Section 5
Delivery System Design Recommendations

5.1 Pipeline Recommendations

The various considerations for pipeline design and construction have been evaluated for the development of project system design recommendations.

5.1.1 Pipeline Design

5.1.1.1 Pipe Pressure Class and Future Expansion

The hydraulic analyses presented in Section 4 recommended that the treated water delivery system consist of pipelines up to 30-inch in diameter and two pumping stations. For the Base Project, which has a delivery capacity of 10 MGD, the maximum working pressure in the pipeline will be 150 psi. However, when the system is expanded to the Phased Project capacity of 15 MGD, the ultimate maximum working pressure in the pipeline will be about 200 psi.

The pipeline will be designed to accommodate the higher pressures that will result at the 15-MGD flow rate. The higher pressures will only occur at the lower elevations along the pipeline route, and the pressure class (rating) of pipe specified for installation will vary based on the pressure expected in each segment of the pipeline.

Pipe is normally supplied by "pressure class," which designates the maximum working pressure that the pipe can accommodate. Depending on the pipe material, the minimum pressure class commonly available is 100 to 150 psi, and increases in pressure class occur in 25 or 50 psi increments. Since pipe with a higher pressure rating is generally more expensive, the entire route will be evaluated during the final design efforts to divide the route into segments based on the maximum working pressure expected. The pipe material will then be specified differently for each of these segments to match the expected working pressures.

A secondary requirement that will govern the pressure class of pipe to be specified is the presence of transient pressures, or surges, that result from changes in pipeline flow. Often called "water hammer," these pressure transients are caused by changes in the flow velocity in the pipeline. At an ultimate flow rate of 15 MGD, the velocity in the 30-inch diameter pipeline will be about 4.6 feet per second. If this flow were suddenly stopped, the resulting maximum pressure transient that might be developed would be about 225 psi above the working pressure in the pipeline. This rise in pressure can be reduced by providing adequate air venting and vacuum relief, by controlling the rate of change of velocity in the pipeline, and by the installation of pressure relief devices. A surge analysis will be completed during the final design of the pipeline to define the measures required to minimize the surge pressure rise that will occur when the velocity of the flow changes.

Most of the commonly specified pipe materials include an allowance for surge pressure in excess of the pipe pressure class. This allowance is typically 50 percent of the working pressure or 100 psi, depending on the pipe material used. The surge analysis will define the measures needed to keep the surge pressures within the surge allowance for the selected pipe material. However, pipe with a higher pressure class may be needed in a few specific locations to accommodate expected surge pressures.

5.1.1.2 Pipe Material Specification

There are several alternative pipe materials that are available for use on this project. The common pipe materials include:

- Ductile Iron Pipe (DIP)
- Reinforced Concrete Cylinder Pipe (RCCP)
- Welded Steel Pipe (WSP)
- High Density Polyethylene Pipe (HDPE)
- Polyvinyl Chloride Pipe (PVC)

Ductile iron pipe has been in use in water systems since the 1950s, but its predecessor, cast iron pipe, has been used for centuries. DIP is available is diameters ranging from 4 to 64 inches and is used extensively for water distribution piping as well as cross-country transmission pipelines similar to the proposed project. DIP is widely available in 50-psi incremental pressure classes with working pressure ratings from 150 to 350 psi. The design of the pipe is governed by AWWA Standard C150 and includes provisions for internal pressure, surge pressure, earth loads, and live loads. Standard DIP is provided with cement mortar lining and a bituminous exterior coating. Pipe joints for buried pipe typically consists of push-on, bell and spigot joints with mechanical gland and follower joints used only at equipment locations. Both of these joints can be provided with restraining appurtenances to keep the joint from separating in situations where thrust may be developed, or the joints may be used with concrete thrust blocking.

Concrete steel cylinder pipe has been used in water systems since the 1940s, but its use has increased dramatically in recent years. RCCP has historically been used mainly for large diameter water transmission pipelines, sewer force mains, and large diameter water distribution piping. The RCCP product most suitable for this project is known as Bar Wrapped Steel-Cylinder Pipe as specified by AWWA Standard C303. This pipe is available in sizes ranging from 10 to 54 inches in diameter and working pressure ratings up to 400 psi.

The C303 pipe consists of a steel cylinder that is wrapped with a smooth, hot-rolled steel bar under moderate tension. The cylinder and bars are then covered with a cement slurry and a dense mortar coating on the exterior of the pipeline. Similar to DIP, a cement mortar lining is typically used on the inside of the pipe. RCCP is normally custom fabricated for each application and the thickness of the cylinder and reinforcing bars are selected based on the specified working pressure and surge pressure design criteria as well as any external load requirements. Pipe joints are similar to DIP and consist of both gasketed, push-on joints and mechanical joints. Thrust restraint is normally accomplished by field welding the steel cylinders together after the joints are assembled in the field, but thrust restraint can also be accomplished with concrete thrust blocks.

Fabricated welded steel pipe has been used for water pipelines since the 1850s and is used today extensively inside pumping stations and in situations where a custom, or fabricated, product is needed. WSP has been used extensively for high-pressure transmission and distribution pipelines and is used extensively in the natural gas and petroleum industries. AWWA Standard C200 governs the design of steel pipe. Since the wall thickness of steel pipe can be fabricated very exactly, steel pipe is normally fabricated using custom design criteria for each installation and is often used in very high-pressure applications. The pipe is typically provided with a cement mortar lining and an exterior coating of either cement mortar, a tape material, polyurethane, or other product. Steel pipe joints in the past have been welded, but joints can also be gasketed, bell and spigot joints. Joint restraint is typically accomplished by field welding similar to RCCP or by the use of concrete thrust blocks.

High-density polyethylene pipe has been used successfully for many years in the natural gas, petrochemical, and related industries. Following the downturn of the petrochemical industry in the early 1980s, HDPE manufacturers broadened their marketing to municipal systems. HDPE is produced from high molecular weight, high-density polyethylene and is manufactured to meet the requirements of AWWA Standard C906. The pipe is available in diameters ranging from 4 to 54 inches and working pressures up to 250 psi. Because of HDPE's low modulus of elasticity, very low surge pressures are developed when velocity in the pipeline changes, and surge is not typically a driving factor in the design of the pipe. However, the maximum working pressure available for HDPE pipe in the 30 to 36-inch diameter range is 160 psi, making the use of HDPE feasible only for small diameter delivery pipelines or at selected locations along the pipeline route where the pressures are within the available ratings.

The pressure rating of HDPE pipe is determined by the wall thickness of the pipe. In addition, HDPE pipe sizes are specified as outside diameters, and at higher pressures when the pipe wall thickness becomes quite thick, the hydraulic performance of the pipe can be impacted. As a result, larger pipe sizes are often needed at higher pressures so equivalent water conveyance is provided.

HDPE joints are typically accomplished by heat fusing pipe sections together using specialized joining equipment. Mechanical joint adapters are also available for connection to other types of pipe. Since all joints are fused together, all joints are restrained and any thrust concerns are typically addressed with the use of concrete thrust blocking. Temporary repairs to HDPE pipe can be made using mechanical devices, but long-term repairs will require replacement of an entire section of pipe utilizing specialized heat fusing equipment to join the pipe.

Polyvinyl chloride pipe, commonly known as PVC pipe, has been used in water distribution systems since the late 1960s. Since the AWWA standard for PVC was issued in 1968, it has become one of the more popular pipe materials used in water distribution systems, but its use for large diameter, long distance transmission pipelines has not been as widespread. PVC pipe is made in diameters ranging from 4 to 48 inches, with the design governed by AWWA Standards C900 and C905.

The pressure rating of PVC pipe varies with pipe diameter. For a 30-inch diameter pipe, the maximum pressure rating available is 235 psi. However, unlike the pipe materials previously discussed, this pressure rating for PVC pipe does not include an allowance for surge pressure. This means that the working pressure plus the surge pressure in a 30-inch PVC pipe should not exceed 235 psi. There are several areas along the proposed pipeline route where the working pressure (minus surge) will approach or slightly exceed 200 psi. Therefore, it appears that PVC may not be suitable for use along the entire pipeline route unless significant measures are taken to control the increase in pressure from surge to no more than about 20 to 30 psi.

However, this assumption should be confirmed during completion of the surge analysis of the final pipeline route. PVC does develop much lower surge pressures due to its lower modulus of elasticity, and it may be possible to use PVC in some locations. In addition, PVC pipe less than 24 inches in diameter has a pressure rating of 305 psi and could likely be used near the delivery points where the pressures are lower and the pipe diameter is smaller.

PVC pipe is joined using gasketed push-on joints similar to the other pipe products. Joint restraint is accomplished by utilizing either a mechanical harness around the push-on joint, or by use of a metallic, mechanical assembly at each joint. Concrete thrust blocks may also be used.

