APPENDIX C

SELECTIONS FROM
PLAN OF OPERATION
E-ICP TEST PROJECT

[[SELECTIONS FROM]]

Plan of Operation

Shell Frontier Oil and Gas Inc.

E-ICP Test Project

Oil Shale Research and Development Project

Prepared for:
Bureau of Land Management

February 15, 2006

4.0 OPERATING PLAN

4.1 General Project Overview and Summary

The E-ICP Project is a research, development, and demonstration project designed to demonstrate the ICP, gather additional operating data and information, and allow testing of components and systems to verify the feasibility of recovering hydrocarbons from oil shale for use in commercial operations. This plan describes the construction, operation, and reclamation of the E-ICP and the supporting facilities. Exhibit I shows a preliminary plot plan.

The oil shale resource for the E-ICP extends from the R-7 through R-2 interval. The ICP is an in situ process using electric heaters to heat the oil shale in place. The heating process pyrolyzes the organic matter in the oil shale and converts this matter into oil and hydrocarbon gas. The oil and gas are then removed from the ground using conventional oil field pumping and extraction technology and processed using conventional oil and gas processing. The recovery is conducted within a contained area to allow recovery of the hydrocarbons while excluding ground water flow through the oil production area. Containment is provided in a freeze wall containment area consisting of a freeze wall system and low permeability barrier above and below the oil shale resource zone. These are described below.

Since the E-ICP project is planned for use in areas below the ground water table, a freeze wall containment area is created to isolate the heated zone from the surrounding ground water. Freezing of the in situ ground water and associated rock matrix creates a containment barrier that prevents migration of fluids into or out of the heated zone area. The freeze wall is constructed by drilling closely spaced holes outside the intended oil shale resource target zone and circulating chilled refrigerant through closed loop piping in each freeze wall hole. Through heat exchange with the surrounding rock matrix, the refrigerant returns to the surface warmer than its inflow temperature and the surrounding rock and associated pore and fracture water is cooled and frozen. This frozen barrier is formed along the entire depth of the freeze hole and continues to grow and thicken until the area between freeze holes is frozen, forming a continuous frozen wall-like barrier that extends through the resource zone and into the impermeable layer at the bottom, thus forming a containment area that confines the heated zone. The freeze wall containment area is maintained through heating and product recovery as well as during ground water reclamation.

Once the freeze wall is established, a series of dewatering holes are drilled to remove the ground water inside the freeze wall containment area prior to heating to allow recovery of the hydrocarbon products. The holes will later be converted to producer holes that will remove the hydrocarbon products. Water from dewatering the freeze wall containment area will be re-injected back into the ground water zones outside the freeze wall into the appropriate water-bearing zones so that classified beneficial uses are maintained. Dewatering and reinjection flow rates will be monitored to allow calculation of the amount of water taken from the freeze wall containment area. Removal of the ground water prior to heating will prevent mixing of the hydrocarbons and ground water. Dewatering will not result in removal of all of the ground water within the containment area as some pore water cannot be removed through pumping during dewatering.

A series of heater holes will also be drilled within the freeze wall containment area. Heaters are installed in these holes to allow heating of the resource interval. The heater holes are placed such that an unheated zone of approximately 125 feet is maintained between the freeze wall barrier and the heated zone so that the freeze wall is not impacted by heating. The heaters raise the temperature of the oil shale and initiate pyrolysis, releasing hydrocarbon products that are then removed using the production holes. A drilling hole schematic is included in Exhibit J.

Products from the pyrolyzed zone are piped to an on-site processing facility, where processing separates the oil, gas, and water. Oil is processed to remove impurities, then shipped off site to existing refineries for refining. Gas from the production holes is also treated and used to supplement energy needs at the site or incinerated as quantities are not sufficient to justify facilities necessary for commercial transportation and sale. Sulfur, produced as a product during processing, is transported off-site as a marketable product. Figure 4.1 shows a simplified diagram describing the steps included in the E-ICP.

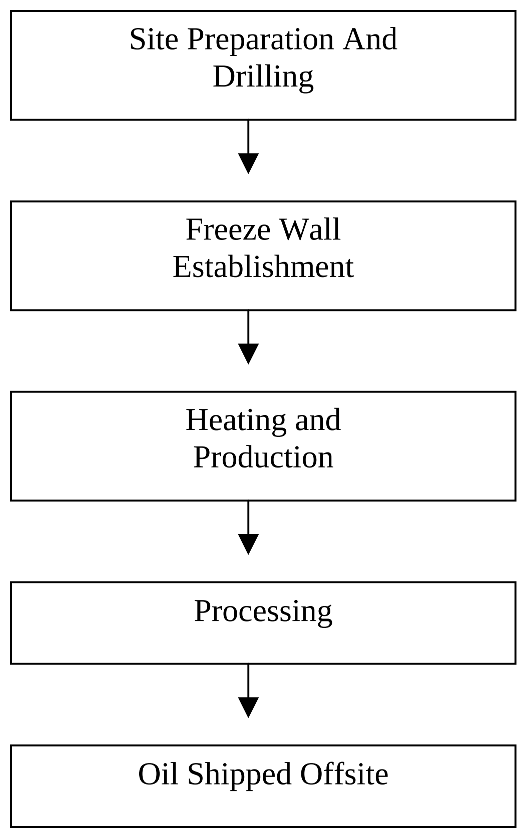

Figure 4.1 Diagram of E-ICP Project

As a part of reclamation, the wells and holes not needed for monitoring are plugged and abandoned in accordance with requirements of the Colorado Office of the State Engineer. Facilities will be demolished and removed and the site will be regraded and revegetated. The paved access road will also be reclaimed, leaving a dirt road access route. The reclamation plan (Section 5) provides details on reclamation of the heated zone and of the site disturbance.

Support facilities include a site access road; construction and drilling support consisting of lay down yards, storage units and office trailers; portable pilot test plants, process control building, change house, utilities, warehouse, shop/ maintenance facilities, laboratory, and other facilities necessary to support the E-ICP Project. Potable water will be trucked to the site and stored for use in the on site potable water system. The following sections contain detailed information on the various process components associated with the E-ICP facility.

4.2 General Site Development and Preparation

Initial construction activities include development of the site access road and fencing of the permit area. The present access to the E-ICP site is from County Road (CR) 5 to CR 24 to CR 24X (see Exhibit C). There are presently three proposed access roads to the site. Based upon input from BLM, one of these roads will be extended to the E-ICP site and expanded to a running width of approximately 24 feet to allow heavy equipment travel in two directions. The access road will be paved with asphalt for the 24-foot width and include appropriate ditches and culverts to maintain drainage control. Soils salvaged during the road construction will be stored in berms located on either side of the road. Figure 4.2 provides additional information on the design of the access road. Access to the E-ICP site from the road will be restricted through an entry gate.

The E-ICP project, excluding the access road, will be fenced with a combination barbed/smooth wire fence with the top wire being smooth. A 12-foot wide fire break will be constructed along the permit boundary fence. Signs reading “Do Not Enter” will be posted at points of logical entrance to the facility, such as roads or trails, to redirect unauthorized personnel. Eight-foot high chain link fencing will be provided around lined ponds (storm water pond, process water pond, and evaporation pond) when these ponds are constructed.

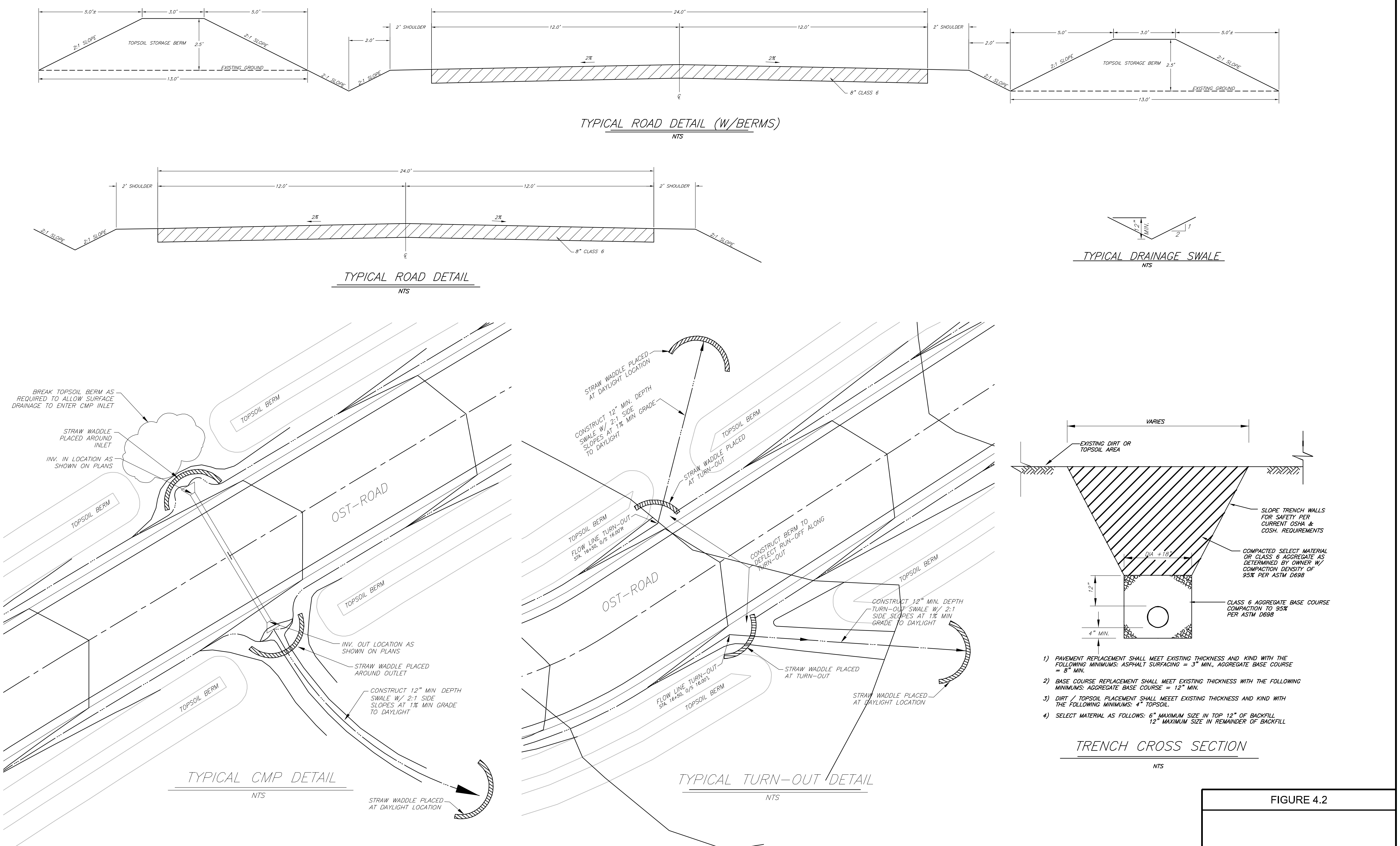

FIGURE 4.2

TYPICAL ACCESS ROAD DESIGN

Drawn By: DD | Date: 02/10/06
Approved By: | Date:

FILE: FIG4.2 TYPACCESSROADDESIGN 3235\Task 45\P00 5-2-05\FEB06
SCALE: NTS
SHELL FRONTIER OIL & GAS INC.

