**GULF COAST GEOPRESSURED - GEOTHERMAL
PROGRAM SUMMARY REPORT COMPILATION**

DOE/ID/13366-77-Vol. 2B

VOLUME II - B

**RESOURCE DESCRIPTION, PROGRAM HISTORY, WELLS
TESTED, UNIVERSITY AND COMPANY BASED RESEARCH,
SITE RESTORATION**

**WORK PERFORMED UNDER U.S. DEPARTMENT OF ENERGY
CONTRACT NO. DE-FG07-95ID13366**

**Chacko J. John, Gina Maciasz, Brian J. Harder
Basin Research Institute
Louisiana State University
208 - Howe Russell Geoscience Complex
Baton Rouge, LA 70803-4101
Phone: 504-388-8328**

JUNE, 1998

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

**GULF COAST GEOPRESSURED - GEOTHERMAL
PROGRAM SUMMARY REPORT COMPILATION**

VOLUME II - B

**RESOURCE DESCRIPTION, PROGRAM HISTORY, WELLS
TESTED, UNIVERSITY AND COMPANY BASED RESEARCH,
SITE RESTORATION**

**WORK PERFORMED UNDER U.S. DEPARTMENT OF ENERGY
CONTRACT NO. DE-FG07-95ID13366**

**Chacko J. John, Gina Maciasz, Brian J. Harder
Basin Research Institute
Louisiana State University
208 - Howe Russell Geoscience Complex
Baton Rouge, LA 70803-4101
Phone: 504-388-8328**

JUNE, 1998

DISCLAIMER

This report was prepared as an account of work sponsored by the U.S. Government. Neither the U.S. Government nor the U.S. Department of Energy, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. References herein to any specific commercial product, process, or service by trade name, mark, manufacture, or otherwise, do not necessarily constitute or imply its endorsement, recommendations, or favoring by the U.S. Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the U.S. Government or any agency thereof.

TABLE OF CONTENTS

THE GEOPRESSURED - GEOTHERMAL RESOURCE RESOURCE DESCRIPTION	1
RESOURCE ORIGIN AND SEDIMENT TYPE	3
GULF COAST RESOURCE EXTENT	7
RESOURCE ESTIMATES	7
PROJECT HISTORY	11
AUTHORIZING LEGISLATION	13
Abstract (P.L. 93 - 410)	14
PROGRAM OBJECTIVES	15
PERCEIVED CONSTRAINTS	15
PROGRAM ACTIVITIES AND STRUCTURE	17
WELL TESTING	17
PROGRAM MANAGEMENT	21
PROGRAM COST SUMMARY	21
FUNDING HISTORY	22
RESOURCE CHARACTERIZATION	25
WELLS OF OPPORTUNITY	30
EDNA DELCAMBRE #1	32
EDNA DELCAMBRE #1 WELL RECOMPLETION	39
FAIRFAX FOSTER SUTTER #2	43
BEULAH SIMON #2	53
P. R. GIROUARD #1	60

PRAIRIE CANAL #1	72
CROWN ZELLERBACH #2	80
ALICE C. PLANTATION #2	93
TENNECO FEE "N" No. 1	95
PAULINE KRAFT NO. 1	102
SALDANA WELL NO. 2	114
G.M. KOELEMAY WELL NO. 1	127
WILLIS HULIN NO. 1 WELL	139
INVESTIGATIONS OF OTHER WELLS OF OPPORTUNITY (NOT TESTED)	162
CLOVIS A. KENNEDY NO. 1 WELL	162
WATKINS - MILLER NO. 1 WELL	162
LUCIEN J. RICHARD et al NO. 1 WELL	163
C & K - FRANK A. GODCHAUX, III, WELL NO. 1	164
DESIGN WELL PROGRAM	166
LAFORCHE CROSSING	168
MG - T / DOE AMOCO FEE No. 1 (SWEET LAKE)	170
ENVIRONMENTAL MONITORING AT SWEET LAKE	202
AIR QUALITY	204
WATER QUALITY	205
MICROSEISMIC MONITORING	205
SUBSIDENCE	206

DOW-DOE L.R. SWEEZY NO. 1 WELL	207
RESERVOIR TESTING	249
ENVIRONMENTAL MONITORING AT PARCPERDUE	266
AIR MONITORING	268
WATER RUN-OFF	269
GROUNDWATER	269
MICROSEISMIC	270
SUBSIDENCE	272
ENVIRONMENTAL CONSIDERATION AT SITE	272
TECHNADRIL - FENIX & SCISSON / DOE GLADYS MCCALL NO. 1 WELL	273
Surface Test Equipment	305
TEST RESULTS - GLADYS McCALL NO. 1 WELL	308
Sand Zone #9 Gas/Brine Testing	309
Sand #9 Reservoir Limit Testing	311
Sand #8 Initial Reservoir Limit Testing	313
Sand #8 Long Term Flow Testing	315
Sand #8 Gas/Brine Ratio	316
Gas Exsolution in the Reservoir (from Eaton Operating Company, Inc., Final Report, 1990)	329
Sand #8 Long Term Reservoir Modeling Studies	331
Calcium Carbonate Scaling	335
Rates of Calcium Carbonate Scaling in the Gladys McCall No. 1 Tubing String	336
HYDROCARBONS IN PRODUCTION GAS AND BRINE	344
ENVIRONMENTAL MONITORING AT THE GLADYS MCCALL SITE	346
Subsidence Monitoring	347
Microseismic Monitoring	350
Water Quality Monitoring	354

PLEASANT BAYOU NO. 2 WELL	355
Review of past production data	384
Production Data	389
1986 Well cleanup and bottom hole pressure measurement	389
Mud Displacement	392
Natural flow cleanup	392
Bottom hole pressure measurement	394
Production starting in 1988	396
Brine Sampling and analyses	407
Brine Analysis results	409
Hydrocarbon sampling and analysis	409
Scaling and Corrosion	419
Reservoir Analysis	420
PLEASANT BAYOU HYBRID POWER SYSTEM (HPS)	426
ENVIRONMENTAL MONITORING AT PLEASANT BAYOU	433
PLUG, ABANDONMENT AND WELL SITE RESTORATION OF THREE GEOPRESSURED - GEOTHERMAL TEST SITES	439
Pleasant Bayou test site	439
Gladys McCall test site	443
Willis Hulin test site	451
APPENDIX - 1	456
APPENDIX - 2	471
APPENDIX - 3	481
APPENDIX - 4	485
APPENDIX - 5	491

LIST OF FIGURES

Figure 1. - - Geopressed basins of the United States. (from Wallace, 1982)	2
Figure 2. - - Thickness of Cenozoic sedimentary rocks in the northern Gulf of Mexico basin (Hardin, 1962).	4
Figure 3. - - Major sediment depocenters, during the Upper Cretaceous, Tertiary and Quaternary, along the northern Gulf of Mexico.	5
Figure 4. - - Generalized sedimentary model of the northern Gulf of Mexico basin, based on percentage sandstone and showing, diagrammatically, the relation of gross lithology to fluid- pressure gradient and growth faulting (modified from Norwood and Holland, 1974). . . .	6
Figure 5. - - Geopressed zone along the Texas and Louisiana Gulf Coast (Bebout, 1982)	8
Figure 6. - - Methane and thermal resource base in geopressed aquifers (thousands of quads) (Division of Geothermal Energy, 1980).	9
Figure 7. - - Major components of implementation strategy (Division of Geothermal Energy, 1980).	20
Figure 8. - - Management Organization of The Division of Geothermal Energy (from Division of Geothermal Energy, 1980).	23
Figure 9. - - Geopressed - Geothermal program management structure.	24
Figure 10. - - Funding history of the geopressed - geothermal research program.	26
Figure 11. - - Location map of Geopressed - Geothermal corridors of South Louisiana. (modified from Bebout, 1982).	27
Figure 12. - - Location map of Geopressed - Geothermal corridors, Texas Gulf Coast (modified from Seni and Walter, 1993).	28
Figure 13. - - Operational top of geopressure along the Texas and Louisiana Gulf Coast, as determined by the occurrence of "low-density" shale.	29
Figure 14. - - Location of wells tested for the DOE geopressed - geothermal research program in the Gulf Coast.	31
Figure 15. - - Edna Delcambre No. 1 Well, Tigre Lagoon Field, Vermilion Parish, Louisiana (from Terratek, 1980).	33

Figure 16. - - Structure map and log of the OHRW-DOE No. 1 Edna Delcambre test well (WOO).	35
Figure 17. - - Geologic Cross Section B-B' with 200° and 250°F Isothermal Surfaces (from Jones, 1978, in Terra Tek Rept., 1980).	36
Figure 18. - - Geological Structure Map of the Planulina No. 6 Sand (from Wolgemuth et.al., 1980, Clark, 1979).	38
Figure 19. - - Schematic of Downhole Hardware for the Edna Delcambre #1 Well (from Wolgemuth et.al., 1980 in Terra Tek Rept. 1980).	41
Figure 20. - - Structure map of the MA-6 sand and log of the Gruy Federal-DOE No. 2 Fairfax Foster Sutter test well (modified from Gruy 1979, from Miller, 1991, in Groat, 1991).	45
Figure 21. - - Fairfax Foster Sutter No. 2 Schematic for Disposal Well (From: Gruy Federal, Inc., Report, 1979).	51
Figure 22. - - Fairfax Foster Sutter No. 2 Schematic of Downhole Condition (From Gruy Federal Inc., Report, 1979).	52
Figure 23. - - Structure map and log of the Beulah Simon #2 test well (From Miller 1991, in Groat, 1991 and modified from Gruy, 1980).	55
Figure 24. - - Schematic of downhole conditions, Beulah Simon No. 2 (from Gruy Federal, Inc., 1980).	59
Figure 25. - - (a) Beulah Simon No. 1 salt water disposal well schematic. (b) Electric log (c) Well status after plugging and abandonment. (From Gruy Federal, Inc., 1980).	61
Figure 26. - - Structure map drawn at the top of the <i>Marg. Tex</i> sand showing the location of the P.R. Girouard Well #1 (From Eaton, 1981).	63
Figure 27. - - A southwest - northeast cross section illustrating the <i>Marg. Tex.</i> #1 sand in the P.R. Girouard #1 well. The cross section line is shown in Figure 26 (From Eaton Operating Co. Report, 1981).	64
Figure 28. - - An east-west cross section through the Cade field area illustrating that the <i>Marg. Tex</i> #1 sand is thickest in the Girouard test well. The cross section line is shown in Figure 26 (From Eaton Operating Co. Report, 1981).	66

Figure 29. - - Electric log of the P.R. Girouard #1 test well showing the <i>Marg. Tex.</i> #1 sand which was tested (From Eaton Operating Co. Report, 1981).	67
Figure 30. - - Schematic drawings of the test well showing conditions before and during testing (From Eaton Operating Co. Report, 1981).	69
Figure 31. - - Schematic of the P.R. Girouard salt water disposal well #1 (From Eaton Operating Co., Report, 1981).	71
Figure 32. - - Structure map on top of the Hackberry sand and log of the Prairie Canal #1 test well (modified from Eaton Operating Co., Final Report, 1981)	74
Figure 33. - - Cross section showing the Hackberry sand tested in the Prairie Canal #1 well. Cross section line shown on Figure 32. (From Eaton Operating Co., Inc., Final Report, 1981).	75
Figure 34. - - Schematic drawings of the Prairie Canal #1 test well showing: (a) condition at time of Eaton takeover of well (b) condition during well testing, and (c) plugged and abandoned condition.	78
Figure 35. - - Schematic illustration of the disposal well completion and wellhead (From Eaton Operating Co., Inc., Final Report, 1991).	79
Figure 36. - - Seismic Structure map of the Tuscaloosa sand in the area of the Crown Zellerbach testwell (From Eaton Operating Co., Final Report, 1981).	82
Figure 37. - - A generalized north south cross section in the area of the Crown Zellerbach #2 well based on seismic data. Cross section line is shown in Figure 36 (From Eaton Operating Company Final Report, 1981).	83
Figure 38. - - A generalized east-west cross section in the area of the Crown Zellerbach #2 well based on seismic data. Refer to Figure 36 for location of cross section line (From Eaton Operating Co., Inc., Final Report, 1981).	84
Figure 39. - - An electric log (dual induction/borehole compensated sonic log) of the Crown Zellerbach #2 well showing the two sands tested (Sands A and B) (From Eaton Operating Co., Final Report, 1981).	85
Figure 40. - - Schematic illustration of the tubular configuration of the well condition (a) at time of Eaton takeover; and (b) during testing. (From Eaton Operating Co., Final Report, 1981).	90

Figure 41. - - Schematic drawing of the disposal well showing (a) condition when Eaton took over operations from Martin; and (b) disposal well tubular configuration as completed for brine disposal and the well head design. (From Eaton Operating Co., Inc., Final Report, 1981).	92
Figure 42. - - Electric log (ISF-Sonic) of the Alice C. Plantation #2 well showing the <i>Marginulina Ascensionensis</i> sands targeted for geopressured - geothermal testing from 16,810 ft. - 16,990 ft., 17,090 ft. - 17,230 ft., and from 17,700 ft. to 17,900 ft	94
Figure 43. - - Structure map on top of the lower <i>Marginulina Ascensionensis</i> sand series (from Gruy Federal Inc., Final Report, Dec. 1978).	96
Figure 44. - - Schematic illustration of the Alice C. Plantation #2 well configuration at the time it was plugged and abandoned by Sun Oil Company and the proposed completion for geopressured - geothermal testing by Gruy Federal Inc., (from Gruy Federal Inc., Final Report, 1978).	97
Figure 45. - - Electric log of the Tenneco Fee "N" #1 well (From Dobson et.al., in, Gruy Federal Inc., Final Report, 1980).	99
Figure 46. - - Structure map on top of the <i>Marginulina Textularia Warreni</i> age W-2 Sand (Miocene) in the area of the Tenneco Fee "N" No. 1 well. (From Gruy Federal, Inc., Final Report, Sept. 1980)	101
Figure 47. - - Condition of Tenneco Fee "N" No. 1 well at (a) time of re-entry and (b) after plugging and abandonment. (From Dobson et.al., in, Gruy Federal, Inc., Final Report, 1980).	103
Figure 48. - - Structure map drawn on top the geopressure - geothermal sand (Anderson Sand) tested in the Pauline Kraft #1 Well (From Eaton Operating Co., Inc., Final Report, 1981).	105
Figure 49.- - Generalized cross section across the Pauline Kraft #1 Well showing the sand tested See Figure 48 for cross section line (From Eaton Operating Company, Final Report, 1981).	106
Figure 50. - - Electric log of the Pauline Kraft #1 Well showing the sand tested for geopressured - geothermal data (From Eaton Operating Co., Inc., Final Report., 1981).	107
Figure 51. - - Schematic diagram of the test well at (a) the time of Eaton takeover, and (b) during testing (From Eaton Operating Co., Final Report, 1981).	109

Figure 52. - - Electric log of the salt water disposal wells showing the two sands perforated for brine disposal (From Eaton Operating Co., Inc., Final Report, 1981).	112
Figure 53. - - Schematic diagram of the actual well completion and surface wellhead of the salt water disposal well (From Eaton Operating Co., Final Report, 1981).	113
Figure 54. - - Structure map drawn on top of the Wilcox 1 st Hinnant Sand in the Martinez Field Area (From Eaton Operating Co., Final Report, 1981).	116
Figure 55. - - A north-south geologic cross section through the Saldana Well No. 2. The cross section line is shown in Figure 54 (From Eaton Operating Co., Inc., Final Report, 1981).	117
Figure 56. - - An east-west geologic cross section in the Martinez Field area incorporating the Saldana #2 geopressured - geothermal test well. The cross section line is shown in Figure 55 (From Eaton Operating Co., Inc., Final Report, 1981).	118
Figure 57. - - Electric log of the Saldana #2 geopressured - geothermal test well showing the testing sand perforated from 9,745 ft. - 9,820 ft. (From Eaton Operating Co., Inc., Final Report, 1981).	119
Figure 58. - - Schematic diagram of the test well showing (a) the downhole configuration at the time of Eaton takeover of the well, and (b) during geopressure - geothermal testing. (From Eaton Operating Co., Inc., Final Report, 1981).	122
Figure 59. - - Electric log of the salt water disposal well showing the four potential sands deemed suitable for brine disposal (From Eaton Operating Co., Inc., Final Report, 1981).	123
Figure 60. - - Schematic drawing of the brine disposal well showing its tubular configuration at (a) the time when Eaton took over operations from Riddle, and (b) when completed for brine disposal from the test well (From Eaton Operating Co., Inc., Final Report, 1981).	125
Figure 61. - - Graph showing the injection rate vs. surface injection pressure for the brine disposal well (From Eaton Operating Co., Inc., Final Report, 1981).	126
Figure 62. - - Electric log from the G.M. Koelemay #1 Well showing the tested sand (From Eaton Operating Co., Inc., Final Report, 1981).	129
Figure 63. - - Structure map drawn on top of the "Leger" Sand tested to obtain geopressured - geothermal data in the G.M. Koelemay Well #1 (From Eaton Operating Co., Final Report, 1981).	130

Figure 64. - - Structural cross section drawn through the G.M. Koelemay No. 1 Well showing the geopressure - geothermal "Leger" Sand. The cross section line is shown in Figure 63 (From Eaton Operating Co., Final Report, 1981).	131
Figure 65. - - Schematic drawing of the test well showing (a) conditions when Eaton took over operations from Lear, and (b) well configurations as completed for testing (From Eaton Operating Co., Inc., Final Report, 1981).	135
Figure 66. - - Electric log of the brine disposal well showing the five potential disposal sands (A,B,C,D, & E). Sand E was completed for salt water disposal (From Eaton Operating Co., Final Report, 1981).	136
Figure 67. - - (a) Graph of injection rate versus surface injection pressure before acid stimulation of the disposal zone (b) Schematic diagram of the disposal well completion and wellhead. Two sets of perforations are shown as the lower zone was plugged with solids during early testing requiring perforation of the upper zone (From Eaton Operating Co., Inc., Final Report, 1981).	138
Figure 68. - - Distribution and depths to Tertiary geopressured - geothermal sandstones in South Louisiana (modified from McCulloh et.al. 1984, from John, 1991, in Groat, 1991, Louisiana State University Technical Support Report 1988 - 1990).	142
Figure 69. - - Depositional setting and sandstone thickness of the <i>Planulina</i> zone of the Hulin prospect area (modified from Hamlin and Tyler, 1988; Bureau of Economic Geology, Annual Report).	143
Figure 70. - - Representative dip cross section of the depositional setting shown in figure 69. Line of cross section is also shown in figure 69 (from Hamlin abd Tyler, 1988, Bureau of Economic Geology, Annual Report).	144
Figure 71. - - Electric log of the Superior Hulin No. 1 geopressured - geothermal aquifer sand showing the perforation depths (From Eaton Operating Company, Final Contract Report, 1986 - 1990).	145
Figure 72. - - Lower <i>Planulina</i> structure map of the Hulin prospect area (adapted from U.S. Department of Energy, 1988, Hulin test plan memorandum dated Sept. 19, 1986, Idaho Falls, Idaho).	146
Figure 73. - - A north - south (dip) cross section of the Hulin prospect area (modified from McCullon and Pino, 1983, in, Louisiana State University, Annual Report 1981 - 1982).	148

Figure 74. - - A strike (east - west) cross section through the Superior Hulin #1 Well (adapted from McCulloh and Pino, 1983, in, Louisiana State University, Annual Report 1981 - 1982). The cross section line (A-A') is shown in figure 73 (inset).	149
Figure 75. - - Seismic structure map of the Hulin prospect contoured at the top of the geopressured - geothermal reservoir tested (map by Don Stevenson; from John 1991, in Groat 1991, Louisiana State University Technical Support Report 1988 - 1990).	150
Figure 76. - - Schematic illustration of the Willis Hulin No. 1 Well completion at the time it was taken over by DOE (Eaton Operating Company, Inc.) From Superior Oil Company in 1984. (From Eaton Operating Company, Inc., Final Contract Report, 1986 - 1990).	152
Figure 77. - - Schematic illustration of the Willis Hulin No. 1 Well as completed by Eaton Operating Company, Inc., for testing (From Eaton Operating Company, Inc., Final Contract Report, 1986 - 1990).	153
Figure 78. - - Schematic illustration of the salt water disposal well as completed by Eaton Operating Company, Inc. (From Eaton Operating Company, Inc., Final Contract Report 1986 - 1990).	159
Figure 79. - - Electric log of the brine disposal well for brine produced from the Superior Hulin #1 test well (From Eaton Operating Company, Inc., Final Contract Report 1986 - 1990).	160
Figure. - - 80. Graph showing the estimated gas content of brine in the C & K - Frank A. Godchaux III, Well No. 1 as compared with the field measurements of gas contents in previously tested wells (From Eaton Operating Company, Inc., 1981)	165
Figure 81. - - Location of the LaFourche Crossing prime prospect area in relation to the Gulf Coast region (From, U.S. DOE, LaFourche Crossing No. 1, October 1978).	169
Figure 82. - - Structure map on top of the <i>Robulus</i> "L" 43 sand in the LaFourche Crossing Prospect area (From Basiouni, 1978).	171
Figure 83. - - Location of the Magma Gulf - Technadril, Department of Energy, Amoco Fee No. 1 test well (From Magma Gulf - Technadril, Annual Report, 1979 - 1981, Volume 1).	173
Figure 84. - - Location of the MG-T / DOE Amoco No. 2 saltwater disposal well (From Magma Gulf - Technadril Annual Report, 1979 - 1981, Volume 1).	174
Figure 85. - - Schematic illustration of the MG-T / DOE Amoco Fee No. 1 Well (Sweet Lake) (From Magma Gulf - Technadril, Annual Report, 1982 - 1985, Volume 3).	176

Figure 86. - - Schematic illustration of the tubular configuration of the saltwater disposal well (From Magma Gulf - Technadril, Annual Report, 1982 - 1985, Volume 3).	177
Figure 87. - - Seismic structure map of the Sweet Lake Prospect contoured on top of the Miogyp sands (From Magma Gulf -Technadril, Annual Report, 1979 - 1981, Volume 1).	178
Figure 88. - - Dual induction log of the <i>Myogypsinoides</i> sequence MG - T / DOE Amoco Fee (Sweet Lake) #1 Well. Black intervals are cased intervals. Sands 3 and 5 were tested in this well (From Magma Gulf - Technadril Annual Report, 1981 - 1982, Volume 2). . .	180
Figure 89. - - Geologic cross section showing the Miogyp sands in the MG-T DOE Amoco Fee N. 1 (Sweet Lake) test well and its Correlation with other wells in the vicinity (From Magma Gulf -Technadril Annual Report, 1982 - 1985, Volume 3).	181
Figure 90. - - Isothermal map of the Miogyp sand (From Magma Gulf - Technadril Annual Report, June 1981).	183
Figure 91. - - Area of graben contoured and planimetered and the saltwater resource estimate for the Miogyp sands under the area contoured (From Magma Gulf - Technadril Annual Report, June 1981).	187
Figure 92. - - Saltwater disposal well electric log showing zones perforated (From Magma Gulf - Technadril Annual Report, 1979 - 1981, Volume 1).	201
Figure 93. - - Schematic illustration of the tubular configuration of the MG - T / DOE Amoco Fee No. 1 test well (Sweet Lake) at the time of plug and abandonment (From Magma Gulf - Technadril Annual Report, 1982 - 1985, Volume 3).	203
Figure 94. - - A Louisiana State map showing the general location of the Parcperdue Field. The inset map shows the test well site and the location of the Parcperdue Field relative to nearby city areas (From Dow Chemical Company, 1980, Volume 1, Drilling and Completion).	208
Figure 95. - - Location and permit plat of The Dow Chemical Company - DOE, L.R. Sweezy No. 1, geopressured - geothermal test well (From, The Dow Chemical Company, 1980, Volume 1, Drilling and Completion).	210
Figure 96. - - Location and permit plat of the The Dow Chemical Company - DOE, L.R. Sweezy No. 2, brine disposal well (From, The Dow Chemical Company, 1981, Volume 1, Drilling and Completion).	211

Figure 97. - - The organization of the drilling and testing program for the DOW-DOE L.R. Sweezy No. 1 geopressured-geothermal test well (From, The Dow Chemical Company, 1980, Volume 1, Drilling and Completion).	213
Figure 98. - - Organization chart for the DOE Parcerdue Project (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).	214
Figure 99. - - Chart showing the commonly recognized paleontological markers in South Louisiana (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).	215
Figure 100. - - Structure map of the Parcerdue prospect contoured on top of the <i>Cib jeff</i> sand (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).	217
Figure 101. - - Net sand isopach map of the <i>Cib jeff</i> sand (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).	218
Figure 102. - - A revised seismic structure map of the Parcerdue prospect after completion and interpretation of the 3-D Seismic Survey over the area. The well numbers correspond to numbers in Table 26 (From, Kinsland, 1985, Final Report, Jan. 1981 - July 1985).	219
Figure 103. - - Dual induction - SFL - sonic log of the Parcerdue test well showing porosity zones (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).	222
Figure 104. - - Vertical profile of the cored interval for the Dow-DOE L.R. Sweezy No. 1 test well (From, Sinha et al 1981, TerraTek Final Report).	224
Figure 105. - - (a) Depth distribution and evolutionary sequence of primary and secondary porosity. (b) Shale porosity versus depth, and flow paths of shale water during compaction and diagenesis (From The Dow Chemical Company, Appendix E - Rock mechanics - TerraTek reports, 1984).	229
Figure 106. - - The different evolutionary stages in the textural development of secondary porosity (From Sinha et al, 1981, TerraTek, Final Report)	230
Figure 107. - - Core test and petrographic analysis intervals (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).	232
Figure 108. - - (a) Schematic description of tests to obtain mechanical and transport properties, (b) Average values of mechanical and transport properties (From, The Dow Chemical Company, Appendix E, - Rock mechanics - TerraTek reports, 1984).	234

Figure 109. - - Schematic illustration showing type of hydrocarbons produced by thermal disintegration and where the Parcperdue sample lie in this scheme: (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).	239
Figure 110. - - Source rock quality of the Parcperdue samples as related to potential hydrocarbon generation (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)	240
Figure 111. - - Schematic illustration of the wellhead and X-Mas tree for the DOW-DOE L.R. Sweezy No. 1 test well (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).	242
Figure 112. - - Casing detail of the DOW-DOE L.R. Sweezy No. 1 well (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)	243
Figure 113. - - Schematic illustration of the wellbore and completion of the DOW-DOE L.R. Sweezy No. 1 test well (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)	244
Figure 114. - - Gravel pack and completion detail of the DOW-DOE L.R. Sweezy No. 1 test well (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)	245
Figure 115. - - Schematic illustration of the well bore and completion detail of the DOW-DOE L.R. Sweezy N. 2, brine disposal well (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)	247
Figure 116. - - Induction sonic electric log of the Parcperdue saltwater disposal well showing the brine disposal zone (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)	248
Figure 117. - - Calculated reservoir boundaries of the Parcperdue geopressed - geothermal reservoir tested (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)	253
Figure 118. - - Cumulative gas and brine production from the DOW-DOE L.R. Sweezy No. 1 test well (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)	254
Figure 119. - - Average production rates and flow periods for the DOW-DOE L.R. Sweezy No. 1 flow tests (From, Garg and Riney, 1984, S-Cubed Topical Report)	255

Figure 120. - - Gas chromatographys of hydrocarbons condensed from the gas streams from three geopressured wells (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)	263
Figure 121. - - Schematic illustration of the DOW-DOE L.R. Sweezy No. 1 well at the time of plug and abandonment (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)	267
Figure 122. - - Parcperdue test site microseismic monitoring array and their geographic locations and elevations of sensors (From, Teledyne Geotech, Mank et al., 1984, Final Report)	271
Figure 123. - - Flowchart showing the testing phase organization for the Gladys McCall No. 1 well (From, Technadril - Fenix and Scisson, v. 2, 1982).	274
Figure 124. - - Organizational chart of the geopressured - geothermal Gladys McCall No. 1 well drilling and testing program (From, Technadril - Fenix and Scisson, March 1981 Report).	275
Figure 125. - - Stratigraphic chart showing the upper Cretaceous, Tertiary and Quaternary formations of the northern Gulf Coast. Formations shown by the lined pattern, occurring in the geopressured zone, have the greatest potential for geopressured - geothermal resource development (From, Bebout, in Wallace, ed., 1982).	276
Figure 126. - - Map showing location of the Gladys McCall design well in the Rockefeller Wildlife Refuge, Cameron Parish, Louisiana (From, Gruy Federal, 1979).	279
Figure 127. - - Index map showing location of the Gladys McCall No. 1 well (From, Gruy Federal Inc., 1978).	280
Figure 128. - - Surveyor's map showing the location of the T- F&S/DOE Gladys McCall test wel (From, Technadril - Fenix and Scisson, 1982, v. 2).	281
Figure 129. - - Distribution and depths to Tertiary geopressured sandstones in south Louisiana (modified from, McCulloh et al, 1982, from, John, 1988).	282
Figure 130. - - Base maps showing seismic lines and apparent seismic fault indications in the Gladys McCall prospect area. These data were used in the structural interpretation shown in figure 128 (From, Gruy Federal, Inc., 1979).	283
Figure 131. - - Structural map contoured on the top of the first of four geopressured aquifers existing between 14,510 ft. and 16,500 ft. and comprising the objective zone in the Gladys McCall test well (From, Gruy Federal, Inc., 1979).	284

Figure 132. - - Structure of the Gladys McCall prospect area, contoured at the 14,560 ft. sand in the T- F&S DOE Gladys McCall No. 1 well by Magma Gulf Company (adopted from Technadril - Fenix and Scisson, 1982, and from John, 1988).	285
Figure 133. - - Dip cross section of the prospect area through the Gladys McCall well showing log correlations, paleontological markers, temperature and mud weights cross section line shown in figure 130. (Modified from Bebout et al, 1983, LSU Annual Report, Nov. 1981 - Oct. 1982; from John, 1988).	287
Figure 134. - - Electric log of the Gladys McCall test well showing potential production zones, thickness and generalized lithology (From John, 1988, Journal of Energy Resources Technology, V. 110, p. 259).	288
Figure 135. - - The formation and mechanism for lateral and vertical extension of connected channel and point bar sandstones (From, John, 1988, Journal of Energy Resources Technology, V. 110, p. 260).	290
Figure 136. - - Temperature gradient survey of the Gladys McCall test well (From Technadril - Fenix and Scisson, Final Report, V. 2, 1985).	296
Figure 137. - - Schematic diagram of the T- F&S/DOE Gladys McCall No. 1 well after completion (From Westhusing and Goldsberry, in Wallace, ed., 1982).	298
Figure 138. - - Schematic diagram of the T- F&S/DOE, Gladys McCall saltwater disposal well, after completion (From Westhusing and Goldsberry, in Wallace, ed., 1982).	299
Figure 139. - - Electric log of the Gladys McCall #1 saltwater disposal well showing the potential brine injection zones, thickness, and generalized lithology of the brine disposal well (From John, 1988, Journal of Energy Resources Technology, V. 110, p. 260	302
Figure 140. - - Schematic illustration of the surface equipment installed to process of produced brine (From Eaton Operating Company, Inc., Final Report, 1990).	306
Figure 141. - - Summary plot of daily brine production for Sand 8 (From Eaton Operating Company, Inc., Final Report, 1990).	317
Figure 142. - - Summary plot of daily gas production from Sand zone 8 (From Eaton Operating Company, Inc., Final Report, 1990).	318
Figure 143. - - Plot of gas / brine ratio for production from Sand zone 8 (From Eaton Operating Company, Inc., Final Report, 1990).	319

Figure 144. - - Plot showing cumulative gas production verses cumulative brine production (From Eaton Operating Company, Inc., Final Report, 1990).	320
Figure 145. - - Calculated bottomhole pressure for the long term flow test of Sand zone 8 of the Gladys McCall No. 1 test well (From Eaton Operating Company, Final Report, 1990).	330
Figure 146. - - Revised dimensions for the Sand zone 8 reservoir proposed by S-Cubed (From, Eaton Operating Company, Inc., Final Report, 1990).	333
Figure 147. - - Horner plot for the build-up pressure data following long term production from Sand zone 8 (From Eaton Operating Company, Final Report, 1990).	334
Figure 148. - - Plot showing the amount of calcium carbonate scale removed by acid treatment as a function of the cumulative quantity of brine produced. The plot shown is for treatments through November 1984, where each treatment series removed all of the wellbore scale. The rate of buildup (slope of the line) is 19.4 pounds of scale formation per 1,000 barrels of brine produced (From Eaton Operating Company, Inc., Final Report, 1990).	340
Figure 149. - - Location of the Gladys McCall geopressured - geothermal benchmark network for monitoring subsidence (From Technical Support for geopressured - geothermal well activities in Louisiana, Louisiana Geological Survey, Annual Report, July 1991).	349
Figure 150. - - Locations of the Gladys McCall microseismic recording stations (From Technical Support for geopressured-geothermal well activities in Louisiana, Louisiana Geological Survey, Annual Report, July, 1991).	352
Figure 151. - - Schematic illustrations of the different component units for microseismic monitoring from the field site to the central recording facility located at Louisiana State University, Baton Rouge (From Louisiana Geological Survey, Annual Report, 1992).	353
Figure 152. - - Well location and site layout map of the Gladys McCall Well No. 1 and the water quality sampling sites (From Eaton Operating Company, Inc., Final Report, 1990) . . .	356
Figure 153. - - Surveyor's well location plot for the Pleasant Bayou No. 1 and No. 2 wells (from, U.S. Department of Energy, Nevada Operation Office, 1979).	359
Figure 154. - - Pleasant Bayou project location on a U.S.G.S. quadrangle map (from, IGT, Final Report, 1992).	360
Figure 155. - - The Pleasant Bayou project location on a road map (from, Institute of Gas Technology, Final Report, 1992).	361

Figure 156. -- Organizational chart of the DOE Nevada Geothermal Operations Office (from, Gruy Federal, Inc., 1981).	362
Figure 157. -- The drilling and testing program organizational chart for the Pleasant Bayou No. 2 well, Brazoria County, Texas (from, Gruy Federal, Inc., 1981).	363
Figure 158. -- The Frio, Vicksburg and Wilcox geopressured - geothermal fairways and location of the Pleasant Bayou (#1 & 2) test well in the Frio fairway (from, Gruy Federal Inc., 1980).	365
Figure 159. -- Stratigraphic column of the Tertiary formations, Texas Gulf Coast and the Foraminiferal markers of the Miocene and Oligocene (from, Gruy Federal, Inc., 1980).	366
Figure 160. -- Frio geopressured - geothermal fairways, depositional models, and reservoir quality (from, Bebout, Loucks and Gregory, 1978).	369
Figure 161. -- Map showing sand percentage of the T ₃ - T ₆ sand complex with 200° and 300° isotherm lines. The Brazoria fairway is indicated by the 20 percent contour in northeast Brazoria County and the main sand depocenter is updip of the 200°F isotherm.	370
Figure 162. -- Location of the Pleasant Bayou area in relation to regional shelf-margin trends, northwestern Gulf of Mexico basin (Winker et.al, Annual Report DOE/ET/27111- 3, 1981).	372
Figure 163. -- Structural map drawn on top of the T ₃ marker, Brazoria Fairway. The Pleasant Bayou test well site is on the southwest flank of the Chocolate Bayou Domal Structural (from, Bebout, Loucks and Gregory, 1979).	373
Figure 164. -- Location line of structural cross section CC ¹ . The Pleasant Bayou well No's 1 and 2 are located in T&R 6S-39E. Numbers on cross section line CC ¹ refer to well names shown in the cross section (from, Bebout, Loucks & Gregory, 1978).	374
Figure 165. -- East-west structural cross section through the DOE Pleasant Bayou Wells (from, Bebout, Loucks and Gregory, 1979)	375
Figure 166. -- Principal depositional environments and sand patterns, high constructive lobate delta systems, Gulf Coast Basin (Fisher, 1969).	376
Figure 167. -- Relationship of porosity and permeability to depositional environments in core intervals from the GCO/DOE No. 2 Pleasant Bayou Geopressured - Geothermal test well (from, Bebout, Loucks and Gregory, 1979; Loucks, Richmann, and Milliken, 1979).	378

Figure 168. - - Block diagram illustrating a coarse grained, bed load fluvial channel similar to the fluvial channel in the facies represented in the target section of the Pleasant Bayou No. 2 well. The cross-sectional view shows the sand bodies to be connected and having good lateral continuity (from, Bebout, Loucks, and Gregory, 1979).	379
Figure 169. - - Electric log of the Pleasant Bayou No. 2 well showing the tested sand reservoir (from, Eaton Operating Company, Final Report, 1990).	381
Figure 170. - - Schematic illustration of the Pleasant Bayou No. 2 well completion of 8/15/83 (from, Eaton Operating Company, Inc., Final Report, 1990).	382
Figure 171. - - Schematic illustration of the Pleasant Bayou No. 2 well completion as recompleted by Eaton Operating Company on 4/3/86 (from, Eaton Operating Company, Inc., Final Report, 1990).	383
Figure 172. - - Electric log of the saltwater disposal well at Pleasant Bayou showing the disposal zones as of May 1989 (from, Eaton Operating Company, Inc., Final Report, 1990) . .	385
Figure 173. - - Schematic illustration of the Pleasant Bayou saltwater disposal well #1 as completed by Eaton Operating Company, Inc., on 5-26-89 (from, Eaton Operating Company, Final Report, 1990).	386
Figure 174. - - Schematic illustration of the Pleasant Bayou saltwater disposal well as completed by Eaton Operating Company on 7/22/90 (from, Eaton Operating Company, Final Report, 1990).	387
Figure 175. - - Process flow diagram for Pleasant Bayou surface facilities (from, Eaton Operating Company, Inc., Final Report, 1990).	391
Figure 176. - - Graph showing brine flow rate for the three years of production as a function of time (from, Eaton Operating Company, Final Report, 1990).	398
Figure 177. - - Graph showing production wellhead pressure as a function of time. The values plotted are 24-hour averages (from, Eaton Operating Company, Final Report, 1990).	400
Figure 178. - - Graph showing production wellhead temperatures as a function of time (from, Eaton Operating Company, Inc., Final Report, 1990).	401
Figure 179. - - Graph showing the perforation gas rate as a function of time i.e. the gas rate as produced through the perforations into the well from the reservoirs (from, Eaton Operating Company, Inc., Final Report, 1990).	402

Figure 180. -- Graph showing the gas/brine ratio as a function of time. A gas/brine ratio of zero is reported for those times when there is no production (from, Eaton Operating Company, Final Report, 1990).	403
Figure 181. -- Graph showing disposal well tubing pressure as a function of time (from, Eaton Operating Company, Final Report, 1990).	405
Figure 182. -- Graphs showing the cumulative production of brine and gas at the Pleasant Bayou No. 2 well from 1988-1990 (from, Eaton Operating Company, Inc., Final Report, 1990).	406
Figure 183. -- Revised structure map on the top of the C zone (from, Riney, 1991, in, Hamlin and Tyler, 1988).	422
Figure 184. -- Southwest - northeast cross section showing details of sandstone and mudstone interbedding along strike down the long axis of the fault block (from, Riney, 1991, in, Hamlin and Tyler, 1988).	423
Figure 185. -- Reservoir simulation model geometry by S-Cubed based on the BEGI model (from, Riney, 1991).	425
Figure 186. -- Schematic illustration of the Hybrid Power System (HPS) installed and tested at Pleasant Bayou (from, Eaton Operating Company, Inc., Final Report, 1990).	429
Figure 187. -- Location of microseismic stations established around the Pleasant Bayou No. 2 test well (from, Louisiana Geological Survey, Annual Report, C.G. Groat, Co-ordinator, 1992).	435
Figure 188. -- Location of Pleasant Bayou geopressured well and benchmark locations set up to monitor subsidence (from, Louisiana Geological Survey, Louisiana State University, Annual Report, C.G. Groat, Co-ordinator, 1992).	436
Figure 189. -- The Pleasant Bayou No. 2 test well site layout and locations of water quality monitoring sampling sites (from, Eaton Operating Company, Final Report, 1990). . . .	437
Figure 190. -- Pleasant Bayou site layout showing the location of the test well and saltwater disposal wells which were plugged and abandoned by Paw Drilling and Well Service, Inc., in accordance with Railroad Commission of Texas regulations (from, Rinehart and Siegal, 1994).	441
Figure 191. -- Pleasant Bayou well site layout showing location of wells plugged in the course of site restoration (modified from Rinehart and Siegal, 1994).	442

Figure 192. - - Grid maps of the test well and injection well pads where NORM survey readings were taken. The readings obtained are also shown (from, Rinehart and Siegal, 1994).	444
Figure 193. - - Locations of the Gladys McCall test well, saltwater disposal well and the ground water sampling wells at the prospect site (from, Rinehart, 1994).	445
Figure 194. - - Grid maps of the Gladys McCall site with readings obtained from the NORM Survey (from, Rinehart, 1994).	448
Figure 195. - - NORM Surveys conducted by Petroleum Environmental Inc., at the Gladys McCall prospect site (from, Rinehart, 1994).	449
Figure 196. - - The Willis Hulin test site layout showing locations of the test well, disposal well, and water wells (from, Rinehart, 1994).	452
Figure 197. - - Grid map of the Willis Hulin test well site with readings obtained from the NORM Survey (from, Rinehart, 1994).	454

LIST OF TABLES

TABLE 1	Estimates of Natural Gas in Geopressed Aquifers	10
TABLE 2	Summary of Test Results, Edna Delcambre No. 1,	40
TABLE 3	Summary of Test Results, Fairfax Foster Sutter No. 2	46
TABLE 4	Chemical Analysis of Gas (7 samples)	48
TABLE 5	Chemical Analysis of Produced Water (20 samples)	49
TABLE 6	Chemical Analysis of Produced Water (McNeese State University)	50
TABLE 7	Summary of Test Results, Beulah Simon No.2 Test Well	56
TABLE 8	Chemical Analysis of Gas (Mole Percent)	57
TABLE 9	Chemical Analysis of Produced Water, Beulah Simon No. 2	58
TABLE 10	Summary of Test Results, P. R. Girouard Well No. 1 Cade Field	68
TABLE 11	Summary of Test Results, Prairie Canal Company Inc. Well No. 1	77
TABLE 12	Summary of Test Results, Crown Zellerbach Well No. 2	87
TABLE 13	Summary of Test Results, Crown Zellerbach Well No. 2	88
TABLE 14	Reservoir characteristics of the geopressed - geothermal sands in the ,Tenneco Fee "N" No. 1 well	100
TABLE 15	Summary of Test Results, Saldana Well No. 2	121
TABLE 16	Summary of Test Results, G.M. Koelemay Well No. 1	132
TABLE 17	Typical Geopressed-Geothermal Well Gas Analyses	156
TABLE 18	Brine Analyses, BEG	158
TABLE 19	Wireline Logs MG-T/DOE Amoco Fee #1	182
TABLE 20	Average Calculated Porosity and Permeability for Miogyp Sands	185

TABLE 21	Average Calculated Salinities for Miogyp Sands	186
TABLE 22	Summary of Testing, Sweetlake Prospect	196
TABLE 23	Revised Chemical Analysis, Production Brine, MG-T/DOE Amoco Fee # 1 ..	197
TABLE 24	Summary of Testing, Sweetlake Prospect, Typical Gas Analysis	198
TABLE 26	(Numbers refer to wells shown on the seismic structure map on Figure 102) ..	220
TABLE 27	Paleontological Report, Lee Roy Sweezy # 1	223
TABLE 28	Permeability and Porosity Analysis	226
TABLE 29	Physical properties of core from the Parcerdue test well	233
TABLE 30	Summary of Results Describing Deformation Characteristics	235
TABLE 31	Organic Carbon Analyses and Gross Lithological Description	237
TABLE 32	Shale Source Rock Characteristics, Dow-DOE No. 1 Sweezy	238
TABLE 33	Summary of Events	250
TABLE 34	Summary of Drawdown and Buildup Analyses, Dow/DOE No.1 L.R. Sweezy	252
TABLE 35	Approximate Flow Rate Data (L.R. Sweezy No. 1)	257
TABLE 36	Dow-DOE L.R. Sweezy No. 1, Brine Analysis	260
TABLE 37	Chromatographic Analysis, L.R Sweezy No. 1	261
TABLE 38	Percentages of six compounds from three geopressed - geothermal test wells	264
TABLE 39	X-Ray Diffraction Analyses of Gladys McCall No. 1 Core	292
TABLE 40	Permeability and Hydraulic Capacity Data, Gladys McCall No. 1	293
TABLE 41	Calculated Salinities, Gladys McCall No. 1	295
TABLE 42	Logging Program, T-F&S/DOE Gladys McCall No. 1	301

TABLE 43	Summary of Perforation of Sand Zone No. 8, T-F&S/DOE Gladys McCall No. 1	304
TABLE 44	Analysis of Brine, Gladys McCall Sand #9	310
TABLE 45	Composite Average of 45 IGT Recombination Analyses	322
TABLE 46	Production Gas Composition at Brine/Gas Separator, T-F&S/DOE Gladys McCall No. 1	323
TABLE 47	T-F&S/DOE Gladys McCall No. 1 Sand Zone No. 8 Brine Composition	324
TABLE 48	Brine Composition of Fluids Produced from T-F&S/DOE Gladys McCall No. 1	325
TABLE 49	Brine Chemistry Analyses, T-F&S/DOE Gladys McCall No. 1	327
TABLE 50	Composite Average of 9 McCall Brine Sample	328
TABLE 51	Acid Treatments to Remove Wellbore Scale	339
TABLE 52	Analysis of Heavy Oil Production, T-F&S/DOE Gladys McCall No. 1	345
TABLE 53	Time-zone markers for the Pleasant Bayou Well #2.	368
TABLE 54	Brine Production Prior to 1983 During the Different Phases of Well Testing ..	390
TABLE 55	Downhole Pressures and Temperatures	397
TABLE 56	Analytical Methods Used	408
TABLE 57	Radium and Radon Activity in the Brine	410
TABLE 58	On Site Brine Analysis, Pleasant Bayou	411
TABLE 59	Brine Analyses Before and After HPS, Analyses Performed at BEG	412
TABLE 60	Average Gas Composition, Measured at IGT by Gas Chromatography	414
TABLE 61	Average Gas Composition, Measured at Core Laboratories by Gas Chromatography	416
TABLE 62	Typical Gas Composition From Geopressured-Geothermal Wells	417

TABLE 63	Pleasant Bayou No. 2 Well Condensate Analyses	418
TABLE 64	Types of Analyses and Analytical Methods Used For Ground/Surface Water Samples Collected From All Three DOE Sites	438

DESIGN WELL PROGRAM

The design well program was developed to acquire information on all reservoir fluid production and environmental parameters in favorable prospects identified by geologic studies. Specifically, the design well program sought to obtain accurate, reliable and long-term information concerning the following:

- (1) The characteristics of geopressured - geothermal reservoirs, including porosity and permeability, extent and distribution of the aquifer sands and shales, degree of compaction, rock composition, and shale dewatering.
- (2) The aquifer fluid properties, including in situ temperature, chemical composition, hydrocarbon content, and pressure.
- (3) The behavior of fluid and reservoir under conditions of fluid production at moderate and high rates, including pressure / time behavior at different flow rates, fluid characteristics under varying production conditions, and other information related to reservoir production drive mechanisms and physical and chemical changes that may occur with various production conditions.
- (4) The evaluation of completion techniques and production strategies for geopressured - geothermal wells.
- (5) Analysis of long-term environmental effects of an extensive commercial application of geopressured - geothermal energy, to the extent determinable during testing. This includes groundwater sampling and analysis and subsidence evaluation. Determine if fluids can be disposed of in an environmentally acceptable manner.
- (6) Reservoir limits determination.

- (7) Long term scaling and corrosion prevention. Develop a modified and successful scale inhibition procedure.
- (8) Long term disposal well performance. Prove the long term injectability of large volumes of spent brine into injection wells.
- (9) Determine the drive mechanisms for design well reservoirs.
- (10) Develop techniques to increase confidence in the ability to locate and evaluate geopressured resources.
- (11) Develop a test procedure which has sufficient accuracy to predict the capability of any geopressured reservoir to be produced for a long term basis.
- (12) Determine source and flow mechanisms for the liquid hydrocarbons and methane obtained from producing geopressured reservoirs.
- (13) Develop surface fluid handling facilities (pumps, separators, valves, compressors, etc.) Which can be safely operated from a remote monitoring location.
- (14) Develop material specifications, equipment specifications, and maintenance procedures which will guarantee over 95 percent annual availability with only a two week annual shutdown for routine maintenance.
- (15) Develop hybrid conversion technology with thermal efficiency at least 20% greater than that from separate combustion and geothermal power cycles (From Eaton Operating Company, Inc., Final Contract Report 1986 - 1990).

LAFOURCHE CROSSING

The Lafourche Crossing Well No. 1 was one of the first wells proposed to be drilled under the DOE Design Well program, but was not drilled, as far as we can determine. This prospect is located near the juncture of Bayou Lafourche and Bayou Terrebonne, approximately 3 miles south of Thibodaux, in Terrebonne Parish, Louisiana (Figure 81). The test well was proposed to be drilled to a total depth of 17,200 ft., to investigate the geopressed sands of Upper and Middle Miocene age which occurred at an approximate depth of 14,000 ft. in the prospect area. The prime prospect area was selected for the geopressed - geothermal resource analysis based on sand thickness, temperature, permeability, and environmental suitability. The geology of the area was documented by detailed investigations by Dr. Don Bebout and the results of these studies were reported by Wrighton et. al. (1981) in the final report by Louisiana State University on technical support for geopressed - geothermal well activities in Louisiana, performed under contract No. AS05-78ET27160 with the U.S. Department of Energy, Oak Ridge Operations, Division of Energy Technology. The Lafourche Crossing test was to be a function of the Louisiana Department of Natural Resources (DNR) under contract with DOE, with LSU, under a separate contract, furnishing technical support. Both the test well and the brine disposal well were designed under the LSU contract by C. Allen Bell, P.E., Inland Enterprises, Inc., P. O. Box 307, Ball, La., 71405 who was an independent consultant: The detailed design, drilling, casing, cementing and completion procedures for both the production and disposal wells are incorporated into Appendix A of the DNR proposal of July 1979 entitled "Design, drilling and completion plans for the Lafourche Crossing Geopressure test well and disposal wells." A

Figure 81. - - Location of the LaFourche Crossing prime prospect area in relation to the Gulf Coast region (From, U.S. DOE, LaFourche Crossing No. 1, October 1978.

documented cost analysis for a total of \$2,071,832 for the test well (in 1980 dollars) was also provided by LSU to DOE which included expenses for a 12 month testing period.

Bassiouni (1978) evaluated the areal extent, depth, thickness, temperature, pressure, porosity, salinity, permeability and dissolved natural gas content of the Lafourche Crossing geopressured water sands and prepared structure net sand maps and cross sections of the prospect area. A structure map on top of the *Robulus* "L" 43 sand is shown in Figure 82. A tentative test well site proposed was approximately 4,500 ft. due east northeast of well No. 10 (Section 137 or 138, T 15 S, R 17 E). A detailed environmental assessment of the Lafourche Crossing prospect area was performed by the U.S. Department of Energy is detailed in a report dated October 1978. Another environmental assessment involving collection of preliminary environmental baseline data for the Lafourche Crossing as well as other proposed prospect areas was performed by the Institute of Environmental Studies, Louisiana State University, Baton Rouge, Louisiana, for the Division of Geothermal Energy, U.S. Department of Energy, under Contract No. ET-78-S-05-5862 (October, 1978). Some geologic, geophysical and geochemical aspects of the Lafourche Crossing Prospect are also discussed in the final report by Pilger (1985) performed under DOE Contract No. DE-AC08-79ET27019.

The compilers of this report were unable to find any documentation regarding why this well was not drilled.

MG - T / DOE AMOCO FEE No. 1 (SWEET LAKE)

The Sweet Lake site is located approximately 15 miles southeast of Lake Charles in Cameron Parish, Louisiana. It was selected by the Department of Energy under the Design Well

Figure 82. - - Structure map on top of the *Robulus* "L" 43 sand in the LaFourche Crossing Prospect area (From Basiouni, 1978).

Program of the Geopressured - Geothermal Program. The Sweet Lake production well and disposal well were drilled under DOE Contract No. DE-AC08-80NV10081 to the Magma Gulf - Technadril Joint Venture. Additional funding was provided by the Gas Research Institute, under GRI Contract No. 5014-321-0290. These funds were used for mudlogging, micropaleontology, organic geochemistry, and rock mechanics. Complete details of drilling, analyses and other studies conducted on the test well are provided in the Magma Gulf - Technadril Annual Report (3 volumes) for the period of February 1982 to March 1985 prepared for the U.S. Department of Energy, Division of Energy Technology under Contract No. DE-AC08-80NV10081. Information for this summary compilation is directly taken from this report. The management organization for the test site and a list of other subcontractors who worked on the Sweet Lake project is given in Appendix 2 at the end of this report.

The first leases in the area of the test well were taken by Magma Gulf Company in 1975 and additional leases were obtained from Amoco Production Company in 1978 for the specific drill site. The drilling and testing proposal was submitted by Magma Gulf - Technadril, Inc., Joint Venture, and the contract with DOE was signed in December 1979. The test well, named MG-T / DOE Amoco Fee No. 1, was spudded on August 22, 1980 and drilling operations were completed on February 26, 1981. The well is located in Section 13, Township 12 S and Range 8 W in Cameron Parish, Louisiana and the salt water disposal well was drilled the vicinity (Figure 83 and 84). Both the MG-T / DOE Amoco Fee No. 1 test well and the MG-T / DOE Amoco Fee No. 2 salt water disposal well are located on a five acre test site on Amoco Fee land which was obtained under a geothermal lease. The initial comprehensive geological and geophysical investigation using well logs and existing seismic data was done under Contract No. E7-78-C-08-1561, and

**SWEET LAKE
GEOTHERMAL WELL**
VICINITY MAP AND
GENERAL LOCATION PLAN
Cameron, La.

Figure 83. -- Location of the Magma Gulf - Technadril, Department of Energy, Amoco Fee No. 1 test well (From Magma Gulf - Technadril, Annual Report, 1979 - 1981, Volume 1).

