Appendix B

Geothermal Exploration and Drilling

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1. EXPLORATION

1.1 Purpose

Geothermal exploration is carried out to help define the geothermal resource in terms of its geometry, boundaries, controls on permeability, temperature distribution and fluid flow paths. Exploration is not only restricted to the pre-development phase; it may be undertaken after generation begins, perhaps in support of a capacity expansion, to identify locations for make-up production wells (drilled to maintain capacity) or to revise an injection strategy. Exploration programs are typically undertaken in stages, with lower-cost and logistically simpler activities undertaken first, gradually advancing to more costly and complicated activities.

The activities described below may take place on any of the lands considered for leasing at Truckhaven.

1.2 Description of Typical Activities

Exploration nearly always begins with a geochemical survey, in which surface waters (if any) and groundwaters (both thermal and non-thermal) are sampled and analyzed. This may involve creating access to areas with no roads or very poor roads (using four-wheel drive vehicles or on foot). In vegetated areas, some cutting of vegetation may be required for access; however, this is unlikely to be the case at Truckhaven, where the vegetation is generally low and sparse. Since there are no springs at the Truckhaven site, sampling of groundwater would entail either drilling wells or using existing wells. Water samples are collected into sealed plastic bottles and taken off-site for analysis. Small amounts of chemicals (such as NaOH) are often placed in the sample bottles prior to sampling to stabilize certain dissolved elements in the sampled water and avoid precipitation in the sample bottle.

In addition, soil gases may be measured by temporarily installing gas collectors. Soil gas sampling may result in minor disturbances to a number of small (< 3 ft^2) areas since the sensors

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are partially buried. The gas collectors are left for a few days before they are removed from the site. Other than this, chemical sampling generally leaves no "footprint."

Geologic mapping is also a common geothermal exploration activity. Before working in the field, it is common to evaluate existing maps, aerial photos and satellite images. Subsequently, the geologist makes on-the-ground observations to obtain more geologic detail and to sample rock units for petrologic or other analyses. This involves obtaining access to the area by some means (often setting out on foot from existing roads or trails), but there is little if any impact on the area being mapped.

Geophysical surveys may also be undertaken, using one of several methods. Airborne methods (gravity, magnetic, IR, etc.) have no impact. Other surveys that may be undertaken could include gravity, magnetic, seismic, resistivity, and measurements of ground temperature by one of several means. The process of and potential disturbances from these various geophysical techniques are discussed below.

Gravity and magnetic surveys are passive measurements. A gravimeter or magnetometer is moved around the area, and measurements are taken at convenient locations, typically along roads. Where road access is limited, the measuring equipment must be carried to each measurement site. This is typically done either on foot, or by using pack animals or all-terrain vehicles. The amount of disturbance to the land from such activities is minimal.

Seismic surveys are typically undertaken by setting up a monitoring array of geophones (with the data transmitted to a central location) and creating a pulse or series of pulses of seismic energy. The pulse is created either by detonating a charge below the ground surface or by a "thumper truck" that is driven through the area on established roads. The monitoring array may be deployed at the ground surface, in small excavations made specifically for burying the geophones, and/or downhole in existing wells. These surveys are typically undertaken over the course of just a few days, thus limiting the impacts associated with the movements of a thumper

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truck or detonation of a charge. The vibrations from the seismic sources are negligible and would not cause damage to existing structures. Longer term deployment of geophones is sometimes undertaken in areas where natural seismic activity occurs; this is a completely passive data collection exercise that records naturally occurring earthquakes.

Resistivity surveys are very common in geothermal exploration, because variation in the earth's resistivity can occur directly as a result of the presence (or absence) of geothermal fluids. There are several possible methods that may be used. Some involve laying out long lines (up to 1,000 feet or more) of cable on the surface, typically along roads, although some convenient off-road areas may also be used for this purpose. Others, such as magneto-telluric (or MT) surveys involve setting up equipment repeatedly in small areas (a few tens of square feet at most at each measurement site) and taking many measurements across the prospect. An MT surveys is sometimes preferred because it evaluates conditions at greater depths than other resistivity methods (*i.e.*, at depths where the resource is likely to exist, rather than the overlying zone). As such, it is quite possible that this method would be used at Truckhaven. In an MT survey, electrodes are buried just beneath the ground surface at each site, and measuring equipment is set up nearby. Each site is monitored for several hours; then the equipment is moved to the next site. The only disturbance is associated with access to the area, and minor, temporary disturbance of the ground surface to bury the sensors. Each site is restored as closely as possible to its original condition before moving on to the next one.

Shallow temperature measurements are another geophysical exploration method. These can be made with a long thermal probe, which is inserted into the ground to a specified depth, allowed to stabilize, and removed after the temperature has been recorded. Alternatively, a hand auger may be used to drill short (< 6 feet deep), narrow-diameter (a few inches at most) holes, into which the probe is temporarily placed. This type of survey is likely to be undertaken on foot in a prospective area.

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2. DRILLING

2.1 Introduction

The results of geologic mapping, geophysical surveys and geochemical surveys are likely to define an area considered to be most prospective for drilling. The developer may choose to move directly to drilling full-diameter wells for either production or injection (discussed in the next section), or temperature gradients wells, which are smaller in diameter and usually shallower than full-diameter wells.