Each of the pipe materials described above can be used in specific applications within the proposed project. The selection of materials must be made based not only on the technical merits of each material, but also with consideration to the cost of the products and the need for competition during the bidding process. HDR's experience has shown that DIP and RCCP are comparable in cost at the larger diameters and both will perform well long-term. However, RCCP has not been competitive at diameters less than about 18 to 24 inches. Steel pipe will also be acceptable in this application, but WSP has typically been higher in cost than DIP and RCCP at the pressures commonly seen in water delivery systems. However, WSP is more economical for high-pressure applications and, given the extended length of pipe at pressures approaching 200 psi, WSP may be competitive on this project. HDPE has not been competitive at the pressures above about 150 psi, due principally to the excessive wall thickness required and the reduction in hydraulic capacity. PVC may be acceptable at some locations within this project, but its use should be verified during the final design surge analysis. PVC has also recently been relatively high in cost due to escalating petroleum prices, but the market may recover by the time this project is ready for bid.

Based on the preceding, HDR's recommendation for pipe materials on this project is as follows:

- For all piping 18 inches and greater: DIP and RCCP will be specified. WSP may also be included if desired by the GBRA.
- For all piping less than 18 inches: DIP and PVC will be specified. If the surge analysis indicates that PVC is not suitable for this application, then DIP and RCCP should be specified to ensure a competitive price.

5.1.1.3 Pipeline Construction

Prior to beginning installation of the pipeline, the construction contractor will stake the right of way easement and the temporary easement as needed for equipment access and storage of materials. Existing fencing materials will be removed at all crossing locations and brace posts will be installed along with temporary fencing where necessary. The permanent easement will then be completed cleared of existing vegetation, and the temporary easement will be cleared selectively as needed for the construction activities. Upon completion, the temporary fencing will be replaced with a metal gate and appropriate signage indicating the presence of an underground utility.

Wherever possible, the pipeline will be installed using open cut construction with a minimum depth of cover of 4 feet over the top of the pipeline. Typically, the pipe will be bedded in a granular material to create a support envelope under the pipe. Alternate bedding materials, such as concrete encasement or cement stabilized backfill, will also be used in special situations such as traffic areas or stream crossings. The excavation will then be backfilled with native or excavated materials that are placed to meet a specified compaction limit to minimize future settling.

Since most of the proposed pipeline will contain rocky materials, it is expected that the contractor will first excavate the pipeline ditch with a rock-trenching machine, commonly called a rock saw. Topsoil will first be removed from the area to be excavated and stored for use during the restoration. The trencher will then excavate for the pipeline, and this excavation is usually temporarily backfilled with the ditch spoil until a second pipe installation crew arrives. The pipe installation crew will then re-excavate the ditch, place the pipe embedment material, install the pipeline, and complete the final backfilling and compaction. In areas where the trenching machine is not needed, excavation will likely be accomplished with a track-mounted backhoe. In this case, the contractor will probably elect to use one crew to excavate and install the pipeline.

After the pipe is installed, the contractor will install all appurtenances, pressure test the pipeline, replace the topsoil, and complete final grading of the easement. The pipeline right-of-way will then be revegetated by seeding with appropriate grasses or by the use of sodding and erosion protection in areas prone to erosion. The only visible features that will remain after the installation is complete will be concrete vault covers and vent pipes for the air/vacuum valves, manhole covers at isolation valves, and signs and markers to indicate the presence of the pipeline. The contractor will warranty the work for one year and will remain responsible during that year for establishment of vegetation and any settling or functional problems associated with the pipe and equipment.

5.1.2 Pipeline Appurtenances

5.1.2.1 Easement Widths

Land acquisition for pipeline construction typically includes two types of easements. A permanent easement is required for the pipeline installation and to allow the owner future access and the right to conduct maintenance activities. The permanent easement also often prohibits the construction of permanent structures within the easement and serves to protect the line from other parallel underground utilities being installed within the easement. This easement will be totally cleared of existing vegetation, contain all physical structures to be installed, and should be negotiated with sufficient legal right for all access and maintenance actions. The permanent easement should be located on private land, outside public right of way, where possible, since the owners of public rights of way can require relocation of pipelines when needed to comply with their ultimate intended purpose for the right of way.

The second easement is a temporary easement to be used only during the construction period. The temporary easement expands the access width on the landowner's property to provide adequate room for the contractor to stage materials and maneuver equipment during the pipeline installation. Temporary easements often include the right to clear vegetation provided the area is revegetated with permanent grasses. However, in selected locations where it might be desirable to minimize the long-term impact on the area, clearing of the temporary easement can be limited.

Our recommendation is that a permanent easement (PE) of a minimum of 30 feet be provided to provide for future maintenance of the line and to protect the line from other parallel underground utilities. Additional permanent easements may be required for all above-ground structures such as air release / vacuum relief valves, blow-off valves, isolation valves, corrosion test stations, etc. The pipeline may be offset from the center of the permanent easement so that the centerline of the pipe is located ten feet from the edge of the easement. This arrangement will facilitate future access to the pipeline for maintenance purposes.

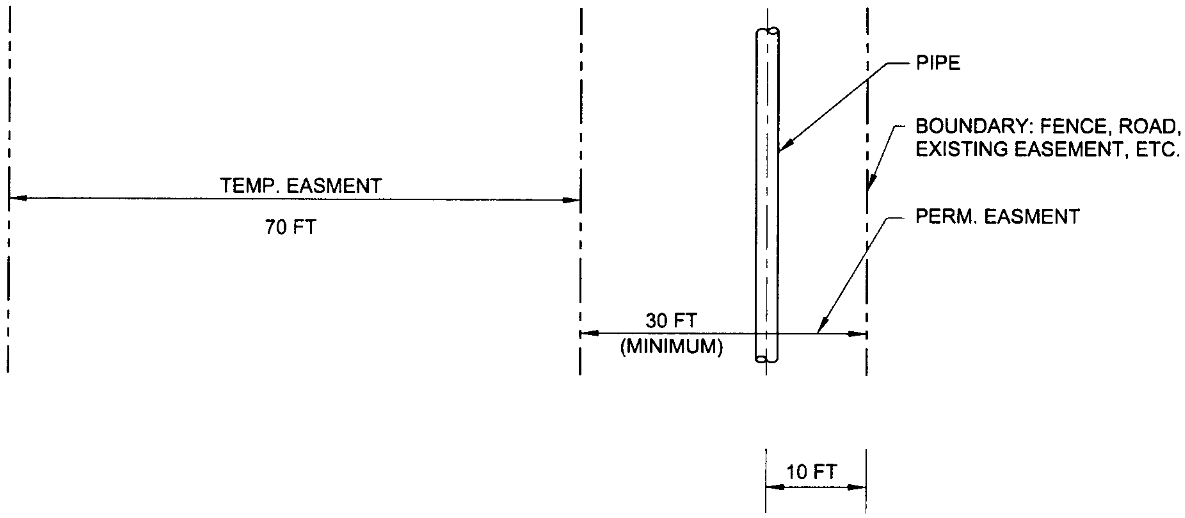
The temporary easement (TE) should be approximately 70 feet wide to provide the contractor a total width about 100 feet during construction. This area should be adequate for equipment access, storage, and staging of materials. In certain locations, additional temporary easements may be required for enlarged contractor storage areas, road crossings, etc.

As shown in Figures 5-1, 5-2, and 5-3 the temporary easement can be adjusted to meet several different conditions. When the pipeline is traversing open areas (cross-country) with no land boundary located adjacent, the TE should be split on either side of the permanent easement. In areas where the pipeline parallels an existing boundary, such as a fence line or road, the temporary easement may be located to one side of the permanent easement. However, it is important to maintain continuity in the configuration of the temporary easement to facilitate construction and lower construction costs, as the contractor does not have to continually change installation methods to accommodate differing easement arrangements.