WELL LOCATION:
MAGMA GULF - TECHNADRIL
Dept. of Energy Amoco No.2 Disposal Well

Commencing at the Southwest corner of Section 13,
T.12 S., R.8 W., go North along the West Line
of Section 1730 feet, thence East at Right
Angles 2815 feet to the Location.
Ground Elevation 8.3'

We hereby certify that we staked the above
Well Location as shown June 16, 1980.
Whitaker & Webb - Civil Engineers.

George F. Webb, Jr.
GEORGE F. WEBB, JR., L.A. REG. NO. 3870

MAGMA GULF - TECHNADRIL
WELL LOCATION
SECTION 13, T.12 S., R.8 W.
CAMERON PARISH, LA.

SCALE: 1" = 1000' JUNE 17, 1980

WHITAKER & WEBB
CIVIL ENGINEERS
LAKE CHARLES, LA.

Figure 84. -- Location of the MG-T / DOE Amoco No. 2 saltwater disposal well (From Magma Gulf - Technadril Annual Report, 1979 - 1981, Volume 1).

was initiated in June 1978. The Sweet Lake site was selected to test the Frio Formation in Louisiana. The primary geopressured - geothermal aquifer is the Miogypsinoïdes (Miogyp) sand of the *Camerina* zone (Upper Frio Formation of Oligocene - Miocene age). The test well was drilled without incident to 13,550'; when the well fork a kick. A random side track was started at 10,564' and reached a total depth of 15,740'. Three strings of pipe were used in this well: 13 $\frac{3}{8}$ inch from 4,050 ft. to surface; 9 $\frac{5}{8}$ inch from 10,230 ft. to surface; and 7 $\frac{5}{8}$ inch from 15,065 ft. to surface. The production tubing is a 5 $\frac{1}{2}$ inch liner from the plugged back total depth of 15,660 ft. to the surface. A schematic illustration of the tubular configuration of the MG - T / DOE Amoco Fee No. 1 test well is shown in Figure 85.

The salt water disposal well was spudded on September 19, 1980 and was drilled to a total depth of 7,440 ft. Two strings of pipe were used in the well: 13 $\frac{3}{8}$ inch from 1,375 ft. to surface; and 9 $\frac{5}{8}$ inch from 7,436' to surface. The production tubing is a 7 inch liner set from plugged back total depth of 7,350 ft. to the surface. Drilling operations on this salt water disposal well were completed on October 13, 1980. A schematic illustration of the salt water disposal well completions is shown in Figure 86.

The Sweet Lake geopressured - geothermal prospect sand aquifer is localized in a graben dipping and widening westward. The basin is located on the north flank of an east-west salt ridge containing the Hackberry, Big Lake and Sweet Lake Structures. A seismic structure map of the Sweet Lake prospect contoured on top of the Miogyp sand is presented in Figure 87. This map was drawn based on a combined study of 27 miles of seismic lines and 17 well logs. The south side of the basin is bounded by a fault down thrown to the north. This fault converges to the east with another major east - west trending fault down thrown to the south. Dip is generally north

MG-T/DOE AMOCO FEE NO. 1 WELL
SWEETLAKE FIELD WILDCAT - CAMERON PARISH, LOUISIANA
COMPLETION OCTOBER 30, 1983
REVISION 1, 6/20/84

Figure 85. -- Schematic illustration of the MG-T / DOE Amoco Fee No. 1 Well (Sweet Lake)
(From Magma Gulf - Technadril, Annual Report, 1982 - 1985, Volume 3).

**MG-T/DOE AMOCO FEE NO.2
SALT WATER DISPOSAL WELL**
RECOMPLETION APRIL 6, 1982

**Figure 86. - - Schematic illustration of the tubular configuration of the saltwater disposal well
(From Magma Gulf - Technadril, Annual Report, 1982 - 1985, Volume 3).**

Figure 87. -- Seismic structure map of the Sweet Lake Prospect contoured on top of the Miogyp sands (From Magma Gulf - Technadril, Annual Report, 1979 - 1981, Volume 1).

westerly into the basin which opens toward the south flank of the South Lake Charles Structure several miles away to the north.

The surface terrain is formed by late Pleistocene deltaic deposits. Alternating massive sands and clays extend to an average depth of 9,000 ft. and overlie the thick shales of the Anahuac Formation.

The Anahuac Formation is underlain by the Frio Formation, the upper member of which is called the *Camerina* zone. Several sands occur within this sequence, the thickest being the basal *Myogypsinoides* sand which is the target sand for the geopressed - geothermal testing. This sand was deposited on the outer shelf in the Upper Oligocene - lower Miocene time. An electric log of the test well (Figure 88) shows the *Miogypsinoides* (Miogyp) sand, the top of which was picked at 14,970' based on paleontological analyses, with the first good sand appearing a little lower in the section. The three key control wells drilled by Union Oil of California (Sweet Lake No. 1, Pan Am Fee No. 1, and Pan Am Fee No. 2) which were used for initial identification of the prospect and the correlation of the Miogyp section in these three wells with the test well is shown in Figure 89. These four wells are the only ones which penetrated the Miogyp sand section in this area. A list of other wireline logs on the test well is shown in Table 19.

The average Gulf Coast temperature gradient is 1.5°F per 100 ft. of depth. However, at the top of the geopressed zone, most temperatures are about 25°F cooler than the average, indicating a lower geothermal gradient in the hydrostatic zone. But within the geopressed zone the gradient is higher than the average, and temperatures are mostly 10°F above average below a depth of 14,000'. Figure 90 is an isothermal map showing the average corrected temperature of 17 wells used in the preliminary study as determined from geothermal gradients prepared on each

Figure 88. - - Dual induction log of the *Miogypsinoides* sequence MG - T / DOE Amoco Fee (Sweet Lake) #1 Well. Black intervals are cased intervals. Sands 3 and 5 were tested in this well (From Magma Gulf - Technadril Annual Report, 1981 - 1982, Volume 2).

CROSS-SECTION OF MIOGYP SAND Sweet Lake Project

Figure 89. - - Geologic cross section showing the Miogyp sands in the MG-T DOE Amoco Fee N. 1 (Sweet Lake) test well and its Correlation with other wells in the vicinity (From Magma Gulf - Technadril Annual Report, 1982 - 1985, Volume 3).

TABLE 19

Wireline Logs MG-T/DOE Amoco Fee #1

<u>Log</u>	<u>Date</u>	<u>Bottom</u>	<u>Top</u>
Borehole Geometry	8/23/80	845	154
Induction Spherically Focused	8/30/80	4046	826
Borehole Geometry	8/30/80	4046	826
Cement Bond	9/19/80	4053	200
Dual Induction-Sonic	9/19/80	10230	4053
Dual Induction-Formation Density-Compensated Neutron	9/19/80	10230	4053
Dipmeter	9/19/80	10230	4053
Cyberlook	9/19/80	10150	6800
Saraband	9/19/80	10200	4050
Salinity Saraband	9/19/80	10200	4050
Temperature	9/22/80	10010	2570
Temperature	10/23/80	13550	surface
Cement Bond	10/23/80	13518	10000
Temperature	10/25/80	12924	8000
Cement Bond	10/25/80	13500	8000
Temperature	10/26/80	13530	8000
Casing Collar and Perforating	10/27/80	12590	12591
Borehole Geometry	11/ 9/80	10608	10234
Induction Spherically Focused-Sonic	10/26/80	15065	10242
Formation Density-Compensated Neutron	12/26/80	15065	10242
Dipmeter	12/26/80	15065	10242
Cyberlook	12/26/80	15065	10242
Saraband	12/26/80	15050	10300
Salinity Saraband	12/26/80	15050	10300
Casing Inspection	12/27/80	10160	surface
Repeat Formation Tester	1/ 5/81	15144	15065
Dual Induction-Sonic	1/17/81	15740	15065
Formation Density-Compensated Neutron	1/17/81	15740	15065
Dipmeter	1/17/81	15740	15065
Cyberlook	1/17/81	15740	15065
Saraband	1/17/81	15740	15065
Salinity Saraband	1/17/81	15740	15065
Temperature	1/22/81	8850	100
Casing Collar and Perforating	1/22/81	10230	surface
Temperature	1/24/81	8783	5000
Temperature	1/30/81	9432	100
Temperature	1/31/81	9432	5000
Temperature	2/ 5/81	9555	100
Temperature	2/ 6/81	9550	100
Cement Bond	2/ 7/81	9579	4000
Variable Density	2/ 7/81	9579	4000
Temperature	6/13/81	15661	surface

(From Magma Gulf - Technadril Annual Report, 1979 - 1981, Volume 1)

Figure 90. -- Isothermal map of the Miogyp sand (From Magma Gulf - Technadriil Annual Report, June 1981).

individual well - at the mid point of the sand. The maximum temperature recorded on the third logging run which reached a depth of 15,065 ft. was 267°F uncorrected and 297°F corrected. The final logging run to total depth of 15,740' recorded an uncorrected temperature of 300°F (329°F corrected).

The seven potentially productive sands with the Miogyp section in the test well (Figure 86) are all fairly clean sands and correlate well with the other individual sands in the three control wells (Figure 87). Table 20 summarizes the porosities and permeabilities that have been calculated in various manners for the seven sands. Electric log calculations have provided values for salinities for the seven sands in the test well and are shown in Table 21. The "Darfman" salinity is based on research at the University of Texas at Austin by Myran Darfman, and it shows that the value is twice the actual value. The Saraband salinity was calculated from the Saraband log computed by Schlumberger.

An approximation of the number of barrels of water in place for each of the potential sands was calculated using net sand thickness from electric logs and isopach maps. Several assumptions were made in doing this and they are described in detail in the Magma Gulf - Technadril Annual Report (1979 - 1981, volume 1) from which all this information is directly taken. The area of the graben planimetered for this purpose and the quantity of brine in place in each of these sands is shown in Figure 91.

Two of the seven sands in the Miogyp section (number from the top) were tested; Sand 5 (15,387 ft. - 15,414 ft.) from June 1981 to February 1982 and Sand 3 (15,245 ft. - 15,280 ft.) from November 1983 to March 1984. In each case a short initial clean-up flow was followed by a buildup test. A reservoir limit determination test was then conducted. When this test had been

TABLE 20

AVERAGE CALCULATED POROSITY AND PERMEABILITY FOR MIOGYP SANDS

<u>Sand Depth</u>	<u>Net Sand</u>	<u>Average Porosity</u>	<u>Average Permeability</u>	<u>Hydraulic Capacity md-ft</u>	<u>Percent Hydraulic Capacity</u>
15080-15144	41'	12.3	175	7,175	4.77
15170-15240	42'	12.1	143	6,006	3.99
15250-15285	27'	15.4	700	18,900	12.57
15305-15355	25'	15.3	750	18,750	12.47
15385-15415	27'	19.0	2960	79,920	53.16
15460-15505	41'	12.2	130	5,330	3.54
15520-15600	51'	12.9	280	14,280	9.50
TOTAL	254'			150,361	100.00

(From Magma Gulf - Technadril Annual Report, June 1981).

TABLE 21
AVERAGE CALCULATED SALINITIES FOR MIOGYD SANDS

<u>Sand Depth</u>	<u>Standard Log Salinity</u>	<u>"Dorfman" Salinity</u>	<u>Saraband Salinity</u>
15080-15144	50,000	125,000	76,000
15170-15240	50,000	125,000	68,000
15250-15285	70,000	140,000	98,000
15305-15355	70,000	140,000	125,000
15385-15415	70,000	140,000	125,000
15460-15505	50,000	125,000	74,000
15520-15600	70,000	140,000	103,000

(From Magma Gulf - Technadril Annual Report, June 1981).

run long enough to observe reservoir barriers, the down hole pressure testing equipment was removed and the well was put on long term production at various rates.

Sand 5 was tested first primarily because of its abnormally high permeability. Further, it also appeared to be separated from the other sands in the Miogyp sequence by thin shale above and below. This sand was perforated on June 16, 1981 at 4 shots per foot. The original reservoir pressure recorded was 12,052 psia, the initial surface pressure 4,749 psia and the original reservoir temperature 299°F. The initial flow test began at 6:18 pm on June 19, 1981 and ended at 8:04 pm on June 22, a total of 3.03 days. During this time 10,574 barrels of brine were produced at an average rate of 3,444 B/D. Initial calculations indicated that the radial exploration of the reservoir during this test reached 7,810 ft. and water permeability was 339 md. Two permeability barriers were noted during this test, at 452 ft. and 1,153 ft. from the well bore. Preliminary conclusions were that these barriers may be sealing faults, sand pinchouts, thinning, minor faulting or a decrease in permeability. Subsequent testing confirmed that the barriers were not the major faults. First gas measurements, eventually proved to be in error due to metering problems, yielded an estimate of 7 - 8 SCF/barrel, which was much lower than the expected gas/water ratio of 25 - 30 SCF/barrel.

At the conclusion of the initial buildup test the well was shut in before beginning the reservoir limit test. This allowed the reservoir to return to near original pressure which was important for reservoir engineering calculations. The bottom hole pressure in the test well decreased to 11,141 psi at the end of the initial flow test. At the end of the buildup period on June 30, 1981 the pressure increased to 11,974 psi which was 78 psi less than the original pressure.

The reservoir limit test commenced on June 30, 1980 at 6:15 pm and ended at 5:00 pm on July 17, a total of 17 days. The average flow rate was 13,350 B/D and approximately 226,300 barrels of brine was produced. The flow rate varied from 16,000 B/D at the beginning to 10,000 B/D at the end. Average flowing temperature during the test was 265°F. The bottom hole pressure dropped from 11,974 psi to 7,804 psi, which was equivalent to a surface pressure of about 700 psi. As the surface facilities did not function efficiently at wellhead pressures of less than 700 psi it was considered to be the lowest desirable pressure and the flow rate was reduced to maintain the pressure. Brine and gas samples were taken by subcontractors for analyses.

The results of the reservoir limit test indicated that Sand 5 alone could not sustain a production rate of 40,000 B/D for any significant length of time. Therefore Sand 5 testing continued for a longer term at variable rates. Perforating other sands was not considered as a viable alternative at this time. The long term testing of Sand 5 continued for 208 days, from July 17, 1981 to February 10, 1982. The flow rate varied from a high of 38,000 B/D to a low of 1,000 B/D. Approximately 1.1 million barrels of brine were produced during this test. On February 10, 1982 the disposal well sanded up and did not accept brine. This was thought to be due to back flow resulting from brief periods of shutting in of the test well for routine maintenance and new operator training. Due to restricted funds during this seven month test period it necessitated operation at only 5,000 B/D for most of the time in order to "preserve the well." Approximately 20 SCF / B of methane gas was recovered from the brine during this test and flared. The short periods of high flow rates demonstrated that the surface facilities and disposal well were capable of handling high flow rates.

From February 10, 1982 to November 11, 1983 the test well was shut in. This was due to

the disposal well sanding up and later detection of a leak in the tubing. A proposal to test Sand 4 was made but was never undertaken. This was because after the problem causing shut in of the test well were rectified it was found that the production well had a backflow of sand and later more tubing leaks were discovered. The tubing was pulled with a larger rig and the new plugged back depth was 15,351 ft. The lower zones were then blocked with a bridge plug and Sand 3 was perforated on November 11, 1983.

This Sand 3 zone was perforated in two intervals from 15,260 ft. to 15,280 ft. and from 15,245 ft. to 15,255 ft. The original reservoir pressure was 11,887 psia (15,245 ft.), the initial surface pressure 3,660 psia, and the original reservoir temperature was 293°F. The well was opened up at a rate of 2,800 B/D at 11:50 am on November 12 and the test concluded at 11:50 am on November 13, at which time it was shut in. Preliminary results indicated that the flow from this zone would be very restricted. The bottom hole pressure decreased from 11,883 psia to 10,133 psia with a flow rate of only 4,000 B/D during 24 hours. The disposal well functioned successfully with a wellhead pressure of only 35-40 psig at a brine production rate of 4,000 B/D.

The buildup test of Sand 3 began at 11:50 am on November 13, 1983. Later a leak was detected at 7:00 pm on pressure instrumentation piping external to the wellhead. The down hole equipment had to be removed in order to repair this leak and it was not rigged up again until November 21. This test concluded at 8:50 am, November 22, for a total of 9.875 days. The bottom hole pressure returned to 11,794 psia which was 93 psi lower than the original reservoir pressure.

The reservoir limit test commenced at 8:50 am, November 22 and concluded at 7:30 am on December 7. This test of Sand 3 was divided into two separate phases. The primary draw

down phase, from November 22-29, was an essentially constant flow phase designed primarily to determine the limits of the Sand 3 reservoir. The down hole pressure dropped from 11,794 to 10,065 psia in the 7 day period. The brine production rate was constant at 2,046 B/D for a total production of 14,322 barrels. The wet gas/water ratio was 24 SCF / B. The second phase, the reservoir depletion phase is actually a combination of the second half of the reservoir limit test and all the long term test. The brine production rate was varied during this phase in order to study gas composition as a function of reservoir pressure. The average production rate during this phase was 2,684 B/D. The well continued to produce brine until 6:44 pm on March 13, 1984, after 114 days of testing. It was shut in at this time mainly due to economic reasons. A total of 276,608 barrels of brine were produced from Sand 3 during a period of 122 days. This period, along with the long term production and testing of Sand 5 demonstrated that all surface facilities operated properly, and that dissolved methane could be removed from brine effectively. Other types of testing had been planned, including perforating all zones to achieve high flow rates and using the brine directly, or the heat from the brine, to grow shrimp or fish etc., but the lack of funds prohibited these activities.

Reservoir testing and calculations indicated that the reservoir was more or less pre-shaped with a flow angle of 25°. While it was restricted in two directions, it was thought to be open an unknown distance in the third direction, probably northwest, which matched the original geologic interpretation. Since no enclosing barrier was observed, the postulated fault to the west did not exist. During testing of the Sand 5 reservoir it was explored to a radial distance of 22,467 ft. and permeability barriers were interpreted to be 318 ft., 645 ft. and 1,289 ft. from the wellbore. Confirmation of the reservoir shape was made by Intercomp using computer modeling. The

general conclusions of the testing of both Sands 5 and 3 were that there are barriers in the reservoir, close to the wellbore. The nature of the barrier, whether due to faulting or permeability decrease etc. cannot be determined from the reservoir engineering data.

In calculating the initial water in place it was assumed that both sands had approximately the same areal extent. During the reservoir limit test of Sand 5, some 300,000,000 barrels of water in place were explored. Assuming a porosity of 22%, a reservoir thickness of 27 ft., Sand 5 covers an area of approximately 11,330 acres. However, since no enclosing boundary was detected the reservoir was larger than this. The reservoir limit test of Sand 3 explored about 20,000,000 barrels of water. However, this sand has a much lower permeability than Sand 5, the testing, explored a much smaller area. Assuming that each of the seven sands covered an area of about 10,000 acres, and using the thickness and porosities in Table 20 the total water in place was calculated to be approximately 1,865.2 million barrels. However, it should be kept in mind that this is only a rough approximation which makes many constant assumptions and also that only a fraction of this amount of water would be ultimately recoverable.

Four conventional 2" diamond cores were obtained from the *Miogypsinoides* sand interval as follows:

<u>Core No.</u>	<u>Cored Interval</u>	<u>Recovered Interval</u>	<u>Core Length</u>
1	15,144'-15,184'	15,144'-15,179'	38.0'
2	15,185'-15,201'	15,185'-15,197.5'	12.5'
3	15,389'-15,411'	15,389'-15,405'	16.0'
4	15,600'-15,634'	15,600'-15,632'	32.0'

The cores were taken under the supervision of Christiansen Diamond Products, Inc., and

the core was handled by Core Laboratories, Inc. Houston. X-ray analysis of cores for sedimentary structures, lithologic description, scanning electron microscope analyses, grain size analysis, rock mechanics and compaction and creep measurements were performed on the cores which were distributed to various subcontractors who included Amoco Production, Hartax, Inc., Institute of Gas Technology, Lawrence Berkely Laboratory, Louisiana Geological Survey, Rice University, Terra Tek, U.S. Geological Survey and the University of Texas. Forty-four sidewall cores were obtained from the test well from 6,490' to 15,075'. As all these samples were above the Miogyp sand they could not be used to evaluate the reservoir. However, the information was used for evaluating variations between the hydro pressured and geopressured formations and in comparing core analysis to wireline log analysis.

The rock mechanics of the Sweet Lake geopressured - geothermal reservoirs were investigated by the University of Texas at Austin under the direction of Dr. Ken E. Gray and was funded by GRI Contract No. 5014-321-0290. Some of the conclusions of these studies are given below and a detailed report is contained in the University of Texas Report CESE-DRM-88:

- (1) As the effective stress increases to a maximum, the compressibility decreases by approximately 55-65%.
- (2) Bulk compressibilities at atmospheric pore pressure are higher than bulk compressibilities at elevated pore pressure under the same effective stress. This indicates that matrix compressibility is a significant factor, which has often been ignored in the past.
- (3) Porosity is reduced by approximately 1-3% under increasing effective stress, but permeability is reduced by 30-45%.
- (4) The uniaxial compaction coefficient changes in the same direction as bulk compressibility.

Under the same effective stress, the uniaxial compaction coefficient is typically one half to one third the value of bulk compressibility.

(5) Compaction is more pronounced in the early stages of reservoir fluid production than in later stages.

These conclusions indicate that compaction of the reservoir rock will contribute to pore pressure maintenance and fluid production at the beginning of production. However, over the long term, the reduction in porosity and permeability and the decreasing effectiveness of compaction to pore pressure maintenance will significantly decrease the contribution of rock compaction to the reservoir drive mechanism. Nine creep tests were performed on the samples under three sets of loading conditions (1) hydrostatic - elevated pore pressure; (2) hydrostatic zero pore pressure; and (3) differential - zero pore pressure. Five of the samples showed creep, and four showed sufficient creep for data analysis. Two mathematical models were developed to explain the creep behavior, but neither of them was chosen over the other.

Reservoir engineering data was analyzed and interpreted by primarily by Intercomp Resource Development and Engineering and later by Dowdle Fairchild and Ancell. Others who conducted investigations and modeling using this data included Systems, Science, and Software (S-Cubed) and the University of Texas. A complete discussion of the S-Cubed analysis and conclusions can be found in Garg (1982). Different interpretations and conclusions were reached by S-Cubed than those by Intercomp. A summary of these interpretation is provided in the Magma Gulf Technadril Annual Report (1982-1985) from which all the information provided here is directly taken.

The chemical and physical analysis of fluids from the Sweet Lake test well were carried out by several different groups: the Magma Gulf Technadril plant operations staff, Professors Hankens and Karkalitz of McNeese State University, Professor Mason Tomson of Rice University and Professor Jack Matson of the University of Houston, Weatherly Laboratories, Institute of Gas Technology and Scientific Consulting and Analysts. A typical average brine analysis for the two sand zones tested is given in Table 22 and a more detailed chemical analysis of the brine is presented in Table 23. The Magma Gulf - Technadril report states that analyses made by separate contractors were very consistent through time.

An average typical gas analysis is presented in Table 24 and separate analysis of the gas from the two zones tested (3 and 5) is shown in Table 25. The gas as expected is predominantly methane with minor amounts of other hydrocarbons, 8-10% carbon dioxide and a trace of H_2S . This analysis is generally quite similar to analyses of gas obtained from other geopressured - geothermal wells, except that the lower temperature Wells of Opportunity seem to have a lower CO_2 content. Also, due to the high CO_2 content (approximately 9%) in the produced gas it was not accepted by any nearby pipeline company and therefore had to be flared during testing. IGT concluded from their analyses that the reservoir brine was at or near saturation with natural gas, sent to Weatherly Laboratories for recombination studies indicated that the brine should contain 34 SCF / B at saturation which meant that the Sweet Lake brine was under saturated. These differences and their reasons were not completely resolved.

The salt water disposal well for the Sweet Lake test site (MG - T / DOE Amoco Fee No. 2 SWD well) was designed to demonstrate the feasibility of successfully disposing large quantities of geopressured - geothermal brine (40,000 barrels per day). These feasibility studies included

TABLE 22

**SUMMARY OF TESTING
SWEETLAKE PROSPECT
TYPICAL BRINE COMPOSITION**

	<u>SAND ZONE</u>	
	<u>NO. 3, MG/L</u>	<u>NO. 5, MG/L</u>
ALKALINITY	256 - 281	256 - 390
CALCIUM	12,500 - 13,400	11,000 - 12,560
CHLORIDES	99,650 - 99,900	92,340 - 100,100
IRON	55.8 - 63.5	52 - 59
MAGNESIUM	700 - 720	630 - 760
POTASSIUM	860 - 990	1,690 - 1,740
SILICA	92 - 93	112 - 120
SODIUM	41,750 - 41,800	42,000 - 46,000
STRONTIUM	1,180 - 1,220	840 - 970
TOTAL DISSOLVED SOLIDS	168,400 - 168,900	156,900 - 166,500

(From Magma Gulf - Technadril Annual Report, 1982 - 1985, Volume 3).

TABLE 23

SCAN
 Scientific Consulting and Analysis, Inc.
 P.O. Box 6642
 Lake Charles, LA. 70606

December 9, 1983

Revised Chemical analysis
 Production Brine
 MG-T/DOE Amoco Fee # 1 Well
 Sweetlake Project
 Sand Zone # 3-15248-15285 ft.
 Sample Collected 11-23-83

Alkalinity	281 mgHCO ₃ ⁻ /L	
Alpha (gross)	71 pCi/L	**
Ammonia	105 mgNH ₃ /L	
Arsenic	<.001 mgAs/L	
Barium	110 mgBa/L	**
Beta (gross)	1050 pCi/L	
Boron	50.6 mgB/L	
Cadmium	.004 mgCd/L	
Calcium	12,500 mgCa/L	**
Chloride	99,650 mgCl/L	
Chromium	.05 mgCr/L	**
Copper	.050 mgCu/L	
Dissolved Solids	168,900 mg/L	
Fluoride	.45 mgF/L	
Gamma (gross)	-----	
Iron	63.5 mgFe/L	
Lead	.008 mgPb/L	
Magnesium	700 mgMg/L	**
Manganese	9.9 mgMn/L	
Mercury	<.001 mgHg/L	
pH	5.20	
Potassium	990 mgK/L	
Radium	210 pCi/L	
Radon (gas)	.3 pCi/L	
Silica	92 mgSiO ₂ /L	
Sodium	41,800 mgNa/L	
Specific Conductance	160,000 mhos/cm	
Specific Gravity	1.1103	
Strontium	1220 mgSr/L	**
Sulfate	<1 mgSO ₄ ⁼ /L	
Sulfide	3 mgS ⁼ /L	
Suspended Solids	.25 mg/L	
Zinc	2.25 mgZn/L	

(From Magma Gulf - Technadril Annual Report, 1982 - 1985, Volume 3).

TABLE 24

**SUMMARY OF TESTING - SWEET LAKE PROSPECT
TYPICAL GAS ANALYSIS**

	<u>Z MOL</u>	
METHANE	88.77	
ETHANE	1.73	
PROPANE	0.35	
ISOBUTANE	0.04	
NORMAL BUTANE	0.06	
PENTANES AND HEAVIER	0.24	
NITROGEN	0.22	
CARBON DIOXIDE	8.59	
HYDROGEN SULFIDE	15 - 30	PPMV

(From Magma Gulf - Technadril, Annual Report, 1982 - 1985, Volume 3).

TABLE 25**SUMMARY OF TESTING****SHEETLAKE PROSPECT****TYPICAL GAS ANALYSIS***

	<u>SAND ZONE</u>	
	<u>NO. 3, % MOL</u>	<u>NO. 5, % MOL</u>
METHANE	89.43	88.77
ETHANE	1.50	1.73
PROPANE	0.20	0.35
ISOBUTANE	0.01	0.04
NORMAL BUTANE	0.02	0.06
NITROGEN	0.20	0.22
CARBON DIOXIDE	8.54	8.59
HYDROGEN SULFIDE	12-20 PPMV	15-30 PPMV

*AT BRINE/GAS SEPARATOR PRESSURE OF 300 PSIG.

(From Magma Gulf - Technadril Annual Report, 1982 - 1985, Volume 3).

injectivity tests, side wall core analysis, the effects of chemical, as inhibitors, as well as chemical effects of the produced brine on long term capabilities of the disposal well sands. Information on the disposal well compilation on the Sweet Lake test well. Wireline data and side wall core analyses indicated that the saltwater disposal well contained numerous sand intervals between 2,500 ft. and 7,500 ft. that were excellent for brine disposal (Figure 92). The sands selected for perforation were between 7,000 to 7,300 ft. and were the lowermost in the section. About 200 ft. of sand was perforated in June 1981 with a Schlumberger gun at 4 shots per foot. The disposal well was not acidized immediately after perforation. However acidization was performed when after flowing the test well the pressure increased to 800 psia. After acid treatment the pressure was reduced to less than 100 psi at full flow. A second acid treatment was necessary later to reduce the back pressure which had again increased. Later on the disposal well began sanding up after periods of shut in of the test well in February 1982. At this time the pressure increased to 800 psi due to fine sand backflow through the perforations and the top of the sand was at 6,902' which was 98 ft. above the top of the perforated zones. Since the PBTD of the disposal well was 7,365', about 462' of sand had backflowed through the perforations. During cleaning operations coiled tubing was lost in the hole and the disposal well sanded up to a depth of 2,600'. The well was cleaned by getting nitrogen and milling the coiled tubing, upto a depth of 4,530'. The 7 inch production tubing was cut at 4,500' and pulled from the hole and a drillable bridge plug was set at 4,627' with 11' of cement above it. The well was then perforated from 3,976 ft. to 4,425 ft. with 4 shots per foot, opening 230' of sands. After performing an injectivity test equivalent to a flow of 24,000 B/D it was determined that acidizing would be necessary only to sustain this high rate

Figure 92. - - Saltwater disposal well electric log showing zones perforated (From Magma Gulf - Technadril Annual Report, 1979 - 1981, Volume 1).

of flow, but would not be necessary at the lower flow rate from the Sand 3 flow test. The disposal well performed satisfactorily during the rest of the testing period.

After the U.S. Department of Energy determined that it could not afford to continue the testing of the Sweet Lake well, DOE directed MG-T on June 7, 1984 to plug and abandon both the production well as well as the saltwater disposal well. Plugging and abandonment procedures were then conducted in strict compliance with the State of Louisiana and Federal regulations and safety considerations. The production well plugging and abandonment procedure was completed on September 14, 1984 and the tubular configuration of the well at this time is shown in Figure 93. The work of plugging and abandonment of the saltwater disposal well started on September 18 and was completed four days later. Site restoration work began in June, when the final decision was made to plug and abandon the wells, and was completed in November 1984.

The final test well total cost were \$8,067,124. Saltwater disposal well costs were \$1,505,592. Testing costs including construction and installation of surface facilities were \$2,286,164. Costs to work over both wells were \$1,184,445. Project administrative costs were \$2,383,805. Plug and abandonment and site restoration costs were \$225,000. Total project costs were \$16,152,154. Detailed costs for other investigations and analyses done in connection with the Sweet Lake project could not be obtained by the compilers of this report within the time frame allocated for report preparation.

ENVIRONMENTAL MONITORING AT SWEET LAKE

In order to evaluate the effects of well testing and production of large quantities of brine on the environment, environmental monitoring for subsidence, seismicity, air quality, and both

MGT/DOE AMOCO FEE NO. 1 TEST WELL
SWEETLAKE PROJECT
PLUG AND ABANDONMENT CONFIGURATION
SEPTEMBER, 1984

Figure 93. - - Schematic illustration of the tubular configuration of the MG - T / DOE Amoco Fee No. 1 test well (Sweet Lake) at the time of plug and abandonment (From Magma Gulf - Technadril Annual Report, 1982 - 1985, Volume 3).

surface and subsurface water, conducted at the Sweet Lake prospect site. In addition to Magma Gulf - Technadrilis Annual Report (1982 - 1985, Volume 3) information on these various types of monitoring can be found in environmental assessment reports by the U.S. Department of Energy (1980), Woodward - Clyde Consultants report for the Gas Research Institute on Subsidence (January, 1982) done under Contract No. 5080-351-0352, Final Report of Ambient Air Survey for Louisiana State University by Core Laboratories, Inc. Lake Charles, LA (1980 - 1982), Meyer and Associates, Inc. (1984) report on Leveling, and the Woodward - Clyde Consultants Final Report on microseismic monitoring (1984) prepared for the Louisiana Geological Survey and Louisiana State University. The environmental monitoring information compiled here is taken directly from the Magma Gulf - Technadril Annual Report (1982 - 1985, Volume 3).

AIR QUALITY

An ambient air quality and meteorological monitoring station was established approximately one mile northwest of the production well site. The station was installed during July 1980 and operated by Core Laboratories, Inc., Lake Charles, Louisiana. The station provided continuous records of hydrogen sulfide, sulphur dioxide, non-methane hydrocarbons, and total hydrocarbons in accordance with established EPA guidelines. Throughout the period of drilling, construction and testing there were no incidents of air pollution resulting from these activities, and no off site environmental impact on air quality. Air quality monitoring was discontinued at the Sweet Lake site at the end of 1981 as there was no continuing problems associated with the site and further monitoring was deemed unnecessary.

WATER QUALITY

Water quality monitoring was conducted by Louisiana State University. Monitoring was continued for a minimal period of time to detect potential contamination which may have logged behind actual abandonment. It is doubtful that enough production and subsurface injection occurred at the Sweet Lake site to adversely impact the natural waters in the area. Historically, subsurface injection from other sources has been shallower and possibly volumetrically greater so that, if detected, natural water contamination by brine may not be blamed solely on geopressured - geothermal production and injection. Three wells were drilled to monitor subsurface water and sampling stations to monitor surface water were established. Though a number of spatial and temporal variations were indicated by the water analysis data, no effects were observed due to the brine injection. Water quality seasonal variability may be due to a large number of causes including saltwater intrusion, waste dispersion or natural diagenetic processes. Also oilfield brines, mostly injected at a much shallower depth than the brines from the Sweet Lake test well, may find their way into shallow subsurface waters up faults or by molecular diffusion through semi-permeable shale membranes.

MICROSEISMIC MONITORING

The Louisiana Geological Survey (LGS) and Louisiana State University (LSU) conducted base line seismic studies at Sweet Lake, in addition to other test areas (Parcperdue, Gladys McCall and Pleasant Bayou) to investigate microseismicity and potential fault activation associated with geopressured - geothermal fluid production and injection. These monitoring programs were designed first, to establish the nature of local seismic activity prior to production,

and, second, to determine if well activities induced changes in the rate of local fault movement.

The Sweet Lake microseismic monitoring network consisted of eight field stations which were maintained by the University subcontractor Woodward Clyde Consultants. Data collected at each field station were multiplexed and transmitted over telephone lines to the central recording facility in Baton Rouge, Louisiana at the campus of LSU. At this central facility, all data were continuously recorded on a magnetic tape recording system. Selected station data were recorded on three drum recorders and the drum records were scanned daily to detect any seismic activity. A large number of microseismic events were recorded by the monitoring network and most of them were later attributed to be due to violent thunderstorm and rainfall activity in the area and surroundings. Of all suspected naturally occurring local seismic events detected during the monitoring period, only two had a seismic signature of known earthquakes in other parts of the country and were easily identifiable.

Sweet Lake had two flow testing periods. The first was for seven months in 1981 - 1982, and the second from November 1983 until the end of March 1984. Continuous seismic monitoring during this entire period has shown no correlation of events with flow testing.

All activity seems to have been at intermittent intervals throughout the three years. Microseismic monitoring continued after about a year (Spring, 1985) after the plugging and abandonment of the test well to access any long term effects that may have resulted from the Sweet Lake testing project. No effects were observed during this period.

SUBSIDENCE

To monitor the effect of geopressured - geothermal production on subsidence rates a

ground deformation monitoring array was installed at the Sweet Lake geopressured - geothermal testing site. Details of the subsidence monitoring are provided in the Annual Report (1982) by Woodward Clyde Consultants for the Gas Research Institute. The information on subsidence compiled here is directly taken from this report. The monitoring network consisted of closely spaced first order level marks, relevelled monthly, and tiltmeters of varying sensitivities with both continuous and periodic readout schedules. This network was operated by Woodward Clyde Consultants in conjunction with the microseismic monitoring array of light seismometers located around the well site. The combined network system began operation in May 1981 and provided data regarding both regional ground deformations and microseismic activity. No correlation was found between ground deformation (neither elevation fluctuation or tilt) or microseismic activity detected within the well site area to well testing activities. All detected deformation was attributed to be the result of ongoing natural processes in the area.

DOW-DOE L.R. SWEEZY NO. 1 WELL

The Dow-DOE L.R. Sweezy No. 1 well is located in the North Parcperdue field in Vermilion and Lafayette Parishes of Louisiana. The field is situated approximately twelve miles south of the city of Lafayette, just off Highway 339. The well is located in Section 26, Township 11 South, Range 4 East. Figure 94 shows a map of Louisiana and the general location of the Parcperdue Field plus the location of the E1 Tigre lagoon, the site of the Edna Delcambre well, the Gladys McCall design well test site, and the Sweet Lake design well test site. An inset of the Parcperdue area showing the test well site is also shown in this Figure (94). The surveyors

Figure 94. -- A Louisiana State map showing the general location of the Parcperdue Field. The inset map shows the test well site and the location of the Parcperdue Field relative to nearby city areas (From Dow Chemical Company, 1980, Volume 1, Drilling and Completion).

location plot of the test well is shown in Figure 95 and the of the saltwater disposal well is shown in Figure 96.

In the preliminary investigations The Dow Chemical Company located a geopressured - geothermal reservoir in the Parcperdue field in Vermilion Parish, Louisiana. This reservoir was situated in the *Cibicides jeffersonensis* (Cib jeff) sand of upper Oligocene age. It had an areal extent of a little more than one square mile, average thickness of 50 ft. and was at an average depth of 13,500 ft. The reservoir was overlain and underlain by thick shale sections and the bounding growth faults isolated the reservoir from outside water influx. In 1977 Dow submitted a proposal to the Department of Energy to test this reservoir by re-entering a plugged dry hole, the Phillips Petroleum No. 1-A Lee Roy Sweezy, T. D. 17,736 ft. Discussions led to the decision that a better alternative would be to drill a new well specifically to test the reservoir. The proposal was revised and in September 1979, Dow was awarded the Department of Energy Contract No. DE-AC08-79ET27255 for drilling and completing production and saltwater disposal wells, and for testing and evaluating the *Cib jeff* reservoir. The DOW-DOE L.R. Sweezy No. 1 well was spudded in January 1981, and was completed to a plug back total depth of 13,534 ft. in August 1981. Testing operations began in April 1982, and ended in February 1983, when the gravel pack gave way and the well sanded in.

Complete detailed information resulting from this project is provided in the final report by The Dow Chemical Company, 1984. This report also includes all final reports from subcontractors on this project as appendices in their entirety. The information compiled here is taken directly from Dow's Final report to the U.S. Department of Energy, Nevada Operations office done under DOE Contract No. DE-AC08-79ET27255. A list of all the subcontractors

R 4 E

I, Ellis L. Jones, hereby certify that the loc'n. of
The Dow Chem. Co. - D.O.E. Lee Roy Sweezy No. 1
is as follows: 1800' NORTH and 1350' EAST from
the Southwest corner of Sec. 26, T27 S - R 4 E,
Vermilion Parish, Louisiana

Ellis L. Jones

REGISTERED LAND SURVEYOR NO. 354 Figure 20
STATE OF LOUISIANA
JOHN E. CHANCE & ASSOCIATES, INC. 8-4

LOUISIANA DEPT. OF CONSERVATION

THE DOW CHEMICAL CO. - D.O.E.

PERMIT PLAT 5000

VERMILION PARISH, LOUISIANA

SCALE: 1" = 1000'

JAN 23, 1980

Figure 95. -- Location and permit plat of The Dow Chemical Company - DOE, L.R. Sweezy No. 1, geopressured - geothermal test well (From, The Dow Chemical Company, 1980, Volume 1, Drilling and Completion).

R 4 E

I, Ellis L. Jones, hereby certify that the loc'n. of
The Dow Chem. Co. - D.O.E. Lee Roy Sweezy No. 2 (S.W.D.)
is as follows: NORTH 1840' and EAST 1160' from
the Southwest corner of Sec 26, T11S-R 4 E,
Vermilion Parish, Louisiana

LOUISIANA DEPT. OF CONSERVATION

THE DOW CHEMICAL CO. - D.O.E.

PERMIT PLAT

Ellis L. Jones

REGISTERED LAND SURVEYOR NO. 354
STATE OF LOUISIANA
JOHN E CHANCE & ASSOCIATES, INC.

Figure 21

VERMILION PARISH, LOUISIANA

8-5

SCALE: 1" = 1000'

MAR. 6, 1980

Figure 96. -- Location and permit plat of the The Dow Chemical Company - DOE, L.R. Sweezy No. 2, brine disposal well (From, The Dow Chemical Company, 1981, Volume 1, Drilling and Completion).

employed on this project is provided in Appendix 3 of this report. The organizational chart for the drilling and testing program is shown in Figure 97 and the general organization of the Parcperdue project is shown in Figure 98. Due to the fact that a large number of investigators covering various diverse disciplines were involved in this like in all the other similar projects, the various results obtained were not in total agreement, and in some instances often contradictory. This was mainly because the results were obtained using different approaches and assumptions, and not because they were wrong. For example, the estimated reservoir sizes varied from 661 acres to over 900 acres, depending on whether geological, geophysical or pressure transient methods were used. In another case, source rock and PVT analysis showed the brine to be undersaturated while some of the chemical analytical results implied free gas and liquid hydrocarbon phases present in the reservoir.

The local geology was determined from surrounding well control, and using pre-existing seismic data. A 3-D seismic project was carried out by the University of Southwestern Louisiana under a separate contract to DOE (DE-AC08-81NV10185) and data obtained from this project resulted in a new interpretation of the structure. Drill cuttings, a 120 ft. whole core, paleontological analysis, and a complete suite of electrical well logs were also used to interpret the local geology.

The geopressured zone at Parcperdue occurs in sediments of Upper and Middle Oligocene age in the Anahuac and Frio formations. Figure 99 shows the paleogeologic zones of the Louisiana Gulf Coast based on foraminiferal picks. The top of the Oligocene is picked at the first occurrence of *Discorbis gravelii*, which is at a depth of about 12,700 ft. in the abandoned Phillips No. 1-A Sweezy well.

GEOPRESSURE WELL DRILLING & TESTING PROGRAM ORGANIZATION CHART

Figure 97. -- The organization of the drilling and testing program for the DOW-DOE L.R. Sweezy No. 1 geopressured-geothermal test well (From, The Dow Chemical Company, 1980, Volume 1, Drilling and Completion).

Figure 98. - - Organization chart for the DOE Parcerdue Project (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).

SERIES	FORMATION	FORAMINIFERAL ZONES		AGE (MILLION YEARS)
MIOCENE	FLEMING	<i>Discorbis</i> (12)		26
		<i>Textularia</i> (L)		
		<i>Bigenaria</i> (2)		
		<i>Textularia</i> (W)		
		<i>Bigenaria humboldti</i>		
		<i>Cristellaria</i> "1"		
		<i>Amphistegina</i> "B"		
		<i>Robulus</i> "43"		
		<i>Operculinoides</i> sp.		
		<i>Robulus chambersi</i>		
		<i>Marginulina ascensionensis</i>		
		<i>Siphonina davis</i>		
		<i>Planulina palmerae</i>		
OLIGOCENE	ANAHUAC	<i>Discorbis gravei</i>		37
		<i>Heterostegina</i> sp.		
		<i>Bolivina perca</i>		
		<i>Marginulina vaginata</i>		
		<i>Marginulina howei</i>		
	FRIO	<i>Camerina</i> "A"		
		<i>Cibicides hazzardi</i>		
		<i>Marginulina texana</i>		
		"Hackberry" fauna		
		<i>Nonion struma</i>		
		<i>Nodosaria blanchi</i>		
		<i>Discorbis</i> "D"		
		<i>Vicksburg (Herpin Sd.)</i>		
EOCENE		COCKFIELD		54
		SPARTA		
		WILCOX		

Figure 99. - - Chart showing the commonly recognized paleontological markers in South Louisiana (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).

The Abbeville field located to the southwest of the Parcperdue field produces from the *Camerina* "A" (Frio) and several Miocene zones. To the south the Tigre Lagoon field, site of the first geopressured test (Edna Delcambre) in 1975 has Miocene age production and the Maurice field to the west produces from the Oligocene (Anahuac and Frio) sands. Parcperdue field produces principally gas from the *Camerina* sands. The *Cib jeff* sand in this field produces gas in some wells and oil in others.

A structure map of the Parcperdue area contained on top of the *Cib jeff* sand is shown in Figure 100. As seen in this figure the Parcperdue area is traversed by a number of faults which intersect to form discrete blocks. The overall general structure is that of a faulted anticline. The objective geopressure - geothermal *Cib jeff* reservoir is in a fault block bounded by faults "A", "B", and "C" as shown in Figure 100. The target sand occurs at a depth of 13,350 ft., is approximately 50 ft. average thickness and represents an offshore barrier bar depositional environment. The areal extent of the *Cib jeff* reservoir in the fault block is approximately one square mile. The *Cib jeff* sand is continuous and relatively consistent in thickness over the test fault block as seen on the isopach map (Figure 101).

A 3-D survey of the area was conducted by Geophysical Systems Corporation (GSC) under a subcontract to the University of Southwestern Louisiana (USL). GSC also performed the data processing. Details of the 3-D Survey are documented in the final report of the USL DOE Contract No. DE-AC08-81NV10185 by Kinsland (1985). This survey resulted in the construction of a slightly different structure map of the area (Figure 102).

Figure 100. - - Structure map of the Parcerdue prospect contoured on top of the *Cib jeff* sand (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).

Figure 101. -- Net sand isopach map of the *Cib jeff* sand (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).

Figure 102. -- A revised seismic structure map of the Parcerdue prospect after completion and interpretation of the 3-D Seismic Survey over the area. The well numbers correspond to numbers in Table 26 (From, Kinsland, 1985, Final Report, Jan. 1981 - July 1985).

TABLE 26

(Numbers refer to wells shown on the seismic structure map on Figure 102).

Well Data

TD = Total Depth
 MH = subsea depth to mapping horizon/seismic 2 way time to mapping horizon

1. Phillips et al. #A-1 Sellers TD 17500 MH -12,630/3.02	16. Texaco #1 Sonnier TD 13620 MH -13310/3.18
2. Phillips et al. #A-1 Guidry TD 17190 MH -13055/3.12 430/-13870/3.32 LF/-16360/3.94	17. Texaco #1 Habert TD 13500 MH -13295/3.18
3. North American Royalties Inc. #1 Collins TD 16433 MH -12555/3.01 -200/-11750/2.85 -200/-13450/3.23	18. Stone #1 Broussard TD 16526 MH Part F/O -13060/3.16 120/-12470/2.99 80/-13060/3.12 110/-14200/3.39 280/-14950/3.57
4. Dow et al #1 Duhon TD 18000 MH - 12,895/3.09 500/-14330/3.42 LF/-17460/4.22	19. Texaco #1 Broussard TD 15274 MH F/O 220/-13125/3.14 -120/-14950/3.58
5. Dow - W.A.R. - Phillips #1 Blanchard TD 16560 MH -13140/3.15 240/-13430/3.22 850/-15250/3.65	20. Stone #2 Broussard TD 13250 MH -13055/3.12 200/-13030/3.12
6. Dow Chemical - W.A.R. #1 Bacque TD 15968 MH -13160/3.15 230/-14000/3.34 850/-15200/3.64	21. Phillips et al #1 Bares TD 17330 MH -13445/3.24 50/-12900/3.08 200/-15550/3.72
7. Dow W.A.R. - Phillips #2-I Blanchard TD 13317 MH -13115/3.14 130/-12350/2.96	22. Superior #1 P. Lablanc TD 18150 MH -13710/3.28 -100/-13700/3.28 150/-16360/3.94
8. Dow - W.A.R. - Phillips #1 (Viguerie) Landry TD 15640 TVD MH -13194/3.16 320/-13340/3.20 350/-14450/3.45 130/-15290/3.66	23. Texaco #1 Bares TD 15368 MH -13330/3.20 150/-14970/3.58
9. Dow/DOE #1 Suezey TD 13600 MH -13305/3.19	24. Stone #1 Baudoin TD 17850 MH Part F/O -12920/3.09 450/-12960/3.09 100/-13620/3.26 -100/-14860/3.55
10. Phillips #1 Suezey TD 17736 MH 13330/3.20 320/-14900/3.56 F/-16550/4.02	25. Stone #1 Green TD 16932 MH -13545/3.25 100/-13700/3.28 540/-14220/3.40 -200/-14900/3.56
11. Phillips #A-1 Denais TD 15995 TVD MH -13085/3.14 30/-12620/3.02 600/-14830/3.41	26. Stone #2 Green TD 16040 MH -13410/3.20 100/-14530/3.48 -390/-15400/3.70
12. Texaco #1 Bacque TD 14950 MH -13165/3.15	27. Stone #1 Alvin Richard TD 16835 MH -13555/3.26 LF/-16200/3.9
13. Texaco #1 Denais TD 12450 MH NDE	28. McRae Ex. #1 Richard TD 12795 MH NDE
14. Phillips #B-1 Habert TD 17805 TVD MH -13085/3.13 150/-12,200/2.94 50/-13030/3.12 430/-13920/3.33	
15. Texaco #1 Sonnier et al TD 12400 MH NOE	

(From, Kinsland, 1985, Final Report, Jan. 1981 - July 1985).

The complete suite of logs run on the production well is listed below:

- Dual induction - Short focus log-sonic (Figure 103)
- Compensated Neutron - formation density
- Saraband computer log
- Mechanical Properties Computer log
- Continuous dipmeter
- Differential temperature
- Borehole geometry
- Continuous directional survey

All the production logs were run by Schlumberger, except the differential temperature log, which was run by Gearhart. Examples of all the logs over the target section are to be found in the final project report by The Dow Chemical Co. (1984).

Paleontological analyses of the well samples was done by George N. May and Associates of Lafayette. A summary of their report is given in Table 27.

Two cores of 60 ft. length and 4 inch diameter each were recovered from the test well across the target reservoir interval between 13,340 ft. to 13,460 ft. Core recovery was excellent considering the unconsolidated nature of portions of the reservoir sand. The coring was done under the supervision of Christiansen Diamond Product, Inc. The upper core was cut just above the top of the sand and the second core cut approximately 45' of shale below the sand. Two feet of shale were recovered from above the sand, and approximately 68 ft. of siltstone and shale were recovered from below. Total sand recovery was approximately 70 ft., approximately half of which represented potential reservoir sand. Figure 104 shows a vertical profile characterizing the

DOW-DOE NO.1 L.R. SWEETZ
SCHLUMBERGER

DUAL INDUCTION-SFL-SONIC

SP (MV)		JLD (OHMM)		CILD (MM/M)	
-160.0 40.00		0.0 10.00		0.0 4000. 0.0	
		SFLA (OHMM)			
		0.0 2.000			
		SFLA (OHMM)			
		0.0 10.00 4000. 0.0			

COMPANY THE DOW CHEMICAL COMPANY		SCHL FR13528
(SIDETRACK HOLE)		SCHL TD13531
WELL LEE ROY SWEETZ NO. 1		DRLR TD13533
FIELD PARC PARQUE		Elev:
COUNTY VERMILION STATE LOUISIANA		KB -
		DF -
		GL -

Figure 103. - - Dual induction - SFL - sonic log of the Parcperdue test well showing porosity zones (From, The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).

TABLE 27

GEORGE N. MAY & ASSOCIATES

Consulting Geologists and Paleontologists

408 HEYMANN BLVD.

P. O. BOX 51858

LAFAYETTE, LOUISIANA 70505

PALEONTOLOGICAL REPORT

DOW CHEMICAL CO.—D.O.E.

LEE ROY SWEZY # 1

SECTION 26-T11S-R4E

PARCERDUE FIELD

VERMILION PARISH, LA.

May 21, 1981

S U M M A R Y

SAMPLE RANGE 11500'	-----	13600'
IN SIPHONINA DAVISI	-----	11500'
CRISTELLARIA 47	-----	11900'
NODOSARIA VERTEBRALIS	-----	12170'
DISCORBIS GRAVELLI	-----	12780'
HET SP. (VERY RARE)	-----	12880'
CIBICIDES JEFFERSONENSIS	-----	13140'
BOLIVINA PERCA	-----	13490'

NO FURTHER DIAGNOSTIC FOSSILS WERE ENCOUNTERED.

Respectfully submitted

George N. May
George N. May

Samples worked by
George May & Bill Grubb

(From, The Dow Chemical Company, 1984, Final Report Appendices)

Figure 104. - - Vertical profile of the cored interval for the DOW-DOE L.R. Sweezy No. 1 test well (From, Sinha et al 1981, Terratek Final Report).

entire cored interval. Terratek, Inc., did the core handling in the field and also performed lithologic and petrographic descriptions of the core, determined physical properties, and did detailed rock mechanics testing of the core material. Samples of the core were sent to Core Laboratories for conventional porosity and permeability determination; to Davell for sieve analysis and acid solubilities, to the Dow laboratory, Freeport, Texas for scanning electron micrography, x-ray diffraction, and x-ray emission studies; and to Geochem Laboratories, Houston, Texas, for source rock (shale) geochemistry. Samples were also taken by the U.S.G.S., Bay St. Louis, Miss. for additional work.

