SECTION 1.0
INTRODUCTION

This report presents an update to the *Preliminary Engineering Report for Upgrading the Marlette Lake – Hobart Reservoir Water Delivery System* (PER), dated December 8, 2000. Brown and Caldwell prepared the PER in 2000 for the Carson Water Subconservancy District (CWSD) as one of a series of Phase II feasibility studies for improving water resource availability in the Carson River watershed. The PER provided a first-order technical and economic evaluation of alternatives for increased delivery of surface water from the Marlette Water System (MWS) to Carson City. Subsequently, AMEC Infrastructure Inc. prepared a second PER in 2001 for the State of Nevada Public Works Board entitled *Preliminary Engineering Report for Marlette Lake Water System – Water Transmission Facilities from Marlette Lake to Red House Diversion Structure.*

This update presents an evaluation of alternatives and system components identified by CWSD from both PERs to increase the delivery of Marlette Lake water to Hobart Reservoir. The technical, economical and environmental feasibility for each alternative is discussed. This update also provides the basis for a detailed Environmental Assessment (EA) of the alternatives to be conducted in the second half of 2004.

The four alternatives identified by CWSD for further evaluation include two gravity flow and two pumping scenarios:

- Alternative 1 -- Gravity flow in borehole;
- Alternative 2 -- Re-established Flume Trail and Incline Tunnel (gravity flow);
- Alternative 3 -- Natural gas-powered pump and pipeline; and
- Alternative 4 -- Diesel-powered pump (modified to increase system capacity and implement environmental improvements to the current delivery system)

1.1 Description of the Marlette Water Delivery System

The MWS is one component of the larger Marlette Hobart Water System (MHWS). Figure 1 shows the location of Marlette Lake, from which water is seasonally pumped with a temporary diesel engine-driven pump through an 8-inch-diameter pipe aligned east-northeast from the lake. The pipeline discharges into a tributary drainage to Hobart Creek upstream from the Hobart Reservoir. In 2003, the average delivery rate was approximately 2.45 cubic feet per second (cfs) or 1,100 gallons per minute (gpm). In addition to receiving pumped water from Marlette Lake, Hobart Reservoir is naturally fed by Hobart Creek and nearby drainages. The reservoir is an impoundment created by a small earth-fill dam with an estimated capacity of 100 acre-feet (AF). It discharges into Franktown Creek, which ultimately feeds the Red House Diversion Structure (Figure 1). Nominally, the existing system operates between early July and mid-October of each year, equivalent to about 110 days or 16 weeks of full-time operation. Seasonal operations are dictated by the need to haul diesel fuel by roads that are impassable during much of the year.

1.2 Description of the Existing Marlette – Hobart Water Delivery System

The MHWS is composed of connected drainages and infrastructure components originally used to divert water for use in the Comstock mining era. Currently, the MHWS delivers water to Carson City and surrounding communities including Virginia City, Gold Hill, and Silver City. The location and features of the MHWS are shown in Figure 1. The MHWS is described in detail in the 2000 PER, which includes a preliminary condition assessment of the existing system. A summary of the system features evaluated in, or related to, this update is provided below.

The Red House Diversion Structure is located where the East Slope Collection system intercepts Franktown Creek. The Red House Diversion Structure is a concrete diversion dam with a tiered emergency overflow. A small impoundment with its standing surface approximately one inch below the overflow at the lowest tier flows through a knife gate into a concrete box. This box discharges directly into an 18-inch-diameter transmission line that conveys system water by gravity to the Tanks (Figure 1).

The East Slope Collection system includes a pipeline and several drop inlets that intersect minor drainages located northwest of the Red House Diversion Structure. Up-gradient of the East Slope Collection area is the Comstock-era flume system that was used to convey flow from a dam located near the center of the western shore of Marlette Lake to the Red House Diversion (Figure 1). The condition of the flume system has degraded to the point where it can no longer be used. In particular, the flume passes through the Incline Tunnel, which has partially collapsed.

The portion of the MHWS located down-gradient of the Red House Diversion Structure is not included in this updated evaluation. These components of the MHWS include the 18-inch-diameter collection pipeline, the Tanks and subsequent conveyance to Carson City via the existing 8-inch-diameter transmission line and to Virginia City via the inverted siphon. A more detailed evaluation of upgrades to these conveyances located down-gradient of the Tanks would be conducted separately.

1.3 Design and Alternative Selection Criteria

The hydraulic basis-of-design for the improved delivery system has been established at 4.2 cfs or about 1,890 gpm. This delivery rate is based on the hydrologic analysis of the MHWS prepared by CWSD staff (Appendix A). The alternatives will be evaluated based on: 1) technical feasibility and constructability; 2) construction and operating costs over a 30-year period; and 3) the results of the EA to be conducted separately from this updated engineering evaluation. Upon completion of the EA, CWSD and other stakeholders such as Carson City, the State of Nevada (Department of Administration – Division of Buildings and Grounds) and the U.S. Environmental Protection Agency (EPA) will select a preferred alternative for implementation.

SECTION 2.0
SYSTEM ALTERNATIVES

This section presents a description of the proposed improvements for each of the four alternatives. CWSD elected not to conduct any additional evaluation of the Flume Trail – Incline Tunnel alternative described in the 2001 PER prepared by AMEC Infrastructure, Inc. Therefore, Alternative 2 in this updated evaluation simply re-produces the information presented in the AMEC report. Alternatives 3 and 4 are very similar in scope, with the major exception of the natural gas supply pipeline required for Alternative 3. The use of hydro-electric power was also evaluated for both of the pumping alternatives to reduce operating costs.