Surface Drainage Controls

A surface water drainage collection and conveyance system will be established to manage drainage throughout the site. The surface drainage control system along with the site grading will route storm water flows from the disturbed areas into a storm water pond prior to discharge to the existing surface drainage system. The surface drainage system consists of ditches, storm sewers, culverts, curbs, and paving. Ditches will be lined with riprap or other material where necessary to assure stability. A storm water pond will be designed to retain the runoff and sediment from a 50-year, 24-hour storm event (2.5 inches). Exhibit K shows the preliminary drainage control plan.

Construction storm water drainage will be managed through a construction Storm Water Management Plan and the use of accepted Best Management Practices (BMP), in accordance with a construction storm water permit. During construction and operations areas of light disturbance that do not report to the storm water pond will be managed using BMPs. Erosion control measures will include stabilization of exposed soils and protection of steep slopes. Exposed soils will be stabilized by mulching, seeding, soil roughening, or chemical stabilization. Steep slopes will be protected by use of geotextiles, temporary slope drains, mulch, or seeding. Sediment controls may include sediment basins, rock dams, sediment filters such as filter cloth, hay bales, erosion blankets, and/or temporary seeding.

Site Preparation

A detailed site plan, including site grading, will be developed for the site during detailed design. The E-ICP site will be graded to provide working levels for support facilities, production, processing, storage tanks, and shipping. Exhibit I is a preliminary plot plan that shows a general layout for all facilities at E-ICP. A detailed design will optimize the layout.

Engineering for the processing and water treatment systems is being conducted. It is anticipated that these facilities will be similar to what will be used at the OST research project, another Shell R&D project, for which more detailed design is complete. A partial list of equipment anticipated for the site is shown on Table 4.1.

Table 4.1 Equipment List

Air Blowers	Granular Activated Carbon Beds	Scrapers
Ammonia Circulation Pumps	H_2S Stripper	Separator
Ammonia Stripper Accumulator	H_2S Stripper Accumulator	Skimmings Concentrator
Ammonia Stripper Condensers	H_2S Stripper Condenser	Slop Oil Equalization Tank And Pumps
Ammonia Strippers	H_2S Stripper Inlet Preheat	Slops Pumps
Backhoes	High Pressure Nitrogen Storage Package	Solids Separation Clarifier
Backwash Water Pumps	Influent Transfer Pumps	Solvent Stripper
Bio-Solids Blower	Instrument Air Package	Sour Water Stripper Cooler
Bio-Solids Pump	Lean Sulfinol Heaters	Spent Carbon Feed Tanks
Biotreater Feed Cooler	Lo-Cat Absorber	SRC Pumps
Biotreater Pumps	Lo-Cat Oxidizer Vessel	Stabilizer Reboilers
Boiler Packages	Lo-Cat Slurry Centrifuge	Stand-By Generator
Bulldozers	Lo-Cat Solution Recirculation Tank	Stripper Effluent Coolers
Carbon Regeneration Furnace	MDEA Carbon Beds	Stripper Feed Pumps
Clarifier Sludge Transfer Pumps	MDEA Cooler	Sulfinol Pumps
Coalescing Filter	MDEA Exchangers	Sulfinol Reboilers
Combustion Products Accumulator	MDEA Pumps	Sulfur Pit
Combustion Products Condenser	Membrane Bio-Reactor Unit	Sulfur Product Tank
Concrete Trucks	Nitrogen Storage And Vaporizer	Sulfur Recovery Unit Reaction Furnace
Condensate Pots	NO2 Gas Absorber	Sulfur Seal Pots
Condensate Pumps	NO2 Gas Compressor	Sulfur Slurry Pumps
Converter Heaters	NO2 Gas Condenser	Sump Pumps
Converters	NO2 Gas Recycle Pumps	Supply Trucks
Deaerator Packages	Oil/Water Separators	SWS Overhead Accumulator
Deep Bed Nutshell Filters	Product Pumps	SWS Pumps
Discharge Coolers	Product Tanks	SWS Reboilers
Dissolved Air Flotation Unit	Quench Tank	SWS Strainers
Drills	Quench Water System	Thickener And Pumps
Equalization Tanks And Pumps	Recirculation Pumps	Utility Vehicles
Filter Press	Refrigeration Units	Vapor Catalytic Combustor
Flare Knock Out Pumps	Regenerated Carbon Storage Tanks	Virgin Carbon Make-Up Silo
Flare Package	Reverse Osmosis Unit	Water Heaters
Fuel Trucks	Sanitary Septic System	Water Pumps
Gas Burners	Scot Cargon Filters	Water Storage Tanks
Gas Compresors	Scot Pumps	Water Trucks

Gas Heaters	Scot Reflux Accumulator	Wet Well/Surge Tank
Glycol Chillers	Scot Regenerator	

Prior to site preparation, the boundaries of the 160-acre site lease will be marked. The storm water pond will be constructed, clean water diversion ditches installed, and BMPs will be implemented. Larger trees will be cut and made available for firewood through a commercial operator. Stumps will be disposed of by burning on site (with the appropriate burn permits) or by hauling off site. Stumps may also be buried on site. Remaining vegetation will be cut and chipped with chips left on the ground to be incorporated into the salvaged soil. Approximately 12 inches of soil will be segregated, removed and deposited in soil storage areas. In areas where 12 inches of soil is not available for salvage, reasonable available soil material will be removed, with a targeted minimum of six inches removed in any location, where available. This material may not all be soil by strict definition, but will support vegetation and hence be suitable for plant growth medium. The soil stockpiles will be seeded with the BLM approved grass seed mix to minimize erosion and associated loss of soil (Section 5.0). Soil stockpiles will also be covered with an erosion control netting to further minimize erosion and promote growth.

4.3 In-situ Conversion Process

Ground freezing as a means of containment was introduced in the 1800s to temporarily strengthen soils and serve as a barrier to ground water flow. Ground freezing continues to be applied in civil and geotechnical engineering to exclude water from areas being excavated; to seal tunnels, mine shafts, or other subsurface structures against flooding from ground water; and to enclose and/or consolidate hazardous or radioactive contaminants during remediation or reclamation operations. The containment system for the E-ICP will consist of a series of drill holes in a close pattern (Exhibit J). Refrigerant will be circulated through the holes in a closed circuit to create a barrier of frozen water in a rock matrix.

The construction of the freeze wall containment area for the E-ICP will allow heating of oil shale to recover products while preventing mixing of products with the ground water system. A freeze wall will be established for the depth of the freeze holes and will encircle the resource target zone creating an enclosed freeze wall containment area. The resource target zone is a carefully selected portion of the oil shale resource. The top and bottom of the resource target zone are low permeability layers that will prevent movement of converted hydrocarbons in a vertical direction. The freeze wall containment area provides lateral containment. The freeze wall will act to prevent liquid movement into or out of the containment area, separating the ground water system from the ICP products. The freeze wall containment area will be maintained and monitored throughout the heating, recovery, and the ground water reclamation phases of the operation. Since the freeze wall will take an extended period of time to thaw, the freeze wall refrigerant circulation may be stopped prior to final flushing if it can be demonstrated that the containment area is sufficiently rinsed and collected rinse water meets appropriate quality.

Freeze Wall Construction

Upon completion of site preparation, about 150-200 freeze holes will be drilled approximately 8 feet apart. These freeze holes will be drilled to a depth of approximately 2,000 feet or the depth of the entire target interval. The configuration of a typical freeze hole is shown on Figure 4.3. Both air-mist fluid drilling and aerated fluid drilling methods are under consideration and are being tested at this time. The air-mist method produces greater volumes of water compared to the aerated fluid method. Drilling methods will be selected based on field conditions and technology. Drilling fluids and additives that may be used are shown in Table 4.2.

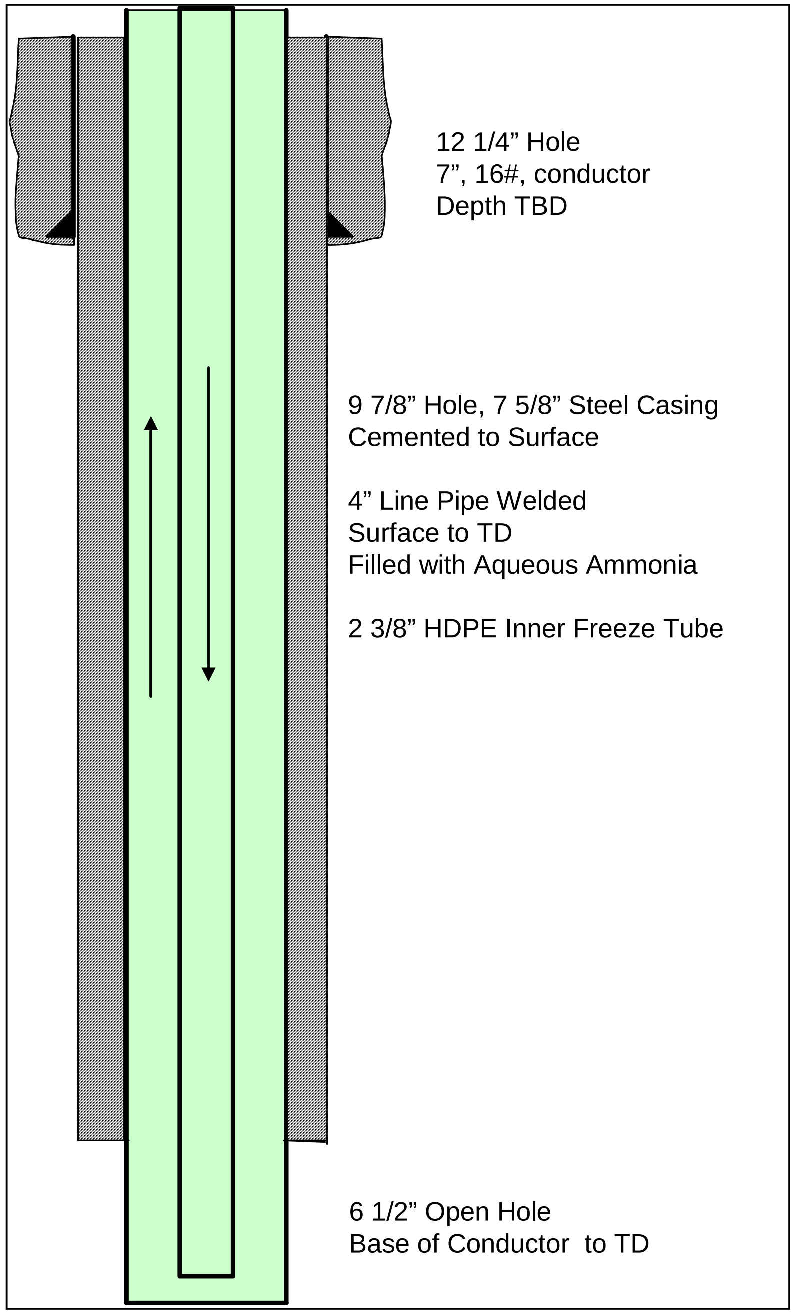

Figure 4.3 Typical Freeze Hole

Table 4.2 Inventory of Drilling Fluid Additives for Use by Shell and its Contractors

Coring and Drilling Projects
Foamers
Baroid Quik-Foam
Bachman 485
Weatherford WFT FM A-100
Gels and Polymers
Baroid EZ-Mud - polymer
Halliburton Quik-Gel – bentonite gel
Halliburton Mud-Gel – bentonite gel
Baroid Quik-Trol and Quik-Trol LV - polymer
Benseal– for plugging back holes and hole abandonment
Baroid Holeplug – for plugging back holes and hole abandonment
Thread Compounds
Jet Lube Well Guard
MacDermid – Vinoleo thread compound for fiberglass casing
Best-O-Life Silicone GGT
Best-O-Life 72733 high temperature high pressure thread compound – not used in water wells or monitor holes.
Lub-O-Seal NM-91 anti-seize
Corrosion Inhibitors
Weatherford Corrfoam
Others
Rock Drill Oil R.D.O. ES
Sodium bicarbonate –pH neutralizer
Mazola Corn Oil – to free stuck pipe
Ventura Ultra-Fry (Canola Oil) – to free stuck pipe
Huskey LVI-50 Rod Grease – lubricate drill rods in dry hole

To complete the freeze hole and provide refrigeration for the length of the hole, an interior steel freeze tube will be installed. The bottom of the steel tube will be sealed with an end cap. A smaller diameter high-density polyethylene (HDPE) inner freeze tube will be installed inside of the steel freeze tube. It is expected to take about six months to complete the drilling for the freeze wall pattern.