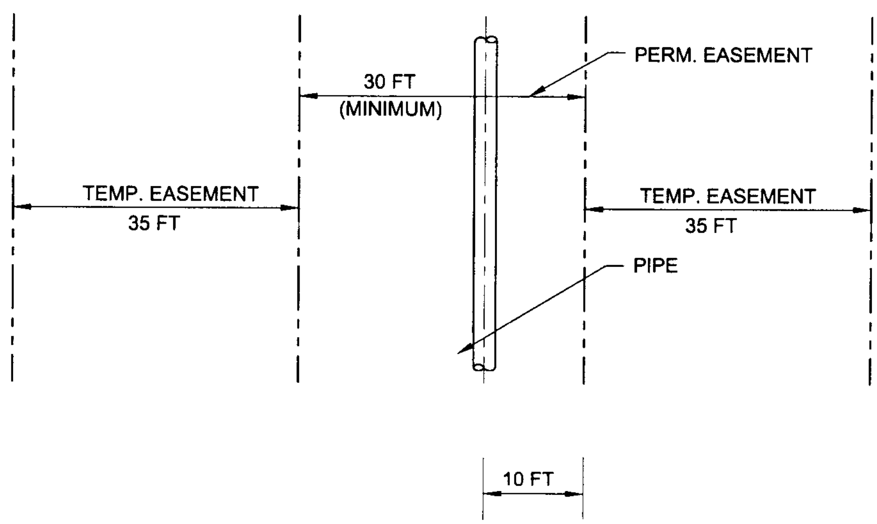
As also shown in the figures, it may be possible to reduce the temporary easement so that about 70 feet of total construction area is provided if an obstruction prevents easement acquisition or if the owner of an adjacent easement allows use of their easement during the construction. However, if temporary easement acquisition is absolutely not possible, the temporary easement may be eliminated in areas not exceeding about 750 to 1,000 feet in length before a significant temporary easement is provided for material staging. Most road and stream crossings can be accomplished within the 100 feet of total easement recommended. However, significant crossings that might require large bore pits or special construction methods that may require additional easement area. These areas should be examined in detail during the final design phase of the project and coordinated with the land acquisition activities.

5.1.2.2 *Roadway and Stream Crossings*

Where allowed, the pipeline will be installed using an open cut construction method. In locations where the pipeline crosses paved roads, significant commercial or residential driveways, or water bodies that cannot be disturbed due to regulatory issues, the construction method will be altered and the installation will be accomplished using a non-open cut method. In most of these instances, the pipeline will be installed by horizontally boring a hole under the structure from a bore pit. A steel casing pipe will then be jacked through the bored hole. This casing pipe will be designed to support the overburden soil pressure plus the appropriate live



