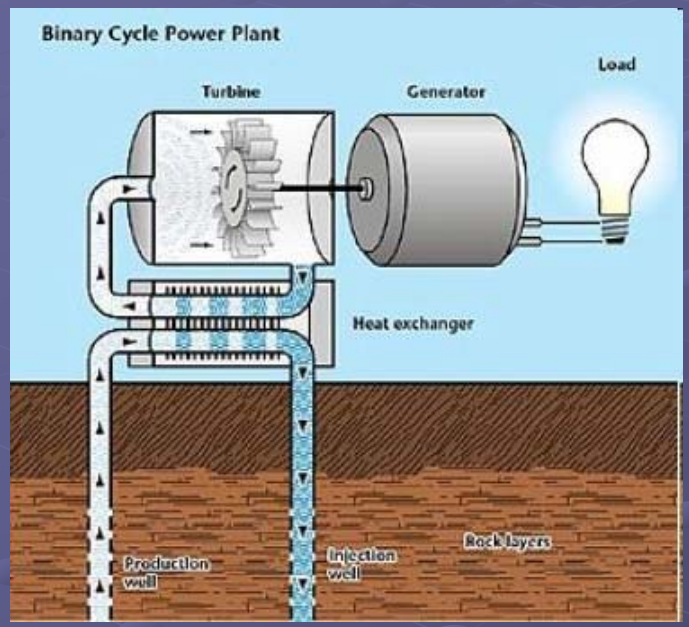
Geothermal Power Generation Potential Poplar Dome, Montana

Susan Petty

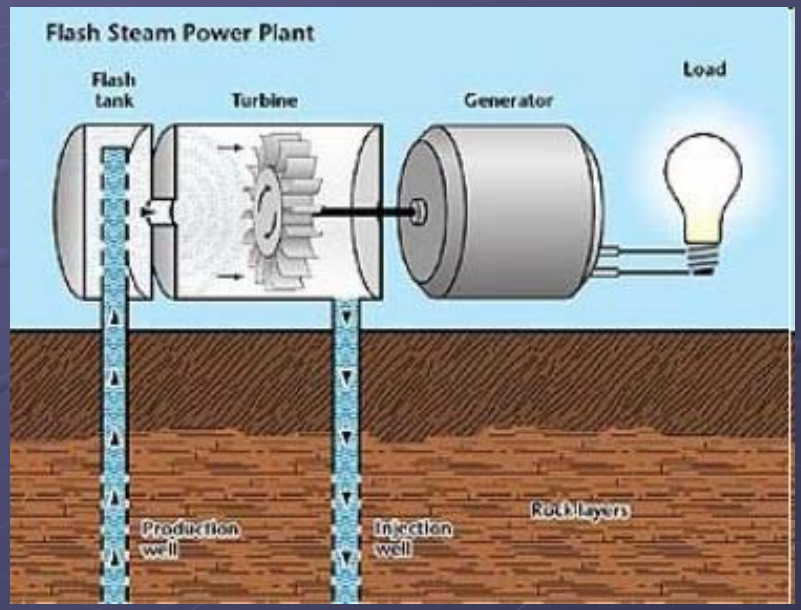
Hot Water Co-Produced With Oil

- Temperatures for power generation
  - Plant Type
    - Binary
    - Flash
- Direct use applications
  - Industrial, commercial, and residential

Plant Types



Binary Technology
(starting at 225° F)



Flash Technology
(starting at 350° F)