Once the drilling is completed, refrigerant at an approximate temperature of -45º F is pumped through the holes. The interior HPDE tube will be used to convey the chilled aqua ammonia to the bottom of the hole and the outer steel pipe allows the solution to return to the surface for recycling back to the refrigeration system (Figure 4.3).

The area immediately surrounding the holes is frozen first. The frozen area continues to expand as refrigerant is re-circulated down each hole. Eventually the frozen "columns" expand to the point where the approximately concentric frozen "columns" are joined and a freeze wall barrier is created as shown in Figure 4.4.

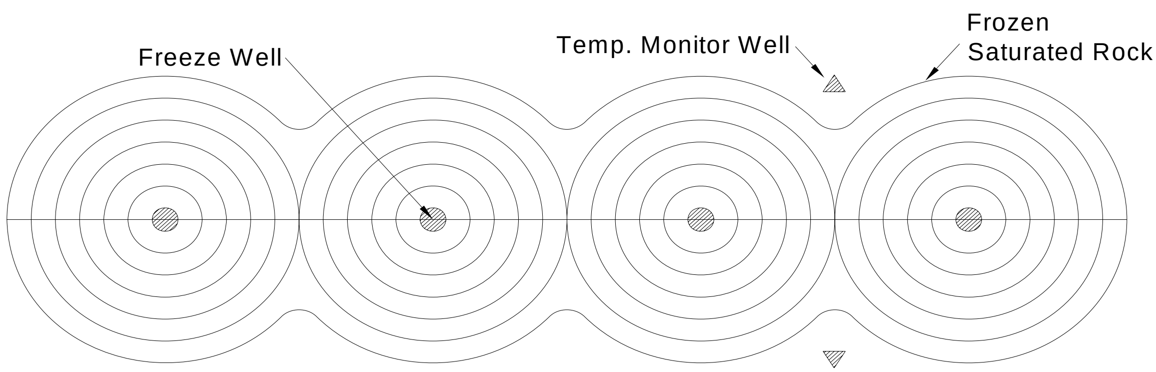

Figure 4.4 Freeze Well

It is anticipated to take approximately 12 to 18 months to establish a continuous freeze wall barrier.

As the circulation of refrigerant continues, the thickness of the freeze wall will continue to grow, although the rate of growth will slow as the wall thickens. Heating in the interior of the containment zone will inhibit inward growth of the freeze wall barrier.

Once the freeze wall is in place, there will be little change in the temperature of the wall throughout the thickness because of the insulating capacity of the rock matrix. In addition, the system can withstand power outages without damaging the integrity of the freeze wall due to the temperature and thickness.

Between the freeze wall and the heated area is a buffer zone about 125 ft wide that prevents the freezing and heating form interfering with each other. The exact width of the buffer depends on the thermal conductivity of the rock and the time required to heat the patterns. The oil shale has a fairly low thermal conductivity, which keeps the buffer to a manageable size and contributes to uniform, steady heating.

The freeze wall containment area will be maintained until it can be demonstrated that the containment system is sufficiently rinsed and collected rinse water meets appropriate quality. The period of time for operation of the freeze wall containment area is currently estimated to be approximately ten to eleven years.

Refrigeration System

As the freeze holes are being drilled and completed, the refrigeration system will be constructed. The refrigeration system will be installed before other process equipment due to the length of time required to establish the freeze wall containment barrier. The plant will contain several refrigeration units, which can each be operated separately.

Appropriate procedures for storage, handling and emergency response for ammonia chemicals used in the refrigeration system will be included in the Process Safety Management Manual to be developed in accordance with Occupational Safety and Health Administration regulations prior to operation. Emergency response procedures including procedures for clean-up of spills and notification requirements will be included in the Emergency Response Plan (ERP) to be developed prior to operations.

Dewatering Within the Freeze Wall Containment Area

Once the freeze wall has been established, drilling will occur inside the freeze wall containment area for both producer wells and heater holes. The functions of these are discussed in later sections of this Operating Plan. Some of the producer holes will initially serve as ground water dewatering holes and their function as dewatering holes is discussed in this section.

There will be several producer holes used for dewatering inside the freeze wall containment area. Figure 4.8 shows the configuration of these holes. A submersible pump is used for dewatering.

Ground water removed from inside the freeze wall containment area prior to heating will be injected into wells located down gradient, and outside the freeze wall or used in the process. This will be accomplished through an above ground piping network that allows this water to be directed from dewatering holes to injection wells. Figure 4.5 shows a typical injection well.

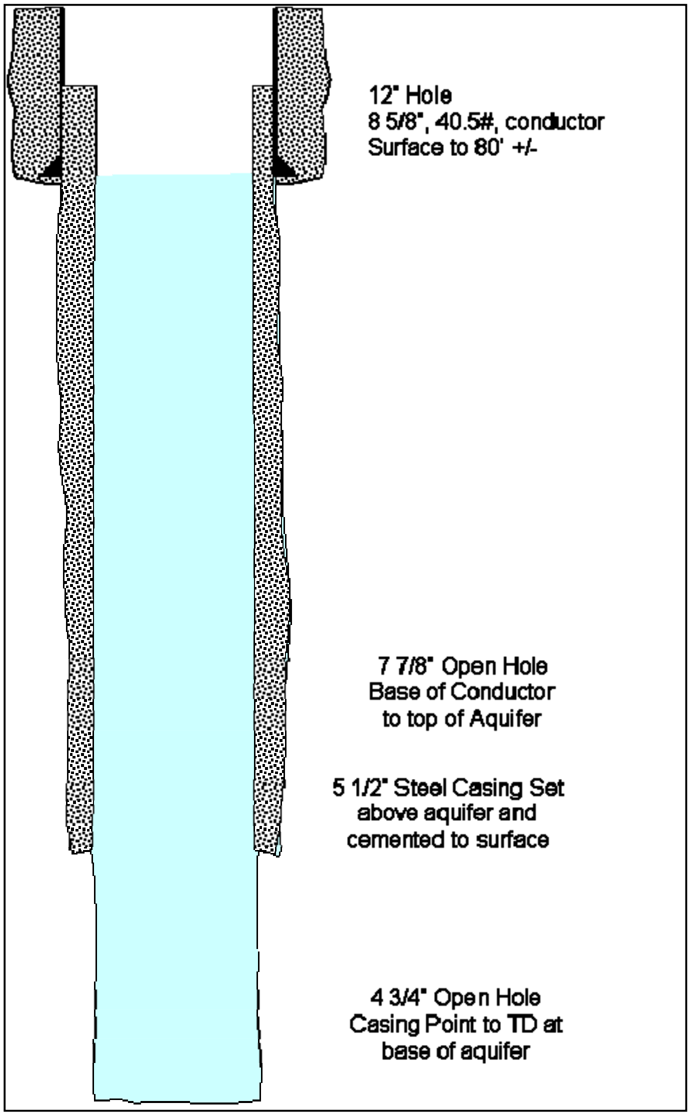

Figure 4.5 Typical Injection Well

Two to four injection wells will be installed outside of the freeze wall as shown on Exhibit J; one upper strata and one lower strata. The dewatering phase is expected to last approximately 4 months, but actual time will be determined by dewatering efficiency.

Once the ability to pump water slows to the point that dewatering is no longer economical or feasible, dewatering operations will cease. During dewatering, the water being re-injected will be monitored periodically for water quality prior to re-injection to ensure that the water is being re-injected into the appropriate strata and that existing classified beneficial uses are not diminished. Dewatering and re-injection flow rates will also be monitored to allow calculation of the amount of water taken from the containment zone and associated rate of re-injection.

Heater System

The R&D project will include about 70 to 100 vertical heaters spaced 20 ft to 40 ft apart. The bare electrode heaters for the proposed location are about 1,950 ft long and are designed to concentrate most of their heat output in the bottom 1,000 ft.

Figure 4.6 shows the cross sectional view of the bare electrode heaters used in E-ICP. The bare electrode heaters will be located in three adjacent wells spaced about 20 - 40 ft apart in the target zone and electrically connected together at the bottom below the target zone. The three electrode wells are electrically configured as a three-phase Wye circuit, with the neutral connection at the bottom connection end. This forms a three-electrode “triad”.

The E-ICP bare electrode heater has three sections: an overburden section, a target zone, and a contact section.

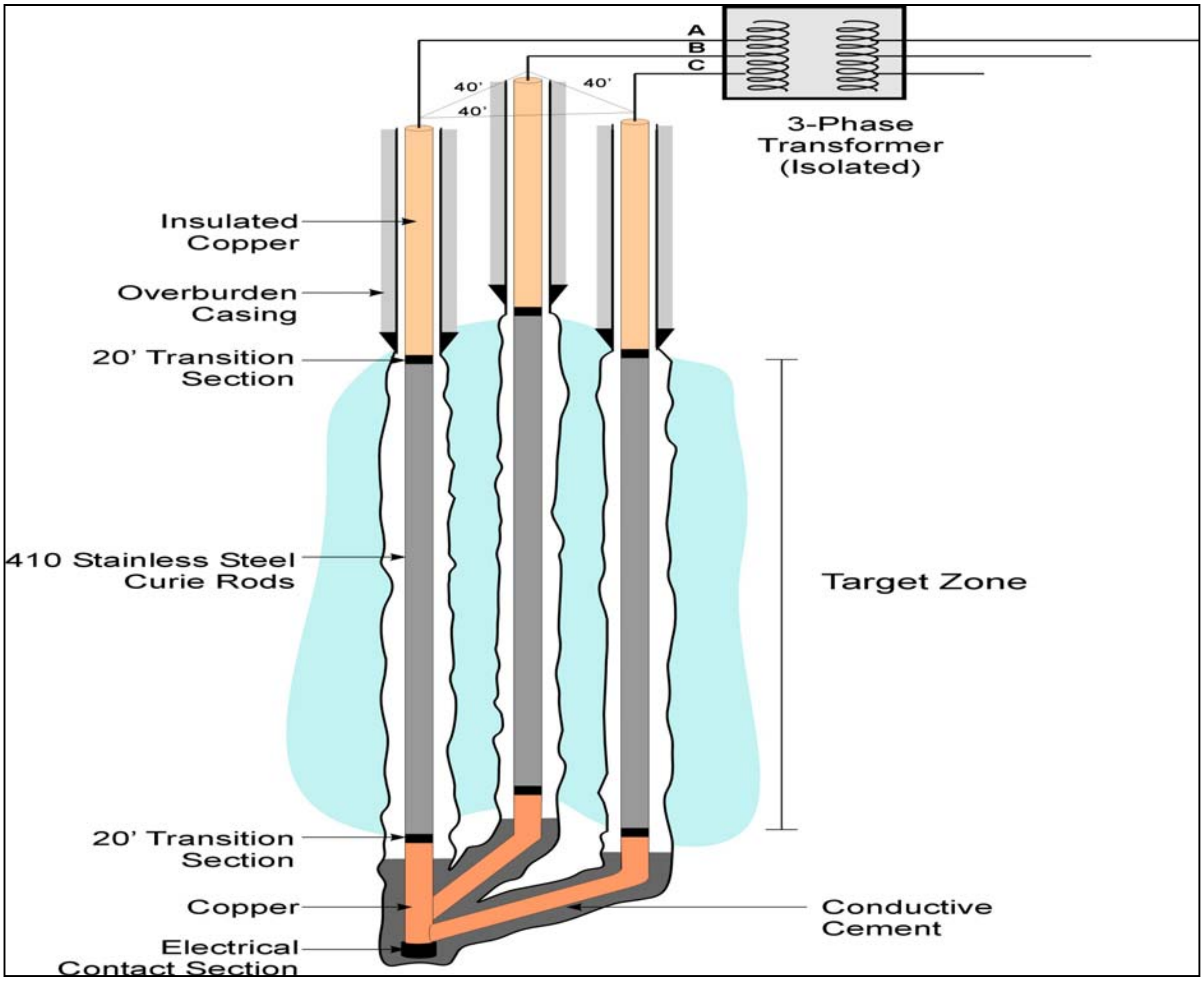

Figure 4.6 Typical Bare Electrode Heater Triad

The well is cased and cemented conventionally in the overburden. The electrode is insulated in the overburden section and consists of a copper rod with polymer insulation to prevent shorting to the casing.