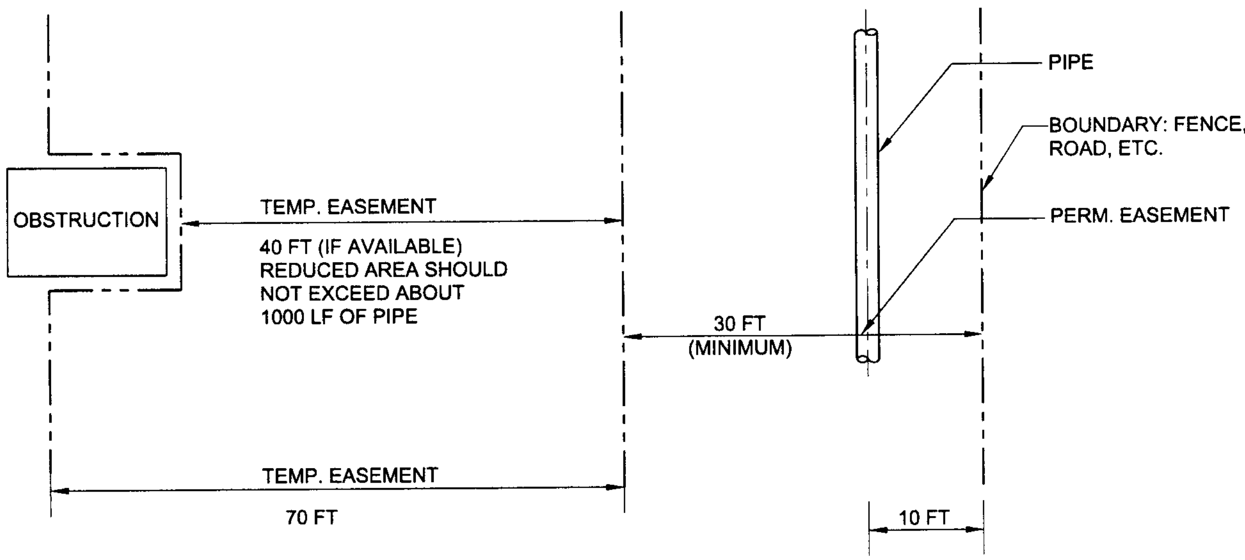
CASE 1: PIPE FOLLOWS EXISTING BOUNDARY



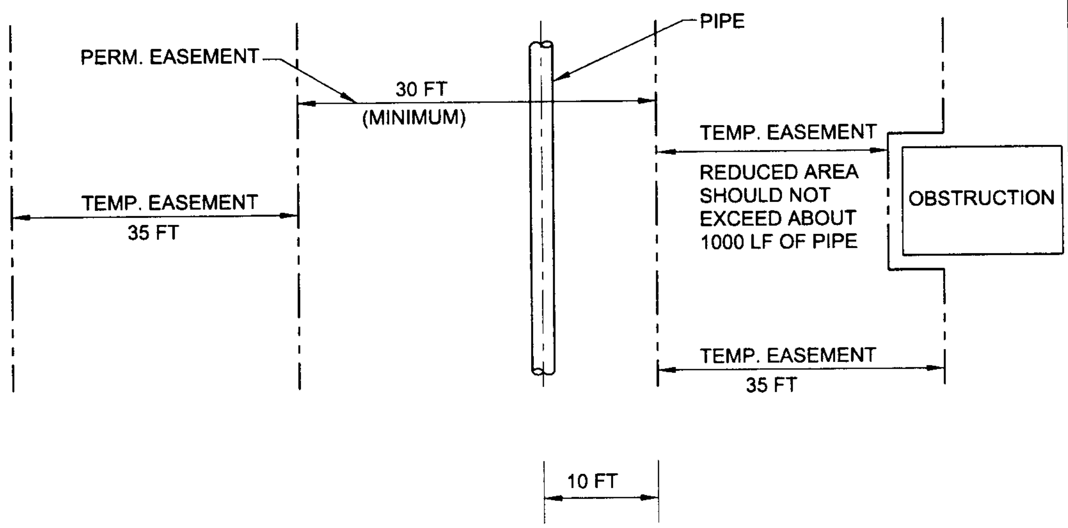
CASE 2: PIPE TRAVERSES CROSS COUNTRY

HDR

GBRA - REGIONAL WATER SUPPLY PROJECT	Date JUNE, 2000
EASEMENT ARRANGEMENTS WITHOUT OBSTRUCTIONS	Figure No 5-1



CASE 3: PIPE FOLLOWS BOUNDARY WITH OBSTRUCTION



CASE 4: PIPE TRAVERSES CROSS COUNTRY WITH OBSTRUCTION

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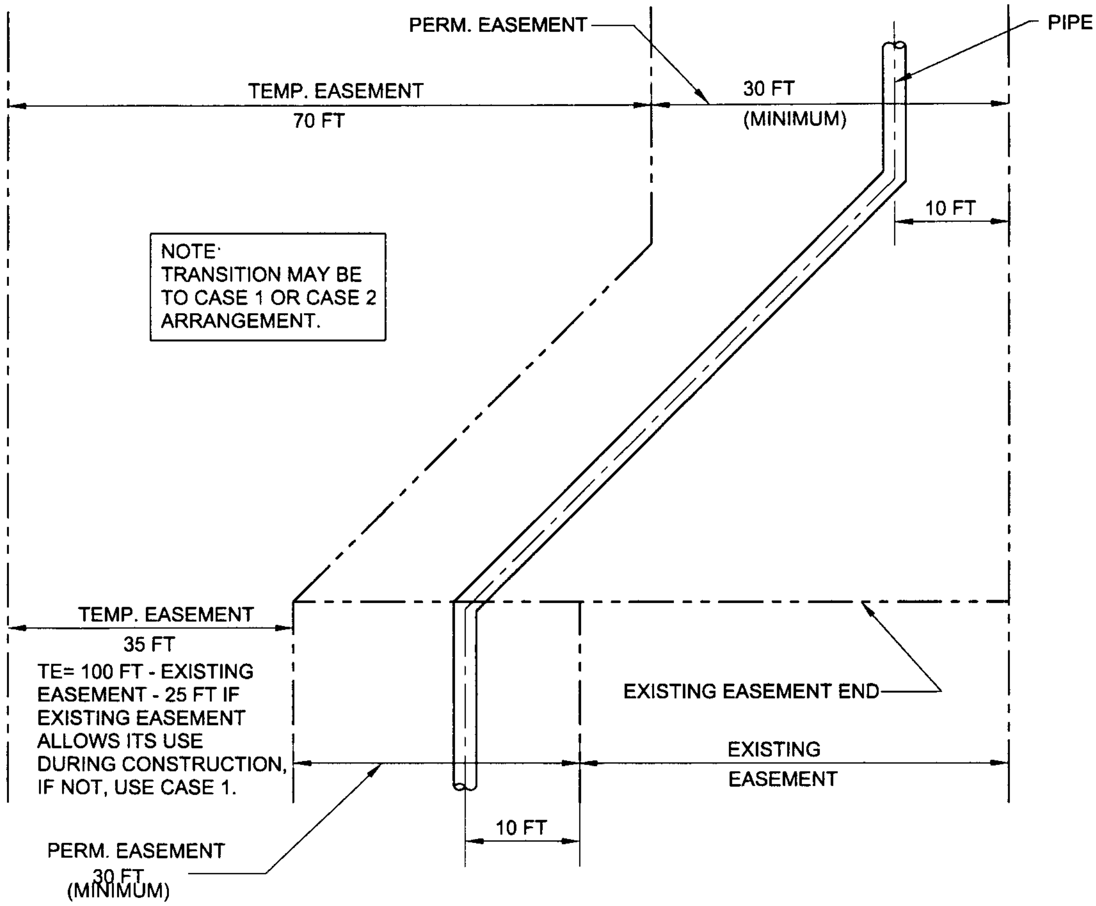
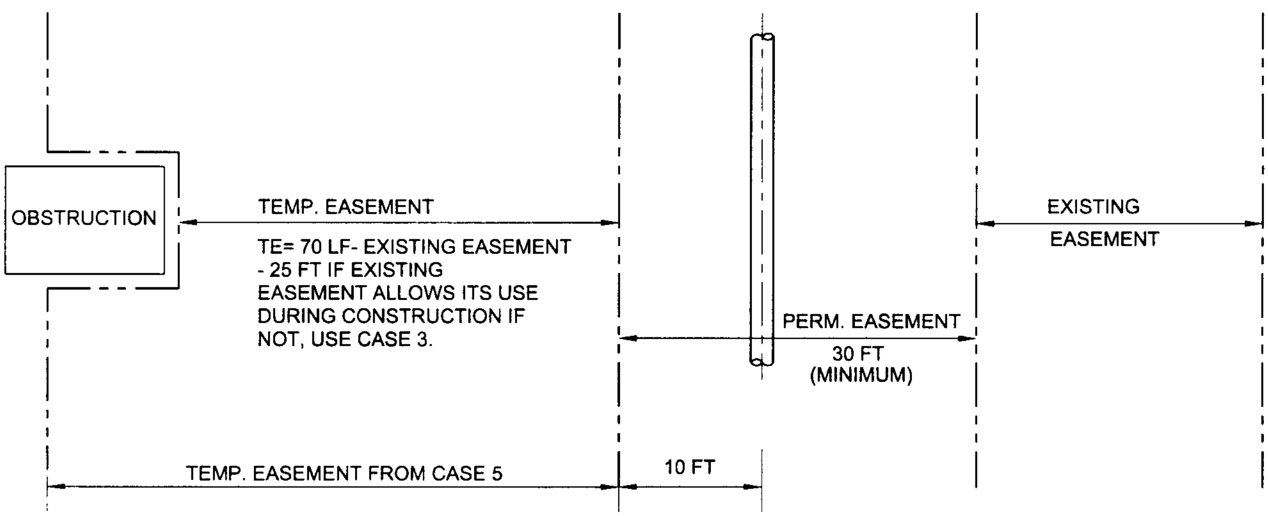
EASEMENTS ARRANGEMENTS WITH OBSTRUCTIONS

Date JUNE, 2000

Figure No 5-2



CASE 5: PIPE FOLLOWS EXISTING EASEMENT



CASE 6: PIPE FOLLOWS EXISTING EASEMENT WITH OBSTRUCTION

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EASEMENT ARRANGEMENTS ADJACENT TO EXISTING EASEMENT

Date
JUNE, 2000

Figure No
5-3

load that might be transmitted through the soil from traffic or wheel loads. The transmission pipeline will then be installed inside the casing pipe where it will be supported on special spacers and runners. The ends of the casing pipe will then be sealed with a casing boot.

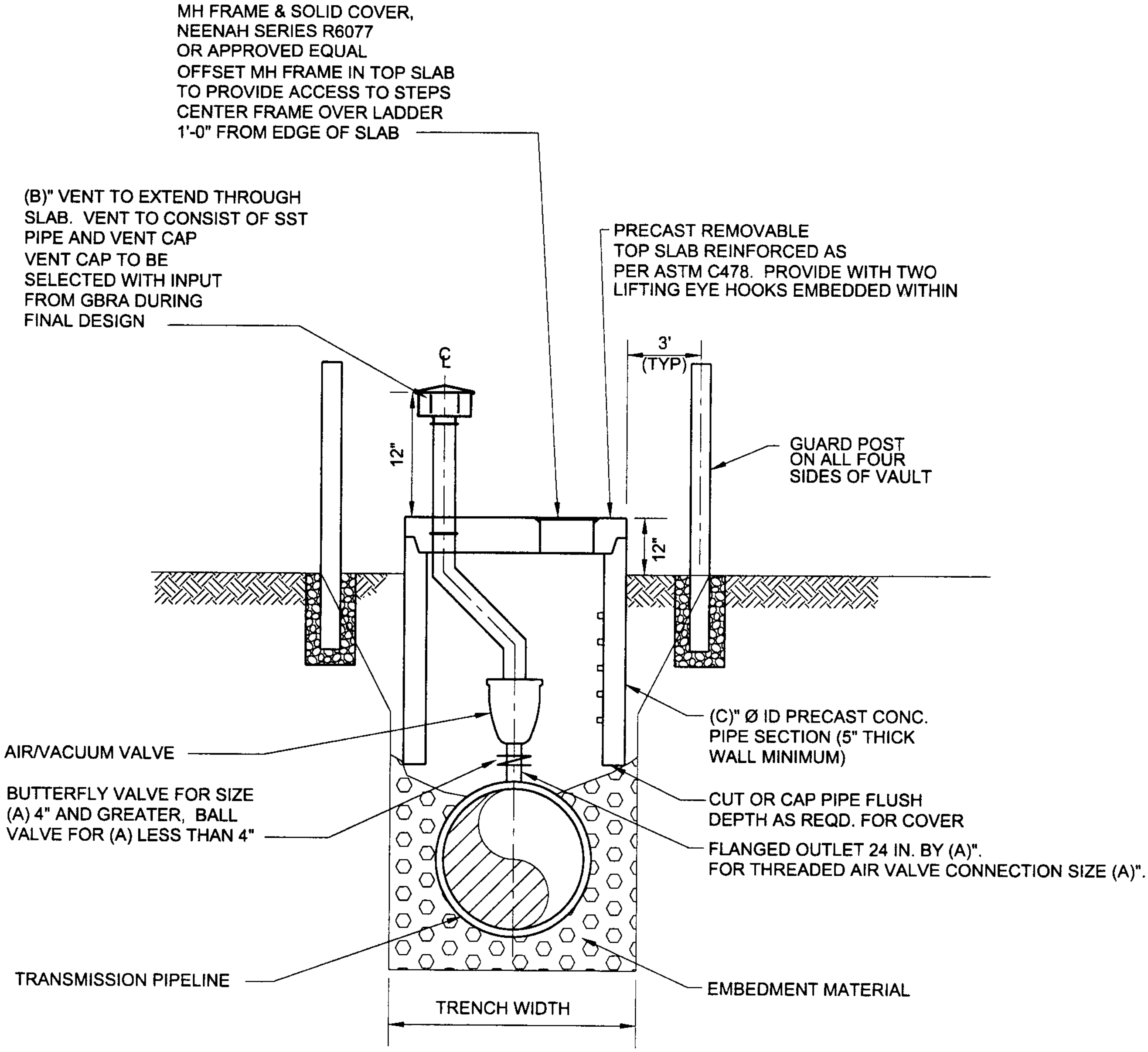
5.1.2.3 System Valves

The pipeline project will include three basic types of valves installed along the pipeline route. Air/vacuum valves will installed at high points along the line to vent air from the pipeline during filling and during operation of the system. These valves will also allow air into the pipeline during surge events and line breaks to prevent the separation of the water column, which can create damaging negative pressures. The sizing and location of the air/vacuum valves will be finalized during the surge analysis and final pipeline design

As shown in Figure 5-4, these valves are located directly on top of the pipeline so air can move freely in and out of the valve. In special situations, the valves can be offset from the top of the pipeline, but this installation is not ideal for air movement and often causes the pipeline to be deepened significantly to provide vertical clearance for the piping and fittings required to connect the valve to the pipeline crown. The air/vacuum valves will be installed in underground vaults. Since the pipeline will contain potable water, the valves must be vented to the atmosphere by a vent pipe connected directly to the valve with an air gap termination above ground. This arrangement is required to prevent the potential for a cross connection with contaminated ground or surface water when the valve is operating in a vacuum mode.

