TUALATIN WATER SUPPLY
FEASIBILITY STUDY PARTNERS

RECONNAISSANCE STUDY
OF
SAIN CREEK TUNNEL

MAY 2003
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RECONNAISSANCE LEVEL STUDY OF
SAIN CREEK TUNNEL

I. INTRODUCTION

The Water Supply Feasibility Study Partners (Partners) is a coalition of the following organizations:

- Clean Water Services
- City of Tigard
- Tualatin Valley Water District
- City of Hillsboro
- City of Beaverton
- City of Sherwood
- City of Tualatin
- City of Forest Grove
- City of Cornelius
- City of North Plains
- City of Banks

The Partners retained MWH Americas, Inc. to perform a reconnaissance level investigation of the technical, economic, and environmental feasibility of constructing a tunnel from the Tualatin River watershed to the watershed controlled by Scoggins Dam. The purpose of the tunnel would be to allow diversion of permitted water supplies for storage in Henry Hagg Reservoir, which is controlled by Scoggins Dam. Hagg Reservoir and Scoggins Dam are currently being separately studied for the potential to raise the reservoir level by 20 and 40-foot increments. Exhibit 1 shows the general location of the project.

Permitted water supplies that would be diverted through the Sain Creek Tunnel consist of two sources:

- Diversions from Barney Reservoir to the Tualatin River, which occurs upstream of Hillsboro Reservoir and nearby Haines Falls.
“excess” water from the Tualatin River watershed beyond the river’s environmental needs and withdrawals by downstream users. Such “excess” water is expected to consist primarily of flood skimming during the spring runoff.

This study was Amendment Number 1 to the scope of work for an existing contract, No. 1530471, authorized by Clean Water Services and dated January 10, 2003. The scope of services for this study is covered by Amendment 1 to the contract. The amount of cost authorized for this study is $46,476.

Key participants in this study and their roles were as follows:

Client contact: Tom VanderPlaat, Senior Water Resources Program Manager, Clean Water Services

MWH Americas:

Lisa Obermeyer, Project Manager
Jim Passage, Project Engineer
Becky Crockett, Environmental and Permitting Considerations
Roger Wilson, Geology and Seismicity considerations
John Haapala, Hydro Power Potential
Steve Thurin, Hydrology/Hydraulics
Mark Hijazi, Structural Engineer

II. BACKGROUND INFORMATION

A. BARNEY DAM RAISE AND DIVERSION

In the 1990s Barney Dam was raised by 50 feet to store water for diversion from the Trask River watershed (westward flowing) to the Tualatin River (eastward flowing). The diverted water is discharged to the Tualatin River upstream of Haines Falls and the adjacent Hillsboro Reservoir, which is owned and operated by the City of Hillsboro. The maximum amount of water that can be diverted into the Tualatin River ranges from about 100 cfs to 200 cfs.

B. GEOLOGIC CONDITIONS

Our review of the State Geologic Map of bedrock conditions in the Coast Range indicates the rock along the prospective tunnel alignment is a diabase (a type of intrusive rock) that is described in the report “Geologic Map of the Tillamook, Nehalem, Enright, Timber, Fairdale, and Blaine 15 Minute
Quadrangles), published by the U.S. Geologic Service as Open File Report 94-21 and dated 1994. The diabase is described as aphyric to plagioclase-phyric, amygdaloidal with smectite clays and zeolite fillings. The significance of this description is simply that the rock’s mineral structure is such that it should fracture when excavated by a tunnel boring machine into fragments that are of consistent pattern and size and which can be readily handled. The diabase is present in localized areas as a pillow form with radial columnar joints. More commonly it appears in tabular bodies with well developed columnar joints and a layered appearance. Photo 1 shows the diabase exposed at Lee Falls, located southeast of the tunnel site but in the same rock formation.

Another source of information on the diabase rock formation comes from the June 1992 report, “Barney Reservoir Expansion Phase 1 – Engineering Report” by Cornforth Consultants, Inc., CH2M Hill, and Economic & Engineering Services, Inc. The State Geologic Map indicates the rock formation under the Barney Dam is the same diabase as exists along the alignment of the proposed tunnel. Thus the geologic and seismic investigations performed for the raise of Barney Dam are considered to have some relevance to this tunnel study.

The Barney Dam report indicates that geologically the northern coast range where it (and the Sain Creek tunnel) are located consists of a thick sequence of submarine basalt flows dating from the Eocene Epoch. These basalt flows are interbedded with deep marine sediments that were later overlain by younger, shallower marine sediments and basalt flows from the Oligocene and Miocene Epochs. All the units were at various times intruded by volcanic dikes, sills, and plugs that welled up through the earth’s mantle.

The basement volcanic rocks are considered to have originated off the ancient coastline as oceanic crust. In the middle Eocene these rocks became accreted to the continental plate due to subduction of the oceanic plate descending under the edge of the continental plate. During this period the Coast Range behaved as a semi-rigid tectonic structure and became mildly tilted and warped, and strongly faulted.

From the late Eocene through the early Miocene the region was relatively quiet geologically speaking, although submarine volcanism and deposition of thick sequences of marine sediments continued.

As subduction of the oceanic plate continued the Coast Range was uplifted. This continued into the late Miocene. The uplifting appears to have subsided during the Pliocene Epoch. Thereafter the current topography of rolling upland hills began to develop.

The diabase (basalt) rock that is located along the tunnel’s entire length is apparently from the same formation as exists under Barney Dam. Rock core recovered from drilling at Barney Dam is probably
representative of what exists along the tunnel route. Photos 11 through 14 show portions of the rock core. These show that the rock quality is high and favorable for use of a tunnel boring machine to construct the tunnel.

Field permeability tests conducted in hard, slightly weathered basalt at Barney Dam yielded values of $2.5 \times 10^{-7}$ centimeters/second. Three of the tests, in slightly weathered basalt, resulted in no water take into the rock formation. These results indicate that sound rock along the tunnel route may be quite impermeable and therefore will not need to be lined to prevent water loss, except possibly in localized areas.

C. REGIONAL SEISMICITY

The State Geologic Map shows the location of known faults in the region but does not address whether they are seismically active or not. The location of known faults relative to the tunnel alignment is shown on Exhibit 2.

The June 1992 report on raising Barney Dam indicates the general area is relatively dormant from a seismic standpoint. Seismic activity from earthquakes is normally a result of movement along faults, although some seismic activity can also be associated with volcanism. The only major fault identified on the State Geologic Map in the vicinity of the tunnel route is the Yamhill River Fault Zone. The closest distance of this fault to the tunnel alignment is 7.75 miles. There is no evidence in published literature reviewed to date to suggest the Yamhill River Fault is seismically active.

Seismologists are rethinking previously held views about the potential for major earthquakes in the Pacific Northwest. This attention is focused on the four types of earthquakes that could occur in the region: crustal, intraplate, interplate, and a random crustal earthquake.

The crustal North American Plate was estimated to be about 30 kilometers thick at the Barney Dam site. Crustal earthquakes would occur due to the release of stresses somewhere within this plate thickness.

Intraplate earthquakes originate in the subducted oceanic crust (Juan de Fuca Plate) which is passing under (subducting) the continental (North American) plate. Earthquakes due to this movement are believed to result as the oceanic crust bends and begins to break up during the subduction process. Intraplate earthquakes would occur at some distance from the tunnel, and Scoggins Dam, and thus their force would be attenuated by the time the shock waves reached the site area.
Interplate (subduction-zone) earthquakes originate at the contact between the continental crust and oceanic crust as the North American Plate overrides the Juan de Fuca Plate. This type of earthquake, while of potentially large magnitude, would likewise occur some distance from the site and would be significantly attenuated when the force reached the site.

For purposes of engineering design it is common to check structures for an earthquake loading that might result from a so-called Random Crustal Earthquake. A “random earthquake” is so called because it can theoretically occur anywhere and is not necessarily associated with a known fault system. For the Barney Reservoir Enlargement Project the Random Earthquake was considered to be a magnitude 6.5 event occurring at a distance of 10 kilometers from the site. Such an earthquake would result in a peak horizontal acceleration at the site of about 0.2g. This is not a large enough ground motion to likely cause significant damage to the tunnel facilities. The effect of such an earthquake on Scoggins Dam is unknown but the issue of seismic stability of Scoggins Dam is being investigated by the U.S. Bureau of Reclamation in connection with their dam safety review the dam, scheduled for 2005.

In a future phase of the tunnel project, if it proceeds, additional seismic investigation and analysis should be performed.

D. ENVIRONMENTAL SETTING AND ASSESSMENT

The prospective tunnel would connect the Tualatin River watershed at Hillsboro Reservoir with the Scoggins Creek watershed at Henry Hagg Lake. The tunnel would discharge into Sain Creek, which is a tributary of Scoggins Creek. Sain Creek flows directly into the reservoir. Exhibit 3 shows two alternative tunnel alignments, both originating from a single intake location.

The area investigated for the tunnel intake consists of the stretch of the Tualatin River between Lee Falls to just upstream of Haines Falls, a distance of about two miles. Potential tunnel intake locations downstream of Lee Falls were not investigated because the elevation of the tunnel entrance would not be high enough to provide adequate head to convey the tunnel flows by gravity to the potential Sain Creek discharge locations.

Similarly, the area along Sain Creek covered by this study ranges between about elevation 340 to elevation 440. No discharge sites below elevation 340 were considered because for the 40 foot Scoggins Dam Raise the new maximum normal pool elevation would be elevation 343.5. Above elevation 440 on Sain Creek the hydraulic capacity of the creek to convey flows of the magnitude planned for diversion becomes very limited, and the head difference from the tunnel intake to the outlet becomes unfavorably
low to effectively allow gravity flow. **Photo 2** shows the gage station and gives some indication of the width of Sain Creek near the lower end of our study reach.