A 6.5 inch hole is drilled in the target section. In the target zone, R-7 through R-2, the bare electrode heater will consist of a 410 SS rod of 1.5 inch diameter. The 410 SS alloy is preferred because of its high Curie temperature (1340 °F), low cost (12% Cr, 0% Ni), resistance to high temperature sulfidation (~20 mils/yr at 1300 °F), low galvanic corrosion, and high temperature creep strength.

At the top and bottom of the heated section are short thermal transition sections (~20 ft) of 347H SS clad copper. These transition sections provide the separation between the high temperature section and the upper and lower copper sections.

The lower intercept section is made from copper rod. The contactor section at the bottom is constructed from copper clad steel.

The three electrode wells in a triad are directionally drilled vertically until the bottom of the target zone. The first well is drilled straight and vertical. The two other wells are directionally drilled straight and parallel to the first well through the target section at a 20 ft to 40 ft separation. Below the target section the second and third wells are deviated by directional drilling to intercept the first well at the bottom.

Figure 4.7 is a sketch of the areal layout of the three (A, B, and C) electrical phases. At the surface, each triad of heaters is connected to an isolated three-phase transformer. Each triad has its own isolated three-phase transformer so there are no conductive paths between the isolated circuits and the rest of the triads or the electrical grid – therefore it is physically impossible for currents to flow to distant electrical sinks. This electrical configuration alone is a substantial cost savings relative to the isolated single phase transformers used for pipe in pepe heaters in conventional ICP (savings of approximately one billion dollars in upfront capital).

In E-ICP, the oil shale behaves as an ohmic resistive element until the formation water has been evaporated. Ohmic heating occurs in the volume between the electrode heater wells and is in addition to thermal conduction heating from the electrode heater wells themselves. Once the water in the oil shale is evaporated, the oil shale becomes highly electrically insulating and the electrical heating is then confined to the wellbore. The bare electrode heater then behaves as a simple thermal conduction heater as in conventional ICP.

E-ICP is not practical unless the bare electrode heater has self-regulating Curie properties that prevent overheating near the top of the target zone, where the voltage is the highest and maximum current leakage occurs. The Curie effect also prevents overheating opposite the rich oil shale layers that have the lowest thermal conductivities. Self-regulation can be achieved by using 410 SS for the bare electrode heater. Because of its ferromagnetic properties, 410 SS behaves as a self-regulating Curie heater (T Curie = 1330 $^{\circ}$F) when energized with alternating current. Other Curie metals and Curie metal composites are possible, but 410 SS is preferred because it meets all the constraints (Curie temperature, corrosion resistance, creep strength) at the minimum cost.

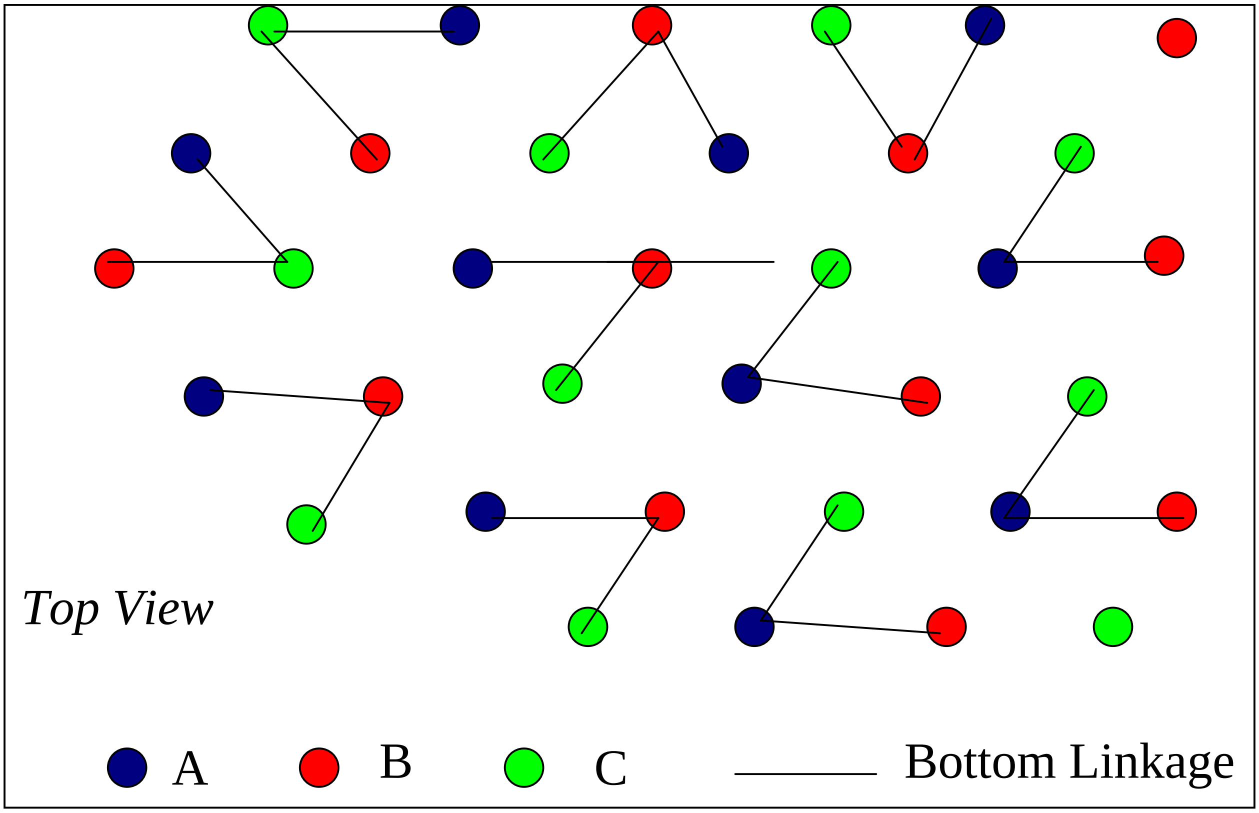

Figure 4.7 Areal Layout of Bare Electrode Heater Triads

The dramatic cost savings of E-ICP is achieved because the bare electrode heater is a simple rod of 410 SS that costs considerably less than a Curie PIP heater. This results in a significant capital savings over the 35-year ICP project lifetime. The E-ICP potentially lowers the heater well capital costs. It therefore may enable economical recovery of hydrocarbons in lower richness oil shale, thus greatly increasing the US oil shale target resource by making much more of the Piceance basin commercially attractive. Shell cost estimates suggest an additional 175 billion barrels of oil shale with richness down to 20 gal/ton would become economically attractive at \$25-\$30/bbl if E-ICP were successful. This 2nd-generation E-ICP heater technology has never been deployed in oil shale, but laboratory data and numerical simulations suggest it has a good probability of being successful.

All the heaters will be installed and energized at about the same time. Heat is injected by thermal conduction only – no steam or heat transfer fluids are injected into the oil shale. The superposition of heat from the array of heaters causes the average reservoir temperature to rise quite uniformly, except within a few feet of the heater holes. Because the process relies on relatively slow thermal conduction, and because the thermal conductivity of oil shale varies by only about a factor of two to three from the richest to the leanest layers, ICP uniformly distributes heat in the target deposit. This results in uniform pyrolysis and high thermal sweep efficiency.

The heaters have to operate between a certain temperature range to achieve heating rates that bring the average reservoir temperature to approximately 600 ºF in approximately four years. The high operating temperature, formation stresses, corrosive gas environment, and long heating duration are severe requirements that have resulted in the development of a new effective heater. Shell continues to work on and improve heater design.

Shell's numerical simulations show that E-ICP will proceed very similarly to the ICP process with self-contained heater wells. At the start, ohmic heating occurs in the oil shale before the free water is vaporized. Water boils first in the near-electrode region and proceeds from the top downwards. After water vaporizes throughout the near-electrode region, electric current flow is confined to the near wellbore and the bare electrode heaters then behave as thermal conduction heaters until pyrolization occurs. The top section of the electrode heater reaches Curie self-regulating temperatures first because of the lower porosities and the absence of dawsonite in the top section. The Curie properties of the electrode heater prevent overheating in the upper section of the formation.

Heating results in expansion of the rock. The rocks have differing thermal conductivities, with the leaner oil shale having greater conductivity than the kerogen-rich oil shale. The design of the heated zone accounts for these conductivities to ensure a sufficient buffer distance to the freeze wall to prevent unacceptable input of heat to the freeze wall. This is a function of the amount of heat put into the system, the conductivity of the rock, the time that the heaters are energized and the distance between the heaters and the freeze wall.

Due to the heating associated with production, heave and subsidence can occur at the surface and compaction can occur within the reservoir. Based upon the small production footprint and the depth of heating, little surface expression of changes within the pyrolyzed zone is anticipated. The surface expressions of heave is expected to be approximately 1.0-1.5 inch and the surface expression of subsidence is expected to be approximately 0.5 – 1.0 inch.

Product Recovery

Upon completion of dewatering, pumps are removed from the dewatering holes and they are converted to producer wells. As heating occurs, the lighter and higher quality vaporized hydrocarbon products, plus steam and non-condensable gases, will flow to the producer holes. Because of the slow heating rate, and the close spacing between holes, the initial reservoir permeability required for fluid transport can be relatively low. There is no need to create permeability by hydraulic or explosive fracturing. The producer wells will collect the converted kerogen products (oil and gas mixed with some water) in the pyrolyzed zone and convey those products to the surface for transport to the processing facilities.

Producer wells will collect the gas and oil produced by the ICP. Initially the producer wells will be used to dewater the freeze wall containment area.