2.1 Alternative 1 -- Gravity Flow in Borehole

This alternative consists of the construction of an intake structure and associated intake controls, and a cased directional boring, which would allow for gravity flow of water from Marlette Lake. The discharge from the borehole would either be directed to a drainage located immediately upstream of Hobart Reservoir (Alternative 1A, shown in Figure 2), as in the existing system, or to Franktown Creek, located immediately downstream of the reservoir (Alternative 1B shown in Figure 3). The down-gradient location would eliminate the deleterious water quality effects (e.g., color and tannin) caused by storage in Hobart Reservoir.

The proposed intake structure, located at the northeastern margin of Marlette Lake, would be constructed from concrete and consist of the following features: wing walls perpendicular to the shore; a trash rack; an automatically actuated ball valve to isolate and throttle flow; and a flow meter to monitor flow and control the ball valve. A conceptual plan view and section of the intake structure is depicted in Figure 4. A preliminary process instrumentation diagram for the intake structure is provided as Figure 5.

The dimensions of the intake structure, to be developed as part of a detailed engineering design, would primarily depend on the depth of the intake below the adjacent shoreline. The proposed system includes SCADA monitoring and control of the flow meter and the throttling valve position, and control of the ball valve to throttle the system to match the design (or other) flow rates. Since telephone service is not available at the site, a satellite communications system is proposed. In addition, a solar system is proposed to provide power for the system monitoring and control features.

Figure 2 shows the proposed gravity transmission main alignment for Alternative 1A, which heads east from Marlette Lake to its discharge point located where the existing pumping system discharges to a tributary drainage to Hobart Creek. The alignment is approximately 9,100 feet long at a slope of 2 percent. Along this alignment, the maximum overburden thickness is approximately 600 feet. Based on the design flow and the alignment slope, a 12-inch diameter transmission line would be sufficient.

As shown in Figure 3, the proposed gravity transmission main alignment for Alternative 1B heads east-northeast from Marlette Lake to Franktown Creek, immediately downstream from Hobart Reservoir. The alignment is approximately 10,300 feet long at a slope of 3 percent, with a maximum overburden thickness of approximately 600 feet. The design flow and the alignment slope for Alternative 1B would also require a 12-inch-diameter transmission line.

Although the anticipated lithology consists of hard granite, a coated steel casing is proposed to eliminate potential problems such as loss of water or partial blockage of an open borehole associated with potential fractures or faults. The pilot hole for the borehole would be drilled beginning at the downhill side of each proposed alignment. Initially, the pilot boring would be curved until the proposed line and slope are met. Thereafter, the line and slope are maintained until the end of the boring is approached, at which point the pilot boring is once again curved to meet the surrounding grade at the exit point adjacent to the Marlette Lake shore.

The following construction-related information is provided by Randy Shipalesky of Direct Horizontal Drilling, located in Spruce Grove, Alberta, Canada. After drilling of the pilot hole is completed, the boring would be opened to accommodate the proposed casing. A hole opener would be put into the drill string on the downhill side of the boring. A second drilling rig, located at the uphill or exit side of the boring would be used to pull the opener through the pilot boring. The entry side drilling rig would be used to provide the rotational torque and to pump the drilling fluid. During installation of the casing, a hole opener is placed ahead of the casing to remove and debris in the boring. Fluid is pumped through the opener to provide lubrication for the casing during installation and also to carry out debris. Directional drilling contractors indicate that the casing would be pulled and not pushed due to the length of the boring.

Typically, where space allows, casing sections greater than 1,000 feet in length would be welded together prior to pulling. Due to space limitations at both the entrance and exit sides of the proposed borehole, such casing lengths would not be feasible. For the MHWS application, it is anticipated that sections no greater than approximately 500 feet in length would be welded prior to pulling. Completion of the boring at both the upstream and the downstream ends would involve the construction of pits to intercept the cased borehole. From the pits, the transmission line would be completed at both ends by traditional trench type pipe installation.

The estimated area required for setting up the drilling equipment at the downhill side of the borehole would be approximately 200 feet by 200 feet. At the uphill side of the boring, an area of approximately 150 feet by 50 feet would be required. Both borehole alignments would require the construction of access roads to the starting location of the boring. Alternative 1A would require an extension of the existing road located along the northeastern shore of Hobart reservoir approximately 0.75 miles to the southwest. Alternative 1B would require extension of the existing road located along the northeastern shore of Hobart reservoir about 0.25 miles to the northwest.

The cost of directional drilling is sensitive to many factors including the following: lithology (compressive strength and crystalline structure of the granite); number of drill bits used during installation; mud motors used during installation; amount of drilling fluid consumed; and the length of casing that can be pre-welded prior to pulling through the borehole. Prior to final design it is recommended that fault mapping and a thorough geotechnical investigation be conducted. In addition, consideration must be given to the amount of land made available to the contractor for welding of casing sections prior to installation and the possible use of a barge on

Marlette Lake for conducting the hole-opening operation and pulling the casing through the borehole.