Direct Use Applications

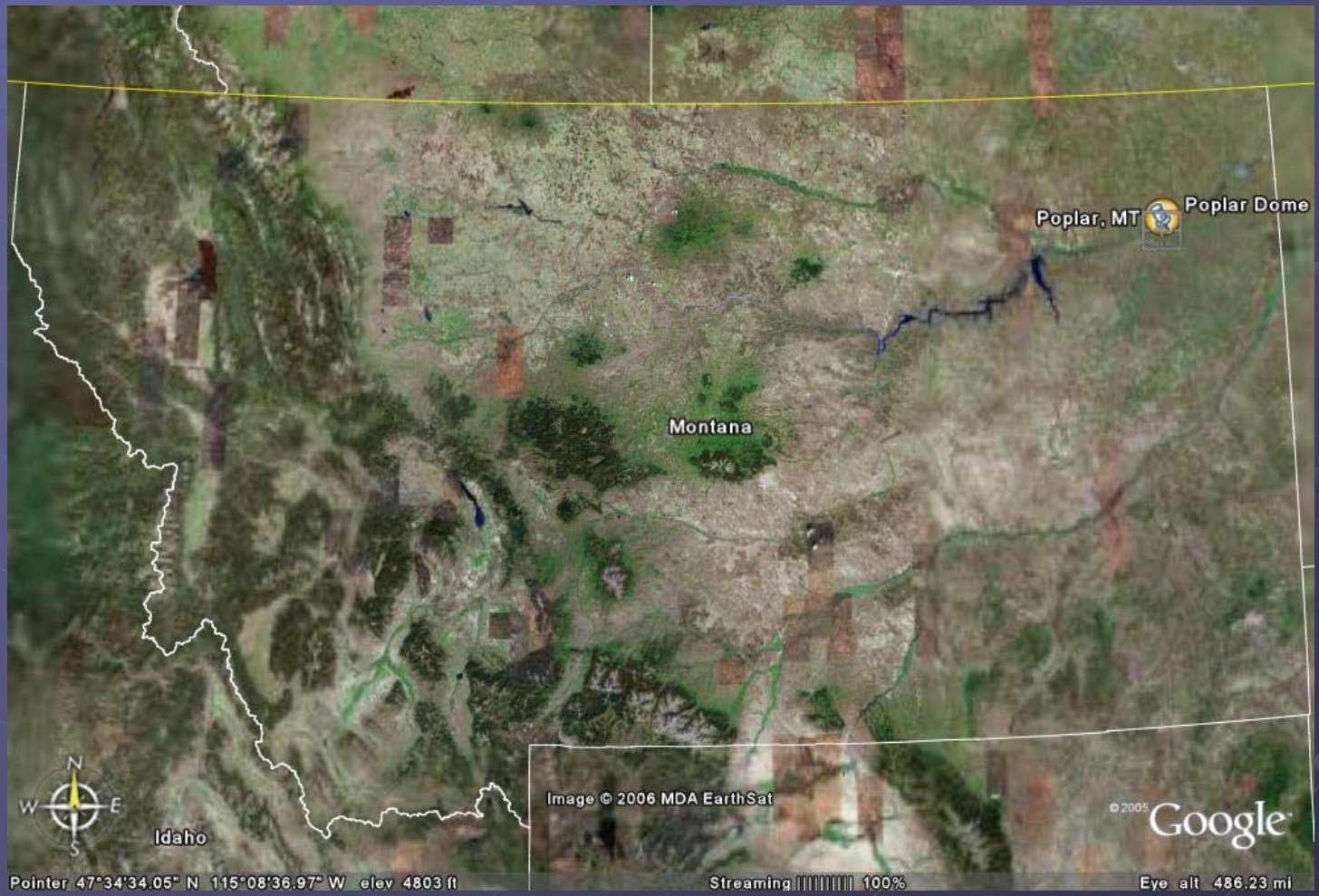
- Green house heating >80°F (Green house)
- Space heating >80°F (Industrial building)
- Food drying >170°F (Onion plant)
- Air conditioning/ice making >175°F

