Geopressured Geothermal Well Tests: A Review

Sabodh K. Garg

Science Applications International Corporation (SAIC)

San Diego, California

June 12, 2007

Geopressured-Geothermal Energy Resource Base

- Wallace, Kremer, Taylor and Wesselman, USGS Circular 790, 1979.
- Thermal energy contained in sedimentary rocks (northern Gulf of Mexico Basin): 107,000 10^{18} Joules

  (1 quad = 10^{18} Joules)

  Recoverable thermal energy: (270-2800) 10^{18} Joules

  Electric capacity: (23,000-240,000) MW for 30 years
- Methane dissolved in pore fluids: 59,000 10^{12} Scf (1670 10^{12} m^3)

  Energy equivalent of recoverable methane: (158-1640) 10^{18} Joules

DOE Geopressured-Geothermal well testing program (1)

- From FY1976 to FY1993, DOE sponsored a Geopressured Geothermal well testing program in order to determine the potential of this resource for commercial exploitation.
- Total program costs were over $195 million dollars (current dollars). The budget peaked at $36 M in FY1980.

- Program Summary Report

  C.J. John, G. Maciasz, B.J. Harder (1998), Gulf Coast Geopressured-Geothermal Program Summary Report Compilation

DOE Geopressured-Geothermal well testing program (2)

- Wells of Opportunity

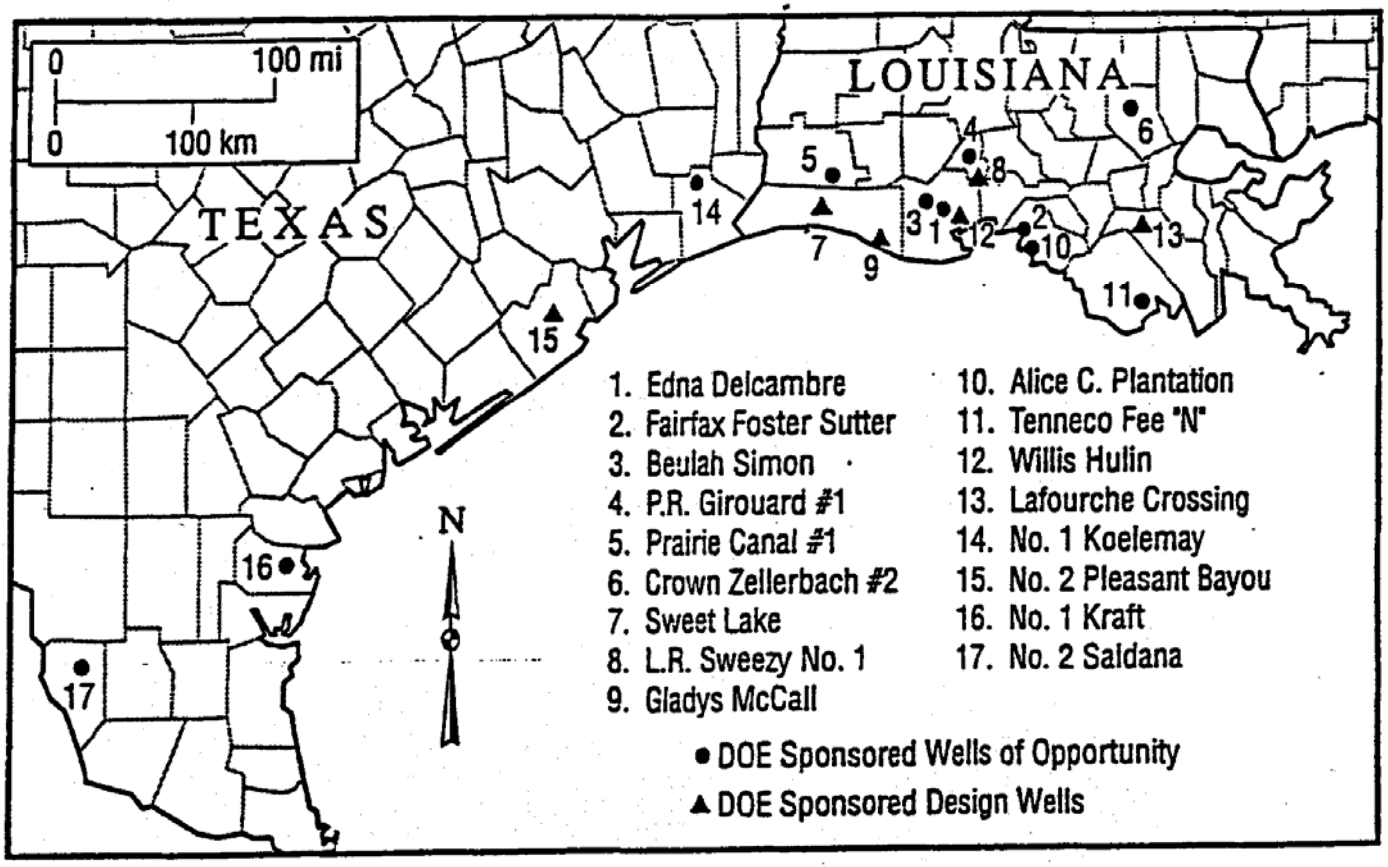
  Short term (less than one month) tests of abandoned or uneconomic oil & gas wells designed to determine fluid characteristics and reservoir parameters.

- Design Wells

  Long term (years?) tests of wells drilled on potentially large volume (> 1 cubic mile) high temperature (> 275 ^{o}F) geopressure prospects

  Ref: Keith Westhusing (1981), Department of Energy Geopressured Geothermal Program, Fifth Conference Geopressured-Geothermal Energy, Baton Rouge, LA

Wells of Opportunity (Figure from John et al., 1998)



Wells of Opportunity – Results (1)

- John et al. (1998)
- R.E. Klauzinski (1981), Testing of six “wells of opportunity” during 1980 and 1981, Fifth Conference Geopressured-Geothermal Energy
- 9 wells produced for short periods (a few days)

  Maximum flow rate: (1950-15,000) BPD

  (13 – 99) m^3/h

Wells of Opportunity – Results (2)

