Promoting Direct-Use Development of Utah's Low-Temperature Geothermal Resources

Three Case Studies

Prepared by the Utah Energy Office
Department of Natural Resources

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Direct-Use Geothermal Case Studies

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EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) promotes the development of renewable energy resources and believes that geothermal energy has the potential to play a significant role in meeting energy needs in the western United States. The Utah Energy Office (UEO), in cooperation with the Utah Geological Survey (UGS) and business operators, examined three sites in Utah where direct use of low-temperature geothermal water supports successful commercial business activity (Figure 1). For this study, a low-temperature geothermal resource is defined as having a temperature less than 212ºF. The geothermal resource near Newcastle, Utah provides space heat for Milgro Greenhouses, LLC, one of the nation's most successful commercial greenhouses. Crystal Hot Springs, located in Draper, provides building heat and culinary hot water for the Utah State Correctional Facility and supports the production of commercial plants and fish at sites nearby. Bonneville SeaBase, located in Grantsville, uses the Grantsville Warm Springs as a way to provide habitat for ocean fish and as a training facility for ocean diving. For each site, a description of geological and geographical characteristics is outlined along with available information about how each business uses geothermal energy.

These sites were chosen for study on the basis of their applicability to other potential direct-use geothermal development. A previous study, conducted by UEO and UGS, suggests that as many as 70 sites in Utah produce geothermal water hot enough to support common commercial business applications, and up to 200 sites have at least some direct-use development potential (Blackett and others, 2004). In addition, as demonstrated by the accidental discovery of the Newcastle geothermal resource, it is possible that additional geothermal areas in Utah may still be undiscovered.

In addition to providing energy savings, the chemical qualities of geothermal water can be crucial to the success of specialized applications, such as fish propagation. However, these same factors also make it difficult to construct the financial comparisons between direct-use of geothermal energy and fossil fuels that help determine geothermal investment value. Further, since the use of geothermal is limited to the site where the resource is found, the unique characteristics of each site and region become vital factors in assessing the energy utility of the geothermal water. In fact, these case studies reveal that the varying characteristics of geothermal resources, combined with climate and regional economic factors, are crucial constraints to

Figure 1. Locations of geothermal direct use study areas.
(courtesy of the Utah Geological Survey)

business development as well as potential assets for business success. Finally, the use of cost-benefit analysis is constrained by several factors: difficulties in predicting the long-term cost of equipment and maintenance, uncertainties about the stability of geothermal flow and difficulties in converting geothermal benefits into financial terms. As a result, this report recommends that effective use of low-to-moderate temperature geothermal energy be preceded by development of a business model that accounts for the geological, geographical and regional economic factors that are associated with each geothermal site. Sensitivity to such factors by the business developer and government regulatory processes can ensure that geothermal plays a useful role in Utah's economy.

NEWCASTLE GEOTHERMAL RESOURCE, MILGRO GREENHOUSES, NEWCASTLE, UTAH

OVERVIEW

Milgro Greenhouses in Newcastle, Utah is one of the most successful businesses to use geothermal water for space heating in the United States. The dry, sunny climate, combined with low-cost geothermal heat, provides an excellent indoor environment for commercial plant production. The Newcastle geothermal resource shows signs of gradual decline in volume and temperature, but is still capable of sustaining additional commercial use. Further study of geologic conditions and hydrologic demand in the immediate area may reveal the best management practices for sustaining the commercial value of this resource.

Newcastle is a small, unincorporated community surrounded by farms in a sparsely populated valley about 30 miles west of Cedar City. Greenhouse use of geothermal water began after discovery of the resource in 1975. Milgro joined the community in 1993 with 527,400 square feet of greenhouse space devoted to the production of cut flowers. Subsequent building additions bring Milgro's Newcastle total to 1.1 million square feet. Other Milgro greenhouses, all located in southern California, add 2.2 million additional square feet to company capacity (B. Gordon, Milgro, verbal communication, various dates 2001-2004).

Milgro recently acquired Royal Van Zanten, a Dutch company that was one of three leading suppliers of chrysanthemum cuttings in the United States. Milgro is now the nation's largest producer of mums and delivers 30 million cuttings to other growers each year. With the Newcastle operation, Milgro has also established itself as one of the nation's largest producers of flower bulbs. The combined production of Milgro greenhouses ranks as the 11th largest in the United States on volume of more than 13 million potted plants and cut flowers per year.

Transportation costs to and from this remote region are high. However, the overall cost of doing business in southern Utah is lower than in southern California, and the Newcastle area is centrally located between major markets in all directions. Local government policies are supportive of new businesses that conserve water and protect air quality. In spite of regional drought conditions and long-term decline in groundwater level, the Newcastle geothermal resource is capable of supporting additional commercial uses. Milgro officials welcome geothermal economic development that is compatible with their operation.

NEWCASTLE GEOTHERMAL RESOURCE

Location and Description

The Newcastle geothermal resource is located at the southeastern margin of the Escalante Valley, in the transition zone between the Basin and Range and Colorado Plateau physiographic provinces (Blackett and others, 1997). The geothermal upwelling is thought to be one of the recharge sources for the regional aquifer in the Escalante Valley.

Milgro operations are located at the base of an alluvial fan on the northwest slope of a small, unnamed range that extends southwest from the Antelope Range at an elevation of about 5,310 feet above sea level (Blackett and others, 1997). Surrounding slopes are composed primarily of Tertiary volcanic rocks. The Antelope Range fault, a range-bounding feature, defines the southwest margin of the Escalante Valley. The Newcastle geothermal resource is considered a cryptic, or blind resource, with no natural surface manifestation. Geothermal water was discovered by accident when the Christensen brothers, owners of a local farm, were drilling for irrigation water in 1975. Original well temperatures reached 226ºF at a depth of about 300 feet. The outflow plume moves northwesterly, producing 190ºF+ water downstream at the Milgro facility. Geothermal production wells at Milgro vary in depth usually from 500 to 600 feet deep with the primary production zone typically between 300 to 500 feet. A variety of geothermal wells serving other greenhouses in the vicinity reach similar depths and temperatures. Geothermal fluid reaches 125°F in the town of Newcastle where it is used to heat a church building.

The federal Bureau of Land Management controls most of the higher land southeast of the main geothermal production area. At one point, the resource was one of 13 "known geothermal resource areas" (KGRAs) in Utah that were designated based on competitive interest in energy development on federal land. Two of the original KGRAs were eventually developed for power generation.

Geothermal Investigations

Limited investigations have defined a shallow, unconfined aquifer that channels geothermal water into the subsurface of the Escalante Valley. Geothermal water rises into Quaternary alluvial fill, then moves northwesterly, cooling as it mixes with cold groundwater at system margins. A maximum geothermal water temperature of 266°F was measured in a 3,000-foot deep exploration well drilled by Unocal in 1981.[1] The well penetrated the shallow geothermal outflow plume, and the maximum temperature was measured at a depth of 346 feet, while the temperature at the bottom of the well was 238°F. In 2001, Milgro drilled an exploratory hole near the same location as the Unocal well. The new drill hole yielded a significant reduction in temperature as the maximum reading was 239°F at a depth of 335 feet. Operational histories at Milgro and at Christensen Farms indicate declining water level probably due to continued production and the effect of drought conditions over the past several years.

Peak heat flow above the geothermal source-zone next to the range front reaches nearly 9,800 milliwatts per square meter (mW/m^2) and declines to about 500 mW/m^2 within a mile in any direction (Henrikson and Chapman, 2002; Blackett and others, 1997). Newcastle geothermal fluid contains approximately 1,100 parts per million (ppm) total dissolved solids (TDS) and a pH of about 8.0, tolerably alkaline for most pipe types.

Further study is needed to determine if water in the geothermal reservoir is meteoric in origin and therefore might recharge when drought conditions ease (R. Blackett, UGS, verbal communication, 2004). Otherwise, if Newcastle geothermal water is a closed system that originated during the last glacier period between 20,000 and 10,000 years ago (late Pleistocene), then water level loss in Milgro wells since 1990 might not be recovered by either increased precipitation or reduced pumping. A well monitored by the U.S. Geological Survey in nearby section 18, T. 36 S., R. 15 W. has shown a water level decline from 1990 to 2004 of more than 31 feet. Between 1993 and 2004, water levels in drill hole NC-11, near Milgro's No. 1 well, showed a decline of nearly 47 feet. It is also possible that this geothermal water is a binary system, composed of both "old" glacial water and on-going precipitation. Laboratory evaluation involving deuterium content could help answer these questions but requires sophisticated equipment and methods that may not yield definitive results (M. Shook, Idaho National Engineering and Environmental Laboratory, verbal communication, May 2004). Meanwhile, shutting down all geothermal pumps for several days could provide an opportunity to measure the rate of recovery in the immediate drawdown area.

Temperature and water-level monitoring equipment has not been installed in any of the area's geothermal production wells. Water level measurements in production wells are difficult to make because of interference between probes and well equipment and because of condensation within the casing. Instead, approximately 30 thermal gradient boreholes, drilled by various groups to varying depths, have been used to characterize the outflow plume and the unsaturated zone above the water table. Many gradient holes have collapsed over the years, leaving no more than eight in usable condition. Temperature gradient profiles from these remaining boreholes exhibit a mixed picture of changes in temperature and water table level from which precise conclusions regarding the outlook for well production cannot be deduced (Blackett and others, 1997). Persistent regional drought conditions may complicate the picture by accelerating water table declines and possibly causing a loss of production well temperature. Limited data from UGS test sites indicate a decline of 5 to 10 meters in water level between 1999 and 2004 (R. Blackett, verbal communication, spring 2004). In the absence of definitive flow testing, there is some indication from Milgro that an increase in

[1] Unocal is an energy resource and project development company with specialized experience developing geothermal resources, www.unocal.com.

pumping results in an increase, rather than a decrease in fluid temperature. The Utah Geological Survey has suggested organizing a monitoring program using a combination of existing, unused wells and a few small-diameter boreholes to gather temperature and water-level information on a regular basis.

Aside from geothermal flow, regional ground water moves northward from the margins of the Bull Valley and Pine Valley Mountains across the Escalante Valley toward Milford Valley and the Black Rock Desert. However, agricultural pumps in the Beryl area intercept much of that migration. Ground water levels in the region have declined steadily over the past several decades with minor recovery during periods of above-average precipitation (e.g. 1981 and 1984). The declines are believed to be the result of well pumping for farm irrigation (R. Blackett, verbal communication, March 2004).

Milgro operates two non-geothermal wells for greenhouse plant watering. Both wells are located within 300 yards of geothermal production wells. This cold-water resource exhibits a pH of about 7.0 and very low conductivity. Long-term decline of the non-geothermal water table at these wells may have accelerated during drought conditions that are now in their sixth year. Milgro officials have not indicated any imminent shortage of cold water for greenhouse irrigation, and the majority of company water rights are sold to area farmers.

MILGRO GREENHOUSE OPERATIONS

History

The Milgro business commenced in 1980 with greenhouse operations in Oxnard, California. The Newcastle facility is now the largest of four greenhouse operations (B. Gordon, verbal communication, 2004). Land acquisition at Newcastle began in 1991 based on the region's desirable climate, low cost of land, relatively light regulatory burden and the presence of high-quality geothermal water.

Acquisitions of additional land in 1998 and 1999 led to a 500,000 square foot expansion of greenhouse space. Covered by an arched, twin-shell plastic roof supported by fiberglass walls, Milgro's five greenhouse zones now total 1.1 million square feet, each zone capable of distinct climate control including temperature, humidity and hours of sunlight. The "double poly" roof provides a dead-air separation zone requiring fan-boosted pressurization and represents the industry's most cost-effective configuration for climate containment in high-sunlight regions.

Geothermal fluid is distributed through a series of pumps, actuated valves, forced air heaters and plastic tubing. Finned aluminum tubing was installed overhead in years past when certain plant species required warm air but cooler soil. That system is no longer in use.

Greenhouse zones are up to 1,400 feet in length, with elevated rolling benches running crosswise above bare soil. Radiant heat is supplied by geothermal water running through 0.5 inch extruded polyethylene plastic pipe on 6-inch centers. In some zones, new cuttings are grown directly in bare soil and then transferred to pots for final growth in other zones. Electric radiant heating is also supplied to certain zones.

Due to the mild nature of Newcastle geothermal water, heat exchangers have been by-passed, and the fluid is run directly to the greenhouses. At any given time, four production wells may be in use. Well pump motors range in size from 30 to 100 horsepower with zone-level pumps of 3 to 15 horsepower supplying additional localized pressure. Production wells use "down-hole" or line shaft pumps that are less efficient than submersible pumps but are able to withstand the combination of temperature and pressure experienced at more than 300 feet below ground. One production well motor is controlled by variable frequency drive circuitry, which acts as an energy-efficient throttle.

Climate Automation

Quality control is vital to Milgro profitability. Uniformity in the number of leaves, buds and plant height are evidence of successful control of growing conditions. Newcastle's desert climate, characterized by low humidity and large seasonal and daily temperature swings, is hostile to outdoor plant growth, but helpful for controlling humidity and insects. Plant loss at Newcastle averages only 5.0% in optimal conditions.

The geothermal system uses software to control hundreds of valves for irrigation and heat control. This total includes main valves at geothermal pumps, 10 zone gates in each of three ranges, plus two other ranges with 40 controls each. At Newcastle, controls are more elaborate and precisely managed than greenhouse operations in southern California, resulting in a somewhat higher cost for electricity and maintenance. Software also monitors outdoor conditions from a weather station installed on the roof and, among other things, can account for changes in wind, including potentially damaging storms. Digital sensors can alter system settings in as little as three minutes.

Milgro has found that it is easier to screen out excessive sunlight in Newcastle than it is to add artificial light for plant growth in places where sunshine is lacking due to shorter days or more frequent cloud cover. Likewise, Milgro has found that it is far easier to induce necessary humidity in a dry climate than it is to remove excess atmospheric moisture during humid conditions often found in more temperate climates.