Empire Farms Geothermal Power Plant/Onion and Garlic Drying Facility

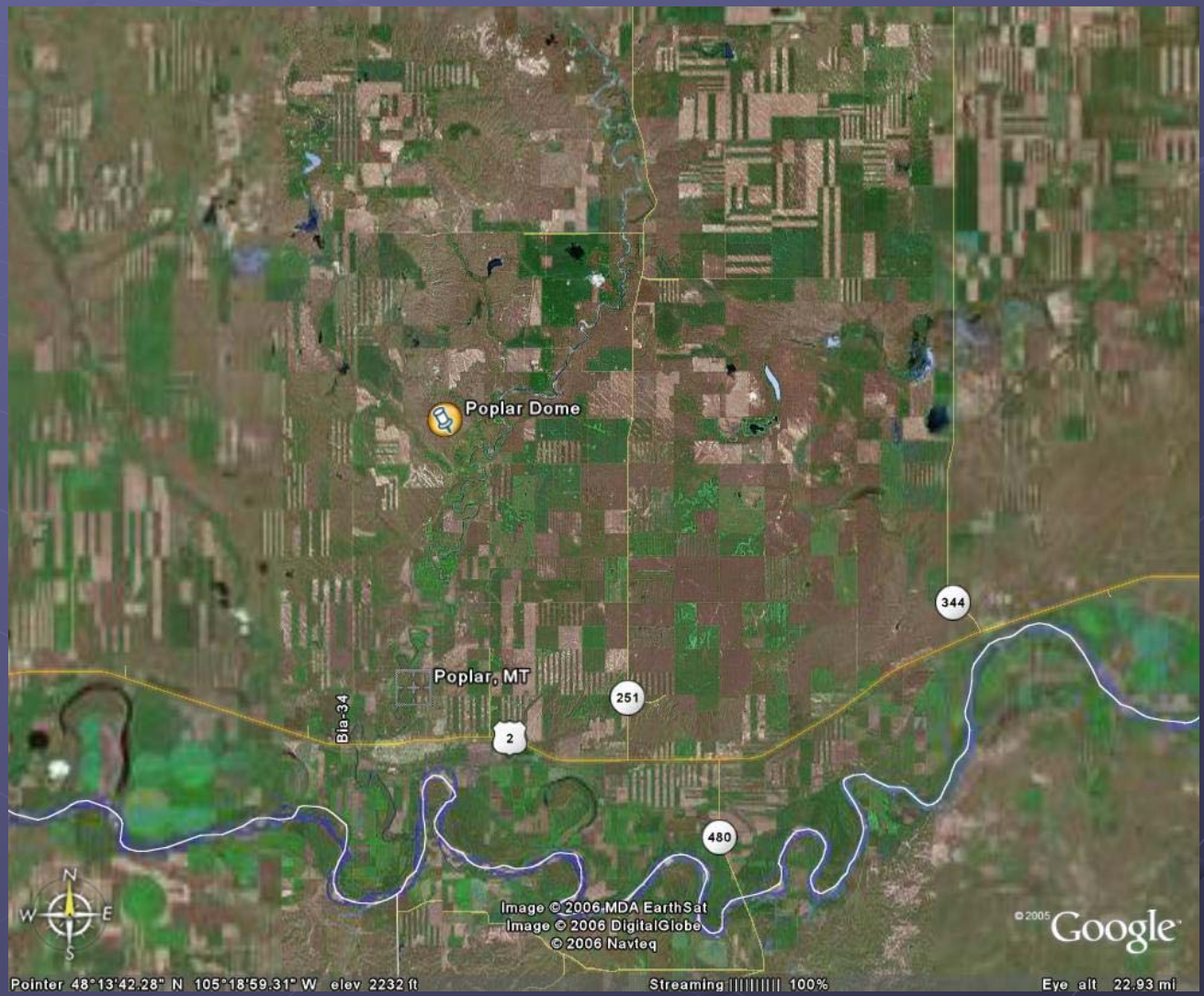
Binary Generation Units

Onion and Garlic Dehydration

Poplar Dome Oil Field