The visible aboveground features of the air/vacuum valve will consist of the vault top, a manhole, and the vent pipe. Where damage by contact is possible, the vault lids will be protected with guard posts on all four sides of the vault. The top of the vault will be a minimal distance above ground to provide positive drainage. However, some air/vacuum valves are quite large (tall) and if the distance between the vault top and natural ground is to be minimized, the pipeline may need to be installed with more that 4 feet of cover so that the valve will fit inside the vault.

Unlike air/vacuum valves, blowoff valves will be located at the low points in the pipeline. Blowoff valves are typically 4 or 6 inches in diameter and are installed to relieve pressure from the pipeline when the line needs to be dewatered for maintenance. Since their diameters are relatively small, these valves are not intended for pipeline flushing but are solely for pressure



VALVE SIZE	(A)-IN	(B)-IN	(C)-IN
2-INCH	2	3	60
4-INCH	4	6	66
6-INCH	6	8	72
8-INCH	8	10	72

AIR/VACUUM VALVE DETAIL

NOT TO SCALE

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AIR/VACUUM VALVE DETAIL

Date
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Figure No
5-4

relief. As shown in Figure 5-5, blowoff valves connect to the side of the pipeline and can be offset from the pipe centerline. The valve is typically installed similar to a fire hydrant having a riser pipe above grade to meet the cross connection requirements.

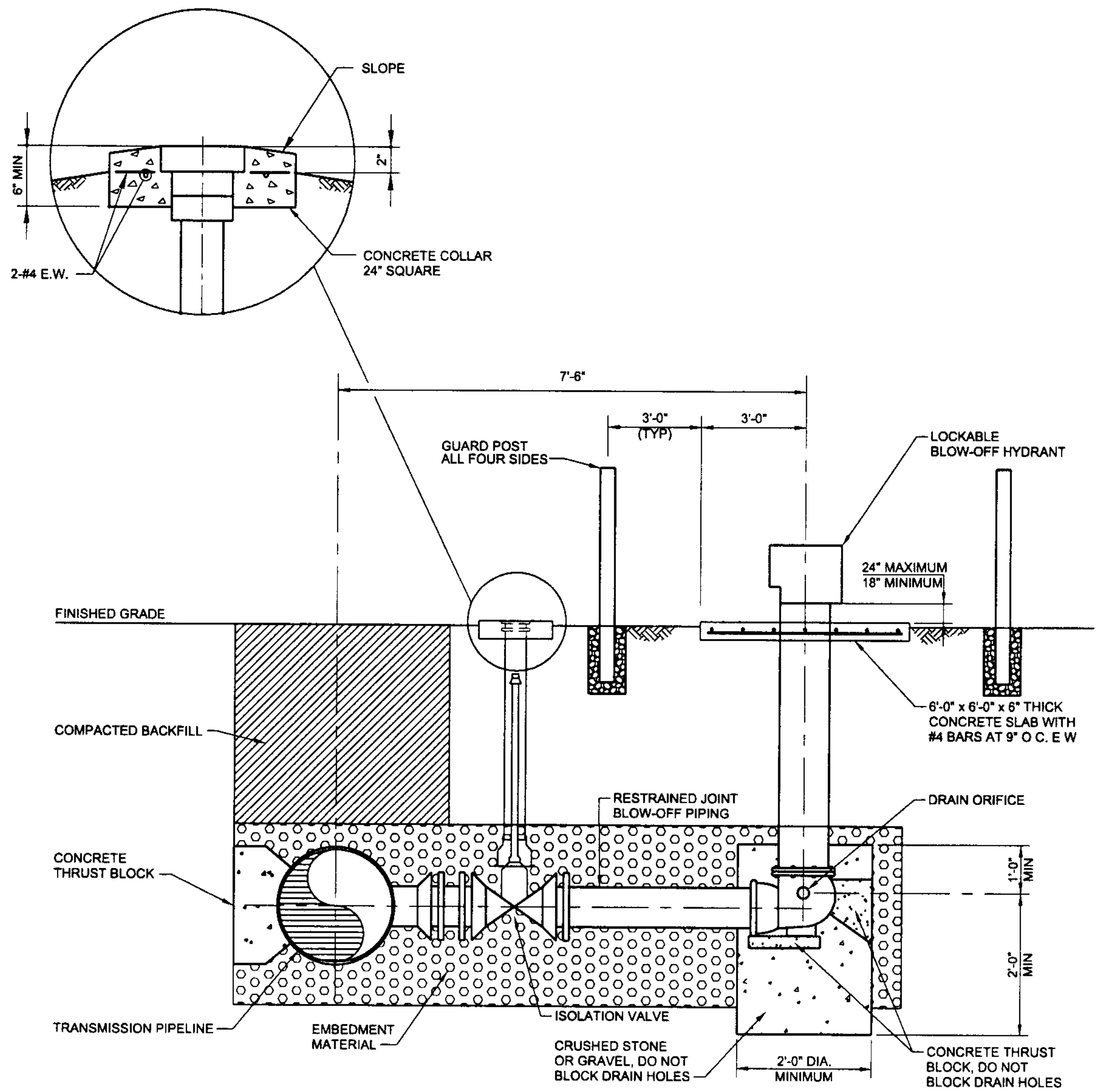
The third type of valve is a line valve used to isolate portions of the pipeline for maintenance. Line valves are typically located at strategic locations along the pipeline. These locations are selected to minimize the amount of water that might be lost during dewatering and to provide operational flexibility.

There are a number of types of valves that may be used in this application, but the most popular valves have been either gate valves or butterfly valves. Gate valves are extremely durable and provide full port flow when open. Butterfly valves are typically less expensive, but have exhibited long-term maintenance concerns in some applications. In addition, butterfly valves impinge on the pipeline cross-section and can prevent or inhibit future maintenance activities, such as television inspection, pigging, or rehabilitation. Our recommendation is that gate valves be provided. The location for these valves will be selected with the concurrence of GBRA during the final design phase after the topographic survey has been completed.

5.1.2.4 Thrust Restraint

Thrust is the force developed at pipeline fittings by the internal pressure (both working pressure and surge) in the pipeline and by the change in momentum of the water each time it changes directions. For unrestrained joints (push-on joints and mechanical joints), thrust forces can cause the joints to separate. Special measures are used to accommodate this force, including the use of concrete blocking that transmit the thrust forces from the pipeline to a larger area of native soil with suitable bearing strength. Thrust forces can also be resolved by the installing restrained pipe joints (either mechanical or welded) that hold the joint together for some distance each side of a fitting until the forces are transmitted to the soil through friction between the pipe and the surrounding soil.

Concrete thrust blocking can be more economical for moderate pressure systems and where soils with adequate bearing strength are present. For this project, the cost of thrust blocks will be somewhat higher due to the additional cost to excavate the rock materials in order to place the block, but the blocks will likely be smaller due to the expected high bearing strength of the native rocky soils. Concrete thrust blocks are effective at handling pipeline thrust forces, but



NOTE
1 PRESSURE CLASS OF BLOW OFF PIPE TO BE SAME AS ADJACENT WATER PIPELINE
2 RESTRAIN ALL PIPE JOINTS, MEGALUG OR APPROVED EQUAL.

BLOW-OFF VALVE DETAIL
NOT TO SCALE

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BLOW-OFF VALVE DETAIL

Date
JUNE, 2000

Figure No
5-5

blocks can move when soil conditions change or be damaged by nearby excavation. When concrete thrust blocking is used, installation of a future parallel pipeline will be much more difficult.

Thrust restraint will be accomplished using both concrete thrust blocks and restrained pipe joints. Engineering judgment will be used during the final design to select the appropriate restraint system to be along the pipeline. In situations where either method will be suitable, the contractor will be allowed to select the most economical method.

5.1.2.5 Pipeline Corrosion Protection

While PVC and HDPE pipe are inherently non-corrosive, metallic materials such as DIP, RCCP, and WSP are subject to corrosion and often require special protection to prevent long-term damage. External corrosion of metallic pipe materials is influenced by several factors. Many soils can aggressively promote corrosion due to their electrical and chemical characteristics. Highly mineralized soils often have low electrical resistively allowing electrical currents to be easily transmitted through the soil and onto the pipeline. These stray electrical currents are the driving factor for pipeline corrosion. Soils with high chloride or sulfate content can be particularly problematic, as can soils that experience frequent wet-dry cycles. In addition to the soil characteristics, other pipelines located adjacent to or that cross the installed pipeline may be cathodically protected and can transmit stray currents to the pipeline.

During the final design of the pipeline, a corrosion survey that includes soil sampling and field observations will be completed to identify visible foreign line crossings, observable catholic protection systems, and determine the characteristics of the soil. This work is typically completed in conjunction with the pipe material suppliers as part of their technical assistance in the selection of their pipe materials and coatings. Based on our experiences with construction of similar pipelines in Texas, it is likely that the pipeline will require protection in addition to the standard coatings that most suppliers provide.