2.2 Alternative 2 -- Re-established Flume Trail and Incline Tunnel

Alternative 2 includes the construction of a new gravity-flow pipeline from Marlette Lake to the Red House Diversion Structure (AMEC, 2001). The pipeline would begin at the existing dam located near the center of the western shore of Marlette Lake and follow the alignment of the existing flume along the western slope of Marlette Peak through the Incline Tunnel to the East Slope Collection pipeline before discharging to the Red House Diversion structure (see Figures 6A through 6D).

The 2001 PER prepared by AMEC serves as the basis for the evaluation of this alternative, which recommended the following construction activities:

- "The flume trail would require grading work in order to provide proper bedding for the pipeline. Due to the rocky, steep terrain, it may be necessary to construct a retainer box structure in which to bed and cover the pipe in order to avoid major rock excavation, to lessen the visual impact to the area, and to provide a suitable surface on which to re-establish the existing hiking/biking trail."
- "The Incline Tunnel would require repairs and rehabilitation to allow for the construction of the gravity pipeline through it. This would entail the removal of the debris from the collapsed areas and the stabilization of the tunnel walls and roof throughout its length. Care should be taken with any rehabilitation to minimize adverse impacts to seepage water entrance into the tunnel. Provisions would be made to allow for the collection of the seepage water and allow the addition of it to the water flow from the lake."
- "The existing pipeline along the east face would be replaced with an 18-inch-diameter pipeline laid along the flume trail alignment at an average gradient of 0.009 ft. /ft. The pipe would be designed to be buried, as opposed to the existing pipe that is exposed. This will lessen the visual impact on the area as well as provide needed protection for the pipeline."..."The existing spring collectors would be rebuilt as needed and connected to the new pipeline."
- "At the Red House Diversion, the pipeline would be connected to the inlet structure to the pipeline to the tanks in place of the existing 12-inch-diameter pipe. No major upgrades are planned for the diversion structure."

According to the PER, the proposed pipeline would be constructed with 18-inch-diameter PVC, C-905, Class 150 pipe. Brown and Caldwell reviewed the recommendations provided by AMEC, with the following observations: 1) the 4.2 cfs basis-of-design indicates that a smaller diameter pipeline (e.g., 12 to 14 inches) may be used for up to two-thirds of the proposed alignment, which would result in construction cost savings; and 2) potential savings that may result from the installation of a smaller diameter pipeline may be offset by costs that the AMEC report did not include for flow monitoring and throttling, SCADA, cleanouts and an intake structure. Costs presented in the 2001 PER are re-produced in this updated evaluation.

2.3 Alternative 3 -- Pumping Station with Natural Gas-Powered Pump

Alternative 3 consists of the construction of an intake structure and a permanent pumping station driven by a natural gas-powered engine. In addition, an upgrade to the existing force main/gravity discharge line would be required to accommodate the conveyance of 4.2 cfs of Marlette Lake water to the existing discharge point, located in the tributary drainage to Hobart Creek immediately upstream of Hobart Reservoir (Figure 7).

The natural gas-fueled engine system would require the installation of a natural gas supply line from the existing Paiute Transmission Line to the pump station at Marlette Lake (Figure 7). The Paiute Transmission Line runs parallel to the 18-inch-diameter water pipeline from the Red House Diversion to the Tanks and, at its closest point, is approximately 3.8 miles from the proposed Marlette pump station. The route for the supply line would be primarily along existing roads and trails.

Southwest Gas would require the installation of a satellite communication meter at the tap, a permanent 10-foot wide easement across lands administered by the U.S. Forest Service, and a temporary 20-foot wide easement during construction (the cost to procure the easements is not addressed in this evaluation). The design of the natural gas-powered fuel supply would conform to National Fire Protection Association (NFPA) guidelines (e.g., NFPA 37 and NFPA 58).

Force main/Gravity Transmission Line

The alignment of the proposed force main/gravity transmission line would follow the existing 8-inch-diameter pipeline, which runs north-northeast from Marlette Lake to the tributary drainage to Hobart Creek. This alignment appears to be the best route because: 1) the topography is consistent with few significant slope changes (i.e., a limited number of low spots; 2) it represents the lowest static lift of any potential adjacent alignments; and 3) it is located on previously disturbed ground, which should reduce environmental impacts associated with new construction. The first 4,500 feet of the proposed alignment slopes upward to the top of the hill at an average grade of approximately 0.1 feet/feet. Thereafter, the alignment slopes downward at an average grade of approximately 0.08 feet/feet. The proposed alignment would transition from a force main to a gravity line at the top of the hill.

The total dynamic head (TDH) and pipeline velocities were calculated for several force main diameters, resulting in the selection of a 12-inch-diameter, Class 350 ductile iron force main because it provides a good balance between reducing dynamic head and maintaining sufficient pipeline velocity to minimize sedimentation. The proposed gravity transmission line diameter will vary in diameter from 10 to 16 inches. The grade on the downslope is such that the vast majority of the gravity transmission line can be 10 inches in diameter. Short sections of the gravity line, comprising less than one-third of the total length, would have to be upsized to accommodate flatter grades.