Located on Fort Peck Indian Reservation



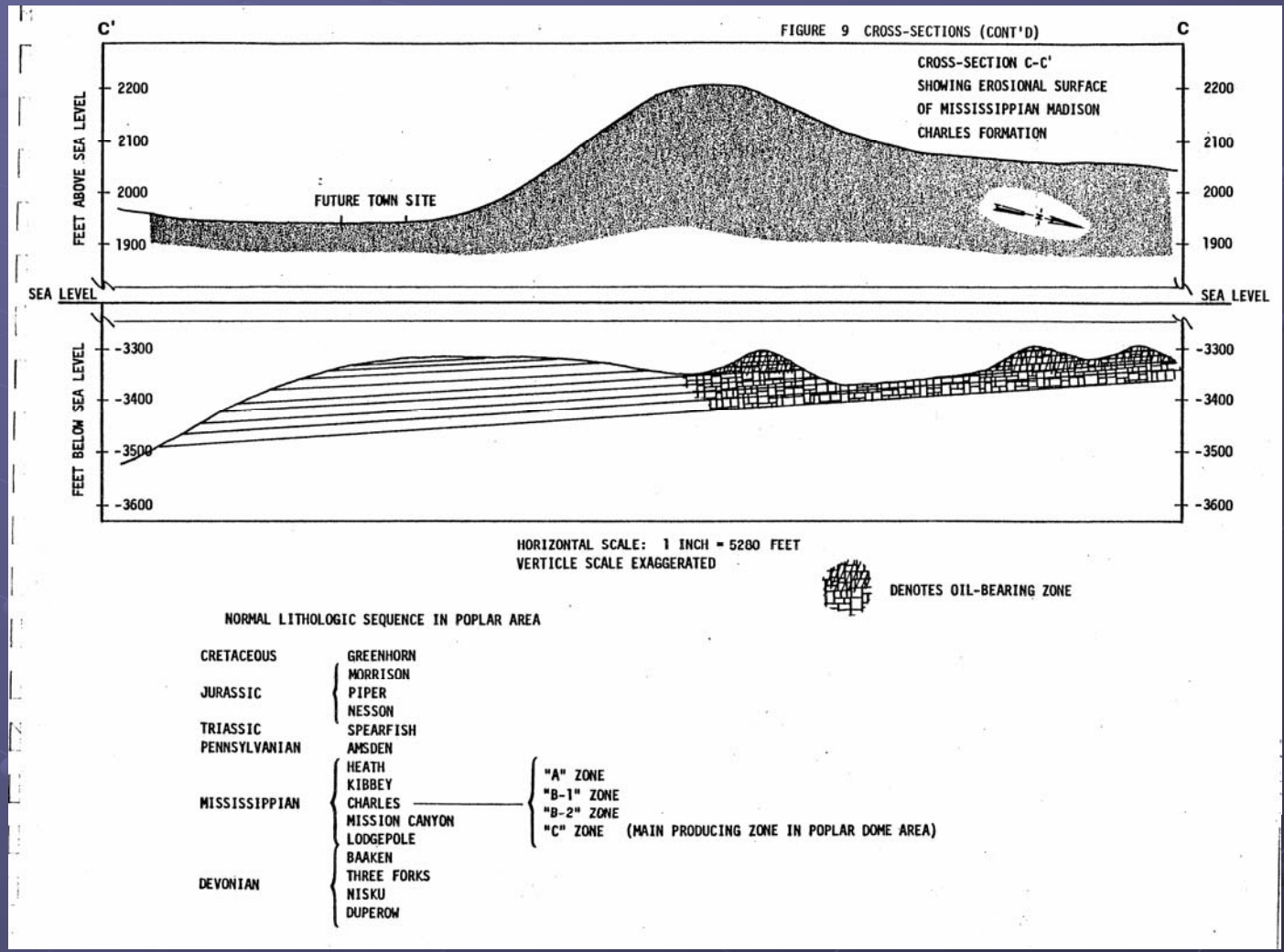
Poplar Dome Oil Field

- Operated by Ballard Petroleum
- Producing oil with hot water from 180°F - 265°F