As noted, annual heating load is greater than cooling load because space heating is needed during cool evenings that prevail even in the summer. Actual cooling load is also larger than indicated by average daily temperatures because strong day-night temperature swings are characteristic of Newcastle's climate. Milgro uses a variety of methods to cool the greenhouses, and the energy implications are important.

First, automated vents, augmented by fans, force unwanted air across the top of the shade cloth and out of buildings. Greenhouses in relatively humid climates may require natural gas heating to drive off humidity as a means of reducing pathogens. Excess humidity is not an issue at Newcastle. In fact, Milgro uses micro-mist equipment, running at water pressure up to 1,100 pounds per square inch, and pad-and-fan evaporative coolers to simultaneously reduce greenhouse temperatures and increase humidity levels. Air misting is designed to achieve full evaporation before leaf contact, thus achieving optimal air temperature reduction while avoiding leaf stains caused by minerals in irrigation water. Atomized moisture can achieve a 10°F temperature reduction at the leaf surface. Evaporative cooling can reduce indoor air temperatures by more than 20°F. Both of these systems use water and electricity economically and can target individual greenhouse zones to closely match changing plant needs throughout different growth cycles.

Typically, Milgro's central digital processor seeks a relative humidity of 75% on air temperature of 75°F. Dead zones for digital response are 4°F and 4% humidity. Required humidity for forcing bulbs can be as high as 96% and is provided by spraying water inside refrigeration units that total about 80,000 square feet in floor area.

Milgro has nine available geothermal wells. Seven wells were developed for production, four of which were acquired as part of property purchases subsequent to initial development. Water temperatures coming out of the different wells vary from 170°F to 240°F. Wells were drilled to depths ranging from 500 to 1,000 feet and completed with 16-inch slotted casing. The geothermal well production zone ranges in depth from 300 to 600 feet. In 2004, Milgro planned to close and fill-in three production wells where sedimentation has reduced efficiency and install three entirely new wells. Six other wells are in use or reserve, some of which can be used for either production or reinjection.

Milgro believes that reinjection of geothermal water should occur 1.2 miles up-gradient to ensure adequate access to the aquifer. Without formal analysis, they estimate a cost of $200,000 for such a facility, which would include pipes, pumps, other associated equipment and land leases. Milgro accepts the risk that reinjection of cooled water could have an effect on output temperature of production wells down-gradient. If that occurs, Milgro anticipates being able to regulate reinjection at an acceptable level.

The initial design of the greenhouse production system was based upon the use of plate heat exchangers to isolate the radiant heating pipe from geothermal fluid. However, due to slow system response time, these heat exchangers were removed from the system in 1998. The benign chemical quality of Newcastle geothermal water causes little scaling or corrosion, which helps eliminate the need for heat exchangers. Milgro briefly used gas-fired boilers for supplying greenhouse heat but found that their response time was too slow to account for weather changes.

Outdoor wind has not been a big problem for the greenhouse, even though high wind conditions are observed several times per year. A recent 70 mph wind event caused no damage to the double-poly roof of greenhouse areas. Occasional micro-bursts are also observed, one of which pulled off a portion of fiberglass panel. Automation software is able to offset windy conditions by closing wall vents as needed to protect equipment from damage.

Milgro's extensive use of automated mechanical devices to control climate adds somewhat to capital cost and operating expense. However, in relative terms, almost all greenhouses require extensive mechanical venting anyway, and digital control of motorized dampers results in slow, relatively inexpensive mechanical movements. Each of five climate zones is separated by vertical curtains. Retractable overhead shade cloth regulates solar insulation, and an additional overhead insulation curtain helps prevent heat loss during cold periods. These vertical separations are in additional to the two roof films that are themselves separated by a forced air current. The result is the ability to maintain temperatures within 1-2°F of optimal, even as seasonal outdoor temperatures vary from –10°F to 105°F, and diurnal changes may swing by 40°F. Without intervention, even a moderate outside temperature of 65°F can produce interior temperatures of 100°F or more.

In the past, Milgro burned natural gas for production of carbon dioxide (CO_2) to enhance plant growth in a portion of one greenhouse zone that totals 80,000 square feet. Gradual expansion of CO_2 use has been considered, but not chosen, due to its cost relative to value in promoting plant growth.

Water Quality

Ion control (pH) in Milgro irrigation water is considered the single most important chemical factor in successful control of production. Milgro tests irrigation water monthly to account for seasonal fluctuations in salts. Newcastle irrigation water is moderate in sulfates, iron, and other constituents. Boron is occasionally a problem. Geothermal water is not tested, as geothermal water is not in direct contact with plant materials. Observations of geothermal pipe interiors, and anecdotal reports by Milgro indicate that TDS and total dissolved gases (TDG), including CO_2 and hydrogen sulfide (H_2S), are low to moderate in quantity. The result is a mild potential for mineral deposition. Removal of plate heat exchangers some years earlier improved response time for overall geothermal heat transfer without incurring appreciable loss of wetted area for heat exchange at the capillary ends of the ethylene propylene monomer pipe. Tight bends, low velocity and potential air intrusion have apparently not caused appreciable mineral deposition, nor has Milgro reported persistent problems with heat transfer performance.

Chemical Applications

Precise rotational chemical applications are required to prevent insect infestations and supply mineral nutrients. Chemicals are added to both the high-pressure mist system and the evaporative coolers to prevent pathogen development and reduce mineralization on pipes and surfaces. Mineral nutrients that are added to irrigation water include molybdenum, copper, zinc, phosphorous, potassium and nitrogen.

Soil Amendments

While many cuttings are grown directly in native soil, pots are eventually needed for grow-out. Milgro relies on Canadian peat moss, delivered by a third party carrier, who blends it with native soil amendments, primarily vermiculite, at a facility in Fillmore. At some point, the company could make use of alternatives to the energy cost of delivering this premium quality mix across the continent. Local supplies of organic waste from lumber milling in the Dixie National Forest and composted livestock and poultry waste from commercial farms in Sanpete and Beaver counties could be successfully blended for potting soil. For other production supplies, such as plastic pots and chemicals, Milgro relies primarily on distant suppliers in California.

Electric Power

As noted, climate control automation is more complex at Newcastle than at Milgro's California facilities. In addition to the major pumps and valves described above, hundreds of small electric motors are needed to move interior curtains and outdoor wall vents. Dozens of additional fan motors supply ventilated air, and hundreds of electric actuators modulate irrigation water flow. A variety of water pumps are needed for localized geothermal circulation, using motors that range in size from 0.3 to 2.5 horsepower.

The mix of pumps and motors varies frequently depending upon heating needs and equipment maintenance schedules. Typically, a base-load geothermal pump running at its 250-horsepower motor rating is augmented by a 75-horsepower pump whose motor is controlled by efficient variable frequency drive circuitry. This combination assures that geothermal heat is provided around the clock, as overnight atmospheric cooling occurs even in warm weather.

In 2004, electricity was provided to Milgro by Utah Power at $0.047 per kilowatthour (kWh), for an average monthly bill of about $20,000. Off-peak discounts offered by the utility company are substantial. However, considering tight climate control requirements, motor and pump phasing options are probably much more limited than would be the case of typical commercial and industrial activities. Based upon cursory examination, power factor penalties may also be substantial. Use of variable frequency controls for one production pump is almost certainly profitable, and might be applied to the other pumps as well.

Meanwhile, electrical power capacity is well in excess of anticipated need, and unlike many rural areas, outages are infrequent and brief. As a precaution, Milgro has four diesel back-up generators.

Transportation

At present, Milgro operations rely entirely on tractor-trailers for receipt of production supplies and delivery of nursery products. Rail shipment is lower in cost but slower in delivering perishable plants, less flexible for breaking shipments at destination points and not immediately available at the Milgro loading docks.

Newcastle is served by Highway 56, a two-lane road in good condition both east and west. Street access points to Milgro in Newcastle have recently been repaved with asphalt topping. A nearby cutoff to Highway 18 gives Milgro truck traffic a nearly straight route to I-15 southbound at St. George. If needed, rail access to Nevada and California exists at Modena, 20 miles to the west, and at Cedar City, about 30 miles to the east.

Milgro financial records indicate that the additional cost of truck transportation to and from the Newcastle facility is roughly equal to the predicted additional cost of natural gas that would be required to heat a similar facility in California. Given this balance, the advantage of the Newcastle site is clearly in the relative ease with which operators trim conditions for optimal light and humidity. As noted, both of these crucial factors are much easier to control where outdoor weather tends to be dry and sunny. So, paradoxically, conditions that are naturally hostile to propagation of cut flowers and bulbs become advantages under carefully controlled greenhouse conditions. The presence of geothermal water makes the financial difference necessary for success.

Increases in diesel fuel prices during 2004 worsen the effect of Newcastle's isolated location. Milgro has anticipated potential periodic spikes in fuel cost, but may be forced to factor higher transportation costs into its business plan if world oil prices persist at the current high level. On the other hand, projections for natural gas prices suggest that all, or most, of rising motor fuel costs may be offset by avoided expense for natural gas.

Maintenance

Maintenance is done on the geothermal heating system during summer, when geothermal load is low. Likewise, maintenance of the shade cloth system occurs during winter when shading requirements are low. Periodic change-out of geothermal production and reinjection pumps is required more frequently than in the past due to increasing intrusion of sand into pump assemblies. The pump for the original well went six years without maintenance of any kind. More recently, overhaul of production pumps is expected to occur every three years, at a cost of about $10,000, if no problems are encountered. Overhaul of the reinjection well pump is similar. However, well maintenance is based on a sealed column of 200 feet in depth, rather than 60 feet to assure that reinjection waters go deep enough before dispersion. Reinjection pressures have caused well shaft erosion, resulting in the drilling of a second reinjection well further north, away from the aquifer recharge zone.[2] Initial problems with corrosion at geothermal pipe valves was cured by the use of Teflon™ parts.

GEOTHERMAL LAW AND RELATED ISSUES

Water Rights

Milgro holds 350 acre-feet of cold water, or irrigation water right. About 75 acre-feet are used for nursery operations, while the remainder is sold to farmers for crop irrigation. Milgro's geothermal water right totals 12.0 cubic feet per second, or 1,166 acre feet per year, of which about 200 acre feet are considered to be in beneficial use.

Water rights in Utah are a sorely tested topic over which endless conflict has occurred throughout recorded history. Considering the desert climate, it is not surprising that the State Engineer for Utah generally operates on the basis that no unappropriated water rights remain in the state. It is commonly believed that water rights have been over appropriated in most basins, adding to concerns about a declining water table caused by drought and well pumping. In fact, measured rainfall in the Modena area, northwest across the valley from Newcastle, amounted to 3.6 inches in 2002, less than half the long-term annual average.[3] Meanwhile, occasional filings for water appropriation are still made for small areas, followed by a submission proving that they have been put to beneficial use.

This process has implications for Milgro and potential additional users downstream. Given that there is little or no unappropriated water right in Utah, consumptive use of irrigation water or geothermal water for either an expansion of Milgro operations or for a cascade user would appear to require the retirement of an equivalent water right elsewhere (K. Christensen, Utah Division of Water Rights, verbal communication, April 14, 2004).

Unlike irrigation water, geothermal water use by Milgro is held by right as a nonconsumptive use under Utah water law because spent fluid is reinjected. The State Engineer's determination may or may not have been made on the basis of whether reinjection actually replenishes the geothermal reservoir. Instead, the practice of reinjection, no matter how effective, may be deemed conceptual evidence that ground water balance is maintained. However, if that geothermal water were to be diverted, even temporarily for aquaculture or a similar use, then two issues of resource consumption may apply. First, exposure of the geothermal fluid to possible pollutants might alter its suitability for subsequent use and thus require some form of remediation. Second, the State Engineer may calculate that evaporation is the primary cause of water resource depletion. As such, consumptive use for ponds may be judged to be a use of water equal to the same area of land irrigated for crops, regardless of whether or not pond liners are used to reduce water loss to the soil.

Even though Milgro has abundant water rights, both geothermal and irrigation, there is little evidence of water waste in the facility particularly by comparison to losses experienced in outdoor corrugate irrigation in Utah's arid climate. At Milgro, drip irrigation and fogging systems are computer-controlled to assure precise water metering for humidity and fungal control. Notably, farming irrigation in the region surrounding Newcastle typically occurs during daylight hours, when the rate of evaporation is high, resulting in substantially greater water use than if irrigation occurred at night. As such, modification of irrigation practices could extend the value of Milgro's unused water right even as expansion of greenhouse facilities may occur. The implication is important for continuing economic development in general, and for geothermal development in particular. Long-term decline in ground water, including geothermal water, could be offset or even reversed by use of more conservative irrigation practices. Aside from obvious implications for water rights, conservative use of water would be weighed as a factor in how Iron County economic development

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[2] Reinjection failure due to high pressure at Bluffdale Flowers, a commercial greenhouse similar to Milgro, resulted in state approval to cease reinjection in favor of surface disposal of geothermal water.

[3] Utah Climate Center, Utah State University, climate.usu.edu

officials would view applications for land development permits, requests for economic development incentives and public investments in infrastructure.

Altogether, the use of heat exchangers and reinjection of spent fluid could continue to exempt geothermal use from distinction as a beneficial consumptive use. On that basis, even aquaculture, or any other similar use could extract additional heat without penalty against water right, except for irrigation water whose chemical quality is altered. Otherwise, any exposure of geothermal fluid to open air for the purpose of temperature modulation would likely constitute consumptive use.

Utah Geothermal Resource Conservation Act

In 1981, the Utah Legislature enacted legislation to encourage the discovery and development of geothermal resources in ways that prevent waste, protect rights and enhance public welfare.[4] The act applies to water that is hotter than 248ºF and provides for the establishment of unit agreements for shared use of geothermal resources within the context of water rights and land ownership. No unit agreement is in place for the Newcastle geothermal resource. If overall land development pressure, requests for appropriation of water rights or expanding interest in Newcastle geothermal energy arise in the future, then application processes and adjudication of water rights by the Utah Division of Water Rights may be required. Such processes may require geophysical study of water-bearing strata to ensure protection of existing rights and uses. Planned reinjection of spent geothermal fluid may not be exempt from such scrutiny.