Within the above described reaches of the Tualatin River and Sain Creek the area is heavily forested with second growth forest. The topographic relief is steep and the terrain is heavily vegetated. The difference in elevation from the recommended tunnel intake to the top of the ridge separating the Tualatin River from the Sain Creek discharge location is in excess of 500 feet.

Within this environmental setting bedrock conditions can be observed at outcrops at Lee and Haines Falls, along the access road to Hillsboro Reservoir, and at the reservoir’s northeast corner. Bedrock is generally of a basalt nature, which is typically an excellent material for tunnel construction. **Photo 3** shows a rock outcrop along the access road near Hillsboro Reservoir.

**E. ALTERNATIVE INTAKE AND OUTLET LOCATIONS INVESTIGATED**

The lengths along the Tualatin River and Sain Creek considered in this study are described above. An inspection of these areas was conducted on April 2, 2003 by Lisa Obermeyer, Becky Crockett, and Jim Passage, all of MWH. They were escorted by Tom VanderPlaat of Clean Water Services.

The inspection consisted of a visual reconnaissance along the access road to Hillsboro Reservoir and along Sain Creek by hiking up an access trail located on the north side of the creek. Access was not readily available along the south side of Sain Creek, which is the side where the tunnel discharge area would be located.

The inspection indicated the preferred alternative would be to locate the tunnel entrance along the northeast shore of the Hillsboro Reservoir where maximum advantage can be taken of the existing features of the site. **Exhibit 4** shows a schematic layout of the existing features at Hillsboro Reservoir. A key advantage of this location is that water can be diverted from just above Haines Falls, which is impassable to steelhead trout, a listed fish species. Locating the tunnel entrance at Hillsboro Reservoir is considered far preferable to any alternative site identified along the stretch of river from Lee Falls to Haines Falls. Although there are several possible tunnel entrance locations between Lee Falls and Haines Falls, none of them has the overall technical, environmental, or economic benefits that a tunnel from Hillsboro Reservoir offers. Among the disadvantages to siting the tunnel entrance directly along the river are the following:

- the need to construct a new weir across the river to create a pool allowing diversion into the tunnel entrance
possible intake of sediment and floating debris during flood skimming

- disruptions on the access road to Hillsboro Reservoir during construction operations

- lack of sufficient laydown area for construction operations without significant environmental disturbance

- impacts to river water quality during construction

- potential need for a longer concrete tunnel entrance before sound rock is encountered and the tunnel can thereafter continue unlined

- location within a stretch of the Tualatin River that potentially contains steelhead trout.

Based on the above evaluation it is our strong opinion that the tunnel entrance should be located at Hillsboro Reservoir with the river intake being located a short distance upstream of Haines Falls.

In order to maximize the benefit from funds made available for this study we have focused our efforts on evaluating the concept of siting the tunnel at Hillsboro Reservoir. It is recognized that if the project proceeds to future phases some additional investigation of other alternatives will be required. Among other possible alternatives would be a pipeline, which would have the advantage of being much smaller in diameter than the tunnel, and pumping stations that would convey the water over the top of the ridge separating the watersheds. As noted elsewhere such a concept would involve pumping the water against a head of about 500 feet. Although the energy costs to pump the water would be a considerable project cost, there is an opportunity to recover some of those costs through generation of hydroelectricity. The head available for generation of hydropower from a surface pipeline would be approximately 700 feet vs. 140 to 240 feet for the gravity flow tunnel alternatives. Investigating such a pipeline and pumping station alternative is beyond the scope of this study.

The recommended project configuration is described in the following sections of this report.

III. RECOMMENDED PROJECT CONFIGURATION

A. GENERAL DESCRIPTION

The project development concept would include an intake on the Tualatin River in approximately the same location as the existing intake to Hillsboro Reservoir. Exhibit 5 shows a schematic layout of the modified Hillsboro Reservoir site. To create a pool from which withdrawals would be made, a rubber...
weir would be constructed across the river at the top of Haines Falls. The rubber weir support structure would make use, to the extent practical, of a concrete sill that has already been constructed across the top of the falls. The concrete sill was evidently constructed to seal gaps in the rock and concentrate the flow to the south side of the falls. Photo 4 shows the concrete sill at Haines Falls.

Water withdrawn from the Tualatin would be conveyed by gravity to the western portion of Hillsboro Reservoir. It would be discharged through the existing dike, or if possible, around the west end of the dike.

The tunnel entrance would be located in the northeast portion of the reservoir where a substantial outcrop of apparently competent rock is exposed above reservoir level. Photo 5 shows the outcrop of rock.

The tunnel would convey flows in a northeasterly direction to a discharge location along the south side of Sain Creek located between elevations of about 340 and 440 feet. The length of the tunnel would vary between about 15,000 feet (2.84 miles) for the elevation 440 discharge site, and 20,600 feet (3.90 miles) for the elevation 340 discharge site.

The tunnel outlet would consist of a reinforced concrete structure equipped with two sleeve-type valves. The structure and valve installations could be designed to accommodate a power generating facility, depending on the economics and other considerations of such a facility.

Flows would be discharged through a short constructed channel to Sain Creek. The channel would be designed to blend as inconspicuously as possible into the surroundings.

A more detailed description of the major components of the tunnel project follows:

**B. TUALATIN RIVER INTAKE AND RUBBER WEIR**

In order to provide a pool of water from which withdrawals can be made a 5-foot high rubber dam would be constructed across the river at the top of Haines Falls. This dam site location has already been altered by placement of concrete to level out the top of the falls, filling in gaps in the rock. A drawing provided by the City of Hillsboro indicates the intake slab elevation is 592.76. With the rubber weir fully inflated the pool would be at about elevation 597.95. The concrete sill already in place extends across approximately 80% of the falls, leaving a narrow gap of about 8 feet width at the south end of the falls (See Photo 4). Exhibit 6 shows a plan, elevation, and section through the rubber weir.
The rubber weir would sit on a new slab of concrete that incorporates, to the extent possible, the existing concrete placement. The north end of the rubber weir would be anchored to the existing north bank concrete wall that retains the earth bank and extends along the river from the intake area to the falls. The south end of the rubber weir would be anchored into a new concrete abutment constructed against the bedrock at the south bank. At the south abutment the rock is partially visible and appears well suited as an anchorage for the rubber weir.

In order to be conservative, our cost estimate assumes the length of the rubber weir to be 80 feet. We were unable to take measurements across the river during our field inspection.

The existing intake for Hillsboro Reservoir consists of an opening flush with the concrete wall connecting to a 36 inch diameter corrugated metal pipe. The intake is located at the outside of a bend in the river and thus is susceptible to entraining sand and gravel, particularly when operating during a significant runoff event.

For this project the existing intake and associated CMP pipe would be replaced with three 60-inch pipes providing a total of 59 square feet of flow area. In sizing the new intake we have assumed that the maximum instantaneous discharge would be 500 cfs. We have sized the intake pipelines to keep the velocity of flow to 10 feet per second or less. Exhibit 7 shows the new river intake.

The intake pipelines will deliver water to a buried concrete distribution chamber. There would be five outlets from the chamber, each regulated by a slide gate or butterfly valve. One outlet (the drain) would be piped to discharge back to the Tualatin River downstream of Haines Falls. Such an outlet currently exists and is a 24 inch diameter corrugated metal pipe. Photo 7 shows the receiving channel of the river and the island separating the main and side channels. Haines Falls is in the background. Refer to Exhibit 8 for the distribution structure site layout.

A second, 36 inch concrete pipe outlet currently leads from an existing control chamber to a small chlorination building. Flows continue from the building through a 36 inch concrete pipe buried along the access road. This 36 inch pipe then connects to an older 18 inch diameter steel pipe which continues to the Hillsboro slow sand filter facility several miles downstream.

If this 36-inch concrete pipe is found to be in good condition it could perhaps be retained and simply be connected into the new concrete distribution chamber.
The other three pipes would convey up to 500 cfs to the existing Hillsboro Reservoir, discharging into the west segment of the pond. Currently two concrete pipes, 36-inches in diameter and 24-inches in diameter convey flows to the pond, penetrating through the existing earth dike.

C. MODIFICATIONS TO HILLSBORO RESERVOIR

1. CONSTRUCTION RELATED MODIFICATIONS

Some modifications will be required to Hillsboro Reservoir to accommodate construction of this project.

If it is feasible to retain the existing 36 inch and 24 inch concrete pipes that discharge into the pond that will be considered, thus eliminating the need to install any new pipes through the earth dike.

In order to construct the tunnel intake, which would be located in the northeast section of the pond, a cofferdam would be constructed to segment the pond into west and east sections. The cofferdam would be located along the north side of the pond, approximately in the location of the existing wood baffles. Photo 7 shows the west section of the pond with the wood baffles barely visible along the waterline. The cofferdam would consist of relatively clean fill and would be constructed by bulldozing the fill from the central earth/rock knob across the pond. The cofferdam may or may not include a gated culvert pipe(s) allowing future flows through the cofferdam to be made, depending on whether the cofferdam is to be removed following construction, or be left in place. To reach the location of the cofferdam, an access road would be constructed along the west perimeter of the pond or along the rock knob. The access road would be designed not to encroach on the pond, if at all possible. However, if bedrock conditions along the alignment would require costly rock excavation then the road would be designed to allow some encroachment into the pond.

Once the west section of the pond was isolated from the east section by the cofferdam, the east section would be drained. Most of the stored water would be discharged back to the Tualatin River, contingent on it meeting water quality requirements. As the pond is lowered, the water near the bottom may require routing through a temporary settling basin.