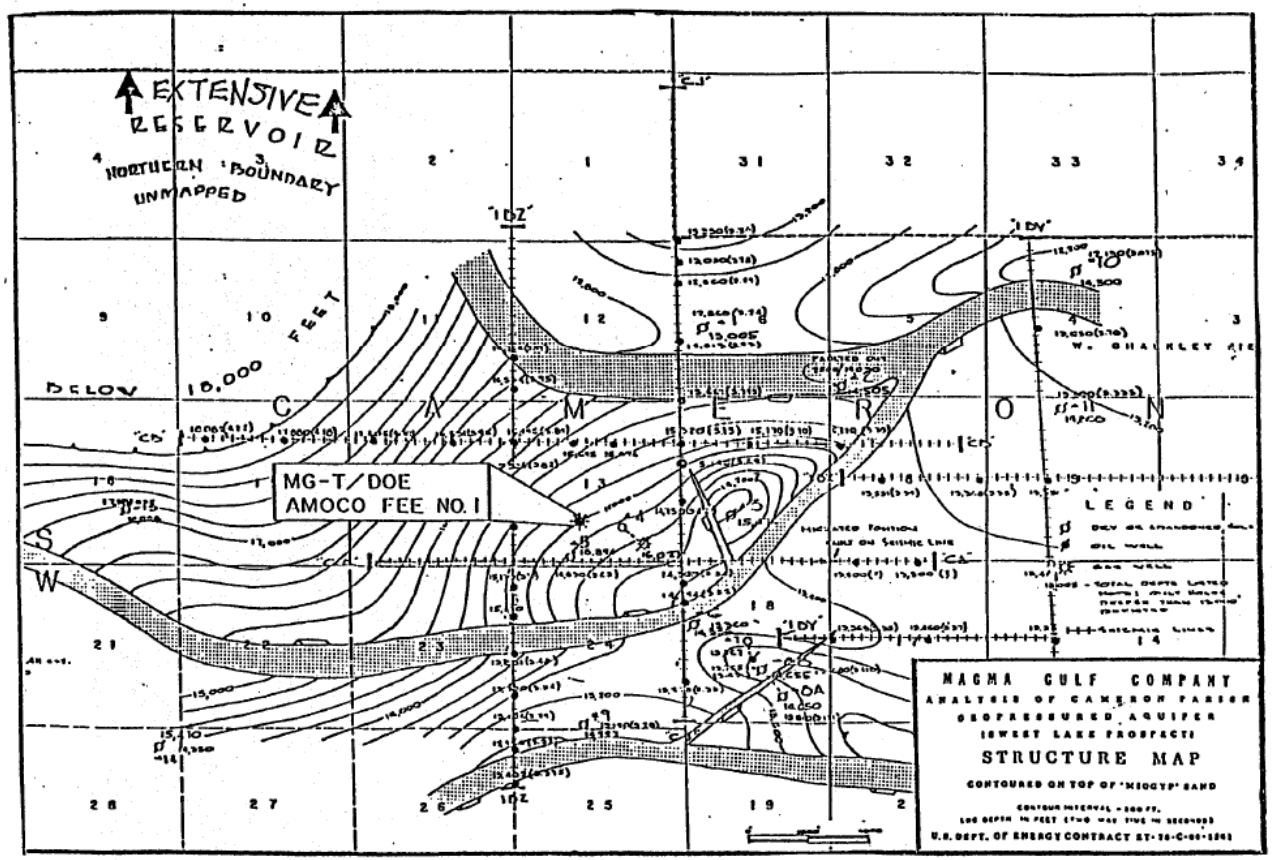
- Reservoir temperature: (238-339) ^{o}F
  (114-171) ^{o}C
- Salinity: (12,800 – 207,000) mg/l
- Permeability: (12-104) md
- Restricted flow zone due to the presence of faults close to the well (100-1000 ft)

Design Wells

- MG-T /DOE Amoco Fee No. 1 Well (Sweet Lake), Cameron Parish, Louisiana
- DOW-DOE L.R. Sweezy No. 1 Well, Parcperdue Field, Vermilion Parish, Louisiana
- Technadril-Fenix & Scisson-DOE Gladys McCall No. 1 Well, Cameron Parish, Louisiana
- Fenix & Scisson-DOE Pleasant Bayou No. 2 Well, Brazoria County, Texas

Ref: T.D. Riney and S.K. Garg, Geopressured geothermal design well test results, Transactions Geothermal Resources Council, Vol. 9(II), pp. 565-568, 1985.

MG-T/DOE Amoco Fee No. 1 Well (1)



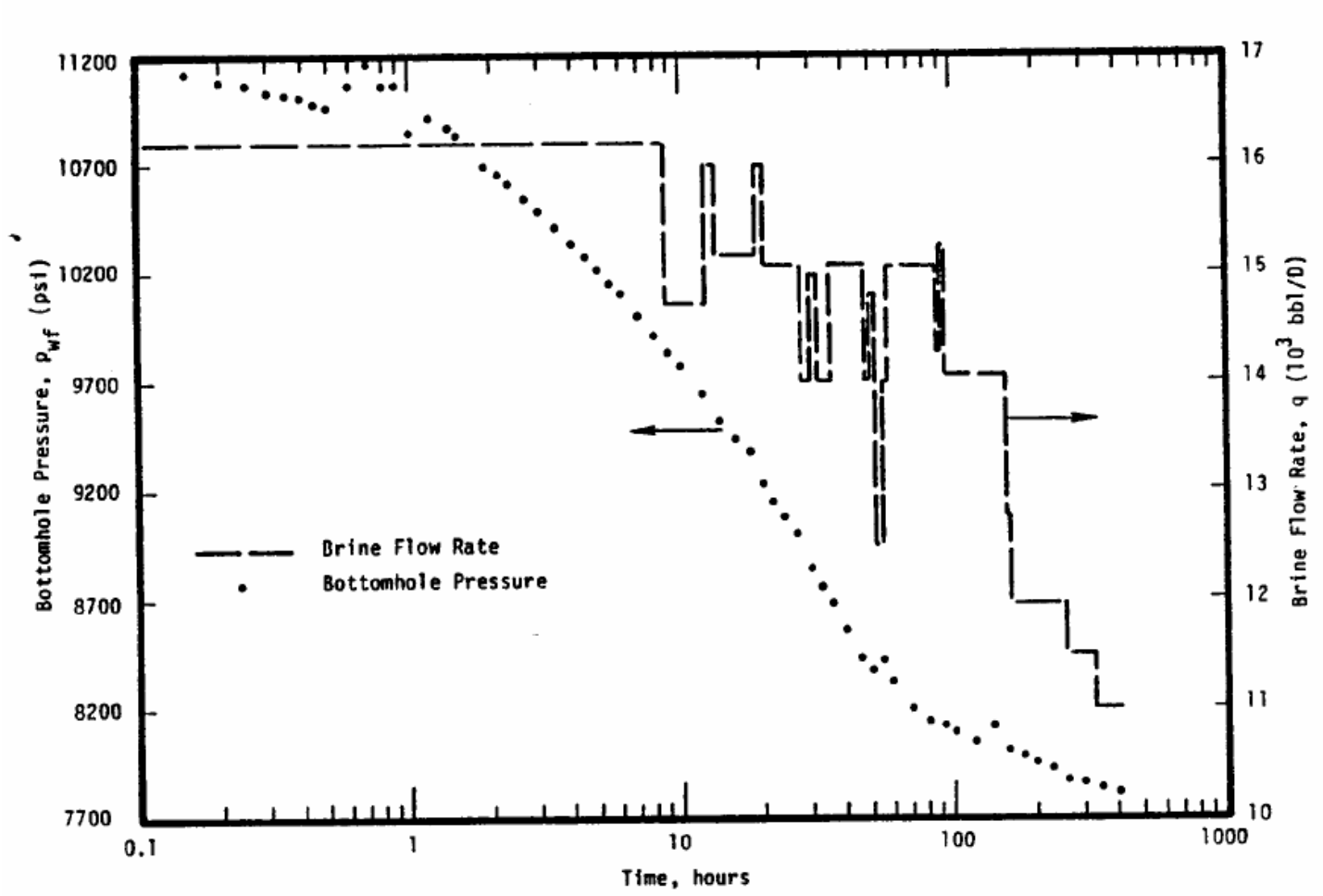
MG-T/DOE Amoco Fee No. 1 Well (2)