Proposed transmission line information is summarized in Table 2-1:

Table 2-1. Summary of Force Main and Gravity Transmission Line

Parameter	Value
Force main	
Material of Construction	Ductile Iron Pipe, Class 350
Diameter/Length	12-inch/4,500 feet
Combination Air Valves	1 Each (minimum)
Gravity Transmission Lines	
Material of Construction	Ductile Iron Pipe, Class 350
Diameter/Length	10-inch/500 feet
Diameter/Length	12-inch/3500 feet
Diameter/Length	16-inch/500 feet

During detailed design, careful consideration should be given to the transient analysis of the force main. At a minimum, combination air/vacuum relief valves would have to be provided at the major grade break and in selected topographic depressions along the alignment.

Due to anticipated shallow depths to granitic bedrock over much of the alignment, the proposed force main/gravity transmission line would be covered instead of being trenched and buried. Certain sections of the alignment, in locations such as road or trail crossings, would be buried. Selected portions of the gravity transmission line may have to be trenched to maintain the required slope.

Pumping Station and Intake Structure

The proposed intake structure, similar to that described for the gravity borehole alternative (Figure 4), would be located at the northeastern margin of Marlette Lake. It would be constructed from concrete and consist of the following features: wing walls perpendicular to the shore; a trash rack; and a manually operated sluice gate to isolate flow. The dimensions of the intake structure would be developed as part of a detailed engineering design, but would primarily depend on the depth of the intake below the adjacent shoreline. A suction line would be provided between the intake and the pump. The pumping station should be located so that the pump is no more than 20 feet above the lowest water level in the intake, and so that net positive suction head margins and requirements are met.

Both horizontal centrifugal and vertical turbine pumps were considered for the Marlette Lake pumping station. Vertical turbine pumps offer the advantage of potentially lower construction costs since the pump impeller and column can be located below grade in a sump, while the engine is located above grade. However, based on the preliminary selections used in this report, it appears that the net positive suction head required for the vertical turbine selections is approximately double that of the horizontal centrifugal selections. This may offset any potential savings associated with vertical turbine pumps. Therefore, we recommend that the selection of the pump type be made during the preliminary design phase when the exact pumping station site is located, the local topography is delineated, geotechnical conditions are investigated, and the minimum water surface elevation of Marlette Lake is determined. At that point the net positive suction head available can be accurately calculated, which will allow the designer to make a cost effective determination based on the suction head requirements of the two pump technologies.

Based on the proposed force main dimensions and alignment, and the design flow rate, the pumping system would operate at a total dynamic head in the range between 470 to 500 feet. These design parameters were used to make preliminary pump selections, resulting in the selection of a single pump that would be capable of meeting the design criteria. Pumps evaluated for this application include PACO 6015-1, Fairbanks Morse 8" 5826 Gormann Rupp PA6E-608, Patterson 13GHC, Patterson 14JMC and Floway 14DOH.

A schematic diagram for the proposed pumping-system configuration is provided in Figure 8. From the suction side to the discharge side, the system includes: screened intake with sluice gate for isolation; suction line; centrifugal pump; swing check valve; pressure gauge; plug valve for isolation purposes; flow meter; and combination air/vacuum release valve. All piping should be Class 350 ductile iron pipe with pressure-rated fittings. As shown in Figure 8, the pumping system would include SCADA monitoring of various engine parameters, check valve position, plug valve position, and the instantaneous flow rate. As with the borehole gravity alternative, SCADA communications would be provided via satellite.

Due to aesthetic concerns, the proposed pumping system would be housed in a building with acoustic, landscaping and architectural treatments. The building size would be approximately 400 square feet and would include ventilation for the pump engines and access for pump/engine maintenance, removal and replacement. For the horizontal centrifugal pump option the building would have two levels with the majority of equipment including pumps, engines and control and monitoring systems located on the lower level. Location of the pumps and appurtenant equipment on the lower level is proposed to increase the suction head available to the pumps. For the vertical turbine pump option the majority of the equipment including the engine and right-angle drive is located on a single level. The pump column and impeller is located in a steel can encased in concrete.

To show a typical configuration for a horizontal pump, a cross-sectional schematic of the proposed pump house building is provided as Figure 9. Conceptually, the upper floor of the building would be partially buried in the sloping hillside adjacent to the shore, with more exposure to the lake side. For the horizontal centrifugal pump option, the lower floor would be completely below grade. For either option, the building would be equipped with: a manual bridge crane or a rolling gantry crane, with a hoist for engine and pump maintenance; lighting; equipment pads; small engine generator to provide power for lighting, controls; monitoring equipment; and a portable air-operated pump for drainage of the crankcase oil. The building would be designed for snow and wind loads, and thoroughly winterized. Winter access to the building may be difficult under heavy snow cover, but it would be marked with snow stakes in case access is required.

Pump Engine Drive

The natural-gas engine for this application would require: lubrication oil storage and supply; exhaust silencers; intake silencers; air pollution control; vibration isolation; governors for speed control; block heating and ventilation. Proposed engine monitoring parameters include: oil temperature and pressure; jacket water temperature; engine speed; intake manifold vacuum (natural gas engines); cylinder exhaust temperature; main bearing temperature; and vibration. The proposed systems would be provided with the following internal logic: start up/shut down; emergency shut down; alarm condition shut down; manual shut-down/start up; timer and logic for lube oil priming pump; and timer and logic for remote devices such as cooling fans and pumps. The lubrication oil and supply system would consist of a double-walled aboveground storage tank with leak detection and a gear pump for transfer of the oil to a day tank. The day tank would supply the engine by gravity with the required lubrication oil. Control of the gear pump would be by a float in the day tank. Excess oil would drain back to the underground storage tank. The pump engines should be rated for continuous duty and, due to the altitude of the pumping station, the engine rating should be lowered by a minimum of approximately fifteen percent.