After the west section of the pond is dewatered any accumulated sediments would be removed, freeing up future additional storage. Cleaning out the east section of the pond would include construction of trenches and a sump(s) to collect seepage entering from the west section of the pond under, or around, the cofferdam.
The rubber weir across the river will create a pool from which water carrying less suspended solids can be withdrawn. If construction of the tunnel portal is scheduled for the summer and fall months, diversions from the river can perhaps be directed to the chlorination building and from there directly to the Cherry Grove slow sand filter. This would take the Hillsboro Reservoir offline and perhaps allow seepage under the cofferdam to be pumped back into the western portion of the pond, which would thus function temporarily as a sedimentation basin, reducing the turbidity and associated environmental impacts of discharging directly to the Tualatin River.

The tunnel entrance would be located along a steep rock face in the northeast section of the east pond segment. Photo 5 shows the exposure of the rock outcrop on the day of the site inspection. To gain access to the intake area a permanent access road would be constructed along the east perimeter of the pond to the tunnel portal. The road would be designed to minimize encroachment into the pond without requiring costly rock excavation into the hillside. The access road material could be crushed rock coming from the construction of the tunnel. Note that construction of the tunnel would proceed from Sain Creek toward Hillsboro Reservoir. Thus construction of the tunnel portal could proceed concurrently with tunneling operations.

2. POST CONSTRUCTION

After construction of the tunnel is completed the cofferdam segmenting the pond would be removed, or alternatively, the cofferdam and the gated pipe through it could remain in place, if there were benefits to doing so.

The existing pond overflow structure, shown in Photo 8, would remain in place, as is, or could be equipped with a fish screen, if necessary. Photo 9 shows the downstream face of the dam, access road along the toe, with the river in the background. This is where releases from the pond are discharged.

The access road would proceed over the top of the earth dam and along the east shore of the pond to construct the intake. It would remain as a permanent feature of the project.

The intake tower and 18-inch gate valve controlling releases from the pond could remain unchanged if found to be in good condition.

The existing crest elevation of the dam is shown as El. 582 on drawings received from the City of Hillsboro. Based on our site inspection the normal pool elevation appeared to be about elevation 580. The post construction pool elevation would remain at about elevation 580. The crest of the dike and dam may need to be raised because the inflow to the pond would now be significantly higher than previously.
Our cost estimate at this phase of the project does not, however, provide for the raising of the dam and dike. Raising the dam and dike would provide a safer operating margin against accidental overfilling of the pond that might overtop and erode the earth dam.

D. INTAKE TO TUNNEL

As described above, the tunnel entrance would be located against the northeast side of the pond through a steep exposure of bedrock. An access road would be constructed against the east bank of the pond.

The tunnel entrance invert elevation would be set at about elevation 565. The tunnel would be about 10 feet in diameter thus providing about five feet of hydraulic head over the tunnel entrance. Exhibit 9 shows a partial plan and section of the intake structure.

At this early stage of project planning we propose that the tunnel intake be constructed as a relatively narrow structure positioned close to the rock face. The structure would be of reinforced concrete founded on bedrock. We currently have no information on the elevation of bedrock along the base of the near vertical rock face. We also do not know whether the rock projects out into the pond away from the rock face. Our cost estimate assumes the intake structure can be founded on rock but without the need for significant rock face excavation. If future subsurface explorations indicate there is a suitable foundation material away from the rock face, the geometry of the intake structure will be changed to make it more hydraulically efficient.

The length of the intake along the rock face has been set at 100 feet to allow for the possible future installation of fish screens meeting the criteria of the Oregon Department of Fish and Wildlife (ODFW). The most significant fish species that could be drawn into the pond, and thus into the tunnel, is cutthroat trout. Although there may be steelhead in the river between Lee Falls and Haines Falls, they are unable to migrate upstream of Haines Falls. Note that the width of the intake (100 feet) is considerably longer than would be necessary if no fish screening is required. In order to be conservative in the cost estimate we have assumed fish screens will be necessary. The cost of the additional structure, fish screens, and screen cleaning system is approximately $555,000. This represents the approximate cost savings if the tunnel intake does not require fish screens. Our experience indicates it is possible to negotiate with ODFW to arrive at a less expensive solution than full screening of the intake.

The tunnel intake would be equipped with two sets of slots, one for possible future fish screens and a second set for installation of stoplogs to allow the tunnel to be dewatered. It is assumed a mobile crane
would be brought to the site to perform these operations, thus the cost estimate does not include provisions for a permanent crane.

E. FOUNDATION INFORMATION NEEDED

In a future phase of the project it will be necessary to obtain information on the subsurface conditions in the area of the tunnel entrance. If the rock surface flattens out and is found at suitable elevations away from the rock face, a more hydraulically efficient intake arrangement can be designed. However, if the rock surface drops off sharply along the rock face the design will need to stay approximately as shown on Exhibit 9.

F. TUNNEL

1. EVALUATION OF ALTERNATIVE OUTLET LOCATIONS

As described in Section II-D above, we have considered possible tunnel outlet locations along the south side of Sain Creek in the stretch between elevations 340 to 440, as measured on the creek channel. Along this length of the creek there are several drainage channels that are shown on the USGS topo maps as intermittent streams. These are shown on Exhibit 3.

In addition, just downstream of the gaging station is a steep slope that appears to have rock near the ground surface. This face is barely visible in the background of Photo 2. This is about the farthest downstream potential exit location for the tunnel. A disadvantage of this discharge site is that the tunnel alignment is the longest of those considered, at about 20,600 feet, and the steep rock face is located immediately adjacent to the stream. This means there is very little space to dissipate the energy of the tunnel releases before flows would enter Sain Creek.

The two alternative discharge sites farther up Sain Creek, which make use of the intermittent drainages, would allow the tunnel outlet to be positioned away from Sain Creek and therefore out of the influence of flood discharges. This both shortens the tunnel length and allows an area for energy dissipation. It also provides a suitable area for mobilization of the construction activities, a laydown area for equipment, and a temporary stockpile location for tunnel spoil. The exact location of the tunnel outlet will also depend to a considerable extent on bedrock presence and quality. Thus a future phase of the project will need to include a subsurface exploration and/or geophysical program to determine the top of rock profile at potential discharge sites along the south side of Sain Creek.
2. EXPECTED GEOLOGIC AND HYDROLOGIC CONDITIONS ALONG TUNNEL ALIGNMENT

As noted in Section II-B, the only information currently available about the geology along the tunnel alignment comes from the State Geologic Map and from the June 1992 report on expansion of Barney reservoir by Cornforth Consultants, CH2M Hill, and Economic & Engineering Services, Inc. The geologic map indicates the rock along the entire length of all potential tunnel routes is a diabase, which is an intrusive rock that is generally very favorable for construction by a tunnel boring machine.

The tunnel is likely to intercept a number of faults and possibly highly fractured zones, which may or may not be filled with clay or other soft infill materials. Given the rock is a diabase, and based on the visual inspection of rock outcrops in the area, the rock quality along the tunnel is expected to be very good. Any sections that are of poor quality can be improved by application of shotcrete. We therefore have based our cost estimates on construction of an unlined tunnel. Our cost estimate includes a separate budgetary allotment for repairs to weak areas such as fault zones.

The tunnel flows will be regulated at the outlet end and thus the tunnel will be pressurized along its entire length with a head varying from a minimum of about 5 feet at the upstream end to a maximum of about 225-240 feet at the outlet end. The minimum ground surface elevation along the two alternative alignments of the tunnel is about El. 580 and the tunnel length where the ground cover is less than about 20 feet is short and can be adjusted, if necessary, by moving the tunnel farther into the hillside. Although the tunnel will be unlined, potentially encounter fractured rock zones, and be pressurized, we expect there will be a net inflow of water due to higher groundwater levels along the tunnel route. The consequence of this, if it bears out, is that releases at the tunnel outlet can perhaps be somewhat larger than the flows diverted into the tunnel.

3. TYPE OF TUNNEL CONSTRUCTION

There are two common means of constructing tunnels: conventional drill and blast or by use of a tunnel boring machine (TBM). The length of the Sain Creek tunnel (between 15,000 to 20,600 feet) is such that a TBM would clearly be the most cost effective method. The minimum size TBM is about 10 feet in diameter, which is larger than needed to hydraulically convey 500 cfs but represents the smallest size TBM currently available in the construction industry. Microtunneling equipment is not suited for this application because of the possible consequences if the smaller microtunneling machine becomes stuck along the tunnel route.
Therefore our cost estimates and construction schedules are based on boring a 10 foot diameter unlined tunnel using a tunnel boring machine and proceeding from the downstream end of the tunnel toward Hillsboro Reservoir. There is a photo in Attachment B, and on the cover of this report, that shows a TMB of a size similar to what would be used on the Sain Creek tunnel.

Construction from the downstream side has the following advantages:

- seepage into the tunnel is directed away from the tunnel heading by gravity
- disruption at the Hillsboro reservoir due to construction activities is minimized
- spoil from the construction can be more directly transported to Scoggins Dam for possible use in the dam raise project, or other related activities.

4. USES FOR TUNNEL SPOIL

The material derived from the TBM construction will consist of rock fragments similar in size to railroad ballast, although perhaps somewhat more elongated. Also, diabase rock generally makes an excellent aggregate for use in concrete and thus could serve as a partial aggregate supply for concrete used to modify the existing spillway (20 foot raise), or construct the new spillway (40 foot raise).

The tunnel spoil will be very clean rock chips and thus may be usable in the dam raise as drainage blanket material, or as bedding under the upstream riprap layer. If commercially purchased, or made by processing, both of these materials are relatively expensive. Thus use of the tunnel spoil in these applications could offer significant cost savings because the cost of such material could realistically range from $3-7 per cubic yard.

The dam raise project will involve substantial costs to relocate sections of the road(s) around the reservoir. The tunnel spoil could also be used for road base material. In addition, the cofferdam and short access roads previously described as necessary along the shoreline of Hillsboro Reservoir could also utilize spoil from the tunnel construction.