- Eight potentially productive sands in the Miogyp sequence (15,000-15,640 ft)
- Fifth sand (15,387-15,414 ft) selected for primary testing
- Flow testing

  Phase I: Initial Flow test (3 days) and subsequent shut-in (~8 days)

  Phase II: Reservoir Determination Test (~17 days)

MG-T/DOE Amoco Fee No. 1 Well (3) Reservoir Determination Test



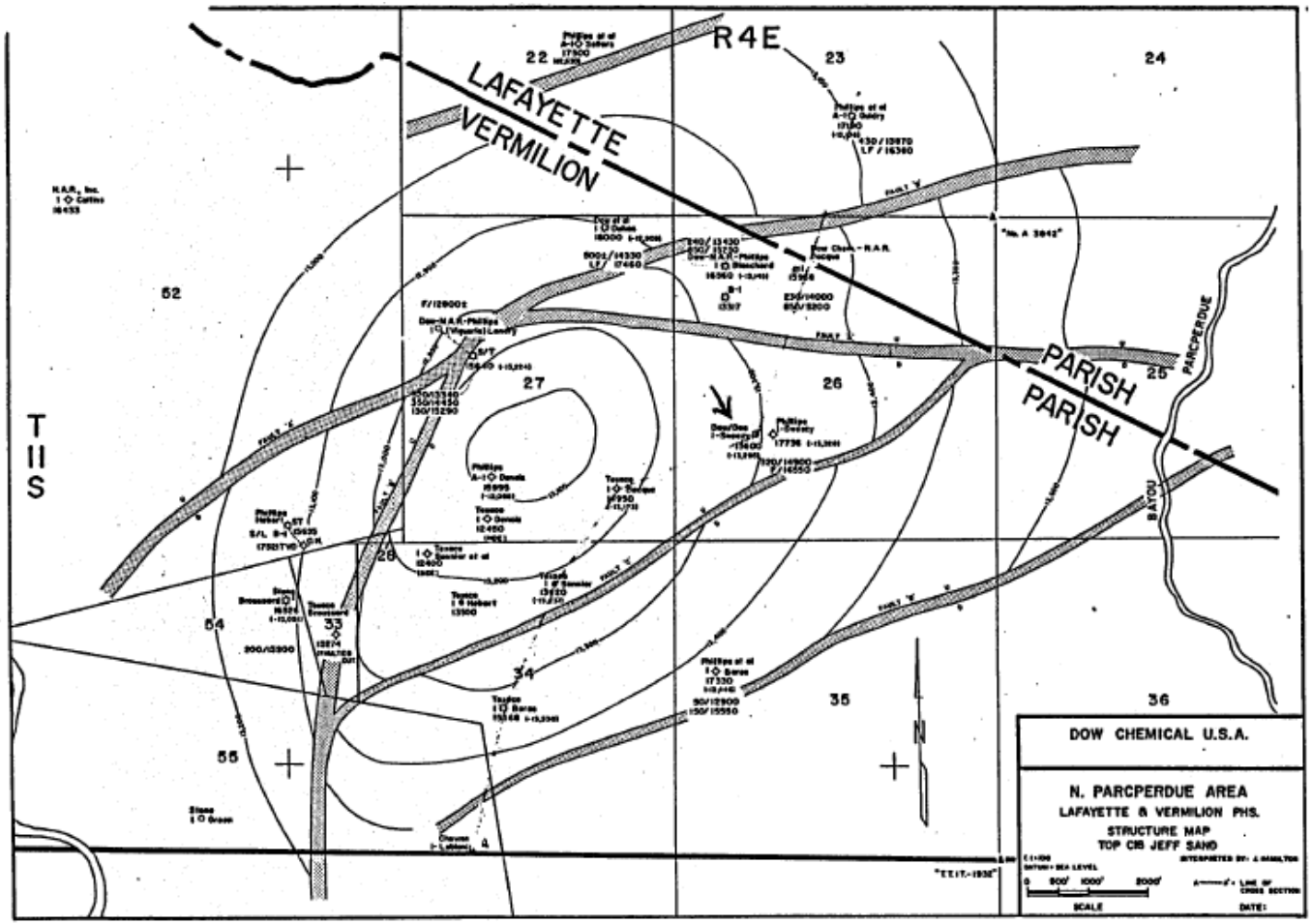
MG-T/DOE Amoco Fee No. 1 Well (4)

- Initial pressure: 12,053 psi (15,337 ft)

  Temperature : 299 ^{o}F

  Salinity: 165,000 mg/l
- During the 17 day flow test, brine discharge rate declined from ~16,000 BPD to 11,000 BPD, and flowing pressure fell by ~3500 psi.
- Well unable to sustain discharge at high rates

DOW-DOE L.R. Sweezy No. 1 Well (1)



DOW-DOE L.R. Sweezy No. 1 Well (2)