Hydro-Electric Power Support

The feasibility of micro-hydroelectric powered motors was evaluated using the method provided in the United States Department of Energy Office of Energy Efficiency and Renewable Energy brief entitled, "*Is a Micro-Hydroelectric System Feasible for You?*". Based on the methods presented in the brief, the estimated power potentially available is approximately 68 kilowatts or 91 horsepower. This estimate was based on the following: the design flow; the entire static head without consideration of dynamic losses; and a system efficiency of 55 percent.

Although the estimated power production is significant, it only represents about one quarter of the power required for pumping. This is the conclusion of Nevada Energy, LLC, a firm evaluating hydro-electric power opportunities for Carson City (William Taber, pers. comm.; 2004). Since the natural-gas engine driven systems cannot use the electric power for supplemental purposes, the implementation of a micro-hydroelectric system is not evaluated further.

2.4 Alternative 4 -- Pumping Station with Diesel-Powered Pump

Alternative 4 is similar to Alternative 3 in all respects, with the exception of the use of diesel fuel instead of natural gas to power the pumping station. It is essentially an upgrade of the existing system with a permanent, higher-capacity pumping station that would still require diesel fuel to be hauled to Marlette Lake on a regular basis. As with Alternative 3, an upgrade to the existing force main/gravity discharge line would be required to accommodate pumping 4.2 cfs from Marlette Lake. The discharge point would be the same as for the existing system, located up-gradient of Hobart Reservoir (Figure 7).

Force main/Gravity Transmission Line

The proposed force main/gravity line alignment would follow the existing 8-inch-diameter pipeline, which runs north-northeast from Marlette Lake to the tributary drainage to Hobart Creek, for the reasons described for Alternative 3. Design criteria for the conveyance would also be the same as presented in Section 2.3.

Pumping Station and Intake Structure

The conceptual design and location of the proposed intake structure would be similar to that described for Alternative 3 (Figure 4). Design criteria for the pumps would be the same, and the conservative two pumps-in-series option described in Section 2.3 would also be applied to Alternative 4, schematically depicted in Figure 8. Process controls would also be similar to that presented for Alternative 3, and the conceptual design of the pump house would also be the same, as shown in Figure 9.

Pump Engine Drives

Infrastructure described for the natural gas powered pumps would be the same for the diesel-fuel powered pumps (e.g., oil storage and supply, silencers, air pollution control and ventilation). Engine monitoring and internal logic systems would also be essentially the same. As described in Section 2.3, the altitude of the pumping station would require that the diesel-fuel powered engines would be de-rated by a minimum of approximately fifteen percent and would be rated for continuous duty.

The diesel-fueled engine would require an automatic fueling system similar to that described for the lubrication oil system. The diesel fuel storage and supply system would consist of a double-walled aboveground steel storage tank with a gear pump that transfers the fuel to a day tank mounted at the engine. The day tank would supply the engine by gravity with the required fuel. Control of the gear pump would be by a float in the day tank. The design should ensure that a small quantity of excess fuel is continuously draining back to the storage tank during engine operation. Fuel transfer piping should be double-walled. The proposed tank would be provided with a leak detection system and a screen wall to minimize the potential for vandalism. The proposed leak detection alarms and fuel level signals would be provided to the SCADA system. The proposed tank was sized to hold approximately a one week's supply of fuel or approximately 3,000 gallons. The fuel truck operated by the State of Nevada has a capacity of approximately 1,200 gallons, which would require refilling of the diesel fuel storage tank an average of 2.5 times per week.

Hydro-Electric Power Support

The application of micro-hydroelectric powered motors for the diesel fuel powered pumping station would be similar to that of the natural gas powered alternative, and is not carried forward in the analysis of alternatives.

SECTION 3.0
EVALUATION OF SYSTEM ALTERNATIVES

This section presents an economic and non-economic evaluation of each alternative. Weighting factors for the evaluation were determined by Brown and Caldwell and CWSD. Additionally, the EA to be conducted will provide more details on the environmental and ecological criteria described in this section.

3.1 Non-Economic Evaluation

Each of the four alternatives was subjectively evaluated in terms of reliability, environmental impact, ecological impact, aesthetic impact, operation and maintenance requirements, system flexibility (i.e., average annual water quantity), system capacity, water quality and constructability.

Reliability

The reliability of each alternative can generally be described as the ability to continuously operate for extended periods, under varying conditions, and with minimal downtime due to major maintenance and repairs. Based on these criteria, the proposed gravity alternatives (Alternatives 1 and 2) rank highly because they do not rely upon mechanical equipment and rely to a much lesser degree on instrumentation and controls for proper operation. The length and slope of flume trail pipeline (Alternative 2) may make it more susceptible to sedimentation and blockages; therefore, it is ranked lower than the directional drilling alternative in this category.