A summary of the permeability and porosity analysis on the core samples performed by Corelab, Lafayette is shown in Table 28. Average porosity was 28% and average permeability was 3,700 md. Terratek, Inc., of Salt Lake City performed the detailed description of the core material and petrographic analysis of thin sections. Complete details of the Terratek investigations can be found in their final report of November 1981 which is also reproduced in the Dow final report (1984). As mentioned earlier, information compiled herein is taken directly from all these reports. Both core examination and well logs indicated two distinct zones, upper and lower, both reflecting the depositional history and diagenesis of the sand and surrounding shale facies (Figure 104). Both zones have similar mineralogies but the ratio of the sand to clay contents differ significantly. The lower sand interval (13,391 ft. - 13,424 ft.) exhibits an abundance of sedimentary structures, and sand grains are mostly subangular, fair to poorly sorted, and average 0.15 mm in size. Detrital grains are predominantly quartz (about 60%), feldspar (5-10%), volcanic lithic fragments (5-10%) and minor mafics. Bonding agents are predominantly clay with some glauconite and carbonate cements. Much of the clay found in this lower zone is

TABLE 28

PERMEABILITY AND POROSITY ANALYSIS

<u>Samp.</u>	<u>Depth</u>	<u>Perm. MD.</u>	<u>Por. %</u>	<u>Description</u>
2	13342.5	260	25.9	SD VF-PG SHY
3	13343.2	810	22.2	SD FG SSLTY
4	13344.5	4550	26.4	SD FG CLN
5	13346.5	4370	29.7	SD FG CLN
6	13348.5	4780	29.2	SD FG CLN
7	13350.0	4740	30.1	SD FG CLN
8	13352.7	5160	27.8	SD FG CLN
9	13355.5	7780	29.6	SD FG CLN
10	13357.6	6580	29.3	SD FG CLN
11	13360.5	3650	28.1	SD FG CLN
12	13362.2	2590	27.8	SD FG CLN
13	13364.0	1420	27.8	SD FG CLN SSLTY
14	13365.5	2300	27.4	SD FG CLN
15	13367.5	5350	28.6	SD FG CLN
16	13368.5	27	22.7	SD VGD SSHY SLIG (L) SSLTY
17	13369.5	825	29.4	SD FG SSLTY
18	13370.5	7620	30.5	SD FG CLN
19	13372.5	4920	30.4	SD FG CLN
20	13375.5	2930	29.1	SD FG SSLTY
23	13390.0	205	28.4	SD VFG SLTY
24	13394.5	410	31.5	SD VFG SLTY
27	13397.5	1260	29.2	SD VF-PG SSLTY
28	13400.0	.06	14.8	SD VFG SSHY SLTY
29	13401.0	36	23.3	SD VFG SLTY
30	13402.0	46	21.1	SD VFG SLTY
32	13404.0	15	21.2	SD VFG VSLTY
33	13406.0	265	25.2	SD VG-PG SSLTY- SLTY
36	13409.0	.26	18.6	SD VFG VSLTY
46	13419.0	0	10.2	SD VFG VSLTY VCALC
61	13438.0	.63	13.1	SD VFG SHY (L) VSLTY
71	13450.0	.35	12.2	SD VFG SS-SHY (L) VSLTY
78	13454.0	1.1	20.9	SD VFG VSLTY

(From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

detrital and was probably produced as a by product of bioturbation. Although the porosity values obtained at bench conditions are high averaging 28%, fluid permeabilities are low for this porosity and is probably due to the high clay content within the pore throats is revealed by SEM photographs during these studies. Further, these clays are loosely bound and appear to be extremely susceptible to mobilization with brine flow through the rock matrix. Therefore clay bridging at pore throats was determined to be a distinct probability during flow testing of this geopressured - geothermal reservoir.

The upper sand interval (13,343 ft. - 13,391 ft.) exhibited larger grain size (average 0.3mm), improved sorting, rounded detrital grains and a greatly reduced clay matrix fraction. The sand is generally friable and in some sections a total of approximately 5 ft. is practically unconsolidated. Mineralogically, detrital grains are predominantly quartz (approximately 70%) with feldspar and volcanic lithic fragments composing 5 - 10% each. Matrix components are authigenic clays (average 3%), trace mafics and early carbonate cement remnants. Bench condition porosities are unusually high (about 30%) and fluid permeabilities are in the range of one hundred millidarcies to one darcy. Permeability values are approximately an order of magnitude higher than those measured from core samples in the lower sand zone. The upper sand zone exhibits fewer sedimentary structures and minimal bioturbation compared to the lower sand interval. Clays found in the upper zone are authigenic and are believed to have occurred late in the diagenesis of the sand.

Secondary porosity development constitutes the predominant form of effective porosity found in the *Cib jeff* sand. Pore geometries have been altered with secondary porosity development. Approximately half of the total sand interval has excellent reservoir potential based

on petrographic analysis. Evidence supporting the existence of secondary porosity was documented in thin section analyses based on the observance of partial dissolution of the soluble constituents, inhomogeneity of packing, recognizable molds, oversized pores, elongate pores, corroded grains, honeycombed grains and fractured grains.

Normal compaction and cementation proceeded with burial of the *Cib jeff* sand, and consequently primary porosity was reduced to less than 10% at depths of a few thousand feet (Figure 105a). The upper zone core sample porosities at bench conditions of about 30% are difficult to understand when considering compaction and loss of fluids within the pore spaces at depths below a few thousand feet. With burial of Gulf Coast sediments, mud with up to 80% pore water is dewatered by compaction until porosity is about 15% at depths of several thousand feet. Figure 105b shows the decrease of shale porosity with depth, and also shows that water squeezed from the mud enters the more permeable sands and flows laterally through the sands toward the surface. Various chemical reactions accompany shale dewatering and water chemistry changes compositionally updip as dissolved ions are exchanged and removed. Fluids from shale dewatering flowed preferentially into the massive upper zone within the *Cib jeff* sand where near complete secondary leaching of carbonate cements, feldspars, and lithic fragments occurred. Migration of abundant clay into pore throats and presence of detrital clays within the lower zone prevented secondary porosity development to the degree of that seen in the upper zone. The textural development of secondary porosity is illustrated in Figure 106. Primary porosity was destroyed with carbonate cementation and initial compaction. Feldspars and lithic fragments were also subjected to partial solution and replacement by carbonate. With diagenesis and flow of pore

(a)

SHALE DEWATERING

(b)

Figure 105. -- (a) Depth distribution and evolutionary sequence of primary and secondary porosity. (b) Shale porosity versus depth, and flow paths of shale water during compaction and diagenesis (From The Dow Chemical Company, Appendix E - Rock mechanics - TerraTek reports, 1984).

Figure 106. -- The different evolutionary stages in the textural development of secondary porosity (From Sinha et al, 1981, TerraTek, Final Report)

fluids through the rock matrix, preferential solution of carbonate occurred, creating secondary porosity.

Permeabilities within the *Cib jeff* sand will be the highest (>100 md) in the upper sand interval where secondary porosity development is greatest. They will also remain higher during production due to the lesser stress sensitivity of this interval. Clay migration poses the biggest threat when producing fluids from the *Cib jeff* sand. Special consideration was advised to be given to avoid high initial flow rates in the well, causing mobilization of authigenic clays and fines into pore throats.

A total of five core samples, numbered 1 through 5 and shown in Figure 107 were selected for mechanical testing. Five shale core samples (D 113, D 123, D 125, D 132 and D 134) also shown in figure 107, were sent to USGS for permeability measurements. A total of seven mechanical tests and five high resolution permeability tests were run on the core material. In addition, the core was characterized by determining six physical properties (Table 29). Terratek performed tests consisting of several hydrostatic, triaxial and uniaxial loading and unloading cycles. Pore pressure reductions were designed to provide measurements for calculating several mechanical and transport properties. A schematic description of these tests is shown in Figure 108a. Average values of the mechanical and transport properties derived from these tests are shown in Figure 108b. A summary of all the test results and ranges of values obtained for different parameters are given in Table 30. Detailed information on these tests are provided in the final report by Terratek (1981).

Three shale samples were selected and sent to Geochem Laboratories, Inc. for geochemical analyses. These analyses included: a) Total organic determination and gross

Figure 107. -- Core test and petrographic analysis intervals (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).

TABLE 29

Physical properties of core from the Parcperdue test well

Sample I.D.	Depth (ft)	Natural Density (gm/cc)	Dry Density (gm/cc)	Effective Porosity (%)	Total Porosity (%)	Permeability (md)	Grain Density (gm/cc)
D113	13,431	2.16	2.06	24.4	25.0		2.72
D123	13,439	2.31	2.09	23.5	23.8		2.73
D125	13,444	2.33	2.09	23.5	25.7		2.73
D132	13,449	2.28	2.03	25.4	25.5		2.72
D134	13,451	2.25	2.02	25.4	26.0		2.70
1	13,345	2.14	1.97	26.1	26.1	1972	2.66
2	13,354	2.16	1.89	28.9	30.1	5524	2.66
3	13,378	2.02	1.84	30.8	30.9	1106	2.66
4	13,368	2.04	1.79	32.8	32.7	1768	2.66
5	13,396	2.04	1.86	30.2	30.3	415	2.67

(From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

(a)

Parameters	Values	Number of Values Used In Averaging
Porosity	$(29.9 \pm 3.81)\%$	16
Young's Modulus	$(1.06 \pm 0.43) 10^6 \text{ psi}$	11
Shear Modulus	$(0.51 \pm 0.25) 10^6 \text{ psi}$	16
Bulk Compressibility	$(4.93 \pm 1.9 \sim 2.82 \pm 0.80) 10^{-6} \text{ 1/psi}$	14 and 10
Compaction Coefficient	$(0.56 \pm 0.16) 10^{-6} \text{ 1/psi}$	7
Permeability Coefficient (at reservoir condition)	6 ~ 914 md	Varies greatly and averaging these may not be meaningful.
Electrical Resistivity at 106°C	217 $\Omega \text{ m}$	1

(b)

Figure 108. -- (a) Schematic description of tests to obtain mechanical and transport properties, (b) Average values of mechanical and transport properties (From The Dow Chemical Company, Appendix E, - Rock mechanics - TerraTek reports, 1984).

TABLE 30

Summary of Results Describing Deformation Characteristics

Rock Type	Sample Number	Depth (ft)	Porosity (%)	Young's Modulus (psi) x10 ⁶	Shear Modulus (psi) x10 ⁶ **	Compressibility ($\frac{1}{\text{psi}}$) x10 ⁻⁶ **	Compaction Coefficient ($\frac{1}{\text{psi}}$) x10 ⁻⁸
Compaction							
Sandstone	6	13,344	28.6	1.26 3.24†	0.58 1.31†	3.30~1.38	0.35 0.30††
	33	13,364	25.8	0.84 1.27†	0.36 0.49†	10.30~1.95	0.35
	35	13,366	28.0	1.69	0.61	6.66~2.26	0.46
	67A	13,389	30.1	0.60	0.25	5.12~3.54	0.72
	68	13,390	26.7	1.55 2.16†	0.35~1.0 0.85†	5.08~3.19	0.65
Shale	129	13,446	20.2	0.54	--	3.15	--†††
Triaxial (to failure)							
Sandstone	41	13,371	36.2	1.18	0.75~0.45	3.52~2.58	--
	42	13,372	33.7	0.97	0.45~0.44	4.87~2.95	--
	75	13,395	27.9	0.96	0.51~0.37	5.59~3.85	--
Creep							
Sandstone	71A	13,393	29.6	1.58	1.06~0.52	4.06~2.83	0.70
	67B	13,389	30.1	0.68	0.30	4.42~3.69	0.66
Compaction or Creep§							
Sandstone	78	13,398	30.2	0.40	0.19	6.06	--
	7	13,344	23.0	--	--	3.24	--
	10	13,346	30.4	--	--	3.45	--
	40	13,369	37.5	--	--	--	--
	48	13,373	33.2	--	--	--	--
	80	13,400	26.7	--	--	3.33§§	--
						2.66§§	--
						2.55§§	--

*The range of values correspond to initial and final stages of triaxial loading phase.

**The range of values correspond to stress range between zero effective stress and reservoir conditions.

†These values were obtained from sonic velocity measurements.

††This value was obtained by repeating the uniaxial compaction phase.

†††Experimental results indicated a compaction coefficient of 0.85×10^{-6} 1/psi in this case.

However, further investigation of the failed specimen indicated that during the testing a horizontal failure (along the bedding) was created in the specimen just above the lateral strain transducer stand-offs and the failure was confined in the upper half of the specimen. This resulted in recording of all the axial compression, but no lateral extension and hence a fictitiously high compaction coefficient.

§Partially completed tests (not completed due to specimen or equipment failure).

§§These values were obtained during subsequent loading cycles.

(From, Sinha et al, 1981, Terratek Final Report)

lithological description, b) pyrolysis analysis, c) C_{15} + Soxhlet extraction, deasphalting and complete liquid chromatography separation of hydrocarbon and non-hydrocarbon fraction, d) C_{15} paraffin - naphthene gas chromatography, e) visual kerogen content, f) vitrinite reflectance analysis, and g) palynological examination. The lithological description and organic carbon analyses are given in Table 31. The results of the vitrinite reflectance analyses indicates an immature thermal maturation of the sediments, with an average percentage R_o of 0.41% and 0.4% respectively for the two core samples analysed. The depth / temperature zones of hydrocarbon generation are shown in Figure 109. The Parcperdue samples lie close to the zone of light oil and gas generation. The sediments analysis from the DOW - DOE L.R. Sweezy N. 1 well from the test target interval (13,418 ft. to 13,448 ft.) Have immature, poor hydrocarbon source character source rock characteristics are summarized in Table 32. On the basis of data obtained from all these analyses, it was determined that these shales may not have been the source of gas in the geopressure zone. The palynological data indicated that these shales were deposited in a near shore environment which did not have large accumulations of organic matter. Source rock quality showed that the Parcperdue samples fell in the region of non oil sources (Figure 110).

Drilling operations for the DOW - DOE L.R. Sweezy No. 1 Production well commenced on January 2, 1981, and were completed on August 14, 1981. The drilling rig, designated Welsh No. 17 and rated at 18,000 ft., was contracted through competitive bidding with Welsh Drilling and Services, Inc., Houston. The contract was a Daywork Drilling Contract and included drill crews, drill pipe, and fuel furnished for a constant 24 hour day rate. All equipment, labor, and expense to move in, rig up, rig down, and move-out were covered by a one time mobilization fee. The final well plan was approved by DOE and schematic illustrations of the wellhead, casing

TABLE 31

ORGANIC CARBON ANALYSES AND GROSS LITHOLOGICAL DESCRIPTION

Well Interval (Feet)	Gross Lithological Description.	GSA Color Code	Total Organic Carbon (% of Rock)
13418.4	100% Shale, noncalcareous, very slightly silty, slightly micromicaceous, very slightly pyritized, subcentimetric silt intercalated, slightly bedded, chunky, moderately soft, olive gray.	5Y 4/1	0.24
13424	100% Shale, noncalcareous, very slightly carbonaceous, glauconitic, very slightly micromicaceous, massive, chunky, moderately soft, olive gray.	5Y 4/1	0.23; 0.24R
13448.5	100% Shale, noncalcareous, very slightly carbonaceous, glauconitic, very slightly micromicaceous, massive, chunky, moderately soft, olive gray.	5Y 4/1	0.27

(From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

TABLE 32

SHALE SOURCE ROCK CHARACTERISTICS

DOW-DOE NO. 1 SWEEZY

	<u>SAMPLE No.</u>		
	<u>1</u>	<u>2</u>	<u>3</u>
DEPTH			
Total organic carbon	0.24	0.24	0.27
Extract Bitumen ppm	46		27
Free HC mg/g	0.13	0.04	0.11
HC Potential mg/g	0.26	0.07	0.11
% Paraffin	36.0		39.5
% Aromatic	63.6		59.8
% Isoprenoid	0.4		0.7
Pristane/Phytane	0.67		1.33
C.P.I.	1.29		1.70
Vitranite Reflect %	0.41		0.40
Maturation Index	1+		1+

(From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

Figure 109. - - Schematic illustration showing type of hydrocarbons produced by thermal disintegration and where the Parcperdue sample lie in this scheme: (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).

Figure 110. -- Source rock quality of the Parcerdue samples as related to potential hydrocarbon generation (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

detail, wellbore completion and the gravel pack completion detail are shown in Figures 111, 112, 113 and 114 respectively. Complete details of the drilling history are provided in The Dow Chemical Company Final Report (1984).

The proposed total depth was 13,600 ft. and the objective was, as mentioned earlier, was the Upper Oligocene *Cib jeff* sand. Drilling proceeded with only minor problems to the top of the *Cib jeff* sand. At this point, two, conventional diamond bit, sixty foot cores were successfully cut. Total depth was reached and the hole was logged in April, 1981. While tripping the drill string out of the hole, the tongs engaged and broke the drill string and 2,463 ft. of drill pipe and bottom assembly fell to the bottom of the hole. Fishing operations failed to recover the entire string and the hole was side tracked to total depth and logged. A second major incident occurred when threads failed while attempting to run casing, and 262 joints of 7 $\frac{5}{8}$ " - 8 $\frac{5}{8}$ " casing dropped into the hole. Again, an incomplete fishing job required a second side track hole. The well was successfully completed in the second side track hole. The unconsolidated nature of the sandstone, as observed in the core, required that the well be gravel packed to minimize sand production. The well was completed in August 1981. The *Cib jeff* sand was perforated from 12,349 ft. - 12,388 ft. and 13,395 ft. to 13,406 ft., using 12 shots per foot with Schlumbergers 4" Big Hole Casing jet. After acidizing the perforated interval and performing all the other completion operations the drilling rig, Welsh Rig 17, was released by Dow Chemical at 0800 hours on August 16, 1981 and rig down and move out was completed on August 26, 1981.

The saltwater disposal well was drilling from February through March of 1982. The well is designated by the State of Louisiana as DOW/DOE L.R. Sweezy No. 1 SWD, but has been referred to in all the reports as DOW/DOE L.R. Sweezy No. 2. This well is located 1,840 ft.

Figure 111. - - Schematic illustration of the wellhead and X-Mas tree for the DOW-DOE L.R. Sweezy No. 1 test well (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983).

DOW CHEMICAL / D.O.E.
L.R. SWEETZ NO.1
CASING DETAIL

Figure 112. - - Casing detail of the DOW-DOE L.R. Sweetz No. 1 well (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

DOW CHEMICAL/D.O.E.
L.R. SWEETZ NO. 1
WELLBORE AND COMPLETION SCHEMATIC

Figure 113. -- Schematic illustration of the wellbore and completion of the DOW-DOE L.R. Sweetz No. 1 test well (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

Figure 114. -- Gravel pack and completion detail of the DOW-DOE L.R. Sweezy No. 1 test well (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

from the south line and 1,160 ft. from the west line of Section 26, Township 11 South, Range 4 East. The location was shown earlier in Figure 95. The drilling rig, designated Well Tech No. 330, was contracted through competitive bidding from Well Tech, Inc. Lafayette, Louisiana. The contract was a day work drilling contract, including drill crews, but did not include drill pipe or fuel. All equipment, labor, and expense to move in, rig up, rig down and move out were covered by a one-time mobilization fee.

The saltwater disposal well was designed to dispose of up to 20,000 barrels of saltwater per day for a period of at least one year. The wellbore and completion details of the furnished well are shown in Figure 115.

The L. R. Sweezy No. 2 disposal well was drilled without incident and a total depth of 5,011 ft. was reached on February 21, 1982. The spud date for this well was 1,130 hours on February 8, 1982. Completion was attempted in the interval 4,520 ft. - 4,660 ft., but after perforating, sand entry was excessive for good disposal operation. The rig work was then temporarily suspended and the rig was released on March 1, 1982. Completion work was resumed on March 18, 1982. The perforated interval 452 ft. - 4,660 ft. was cleared of tight spots and sand was circulated out to plug back total depth of 4,956 ft. until hole stayed sand free. After this a gravel pack assembly was put in place and the gravel pack was acidized. Work on the saltwater disposal well was completed on March 25, 1982.

The disposal zones are located in Miocene sands. The well was logged with an Induction - electrical B.H.C. sonic log and a Compensated Density / Compensated Neutron log. This latter log (CD/CN) failed due to large diameter washout through the disposal formation. The logs were run by GO International. The IES / Sonic log is shown in Figure 116. No whole core, sidewall

DOW CHEMICAL/D.O.E.
L. R. SWEETZ N. 2
WELLBORE AND COMPLETION DETAIL

Elevations:
RT to THF - 15.3'
RT to BHF - 17.1'

16", 1/2" wall, Grade B, welded
Driven to 185' (168' penetration w/147 BPF w/D-22 hammer)

Tubingless Completion - Injection Down 7 5/8" Casing

10 3/4" casing @ 2721'
0' - 1650' 40.5#/ft., K-55, STAC
1650' - 2721' 55.5#/ft., AR-95, BTRC
Cemented w/1200 SXS Dowell Light Wate @ 12.5 ppg +
1050 SXS Class 'H' w/.5% CaCl₂ + .2% D-46 mixed @ 15.6 ppg.
Had 44 bbls cement returns @ Surface.

ITEM	DESCRIPTION	O.D. (IN)	I.D. (IN)	LENGTH (FT)	TOP (FT)
1	Dowell Model 16E G. P. Packer w/part closing sleeve	6.437	3.25	7.90	4,337.60
2	5 Jts. 4", 11.60#/ft Blank w/ weld-on centralizers each 15'.	4.0	3.428	31.83 31.82 31.83 31.83 8.60	4,345.50
3	5 JTS. 4", .012 gauge stain- less steel all-welded screen (Howard Smith) w/weld-on centralizers each 15'. Blank on each jt. - .90' bottom, 1.20' top.	4.545	3.428	23.20 31.80 32.80 31.80 31.80	4,513.25
4	Wash Pipe Seal Sub	4.00	2.750	1.35	4,664.45
5	Tattle-Tail Screen 4", .012 gauge stainless steel all-welded	4.545	3.428	6.15	4,665.80
6	X-over 4", NU x 3 1/2", SRD	4.688	3.428	.55	4,671.85
7	Baker Model 'E' Locator/ snap-latch	5.00	3.00	.50	4,672.50
8	with Baker 91-40 seals w/mule shoe	4.00	3.00	3.22	4,673.00
9	End of Tubing				4,676.22
	Baker Model 'F' Packer (size 91-40) Set w/elect. line @ IEL measurements.	6.50	4.00	2.10	4,673

Brine Disposal Sand - Perforated: 4520' - 4560' w/4 SPF
4560' - 4607' w/8 SPF
4607' - 4640' w/12 SPF
4646' - 4660' w/12 SPF

All perforations IEL measurements w/5" Big Hole Jet.
Gravel-packed w/20-40 mesh sand--4,425 lbs in annulus and 3,450 lbs in formation.

Minimum Restrictions: 3.25" @ 4,337' - Top of G. P. packer
2.75" @ 4,664' - Seal Bore Sub.

7 5/8", 26.4#/ft., J-55, LT&C Casing @ 5001' cemented with 250 SXS Dowell Light Wate @ 12.5 ppg + 1000 SXS Class 'H' w/.5% D-65 + .2% D-46 mixed @ 16.2 ppg. Had 63 bbls cement returns to surface.

Figure 115. -- Schematic illustration of the well bore and completion detail of the DOW-DOE L.R. Sweetz N. 2, brine disposal well (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

DOW-DOE L.R. SWEETZ NO. 2
(NO.1 SWD) GEARHART
INDUCTION ELECTRICAL/BHC SONIC LOG

Figure 116. - - Induction sonic electric log of the Parcedue saltwater disposal well showing the brine disposal zone (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

core, or formation tests were run. A summary of formation characteristics is given below:

Perforation depth: 4,520 ft. to 4,660ft.

Net sand thickness: 134 ft.

Bottom Hole Temperature: 101°F

Formation Salinity (R_{wa}): 25,000 ppm

Sonic Porosity: 35%

RESERVOIR TESTING

Eleven pressure draw down and build up tests were conducted in the test well from April 1982, through January 1983, to obtain adequate short-term and long term pressure responses under variable flow conditions. A summary of all these tests is given in Table 33. Long term build up analyses were performed first and long term draw down analyses second. The long term build up analysis yielded simultaneous evaluations of permeability - thickness, $k (pi) h$; permeability at initial pressure $k (pi)$, skin effect, s ; turbulent flow constant, D ; hydraulic diffusivity, $k/\phi\mu c_t$; and four boundary distances d_1, d_4 , comprising a rectangular shape approximation of the aquifer. From these results, the initial aquifer water volume, W ; the average rock compressibility, c_f ; and static aquifer pressure, P ; were determined. Long term draw down analyses were performed next to compute W , c_f and P . With exception to c_f , reasonable comparisons were found between W and P . Significantly different rock compressibility values were obtained from the build up and draw down analyses at essentially equal static aquifer pressures.

TABLE 33
SUMMARY OF EVENTS

TEST NO. DATE	TOTAL DURATION (HOURS)	Q _w AVERAGE FOR FLOW (BBL/D)	Q _w LAST PRIOR TO SHUT-IN (BBL/D)	CUMULATIVE TOTALS FROM RATE SCHEDULE		FINAL MEASURED PRESSURE IN EVENT (PSIA)
				WATER SEP BBL	GAS MSCF	
DD1&2 4/26 & 4/28/82	5.72	1467	14,016	2843.35	58.88	10,548.178
BU2 4/28/82	7.25	-	-	2843.35	58.88	11,282.809
DD3 5/12-13/82	30.84	6449	6445	11,396.70	211.99	10,968.888
BU3 5/13-17/82	96.08	-	-	11,396.70	211.99	11,397.801
DD4 5/17-18/82	25.69	8562	8646	20,771.50	407.20	10,718.872
BU4 5/18-20/82	34.34	-	-	20,771.50	407.20	11,385.300
DD5 5/20-26/82	144.02	10,914	10,752	86,264.20	1,584.98	10,247.650
BU5 5/26-6/2/82	170.42	-	-	86,264.20	1,584.98	11,284.480
DD7&8 6/2-28/82	624.00	9491	9465	313,679.00	6,352.60	10,191.810
BU8 6/28-7/2/82	187.13	-	-	313,679.00	6,352.60	11,037.040
DD9 7/6-8/27/82	1,248.00	9353	9360	798,809.00	14,436.30	10,136.553
BU9 8/27-30/82	72.02	-	-	798,809.00	14,436.30	10,506.683
DD10 8/31-11/2/82	1,539.10	8434	8520	1,310,150.00	22,592.10	9,905.980
BU10 11/2-5/82	72.42	-	-	1,310,150.00	22,592.10	10,210.260
DD11 11/15/82-1/19/83	1,560.00	8346	8334	1,846,840.00	30,591.10	9,637.620
BU11 1/19-23/83	72.41	-	-	1,846,840.00	30,591.10	9,891.640

(From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

A meaningful aquifer description was obtained from analyses of the late time draw down and build up behaviors after sufficient flow time was achieved for all aquifer boundaries to influence the pressure response at the well. Other analyses results such as permeability, skin effect and turbulent flow constant obtained from linear profile trends at earlier test times appear to be influenced by the propagation of rock compaction. This early-time transient nature of rock compaction coupled with its relatively large magnitude causes a gradient permeability to develop around the wellbore. The region of reduced permeability prior to stabilization of the pressure responses significantly reduces the flow efficiency of aquifer fluids into the wellbore. The analyses results are summarized in Table 34. The average calculated boundary distances of the approximate rectangle aquifer shape are 274 ft., 2,740 ft., 2,403 ft. and 10,309 ft., respectively, from the wellbore. These boundaries enclosed an aquifer area of approximately 880 acres in an elongated rectangle shape. A reasonable comparison of this shape with the geologic results is shown as superposed on the structure map of Figure 117. It is possible that part of the closing geologic fault shown in Section 34 on this map is non sealing due to sand thickening and a relatively small fault throw.

A graphic representation of gas and brine production from startup in April 1982, to shut-down in February 1983, is shown in Figure 118. The major shut-in events, build up tests and equipment repairs, are labeled. The average production rates and the periods of performance of the flow tests made on the DOW - DOE L.R. Sweezy No. 1 test well are depicted in Figure 119. The short term tests, flow test No. 1 through flow test No. 4 were designed to estimate formation properties and for draw down periods measured in hours. Intermediate - term tests, flow test No. 5 through flow test No. 8, were for a few days and were designed to test for reservoir boundaries.

TABLE 34

SUMMARY OF DRAWDOWN AND BUILDUP ANALYSES
DOW/DOE NO. 1 L. R. SWEETZ WELL

TEST TYPE/NO.	S_y (psi)	S_y (+ft)	$k(p)$ (md)	s (-)	D (1/SBPD)	W (MMB)	$\bar{p}$ (psia)	C_f (v/v/ft/psi)	D_1 (ft)	D_2 (ft)	D_3 (ft)	D_4 (ft)
BU2	0.73	-	402.6	2.25	0.000447	-	-	-	-	-	-	-
	0.09	-	758.4	8.36	0.000968	-	-	-	-	-	-	-
DD3	0.70	-	195.4	-6.18	0.000000	-	-	-	-	-	-	-
BU3	0.03	-	746.0	16.25	0.002039	-	-	-	-	-	-	-
	0.06	-	1477.1	34.50	0.004923	-	-	-	-	-	-	-
DD4	1.20	-	174.2	-6.08	0.000000	-	-	-	-	-	-	-
BU4	0.32	-	341.1	-4.05	0.001782	-	-	-	-	-	-	-
	0.05	-	669.7	12.09	0.002003	-	-	-	-	-	-	-
DD5	3.36	-	185.0	-6.03	0.000000	-	-	-	-	-	-	-
BU5	0.01	-	840.5	30.52	0.001689	-	-	-	-	-	-	-
	0.04	-	959.8	32.64	0.002242	-	-	-	-	-	-	-
DD7&8	0.42	-	117.3	-6.05	0.000000	-	-	-	-	-	-	-
	3.57	7040	-	-	-	96.047	11300.8	21.020	-	-	-	-
BU8	0.17	-	264.5	0.74	0.000762	-	-	-	-	-	-	-
	0.05	-	507.0	10.49	0.001218	-	-	-	-	-	-	-
	1.27	-	796.4	17.89	0.002103	96.127	11320.6	5.768	275	2678	2436	10272
DD9	2.30	-	379.7	-8.75	0.000000	-	-	-	-	-	-	-
	3.64	9645	-	-	-	95.096	11176.1	29.032	-	-	-	-
BU9	0.03	-	857.1	7.14	0.000760	-	-	-	-	-	-	-
	0.10	-	1410.4	15.18	0.001483	-	-	-	-	-	-	-
	0.38	-	1022.7	7.32	0.001101	82.300	11163.4	8.598	270	2739	2498	8181
DD10	0.95	-	844.7	-6.23	0.000000	-	-	-	-	-	-	-
	0.82	2764	-	-	-	100.414	11109.2	36.305	-	-	-	-
BU10	0.09	-	398.3	-1.55	0.000466	-	-	-	-	-	-	-
	0.32	-	1204.3	6.68	0.001314	-	-	-	-	-	-	-
	0.52	-	993.2	3.56	0.001009	101.511	11078.1	8.916	285	2900	2397	10049
DD11	0.08	-	652.7	-6.06	0.000000	-	-	-	-	-	-	-
	1.71	5609	-	-	-	95.305	10964.8	38.009	-	-	-	-
BU11	0.03	-	669.1	-0.77	0.000497	-	-	-	-	-	-	-
	0.11	-	1368.2	6.64	0.001095	-	-	-	-	-	-	-
	0.32	-	1090.2	3.72	0.000727	95.974	10988.9	11.299	265	2642	2281	10605

(From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

Figure 118. - - Cumulative gas and brine production from the DOW-DOE L.R. Sweetz No. 1 test well (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

Figure 119. -- Average production rates and flow periods for the DOW-DOE L.R. Sweezy No. 1 flow tests (From Garg and Riney, 1984, S-Cubed Topical Report)

Long term tests, flow test No. 9 through flow test No. 12, were designed for draw down periods of about 60 days in order to examine the depletion behavior of the reservoir. A detailed summary of the flow rate data is presented in Table 35.

Detailed analysis of the flow data from the DOW / DOE L.R. Sweezy No. 1 well simulation modeling and history match calculations is provided in a topical report by S-Cubed, California, authored by Gury and Riney (1984). This S-Cubed report concluded that it is likely that the pressure response from the short-term and intermediate-term flow tests is, primarily, the result of stress-induced hysteresis information permeability and compressibility. The pressure response from long term flow tests may involve additional formation drive mechanisms such as shale recharge and formation creep.

Overall, the well testing and pressure analyses efforts were successful in producing a reliable aquifer description. An important insight gained was in regard to the predominant influence of rock compressibility on aquifer fluid displacement and ultimate recovery. In geopressured systems having this degree of pore volume relaxation, it is doubtful that viable rates could be sustained for pressure depletion below the hydrostatic pressure gradient or at pressure less than approximately 600 psia. This result in turn leads to abnormally low recoveries ranging from 10 - 15% of the water and solution gas initially in place. Similar situations of abnormally low recovery efficiencies in geopressured oil and gas reservoirs have been experienced in several geographic areas.

During production testing one of the most significant problems encountered was the production of fine grained sand, sometimes in large slugs at high production rates. This sand problem continued throughout the life of the well, requiring constant monitoring of sand

TABLE 35
Approximate Flow Rate Data (L.R. Sweezy No. 1)

Flow Test	Cumulative Time (hrs)	Average Flow Rate (BPD)	Flow Test	Cumulative Time (hrs)	Average Flow Rate (BPD)
No. 1	0-2.5833 2.3833-40.626	6939 0	No. 10	3037.59-3067.51 3067.51-3212.11 3212.11-3378.91 3378.91-3382.54 3382.54-4527.13 4527.13-4529.28 4529.28-4531.38 4531.38-4537.51 4537.51-4554.93 4554.93-4872.84	8706 0 9221 0 9032 0 5166 0 8754 0
No. 2	40.626-46.521 46.521-195.723	8285 0			
No. 3A	195.723-198.773 198.773-378.273	2172 0			
No. 3	378.273-409.116 409.116-505.790	6455 0	No. 11	4872.84-4886.01 4886.01-4887.59 4887.59-5385.28 5385.28-5387.68 5387.68-5531.34 5531.34-5561.51 5561.51-6376.81 6376.81-6380.76 6380.76-6398.56 6398.56-6404.01 6404.01-6423.93 6423.93-6549.43	4887 0 8101 0 8313 0 8948 0 8290 0 8228 0
No. 4	505.790-531.476 531.476-565.821	8615 0			
No. 5	565.821-691.044 691.044-691.344 691.344-709.837 709.837-886.128	11,000 0 11,000 0			
No. 6	886.128-1055.86 1055.86-1095.88	9060 0			
No. 7	1095.88-1382.49 1382.49-1384.78	9509 0	No. 12		
No. 8	1384.78-1506.38 1506.38-1696.68	9413 0			
No. 9	1696.68-2197.73 2197.73-2205.91 2205.91-2248.09 2248.09-2254.86 2254.86-2925.84 2925.84-2928.49 2928.49-2943.83 2943.83-3037.59	9390 0 9307 0 9496 0 9509 0		6549.43-6830.39	7249

(From Garg and Riney, 1984, S-Cubed, Topical Report)

production and effectively limiting production rates to less than 10,000 barrels per day. The sand problem culminated in the catastrophic massive sanding which occurred on February 5, 1983. The exact cause of the sanding could not be determined. Later reviews indicated that failure to pre-pack and stage pack the gravel may have left a zone of weakness in the gravel pack through which sand was able to flow and cut out the screen. The stem-and-seat type adjustable chokes used to control flow were designated for gas wells and would not operate properly with high velocity brine. The carbide facings were repeatedly cut and fractured, and the face of the high pressure, high velocity water at the back of the stem flange caused the stem to close against the seat, shutting off flow. The adjustable chokes were exchanged for a system of dual positive chokes, which performed adequately in this application.

Corrosion was monitored with an electric corrosion meter and was minimal except in spots subjected to high turbulence. Scale was not a problem due to the fairly low salinity of the brine. However, a scale inhibitor was used. Water salinity was calculated using several different methods; however, a simple R_{wa} calculation produced the most accurate estimate of salinity - 100,000 parts per million.

Disposal well management was a major concern. The separator operating pressure of 600 psi to 650 psi limited the maximum disposal well backpressure to approximately 400 psi. A number of techniques were used to keep the backpressure in the acceptable range, including: conventional acidization of the well, adding dry citric acid to the filter cannisters, short (30 second to 1 minute) backflusing of the well to clean the formation face, long (24 hour) backflow of the injection well to the brine pit to remove gas which had broken out in the formation, and injection of a surfactant into the flow steam.

Gas measurement was quite difficult due to the low volume of gas produced and the inability to maintain a constant backpressure on the gas line. An orifice meter was used initially to meter gas; it was replaced with a positive displacement meter; finally the two were used in conjunction.

A full suite of PVT (pressure, volume, temperature) measurements was made on the reservoir fluid. This data, together with the gas measurements made at the surface, indicated a gas to water ratio of approximately 17.2 SCFG/BBL water, with an additional 3 SCFG being re-injected into the disposal formation. The methane saturation value for this fluid would be approximately 30 SCFG/BBL; hence, the brine is undersaturated and no free gas is likely in the reservoir. The reservoir bubble point is 8550 psia.

Samples of water and gas were taken at frequent intervals for chemical analysis. Most of the brine constituents remained fairly constant throughout production; calcium, zinc, and bromine, however, showed a sharply decreasing concentration with production. None of the trace element data indicated a source of brine from outside the formation - from shale de-watering, for example. Total dissolved solids in the formation brine was 99,700 Mg/L. An average brine analysis is shown in Table 36. These brine analyses were performed by the University of Southwestern Louisiana, Lafayette.

Gas was analyzed using chromatographic techniques. The gas was composed of approximately 94% methane, 2.5% ethane, 2.5% carbon dioxide, and 1% other gases. An analysis of the solution gas performed by Weatherly Laboratories, Inc., is shown in Table 37.

TABLE 36
DOW-DOE L.R. Sweezy No. 1
Brine Analysis

<u>DETERMINATION</u>	<u>MEAN VALUE</u>
Density @ 25°C	1.062 ± 0.000 g/mL
Conductivity @ 25°C	121,700 ± 641 mhos/cm
Viscosity @ 25°C	1.045 ± 0.001 ep
pH (equilibrium)	6.37 ± 0.02
alkalinity	1540 ± 23 mg/L
total dissolved solids	99,700 ± 240 mg/L
total hardness (as CaCO ₃)	5410 ± 140 mg/L
sodium	33,890 ± 170 mg/L
potassium	176 ± 4 mg/L
magnesium	262 ± 3 mg/L
boron	60.2 ± 0.6 mg/L
manganese	1.1 ± 0.09 mg/L
silica	68.4 ± 1.1 mg/L
ammonia	48.0 ± 0.8 mg/L
iron	2.10 ± 0.09 mg/L
zinc	1.92 ± 0.16 mg/L
calcium	1710 ± 30 mg/L
strontium	245 ± 11 mg/L
chloride	55,720 ± 140 mg/L
hydrogen carbonate	380 ± 13 mg/L
sulfate	522 ± 4 mg/L
carbonate	0.04 ± 0.003 mg/L
fluoride	1.65 ± 0.07 mg/L
bromide	110 ± 15 mg/L
iodide	36.3 ± 1.6 mg/L

(From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

TABLE 37

WEATHERLY LABORATORIES, INC.

Dow Chemical U.S.A.
L. R. Sweezy Well No. 1
Parcperdue FieldSolution Gas From
3500 psi sample.-
Differential Liberation
(Calculated Nitrogen Free)

Chromatographic Analysis

	Dry	Wet
	Mole %	
Water		13.86
Carbon Dioxide	2.50	2.15
Nitrogen	----	----
Methane	94.77	81.64
Ethane	2.15	1.85
Propane	0.52	0.45
Iso-Butane	0.05	0.04
N-Butane	0.01	0.01
Iso-Pentane	0.00	0.00
N-Pentane	0.00	0.00
Hexanes	0.00	0.00
Heptanes Plus	<u>0.00</u>	<u>0.00</u>
TOTAL	100.00	100.00
Gravity (Air=1.00)	0.5943	0.5982
Gas Deviation Factor (Z) =	0.958 @ 3500 psia & 237.4°F	
Ebls. Gas in Res./MMSCF (Bg) =982	@ 3500 psia & 237.4°F	

(From The Dow Chemical Company, 1984, Final Report, Appendices)

Early in the production of the well, a yellow color was noted in the gas flare along with some smokiness of the flame. A dry-ice/acetone cold trap was placed in the gas stream to attempt to condense out the hydrocarbons that were responsible for the unusual flame. The material condensed was highly aromatic in nature; approximately 33% benzene, 36% toluene, with the remainder made up of ethylbenzene and xylenes. The amount of aromatic material in the gas stream apparently increased during production; in September, 1982, aromatic condensate was noted in the drainage from the water drip pot in the gas line. This continued to increase until most of the material from the drip pot was condensate. In November, 1982, approximately one barrel of heavy, dark, highly paraffinnic oil was discovered while cleaning the separator. The well continued to produce small quantities of oil for the remainder of the production test. The source of the condensate and oil is unclear; possible explanations involve the solubility of hydrocarbons in brine, coning of thin layers of oil, and movement of dead, or "irreducible" oil.

The presence and significance of this aromatic condensate in the DOW - DOE L.R. Sweezy No. 1 test well generated interest in determining if similar condensates could be obtained from the Pleasant Bayou #2 geopressured - geothermal well in Brazoria County, Texas, and/or from the Gladys McCall #1 geopressured - geothermal test well in Cameron Parish, Louisiana. Hydrocarbons collected from these wells were compared to that already obtained from the L.R. Sweezy No. 1 well. The three well samples were found to contain very similar, primarily aromatic, hydrocarbons in the gas exsolved from the brine. The gas chromatographs of these condensates are shown in Figure 120. The six major components are labeled: B = benzene, T = toluene, E = ethyl benzene and O, M, and P, for orthometa - and para - xylene respectively. The mole percents of the six compounds from each of the three wells is shown in Table 38.

Figure 120. -- Gas chromatographs of hydrocarbons condensed from the gas streams from three geopressed wells (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

TABLE 38
Percentages of six compounds from three geopressured - geothermal test wells

COMPOUND	MOLE PERCENT			
	WELL:	Sweezy	Gladys McCall	Pleasant Bayou
Benzene		32.96	66.94	51.05
Toluene		36.04	23.44	33.91
Ethylbenzene		7.53	2.51	2.96
o-Xylene		11.19	2.62	4.07
m-Xylene		10.39	3.85	6.87
p-Xylene		1.89	0.65	1.14

(From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

The semiquantitative results obtained earlier by the University of Southwestern Louisiana (USL), Lafayette, LA, indicated that the amount of condensate in the separator gas from the wells are: L.R. Sweezy #1 = 15 ml/MCF; Gladys McCall #1 = 86 ml/MCF and Pleasant Bayou #2 = 123 ml/MCF. Further, it was also noted that the condensates from the sampled wells are very much different in character than a condensate sample taken from a producing gas well whose producing zone is in the same sand as the DOW - DOE L.R. Sweezy #1 well, but across a fault.

On February 5, 1983, when the massive sanding incident shut down the production well permanently, the cumulative brine production was 1,936,323 barrels and the cumulative gas production was 31,498 Mscf. The ultimate predicted recovery based on abandonment at the bubble point of 8,550 psia and a production rate of 8,500 separator barrels per day is 11,078,051 barrels brine and 183,563 Mscf gas over a period of 3.7 total years. This represents a recovery of 11.4% of the water in place, two to three times greater recovery than predicted from water compressibility. The difference is due to the very high rock compressibility; ultimately, however, damage to flow efficiency due to the high formation compressibility may preclude the ability to flow the well at acceptable rates to full depletion.

After catastrophic sanding of the production well, surface equipment, and the disposal well on February 5, 1983, it was decided to plug and abandon the two wells: The Department of Energy decided to abandon all down hole tubulars in place for economic reasons: Plugging and abandonment procedures were conducted in strict compliance of all State of Louisiana and Federal regulations and with constant adherence to the best safety consideration. All plugging and abandonment procedures for the DOW/DOE L.R. Sweezy No. 1 test well was completed on

April 14, 1983. Figure 121 illustrates the details of the plugs in place and the well bore configuration at the time of plugging and abandonment.

The L.R. Sweezy No. 2 saltwater disposal well became plugged with sand at 4,448 feet when the test well sanded up. A permit was then obtained from the State of Louisiana Department of Conservation to place bottom and top cement plugs. The bottom plug is from 4,337 ft. to 4,151 ft. and the top plug was set from 250 ft. to 50 ft. Dowell moved off location on March 30, 1983. The well head was removed, the casing cut off six feet below the ground level and steel plates were welded on all casing strings. The L.R. Sweezy No. 2 salt water disposal well was abandoned on April 13, 1983. Site restoration activities began in March 1983, when the final decision was made to plug and abandon the wells, and was completed, except for re-seeding, by June 1983 which was delayed due to excessive rainfall. Site restoration work included treating reserve pit fluids before discharging into the drainage ditches, removing brine and sludge from the site ring ditch with vacuum trucks, removing polluted soil to a disposal site and replacing it with top soil which was spread over the pit area. Site renovation included disposing of all boards, removing all piping for water and sewage systems, cutting wood pilings at least 4 ft. below ground surface, backfilling reserve and salt water pits, re-routing drainage ditch to original location, remove all fencing, electrical poles, wiring boxes, etc. and fertilizing and spreading grass seed over the entire location.

ENVIRONMENTAL MONITORING AT PARC PERDUE

The environmental monitoring of this project was extensive, and included air, groundwater, surface water, and microseismic observation. The work is carried out by Louisiana

Figure 121. -- Schematic illustration of the DOW-DOE L.R. Sweezy No. 1 well at the time of plug and abandonment (From The Dow Chemical Company, 1984, Final Report, Sept. 1979 - Dec. 1983)

State University (LSU), Oak Ridge National Laboratory (ORNL) and The Dow Chemical Company. Environmental mitigation and monitoring commitments were outlined by ORNL in an Environmental Assessment (EA) prepared for this project. To insure implementation and compliance to the EA, ORNL personnel periodically visited the site throughout all phases of the project.

Air, water, seismic and subsidence monitoring at the site were conducted by LSU personnel under separate contract to DOE. Microseismic work was subcontracted by LSU to Teledyne Geotech. Details of the microseismic monitoring are to be found in the Teledyne Geotech progress reports, Technical Report No. 81-1 (1981), TR No. 82-1 (1982), TR No. 83-2, and Final Report No. 84-2 (1984). Subsidence monitoring by leveling was subcontracted by LSU to Vernon F. Meyer and Associates, Inc., Sulphur, La., and details of the methodology and findings can be found in their reports of May 1983 and April 1984. A reconnaissance noise survey near the Parcperdue geopressured well test site was also conducted by Teledyne Geotech and details of this are provided in their undated report. The monitoring program consisted of three phases:

1. baseline monitoring before drilling to establish background data,
2. monitoring during drilling and testing the wells,
3. monitoring after project completion for consequences of the research.

AIR MONITORING

Ambient air quality and meteorology were monitored from a mobile monitoring station located about one-half mile northwest of the Parcperdue well. The LSU subcontractor provided

continuous records of H₂S, SO₂, nonmethane hydrocarbons, total hydrocarbons (THC), wind speed, wind direction, temperature, and precipitation. These readings were recorded from July 1, 1980, through October 31, 1981.

No significant air quality impacts were detected during this period which covered preconstruction, well drilling, and short term flow testing of the production well.

WATER RUN-OFF

Surface water flow through the Parcperdue site is generally southward toward Leblanc Ditch which is hydraulically connected to the Vermilion River to the west and Bayou Parcperdue to the east. Three surface water sampling stations were located radially south of the site at distances of 1½ to 3 miles. One station was on Bayou Parcperdue below the ditch entry, one on the ditch SSE of the test site, and one on the ditch near the Vermilion River.

Sampling from the three stations was set-up on a monthly basis beginning in January 1980. Then because of funding cutbacks and the small changes noted in monthly samples, the frequency was changed to quarterly in 1981.

The sampling program indicated seasonal variations in surface water quality but no significant alteration was attributable to testing activity.

GROUNDWATER

Sampling of groundwater at the site was first accomplished from two existing domestic wells, 50 and 100 feet deep, located approximately 50 feet west of the Parcperdue production well. As development of the site continued, four water wells were drilled to 180, 90, 130, and

130 feet in close proximity to the test well.

Monthly sampling began in January 1980, and was changed to quarterly in 1981. As with surface water, some seasonal variation in water quality was noted, but no significant alteration was attributable to testing activity.

MICROSEISMIC

The Louisiana Geological Survey and LSU conducted base-line seismic studies at Parcperdue to investigate microseismicity associated with geopressured - geothermal fluid production.

The microseismic survey consisted of five continuous recording seismograph stations located around the test site at distances of 1½ to 4 miles. These stations were on-line from November 1981 through the completion of project field work. The microseismic monitoring array is depicted in Figure 122.

Each station consisted of a Teledyne Geotech S-500 seismometer which is locked in a borehole at a depth of approximately one hundred feet. The signal from the seismometer is magnified using a Teledyne Geotech 42.50 amplifier and then FM multiplexed to a vocie-band carrier frequency for transmission to a common data collection point at Youngsville, Louisiana. Data transmission is via telephone telemetry circuits. At Youngsville, the signals from the five stations are amplitude conditioned and multiplexed together for transmission via AT&T long lines to the Teledyne Geotech Laboratory at Garland, Texas.

The results of this study have demonstrated that seismicity is enhanced by the brine production; however, neither the increased number of events, nor the size of the induced

Site	Latitude (N) Deg Min Sec	Longitude (W) Deg Min Sec	Elevation Feet	Magnification x 1000 @ 5 Hz	VCO Hz
LSU1	30 04 23.7	91 58 55.5	-74	180	1020
LSU2	30 04 42.6	92 01 53.4	-80	198	1360
LSU3	30 02 57.0	92 00 25.5	-80	169	2040
LSU4	30 02 06.0	92 02 46.5	-72	155	2380
LSU5	30 04 02.4	92 03 15.3	-79	154	1700

Figure 122. - - Parcerdue test site microseismic monitoring array and their geographic locations and elevations of sensors (From Teledyne Geotech, Mank et al., 1984, Final Report)

microearthquakes constitute a serious hazard or risk due to ground accelerations. Whether or not these microearthquakes cumulatively constitute a long-term subsidence risk is not answered by these data.

SUBSIDENCE

A first order leveling survey was conducted at the Parcperdue site prior to drilling. Then, more than a dozen benchmarks in the vicinity of the well were releveled between the drilling and testing phases of the production well. No subsidence related to the well testing activities were noted during the monitoring period.

ENVIRONMENTAL CONSIDERATION AT SITE

At the well site, precautions to preclude adverse environmental impact of the research area included: 1) ring levee and ditch around the entire research area, 2) lined brine holding pit for emergencies, 3) lined reserve pit for drilling mud, well tailings and fresh water, 4) lining underneath boards around production and disposal wells, 5) flaring of geopressured gas stream. Most environmental endeavors on-site proved very successful. However, the one sensitive incident was some leakage of brine from the saltwater pit through a tear in the liner. The contaminated soil was removed and replaced during site restoration.

No negative environmental effects were observed as a result of the production of geopressured water at the Parcperdue site.

TECHNADRIL - FENIX & SCISSION / DOE GLADYS MCCALL NO. 1 WELL

The T-F&S/DOE Gladys McCall No. 1 well was drilled under the DOE design well program to test deep, large geopressured - geothermal brine aquifers in order to provide basic data with which to determine the technological and economic viability of producing energy from these unconventional resources. Technadril - Fenix and Scisson (T-F&S) was selected competitively by DOE in July 1980 to drill, complete and test the well. The T-F&S organization was reduced very substantially upon reduction of its DOE contract from a four well program to only a one well program, and further reduced upon completion of the drilling phase of the Gladys McCall No. 1 well. The organizational chart shown in Figure 123 depicts the T-F&S management organization utilized during the well workover and production testing phase of the project. The relationships of the primary organizations involved in the drilling and testing program of the Gladys McCall well is depicted in Figure 124. T-F&S began site work at the Gladys McCall prospect, which is located about six miles east of the town of Grand Chenier in Cameron Parish, Louisiana, in November 1980. The brine production well was spudded on May 27, 1981, and drilling operations were completed on November 2, 1981, after rising 160 days of rig time. The well was drilled to a total depth of 16,510 ft. as had been planned after a directionally drilled sidetrack at 15,295 ft., and was plugged back to a depth of 15,831 ft. The geopressured - geothermal target sand section occurs at a depth of 14,412 - 15,860 ft. and consists of eleven distinct sand bodies comprising almost 1,100 net feet thickness of sand which will be described later in this section. The sand belongs in the Fleming Formation of Lower Miocene age (Figure 125).

Figure 123. -- Flowchart showing the testing phase organization for the Gladys McCall No. 1 well (From Technadril - Fenix and Scisson, v. 2, 1982).

Figure 124. -- Organizational chart of the geopressured - geothermal Gladys McCall No. 1 well drilling and testing program (From Technadril - Fenix and Scisson, March 1981 Report).

SYSTEM	SERIES	GROUP/FORMATION
QUATERNARY	RECENT PLEISTOCENE	UNDIFFERENTIATED HOUSTON
TERTIARY	PLIOCENE	GOLIAD
	MIOCENE	FLEMING
		ANAHUAC
	? — ?	
	OLIGOCENE	FRIO
	EOCENE	VICKSBURG
		JACKSON
		CLAIBORNE
		WILCOX
		MIDWAY
CRETACEOUS	UPPER	NAVARRO
		TAYLOR
		AUSTIN
		TUSCALOOSA

Figure 125. -- Stratigraphic chart showing the upper Cretaceous, Tertiary and Quaternary formations of the northern Gulf Coast. Formations shown by the lined pattern, occurring in the geopressed zone, have the greatest potential for geopressed - geothermal resource development (From Bebout, in Wallace, ed., 1982).