- Test designed to determine the production characteristics of a small Geopressured reservoir from initial fluid withdrawal to final depletion
- Total well depth: 13,612 ft

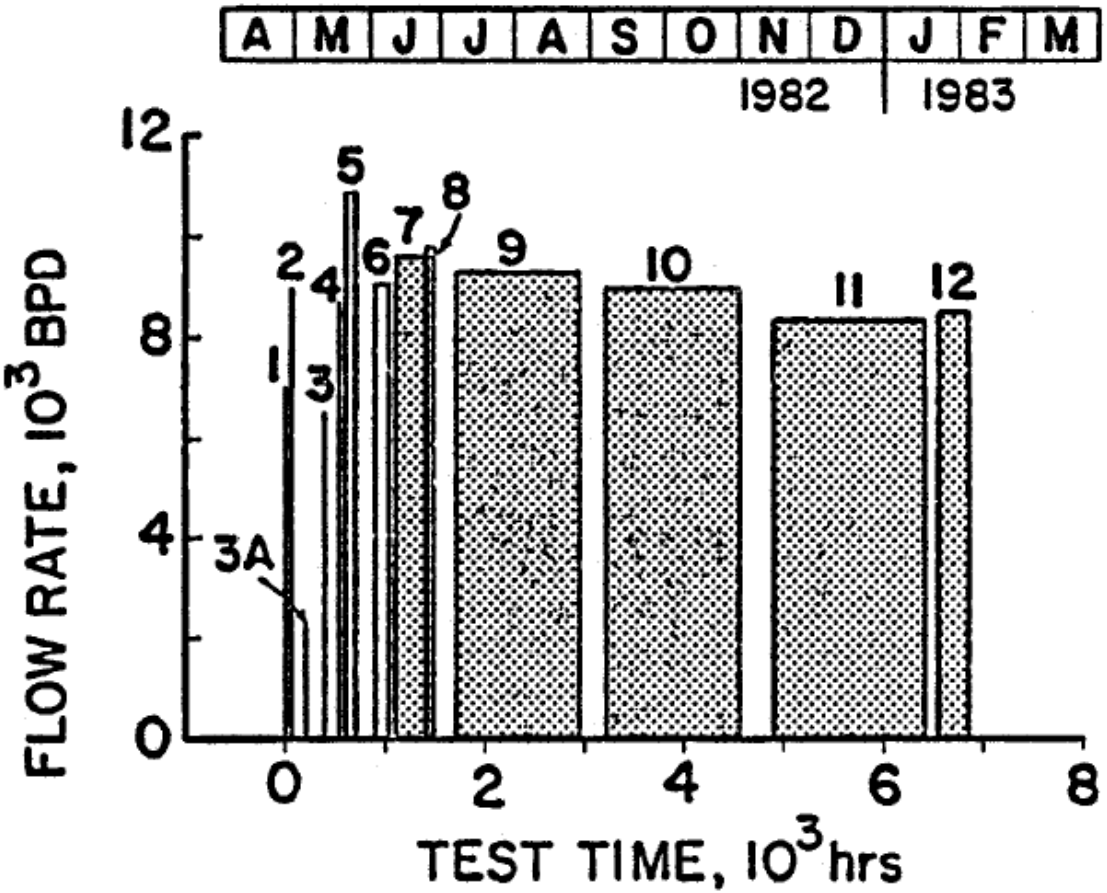
  Perforated intervals: 13,349-13,388 ft

  13,395-13,406 ft
- Initial pressure: 11,410 psi (13,395 ft)

  Temperature: 237 ^{o}F

  Total dissolved solids: 99,700 mg/l

DOW-DOE L.R. Sweezy No. 1 Well (3) Flow Tests



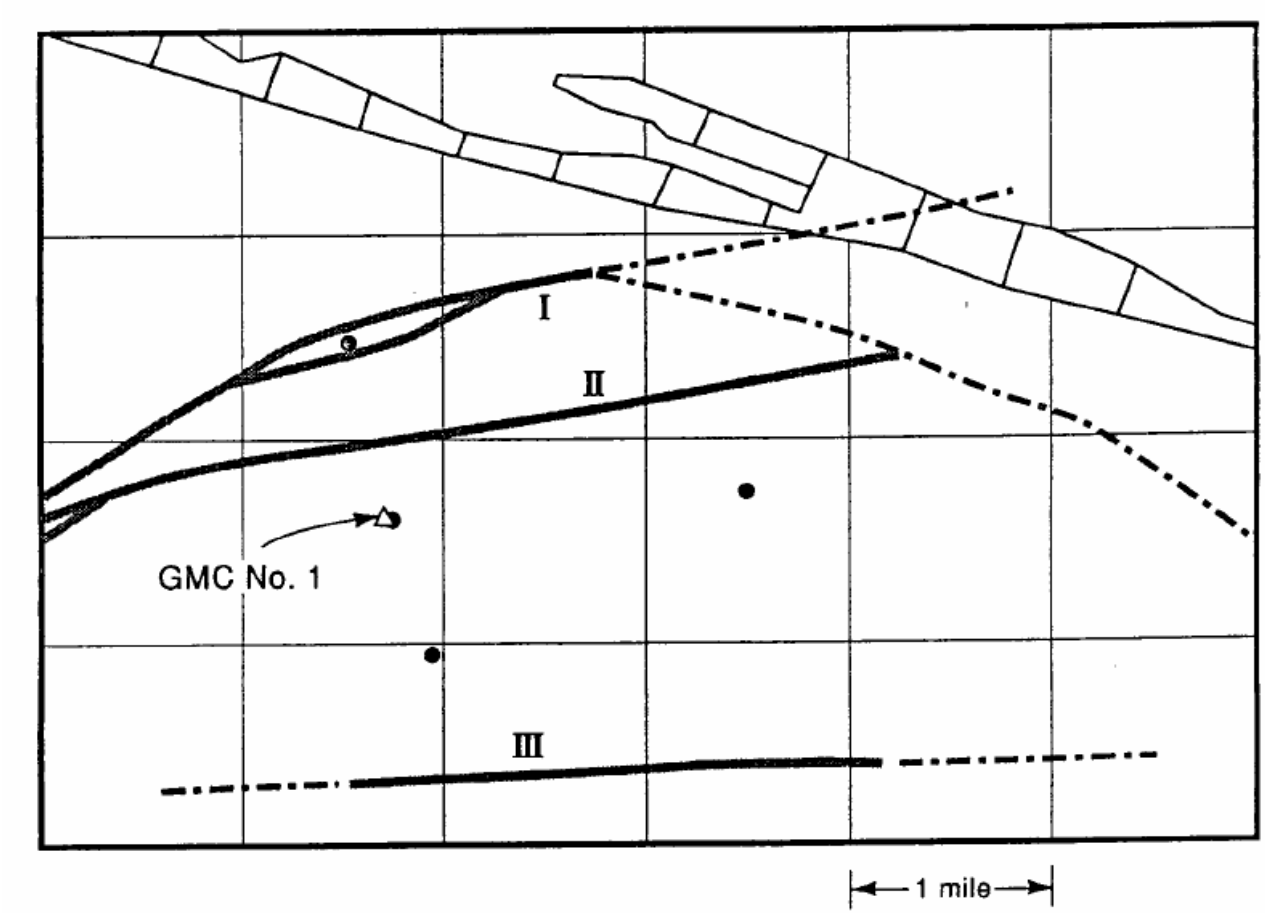
DOW-DOE L.R. Sweezy No. 1 Well (4)