Note that the volume of tunnel spoil would range from about 57,000 cubic yards to 80,000 cubic yards depending on the final route of the tunnel.

5. TBM AVAILABILITY AND MOBILIZATION

Tunnel boring machines are relatively unique pieces of construction equipment and quite costly to manufacture. As a result, new machines are rarely manufactured for a tunneling job unless the job is very
large or has some unusual aspect. Typically contractors will utilize an existing machine available on the open market. Fortunately, the supply of available TBM’s relative to demand for their services is such that one can usually be scheduled to undertake a project in a reasonably timely manner.

The size of tunnel typically constructed by TBM’s ranges from a minimum of about 10 feet in diameter to over 30 feet. For the Sain Creek tunnel a TBM capable of boring a tunnel of about 10 feet diameter would be more than adequate from a hydraulic standpoint to transfer the planned diversion. A photo in Attachment B shows a TBM of a size similar to what might be used for construction of the Sain Creek Tunnel.

The TBM would be mobilized to the site in pieces and assembled at the site. The pieces are of a size and weight that they can be brought to the site without exceeding bridge weight limits or highway width restrictions. The two off-channel drainage features along the south side of Sain Creek have enough laydown area for TBM mobilization and assembly, and are located at an elevation sufficiently above Sain Creek as to be out of the way of flood flows.

Note that a new access road will need to be constructed to the selected tunnel outlet site. The access road would continue from the existing road which leads to the Sain Creek gage station. The maximum length of this access road would be about one mile.

In addition, a new bridge would need to be constructed to provide access to the south side of Sain Creek. The bridge would probably be located near the existing stream gage site.

G. TUNNEL OUTLET

1. CONTROL OF RELEASES

Control over releases would occur at the downstream end of the tunnel through two enclosed, sleeve-type valves, each having a capacity of about 500 cfs. These are relatively expensive valves but offer good energy dissipate and flow regulation benefits. Bailey Poly-jet is one manufacturer of sleeve valves. Manufacturers’ literature is enclosed in Attachment C. Exhibit 10 shows the tunnel outlet structure arrangement.

The tunnel would be pressurized and for releases up to 500 cfs the velocity of flow in the tunnel would be about 6 feet per second or less. Incorporating two sleeve valves provides full flow redundancy and is a conservative approach at this stage of the project. Having two fully redundant valves provides a full capacity bypass in the event extended maintenance was required on either valve.
The sleeve-valve(s) will dissipate the energy of the release with flows discharging into a trapezoidal concrete discharge basin. Tunnel discharges will fill the basin and flow into the conveyance channel back to Sain Creek.

### 2. DISCHARGE CHANNEL TO SAIN CREEK

After flows exit the outlet basin they will be conveyed to Sain Creek using the existing intermittent drainage channel. Exhibit 3 shows the approximate location of the three possible outlet locations and give some idea of the length of return channel that would be necessary. Modifications will be made to the existing channel to minimize the potential for erosion since the naturally occurring drainage channel does not presently have the hydraulic capacity needed. Such modifications would possibly consist of widening the channel by clearing brush and trees, placement of an environmentally friendly bank protection system to control the channel geometry and prevent bank erosion, and potentially construction of check structures across the channel to limit velocities and the movement of sediment into Sain Creek.

### H. POTENTIAL FOR HYDROELECTRIC POWER GENERATION

As noted above, the outlet control structure could be designed to permit installation of a small hydro turbine and generator, either as part of the initial construction, or for later installation.

Depending on the location of the outlet structure, the gross head available for power generation would range from about 100 feet to 240 feet. Assuming a constant discharge rate of 200 cfs, the instantaneous generating capability would range from 1.44 MW to 3.45 MW, depending on the selected tunnel outlet elevation.

The Sain Creek Tunnel would divert flows only during the months of December through March. If a constant 200 cfs were discharged for four months the amount of energy produced would range from 4.147 to 9.936 million kilowatt hours depending on the location of the outlet works and head available for generation.

It does not appear at this time that developing the hydroelectric potential of the Sain Creek Tunnel would be economical. We estimate the cost of the hydro civil, mechanical and electrical work to be approximately $2,055,000. For this reason we have separated the cost of the hydro facility from the rest of the tunnel cost and show it as a separate line item at the bottom of the cost estimate on Exhibit 11.

The construction of the hydro facility is not shown on the construction schedule as it is assumed it would occur at a later date.
IV. ENVIRONMENTAL CONSIDERATIONS

A. OVERVIEW

Tunneling for purposes of water conveyance in an area that is heavily forested provides the opportunity to minimize impacts to the natural environment. Further, because the construction impacts are usually confined to only two small sites (tunnel intake and discharge locations), they can be well defined and therefore more easily mitigated. This type of project is expected to have limited environmental impacts to:

- Forest vegetation
- Riparian/wetland areas
- Wildlife and wildlife habitat
- Fish and aquatic resources
- Stream flow
- Water quality
- Land use and ownership
- Special status species
- Traffic impacts
- Nature and disposal of tunnel spoil
- Permitting

These potential environmental impacts are discussed below. Most of these impacts are localized to the tunnel intake at the Hillsboro Reservoir and the outlet along Sain Creek. They can be further defined and mitigated during project design.

B. FOREST VEGETATION

Potential forested areas that could be impacted by the tunnel project are located at the tunnel intake at Hillsboro Reservoir and at the discharge area along Sain Creek. Both of these locations contain a mix of medium aged, fairly uniform, dense stands of second growth Douglas Fir and Western Red Cedar. Some western hemlock also occurs within these second growth timber stands. Other vegetation in the timber understory includes alder, big leaf maple, vine maple, swordfern, Oregon grape and salal. While most of these timber areas are less than 80 years old, some areas potentially could provide suitable habitat for
spotted owls. Information pertaining to the suitability of forest habitat for spotted owls is likely to exist for publicly owned lands.

C. RIPARIAN/WETLAND AREAS

The predominant riparian/wetland areas are located at the discharge locations along Sain Creek. The project approach to utilize and reinforce existing intermittent drainages to allow the discharge of diversion water into Sain Creek would impact existing riparian habitat and adjacent wetlands. The extent of impact would be determined through project design and could include the enhancement and expansion of riparian/wetland areas associated with Sain Creek, if desired.

Off channel wetlands could be constructed to allow the discharge to more gradually flow into Sain Creek. This would minimize the need for rockery in the channel for erosion and sediment transport control and would increase habitat for aquatic and amphibian species.

D. WILDLIFE AND WILDLIFE HABITAT

The habitat in the project location is predominantly mid-aged douglas-fir forest canopy which breaks with drainages that are predominantly alder, big leaf maple, vine maple, Oregon grape and salal. These areas contain an abundance of wildlife that are common to this age and type of western Oregon forest stand including Roosevelt elk, black-tailed deer, black bear, song birds, migratory birds, bats, voles, tree-frogs, turtles and snakes. The area is a popular hunting area for those seeking big game animals, particularly elk and deer. The Sain Creek Tunnel project would likely have only a minimal localized and temporary impact on wildlife and wildlife habitat during construction.

E. FISH AND AQUATIC RESOURCES

Fish and aquatic resources that potentially could be impacted are those associated with the tunnel intake at the Hillsboro Reservoir on the upper Tualatin River and the discharge to Sain Creek above Hagg Lake (tributary of Scoggins Creek). Both of these stream locations contain an abundance of fish and aquatic species.

Historically, these tributary streams were home to both anadromous and resident fish species including steelhead trout, Pacific lamprey, cutthroat trout, sculpin, bass, pike minnow, perch and crappie. Anadromous fish are currently limited to the upper Tualatin River below Haines Falls and to Sain Creek below Scoggins Dam. Haines Falls on the Tualatin River (a natural anadromous fish barrier), and Scoggins Dam on Scoggins Creek, effectively prohibit anadromous fish from reaching the proposed
tunnel intake and discharge locations. Therefore, project impacts to anadromous fish are expected to be limited to those associated with downstream water quantity and water quality.

Resident fish including cutthroat trout could be impacted by project construction and operation as well as changes to water quantity and quality. Project design considerations will need to include evaluation of fish screen options to maintain resident species within their native streams. This will require close coordination with the Oregon Department of Fish and Wildlife (ODFW). Isolation of stream and reservoir work areas will also be required during construction to minimize direct impacts to fish.

F. STREAM FLOW

The proposed diversion of 15,000-20,000 AF the winter months and 10,700 AF during the period from mid-June through August 31 from the upper Tualatin River to Sain Creek potentially could have a significant impact on both species and habitat in the immediate project area, as well as downstream within both these tributaries. The mid-June through August diversion is based on diverting up to 70 cfs from Barney Reservoir during these summer months. However, this diversion is planned to occur during the winter months of December through March. The proposed winter diversion schedule coupled with up to 70 cfs released into the upper Tualatin from the Barney reservoir from mid-June through August 31 may result in a net overall benefit to water quality conditions in the Tualatin River. Careful evaluation of “available” stream flow will need to occur during project preliminary design. An initial estimate of “available” flow conducted by Clean Water Services (CWS) indicate the following diversion scenario:
Table VI-1. Diversions through tunnel.