An abandoned well, located about fifty feet east of the production test well (Getty-Buttes Gladys McCall No.1) originally drilled in 1965 to a depth of 15,598 ft. as a hydrocarbon exploratory prospect, was successfully re-entered and recompleted at a depth of 3,514 ft. for use as a disposal well during November 20 - December 4, 1981. A complete report titled "Geopressured - Geothermal Well Report, Volume 1 - Drilling and Completion," DOE/ET/27217 prepared by Technadril - Fenix and Scisson for the Department of Energy, Idaho Operations office under Contract DE-AC07-80ET27217 in 1982 covers the details and completion of the T-F&S/DOE Gladys McCall No. 1 production well and the re-entry and completion of the T-F&S/DOE Gladys McCall saltwater disposal well No. 1. Volume 2 of this report covering the period February 1982 - October 1985, provides all the details on well workover and production testing and has complete appendices (1-12) containing the results of various tests conducted by subcontractors on this project. Information gathered in this compilation is taken directly from these Technadril - Fenix and Scisson reports. According to this report a total of \$25,716,110.93 was expended by Technadril - Fenix and Scisson on this well for the period ending October 28, 1985 on various operations and well testing. Eaton Operating Company Inc., Houston, Texas, and its two prime subcontractors, the Institute of Gas Technology (IGT), Chicago, IL and The Ben Holt Co. (BHC), Pasadena, CA, assumed operations of the Department of Energy's (DOE) three Gulf Coast Geopressured - Geothermal Field sites in September 1985 for five years (fiscal years 1986-1990). The Eaton Operating Company Inc., final report covering this period was issued in 1990 and contains a summary of their activities. This report was prepared by Eaton Operating Co., Inc. for the U.S. DOE Idaho Operations office under DOE Contract No. DE-AC07-851D12578.

The T-F&S/DOE Gladys McCall No. 1 well site is located about six miles east of Grand Chenier and is about 55 miles southeast of Lake Charles in Cameron Parish, Louisiana (Figure 126). More specifically it is located in Section 27, Township 15 S, Range 5 W. It is 2.2 miles out in the marsh, south of Highway 82 (Figure 127). A surveyors map showing the exact location of the T-F&S/DOE Gladys McCall well is shown in Figure 128.

Information about the patterns of regional sandstone distribution, subsurface temperatures, porosity, permeability, formation pressures, salinity, and subsurface structure are essential for the successful identification and exploration of geopressed - geothermal reservoirs. Regional geologic studies conducted at the Louisiana Geological Survey provided vital information on locating the most suitable geopressed - geothermal prospect sites, including the Gladys McCall test site. Figure 129 shows one of the maps resulting from these studies and shows the distribution and depths of geopressed sandstones in South Louisiana.

Preliminary studies of the geology and structure of the area were conducted by Gruy Federal, Inc., 1979 and later by D.G. Bebout (Louisiana Geological Survey) and Magma Gulf Company. Work by D.G. Bebout was supported by the Department of Energy, Division of Geothermal and Hydropower Technologies, under Contract No. DE-AC08-81NV10174.

The structural interpretation made by Gruy Federal Inc. on the basis of log data from adjacent wells and the available seismic lines in the area (Figure 130) is shown in Figure 131. This interpretation was made on top of the first of four geopressed aquifers known to exist between about 14,560 ft. and 16,500 ft. based on log data from existing wells. This earlier interpretation was revised by Technadril - Fenix and Scisson after drilling of the Gladys McCall well and the revised interpretation is shown in Figure 132. This well was drilled in 1981 to a total depth of

Figure 126. -- Map showing location of the Gladys McCall design well in the Rockefeller Wildlife Refuge, Cameron Parish, Louisiana (From Gruy Federal, 1979).

GRUY FEDERAL, INC.
Houston, Texas
Crab Lake Field Area
Cameron Parish, Louisiana
PLAT SHOWING EXISTING ROAD
FROM STATE HWY. NO. 82 TO Well Loc.
GETTY & BUTTES - Gladys McCall No. 1
IN SEC. 27, T. 15S., R. 5W

Figure 127. - - Index map showing location of the Gladys McCall No. 1 well (From Gruy Federal, Inc., 1978).

Figure 128. -- Surveyor's map showing the location of the T- F&S/DOE Gladys McCall test well (From Technadril - Fenix and Scisson, 1982, v. 2).

Figure 129. -- Distribution and depths to Tertiary geopressed sandstones in south Louisiana (modified from McCulloh et al, 1982, from, John, 1988).

Figure 130. -- Base maps showing seismic lines and apparent seismic fault indications in the Gladys McCall prospect area. These data were used in the structural interpretation shown in figure 128 (From Gruy Federal, Inc., 1979).

Figure 131. -- Structural map contoured on the top of the first of four geopressed aquifers existing between 14,510 ft. and 16,500 ft. and comprising the objective zone in the Gladys McCall test well (From Gruy Federal, Inc., 1979).

Figure 132. -- Structure of the Gladys McCall prospect area, contoured at the 14,560 ft. sand in the T-F&S DOE Gladys McCall No. 1 well by Magma Gulf Company (adopted from Technadril - Fenix and Scisson, 1982, and from John, 1988).

16,510 ft. and plugged back to 15,831 ft. It lies in the Miocene geopressured - geothermal trend. Wells in this area have penetrated some of the thickest geopressured sand sections in Louisiana or Texas. The test well penetrated upper (4,000 - 6,000 ft.), middle (6,000 - 11,000 ft.), and lower Miocene (11,000 ft to total depth) sections with the section below 14,400 ft. being geopressured. Approximately 1,150 ft. of net sand is present in this well from 14,412 to 16,320 ft.

Geopressured - Geothermal reservoirs in the Gladys McCall well are structurally controlled by three major growth faults and the prospect is located in one of several growth faults that are successively downthrown to the coast. One of the faults cuts the Gladys McCall well at about 16,350 ft. and forms the northern boundary of reservoirs in the prospective production zone. Formation dip in the well is south to southeast, but within the prospective zone rollover into the fault becomes pronounced. Throughout much of the zone the dip is north at angles of 10 - 30 degrees (from, Wethusing and Goldsberry, in Wallace, ed, 1982).

A dip (north - south) cross section of the area through the Gladys McCall test well is shown in Figure 133. Log correlations are relatively straight forward at shallower depths, but tend to get more complex below 15,000 ft. (John, 1988). Details of log correlations and faults in the prospect area are provided in Bebout, 1982 (in Wallace, ed., 1982) and in the Technadril - Fenix and Scisson final report (1985). The electric log of the Gladys McCall well shows eleven potential production zones (Figure 134). The stratigraphic section of the Gladys McCall well consists of alternating massive sandstones and shales, with the shales becoming increasingly thick below 11,000 ft. The target sand section is of lower Miocene age and lies between two key microfossils *Cristellaria A* (11,000 ft.) and *Siphonina davisii* (16,440 ft.). The former marks the

Figure 133. -- Dip cross section of the prospect area through the Gladys McCall well showing log correlations, paleontological markers, temperature and mud weights cross section line shown in figure 130. (Modified from Bebout et al, 1983, LSU Annual Report, Nov. 1981 - Oct. 1982; from John, 1988).

Figure 134. -- Electric log of the Gladys McCall test well showing potential production zones, thickness and generalized lithology (From John, 1988, Journal of Energy Resources Technology, V. 110, p. 259).

outer shelf (ecozone - 3) environment while the latter is characteristic of the upper slope (ecozone - 4) environment, indicating that sands constituting the target section were probably deposited in a shelf environment by distributary channel systems.

One of the major uncertainties in geopressured - geothermal resource development is reservoir size and production longevity. The surprisingly successful production performance at the Gladys McCall test well generated a great deal of interest in the predictive ability of different reservoir models. The size and geometry of a sandstone body are largely a product of the depositional environment. In order to explain the results observed at Gladys McCall, John (1988) proposed a geological model to explain the formation and mechanism for lateral and vertical extension of connected channel and point bar sandstones (Figure 135). In this model it was proposed that the geopressured - geothermal target section represented a genetic unit generated within the same channel system which consisted of interconnected channel and point bar sandstones (Figure 135). In this model it was proposed that the geopressured - geothermal target section represented a genetic unit generated within the same channel system which consisted of interconnected channel and point bar sandstones deposited through time. This allowed for a large reservoir. Further, the whole thickness of the sand section, though appearing on the electric log as possibly different and separated sandstones, may behave as a single sand body allowing fluid communication during brine production. Also, long-term high-volume brine production, as in the case of the Gladys McCall test well, may cause fractures and subsurface faults within and near the reservoir to accommodate the stresses and volume depletion associated with such production, which could not be detected at the surface.

Figure 135. -- The formation and mechanism for lateral and vertical extension of connected channel and point bar sandstones (From, John, 1988, Journal of Energy Resources Technology, V. 110, p. 260).

Information on the diamond cores and sidewall cores taken in the Gladys McCall well provided below is taken directly from the Technadril - Fenix and Scisson report dated January 1982.

Three diamond cores were taken in the upper part of the target sand, at the following depths: Core No. 1 - 15,167 - 15,177 ft.; Core No. 2 - 15,179 - 15,192 ft.; Core No. 3 - 15,348 - 15,374.5 ft. In addition, 28 sidewall cores were taken over the entire production interval. The core analyses was performed by Core Laboratories and the results are provided in Appendix 4. There is a major discrepancy between the diamond core porosities and the sidewall core porosities for the same depth, notably 15,350 ft. and 15,360 ft. The diamond core porosities are 12.9% and 10%, respectively, while the sidewall core porosities are 26% and 22%. The diamond core porosities are most likely nearer the true values. The high values of the sidewall cores are probably due to the exposure of the formation to the drilling mud for a long period of time and the percussion effect when the bullet hit the formation. The neutron - density log showed an average porosity of 15%, and the sonic log 10% which are in general agreement with the diamond core porosities. The cuttings from 15,600 - 15,900 ft. showed a large amount of very fine grained white material, which the mud logger called anhydrite. Samples were sent to Accumin Analysis and Core Laboratories for XRD analysis. The results of these analyses are shown in Table 39. No anhydrite was noted.

Permeabilities for 6 of the 11 zones in the target sand sequence were estimated from diamond and sidewall core data. No estimations were made on other zones as there was no data. An estimate of permeability to water was made from the measured air permeability, and the KL and $\%Kh$ calculated for the six zones. These data are given in Table 40. The six zones were

TABLE 39

X-RAY DIFFRACTION ANALYSES
OF
GLADYS McCALL NO. 1 CORE

<u>Mineral</u>	<u>Percentages</u>		
	<u>Accumin Analysis</u>		<u>Core Laboratories</u>
Quartz	79	68	91
Feldspar	3	2	6
Calcite	1	1	0
Barite	7	20	NR
Kaolinite	7	6	2-3
Illite	3	3	
Chlorite	trace	trace	trace

(From, Technadril - Fenix and Scisson, V. 2, 1982).

TABLE 40

PERMEABILITY AND HYDRAULIC CAPACITY DATA

GLADYS McCALL NO. 1

Sand Zone No.	Interval	Net Thickness	Preliminary Estimate, Ka	Preliminary Estimate, Kw	Preliminary Kwh	Preliminary % Kwh	Intercomp Kwh	Intercomp Kw	Intercomp % Kwh
1	14,412-14,465	54'	-	-	-	-	7.30	394.2	2.12
2	14,550-14,772	223'	178	34	7,582	37.33	17.81	3,971.0	21.35
3	14,782-14,800	19'	-	-	-	-	24.96	474.0	2.55
4	14,920-14,969	50'	113	24	1,200	5.91	29.25	1,462.0	7.86
5	15,031-15,066	36'	-	-	-	-	2.11	76.0	0.41
6	15,098-15,108	11'	-	-	-	-	7.85	86.0	0.46
7	15,120-15,137	18'	-	-	-	-	12.96	233.0	1.25
8	15,158-15,490	333'	109	23	7,659	37.71	16.02	5,335.0	28.68
9	15,508-15,636	129'	49	12.5	1,612.5	7.94	27.49	3,546.0	19.06
10	15,642-15,783	142'	44	11	1,562	7.69	15.63	2,219.0	11.93
11.	15,784-15,860	77'	35	9	693	3.41	10.46	805.0	4.33
TOTAL		1,092'			20,308.5	99.99		18,601.0	100.00

(From, Westhusing and Goldsberry, in Wallace, ed., 1982).

estimated to have some 20,000 md - ft. available which was considered to be sufficient to produce 40,000 B/D of brine. Two-thirds of the Kh was contained in the two thickest sandstone intervals, zones 2 and 8.

Intercomp Resource Development and Engineering, Inc., made a more rigorous calculation of permeability through a computer program using the open hole log data. Their calculated permeability (K), Kh, and %Kh for the 11 zones are also given in Table 40. Permeabilities to water ranged from 2 to 30 md, with a total available Kh of 18,600 md-ft. This was considered sufficient to produce 40,000 B/D of brine. Zones 2 and 8 contain approximately 50% of the total Kh, with zones 9 and 10 making up another 30%. The remaining zones are of lesser importance.

The salinity of the brine had been estimated from other wells in the area at about 100,000 ppm NaCl. Preliminary values for salinities were calculated from the electric logs by five methods: conventional SP, R_{wa} , Dunlap's Kf, conductivity and shale resistivity. For each sand, minimum and maximum resistivity values were used, so that there are two calculations. These results are tabulated in Table 41. Intercomp also calculated salinity from the log data using an in-house computer program and their results are also shown in Table 41. It was estimated before testing that a brine of 125,000 ppm salinity, and 13,000 psi and 285°F should contain about 32 SCF/B methane at saturation. This value was similar to that obtained from testing.

A Welex wireline temperature gradient survey was run on February 25, 1982 prior to perforation of the well with 10.3 ppg calcium chloride in the wellbore, and following an equilibrium period of 40 days. These data are shown in Figure 136, and indicated a temperature of about 315°F at a depth of 15,600 ft. The apparent overall geothermal temperature gradient

TABLE 41

CALCULATED SALINITIES - GLADYS McCALL NO. 1

Sand Zone No.	Interval, ft.	SP	Rwa	Kf	Conductivity	Shale	Intercomp
1	14,412-14,465	65,000	90,000	143,000	65,000	78,000	60,600
		60,000	140,000	135,000	100,000	72,000	
2	14,500-14,772	60,000	300,000	135,000	300,000	72,000	66,600
		65,000	130,000	143,000	130,000	78,000	
3	14,782-14,800	55,000	75,000	132,000	55,000	70,000	65,200
		55,000	105,000	132,000	60,000	70,000	
4	14,920-14,969	45,000	120,000	125,000	120,000	58,000	64,800
		45,000	90,000	125,000	90,000	58,000	
5	15,301-15,066	25,000	300,000	108,000	300,000	48,000	113,200
		25,000	115,000	108,000	105,000	48,000	
6	15,098-15,108	35,000	250,000	113,000	80,000	52,000	69,600
		35,000	-	113,000	39,000	52,000	
7	15,120-15,137	45,000	80,000	125,000	40,000	58,000	75,800
		45,000	300,000	125,000	300,000	58,000	
8	15,158-15,490	55,000	300,000	132,000	300,000	70,000	71,600
		55,000	85,000	132,000	80,000	70,000	
9	15,508-15,636	65,000	115,000	143,000	48,000	78,000	88,000
		65,000	120,000	143,000	62,000	78,000	
10	15,642-15,783	55,000	90,000	132,000	78,000	70,000	91,500
		45,000	92,000	125,000	80,000	58,000	
11	15,784-15,860	55,000	80,000	132,000	78,000	70,000	82,100
		45,000	300,000	125,000	300,000	58,000	

(From, Technadril - Fenix and Scisson, V. 2, 1982).

Figure 136. - - Temperature gradient survey of the Gladys McCall test well (From Technadril - Fenix and Scisson, Final Report, V. 2, 1985).

was 1.55°F/100 ft., and 1.67°F/100 ft. over the depth interval from 12,600 - 15,600 ft. The average Gulf Coast geothermal gradient is 1.5°F per 100 ft.

The Gladys McCall test well spudded on May 27, 1981, and drilling operations were completed on November 2, 1981. This test well, which is shown schematically in Figure 137 as completed, was drilled to a total depth of 16,510 ft., after a directionally drilled sidetrack at 15,295 ft. The 13 $\frac{3}{8}$ in. casing was set at 4,490 ft. and cemented from that depth to the surface. The 9 $\frac{5}{8}$ in. casing was cemented from a landing depth of 14,426 ft. to the surface. A 7" liner was cemented from a subsurface depth of 15,958 ft. back to a depth of 6,000 ft., and tied back to the surface inside the 9 $\frac{5}{8}$ in. casing. The plugged back total depth of the test well is 15,831 ft. Other completion details are provided in the Technadril - Fenix and Scisson final report (1985) from which the above information was directly taken.

An existing well, formerly the Getty - Buttes, Gladys McCall No. 1, was recompleted to function as the disposal well. This well was drilled originally to a depth of 15,598 ft. as a hydrocarbon exploratory prospect in 1965. Gruy Federal unsuccessfully attempted to recomplete and test the well, as a geopressured - geothermal Well of Opportunity during November - December 1978. The plugged back total depth, following the unsuccessful recompletion attempt, was reported by Gruy Federal to be 3,410 ft. This well was renamed as the T-F&S/DOE, Gladys McCall SWDW No. 1, was reentered and completed successfully as a salt water disposal well by T-F&S during the November 20 - December 4, 1981 period. The schematic diagram of this well as recompleted is shown in Figure 138. The 10 $\frac{3}{4}$ in. casing in the well was cleaned out to a depth of 3,492 ft. and successfully pressure tested at 1,500 psig (pounds per square inch - gauge). Completion details are provided in the Technadril Fenix and Scisson final report (1985).

Figure 137. -- Schematic diagram of the T-F&S/DOE Gladys McCall No. 1 well after completion (From Westhusing and Goldsberry, in Wallace, ed., 1982).

Figure 138. -- Schematic diagram of the T-F&S/DOE, Gladys McCall saltwater disposal well, after completion (From Westhusing and Goldsberry, in Wallace, ed., 1982).

The logging program conducted for the T-F&S/DOE Gladys McCall No. 1 test well and that for the T-F&S/DOE Gladys McCall No. SWDW No. 1 is shown in Table 42. The electric log for the salt water disposal well is shown in Figure 139. As seen in this figure, eight potential disposal zones were identified in this well between 2,000 - 3,500 ft. In view of the anticipated plugging and pressure drop buildup problems associated with high volume brine disposal as a function of time, several sands were initially perforated in the lower part of the well. The following sands were perforated using 4 inch Schlumberger casing guns loaded with 4 shots per foot:

<u>Depth</u>	<u>Thickness</u>
3,050 - 3,140 ft.	90 ft.
3,193 - 3,228 ft.	45 ft.
3,305 - 3,370 ft.	65 ft.
3,470 - 3,500 ft.	<u>30 ft.</u>
Total 230 ft.	

The formation pressure in this disposal well at a depth of 3,050 ft. (top of perforations) was estimated to be only 2,074 psig (fracture gradient - 0.68 psi foot). This fracture pressure corresponds to a static wellhead pressure of only about 686 psig considering that the hydrostatic pressure of 8.75 ppg brine is 1,338 psig at this depth; therefore the static wellhead pressure had to be kept below 686 psig to insure protection of the integrity of the fresh water sands higher in the well. Appropriate protective systems (relief valves, ESD systems) were included in the design of the surface facilities to preclude the possibility of formation fracture, and thus to insure protection of the fresh water sands (from, Technadril - Fenix and Scisson, Final Report, v. 2, 1985).

TABLE 42

LOGGING PROGRAM
T-F&S/DOE GLADYS McCALL NO. 1 WELL

Date	Log	Bottom Interval	Top Interval
6-7-81	Directional	4500	873
6-7-81	Borehole Geometry	4500	873
6-7-81	Dual Induction SFL Sonic	4500	873
7-11-81	Dipmeter	14483	9986
7-11-81	Dipmeter	14474	9986
7-11-81	Dipmeter	14483	4486
7-11-81	Compensated Neutron - Formation Density	14483	4188
7-11-81	Compensated Neutron - Formation Density	14483	4486
7-11-81	Dual Induction SFL Sonic	14483	4486
7-11-81	Temperature	14486	Surface
7-11-81	Directional	14483	4486
7-13-81	High Resolution Thermometer	14486	Surface
7-18-81	Temperature	14350	100
7-31-81	Dual Induction SFL Sonic	15065	14414
8-17-81	*Casing Inspection & Electronic Caliper	14400	Surface
8-28-81	Directional	15502	14414
8-28-81	Borehole Geometry	15502	14414
8-29-81	Dual Induction SFL Sonic	15494	14750
10-13-81	Borehole Compensated Sonic	16498	14412
10-13-81	Sonic	16498	14412
10-13-81	Cyberlook	16498	14412
10-13-81	Volan	16440	14420
10-14-81	Cyberdip	16498	14412
10-14-81	Dipmeter	16498	14412
10-14-81	Dipmeter	16482	14436
10-14-81	Directional	16498	14412
2-25-82	**Temperature	15636	Surface
2-26-82	**Gamma Ray - CCL	16510	14425
2-27-82	**Perforating Record	15627	15597
3-3-82	**Fluid Travel	14100	Surface
12-10-82	**Gamma Ray - CCL	15690	14500
12-10-82	**Perforating Record	15597	15567
12-16-82	**Perforating Record	15541	15511
3-3-83	**Fluid Travel	13401	Surface
3-13-83	**Fluid Travel	13401	Surface
5-30-83	***Minimum ID Caliper	13401	Surface
6-4-83	**CCL	14050	Surface
8-31-83	**Gamma Ray - CCL	15317	13500
9-9-83	**Gamma Ray - CCL	15474	13500
9-15/20-83	**Perforation Records (11 Logs)	15470	15160

NOTE: All logs are Schlumberger except as noted.

*NL McCullough
**Welex
***Dialog

LOGGING PROGRAM
T-F&S/DOE GLADYS McCALL SWDW No. 1 WELL
(Salt Water Disposal Well)

Date	Log	Bottom Interval	Top Interval
12-1-81	Cement Bond Variable Density	3500	200
12-2-81	Gamma Ray - CCL	3500	2000
12-2/4/81	Perforation Records	3500	3050

NOTE: All logs are Schlumberger

(From Technadril - Fenix & Scisson, Final Report, Feb. 1982 - Oct. 1985, V. 2, 1985).

Figure 139. - - Electric log of the Gladys McCall #1 saltwater disposal well showing the potential brine injection zones, thickness, and generalized lithology of the brine disposal well (From John, 1988, Journal of Energy Resources Technology, V. 110, p. 260).

A complete report covering the drilling and completion of the Gladys McCall No. 1 test well was prepared by T-F&S and issued by DOE in January 1982 as DOE/ET/27217 - Volume 1. After reviewing all the available data and holding several discussions between DOE and T-F&S personnel and the various consultants involved in was the consensus view that the initial testing and reservoir limit determination should be in the sand zone No. 9 (15,508 - 15,636 ft.) Followed by perforation and testing of sand zones 8 and 2, in that order. However, during the course of the testing only sand zones 9 followed by zone 8 were perforated and tested. Sand zone 9 was perforated by Welex with four shots/foot using a 2¾ inch perforating gun after running a Gamma Ray - CCL log.

<u>Date</u>	<u>Depth</u>	<u>Thickness of perforated zone</u>
February 27, 1982	15,597 - 15,627 ft.	30 ft.
December 10, 1982	15,567 - 15,597 ft.	30 ft.
December 16, 1982	15,511 - 15,541 ft.	<u>30 ft.</u>
		<u>90 ft. total</u>

The delays were caused due to development of leaks and loss of tools resulting in operations to correct these problems.

After sand zone No. 9 had been plugged off and well workover operations had been completed in early September 1983, preparatory work for the perforation and testing of Sand zone No. 8 began. Welex made a total of eleven gun runs perforating 310 feet in Sand zone No. 8 during the period from Sept. 15 - 20, 1983. A summary of these perforation operations is presented in Table 43. Following perforation Welex tied in again to the short 7 inch casing joint

TABLE 43

SUMMARY OF PERFORATION OF SAND ZONE NO. 8 (15,158 - 15,490 FEET)T-F&S/DOE GLADYS McCALL NO. 1SEPTEMBER 15-20, 1983

<u>GUN RUN NO.</u>	<u>GUN LENGTH, FT.</u>	<u>NO. OF SHOTS</u>	<u>SHOTS FIRED</u>	<u>SHOTS MISFIRED</u>	<u>% SHOTS FIRED</u>	<u>INTERVAL PERFORATED, FEET</u>
1	20	80	60	20	75	15,450 - 15,470
2	30	120	118	2	98	15,420 - 15,450
3	30	120	112	8	93	15,390 - 15,420
4	30	120	100	20	83	15,360 - 15,390
5	30	120	113	7	94	15,330 - 15,360
6	30	120	110	10	92	15,300 - 15,330
7	30	120	94	26	78	15,270 - 15,300
8	30	120	100	20	83	15,240 - 15,270
9	30	120	112	8	93	15,210 - 15,240
10	30	120	114	6	95	15,180 - 15,210
11	20	80	74	6	93	15,160 - 15,180
Total/Avg.	310	1240	1107	133	89	15,160 - 15,470

Perforating Gun - Welox 2 3/4-Inch Sidewinder - 11g SSB Charges

- Entrance Hole Diameter - 0.37-Inch

- Penetration Depth - 10.55-Inches (Berea Sandstone)

(From Technadril - Fenix Scisson, Final Report, 1985).

at 14,686 - 14,724 feet, and then tagged bottom at 15,547 feet; thus about 17 ft. of fill occurred during the perforation of Sand zone No. 8.

Surface Test Equipment

The following information is taken directly from the Eaton Operating Company, final report (1990) to DOE under Contract No. DE-AC07-851D12578: A schematic diagram of the surface equipment installed to process the produced brine is shown in Figure 140. The numbered points indicate where samples were taken. To accommodate the high brine flow rate a block "Y" was installed on the wellhead which diverted the flow up the well into two 45° heavy walled flow loops. These two flow loops made sweeping curves to the ground to another steel flow block which recombined the flow into a single stream before it entered the horizontal surface pipe. The brine flow rate was controlled by a Willis choke. The carbide disks in the Willis choke withstood the forces of the large pressure drop (several thousand psi) quite well. The intense turbulence of the fluid leaving the choke, however, caused erosion of the interior pipe wall. This section of pipe was initially low carbon steel but was subsequently clad with stainless steel which had the metallurgical toughness to withstand the abrasive high flow rate turbulence of the brine exiting from the choke.

The piping and valves to carry brine flow were generally 5 inch diameter, or larger, to accommodate rates up to 40,000 barrels per day. Equipment downstream of the choke was designed to operate at pressures up to 1,000 psi and temperatures up to 300°F. The separators were of standard design with an internal diameter of 54 inches and a length of 30 feet, and normal rating of 1,440 psi. Brine exiting the separators was filtered prior to injection into the disposal

well. The gas from the separator was cooled and dehydrated prior to sale. Some gas was occasionally flared on location due to compressor malfunction or other reasons when the gas could not be sent to sales. Carbon dioxide was not removed since a sales contract was obtained which allowed up to 10% carbon dioxide in the gas.

During the test there were several modifications or improvements made to the system. Initially, there was only one separator in the system, but in July, 1984 the second separator was added. The two separators operated in series. Gas was separated from the brine in the first separator at pressures high enough to enter the gas into the sales line without further compression. This was typically 1,000 psig. The carbon dioxide content from this separator was normally below the 10% sales contract limit. The brine then passed to the second separator which was operated at a lower pressure. This lower pressure was sufficient to drive the spent brine down the disposal well and at the same time control the amount of carbon dioxide in the gas. The gas from the second separator was richer in carbon dioxide, and exceeded the 10% sales contract limit, due to the difference in solubility of carbon dioxide at the lower pressure. This second separator was therefore operated at a pressure (typically 400-500 psi) such that when its gas was commingled with the gas from the first separator the resultant concentration of carbon dioxide in the gas sent to sales would not exceed the 10% sales contract limitation. Gas from the second separator has to be compressed back up to the sales line pressure. The dissolved gas remaining in the brine after passing through the low pressure separator went into the disposal well.

While an inhibitor chemical was injected into the surface equipment and piping to prevent formation of calcium carbonate scale no corrosion inhibitor was used. Internal corrosion of the surface piping and equipment was thus moderate and required occasional repair or replacement of

some parts of the flow system, such as valves, flanges, or pipe segments, when corrosion induced leaks developed.

TEST RESULTS - GLADYS McCALL NO. 1 WELL

Two sand reservoir zones were tested - Sand zone #9 followed by Sand zone #8. The testing of the well was initiated by Technadril - Fenix and Scisson. Flow testing of Sand zone #9 (15,508 - 15,630 ft.) began at 12:30 pm on December 16, 1982 at a rate of 2,000 B/D of brine. Details of the original drilling, completion and initial testing of this well prior to October 1985, at which time the well operations were taken over by Eaton Operating Company, Inc., Houston, Texas, are provided in the following reports by Technadril - Fenix and Scisson:

- (1) Volume I - Drilling and Completion (Gladys McCall), January, 1982.
- (2) Volume II - Testing plan, January, 1982.
- (3) Volume III - Well Workover and Production testing for the period February 1982 - October, 1985.

The Gladys McCall No. 1 well produced over twenty-seven barrels of brine and 676 million SCF of gas from the brine. In addition to the Technadril - Fenix and Scisson report, information and details of the well testing are to be found on the Eaton Operating Company monthly reports and the reports prepared by the Institute for Gas Technology under a subcontract for Eaton Operating Company. The latter's final contract report (1990) contains a summary of the well testing activities. The Eaton Operating Company report includes the results of the earlier testing (conducted by Technadril - Fenix and Scisson) with the results of the testing done under

their contract with DOE and presents the overall finding of the project. The following information is compiled directly from The Eaton Operating Company final report.

Sand Zone #9 Gas/Brine Testing

The initial brine flow periods between December 2, 1982 and December 22, 1982 were for initial well clean up and sampling. Samples of gas and brine were taken on December 22, 1982 and sent for analyses by Rice University personnel. The results of these analyses are shown in Table 44.

To determine the gas/brine ratio a separator study was made and a laboratory PVT analysis was performed by Weatherly Labs. This study found the bubble point pressure to be 12,936 psia for a gas/brine ratio of 30.4 scf/bbl at 298°F. This laboratory measurement compared well with the actual bottom hole pressure of 12,911 psia measured at a depth of 15,460 (also at a temperature of 298°F). The close agreement between the laboratory bubble point measurement and actual bottom hole pressure indicated that the sand 9 reservoir brine was saturated with gas. This was the basis for the initial reports that the brine was saturated with gas (Technadril - Fenix and Scisson, 1985).

Subsequent review of the early test data, performed under this contract, gave reason to suspect that the brine in sand #9 was not fully saturated, but was in fact undersaturated similar to the brine in sand #8. The reason for this had to do with the difficulty the field personnel had in getting accurate gas flow measurements from the orifice meters during the first few months of the project. The procedures used to calculate the gas rate for the brine produced from sand #9 test resulted in the field measurement values for gas production being too high. Consequently, when

TABLE 44

Analysis of Brine from Gladys McCall Sand #9

Specific Gravity	1.045
Total Dissolved Solids	96,300 ppm
Chlorides	57,900 ppm
Calcium	4,130 ppm
Sulfate	< 5 ppm

Gas Chromatographic Analysis for Sand #9

Sample Date	<u>Component Concentration (MOL. %)</u>	
	12/22/82*	3/23/83**
Methane	86.9186.93	
Ethane	2.452.43	
Propane	0.560.55	
Isobutane	0.090.08	
N-Butane	0.090.08	
Isopentane	0.020.04	
N-Pentane	0.010.03	
Hexanes	0.030.51	
Heptanes Plus	0.060.15	
Nitrogen	0.280.26	
Carbon Dioxide	9.508.94	

* Separator at 500 psig

** Separator at 700 psig

(From Eaton Operating Company, Inc., Final Report, 1990).

Weatherly Labs did the recombination test they did it for an incorrectly high gas/brine ratio and obtained a bubble point that was higher than the actual bubble point in the reservoir. Had Weatherly Labs done the recombination studies for a gas/brine ratio less than 30.4 scf/bbl they would have obtained a bubble point less than the reservoir pressure, and it would have been concluded that the reservoir was undersaturated.

Sand #9 Reservoir Limit Testing

The flow from March 21, 1983 through April 17, 1983 was for a reservoir limit test of sand #9. A bottom hole pressure gauge was lowered into the hole and operational most of the time from April 14th to April 17th. A total of 99,416 barrels of brine were produced in 23.8 days for an average rate of 4,181 bbls/d. The following build-up test was interrupted early when the mast on the truck supporting the wireline collapsed, causing the wireline to drop into the hole.

The draw-down and build-up data was independently analyzed by four parties; 1) J. Donald Clark, Petroleum Consultant, 2) Dowdel Fairchild and Ancell, 3) S-Cubed, and 4) Scientific Software-Intercomp. Their results were as follows:

Clark (Technadril - Fenix and Scisson, 1985) (Clark, 1985) noted five possible straight line slopes on the semi-log plot of bottom hole pressure ranging from 16.7 psi/cycle to 45.2 psi/cycle during the first 24 hours. None of the adjacent segments reached the 2:1 ratio indicative of a boundary, therefore he concluded that the changes were due to lenticularity of the formation rather than being caused by sealing geological faults. He calculated a hydraulic flow capacity of 10,153 md-ft., a permeability to brine of 84.6 md, and a skin factor of +1.98. He further calculated that the transient pressure wave explored the reservoir to a radial distance of 13,019 feet and that the in-place volume of brine was about 170 million barrels. These calculations were

all done with generally accepted petroleum engineering methods based on various plots of the data.

Dowdel, Fairchild and Ancell (Technadril - Fenix and Scisson, 1985) used a single phase, two dimensional, numerical reservoir simulator to match the experimental pressure data. The active grid blocks and properties of the grid blocks were adjusted until the calculated pressures were a good match to the experimental pressures. This match resulted for a model that assumed two separate reservoirs and parallel faults, one about 750 feet from the well, and the other about 1,000 feet from the well. The resulting flow capacity was about 1,170 md-ft. and the permeability was about 90 md. The transient pressure wave was calculated to have explored the reservoir to a distance of about 20,000 feet and that the in-place brine was about 184 million barrels. Predictive calculations for flow rates in the range of 15,000 - 35,000 barrels showed that this level of production would exhaust this size of a reservoir in about a year.

S-Cubed (Technadril - Fenix and Scisson, 1985) noted that the semi-log plot of the draw-down data had slopes of 2,546 and 92 psi/cycle in the first 100 hours of the test and that a doubling of the initial slope occurred at about 29 hours. From this they concluded that there was a boundary at a distance of about 960 feet from the well. From a Horner plot they derived a permeability of 67 md and a skin factor of +0.54. Noting that the last 145 hours of the test gave an apparent constant slope of 0.332 psi/hr they calculated that the in-place brine was at least 85 million barrels. They cautioned, however that this was a minimum value, and that the reservoir could be larger.

Scientific Software-Intercomp (Technadril - Fenix and Scisson, 1985) (Scientific Software-Intercomp, 1983) first analyzed the data using the normal plots of the data and reservoir

engineering methods to determine the reservoir properties. From the semi-log pressure draw down plot they derived a flow capacity of 9,544 md-ft, a permeability of 74.6 md and a skin factor of -0.74. From a Horner type pressure build-up plot they calculated the flow capacity to be 10,689 md-ft, the permeability to be 83.5 md and a skin factor of +0.17. Finally, they used a numerical reservoir simulator (BETA II) to model the test. The grid blocks and properties of the reservoir rock in the grid blocks were adjusted as needed in repeated simulation runs until the calculated pressure matched the experimental pressures. The final match model had an in-place brine volume of about 135 million barrels.

Although there are some differences in the exact values of the reservoir parameters as calculated by the four different groups they are in general agreement that the reservoir was rather small and would not support long term production. With this conclusion there was no need to further test this sand. Sand #9 was therefore plugged back and attention was next given to the next higher aquifer, sand #8. (From, Eaton Operating Company, Inc., Final Report, 1990).

Sand #8 Initial Reservoir Limit Testing

The first pressure transient test of sand #8 was initiated on September 27, 1983. The flow rate started at 14,520 bbl/d and then was reduced to 13,703 bbl/d. This test lasted only 9 hours due to several equipment problems that required removing the bottom-hole pressure tool from the hole and discontinuing production. This brief test did however provide adequate data for an initial interpretation of the reservoir properties, as reported by J.D. Clark (Clark, 1985). He reported a productivity of 39,568 md-ft. and a skin factor of +1.05. Assuming 300 feet of net pay, the permeability was 132 md.

After repair of the equipment the pressure transient test was restarted on October 7, 1983 with an initial flow rate of 13,407 bbl/d. Flow was continued for 21 days, until October 28, with an average production rate of 12,985 bbls/d. The bottom-hole pressure gauge was placed in the hole on October 5th and removed on November 30th, thus providing a continuous record for the draw-down and 32 days of the build-up. The data was analyzed by both J.D. Clark and S-Cubed. J.D. Clark reported (Clark, 1985) that the curved lines resulting on the semi-log graphs he used to interpret the data were an excellent example of lenticular type sand deposits and that there was no evidence of a linear type permeability barrier (such as a near by sealing fault). For the early time production data he calculated a productivity and a reservoir volume with a graphical method that indicates when steady state production apparently occurs. This graph indicated a reservoir volume of about 550 million barrels of brine. Similar graphical analysis of the pressure build up data yielded an initial productivity of 39,752 md-ft. The line on the semi-log time plot and Horner plot was straight only for times less than one day, therefore the reported value for productivity of approximately 39,000 md-ft. is valid for only a limited volume of reservoir near the wellbore. Clark made no attempt to interpret the data once it deviated upwards away from the straight line portion of the semi-log plot.

S-Cubed did a similar, but more extensive, analysis of the October-November 1983 pressure transient test data (Pritchett, Riney, S-Cubed, 1985). They fitted both the draw-down and build-up data to four straight line segments on a semi-log time plot, as is commonly done for petroleum engineering analysis. They then made conjectures about how each of these straight line segments related to the reservoir geometry. On the basis of the slopes of the plots doubling at 9.5 hours and 31.5 hours they estimated the distances to the two nearest faults as being 780 feet and

1,410 feet. Using the second straight line segment on the draw down plot they calculated a reservoir permeability of 113 md. Similar calculations for the build-up data gave a calculated productivity of 44,090 md-ft. and a permeability of 133 md. To estimate the reservoir volume they hypothesized that the pressure was approaching the final pressure exponentially. With this hypothesis (later found to be incorrect) they calculated a reservoir volume of 433 million barrels.

For numerical simulation, S-Cubed used a simple rectangular reservoir with parallel edges at the distances of 780 and 1,410 feet from the well, as estimated from their analysis of the pressure transient data. This was a reasonable assumption based on the geological analysis of east-west growth faults through the reservoir area. With these widths and a height of 328 feet, the long distance out to the end boundaries was 10,827 feet. By using a permeability of 160 md near the wellbore and 20 md for distances beyond 3,600 feet they were able to calculate a pressure draw-down and build-up curve that closely matched the actual reservoir limit test data. (From, Eaton Operating Company, Final Report, 1990).

Sand #8 Long Term Flow Testing

Long term flow testing was initiated in December 1983 and concluded in October 1987. This test was the most definitive test of the well. Sand #8 proved to be a much larger reservoir than estimated from the initial reservoir limit test and capable of sustaining long term brine production.

A test program was established where the flow rates and other production measurements were manually taken at two hour intervals and then manually summarized each day for daily reports. Although a computerized data acquisition system was installed in January, 1986 it was

operated in parallel with the manual data acquisition and the manually obtained data continued to be the reported data.

The initial daily reported data included the production and gas sales, but did not include the gas remaining in solution and sent to the disposal well or account for the fact that the brine flow measurements were made at non standard conditions. Much of this field data has been previously reported (Technadril - Fenix and Scisson, 1985). This manual data was revised by IGT (after the end of the test) to standard conditions and to include the gas remaining in solution after going through the separators. Plots of this revised data for brine production and gas production for sand #8 are shown in Figures 141 and 142. The gas/brine ratio is given in Figure 143 which plots the gas volumes in Figure 141 divided by the brine volumes in Figure 142. If the brine and gas measurements had been perfect, the gas/brine ration plot would be a straight line. In practice, however, since there were some difficulties in the manual reading and reporting (especially in the first few months) there are spurious high or low spikes in the plot. (From, Eaton Operating Company, Inc., Final Report, 1990).

Sand #8 Gas/Brine Ratio

Cumulative gas production versus cumulative brine production from these calculations is presented in Figure 144. The overall gas to brine ratio (the slope of the line) is 28.9 SCF/STB for production up to about 10 million barrels. A slight bend in the curve then occurs for a gas to brine ratio of 28.6 SCF/STB. This slight change in the ration (slope) at 10 million barrels is believed to be due to problems in the data acquisition, and not a real change in the gas/brine ratio. The overall average gas/brine ratio is calculated to be 28.7 SCF/STB as it is produced from the

**Gladys McCall Well Test
Sand 8 Daily Brine Production**

Figure 141. - - Summary plot of daily brine production for Sand 8 (From Eaton Operating Company, Inc., Final Report, 1990).

**Gladys McCall Well Test
Sand 8 Daily Gas Production**

Figure 142. - - Summary plot of daily gas production from Sand zone 8 (From Eaton Operating Company, Inc., Final Report, 1990).

Figure 143. - - Plot of gas / brine ratio for production from Sand zone 8 (From Eaton Operating Company, Inc., Final Report, 1990).

Figure 144. -- Plot showing cumulative gas production verses cumulative brine production (From Eaton Operating Company, Inc., Final Report, 1990).

well. The gas to sales is lower than the gas produced since it excludes the unrecovered gas that stays dissolved in the brine sent to the disposal well, and the losses that occurred through leaks in the system and occasional flaring.

Throughout the long term flow test IGT periodically took complete suites of samples from the various gas and brine streams from which the composition of the gas could be determined which would be representative of the total gas as it was produced from the well. This sampling included stripping the remaining gas out of samples of brine being sent to the disposal well. Table 45 gives the composite average of all 45 of the recombination tests.

The recombination study value of 30.15 SCF/BBL compares well to the value of 28.7 SCF/BBL from actual production when about 2-3% carbon dioxide (the extra CO₂ content above the 10% sales gas) is subtracted out of the recombination studies. (From, Eaton Operating Company, Final Report, V. 2, 1985).

A comparison of the production gas composition at a brine gas separator pressure of 500 psig for the sand zones #8 and #9 is shown in Table 46.

Rice University personnel headed by Dr. Mason Tomson were on site during part of the Sand zone #8 drawdown test to characterize the production brine, and to provide advice and assistance in the areas of scaling and corrosion. The Sand zone #8 brine composition as determined by Rice University personnel on October 11, 1983 is given in Table 47. These data indicated that the brine from Sand zone #8 was very similar to that of Sand zone #9. A comparison of the average brine compositions from Sand zone's 8 and 9 is provided in Table 48 (from Technadril - Fenix and Scisson, Final Report, v. 2, 1985).

TABLE 45

Composite Average of 45 IGT Recombination Analyses*

<u>Component</u>	<u>Mol %</u>	<u>Std. Dev.</u>
Carbon Dioxide**	12.64	0.83
Nitrogen***	0.24	0.06
Methane	84.10	0.89
Ethane	2.21	0.05
Propane	0.47	0.02
Isobutane	0.07	0.01
N-butane	0.06	0.01
Isopentane	0.02	0.01
N-pentane	0.01	0.01
Hexanes Plus	0.17	0.22

	<u>SCF/BBL</u>	
Gas/Brine Ratio	30.15	1.09

* 45 Recombinations

** All carbon dioxide striped out of brine.

*** Sampling contamination, not actually in gas.

(From Eaton Operating Company, Inc., Final Report, 1990).

TABLE 46

Production Gas Composition at Brine/Gas
 Separator Pressure of 500 psig for
 T-F&S/DOE Gladys McCall No. 1 Well (Durrett, 1984)

<u>Component</u>	<u>Sand Zone</u>	
	<u>No. 8</u> <u>(% Mole)</u>	<u>No. 9</u> <u>(% Mole)</u>
Methane	85.96	86.52
Ethane	2.34	2.39
Propane	0.52	0.54
Isobutane	0.09	0.08
N-Butane	0.07	0.08
Isopentane	0.02	0.04
N-Pentane	0.01	0.03
Hexanes	0.00	0.01
Heptanes Plus	0.11	0.16
Nitrogen	0.25	0.25
Carbon Dioxide	10.63	9.90
Hydrogen Sulfide	20 ppm	13 ppm

(From Technadril - Fernix & Scisson, Final Report, Feb. 1982 - Oct. 1985, V. 2, 1985).

TABLE 47

T-F&S/DOE GLADYS McCALL NO. 1
SAND ZONE NO. 8
BRINE COMPOSITION

SAMPLED: OCTOBER 11, 1983

TOTAL DISSOLVED SOLIDS	92,800 PPM
CHLORIDES	54,600 PPM
ALKALINITY (As HCO_3^-)	610 PPM
CALCIUM	4,080 PPM
IRON (FERROUS)	26 PPM
SILICA	18 PPM
SULFUR	NONE DETECTED
SULFATE	NONE DETECTED
SPECIFIC GRAVITY	1.053 (8.77 PPG)

(From Technadril - Fenix & Scisson, Final Report, Feb. 1982 - Oct. 1985, V. 2, 1985).

TABLE 48

Brine Composition of Fluids Produced
from T-F&S/DOE Gladys McCall No. 1 Well (Durrett, 1984)

	<u>Sand Zone</u>	
	<u>No. 8</u> <u>(ppm)</u>	<u>No. 9</u> <u>(ppm)</u>
Total Dissolved Solids	97,800	95,500
Chlorides	59,290	58,600
Alkalinity (As HCO ₃)	522	527
Calcium	4,040	4,080
Iron (Ferrous)	14	34
Silica	100	140
Specific Gravity	1.064	1.045

(From Technadril - Fenix and Scisson, Final Report, Feb. 1982 - Oct. 1985, V. 2, 1985).

The methane content remaining in the brine after removal of gas in the separator is consistent with Henry's Law in that its solubility is close to a linear dependence. For every 100 psi of methane partial pressure, 0.56 SCF/STB of methane will remain in the brine. This value for the Gladys McCall well can be compared to similar values for other DOE projects. A value of 0.62 SCF/STB/100 psi was obtained for the Wainoco P.R. Girouard #1 well, 0.60 SCF/STB/100 psi for the Pleasant Bayou #2 well and 0.53 SCF/STB/100 psi for the HO&M Prairie Canal #1 well.

Brine chemistry analyses, during well testing by Technadril - Fenix and Scisson, were performed by Scientific Consulting and Analysis, Inc. (SCAN) of Lake Charles, Louisiana, on samples taken at periodic intervals throughout the long term testing phase of the Gladys McCall project. These brine chemistry data are presented in Table 49. The fluid from the Gladys McCall No. 1 well can be characterized grossly as a sodium chloride calcium chloride brine with an average total dissolved solids content of about 94,000 mg/L, and a degassed or equilibrated specific gravity of 1.0634 (i.e. 8.86 ppg or 372 lbs/bbs). The average sodium content and calcium content is about 31,700 mg/L and 3,900 mg/L, respectively, and chloride is about 57,100 mg/L. The remainder of the various elements shown in Table 47. The brine is essentially saturated with natural gas as produced at the wellhead (from, Technadril - Fenix and Scisson, Final Report, V. 2, 1985).

Brine samples were also analyzed periodically during the time Eaton Operating Company, Inc., was operating the well. The composite average of nine different analyses for samples taken between November, 1983 and September, 1986, is presented in Table 50.

TABLE 49

BRINE CHEMISTRY ANALYSES
T-F&S/DOE GLADYS McCALL NO. 1 - SAND ZONE NO. 8

DATE	10/28/1983	2/7/1984	8/7/1984	10/12/1984	12/1/1984	2/28/1985	5/1/1985
Alkalinity, mg HCO ₃ /L	---	232	288	285	288	337	281
Alpha (Gross), pCi/L	40	1,570	72	68	60	56	35
Ammonia, mg/L	---	280	135	50	100	60	81
Arsenic, mg/L	0.013	0.005	<0.005	<0.005	<0.005	<0.005	0.015
Barium, mg/L	420	60	80	44	125	95	470
Beta (Gross), pCi/L	340	1,870	380	345	310	470	510
Boron, mg/L	36	38.5	40.8	40.6	41.5	40.3	40.4
Cadmium, mg/L	0.015	0.022	0.005	0.020	0.030	0.015	0.015
Calcium, mg/L	4,040	3,643	4,330	3,840	3,830	3,730	3,690
Chloride, mg/L	59,390	58,700	57,750	56,300	55,200	56,600	56,100
Chromium, mg/L	0.04	<0.02	<0.02	<0.02	0.11	0.04	0.03
Copper, mg/L	0.015	0.075	0.035	0.020	0.020	0.035	0.035
Dissolved Solids, mg/L	97,800	94,900	95,100	93,600	91,700	93,500	91,600
Fluoride, mg/L	0.14	0.40	0.17	0.27	0.16	0.20	0.19
Gamma (Gross, pCC/L	1,530	1,290	180	150	230	180	250
Iron, mg/L	14.0	18.6	23.6	22.0	89.3	25.6	26.5
Lead, mg/L	<0.05	<0.05	<0.05	<0.05	0.16	<0.05	0.08
Magnesium, mg/L	354	318	370	348	300	305	306
Manganese, mg/L	2.1	1.4	1.6	1.7	3.1	2.4	2.1
Mercury, mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
pH	---	7.2	6.9	6.2	6.3	6.6	6.3
Potassium, mg/L	430	780	833	825	807	810	817
Radium, pCi/L	17	33	72	41	45	47	53
Radon, pCi/L	---	49.3	26	20	30	33	36
Silica, mg/L	100	127	129	130	128	128	132
Sodium, mg/L	29,750	30,200	38,400	33,900	32,150	31,700	32,550
Specific Conductance, mhos/cm	---	111,800	117,800	109,000	111,400	107,200	110,000
Specific Gravity	1.0639	1.0637	1.0626	1.0610	1.0632	1.0666	1.0627
Strontium, mg/L	540	473	420	444	427	400	433
Sulfate, mg/L	<1	<1	2.8	<1	2.0	1.1	3.3
Sulfide, mg/L	---	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Suspended Solids, mg/L	---	0.40	3.3	1.1	0.6	0.5	2.5
Zinc, mg/L	0.29	0.26	0.28	0.24	0.21	0.28	0.37

(From Technadril - Fenix and Scisson, Final Report, Feb. 1982 - Oct. 1985, V. 2, 1985).

TABLE 50

Composite Average of 9 McCall Brine Samples

Component	Units	Average	Std.Dev. ^{***}
Alkalinity	mg HCO ₃ /L	314	76
Ammonium	mg NH ₄ /L	118	84
Arsenic	mg As/L	<0.32	0.88
Barium	mg Ba/L	269	228
Boron	mg B/L	34	12
Cadmium	mg Cd/L	0.05	0.06
Calcium	mg Ca/L	3871	209
Chloride	mg Cl/L	56767	1484
Chromium	mg Cr/L	<0.09	0.16
Copper	mg Cu/L	<0.08	0.16
Fluoride	mg F/L	0.25	0.13
Iodide	mg I/L	44	(only one sample)
Iron	mg Fe/L	30.5	22.5
Lead	mg Pb/L	<0.09	0.06
Lithium	mg Li/L	25.4	0.85
Magnesium	mg/L	321	29
Manganese	mg Mn/L	2.0	0.48
Potassium	mg K/L	796	151
Silica	mg SiO ₂ /L	126	14
Sodium	mg Na/L	32811	2544
Strontium	mg Sr/L	430	58
Sulfate	mg SO ₄ /L	<2.6	2.8
Zinc	mg Zn/L	<0.28	0.1
T.D.S.*	mg/L	94350	2203
Gross Alpha	pCi/L	55**	15
Gross Beta	pCi/L	393**	80
Gross Gamma	pCi/L	200**	40

* Total Dissolved Solids.

** One unreasonable measurement omitted from the average.

*** Components with wide scatter in the measurements may have Standard Deviations larger than the average.

(From Eaton Operating Company, Inc., Final Report, 1990).

Gas Exsolution in the Reservoir (from Eaton Operating Company, Inc., Final Report, 1990)

The laboratory PVT studies found the bubble point of the gas in the #8 sand to be 9,200 psia which was considerable lower than the measured reservoir pressure of 12,821 psia (at 15,160 ft). This indicates that the reservoir is undersaturated and initially should flow only brine and no free gas. Once the pressure in the reservoir is lowered below the bubble point however, it is possible for some of the gas to come out of solution into a free gas phase.

Calculated bottomhole pressure for the long term flow test is shown in Figure 145. During most of 1986 and the early part of 1987 the bottomhole pressure (and pressure in the reservoir near the wellbore) was below the 9,200 psia bubble point pressure. Gas could thus come out of solution in the reservoir before it reached the wellbore and become trapped in the pores of the reservoir rock.

IGT monitored gas rates and composition following a step increase in drawdown on two occasions as a "bubble test" to determine whether free gas might have come out of solution and accumulated in the reservoir rock near the reservoir. If a bubble had accumulated in the reservoir then a step change in the reservoir flow rate would cause the trapped gas to expel a bubble of free gas that would be seen as a temporary increase in the gas/brine ratio. The first was on February 12, 1986 and the second was on April 14, 1987. Both tests found only small changes in the gas/brine ratios and compositions which only suggested, but did not conclusively prove, that the bottomhole pressure was below the bubble point pressure such that free gas had accumulated in the reservoir. If free gas had accumulated in reservoir rock pores at near wellbore it was a very small amount (a few MCF or less).

Figure 145. -- Calculated bottomhole pressure for the long term flow test of Sand zone 8 of the Gladys McCall No. 1 test well (From Eaton Operating Company, Final Report, 1990).

Sand #8 Long Term Reservoir Modeling Studies

When S-Cubed prepared their paper on the numerical model of the McCall reservoir for the Sixth Geopressured-Geothermal Conference in 1985 (Pritchett & Riney, S-Cubed, 1985), they had one year's worth of production data from the long term flow test in addition to the previous short term reservoir limit test data. From this new data they found that the actual bottom-hole pressures were higher than the pressures predicted by the previous calculations. They therefore needed to increase the size of the reservoir in their model to match the new data. Since the previous model calculation fit the early time well, they simply added the additional volume to the remote ends of the model. There was no accurate geological information as to where the extra volume should be placed to match the actual reservoir. Several cases with different assumptions of volume were run, and a good fit to the data was found for a revised reservoir volume of 1.2 billion barrels. This revised volume was approximately three times the volume initially deduced from the 21 day pressure transient test.