Ductile iron pipe is typically provided with a standard bituminous coating on the outside of the pipe. Various alternative methods have been used with DIP to achieve added corrosion protection, but the most common is the installation of a polyethylene membrane, or bag around the outside of the pipe. The polyethylene material is nominally about 4 mils thick and serves to protect the pipe by forming an electrically disbonded barrier to the soil. This barrier substantially reduces contact with ground water and with the soil, and limits the transmission of stray currents to the pipe. This method has been researched extensively by the Ductile Iron Pipe Research Institute (DIPRA) and is has been used widely with DIP. WSP is normally protected by a similar disbonded barrier. However, mortar coatings, tape coatings and urethane coatings have been used more extensively than the polyethylene membrane.

RCCP in more resistant to corrosion because of the mortar coating on the steel cylinder is resistant to attack. As long as the mortar remains intact, the underlying steel cylinder is largely protected. However, in several installations in Texas, HDR has recommended the installation of the polyethylene membrane with RCCP when highly corrosive soils and frequent wet-dry cycles are present.

The installation of a disbonded membrane around mortar coated pipe, such as RCCP and WSP, has been sometimes criticized as unnecessary and as being an incomplete barrier that is subject to rips and tears during construction. While it is probable that the wrap will have imperfections and small tears will result during installation, the purpose of the membrane is to act as a barrier and limit, but not eliminate contact with groundwater and the soil environment. Even if the membrane is not complete or perfect, the renewable flow of groundwater across the mortar surface is expected to be reduced over a hundred-fold. The membrane essentially holds the water inside the membrane against the pipeline and prevents its rapid replacement with water containing additional ions that can continue to attack the steel or mortar surfaces. The small amount of water held in the annular space between the wrap the pipe will dissolve a small portion of the interstitial free lime as it penetrates the mortar. The pH of the water will rise to approximately 12, becoming a passivating agent for the underlying steel. In short, the function of the membrane is to substantially reduce the surface renewal rate of water contacting the pipeline mortar.

The water held within the membrane is also desirable because it prevents the mortar coating from drying and cracking during wet-dry cycles. Most structural failures associated with RCCP are related to the cracking of the concrete/mortar coating that ultimately leads to exposure and corrosion of the steel cylinder and reinforcing.

With care, it is possible to design a cathodic protection systems for any of the steel pipe pipe materials under consideration. However, the cost of cathodic protection can be substantially greater than the cost of installing the polyethylene wrap with no guarantee of increased protection. Moreover, some pipe materials such as RCCP can have material characteristics that increase the cost of cathodic protection systems to prevent damage to the pipe materials.

Our recommendation is that all metallic pipe joints be electrically bonded and corrosion test stations be installed about every 1,500 to 2,000 feet along the pipeline. This arrangement allows the owner to periodically measure the electrical potential between the pipe and the adjacent soil and identify areas of active corrosion. If a problem is detected, more aggressive corrosion protection systems, such as a localized cathodic protection system, can then be installed.

In locations where the pipeline crosses other existing pipelines, the presence of existing cathodic protection systems such as buried anode beds or impressed currents, will be of concern for metallic materials. If the proposed transmission pipeline crosses or is adjacent to a foreign pipeline with either buried anode beds or an impressed current system, there is the increased risk of corrosion due to stray currents generated by the foreign line. In this situation, the pipeline will be encased in a double layer of polyethylene encasement for 1,000 feet either side of the foreign line and dielectric couplings will be installed at the termination of the double layer encasement. This arrangement will protect the pipeline from the foreign line and isolate the section of pipe most vulnerable to corrosion. In addition, special corrosion test stations will be installed within the double encased section and at the foreign lined crossing to monitor in the potential between the pipeline, soil, and the foreign line. Should monitoring in the future indicate that the impressed current system is causing corrosion of the transmission pipeline, additional corrosion protection can be installed at that time.

5.2 Pump Station Recommendations

As discussed previously in Section 4, System Hydraulics, two main treated water pump stations are recommended in addition to a 30 hp booster pump station for delivery to the Bergheim (Cordillera Ranch) area. One main pump station is to be located at the WTP site and the other is to be a remote pump station located along the route west to Boerne, near the Fair Oaks Ranch delivery point. Vertical turbine pumps are recommended at the pump stations, requiring three pumps initially for the 10 MGD base project for the major treated water pump stations and two pumps initially for the 30 hp station for pumping of flow to the Bergheim (Cordillera Ranch) area. Flows to the Bergheim area were evaluated as 0.9 MGD for the initial base project and 1.5 MGD for the phased project expansion capacity. Addition of a pump at each pump station, together with other modifications, will accomplish future expansion to full system capacity.

5.2.1 Pump Station Features

The WTP and remote pump stations will be similar in design and capacity, but there are a few differences. The pump station at the WTP will house the three 200-hp treated water pumps with space for a fourth pump as described previously, but it will also house the plant's backwash pumps. Pursuant to TNRCC regulations, separate backwash pumps are required. Two pumps with VFDs should be provided with one normally operating when called for and the second serving as a standby unit. The remote pump station will include provisions for chlorine feed as well as house the three 250-hp treated water pumps with VFDs with space for a fourth pump. The Bergheim area booster pump station will be a simple in-line pump station, housing only the two 30-hp treated water pumps with space for a third.

5.2.1.1 Pump Arrangement

The proposed layouts for the WTP and remote treated water pump stations are provided in Figures 5-6 and 5-7, respectively. The vertical turbine pumps are configured in suction barrels or cans, with the buried suction inlet entering beneath the building floor slab. An isolation valve is provided just outside the building along the suction line of each pump. The discharge of each pump is configured with a air/vacuum release valve, pump check/control valve, and isolation valve. Each discharge line leads to a common header housed within a concrete trench in the pump station building. Piping within the pump station would be constructed of flanged ductile iron or welded steel pipe, both of which would be fully restrained. Additional surge control valves, if required, would be placed in vaults outside the building with a blowback line to the clearwell.

The small booster pump station proposed for service to the Bergheim area would require 30 hp pumps, configured in-line to boost system pressures within the 12-inch diameter piping from the 30-inch diameter mainline.

5.2.1.2 Pump Station Facilities

Additional pump station facilities recommended for adequate access and operation include provision of an equipment access door, bridge crane, and electrical/control room. A large roll-up door is provided for removal of pumping equipment and piping appurtenances during maintenance and repair, as necessary. A bridge crane may provided to facilitate removal of the equipment, or, alternatively, roof hatches may be provided for removal of the pumps with a crane. An electrical/control room is provided to house the motor control center and control equipment. A chlorine storage and feed room for disinfection residual adjustment is recommended for the remote pump station. Construction features of the building would be as described in the Basis of Design Report for Contract A.

5.2.2 Future Expansion

The capacity of the system may be expanded to provide up to 15 MGD from the WTP without violating the 200 psi maximum piping pressure class constraint within the majority of the system. A limited portion of the system would be just over 200 psi (210 psi) in a low point segment of the system. The pipelines and appurtenances should be constructed for the future expansion condition, accordingly. With this total cost-savings approach, only the pumping equipment would require modification when the additional capacity is needed in the future.

Expansion of the system would entail addition of new pumps as well as modification of the existing WTP pumps. Two additional stages would have to be added to each of the three existing pumps at the WTP and addition of a new (fourth) pump would be required. All of these WTP pumps would require 400-hp motors. Expansion of the remote pump would simply require addition of a fourth 250-hp pump and motor. For the Bergheim area booster pump station, an additional 30-hp pump and motor would be required for future expansion of the system.

5.3 Storage Facilities

As described previously in Section 4, recommended storage facilities for the system include raw water, treated water, and remote treated water storage. The raw water reservoir located on Startz Hill will serve as a head tank, providing water to the treatment plant under a relatively constant flowrate and pressure thereby eliminating head and flow fluctuations at the plant's inlet and protecting the WTP from hydraulic transients. Storage within the treated water delivery system should be provided both at the WTP and remote pumping station. The storage facilities serve both for storage and also control for the pumps within the system.

Various materials and types of construction are available for construction of tanks in the anticipated size range. These include wire-wrapped, post-tensioned concrete (similar to tanks constructed by Natgun or Preload), welded steel, galvanized bolted steel, and glass-fused bolted steel (Aquastore tanks as manufactured by A.O. Smith). Of these options, concrete and glass-fused steel require the least maintenance over the life of the tanks, while welded steel and bolted galvanized steel are the most economical. Post-tensioned concrete is most expensive. Based on recent bid experience with similar sized tanks, glass-fused steel is slightly more expensive than welded steel, but its life-cycle cost is significantly less since the tanks do not require regular repainting. Welded steel tanks must usually be painted every 8-15 years. Balancing economy and reduced maintenance, glass-fused steel is the recommended choice of tank material; although, alternate bids should be taken for welded steel to avoid a sole-source bid situation for the glass-fused steel tank.