<table>
<thead>
<tr>
<th>Proposed Flow Diversions</th>
<th>Month</th>
<th>cfs</th>
<th>AF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>December</td>
<td>100</td>
<td>6,150</td>
</tr>
<tr>
<td></td>
<td>January</td>
<td>100</td>
<td>6,150</td>
</tr>
<tr>
<td></td>
<td>February</td>
<td>80</td>
<td>4,443</td>
</tr>
<tr>
<td></td>
<td>March</td>
<td>40</td>
<td>3,332</td>
</tr>
<tr>
<td></td>
<td>April</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>May</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>Mid June</td>
<td>70</td>
<td>2,083</td>
</tr>
<tr>
<td></td>
<td>July</td>
<td>70</td>
<td>4,304</td>
</tr>
<tr>
<td></td>
<td>August</td>
<td>70</td>
<td>4,304</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>30,766 Acre-feet</strong></td>
</tr>
</tbody>
</table>

The projected diversion flows primarily represent “available water” in the Tualatin drainage resulting from flood skimming during winter and spring runoffs. This kind of diversion scenario avoids diversion from the upper Tualatin during the most critical summer and fall months, when the lack of summer water results in downstream water quality concerns, including increased stream temperature. From mid-June through August the tunnel would convey only water transferred from Barney Reservoir. This would return the lower Tualatin River flows to their historical pattern.

The issue of flow diversions from the upper Tualatin River and the subsequent discharge of flows to Sain Creek are potentially the most significant environmental impacts associated with the Sain Creek Tunnel project. A careful analysis of the direct, indirect and cumulative effects of this action will need to be completed early in the project to determine if the potential impacts can be mitigated to the satisfaction of the regulatory agencies in order to insure project approvals. Key considerations that need to be addressed in the flow analysis include:

- water availability
- water rights
- adequate flows for fish life cycles (spawning, rearing, mitigation)
- flow discharge impacts to Sain Creek wetland/riparian habitat
- water quality
• sediment transport (Sain Creek)

• prior permit conditions/Committants (Barney Reservoir Flow Allocations)

• potential fish bearing instinct disruption

G. WATER QUALITY

The major beneficial uses of water in the upper Tualatin-Scoggins watershed are for domestic and municipal consumption, cold water fisheries, warm water fisheries (in Henry Hagg Lake), water contact recreation, irrigation, maintenance of downstream water quality, livestock watering, and wildlife. The water quality parameters that these beneficial uses are dependent on include water temperature, nutrient levels, suspended sediment/turbidity levels, dissolved oxygen and bacterial levels (Upper Tualatin-Scoggins Watershed Analysis, BLM, Feb. 2000).

Generally, the best water quality occurs in the forested portion of the watershed, particularly within the Tualatin River section above Cherry Grove. The river is well shaded with abundant stream turbulence which leads to well-oxygenated waters. Diversion of winter-time and early spring flood waters would not likely have a detrimental impact to the upper Tualatin River or to Sain Creek.

Discharge of the diverted flow from Hagg Lake into Scoggins Creek and ultimately into the Tualatin River for irrigation users may provide the opportunity to enhance water quality conditions. Increased diversion flows into Scoggins Creek and the Tualatin River can decrease water temperature, increase dissolved oxygen levels and lower phosphorus and nitrate levels. These water quality benefits potentially can be realized most significantly if the discharges are planned during the low flow summer months. The timing and amount of these diversions will depend on the overall schedule of water releases that are established for Scoggins Dam to meet diversion demands as well as water quality and fish needs.

Potential water quality impacts could occur in the Tualatin River between Cherry Grove and the confluence of Scoggins Creek and the Tualatin River with the diversion of water away from this stretch of the Tualatin River. This potential impact should be evaluated in further detail during project preliminary design. However, since the planned diversions are winter and spring flood waters, it would appear that they would have a beneficial effect on water quality in this area. The effect could be a decrease in flood magnitude, thus decreasing bank scour events, which can increase stream sedimentation.
H. LAND USE AND OWNERSHIP

A review of land ownership maps contained in the Bureau of Land Management (BLM) Upper Tualatin-Scoggins Watershed Analysis, February 2000, indicates that the tunnel, tunnel intake and discharge sites potentially would be located on both public (City of Hillsboro) and private land. A section of the tunnel near Sain Creek is in close proximity to federally owned (BLM) land.

Land ownership can be a significant factor in project costs to acquire private land or easements. It can also affect the extent of environmental studies and regulatory review to obtain project permits. If the project encroaches on federally owned land (BLM), the BLM will be a review and coordination partner during any federal permitting process (Corp of Engineers Section 404). Further, an additional level of environmental analysis will be required on the BLM owned lands for BLM listed “survey and manage species”.

I. SPECIAL STATUS SPECIES

Special status species are those species that are listed by federal or state agencies (NOAA Fisheries, US Fish and Wildlife Service, Oregon Department of Fish and Wildlife, Oregon Department of Agriculture) as sensitive, threatened or endangered. The Oregon Natural Heritage Program has identified multiple (50+) birds, plants, animals, amphibians, insects and fungi that are identified as special status species and potentially could occur within the project area. Of the 50+ species listed, only a few are likely to be impacted by the project. These potentially include Nelson’s sidalsea, Oregon silverspot butterfly, steelhead trout, marbled murrelet, bald eagle, and the northern spotted owl. Further determination of these species utilization adjacent to and within the project area should be determined during preliminary design.

J. TRAFFIC IMPACTS

Traffic associated with equipment mobilization and on-going tunnel construction and boring are not expected to have a significant impact on the rural roads in the area. Some congestion may occur around Hagg Lake during the summer months due to increased recreational activities. This congestion can be avoided by requiring construction related traffic to traverse the roads during off-peak summer travel times.

The most significant traffic impact will be from the truck transport of tunnel spoils to temporary or permanent disposal sites. At maximum tunnel boring efficiency, up to 44 dump trucks per day will be utilizing rural transport routes to dispose of tunnel spoils. This could pose a potential concern by area residents and increase road hazards for motorists using the area – especially during the summer months.
To minimize potential traffic hazards associated with transport of spoils, the disposal sites should be located in close proximity to the tunnel boring operation to the extent feasible, ingress and egress areas need to be safely designed and posted, and dump truck traffic routes need to be posted.

**K. NATURE AND DISPOSAL OF TUNNEL SPOILS**

Spoils generated by the tunnel boring machine will consist of clean, hard rock fragments similar in size to rock typically used as railroad ballast. The rock along the tunnel alignment is a diabase, which is an intrusive basalt. It is hard and relatively brittle. Thus, when excavated by the TBM there should be minor amounts of fine-grained materials or “rock flour.” As a result, the seepage water exiting the tunnel during construction is expected to be relatively clean and can probably be discharged into a small settling basin before being released to Sain Creek.

The two potential alignments of the tunnel measure about 15,000 feet and 20,600 feet in length. The volume of intact rock for a 10 foot diameter tunnel would be 44,000 cubic yards and 61,000 cubic yards respectively. The volume of rock chips is larger than the volume of intact rock excavated, typically by about 30% for rock of this nature. Applying a 30% “bulking factor” to the above volumes of intact rock indicates the tunnel spoil volume that will require removal from the site will be on the order of 57,000 cubic yards for the shorter length tunnel, and 80,000 cubic yards for the longer tunnel, which terminates closer to the mouth of Sain Creek.

Rates of tunneling progress using a TBM can vary widely depending on rock and water conditions encountered, mechanical breakdowns of the machine, operator experience, etc. Good, average, and marginally acceptable rates of progress are given in Table IV-1 below, along with the resulting volume of spoil material to be disposed of on an average daily basis. Also included in the table is the average daily number of ten cubic yard dump trucks that would be exiting the construction site to transport material to the disposal site, or areas where the spoil could be utilized in other construction activities related to raising Scoggins Dam. As noted in Section III-F-4 there are a number of possible beneficial uses of the tunnel spoil, which would require it to be transported to a number of different locations around Hagg Lake, as well as possibly to Hillsboro Reservoir. The estimated number of trucks would all be using some portion of West Shore Drive to transport the tunnel spoils.
Table IV-2. Disposal of tunnel spoil.

<table>
<thead>
<tr>
<th>Qualitative Tunneling Progress</th>
<th>Approximate Rate of Tunnel Advance</th>
<th>Average Daily Volume of Tunnel Spoil Produced</th>
<th>Average Daily Number of 10 Cubic Yard Trucks Needed</th>
<th>Approximate No. of Days of TBM Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>150 Ft/Day</td>
<td>436 Cubic Yards</td>
<td>44 Truckloads</td>
<td>100 Days</td>
</tr>
<tr>
<td>Average</td>
<td>100 Ft/Day</td>
<td>290 Cubic Yards</td>
<td>29 Truckloads</td>
<td>150 Days</td>
</tr>
<tr>
<td>Poor</td>
<td>65 Ft/Day</td>
<td>189 Cubic Yards</td>
<td>19 Truckloads</td>
<td>231 Days</td>
</tr>
</tbody>
</table>

The TBM construction can occur during any portion of the year and would likely proceed 5-6 days per week, based on two 10-hour shifts per day. Our cost estimate does not include any provision for extra costs due to restrictions on construction activities, or disposal of spoils. Our cost estimate for disposal of tunnel spoils does not assume any “salvage” value for the spoil. Material of this nature, if used as part of the concrete aggregate or drain blanket material in raising Scoggins Dam, would have a value that would offset the cost of the tunnel construction. If the contractor was prohibited from transporting spoils on weekends or holiday periods because of recreational use of Hagg Lake and West Shore Drive, that would potentially require stockpiling and double handling of spoils and may result in additional costs.

L. PERMITTING

Permit requirements are dependent on which agencies have jurisdiction over the project, the extent of environmental impacts expected, and whether or not the tunnel project is separate or combined with other municipal water projects planned in the basin. The following permits will be required for all potential permitting scenarios:
Table IV-3. Permit requirements.