During the four years of production S-Cubed periodically updated the model in light of the most recent data. In April, 1985 and January, 1986 there were short term build-up tests from which the flow capacity could be recalculated. For both of these tests the flow capacity was calculated to be 28,340 md-ft. rather than the previous 44,090 md-ft. These tests were done after scale inhibitor injection into the well so S-Cubed interpreted this reduction due to partial plugging of the perforations or formation below a shale stringer in the formation. The numerical model was therefore modified to include a stringer in the production interval that partially penetrated the formation. There were also increases in the skin factor attributed to the inhibitor injection. To

continue matching the pressure data with the model in 1986, the total reservoir volume in the model needed to be increased from 1.2 billion barrels to 2.5 billion barrels.

To match the reservoir pressure after three years of pressure build-up (following the long term flow test), S-Cubed found that the total volume in the model needed to be increased even more. Figure 146 shows the dimensions of the model as it had evolved by 1990. The reservoir volume needed to match the pressure data had to be increased from the previous 2.5 billion barrels to a new volume of 7.8 billion barrels. The bottomhole pressure build-up, which continued to rise beyond the upper limits that would occur for the smaller volume models. Where the influx of fluid (presumed to be water) came from was unknown, but it was speculated to be influx from sands either above, below or adjacent to Sand #8. There may also have been some shale dewatering. In the 1990 revision of the model the needed additional reservoir volume was placed above the previous grid and partially isolated from the previous grid by a partial penetrating barrier. The permeability of this new volume needed to be low and was set to 0.2 md. Both the horizontal and vertical permeability of this layer and the vertical permeability of the Sand #8 below it were also set to this low value. There was no need to invoke any nonlinear mechanisms for the model, such as irreversible pore volume compaction. If there was any nonlinear effects they would probably occur close to the wellbore and be masked by the skin factor such that their effects would be difficult to determine from either the experimental data or reservoir modeling.

The build-up pressure data following the long term production is plotted on a Horner plot in Figure 147. On the Horner plot the final pressure to which the reservoir will recover after production is found where the extrapolation of the build-up curve intersects the $(T+dt)/dt=1$ axis.

Figure 146. - - Revised dimensions for the Sand zone 8 reservoir proposed by S-Cubed (From, Eaton Operating Company, Inc., Final Report, 1990).

Figure 147. -- Horner plot for the build-up pressure data following long term production from Sand zone 8 (From Eaton Operating Company, Final Report, 1990).

From this projected pressure and the material balance equation the reservoir fluid volume can be estimated. The Horner plot for the McCall pressure build-up data curve is not a straight line and does not extrapolate as a straight line to the $(T+dt)/dt=1$ axis. The point marked P_f is the end point that should be reached for the 1990 S-Cubed model with 7.8 billion barrels in the reservoir. Whether the build up will continue to build up to the value used by S-Cubed in their 1990 computer model is uncertain since the extrapolation requires a curved line of unknown shape.

A possible conclusion from the Horner plot combined with the S-Cubed model is that there is a part of the reservoir intersected by the wellbore and Sand #8 containing 430,000-550,000 barrels of brine with high flow capacity (39,000-44,000 md-ft) and that this high flow capacity part of the reservoir is in contact with a huge volume (at least as large as the S-Cubed model) which has a very low effective flow capacity. The S-Cubed rectangular model takes all of the known geology into account. The exact shape and orientation of the reservoir is only poorly known however due to the lack of other wells in the area which can be used to establish the geology and formation properties at the distances indicated by its size. It must also be remembered that when a numerical model matched the measured pressure data the reservoir description is not unique, but only one of many possible geological configurations. The fact that the S-Cubed model matches the data quite well is an indication that the volumes are approximately correct even if the exact shape of the reservoir is not known (from, Eaton Operating Company, Final Report, 1990).

Calcium Carbonate Scaling

The most serious operating problem that has been encountered during the first year of

long term testing is the formation of calcium carbonate scale deposits in the 5-inch production tubing string, particularly at brine production rates of 20,000 B/D and higher. Scale deposits equivalent to a uniform thickness of about 0.22 inches were formed in the tubing string during January and February. It was determined by laboratory and field experimentation with the assistance of Tomson and colleagues (1984a) of Rice University that these downhole scale deposits can be removed easily with inhibited 15%w hydrochloric acid. The first series of downhole acid treatments were done in March, and resulted in the removal of some 34,000 lbs. Of scale from the tubing string. It was necessary to do additional downhole acid treatments in July and November resulting in the removal of 25,000 lbs. (0.17 inch thickness) and 50,000 lbs. (0.36 inch thickness) of scale, respectively.

A series of 30+ day test runs were conducted during the year to determine scaling tendency as a function of brine production rate. These data are summarized in Table 4. It was found that scaling was minimal or non-existent at a production rate of 15,000 B/D, but quite serious at 20,000 B/D and still worse at 25,000 B/D.

Rates of Calcium Carbonate Scaling in the Gladys McCall No. 1 Tubing String.

Brine Production Rate, B/D	<u>15,000</u>	<u>20,000</u>	<u>25,000</u>
Total Loss In Flowing	3.3	17.1	31.9
Surface Pressure, PSI/DAY			
Loss In Reservoir Pressure, PSI/DAY	1.8	4.5	8.7
Apparent Increase in Frictional	1.5	12.6	23.8

From previous tests of geopressured-geothermal wells it was known prior to beginning the

testing at McCall that calcium carbonate scale formation in the brine flow lines would be a problem unless measures were taken to combat it. Therefore, scale inhibitor was injected into the surface flow lines from the beginning of the flow tests. The inhibitor used was a polyphosphonate (Dequest 2000) manufactured by Monsanto Chemical Company. The pure chemical was diluted with water to an active strength of about 2-3% then injected with a chemical pump into the brine flow line upstream of the choke so the concentration in the brine was about 0.5 ppm (by volume). Initially, the acid form of the polyphosphonate was used. This proved to be excessively corrosive on the injection piping and equipment so a switch was made to the neutralized form of the chemical.

While the injection of scale inhibitor upstream of the choke protected the surface piping and equipment from scale formation (but not corrosion), it did not protect the tubing in the well or the wellhead upstream of the injection point. Formation of scale in the production well tubing soon became apparent from degraded well performance. Inspection of the wellhead and flow lines revealed the scale. Acid was used to remove the scale. During March 7-14, 1984 the first of several series of acid treatments and intervening evaluations was performed. While this treatment removed the scale, it was only a temporary measure.

With resumption of brine production after each acid treatment, scale immediately began reforming. To monitor the scale buildup the flow line between the wellhead and the surface inhibitor injection point would be periodically inspected. The increased friction pressure in the flowing well was also monitored. When the scale buildup became a problem with its weight on the tubing, too much pressure drop, or problems with the equipment, such as seizing of the valves, another acid treatment was performed.

A typical acid treatment consisted of about 150 barrels of 15% HCl pumped into the well with spacer pads of brine in order to spot the acid at the desired points in the tubing. Each treatment was allowed to soak for about an hour before back flowing it out of the well. Table 51 tabulates the total amount of acid used for each treatment series and the estimated amount of calcium carbonate scale removed.

The rate of calcium carbonate scale buildup is calculated by plotting the cumulative amount of scale removed by the acid treatments as a function of the cumulative amount of brine produced (Figure 148). To prevent scale formation in the wellbore, inhibitor "squeeze" treatments were performed with consultation from Dr. Mason Tomson of Rice University. The treatments consisted of first mixing a "pill" of a few percent phosphonate in brine. The pill was then pumped into the well and forced out into the reservoir formation. In the reservoir, the inhibitor chemical either absorbs onto the surfaces of the rock or reacts chemically to form a phosphonate precipitate. When brine production is resumed after the treatment the inhibitor slowly redissolves into the brine that passes through the treated zone, thus inhibiting scale formation in the brine before it enters the wellbore.

The first inhibitor squeeze treatment for the McCall well was attempted on November 28, 1984. This attempt was not successful. The pill consisted on 23 drums of Champion Chemical T-120 (Equivalent to Monsanto Dequest 2000) and 20 barrels of 15% HCl mixed with 450 barrels of hot brine produced from the well. When this was pumped into the well the pumping pressure abruptly increased when the pill reached the bottom of the well and was starting to go out into the reservoir. Plugging of the perforations was occurring so the job was aborted. Backflushing the pill revealed a large amount of calcium and iron phosphonate solids. It was subsequently

TABLE 51

Acid Treatments to Remove Wellbore Scale

<u>Dates</u>	<u>Acid (15%HCl)</u> (bbls)	<u>Scale Removed</u> (pounds)
March 7-14, 1984	360	33,700
July 10-12, 1984	410	24,800
November 12-16, 1984	754	49,900
May 16, 1985	150	3,000

(From Eaton Operating Company, Inc., Final Report, 1990).

Figure 148. -- Plot showing the amount of calcium carbonate scale removed by acid treatment as a function of the cumulative quantity of brine produced. The plot shown is for treatments through November 1984, where each treatment series removed all of the wellbore scale. The rate of buildup (slope of the line) is 19.4 pounds of scale formation per 1,000 barrels of brine produced (From Eaton Operating Company, Inc., Final Report, 1990).

concluded that the acid in the pill had reacted with calcium carbonate scale that remained on the tubing from previous production, and the tubing itself. The dissolved calcium and iron then reacted with the phosphonate to precipitate insoluble calcium and iron phosphonate solids. Production was resumed without the benefit of the inhibitor while the treatment was redesigned to use a neutralized form of the chemical.

The squeeze was again attempted on May 28, 1985. This treatment was also not successful. After injecting an initial 27 barrel slug of 3% neutralized phosphonate inhibitor (Champion Chemical T-132) diluted in 15% synthetic sodium chloride brine, the resistance to pumping suddenly increased, similar to the first squeeze attempt, which again stopped further injection. Backflushing of the pill (still in the wellbore) produced a large amount of solids consisting of calcium-inhibitor salts and/or iron oxides. The solids had also formed in the wellbore and had plugged the formation similar to the first squeeze attempt. The source of the problem was traced to part of the sodium chloride salt used to make the synthetic brine. Although a sample of the solid salt used to make the synthetic brine was analyzed and found free of calcium it turned out that the supplier had provided salt from two different sources and only one of the sources was sampled. The chemists were unaware that two sources had been used. The unsampled salt from the second source turned out to be contaminated with calcium chloride. The pill and synthetic brine had been mixed and stored in several different tanks on location such that the problem with the calcium contaminated brine was not known until they were mixed during pumping into the well.

Following these two unsuccessful inhibitor squeeze treatments the procedure was replanned and successfully accomplished on June 25, 1985. Stringent quality control was

exercised to insure that the fluids were not contaminated and that precipitate would not form in the wellbore. The successful pill consisted of 550 gallons of Champion T-132 dissolved in 87 barrels of 15% sodium chloride brine to give a final volume of 100 barrels. The pill was pumped into the formation with a 300 barrel spearhead of 15% sodium chloride brine ahead of the pill and a 100 barrel overflush of 10 pounds per gallon of calcium chloride brine behind the pill. The purpose of the calcium chloride was to enhance precipitation of the phosphonate inhibitor in the formation. As the calcium chloride solution was being pumped into the formation the injection pressure dramatically increased, indicating that the desired precipitation of the inhibitor in the reservoir was occurring. The well was then shut in for 24 hours to enhance the absorption/precipitation of the inhibitor before resumption of production. Sampling of the initial production (flow back of the injected fluids) revealed that 40% of the inhibitor was retained in the formation rock and 60% of the inhibitor was immediately flushed back out.

When production was resumed the amount of inhibitor released into the produced brine was sufficient to prevent scale formation in the wellbore. The concentration of phosphonate in the produced brine was in the range of about 1 ppm shortly after the inhibitor squeeze, and decreased to levels below the detection limit of the analysis procedure (tenths of a part per million) while effective scale inhibition was continuing to occur. Inhibition was occurring at inhibitor concentration levels lower than were expected to be effective. Periodic analysis of the brine for phosphonate and inspection of the piping was done to determine the time for the next treatment.

The second (and last) inhibitor squeeze was performed on February 5, 1986. For this squeeze the pill consisted of 100 barrels of 3% phosphonate (Champion T-132) in 10% synthetic sodium chloride brine. It was pumped in with a 100 barrel spearhead of plain brine and an

overflush of 1200 barrels of brine. This treatment successfully controlled scale formation in the wellbore until the termination of the flow test in October 1987.

The first successful phosphonate scaling inhibitor pill, that was squeezed into the well in 1985, allowed the production of 3,416,359 barrels of brine before indications of scaling were found on the filters in the low pressure portion of the production system. This treatment consisted of 100 barrels of a 6% phosphonate solution. An additional 2,014,051 barrels of brine were produced after the filter scaling occurred (5,430,410 total) by adding a small amount of scaling inhibitor in the low pressure portion of the system. No scaling deposits were found in the high pressure side of the system during the entire production period.

The second successful phosphonate pill was squeezed on February 4, 1986. 3,261,359 barrels of brine were produced before scaling occurred on the filters, on the low pressure side of the system, on June 2, 1986. This inhibitor treatment used a 3% phosphonate solution. Additional surface inhibition treatment was begun in May 1986. 13,259,353 barrels of brine were produced after the second inhibitor squeeze, until the well was shut in. (Total production after both squeezes - 18,689,763 barrels.)

The well was shut in on October 30, 1987, for pressure buildup. The well was later plugged and abandoned in 1994. The shut-in bottom hole pressures were recorded for four days. Additional pressures were recorded at 7 days, 10 days, 19 days, 37 days, 54 days, 79 days, 116 days, 172 days, 262 days, 374 days, 500 days, 750 days, and 939 days after shut-in. (Last recording - May 22, 1990; BHP - 12,008 psi; BHT - 299.3°F; @ 15,150'.) (From, Eaton Operating Company, Inc., Final Report, 1990).

HYDROCARBONS IN PRODUCTION GAS AND BRINE

The presence of small amounts of condensible hydrocarbons in the separator gas was observed in several of the test wells. The hydrocarbons were trapped from the separator gas through the use of a series of dry ice/acetone traps at about -70°C , and then analyzed by gas chromatography. This work was done by Dean Keely and John Meriwether of the University of Southwestern Louisiana (USL) in Lafayette. They determined that this so called "Cryocondensate" was largely aromatic in nature, quite different from the usual primarily aliphatic nature of condensates from conventional natural gas wells. The study and analyses of hydrocarbons associated with brines from the DOE geopressured - geothermal test wells was performed by USL under their co-operative agreement with DOE #DE-FC07-901D12945 and details are provided in their annual reports and the final report. Most of the data are from the Gladys McCall well as it was flow tested for the longest duration. The cryocondensates were determined to be almost exclusively aromatic hydrocarbons, ($\text{C}_6\text{-C}_9$) primarily benzene, toluene, ethyl benzene, and the xylenes, but contain over 95 compounds which were characterized using gas chromatography - mass spectroscopy. At the Gladys McCall well the cryocondensate concentration ranged from 25-40 ppm in the brine.

When the Sand zone #8 cumulative brine production had reached about 6.6 million barrels on January 19, 1985, a heavy waxy oil accumulation was noted in the first stage separator. No heavy oil production had been noted at any time before January 19, 1985. A sample of the heavy oil was submitted to Southern Petroleum Laboratories, Lafayette, LA, for analysis and the results are shown in Table 52. The oil, which has a paraffin wax content of about 65%, was produced at levels of 24-28 ppm during February and March 1985; however, the heavy oil production

TABLE 52

ANALYSIS OF HEAVY OIL PRODUCTIONT-F&S/DOE GLADYS McCALL NO. 1

Samples: January 19, 1985

ASTM DISTILLATION

Initial Boiling Point	-	506°F
5% Recovered	-	550°F
10% Recovered	-	590°F
20% Recovered	-	624°F
30% Recovered	-	650°F
40% Recovered	-	675°F
50% Recovered	-	700°F
60% Recovered	-	730°F
70% Recovered	-	740°F
Sample Cracked	-	760°F

Total Recovery	-	70%
Residue	-	21%

API Gravity at 60°F	-	32.9
Color	-	Light Amber
Pour Point	-	90°F
Reid Vapor Pressure at 100°F	-	0.2 PSIG
BS&W	-	0.25%
Paraffin Wax Content	-	65%
Sulfur Content	-	0.12%w
Asphaltenes Content	-	2.0%w
Flash Point (Open Cup)	-	330°F

(ANALYSIS BY SOUTHERN PETROLEUM LABORATORY)

(From Technadril - Fenix and Scisson, Final Report, Feb. 1982 - Oct. 1985, V. 2, 1985).

decreased sharply to about 8 ppm in April 1985, and later averaged only 3-4 ppm. Total production of this heavy oil during the January 23 - October 31, 1985 period was 1,800 gallons or an average of 7.7 ppm basis brine production. Technadril - Fenix and Scisson called this heavy oil as more of an operational headache than of any real economic value. They also noted that after the test well was shut in, there was no heavy oil production for a period of time. The compilers of this report were not able to find any documented information on the heavy oil production from the Gladys McCall test well after October, 1985.

ENVIRONMENTAL MONITORING AT THE GLADYS MCCALL SITE

The chief environmental issues associated with the development of geopressured - geothermal resources in the Gulf Coast region are land-surface subsidence, growth fault activation, and water quality. A plan for monitoring these impacts was developed before resource testing began and was implemented at the test well sites. Other than some temporary changes in water quality, which appear to have been caused by surface pit leaks and by the use of drilling muds, the environmental monitoring program at Gladys McCall (as well as other test sites) has revealed no adverse environmental impacts that could be related to fluid production or disposal.

An environmental assessment was conducted by the U.S. Department of Energy for the Gladys McCall Well Site and published in February 1981 (DOE-EA-1034). This environmental assessment was prepared in compliance with the requirements of the National Environmental Policy Act (NEPA) of 1969 and Executive Orders 11888 Floodplain Management and 11990 Protection of Wetlands. The assessment addressed the expected impacts of drilling and testing a geopressured - geothermal design well as part of the Geopressure Subprogram of the DOE

Division of Geothermal Energy.

The environmental monitoring program at the Gladys McCall test site was carried out by the Louisiana Geological Survey, Louisiana State University (LGS-LSU). Subsidence, microseismic and water quality monitoring was done by LGS-LSU. Details of yearly environmental monitoring activities are provided in their annual reports entitled "Technical support for geopressured - geothermal well activities in Louisiana," C.G. Groat, Program Coordinator. The environmental monitoring work was performed by LGS-LSU under DOE Contract No. DE-FC07-85NV10425. The information compiled here is taken directly from these LGS-LSU reports and the Geothermal Energy Symposium Proceedings (1988) where the LGS-LSU environmental monitoring work was presented by Van Sickle, Trahan and Stevenson. Microseismic monitoring was subcontracted by LGS-LSU to Woodward-Clyde Consultants who set up the microseismic monitoring network in the vicinity of the Rockefeller Refuge around the Gladys McCall Geopressured well site and began monitoring work between April 1981 - March 31, 1982. Details of their activities are described in their report for this period (July 1982, Report #80C5288). Water quality analysis was subcontracted by LGS-LSU to Southern University and A&M College, Baton Rouge. The microseismic monitoring work was later taken over by LGS-LSU, and the water quality monitoring and analysis were taken over by Eaton Operating Company who subcontracted the work to IGT in October 1990.

Subsidence Monitoring

Direct field measurements were used to determine baseline rates of subsidence in the prospect area before well testing and to monitor changes in land surface elevation during and after

well testing.

A network of closely spaced benchmarks were installed to intersect the projected surface positions of major faults. These benchmarks were surveyed and tied to the regional vertical control network which is periodically resurveyed by the National Geodetic Survey (NGS). The determination of baseline subsidence rates was augmented by the comparison of data from historical surveys conducted in the region. The network of benchmarks installed around the Gladys McCall test well site in the Rockefeller Wildlife Refuge is shown in Figure 149.

Each benchmark consists of a steel rod driven to 30m or to refusal (usually more than 15m). Repeated surveys of the subsidence monitoring networks reveal elevation changes on the order of a few millimeters or more. The standard error of the first order, double run geodetic surveys employed in this project is equal to $1\text{mm} \times (\text{line distance in km})^{1/2}$. All marks and survey techniques conform to NGS requirements for first order vertical control.

Analysis of geodetic leveling data for vertical movement usually relies on a presumed rate of motion at some reference point along the survey network. Normally the elevation of a benchmark in a stable region is assumed invariable or fixed during two or more epochs of surveying. The identification of stable benchmarks in South Louisiana is difficult, if not impossible, because much of the land surface is subsiding. Relative changes in elevation, however, it can be determined by referencing geodetic leveling data to key benchmarks that exhibit relatively constant rates of motion. This approach was used to develop long term and recent subsidence profiles for Gladys McCall and other DOE tested prospects (Parcperdue, Sweet Lake, and Pleasant Bayou).

Figure 149. -- Location of the Gladys McCall geopressured - geothermal benchmark network for monitoring subsidence (From Technical Support for geopressured - geothermal well activities in Louisiana, Louisiana Geological Survey, Annual Report, July 1991).

The Gladys McCall subsidence monitoring benchmark network (Figure 149) consisted of benchmarks spaced approximately 1km apart along Highway 82, the access road to the test well, a north-south wildlife refuge road and the Gulf shoreline. The network was surveyed in 1981, 1982, 1986, 1988, 1990, and 1992. Surveys indicated that area-wide subsidence generally decreased from west to east. For the Gladys McCall site, although elevation changes are variable for each two year period for the first eight years, there appears to be an overall elevation drop concentrated near the site between 1988 and 1990, followed by a rebound. This is probably not related to testing since the elevation drop occurred after testing was stopped and was explained as being a localized reaction to an unrelated event. The changes in elevation, ranging from 4 to 10mm/yr, are small but remain larger than the rate of regional subsidence which is no greater than 5mm/year. However, it is uncertain whether the elevation changes are due to geopressured - geothermal well testing activities, or whether they are a reflection of the local rate of subsidence due to natural processes or other local or human induced activities. In general, the subsidence monitoring studies at Gladys McCall have demonstrated variable, but small elevation changes. However, there is no conclusive evidence indicating that regional and local subsidence rates have been altered due to fluid withdrawal during geopressured - geothermal well testing.

Microseismic Monitoring

Microseismic monitoring work at the Gladys McCall well test site was carried out by the Louisiana Geological Survey, Louisiana State University, and detail of this work are reported in their annual reports. Information compiled here is taken directly from these reports.

The DOE geopressured - geothermal research program funded microseismic monitoring

stations established by the Louisiana Geological Survey, Louisiana State University were the first continuous recording seismic networks in the Gulf Coast region. To determine the effects of fluid production and disposal on local growth fault activity, microseismic monitoring stations were established at the Gladys McCall prospect site (Figure 150). The network consisted of short period vertical motion seismometers. To reduce surface noise interference the seismometers were installed in boreholes upto 30m deep. The seismic signals detected at each site were amplified and transmitted via phone lines to the Louisiana Geological Survey seismological laboratory in Baton Rouge (Figure 151). Seismic data received from the field were recorded in two different formats. First, the phone lines were fed directly into a continuous recording 14-track analog tape recorder with a time code for reference. From these tapes any signal of interest could be digitized and saved for further analysis and computer storage. Second, the phone signals were selectively demultiplexed into individual station signals and continuously recorded on visual drum recorders for daily analysis. Paper drum records were scanned daily to detect possible seismic activity. All events that might have been local microearthquakes were processed to obtain hypocenter locations and relative magnitudes. Magnitudes were calculated based on event duration. Since a magnitude scale has not been developed for the Gulf Coast, the absolute values of the computed magnitudes may not be valid, but do serve as good indicators of the relative size of the events.

Microseismic monitoring at the Gladys McCall test site began in July 1981 and continued until December 1991, when the network was dismantled. Flow testing of the Gladys McCall test well ended in October, 1987. Post testing phase of microseismic monitoring did not show any signs of microseismic activity induced by the previous well testing. At Gladys McCall two small suspected seismic events were recorded on February 14 and October 24, 1985 of magnitude <0.0 .

Figure 150. -- Locations of the Gladys McCall microseismic recording stations (From Technical Support for geopressured-geothermal well activities in Louisiana, Louisiana Geological Survey, Annual Report, July, 1991).

Schematic of seismometer field site.

Schematic of multiplex site

Schematic of central recording facility.

Figure 151. -- Schematic illustrations of the different component units for microseismic monitoring from the field site to the central recording facility located at Louisiana State University, Baton Rouge (From Louisiana Geological Survey, Annual Report, 1992).

The events computed shallow depths (<2.0 km) and epicentral location placed them in close proximity to areas of possible influence by brine production and disposal. However, this could not be proved conclusively. During the period of microseismic monitoring many different and curious signal characteristics have been recorded by the networks, but none of these were attributed to be resulting from geopressured - geothermal brine production and disposal.

Water Quality Monitoring

Geopressured - geothermal brines are characteristically high in total dissolved solids (TDS), sodium (Na), chlorine (Cl), baron (B) and other potentially toxic constituents. Gustavson (1978) provided a thorough review of the potential ecological impacts of geopressured - geothermal discharges into surface water. Water quality monitoring stations were established at Gladys McCall and other geopressured - geothermal prospect sites to determine the effects of brine contamination from accidental spills and from leaks in the production / injection system or from storage facilities. Surface water sampling stations were positioned down the hydrologic gradient from each test site, at appropriate points for determining the background effects of other sources of flow into the system, such as seawater intrusion or land surface runoff. Groundwater observation wells were installed in near surface aquifers containing fresh groundwater. The observation wells were located in the path of the most likely migration of geopressured - geothermal fluids from the production - injection flow system based on the direction of local groundwater flow.

Sampling of ground and surface water was conducted monthly during the first two years of well development and testing at each site, including Gladys McCall. Quarterly samples were

taken thereafter the samples were analyzed for standard physical and chemical parameters and for constituents which would indicate contamination by geopressured - geothermal fluids. These analyses included: ammonia (NH_4), sulfate (SO_4), chlorine (Cl), sodium (Na), potassium (k), magnesium (Mg), cadmium (Cd), manganese (Mn), calcium (Ca), chromium (Cr), barium (Ba), lead (Pb), arsenic (As), boron (B), mercury (Hg), hardness (CaCO_3), total organic carbon (C), dissolved oxygen (O_2), specific conductance (SC), pH, turbidity, and temperature. Water analyses, as mentioned earlier was performed by Southern University and A&M College under a subcontract to LGS-LSU. Later this work was conducted by Eaton Operating Company Inc., Houston who subcontracted the work to the Institute of Gas Technology. The layout of the Gladys McCall test site and the water sampling stations are shown in Figure 152.

Although drilling fluid contamination was detected in surface and groundwater near the vicinity of the well, no long term effect on the water quality was observed due to geopressured - geothermal well testing.

PLEASANT BAYOU NO. 2 WELL

The Pleasant Bayou No. 2 well was the first design well drilled and completed in the U.S. Department of Energy (DOE) geopressured - geothermal energy program. It was drilled in 1979 after mechanical problems precluded completion of the Pleasant Bayou No. 1 well, which was subsequently used as the brine disposal well. The well location was selected in a multi-year, multi-department research program at the University of Texas in Austin that was coordinated by the Center for Energy Studies at the University. The contractor to DOE for the drilling and initial testing was General Crude Oil Company. Surface facilities designed for long-term, high rate

Figure 152. - - Well location and site layout map of the Gladys McCall Well No. 1 and the water quality sampling sites (From Eaton Operating Company, Inc., Final Report, 1990).

testing were operated with Fenix and Scisson as the prime contractor. Testing began in 1980 and continued for about 6 weeks at an average rate slightly below 12,000 barrels per day in 1980. A few days of attempts to flow the well at a brine rate of 29,000 barrels per day in 1981 ended with the need to pull the tubing to remove over 14,000 ft. of wireline. During the period from September 1982 through April 1983, almost 3.5 million barrels of brine were produced at an average brine rate of about 18,200 stock tank barrels per day (STB/d). Scale buildup in the production tubing and wellhead interfered with the planned deduction of bottom hole pressure from wellhead pressure. The 5½ inch tubing contained ¼ to ¾ inch of scale in almost 12,000 feet of its length, and the tubing parted at a depth of 5,225 ft. about 3 weeks after the well was shut in. The Pleasant Bayou location was inactive from 1983 until the clean out of the production and disposal wells by Eaton Operating Company in 1986. The surface facilities were rehabilitated in 1987 and 1988. After shakedown of the system, additional repair of wellhead valves, and injection of an inhibitor pill, continuous long term production was started in June 1988. Testing ended on August 31, 1990 (from, Institute of Gas Technology, Final Report, 1992).

The Pleasant Bayou No. 1 well was spudded by General Crude Oil Company (GOC) on July 2, 1978. Drilling proceeded in accordance with a previously approved drilling and testing plan, and on November 17, 1978, a depth of 15,765 was reached. Unstable hole conditions resulted in the pipe becoming stuck during an attempt to cut core No. 10. A series of hole problems, including bridges, well kicks, stuck pipe formation breakdowns, and erosion at some places in the intermediate casing, forced the plugging back of Pleasant Bayou No. 1 to the bottom of the 13¾ inch casing at approximately 8,400 ft. This hole was later converted for use as the disposal well for the Pleasant Bayou No. 2 test well. The test well, the GCO-DOE Pleasant

Bayou No. 2, is located on a five acre test site 40 miles south of Houston, Texas, in Perry and Austin Survey Abstract 107, Brazoria County, 11,404.79 feet southwest of the northeast line and 1,498.66 feet southeast of the northwest line, on the east bank of Chocolate Bayou on General Crude Oil Company's Martin Ranch property near Alvin, Texas (Figure 153). This location on a United States Geological Survey quadrangle map is shown in Figure 154 and the road map (Figure 155) shows the accessibility to the well site. Pleasant Bayou No. 2 well started drilling on January 25, 1979 and it was drilled to a total depth of 16,500 ft. and completed as a geopressured - geothermal well on July 11, 1979.

The organizational setup of the Energy Applications Division of the Geothermal Branch of DOE at the time of the Pleasant Bayou well project is shown in Figure 156. The organizational chart for the original drilling and testing program is outlined in Figure 157. Testing work at the Pleasant Bayou No. 2 geopressured - geothermal reservoir and the brine injection reservoirs was carried out through the assistance of several other organizations, either through subcontracts, contracts of DOE with other organizations, or other means. The project was co-ordinated in the beginning by Fenix and Scisson whose responsibility included ensuring the timely and successful coordination with institutions providing complementary research work in support of the testing. General well test support, reservoir formation rock mechanics, reservoir modeling and simulation, and resource geologic assessment was provided by the Center for Energy Studies, the Petroleum Engineering Department and the Bureau of Economic Geology, of The University of Texas at Austin. Environmental monitoring was conducted by the Bureau of Economic Geology, The University of Texas at Austin initially and later by the Louisiana Geological Survey, Louisiana State University at Baton Rouge. Work as scaling, corrosion inhibitors and brine chemistry was

Figure 153. -- Surveyor's well location plot for the Pleasant Bayou No. 1 and No. 2 wells (from, U.S. Department of Energy, Nevada Operation Office, 1979).

Figure 155. - - The Pleasant Bayou project location on a road map (from, Institute of Gas Technology, Final Report, 1992).

Figure 156. -- Organizational chart of the DOE Nevada Geothermal Operations Office (from, Gruy Federal, Inc., 1981).

Figure 157. -- The drilling and testing program organizational chart for the Pleasant Bayou No. 2 well, Brazoria County, Texas (from, Grady Federal, Inc., 1981).

done by the Rice University, Environmental Science Department, Houston, Texas. Brine injectivity studies were performed by the Lawrence Livermore National Laboratory. Computer simulation and modeling of the reservoirs were done by S-Cubed (Systems, Science, and Software), LaJolla, California and Intercomp Research and Engineering, Inc., Houston, Texas. Core shale and reservoir fluid nuclear analysis was done by the U.S. Geological Survey, Gulf Coast Hydrosience Center, Bay St. Louis, Mississippi. Other details about work required by from each of the organizations under the various contracts and names of personnel involved are given in the Gruy Federal, Inc., report of July, 1981. Information on subcontractors after Eaton Operating Company took over site operations in 1985 can be found in the final report by Eaton Operating Company (1990).

The Center for Energy Studies and the Bureau of Economic Geology (BEG) of The University of Texas at Austin undertook a comprehensive study of the geopressured - geothermal resources in the Texas Gulf Coast and it was mainly on the basis of these geological studies that the Pleasant Bayou Well location was selected. Their initial studies centered on the Frio formation and subsequent investigations examined the Vicksburg and Wilcox formations. The principal geothermal fairways as identified by these studies are shown in Figure 158. The principal geopressured - geothermal zone in the Brazoria fairway is the Frio Formation of Upper Oligocene, Tertiary age (Figure 159) which is several thousand feet thick. This thickness is too great for the formation to be used as a mapping unit in identifying trends and depositional environments. This led to the division of the Frio into six subunits in the lower and middle Texas Gulf Coast. This division was based on the following assumptions: 1) micropaleontologic or foraminiferal markers (Figure 159), which always occur in the same vertical sequence within the

Figure 158. -- The Frio, Vicksburg and Wilcox geopressured - geothermal fairways and location of the Pleasant Bayou (#1 & 2) test well in the Frio fairway (from, Gruy Federal Inc., 1980).

AGE	SERIES	GROUP/FORMATION	SERIES	GROUP/FORMATION	
Quaternary	Recent	Undifferentiated			
	Pleistocene	Houston			
	Pliocene	Goliad			
Tertiary		Fleming			
	Miocene	Anahuac			
	?	?			
	Oligocene	Frio			
		Vicksburg			
		Jackson			
		Claiborne			
	Eocene	Wilcox			
		Midway			
			Miocene	Anahuac	Discorbis nomada Heterostegina texana
			Oligocene	Frio	Marginulina vaginata Cibicides hazzardi Ngnion struma Nodosaria blampiedi Textularia mississippiensis Anomalie bilateralis
				Vicksburg	Textularia warreni

Figure 159. - - Stratigraphic column of the Tertiary formations, Texas Gulf Coast and the Foraminiferal markers of the Miocene and Oligocene (from, Gruy Federal, Inc., 1980).

Frio, are time dependent as well as environmentally controlled, and they define a gross correlation fabric; 2) on a regional scale, the Frio thickness and dips uniformly down towards the Gulf; and 3) shale zones are more reliable correlation markers than thick sands because they are more widespread and represent longer periods of time for deposition.

On regional cross sections of the Frio in the Upper Texas Gulf Coast, the formation has been subdivided into the six subunits using "T" markers. On dip sections, each unit shows (1) a main sand depocenter which is shifted gulfward insuccessively younger units; (2) a predominantly shale area with numerous thin, discontinuous sands updip of the high sand area, and (3) a predominantly shale area with sparse, thin sands downdip. The "T-zone" markers at the Pleasant Bayou No. 2 well and the depths at which they have been identified are shown in Table 53 (from, Gruy Federal, Inc., 1980).

The Brazoria Fairway, where the Pleasant Bayou well is located, in southwestern Galveston and southern Brazoria Counties, Texas, was identified through the regional study of the Frio Formation along the Upper Texas Gulf Coast (Figure 160). Potential sandstone reservoirs in this fairway occur in the T5-T6 correlation unit (*Anomalina Birateralis* zone) and are indicated on a sandstone percent map (Figure 161) by the 20 percent contour in the north-central portion of the fairway, an area of thick sandstone (from Bebout, Loucks and Gregory, 1979). The Pleasant Bayou area is located within a zone of syndepositional down to the basin faults that were most active during early Frio time. This fault zone also marks a rapid change in lithofacies, both in terms of sandstone percentage and in log character. This relationship has been interpreted by Winker et al (1981) to mean that the Pleasant Bayou reservoir sandstones were deposited near the

TABLE 53
Time-zone markers for the Pleasant Bayou Well #2.

<u>"T" Marker Zone</u>	<u>Depth (ft)</u>	<u>Paleontological Markers</u>
T0 - T1	-8,780 to -9,140 (-2,676 to -2,786 m)	MI, MV, MH
T1 - T2	-9,140 to -9,740 (-2,786 to -2,969 m)	CH, MT
T2 - T3	-9,740 to -10,740 (-2,969 to -3,273 m)	NS, NB
T3 - T4	-10,740 to -12,070 (-3,273 to -3,679 m)	TM
T4 - T5	-12,070 to -13,600 (-3,679 to -4,145 m)	
T5 - T6	-13,600 to ? (-4,145 to ? m)	

(From, Eaton Operating Company, Inc., Final Report, 1990 in, Gruy Federal, Inc., 1980).

Figure 160. - - Frio geopressed - geothermal fairways, depositional models, and reservoir quality (from, Bebout, Loucks and Gregory, 1978).

Figure 161. -- Map showing sand percentage of the T₅ - T₆ sand complex with 200° and 300° isotherm lines. The Brazoria fairway is indicated by the 20 percent contour in northeast Brazoria County and the main sand depocenter is updip of the 200°F isotherm.

contemporaneous shelf edge (Figure 162) (from Winker et al, Annual Report No. DOE/ET/27111-3, 1981).

Deltaic sedimentation, growth faults and salt dome characterize the depositional and structural style (salt withdrawal basin) in the Brazoria Fairway (Figure 163). The Pleasant Bayou site lies near the western edge of a dendritic network of faults. An east - west fault is seen just south of the well. The Pleasant Bayou wells were drilled in a synclinal area on the southwest flank of a domal structure forming the Chocolate Bayou area. The strata in the test well area based on information from the dipmeter survey run in the well, are dipping at 7 degrees to the southwest. No faults of any significant magnitude were recognized in the prospective zone in either of the test wells (Pleasant Bayou #1 or 2). A geologic cross section (C - C') through the Pleasant Bayou wells (Figure 164) is shown in Figure 165. The correlation lines in this cross section represent the time marker zones developed for the area based on paleontologic markers. A depositional model by Fisher (1969) of a high constructive delta (Figure 166) best illustrates the distribution of sandstone and shale within the T5 - T6 depositional complex into which the Pleasant Bayou test wells were drilled.

Bebout, Loucks, and Gregory 1978) originally proposed a geopressured - geothermal test well site that predicted 840 ft. of sandstone beneath the T5 marker at a depth of 14,000 ft. Thirty percent of the sandstone was estimated to have permeabilities higher than 20 md. At the actual test well site, 1.75 miles to the northeast of the originally suggested site, the top of the T5 marker was projected at 13,600 ft. and the amount of sandstone to be penetrated was approximately 690 ft. The DOE Pleasant Bayou No. 2 well was drilled in this site and the T5 marker occurred at 13,960 ft., indicating a slightly deeper dip into the salt withdrawal basin than originally predicted.

Figure 162. -- Location of the Pleasant Bayou area in relation to regional shelf-margin trends, northwestern Gulf of Mexico basin (Winker et.al, Annual Report DOE/ET/27111-3, 1981).

Figure 163. -- Structural map drawn on top of the T₁ marker, Brazoria Fairway. The Pleasant Bayou test well site is on the southwest flank of the Chocolate Bayou Domal Structural (from, Bebout, Loucks and Gregory, 1979).

Figure 164. - - Location line of structural cross section CC¹. The Pleasant Bayou well No's 1 and 2 are located in T&R 6S-39E. Numbers on cross section line CC¹ refer to well names shown in the cross section (from, Bebout, Loucks & Gregory, 1978).

Figure 165. - - East-west structural cross section through the DOE Pleasant Bayou Wells (from, Bebout, Loucks and Gregory, 1979).

Figure 166. - - Principal depositional environments and sand patterns, high constructive lobate delta systems, Gulf Coast Basin (Fisher, 1969).

A total of 660 ft. of sandstone occurs beneath the T5 marker, slightly less than the 690 ft. predicted. Core analyses from the Pleasant Bayou No. 2 well indicated that the highest permeability occurred in mud-free channel sandstones and the lowest permeability occurred in associated muddy delta plain and interdistributary facies (Figure 167).

The reservoir with the best overall quality is a medium to coarse grained, bed load fluvial channel deposit. A model proposed for this type of depositional environment by Bebout, Loucks and Gregory (1979) indicates that this type of reservoir can have both excellent dip and strike continuity as (Figure 168). Perforation in the Pleasant Bayou No. 2 well are in this highly permeable fluvial channel sandstone from 14,650 ft. to 14,710 ft.

The original drilling, completion, and initial testing of this well prior to October 1985 when work was taken over by Eaton Operating Company, Inc., is described in the following reports:

- (1) Drilling and Completion of Pleasant Bayou No. 2, Brazoria County, Texas; Volume 1 - Final Report; compiled by John Rodgers, Gruy Federal, Inc., for Fenix and Scisson, Inc., December 31, 1982.
- (2) Pleasant Bayou Geopressured/Geothermal Testing Project, Brazoria County, Texas, Final Report, Fenix and Scisson, Inc., July 1985.
- (3) Drilling and completion of Pleasant Bayou No. 1 and Pleasant Bayou No. 2 and evaluation of preliminary tests, Compiled by John A. Rodgers, Gruy Federal, Inc., for Fenix and Scisson Inc., November 1980.
- (4) Testing of Pleasant Bayou No. 2, Compiled by John A. Rogers, Gruy Federal, Inc., for Fenix and Scisson, Inc., February 19, 1981.

GENERAL CRUDE/DOE
2 Pleasant Bayou

Figure 167. - - Relationship of porosity and permeability to depositional environments in core intervals from the GCO/DOE No. 2 Pleasant Bayou Geopressured - Geothermal test well (from, Bebout, Loucks and Gregory, 1979; Loucks, Richmann, and Milliken, 1979).

Figure 168. - - Block diagram illustrating a coarse grained, bed load fluvial channel similar to the fluvial channel in the facies represented in the target section of the Pleasant Bayou No. 2 well. The cross-sectional view shows the sand bodies to be connected and having good lateral continuity (from, Bebout, Loucks, and Gregory, 1979).

(5) Geopressured - geothermal production test plan, Phase II, Gruy Federal Inc., July 1981.

During the drilling of the Pleasant Bayou No. 1, diamond cores were taken. A total of 9 cores were taken at depths between 4,300 - 4,350 ft., 6,700 - 6,750 ft., 10,215 - 10,270 ft., 11,732 - 11,792 ft., 12,580 - 12,634 ft., 14,053 - 14,104 ft., 14,745 - 14,771 ft., 15,147 - 15,202 ft., and 15,543 - 15,593 ft. A total of 461 feet of core was cut, but only 321.5 ft. were recovered (Gruy Federal, 1980). Sidewall cores were also taken. During the drilling of Pleasant Bayou No. 2, three cores were cut between 14,666 - 14,716 ft., 15,615 - 15,664 ft., and 15,664 - 15,675 ft. Details of the core analyses of all these cores are provided in Appendix 5 of this volume. A detailed paleontological analysis was done on samples from the Pleasant Bayou No. 1 well by ECO - Pal and this information is available in the Gruy Federal, Inc., Report of November 1980.

An electric log of the producing well, showing the production zone is shown in Figure 169. Prior to Eaton Operating Co., Inc. taking over well operations, a tubing failure has occurred, and after a fishing job which lasted several months was suspended, the well was temporarily placed in an abandoned status in 1983. The completion of the well at this point is shown in Figure 170. Eaton Operating Company, Inc., Houston, Texas, later successfully cleaned out the well and recompleted it as shown in Figure 171. Two successful scale inhibitor squeezes were performed in this well after recompletion. The first one was done in April 1988 and the second one was done in November 1989. After producing 4,950,000 barrels of brine, some scaling was detected in the low pressure system. Surface inhibition was begun, and a total of 7,720,000 barrels was produced after this squeeze, until November 1989 when the second squeeze was performed. After this 2,750,000 barrels of brine were produced before surface inhibition was again started on May 16, 1990. The well continued to produce 796,785 barrels of

--Pleasant Bayou No. 2 dual induction focused log :
test zone, 14,644' to 14,706'.

(From Gruy, 1982)

Figure 169. -- Electric log of the Pleasant Bayou No. 2 well showing the tested sand reservoir (from, Eaton Operating Company, Final Report, 1990).

CONDITION OF No. 2 WELL 8/15/83

(From Fenix & Scisson, 1985)

Figure 170. - - Schematic illustration of the Pleasant Bayou No. 2 well completion of 8/15/83 (from, Eaton Operating Company, Inc., Final Report, 1990).

EOC/DOE PLEASANT BAYOU No. 2
Brazoria County, Texas

Figure 171. - - Schematic illustration of the Pleasant Bayou No. 2 well completion as recompleted by Eaton Operating Company on 4/3/86 (from, Eaton Operating Company, Inc., Final Report, 1990).

brine, for a total of 3,546,785 barrels as of August 1990, after the second squeeze. The well produced a grand total of 11,266,785 barrels of brine after two squeezes (from, Eaton Operating Company, Inc., Final Report, 1990).

The saltwater disposal well electric log is shown in Figure 172. Initial perforations for the first phase of well testing were between 6,460 - 6,480 ft., 6,494 - 6,514 ft., and 6,518 - 6,538 ft. As the well was sanded up and had a tubing leak when Eaton Operating Company, Inc., assumed the well in 1985, they reworked and recompleted the well in October 1980, prior to the commencement of flow testing of the Pleasant Bayou No. 2 well. It was again necessary to wash sand out of the well in June, 1988. Additional intervals were perforated, as seen in Figure 172, on May 26, 1989, due to increased injection pressures. These perforation intervals were between 6,060 - 6,092 ft., 6,100 - 6,190 ft., and 6,198 - 6,216 ft. A schematic of the well at that time is shown in Figure 173. With continuing brine injection, the well sanded up again and it was again reworked and recompleted in July 1990, as shown in Figure 174 (from, Eaton Operating Company, Inc., Final Report, 1990). All perforations in the saltwater disposal well were subjected to acid treatment and injectivity tests before injection of brine from the test well took place.

Review of past production data

Three flow tests and one buildup on the Pleasant Bayou No. 2 geopressured - geothermal test well were analyzed to estimate reservoir properties during preliminary testing. This testing took place from November 15, 1979 to January 4, 1980 and are reported in a summary document titled "Testing of Pleasant Bayou No. 2" by Rodgers (1981). An estimated 274,000 barrels of

Figure 172. - - Electric log of the saltwater disposal well at Pleasant Bayou showing the disposal zones as of May 1989 (from, Eaton Operating Company, Inc., Final Report, 1990).

EOC/DOE PLEASANT BAYOU SWDW No. 1
Brazoria County, Texas

Figure 173. - - Schematic illustration of the Pleasant Bayou saltwater disposal well #1 as completed by Eaton Operating Company, Inc., on 5-26-89 (from, Eaton Operating Company, Final Report, 1990).

EOC/DOE PLEASANT BAYOU SWDW No. 1
Brazoria County, Texas

Figure 174. - - Schematic illustration of the Pleasant Bayou saltwater disposal well as completed by Eaton Operating Company on 7/22/90 (from, Eaton Operating Company, Final Report, 1990).

brine were produced during initial production tests on the Pleasant Bayou No. 2 and injected into the Pleasant Bayou No. 1 disposal well.

Phase I testing consisted of a 45 day drawdown and a longer buildup, during which pumps were installed to inject scale inhibitor to control calcite scaling. Separator modifications were made to minimize two-phase flow through meters and to increase the accuracy of flow measurements. The well was opened on September 16, 1980, and flowed at a maximum rate of 19,200 B/D and also at lower rates (6,000, 10,800, 15,340, and 13,400 B/D). The average gas to water ratio, at separator conditions, for the phase 1 test was 22.35 scf/bbl. Gas to water ratio for the reservoir fluid was about 29:1 (methane content of the reinjected fluid was approximately 7 scf/bbl. A summary of the results of the production and pressure studies during the Phase 1 testing are given below:

Bottom hole temperature -----	309.2°F
Permeability -----	159.8md
Fluid viscosity -----	0.36cp
Areal extent of reservoir -----	36,000 acres
Maximum temperature of produced brine -----	277°F
Gas: brine ratio (separator conditions) -----	22.0:1
Gas content of residual separator fluid -----	7 scf/bbl
Methane content of gas -----	87 percent
Dissolved solids in brine -----	130,000 mg/l
Calcium -----	9,000 mg/l

Chloride -----79,000 mg/l
Sodium -----38,000 mg/l
Total hardness as CaCO₃ -----28,000 mg/l

(From, Gruy Federal, Inc., 1981).

A summary of prior production in terms of phases and well testing has been provided in the Eaton Operating Company, Inc. final report (1990) and also in the Institute of Gas Technology final report for Eaton Operating Company, Inc. (1990). This summary is shown in Table 54.

The process flow diagram for the Pleasant Bayou surface facilities is shown in Figure 175.

Production Data

Details of production data are provided in summary in the Eaton Operating Company final report (1990) and the Institute of Gas Technology report (1990) done for Eaton Operating Company under a subcontract. The information compiled below is taken directly from these sources:

1986 Well cleanup and bottom hole pressure measurement:

This section covers details of the well cleanup on March 30-31, 1986 and the bottom hole pressure measurement performed April 1, 1986. During preceding weeks, the packers and fish left in the well in 1983 were removed, and new 5½", 23# tubing was installed to a depth of 13,968' (bottom of the mule shoe on the seal assembly) from the kelly bushing height of 31' above ground level. The tubing was filled with 16.0 #/gal lignosulphonate mud at this time.

TABLE 54

Brine production prior to 1983 during the different phases of well testing

Date Span	Hrs of Flow	Cum Brine	Avg Brine Rate	GWR
Phase 0				
07/09/79-07/10/79	8.70	539	1,487	16.68
07/10/79-07/10/79	11.25	1,031	2,200	20.70
11/15/79-11/15/79	3.29	2,356	17,187	19.63
11/15/79-11/18/79	65.60	49,082	17,957	19.63
11/23/79-11/26/79	67.66	45,241	16,048	21.00
12/03/79-12/14/79	<u>252.47</u>	<u>177,149</u>	<u>16,840</u>	<u>20.70</u>
Sub-totals & Avg.	408.97	275,398	16,161	20.54
Phase I				
09/04/80-09/04/80	6.66	2,310	8,324	16.68
09/16/80-10/31/80	<u>1,082.50</u>	<u>537,346</u>	<u>11,913</u>	<u>22.35</u>
Sub-totals & Avg.	1,089.16	539,656	11,891	22.33
Phase IIA				
07/02/81-07/17/81	264.92	230,898	20,918	18.65
Phase IIB				
09/22/82-10/23/82	690.50	539,736	18,760	21.68
Phase IIB Cont.				
10/24/82-04/14/83	<u>3,898.40</u>	<u>2,948,653</u>	<u>18,153</u>	<u>22.02</u>
Grand Totals & Avg.	<u>6,351.95</u>	<u>4,534,339</u>	<u>17,193</u>	<u>21.78</u>

(From, Eaton Operating Company, Inc., Final Report, 1990).

Figure 175. -- Process flow diagram for Pleasant Bayou surface facilities (from, Eaton Operating Company, Inc., Final Report, 1990).

The clean-out was monitored by IGT to provide data for real-time control of operations, as well as for documentation. Data consisted of tubing and annulus pressures, plus level in the two frac tanks used to collect returned liquids and solids.

Mud Displacement

The initial step in clean-out was displacement of mud from the well by pumping fresh water down 1¼" continuous tubing to depths that were increased step-wise after bottoms up. For the first eleven hours, liquids and solids entering the tanks were a mixture of mud from the well and the fresh water pumped to displace the mud.

Natural flow from the well did not occur before complete displacement of mud from a depth of 4,500'. However, natural flow began before bottoms up from a tubing depth of 4,500'. However, natural flow began before bottoms up from a tubing depth of 5,500'. The tubing was pulled from the well, and a total of about 50 barrels were produced by natural flow. However, plugging of the two ⅜" holes in the Willis type M3G choke precluded continuous production from the well.

Natural flow cleanup

The annulus pressure increased due to heating by natural flow prior to plugging of the Willis choke. Tubing pressure spikes were observed due to pumping fresh water into the choke in attempts to break loose plugs.

Declining tubing pressures were observed while awaiting delivery and installation of a surface choke manifold. This manifold provided a straight through, 2", heavy wall pipe, plus two

positive chokes. On March 31, flow through the pipe in the choke manifold was started. For about 15 minutes, flow rates were in the range of 1,500 to 4,500 BPD. Then, as flow rate and tubing pressure rapidly increased, flow was switched to a 1" positive choke. The well was shut in at 1:55 AM. Total production during this period was about 500 barrels or slightly more than 1.5 well volumes. The average rate was about 12,000 BPD, and the peak rate observed in a 5 minute interval was 40,000 BPD.

On March 31, the casing pressure was bled off for the first time, and flow from the tubing through a ½" positive choke was started to obtain data for evaluation of the condition of the perforations. Tank strap data verified that the flow rate averaged 7,000 BPD. At bottoms up (300 barrels produced), flow tubing pressure increased from 3,880 psia to 3,970 psia. This was interpreted as meaning that an additional slug of mud had been pushed from the perforations to the surface and that an additional, higher rate flow should be performed to be confident that the well was reasonably well cleaned up. A dip to a tubing pressure of 3,580 psia at the end of the flow was the result of a communication failure which resulted in the service company man switching to a ¾" choke, rather than shutting in the well until brine could be removed from the tanks. Total production during this flow was 450 barrels or 1.5 well volumes.

Also on March 31, and after removing enough brine to provide the required tank capacity, production of 500 barrels through a ¾" positive choke began. The production rate averaged 14,000+ BPD. The drawdown from shut-in pressure was 600 psi at both the beginning and the end of the test. Further, no step-in flowing tubing pressure was observed at bottoms up (300 barrels produced). This was interpreted as evidence of adequate cleanup of the well.

Bottom hole pressure measurement

The heights of the wellhead and the wireline mast were such that the desired number of sinker bars could not be used. Tubing pressure was reduced shortly after 15 days by blowing brine through the needle valve on the lubricator in an attempt to get the wireline to go downhole. This was unsuccessful.

After obtaining heavier sinker bars, a sinker bar trip into the well was successfully made. The tool tagged up hard at a wireline depth of 14,042' below a reference depth of 31' above ground level (original rig KB). After clean-out, drill pipe rotation at 14,028' was required to achieve greater penetration, and this is believed to be the depth actually reached with the wireline.