2.2 Temperature-Gradient Wells

Temperature-gradient drilling enables the investigation of temperatures at shallow depths in and around a geothermal system. This helps to define the distribution of temperatures in the subsurface, and to extrapolate temperatures to different depths. It also provides valuable information on the shallow hydrology and may enable sampling of groundwater where the number of existing wells is limited. Temperature-gradient wells investigate conditions above the geothermal reservoir and are not used for either production or injection. Their depth may range from perhaps 100 feet to 3,000 feet or more, depending on the potential characteristics of the geothermal resource, local hydrologic conditions, and other factors. The number of gradient wells is also quite variable, depending on the geometry of the system being investigated and the size of the anticipated power development. Water samples are typically taken of any groundwater encountered during drilling. Then the wells are typically completed with sealed, water-filled tubing from surface to bottom, often with cement around the tubing. Later in the project, the tubing may be perforated to allow monitoring of groundwater pressure.

Drilling equipment for temperature-gradient drilling is selected based on the depths and design of the wells to be drilled, and the physical and logistical conditions of the drilling sites. Most gradient wells are drilled with a small rotary rig (often truck-mounted) similar to that used for drilling water wells, or a diamond-coring rig, similar to that used for geologic sampling in

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mineral exploration and civil works projects. Neither requires much site preparation, but some auxiliary equipment is needed, including water trucks, tanks for mixing and holding drilling fluids, vehicles to transport supplies and personnel, and in some cases a backhoe to make minor excavations at the drilling site. After the wells are completed, temperature profiles are measured periodically in each well using a small downhole temperature probe, which is typically transported in a small truck.

Temperature-gradient drilling requires road access; therefore, some construction of new roads or improvement of existing ones (*e.g.*, grading) may be required. At the well site itself, a small cellar (typically less than 3 feet square and less than 3 feet deep) may be excavated to allow the conductor casing to be set beneath the rig. In most cases, little or no leveling or grading is needed. Drilling may take up to several weeks. First, a hole is drilled to about 30 feet, and a conductor pipe (typically 8 to10 inches in diameter) is cemented into place. Next, a smaller-diameter hole (7 to 8-1/2 inches) is drilled to perhaps 300 feet, where a second casing is cemented. The final hole (commonly less than 6 inches in diameter) is then drilled to the final depth. A string of tubing (typically 3 inches in diameter or less) may be run from the surface to the bottom of the well and cemented in place. As discussed above, this tubing would be sealed at the bottom to allow stable temperature gradients to be measured.

After drilling, the rig and other equipment are moved off the site and all materials and refuse are removed. If a cellar has been excavated, it is back-filled to restore the ground to its natural level. The well is left with the inner tubing protruding slightly above the ground surface to allow access for later temperature logging; the outer casings are cut off near ground level. In the months after completion, the well site is likely to be visited several times for temperature measurements, until a completely stabilized profile is obtained. After this, the wells can be left for periodic monitoring, or they can be abandoned, which involves excavating the ground around the well to a depth of about 3 feet, cutting off the casing and tubing, plugging the tubing with cement, and back-filling and grading of the site to restore the natural contour.

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The materials used in drilling temperature-gradient wells consist of the casing and tubing (typically carbon steel), cement (typically Portland cement), mud materials to lubricate and cool the drilling string and stabilize the hole (including bentonite, sodium bicarbonate, caustic soda, liquid polymer and lost circulation material such as sawdust or nut hulls), fuel for the rig and other equipment, and lubricants.

The time required to drill and complete each well depend most strongly on well depth, but also on the type of drilling equipment used. It is reasonable to expect a maximum of several weeks per well. The drilling rigs typically operate in a single-shift mode (*i.e.*, 10 to 12 hours each day), but occasionally operate around the clock. The number of vehicle trips per well may vary from a few tens to a few hundred, depending primarily upon the well depth, but is unlikely to exceed 10 per day. The weight of the heaviest vehicles is unlikely to exceed 55,000 pounds (lbs); most material and personnel trips will be made with lighter vehicles. Exhaust from these vehicles and the rig engines is controlled with standard air-pollution control equipment (such as catalytic converters) to maintain air quality. The rig engines may be as large as 600 horsepower (HP) and will operate continuously throughout the drilling shift. Water trucks are often used to control the dust generated by excavation, grading, or vehicle movements on unpaved roads.

Since the temperature-gradient wells produce no geothermal fluids and generally do not directly contact the geothermal reservoir, no impact from discharge of geothermal fluids is likely to occur. Artesian pressures are known to exist in the Truckhaven area, so any temperature-gradient well drilled to a depth below the groundwater table would be drilled with blow-out prevention equipment. If a gradient well does penetrate a geothermal zone, a significant release of geothermal fluids at the surface is unlikely because of the use of blow-out prevention equipment and because of the relatively small diameter of the wells. If zones with artesian pressure are encountered during temperature-gradient drilling, the well will be completed with cemented tubing to prevent cross-flow to shallower zones.

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The fluids used in the course of the drilling operations need to be handled properly to avoid release into the environment. These fluids include drilling mud (bentonite clay, activated montmorillonite clay and crystalline silica-quartz), drilling mud additives (caustic soda, sodium bicarbonate, and anionic polyacrylamide liquid polymer), cement (Portland cement and calcium chloride), fuel (diesel), lubricants (typically petroleum-based) and coolants. The potential for spills of drilling mud is minimized by the use of tanks or a sump on the well pad. The potential for spills of the other fluids is similar to that in any project involving the use of vehicles and motorized equipment.

2.3 Drilling Full-Diameter Wells

The potential impacts associated with drilling full-diameter wells are similar to those for temperature-gradient wells, although at a larger scale. The important differences for full-diameter wells are as follows:

- The access roads need to be of a higher standard than for a gradient-well drilling rig, as the rig for a full-diameter well is transported to the site by tractor-trailer trucks. It is highly likely that new roads would be needed for this activity at Truckhaven.