5.4 Disinfection

The two disinfectants that are commonly used to achieve secondary disinfection are free chlorine and chloramines. Free chlorine historically has been the principal disinfectant used in the United States; yet, utilities have been moving away from its use due to its propensity to react with organic matter in the water to form disinfection by products (DBPs), specifically total trihalomethanes (TTHMs) and haloacetic acids (HAAs), at elevated levels. Thus, the residual is less stable when organic matter is present due to the chlorine demand and depletion of residual. In contrast, chloramines provide a very stable residual and form TTHMs at a much slower rate than free chlorine. Even though free chlorine is the preferred secondary disinfectant based on the requirements of the principal customers, the following discussion includes consideration of chloramines for reference purposes.

Disinfection must be maintained throughout the transmission pipeline. Because many of the customers will ultimately further distribute the delivered potable water, the transmission pipeline does not behave precisely like a distribution system. Yet, there are some customers that will directly use the transmitted water. Therefore, per Texas Natural Resource Conservation Commission (TNRCC) regulations, a free chlorine residual of 0.2 mg/L or a chloramine residual of 0.5 mg/L should be maintained at all reaches of the treated water delivery system. In addition to maintaining a residual in the transmission pipeline for disinfection purposes, maintaining a residual in the transmission pipeline will aid with maintenance of the line due to biological growth.

The first step in determining disinfection requirements in the transmission system was to identify the approximate residence time of the transmitted water for each customer. Three conditions for each customer were analyzed:

- Initial (10 MGD): the initial customer requested demand
- Ultimate (10 MGD): anticipated customer demand when customers fully expand their systems
- Future (15.0 MGD): the anticipated regional demand

The range of residence times from the treatment plant to the customer delivery points is as shown in Table 5-1. Therefore, a customer like San Antonio Water System (SAWS) will receive water that has been in the transmission system for 12 hours or as long as 15 hours between the phased and initial conditions, respectively. The controlling case regarding residence time is the ultimate condition where a residual must be maintained for a longer period of time in the transmission system.

5.4.1 Disinfectant Residual Decay

In order to determine the disinfection requirements for the transmission pipeline, a comparison between free chlorine and chloramines was performed to determine the ability of the disinfectants to maintain a residual in the transmission pipeline. The USEPA WTP Model Version 2.0 was used to determine disinfectant residuals in the transmission pipeline. In order to model and to obtain finished water results (e.g., disinfectant residual) throughout the transmission pipeline, raw water quality parameters in conjunction with an expected treatment scenario are required input into the model. Table 5-2 provides the historical Canyon Lake water quality parameters that were utilized in the program.

The following plant flow rates were used:

- Average – 10.0 MGD
- Peak Hourly – 15.0 MGD

Table 5-1.
Approximate Residence Time at Customer Delivery

Customer	Initial (Days)	Ultimate (Days)	Phased (Days)
Plant to Junction			
Others	0.0	0.0	0.0
Apex	0.2	0.2	0.1
Craig Elbel, Double J. Ranch, Clyde Johnson, Lost Owl	0.2	0.2	0.1
Comal I.S.D.	0.3	0.3	0.2
Junction to Boerne			
Murcia	0.4	0.4	0.3
Cordillera	0.5	0.5	0.3
Fair Oaks	0.5	0.5	0.4
Boerne	0.6	0.6	0.5
Tapatio/Kendall Co. Utility Co.	0.6	0.6	0.5
SAWS	0.6	0.6	0.5
Junction to Bexar MWD			
Bulverde Hills	0.3	0.3	0.2
SARA	0.4	0.4	0.3
Bexar MWD	0.4	0.4	0.3

[1] Customer delivery points were determined using HDR's existing convention for modeling of the hydraulics of the transmission line.

Table 5-2.
Canyon Lake Raw Water Quality Parameters

Parameters	Units	Value
pH		8.2
TOC	Mg/L as C	3.0
Alkalinity	mg/L as CaCO3	175
UV254	cm-1	0.040
Ca Hardness	mg/L as CaCO3	100
Mg Hardness	mg/L as CaCO3	100
Bromide	mg/L	1.2
Ammonia	Mg/L as N	0.1
Temperature	(C	20.0

Because an accepted recommendation for a treatment technology selection had not been made from the Contract A study at the time of evaluation, for modeling purposes, the following treatment processes were used in the model:

- Rapid Mix – with a coagulant dose of 30 mg/L as Alum (Al2(SO4)3 – 14 H20)
- Flocculation
- Sedimentation
- Filtration
- Contact Tank (Clearwell)

Four different scenarios were modeled to encompass a range of what the residual in the transmission pipeline may be or required to be:

- Scenario 1: Free Chlorine Residual of 0.5 mg/L at the furthest customer (used as a preliminary objective to identify rate of chlorine residual decay)
- Scenario 2: Free Chlorine Residual of 0.2 mg/L at the furthest customer (TNRCC value for distribution systems for free chlorine)
- Scenario 3: Chloramine Residual of 1.5 mg/L leaving the plant (used as a preliminary objective to identify rate of chloramine residual decay)
- Scenario 4: Chloramine Residual of 0.5 mg/L at the furthest customer (TNRCC value for distribution systems using chloramines)

In all cases, free chlorine was utilized as the primary disinfectant. Table 5-3 outlines the disinfection dosages utilized in the four scenarios.

Table 5-3.
Primary and Secondary Disinfectant Dosages

Scenario	Primary Disinfection Dose (mg/L)	Secondary Disinfectant	Secondary Disinfectant Dose (mg/L)
1	1.0	Free Chlorine	0.5
2	1.0	Free Chlorine	0.0
3	1.0	Chloramines	0.8 Cl2/0.4 NH4
4	1.0	Chloramines	0.5 Cl2/0.8 NH4

As stated earlier, three conditions for each customer were analyzed:

- Initial (10 MGD)
- Ultimate (10 MGD)
- Future (15.0 MGD)

In order to capture the expected residence times for each customer, all scenarios were analyzed for the following residence times (in days):

- 0.0 (WTP finished water)j
- 0.1
- 0.2
- 0.3
- 0.4
- 0.5
- 0.6
- 0.7
- 0.8
- 0.9
- 1.0
- 3.0
- 5.0
-

The furthest customer delivery point will receive treated water with a residence time of approximately 14.5 hours (or 0.6 days). Other residence times of 3.0 and 5.0 days were analyzed based on estimates from customers to which the water would reach their customers' taps.

The results for each scenario are as follow:

- Scenario 1: The goal of this scenario was to achieve 0.5 mg/L free chlorine residual at the furthest customer. This goal was achieved with only a 0.5 mg/L secondary dose leaving the plant. Therefore, a disinfection booster station would not be required for this scenario.
- Scenario 2: The goal of this scenario was to achieve 0.2 mg/L free chlorine residual at the furthest customer. This goal was achieved without the addition of free chlorine as a secondary disinfectant, i.e., the primary disinfectant dose was adequate to achieve a residual in the transmission system. Therefore, a disinfection booster station would not be required for this scenario.
- Scenario 3: The goal of this scenario was to achieve a 1.5 mg/L combined chlorine residual leaving the plant. A secondary chlorine dose of 0.8 mg/L and ammonia dose of 0.4 mg/L were applied to meet the goal. After five days, a 1.2 mg/L combined residual would be expected in the transmission water. Therefore, a disinfection booster station would not be required for this scenario.
- Scenario 4: The goal of this scenario was to achieve a 0.5 mg/L combined chlorine residual at the furthest customer. Various scenarios were run to achieve this goal; the results which best achieve the goal are where a 0.9 mg/L chloramine residual was achieved at the furthest customer. In fact, a residual of 0.9 mg/L is projected to remain even after five days residence time. Therefore, a disinfection booster station is not required for this scenario.

As shown in the above four scenarios, the doses required to meet the outlined disinfectant residuals were realistic doses of either free chlorine or free chlorine with ammonia to form chloramines. Thus, it is evident that practical secondary disinfectant doses can be added at the water treatment effluent to achieve the desired disinfectant residual at the furthest customer in the transmission system. A disinfection booster station is not required for the transmission pipeline.

5.4.2 Disinfectant Residual Adjustment and Monitoring

Although a disinfection booster station is not shown to be required along the transmission line, residual monitoring should be performed at various points and residual adjustment facilities should be provided at the remote pump station. Measurement of residual at the remote pump station, SAWS, and Bexar Metropolitan Water District would provide an indication that adequate disinfection residual is being maintained throughout the transmission system. Because the transmission line extends over forty miles away from the water treatment plant, manual residual monitoring would be difficult. Therefore, it is recommended that automatic residual monitoring be performed and reported through the SCADA system.