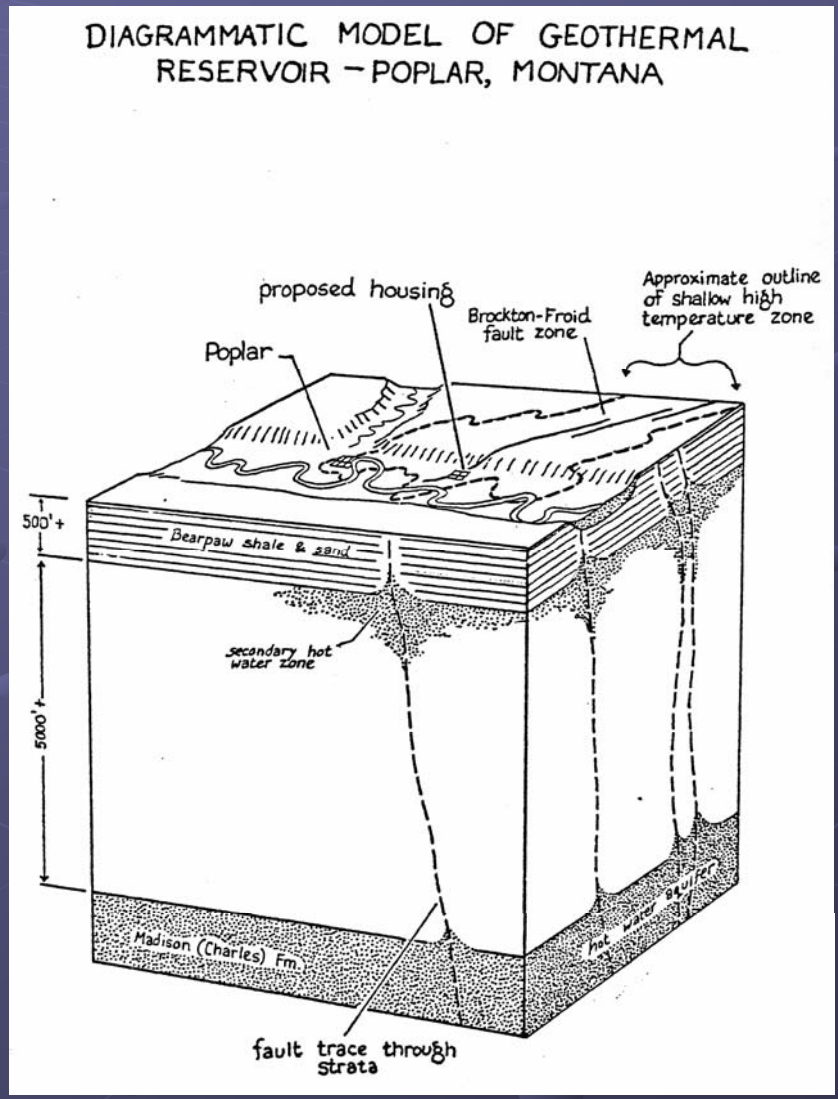
Poplar Dome

- Elongate dome
- North South orientation
- Cretaceous at surface
- Mississippian production

Poplar Dome Cross Section



3D Poplar Diagram



Production from Madison Limestone

- Mainly from Charles zone
- Mission Canyon
- Lodgepole
- Production depth – 5400 – 8600 ft
- Other fields in Williston Basin produce from deeper zones
- Deeper zones may have higher temperatures

Hot water production

- Oil separated
- Stored in tanks for cooling
- Injected into Bearpaw Fm and Madison Ls.
- Some possible movement of injected brines into shallow ground water

Water temperatures

- Average production 190°F
- Some wells produce 265°F water
- Highest temperature not necessarily deepest wells
- Highest temperatures on southern limb of dome
- High temperature possibly related to Brockton Fault zone