The downhole Panex instrument run was made on April 1. The weight of the downhole tools was so low that several hundred feet of wire was in the well before tension lifted the ground level sheave off the ground. This was apparently accompanied by slippage of wire through the odometer (depth-measuring device). The trip out of the hole revealed a depth discrepancy of 109'. Because tension was adequate for proper odometer operation on the trip out, a 109' depth correction is made as discussed below.

During the trip into the well, 10 minute stops were made at indicated depths of 12,000' and 13,000' to establish a pressure gradient for extrapolation to the depth of perforations. The tool tagged up hard at an indicated depth of 13,887' for the Panex sensor. The sensor was 25' above the bottom of the sinker bars. Including this 25' and the 109' correction, the tool appears to have tagged up at a depth of 14,021' below the original rig KB of 31' above ground level. This is very close to the driller's depth of 14,028' where drill pipe rotation was required to achieve greater penetration after clean-out. Accepting this depth as a downhole depth reference and

recognizing that the Panex sensor was 25' above the bottom of the wireline hardware, the deepest pressure was recorded at a depth of 14,003'. Indicated wireline depth to the sensor from 33' above ground level was 13,887'. Thus, the correction from observed wireline depth to actual depth, referenced to the top of the liner, is 118'. Note that this value differs from the depth correction of 109' that was incorporated in the data report by Milton M. Cooke Petroleum Engineers (Cooke) by 9'. The reason is that Cooke reported from an assumed original rig Kelly bushing height of 33' and corrected only for the differences between odometer readings before and after the trip downhole.

A correction to reported pressures is also required before drawing conclusions about bottom hole pressure. When the downhole Panex instrument was in the lubricator, it indicated a pressure of 4,230 psia. At the same time, a deadweight tester indicated a pressure of 4,241 psig (4,256 psia) at the bottom of the lubricator. Assuming that the lubricator was filled with brine with a pressure gradient of 0.46 psi/ft and that the Panex sensor was 32' above the deadweight tester, the deadweight tester value corresponds to 4,241 psia at the Panex. Thus, the Panex reading in the lubricator was low by 11 psi. When open to the atmosphere, the Panex read 18 psia or a value that is high by 3 psi. The functional relationship between the discrepancies and pressure is not known. It will be assumed that reported downhole pressures in the vicinity of 10,000 to 11,000 psia have a range of uncertainty from being correct on the one hand, to being low by an amount calculated from linear extrapolation of the discrepancies noted above on the other hand. This results in the following equation for an upper limit of true downhole pressure:

$$P_{\max} = -3.06 + 1.003324 * P_{\text{indicated}}$$

With the 118' correction to depth, the probable range of actual bottomhole pressures is as shown

in Table 55. The table also shows calculated values (assuming 0.454 and 0.455 psi per foot pressure gradients) at the mid-point of the perforated interval (14,674' Induction Log depth).

Another discrepancy was noted in comparing the new measurement to "original reservoir pressure". The first measurement of bottom hole pressure was on November 15, 1979 (11,275.4 psia at 14,750'), using an assumed pressure gradient of 0.44 psi/ft gave a value of 11,241 psia at 14,674'. But for another measurement on September 16, 1980, extrapolation of reported pressures at 14,000' and 14,500' to a depth of 14,674' gave a value of only 11,166 psia. The net result is a difference of 75 psi in measurements. It should have differed only by the drawdown caused by producing about 275,000 Bbls. With this uncertainty in the original reservoir pressure and the estimated uncertainty in the data for April 1, 1986, the range of values for actual reservoir drawdown is 130 psi to 238 psi.

Production starting in 1988

Details of the production data from the first instrumented flow on March 7, 1988, and a detailed log of significant events are provided in the Institute of Gas Technology's (1990) Final report to Eaton Operating Company, Inc. The report also includes the reason for the variations in producing conditions with time. Brine flow rate for the three years of production as a function of time is shown in Figure 176.

The reason for the overall decline with time was maintaining disposal well injection pressure low enough for operation of the Hybrid Power System (HPS) without exceeding the working pressure rating of 600 psi for the brine side of the heat exchangers in that system.

Production wellhead pressure for the past three years is shown as a function of time in

TABLE 55

DOWNHOLE PRESSURES AND TEMPERATURES

-----Depth-----		-----Pressure-----		Temperature Reported (Deg. F)
(Corrected) (feet)	Reported (psia)	Maximum (psia)	Gradient (psi/ft)	
12,118	9,843.3	9,873.0	0.4524-0.4538	267.1
13,118	10,295.7	10,326.9	0.4539-0.4553	277.9
14,003	10,698.3	10,730.8		293.5
Calculated Pressures at the mid-point of perforations:				
	14,674.0	11,002.9	11,036.1	

(From, Eaton Operating Company, Inc., Final Report, 1990).

Figure 176. -- Graph showing brine flow rate for the three years of production as a function of time (from, Eaton Operating Company, Final Report, 1990).

Figure 177. The values plotted are 24-hour averages. With one exception, all values below 2,800 psi are the result of the pressure transmitter being isolated from the actual pressure in the wellhead below the master valve. The exception is a couple of hours on the evening of June 20, 1988, when the brine rate was 25,000 STB/D and the tubing pressure dropped to 2,550 psia. The next highest rate, 22,500 STB/D overnight on June 21-22, 1988, was accompanied by a minimum flowing tubing pressure of 2,875 psia.

Production wellhead temperatures are shown as a function of time in Figure 178. The values in the range of 50°F to 100°F are ambient temperature at times when brine was not flowing. The zero values are times when actual temperature data was not being recorded. Note that the flowing brine temperature at the HPS went down from 291°F to 286°F in only four (4) hours after the brine rate was decreased from 17,100 STB/D to 12,200 STB/D on April 27, 1989.

The perforation gas rate as a function of time is shown in Figure 179. This gas rate is the sum of the measured gas rates from the two separators, plus the result of calculating the amount of gas remaining in solution in brine leaving the separators.

The gas brine ratio as a function of time is shown in Figure 180. This ratio is calculated by dividing the perforation gas rate by the brine rate measured at the orifice meters at the HPS. A gas/brine ratio of zero is reported for those times when there is no production. The small variations from the overall average of near 24 SCT/STB are believed to reflect measurement uncertainty or error.

The range of flowing bottom hole pressures was very small for the entire two years of flow. The highest flowing bottom hole pressure was about 10,100 psia in June and July of 1988, plus during the May 1989 production with brine rate reduced to 12,200 STB/D. With the

Figure 177. -- Graph showing production wellhead pressure as a function of time. The values plotted are 24-hour averages (from, Eaton Operating Company, Final Report, 1990).

Figure 178. -- Graph showing production wellhead temperatures as a function of time (from, Eaton Operating Company, Inc., Final Report, 1990).

Figure 179. - - Graph showing the perforation gas rate as a function of time i.e. the gas rate as produced through the perforations into the well from the reservoirs (from, Eaton Operating Company, Inc., Final Report, 1990).

Figure 180. -- Graph showing the gas/brine ratio as a function of time. A gas/brine ratio of zero is reported for those times when there is no production (from, Eaton Operating Company, Final Report, 1990).

exception of the few hours of flow at rates above 20,000 STB in June 1988, the minimum value of calculated flowing bottom hole pressure was 9,760 psia at 14,644 feet at the end of May 1990. This value is only 340 psi less than the highest flowing bottom hole pressure. The difference in calculated solubilities for methane in Pleasant Bayou brine is only 0.3 SCF/STB for these two pressures and a temperature of 308°F. This difference is comparable to the observed variations from the overall average of 24 SCF/STB.

Disposal well tubing pressure is shown as a function of time in Figure 181. The early June 1988 clean-out made possible injection of about 20,000 STB/D at a pressure a little below 600 psia. By February 1989, the injectivity had deteriorated to where a pressure of about 618 psia was required to dispose of 17,500 STB/D. Then, the addition of only 10 barrels of concentrated hydrochloric acid to the flowing stream such that the acid concentration was 1.6% in the brine reduced the injection pressure to 501 psia. This was low enough for the planned operation of the HPS to take place with only a modest reduction in brine rate.

The minimum brine rate during the test of the Hybrid Power System (HPS) set up at the Pleasant Bayou test site (to be described later in this compilation) was about 15,600 STB/D, a value comfortably above the HPS design brine rate of 10,000 STB/D. The step-wise variations in injection pressure within the range of 400 to 550 psia, in the time interval of September 1989 through May 1990, are due to changes in density of injected brine due to cooling of brine by the HPS or to the stopping thereof.

The total cumulative production of brine and the total cumulative production of separated gas through September 30, 1990 is shown in Figure 182.

Figure 181. -- Graph showing disposal well tubing pressure as a function of time (from, Eaton Operating Company, Final Report, 1990).

Figure 182. -- Graphs showing the cumulative production of brine and gas at the Pleasant Bayou No. 2 well from 1988-1990 (from, Eaton Operating Company, Inc., Final Report, 1990).

Brine Sampling and analyses

The Institute of Gas Technology (IGT) used the University of Texas at Austin, Bureau of Economic Geology's Mineral Studies Laboratory for the bulk of the brine analyses. This same laboratory had analyzed the brines from the Gladys McCall and Hulin test wells. The analytical techniques used are listed in Table 56. In addition to running the samples, there was a duplicate analysis performed for each suite of samples as a check on reproducibility and an analysis of appropriate standards. Details of the laboratory procedures are provided in the laboratory reports to IGT.

Two brine analyses, alkalinity and iron, were performed on location because the time needed to transport the samples to a laboratory may have seriously affected the accuracy of the analyses. The procedures and chemicals used are described in the Hach Water and Wastewater Analysis Handbook. These tests were also subsequently run in the laboratory, but the field data is believed to be the most reliable. Sulfide was also looked for in the brine on an occasional basis, but sulfide had not been present at concentrations above the lower limit of detection of about 0.5 mg/L.

Total carbon dioxide measurements were made following procedures described in Parametric Study of Separator Performance (Hayden and Randolph, 1981). This includes collecting brine samples under pressure, cooling the samples, quantitatively flashing off and measuring dissolved gas, and finally using an acid liberation/nitrogen purge gravimetric technique to recover any remaining carbon dioxide.

Brine samples were also collected and sent to other parties. Dr. T. Kraemer of U.S.G.S. was sent filtered, acidified, diluted brine samples for radium-226 and radium-228 analyses. His

TABLE 56

ANALYTICAL METHODS USED

<u>Element</u>	<u>Method</u>
Sodium, Potassium, Magnesium, Iron Manganese, Strontium, Calcium, Chromium, Barium, Zinc, Lithium, Silica, Copper, Nickel, Arsenic, Cadmium, Lead, Tin, Boron	Inductively Coupled Plasma-Optical Emission Spectroscopy
Mercury	Cold-Vapor Atomic Absorption
Ammonia	Distillation-Titration
Chloride	Titration
Sulfate	Turbidimetric
Bromide, Iodide	Spectrophotometric
Fluoride	Ion Electrode
Alkalinity*	pH Titration
Density, TDS	Gravimetric
Sulfide*, Iron*	Colorimetric
Radium	Radon Generation

* Sample is also analyzed for this element on site. The sulfide measurements have not revealed detectable levels of sulfide in the brine.

(From, Eaton Operating Company, Final Report, 1990).

analyses results are shown in Table 57. The radium activity has declined by 17% since 1979, most of the decline occurring between 1979 and 1982. The decline was attributed to actual precipitation of a radium-barium-strontium sulfate material within the formation itself. Finally, IGT used the in-house analytical laboratory to perform per million quantification of organic acids in the brine, as well as subpart per million analyses for phosphonate. The organic acids were determined by Gas Chromatography/Mass Spectroscopy. The phosphonate concentration was determined using a butyl alcohol extraction/colorimetric analysis.

Brine Analysis results

The results of the brine analyses performed on site are shown in Table 58. These include alkalinity, for samples collected from just after the primary choke and from just before the disposal well, and iron analyses. The results of brine analyses performed by the Bureau of Economic Geology before and after HPS is shown in Table 59. The samples were collected from just after the primary choke (upstream of the HPS) and from the outlet of the HPS before the brine commingles with hot brine from the bypass.

Hydrocarbon sampling and analysis

Gas samples were routinely collected at the large separator, small separator and sales/flare meter runs. The location of these meters in the gas processing equipment are shown by the three "S"s in Figure 175. The separator meter runs contain hot, wet gas and a small quantity of condensed water. The sales/flare gas has been cooled and dehydrated.

TABLE 57

RADIUM AND RADON ACTIVITY IN THE BRINE

<u>Date</u>	<u>Radium 226, dpm/L Water (# Samples)</u>	<u>Radon 222, dpm/L Gas at STP</u>
1979	1590 $\pm$ 41 (9)	350.7
1980	1513 $\pm$ 21 (14)	
1982	1398 $\pm$ 42 (7)	
1983	1435 $\pm$ 71 (6)	
July 1988	1360 (1)	259.1
Oct. 1988	1335 (1)	
Nov. 1988	1355 (1)	
Apr. 1989	1358 (1)	
Dec. 1989	1312 (1)	

(From, Institute of Gas Technology, Final Report, 1992).

TABLE 58

ON SITE BRINE ANALYSIS - PLEASANT BAYOU

Date	Cum. Brine (STB)	Alkalinity at Chokes (mg CaCO ₃ /L)	Alkalinity at Disposal Well (mg CaCO ₃ /L)	Iron (mg Fe/L)
06/20/88	319,528	311		
07/01/88	519,309	309	310	60
07/12/88	731,743	315	315	62
07/21/88	902,220	309	310	58
07/25/88	977,993	310	312	60
08/18/88	1,416,161	313	323	62
08/24/88	1,529,320	309	316	62
10/03/88	2,021,817	322	319	
10/17/88	2,283,736	314	319	
10/31/88	2,533,071	316	314	
11/30/88	3,089,257	309	304	
12/20/88	3,458,467	310	304	
01/10/89	3,845,004	304	304	
01/20/89	4,019,919	325	315	62
02/09/89	4,370,682	314	334	
02/28/89	4,702,614	325	325	
03/20/89	5,050,904	305	315	
04/04/89	5,308,701	325	315	
04/27/89	5,701,127	325	315	
06/06/89	6,067,731	306	314	
07/07/89	6,574,702	304	306	
08/23/89	6,975,753	304	304	57
11/07/89	7,584,851	305	305	
12/19/89	8,136,582	305		
02/06/90	8,913,443	315	315	
03/22/90	9,608,870	304	314	57
04/19/90	10,048,232	315	315	

(From, Eaton Operating Company, Inc., Final Report, 1990).

TABLE 59

. BRINE ANALYSES BEFORE AND AFTER HPS,
ANALYSES PERFORMED AT BEG

Date	<u>22-Mar-90</u>	<u>22-Mar-90</u>
Relative to HPS	Before	After
Brine Temp, °F	291	151
Spec Gravity @ 60°F	1.085	1.084
Total Dissolved		
Solids, mg/L	140,480	137,380
Alkalinity, as		
mg CaCO ₃ /L	316	315
Ammonia	84	85
Arsenic	<0.1	<0.1
Barium	797	784
Boron	27	27
Bromide	88	86
Calcium	7,880	7,810
Chloride	70,500	71,000
Fluoride	1.4	1.4
Iodide	20	19
Iron	42	44
Lithium	28	28
Manganese	16	16
Magnesium	602	603
Potassium	602	611
Silica, as SiO ₂	111	110
Sodium	36,100	36,000
Strontium	904	896
Sulfate	<5	<5
Zinc	0.5	1.4

(From, Institute of Gas Technology, Final Report, 1992).

Gas samples destined for laboratory analyses were collected in evacuated, teflon-lined, 304 stainless steel cylinders rated at 1,800 psi working pressure. The sample lines were purged, and then the cylinder was connected and filled on time. There was no sequential filling and purging process. The samples were sealed and sent to the laboratory, either IGT or Core Laboratories Chomaspec, for analysis. At the laboratory, either IGT or Core Laboratories Chomaspec, for analysis. At the laboratory, the sample cylinders are preheated to line temperature prior to withdrawing an aliquot for analysis. This prevented liquid condensation from interfering with the analysis. The samples were analyzed by gas chromatography.

On site analyses for carbon dioxide and hydrogen sulfide were performed using Draeger tubes following the Gas Processors Association "Tentative Method of Test for Hydrogen Sulfide in Natural Gas Using Stain Tubes" (1977). Tests were also occasionally run for mercury and ammonia. (From, Eaton Operating Company, Inc., Final Report, 1990).

The results of gas analyses performed by IGT are given in Table 60. This table shows the average of results of IGT analyses performed on sales/flare gas and the large and small separator gases. The IGT analyses report concentrations of hydrocarbons through tetradecanes (C_{14}) or higher, the concentration of ringed hydrocarbons through the C_3 naphthalenes, and the concentration of helium and molecular hydrogen. Minimum detection thresholds are 0.01 mole percent for hydrocarbons and 0.0005 mole percent for hydrogen and helium. Gas compositions are similar to the Pleasant Bayou sales contract analyses reported in the period from October 1982 to April 1983. During this time, the carbon dioxide averaged 12.3%, nitrogen 0.52%, specific gravity 0.703, and heating value (unspecified as to wet or dry and as to the pressure base) average 929 Btu/SCF.

TABLE 60

AVERAGE GAS COMPOSITION, MEASURED
AT IGT BY GAS CHROMATOGRAPHY

	Large Separator Gas, mole %	Small Separator Gas, mole %	Sales/Flare Gas, mole %
Number of Analyses	14	11	21
Helium	0.009	0.009	0.009
Hydrogen	0.016	0.016	0.020
Nitrogen	0.52	0.54	0.54
Carbon Dioxide	10.26	10.42	10.35
Methane	84.72	84.68	84.73
Ethane	2.93	2.90	2.92
Propane	0.94	0.91	0.94
iso-Butane	0.147	0.143	0.147
<i>n</i> -Butane	0.134	0.130	0.133
iso-Pentane	0.039	0.037	0.040
<i>n</i> -Pentane	0.019	0.018	0.020
neo-Pentane	0.001	0.001	0.001
Hexanes	0.016	0.015	0.015
Heptanes	0.020	0.017	0.020
Octanes	0.012	0.009	0.010
Nonanes	0.003	0.001	0.002
Decanes	0.001	0.001	0.001
Undecanes	0.002	0.001	0.001
Dodecanes	0.002	0.001	0.001
Tridecanes	0.001	0.000	0.001
Tetradecanes +	0.002	0.001	0.001
Benzene	0.079	0.069	0.054
Toluene	0.053	0.038	0.027
C2 Benzenes	0.027	0.016	0.010
C3 Benzenes	0.010	0.005	0.003
Naphthalene	0.003	0.001	0.001
C1 Naphthalenes	0.003	0.002	0.001
C2 Naphthalenes +	0.002	0.002	0.001
Heating Value, Btu/SCF			
Dry, 14.65 psia, 60°F	953	948	949
Gravity (air=1.000)	0.69	0.69	0.69

(From, Institute of Gas Technology, Final Report, 1992).

Table 61 shows the average results of the Core Laboratories analyses on small and large separator gases and the sales/flare gas. These analyses are through decanes plus, although ringed hydrocarbons are not differentiated from the saturated hydrocarbons.

Table 62 presents gas compositions, analyzed by IGT, from ten geopressure - geothermal test wells. The Pleasant Bayou gas contains more heavier hydrocarbons, from propane through decane, than were found in all geopressured - geothermal well tests except the Koelemay well. The Koelemay well coned in a gas condensate cap and became a commercial oil and gas producer. The presence of high concentrations of propane plus hydrocarbons in the produced gas may suggest that the brine is in contact with an oil or wet gas deposit.

At the same time, the PVT tests provide evidence that shows that the Pleasant Bayou brine is undersaturated with gas at reservoir conditions. There is geologic evidence that the aquifer is in direct contact with producing hydrocarbon wells located within 15 miles of the well. These producing zones, however, are several thousand feet updip of the sand at the Pleasant Bayou well. This may explain both the presence of heavy hydrocarbons and the undersaturated gas content (from, IGT final report, August 1992).

There were small amounts of hydrocarbon liquid samples collected at various locations in the gas processing unit and glycol dehydrates. An analyses of these samples and the sample locations are given in Table 63. Cryocondensate sampling and analyses were performed by Dr's Keeley and Meriwether of the University of Southwestern Louisiana (USL), Lafayette, Louisiana. Cryocondensate samples are those hydrocarbons that can be condensed by passing produced gas through a dry - acetone bath held at -78°C and that can be extracted from cooled brine with hexane. The concentrations are then related to the brine production. The concentration averaged

TABLE 61

AVERAGE GAS COMPOSITION, MEASURED AT CORE LABORATORIES
BY GAS CHROMATOGRAPHY

	Small Separator <u>Gas. mole %</u>	Large Separator <u>Gas. mole %</u>	Sales/Flare <u>Gas. mole %</u>
Number of Analyses	7	7	5
Nitrogen	0.49	0.51	0.51
Carbon Dioxide	11.71	11.22	11.70
Methane	83.51	83.84	83.25
Ethane	2.86	2.93	2.86
Propane	0.88	0.94	0.92
iso-Butane	0.14	0.15	0.14
n-Butane	0.13	0.13	0.13
iso-Pentane	0.04	0.04	0.03
n-Pentane	0.02	0.02	0.02
Hexanes	0.03	0.03	0.03
Heptanes	0.08	0.07	0.10
Octanes	0.06	0.05	0.06
Nonanes	0.02	0.02	0.03
Decanes +	0.04	0.04	0.02
Heating Value, Btu/SCF			
Dry, 14.65 psia, 60°F	941	947	940
Gravity (air=1.000)	0.704	0.700	0.703

(From, Institute of Gas Technology, Final Report, 1992).

TABLE 62

TYPICAL GAS COMPOSITIONS FROM GEOPRESSURED-GEOTHERMAL WELLS^a

Well	Hulin	Girouard	Koelemay	Saldana	Prairie Canal	Crown Zellerbach	Amoco Fee	Sweezy	Gladys McCall	Pleasant Bayou
Date	1/7/90	7/80	9/80	11/80	2/81	6/81	8/81	9/82	6/87	2/90
Pressure, psia	295	277	260	218	272	283	236	NR	1015	693
Gas Temp, °F	185	189	165	179	160	110	-	NR	300	292
Brine Temp, °F	221	215	201	216	229	197	160	NR	294	271
<u>Mole Percent of:</u>										
Helium	0.01	0.01	0.01	<0.01	<0.01	0.03	<0.01	NA	<0.01	0.01
Hydrogen	0.05	NA ^c	NA	NA	NA	NA	0.01	NA	<0.01	0.02
Nitrogen	0.11	0.20	0.27	0.10	0.11	0.44	0.20	0.12	0.28	0.52
Carbon Dioxide	16.70	6.00	7.50	17.18	10.06	25.00	8.13	1.08	8.47	10.40
Methane	81.20	91.50	83.87	78.75	86.94	69.10	89.28	95.61	88.04	84.70
Ethane	1.68	1.80	4.67	2.97	2.29	4.03	1.74	1.95	2.41	2.88
Propane	0.16	0.29	2.19	0.66	0.30	0.76	0.39	0.32	0.52	0.97
iso-Butane	0.01	0.12	0.38	0.07	0.03	0.10	0.02	0.06	0.08	0.15
n-Butane	0.01	0.08	0.58	0.10	0.02	0.10	0.05	0.11	0.07	0.14
Pentanes	<0.01	<0.01	0.24	0.07	<0.01	0.04	0.01	NR	0.03	0.06
Hexanes +	0.02	<0.01	0.25	0.06	<0.01	0.03	<0.01	NR	0.03	0.06
Benzene	0.03	0.01	0.02	0.07	0.02	0.18	0.10	0.02	0.05	0.07
Toluene	0.01	<0.01	0.02	0.06	0.01	0.18	0.07	0.01	0.01	0.04
C2 Benzenes	<0.01	<0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.02
Heating Value ^b	860	970	1040	892	928	815	NR	NR ^d	960	951
Gravity (air=1)	0.728	0.631	0.698	0.766	0.667	0.838	NR	NR	0.660	0.691

^a Analyses performed at IGT by mass spectrometry or gas chromatography.^b Heating value in Btu/SCF, Dry, 14.7 psia, 60°F.^c NA = Not analyzed.^d NR = Not recorded.

(From, Institute of Gas Technology, Final Report, 1992).

TABLE 63

PLEASANT BAYOU NO. 2 WELL CONDENSATE ANALYSES

A	Gas line out of the separators, before the back pressure-control valve.					
B	Coalescing filter after the gas cooler.					
G	Valve just upstream of Enron sales meter run.					
H	Valve in HPS gas meter run.					
I	Liquid knockout pot on Mustang generator skid.					
J	Normal gunbarrel condensate.					
Sample Location Date	A 5/24/90	B 5/24/90	G 5/24/90	H 5/24/90	I 5/24/90	J 5/24/90
Benzene	0.18	4.12	0.70	1.71	0.27	2.45
C7-	0.08	1.15	0.09	0.34	0.07	0.41
Toluene	0.42	8.05	1.65	3.06	0.62	7.29
C8	0.06	1.14	0.19	0.51	0.10	0.86
Ethylbenzene	0.10	1.88	0.37	0.53	0.12	1.92
<i>m,p</i> -Xylenes	0.37	6.02	1.22	1.69	0.42	6.25
<i>o</i> -Xylene	0.25	3.87	0.65	0.83	0.22	3.99
C9	0.03	0.52	0.12	0.23	0.04	0.49
C3-Benzenes	0.86	9.15	1.19	1.35	0.37	8.56
C10	0.13	0.51	0.12	0.16	0.01	1.55
C11	0.48	3.89	0.48	0.50	0.09	3.96
Naphthalene	2.90	8.59	0.53	0.32	0.11	8.88
C12	1.21	5.61	0.43	0.35	0.06	5.48
C13	0.97	2.51	0.40	0.24	0.21	2.18
C1-Naphthalenes	11.16	14.92	3.26	2.84	2.87	10.53
C14	1.49	3.41	0.51	0.49	0.69	7.30
C2-Naphthalenes	17.60	11.48	a	a	a	12.33
C15	1.72	1.69	23.39	22.91	23.46	2.10
C3-Naphthalenes	9.85	3.83	a	a	a	4.04
C16	3.09	1.37	19.50	19.22	23.28	1.85
C17	10.01	2.44	13.47	13.35	14.32	2.50
C18	9.16	1.31	8.80	8.79	8.44	1.69
C19	6.38	0.84	6.62	6.46	6.07	0.99
C20	6.77	0.59	4.81	4.28	4.42	0.83
C21	4.26	0.34	2.78	2.24	2.77	0.45
C22	2.40	0.19	1.66	1.30	1.78	0.26
C23	3.42	0.21	1.81	1.34	2.03	0.35
C24	1.55	0.11	1.07	0.89	1.30	0.17
C25	1.05	0.09	0.95	0.89	1.22	0.13
C26+	3.05	0.17	3.23	3.19	4.66	0.21

^a Due to the nature of these samples, the C2 and C3 naphthalenes could not be accurately resolved and quantified from the smaller neighboring hydrocarbons. While the bulk of the material is naphthalenes, they have been included in the generic C15 and C16 data. Similarly, C4 naphthalenes are included with the C17 and C18 data.

(From, Institute of Gas Technology, Final Report, 1992).

about 34 μ l per liter of brine. The composition of the cryocondensate should reflect the composition of the heavier hydrocarbons in the gas analysis. That is, the cryocondensate should consist primarily of benzene, with rapidly decreasing quantities of toluene, C₂ benzenes and naphthalenes. This was found to hold true - more than half of the cryocondensate is benzene and toluene (from, IGT final report, August, 1992).

Scaling and Corrosion

The need for controlling scaling was recognized and well known to all parties concerned with geopressured - geothermal well testing. The end of earlier Phase-2 testing in April 1983 was due to parting of the tubing in the production well. When the tubing was removed from the well, it was found that it was scaled to a thickness of almost 1/2" thick at the top of the tubing, and scale was continuous to below 12,000'. Scaling had been a serious problem prior to the parting of the tubing.

The production and disposal wells were worked over in 1986 and shut in. After reinstalling the production equipment, the brine well was placed on production in March 1988. A total of 8,579 barrels of brine were produced before a scale inhibitor pill was injected into the producing formation (see Appendix B-2 for details). Some scaling was detected in the low pressure portion of the production system (none in high pressure portion) after 4,950,000 barrels of brine had been produced after the scale inhibitor squeeze. A scale inhibitor was then injected into the surface well stream, as it came out of the well. The well was produced for a total of 7,720,000 barrels of brine after the initial inhibitor squeeze. In November 1989, a second scale inhibitor squeeze was performed. A total of 2,750,000 barrels of brine was produced after the

second squeeze before surface inhibition was started again on May 16, 1990. A total of 1,419,816 more barrels of brine have been produced (as of September 30, 1990) (grand total production after the two scale inhibitor squeezes is 11,881,239 barrels).

Coupons were installed at three locations for scale and corrosion monitoring. These were:

- 1) Between the chokes at a location upstream of the choke at the entrance to the large separator.
- 2) A short distance downstream of the point where the brine streams from the two separators commingle.
- 3) Between the brine filter skid and the disposal well.

No significant scaling was observed, but measurable corrosion rates were, as several different corrosion inhibitors were tested.

The production equipment had been redesigned before reinstallation under Eaton Operating Company's contract. The experience gained at the Gladys McCall site was utilized, some of the new features used at Pleasant Bayou were:

- 1) Use of larger piping to maintain flow velocity rates below 15'/second.
- 2) Use of stainless steel sections at critical areas to replace conventional piping.
- 3) Elimination of as many turns as possible.

These design features plus the use of corrosion chemicals injected into the surface stream were effective in controlling corrosion rates. (From, Eaton Operating Company, Inc., Final Report, 1990).

Reservoir Analysis

Reservoir analysis and modeling for the Pleasant Bayou reservoir was performed by S-

Cubed, LaJolla, California, who produced a topical report on the subject (Riney, 1991). S-Cubed performed the work under a subcontract to the University of Texas at Austin (UTA). The UTA research efforts were performed for the U.S. Department of Energy under its Co-operative Agreement No. DE-FC07-85NV10412. S-Cubed employed a numerical reservoir simulator as a tool for synthesizing and integrating the geological information, formation rock and fluid properties data from laboratory tests, and well data from testing (1979-1983 and 1988-1990) of Pleasant Bayou No. 2 well. A reservoir model which provided a detailed match to the well history was constructed by S-Cubed. It was made within a geologic framework described by the Texas Bureau of Economic Geology and relied on the pressure transient data from the reservoir limits test conducted in 1980 and those conducted with the 1988-1990 production testing.

The structure map on top of the C zone as revised by BEG (Hamlin & Tyler, 1988) is shown in Figure 183. Locations of deep control wells and the Pleasant Bayou No. 2 test well are also shown. Large growth faults forming major lateral boundaries for the Pleasant Bayou fault block are well established except for the Southern boundary; no deep control wells penetrate the C zone in the large area south of the Pleasant Bayou No. 2 test well. Porosity pinch outs in conjunction with smaller internal faults were believed to form the Southern boundary of the fault block. The Southern boundary was fixed at 3 miles South of the test well for reservoir volume calculations.

A southwest - northeast cross section of the C zone is shown in Figure 184. Only the upper and basal mudstones are continuous throughout the Pleasant Bayou fault block and form the upper and lower boundaries of the reservoir. This cross section along the long axis of the fault block shows multiple thick sandstones in the Danbury salt withdrawal basin, the three

Figure 183. - - Revised structure map on the top of the C zone (from, Riney, 1991, in, Hamlin and Tyler, 1988).

Figure 184. -- Southwest - northeast cross section showing details of sandstone and mudstone interbedding along strike down the long axis of the fault block (from, Riney, 1991, in, Hamlin and Tyler, 1988).

sandstone units in the test well, the single massive sandstone at Chocolate Bayou, and thinly interbedded sandstones and mudstones to the northeast. Hamlin and Tyler (1988) concluded that the Chocolate Bayou area is an important region of vertical communication within the reservoir. By constructing other similar cross sections for this zone the sandstone and mudstone distributions were delineated for the entire C zone reservoir and the sandstone volume was estimated to be approximately 2.3 mi^3 . The thicker sandstones are composed of distributary channel fill and channel mouth bar deposits that have porosities similar to the perforated interval in the test well ($\varphi_1 \sim 0.18$). Thinner sandstones were considered to have lower porosities ($\varphi_2 \sim 0.09$). On the basis of this measured sandstone volume and assumed porosity distribution, the sandstone pore volume of this zone was estimated to be 8.3 billion barrels, and 75 to 80 percent of this was thought to be interconnected i.e. the effective pore volume was estimated to be about 6.2 to 6.6 billion barrels.

A rectangular configuration suggested to be a reasonable approximation to the geometry, volume and porosity distribution for the test zone reservoir is shown in Figure 185. The boundaries of the configuration represent average reservoir length, width, thickness and horizontal porosity layers approximate the geometry of the major reservoir sandstones. The model configuration consists of a main high-porosity ($\varphi_1 = 0.18$) reservoir sand sandwiched between two low porosity ($\varphi_2 = 0.09$) layers which represent thinner, more isolated sandstones comprising the remote volume of the reservoir. S-Cubed has superimposed the approximate locations of three interval faults in the main reservoir sand, (F_1 , F_2 and F_3) which are the interval faults that were identified in Figure 183 on the basis of seismic and well data. The geologically based configuration does not provide information regarding formation compressibility,

Figure 185. -- Reservoir simulation model geometry by S-Cubed based on the BEGI model (from, Riney, 1991).

transmissivity, fluid properties or the major effective connection zones between the remote volume layers and the main reservoir layer. However, it did provide a framework within which the reservoir simulation model was synthesized by S-Cubed using the various data sets available. Further details of the reservoir simulation and modeling, relative to the Pleasant Bayou No. 2 well can be found in the S-Cubed topical report by Riney (January, 1991). An integrated approach to the reservoir engineering at the Pleasant Bayou geopressured - geothermal reservoir was presented by Shook (1992), who presented a numerical model based on a variety of data including geological and geophysical interpretations, pressure transient analyses and well operations. Transient tests suggested water influx from an adjacent aquifer during the long term testing of Pleasant Bayou. The presence of an internal faults, not previously identified in the BEG studies was noted, and it was stated that this fault exhibited pressure dependent behavior. Below some pressure difference across the fault, it remained a no flow barrier and above this threshold pressure drop the barrier fell and fluid moved across the fault. A history match using the hypothesized "leaky fault" model was presented by Shook (1992). The prediction phase of the study indicated that Pleasant Bayou No. 2 well was capable of producing 20,000 STB/d through 1997, with the final bottomhole pressure approximately 1,600 psi above abandonment pressure.

PLEASANT BAYOU HYBRID POWER SYSTEM (HPS)

The following summary of the Pleasant Bayou Hybrid Power System is taken directly from the Eaton Operating Company, Inc., Final Report (1990).

Geopressured - geothermal resources contain a tremendous amount of energy. These resources can contribute significantly to the national electricity supply only technical and

economic obstacles are overcome. From an economic standpoint, the cost of building and operating power plants, along with the cost of wells and the productive life of the reservoirs, are primary concerns. From a technical standpoint, operation of a power plant with the corrosive, highly saline brine and impure wellhead gas presents special problems.

Power plant performance under the harsh conditions of a geopressured resource was unproven, so a demonstration power plant was built and operated on the Pleasant Bayou geopressured resource in Texas. This one megawatt facility provided valuable data over a range of operating conditions. In addition, an extended run at maximum power production demonstrated that power can be produced reliably with no serious operating problems.

This power plant was a first-of-a-kind demonstration of the hybrid cycle concept. A hybrid cycle was used to take advantage of the fact that geopressured resources contain energy in more than one form - hot water and natural gas. Studies have shown that hybrid cycles can yield thirty percent more power than stand-alone geothermal and fossil fuel power plants operating on the same resource. In the hybrid cycle at Pleasant Bayou, gas was burned in engines to generate electricity directly. Exhaust heat from the engines was then combined with heat from the brine to generate additional electricity in a binary cycle. Heat from the gas engine was available at high temperature, thus improving the efficiency of the binary portion of the hybrid cycle.

The hybrid cycle experiment at Pleasant Bayou was not meant to be an optimized hybrid cycle experiment. Isobutane is not the optimum working fluid for a standard binary cycle on a resource with a temperature as low as that of Pleasant Bayou. For example, propane could be used instead of isobutane to generate more power. However, propane has a higher vapor pressure than isobutane, so it could not be used with the existing equipment available to the

project. An optimized cycle would include a pressure reduction turbine to recover the energy from the high pressure brine. An ebullient cooled engine could also be used to recover the jacket heat from the engines.

A major portion of the equipment used in the hybrid cycle experiment was used in the Direct Contact Heat Exchange Experiment (DCHX) facility at East Mesa, California. This equipment is owned by DOE and was made available for this experiment. The primary goal of this test was to demonstrate the hybrid cycle on a geopressured resource and to gain operating data over an extended time period. These goals were met by employing used equipment even if design power production was less than optimum.

The turbine, condensers, isobutane circulating pump, and accumulator were used first at the DCHX facility and then at Pleasant Bayou. Modifications to the turbine rotor and the nozzles were made due to the lower inlet pressure and higher isobutane flow at Pleasant Bayou. The four Baltimore Aircoil condensers showed evidence of substantial corrosion in the tube bundles. Several tubes failed the hydrotest and were subsequently plugged. The isobutane pump required the removal of several stages in order to satisfy the flow and pressure requirements of this test.

New heat exchangers were designed and purchased for this test (Figure 186). E-1-N, the brine-to-isobutane heater, is a shell-and-tube exchanger with single tube and shell passes with true countercurrent flow. E-2-N, the brine-to-isobutane boiler, was designed to vaporize 86% of the isobutane. Brine on the tube side makes eight passes through the U-tube bundle. E-3-N, the exhaust gas-to-isobutane boiler, was designed to vaporize the remainder of the isobutane. Exhaust gas entered the exchanger at 1130°F and cooled to 300°F while isobutane vaporized at a constant 210°F. This large temperature difference was a primary design concern. Several

Figure 186. -- Schematic illustration of the Hybrid Power System (HPS) installed and tested at Pleasant Bayou (from, Eaton Operating Company, Inc., Final Report, 1990).

different design alternatives were considered before a final design selection was made. A horizontal reboiler type exchanger, with a U-tube bundle with separate inlet and outlet channels, was selected. Both brine exchangers were made of carbon steel; the exhaust gas exchanger was stainless steel.

The largest fraction of the hybrid cycle power output was from burning wellhead natural gas in the gas engines. Two Caterpillar 398 engines were used in this project. Their design power production was 650 kW.

Construction began in earnest in the beginning of 1989. Brine and isobutane circulation began on September 3, 1989. The turbine and gas engines were started for the first time on October 19, 1989. Tests were conducted primarily in November and December of 1989. The well was shut in for maintenance from November 17 through November 24, 1989. From this time until the well was shut in on May 30, 1990, the plant ran at or near design output except for an occasional outage. The plant was shut down a month earlier than scheduled when it became apparent that the injection well required rework.

Tests were conducted that characterized system performance at design isobutane flow, at maximum isobutane flow, and at lower exhaust gas flows. It was determined that maximum power output was achieved at maximum isobutane flow.

The brine inlet to the binary cycle was 18 to 20 Fahrenheit degrees higher than design. This reduced the amount of brine required to heat and vaporize the isobutane from 170,000 to 145,000 lbs/hr. The turbine and gas engines achieved their design power output at design conditions. The actual parasitic load ranged from 260 to 306 kW instead of the design value of 209 kW. The power drawn by the circulating pump was higher than design since the pump output

was higher than design. Over the course of the test, 1,443,250 STB of brine and 39,250 MCF of gas flowed through the geopressured hybrid power system.

Heat transfer performance of both of the brine exchangers was better than design.

No trend towards increased fouling was apparent over the course of the extended test run. These heat exchangers were inspected at the conclusion of the test. Very little scale was apparent on the heat exchanger tubes contacting brine. However, fouling in the exhaust gas exchanger was significant. Carbon deposits from the gas engine exhaust caused fouling of the heat exchange surface, thus degrading performance. Fouling increased uniformly while the engines were running. Each time flow through this exchanger was shut down and restarted, soot blew out of the exchanger and heat transfer improved dramatically.

The turbine operated for 2902 hours at Pleasant Bayou. Some problems with high vibration occurred early in the test. After these problems were solved in March, the turbine ran without any turbine-related outages until the test was completed. Turbine efficiency was approximately 70%, and output ranged from 580 kW to 470 kW.

Turbine output varies with wet bulb temperature. At higher wet bulb temperature, the turbine back pressure is higher, and less power is produced. The design power output of 541 kW was produced at the design turbine back pressure of 70 psi. However, at the design wet bulb temperature of 64°F, the turbine output was approximately 20 kW lower than design due to high back pressure. One cause of this was reduced capacity in the condenser due to tubes being plugged. Additionally, the accumulator pressure was higher than design, since the vapor pressure of the isobutane used at Pleasant Bayou had a higher vapor pressure than isobutane with the design composition. Noncondensables, such as air in the lines, may also have contributed to

higher turbine back pressure.

Both gas engines operated consistently and reliably. GE-1-N ran 4585 hours, and GS2-N ran 4832 hours. Few operational difficulties, associated with operating with impure wellhead gas, were experienced.

The hybrid power system demonstration at Pleasant Bayou was successful in all respects. Design power output was achieved, and 3,445 MWh of power were sold to the local utility over the course of the test. Plant availability was 97.5%, and the capacity factor was over 80% for the extended run at maximum power production.

Furthermore, several concerns about operating a commercial power plant on the Pleasant Bayou resource were favorably resolved. Scale and corrosion inhibitors were shown to be effective throughout the operating range of brine temperatures. Heat exchanger fouling, due to scale deposition from the high salinity brine, was not a problem. Although uninhibited brine is highly corrosive, inhibitors reduced corrosion to such low levels that carbon steel can be used for brine piping and heat exchangers. By using carbon steel as the primary material of construction, the cost of the power plant can be kept in line with other binary cycle power plants which are commercially competitive.

The only significant problem encountered during the test was excessive fouling in the exhaust gas exchanger. However, this is a relatively minor problem which can probably be solved at low cost.

Successful operation of the hybrid cycle power plant demonstrated that there are no technical obstacles to electricity generation at Pleasant Bayou. In addition, a power plant can be built and operated with no economic obstacles when compared to commercial facilities at other

geothermal resources.

The U.S. Department of Energy (DOE) and Electric Power Research Institute (EPRI) co-funded this hybrid cycle demonstration power plant on a geopressed resource. The Ben Holt Co., under contract to EPRI, designed the facility and procured new and refurbished equipment. Construction and operation were under a separate contract funded by DOE. For this work, Holt teamed with Eaton Operating Company, Inc., the prime contractor (Houston, Texas), as the subcontractor for the Hybrid Power System, and with the Institute of Gas Technology (Chicago, Illinois), the subcontractor for operation and data collection for the production system. (From, Eaton Operating Company, Final Report, 1990).

ENVIRONMENTAL MONITORING AT PLEASANT BAYOU

An environmental analysis of the Brazoria Geopressed - Geothermal prospect area which included data on current land use, substrate lithology, soils, natural hazards, water resources, biological assemblages, meteorological data and regulatory considerations was performed by the Bureau of Economic Geology, The University of Texas at Austin (White, McGraw and Gustavson (1978) under DOE contract No. EG-77-S-05-5401. This study established baseline environmental information prior to the beginning of well testing at Pleasant Bayou. The U.S. Department of Energy also conducted an environmental assessment, and published a report on its findings in march 1978 (DOE/EA-0013).

Other environmental baseline monitoring work included initial work on air quality monitoring by Radian Corporation, Austin, Texas and Microseismic monitoring by Teledyne Geotech, Garland, Texas. These investigations were done under subcontract to the Bureau of

Economic Geology, Austin, Texas and details of these can be found in the Annual Reports by Gustavson, Howard and McGookey (1982, DOE/ET/27111-7) done under contract No. DE-AC08-79ET27111.

Later, Louisiana Geological Survey, Louisiana State University, conducted the microseismic and subsidence monitoring at the Pleasant Bayou prospect site. The methodology used for conducting the microseismic and subsidence monitoring was the same as that used at other locations in Louisiana. They are described in the environmental monitoring section for the Gladys McCall test well in Louisiana in this report. Figure 187 shows the microseismic stations set up at Pleasant Bayou, and Figure 188 shows the benchmarks set up in the area for monitoring subsidence. Details of the microseismic recordings and subsidence surveys are available in the annual reports of the Louisiana Geological Survey, Louisiana State University (Technical Support for Geopressured - Geothermal well activities in Louisiana, C.G. Groat, Program Co-ordinator, 1987, 1991, 1992, 1994).

Groundwater and surface water sampling was conducted by Eaton Operating Co., Inc., who subcontracted the work to the Institute of Gas Technology. Water analyses were performed by EPA approved laboratories. Water sampling sites at the Pleasant Bayou prospect area is shown in Figure 189. The types of analyses and analytical methods used for water sample analyses from Pleasant Bayou, as well as the Gladys McCall and Hulin prospects are shown in Table 64.

Long term environmental monitoring at the Pleasant Bayou prospect site did not reveal any environmental problems that could be attributed to the drilling and production testing of the geopressured - geothermal test well. This result was therefore similar to that observed at all the

- ▲ MICROSEISMIC STATION LOCATION
- ⊙ MULTIPLEX SITE AND MICROSEISMIC STATION LOCATION
- GEOPRESSURED - GEOTHERMAL WELL SITE

Figure 187. -- Location of microseismic stations established around the Pleasant Bayou No. 2 test well (from, Louisiana Geological Survey, Annual Report, C.G. Groat, Co-ordinator, 1992).

Figure 188. -- Location of Pleasant Bayou geopressedured well and benchmark locations set up to monitor subsidence (from, Louisiana Geological Survey, Louisiana State University, Annual Report, C.G. Groat, Co-ordinator, 1992).

Pleasant Bayou Test Site
Brazoria County, Texas

Well Location Map

Figure 189. - - The Pleasant Bayou No. 2 test well site layout and locations of water quality monitoring sampling sites (from, Eaton Operating Company, Final Report, 1990).

TABLE 64

TYPES OF ANALYSES AND ANALYTICAL METHODS
 USED FOR GROUND/SURFACE WATER SAMPLES
 COLLECTED FROM ALL THREE DOE SITES
 (Gladys McCall, Pleasant Bayou, Hulin)

<u>METALS</u>	<u>METHOD</u>
Arsenic	3010/7060 GFAA
Barium	3010/6010 ICP
Boron	3010/6010 ICP
Cadmium	3010/6010 ICP
Calcium	3010/6010 ICP
Chromium	3010/6010 ICP
Copper	3010/6010 ICP
Iron	3010/6010 ICP
Lead	3010/7421 GFAA
Magnesium	3010/6010 ICP
Manganese	3010/6010 ICP
Mercury	7471/7471 CVAA
Selenium	3010/7740 GFAA
Silver	3010/7060 ICP
Zinc	3010/6010 ICP
<u>ANIONS</u>	<u>METHOD</u>
Sulfate	9035,9036,9038
Phosphate	
Nitrate (as N)	9200
Ammonia	
Chloride	9250,9251,9252
Fluoride	Standard Methods 340.3
<u>ORGANIC COMPOUNDS</u>	<u>METHOD</u>
Volatiles	8240, including tentatively identified compounds and trihalomethanes; or proposed 8260 (if promulgated)
Semivolatiles	8270
Endrin, Lindane,	8080
Methoxychlor,	8080
Toxaphene	8080
2,4-D and 2,4,5-TP Silvex	8150
<u>COLIFORM BACTERIA</u>	9132

(From, Eaton Operating Company, Inc., Final Report, 1990).

other geopressured - geothermal prospects that were tested under the U.S. Department of Energy's Geopressured - Geothermal research program.

PLUG, ABANDONMENT AND WELL SITE RESTORATION OF THREE GEOPRESSURED - GEOTHERMAL TEST SITES

Details of the plugging and abandonment operations and well site restoration work done in 1994 at the Pleasant Bayou (Brazoria County, Texas), Gladys McCall (Cameron Parish, Louisiana) and the Hulin (Vermilion Parish, Louisiana) geopressured - geothermal test well sites are contained in the following three publications:

- 1) Geothermal well site restoration and plug and abandonment of wells, DOE Gladys McCall Test site, and DOE Willis Hulin Test site, by Ben N. Rinehart, EG&G Publication No. EGG-EP-11414, work performed under DOE Contract No. DE-AC07-761D01570, August, 1994.
- 2) Geothermal well site restoration and plug and abandonment of wells, DOE Pleasant Bayou test site, Final Report, by, Ben N. Rinehart and Ben H. Siegal, March 13, 1994.
- 3) Final report on well plug and abandonment operations and well site restoration, U.S. DOE geopressured - geothermal program, Louisiana and Texas wells, Report for EG&G Idaho, Inc., by D-O-R Engineering, Inc., August 30, 1994.

The information on this activity compiled here is taken directly from the above mentioned reports.

Pleasant Bayou test site

The Pleasant Bayou well site, located in Brazoria County, Texas consists of a fenced in

area approximately 13 acres in size. This area is completely surrounded by Occidental Chemical Corporation (OxyChem) property with access roads across OxyChem land. Figure 190 shows the general layout of the site with production and injection well locations.

The contract for the restoration and close out of the Pleasant Bayou site was awarded to ECO Solutions, Inc. on December 3, 1993 (#C93-160681). The restoration plan tasks of (1) initial soil and water sampling and analysis, (2) removal and disposal of concrete, utility poles and trash, (3) removal and disposal of well pad and road rock, (4) removal and disposal of well pad boards, (5) removal and disposal of site fences, (6) plugging of monitoring and freshwater wells, and (7) site leveling and general dirt work and clean up.

The water wells associated with the site consisted of three monitor wells and three freshwater wells. It was found that one of the freshwater wells was plugged and two of the monitor wells were located outside the fenced site area. It was requested that one of the freshwater wells not be plugged and was left for future use. These wells were named MWN, MWE, and MWS and the water well on location was the firewater well. The location of these wells are shown in Figure 191. All these wells were plugged by a certified waterwell contractor (O'Day Drilling Company, Inc.) And appropriate notifications were sent to the Texas Railroad Commission. The Pleasant Bayou No. 2 test well and the saltwater disposal wells were plugged and abandoned by PAW drilling and Well Service, Inc., according to Texas Railroad Commission regulations. The Pleasant Bayou No. 2 operations were completed on December 21, 1993 and the saltwater disposal well work was completed on January 3, 1994.

All soil samples were tested for TCLP metals and one of the samples was also tested for PCP. This latter sample was retrieved from under the center of the testwell pad which would best

Figure 190. - - Pleasant Bayou site layout showing the location of the test well and saltwater disposal wells which were plugged and abandoned by Paw Drilling and Well Service, Inc., in accordance with Railroad Commission of Texas regulations (from, Rinehart and Siegal, 1994).

Figure 191. - - Pleasant Bayou well site layout showing location of wells plugged in the course of site restoration (modified from Rinehart and Siegal, 1994).

characterize any contamination from the location board mats. Test methods included method 1311 and EPA test methods for evaluating waste. Based on the parameters tested, the samples (taken from depths of 6 inches and 18 inches) did not exceed the EPA regulatory threshold for RCRA characteristics and TCLP toxicity characteristics.

A NORM survey was performed on the well pads on February 2, 1994. The method used consisted of laying out a 20 ft. by 20 ft. grid over the well pad areas which covered an area of 180 ft. x 240 ft. for the test well pad and 90 ft. x 110 ft. for the injection well pad (Figure 192). Meter readings were taken at each point on the grid and recorded. A control point reading was also taken 20 ft. outside the area of investigation. A Ludlum Model 19 Micro R Meter was used to perform the survey. All readings taken were under regulatory threshold limits (from, Rinehart and Seigel, 1994).

Gladys McCall test site

The final phase of the U.S. Department of Energy's work connected with their geopressured - geothermal research program at the Gladys McCall test site in Cameron Parish, Louisiana consisted of the plug and abandonment (P&A) of the test well, saltwater disposal well and the groundwater sampling and monitoring wells, followed by site restoration. Eaton Operating Company of Houston, Texas, was responsible for the operation of the well site, and EG&G, Idaho, Inc. of the Idaho National Engineering Laboratory, Idaho Falls, Idaho, was contracted by DOE - ID (Contract No. DE-AC07-76ID01570) for the P&A of the wells when the DOE contract with Eaton Operating Company was terminated. A layout of the Gladys McCall test site is shown in Figure 193.

Figure 192. -- Grid maps of the test well and injection well pads where NORM survey readings were taken. The readings obtained are also shown (from, Rinehart and Siegal, 1994).

Figure 193. -- Locations of the Gladys McCall test well, saltwater disposal well and the ground water sampling wells at the prospect site (from, Rinehart, 1994).

The property lease agreement of the Gladys McCall site was held by Eaton Operating Company (DOE Contract No. DE-AC07-85ID12578) until the contract was cancelled on July 19, 1993, at which time DOE-ID took over the lease agreement. The well identification numbers for the Gladys McCall wells are as follows:

- 1) Production well - Serial No. 174825, API No. 17-02321648
- 2) Saltwater disposal well - Serial No. 159587

(From, Rinehart, 1994).

All water wells at the site (Figure 193) were plugged by a certified water well contractor. These well plugging and abandonment operations were certified using the appropriate forms (DOTD-GW-2) which were submitted to the Louisiana Department of Transportation and Development, Water Resources Section.

The water wells were sampled by using a new boiler/sample tube for each well. A volume of twice the wellbore was bailed and then a single sample taken from each well and tagged and recorded on the Chain of Custody form. Four water samples were obtained and analyzed by testing for metals and chloride concentration using EPA methods EPA/200.7 and SM 17 4500-C₁B. All readings were below EPA regulatory limits.