Other State Policies and Incentives

The Utah Department of Agriculture believes that aquaculture in Utah is a potentially large and profitable industry. The department encourages aquaculture by providing consulting services and low interest loans (K. Hauck, Utah Department of Agriculture, verbal communication, April 28, 2004). Administrative rules govern registration and fish health monitoring at agricultural facilities and public and private fishing facilities. This rule also addresses the importation of aquatic animals, including fish, fish eggs and gametes into the State of Utah. The program is based on the monitoring of facility operations and aquatic animal movements to prevent exposure and spread of pathogens that adversely affect both cultured and wild aquatic animal stocks. A certificate of registration is required for reportable pathogens, in addition to compliance with rules for quarantine, general importation and entry permits, as specified in administrative rules.

The State recognizes the importance of water quality in an arid environment and makes referrals for water quality testing. A variety of water quality difficulties limit aquaculture success: pH, hardness, alkalinity, ammonia, nitrites, heavy metals and TDG. In particular, problems with hardness are frequently observed in Utah water, often causing calcinosis in aquatic species. Dissolved gases are also a common, though ephemeral problem, for which the State offers technical advice for remediation. A number of new aquaculture operations are under development in Utah, gradually adding to a cumulative body of experience that should be available to potential developers through both the State of Utah, Utah Farm Bureau and other associations.

The Industrial Assistance Fund (IAF), from the Utah Department of Community and Economic Development (DCED) is a job-creation incentive available to companies seeking to relocate to Utah. It is also available to existing Utah companies seeking to expand operations within the state. The IAF provides grants for the creation of jobs paying higher than prevailing wages within the community. Grant disbursements are made on a post-performance basis after jobs have been created and retained. Applications for assistance are reviewed and approved by DCED’s board.

DCED’s Enterprise Zone Program was established in 1988. An enterprise zone comprises an area identified by local elected and economic development officials and is then designated by the state. Under the program, certain types of businesses locating to or expanding in a designated zone may claim tax credits provided in the law. No part of Iron County, where Milgro is located, is a designated enterprise zone. However,

[4] Utah Code Title 73, Chapter 22, amended 1987 and 1988

an initiative for such designation could be invoked for the Newcastle area and an overall expansion of program incentives may occur again, as happened by legislative action in 1996.

Local Government Policy

Iron County economic development policies do not actively promote development in the Newcastle area. Unlike much of Utah and surrounding states, the county has not developed specific long-range plans for urban growth and the provision of public services for this isolated rural area. Instead, land development is directed into existing urban areas and designated corridors that are already served by infrastructure. Newcastle is a clearly defined community from pioneer times but remains unincorporated and without its own policies and services.

Regulatory land-use constraints are growing in Iron County due to concerns about water supply and prevention of ground water contamination (A. McArthur, Iron County Economic Development Department, verbal communication, 2004). The county and its incorporated communities use a combination of land-use zoning districts and restraints on water and sewer permits to keep land development contained within existing urban areas and growth corridors. Otherwise, only genuine rural uses, including agriculture, ranching and mining, are allowed outside incorporated municipalities.

The Milgro site is adjacent to, but not within, the county tier III overlay zone that calls for eventual incorporation as a municipality (R. Erickson, Iron County Land-Use Planner, verbal communication, April 13, 2004). Instead, Milgro facilities are located in a tier IV overlay zone, with either county R-5 or A-20 agriculture as optional base zones for land development regulation. As such, the R-5 and A-20 zones allow commercial agriculture. Thus, Milgro nursery activities, or any similar uses, require only a building permit and well and septic disposal permits on building lots of at least 20 acres. Geothermal pumping and reinjection activities are governed by permit processes from the Utah State Engineer and Utah Division of Water Rights. The same is true of culinary water and irrigation water.

In order to accommodate greenhouse uses, Iron County relaxed the zoning standard that limits building coverage to 5% of building lot area (C. Nay, Iron County Building Inspector, verbal communication, April 14, 2004). Instead, because of expansive site needs inherent with greenhouses, maximum building coverage is limited only by the usual building setbacks, usually 10 to 20 feet, with some additional or concurrent limitation for utility easements and other rights-of-way. Only greenhouses were specified in this allowance.

The opinion of the Iron County building inspector is that aquaculture and other non-greenhouse direct uses of geothermal water would be limited to the 5% building coverage rule. The inspector also believes that aquaculture facilities, such as tanks, ponds and other surface structures, would count as covered surface toward the 5% maximum allowable coverage. Thus, non-greenhouse geothermal direct-use projects would have much more stringent building limitations.

State and Federal Funds

Milgro has benefited from U.S. Department of Energy (DOE) studies on geothermal waters and energy. However, Milgro has not acquired direct federal grant money for company-specific geothermal investigation. In the past, Milgro sought DOE funds for direct reservoir engineering analysis and applied for funds to characterize the geothermal resource for electric power production. Applications were not successful, and no further action has been taken.

In 2001, Milgro was considered by the Utah Energy Office for a state-funded low-interest business loan to upgrade lighting equipment. The loan program was discontinued before a contract with Milgro was arranged. However, the lighting audit found that mass replacement of incandescent lamps with compact fluorescent light bulbs (CFLs) could improve lighting quality in both offices and greenhouses while saving up to 50% in energy cost. Replacement of incandescent with longer-lasting CFLs would also save money by lengthening lamp replacement intervals, reducing unintended heat and providing an opportunity for selecting lamps with a radiation spectrum more appropriate for plant growth.

ECONOMIC ISSUES

The Regional Economy

The Escalante Valley where Newcastle and Milgro are located have grown little in population and housing since pioneer times. However, the larger region of Iron County and nearby Washington County have developed tremendously, providing an increase in diversification and business support for Milgro operations.

Population in nearby Cedar City currently totals about 24,000, with 10,000 more residents in other parts of Iron County. The Cedar City area hosts one of the nation's first and most aggressive economic development programs. As a result, Iron County was, for a time, the 3rd wealthiest county in Utah (C. Krause, Iron County Economic Development Director, verbal communication, various dates, 2004). Workforce development is the most important county and city issue, and economic development officers focus closely on their ability to respond quickly to prospective business proposals that bring employment.

At present, Cedar City area wages are 74% of national average and 85% of Utah average but are on the rise. Equally important, the rate of unemployment is lower than both national and Utah average, at just 3.4% in 2004. The Iron County economy weathered the current recession better than comparison areas and actually gained ground in some respects.

Water conservation policies are such that even viable industrial clients are discouraged from relocation to Iron County if they require substantial use of water, such as beverage bottling and food processing companies. Iron County officials lament that irrigation practices of existing local agriculture appear out-of-step with modern techniques. As noted in this report, drip irrigation has not replaced large circulars that operate during the day, resulting in heavy water losses to evaporation.

The State of Utah offers industrial development bonds for new industry, but Iron County will not add additional incentives for industries failing to meet the wage goal. Many Iron County residents commute daily to Circle Four Farms in Milford, about one hour distant. Local officials consider that company to be a particularly popular employer. The trend toward very large industrial agriculture facilities in remote regions such as western Utah is growing and local government regulatory policies and tax structure will increasingly take a position for or against operations such as Milgro.

Recent Milgro Development Options

In addition to the recent expansion of greenhouse space to 1.1 million square feet, Milgro has leased greenhouse space from other operators in the area. Milgro encourages further development of geothermal energy by other companies as well. In 1999, the ORMAT Corporation of Sparks, Nevada, was asked to consider low temperature geothermal power generation in Newcastle using Rankin cycle equipment. After investigation, ORMAT determined that well temperature did not reach the minimum 240°F for either binary or combined cycle power production. Nonetheless, Milgro indicates that Gardner Engineering is currently drilling up-gradient on federal land to investigate the potential for low temperature geothermal electric power production. Allegedly, steam flash would be generated at induced low atmospheric pressure for potential power generation of 1.0 MW. Milgro indicates that the pattern of land and water right ownership in the area would ultimately require project cooperation from Milgro.

Milgro officials briefly considered the possibility of using a head drop of more than 100-feet across company-owned property to generate electricity. A new well placed on higher ground could generate gravity flow to spin a small in-line turbine inside pipe leading to the greenhouses. However, given the relatively low cost of both natural gas and electricity available to Milgro, power generation by low-head hydroelectric power is an expensive option that might, at best, meet only a small portion of Milgro's energy needs.

Milgro Company Issues

Milgro operations in California have not grown in recent years. Indeed, a number of independent greenhouse companies in California have closed due to the high costs of doing business in that state. This trend is consistent with strong business cycles in California that account for a large portion of overall economic growth in Iron County and other parts of southern Utah and Nevada. Meanwhile, Milgro began development work in Newcastle in 1991 and commenced operations in 1993. Expansion in 1998 included the purchase of more than 100 acres of additional land and construction of 500,000 more square feet of greenhouse space.

More recent acquisition of Royal Van Zanten added sales along with some vertical integration of the market for plant cuttings. The opening of a Milgro-related trucking facility in St. George, 50 miles south of Newcastle, assures adequate tractor-trailer capacity to meet shipping requirements for volume and flexibility. In the past year, Milgro has expanded its refrigerated space by 20,000 square feet, for a current total of 80,000 square feet. Climate controls can be zoned to range from freezing to near ambient air temperature for forcing bulbs, hardening plant starts and storing product.

As is typical of western U.S. agriculture, Milgro relies upon a combination of migrant labor and highly skilled horticulturalists. Together, average Milgro employee income is well above minimum wage. Iron County business development incentives are intended to reward enterprises that help prevent social service burdens on hard-pressed public budgets.

In addition to its 1.1 million square feet of enclosed space, Milgro recently began leasing a total of 140,000 square feet of additional greenhouse space located 0.25 miles east of Milgro's main operation. Due to persistent difficult business conditions, Milgro has no discretionary money for new plant investment or for geothermal investigative studies. The company has been soliciting potential business partners, particularly for cascade users of geothermal outfall. According to Milgro, the Utah tax structure is similar to, but more moderate than in California. Workman's compensation fund levies, in particular, are much lower in Utah. Fees and performance requirements for state, local and special district permits are both fewer and easier to meet than in California.

As noted for climate and transportation issues, the Newcastle location presents a mixed picture of advantages and disadvantages. On one hand, Iron County economic development strategy builds on the fact that Cedar City lies within one day's motor transport of 86% of the urban area of the Mountain West and southern California coast. Milgro ships to all 50 states, and substantial product deliveries reach as far east as Denver. However, the vast majority of deliveries are to southern California and San Francisco.

Newcastle is at a competitive disadvantage in being located almost 400 miles from the wide variety of specialized services and supplies available in southern California. In recent years, business diversification in the Salt Lake City area has met more of Milgro's needs but is also relatively distant, at about 280 miles from Newcastle. Milgro acknowledges that Cedar City has successfully developed a strong industrial economic base but has little diversity in products and services of value to Milgro.

Regional transportation conditions may have influenced Milgro to acquire its own fleet of long-haul tractor-trailers as an independent, dedicated arm of the greenhouse business. At present, local industry makes heavy use of economical rail transportation for receiving large, homogeneous shipments of raw materials. However, most finished products are shipped out by tractor-trailer in smaller, more heterogeneous loads. The result is that the number of loaded outbound trucks outnumbers inbound traffic, requiring that additional empty trucks "dead head" into Cedar City to make up the difference. Premiums, or surcharges by trucking companies are considered by county officials to have a material effect on local manufacturing profitability. Meanwhile, Milgro recently expanded its own fleet from 15 to 18 tractor-trailers.

POTENTIAL GEOTHERMAL DEVELOPMENT

Milgro has only used the Newcastle geothermal resource for space heating since its discovery 30 years ago. However, the known resource temperature range of 125ºF to 243ºF can be blended with cold water or heated to a suitable level for a wide variety of commercial needs. Aquaculture and recreation temperature needs range from 60ºF to 110ºF. Agriculture and industrial uses often require resource temperatures well above boiling (2l2ºF) and commonly above 300ºF. A wide variety of processes, such as timber drying, sludge digestion and certain dairy processes, can use geothermal heat in the range of Milgro's minimum discharge temperature of about 110ºF (Lund, 1998). Alternatively, Milgro could subordinate its flow to an upstream user that would turn out tail water still warm enough for greenhouse use.

At present, worldwide use of geothermal water for agriculture and industry is very small, but the range of applications is wide: heap-leaching of mining ore and crop processing activities that can include dehydration, milling, compressing, separating and purifying. In general, the potential utility of geothermal for industrial and agriculture is governed by a positive relationship between geothermal resource temperature and distance to the point of use: the higher the temperature the further it can be transported.

Outfall, or effluent water from a primary geothermal user sometimes retains inadequate heat to be of use to a secondary user. So, heat augmentation by conventional means, such as a gas-fired boiler, could take advantage of the fact that in the Newcastle climatic region, optimum geothermal temperature is required for only short periods of time during the year. Thus, Milgro's outfall water temperature of between 110ºF-160ºF could be boosted to a useful level for other industries. In terms of space heating requirement, Newcastle's approximate 5,900 annual heating degree days might well be fully covered by the lower heat content of outfall from Milgro.[5] This also might be true for aquaculture, where Milgro's reinjection water is still more than 20ºF above typical pond requirements.

Milgro welcomes geothermal investigation and cooperative business planning for secondary use of its resource. However, lack of adequate understanding of the geothermal resource hampers corporate investment planning. Milgro has made tremendous investment in the Newcastle facility. Current drought conditions and potential long-term effects of the company's own practice of reinjecting waste water downstream of the geothermal center add to suspicions that the geothermal resource may be in long-term decline.