Temperature vs. Depth

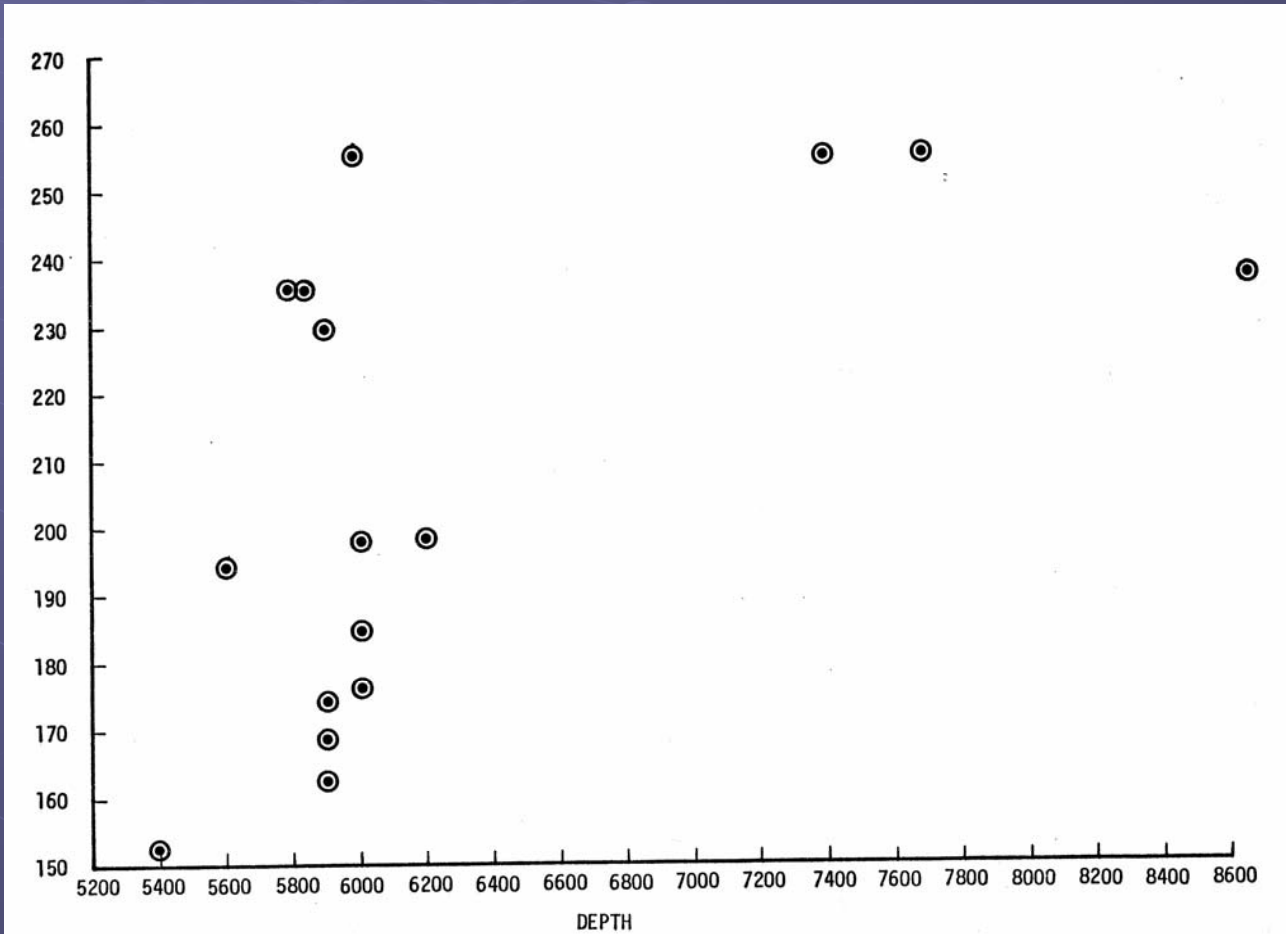


FIGURE 11 CORRELATION-TEMPERATURE VS. DEPTH

Temperature Contour Map

Location, Depth, and Temperature

TABLE I-2. BOTTOM-HOLE TEMPERATURES FROM DRILL-STEM TESTS.

Well Location Map Number	Well	Depth (ft)	Temperature (°F)
1	States Oil - Huron #1	6,000 7,400	186 256
3	Murphy Oil - Lowe #1	7,700	256
34	Partee #1	5,800	236
35	Natol #1-26	5,800	236
37	Murphy #63	5,900	174
38	Ajax #1	5,900	168
39	Empire #1	6,000	176
40	Delhi #1	6,000	260
41	Byers #1	5,900	165
42	Buttes #1	8,900	243
43	Juniper #1	5,900	230
44	Hickerson-Wilke #1	5,900	198
45	Hickerson-Jerome #1	5,900	185
46	Davis Oil #1	5,600	194
47	Shoreline #1	5,400 6,200	150 198

Production rates

- ~40,000 BPD total water over 180°F
- ~20,000 BPD water over 260°F
- Could increase production of 260°F water to 40,000 BPD from existing wells with stimulation
- Could maximize hot water production by drilling and stimulating geothermal wells

Scenarios for Economics

- Wells of opportunity
- Enhanced productivity
- Geothermal development using EGS technology