- To avoid excessive sand production, production kept below ~10,000 BPD.
- After a surge in sand production, well abandoned in early 1983.
- Total fluid production: 1.85 million barrels

  ($0.294\ 10^6\ m^3$)
- Inferred reservoir volume: 1.8 billion ft^3

  ($52\ 10^6\ m^3$)

Technadril-Fenix & Scisson-DOE Gladys McCall No. 1 Well (1)



Technadril-Fenix & Scisson-DOE Gladys McCall No. 1 Well (2)

- Test designed to demonstrate long-term production potential of a Geopressured reservoir
- Total well depth: 16,510 ft

  Target sands: 14,412-16,320 ft (~1150 ft sand)
- Sand 9: 15,508-15,630 ft, rapid pressure drawdown, sand zone sealed off

Technadril-Fenix & Scisson-DOE Gladys McCall No. 1 Well (3)

- Sand Zone 8: 15,158-15,490 ft (332 ft)

  Initial pressure: 12,784 psi (15,100 ft)

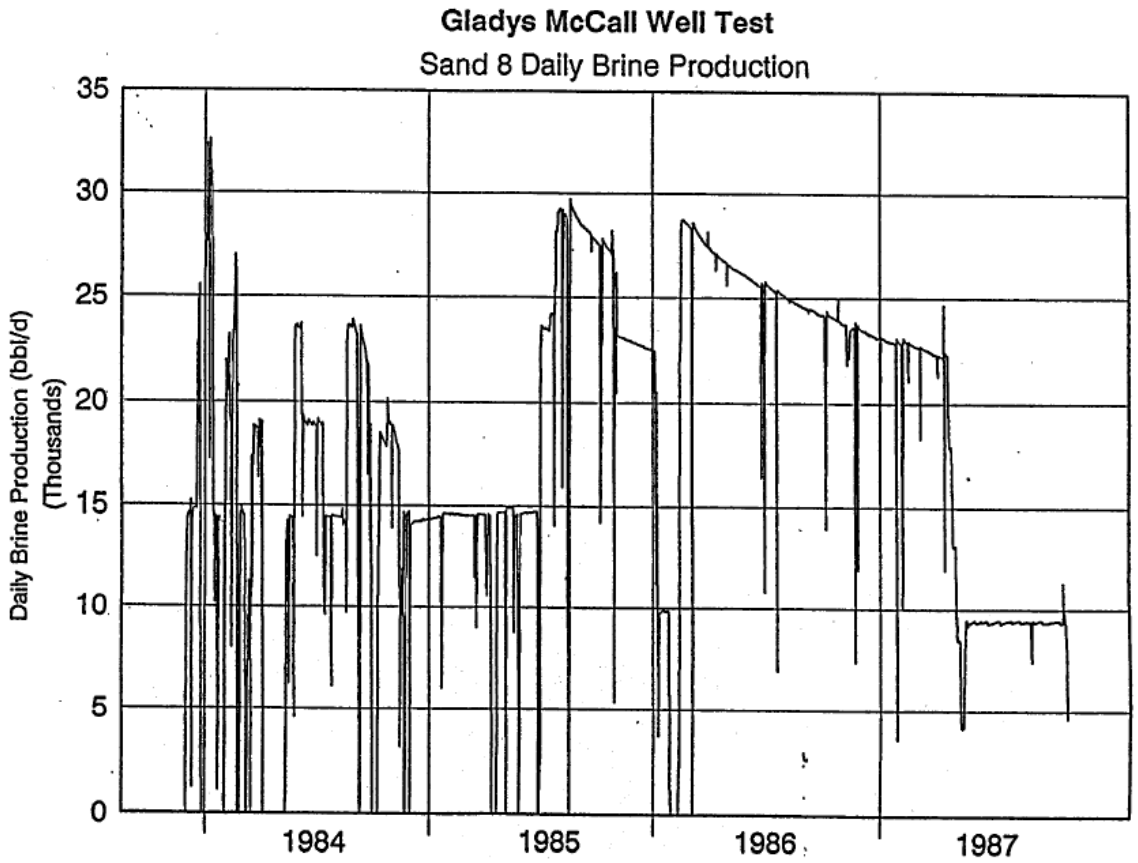
  Temperature: 289 ^{o}F

  Total dissolved solids: 97,800 mg/l
- Production at various rates from October 1983 to October 1987