The pumping/mechanical alternatives (Alternatives 3 and 4) should be reasonably reliable if proper maintenance is provided. The mechanical alternative costs are based on the assumption that spares would be provided for any systems that would require more than two-weeks lead time. In addition, the existing pumping system may be used during failures or during maintenance operations. Since operation of the system is seasonal, major maintenance could be scheduled during times when the system is not in operation. Natural-gas-fueled engines (Alternative 3) are typically larger and cleaner burning than their diesel-fueled counterparts

(Alternative 4), resulting in more reliable system operation. In addition, diesel-fueled engines can be more difficult to start than natural-gas-fueled engines. As a result, both pumping alternatives are ranked lower than the gravity alternatives, with the diesel-fueled-engine alternative ranked lowest of all.

Environmental Impact

The alternatives are ranked with respect to their impact on the surrounding environment. Included in this category are the potential for air and water pollution, and the depletion of resources such as energy. The gravity alternatives do not use fuel and should not deplete resources or constitute a source of potential air and water pollution. As a result these alternatives are ranked highly in this category.

Natural-gas-fueled engines are cleaner burning than diesel engines, which should result in less potential for air pollution. However, both proposed engine alternatives include air pollution control systems. An additional disadvantage for the diesel-fueled-engine alternative is that significant fuel handling and storage would be required. Although the proposed diesel-fueled-engine alternative includes contingencies for fuel leaks and spills, the potential for such occurrences still exists. As a result, the natural-gas-fueled engine alternative is ranked more highly than the diesel alternative.

Ecological Impact

This category includes short-term (construction-related) and long-term impacts to the ecology. The primary impacts to the ecology include erosion and habitat/vegetation loss related to the amount of land required to be cleared to construct the alternative. All of the proposed alternatives include stormwater/erosion related controls and re-vegetation. However, such controls are imperfect and vegetation cleared for construction purposes can take considerable time to re-establish.

The borehole alternatives (Alternatives 1A and 1B) would require the most clearing immediately adjacent to Marlette Lake and the point of discharge, and a number of improvements to existing access roads would have to be made in order to access Marlette Lake and the proposed discharge locations at Hobart Reservoir. Some of these road improvements would likely require the blasting of rock at narrow turns along the Lakeview to Hobart Reservoir road.

The remaining three alternatives involve construction that will be primarily conducted on previously disturbed land. The main exception to this is the natural gas pipeline included as part of Alternative 3, which would partially be constructed on previously disturbed land. In order of decreasing impact to land, the alternatives are ranked in the following order: Alternative 2; Alternative 3; Alternative 4; and Alternatives 1A and1B.

Aesthetic Impact

This category includes long-term noise and visual impacts associated with the alternatives. Visual impacts associated with clearing of the land were considered in the ecological impact category. Although the proposed pumping alternatives include noise abatement and architectural treatment of the facilities, they would have the greatest aesthetic impact of the alternatives and are ranked lower in this category. The visual and noise impact of the remainder of the alternatives is minimal and they are ranked high in this category.

Operation and Maintenance

This category addresses the ease of operation and maintenance (O&M) for each alternative. Although this category is included in the economic analysis of the alternatives, it is also included here as a means of addressing the complexity of the alternatives, identifying the type of operations and maintenance personnel that may be required, and identifying potential problems associated with operations and maintenance of the alternatives.

The pumping alternatives would require the most operations and maintenance time. In addition, those alternatives would also require the most skilled personnel with expertise in mechanical, electrical, instrumentation and control systems. As a result the pumping alternatives are ranked low in this category.

Pipeline maintenance is also a concern for all of the alternatives considered. The flume trail pipeline is the longest of the options considered, and as a result would require the most maintenance and inspection. Access to the flume trail pipeline for cleaning and inspection purposes would also be problematic. The borehole options also pose special concerns for cleaning in that there is no intermediate access point for cleaning; therefore, specialized cleaning equipment may be required. However, the slopes for the boreholes would be consistent so there is less likelihood that sedimentation would occur.

System Flexibility

System flexibility refers to the ability of each alternative to deliver water from Marlette Lake during the non-summer months (i.e., the ability to deliver more water on an average annual basis). For example, Carson City may wish to use Marlette Lake water for aquifer storage and recovery programs during the late fall-early winter or springtime as underground capacity is available. The only alternative which would be limited to the seasonal operational period between early July and mid-October of each year (approximately 110 days) is Alternative 4 because of the limited access for hauling diesel fuel to the Marlette Lake pumping station. However, all of the gravity alternatives would have a higher ranking than the natural-gas powered pumping station because maintenance access for the natural gas engines alternative would be more critical than for the borehole alternatives.

System Capacity

The capacity of the borehole and Flume Trail-Incline Tunnel alternatives is not limited to the 4.2 cfs design criteria, as it would be for the pumping alternatives. Therefore, if short periods of greater demand are required for the upgraded delivery system, the 12-inch-diameter gravity transmission line for Alternatives 1A/1B would have the capacity to deliver about 5.3 cfs (2,600 gpm) and Alternative 2 could provide even greater delivery rates. The pumping alternatives would be limited to the 4.2 cfs design, unless additional pumping capacity was built into the final design, which was not considered in this evaluation.

Water Quality

This category is used to rank the alternatives based on their ability to provide the highest quality of water to the system. The flume trail pipeline alternative provides a direct connection between Marlette Lake and the Red House Diversion and, as a result, no significant degradation in raw water quality should occur during conveyance. Alternatives with discharge locations upstream of Hobart Reservoir (Alternatives 1A, 3 and 4) would likely result in some degradation of the relatively high quality Marlette Lake raw water. This is due to the presence of tannins and humic substances in the reservoir, and the presence of sediments in the reservoir and in the receiving and discharge streams. Alternative 1B, the borehole alternative that discharges downstream from Hobart Reservoir offers intermediate potential for degradation of the water quality during conveyance.

