementation and enforcement authorities at its disposal including the development and implementation of the continuing planning process required under section 303(e) of the Federal Water Pollution Control Act Amendments of 1972, and applicable federal regulations thereunder. It is also the intent that cognizance will be taken of the need for information as contemplated under section 304 of the federal act with emphasis on silviculture and agriculture, and for participation in cooperative programs with other state agencies and private groups with respect to the management of related problems. The Washington department of ecology's planned program for water pollution control will be defined and revised annually in accordance with section 106 of said federal act and regulations. Further, it shall be required that all activities which discharge wastes into waters within the state or otherwise adversely affect the quality of said waters be in compliance with the wastes treatment and discharge provisions of state or federal law.

WAC 173-201-100 -----IMPLEMENTATION. (1) Discharges from Municipal, Commercial and Industrial Operations. The primary means to be utilized for controlling municipal, commercial and industrial waste discharges shall be through the issuance of waste disposal permits as provided for in RCW 90.48.160 and following.

(2) Miscellaneous Waste Discharge or Water Quality Effect Sources. The director shall, through the issuance of regulatory permits, directives, and orders as are appropriate, control miscellaneous waste discharges and water quality effect sources not covered by subsection (1) hereof. It is noted that from time to time certain short-term activities which are deemed necessary to accommodate essential activities or to otherwise protect the public interest may be specially authorized by the director under such conditions as the director may prescribe even though such activities may result in a reduction of water quality conditions below those criteria and classifications established by this regulation.

WAC 173-201-110 -----SURVEILLANCE. A continuing surveillance program to ascertain whether the regulations, waste disposal permits, order, and directives promulgated and/or issued by the department are being complied with, will be conducted by the department staff as follows:

- (1) Inspecting of treatment and control facilities.
- (2) Monitoring and reporting of waste discharge characteristics.
- (3) Monitoring of receiving water quality.

WAC 173-201-120 -----ENFORCEMENT. To insure that the provisions of chapter 90.48 RCW, the standards for water quality promulgated herein, the terms of waste disposal permits, and other orders and directives of the department are fully complied with, the following enforcement tools will be relied upon by the department, in cooperation with the attorney general as it deems appropriate:

(1) Issuance of regulatory notifications, orders, and directives as provided for in RCW 90.48.120. Under this section, whenever it is the department's opinion that a person is polluting or is about to pollute the state's waters, the department shall notify said person of the department's determination. Within thirty days said person shall notify the department of the action he has taken with regard to said notification, whereupon the department shall issue such order or directive as it deems appropriate. Thereafter any person feeling aggrieved may request a department hearing relating to said order or directive; the same being conducted in accordance with chapter 43.21B RCW, and chapter 371-08 WAC. Any party to the hearing may request review of the department's order issued after said hearing in a superior court of this state, if the hearing is informal, or to the court of appeals if the hearing is formal.

(2) Initiation of actions requesting injunctive or other appropriate relief in the various courts of the state as provided for in RCW 90.48.037.

(3) Levying of civil penalties as provided for in RCW 90.48.144. Under this section, the director of the department may levy a civil penalty up to five thousand dollars per day against a person who violates the terms of a waste discharge permit, or who discharges without such a permit when the same is required, or violates the provisions of RCW 90.48.080. If the amount of the penalty, which is subject to mitigation or remission by the department, is not paid within fifteen days after receipt of said notice, the attorney general, upon request of the director, shall bring an action in superior court to recover the same.

(4) Initiation of a criminal proceeding by the appropriate county prosecutor, as provided for in RCW 90.48.140.

(5) Issuance of regulatory orders or directives as provided for in RCW 90.48.240.

WAC 173-201-130 DEFINITIONS. For the purpose of this chapter, the following definitions are applicable:

(1) "Natural condition" means the resulting water quality in the absence of any measurable pollutional effect due to human activities excepting only the effects of depth, volume, surface area or shoreline configuration resulting from the legal physical alteration of a water body.

(2) "Acute biological shock condition" means that dose or circumstance which has been demonstrated by field or laboratory observations to directly result in mortalities of food, game, or commercial fish species.

(3) "Permit" means a document issued for a wastes source specifying the wastes treatment and control requirements and wastes discharge conditions.

(4) "Total coliform organisms" mean total coliform organisms per 100 milliliters.

- (5) "Temperature" means temperature expressed in degrees Fahrenheit.
- (6) "pH" means the negative logarithm of the hydrogen-ion concentration.
- (7) "Turbidity" means the optical property of a sample demonstrating the scattering and absorption of light caused by suspended material as expressed in Jackson Turbidity Units (JTU).
- (8) "Mean detention time" means the time obtained by dividing a reservoir's mean annual minimum total storage by the 30-day ten-year low-flow from the reservoir.

WAC 173-201-140 MISCELLANEOUS. (1) The water quality criteria adopted in this chapter shall be the sole criteria for the various waters in the State of Washington.

(2) The criteria, classifications and achievement considerations established by this chapter shall be reviewed from time to time by the department to insure that the quality of the waters of the state may be enhanced wherever possible through appropriate modifications of this chapter.

(3) These rules contemplate and it is the specific intent of the department of ecology to evaluate the watercourse classifications under WAC 173-201-060 through 080 hereof in the near future, with special emphasis placed on those waters constituting reaches of streams in nonurban areas, and, if deemed appropriate, initiate rule-making proceedings by September 1, 1973, as to any needed changes in classification. Additionally, the department shall, in light of concerns expressed both for high water quality and for the carrying on of activities on land which have an effect on certain water reaches, continue with expedition to examine all waters of the state, the needs for the protection of the same and related concerns, and if after such evaluation, it appears appropriate, initiate rule-making procedures to modify this chapter.

(4) Chapters 372-12 and 372-64 WAC are repealed.

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