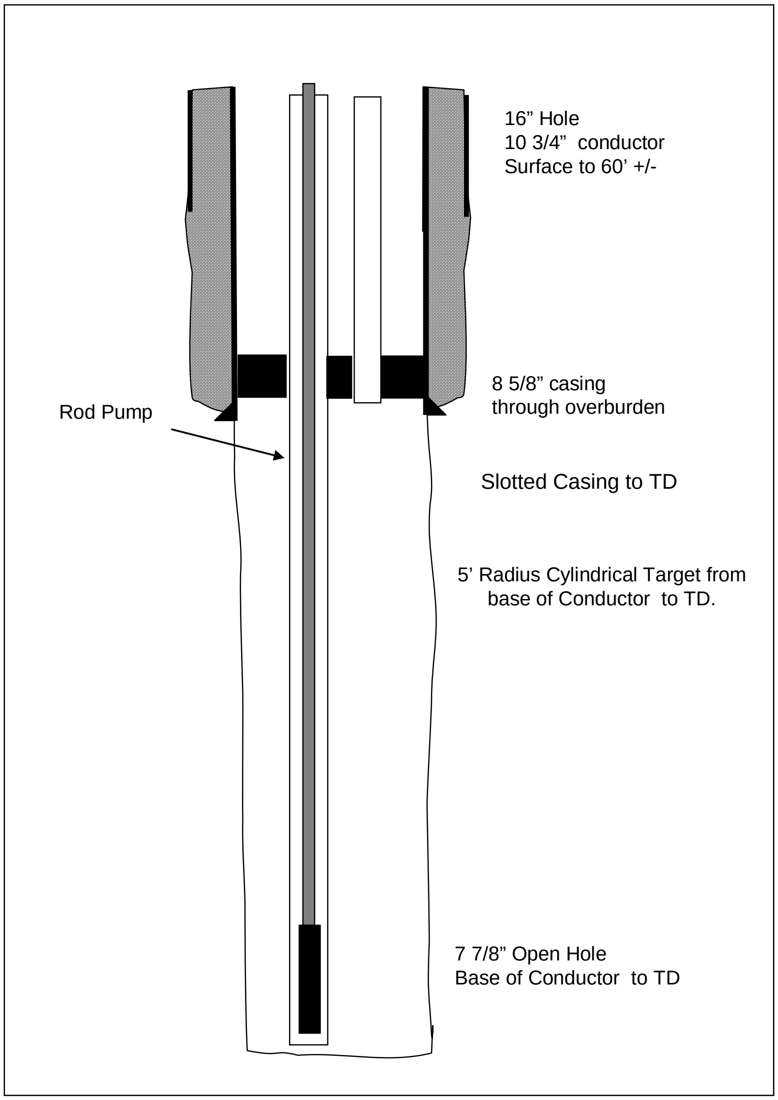

Figure 4.8 Typical Producer Hole

Producer holes are similar in design to traditional oil field wells. They have a perforated liner that allows liquids and gases to flow from the nearby rock into the holes. From there the fluids are pumped to the surface and gathered. Producer holes are installed among the heaters on a ratio of about 5-7 heaters per producer. This R&D project has about 20 producers, which are approximately 1,950 ft deep (Figure 4.8).

A pump with lift assist is used to bring the liquids to the surface. Such lift systems are used on conventional oil and gas production. Standard oil and gas production lift systems, as well as some experimental lift systems, will be used. This will enable operating personnel to determine the best system for use in future operations.

At the start of the heating cycle, cutter stock (purchased diesel or jet fuel) is injected into the inlet of the down-hole production pumps to prevent plugging from bitumen which is produced when the pyrolyzed zone is relatively cool. The cutter stock may also be circulated in the above ground field collection piping to prevent plugging. Both the cutter stock and the treated gas used in the chamber lift system will be recovered and treated in the processing system.

In general, the down hole heating process will be sufficient for release of the hydrocarbons from the kerogen, and movement toward the producer holes. At later stages of production, the hydrocarbons released from the kerogen may be removed with the assistance of water injection holes. These water injection holes will be located inside the freeze wall containment area, but outside the heated pattern. These holes will be used to inject water into the pyrolyzed zone. The intent is to assist in collecting and pumping fluid from the producer holes, while protecting the freeze wall. The recovered fluid (a mixture of water and hydrocarbons) will be collected for further processing.

The temperature of product from the producer holes will be approximately 400 °F. The product is quenched to cool the material for transport to the processing facility. Quench water brought to the well head is mixed with the heated product coming from the producer hole. This results in a mixture of water and hydrocarbon. The mixture is piped to the processing facility at about 250°F.

Oil and gas production is approximately 600 barrels of oil or 1,500 barrels of oil equivalent (oil and gas) per day at full production for the E-ICP.

When production is completed, producer holes will revert back to water collection holes during the cooling and water reclamation phase of the project. The collection system will be used to capture and transport water to the water reclamation plant.

Field Collection Network

The field collection network will consist of headers and piping to collect oil and gas from the producer holes for transport to the processing facility. Figure 4.9 is a photograph of a typical production field piping network. The piping network at the E-ICP site is expected to look similar to that shown in this photograph. Power is distributed throughout the surface of the production zone.

Figure 4.9 Photograph of Field Piping Network

The above ground collection system will operate under a nominal pressure of 60 psi. Pressure is monitored with instrumentation throughout the system, with readouts in the process control room. Visual inspections of the above ground piping network will be made on a regular basis. If there is a drop in pressure in the collection system indicative of a potential leak or break, that portion of the system can be shutoff until repairs are made. Surges in pressure will be relieved by a pressure release valve. Appropriate procedures for storage, handling and emergency response for the product recovery system will be included in Materials Handling and Waste Management Plan or the ERP to be developed for the site.

Processing System

The recovered product will include a mixture of liquid hydrocarbons, gas, and water that will be processed further to remove impurities and ready the products for transport off site or reuse in the recovery process. The recovery process is a typical process used in the oil and gas industry.
The processing system location is shown on Exhibit I with a more detailed, process block flow diagram shown on Figure 4.10.

The initial processing will separate the recovered product into three streams: liquid hydrocarbons, sour gas, and sour water. The term sour refers to the presence of sulfur compounds and carbon dioxide. Once the three streams have been separated, each stream is further processed to remove impurities. Except as noted in the following discussions, the waste streams generated during much of the processing are recycled back into the processing for further treating.

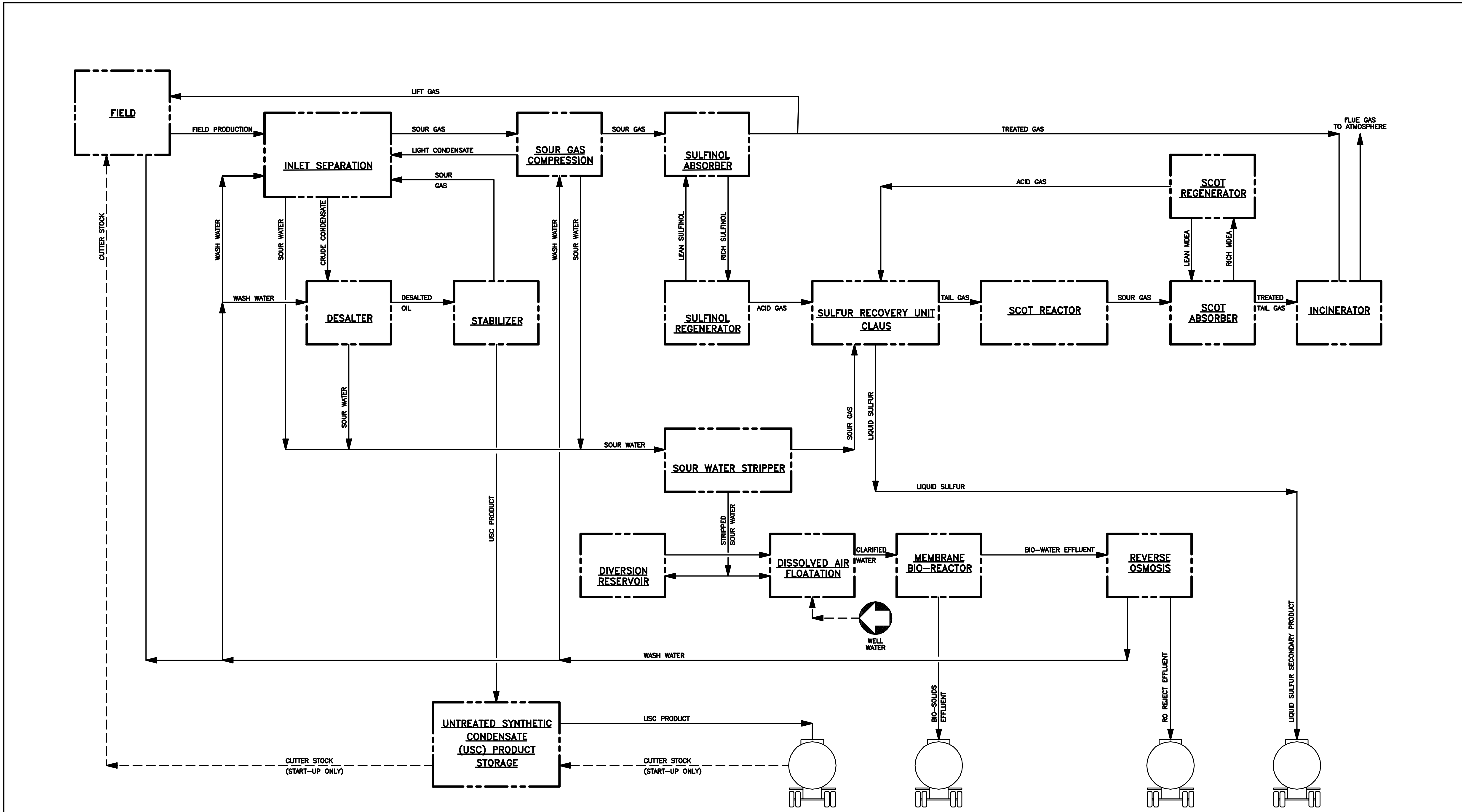

FIGURE 4.10

PROCESSING BLOCK FLOW DIAGRAM
E-ICP Project

Liquid Hydrocarbons

The liquid hydrocarbons go through a two-step process to remove additional water and gas and create the liquid hydrocarbon product. The first step in the process will involve removal of salt in the hydrocarbons through a desalting process. The hydrocarbon product is mixed with water and the salt is dissolved. The oil and water mixture is then separated using large electro-charged plates. The salty water is pulled to the bottom and the cleaned oil floats on top. The salty water is then sent for water treatment along with the sour water and the oil moves on to the next step.

The second step involves stabilizing the hydrocarbon product for transport through a distillation process. The distillation process separates the lighter gaseous and water fractions from the heavier liquid fractions and lowers the vapor pressure in the heavier fractions to that allowed for storage and transport. The liquid and gaseous streams are returned to the processing system for further processing.

The liquid hydrocarbon product is then sent to storage tanks. The product, known as Untreated Synthetic Condensate (USC) will be stored in tanks located as shown on Exhibit I prior to transport off site. The tanks will be located within a containment area with curbing to contain any spills. Any spills will be collected and sent back to the processing system.

USC will be shipped off site for further processing. The tank loading area is a concrete area with curbed containment. Any spills will be collected and sent back to the processing system. The truck loading area will be equipped with heat sensors that control a foam system for fire suppression, if needed.

Gas Stream

The gas stream separated from the hydrocarbon product is treated through a multi-step process to remove sulfur and any remaining hydrocarbons and water. Hydrocarbons and water removed during the gas stream processing are returned to the hydrocarbon or sour water processing streams.