- The number of trips for both heavy and light vehicles would be significantly greater. Getting the rig and ancillary equipment to the site may require 15 to 20 trips by full-sized tractor-trailers; the same number would be required to de-mobilize the rig. The

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- size of the material-supply trucks and water trucks would necessarily be larger than for a temperature-gradient well, and the number of trips would be proportionally greater, given the greater well depth.

- The drilling pad would typically be larger to accommodate the larger rig, auxiliary equipment and personnel. Figure 1 shows a typical well pad layout, which may cover an area ranging from 30,000 to 50,000 square feet, depending on the rig to be used and the depth of the well.

- Considerably more on-site fuel storage would be required. As shown in Figure 1, the fuel storage area is typically contained by an earthen berm, allowing for containment of any spills.

- A deeper (6-10 feet), cement-lined cellar may be constructed for each well.

- As in the case of the gradient drilling, the full-diameter well is drilled in stages of successively smaller diameter. However, the overall diameters are larger by definition. A typical completion diagram for a full-diameter well is shown in Figure 2.

- Protection of groundwater from contamination by geothermal fluids is facilitated by the use of multiple casing strings, whose depths are specified partly on the basis of the depths of groundwater aquifers. In addition, redundant blow-out prevention (BOP) equipment is used. Typical BOP equipment for use when drilling out from the 13-3/8-inch production casing is shown in Figure 3; similar equipment is used at each stage of drilling.

- Water for mixing drilling fluids would be needed in much greater quantities than for gradient wells. Such water is typically obtained from local water wells and is transported to the site by truck or temporary irrigation pipelines.

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- While a temperature-gradient drilling operation can be run by about 3 on-site personnel and others traveling to the site periodically with materials and supplies, a full-diameter drilling operation typically has from 10 to 15 people on-site at all times, with more people coming and going periodically with equipment and supplies.

- Rig operations are likely to last longer, because full-diameter wells are expected to be deeper than temperature-gradient wells. However, exhaust emission and dust are still controlled to meet applicable air quality standards for the duration of the drilling operation.

- Rigs for full-diameter wells typically operate around the clock. Noise control measures (such as the positioning of tanks and the use of baffling) may be employed to meet applicable noise limits.

- When a full-diameter well is abandoned, the procedure is more comprehensive, typically entailing setting numerous cement plugs at several depths in the well, and more grading and re-vegetation to restore the well site.

Despite the impacts of drilling discussed above, temperature-gradient and full-diameter geothermal wells have been drilled safely, successfully and without major environmental impact all over the world. While some effects are an inevitable outcome of drilling, such as the construction of well pads and the temporary effects of vehicle traffic, environmental impacts are typically minimized by the combination of good planning and good regulatory oversight. Geothermal drilling operations at Truckhaven would be overseen by the California Division of Oil, Gas and Geothermal Resources (CDOGGR), which has a long history of regulating drilling in many different environments.

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2.4 Well Workovers, Repairs and Maintenance

There are several reasons why a well may need to be worked over after it has been completed. It may experience a mechanical failure such as a casing collapse, which renders it unusable as a producer or injector. It may suffer a decline in productivity that could be remediated by some intervention, such as a scale clean-out. Since the wellfield represents a significant portion of the investment in a geothermal field, a diligent operator seeks to monitor its wells and maintain them in the best possible condition, within the constraints of operating budgets.

In some cases, a drilling rig may not be required for remediation. Sometimes a coiled-tubing unit can be mobilized for scale clean-outs or other activities. While a certain amount of disturbance comes with the mobilization of any equipment, coiled-tubing operations are typically more compact and of shorter duration than those requiring a drilling rig.

If a well has a major problem, a drilling rig needs to be mobilized to the site. Depending on the nature of the problem, it may be possible to have a smaller rig than was used to originally drill the well. The impact of workover operations is a function of the size of the rig, the duration of the operation, and the nature of the problem. As for the initial drilling of each well, any remedial actions must be approved in advance by CDOGGR, and any operations that entail demonstration of the mechanical integrity of the well would typically be witnessed by a CDOGGR staff member.

Figure GX1. Drilling Pad Layout For Full-Diameter Wells (Not to Scale)