<table>
<thead>
<tr>
<th>Required Permits</th>
<th>Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean Water Act 404</td>
<td>US Army Corp of Engineers</td>
</tr>
<tr>
<td>Biological Opinion/ITS for ESA Species</td>
<td>NOAA Fisheries &amp; US Fish and Wildlife</td>
</tr>
<tr>
<td>Fill Removal</td>
<td>Oregon Division of State Lands</td>
</tr>
<tr>
<td>Clean Water Act 401 Water Quality Certification</td>
<td>Oregon Dept. of Environmental Quality</td>
</tr>
<tr>
<td>NPDES – Stormwater/Construction</td>
<td>Oregon Dept. of Environmental Quality</td>
</tr>
<tr>
<td>Forestry Permit</td>
<td>Oregon Dept. of Forestry</td>
</tr>
<tr>
<td>Water Rights</td>
<td>Oregon Water Resources</td>
</tr>
<tr>
<td>Land Use / Building Permit</td>
<td>Washington County</td>
</tr>
</tbody>
</table>

V. COST ESTIMATES AND CONSTRUCTION SCHEDULE

A. COST ESTIMATE

We have prepared a construction cost estimate for the Sain Creek Tunnel Project described in this reconnaissance level report. The costs include modifications at Hillsboro Reservoir to make it suitable to serve as the forebay to the tunnel. The cost estimate assumes the Tualatin River intake remains unscreened against fish entrainment, as is presently the case. The cost estimate does, however, include provisions for installing fish screens and appropriate screen cleaning facilities at the tunnel intake structure. Modifications at Hillsboro Reservoir also include installation of a rubber weir across the top of Haines Falls.

The cost estimate is based on use of a tunnel boring machine (TBM) to excavate a tunnel of approximately 10 foot diameter. Rock conditions along the tunnel are anticipated to be favorable for TBM construction based on review of available information. Note that no field exploration has been performed for this study. A field drilling and sampling program should be conducted if the project proceeds to future phases. The cost estimate includes an allowance for field exploration, sampling, and laboratory testing as well as more detailed field survey information that will be needed at Hillsboro Reservoir and at prospective tunnel outlet sites.
We consider the project to be relatively benign from an environmental impact standpoint. Accordingly, we have included an allowance of $500,000 for environmental investigations, field studies, permitting and agency negotiations and a further $500,000 for environmental mitigation, based on our experience and judgment. We consider the allowances to be somewhat conservative, but caution that our estimated environmental costs at this early stage of the project are based on limited discussions with environmental review agencies. Thus final costs related to environmental issues and approvals could vary significantly from our estimate.

The cost estimate reflects two alternative tunnel alignments and three candidate discharge locations along Sain Creek. As more geologic, hydrologic, and environmental information becomes available, the location of the outlet along Sain Creek will be refined, which will then set the final tunnel route and length.

For this reconnaissance level report the tunnel construction itself is, by far, the most significant item of cost. We have investigated the probable tunnel construction cost based on our in-house expertise, through personal communications with other outside sources of expertise, and by contacts with tunnel contractors and manufacturers of tunnel boring machines. We have expended additional engineering design efforts on other major project features such as the tunnel intake and outlet structures, and the rubber weir at Haines Falls, in order to develop a specific estimated cost for these project features.

For other project features, such as the Tualatin River intake, and the pipelines to and from Hillsboro Reservoir, our cost is based on an estimated allowance that we consider will be adequate to cover the necessary modifications. This applies to the access road and bridge to the tunnel outlet area, and modifications to the discharge channel construction to return flows to Sain Creek.

Based on the above assumptions, we estimate the cost of the Sain Creek Tunnel Project to range from about $21,000,000 to $24,300,000, depending on the location of the tunnel outlet. This estimate excludes the cost of a hydroelectric generation facility.

Our cost estimate includes a budgetary allowance for further field geologic/geotechnical investigations of $200,000.

Detailed engineering design and preparation of contract documents is based on 12 percent of overall construction costs. We have included an allowance of $600,000 for Owners Administration during construction based on an estimated 20 months duration of the services.
A budget allowance is also included for environmental studies, preparation of an environmental impact statement, construction permitting, and obtaining necessary environmental agency approvals.

As a separate line item we have included a budget allowance for possible environmental mitigation, although at this early stage we do not know the extent to which mitigation will be required, or its nature.

**Exhibit 11** presents the estimate of construction and other related project costs. The backup to the cost estimate is included in Attachment D.

**B. CONSTRUCTION SCHEDULE**

We believe the project can be constructed in a period of about 18 months. The major item of construction activity, which will dictate the overall time required to complete the project, is boring of the tunnel. Ancillary activities such as modifications at Hillsboro Reservoir, installation of the rubber weir at Haines Falls, and outlet channel modifications can proceed concurrently with tunnel construction. The earliest the tunnel construction could commence is spring of 2005. Our construction schedule assumes the tunnel construction begins as soon as possible. We note, however, the raising of Scoggins Dam is not expected to begin construction until June 2008. If it were decided to undertake the tunnel and dam raise together the work on the tunnel could begin in the spring of 2008 and the rock from the tunnel excavation could still be used in the raising of the dam, construction of the spillway or relocation of the reservoir perimeter roads.

Based on an average rate of tunnel advance of 100 feet per day, the actual work of the TBM will take from 150 to 206 working days depending on the selected alignment of the tunnel.

We assumed in our construction schedule that the necessary access road and bridge across Sain Creek can be constructed in three months, regardless of which outlet location is selected.

Mobilization of the TBM, its assembly on site, and construction of the starter tunnel, which would be accomplished by drill and blast methods, is expected to take a further 2-3 months. **Exhibit 12** shows the proposed construction schedule.
PHOTOGRAPHS

Photo 1. Lee Falls showing good quality of exposed basalt (diabase).

Photo 2. Gage station on Sain Creek. Note width of creek in background. There appears to be a steep rock face along the south side of the creek just downstream of the gage where the tunnel could exit the rock.
Photo 3. Rock outcrop near Hillsboro Reservoir. Rock is fractured and weathered but appears suitable for tunnel construction.
Photo 4. Concrete sill placed across top of Haines Falls to seal gaps in the rock and create a pool for the Hillsboro Reservoir intake. Note “falls” occur along right (south) side of river. South bank appears to be suitable for anchorage of a rubber weir structure.

Photo 5. Shows steep rock face in northeast corner of Hillsboro Reservoir. Tunnel intake structure would be constructed along this rock face. Crown of tunnel would be submerged about 5 feet below reservoir water surface elevation.
Photo 6. Width of Tualatin River near intake to Hillsboro Reservoir on April 2, 2003. New intake would be constructed through the concrete wall at left side of photo. During intake modifications, river would be diverted along south bank, away from area of construction.

Photo 7. Shows Haines Falls in background and channel to Tualatin River into which bypass releases from intake would be discharged, as well as overflow releases from Hillsboro reservoir.
Photo 8. West section of reservoir as viewed from the top of the dike. Rock knob appears along right side of photo. Wood baffles are barely visible along waterline at back of pond. Modifications to reservoir would include a cofferdam in the approximate location of the baffles, which would require construction of an access road along either shore of the reservoir.

Photo 9. Hillsboro Reservoir crest of earth dam and overflow structure, which discharges to the river. Note steep shoreline with rock near the ground surface. A permanent access road would be constructed along this bank to the new tunnel intake structure.
Photo 10. View from top of Hillsboro Dam looking back to river. Access road leads to the intake upstream of Haines Falls.

Photo 11. Core from Barney Dam Borehole B-114 at depth of approximately 50 feet. Note excellent quality of the rock.
Photo 12. Core from Barney Dam Borehole B-115 at depth of approximately 50 feet. Rock is of excellent quality for use of a tunnel boring machine.

Photo 13. Core from Barney Dam Borehole B-116 at depth of approximately 50 feet.
Photo 14. Core from Barney Dam Borehole B-117 at depth of approximately 60 feet. Core is more fractured than in other boreholes.
EXISTING CONCRETE ABUTMENT WALL

CRACK CONTROL JOINT @ APPROX. CENTER

D/S ANCHORING LINE

U/S ANCHORING LINE

T.O.C. EL 592.75

EXISTING CONCRETE SILL

RUBBER DAM BODY (WHEN DEFLATED)

RUBBER DAM BODY (WHEN INFLATED)

HANSE FALLS

12' X 15'
RUBBER DAM SYSTEM CONTROL EQUIPMENT BUILDING

80'-0" ESTIMATED WIDTH

TULATIN RIVER

PLAN

SCALE: 1/8"=1'-0"

HANSE FALLS

FISH DISCHARGE FACILITY

CREST EL AND NORMAL D.W.
WSEL 597.75

T.O. CONC. & DATUM LEVEL OF RUBBER DAM EL 592.75

RUBBER DAM BODY (WHEN INFLATED)

2" PRESSURE SENSING INLET

DATUM LEVEL OF RUBBER DAM EL 592.75

T.O.C. EL 592.75

NORMAL OPERATING/OHV
WSEL 597.75

EL 592.42

EL 588.52

EL 580.25

HANSE FALLS

FLOW

BASALT BEDROCK

EXISTING CONCRETE SILL

SECTION

SCALE: 1/8"=1'-0"

EL 592.75

T.O.C. EL 600.25

EL 588.52

FOUNDATION CONDITION OF WALL IS PRESENTLY UNKNOWN

UPSTREAM ELEVATION

SCALE: 1/8"=1'-0"

ROCK FOUNDATION

WATER SUPPLY
FEASIBILITY STUDY

SAIN CREEK TUNNEL
RUBBER DAM
ELEVATION AND SECTION

Exhibit 6
### SAIN CREEK TUNNEL
CONSTRUCTION COST ESTIMATE
SUMMARY SHEET

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>COST</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Mob. &amp; Demob.</td>
<td>$1,271,000</td>
<td>10% of Subtotal</td>
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<tr>
<td>Rubber Dam Construction</td>
<td>$476,000</td>
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<tr>
<td>River Intake Structure</td>
<td>$166,000</td>
<td></td>
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<tr>
<td>Distribution Box</td>
<td>$160,000</td>
<td></td>
</tr>
<tr>
<td>Tunnel Inlet Screen Structure</td>
<td>$742,000</td>
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<tr>
<td>Tunnel</td>
<td>$9,538,000</td>
<td>Short Route (15,100 Feet)</td>
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<tr>
<td>Tunnel Outlet Facilities</td>
<td>$1,523,000</td>
<td></td>
</tr>
<tr>
<td>Sain Creek Return Channel</td>
<td>$100,000</td>
<td></td>
</tr>
</tbody>
</table>