Uses at Newcastle

The Christensen family has produced alfalfa and various grains for many years in the Newcastle area. The family was the first successful user of Newcastle geothermal waters for commercial greenhouse production after attempts to cool the water for irrigation proved infeasible. Pony pack bedding plants and other "color" products were grown successfully for several years. However, a large-scale market buy-out of smaller retail markets along the West Coast in the 1980s temporarily ended Christensen's production. The facility was closed and sold, for a time, prior to repurchase by the family in the 1990s (M. Christensen, Christensen family farms, verbal communication, May 2004).

Christensen has equipment for producing CO_2 from natural gas combustion and may produce some during winter months to aid plant growth. Natural gas also provides back-up heat for cold winter periods but is seldom used. At present, hydroponic tomatoes for Utah retail sale are produced in nine buildings measuring 130 feet by 40 feet each, totaling more than one acre. In the opinion of the operator, these buildings are in poor condition, though greenhouse covers were recently replaced. Some flowers are produced routinely as well. The family is actively interested in expanding operations by 300,000 additional square feet (R. Christensen, Christensen family farms, verbal communication, May 2004). They have tested markets for peppers, cucumbers, lettuce, basil and other grocery and garden center products.

Christensen does its own trucking. At one point, they held a strong market in Las Vegas. However, current prices for their products do not justify current fuel costs for that distance. In contrast, opportunity for market expansion in Utah is limited only by Christensen's ability to get construction funding for plant expansion. Some family members believe that the range of possible greenhouse products is wide enough to allow specialization by Christensen in product lines that avoid having to compete with large-scale, low-cost suppliers.

Aside from Milgro and Christensen, Utah Natural Growers greenhouse produced organic tomatoes during the 1990s. They have since closed, and the facilities are now owned by Milgro. In addition, a local church building in Newcastle uses conventional forced air and heating coil equipment to provide space heat from geothermal water with a temperature of about 125ºF (S. Christensen, Christensen family farms, verbal communication, 2004).

[5] Utah Climate Center, Utah State University, climate.usu.edu

Other Possible Geothermal Uses

Mining and timber production were among historic activities that helped establish the economy of southern Utah. At present, the economic region surrounding Newcastle is dominated by low-intensity farming. A base of light industry is growing along the I-15 freeway corridor to the east, as are residential and retail service industries that are largely based on education and tourism in the Cedar City area. The size of the Newcastle geothermal resource and its remote location, suggest a limited range of possible additional uses.

Crop Processing

Alfalfa production is the primary farm crop in western Iron County and surrounding areas (S. Christensen, verbal communication, 2004). Alfalfa from southern Utah is delivered locally, regionally and to the Pacific Rim. Alfalfa is typically field-dried and then either baled, double-baled, cubed or palletized. Each succeeding level of compression requires substantially greater processing energy, and geothermal heat could be useful in some processes.

Other factors also weigh against the utility of Newcastle geothermal for processing of field crops. The gross total processing potential of geothermal heat is a very small fraction of total crop production, so diversion of some yield to a geothermal site works against economies of scale. Abundant sunshine and low relative humidity at all times of the year are an economic windfall not enjoyed by most other world and national agricultural regions. Field drying in Utah reduces alfalfa moisture from 70% to as little as 20%, compared to as much as 60% remaining moisture from field drying in midwestern states.

Under such conditions, augmentation with geothermal heat for additional drying might still be useful, particularly if that activity had first use of Newcastle water at approximately 195ºF. Initial sun drying, and then further desiccation by mechanical action, can help preserve some nutritional properties of palletized and cubed alfalfa and return the field more quickly to service for second or third cropping. Geothermal heat, when augmented to low temperature steam, aids in the extrusion process. Such action requires air-drying temperatures as low as 176ºF from fluid as low in temperature as 220ºF (Lund, 1998). The literature indicates potential production of 25,000 to 30,000 tons per year of palletized alfalfa from a geothermal well of unstated size. Similar resource temperatures are given for potato processing, of which significant tonnages are grown in the Newcastle area.

It is widely known that the groundwater table has been declining for many years across the region. That rate of decline may have accelerated during drought conditions of the past several years. Dry farming of grain in alternating years in many areas has proven successful, although at sharply lower annual average yields. Meanwhile, urbanization of farmland converts agricultural water to municipal use. Over time, the price of culinary water has risen substantially, especially during the past several years of regional drought.

All of these trends suggest the rising value of irrigation and geothermal water rights held by Milgro. The chemical quality, as well as temperature of geothermal fluid, would be an issue for the flaking process. Milgro geothermal fluid would appear to be relatively more suitable than other Utah geothermal water, as its dissolved solids total just 1,246 milligrams per liter (mg/L). This level is within acceptable State of Utah secondary drinking water standards.[6] For all agriculture operations, augmenting geothermal heat to boiling temperature, or higher, would appear to be at least helpful, if not necessary, and some evaluation of chemical qualities might be needed for use in specialty crops (K. Johnson, Utah Division of Environmental Quality, verbal communication, 2004).

Grain drying may also be adapted to take advantage of geothermal energy, given that in most conditions, dryer air need only be 10ºF to 20ºF above ambient. For harvest seasonal temperatures, Newcastle geothermal water could easily boost dryer air to suitable temperature by a water coil in the fan duct. Grain is generally a secondary, or subordinate rotational crop to alfalfa in southern Utah, though combined tonnages of many fields in rotation are still considerable. Pearl barley and other grains are commonly produced in the Newcastle area as off-year rotation crops.

[6] Utah Rule 309-200, Monitoring and water quality: Drinking water standards, rules.utah.gov/publicat/code/r309/r309-200.htm

Balneology and Tourism

A variety of sources reference the potential for health spas and marine aquariums based on Newcastle geothermal water. A number of successful spas exist in Utah, although none as remotely located relative to population centers as the Newcastle resource. Bonneville SeaBase is one of the few large marine aquariums in Utah and is commercially viable only in conjunction with ancillary uses (see case study in this report). Local economic development officials and state and regional experts in tourism, travel and recreation are favorable to the concept of geothermal development for swimming, health spas and sport fishing, but are unaware of any plans for such uses at the Newcastle resource.

Many sources point to rising popularity of remote sites for urban-weary vacationers. However, the Newcastle area lacks a nearby ancillary attraction, such as unusual scenery or other tourist attractions for which recreational geothermal would be benefited. The Shakespearean Festival 35 miles away in Cedar City and the popularity of St. George for retirement and second homes could eventually provoke recreational interest in the Newcastle area.

Aquaculture

Utah hosts about 30 commercial aquaculture operations, and the Utah Farm Bureau hosts a committee for aquaculture development (S. Smith, owner of Trout of Paradise; R. Balls, Utah Farm Bureau; and C. Wilson, Utah Fisheries Experiment Station, verbal communication, 2004). Most activities involve raising trout for sport fishing. However, shrimp, bass, catfish, prawns and even sharks are raised at Utah facilities. The need for warm water is commonly mentioned by those involved in aquaculture, along with careful control of water quality and compliance with fish and game regulations.

As noted, introduction of geothermal water to an open pond constitutes a “consumptive use” for which a water right is required and for which losses due to evaporation and soil percolation are presumed to equal that for farmland. As such, that water is assumed to be no longer available for other agricultural use. The value of any aquaculture product would be offset by a corresponding loss of potential productive capacity to which that same water could have been applied.

More than a dozen commercially valuable aquatic species can tolerate temperatures within the range bounded by the Newcastle climate and the expected outfall water temperature from Milgro. In fact, some precooling with ambient water will likely be needed. Successful control of water temperature can as much as double growth rates. Catfish can reach market size in four to six months at water temperatures of 65ºF to 80ºF, trout in four to six months at 55ºF to 65ºF and prawns in six to nine months at 80ºF to 85ºF. Water quality and disease control are very important, both of which can be easily controlled in the desert climate and relatively clean water available at Newcastle.

Miscellaneous Industrial Uses

The Newcastle region is host to a variety of commercial timber species for which retail milled products are a long-time industry. However, as with other agricultural products, the location of markets and the scale of processing relative to economic value are such that Newcastle geothermal energy would have little attraction. Likewise, feedlot waste at Circle Four Farms to the north might benefit from augmentation of heat for bio-digestion. However, travel distance and the potential energy requirements are wholly out-of-scale with available geothermal energy.

One possible option might be the use of geothermal water to aid in composting feedlot waste and timber slash to a marketable soil amendment, particularly for the Las Vegas market where large quantities of Utah forest products are consumed in outdoor landscaping. For more sensitive uses of soil amendments, such as for commercial plant propagation, rigorous standards of quality control give great preference to virgin beds of peat moss that are still abundant in North America. So, the variety of organic materials in Utah for which processing by geothermal energy might apply will probably languish until the long-term cost structure changes. Newcastle appears to be located away from the main pathway of soil amendments between major national forests and consumer markets in Las Vegas and southern California but could be well placed for forest product industries located closer to Newcastle.

Among the variety of commercial minerals found in southwestern Utah, gold and perlite are potential subjects for processing using geothermal fluid. Perlite is popular as an insulation material, as a soil amendment and as an additive in a variety of other commercial products. Processing of perlite into an expanded, low-density form requires a combination of dry heat and steam (B. Tripp and R. Bon, UGS, verbal communication, April 2004). Geothermal fluid could either be flashed to steam or applied directly. At present, the Newcastle geothermal resource may be too small and distant from known mineral resources. The Sulphurdale and Roosevelt hot springs are closer to perlite bodies and provide hotter water in greater volume. Further study and a rising energy cost basis among mineral industries may be needed before geothermal resources such as Newcastle become useful.

Heat from geothermal water could enhance the recovery rate of precious metals at heap-leaching operations and leaching for precious metals is done in Utah and surrounding states. However, mechanical leaching is limited exclusively to the mine site, as transport costs of very low-grade ore are prohibitive. Utah mine records indicate that gold and silver were recovered intermittently at operations in the immediate vicinity of Newcastle, including several million tons of ore that were milled during an indeterminate period that ended around 1983 (Shubat and McIntosh, 1988). Those operations have since undergone surface reclamation, but plans for a recycling facility using stockpiled ore and waste were considered as recently as 1998 (R. Gloyn, UGS, verbal communication, May 2004). Remaining reserves are substantial, and world prices for precious metals could combine with changes in technology to someday justify the reopening of old mines.

Whether or not these remaining ores are primarily in sulfite or oxide form could help determine their suitability for leaching and the extent to which low temperature geothermal water could enhance leachate effectiveness. In any case, measurement of the Newcastle geothermal plume through north-trending alluvium indicates sharply reduced heat values before reaching the general margin of the gold ore body (Blackett and others, 1997). The fact that the Newcastle resource was discovered by accident suggests the possibility that other cryptic resources may exist within useful distance of ore bodies containing precious metals.

QUANTIFYING THE VALUE OF NEWCASTLE GEOTHERMAL ENERGY

For this report, effort was made to identify and compare the full costs and benefits associated with Milgro's use of geothermal energy at Newcastle. Unlike fossil fuels and electricity generation, geothermal energy is not portable and must be evaluated in the geography of its setting. Moreover, the chemical qualities of geothermal water can vary widely between regions and across time, presenting great challenges for facility design, maintenance and performance.

Some factors, such as direct savings in avoided natural gas expense, can be compared directly to additional motor transport costs to and from markets. However, many of the most important factors examined in this report are difficult to quantify. For instance, practical experience shows that geothermal heating systems can respond to changing weather faster than natural gas systems. Early experience at Newcastle showed that a natural gas-fired boiler and closed loop system responded slowly to daily changes in space heating demand. The result was increased risk of plant shock and excessive fuel consumption from starting boiler burn times as early as noon when solar heat gain was still underway. These same weather patterns, however, also require more complex and expensive greenhouse cooling equipment and venting systems. In addition, the outlook for energy costs and the reliability of the geothermal aquifer involves substantial uncertainty. Altogether, any precision afforded by known costs and benefits may be overwhelmed by the uncertainties of other business conditions.

The immediate value of Newcastle geothermal energy is that it saves more than $500,000 in annual natural gas expense that would occur if the same plant had been built in southern California. These savings are offset by the additional cost of motor fuel to reach commercial markets that also exceeds $500,000 per year. The cost of both fuels is projected to rise substantially over the projected life of the Newcastle facility. Therefore, the true benefit of the Newcastle geothermal resource is that it is located in a dry, sunny climate where greenhouse conditions can be carefully controlled.

Milgro could abandon geothermal use at any time and re-employ natural gas-fired boiler equipment. In fact, early in its history at Newcastle, Milgro briefly used a propane boiler and plate heat exchangers for hot water circulation. That system was abandoned and some of the equipment removed. Questar has since brought natural gas service to the site with sufficient capacity for any likely scenario, which Milgro views as back-up energy in case of geothermal failure (B. Sorensen, Questar Gas Company, verbal communication, April 27, 2004).

An advantage of gas-fired heat is that make-up water will be a relatively small amount of the system, and chemical qualities can be controlled. However, Newcastle geothermal water requires little attention to pipe preservation. Even a gas-fired boiler using clean water requires regular attention to scale control and corrosion. In any case, Milgro estimates that the annual maintenance cost of a suitably sized gas boiler is about the same as the budget for maintaining geothermal wells, including periodic overhauls.

Potential savings in operating expense might be found in maximizing heat transfer per unit of pumping cost. Industry standards for boiler heating systems have been based on a hot water supply temperature of 180ºF to 200ºF with a typical temperature drop of about 20ºF (K. Rafferty, Geo-Heat Center, verbal communication, 2004). As such, the apparent drop of 75-80ºF across the greenhouse system suggests that a high level of heat transfer occurs per unit of pumping cost. However, it is noteworthy that the rate of heat transfer in most hot water systems rises asymptotically with water velocity above about 1.8 feet per second. Below optimum velocity, laminar flow may retard heat transfer, while above that range improvements in turbulence are only very gradual (J. Hood, UEO, verbal communication, June 2004). From operational experience, Milgro believes that transfer efficiency increases with velocity, thus justifying relatively greater pumping expense. If a formal engineering study were to justify a lower rate of flow, then electricity cost and pump maintenance might be reduced and reinjection of geothermal fluid down-gradient from the resource might be viewed as less of a threat to resource stability.