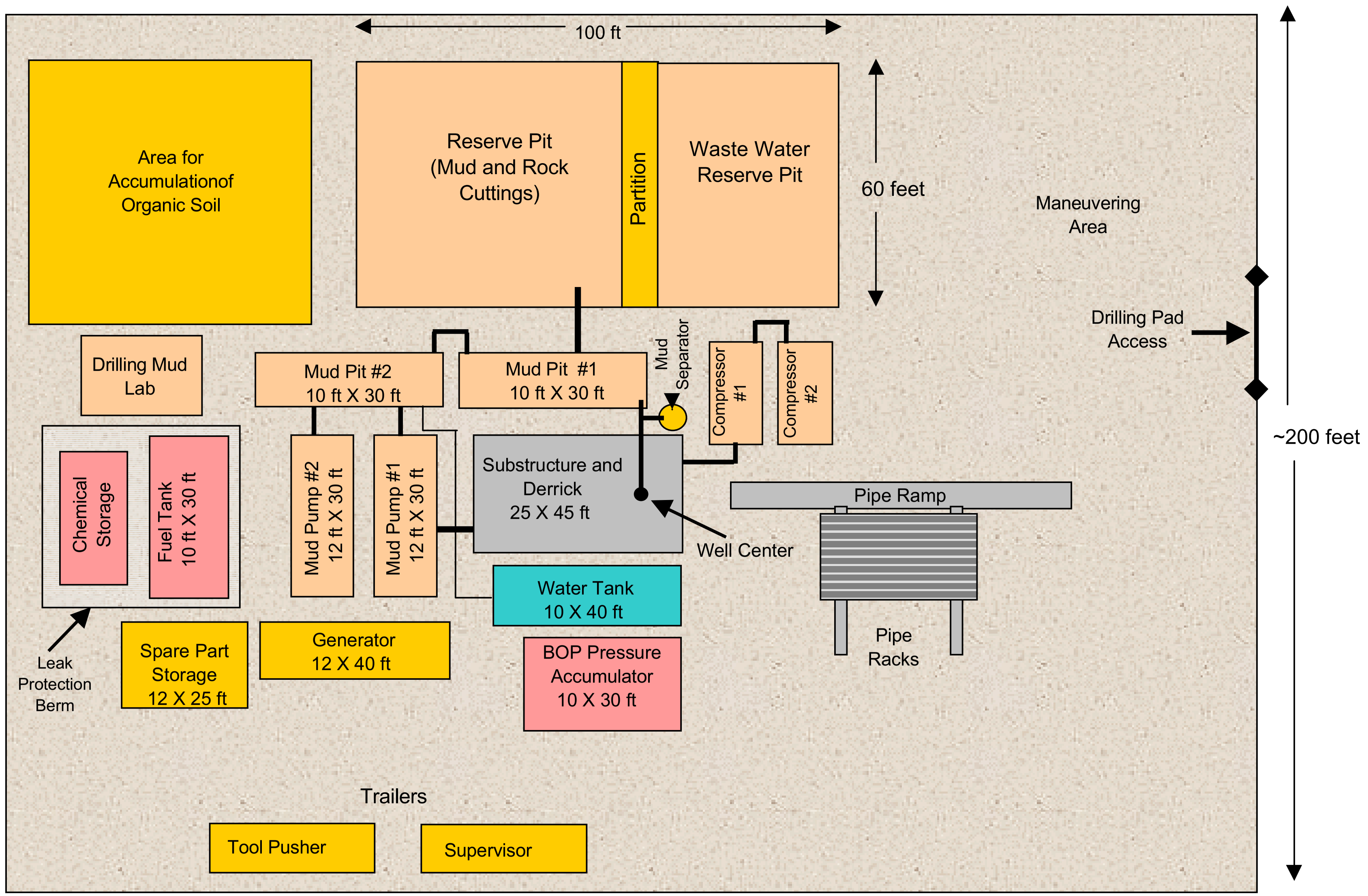

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Figure GX2: Typical Full-Diameter Well Completion