**SUBTOTAL OPINION OF PROBABLE CONSTRUCTION COST:** $13,976,000

- Construction Estimate Contingency 10% $1,398,000
- Engineering Design and Services 12% $1,678,000
- Construction Management 8% $1,119,000
- Owner's Contract Administration During Construction LS $600,000

**Subtotal** $18,771,000

- Geotechnical Field Explorations and Laboratory Testing LS $200,000
- Environmental Studies, Permitting, and Agency Negotiations LS $500,000

**Subtotal** $19,471,000

- Land Acquisition LS $1,000,000
- Environmental Mitigation LS $500,000

**TUNNEL PROJECT TOTAL (ROUNDED)** $20,971,000

- Future Hydropower Facility $2,055,000

**Notes:**

1. Sales tax is not included.
2. Numbers are rounded up to the nearest $1000.
3. Numbers are present value (no adjustment for future Value)
4. Longer route of 20,600 feet would add approximately $3,300,000 to the cost.
## SAIN CREEK TUNNEL

**Rubber Dam Construction** | **$476,000**
---|---
Erosion Control | $1,000
Clearing and Grubbing | $2,000 Sandbags
Cofferdam | $5,000
Rubber Dam | $335,000
Electrical | $101,000
Civil Sitework | $16,000
Control Equipment Bldg. | $16,000
Sain Creek Tunnel

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Unit</th>
<th>Base Price</th>
<th>Additional Cost</th>
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<tr>
<td><strong>Rubber Dam</strong></td>
<td></td>
<td></td>
<td><strong>$332,250</strong></td>
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<tr>
<td>Excavation</td>
<td>400</td>
<td>CY</td>
<td>$5</td>
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<tr>
<td>Reinforced Concrete</td>
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<td>CY</td>
<td>$650</td>
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<tr>
<td>Native backfill</td>
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<td>CY</td>
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<td>$1,500</td>
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<tr>
<td>Bridgestone Equipment/Materials</td>
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<tr>
<td><strong>Electrical</strong></td>
<td></td>
<td></td>
<td><strong>$100,800</strong></td>
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<td>Utility Meter &amp; Main Disconnect</td>
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<td>$2,960</td>
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<td>$4,540</td>
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<tr>
<td>Installation of rubber dam equipment</td>
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<tr>
<td>Indoor Lighting/recept</td>
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<tr>
<td>4&quot; PVC conduit, underground</td>
<td>100</td>
<td>FT</td>
<td>$19</td>
<td>$1,900</td>
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<tr>
<td>1-1/2&quot; PVC conduit, underground</td>
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<td>$14</td>
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<tr>
<td>1-1/2&quot; RGS conduit, above grade</td>
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<td>FT</td>
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<td>$840</td>
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<tr>
<td>3/4&quot; RGS conduit, above grade</td>
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<tr>
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<td>#8 AWG, THWN, CU Cable</td>
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<tr>
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<td>10' CU ground rod</td>
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<td>Flow Measurement Equipment/Controls</td>
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<td>Alarm / Phone Line</td>
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<td><strong>Control Equipment Bldg.</strong></td>
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<td><strong>$15,360</strong></td>
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<tr>
<td>12'x16' Pre-Engineered Metal Bldg.</td>
<td>192</td>
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<td><strong>Civil Sitework</strong></td>
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<tr>
<td>Gravel Surfacing</td>
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<td>SY</td>
<td>$6</td>
<td>$7,800</td>
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<tr>
<td>Riprap</td>
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<td>CY</td>
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<td>$4,000</td>
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<td>Fencing</td>
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<td>$20</td>
<td>$2,000</td>
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<tr>
<td>Fence Gates</td>
<td>2</td>
<td>EA</td>
<td>$1,000</td>
<td>$2,000</td>
</tr>
</tbody>
</table>
SAIN CREEK TUNNEL

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>River Intake Structure</td>
<td>$166,000</td>
</tr>
<tr>
<td>Erosion Control</td>
<td>$5,000</td>
</tr>
<tr>
<td>Clearing and Grubbing</td>
<td>$2,000</td>
</tr>
<tr>
<td>Demolition and Removal of Existing Intake</td>
<td>$5,000</td>
</tr>
<tr>
<td>Cofferdam</td>
<td>$10,000 Sandbags</td>
</tr>
<tr>
<td>Concrete Intake Structure</td>
<td>$53,000</td>
</tr>
<tr>
<td>Metals</td>
<td>$28,000</td>
</tr>
<tr>
<td>60&quot; CMP Culverts to Dist. Box</td>
<td>$45,000</td>
</tr>
<tr>
<td>Trash Rake</td>
<td>$18,000</td>
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</table>
Sain Creek Tunnel

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Unit</th>
<th>Rate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Concrete Intake Structure</strong></td>
<td></td>
<td></td>
<td></td>
<td>$52,072</td>
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<tr>
<td><strong>Footing</strong></td>
<td></td>
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<tr>
<td>Intake Footing Slab EL 592.75</td>
<td>Rect.</td>
<td>59</td>
<td>CY</td>
<td>$400</td>
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<tr>
<td></td>
<td>Rect.</td>
<td>4</td>
<td>CY</td>
<td>$400</td>
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<tr>
<td></td>
<td>Trian.</td>
<td>3</td>
<td>CY</td>
<td>$400</td>
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<tr>
<td><strong>Intake Walls</strong></td>
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<td>$25,839</td>
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<td>Pipe Wall</td>
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<td>Left &amp; Right Walls</td>
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<td>CY</td>
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<td>Embedded Stop Log &amp; Trash Rack Guides W4x13</td>
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<td>Stop logs (4x12 planks)</td>
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<td>Tarshrack</td>
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<td>SF</td>
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<td>Hand Rail</td>
<td>95</td>
<td>LF</td>
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<td>60&quot; CMP Culverts to Dist. Box</td>
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<td>$44,775</td>
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<tr>
<td>Trench Excavation</td>
<td>75</td>
<td>LF</td>
<td>$60</td>
<td>$13,500</td>
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<tr>
<td>Bedding</td>
<td>75</td>
<td>LF</td>
<td>$30</td>
<td>$6,750</td>
</tr>
<tr>
<td>60&quot; Dia. Corrugated Metal Pipe</td>
<td>75</td>
<td>LF</td>
<td>$109</td>
<td>$24,525</td>
</tr>
<tr>
<td>60&quot; CMP Culverts to Dist. Box</td>
<td>3</td>
<td></td>
<td></td>
<td>$44,775</td>
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<tr>
<td><strong>Trash Rake</strong></td>
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<td></td>
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<td>$7,875</td>
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<tr>
<td>Electrical and Setup</td>
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<td>LS</td>
<td>$10,000</td>
<td>$10,000</td>
</tr>
</tbody>
</table>
Sain Creek Tunnel

**SAIN CREEK TUNNEL**

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution Box</td>
<td>$160,000</td>
</tr>
<tr>
<td>Demolition and Removal of Existing Dist. Box</td>
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</tr>
<tr>
<td>Site Grading</td>
<td>$2,000</td>
</tr>
<tr>
<td>Structural Fill</td>
<td>$6,000</td>
</tr>
<tr>
<td>Concrete Distribution Box</td>
<td>$85,000</td>
</tr>
<tr>
<td>60&quot; CMP Culverts to Reservoir</td>
<td>$45,000</td>
</tr>
<tr>
<td>Gates</td>
<td>$17,000</td>
</tr>
</tbody>
</table>
Sain Creek Tunnel

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Unit</th>
<th>Rate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Fill</td>
<td></td>
<td></td>
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<td>$5,832</td>
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<tr>
<td>4&quot; Compacted Structural Fill</td>
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<td>CY</td>
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<td>Fill Behind Walls (2’ ave. thick.)</td>
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<td>Box Walls</td>
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<td>$66,071</td>
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<tr>
<td>N &amp; S Walls</td>
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<td>CY</td>
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<td>$17,254</td>
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<tr>
<td>E &amp; W Walls</td>
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<td>CY</td>
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<tr>
<td>Steel Grating Support Beams</td>
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<td>LF</td>
<td>$55</td>
<td>$3,900</td>
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<td>Steel Grating</td>
<td>620</td>
<td>SF</td>
<td>$20</td>
<td>$12,400</td>
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<tr>
<td>60&quot; CMP Culverts to Reservoir</td>
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<td></td>
<td>$2</td>
<td>$44,775</td>
</tr>
<tr>
<td>Trenching</td>
<td>75</td>
<td>LF</td>
<td>$60</td>
<td>$13,500</td>
</tr>
<tr>
<td>Bedding</td>
<td>75</td>
<td>LF</td>
<td>$30</td>
<td>$6,750</td>
</tr>
<tr>
<td>60&quot; Dia. Corrugated Metal Pipe</td>
<td>75</td>
<td>LF</td>
<td>$109</td>
<td>$24,525</td>
</tr>
<tr>
<td>Gates</td>
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<td>$16,700</td>
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<tr>
<td>6x 6 Slide Gate</td>
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<td>$4,000</td>
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<tr>
<td>3x 3 Slide Gate</td>
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<td>2x2 Slide Gate</td>
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<td>EA</td>
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<td>$2,100</td>
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</table>
SAIN CREEK TUNNEL