SUMMARY

Geothermal energy presents an opportunity to reduce or even avoid use of fossil fuels for space heating. However, unlike other forms of energy, geothermal heat for direct use is not portable. Instead, the value of geothermal for direct use is closely tied to the climate, geography, resource chemistry and other factors associated with the surrounding region. Most geothermal resources for direct use in the United States are located in arid, sunny and lightly populated regions of western states, including Utah. As such, geothermal energy can reduce business energy expense but often at increased transportation costs. Milgro operations at Newcastle demonstrate that while these differential energy costs may offset each other, the sunny, arid weather can provide outstanding plant growing conditions. Overall, the combination of conditions in Newcastle, including the geothermal resource itself, are difficult to compare with alternatives in precise quantitative terms.

Instead, Milgro officials emphasize that the availability of geothermal energy should not be viewed as a basis for starting a business, but as an optional resource for an established, profitable activity. Milgro's apparent lack of concern over the uncertainty of geothermal stability should be considered in light of uncertainties and rising costs inherent with doing business in California. Likewise, the problems of daily temperature swings and occasional severe weather in Newcastle are offset by cost savings from abundant sunshine and the responsiveness of geothermal flow to changing needs. Equally important, a variety of other factors associated with the site, including government policies and regulations, provide additional business planning factors that have generally favored Newcastle over alternative locations in California or other states.

CRYSTAL HOT SPRINGS, DRAPER, UTAH

OVERVIEW

For more than 100 years, Crystal Hot Springs has provided geothermal water to a wide variety of community uses. At present, these uses include building heat for dormitories at the Utah State Correctional Facility, a commercial greenhouse next door to the prison and a nearby fish farm. Well known from pioneer times, this collection of geothermal springs and ponds is located in Draper, Utah about 15 miles south of Salt Lake City. This geothermal resource contains low concentrations of salts and sulfur and is mild enough for watering cattle. It also meets state standard as a secondary drinking water source. However, dissolved oxygen and other elements still require careful management to prevent pipe corrosion and mineralization. Current regional drought conditions have reduced geothermal flow, but with careful management, Crystal Hot Springs can support new commercial uses in addition to those already in existence.

CRYSTAL HOT SPRINGS GEOTHERMAL RESOURCE

Located at N 40° 28’34”, W 111° 57'20”, Crystal Hot Springs is an artesian geothermal flow that fills a number of ponds and a small lake, which scuba divers have measured at more than 50 feet deep. In 2003, temperatures were reported at 195°F in a 400-foot deep production well, consistent with other reports and investigations done over the years (W. Grosvenor and B. Munson, Johnson Controls, verbal communication, July 2004). Occasional well pump testing over the last 30 years consistently reports artesian flow at 600 to 1,000 gallons per minute (gpm) (W. Grosvenor and B. Munson, verbal communication, 2004). Pumping of geothermal well water causes an immediate decline in artesian flow.[7] Elsewhere in the Salt Lake Valley, groundwater measurements taken since the 1930s show a steady decline in the water table totaling up to 40 feet (P. Haraden, Utah Division of Water Resources, verbal communication, Spring of 2003). The primary cause of this decline is believed to be well pumping, and periods of recharge coincide with high levels of annual precipitation.

Crystal Hot Springs is within the municipal boundary of Draper City, a fast-growing community located at the southern end of Salt Lake Valley. The valley is a 400-square mile geographic basin of unconsolidated alluvium that is bounded by the Wasatch Mountains on the east and the Oquirrh Mountains on the west. The Crystal Hot Springs geothermal system rises from the northern base of an east-west ridge known as the Traverse Range (Murphy and Gwynn, 1979). This feature is intermediate in elevation between the Wasatch Range to the east and the valley grabens to the north and south. A series of northeast striking normal faults, with a combined displacement of at least 3,000 feet, separate the Traverse Range from the Jordan Valley graben to the north. The spring system is located between two closely spaced range-front faults that are intersected by a north-northeast striking fault.

The Salt Lake Valley is characterized as a cold desert with total annual precipitation seldom exceeding 15 inches, although the Wasatch Range, where system recharge may occur, receives considerably more precipitation.[8] Crystal Hot Springs is located at the south end of the Salt Lake Valley at about 4,550 feet above sea level. As such, winter low temperatures may reach 0ºF, while summer high temperatures commonly reach 100ºF. Windy conditions are frequent because mountains to the east and west create a funnel effect and there is little terrain or vegetation to block air flow. The area experiences about 270 sunny days per year, although the nearby Traverse Ridge is known for occasional storms. Relative humidity can descend to as little as 20%.

The Wasatch fault system, marking the base of the Wasatch Range, exhibits predominately vertical movement and represents the longest and most tectonically active geologic structure in Utah with abundant

[7] Undated report by J. F. Dunyon, probably after 1979, as referenced by W. Gwynn, UGS, interview May 19, 2004, and file notes, Utah Division of Water Quality.
[8] Utah Climate Center, Utah State University, climate.usu.edu

evidence of surface rupturing events. The Wasatch fault is crosscut by numerous underlying, older faults and folds that complicate understanding of geothermal resources found on both slopes of the range. The entire region is also part of the Intermountain Seismic Belt that produces terrestrial heat flow averaging about 107 milliwatts per square meter (mW/m^2) (Blackett and Wakefield, 2004). In contrast, the adjacent Colorado Plateau region exhibits average terrestrial heat flow of about 57 mW/m^2.

The geothermal system is fed by mountain rain and snowfall that descends through fractured bedrock (Blackett and Wakefield, 2004). The Crystal Hot Springs resource is considered to be fault-controlled with geothermal energy originating from normal heat flow of the Basin and Range province, rather than by cooling of igneous rock at depth (Murphy and Gwynn, 1979).

The surface expression of Crystal Hot Springs consists of several springs found within a 70-acre area that lies mostly within state prison property (Murphy and Gwynn, 1979). Some of the warm springs feed small ponds located at the eastern edge of the geothermal zone, while others are present at the bottom of Crystal Pond, a small lake at the western edge. It is believed, but not verified, that the Crystal Hot Springs resource rises from a limestone reservoir that produces substantial amounts of carbon dioxide. As such, corrosion of metal pipes and fittings may still occur even if best efforts keep oxygen and other gases from entering at points in the mechanical system above ground (B. Munson, verbal communication, 2004).

Water analyses in 1979 reveal silica, calcium, magnesium, sodium, and related minerals in concentrations below 230 parts per million (ppm) (Murphy and Gwynn, 1979). Chlorine was higher, at 590 ppm. Water quality testing done for discharge permit approval indicated levels of arsenic, manganese, potassium, various chlorides and radium slightly higher than found in the Jordan River receiving waters.[9] Total dissolved solids (TDS) registered at 1,462 ppm in 1979, which is slightly lower than tests done more recently that found TDS at about 1,750 ppm. A pH measurement of 5.9 was recorded in 1979, somewhat more acidic than recent test results that ranged from 6.0 to 6.5.[10] Well pumping tests in 1979 proved steady flow at 650 to 1,000 gallons per minute (gpm).[11]

In 2003, a nearby well was pump-tested with a maximum flow of 1,100 gpm (Johnson Controls, 2003). However, no known tests have been made to measure drawdown within a cone of depression or projected rates of recovery under various pumping scenarios.[12] Temperature-gradient measurements revealed an elliptical area 200 yards wide in which temperatures exceeded 190ºF. Measurements also showed a roughly concentric area 600 yards wide with a temperature of at least 90ºF at a depth of 200 feet.

GEOTHERMAL USES

Crystal Hot Springs has been commercially exploited since the late 1800s, at various times supporting beverage brewing, stock watering, log floating, beaver raising, recreational swimming and medicinal bathing. At present, geothermal water is used for production of fish for commercial sale, greenhouse production of cut flowers and building heat at the prison. As such, Crystal Hot Springs may be one of the better examples of a multiple-use development of geothermal energy in the region.

Prison Building Heat

In 1983, the Utah Department of Corrections installed a geothermal well and heat exchange equipment to supply space heat to Oquirrh 4, a minimum-security dormitory facility that also included a gymnasium, offices and a cafeteria. That equipment met winter season building heat requirements and year-round hot water needs until 1985 when corrosion resulted in severe pitting of stainless steel pipes. Mineral

[9] Utah Pollutant Discharge Elimination System Report, UT-0024082, Utah Department of Environmental Quality
[10] Utah Division of Water Rights, file notes on surface water discharge permits, June 2004
[11] File notes on Crystal Hot Springs for investigative study performed by CH2M Hill Engineering Company
[12] Well pumping tends to lower the measured depth of a water table in a concentric area around a well causing a "cone of depression" that typically varies inversely with distance from the well. Water table levels in such a cone typically recover to the average water table depth in the absence of pumping.

build-up also caused pump shaft failure. Corrections drilled a second well to be used as either a backup or for re-injection. Both wells were abandoned in place, along with the original heat exchanger and related equipment. Since then, the discharge permit for one well has expired and its location has been lost to memory. Prison officials plan to eventually search for the missing well, determine if it can be rehabilitated and verify whether or not lapsed water rights and state permits for pumping and discharge can be renewed.

In 2003, the Utah Department of Corrections contracted with Johnson Controls, a world-wide energy service company, to re-establish a geothermal building heat and culinary water system in two phases. This new geothermal facility is part of a larger contract awarded to Johnson Controls for improved facilities management at the Draper prison, the largest correctional facility in the region. The overall contract includes improvements for energy, water and waste management services at a cost of $5.7 million. Energy control measures include the installation of more efficient lighting and motors, use of digital building climate controls and the two-phase geothermal system.

The Johnson Controls performance guarantee calls for annual savings of about $228,000 on energy improvements and $175,000 in annual savings for improvements in water, sewer and solid waste handling. Currently, base year energy consumption at the prison complex totals 19.5 million kilowatthours (kWh) and 1.9 million therms of natural gas for about 1.1 million square feet of buildings (Johnson Controls, 2003).

Phase I of the geothermal portion of the project calls for supplying culinary hot water and building heat for the Oquirrh 4 complex. Built in 1987, each of the four units at Oquirrh 4 contains 9,714 square feet of floor area. All units are constructed of hollow concrete masonry, built-up roof and single pane windows. These units were originally heated by ducted forced air coils supplied with steam from a campus distribution system fired by natural gas. That mechanical system is still in place and can be supplied interchangeably by either campus steam or hot water from the geothermal plate-and-frame heat exchanger.

Phase I geothermal improvements refurbished one of the old geothermal wells and installed a line-shaft constant speed pump to supply hot water to an existing equipment building. Inside the building, a new heat exchanger and variable speed drive for heat control were also installed along with measurement equipment and system controls. Among other things, the holding tank from the 1983 system was removed as part of an effort to prevent air intrusion believed to contribute to corrosion and mineral deposition. The constant speed pump installed in Phase I is set at 240 gpm on maximum capacity of 300 gpm. Entering water temperature is about 185°F. The system uses the existing coil and fan equipment from the original steam system. A variable speed drive on the clean side governs the rate of heat exchange, with a 40°F drop in geothermal temperature set as an efficiency goal. Actual outfall water temperature is about 160°F. Constant speed pump pressure is applied to the geothermal side in order to prevent precipitation of minerals that might otherwise occur during periods of slack demand.

Johnson Controls avoided installing probes for flow measurement piping in order to reduce the number of potential places where air intrusion could occur. Instead, a sensor to measure geothermal heat is in place to calculate energy passing through the heat exchanger. Strainers that would normally be in place have also been omitted in order to reduce points of potential corrosion. Piping on the geothermal side is made of fiberglass-reinforced plastic, considered a good general alternative to stainless steel for the chemical and temperature conditions experienced at Crystal Hot Springs. The vertical turbine pump is located seven feet down in a 1,000-foot deep well.[13]

During project evaluation, Johnson Controls found the existing heating system at Oquirrh 4 to be in poor condition and variable air volume vanes were rigid and inoperable. Meanwhile, to meet air quality needs, outside air is still used for both ventilation and winter heating. As such, there is no return air circuit resulting in substantial heating system inefficiency. As a result, Johnson Controls estimates that use of geothermal heat probably saves more in natural gas for the Oquirrh 4 facility than its proportionate share of square footage served by the overall prison gas-fired steam facility. As is common with large institutional uses, general lack of sub-metering prevents the accumulation of itemized data on cost savings.

Thermostatic controls are set higher on the campus steam side to prevent heat from that system entering the Oquirrh 4 loop unless geothermal flow fails. During the first six months of geothermal system

[13] Bell and Gossett enclosed line shaft, 12-inch conductor casing to 40 feet, 4-inch pump column with Schedule 40 liner to 1,000 feet, slotted bull nose fluid entry below the pump bowl and impellers.

operation, natural gas-fired steam was needed only once when the geothermal pump failed due to ingestion of well debris left from the 1983 geothermal system. As expected, system controls made a smooth switch to campus steam heat when the geothermal pump failed.

Phase II geothermal development, planned for late 2004, calls for replacement of the fixed speed 10-horsepower geothermal well pump by a 25-horsepower variable speed drive that can potentially deliver up to the full water right of 750 gpm. The practical expectation is for a baseload of about 600 gpm. A second heat exchanger will also be added. This larger geothermal flow will continue to supply space heat for the Oquirrh 4 cellblock and will also supply the prison furniture shop, sewing shop and special service dormitory. Altogether, geothermal heat will eventually supply space heat and culinary hot water for a total of 252,350 square feet of building area.

Under Phase II, geothermal input temperature is expected to exceed 185ºF, dropping to 165ºF at discharge during warm weather and 135ºF in winter. A variety of other improvements will be needed to ensure system performance including fan/coil unit heaters in the prison industry buildings, upgraded insulation and thermostats in individual sections. Phase II improvements will continue to send the usual 200 gpm discharge flow to prison fish ponds. However, discharge by buried pipe to the cooling pond will rise from about 40 to 400 gpm or more. After Phase II geothermal improvements are operational, the existing back-up boiler will be conditioned to better fit with the geothermal system.