The gas is first compressed and cooled. Any condensed sour water and hydrocarbons are collected and sent back for further processing. The gas is then passed through columns and contacted with an amine-based solution that will absorb organic sulfur compounds, carbon dioxide, and acids. The treated gas collected after passing through the columns is then sent to the chamber lift system for use in product recovery, or used to supplement site fuel needs, or is incinerated. The solution is further processed to remove the high sulfur content gas and carbon dioxide and is then recycled back for reuse. The acid gas from the solution is sent to a conventional Claus sulfur recovery unit where it is converted to liquid sulfur. Gas which does not get converted to liquid sulfur in the sulfur recovery unit undergoes further treatment in a conventional SCOT (Shell Claus Offgas Treating) unit to remove the bulk of the remaining sulfur compounds. Methyl diethanolamine (MDEA) is used to strip the organic sulfur in this processing segment and then the MDEA is regenerated for reuse.

The sour gas processing employs the use of Sulfinol M, a proprietary solution containing MDEA, Sulfolane, and water. The MDEA and Sulfolane will be stored in tanks located within the processing system area (see Exhibit I for the processing area location). The Sulfolane and MDEA will be trucked to the site and unloaded into the tanks. Both the Sulfolane and MDEA are recycled for reuse in the process so large quantities are not required to be shipped to the site on a regular basis.

The gas processing results in products that include treated gas and liquid sulfur. The liquid sulfur will be stored in an enclosed concrete vault. The concrete vault will include steam coils in the bottom to maintain the sulfur as a liquid until shipped offsite. The tanker will be loaded in a curbed, concrete loadout area adjacent to the processing facility and concrete vault. Any spills will be collected and returned to the processing facility.

The treated gas will be incinerated on site, or used to supplement natural gas requirements used in processing. An incinerator was chosen to control the burn temperature to reduce the carbon monoxide and NO_x emissions. The incinerator operates at a temperature of approximately 1500° F. The exhaust gas from the incinerator is composed mainly of nitrogen, carbon dioxide, and water vapor. It also contains smaller amounts of nitrogen oxides, sulfur oxides, and carbon monoxide. A permit will be obtained from the Colorado Air Pollution Control Division for the incinerator exhaust gas.

As in other conventional treatment facilities for oil and gas, over pressure protection systems are provided as a safety feature. These safety systems provide pressure relief through a piping system that terminates at a lighted flare. The flare combusts any hydrocarbon in the relief stream to prevent the undesirable accumulation of combustible vapor. The flare location is shown on Exhibit I. The flare will not be routinely used, but is for emergency pressure release.

Water Stream

The sour water stream is run through a multi-step process to improve the water quality for reuse or discharge. The first step is a distillation process that removes ammonia, hydrogen sulfide gas, and light hydrocarbons. The vapor is sent for further treating in the gas stream segment of the processing system. The water is sent to a flotation cell and compressed air is used to generate gas bubbles that carry hydrocarbons and solids to the surface of the water in a froth layer that is then skimmed off. The froth layer is stored in a tank for eventual shipment from the site. The water continues to the next step of processing which is the membrane bio-reactor. The membrane bio-reactor uses bacteria, protozoa, and rotifers to remove organic material and convert this matter to biomass and other byproducts such as carbon dioxide, nitrogen gas and sulfates. Excess biosolids are collected and stored in a 214,000 gallon tank for shipment offsite. The water then goes through a reverse osmosis process to remove dissolved salts and other ions. Reject water from the reverse osmosis is directed into a tank for storage and transport offsite. Clean water is recycled back for use in the as quench water or in the processing facility.

The only additions for the water processing are compressed air and the bacteria, protozoa and rotifers. Tanks for storage of waste streams from the water treatment (air flotation solids, excess biosolids, and reject water from the reverse osmosis) will be located within concrete lined and curbed containment. The loadout area will be located north of the storm water pond as shown on Exhibit I and will also be a concrete lined and contained area. Any spilled materials will be sent back to one of these storage tanks.

The purified water stream is recycled for use as boiler feed water, washes for condenser units and as temperature regulating quench water. Any water not needed for the project will be discharged to the Yellow Creek drainage following treatment to the applicable standards. A Colorado Discharge Permit System permit will be obtained from the Colorado Water Quality Control Division for this discharge.

Processing System Pilot Scale Test Skids

Small "slipstream" volumes of gas, oil, and sour water will be processed in pilot scale test facilities located on skids to provide easy movement. These small plants will be used to conduct testing and collect data on USC processing methods. The pilot scale tests will be conducted within the process facilities area. Pilot scale testing will be used to evaluate the potential for additional processes to assist in further refining the products from the ICP process. Wastes from the pilot scale facilities will be handled in the process water treatment plant or the gas cleaning systems. Spills will be captured and treated in the process water treatment plant.

Process Water Pond

The Process Water Pond is a lined pond that is used as storage capacity for the stripped sour water from the Sour Water Stripper. This pond will be used to provide extra storage and in the event that the Dissolved Air Floatation, Membrane Bio-Reactor, or the Reverse Osmosis Units are off line for maintenance or repair or during periods when additional storage is needed. The stripped sour water can be diverted and stored in the Process Water Pond until the water treatment units are functional again. It is expected that the pond will be used for storage on a routine basis and will not remain empty for long periods of time. Pond sizing and design will be defined by further engineering studies.

The process water pond will be fenced with an eight-foot high chain link fence to prevent wildlife from entering the pond and causing liner damage.

4.4 Recovery Efficiency and Energy Balance

Although Shell's economic model contains many inputs, ICP economics depends heavily on the following three subsurface process performance metrics:

- Recovery Efficiency – the ratio of produced ICP oil to Fischer-assay oil in place
- Energy Balance – the ratio BTU's out as oil and gas to the BTU's input via electrical power
- Product Quality – the composition and properties of produced ICP fluids (e.g. API gravity)

The high recovery efficiency of ICP (~100% of Fischer assay BOE, Barrel of Oil Equivalent) results from the slow, uniform heating process and also from the in situ vaporization of the hydrocarbons.

ICP makes more complete use of the oil shale resource. The entire oil shale column is pyrolized, including lower grade zones that could not be mined economically for surface retorting. ICP also can access deeper oil shale resources than are uneconomical to mine. Overall, much more oil and gas may be recovered from a given area utilizing the ICP process.

There are locations of thick resources in the Piceance Basin that could yield in excess of one million barrels of shale oil per acre. The economics of the ICP process could be improved dramatically if bare electrode heaters were installed that combined both thermal conduction heating with some ohmic heating of the oil shale formation. The bare electrode ICP process is called E-ICP and is a patented 2nd-generation in-situ heating technology. By dramatically lowering the heater well capital costs, E-ICP may economically recover hydrocarbons in lower richness oil shale, thus greatly increasing the US oil shale target resource by making much more of the Piceance basin commercially attractive.

ICP requires energy input for heating, freeze wall construction, processing, and maintenance but still generates three to four times as much net energy as it consumes. This energy ratio is very comparable to steam injection in heavy oil projects.

Support Facilities

Support facilities associated with the E-ICP and processing facilities include the building complex near the project entrance, the utility building and substations, a process control and locker/change house building, loading / unloading facilities, construction support, and driller support. Sanitary wastes from these facilities will be piped to the process water treatment building and treated in the Bio-Reactor. Solid waste (trash) will be disposed off site at an approved facility.

Security will be provided at the site. Trucks, visitors and employees will be required to enter through the security gate to access the work site.

The maximum number of people employed at the site will occur during construction and drilling. An estimated maximum of approximately 700 individuals will be employed at the site during the construction and drilling period. Once construction is completed, the maximum expected employment at the site will be approximately 150. Shifts will typically be nine-hours per day, with some operators working twelve hour shifts. Parking will be available in a parking lot just inside the main gate. An automated exit gate will be installed. Traffic will range from 300 to 650 vehicles per day, including personal automobiles and supply and product trucks.

Emergency Response personnel will be on site or on call. Written emergency procedures will be included in the Process Safety Management Manual to be developed in accordance with Occupational Safety and Health Administration regulations prior to operation and in the Spill Prevention Control and Countermeasures (SPCC) and Emergency Response Plan (ERP). Copies of this manual will be located in the control room and guard shack. Employee training will include safety, chemical handling, spill control and cleanup, and other emergency procedures.

Buildings

Buildings that are likely to be needed include a process control and change house, guard shack and gate, warehouse, shop building, laboratory building, and potable water tank and delivery system (see Exhibit I). The warehousing and maintenance shop will provide routine services for the operation. Trailers will be used for support of drilling activities e.g. warehousing, change house and offices.

Spill containment and cleanup procedures developed as part of the SPCC and the ERP will be implemented for any regulated chemicals used or stored in these facilities.

Utilities

Power is brought into the site from an electrical substation constructed, owned, and operated by White River Electric Association (WREA), just outside the permit boundary. Substations on the project site will be maintained on site for power distribution to the project. It is anticipated that WREA will obtain the permits necessary for the substation and distribution line. An approximate location is shown on Exhibit I. An electrical sub yard for heaters is located adjacent to the freeze wall containment area to support the heating process. An additional electrical sub yard is located just east of the WREA substation and services the rest of the facilities.

Natural gas is brought on site via a pipeline from a commercial supplier located in proximity to the site and distributed to the processing facility. A stand-by diesel generator is located in the utility building. Arguments of power and gas lines have not been finalized. A small diesel storage tank will be located inside the curbed building to provide fuel for the stand-by generator.

4.5 Water Management

Water requirements vary throughout the project life. Water uses include construction, potable water, dust control, drilling, processing, filling and cooling of the heated interval for reclamation, and rinsing of the zone inside the freeze wall.

Water Supply and Water Requirements

Water will be trucked to the site for construction and drilling activities. Potable water will be trucked to the site throughout the life of the facilities.

Onsite water will be used for most operational uses and will be supplied from water wells drilled for that purpose. A primary and a backup water supply well are planned. The well will supply water needed for processing and reclamation. Peak pumping demand will occur during the fill and cool phase of the reclamation cycle (see Section 5.0). If the water well is available during construction and drilling, then this water will supplement or replace construction and drilling water trucked to the site.

Water needs for each phase of the operation are outlined below. The projected water needs are estimates and are subject to change as additional information becomes available and facility designs are finalized. Water rights required for the project will be acquired prior to the startup of the operation.

Construction Water

Construction water will be trucked to the site as necessary for use in compaction, dust control and miscellaneous construction water needs. Potable water needs during construction will be brought to the site. Water required for drilling will be trucked to the site until water from the on site water supply well is available to supplement or replace trucked water.

Operations and Reclamation Water

Water will be needed for various processing and operating needs. Water removed with the hydrocarbon products will be treated in the processing facilities and recycled or discharged. Figure 4.11 provides a general schematic of the process water management. It is currently anticipated that there will be excess water available during the initial processing period as a result of water within in the freeze wall containment area and that there will be no need for the water supply well to provide water for processing during this initial period. As processing progresses, there will be a need for additional water in processing.

Water is also needed to conduct reclamation filling and cooling of the heated interval within the freeze wall containment barrier as well as rinsing of the heated interval. This water will be a combination of recycle water and make up water from the water supply well as needed. During reclamation a water supply will be needed for initial stages of flushing and cooling. Figure 4.12 provides a general schematic of the reclamation water management.