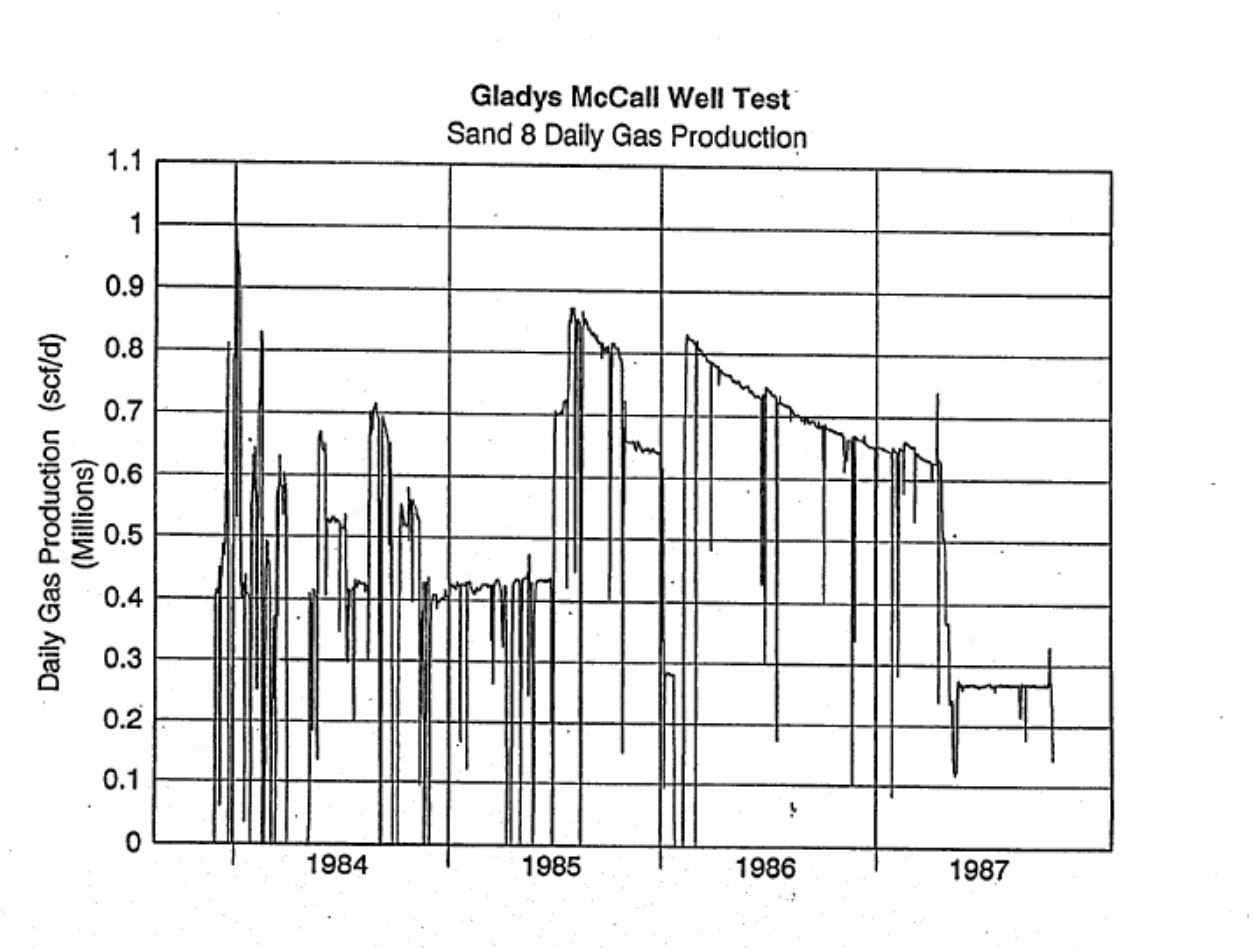
  Maximum discharge rate: > 30,000 BPD

  Average discharge rate: 19,600 BPD

Technadril-Fenix & Scisson-DOE Gladys McCall No. 1 Well (4)



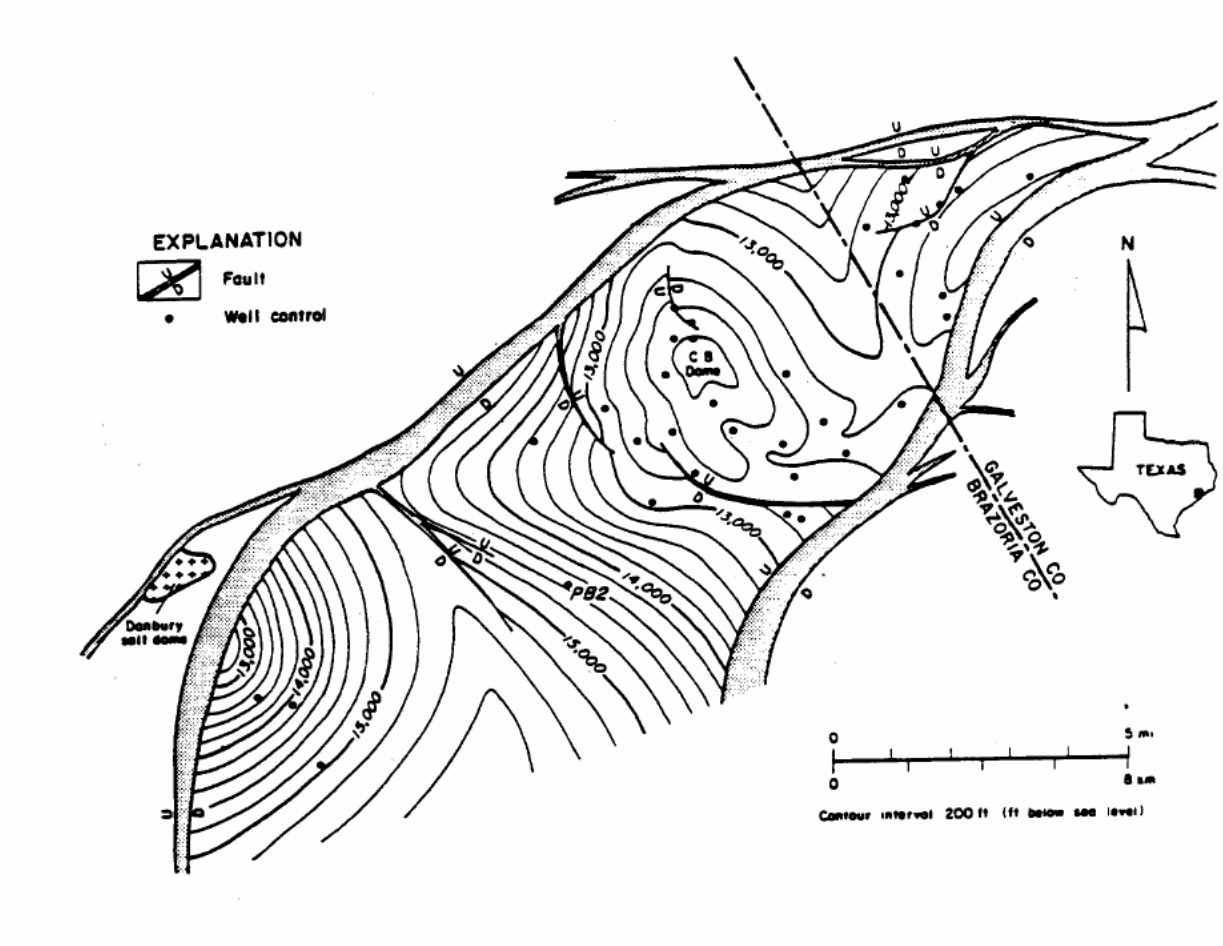
Technadril-Fenix & Scisson-DOE Gladys McCall No. 1 Well (5)