Phase I of the geothermal performance contract calls for capital expenditures of $519,000 intended to produce guaranteed annual energy savings of $68,944 in deferred natural gas cost. Those savings are tempered by an expected base increase of $1,068 in additional annual electricity charges for pumping geothermal fluid and electronic controls. Geothermal improvements are projected to have a payback period of 7.6 years and a predicted equipment life of 17 years. In contrast, the overall performance contract has a combined estimated payback period of 15 years. Phase II geothermal improvements are expected to cost $1,523,611 and should produce annual natural gas savings of $123,813, offset by an increase in electricity cost of $69,145 for pumping geothermal water. Phase I became operational in January of 2004, providing initial monthly savings of $17,000 in deferred natural gas costs.

Bluffdale Flowers

In 1981, Utah Roses established a commercial greenhouse using 450 gpm of geothermal water pumped from a 1,000 foot deep well on property located immediately adjacent to the prison. That facility was sold and renamed Bluffdale Flowers in 1998. In the interim, some 250,000 square feet of greenhouse space was constructed for raising roses and other ornamental flowers.

In 1983, at about the same time the prison was developing its first attempt at geothermal building heat, Utah Roses used U.S. Department of Energy (DOE) funding to install a geothermal production well at one of their greenhouses located in Sandy City, about 5 miles north of Crystal Hot Springs. Well depth eventually reached 5,000 feet but produced only about 200 gpm of water at 120ºF and was therefore abandoned. Eventually, the entire greenhouse operation in Sandy was abandoned and operations were consolidated at the Crystal Hot Springs site.

At present, Bluffdale Flowers uses a 40-horsepower line-shaft pump running at constant speed to supply geothermal water from a well depth of about 200 feet. Space heat is provided through plate-and-frame heat exchangers showing an intake temperature of about 190°F and discharge temperature of 140°F. Geothermal pumping is limited to the cool months of September to May during the hours of 4:00 pm to 8:00 am. There is not a back-up heat system, and indoor greenhouse temperatures on winter nights may descend to near freezing. A brief experiment with by-passing the heat exchanger caused rapid mineral fouling of capillary piping. Discharge water travels by 8-inch pipe to Crystal Pond where it cools to about 80°F before traveling about 1,000 feet by open ditch to High Tech Fisheries, a downstream user of the geothermal water (described below).

For several years, attempts were made to reinject spent geothermal water for aquifer recharge. However, artesian effect and low permeability resulted in surface leakage and pump failure. After deliberation, the State of Utah Division of Water Rights was persuaded to grant a permit for surface discharge of spent fluid. As such, even though greenhouse use of heat-exchanged water is a "non-contact" use of the geothermal resource, surface disposal exposes the fluid to chemical alteration.

The state-issued discharge permit requires semi-annual water tests for metals including cadmium, copper, lead, mercury, radium and others. Some concern has been raised regarding tests of outfall water that show TDS at 1,700 ppm, close to the state maximum limit of 2,000 ppm, and pH readings as low as 5.9.

Bluffdale Flowers is in the process of expanding greenhouse space from 250,000 to 500,000 square feet. To provide winter space heat, discharge water at about 140°F will be reheated using natural gas boilers to about 180°F and circulated through that additional space before discharging enroute to High Tech Fisheries further downstream.

Water rights total about 2.0 cubic feet per second, which would allow Bluffdale Flowers to augment geothermal flow by running the idle reinjection pump in reverse, resulting in a potential doubling of geothermal flow to about 900 gpm.

Managers at Bluffdale Flowers note that artesian flow is substantially lower in 2004 compared to recent years, as evidenced by the fact that natural ponds are nearly empty during early summer. Ordinarily, these ponds would actually deepen as summer progresses due to cessation of greenhouse and prison use of geothermal water during previous warm months. Informal discussion among various parties in the area suggest that persistent regional drought conditions account for a large fraction of diminished geothermal spring flow. More recently, discussion has focused on the possible role of prison geothermal pumping as a cause of spring flow reduction for other geothermal users. These concerns add interest to the widespread belief that water rights have been overappropriated by the State Engineer. As noted above, regular groundwater monitoring in the Salt Lake Valley indicates that over the last several decades, wells have caused a steady decline in the water table (Burden and others, 2003).

High Tech Fisheries

In the past, a number of aquaculture operations have used outfall from either the prison, Bluffdale Flowers or directly from Crystal Pond, the largest of several ponds fed by Crystal Hot Springs. The most successful of these downstream geothermal users is High Tech Fisheries, a 25-year old commercial producer of tropical fish based around Crystal Pond. High Tech is a contract operator on behalf of Utah Correctional Industries, an enterprise of the state prison system. As such, the land, water rights and facilities are largely state-owned. Labor is provided by prison inmates.

Crystal Pond varies widely in size, up to about three acres, but currently covers only about one acre in surface area due to persistent regional drought conditions. The pond was once host to a large variety of fish but is presently occupied only by a few hardy species of low-value fish that help control mosquitoes. High Tech Fisheries uses discharge water from Bluffdale Flowers and from the prison geothermal facility to feed Crystal Pond, which is also supplied by artesian springs.

Discharge water from Bluffdale Flowers leaves that facility at about 140°F and travels through a succession of eight-inch piping, open ditches and intermittent ponds, before arriving at High Tech at an acceptable temperature of about 80°F. Discharge water from the prison geothermal facility travels entirely by pipe to High Tech. Together, this flow moves successively through covered greenhouse space totaling about 4,500 square feet, occupied by some 80 fish propagation tanks that vary in size from 200 to 1,000 gallons. Many of the fish originate from Africa's Lake Malawi where water conditions are similar to those produced at Crystal Hot Springs. At times, this facility has also produced a variety of vegetables for commercial sale, including corn, tomatoes, squash and peppers. Propagation of aquarium plants for retail sale was also tried for a time, but proved unsuccessful.

During cold weather, geothermal water may arrive at fish tanks at temperatures as low as 60°F, only marginally viable for fish propagation. In the past year, High Tech also reports that combined inflow to Crystal Pond is down by about 50%, resulting in the pond's lowest water level in 30 years. As a result, High Tech currently recirculates its own outfall water back into Crystal Pond in order to maintain adequate supply to the fish tanks. Concern has been raised by High Tech that declining water supply may also be due, in part, to recent re-establishment of prison geothermal use and recommends that consideration be given to circulating additional prison geothermal discharge water through High Tech before final outfall to wetlands or the Jordan River.

At present, about 200 gpm of geothermal outflow from the prison goes directly to High Tech. The remaining 40 gpm is sent to a cooling pond that is planned for new wetland development. About 450 gpm of geothermal discharge flows toward High Tech from Bluffdale Flowers, although an unknown amount is lost to evaporation and seepage along that path. High Tech does not directly measure the combined total of inflow to Crystal Pond from these various sources. Discharge water from High Tech Fisheries ordinarily travels about 800 feet in a ditch to a collector canal running through farm fields before either percolating fully into soil or reaching the Jordan River.

Original plans called for discharge of geothermal water from the prison to percolate into the soil through open ditches, with no significant surface flow off-site. However, the need for mosquito abatement resulted in redirection of geothermal water through a buried 14-inch concrete pipe running about 1.5 miles before entering a cooling pond. The pond is designed to overflow into the Jordan River through a culvert running under the Bangerter Highway reaching the river at a temperature close to ambient.

UDOT Wetland Development

The Utah Department of Transportation (UDOT) plans to use geothermal discharge water, in combination with other surface flow, to create a new wetland in the area below the lowest pond at Crystal Hot Springs. This end-use of geothermal water helps fulfill UDOT's need for wetland creation to offset loss of wetland caused by highway development elsewhere. As such, geothermal water is expected to reach ambient temperature before entering the river, having dissipated heat through a combination of at least three different beneficial uses and passing through thousands of feet of ditches and piping before disposal.

MANAGEMENT ISSUES

Water Quality

Discharge permits issued by the Utah Division of Water Quality must be renewed every five years and include specifications for periodic testing of discharge water based upon expectations of how beneficial use will affect water quality. Discharge permits for both the prison and Bluffdale Flowers set a maximum TDS loading of 2,000 ppm for geothermal outfall to the Jordan River. The most recent laboratory analysis of geothermal fluid read 1,750 ppm TDS. In the event of a violation, treatment to achieve compliance would be required. For non-contact geothermal flow, such as for prison building heat, there is arguably no basis for requiring remediation. For Bluffdale Flowers and High Tech Fisheries, remediation is appropriate and could include diversion of nearby Corner Canyon water for dilution of geothermal outfall if water fails to meet discharge standards.

System Design and Maintenance

Files held by the Utah Division of Water Rights provide undocumented references to a 1989 report on the 1983-1985 geothermal operation at the prison. These references described how geothermal water had severely pitted stainless steel pump impellers and how mineral build-up had caused pump shafts to seize and fail. Recent x-ray diffraction analysis of mineral scale deposits reveals layers of eroded metal pipe lining mixed with quartz, calcite, aragonite, anhydrite, pyrite and other minerals (M. Glenn, UEO; S. Lutz, Energy and Geoscience Institute, written communication, April, 2004). These conditions suggest the presence of excessive amounts of gas in the geothermal fluid. Ineffective adaptation of portions of the existing steam heat system for geothermal use may have led to leaks that were the primary pathways for corrosion. Further, the condition of pipes, strainers and other metal components of the pump and pipe assembly suggests that oxygenated groundwater may have mixed with upwelling geothermal fluid to provide a corrosive combination of heat and oxidation.

Uncontrolled mineral precipitation is also a concern for heat exchanger efficiency. Mineral deposition not only compromises pump efficiency and longevity, but may reduce wetted surface area at the heat exchanger, which correspondingly reduces heat capture per unit of applied pump power. Use of a constant speed pump on the geothermal side helps prevent air intrusion by maintaining positive pressure at all times and helps assure a flow-speed high enough to prevent eddy precipitation of minerals. Maintenance of a layer of CO_2 gas in the surge tank may also help prevent mineral precipitation and oxidation of metal parts.

The causes of system failure in 1983 may have been partially resolved by improved design in the 2004 facility. However, an incomplete understanding of geothermal chemistry may still prove troublesome in the long run, even if at a slower rate. The University of Utah has offered to supply a complete baseline analysis of geothermal chemistry at a cost of $3,000. This information is valuable for determining suitable composition of geothermal equipment, but may also help ensure that water chemistry is not toxic to plants and animals expected to appear in UDOT wetlands.[14]

At Bluffdale Flowers, problems with reinjection of spent geothermal fluid resulted in eventual approval by the Division of Water Rights to cease reinjection. That well is available for possible use in expanded geothermal production. Bluffdale Flowers and High Tech Fisheries both express concern about expansion of the prison geothermal system. Drought conditions and pumping of geothermal water at the prison are believed to be the cause of reduced flow to natural springs. Low flow could worsen when pumping at the prison enters Phase II of the geothermal development plan and when spent geothermal fluid is diverted to wetland use. Bluffdale Flowers is studying the possibility of reheating spent geothermal fluid and using the idle reinjection well to pump more water in support of an expansion of greenhouse space. High Tech Fisheries, being furthest downstream, may need to resort more fully to recirculation of spent water in order to provide adequate flow for fish tanks and to maintain fish populations in Crystal Pond. In addition, more extensive piping upstream between these commercial uses might prevent additional loss of volume and temperature of entering flow.

POTENTIAL GEOTHERMAL DEVELOPMENT

The use of geothermal water for building heat, a commercial fish farm, greenhouse plant production and possible wetland development, combine to make Crystal Hot Springs one of the best-developed geothermal sites in the region. Even so, discarded outfall water remains warm enough for additional cascade use. Aquaculture is a likely candidate considering water conditions and evidence that local markets for aquarium fish are expanding (L. Nelson, Bonneville SeaBase, verbal communication, Spring 2004). There is ample open ground in the area and access to urban services. However, the potential for further economic use of Crystal Hot Springs is limited by three factors: local and regional economic conditions including government regulation, drought conditions that have reduced geothermal flow and the need for careful management of outfall water from one use to the next.

Local Economy

Southern Salt Lake County is experiencing vigorous urban growth with the Draper area being one of the fastest growing communities in Utah. Along with a mix of higher-end residential and supporting commercial retail uses, there is a strong market for recreational activities of all kinds. Within several years, open land in all directions will be nearly filled with urban development. The geothermal resource is well placed for commercial development, particularly in conjunction with complementary retail uses.

The geothermal system is located 0.4 miles from the Denver and Rio Grande railroad, about 0.6 miles from the Jordan River, and 0.4 miles from an interchange with Interstate 15. Expansion of mass transit service to the area may also occur, as Crystal Hot Springs is located midway between the two largest urban

[14] Among other elements, the following are either known or suspected to be present in Utah geothermal waters: arsenic, antimony, thorium, selenium, boron, radium and barium. H_2S and CO_2 are mildly caustic and may not contribute strongly to corrosion but can contribute to bearing failure and general system clogging.

areas in the region, the Salt Lake Valley and Utah County, which together contain about 1.4 million people. The Bangerter Highway is located two miles to the north with immediate access to the Salt Lake International Airport and to Interstate 80 that connects San Francisco and New York City.

In historic times, Crystal Hot Springs was the subject of active economic promotional interest and a wide variety of commercial endeavors were tried for profit. Subsequent development of the prison complex, with dozens of buildings and hundreds of acres behind barbed wire fencing, cast a drab, even forbidding, visage over a neighborhood that is otherwise characterized by farming. The state's power of eminent domain to acquire additional land in support of prison facilities further limits the city's confidence in its land development vision for the immediate area.

In any case, the rapid pace of urban expansion will eventually exploit every point of possible economic interest. It is conceivable that the intensity of the cityscape could prompt relocation of the prison to a more remote place, thus releasing nearly 700 acres of prime acreage to development along with its underlying geothermal resource. The likely pace of rising energy costs, particularly for natural gas, will only add to the future value of geothermal energy at this location.