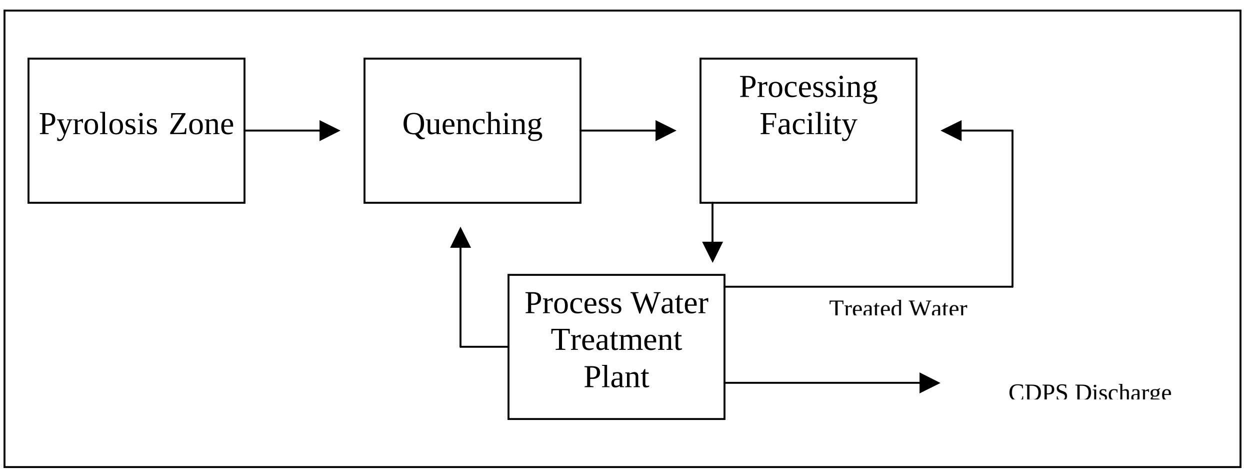

Figure 4.11 Processing Water Management

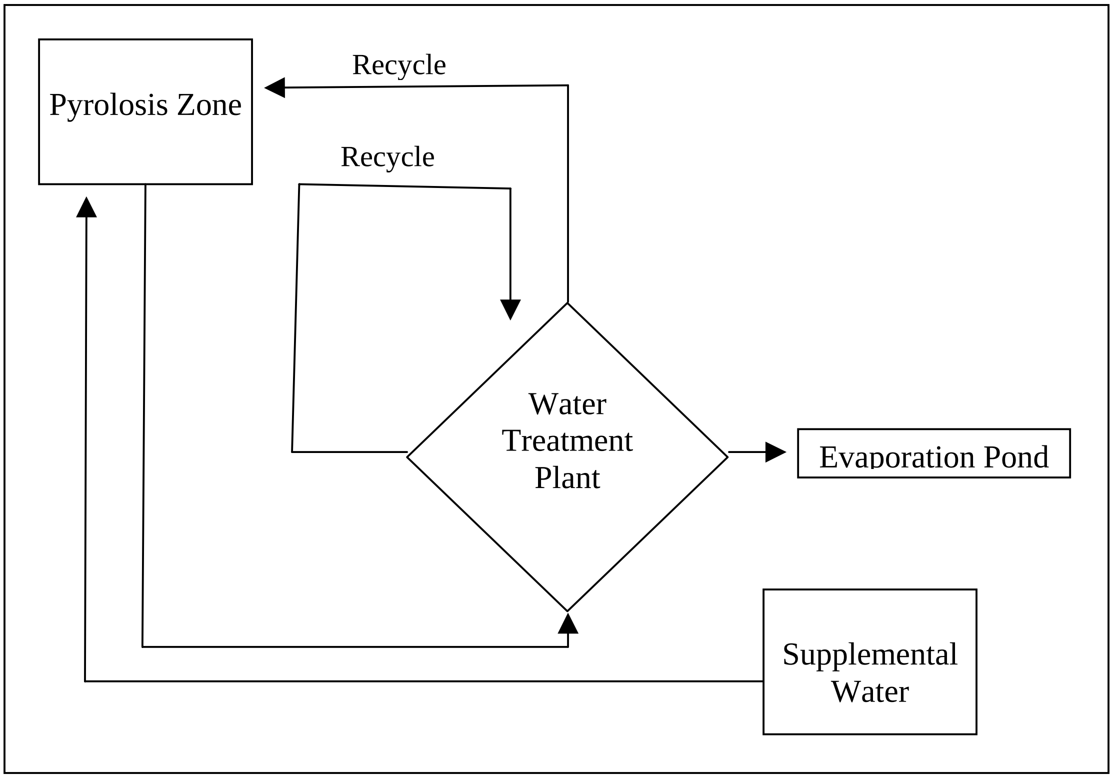

Figure 4.12 Reclamation Water

Water Discharge

Water that cannot be recycled or otherwise used will be treated to appropriate discharge standards in the process water treatment plant and released to a surface drainage under a Colorado Department of Public Health and Environment Colorado Discharge Permit.

Water Injection

Once the freeze wall is formed the containment area will be dewatered by pumping. This intercepted natural ground water will be pumped from the freeze wall containment area and injected down gradient of the freeze wall through injection wells. The injection wells will be permitted with the EPA Underground Injection Control program for Class V injection wells authorized by rule. Water of appropriate quality will be injected into appropriate zones so that similar water quality is maintained. Figure 4.13 shows a typical schematic for water management during dewatering and injection.

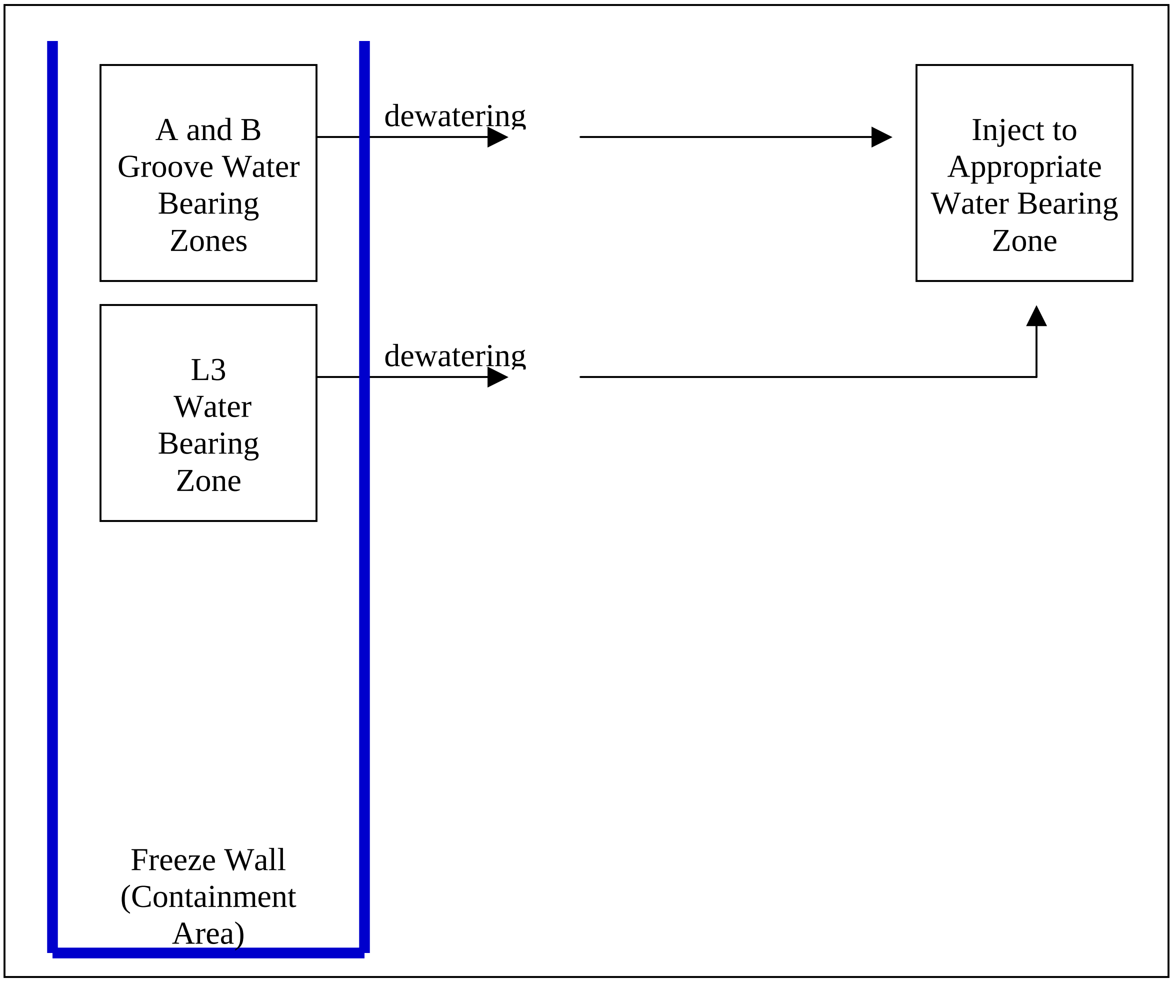

Figure 4.13 Dewatering and Injection Water Management

4.6 By-products and Wastes

During the course of the R&D project, construction and operation, a variety of by-products and waste materials will be generated. They include construction waste, drill hole cuttings, garbage and miscellaneous solid and sanitary wastes.

Surface construction operations will result in a variety of small waste products that could include paper, wood, scrap metal, refuse, garbage, etc. These materials will be collected in appropriate containers and recycled or disposed off site in accordance with applicable regulations

Approximately 200,000 cubic feet of earth and rock materials will be generated during drilling operations for the project. Drill cuttings removed from the drilled holes will be dewatered so the water can be recycled back to the drill rigs. The dewatered cuttings will be placed into a cutting pit as shown on Exhibit I. These non-toxic, non-acid forming drill cuttings will be separated from free water and will be buried below grade. Burial depth and soil coverage will be sufficient such that the materials will not impede revegetation.

During operation, garbage from the site will be collected in appropriate containers and disposed off site. Waste oils, reagents, lab chemicals that are not collected sumps and treated at the water treatment plants will be recycled or disposed off site in accordance with applicable regulations.

Sanitary Waste

A combination of sanitary waste handling methods will be employed. Some sanitary waste, such as that collected in temporary toilet facilities may be shipped to an approved facility for offsite treating and disposal. Any gray water or black water disposed onsite will be treated in an appropriate sewage processing unit or disposed according to standards via an approved septic system with clarifier and drain field.

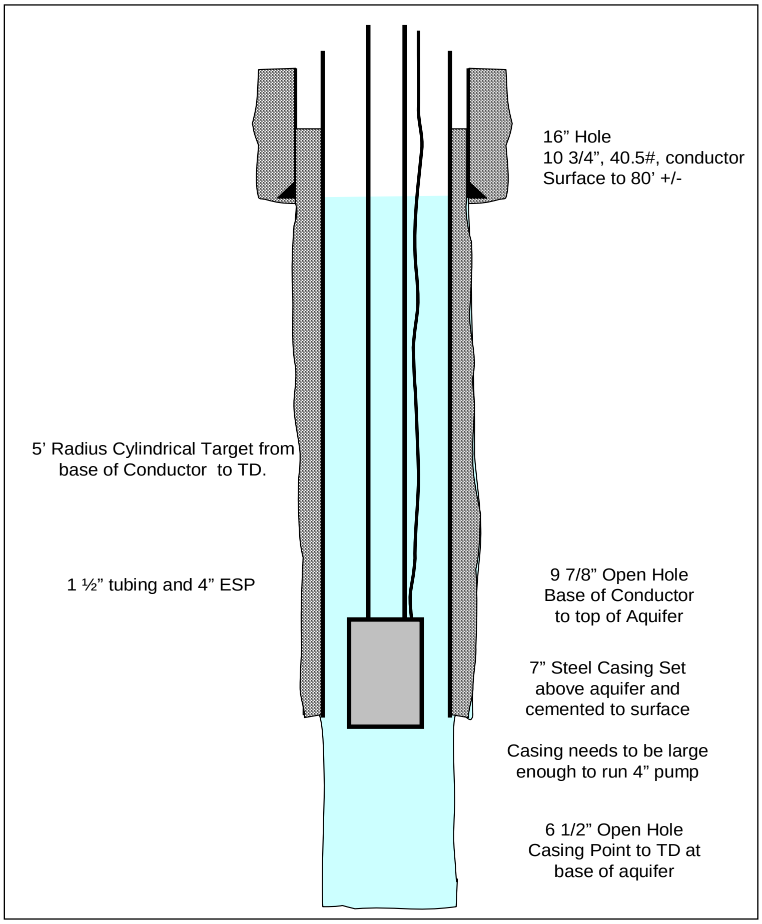

Figure 4.14 Typical Level Monitor Hole

4.7 Monitoring and Response

The E-ICP project is a research, development, and demonstration program designed to demonstrate the ICP, gather additional operating data and information, and allow testing of components and systems. As a result, monitoring is inherent in the design of the project. ICP process monitoring will be designed to gather data on the functioning of the various system components. Shell will conduct extensive compliance monitoring as part of permit requirements, e.g. air, water and mining permits. These will be defined as part of the permitting process.