Constructability

This category addresses the constructability of each alternative. Although this category is also accounted for indirectly in the economic analysis of the alternatives, it is included here as a means of addressing the complexity of the construction, and identifying potential constructability issues.

Both of the borehole alternatives (Alternatives 1A and 1B) pose the greatest constructability concerns. The geotechnical characteristics of the alignments are relatively unknown and the lengths of the proposed borings are approximately forty percent greater than any other directional borings known to have been completed. As a result these alternatives are ranked lowest in this category. The flume trail pipeline construction also poses problems with access and unknowns associated with rehabilitation of the Incline Tunnel. The pumping alternatives represent relatively standard construction and do not pose significant constructability concerns.

Summary of the Non-Economic Ranking of the Alternatives

Table 3-1 presents the results of the non-economic evaluation based on the factors described above. The value 5 is the highest ranking in each category and the value 1 is the lowest ranking. Weighting factors and rankings were established by CWSD.

Table 3-1. Non-Economic Comparison of Alternatives						
	Alternative					
	Weighting Factor	Alternative 1A (Borehole Discharging Upstream of Hobart Reservoir)	Alternative 1B (Borehole Discharging Downstream of Hobart Reservoir)	Alternative 2 (Flume Trail – Incline Tunnel)	Alternative 3 (Natural –Gas-Engine Driven Pump)	Alternative 4 (Diesel-Engine-Driven Pump)
Reliability	15%	5	5	4	3	2
Environmental Impact -	15%	4	4	4	3	2
Ecological Impact	5%	2	2	2	4	4
Aesthetic Impact	5%	5	5	5	4	3
O&M	10%	5	5	3	4	1
System Flexibility	10%	5	5	4	4	1
System Capacity	10%	4	4	4	3	3
Raw Water Quality	10%	4	5	5	4	4
Constructability	20%	2	2	1	4	5
Weighted Average Score	---	**3.90**	**3.95**	**3.35**	**3.60**	**2.95**

Weighting factors were developed with a consideration for the similarity of evaluation categories. For example, the environmental, ecological and aesthetic categories are similar and contain some overlap, and the long-term environmental category was weighted three times as heavily as the short-term ecological impacts experience during construction, which would be mitigated after construction. The constructability category includes the potential for the project to be successfully built, potential construction-related issues such as permitting, and the level of uncertainty associated with construction-related contingencies. Note that the O&M and constructability categories also have some consideration in the economic evaluation of the alternatives. Based on the weighted average score in Table 3-1, the following ranking of alternatives is presented for non-economic criteria (from highest to lowest):

- Alternative 1B Gravity flow in borehole; discharge downstream of Hobart Reservoir
- Alternative 1A Gravity flow in borehole; discharge upstream of Hobart Reservoir
- Alternative 2 Natural gas-powered pump and pipeline
- Alternative 3 Re-established Flume Trail and Incline Tunnel (gravity flow)
- Alternative 4 Diesel-powered pump and pipeline

3.2 Economic Evaluation

Engineer's estimates of construction operation and maintenance (O&M), and net-present-worth costs are provided below. These are opinions of probable costs, and should be viewed as preliminary and subject to refinement upon the completion of more detailed engineering studies.

Construction Costs

Construction costs are based on *2002 Heavy Construction Cost Data* (RS Means), historical cost data for similar engineering projects adjusted for inflation at three percent per annum, manufacturers' estimates of equipment costs, and drilling cost estimates. The estimate for Alternative 2 was based on the AMEC PER, also adjusted three percent per annum to account for inflation. A summary of the construction cost estimates is provided in Table 3-2 and more detailed cost components are provided in Appendix B.

Table 3-2. Construction Cost Estimates

Alternative	Construction Cost (million dollars)
Alternative 1A	10.8
Alternative 1B	11.0
Alternative 2	12.4
Alternative 3	3.5
Alternative 4	2.6

The estimate for each alternative, with the exception for Alternative 2, includes the following cost add-ons or mark-ups: engineering at 12 percent; construction management at eight percent; general conditions and contractor indirect costs at 15 percent; and contingency at 30 percent. The general conditions and contractor in-direct costs and mark-ups includes the following:

surveying; mobilization/demobilization; project supervision and accounting; site equipment including trailers, lighting and other incidentals; labor, equipment and material mark-ups; subcontractor markups; performance, payment and other bonds; permitting; insurance; use or privilege taxes; startup and commissioning costs; material shipping and handling; and worker's travel and subsistence.

Operations and Maintenance Cost Estimates

A summary of the O&M costs is provided in Table 3-3, and more detailed cost drivers are provided in Appendix B. Costs are based on estimated fuel consumption for Alternatives 2 and 3 and the number of labor hours, equipment use and other related maintenance activities developed during discussion with the Nevada Department of Administration – Division of Buildings and Grounds (DBG) and the CWSD (Mike Leahy and Ed James, pers. comm., 2004). The estimate Alternative 2 is based on the AMEC PER and is adjusted three percent per annum to account for inflation. The net present worth of the probable O&M cost for each alternative is also summarized in Table 3-4. The net present worth is based on a 30-year period and a discount rate of five percent, set by CWSD (Ed James, pers. comm., 2004).