Government Regulation

Crystal Hot Springs and the entire line of its outfall to the Jordan River are located within the Draper City municipal boundary. However, the Utah correctional facility is located entirely on state-owned land. Under Utah law, land use on state property is not subject to local government restrictions. However, Bluffdale Flowers and surface outfall lines are subject to municipal zoning and building code requirements. At present, Draper City has a well-developed long-range master plan for community development and associated zoning ordinances (B. Goins, Draper City Long Range Planning Manager, verbal communication, May 28, 2004). The prison property is designated cultural/institutional and zoned for industrial use. Surrounding areas are designated for a mix of commercial, residential and agricultural uses. These designations can accommodate the range of uses to which geothermal direct use can be applied, particularly under conditional use guidelines that are intended to provide flexibility and acknowledgement of activities that conserve or enhance natural resources.

City officials admit to having shown little interest in the prison and its geothermal resources. However, land-use officials recognize that the hundreds of acres of vacant land surrounding Crystal Hot Springs lie in the direct path of vigorous urban development, and there is great community interest in any natural feature that lends relief to the otherwise monotonous pattern of typical urban development. There is also acknowledgment that a general lack of civic experience with geothermal waters limits long-range planning attention.

State and municipal licenses also apply. Aquaculture activities are regulated by the Utah Department of Agriculture. The Utah Division of Water Rights governs access to ground water and surface water bodies, and the Utah Division of Water Quality governs the discharge of those waters. Current Utah water-use doctrine states that essentially all waters of the state are considered to have been fully appropriated by proofs of beneficial use submitted to the state and approved in the past. As such, any alteration in the use of Utah water may be subject to a corresponding change in some other established use or right.

Discharge permits under Utah's Pollutant Discharge Elimination System are typically based upon initial water quality testing, how proposed water use will alter its chemical quality and water quality needs of receiving waters (P. Gessel, Utah Division of Water Quality, verbal communication, June 9, 2004). Discharge permits may specify limits on TDS, TSS, pH, biological oxygen demand and specific minerals and metals of concern. These are verified by periodic testing, the extent to which is also specified by permit. The receiving water for discharge, in this case the Jordan River, is designated a cold water fishery. As such, when the prison discharge permit is renewed in 2005, there is potential for consideration of how geothermal heat may need to be further mitigated. The current prison discharge permit was issued in 2000 and requires monthly monitoring to ensure that TDS remains below 2,000 ppm, TSS below 25 ppm and pH between 6.5 and 9.0.

Business Options

Technical and financial resources for geothermal development in Utah are well established with two successful power plants and more than 30 fish farms using geothermal water. However, without the benefit of further geothermal investigation, there is no indication that Crystal Hot Springs produces adequate heat or volume to support power generation. Instead, the temperature and mineral content of Crystal Hot Springs may be more suitable for drying grain or alfalfa, both of which are grown in surrounding fields. Of course, field drying of large volume crops is also effective and economical in Utah's sunny climate. So, geothermal heat might be best suited for drying small volumes of specialty grains that are sold at high margin and are not typically field-dried (F. Balls, verbal communication, summer 2004).

Commercial fish farming is a rapidly growing industry worldwide, providing controlled growth conditions and placing production sites closer to markets. Geothermal water allows the commercial production of valuable warm water aquatic species in temperate climates such as Utah. A wide variety of commercial species are potentially suitable for the temperature and mineral condition of Crystal Hot Springs including oysters, lobsters, shrimp, salmon, prawns, catfish, eel, carp, trout, perch and bass. For more sensitive species, mechanical heat exchangers could be used to isolate minerals in geothermal water from propagation areas. With more effective piping of geothermal outfall water, there may be enough heat to use heat exchangers and still provide input temperatures of at least 65ºF, a typical minimum for most warm-water species.

Relatively new technology using in-line turbines for power generation can sometimes be profitably installed on low head resources. There is a 70-foot drop in elevation across more than 1.0 mile of traverse to the confluence with the Jordan River. However, considering the availability and low cost of grid power, hydrology at Crystal Hot Springs is inadequate for cost-effective power generation.

COSTS AND BENEFITS OF CRYSTAL HOT SPRINGS GEOTHERMAL USE

The escalating cost of natural gas in 1982 was cited by the Utah Department of Corrections as a reason for choosing geothermal water to heat prison buildings. In 2003, the rising price of natural gas was again an important factor in estimating benefits of geothermal heat. The long history of the direct uses of Crystal Hot Springs waters made that energy source attractive to Utah Corrections in spite of the immediate availability of natural gas and previous problems with corrosion and equipment failure.

Comparison of costs and benefits between direct use of geothermal energy and the best alternative energy source should include three evaluation categories: site constraints caused by the lack of portability of geothermal energy, differences in quality and serviceability between energy sources and the life cycle cost of equipment, operation and maintenance per unit of energy delivered by various competing sources of energy.

In the case of Crystal Hot Springs, grid-supplied electricity and natural gas are both already in use at the prison, and district heating facilities are already in place to distribute steam to any location. As such, there is no significant new fixed cost in supplying natural gas and electricity to facilities that are served, or will be served, by geothermal water. With use of a closed loop heat exchange system on the building side, there is also no apparent difference in quality between sources of energy as the heat exchanger and cold side water conditioning system assure consistent water chemistry regardless of which heat source is in use.

In the performance contract, Johnson Controls based projected savings from geothermal use on the avoided cost of natural gas at $0.34 per therm, diesel oil at $0.70 per therm and $2.02 per therm for electricity in resistance heating. Accurate calculation of savings is compromised by the fact that the Draper correctional facility contains no sub-metering of steam heat demand across 1.1 million square feet of building area. As such, neither the original 1982 geothermal facility nor the 2004 upgrade can state the actual amount of deferred natural gas. Instead, Johnson Controls estimated energy savings from geothermal use by two means:

1. Apportionment of overall natural gas and electricity costs for the entire prison on a square foot basis, with adjustments for peculiarities in the use of buildings supplied by geothermal heat.

2. Calculation of the amount of heat energy supplied to the geothermal system as a function of temperature drop across the heat exchanger, multiplied by the volume of geothermal fluid supplied over time, with a usage factor of 25% added to estimate total actual consumption.

For calculating domestic hot water savings, Johnson Controls used an MS Excel spreadsheet. For heat supplied to certain building areas, the avoided cost of natural gas was projected across the forecast period using eQuest computer simulation software. The model took into account the fact that buildings heated by geothermal water are poorly insulated and served by weak climate controls. However, software did not fully account for use of only outside air, no furnace return air supply for the Oquirrh complex and inadequate building warmth in some shop areas. As a result, it is believed that cost savings are under estimated in Oquirrh 4 and over-estimated in shop areas. For life cycle purposes, electric motors are projected to last 18 years, pumps should last 10 years and the heat exchanger should last 24 years.

The life cycle cost of electricity for pumping geothermal fluid was calculated using forecast pumping rates and pressure head and typical pump efficiency values. These values were multiplied by the projected number of annual operating hours during the forecast period. To document geothermal system benefits, the Leonardo Academy has been hired to produce an environmental and business report on the geothermal project that will be available sometime after August 2004.[15]

SUMMARY

Crystal Hot Springs will continue to provide water and energy for commercial uses into the foreseeable future. Further study of resource hydrology could assist with long-term planning for further economic development and help prevent conflicts between users and their respective water rights. There may be enough geothermal water for development of additional uses of Crystal Hot Springs if drought conditions ease and more care is taken in conserving geothermal flow between users. The use of geothermal water at the prison is based upon a financial plan that estimates the dollar value of this natural resource. Financial plans like these might serve as models for other geothermal uses that together might help illustrate its value and the important issues that must be considered in its use.

[15] Leonardo Academy, Madison, Wisconsin, is a non-profit corporation devoted to addressing energy and environmental issues, including evaluation of energy efficiency measures and policy alternatives, www.leonardoacademy.org.

GRANTSVILLE WARM SPRINGS, BONNEVILLE SEABASE, GRANTSVILLE, UTAH

OVERVIEW

Bonneville SeaBase is a commercial SCUBA[16] diving facility established at a collection of small ponds fed by the Grantsville Warm Springs. Located at the edge of Utah's west desert, about 39 miles west of Salt Lake City, SeaBase bills itself as "Utah's inland sea for snorkelers and divers".[17] The site is located about 3.5 miles south of the Grantsville interchange on Interstate 80, and about the same distance north of the town of Grantsville, population 6,500. SeaBase hosts dive training, school field trips, aquatic studies, scout troop excursions, other group events and visits from curious travelers.

The region is known for the Great Salt Lake, whose south shore is five miles to the north, and the Bonneville Salt Flats, 50 miles west, where generations of motor vehicle speed records have been set. Grantsville Warm Springs, and other geothermal springs in the area, are relatively low in temperature and high in mineral content. These characteristics greatly limit the range of possible commercial uses. However, a greater understanding of this resource could help make productive uses more feasible in the future.

GRANTSVILLE WARM SPRINGS GEOTHERMAL RESOURCE

Located at N 40° 38.784', W 112° 31.475', the Grantsville Warm Springs is a collection of more than 20 naturally flowing, low-temperature geothermal springs that fill four "hot pots" that vary in depth from 15 feet to more than 60 feet. Temperatures at depth reach 90ºF, while surface temperatures vary with the season, from a high of about 85ºF in summer to 61ºF in winter. A drilled well at the site provides additional geothermal water that naturally overflows unless it is pumped into the ponds.

The springs, situated along the northeast flank of the Stansbury Range, rise from fractured bedrock and alluvium. This range consists mainly of Paleozoic quartzite and carbonate rocks folded and thrusted along a generally north-south alignment (Mundorff, 1970). The surrounding region is typical of the Basin and Range province.

The Grantsville Warm Springs is more saline than most of its neighbors, with a specific gravity of about 1.0 and a total dissolved solids (TDS) concentration of about 26,500 milligrams per liter (mg/L) or roughly 3% mineral content. Magnesium and sodium are present in concentrations slightly lower than most ocean water. In contrast, calcium is present at levels somewhat higher than ocean water and requires chemical treatment to prevent blockage in pipes. By comparison, the nearby Great Salt Lake ranges between 15% to 27% salt, or TDS well over 100,000 mg/L. SeaBase staff believes that relatively higher concentrations of magnesium in Great Salt Lake water is evidence that geothermal water is not affected by the Great Salt Lake.

SeaBase reports that spring flow is declining, although much of the loss may be drought-related. Occasional events of heavy precipitation coincide with an increase in resource flow. During such events, SeaBase requires less pumping to supplement artesian flow into ponds. In late 2004, an increase in precipitation has resulted in greater geothermal flow. If sustained, SeaBase will be in a position to consider expanded commercial aquaculture in surface tanks without affecting pond conditions.

The Basin and Range province of northern Utah is characterized as a cold desert, with total annual precipitation seldom exceeding 15 inches. Relative humidity can reach as low as 15%, during both warm and cool seasons. Cloud cover is infrequent, providing about 300 days of sunshine per year. Winter low temperatures may fall below 0ºF, while summer high temperatures often reach 100ºF. Windy conditions are frequent, and there is little micro-terrain or vegetation to block air flow to and from the Great Salt Lake. Se-

[16] Self-contained underwater breathing apparatus
[17] Unless otherwise noted, specific information about Bonneville SeaBase was derived from their web site (www.seabase.net) and personal interviews with facility staff.

aBase records indicate that evaporation from uncovered ponds is strongly affected by wind conditions and amounts to at least 10% of total geothermal flow.

The Grantsville Warm Springs are located in the Tooele Valley at about 4,290 feet above sea level. The peaks of the adjacent Stansbury Mountains exceed 11,000 feet elevation, providing abundant springtime runoff. The valley consists of salt marshes, flats or playas that are either sterile to vegetation or occupied by a mixture of salt grass and low brush. Few trees of any size are native to the area.

SEABASE OPERATIONS

The opportunity to interact with true ocean creatures in a saline environment attracts clients and curious visitors to SeaBase from across the United States and from foreign countries. The operation is associated with Neptune Divers, based in Salt Lake City, who provide dive certifications and act as a gateway to a variety of other organizations and services, including ocean diving tours to Thailand and other exotic places. In addition, SeaBase operators have participated in the transfer of marine animals to and from large aquariums and have cooperated in university study projects.

Facilities

Established in 1988, Bonneville SeaBase is a full-service commercial business specializing in SCUBA-related recreation including training, equipment rental and related services. Amenities include warm freshwater showers, overnight outdoor camping, trailer rentals and limited retail sales of dive-related items. The site consists of four dive pools, two of which are covered by aluminum and plastic structures to help control water surface conditions. The surface area of the pools totals about 30,000 square feet. Pool water is continuously freshened by mild artesian flow from underlying springs.

Pools are stocked with tropical marine animals including angels, damsels, groupers, grunts, hogs, puffers, nurse sharks, jacks, mollies, tangs, triggers and shrimp. At various times, a variety of other animals and plant species have been introduced at SeaBase with varying success. An enclosed greenhouse "laboratory" contains isolated tanks where tests are conducted for introduction of new species or for evaluating habitat problems. At present, a variety of sea coral and green plants are being tested for adaptation in the pools. In addition, horseshoe crabs and sea horses inhabit a very small pond that is separate, but not fully isolated from the other ponds.

In addition to artesian flow, a drilled well located about 50 feet east of the main building provides additional geothermal flow that is alternately fed into the water purification circuit or piped into some of the open pools to improve circulation. A separate drilled well nearby provides additional flow for pond circulation. Constant speed pump motors of 25 horsepower are capable of providing a combined total of 200 gallons per minute (gpm). There is no overall automatic flow control, and overflow from geothermal pools goes directly into an open ditch for soil percolation. SeaBase routinely routes surface overflow to and from different ponds for habitat maintenance. In any case, water continuously overflows the ponds and is directed through open ditches for soil percolation and evaporation. There is no firm understanding of how this system of flows affects groundwater recharge.