Because this is an R&D project, extensive monitoring and instrumentation are provided for subsurface analysis. Temperatures, pressures, and levels are measured inside the heated patterns, inside the freeze wall and outside the freeze wall. Figures 4.14 - 4.15 show temperature, geomechanics, and level monitoring sketches.

Outside the freeze wall (Figure 4.17), pumper holes provide secondary containment in the unlikely event hydrocarbon escapes through the wall.

Environmental monitoring that will be done to demonstrate other environmental protection measures for the site are described in this section.

Surface Water Monitoring

A proposed quarterly surface water sampling program will be performed on sampling sites identified in Table 4.3. The locations for these sites are shown in Exhibit L. The sampling parameters are detailed in Table 4.4. All monitoring records will be maintained at the project site.

Table 4.3 E-ICP Surface Water Monitoring Locations

Stream Sites	Upstream	Corral Gulch	CR242
	Downstream	Corral Gulch	CR408
	Upstream	Stake Springs Draw	CR407
	Downstream	Stake Springs Draw	CR411
	Downstream	Yellow Creek	CR255

Table 4.4 Surface Water Sampling Parameters

Parameter	Unit	Parameter	Unit
Discharge	gpm	Boron, dissolved	mg/L
Field pH	SU	Cadmium, dissolved	mg/L
Field Conductivity	umhos/cm	Chromium dissolved	mg/L
Field Temperature	°C	Chromium, Trivalent Dissolved	mg/L
Field Dissolved Oxygen	mg/L	Chromium, Total	mg/L
Field Turbulence	ntu	Copper, dissolved	mg/L
Residue, Filterable (TDS)	mg/L	Iron, total recoverable	mg/L

Table 4.4 Surface Water Sampling Parameters

Parameter	Unit	Parameter	Unit
Calcium, dissolved	mg/L	Lead, dissolved	mg/L
Magnesium, dissolved	mg/L	Manganese, dissolved	mg/L
Sodium, dissolved	mg/L	Mercury, total	mg/L
Hardness as $CaCO_3$	mg/L $CaCO_3$	Nickel, dissolved	mg/L
Bicarbonate as $CaCO_3$	mg/L	Selenium, dissolved	mg/L
Chloride	mg/L	Silver, dissolved	mg/L
Sulfate	mg/L	Zinc, dissolved	mg/L
Sulfide as S	mg/L	Benzene	ug/L
Nitrogen, Ammonia	mg/L	Toluene	ug/L
Nitrate/Nitrite as N	mg/L	Ethylbenzene	ug/L
Arsenic, dissolved	mg/L	Xylene	ug/L

Ground Water Monitoring

Ground water monitoring will be conducted outside of the freeze wall barrier to monitor ground water quality during operation and after reclamation.

Ground water monitoring will consist of monitoring of the water bearing units including the Uinta, A and B Groove, L5, L4 and L3 contingent upon multiple zone completion as discussed below.

Multiple zone completions are being tested for some wells interior to the freeze wall containment at FWT, another Shell R&D Project. Multiple completion wells are equipped with isolation packers to prevent crossflow between zones. Sample ports in the tubing string will allow for collection of pressure data and water samples. Should the information gained from the multiple zone completion wells demonstrate this type of completion is appropriate for ground water quality monitoring, then multiple zone completions could be proposed for ground water monitoring at a later date, subject to approval. Compliance monitoring of these zones will occur using dedicated single completions in each zone.

Planned ground water monitoring for the E-ICP will include one upgradient completion in each unit and downgradient completions in each unit. Additional wells may be installed within the project area for early detection of potential problems.

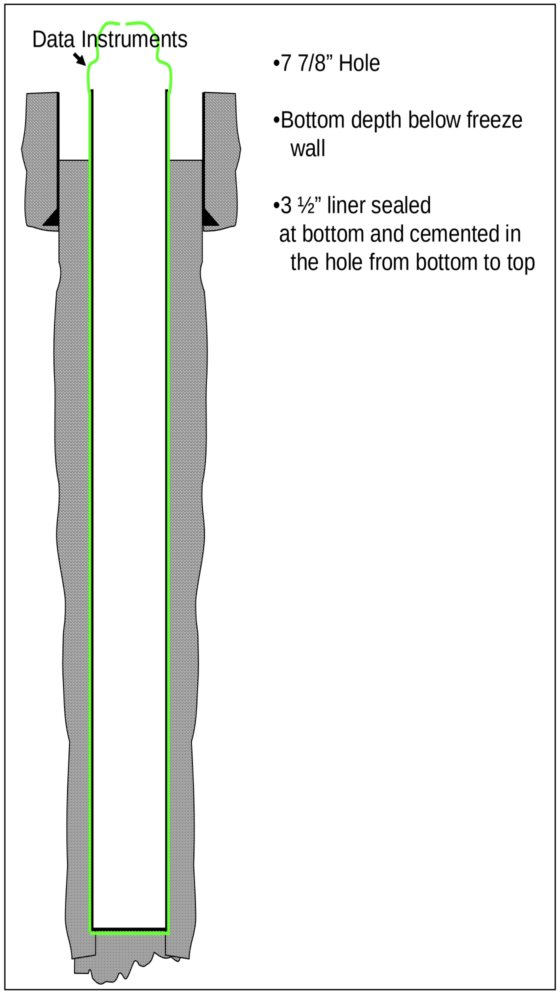

Figure 4.15 Typical Geomechanics Monitor

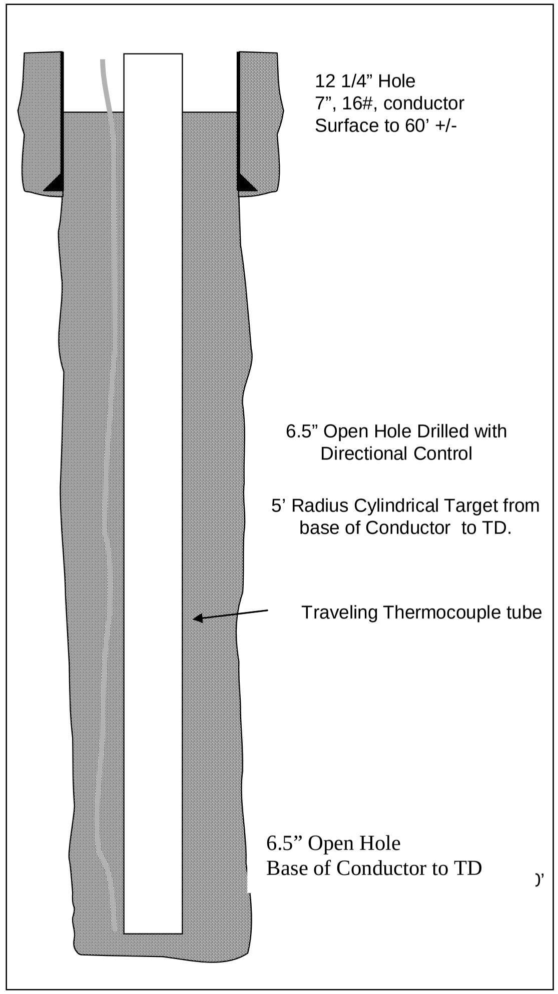

Figure 4.16 Typical Temperature Monitor

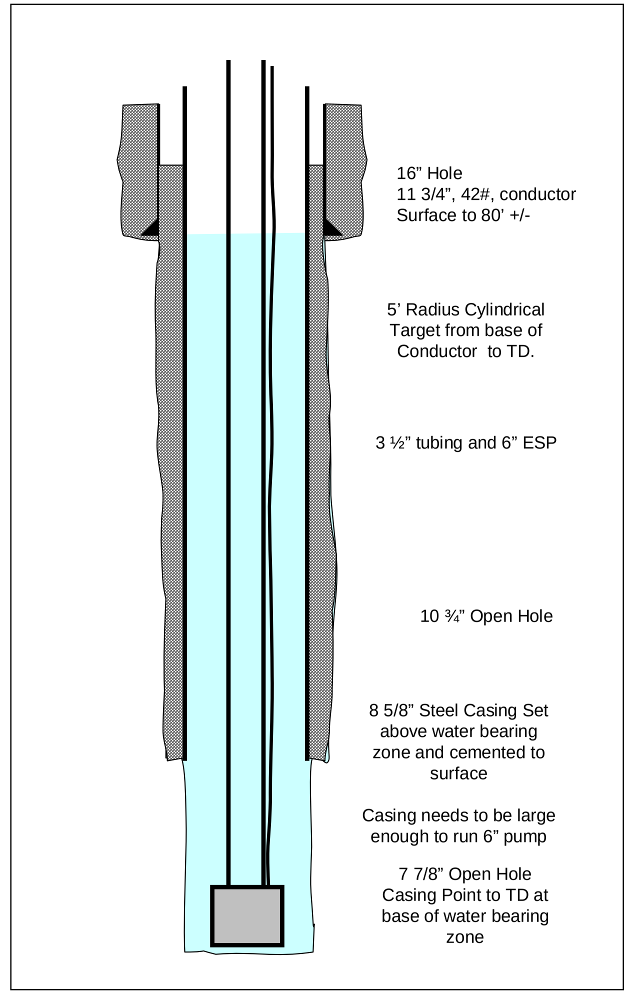

Figure 4.17 Typical Pumper Hole

Facilities Monitoring

Routine visual inspections and operational warning systems will facilitate monitoring of containment systems and features at the E-ICP site. These will include the following:

- Piping systems will be pressured tested prior to use. The pipe systems will have pressure monitors to alert operators when a loss of pressure occurs that could be indicative of a potential problem.
- Sumps within concrete containment areas will be visually monitored on a daily basis and any liquids present in these sumps would be pumped to the process water treatment plant or sent off site for disposal at an appropriate facility.
- Storm water management systems would be inspected on a periodic basis as prescribed in the Storm Water Management Plan.
- A SPCC will be developed to address spill prevention and response for petroleum products at the site. The SPCC plan will prescribe inspection types and frequencies for petroleum related vessels and containments.

In addition, an ERP will be developed for responding to emergencies at the site while ensuring worker safety. The Plan will include designation of responsible personnel, an outline of procedures to be followed, a list of chemicals to be used or stored on site, a list of materials available to control spills or leaks, and notification requirements.