Table 3-3. Estimate of Probable Operations and Maintenance Cost

Alternative	Estimate of Probable Annual Operations and Maintenance Cost (thousand dollars)	Estimate of Probable Operations and Maintenance Net Present Worth (thousand dollars)
Alternative 1A or 1B	18	121
Alternative 2	47	309
Alternative 3	103	684
Alternative 4	146	969

These O&M cost estimates are based on seasonal system operation between early July and mid-October of each year (approximately 110 days per year or 16 weeks). All electrical and mechanical equipment is assumed to have a useful life of approximately thirty years, and no replacement costs are included in the O&M estimates (note that since the proposed systems operate only thirty percent of the year, the net useful operating life assumed is effectively nine years).

As indicated above, inspection and supervisory labor hours associated with the alternatives were provided by CWSD and State of Nevada DBG staff. The estimates for Alternative 1A and Alternative 1B assume ten hours per week of supervision during operation. The Alternative 3 and Alternative 4 (pumping system alternatives) estimates assume 15 and 20 hours per week of supervision during operation, respectively. For the borehole alternatives, twenty hours per week was allotted for system inspections and low-level maintenance. The Alternative 3 and Alternative 4 estimates assume 15 and 20 hours per week of system inspections and low level maintenance, respectively.

Net Present Worth

The net present worth for each alternative, summarized in Table 3-4, was calculated by summing the construction cost estimates and the O&M net present worth presented in Tables 3-2 and 3-3, respectively.

Table 3-4. Estimate of Net Present Worth

Alternative	Estimate of Probable Net Present Worth (million dollars)
Alternative 1A	10.9
Alternative 1B	11.1
Alternative 2	12.7
Alternative 3	4.1
Alternative 4	3.6

Unit Cost Comparison of Alternatives

The unit cost comparison for each alternative, as summarized in Table 3-5, was calculated using the average amount of water that could have been delivered from Marlette Lake during the period of 1987 to 1994. The average water delivery is based on a hydrologic analysis for the Marlette Lake drainage, and infrastructure-related delivery constraints to Carson City and Virginia City. The analysis also assumes that the borehole and flume alternatives would have a maximum capacity of 5.0 cfs, while Alternatives 3 and 4 maximum capacity would be 4.2 cfs. All the alternatives except for Alternative 4 would be able to operate on a year-round basis. A more detailed description of the hydrologic analysis is discussed in Appendix A.

The annual cost for each alternative was calculated by dividing the Net Present Worth values from Table 3-4 by 30 years.

Table 3-5. Unit Cost Comparison

Alternative	Annual Cost (thousand dollars)	Average Annual Delivery (thousand gallons)	Unit Cost (dollars per thousand gallons)
Alternative 1A	364	326	1.12
Alternative 1B	372	326	1.14
Alternative 2	425	326	1.30
Alternative 3	145	313	0.46
Alternative 4	130	242	0.54

SECTION 4.0
SUMMARY OF ALTERNATIVES

Table 4-1 provides a summary of the alternatives (shown in Figure 10) for the non-economic criteria and the net present worth evaluation presented in Section 3.0.

Table 4-1. Summary Evaluation of Alternatives

Evaluation Criteria	Alternative 1A (Borehole Discharging Upstream of Hobart Reservoir)	Alternative 1B (Borehole Discharging Downstream of Hobart Reservoir)	Alternative 2 (Flume Trail – Incline Tunnel)	Alternative 3 (Natural –Gas-Engine Driven Pump)	Alternative 4 (Diesel-Engine-Driven Pump)
30-Year Net Present Worth, million dollars	10.9	11.2	12.7	4.3	3.9
30-Year Net Present Worth Ranking	3	2	1	4	5
Unit Cost	2	3	1	5	4
Non-Economic Factors	4	5	2	3	1
Total	**9**	**10**	**4**	**12**	**10**

- Note: 5 = highest ranking and 1 = lowest ranking for each alternative

The alternative with the lowest net present worth (Alternative 4) scored the lowest in terms of non-economic factors. However, careful management of the design, construction, operation and maintenance of Alternative 4 (and Alternative 3) may mitigate some of the low rankings for the subjective non-economic criteria (e.g., reliability, environmental impact, ecological impact, aesthetic impact and operation and maintenance of the pumping alternatives). The generally similar net present worth estimates for Alternatives 3 and 4 suggest that the added system flexibility and lowest unit cost associated with natural gas-powered pumping may outweigh the added costs for constructing and operating Alternative 3.

The gravity borehole alternatives have a net present worth cost approximately $7 million greater than the pumping alternatives, principally due to much higher construction costs. The cost of these may be too great for the added system flexibility and capacity to warrant further consideration. Re-establishment of the Flume Trail-Incline Tunnel delivery system has the highest net present worth cost of the alternatives, and should be eliminated from further consideration.

SECTION 5.0

REFERENCES

Brown and Caldwell, 2000, *Engineering Report for Upgrading the Marlette Lake Hobart Reservoir Water Delivery System*, prepared for the Carson Water Subconservancy District.

AMEC Infrastructure Inc., 2001, *Preliminary Engineering Report for Marlette Hobart Water System: Water Transmission Facilities from Marlette Lake to Red House Diversion Structure*, prepared for the State of Nevada Public Works Board.