Over the years, the pools have been excavated, contoured and interconnected to improve safety and provide greater interest and opportunity for both divers and marine animals. The deepest pool has been excavated to 62 feet in order to accommodate more intensive SCUBA training. Facilities also include a 2,000 square foot main recreation center containing showers and dressing rooms, equipment rental counter, gift shop and related facilities. Auxiliary buildings include about 5,000 square feet of sheds and equipment rooms and two single-family homes for resident employees. Chemical toilets are provided for client use, while employee residences have septic systems. Outdoor camping and barbecue facilities are available and a recreational aviation business located at an adjacent airport provides additional business traffic. A portion of geothermal well water is diverted every few days for production of fresh water using military surplus reverse osmosis equipment. Average daily production of fresh water from geothermal brine averages about 300 gallons per day and is used for bathing and cooking. Otherwise, no fresh water is available.

Energy Use

The warmth of geothermal water is a primary attraction for SeaBase that cannot feasibly be replaced by any reasonable alternative source of energy. Recently, Questar natural gas service reached SeaBase at a hook-up cost of $18,000 and is now used for heating most of the buildings and for culinary water at a lower unit cost than propane delivered by truck. Propane continues to be used for heating some buildings and for other minor miscellaneous uses. Before the availability of natural gas, hot water for domestic use, including showers, was also provided by small electric resistance heaters and by solar heat collection equipment mounted on the roof of the main recreation building. Overall cost of heat for domestic water and space heating needs is now somewhat lower than the peak monthly cost of about $2,000 for the combination of propane, electricity and solar equipment used in the past.

Electricity is also used for building lighting, well pumps, air compressors, refrigeration equipment and water desalination. SeaBase staff report that power outages are frequent. Staff interest in developing alternative energy from photovoltaic and wind is tempered by the recognition that these sources also vary in reliability. There is no systematic sub-metering of electricity demand that might help determine best options for achieving greater efficiency. However, general observation of equipment and practices suggest that SeaBase could reduce electricity load by invoking the same energy control measures that are typically recommended for most commercial businesses in Utah: add building insulation, use compact fluorescent light bulbs and up-grade motors and motor controls.

GEOTHERMAL DEVELOPMENT ISSUES

Water Quality and Quantity

The success of SeaBase rests upon the clarity of water and its ability to sustain marine life while simulating ocean dive conditions. Operators try to influence the balance of water chemistry and aquatic life and carefully limit the activities of divers and swimmers. However, the warmth and mineral content of spring water, in combination with slow circulation and limited exposure to wind across covered pools, provides conditions conducive to algal plant growth. In spite of best efforts, pool water is always cloudy, with visibility in different areas ranging from 15 feet to as little as four or five feet. Marine life produces substantial waste, and divers inevitably kick-up large amounts of silt that can especially degrade conditions during periods of heavy use. At times, water visibility is only marginally suitable for both marine animals and water recreation. Operators cite this situation as a limiting factor to building the popularity of SeaBase as a recreation and training facility and substantial expense and attention goes into solutions to water quality.

Efforts have been made to introduce marine creatures that help balance interactions between brine, plants and animals. Various invertebrates, including anemones, “sea squirts” and sailfin mollies have been marginally successful. Experience so far shows that anemones do not thrive in the brine, while mollies successfully clear vegetation but produce excessive waste of their own.

Due to lack of funds and skepticism by some outside experts as to the validity of trying to establish an ocean habitat in Utah, SeaBase does not have a full-fledged, scientific water quality management program. Instead, SeaBase operators gather knowledge from a variety of sources and rely on practical experience from trial and error and constant observation. Meanwhile, operators are also occupied with business management tasks and key people frequently travel out-of-state and overseas as either tour guides or in pursuit of marine animals or other resources. SeaBase also lacks full understanding of the geothermal resource because the low temperature of geothermal water at the Grantsville Warm Springs has attracted relatively little professional geologic interest.

A 1970 study estimated artesian flow at 400 gpm (R. Blackett, verbal communication, May 2004). SeaBase operators acknowledge an overall decline in flow since first developing the resource and particularly since regional drought conditions began in about 1998. At present, estimated spring flow ranges from 226 to 300 gpm. Recent wetter weather in Utah has added considerably to current spring flow. Automated software now tracks measurements taken from a weir at the north end of SeaBase property where overflow geothermal water is directed for dispersal. Operators also note that a recent increase in non-geothermal irrigation by upstream neighbors may be affecting geothermal aquifer recharge. In any case, spring flow remains more than adequate to stock the ponds and provide at least some circulative effect.

Water quality testing was done frequently in the past to establish a baseline understanding of the spring's chemistry. Since then, occasional tests, particularly for oxygen levels in pool depths, help assure stable conditions. The solitary auxiliary well helps pools circulate and moderates saline content. Sulfur and magnesium content in the brine are both lower than typically found in sea water, which presents a problem for some species of ocean-dwelling fish that have been introduced at SeaBase. In contrast, phosphates and copper in the water are relatively high, which provokes additional difficulties with unwanted algal growth.

Water Rights

In Utah and the West, water rights are a sorely tested issue for which there is a great body of law and controversy. SeaBase operators are in the process of "proving-up" water rights by periodically submitting applications with the Utah State Engineer. The recently installed combination of weir and automated flow measurement is used for estimating geothermal flow and evaporation from ponds. Meanwhile, landowners uphill to the west are also in the process of proving water rights by heavily watering their property. It is believed that this activity is prefatory to converting that water from agricultural use to culinary use when the site is developed for commercial activity in the future. In any case, the combination of evaporative loss and soil percolation in this desert climate are sufficient to establish SeaBase activities as a consumptive use for which water right proofs are being sought. This process is somewhat complicated by competing water rights held by neighboring landowners, including disputes over prior rights and uncertainty over the source of geothermal and other groundwater flow. SeaBase staff also report difficulty in understanding and complying with regulatory requirements and legal processes that control water use in Utah.

SeaBase Competitive Position

SeaBase operators describe their facility as a "labor of love" that depends somewhat upon voluntary contributions of time, materials and technical support, in addition to revenues from customers. Bonneville SeaBase may be unique in the United States as a deep inland marine facility hosting true ocean creatures, however, even in arid Utah, there are a number of alternative sites for dive and snorkel training and recreation. Several other dive companies are active along the Wasatch Front, including a geothermal facility at Midway, Utah, located about as far to the east of Salt Lake City as SeaBase is to the west. Unlike SeaBase, that facility is surrounded by additional amenities including a popular state park and extensive mountain and fresh water recreational facilities for all seasons.

In addition, a number of cold water lakes and ponds in the region are popular for diving. At least two geothermal lakes are also frequented by divers, particularly Blue Lake, a 400-acre fresh water body that is heated by geothermal flow. Water visibility is superior to SeaBase, but the lake is located 130 miles from Salt Lake City. Dive facilities there are primitive and no services are provided.

The schedule of prices for recreation and training at SeaBase are nominal and, for many clients, perhaps less than the cost of travel to reach the site. For simulation of underwater ocean conditions there is probably no fully comparable facility in the region.

Regulatory and Land-Use Constraints

The Utah Department of Agriculture regulates the transport and use of aquatic animals. County land-use controls, building inspection and various local and state licenses govern business practices. At times, questions about the legality of transporting and holding various aquatic species have arisen. It is not clear whether or not these issues are yet resolved. According to SeaBase, the unique status of aquatic environment and animal life may not be fully appreciated by existing Utah law and administrative rules. Among other things, state officials may require the killing of mature fish for laboratory testing in order to comply with current health regulations. According to SeaBase, doing so would be both unnecessary and expensive.

Adult fish cost up to several thousand dollars and tests conducted on one animal would not necessarily indicate the health status of the others, nor prove compliance with standards. In any case, SeaBase also believes there is no evidence that the Grantsville Warm Springs are connected in any way to the surrounding environment. As such, SeaBase staff believes that their water quality problems should be viewed as a private matter.

County land-use planning has designated areas west of SeaBase entirely for industrial development (R. Clark, Tooele County Chamber of Commerce, verbal communication, 2004). View-shed standards to protect mountain vistas further limit types and extent of construction. The area surrounding SeaBase is designated for commercial use, with emphasis on outdoor recreation, such as sky diving. Very low density residential and agriculture are allowed in surrounding areas as well. There is no practical limit to the opportunity for commercial development in the immediate vicinity that could provide spin-off commercial traffic for SeaBase.

Meanwhile, the wide-open spaces of Tooele County and the west desert may be less open to development than they appear. Federal land, in the form of national forest, military training areas and storage depots, cover about 200 square miles to the west and south. The Tooele Army Depot, with its famous and immense reservation of chemical warfare agents, is probably a minimal issue for SeaBase clientele, but will probably continue to limit general urban development in the valley until destruction of those weapon stockpiles is complete. The Great Salt Lake blocks all development to the north while a large portion of lands in between are compromised by wetland designation, marshes and sterile saline soils.

Regional Economic Trends

Eastern Tooele County is experiencing substantial new housing construction and associated retail services, both arising from spillover urban growth from the Wasatch Front. Aside from that growth, the county is economically stagnant, with both hard-rock mining and agriculture in decline. Remaining primary mineral industries in the area extract lime, magnesium, aragonite, sand, gravel, sodium, phosphate and dolomite. None of these industries is labor intensive, and no new business expansion is expected.

Almost all SeaBase clients arrive by Interstate 80, which also carries cross-country traffic and serves as a major conduit for Utah residents traveling to casino resorts just across the Nevada border. However, the freeway interchange leading to SeaBase provides no traveler services and therefore provides little attractive interest toward SeaBase. Instead, motels, restaurants and truck stops are located at the Tooele exit 10 miles further east. Gradual expansion of I-80 traffic and urban growth in Grantsville will eventually result in development of freeway-oriented services at the exit leading to SeaBase. The Salt Lake International airport is located about 30 minutes east of SeaBase and is the port of entry for many of their aquatic animals.

Industry-zoned property located across the highway to the west is slated for a Walmart regional distribution center. It is believed that this facility will generate substantial highway traffic, perhaps leading to freeway-oriented development that could draw traffic toward SeaBase. Other surrounding property will not be developed for some time but will inevitably bring additional highway traffic and exposure.

POTENTIAL GEOTHERMAL DEVELOPMENT

Industrial Processes

Worldwide, hundreds of industrial processes use low-temperature geothermal water. However, the low volume, high mineral content and low temperature of the Grantsville Warm Springs are inadequate for significant industrial use. Moreover, there are no significant nearby industries that require heated water.

Aquaculture

Commercial fish farming is a potentially viable economic use. Oysters, lobsters, shrimp, salmon, prawns, catfish, eel, carp, trout, perch and bass can tolerate water temperatures ranging from 61ºF to 90ºF, which straddles the range of temperatures observed at SeaBase. Saline conditions will be a limiting factor for many species but may be particularly favorable for tuna. Previous SeaBase experience with excavating geothermal pools should be applicable for installation of an isolated raceway system that is necessary for tuna production.

Cultivation of aquarium fish was tried at SeaBase in 1998 with some success. In fact, SeaBase staff experience is that "tank-raised" species adapt more successfully to life in aquariums and are less prone to disease. Effective production techniques were well into development when internal management problems interfered with operations and the facility was shut down. Most of the tanks, pumps and control systems have since been dismantled.

Since that time, market conditions have improved and prices for hobby fish have risen from less than $3.00 per animal to as much as $12.00 in the Salt Lake area. Meanwhile, SeaBase operators lack the capital and time to restart that arm of the business.

Ancillary Recreation

Bonneville Skybase is a business offering powered parachute flight and flight training services, with a runway and hangar located on SeaBase property to the north. The facility provides full-service instruction, equipment rental, certification and related services, but operates only intermittently based upon customer demand and weather conditions. The presence of SkyBase contributes to the overall customer traffic and market visibility of SeaBase, particularly because both facilities focus on outdoor recreation whose full enjoyment requires specialized equipment and training.

SeaBase operators are very interested in developing other ancillary commercial activities and frequently entertain proposals. However, firm offers and financing have been slow to materialize, and SeaBase continues on as a largely stand-alone operation.

Power Production

As noted, SeaBase has abandoned its rooftop solar energy collection equipment and most of its propane use in favor of newly available natural gas. However, frequent power outages from grid-supplied electricity has led SeaBase to briefly consider the use of inline micro turbines to generate electricity from outfall water leaving the ponds. It is estimated that 12 feet of head exists across the property and, as noted, flow averages slightly more than 300 gpm. Capturing a substantial portion of that head would require construction of a penstock to convert surface slope to direct fall. Market availability of small-scale power generation equipment, with alternating current output, would appear to be less expensive than many typical small-scale renewable systems since a power inverter, with its associated power loss of up to 15%, might be avoided. Still, load control equipment is expensive, and with the retail price of electricity less than $0.07 per kilowatthour (kWh), there is little possibility that on-site hydropower development would be even remotely cost effective. The same is probably true for other off-grid power options such as wind and solar. The availability of grid power, even if unreliable, makes all off-grid options, particularly if used with batteries, uneconomical.

Under ideal conditions, hydroelectric power generation at this site might produce about 1,750 kWh per year. At commercial rates in Utah, the avoided cost of grid power would total roughly $100 per year. Equipment for that level of power production would probably cost at least $5,000, resulting in a break-even return-on-investment much longer than the expected life of the equipment. As noted, a much more cost effective option would be to install more energy efficient equipment, particularly lighting, and practice ordinary conservation practices. In particular, careful management of geothermal pumping could reduce electricity demand while still maintaining adequate pond circulation.

SUMMARY

SeaBase is a unique geothermal facility that provides an ocean-like environment in the middle of the desert. The facility could benefit from further geotechnical study in order to better understand the geothermal resource and most efficient management practices. Of greater need is development of a biological model of brine interactions with weather, aquatic habitat and diving activities in order to resolve water clarity issues. Improved water clarity and the ability to modulate water chemistry would enhance habitat quality for marine animals and provide a more enjoyable and effective environment for dive training. The facility has the potential for generating additional commercial activity by raising fish for commercial sale.

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