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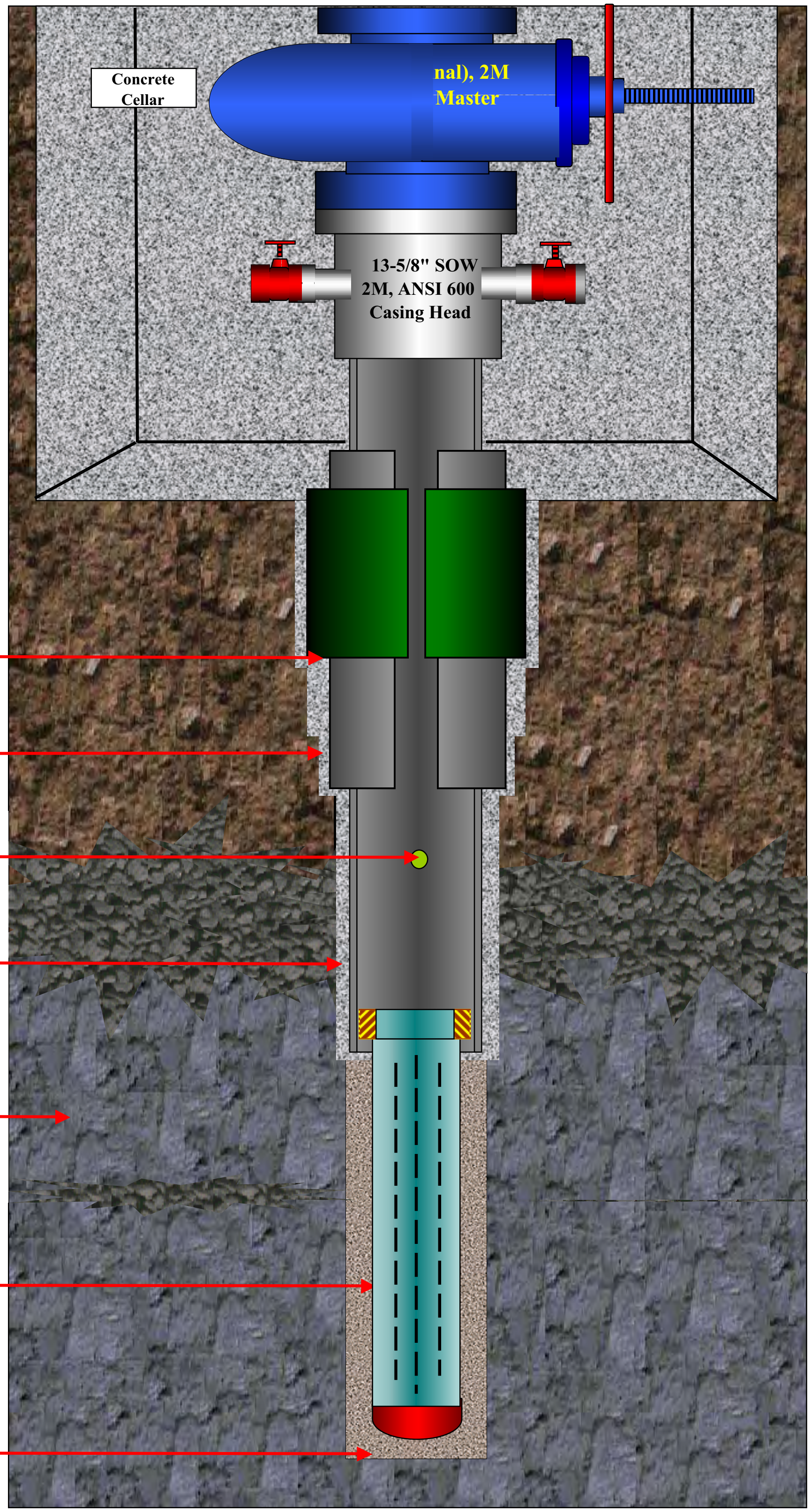
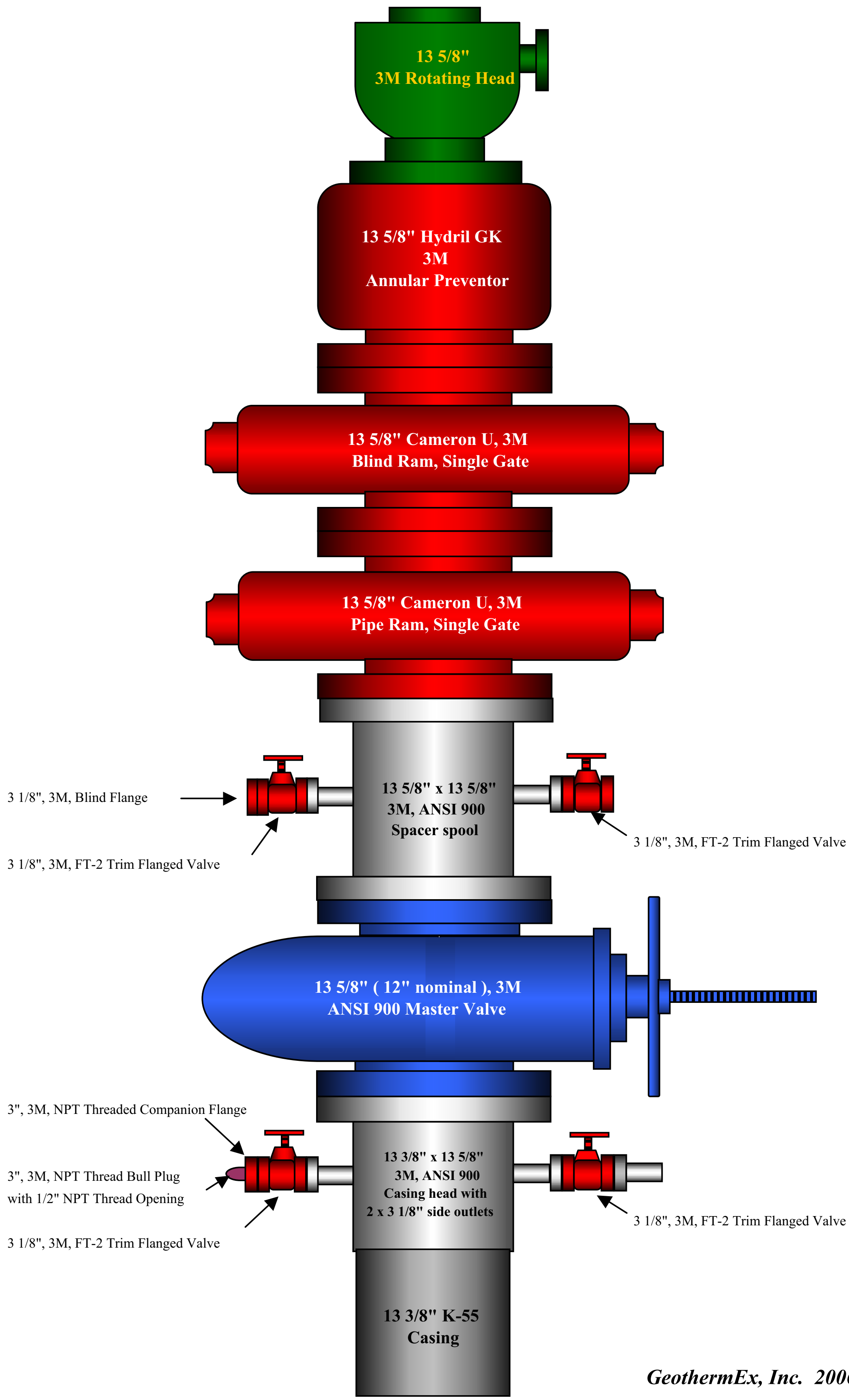


Figure GX3. Blowout Prevention Equipment for Drilling Below the 13-3/8-inch casing



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3. POWER PLANT CONSTRUCTION

3.1 Siting, Access, and Land Use

Power plant construction requires access via good-quality roads (those capable of accommodating large tractor-trailer trucks). Roads constructed to reach sites for full-diameter wells could also be used to access the power plant site, if the plant is located near one or more of the wells. If topography allows, the power plant may be positioned so as to be less visible from well-traveled roads; however, there are locations (*e.g.*, Steamboat, Nevada) where power plants are visible from main roads. A site with reasonable air circulation may be required for efficient operation of the plant's condensers.

Given the anticipated reservoir temperature of approximately 365 degrees Fahrenheit (°F) at Truckhaven, it is likely that geothermal power plants in this field would utilize binary conversion technology. The plants could use either air-cooled or water-cooled condensers to condense the binary working fluid after its transit through the turbines. If water-cooled condensers are used (or if the plant uses flash conversion technology with cooling towers), plumes of water vapor (sometimes incorrectly called "steam plumes") may be visible on cold days.