Composite soil samples were obtained by taking three separate soil portions on a grid pattern laid over the two well pad areas. Ten soil samples were obtained, 5 each from depths of 6 inches and 18 inches, respectively. All soil samples were tested for toxicity characterization leaching procedure (TCLP) metals, and one sample was also tested for pentachlorophenol (PCP). This latter sample was obtained from the center of the test well pad, which would best characterize any contamination from the location board mats. The samples were tested using

Method 1311 and the EPA test methods for evaluating waste. Based on the parameters tested, none of the samples exceeded the EPA regulatory threshold for Resource Conservation and Recovery Act (RCRA) characteristics and TCLP toxicity characteristics (from, Rinehart, 1994).

The survey of the Gladys McCall location for naturally occurring radioactive material was performed, as required by the State of Louisiana regulations. NORM was found at the Gladys McCall site in a quantity large enough for Louisiana regulations to require prior approval of cleanup and disposal. The method used for the NORM survey was to layout a 20 ft. by 20 ft. grid over the well pad areas for the test well pad and the injection well pad. Meter readings were taken at each point on the grids and recorded and a control point reading was also taken 20 ft. outside the surveyed area (Figure 194). A Ludlum Model 19 Micro R Meter was used to perform the survey. Many readings taken at Gladys McCall were above the regulatory threshold limits, prior to cleanup, at the Gladys McCall site.

Petroleum Environmental, Inc., Metairie, Louisiana, performed a NORM survey and found NORM inside the low-pressure separator and a separator blow down line. They used a 10 ft. by 10 ft. grid method and the Ludlum Model 19 NORM meter and surveyed the land inside the ring levee, and outside the ring levee. They detected twelve "hotspots" in the area surveyed (Figure 195). After the NORM contaminated solids were removed by shovels and backhoe, they were loaded into 15, 17 H DOT approved drums and their NORM readings were determined as follows:

(1) 130 M/R	(6) 170 M/R	(11) 30 M/R
(2) 600 M/R	(7) 120 M/R	(12) 600 M/R
(3) 250 M/R	(8) 700 M/R	(13) 60 M/R

Site Survey

W-N-E-S

Natural Background = 6 uR/hr.

= WATER

**GATE
BRIDGE**

PIPES

SURVEYOR: David Boudoin TITLE: R.S.O. / Surveyor
DATE: 23 MARCH 1994 TIME: 1130 Hrs
INST. TYPE: Ludlum 3 SERIAL #: 99393 CAL DUE DATE: 6-10-94
's are in uR/hr ☐ = appx. 10m x 10m SIGNATURE _____

Figure 194. -- Grid maps of the Gladys McCall site with readings obtained from the NORM Survey (from, Rinehart, 1994).

CLIENT: E.G.G.
LOCATION: GLADYS MCCALL SWD WELL

DATE: 12/23/93
REMARKS: SHADED AREA
WHERE CONTAMINATED
DRUMS STORED

SURVEYOR: JOSEPH ESNAUD III
DATE: 12/23/93

INSTRUMENT TYPE:
LUDLUM MODEL 19
SERIAL # 98094 CAL6/1793

PRELIMINARY SURVEY

DRAWING #1

FINAL SURVEY
DRAWING #2

Figure 195. -- NORM Surveys conducted by Petroleum Environmental Inc., at the Gladys McCall prospect site (from, Rinehart, 1994).

(4) 400 M/R

(9) 900 M/R

(14) 85 M/R

(5) 300 M/R

(10) 75 /MR

(15) 50 /MR

After the site was cleaned and NORM removed, Petroleum Environmental, Inc., did another survey rising a 10 x 10 ft. grid. The NORM background readings of the site and surrounding area were between 3 and 5 M/R. All the twelve hot spots were reduced to less than or equal to the area's background (from, Rinehart, 1994). This NORM material was later transported to Source Environmental Services, Inc., yard at Intracoastal City in March, 1994 where the material was "minimized" and reduced to 5 drums of NORM which was later transported in May 1994 to the Hanford Reservation in Richland, Washington for final storage. The Louisiana Department of Environmental Quality provided a release for unrestricted use of the Gladys McCall property on August 17, 1994, (from, DOR Engineering, Inc., 1994).

The plug and abandonment operations of the Gladys McCall No. 1 was performed by PAW drilling and Well Service, Inc., Lafayette, Louisiana. The casing was cut off 5 ft. below ground level and a steel plate was welded on top and inspected on January 6, 1994. This concluded the abandonment of the Gladys McCall No. 1 test well. The Gladys McCall saltwater disposal well was abandoned on November 29, 1993, according to records submitted to the Louisiana Office of Conservation by PAW drilling and Well Service, Inc. All associated production facilities and equipment at the site was removed by PAW in December 1993 (from, DOR Engineering, Inc., 1994).

Central Industries, Inc., Scott, Louisiana, was awarded the contract for the site restoration. They commenced restoration of the Gladys McCall site in September 1993 and completed the work on January 14, 1994.

Willis Hulin test site

The property lease agreement for the Willis Hulin site was held by DOE under lease agreement No. DE-R-84NV10374. This property was surrounded by the Hulin farm. A general layout of this site is shown in Figure 196. The well identification numbers of the test well and the saltwater disposal well are as follows:

- 1) Production well - Serial No. 158468, API No. 17-113207850000
- 2) Disposal well - Serial No. 972009, API No. 17-113880870000

At the time of plug and abandonment operations, all production operations had been shut down for several years.

The water wells associated with the Willis Hulin well site consisted of four monitor wells and two freshwater wells. It was requested that one of the freshwater wells (outside the fence by entrance road) be left for future use, and therefore, was not plugged. All the Hulin site water wells were plugged and abandoned in accordance with the State of Louisiana rules and regulations and appropriate certifications forms (DOTD-GW-2) were submitted to the Louisiana Department of Transportation, Water Resources Section (from, Rinehart, 1994).

The soil and water sampling program consisted of retrieving a water sample from each of the Willis Hulin water wells to be plugged and retrieving soil samples in and around the well pad areas. This was the same method carried out also at the Gladys McCall well site. Water samples were tested for metals and chloride concentration using Environmental Protection agency methods EPA/200.7 and SM 17 4500 -C1B. All readings were below regulatory limits.

As in the case of the Gladys McCall site, composite soil samples were obtained by taking three separate soil portions on a grid pattern laid over the two well pad areas from depths of 6

Figure 196. - - The Willis Hulin test site layout showing locations of the test well, disposal well, and water wells (from, Rinehart, 1994).

inches and 18 inches. In all, ten samples were taken, 5 each, from the two different depths (Figure 197). Test methods included Method 1311 and EPA methods for evaluating waste. Based on the parameters tested, the soil samples did not exceed the EPA regulatory threshold for Resource Conservation and Recovery Act (RCRA) characteristics and toxicity characterization leaching procedure (TCLP) characteristics (from, Rinehart, 1994).

A survey for NORM was also carried out at the Willis Hulin site. For this survey a 20 ft. by 20 ft. grid was made over the well pad areas and the injection well pad and meter readings using a LUDLUM Model 19 Micro R meter were taken at each point on the grids and recorded (Figure 197). All readings taken were under regulatory threshold limits at the Willis Hulin site.

The plug and abandonment operations at Willis Hulin of the geopressured - geothermal test well and the saltwater disposal well were performed by PAW Drilling and Well Service, Inc. in full compliance with the State of Louisiana, Department of Conservation rules and regulations. Operations began on February 11, 1994 on the production well and were completed on March 11, 1994. The saltwater disposal well plug and abandonment work started on March 14, 1994 and was completed on March 17, 1994. Casing was cut off 5 ft. below the ground and steel plates were welded on top of it.

Central Industries, Inc., of Scott, Louisiana, who did the site restoration work at Gladys McCall was also awarded the site restoration contract for the Willis Hulin site. Restoration work at the Hulin well site commenced in February 1994 and was completed on April 13, 1994 (from, Rinehart, 1994).

The plug and abandonment and site restoration work at the three geopressured - geothermal test well sites (Pleasant Bayou, TX, Gladys McCall and Willis Hulin, CA) was carried

Source Environmental Services, Inc.

Site Survey

CLIENT: D.O.E. DATE: 5 May 1994
 LOCATION: Jewitt Hulin, Erath, La. REMARKS: Confirmatory Survey

Natural Background = 5 uR/Hr.

- x1 - Soil Sample Location : Devoid of vegetation
0"-6" - Light tan clay
6"-18" - Dark brown clay
- x2 - Soil Sample Location : Devoid of vegetation
0"-18" - Tan/gray clay
18"-24" - Dark gray/black clay
- x3 - Soil Sample Location : Devoid of vegetation
0"-12" - Light gray clay/dark gray clay
12"-18" - Light gray clay
- x4 - Soil Sample Location : Sparse vegetation
0"-6" - Light brown clay
6"-12" - Dark gray sandy clay/black clay
12"-18" - Light tan clay
- x5 - Soil Sample Location : Devoid of vegetation
0"-6" - Light brown/gray clay
6"-18" - Dark brown clay/black clay
18"-24" - Light brown clay
- A - Sump /switch and 3" PVC pipe protruding from ground
- B - 4" PVC pipe protruding from ground, 23 uR/Hr.
- C - (2 locations) Electrical Boxes
- D - 6x6 Concrete slab
- E - (2 locations) Pipe deck structures
- F - Rack of trash pipe, PVC pipe, grating, 10 uR/Hr.
- G - Cable warning marker, 8" pipe protruding from ground, 12 uR/Hr.
- H - 2 holes in levee, 23 uR/Hr.
- L - Light poles (2)
- T - Propane tank

SURVEYOR: David Baudoin TITLE: R.S.O./Surveyor
 DATE: 5 May 1994 TIME: 1800-1430 Hrs
 INST. TYPE: Ludlum 8 SERIAL#: 89398 CAL. DUE DATE: 6-10-94
 # 's are in uR/hr ☐ = appx. 10m x 10m SIGNATURE _____

Figure 197. - - Grid map of the Willis Hulin test well site with readings obtained from the NORM Survey (from, Rinehart, 1994).

out by EG&G, Idaho, Inc., under the day to day project management of Mr. Bennie N. Rinehard. As a result of Quality Project Management Procedures carried out by EG&G, Idaho, who replaced the site operator (Eaton Operating Company, Inc., Houston, TX), a total costs savings of \$3,191,782 was achieved.

APPENDIX - 1

[Provided by DOE Headquarters, Washington, D.C.]

LEGISLATIVE HISTORY OF PUBLIC LAW 93-410
GEOHERMAL ENERGY RESEARCH, DEVELOPMENT AND
DEMONSTRATION ACT OF 1974

<u>Date</u>	<u>Action</u>
09/03/74	Public Law 93-410
08/21/74	House agreed to conference report
07/11/90	Measure passed Senate, amended, in lieu of S. 2465
07/10/74	Measure passed House, amended, roll call #369 (404-3)
06/17/74	Reported to House, H. Rept. 93-1112
05/21/74	Referred to House Committee on Science and Astronautics

**GEOHERMAL ENERGY RESEARCH, DEVELOPMENT,
AND DEMONSTRATION ACT OF 1974**

For Legislative History of Act, see p. 5234

PUBLIC LAW 93-410; 88 STAT. 1079

[H. R. 14920]

An Act to further the conduct of research, development, and demonstrations in geothermal energy technologies, to establish a Geothermal Energy Coordination and Management Project, to provide for the carrying out of research and development in geothermal energy technology, to carry out a program of demonstrations in technologies for the utilization of geothermal resources, to establish a loan guaranty program for the financing of geothermal energy development, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That:

SHORT TITLE

Section 1. This Act may be cited as the "Geothermal Energy Research, Development, and Demonstration Act of 1974".

FINDINGS

Sec. 2. The Congress hereby finds that—

(1) the Nation is currently suffering a critical shortage of environmentally acceptable forms of energy;

(2) the inadequate organizational structures and levels of funding for energy research have limited the Nation's current and future options for meeting energy needs;

(3) electric energy is a clean and convenient form of energy at the location of its use and is the only practicable form of energy in some modern applications, but the demand for electric energy in every region of the United States is taxing all of the alternative energy sources presently available and is projected to increase; some of the sources available for electric power generation are already in short supply, and the development and use of other sources presently involve undesirable environmental impacts;

(4) the Nation's critical energy problems can be solved only if a national commitment is made to dedicate the necessary financial resources, and enlist the cooperation of the private and public sectors, in developing geothermal resources and other nonconventional sources of energy;

(5) the conventional geothermal resources which are presently being used have limited total potential; but geothermal resources which are different from those presently being used, and which have extremely large energy content, are known to exist;

(6) some geothermal resources contain energy in forms other than heat; examples are methane and extremely high pressures available upon release as kinetic energy;

(7) some geothermal resources contain valuable byproducts such as potable water and mineral compounds which should be processed and recovered as national resources;

(8) technologies are not presently available for the development of most of these geothermal resources, but technologies for the generation of electric energy from geothermal resources are potentially economical and environmentally desirable, and the development of geothermal resources offers possibilities of process energy and other nonelectric applications;

(9) much of the known geothermal resources exist on the public lands;

(10) Federal financial assistance is necessary to encourage the extensive exploration, research, and development in geothermal resources which will bring these technologies to the point of commercial application;

(11) the advancement of technology with the cooperation of private industry for the production of useful forms of energy from geothermal resources is important with respect to the Federal responsibility for the general welfare, to facilitate com-

merce, to encourage productive harmony between man and his environment, and to protect the public interest; and

(12) The Federal Government should encourage and assist private industry through Federal assistance for the development and demonstration of practicable means to produce useful energy from geothermal resources with environmentally acceptable processes.

DEFINITIONS

Sec. 3. For the purposes of this Act—

(1) the term "geothermal resources" means (A) all products of geothermal processes, embracing indigenous steam, hot water, and brines, (B) steam and other gases, hot water and hot brines, resulting from water, gas, or other fluids artificially introduced into geothermal formations, and (C) any byproduct derived from them;

(2) the term "byproduct" means any mineral or minerals which are found in solution or in association with geothermal resources and which have a value of less than 75 percent of the value of the geothermal steam and associated geothermal resources or are not, because of quantity, quality, or technical difficulties in extraction and production, of sufficient value to warrant extraction and production by themselves;

(3) "pilot plant" means an experimental unit of small size used for early evaluation and development of new or improved processes and to obtain technical, engineering, and cost data;

(4) "demonstration plant" means a complete facility which produces electricity, heat energy, or useful byproducts for commercial disposal from geothermal resources and which will make a significant contribution to the knowledge of full-size technology, plant operation, and process economics;

(5) the term "Project" means the Geothermal Energy Coordination and Management Project established by section 101(a);

(6) the term "fund" means the Geothermal Resources Development Fund established by section 204(a); and

(7) the term "Chairman" means the Chairman of the Project.

TITLE I—GEOTHERMAL ENERGY COORDINATION AND MANAGEMENT PROJECT

ESTABLISHMENT

Sec. 101. (a) There is hereby established the Geothermal Energy Coordination and Management Project.

(b)(1) The Project shall be composed of six members as follows:

(A) one appointed by the President;

(B) an Assistant Director of the National Science Foundation;

(C) an Assistant Secretary of the Department of the Interior;

(D) an Associate Administrator of the National Aeronautics and Space Administration;

(E) the General Manager of the Atomic Energy Commission;
and

(F) an Assistant Administrator of the Federal Energy Administration.

(2) The President shall designate one member of the Project to serve as Chairman of the Project.

(3) If the individual appointed under paragraph (1)(A) is an officer or employee of the Federal Government, he shall receive no additional pay on account of his service as a member of the Project. If such individual is not an officer or employee of the Federal Government, he shall be entitled to receive the daily equivalent of the annual rate of basic pay in effect for level IV of the Executive Schedule (5 U.S.C. 5315) for each day (including traveltime) during which he is engaged in the actual performance of duties vested in the Project.

(c) The Project shall have overall responsibility for the provision of effective management and coordination with respect to a national geothermal energy research, development, and demonstration program. Such program shall include—

(1) the determination and evaluation of the resource base;

(2) research and development with respect to exploration, extraction, and utilization technologies;

(3) the demonstration of appropriate technologies; and

(4) the loan guaranty program under title II.

(d)(1) The Project shall carry out its responsibilities under this section acting through the following Federal agencies:

(A) the Department of the Interior, the responsibilities of which shall include evaluation and assessment of the resource base, including development of exploration technologies;

(B) the National Aeronautics and Space Administration, the responsibilities of which shall include the provision of contract management capability, evaluation and assessment of the resource base, and the development of technologies pursuant to section 102(b);

(C) the Atomic Energy Commission, the responsibilities of which shall include the development of technologies; and

(D) the National Science Foundation, the responsibilities of which shall include basic and applied research.

(2) Upon request of the Project, the head of any such agency is authorized to detail or assign, on a reimbursable basis or otherwise, any of the personnel of such agency to the Project to assist it in carrying out its responsibilities under this Act.

(e) The Project shall have exclusive authority with respect to the establishment or approval of programs or projects initiated under this Act, except that the agency involved in any particular program or project shall be responsible for the operation and administration of such program or project.

PROGRAM DEFINITION

Sec. 102. (a)(1) The Chairman, acting through the Administrator of the National Aeronautics and Space Administration, is authorized and directed to prepare a comprehensive program definition of an integrated effort and commitment for effectively developing geothermal energy resources. Such Administrator, in preparing such comprehensive program definition, is authorized to consult with other Federal agencies and non-Federal entities.

(2) The Chairman shall transmit such comprehensive program definition to the President and to each House of the Congress. Interim reports shall be transmitted not later than November 30, 1974, and not later than January 31, 1975. Such comprehensive program definition shall be transmitted as soon as possible thereafter, but in any case not later than August 31, 1975.

(3) As part of the comprehensive program definition required by paragraph (1), the Chairman, acting through the Geological Survey, shall transmit to the President and to each House of the Congress a schedule and objectives for the inventorying of geothermal resources.

(b) The National Aeronautics and Space Administration is authorized to undertake and carry out those programs assigned to it by the Project.

RESOURCE INVENTORY AND ASSESSMENT PROGRAM

Sec. 103. (a) The Chairman shall initiate a resource inventory and assessment program with the objective of making regional and national appraisals of all types of geothermal resources, including identification of promising target areas for industrial exploration and development. The specific goals shall include—

(1) the improvement of geophysical, geochemical, geological, and hydrological techniques necessary for locating and evaluating geothermal resources;

(2) the development of better methods for predicting the power potential and longevity of geothermal reservoirs;

(3) the determination and assessment of the nature and power potential of the deeper unexplored parts of high temperature geothermal convection systems; and

(4) the survey and assessment of regional and national geothermal resources of all types.

(b) The Chairman, acting through the Geological Survey and other appropriate agencies, shall—

(1) develop and carry out a general plan for the orderly inventorying of all forms of geothermal resources of the Federal lands and, where consistent with property rights and determined by the Chairman to be in the national interest, of non-Federal lands;

(2) conduct regional surveys, based upon such a general plan, using innovative geological, geophysical, geochemical, and stratigraphic drilling techniques, which will lead to a national inventory of geothermal resources in the United States;

(3) publish and make available maps, reports, and other documents developed from such surveys to encourage and facilitate the commercial development of geothermal resources for beneficial use and consistent with the national interest;

(4) make such recommendations for legislation as may from time to time appear to be necessary to make Federal leasing policy for geothermal resources consistent with known inventories of various resource types, with the current state of technologies for geothermal energy development, and with current evaluations of the environmental impacts of such development; and

(5) participate with appropriate Federal agencies and non-Federal entities in research to develop, improve, and test technologies for the discovery and evaluation of all forms of geothermal resources, and conduct research into the principles controlling the location, occurrence, size, temperature, energy content, producibility, and economic lifetimes of geothermal reservoirs.

RESEARCH AND DEVELOPMENT

Sec. 104. (a) The Chairman, acting through the appropriate Federal agencies and in cooperation with non-Federal entities, shall initiate a research and development program for the purpose of resolving all major technical problems inhibiting the fullest possible commercial utilization of geothermal resources in the United States. The specific goals of such programs shall include—

(1) the development of effective and efficient drilling methods to operate at high temperatures in formations of geothermal interest;

(2) the development of reliable predictive methods and control techniques for the production of geothermal resources from reservoirs;

(3) the exploitation of new concepts for fracturing rock to permit recovery of contained heat reserves;

(4) the improvement of equipment and technology for the extraction of geothermal resources from reservoirs;

(5) the development of improved methods for converting geothermal resources and byproducts to useful forms;

(6) the development of improved methods for controlling emissions and wastes from geothermal utilization facilities, including new monitoring methods to any extent necessary;

(7) the development and evaluation of waste disposal control technologies and the evaluation of surface and subsurface environmental effects of geothermal development;

(8) the improvement of the technical capability to predict environmental impacts resulting from the development of geothermal resources, the preparation of environmental impact statements, and the assuring of compliance with applicable standards and criteria;

(9) the identification of social, legal, and economic problems associated with geothermal development (both locally and regionally) for the purpose of developing policy and providing a framework of policy alternatives for the commercial utilization of geothermal resources;

(10) the provision for an adequate supply of scientists to perform required geothermal research and development activities; and

(11) the establishment of a program to encourage States to establish and maintain geothermal resources clearinghouses, which shall serve to (A) provide geothermal resources developers with information with respect to applicable local, State, and Federal laws, rules, and regulations, (B) coordinate the processing of permit applications, impact statements, and other information which geothermal resources developers are required to provide, (C) encourage uniformity with respect to local and State laws, rules, and regulations with respect to geothermal resources development, and (D) encourage establishment of land use plans, which would include zoning for geothermal resources development and which would assure that geothermal resources developers will be able to carry out development programs to the production stage.

(b) The Chairman, acting through the appropriate Federal agencies and in cooperation with non-Federal entities, shall implement a coordinated program of research and development in order to demonstrate the technical means for the extraction and utilization of the resource base, including any byproducts of such base, and in order to accomplish the goals established by subsection (a). Research authorized by this Act having potential applications in matters other than geothermal energy may be pursued to the extent that the findings of such research can be published in a form for utilization by others.

DEMONSTRATION

Sec. 105. (a) The Chairman, acting through the appropriate Federal agencies and in cooperation with non-Federal entities, shall initiate a program to design and construct geothermal demonstration plants. The specific goals of such program shall include—

(1) the development of economical geothermal resources production systems and components which meet environmental standards;

(2) the design of plants to produce electric power and, where appropriate, the large-scale production and utilization of any useful byproducts;

(3) the involvement of engineers, analysts, technicians, and managers from industry field and powerplant development, which shall lead to the early industrial exploitation of advanced geothermal resources;

(4) the provision for an adequate supply of trained geothermal engineers and technicians;

(5) the provision of experimental test beds for component testing and evaluation by laboratories operated by the Federal Government, industry, or institutions of higher education;

(6) the construction and operation of pilot plants; and

(7) the construction and operation of demonstration plants.

(b) In carrying out his responsibilities under this section, the Chairman, acting through the appropriate Federal agencies, and in cooperation with non-Federal entities, may provide for the establishment of one or more demonstration projects utilizing each geothermal resource base involved, which shall include, as appropriate, all of the exploration, siting, drilling, pilot plant construction and operation, demonstration plant construction and operation, and other facilities and activities which may be necessary for the generation of electric energy and the utilization of geothermal resource byproducts.

(c) The Chairman, acting through the appropriate Federal agencies, is authorized to investigate and enter into agreements for the cooperative development of facilities to demonstrate the production of energy from geothermal resources. The responsible Federal agency may consider—

(1) cooperative agreements with utilities and non-Federal governmental entities for construction of facilities to produce energy for commercial disposition; and

(2) cooperative agreements with other Federal agencies for the construction and operation of facilities to produce energy for direct Federal consumption.

(d) The responsible Federal agency is authorized to investigate the feasibility of, construct, and operate, demonstration projects without entering into cooperative agreements with respect to such projects, if the Chairman finds that—

(1) the nature of the resource, the geographical location, the scale and engineering design of the facilities, the techniques of production, or any other significant factor of the proposal offers opportunities to make important contributions to the general knowledge of geothermal resources, the techniques of its development, or public confidence in the technology; and

(2) there is no opportunity for cooperative agreements with any utility or non-Federal governmental entity willing and able to cooperate in the demonstration project under subsection (c)

(1), and there is no opportunity for cooperative agreements with other Federal agencies under subsection (c)(2).

(e) Before favorably considering proposals under subsection (c), the responsible Federal agency must find that—

(1) the nature of the resource, the geographical location, the scale and engineering design of the facilities, the techniques of production, or any other significant factor of the proposal offers opportunities to make important contributions to the general knowledge of geothermal resources, the techniques of its development, or public confidence in the technology;

(2) the development of the practical benefits as set forth in paragraph (1) are unlikely to be accomplished without such cooperative development; and

(3) where non-Federal participants are involved, the proposal is not eligible for adequate Federal assistance under the loan guaranty provisions of title II of this Act.

(f) If the estimate of the Federal investment with respect to construction and operation costs of any demonstration project proposed to be established under this section exceeds \$10,000,000, no amount may be appropriated for such project except as specifically authorized by legislation hereafter enacted by the Congress.

(g)(1) At the conclusion of the program under this section or as soon thereafter as may be practicable, the responsible Federal agencies shall, by sale, lease, or otherwise, dispose of all Federal property interests which they have acquired pursuant to this section (including mineral rights) in accordance with existing law and the terms of the cooperative agreements involved.

(2) The agency involved shall, under appropriate agreements or other arrangements, provide for the disposition of geothermal resource byproducts of the project administered by such agency.

SCIENTIFIC AND TECHNICAL EDUCATION

Sec. 106. (a) It is the policy of the Congress to encourage the development and maintenance of programs through which there may be provided the necessary trained personnel to perform required geothermal research, development, and demonstration activities under sections 103, 104, and 105.

(b) The National Science Foundation is authorized to support programs of education in the sciences and engineering to carry out the policy of subsection (a). Such support may include fellowships, traineeships, technical training programs, technologist training programs, and summer institute programs.

(c) The National Science Foundation is authorized and directed to coordinate its actions, to the maximum extent practicable, with the Project or any permanent Federal organization or agency having jurisdiction over the energy research and development functions of the United States, in determining the optimal selection of programs of education to carry out the policy of subsection (a).

(d) The National Science Foundation is authorized to encourage, to the maximum extent practicable international participation and cooperation in the development and maintenance of programs of education to carrying out the policy of subsection (a).

TITLE II—LOAN GUARANTIES

ESTABLISHMENT OF LOAN GUARANTY PROGRAM

Sec. 201. (a) It is the policy of the Congress to encourage and assist in the commercial development of practicable means to produce useful energy from geothermal resources with environmentally acceptable processes. Accordingly, it is the policy of the Congress to facilitate such commercial development by authorizing the Chair-

man of the Project to designate an appropriate Federal agency to guarantee loans for such purposes.

(b) In order to encourage the commercial production of energy from geothermal resources, the head of the designated agency is authorized to, in consultation with the Secretary of the Treasury, guarantee, and to enter into commitments to guarantee, lenders against loss of principal or interest on loans made by such lenders to qualified borrowers for the purposes of—

- (1) the determination and evaluation of the resource base;
- (2) research and development with respect to extraction and utilization technologies;
- (3) acquiring rights in geothermal resources; or
- (4) development, construction, and operation of facilities for the demonstration or commercial production of energy from geothermal resources.

(c) Any guaranty under this title shall apply only to so much of the principal amount of any loan as does not exceed 75 percent of the aggregate cost of the project with respect to which the loan is made.

(d) Loan guaranties under this title shall be on such terms and conditions as the head of the designated agency determines, except that a guaranty shall be made under this title only if—

(1) the loan bears interest at a rate not to exceed such annual per centum on the principal obligation outstanding as the head of the designated agency determines to be reasonable, taking into account the range of interest rates prevailing in the private sector for similar loans and risks by the United States;

(2) the terms of such loan require full repayment over a period not to exceed thirty years, or the useful life of any physical asset to be financed by such loan, whichever is less (as determined by the head of the designated agency);

(3) in the judgment of the head of the designated agency, the amount of the loan (when combined with amounts available to the qualified borrower from other sources) will be sufficient to carry out the project; and

(4) in the judgment of the head of the designated agency, there is reasonable assurance of repayment of the loan by the qualified borrower of the guaranteed indebtedness.

(e) The amount of the guaranty for any loan for a project shall not exceed \$25,000,000, and the amount of the guaranty for any combination of loans for any single qualified borrower shall not exceed \$50,000,000.

(f) As used in this title, the term "qualified borrower" means any public or private agency, institution, association, partnership, corporation, political subdivision, or other legal entity which (as determined by the head of the designated agency) has presented satisfactory evidence of an interest in geothermal resources and is capable of performing research or completing the development and production of energy in an acceptable manner.

PAYMENT OF INTEREST

Sec. 202. (a) With respect to any loan guaranteed pursuant to this title, the head of the designated agency is authorized to enter into a contract to pay, and to pay, the lender for and on behalf of the borrower the interest charges which become due and payable on the unpaid balance of any such loan if the head of the designated agency finds—

(1) that the borrower is unable to meet interest charges, and that it is in the public interest to permit the borrower to continue to pursue the purposes of his project, and that the probable net cost to the Federal Government in paying such interest will be less than that which would result in the event of a default; and

(2) the amount of such interest charges which the head of the designated agency is authorized to pay shall be no greater than the amount of interest which the borrower is obligated to pay under the loan agreement.

(b) In the event of any default by a qualified borrower on a guaranteed loan, the head of the designated agency is authorized to make payment in accordance with the guaranty, and the Attorney General shall take such action as may be appropriate to recover the amounts of such payments (including any payment of interest under subsection (a)) from such assets of the defaulting borrower as are associated with the project, or from any other surety included in the terms of the guaranty.

PERIOD OF GUARANTIES AND INTEREST ASSISTANCE

Sec. 203. No loan guaranties shall be made, or interest assistance contract entered into, pursuant to this title, after the expiration of the ten-calendar-year period following the date of enactment of this Act.

• GEOTHERMAL RESOURCES DEVELOPMENT FUND

Sec. 204. (a) There is established in the Treasury of the United States a Geothermal Resources Development Fund, which shall be available to the head of the designated agency for carrying out the loan guaranty and interest assistance program authorized by this title, including the payment of administrative expenses incurred in connection therewith. Moneys in the fund not needed for current operations may, with the approval of the Secretary of the Treasury, be invested in bonds or other obligations of, or guaranteed by, the United States.

(b) There shall be paid into the fund the amounts appropriated pursuant to section 304(c) and such amounts as may be returned to the United States pursuant to section 202(b), and the amounts in the fund shall remain available until expended, except that after the expiration of the ten-year period established by section 203, such amounts in the fund which are not required to secure outstanding guaranty obligations shall be paid into the general fund of the Treasury.

(c) Business-type financial reports covering the operations of the fund shall be submitted to the Congress by the head of the designated agency annually upon the completion of an appropriate accounting period.

TITLE III—GENERAL PROVISIONS

PROTECTION OF ENVIRONMENT

Sec. 301. In the conduct of its activities, the Project and any participating public or private persons or agencies shall place particular emphasis upon the objective of assuring that the environment and the safety of persons or property are effectively protected; and the program under title I shall include such special research and development as may be necessary for the achievement of that objective.

REPORTING REQUIREMENTS

Sec. 302. (a) The Chairman of the Project shall submit to the President and the Congress full and complete annual reports of the activities of the Project, including such projections and estimates as may be necessary to evaluate the progress of the national geothermal energy research, development, and demonstration program and to provide the basis for as accurate a judgment as is possible concerning the extent to which the objectives of this Act will have been achieved by June 30, 1980.

(b) No later than one year after the termination of each demonstration project under section 105, the Chairman of the Project shall submit to the President and the Congress a final report on the activities of the Project related to each project, including his recommendations with respect to any further legislative, administrative, and other actions which should be taken in support of the objectives of this Act.

TRANSFER OF FUNCTIONS

Sec. 303. (a) Within sixty days after the effective date of the law creating a permanent Federal organization or agency having jurisdiction over the energy research and development functions of the United States (or within sixty days after the date of the enactment of this Act if the effective date of such law occurs prior to the date of the enactment of this Act), all of the research, development, and demonstration functions (including the loan guaranty program) vested in the Project under this Act, along with related records, documents, personnel, obligations, and other items to the extent necessary or appropriate, shall, in accordance with regulations prescribed by the Office of Management and Budget, be transferred to and vested in such organization or agency.

(b) Upon the establishment of a permanent Federal organization or agency having jurisdiction over the energy research and development functions of the United States, and when all research and development (and other) functions of the Project are transferred, the members of the Project may provide advice and counsel to the head

of such organization or agency, in accordance with arrangements made at that time.

AUTHORIZATIONS OF APPROPRIATIONS

Sec. 304. (a) For the fiscal years ending June 30, 1976, and September 30, 1977, 1978, 1979, and 1980, only such sums may be appropriated as the Congress may hereafter authorize by law.

(b) There are authorized to be appropriated to the National Aeronautics and Space Administration not to exceed \$2,500,000 for the fiscal year ending June 30, 1975, for the purpose of preparing the program definition under section 102(a).

(c) In addition to sums authorized to be appropriated by subsection (b), there are authorized to be appropriated to the fund not to exceed \$50,000,000 annually, such sums to carry out the provisions of the loan guaranty program by the Project under title II.

Approved Sept. 3, 1974.

APPENDIX - 2

Sweet Lake Geopressured - Geothermal Project Management Organization and list of subcontractors

**(From Durham, C.O., Jr., F.D. O'Brien and R.W. Rodgers, 1981,
Sweet Lake Geopressured - Geothermal Project: Annual Report
February 1982 - March 1985,
DOE Contract NO. AC07-80NV10081, Magma Gulf
Technadril, Houston, Texas, Volume 3, 458 p)**

MANAGEMENT ORGANIZATION

The Joint Venture Executive Committee consisted of three members: Dr. C. O. Durham of Magma Gulf Co. served as Chairman and Program Coordinator to ensure that the program operated according to plans, schedules and budgets and served as liaison with the DOE. J.I. Marshall of Technadril, Inc. served as Deputy Chairman to oversee costs and schedules. R. W. Rodgers of Magma Gulf Co. served as Project Manager to provide overall supervision of the project. Reporting to the Project Manager were deputy project managers, assigned to specific aspects of the project.

Key Personnel

Magma Gulf Company

- Dr. C. O. Durham, Jr.
Chairman of Joint Venture Executive Committee
President of Magma Gulf Company
Program Coordinator for Sweet Lake Project
- R. W. Rodgers
Member of Joint Venture Executive Committee
Operations Project Manager for Sweet Lake Project
- K. S. Hoffman
Deputy Project Manager - Research for Sweet Lake Project.

Technadril, Inc.

- J. I. Marshall
Deputy Chairman of Joint Venture Executive Committee
President of Technadril, Inc.
- C. S. Adkins, Jr.
Deputy Project Manager - Drilling & Construction for Sweet
Lake Project
- A. L. Wyand
Deputy Project Manager - Administration for Sweet Lake
Project
- C. D. Mitchell
Site Manager for Sweet Lake Project - Drilling phase
- Larry Durrett
Deputy Project Manager - Testing Phase
- Jonne Berning
Site Manager - Testing Phase
- Frank O'Brien
Administrative Deputy and Technical Director

The management program remained in effect until the completion of the drilling phase of the project. At this time it became necessary for R. W. Rodgers to return to his University duties. Dr. C.O. Durham acted as Project Manager during the testing phase. In addition Larry Durrett of Technadril, Inc. became testing Manager and Jonne Berning of Technadril, Inc. became Site Operations Manager. Frank O'Brien of Technadril served as Deputy Administrator acting for J. I. Marshall and A. L. Wyand during the completion phase, and served as Technical Director during the testing phase. Carl Guillot served as consultant for the design and construction of the surface facilities. J. Don Clark served as consultant for reservoir testing.

The following list represents the major important subcontractors for the project with total costs of \$10,729,045. Additionally, some 30 vendors supplied lesser services, supplies, and equipment.

SUBCONTRACTORS - UNDER DOE CONTRACT - DRILLING

Amoco Production - Tubing	Houston, Tx. \$18,020
Analytical Stress Relieving - , Stress tests - welding	Houston, Tx. \$11,000
Baker Packers - Packers	Houston, Tx. \$47,450
Benton Casing - Casing crews	Houma, La. \$52,824
Big Diamond Trucking - Hauling-cuttings, drilling mud	Lake Charles, La. \$272,686
Brown Pipe & Supply - Tubing-recompletion test well	Houston, Tx. \$58,000
Brown Oil Tools - Tools	Houston, Tx. \$99,248
Brown Tool & Supply - Tools	Lafayette, La. \$128,087
Byrom & Co. - Drilling consultants	Houston, Tx. \$34,582
Chickasaw Distributors, Inc. - Casing	Dallas, Tx. \$956,138
Christensen Diamond Products Co. - Diamond coring	Salt Lake City, Utah \$10,951
Completion Technology - Completion recommendations	Houston, Tx. \$3,245
Crosby Valve - Safety valves	Providence, RI. \$10,119
Dave's Welding Service - Welding	Schriever, La. \$24,800
Jeff Davis Electric Coop - Electrical power	Jennings, La. \$29,651
Dia-Log - Wireline services	Houston, TX. \$28,956

Dresser Magcobar - Drilling fluids	Houston, Tx. \$695,599
J. F. Eggleston - Drilling consultant	Carencro, La. \$19,648
Energy Resource Management - Work over procedures	Houston, Tx. \$4,000
FMC Corporation - Part of production wellhead Disposal wellhead	Dallas, Tx. \$191,600
Franks Casing Crew Casing crew	Lafayette, La. \$27,400
The Foxboro Co. - Instrumentation	Houston, Tx. \$11,233
Geolograph Pioneer - Wireline services	Houston, Tx. \$83,549
Gearhart Owens, Inc. - Logging	Lafayette, La. \$27,010
G&G Valve & Supply, Inc. - Valves	Lake Charles, La. \$62,985
Goldrus Drilling Co. - Rig and crews-disposal well	Houston, Tx. \$241,340
Grant Tubular Corporation - Casing	Houston, Tx. \$244,023
Gray Tool Co. - Chokes and upper section test wellhead	Houston, Tx. \$62,846
Greene's Pressure Testing - Test blow-out preventers	Lafayette, La. \$23,385
Halliburton, Co. - Cementing	Houston, Tx. \$414,851
Richard Hanks Welding Service - Welding	LeCompte, La. \$41,014
Russell Lee Jacobs - Blowout insurance	Houston, Tx. \$47,112
T. J. LeMarie's Welding Welding	Abbeville, La. \$6,500
Lincoln Big Three - Welding gases	Baton Rouge, La. \$6,469

N. L. McCulloch - Bridge plug	Lake Charles, La. \$12,667
McKinley Oil Field Service - Construction	Longview, Tx. \$20,745
NOWSCO - Disposal well cleanout	Lake Charles, La. \$2,100
Oceanography International - Sand detectors	College Station, Tx. \$15,500
Oil Field Rental Service Co. - Rental tools	Houston, Tx. \$130,077
Oil Technology Services - Quality assurance - tubing	Houston, Tx. \$158,977
Oil Quip, Inc. - Tubulars	Houston, Tx. \$567,920
Oilwell - Tubulars	Houston, Tx. \$133,636
Ortego Oil & Supply - Rig fuel	Opelousas, La. \$221,564
Otis Engineering - ESD System	Dallas, Tx. \$70,019
Otis Pressure Control - Packer-recompletion-wireline serv.	Houston, Tx. \$17,402
Patterson Truck Line - Hauling	Houston, Tx. \$6,967
Petroleum Well Service - Drilling consultants	Sour Lake, Tx. \$73,872
Projects Design - Drafting	Houston, Tx. \$17,179
Quality Inspection and Control, Inc. - Pipe inspection	Houma, La. \$8,179
Mike Queenan Equipment - Construction equipment	Lake Charles, La. \$27,080
Resource Drilling, Inc. - Rig and crews-test well	Houston, Tx. \$2,056,434
Rig Housing - Site office	Lafayette, La. \$9,308
Rig Water, Inc. - Rig water	Church Point, La. \$12,937

Sandair - Air compressors	Houston, Tx. \$28,007
Schlumberger - Logging, sidewall coring, perforating test well and disposal	Houston, Tx. \$347,978
Security Bits - Drill Bits	Houston, Tx. \$22,190
Smith Pipe & Supply Co. - Casing	Houston, Tx. \$158,556
South Central Bell - Site telephones	Shreveport, La. \$12,586
Southwestern Bell - Telephone	Houston, Tx. \$3,012
Sperry-Sun, Inc. - Logging - Well surveys	Houston, Tx. \$16,450
Taylor Instruments - Control instruments	Houston, Tx. \$16,486
Tong Rentals - Rental tools	Lafayette, La. \$18,858
Totco - Surveys	Norman, Ok. \$7,004
Tri State Oil Tool - Drilling tools	Houston, Tx. \$45,585
Universal Engineering - Field construction	Sulphur, La. \$87,677
Universal Tubular - Tubing Coating	Corpus Christi, Tx. \$3,384
O'Dell Vinson Oil Field Contracting - Site preparation	Lake Charles, La. \$1,098,355
Warren Automatic Tool Co. - Drilling monitors	Houston, Tx. \$38,866
Washington Maritime - Disposal services	Lake Charles, La. \$161,974
Watson Electric - Electric contracting	Jennings, La. \$135,727
Willis Co. - Chokes	Pasadena, Ca. \$14,162

Wilson Down Hole Services - Houston, Tx.
Fishing tools \$35,143

Welex - Houston, Tx.
Logging - Perforating test well \$34,837

SUBCONTRACTORS - DOE CONTRACT - TESTING

Air Power Service Co. - Houston, Tx.
Air Compressors \$24,240

Accumin Analysis - Houston, Tx.
SEM core photos No charge
Photomicrographs of thin sections

Aymonds Welding - Iowa, La.
Welding \$8,318

Baker Sand Control - Houston, Tx.
Sand production and control \$1,800

J. Donald Clark, Consultant - Houston, Tx.
Reservoir limit analysis \$17,352

Ken Davis, Assoc. - Baton Rouge, La.
Perforation - completion \$4,700
recommendations

Diamond Pittsburgh Paint - Sulphur, La.
Paint - surface equipment \$6,009

Dowdle, Fairchild, and Ancell - Houston, Tx.
Reservoir modeling \$6,400

Engineering Speciality Services, Inc. - Houston, Tx.
Design of surface facilities \$50,388

Intercomp Research & Engineering, Inc. Houston, Tx.
Reservoir modeling Separate DOE contract

Kaye Instruments - Bedford, Mass.
Control instruments \$17,730

Kodiak Fabrication Ind. Inc. - Houston, Tx.
Separator skid \$252,345

McNeese University (Karkalits-Hankins) Lake Charles, La.
Chemical analysis \$11,600

Jack Matson Consulting Engineer - Houston, Tx.
Scale and corrosion chemistry \$6,840
inhibitor chemistry

F. S. Millard, Consultant - 478 201 1002 Houston, Tx.
Log interpretation \$750

Milton Roy - Inhibitor pumps	Philadelphia, Pa. \$16,905
Mobile Quarters - Control trailer	Rayne, La. \$24,720
Moody Price - Instruments	Baton Rouge, La. \$7,082
Panelmasters Intl. - Control panels	Houston, Tx. \$18,731
Pilgrim Steel - Flare	Glassboro, N. J. \$11,626
Pioneer Centrifuging Co. Inc. - Filters	Liberty, Tx. \$71,842
Puffer Sweiven - Instruments	Stafford, Tx. \$13,268
Reservoir Data, Inc. - Monitoring bottom-hole pressure and temperatures	Houston, Tx. \$106,039
Rice University (Mason Tomson) - Scale and corrosion chemistry pilot plant monitoring	Houston, Tx. \$6,000
Russell Sensat Welding - Welding	Ragley, La. \$29,960
Systems Science and Software - Reservoir Behavior	LaJolla, Ca. Separate DOE contract
University of California - Lawrence Livermore Laboratory Brine Injection	Livermore, Ca. Separate DOE Contract
Weatherly Laboratories, Inc. - Gas recombination analysis	Lake Charles, La. \$12,400

SUBCONTRACTORS - (GRI CONTRACT TO MG-T)

Core Laboratories - Core analysis	Houston, Tx. \$10,305
Hartax, Int. - Geochemistry	Baton Rouge, La. \$31,393

IDL -
Mud Log

Houston, Tx.
\$58,800

Paleo-Data, Inc. -
Paleontology

New Orleans, La.
\$25,773

SUBCONTRACTORS - INDIRECT - THROUGH DOE CONTRACT TO L.S.U.

Louisiana State University -
Clay Diagenesis

Baton Rouge, La.

Louisiana State University -
Energy Program Office
Environmental Monitoring

Baton Rouge, La.

U.S. Geological Survey -
Clay and formation water analysis

NSTL Station, Miss.

U.S. Geological Survey -
Thermal Conductivity

Menlo Park, Ca.

APPENDIX - 3

Parcperdue (Dow-DOE L.R. Sweezy No. 1) Project

Major Subcontractors

**(From, Hamilton, J.R., and J.G. Stanley, ed's, 1984,
Parcperdue Geopressure - Geothermal project: Final
Technical Report, September 28, 1979 thru December 31, 1983,
DOE Contract No. DE-AC08-79ET27255, The
Dow Chemical Company USA, 443 p).**

MAJOR SUBCONTRACTORS PARCPERDUE PROJECT

Welsh Drilling & Services, Inc.,	Houston, TX
Rig & crews-production well	\$2,209,979
WellTech, Inc.	Lafayette, LA
Rig & crews-disposal well	\$236,692
Johnston-Macco Schlumberger	Lafayette, LA
Well testing-surface	\$660,813
Otis Engr. Corp.	Houma, LA
Well testing-downhole	\$370,323
Otis Engr. Corp.	New Iberia, LA
Well completion & plugging	\$117,233
Otis Engr. Corp.	Dallas, TX
Reservoir Analysis	\$78,875
NL Baroid	Houston, TX
Drilling mud & chemicals	\$603,609
Central Industries, Inc.	Scott, LA
Site prep., maint., & restoration	\$533,248
B&M Oilfield Supply	Broussard, LA
Bits & supplies	\$53,255
Circle M Supply	Lafayette, LA
Bits & supplies	\$52,218
Dunigan Tool & Supply	Abilene, TX
Casing - 10-3/4"	\$496,105
Eastman Whipstock, Inc.	Lafayette, LA
Well Surveying	\$56,543
Elder Leasing Co.	Houston, TX
Trailer Rental	\$40,121
FMC Corporation	Broussard, LA
Production wellhead & maint.	\$205,636

E. L. Farmer & Company	Odessa, TX
Hauling-tubulars	\$50,751
Gearhart Industries, Inc.	Lafayette, LA
Logging, perforating, tools	\$139,587
Grant Oil Country Tubular Corp.	Houston, TX
8-5/8" & 7-5/8" Casing, tubing 5-1/2"	\$675,169
Greene's Pressure Testing	Lafayette, LA
Blow-out preventor testing	\$28,695
Gulf Coast Vacuum Services, Inc.,	Abbeville, LA
Hauling-saltwater & sludge	\$26,683
Howard Trucking Co., Inc.,	New Iberia, LA
Hauling - parts, supplies, etc.	\$28,786
Inland Enterprises, Inc.	Ball, LA
Drilling consultant	\$185,824
Fred S. James & Co.	Houston, TX
Well blowout insurance	\$105,203
McEvoy Oilfield Equipment	Lafayette, LA
Disposal wellhead & maint.	\$23,533
NL McCullough	Houston, TX
Logging, casing cutting	\$31,342
National Security Service	Lafayette, LA
Security guards	\$47,323
Oil Field Rental Service Co.	Lafayette, LA
Drill pipe & tools rental	\$288,093
PALCO Linings, Inc.	Stanton, CA
Salt water pit lining	\$31,677
Production Rentals, Inc.	Lafayette, LA
Pump rental, filters	\$26,812
Redman Pipe & Supply	Tulsa, OK
16" casing	\$261,554
REAMCO, Inc.	Lafayette, LA
Stabilizers, rental tools	\$67,882
Rig Housing Services, Inc.	Lafayette, LA
Personnel trailer rentals	\$72,130
Roy Young, Inc.	Abbeville, LA
Hauling-equipment, vacuum trucks	\$40,215
Schlumberger Well Services	Lafayette, LA
Logging, perforating	\$245,650

Sperry-Sun, Inc.	Houston, TX
Logging, casing cutting	\$30,307
SWACO-Dresser Industries	Lafayette, LA
Choke & degasser rental	\$37,308
SWECO, Inc.	Lafayette, LA
Mud cleaner rental	\$59,051
TerraTek, Inc.	Salt Lake City, UT
Core testing, reservoir studies	\$103,558
Texas Iron Works	Houston, TX
Liner tools	\$63,176
TIMCO, Inc.	Lafayette, LA
Casing driving & handling	\$239,855
Tri-State Oil Tool Industries, Inc.	Bossier City, LA
Fishing, tool rental	\$68,960
Univ. of Southwestern Louisiana	Lafayette, LA
Chemical & physical analysis	\$341,745
Varian Associates, Inc.	Sunnyvale, CA
Laboratory equipment	\$32,066
Kelly Services, Inc.	Lafayette, LA
Secretarial Services	\$41,108

The above list represents subcontract expenditures exceeding \$9 million with some 40 vendors. More than 100 other vendors supplied lesser services, equipment, and supplies. Total subcontracting activity was \$9.5 million, excluding the Dowell Division of The Dow Chemical Company. Of that total, ten percent was contracted to Small Business firms and four percent to disadvantaged firms.

APPENDIX - 4

- 1. Porosity and Permeability of Gladys McCall #1 diamond cores by Core Laboratories.**
- 2. Sidewall core analyses of the Gladys McCall #1 well by Core Laboratories.**

(From, Technadril - Fenix and Scisson, v. 2, 1982)

1. Analyses of diamond cores by Core Laboratories - Gladys McCall #1

DEPTH INTERVAL: 15182.0 TO 15374.0

FEET OF CORE ANALYZED : 33.0 FEET OF CORE INCLUDED IN AVERAGES: 28.0

-- SAMPLES FALLING WITHIN THE FOLLOWING RANGES WERE AVERAGED --

PERMEABILITY HORIZONTAL RANGE (MD.)	:	7.4 TO	545.	(UNCORRECTED FOR SLIPPAGE)
FLUID POROSITY RANGE (%)	:	10.4 TO	100.0	
OIL SATURATION RANGE (%)	:	0.0 TO	0.0	
WATER SATURATION RANGE (%)	:	61.9 TO	97.4	

SHALE SAMPLES EXCLUDED FROM AVERAGES.