Technadril-Fenix & Scisson-DOE Gladys McCall No. 1 Well (6)

- Total brine production: 27.1 million barrels ($4.3\ 10^6\ m^3$)
- Total gas production: 676 million scf ($19.1\ 10^6\ m^3$)
- Gas/ brine ratio: 24.9 scf/bbl
- Estimated reservoir pore volume: 7.8 billion barrels ($1.2\ 10^9\ m^3$)

Pleasant Bayou No. 2 Well (1)



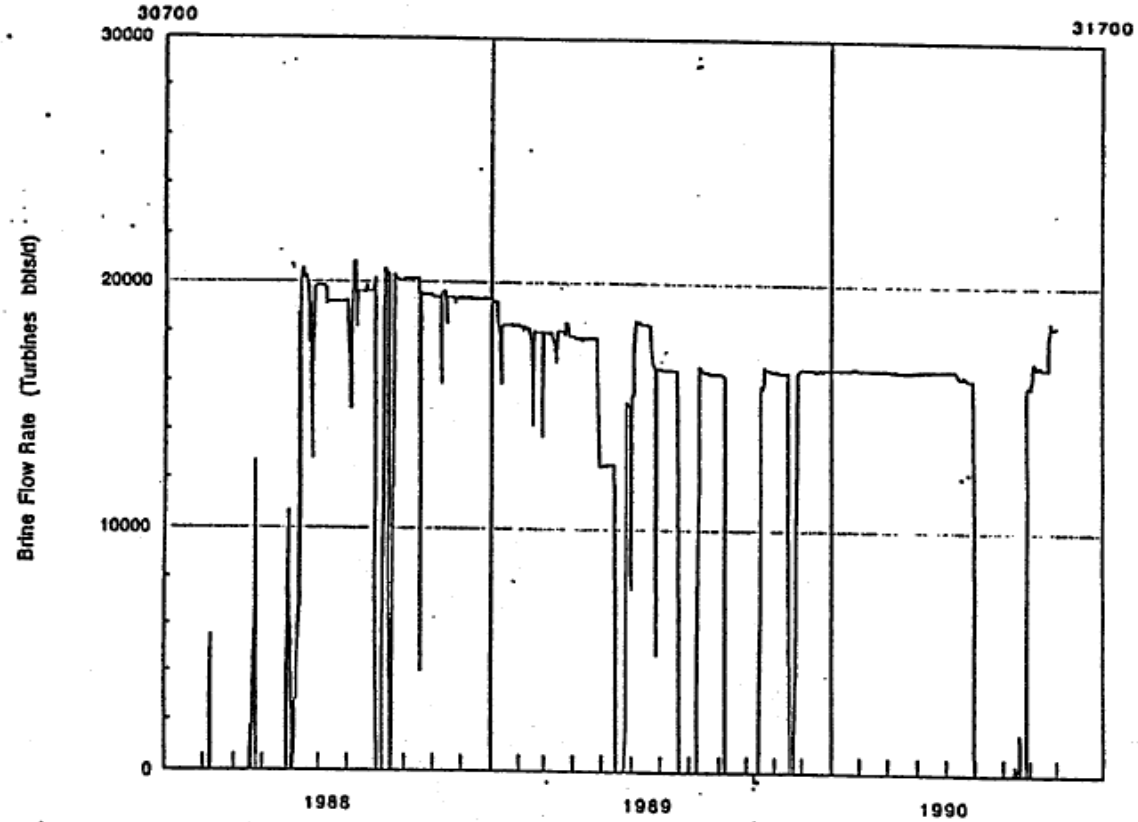
Pleasant Bayou No. 2 Well (2)

- Total depth: 16,500 ft
  Perforated interval: 14,644-14,704 ft
  (Frio Formation)
  Initial pressure: 11,168 psi (14,674 ft)
  Temperature: 306 ^{o}F
  Total dissolved solids: 130,000 mg/l
- Initial Testing: 3 short-term flow tests in 1979-1981

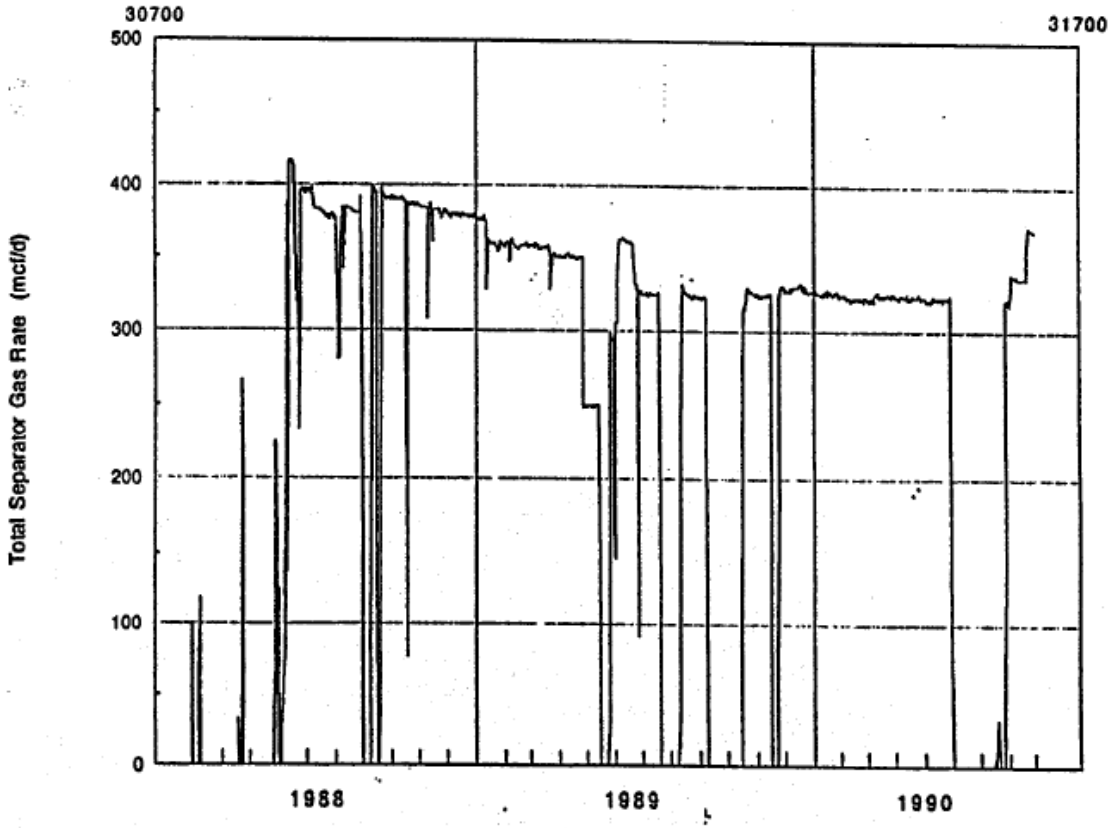
Pleasant Bayou No. 2 Well (3)