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunnel Inlet Screen Structure</td>
<td>$742,000</td>
</tr>
<tr>
<td>Erosion Control</td>
<td>$5,000</td>
</tr>
<tr>
<td>Clearing and Grubbing</td>
<td>$2,000</td>
</tr>
<tr>
<td>Earth Fill Cofferdam</td>
<td>$121,000</td>
</tr>
<tr>
<td>Dewatering</td>
<td>$20,000</td>
</tr>
<tr>
<td>Excavation</td>
<td>$52,000</td>
</tr>
<tr>
<td>Concrete for Intake Structure</td>
<td>$179,000</td>
</tr>
<tr>
<td>Misc. Metals</td>
<td>$42,000</td>
</tr>
<tr>
<td>Screens and Baffles</td>
<td>$290,000</td>
</tr>
<tr>
<td>Bulkheads</td>
<td>$31,000</td>
</tr>
</tbody>
</table>

Cost Estimate.xls  Tunnel Screen Struct.  1 of 3  7/15/2003  12:20 PM
### Sain Creek Tunnel

**Earth Fill Cofferdam**  
$120,400  
\[\text{Assumed Req'd Length} \quad 100'\]  
\[\text{Cofferdam} \quad 2370 \quad \text{CY} \quad $27.00 \quad $64,000\]  
\[\text{Temp Access Road to Construct Cofferdam} \quad \text{Assumed Required Length} \quad 150'\]  
\[\text{2083 CY} \quad $27.00 \quad $56,250\]  

**Dewatering**  
$20,000  
\[\text{Pumping out of work Area} \quad 5 \quad \text{MO} \quad $4,000.00 \quad $20,000\]

**The Following Assumes Req'd Length of Screen Structure**  
100' over 9 Piers

<table>
<thead>
<tr>
<th>Excavation</th>
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<th>Rock Excavation</th>
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</thead>
<tbody>
<tr>
<td>Rock Excavation For Concrete Footing</td>
<td>833 CY</td>
<td>$50</td>
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<tr>
<td>Piles Piers</td>
<td>90 LF</td>
<td>$110</td>
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</table>

**Concrete for Intake Structure**  
$178,659

<table>
<thead>
<tr>
<th>Footing</th>
<th>$60,400</th>
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</thead>
<tbody>
<tr>
<td>Footing Slab EL 65</td>
<td>Rect. 136 CY</td>
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<tr>
<td>Concrete in Piers</td>
<td>Rect. 10 CY</td>
</tr>
</tbody>
</table>

**Concrete Pier Walls**  
$72,423  
\[\text{Pier's Round Ends} \quad 18.56 \quad \text{CY} \quad $700 \quad $12,989\]  
\[\text{Piers (Front)} \quad \text{Rect.} \quad 39 \quad \text{CY} \quad $550 \quad $21,656\]  
\[\text{Piers (Back)} \quad \text{Rect.} \quad 51 \quad \text{CY} \quad $550 \quad $28,153\]  
\[\text{Piers at the Tunnel Entrance} \quad \text{Add Rect.} \quad 18 \quad \text{CY} \quad $550 \quad $9,625\]  

**Deck Slab**  
$45,836  
\[\text{Bridge Deck Slab} \quad 58.64 \quad \text{CY} \quad $650 \quad $38,117\]  
\[\text{Bridge Deck Slab Supprrting Beams} \quad 11.88 \quad \text{CY} \quad $650 \quad $7,719\]  

**Misc. Metals**  
$41,380  
\[\text{Guard Rail} \quad 200 \quad \text{LF} \quad $70 \quad $14,000\]  
\[\text{Hand Rail} \quad 200 \quad \text{LF} \quad $55 \quad $11,000\]  
\[\text{Screen and Stop Bulkhead Guides} \quad 544 \quad \text{LF} \quad $20 \quad $10,880\]  
\[\text{Grating Access Hatch} \quad 1 \quad \text{LS} \quad $4,000 \quad $4,000\]  
\[\text{Access Ladder} \quad 1 \quad \text{LS} \quad $1,500 \quad $1,500\]  

**Screens and Baffles**  
$289,200  
\[\text{Screen Panels} \quad 9 \quad 1377 \quad \text{SF} \quad $85 \quad $117,045\]  
\[\text{Baffles} \quad 9 \quad 1377 \quad \text{SF} \quad $60 \quad $82,620\]  
\[\text{Brush Screen Cleaning System} \quad 9 \quad 1377 \quad \text{SF} \quad $65 \quad $89,505\]  

**Bulkheads**  
$30,200  
\[\text{Bulkhead Panels} \quad 1 \quad 315 \quad \text{SF} \quad $96 \quad $30,192\]
A Canal:

<table>
<thead>
<tr>
<th>Item</th>
<th>Area (sf)</th>
<th>Ave. Bid Price</th>
<th>Estimated Cost/sf</th>
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</thead>
<tbody>
<tr>
<td>Screens</td>
<td>5784</td>
<td>$490,347</td>
<td>$84.78 Primary and Sec.</td>
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<td>Baffles</td>
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<td>$335,589</td>
<td>$58.02 Primary and Sec.</td>
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<td>Screen Cleaning System</td>
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<td>$63.45 Primary and Sec.</td>
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<tr>
<td>Bulkheads</td>
<td>1134</td>
<td>$108,000</td>
<td>$95.24 Primary and Sec.</td>
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**SAIN CREEK TUNNEL**

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Unit</th>
<th>Cost</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunnel Construction</td>
<td>15,100</td>
<td>LF</td>
<td>$600</td>
<td>$9,060,000</td>
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<tr>
<td>Shotcrete</td>
<td>149</td>
<td>CY</td>
<td>$254</td>
<td>$38,000 Means B. 161 Adjusted</td>
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<td>Disposal of Spoil Materials</td>
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<td>CY</td>
<td>$7</td>
<td>$400,000 30% Flushing Fac</td>
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<tr>
<td>Dealing with Water in Tunnel</td>
<td>66.62</td>
<td>CFS</td>
<td>$600</td>
<td>$40,000</td>
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</table>

Assuming Route Length of 15,100 feet, 2.86 miles.
Cost Estimate.xls  Tunnel  2 of 2  7/15/2003  12:20 PM

Circumference 31.42 feet
Inside Area (A1) 78.54 sf
Inside Volume (V1) 43924 cy
Shotcrete Thickness 3 in
Area (A2) 86.59 sf
Shotcrete/ LF 8.05 cf
Length of Lining 500'
Total Volume of Shotcrete 149 cy
Expected Water in Tunnel/ft 2.0 gpm/ft
Total Water to Deal With 29,898 gpm = 67 cfs
## SAIN CREEK TUNNEL

### Tunnel Outlet Facilities

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erosion Control</td>
<td>$5,000</td>
</tr>
<tr>
<td>Clearing and Grubbing</td>
<td>$2,000</td>
</tr>
<tr>
<td>Excavation and Backfill</td>
<td>$10,000</td>
</tr>
<tr>
<td>Piping</td>
<td>$282,000</td>
</tr>
<tr>
<td>Valves</td>
<td>$968,000</td>
</tr>
<tr>
<td>Gates</td>
<td>$40,000</td>
</tr>
<tr>
<td>Equipments</td>
<td>$12,000</td>
</tr>
<tr>
<td>Buildings</td>
<td>$ 93,000</td>
</tr>
<tr>
<td>Concrete Structures</td>
<td>$ 120,000</td>
</tr>
</tbody>
</table>

**Total Cost:** $1,523,000
### Piping
- **96" Sleeve Transition in Tunnel**: 20 LF, $1,000, $20,000 (Educated Guess w/install, MHH (Tacoma Pipe $320/LF of 48"))
- **96" x 84" Reducer**: 1 EA, $4,000, $4,000 (Guess w/install, MHH)
- **Total 84" Pipe**: 140 LF, $857, $120,000 (Guess w/install, MHH)
- **84" Y**: 2 EA, $45,500, $90,000 (Guess w/install, MHH)
- **84" Elbow**: 1 EA, $15,000, $15,000 (Guess w/install, MHH)

### Concrete Encasement
- **Concrete Encasement**: 65.45 CY, $500, $32,725

### Valves
- **96" Butterfly Valves**: 2 EA, $112,500, $225,000 (Guess w/install, MHH)
- **90" Sleeve Valves**: 2 EA, $33,750, $67,500 (Guess w/install, MHH)
- **Nuts/Bolts/Flanges**: 10%, LS, $45,625, $45,625 (Guess w/install, MHH)

### Gates
- **84" Flap Gates**: 2 EA, $20,000, $40,000 (Guess w/install, MHH)

### Equipment
- **Pressure Gauges**: 4 EA, $3,000.00, $12,000 (SP)
- **Dresser Couplings**: 3 EA, $15,000.00, $45,000 (SP)

### Buildings
- **Sleeve Valves Building**: 925 SF, $100, $92,500

### Concrete Structures
- **Stilling Basin Footing Slabs**: 170 CY, $400, $68,000
- **Stilling Basin Walls**: 85 CY, $600, $51,022

### Thickness Area Volume

<table>
<thead>
<tr>
<th>Slabs</th>
<th>Thickness</th>
<th>Area</th>
<th>Volume</th>
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<td>1440</td>
<td>80</td>
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<tr>
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<td>1400</td>
<td>78</td>
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<tr>
<td>Stilling Basin Footing Slab</td>
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<td>220</td>
<td>12</td>
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<tr>
<td>Turbine Channel Slabs</td>
<td>1.5</td>
<td>576</td>
<td>32</td>
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</tbody>
</table>

### Walls
- **Stilling Basin Walls**: 1 foot, 14 feet, 164 feet, 85 cy
- **Turbine Channel Walls**: 1 foot, 14 feet, 64 feet, 33 cy

**Cost Estimate.xls** Tunnel Outlet
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# SAIN CREEK TUNNEL

<table>
<thead>
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### Sain Creek Tunnel

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**Cost Estimate.xls**

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