The amount of geothermal plant capacity to be installed at Truckhaven will depend on the resource capacity that is proven by drilling. Recent estimates of resource capacity at Truckhaven have ranged from 25 MW estimated in the Western Governors Association report, which can be found on their website (http://www.westgov.org/wga/initiatives/cdeac/Geothermal-full.pdf) to 150 MW estimated by Iceland America Energy ((http://www.icelandamericaenergy.com). Regardless of the total size of the resource, it is likely that power plant(s) will be developed in increments of 20 to 50 MW of plant capacity, with separations of a mile or more between plants. A typical plant size of 30 MW would utilize a site area of up to 15 acres to accommodate all the needed equipment, which would include (in addition to the power plant itself) space for pipelines supplying the brine from the production wells and distributing the cooled brine back to the

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injection wells, a switch yard, space for moving and storing equipment, and buildings needed for various purposes (power plant control, fire control, maintenance shop, etc.). The power plant itself would occupy approximately 25 percent of this area for a water-cooled plant, or about 50 percent for an air-cooled plant (more area is required for the cooling fans in an air-cooled plant). A 50 MW plant would require a larger footprint, on the order of 20-25 acres, depending on the conversion technology used. Figure 4 (courtesy of Ormat) shows a schematic layout of an air-cooled binary plant with a capacity of about 30 MW.

After construction is complete, the area around the power plant that is no longer needed for access and maintenance would be re-graded and re-vegetated with local species.

3.2 <u>Wellfield Equipment</u>

A geothermal power plant is typically supported by pipeline systems in the vicinity of the plant. These pipeline systems include a gathering system for produced geothermal fluids, and an injection system for the disposal of geothermal fluids after heat extraction by the plant. The pipeline routes are highly site-specific, but typically are located along access roads where possible. Pipelines are usually less than 24 inches in diameter, and their lengths are minimized to the extent possible to reduce cost and heat loss. In some projects, new pipeline corridors across previously undisturbed areas may be chosen for logistical reasons. Since the pipelines are typically constructed on supports above ground, there is little if any impact to the surrounding area once construction and re-vegetation of the pipeline corridors are complete. Small animals can easily pass beneath the pipelines. Their height is typically a few feet (<5 feet) above ground surface, and they are painted to blend in with the environment, thus minimizing their visual impact. Production pipelines are typically insulated, while injection pipelines

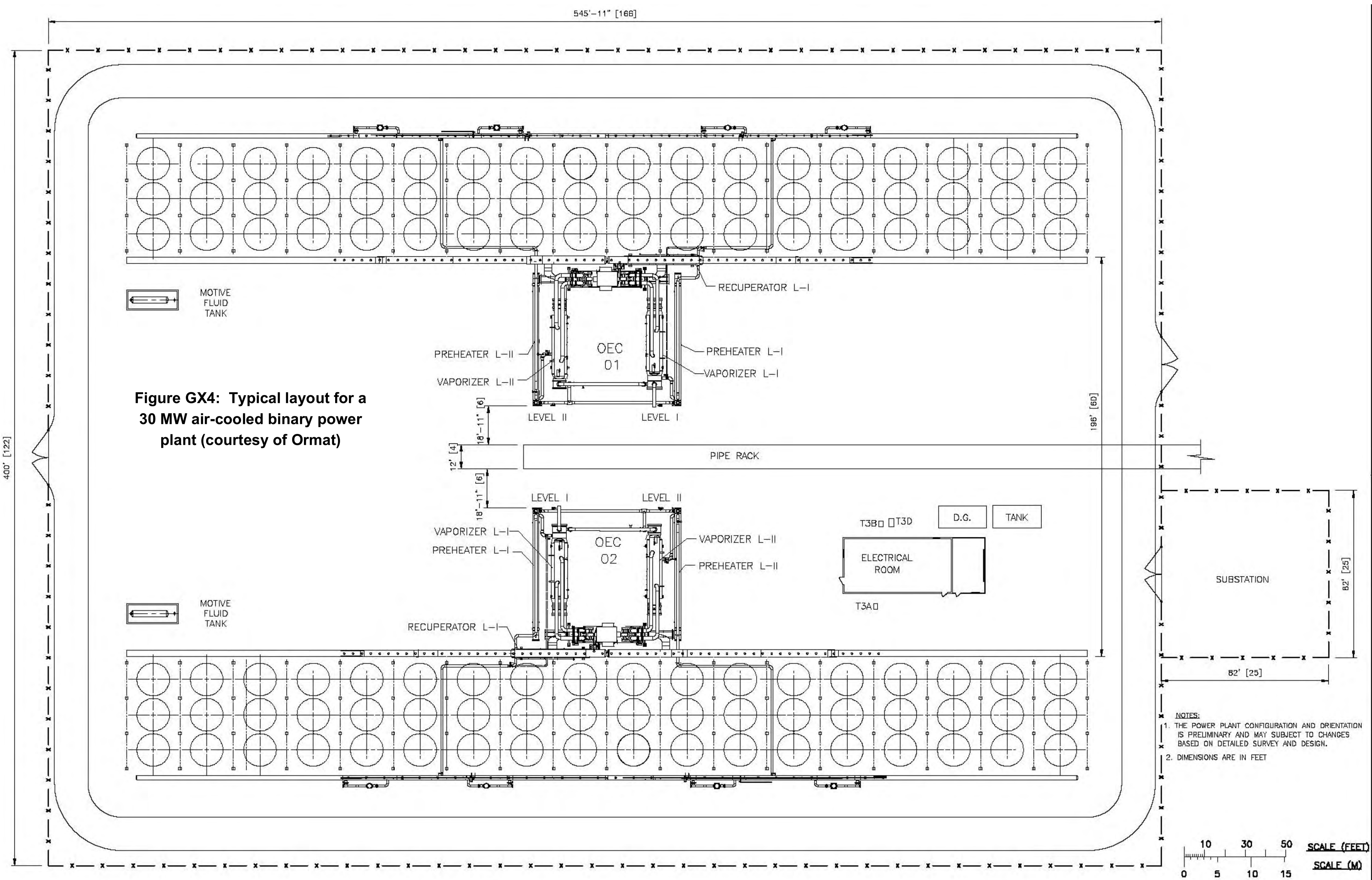

Figure GX4: Typical layout for a 30 MW air-cooled binary power plant (courtesy of Ormat)