Wendell-Amedee Binary Plant

Wells of Opportunity

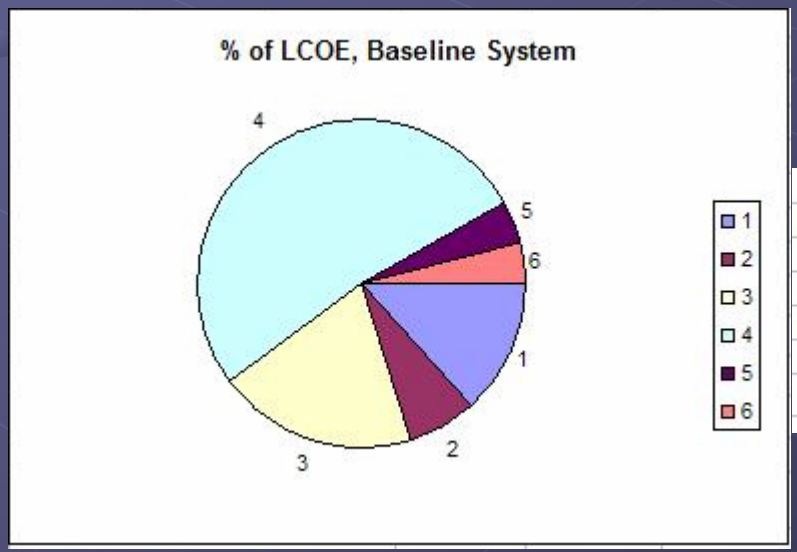
- Use 20,000 BPD at 265°F to produce power (583 gpm)
- Use power to run field parasitics
- Use existing wells-no cost
- Surface piping in one area of field
- Remainder of fluids for direct use
- Inject at depth enhance oil recovery
- Reduce risk of seepage into groundwater aquifers

Enhanced Water Production

- Recomplete dry holes to maximize production
- 5 wells – dry or abandoned wells
- 350 gpm each well
- Stimulate to enhance productivity
- Electric submersible pumps
- 265°F
- Remainder of water also available for direct use
- Inject deep to enhance recovery and protect groundwater

Wells of Opportunity Cost

	A	B	C	D	E
1	GETEM		BINARY SYSTEM INPUT SHEET		
2	Version:		GETEM-2005-E2-(dje-Feb-01-06)		
3	BINARY Case Name:		BINARY Reference Case for MYP-late-2005 (2005 and 2010)		
4	File Name:		GETEM-2005-E2-dje-BINARY-and-FLASH-Feb-01-2006		
5			Baseline	Change	Improved
6	Case Date:	3/10/2006	2005		2010
7	Cost of Electricity, cent/kWh		11.61	-41%	6.88
8	Input		Baseline	Change	Improved
9	Global Economic Parameters				
10	Fixed.Charge.Rate	Ratio	0.128	1.00	0.128
11	Utiliz.Factor	Ratio	0.95	1.00	0.95
12	Contingency	%	5%	1.00	0.05
13					
14	Input parameters				
15	Temperature of GT Fluid in Reservoir	Deg-C	135	1.15	155
16	Plant Size (Exclusive of Brine Pumping)	MW(e)	3.0	1.00	3.00
17	Number of independent power units		1	1.00	1.00



Legend for Pie Chart Sectors:
1. Exploration and Confirmation
2. Wells in Field, after Confirmation phase
3. Field, Other (Pipes, Pumps, Well Stimulation, Make Up Costs)
4. Power plant
5. Royalty
6. Contingency

Enhanced Water Production Cost

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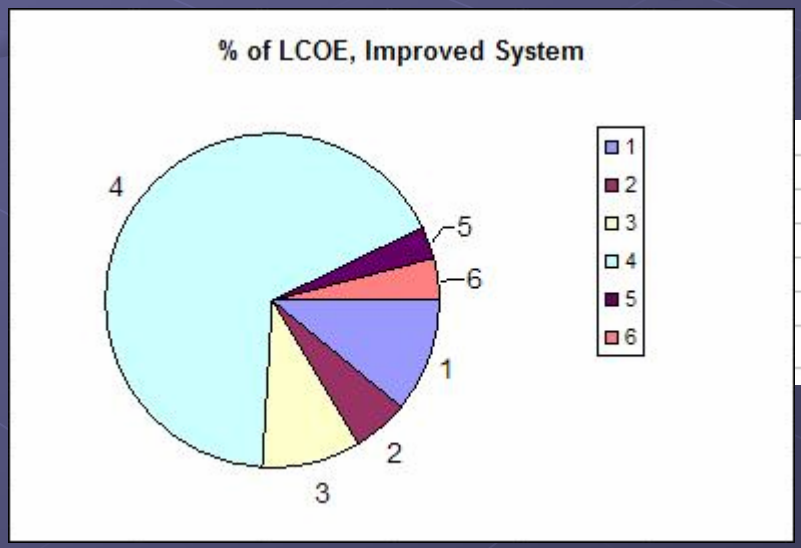

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Future Work

- Look at economics of developing EGS
- Coordinate with tribal council
- Assess demand for power in area
- Look for direct uses of hot water