AVERAGES FOR DEPTH INTERVAL: 15182.0 TO 15374.0

AVERAGE PERMEABILITY (MILLIDARCIES)		PRODUCTIVE CAPACITY (MILLIDARCY-FEET)	
ARITHMETIC PERMEABILITY	: 126.	ARITHMETIC CAPACITY	: 3531.
GEOMETRIC PERMEABILITY	: 94.	GEOMETRIC CAPACITY	: 2629.
HARMONIC PERMEABILITY	: 74.	HARMONIC CAPACITY	: 2060.
AVERAGE POROSITY (PERCENT)	: 15.4	AVERAGE TOTAL WATER SATURATION (PERCENT OF PORE SPACE)	: 83.9
AVERAGE RESIDUAL OIL SATURATION (PERCENT OF PORE SPACE)	: 0.0	AVERAGE CONNATE WATER SATURATION ** (PERCENT OF PORE SPACE)	: 83.9

** ESTIMATED FROM TOTAL
WATER SATURATION.

1. Analyses of diamond cores by Core Laboratories (continued) - Gladys McCall #1

SMP NO	DEPTH	PERM MD HORZ(KA)	POR %	OILZ PORE	WTRZ PORE	PROB PROD	GASZ BULK	DESCRIPTION
CORE NO.1 CUT 12' REC 10' 15167' TO 15179'								
	15167.0-77.0							SHALE
	15177.0-79.0							LOST CORE
CORE NO.2 CUT 19' REC 13' 15179' TO 15198'								
	15179.0-82.7							SHALE
1	15182.7-84.0	64.	18.8	0.0	83.8	WTR	3.1	SD FG CLN NO FLU
	15184.0-84.8							SD VF-FG SLTY VCALC
2	15184.8-86.0	220.	18.0	0.0	83.8	WTR	2.9	SD FG CLN NO FLU
3	15186.0-87.0	185.	20.1	0.0	61.9	WTR	7.7	SD FG CLN NO FLU
	15187.0-87.5							SD FG SLTY VCALC
4	15187.5-89.0	93.	18.2	0.0	64.3	WTR	6.5	SD FG CLN NO FLU
5	15189.0-91.0	545.	20.8	0.0	83.3	WTR	3.5	SD FG CLN NO FLU
	15191.0-92.0							SD FG CLN
	15192.0-98.0							LOST CORE
CORE NO.3 15348' TO 15375' CUT 27' REC 26.5'								
6	15348.0-50.0	145.	12.2	0.0	88.9	WTR	1.4	SD FG CLN NO FLU
7	15350.0-52.0	61.	12.7	0.0	85.5	WTR	1.8	SD FG CLN NO FLU
8	15352.0-54.0	150.	14.7	0.0	86.5	WTR	2.0	SD FG CLN NO FLU
9	15354.0-56.0	65.	12.2	0.0	97.4	WTR	0.3	SD FG CLN NO FLU
10	15356.0-58.0	21.	15.6	0.0	91.9	WTR	1.3	SD FG CLN NO FLU
11	15358.0-60.0	90.	10.4	0.0	68.9	WTR	3.2	SD FG CLN NO FLU
12	15360.0-62.0	115.	16.8	0.0	95.6	WTR	0.7	SD FG CLN NO FLU
13	15362.0-64.0	90.	15.1	0.0	77.3	WTR	3.4	SD FG CLN NO FLU
14	15364.0-66.0	30.	15.1	0.0	83.2	WTR	2.3	SD FG CLN NO FLU
15	15366.0-68.0	135.	16.1	0.0	73.6	WTR	4.2	SD FG CLN NO FLU
16	15368.0-70.0	80.	13.6	0.0	82.2	WTR	2.4	SD FG CLN NO FLU
17	15370.0-72.0	7.40	15.2	0.0	78.6	WTR	3.3	SD FG CLN DNS NO FLU
18	15372.0-74.0	55.	13.6	0.0	81.5	WTR	2.5	SD FG CLN NO FLU
	15374.0-74.5							SD FG CLN NO FLU
	15374.5-75.0							LOST CORE

2. Sidewall core analyses by Core Laboratories - Gladys McCall #1

REC IN	DEPTH FEET	PERM MD(*)	POR %	OIL% PORE	WTR% PORE	PROB PROD	OIL% BULK	GAS% BULK	GAS DET	CRIT WTR%	DESCRIPTION
0.6	14570.0	16.	19.3	4.9	72.2	OIL	1.0	4.4	0	62	SD VFG SHY LAM VSLTY STKS GLD FLU
0.0	14605.0										EMPTY BOTTLE
0.8	14625.0	160.	25.9	10.3	69.0	OIL	2.7	5.4	0	46	SD VFG CLN VSLTY GLD FLU(37API)
0.5	14645.0	94.	23.8	2.7	77.8	WTR	0.6	4.6	0	50	SD VFG VSSHY VSLTY FT FLU
0.5	14660.0	4.2	14.9	0.0	89.9	(6)	0.0	1.5	0	62	SD VFG VSHY VCALC NO FLU
0.0	14685.0										MUDCAKE
0.8	14715.0	275.	27.3	10.3	73.6	OIL	2.8	4.4	0	42	SD VFG CLN SLTY GLD FLU(35API)
0.0	14730.0										EMPTY BOTTLE
0.8	14745.0	285.	27.9	9.6	73.7	OIL	2.7	4.6	0	42	SD VFG CLN SLTY GLD FLU(35API)
0.8	14790.0	240.	27.1	14.3	68.0	OIL	3.9	4.8	0	43	SD VFG CLN SLTY GLD FLU(33API)
0.5	14935.0	205.	26.5	16.7	63.3	OIL	4.4	5.3	0	45	SD VFG CLN SLTY GLD FLU
0.5	14950.0	22.	22.5	2.2	80.0	WTR	0.5	4.0	0	63	SD VFG SSHY VSLTY FT FLU
0.5	15285.0	37.	22.8	2.1	82.5	WTR	0.5	3.5	0	59	SD VFG SSHY VSLTY FT FLU
0.5	15350.0	190.	26.1	4.9	79.7	WTR	1.3	4.0	0	45	SD VFG CLN SLTY FT GLD FLU
0.5	15360.0	28.	22.4	2.5	86.0	WTR	0.6	2.6	0	61	SD VFG SSHY VSLTY FT FLU
0.5	15400.0	38.	22.9	4.9	87.3	WTR	1.1	1.8	0	58	SD VFG SSHY VSLTY FT GLD FLU
0.5	15420.0	84.	25.2	1.7	85.5	WTR	0.4	3.2	0	53	SD VFG VSSHY VSLTY FT FLU

2. Sidewall core analyses by Core Laboratories (continued) - Gladys McCall #1

REC IN	DEPTH FEET	PERM MD(*)	POR %	OILZ PORE	WTRZ PORE	PROB PROD	OILZ BULK	GASZ BULK	GAS DET	CRIT WTRZ	DESCRIPTION
0.8	15460.0	40.	23.6	3.3	86.5	WTR	0.8	2.3	0	59	SD VFG SSHY VSLTY FT GLD FLU
0.5	15470.0	31.	23.3	2.2	81.5	WTR	0.5	3.8	0	61	SD VFG SSHY VSLTY FT FLU
0.8	15500.0								0		SHALE
0.5	15520.0	20.	22.8	1.5	87.4	WTR	0.3	2.5	0	64	SD VFG SSHY VSLTY FT FLU
0.0	15540.0										EMPTY BOTTLE
0.5	15550.0	78.	25.3	3.0	82.6	WTR	0.8	3.7	0	54	SD VFG VSSHY VSLTY FT FLU
0.3	15610.0					(3)			0		SD VFG SSHY VSLTY FT FLU
0.0	15620.0										EMPTY BOTTLE
0.3	15660.0					(3)			0		SD VFG SSHY VSLTY FT FLU
0.0	15680.0										EMPTY BOTTLE
0.0	15720.0										EMPTY BOTTLE
0.0	15760.0										EMPTY BOTTLE
0.5	15810.0	35.	23.7	1.7	86.7	WTR	0.4	2.7	0	61	SD VFG SSHY VSLTY FT FLU
0.0	15835.0										EMPTY BOTTLE
0.8	15890.0								0		SHALE CALC
0.8	16020.0								0		SHALE CALC

2. Sidewall core analyses by Core Laboratories (continued) - Gladys McCall #1

REC IN	DEPTH FEET	PERM MD(*)	POR %	OIL% PORE	WTR% PORE	PROB PROD	OIL% BULK	GAS% BULK	GAS DET	CRIT WTR%	DESCRIPTION
0.0	16040.0										EMPTY BOTTLE
0.5	16160.0	48.	24.1	0.0	85.7	WTR	0.0	3.4	0	57	SD VFG SSHY LAM SLTY NO FLU
0.3	16166.0					(3)			0		SD VFG SSHY VSLTY NO FLU
0.0	16185.0										EMPTY BOTTLE
0.5	16215.0	96.	24.5	1.2	91.0	WTR	0.3	1.9	0	50	SD VFG VSSHY CALC FT FLU
0.5	16230.0	415.	27.2	0.0	89.3	WTR	0.0	2.9	0	39	SD VFG CLN SSLTY NO FLU
0.0	16240.0										EMPTY BOTTLE
0.0	16245.0										EMPTY BOTTLE
0.5	16250.0	18.	21.7	0.0	84.6	WTR	0.0	3.3	0	64	SD VFG SSHY VSLTY NO FLU
0.8	16315.0	6.5	17.2	0.0	91.9	(6)	0.0	1.4	0	64	SD VFG SHY LAM V CALC NO FLU
0.0	16350.0										EMPTY BOTTLE
1.0	16455.0								0		SHALE CALC

PLEASE NOTE: GRAVITY OF OIL RETORTED FROM MUDCAKE
@ 14685' = 37 API

(3) INSUFFICIENT SAMPLE

(6) LOW PERMEABILITY

(*) PERMEABILITY VALUES FOR PERCUSSION TYPE SIDEWALL
CORES DETERMINED EMPIRICALLY.

NOTE: CRIT WTR% IS AN ESTIMATE OF THE MAXIMUM WATER EACH SAMPLE COULD CONTAIN IN THE FORMATION IF IT IS HYDROCARBON PRODUCTIVE. IT IS SOLELY DEPENDENT UPON THE PERMEABILITY AND POROSITY AND HAS NO RELATIONSHIP TO THE WATER % PORE MEASURED IN THE SAMPLE. IN PRODUCTIVE ZONES THE WATER SATURATION CALCULATED FROM THE INDUCTION LOG TRUE RESISTIVITY SHOULD BE LESS THAN THE CRITICAL WATER.

APPENDIX - 5

- 1. Core Analysis of Pleasant Bayou No. 1 Well by Core Laboratories**
- 2. Sidewall Core Analysis of Pleasant Bayou No. 1 Well by Core Laboratories**
- 3. Core Analysis of Pleasant Bayou No. 2 Well by Core Laboratories**

(From, Gruy Federal, Inc., 1980)

1. Pleasant Bayou No. 1

Petroleum Reservoir Engineering
DALLAS, TEXAS

GENERAL CRUDE-DEPT. OF ENERGY
PLEASANT BAYOU NO. 1
WILDCAT
BRAZORIA COUNTY, TEXAS

DATE: 7-17-78
FORMATION:
DRLG. FLUID: WATER BASE MJD
LOCATION:

FILE NO: 2202-10173-3
LABORATORY: HOUSTON, TEX.
ANALYSTS: BRAXTON
ELEVATION:

CONVENTIONAL CORE ANALYSIS

SMP NO	DEPTH	PERM MD HORZ (KA)	POR %	OIL% PORE	WTR% PORE	PROB PROD	GAS% BJLK	GRN. DEN.	DESCRIPTION
	4300.0-50.0	CORE NO. 1 CUT 50 FT. REC. 12 FT.							
	4300.0-38.0	LOST CORE							
	4338.0-39.0								
1	4339.0-40.0	456	36.6	0.0	93.0		2.6	2.59	SD F-MG CLN W/SH STKS & VSHY INCLS FOSS LMY N FLU
	4340.0-41.0								SD F-VFG CLN W/SHY INCLS TOP 1/4" VSLTY SHY LMY N FLU
2	4341.0-42.0	305	36.5	0.0	93.2		2.5	2.66	SD F-VFG SSLTY FOSS W/A THIN SH STK LMY N FLU
	4342.0-43.0								SD F-VFG SSLTY FOSS VLMY N FLU
3	4343.0-44.0	315	37.8	0.0	92.7		2.8	2.64	SD F-VFG SSLTY FOSS VLMY N FLU
	4344.0-44.9								SD VFG VSHY VCARB VLMY N FLU
4	4344.9-46.2	<0.1	5.3	0.0	37.7		3.3	2.62	SD VFG DNS VLMY FOSS N FLU
	4346.2-47.0								RETAINED BY CLIENT
	4347.0-48.0								SHALE SSDY VLMY SFOSS
	4348.0-49.4								RETAINED BY CLIENT
5	4349.4-49.8	0.3	25.0	0.0	83.8		4.0	2.60	SD VFG VSLTY VLMY FOSS N FLU
	4349.8-50.0								SHALE RINGTAIL SLTY VLMY
	6700.0-50.0	CORE NO. 2 CUT 50 FT. REC. 9 FT.							
	6700.0-01.5	CRUSHED SHALE & FG SD MUDSHOT II FLU							
	6701.5-03.0								
	6703.0-04.0	SHALE GREY VLMY RINGTAIL W/DMS VFG SD STK N FLU							
	6704.0-05.0	CRUSHED SHALE & MUDSHOT SD N FLU BROKEN SHALE & DNS FG SD VLMY N FLU							

1. Pleasant Bayou No. 1 (continued)

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS

PAGE NO. 2

GENERAL CRUDE-DEPT. OF ENERGY
PLEASANT BAYOU NO. 1

DATE: 7-17-78
FORMATION:

FILE NO: 2202-10173-3
LABORATORY: HOUSTON, TEX.

SMP NO	DEPTH	PERM MD HORZ (KA)	POR %	OIL% PORE	WTR% PORE	PROD PROD	GAS% BULK	GRN. DEN.	DESCRIPTION
6	6705.0-06.0 6706.0-07.0	<0.1	6.6	0.0	69.7		2.0	2.66	SD VFG DNS VLMY N FLU SHALE W/HD DNS VFG SD INCLS VLMY N FLU
7	6707.0-08.0 6708.0-09.0 6709.0-50.0	31	20.0	0.0	82.6		3.5	2.62	SD F-VFG SLTY W/HD DNS KNOTS FOSS VLMY N FLU SHALE W/HD DNS F-VFG SD INCLS FOSS VLMY N FLU LOST CORE
	10215.0-70.0	CORE NO. 3 CUT 55 FT. REC. 53 FT.							
8	10215.0-16.0 10216.0-16.6 10216.6-17.7 10217.7-19.0	<0.1	9.3	0.0	87.5		1.2	2.65	SD VFG VSLTY LMY N FLU SD VFG VSLTY LMY N FLU SHALE RINGTAIL SD VFG SSHY LMY N FLU
9	10219.0-20.0 10220.0-21.0	<0.1	15.4	0.0	83.8		2.5	2.70	SD VFG VSLTY LMY N FLU SD VFG VSLTY SLMY N FLU
10	10221.0-22.0 10222.0-23.0	0.4	18.8	0.0	71.8		5.3	2.69	SD VFG VSLTY W/SML SH INCLS SLMY N FLU SD VFG VSLTY SLMY N FLU
11	10223.0-24.0 10224.0-25.0	0.3	15.4	0.0	71.4		4.4	2.69	SD VFG VSLTY LMY N FLU SD VFG VSLTY LMY N FLU
12	10225.0-26.0 10226.0-27.0	6.1	18.8	0.0	70.2		5.6	2.67	SD VFG VSLTY LMY N FLU SD VFG VSLTY BOT 1/4' SH LMY N FLU
13	10227.0-28.0 10228.0-29.0	<0.1	10.0	0.0	94.0		0.6	2.65	SD VFG-SILT W/SH STKS SLMY N FLU SD VFG-SILT W/SH STKS BOT 1/4' SH SLMY N FLU
	10229.0-30.0 10230.0-48.0 10240.0-49.0								SHALE RINGTAIL TOP 1/2' VSLTY SHALE RINGTAIL OCCASIONAL SILT STKS SD VFG VSLTY W/SH STKS SLMY N FLU
14	10249.0-50.0	<0.1	12.7	0.0	92.0		1.0	2.69	SD VFG VSLTY W/SH STKS BOT 1/4' VSHY N FLU
15	10250.0-51.0 10251.0-52.0	0.1	12.1	0.0	88.6		1.4	2.70	SD VFG VSLTY W/LG SH STKS SLMY N FLU SD VFG VSLTY BOT 1/2' VSHY SLMY N FLU

1. Pleasant Bayou No. 1 (continued)

Petroleum Reservoir Engineering
DALLAS, TEXAS

GENERAL CRUDE-DEPT. OF ENERGY
PLEASANT BAYOU NO. 1

DATE: 7-17-70
FORMATION:

FILE NO: 2202-10 73-3
LABORATORY: HOUSTON, TEX.

SMP NO	DEPTH	PERM MD HORZ (KA)	POR %	OIL% PORE	WTR% PORE	PROD PROD	GAS% BULK	GRN. DEN.	DESCRIPTION
	10252.0-53.0								SD VFG VSLTY VSHY SLMY N FLU
16	10253.0-54.0	0.1	13.1	0.0	81.8		2.4	2.69	SD VFG VSLTY W/SML SH LAMS SLMY N FLU
	10254.0-55.0								SD VFG VSLTY BOT 1/2' SHY SLMY N FLU
17	10255.0-56.0	0.1	9.8	0.0	91.0		0.9	2.71	SD VFG VSLTY SHY SLMY N FLU
	10256.0-57.0								SD VFG VSLTY W/SH STKS SLMY N FLU
18	10257.0-58.0	0.2	20.7	0.0	75.4		5.1	2.67	SD VFG VSLTY SLMY N FLU
	10258.0-59.0								SD VFG VSLTY SLMY N FLU
19	10259.0-60.0	0.4	15.3	0.0	62.2		5.8	2.68	SD VFG VSLTY BOT 1/2' VSHY LMY N FLU
	10260.0-61.0								SD VFG VSLTY VSHY LMY N FLU
20	10261.0-62.0	0.1	17.4	0.0	68.9		5.4	2.68	SD VFG VSLTY SLMY N FLU
	10262.0-63.0								SD VFG VSLTY BOT 1/3' SH SLMY N FLU
21	10263.0-64.0	0.1	17.0	0.0	83.2		2.9	2.70	SD VFG VSLTY SHY STKS SLMY N FLU
	10264.0-65.0								SD VFG VSLTY SLMY N FLU
22	10265.0-66.0	0.1	11.0	0.0	91.3		1.0	2.71	SD VFG VSLTY W/SML SH STKS SLMY N FLU
	10266.0-67.0								SD VFG VSLTY W/SML SH STKS SLMY N FLU
23	10267.0-68.0	<0.1	6.3	0.0	74.5		1.6	2.71	SD VFG VSLTY VLMY N FLU
	10268.0-70.0								LOST CORE
	11732.0-86.0	CORE NO. 4 CUT 54 FT. REC. 54 FT.							
	11732.0-33.0								SD VFG CLN N FLU
24	11733.0-34.0	<0.1	7.3	0.0	47.9		3.8	2.68	SD VFG CLN BOT 1/4' VSLTY VLMY N FLU
	11734.0-35.0								SD VFG VSLTY VLMY N FLU
25	11735.0-36.0	31	21.5	0.0	84.2		3.4	2.66	SD F-VFG CLN N FLU
	11736.0-37.0								SD VFG CLN N FLU
26	11737.0-38.0	1.1	18.3	0.0	85.2		2.7	2.67	SD VFG CLN N FLU
	11738.0-39.0								SD VFG CLN N FLU
27	11739.0-40.0	36	23.9	0.0	88.7		2.4	2.66	SD VFG CLN N FLU
	11740.0-41.0								SD F-VFG CLN N FLU
28	11741.0-42.0	83	23.9	0.0	77.8		5.3	2.66	SD F-VFG CLN N FLU
	11742.0-43.0								SD F-VFG CLN N FLU
29	11743.0-44.0	19	21.8	0.0	81.7		4.0	2.66	SD F-VFG CLN N FLU

1. Pleasant Bayou No. 1 (continued)

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS

PAGE NO. 4

GENERAL CRUDE-DEPT. OF ENERGY
PLEASANT BAYOU NO. 1

DATE: 7-17-78
FORMATION:

FILE NO: 2202-10173-3
LABORATORY: HOUSTON, TEX.

SMP NO	DEPTH	PERM MD HORZ (KA)	POR %	OIL% PORE	WTR% PORE	PROD PROD	GAS% BULK	GRN. DEN.	DESCRIPTION
30	11744.0-45.0								SD F-VFG CLN W/SLTY STKS N FLU
	11745.0-46.0	2.7	20.1	0.0	76.6		4.7	2.67	SD F-VFG CLN W/SLTY STKS N FLU
	11746.0-47.0								SD F-VFG CLN N FLU
31	11747.0-48.0	7.7	21.2	0.0	79.7		4.3	2.66	SD F-VFG CLN N FLU
	11748.0-49.0								SD F-VFG CLN N FLU
32	11749.0-50.0	20	17.4	0.0	83.9		2.8	2.65	SD F-VFG CLN N FLU
	11750.0-51.0								SD F-VFG CLN N FLU
33	11751.0-52.0	17	20.9	0.0	89.5		2.2	2.65	SD F-VFG CLN N FLU
	11752.0-53.0								RINGTAIL SH W/VS LTY STK @ BOT & CLN S
34	11753.0-54.0	40	23.6	0.0	84.7		3.6	2.66	@ TOP N FLU
	11754.0-55.0								SD VFG VSLTY VLMY W/SH STKS N FLU
									SD F-VFG CLN W/SLTY STKS & INCLS SLMY
35	11755.0-56.0	0.1	12.9	0.0	83.7		2.1	2.66	N FLU
	11756.0-57.0								SD F-VFG CLN SLMY N FLU
36	11757.0-58.0	40	19.0	0.0	84.2		3.0	2.64	SD F-VFG CLN SLMY N FLU
	11758.0-59.0								SD F-VFG CLN N FLU
37	11759.0-60.0	36	18.9	0.0	87.3		2.4	2.67	SD F-VFG CLN N FLU
	11760.0-61.0								SD F-VFG CLN 2/3' SH N FLU
38	11761.0-62.0	17	14.4	0.0	73.6		3.8	2.65	SD F-VFG CLN W/FOS @ BOT SHY LMY STKS
	11762.0-63.0								N FLU
									SD F-VFG CLN FOS LMY N FLU
39	11763.0-64.0	12	14.9	0.0	86.6		2.0	2.66	SD FG SSLTY VFOS N FLU
	11764.0-65.0								SD FG SSLTY W/SLTY STKS VSHY @ TOP N
40	11765.0-66.0	0.3	13.4	0.0	83.6		2.2	2.70	FLU
	11766.0-67.0								SD VFG VSLTY VSHY STKD N FLU
									SD VFG VSLTY VSHY STKD 1/6' FG CLN SD
41	11767.0-68.0	60	19.4	0.0	86.1		2.7	2.65	N FLU
	11768.0-69.0								SD FG CLN N FLU
									SD MG CLN VFOS N FLU
42	11769.0-70.0	110	20.1	0.0	89.1		2.2	2.64	SD FG CLN SFOS N FLU
	11770.0-71.0								SD FG CLN N FLU

1. Pleasant Bayou No. 1 (continued)

GENERAL CRUDE-DEPT. OF ENERGY
PLEASANT HAYOU NO. 1

DATE: 7-17-78
FORMATION:

FILE NO: 2202-10173-3
LABORATORY: HOUSTON, TEX.

SMP NO	DEPTH	PERM MD HORZ (KA)	POB %	OIL% PORE	WTR% PORE	PROB PROD	GAS% BULK	GRN. DEN.	DESCRIPTION
43	11771.0-72.0	179	20.6	0.0	87.9		2.5	2.65	SD FG CLN N FLU
	11772.0-73.0								SD FG CLN N FLU
44	11773.0-74.0	0.1	0.1	0.0	66.7		2.7	2.67	SD FG W/SH STKS VLMY TOP 1/4' CLN II FL
	11774.0-75.0								SD FG W/SH STKS VLMY BOT 1/3' CLN II FL
45	11775.0-76.0	22	16.8	0.0	86.9		2.2	2.64	SD F-VFG CLN N FLU
	11776.0-77.0								SD F-VFG CLN BOT 1/2' FG VLMY N FLU
46	11777.0-78.0	0.7	17.4	0.0	73.0		4.7	2.66	SD F-VFG CLN N FLU
	11778.0-79.0								SD VFG SSLTY LMY N FLU
47	11779.0-80.0	0.1	14.9	0.0	62.4		5.6	2.68	SD VFG SSLTY LMY N FLU
	11780.0-81.0								SD VFG SLTY SHY N FLU
48	11781.0-82.0	<0.1	13.0	0.0	84.6		2.0	2.71	SD VFG SLTY SHY INCLS N FLU
	11782.0-83.0								SD VFG SLTY N FLU
49	11783.0-84.0	<0.1	12.7	0.0	85.0		1.9	2.68	SD VFG SLTY SHY STKS N FLU
	11784.0-85.0								SD F-VFG CLN N FLU
50	11785.0-86.0	0.3	15.9	0.0	84.9		2.4	2.67	SD F-VFG SLTY VSHY STKS N FLU
12580.0-12634.0 CORE NO. 5 CUT 54 FT. REC. 52 FT.									
12580.0-83.5									
12583.5-32.0									
12632.0-34.0									
14053.0-14106.0 CORE NO. 6 CUT 53 FT. REC. 53 FT.									
51	14053.0-54.0	0.3	18.2	0.0	85.7		2.6	2.68	SD VFG VSLTY W/SH STKS N FLU
	14054.0-55.0								SD VFG VSLTY N FLU
52	14055.0-56.0	0.4	19.0	0.0	61.6		7.3	2.68	SD VFG VSLTY W/SH STKS N FLU
	14056.0-57.0								SD VFG VSLTY N FLU
53	14057.0-58.0	13	23.3	0.0	83.7		3.8	2.66	SD VFG VSLTY N FLU
	14058.0-59.0								SD VFG VSLTY N FLU
54	14059.0-60.0	6.0	20.9	0.0	75.6		5.1	2.66	SD VFG VSLTY N FLU
	14060.0-61.0								SD VFG VSLTY N FLU

SHALE W/LG VSLTY STKS
SHALE RINGTAIL W/OCCASIONAL VSLTY STKS
LOST CORE

1. Pleasant Bayou No. 1 (continued)

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS

GENERAL CRUDE-DEPT. OF ENERGY
PLEASANT BAYOU NO. 1

DATE: 7-17-78
FORMATION:

FILE NO: 2202-10173-3
LABORATORY: HOUSTON, TEX.

SMP NO	DEPTH	PERM MD HORZ (KA)	POR %	OIL% PORE	WTR% PORE	PROD PROD	GAS% BULK	GRN. DEN.	DESCRIPTION
55	14061.0-62.0	17	20.3	0.0	91.6		1.7	2.66	SD VFG VSLTY N FLU
	14062.0-63.5								SHALE SLTY W/SDY STKS N FLU
	14063.5-80.5								SHALE RINGTAIL
56	14080.5-81.0	0.3	8.1	0.0	76.5		1.9	2.65	SD VFG DNS N FLU
	14081.0-82.0								SD VFG DNS N FLU
57	14082.0-83.0	5.4	15.7	0.0	63.7		5.7	2.65	SD VFG DNS W/SH STKS N FLU
	14083.0-84.0								SD VFG CARB INCL VSLTY N FLU
58	14084.0-85.0	<0.1	11.7	0.0	88.0		1.4	2.70	SD VFG CARB INCL VSLTY N FLU
	14085.0-86.0								SD VFG CARB INCL VSLTY N FLU
59	14086.0-87.0	<0.1	10.3	0.0	72.8		2.8	2.70	SD VFG CARB INCL VSLTY N FLU
	14087.0-88.0								SD VFG SML CARB INCL VSLTY N FLU
60	14088.0-89.0	0.1	13.8	0.0	89.8		1.4	2.68	SD VFG SML CARB INCL VSLTY N FLU
	14089.0-90.0								SD VFG SSLTY (SWIRLS) VSLTY N FLU
61	14090.0-91.0	0.1	17.7	0.0	86.4		2.4	2.69	SD VFG SSLTY (SWIRLS) VSLTY N FLU
	14091.0-92.0								SD VFG SSLTY STKS VSLTY N FLU
62	14092.0-93.0	0.1	14.6	0.0	85.6		2.1	2.69	SD VFG SHY STKS VSLTY N FLU
	14093.0-94.0								SD VFG SHY STKS VSLTY N FLU
63	14094.0-95.0	0.1	13.0	0.0	80.4		2.6	2.68	SD VFG SHY STKD VSLTY N FLU
	14095.0-96.0								SD VFG VSLTY N FLU
64	14096.0-97.0	0.1	18.0	0.0	92.2		1.4	2.69	SD VFG VSLTY N FLU
	14097.0-98.0								SD VFG VSLTY N FLU
65	14098.0-99.0	<0.1	17.6	0.0	89.8		1.8	2.69	SD VFG VSLTY N FLU
	14099.0-00.0								SD VFG VSLTY N FLU
66	14100.0-01.0	<0.1	17.7	0.0	87.6		2.2	2.69	SD VFG SSHY STKS VSLTY N FLU
	14101.0-02.0								SD VFG SSHY STKS VSLTY N FLU
67	14102.0-03.0	0.1	15.2	0.0	88.2		1.8	2.69	SD VFG SSHY STKS VSLTY N FLU
	14103.0-04.0								SD VFG SSHY STK VSLTY BOT 1/2' SH H FL
68	14104.0-05.0	1.2	15.3	0.0	68.6		4.8	2.65	SD VFG VSLTY N FLU
	14105.0-06.0								SD VFG VSLTY N FLU

14747.0-83.0 CORE NO. 7 CUT 36 FT. REC. 20.5

1. Pleasant Bayou No. 1 (continued)

GENERAL CRUDE-DEPT. OF ENERGY
PLEASANT BAYOU NO. 1

DATE: 7-17-78
FORMATION:

FILE NO: 2202-10173-3
LABORATORY: HOUSTON, TEX.

SMP NO	DEPTH	PERM MD HORZ (KA)	POR %	OIL% PORE	WTR% PORE	PROD PROD	GAS% BULK	GRN. DEN.	DESCRIPTION
69	14747.0-48.0	96	16.5	0.0	46.7		8.8	2.67	SD F-MG SSLTY N FLU
	14748.0-49.0								SD F-MG SSLTY N FLU
70	14749.0-50.0	114	19.1	0.0	50.8		9.4	2.66	SD F-MG SHY STKS N FLU
	14750.0-51.0								SD F-MG SHY STKS N FLU
71	14751.0-52.0	107	17.9	0.0	52.5		8.5	2.66	SD FG SSLTY N FLU
	14752.0-53.0								SD FG SSLTY N FLU
72	14753.0-54.0	332	20.3	0.0	45.8		11.0	2.66	SD FG SSLTY N FLU
	14754.0-55.0								SD F-MG SSLTY SH INCLS N FLU
73	14755.0-56.0	0.8	11.6	0.0	75.0		2.9	2.70	SD VFG VSLTY W/LG SH STKS & INCLS N FL
	14756.0-57.0								SD VFG VSLTY W/MNY SH STKS SLICKENSIDE N FLU
74	14757.0-58.0	8.2	17.8	0.0	53.4		8.3	2.69	SD FG VSLTY W/SML SH INCLS LMY N FLU
	14758.0-59.0								SD F-MG SSLTY N FLU
75	14759.0-60.0	1041	21.6	0.0	54.2		9.9	2.65	SD F-MG SSHY STK N FLU
	14760.0-61.0								SD F-MG SSLTY N FLU
76	14761.0-62.0	701	20.7	0.0	38.6		12.7	2.66	SD MG SSLTY N FLU
	14762.0-63.0								SD FG SSLTY N FLU
77	14763.0-64.0	134	17.0	0.0	42.9		9.7	2.67	SD F-MG SSHY STKS N FLU
	14764.0-65.0								SD F-MG SSLTY N FLU
78	14765.0-66.0	129	18.3	0.0	48.6		9.4	2.67	SD F-MG SSHY STKS BOT 1/4' F-VFG VSHY STKS N FLU
	14766.0-67.0								SD F-MG SSLTY N FLU
79	14767.0-67.5	266	18.9	0.0	63.5		6.9	2.66	SD F-MG SSHY STKS N FLU
	14767.5-68.0								LOST CORE
	15147.0-87.0	CORE NO. 8 CUT 40 FT. REC. 40 FT.							
80	15147.0-48.0	<0.1	0.8	0.0	25.0		0.6	2.60	SD VFG DNS 1/2' VSHY N FLU
	15148.0-49.0								SD VFG SHY LAM N FLU
81	15149.0-49.5	0.4	7.8	0.0	89.7		0.8	2.65	SD VFG SHY LAM SLTY N FLU
	15149.5-51.0								SHALE N FLU
	15151.0-54.0								SHALE W/SD STKS N FLU

1. Pleasant Bayou No. 1 (continued)

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS

PAGE NO. 8

GENERAL CRUDE-DEPT. OF ENERGY
PLEASANT BAYOU NO. 1

DATE: 7-17-78
FORMATION:

FILE NO: 2202-10173-3
LABORATORY: HOUSTON, TEX.

SMP NO.	DEPTH	PERM MD HORZ (KA)	POR %	OIL% PORE	WTR% PORE	PROD PROD	GAS% BULK	GRN. DEN.	DESCRIPTION
02	15154.0-55.0	<0.1	5.4	0.0	87.0		0.7	2.67	SD FG VSHY STKD SLTY N FLU
	15155.0-58.0								SHALE W/SD STKS N FLU
03	15158.0-58.5	0.1	6.6	0.0	89.4		0.7	2.70	SD FG SHY STKD N FLU
	15158.5-59.0								SHALE N FLU
	15159.0-60.0								SD FG VSHY STKD N FLU
04	15160.0-61.0	<0.1	3.0	0.0	63.3		1.1	2.66	SD FG SHY STKD SLMY N FLU
	15161.0-62.0								SD FG SSHY STKD SLMY N FLU
05	15162.0-62.5	<0.1	2.6	0.0	73.1		0.7	2.65	SD FG SSHY STKS SLMY N FLU
	15162.5-65.0								SHALE W/SD STKS N FLU
06	15165.0-65.5	<0.1	2.3	0.0	65.2		0.8	2.60	SD FG SSHY STKS SLMY N FLU
	15165.5-67.0								SHALE W/SD STKS N FLU
07	15167.0-68.0	0.4	7.8	0.0	87.2		1.0	2.69	SD FG VSHY STKD SLMY N FLU
	15168.0-69.0								SD FG VSHY STKD SLMY N FLU
08	15169.0-69.5	<0.1	7.5	0.0	73.3		2.0	2.69	SD FG SSHY N FLU
	15169.5-71.0								SD FG VSHY STKD N FLU
09	15171.0-72.0	0.1	5.8	0.0	58.6		2.4	2.65	SD FG LMY N FLU
	15172.0-73.0								SD FG SSHY STKD LMY N FLU
90	15173.0-74.0	0.1	8.0	0.0	40.0		4.8	2.66	SD FG LMY N FLU
	15174.0-75.0								SD FG LMY LG SH STK N FLU
91	15175.0-76.0	0.3	9.9	0.0	51.0		4.8	2.67	SD FG LMY LG SH STK N FLU
	15176.0-77.0								SD FG LMY N FLU
92	15177.0-78.0	0.4	13.1	0.0	48.1		6.8	2.68	SD FG SML SH INCLS N FLU
	15178.0-79.0								SD FG SML SH INCLS SLMY N FLU
93	15179.0-80.0	0.2	13.7	0.0	45.3		7.5	2.68	SD FG SLMY N FLU
	15180.0-81.0								SD FG SLMY N FLU
94	15181.0-82.0	0.1	8.3	0.0	31.3		5.7	2.67	SD FG SLMY N FLU
	15182.0-83.0								SD FG SLMY N FLU
95	15183.0-84.0	0.4	17.5	0.0	44.6		9.7	2.69	SD FG SLMY N FLU
	15184.0-85.0								SD FG SLMY N FLU
96	15185.0-86.0	0.4	15.8	0.0	46.8		8.4	2.67	SD FG SLMY N FLU
	15186.0-87.0								SD FG SLMY N FLU

FEV2VF

15543.0-93.5 CORE NO. 9 CUT 50 FT. REC. 37.5

1. Pleasant Bayou No. 1 (continued)

GENERAL CRUDE-DEPT. OF ENERGY
PLEASANT BAYOU NO. 1

DATE: 7-17-78
FORMATION:

FILE NO: 2202-10173-3
LABORATORY: HOUSTON, TEX.

SMP NO	DEPTH	PERM MD HORZ (KA)	POR %	OIL% PORE	WTR% PORE	PROD PROD	GAS% BULK	GRN. DEN.	DESCRIPTION
97	15543.0-44.0	<0.1	7.7	0.0	77.9		1.7	2.66	SD FG SSLTY DNS DOT 1/2' SH LAMS N FLU
	15544.0-45.0								SD VFG DNS VSHY LAMS N FLU
98	15545.0-46.0	<0.1	7.1	0.0	84.5		1.1	2.65	SD VFG DNS VSHY W/SH INCLS N FLU
	15546.0-47.0								SD VFG DNS VSHY W/SH INCLS N FLU
99	15547.0-48.0	<0.1	8.9	0.0	73.0		2.4	2.65	SD VFG DNS SLTY W/SH LAMS N FLU
	15548.0-49.0								SD VFG SLTY DNS N FLU
100	15549.0-50.0	<0.1	6.5	0.0	69.2		2.0	2.67	SD VFG SLTY DNS N FLU
	15550.0-51.0								SD VFG SLTY DNS W/SHY STKS N FLU
101	15551.0-52.0	<0.1	6.9	0.0	81.2		1.3	2.68	SD VFG DNS SHY W/SH LAMS N FLU
	15552.0-53.0								SD VFG DNS SHY W/SH LAMS N FLU
102	15553.0-54.0	<0.1	6.6	0.0	63.6		2.4	2.63	SD VFG DNS SLTY N FLU
	15554.0-55.0								SD VFG DNS SLTY N FLU
103	15555.0-56.0	<0.1	6.5	0.0	76.9		1.5	2.63	SD VFG DNS SLTY N FLU
	15556.0-57.0								SD VFG DNS VSHY W/SH LAMS N FLU
	15557.0-58.5								SHALE
	15558.5-62.5								SHALE VSLTY
104	15562.5-63.0	<0.1	8.7	0.0	81.6		1.8	2.66	SD VFG VSLTY DNS N FLU
	15563.0-76.0								LOST CORE
105	15576.0-77.0	0.1	17.0	0.0	21.2		13.4	2.67	SD VFG SLTY N FLU
	15577.0-78.0								SD VFG SLTY N FLU
106	15578.0-79.0	0.4	17.9	0.0	24.0		13.6	2.65	SD VFG SLTY N FLU
	15579.0-80.0								SD VFG SLTY N FLU
107	15580.0-81.0	<0.1	12.4	0.0	25.8		9.2	2.66	SD VFG SLTY N FLU
	15581.0-82.0								SD VFG SLTY DOT 2/3' SH N FLU
108	15582.0-83.0	<0.1	14.0	0.0	84.3		2.2	2.66	SD VFG SLTY N FLU
	15583.0-84.0								SHALE
109	15584.0-85.0	<0.1	6.1	0.0	70.5		1.8	2.73	SD VFG VSHY N FLU
	15585.0-86.0								SD VFG SLTY N FLU
110	15586.0-87.0	<0.1	12.5	0.0	84.8		1.9	2.67	SD VFG SLTY N FLU
	15587.0-88.0								SD VFG SLTY N FLU
111	15588.0-89.0	0.4	16.8	0.0	24.4		12.7	2.67	SD VFG SLTY N FLU
	15589.0-90.0								SD VFG SLTY N FLU
112	15590.0-91.0	<0.1	2.6	0.0	53.8		1.2	2.63	SD VFG SLTY DNS N FLU
	15591.0-92.0								SD VFG VSHY W/SLTY INCLS N FLU
113	15592.0-93.0	<0.1	5.2	0.0	71.2		1.5	2.66	SD VFG VSLTY W/SH INCLS N FLU
	15593.0-93.5								SD VFG SLTY TOP SH N FLU

These analyses, opinions or interpretations are based on observations and materials supplied by the client to whom, and for whose exclusive and confidential use, this report is made. The interpretations or opinions expressed represent the best judgment of Core Laboratories, Inc. (all errors and omissions excepted); but Core Laboratories, Inc. and its officers and employees, assume no responsibility and make no warranty or representations, as to the productivity, proper operations, or profitability of any oil, gas or other mineral well or sand in connection with which such report is used or relied upon.

2. Pleasant Bayou No. 1 (Sidewall Core Analysis)

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS

GENERAL CRUDE-DEPT. OF ENERGY
PLEASANT BAYOU NO. 1
WILDCAT
URAZORIA COUNTY, TEXAS

DATE: 7-29-78
FORMATION:
DRLG. FLUID: WATER BASE MUD

FILE NO: 2202-10173-3
ANALYSTS: WELLS
LABORATORY: HOUSTON
CORES:

SIDE WALL CORE ANALYSIS

REC IN	DEPTH FEET	PERM MD(*)	POR %	OIL% PORE	WTR% PORE	PROD PROD	OIL% BULK	GAS% BULK	GAS DET	CRIT WTR%	DESCRIPTION
1.1	2045.0	1950	33.3	0.0	81.3	WTR	0.0	6.2	TR	37	SD FG SSLTY VLMY N FLU
	2185.0										SHALE VLMY N FLU
0.7	2280.0	300	36.0	0.0	89.3	WTR	0.0	3.8	TR	47	SD FG SLTY VLMY N FLU
	2335.0										SHALE VLMY
0.8	2435.0	235	35.8	0.0	84.1	WTR	0.0	5.7	0	49	SD FG SLTY VLMY N FLU
1.5	2795.0	245	34.7	0.0	79.8	WTR	0.0	7.1	0	49	SD FG SLTY VLMY N FLU
	2820.0					(3)					MUDCAKE W/TR FG SLTY SD
0.9	2875.0	5.0	24.5	0.0	87.2	(6)	0.0	3.2	0	75	SD FG VSLTY VLMY N FLU
	2915.0										MUDCAKE
1.1	3066.0	4.8	20.0	0.0	81.1	(6)	0.0	3.8	0	71	SD FG VSLTY VLMY N FLU
	3159.0										MUDCAKE
0.8	3160.0	5.6	22.7	0.0	82.2	(6)	0.0	4.0	0	73	SD FG VSHY VLMY N FLU
0.7	3173.0	335	36.5	0.0	83.2	WTR	0.0	5.1	0	46	SD FG SHY VLMY N FLU
1.1	3318.0	1250	32.1	0.0	80.8	WTR	0.0	4.9	0	37	SD FG SSHY VLMY N FLU
1.5	3770.0	135	30.8	0.0	87.0	WTR	0.0	4.0	0	53	SD F-VFG SHY VLMY N FLU

These analyses, opinions or interpretations are based on observations and materials supplied by the client to whom, and for whose exclusive and confidential use, this report is made. The interpretations or opinions expressed represent the best judgment of Core Laboratories, Inc. (all errors and omissions excepted); but Core Laboratories, Inc. and its officers and employees, assume no responsibility and make no warranty or representations, as to the productivity, proper operation, or profitability of any oil, gas or other mineral well or sand in connection with which such report is used or relied upon.

2. Pleasant Bayou No. 1 (Continued)

GENERAL CRUDE-DEPT. OF ENERGY
PLEASANT BAYOU NO. 1

DATE: 7-29-78
FORMATION:

FILE NO: 2202-10173-3
ANALYSTS: WELLS

REC IN.	DEPTH FEET	PERM MD(*)	POR %	OIL% PORE	WTR% PORE	PROB PROD	OIL% BULK	GAS% BULK	GAS DET	CRIT WTR%	DESCRIPTION
1.3	3860.0								0		SHALE VLMY
	4232.0										NO RECOVERY
1.2	4325.0	185	31.0	0.0	88.9	WTR	0.0	3.4	0	49	SD F-VFG SLTY W/LG VFOS SHY STKS N FLU
0.8	4340.0	33	30.4	0.0	88.4	WTR	0.0	3.5	TR	67	SD VFG VSLTY VLMY N FLU
1.2	4568.0	19	28.3	0.0	82.3	WTR	0.0	5.0	0	70	SD VFG VSLTY VLMY N FLU
1.5	4571.0	5.1	25.2	0.0	79.8	(6)	0.0	5.1	0	75	SD VFG VSHY VLMY N FLU
0.4	4574.0	30	28.4	0.0	84.8	WTR	0.0	4.3	0	66	SD VFG VSHY VLMY N FLU
1.0	4582.0	185	31.2	0.0	84.2	WTR	0.0	4.9	0	49	SD F-VFG SLTY VLMY N FLU
0.6	4697.0								0		MUDCAKE
1.0	4708.0					(1)	0.0		0		SD FG CLN CARB N FLU
1.5	5410.0	145	32.0	0.0	89.8	WTR	0.0	3.3	0	53	SD FG SHY SLMY N FLU
0.7	5825.0								0		MUDCAKE
1.6	5985.0	9.8	21.5	0.0	75.8	(6)	0.0	5.2	0	69	SD MG VSHY STKD FOS VLMY N FLU
0.4	6100.0	4.4	23.8	0.0	87.8	(6)	0.0	2.9	0	74	SD VFG VSHY VLMY N FLU
0.6	6513.0	28	25.6	0.0	79.6	WTR	0.0	5.2	0	65	SD VFG SLTY LMY N FLU
1.5	717800.0								1		SHALE VLMY
1.4	8100.0								0		SHALE VLMY
1.1	8400.0								0		SHALE VLMY

(1) ALTERED CORE

(3) INSUFFICIENT SAMPLE

(6) LOW PERMEABILITY

CRIT WTR% = CRITICAL WATER SATURATION

(SEE ATTACHED EXPLANATION)

(*) PERMEABILITY VALUES FOR PERCUSSION TYPE SIDEWALL
CORES DETERMINED EMPIRICALLY.

These analyses, opinions or interpretations are based on observations and materials supplied by the client to whom, and for whose exclusive and confidential use, this report is made. The interpretations or opinions expressed represent the best judgment of Core Laboratories, Inc. (all errors and omissions excepted); but Core Laboratories, Inc. and its officers and employees, assume no responsibility and make no warranty or representations, as to the productivity, proper operations, or profitability of any oil, gas or other mineral well or sand in connection with which such report is used or relied upon.

3. Pleasant Bayou No. 2

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS

GENERAL CRUDE OIL CO. - D.O.E.
PLEASANT BAYOU NO. 2
WILDCAT
BRAZORIA COUNTY, TEXAS

DATE : 10-MAY-79
FORMATION : FRIO
DRLG. FLUID: WATER BASE MUD
LOCATION :

FILE NO : 2202-10763
LABORATORY: HOUSTON
ANALYSTS : MEHALL
ELEVATION :

CONVENTIONAL CORE ANALYSIS

SMP NO	DEPTH	PERM MD HORZ(KA)	POR %	OIL% PORE	WTR% PORE	PROD PROD	GAS% BULK	GRAIN DEN(M)	DESCRIPTION
CORE NO. 1 14666.0-14716.0 CUT 50 FT REC. 32 FT									
	14666.0-84.0								LOST CORE
	14684.0-85.0								SD VF-CG W/PEBS VLMY MIN FLU
1	14685.0-86.0	0.07	2.5	0.0	56.0		1.1	2.66	SD VF-CG W/PEBS VLMY MIN FLU
	14686.0-87.0								SD VF-CG W/PEBS VLMY MIN FLU
2	14687.0-88.0	19.	14.7	0.0	61.9		5.6	2.65	SD VF-MG W/SH MICA SH LAM LMY SPTY MIN FLU
	14688.0-89.0								SD VF-MG SLMY N FLU
3	14689.0-90.0	105.	20.6	0.0	84.0		3.3	2.64	SD VF-MG SLMY N FLU
	14690.0-91.0								SD VF-MG SLMY N FLU
4	14691.0-92.0	124.	18.1	0.0	76.8		4.2	2.64	SD VF-MG SM SLTY SH LAM SLMY N FLU
	14692.0-93.0								SD VF-MG SLTY SH LAM N FLU
5	14693.0-94.0	15.	14.7	0.0	68.7		4.6	2.64	SD VF-MG SM SLTY SH LAM N FLU
	14694.0-95.0								SD VF-MG N FLU
6	14695.0-96.0	38.	15.5	0.0	71.6		4.4	2.65	SD VF-MG FEW SM SH INCLS SLMY N FLU
	14696.0-97.0								SD VF-MG N FLU
7	14697.0-98.0	120.	16.2	0.0	77.2		3.7	2.64	SD VF-MG N FLU
	14698.0-99.0								SD VF-MG N FLU
8	14699.0-00.0	397.	17.6	0.0	72.7		4.8	2.64	SD VF-MG N FLU
	14700.0-01.0								SD VF-MG N FLU
9	14701.0-02.0	230.	19.6	0.0	85.2		3.1	2.64	SD VF-MG N FLU
	14702.0-03.0								SD VF-MG N FLU
10	14703.0-04.0	3.29	12.0	0.0	68.3		3.8	2.65	SD VF-MG SM SH LAMS SLTY SLMY N FLU
	14704.0-05.0								SD VF-MG N FLU
11	14705.0-06.0	275.	19.4	0.0	79.4		4.0	2.64	SD VF-MG TOP 6" SLTY W/SH SH LAM
	14706.0-07.0								SD VF-MG N FLU
12	14707.0-08.0	185.	17.6	0.0	75.6		4.3	2.64	SD VF-MG SM SH LAM N FLU
	14708.0-09.0								SD VF-MG N FLU
13	14709.0-10.0	475.	20.9	0.0	84.7		3.2	2.64	SD VF-MG N FLU
	14710.0-11.0								SD VF-MG N FLU
14	14711.0-12.0	140.	17.5	0.0	85.1		2.6	2.64	SD F-VFG SSGHY STKS SLMY N FLU
	14712.0-13.0								SD VF-MG N FLU
15	14713.0-14.0	466.	19.6	0.0	73.5		5.2	2.63	SD VF-MG N FLU
	14714.0-15.0								SD VF-MG N FLU
16	14715.0-16.0	515.	20.5	0.0	81.0		3.9	2.64	SD VF-MG N FLU

3. Pleasant Bayou No. 2 (Continued)

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS

GENERAL CRUDE OIL CO. - D.O.E.
PLEASANT BAYOU NO. 2
WILDCAT
BRAZORIA COUNTY, TEXAS

DATE : 10-MAY-79
FORMATION : FRIO
DRLG. FLUID: WATER BASE MUD
LOCATION :

FILE NO : 2202-10763-4
LABORATORY: HOUSTON
ANALYSTS : MEHALL
ELEVATION :

CONVENTIONAL CORE ANALYSIS

SMP NO	DEPTH	PERM MD HORZ(KA)	POR %	OIL% PORE	WTR% PORE	PROD PROD	GAS% BULK	GRAIN DEN(M)	DESCRIPTION
CORE NO. 2 15615.0-15664.0 CUT 48 FT REC 49 FT									
17	15615.0-16.0	200.	22.9	0.0	84.7		3.5	2.65	SD VF-CG SLTY W/PEBS MIN FLU
	15616.0-17.0								SD VF-CG SLTY W/PEBS MIN FLU
18	15617.0-18.0	72.	13.6	0.0	50.7		6.7	2.65	SD VF-MG SLTY MIN FLU
	15618.0-19.0								SD VF-MG SLTY MIN FLU
19	15619.0-20.5	14.	21.0	0.0	49.0		10.7	2.64	SD VF-MG SLTY MIN FLU
	15620.5-31.0								SHALE LIG
20	15631.0-32.0	0.02	11.0	0.0	35.5		7.1	2.64	SD F-VFG VSLTY W/CARB STKS MIN FLU
	15632.0-33.0								SD F-VFG VSLTY W/CARB STKS MIN FLU
21	15633.0-34.0	0.05	12.0	0.0	30.0		8.4	2.65	SD VF-MG VSLTY W/CARB STKS MIN FLU
	15634.0-35.0								SD VF-MG VSLTY W/CARB STKS MIN FLU
22	15635.0-36.0	0.02	15.7	0.0	58.6		6.5	2.65	SD VF-MG VSLTY W/CARB STKS MIN FLU
	15636.0-37.0								SD VF-MG VSLTY W/CARB STKS MIN FLU
23	15637.0-38.0	0.44	11.8	0.0	38.1		7.3	2.64	SD VF-MG VSLTY W/CARB STKS MIN FLU
	15638.0-39.0								SD VF-MG VSLTY W/CARB STKS MIN FLU
24	15639.0-40.0	0.56	12.5	0.0	40.8		7.6	2.64	SD VF-MG VSLTY MIN FLU
	15640.0-41.0								SD VF-MG VSLTY MIN FLU
25	15641.0-42.0	0.44	11.8	0.0	38.9		7.2	2.65	SD VF-MG VSLTY MIN FLU
	15642.0-43.0								SD VF-MG VSLTY MIN FLU
26	15643.0-44.0	0.36	11.8	0.0	43.2		6.7	2.65	SD VF-MG VSLTY W/SH LAMS MIN FLU
	15644.0-45.0								SD VF-MG VSLTY W/SH LAMS MIN FLU
27	15645.0-46.0	0.32	9.6	0.0	26.0		7.1	2.64	SD VF-MG VSLTY MIN FLU
	15646.0-47.0								SD VF-MG VSLTY MIN FLU
28	15647.0-48.0	0.49	10.1	0.0	21.8		8.3	2.64	SD VF-MG VSLTY MIN FLU
	15648.0-49.0								SD VF-MG VSLTY MIN FLU
29	15649.0-50.0	0.78	10.4	0.0	41.3		6.7	2.64	SD VF-MG VSLTY MIN FLU

3. Pleasant Bayou No. 2 (Continued)

GENERAL CRUDE OIL CO. - D.O.E.
PLEASANT BAYOU NO. 2

DATE : 10-MAY-79
FORMATION : FRIO

FILE NO : 2202-10763-4
LABORATORY: HOUSTON

CONVENTIONAL CORE ANALYSIS

ANALYST: MEHALL

SMP NO	DEPTH	PERM MD HORZ(KA)	POR %	OIL% PORE	WTR% PORE	PROD PROD	GAS% BULK	GRAIN DEN(M)	DESCRIPTION
30	15650.0-51.0								SD VF-MG VSLTY MIN FLU
	15651.0-52.0	0.16	8.7	0.0	27.6		6.3	2.64	SD F-MG VSLTY SLMY MIN FLU
	15652.0-53.0								SD F-MG VSLTY MIN FLU
31	15653.0-53.5	0.34	9.8	0.0	26.5		7.2	2.66	SD VF-MG VSLTY MIN FLU
	15653.5-54.8								SD F-VFG VSHY MIN FLU
32	15654.8-56.0	0.25	11.0	0.0	14.5		9.4	2.64	SD VF-MG SSLTY MIN FLU
	15656.0-57.0								SD VFG VSHY MIN FLU
33	15657.0-58.0	0.13	8.5	0.0	81.2		1.6	2.69	SD VFG VSLTY VSHY MIN FLU
	15658.0-59.0								SD VFG VSLTY VSHY MIN FLU
34	15659.0-60.0	0.12	8.7	0.0	81.6		1.6	2.69	SD VFG VSLTY W/SH LAMS MIN FLU
	15660.0-61.0								SD VFG VSLTY W/SH LAMS MIN FLU
35	15661.0-62.0	0.52	11.6	0.0	44.8		6.4	2.64	SD VF-MG VSLTY VFT FLU
	15662.0-63.0								SD VF-MG VSLTY MIN FLU
36	15663.0-64.0	43.	10.5	0.0	78.1		2.3	2.64	SD VF-CG SLTY SLHY MIN FLU
CORE NO. 3 15664.0-15675.0 CUT 11 FT REC. 11 FT									
	15664.0-65.0								SD VF-CG SLTY SLHY MIN FLU
37	15665.0-66.0	169.	19.5	0.0	92.3		1.5	2.64	SD VF-CG SLTY SLHY MIN FLU
	15666.0-67.0								SD VF-CG SLTY SLHY MIN FLU
38	15667.0-68.0	729.	19.4	0.0	92.3		1.5	2.64	SD VF-CG SLTY SLHY MIN FLU
	15668.0-69.0								SD VF-CG SLTY SLHY MIN FLU
39	15669.0-70.0	3.87	9.0	0.0	34.4		5.9	2.64	SD F-VFG VSLTY VLHY MIN FLU
	15670.0-71.0								SD VFG VSHY STKD MIN FLU
	15671.0-75.0								SHALE

(M) = MEASURED

DISTRIBUTION OF FINAL REPORTS

15 15664.0-75.0
15668.0-75.0
15671.0-75.0
COPIES TO:

2 CC GENERAL CRUDE OIL CO.
2700 ONE ALLEN CENTER
P. O. BOX 2252
HOUSTON, TEXAS 77001
ATTN: MR. CHARLES JONES

2 CC GENERAL CRUDE OIL COMPANY
27TH FLOOR
ONE ALLEN CENTER
HOUSTON, TEXAS 77001
ATTN: MR. CLIFF DYE

2 CC UNIV. OF TEXAS AT AUSTIN
BUREAU OF ECONOMIC GEOLOGY
P. O. BOX X
AUSTIN, TEXAS 78712
ATTN: DR. D. G. DEBOUT