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(which transmit cooler fluid) are usually left unclad. Pipeline expansion and contraction is accommodated by expansion loops. These are large, U-shaped bends, with the contraction or expansion of the U being accommodated by slides or rollers mounted on the pipeline on either side of the U. These expansion loops are commonly horizontally oriented, but occasionally vertical (*e.g.*, where a road crosses a pipeline corridor).

A small shed (usually no more than 10 feet x 10 feet) may be constructed at each well site to house certain equipment (*e.g.*, flow-metering equipment, electrical equipment, lubrication oil for the pump, etc.). As with the pipeline, the sheds are painted to blend in with the environment.

3.3 Personnel

The number of personnel required during construction varies significantly, but at any one point there may be a few hundred laborers and professionals on-site, with attendant vehicle traffic.

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4. POWER PLANT OPERATION

4.1 Overview

In a binary-cycle geothermal power plant, which is likely to be the type constructed at Truckhaven, the heat from the produced geothermal fluid is transferred to a working fluid that boils at a lower temperature than water. It is the working fluid (such as iso-butane or n-pentane) that expands through a turbine to generate electricity, rather than the geothermal fluid itself. The geothermal fluid and the working fluid are maintained in separate, sealed loops to prevent them from mixing and/or escaping to the environment.

Geothermal wells supplying binary geothermal power plants are typically pumped (rather than self-flowing). Standard line-shaft pumps are the most commonly used downhole pumps. These are contained within their own casing and consist of several pumps stages in a vertical arrangement. Lubricating oil is used to keep the bearings from seizing up. The production well system is maintained at a pressure greater than the “bubble point” (*i.e.*, the pressure at which boiling would occur) to keep all gases in solution, thus avoiding pump cavitation and efficiency losses in the power plant’s heat exchangers.

Hot water from the production wells is gathered in a series of pipelines and delivered to the power plant site, where it is then passed through several heat exchangers, which transfer heat from the geothermal fluid to the working fluid (see Figure 4). After flowing through the heat exchanger, the cooled geothermal fluid enters the injection system to be returned to the reservoir via the injection wells. This type of system incurs no loss of geothermal fluid; only a portion of the heat (but no mass) is removed. No geothermal fluid or steam is emitted to the atmosphere.

The working fluid flashes into a vapor phase in the heat exchangers and is then passed through a condensing turbine. Electricity is created from a generator attached to the turbine shaft. After passing through the turbine, the secondary fluid is condensed into a liquid phase and the process is repeated. Like the geothermal fluid, the secondary fluid is also maintained in a closed loop,

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thus avoiding any leakage to the atmosphere or mixing with the geothermal fluid. Condensation of the working fluid in a binary power plant may be achieved either through air-cooling or water-cooling; however, given the high ambient summer temperatures at Truckhaven, water cooling would be the preferred option (if an adequate supply of cooling water is available), as it will result in greater generation efficiency. The cooling water could possibly be purchased from the Imperial Irrigation District for circulating through the cooling system. Some evaporative water loss is expected; the amount of loss increases during the hotter summer months.

4.2 House Power

The power plant itself requires electricity to operate, as do the production and injection pumps. This "parasitic power" is either purchased from the local utility, or the plant may provide its own electricity, with less net power being available for sale. A source of outside power is required on-site in any case for cold starts. The energy consumption of the plant and pumps varies significantly, but is typically no more than about 30% of the gross generation. That is, if a plant is designed to produce 20 MW net, it may consume as much as 10 MW in supplying its own parasitic power needs.

4.3 Plant Maintenance and Chemicals

The power plant is maintained on a regular schedule, with major maintenance overhauls typically scheduled every two to five years. It is usually necessary either to reduce the output of the plant (*e.g.,* by shutting down one set of energy conversion units) or to shut down the entire plant for a few days while the equipment is inspected and serviced.

The routinely used chemicals that are specific to binary geothermal power plants include the hydrocarbon working fluid (such as iso-butane or n-pentane) and the lubricating oil used in the downhole pumps. If a well's pressure falls below the "bubble point," it is possible that downhole scaling might occur. This would require either a mechanical clean-out with a drilling rig or coiled-tubing unit, or an "acid job," during which acid (typically HCl or less commonly HF) is

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injected into the wellbore to dissolve the scale. If scaling is persistent, the operator may choose to adopt routine injection of a scale-inhibitor chemical, such as polymaleic anhydride or polyacrylic acid, used in dosages of 1-10 parts per million.

4.4 Emissions, Noise and Visual Impacts

Air emissions are only those associated with vehicles and motorized equipment; as discussed above, the working fluid and geothermal fluid in binary plants are both kept in closed-loop systems that are never exposed to the open air. On cold days, water-cooled condensers may emit a plume of water vapor.

The noise associated with a binary plant is localized and is associated with the cooling fans, pumps and generators. The electric motors for pumped wells are above-ground for line-shaft pumps; the noise from such pumps is also limited to the localized area around each well.

Any visual impact is minimized by the low profile of the power plant, which is typically about two stories high (see Figure 5, courtesy of Ormat) and choosing colors for exterior materials that blend in with the landscape.