- Long-term flow test 1
  September 1982-April 1983
  Total brine production: 3.5 million barrels
  Average production rate: 18,200 bpd
- Long-term flow test 2
  June 1988 – August 1990
  Total brine production: 11.9 million barrels
  Total Gas production: 232 million Scf
  Gas/brine ratio: 19.5 scf/bbl

Pleasant Bayou No. 2 Well (4)



Pleasant Bayou No. 2 Well (5)



Pleasant Bayou No. 2 Well (6)

- G. M. Shook, An integrated approach to Reservoir Engineering at Pleasant Bayou Geopressured-Geothermal Reservoir, Idaho National Laboratory Report, 1992.
- Key conclusion: Pleasant Bayou No. 2 well capable of producing at 20,000 bpd for several years.

Pleasant Bayou No. 2 Well (7)

- Hybrid Power Plant (1 MW net)

  Produced methane burned to produce electricity.

  Gas engine exhaust and produced brine used in a binary power plant to generate additional power.
- Power plant operated for ~121 days (October 1989-May 1990)

Conclusions (1)

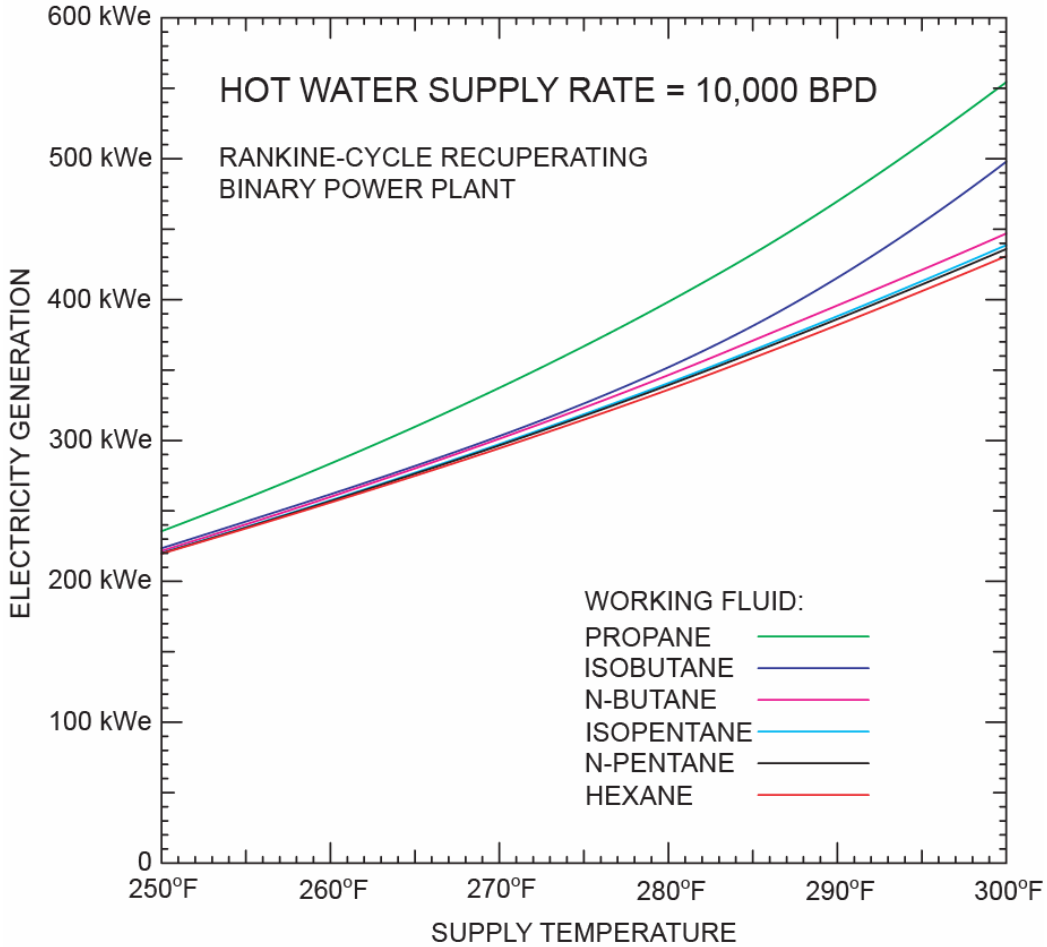
- Wells of opportunity (i.e. abandoned hydrocarbon wells) generally incapable of sustaining production at high rates.
- Design well test program demonstrates the existence of large (~1 cubic mile)

  Geopressured reservoirs.
- Two of the design wells produced at ~20,000 BPD for several years.

Conclusions (2)

- Because of the high salinity, it will be necessary to inject the waste brine.
- Design wells completed with 7-inch liner in a 8.5-inch hole. Production through a 5-inch production tubing. A different completion scheme may be needed to sustain production rates greater than 20,000 BPD.
- Hybrid power plant at Pleasant Bayou site was not optimized for electric power production.

Conclusions (3)



Conclusions (4)

- Ref: J. W. Pritchett, Electrical Generating Capacities of Geothermal Slim Holes, DOE/ID/13455, October 1998.
- With an inlet temperature of 300 ^{o}F and a brine supply rate of 20,000 BPD, a binary power plant can generate (0.85 – 1.1) MWe.

Conclusions (5)

- With a brine production of 20,000 bpd, it is reasonable to expect a gas production rate of ~400,000 scf/day.
- Assuming a thermal to electric conversion efficiency of 40%, 400,000 scf/day of natural gas may be used to generate about 2 MWe.