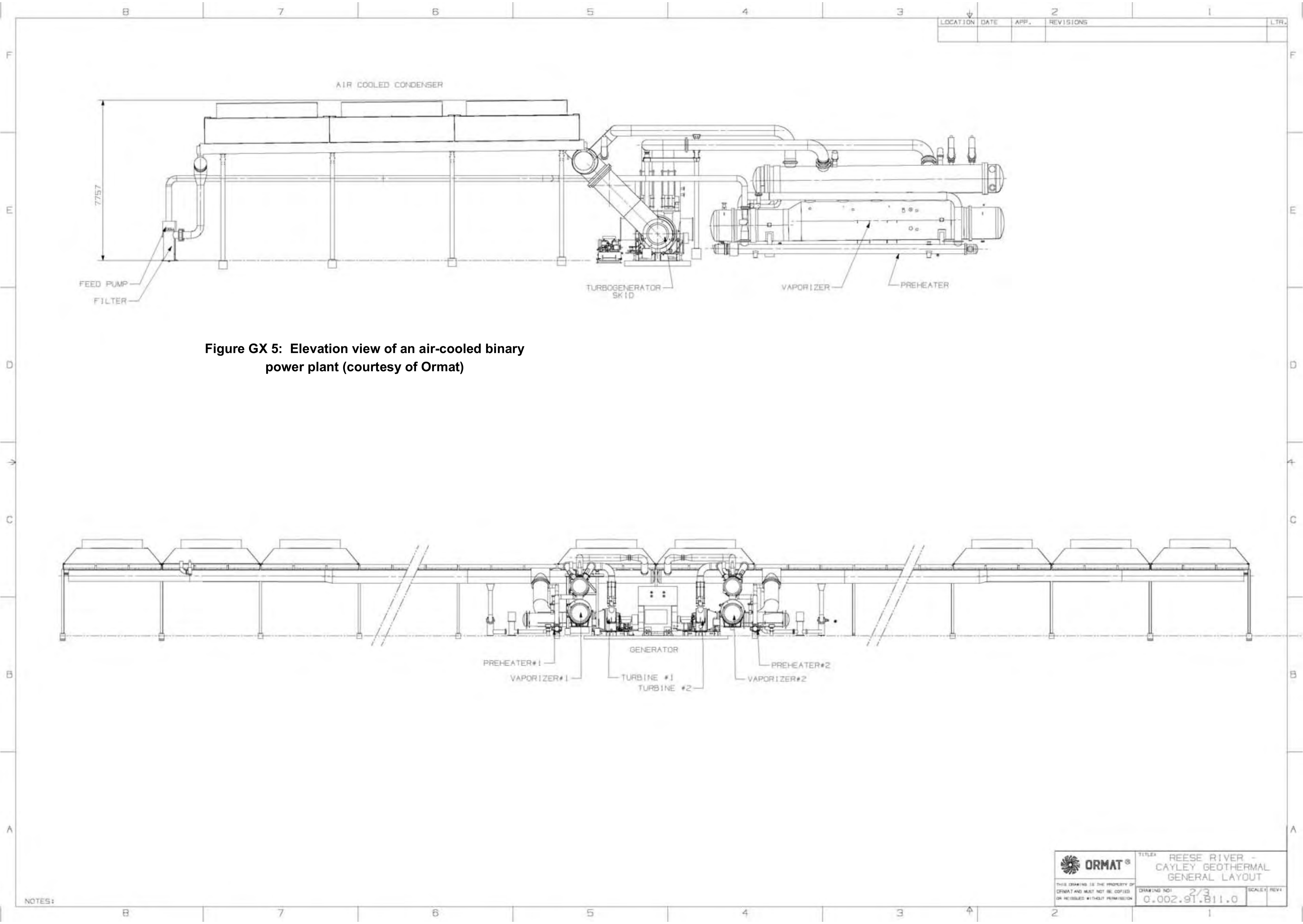

Figure GX 5: Elevation view of an air-cooled binary power plant (courtesy of Ormat)

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4.5 Personnel Requirements

The number of people required for routine operation of a power plant only is typically three per shift. However, additional personnel (perhaps as many as 12 total, depending on plant size) may be on-site during the day for maintenance and management. For comparison, the Heber geothermal facility in the southern part of the Imperial Valley (combining both binary and flash plants with a total capacity of about 130 MW gross) has a staff of 47 people including both operating and administrative staff (reference: GRC Imperial Valley Field Trip, 10 September 2006).

4.7 Wellfield Maintenance

As discussed above, wells may periodically require some maintenance, which may or may not require the presence of a drilling rig. One of the most common maintenance tasks for pumped wells is removing and replacing the pump. This is done only as needed (on the order of once every several years), typically using a crane or boom truck.

The wells may be routinely sampled for changes in chemical composition via a port in the flow line. Periodic temperature and pressure surveys may be run in both the production and injection wells (for pumped production wells, this can only be done when the pump is out of the well) to evaluate how subsurface conditions are changing. Idle wells may be used for pressure monitoring, either at the wellhead (for artesian wells) or downhole. If the latter, an instrument is placed at a specified depth in the well, and the pressure readings are transmitted to the surface where they are recorded for a specified time period.

Tracer testing is another typical wellfield activity. In this type of test, a chemical is added to the injection stream, and samples are collected at each production well over a period of time. The tracers that are typically used in geothermal are non-toxic, organic compounds (such as

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fluorescein) that reach only minute concentrations (usually less than 100 parts per million) in reservoir fluids and degrade over several months at reservoir temperatures. The formations exposed to tracer testing are the same as those used for routine production and injection, and are thus isolated from any potable groundwater by appropriate well casing configurations.