Residual adjustment facilities should be provided at the remote pump station in the unlikely event that the residual decay is greater than expected or unforeseen events lead to a reduction in the chlorine residual. The facilities should provide flow-paced chlorination based on the residual in the reservoir versus a set-point residual required in the pump station's discharge. The facilities should include cylinder storage and handling, vacuum feed with automatic switchover, on-line cylinder weighing, and dual chlorinators. The pump station discharge would be used as feed water for the chlorine ejectors with solution discharge back to the suction header of the pumps.

5.4.3 Point-of-Delivery Adjustment

As outlined in the TNRCC regulations, a free chlorine residual of 0.2 mg/L or a chloramine residual of 0.5 mg/L must be achieved at the furthest reaches in a distribution system. Therefore, a residual at or above these levels, depending on where the customer is located along the transmission pipeline, will be conveyed to each customer at their delivery point. A typical delivery point will consist of a ground storage tank where the water will be stored for various lengths of time, depending on each customer and their customer's demands. Thus, customers may need to reapply disinfectant before distribution in order to achieve the regulated disinfectant residual in their own distribution systems. The need for customer disinfectant adjustment is entirely dependent on the configuration and usage patterns of each customer's distribution system.

5.4.4 Design Recommendation

To summarize the findings of the study to determine if satellite disinfection is required:

- Through the use of the USEPA WTP Model, it was determined that with the use of either free chlorine or chloramines, a practical dose can be used to achieve a variety of disinfectant residuals at the furthest customer point in the system. Remote disinfection booster stations are therefore not required along the transmission line.
- Although a booster disinfection system is not shown to be required along the transmission line, residual monitoring should be performed at the remote pump station an the SAWS and Bexar Metropolitan Water District delivery points, and residual adjustment facilities should be provided at the remote pump station.
- Customers may need to adjust the disinfectant residual before redistribution of the transmitted water based on the final use and delivery points for their customers.

5.5 Controls, Instrumentation, and SCADA

5.5.1 Delivery System Control Strategy

The primary control function of the delivery system is twofold:

- To operate the pumps at the two pump stations to regulate the flow of excess water (water not used by in-district customers) to SAWS and BMWD.
- To maintain the level in the storage reservoir at the remote pump station. Doing so properly will ensure adequate flow and pressure to the In-District customers.

The secondary functions are to monitor deliveries to the In-District customers and restrict the delivery flowrates to those set forth in the customer's service contracts as well as provide monitoring data to the Supervisory Control and Data Acquisition (SCADA) system regarding pressures and disinfectant residuals.

The operation of the primary control function can be briefly described as follows:

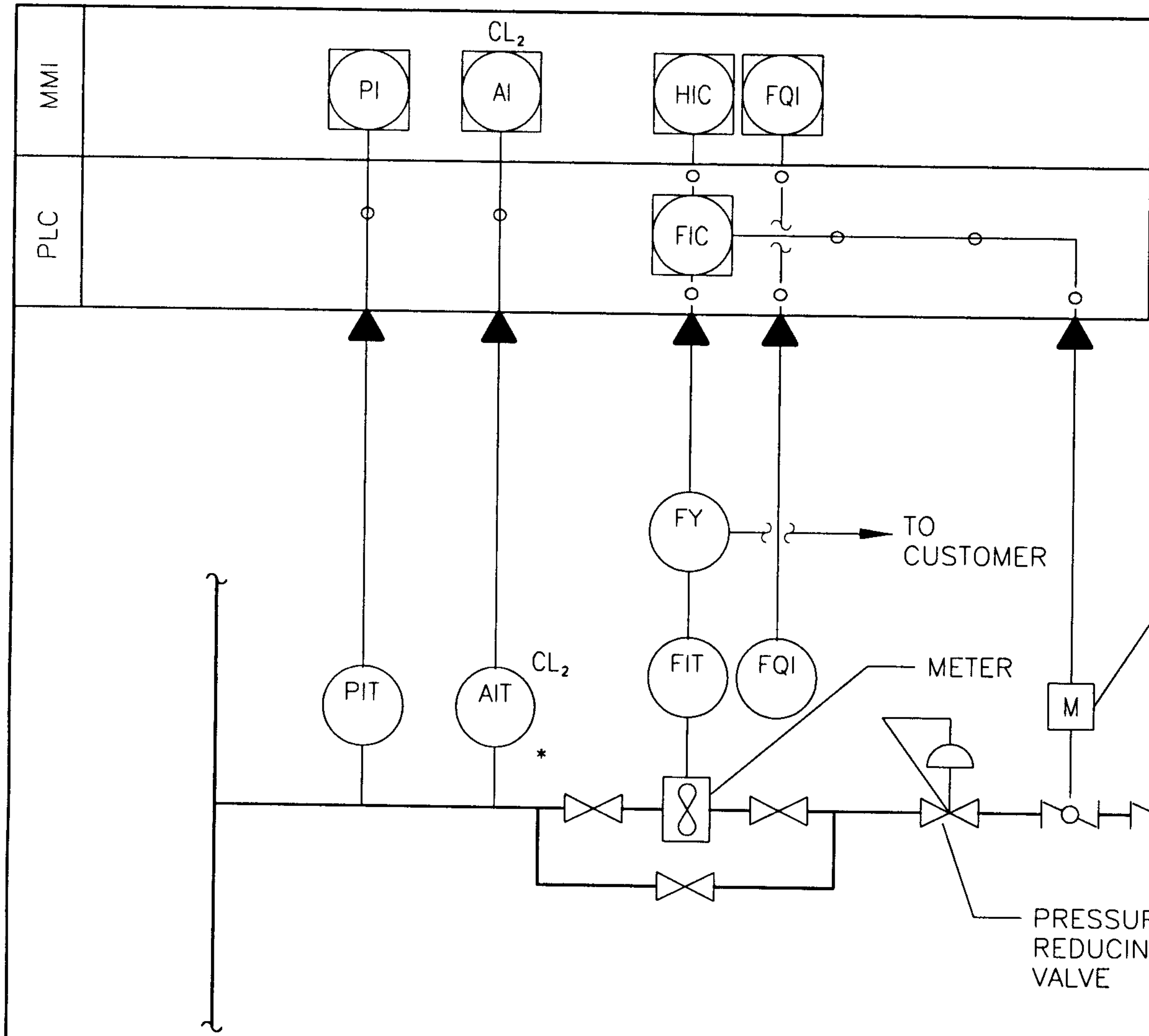
Flow to BMWD will be measured and controlled by a modulating valve. The SAWS delivery will be through a pressure relief valve that will create a constant hydraulic grade line at the delivery point. A pressure relief valve is necessary since the SAWS deliver point is not at the high point in the delivery system, and a minimum system pressure of 10 PSI must be maintained at all points in the transmission pipeline.. The hydraulic effect on the delivery system is essentially the same as an overflow into a standpipe or reservoir. The flowrate to SAWS will be adjusted by altering the pumping rate at the remote pump station with variable speed drives and pump staging.

Under steady-state conditions, water will be delivered to the In-District (ID) customers, SAWS, and BMWD at flowrates appropriate for the conditions. Over time, the ID flowrates will change depending on the customers' needs from hour to hour. If the flows to the customers upstream of the remote pump station change, it will affect the flowrate to BMWD and the fill/draw rate at the storage reservoir at the remote pump station. SCADA will calculate the net change and adjust the BMWD valve position and pumping rate to SAWS and adjust both to reestablish a uniform flow split and reservoir equilibrium. If ID flows decrease and BMWD is already receiving flow at the maximum rate they stipulated, the pumping rate to SAWS would be increased.

If the flows to the ID customers downstream of the remote pump station change, it will affect the flowrate to SAWS but have no effect on the storage reservoir at the remote pump station. SCADA will calculate the change in SAWS flowrate and adjust the remote pumping rate and BMWD valve position to maintain equilibrium.

Control provisions will be made for the worst-case scenario of the customers being unable to receive their projected water deliveries, either because of a delivery system problem or failure within the customer(s) system(s). In that event, it is possible that deliveries to SAWS and/or BMWD may not be able to equal the production of the WTP's pump station, which would cause the storage reservoir at the remote pump station to fill. In this case, SCADA would begin to taper the pumping rate from the plant to prevent the reservoir from overflowing, and plant production would be curtailed. Provisions will also be made to proportionately reduce each customer's maximum delivery rate in the event plant production is curtailed.

The logic required for control of the ID customer's connections would be much simpler. A typical customer metering and flow control process and instrumentation diagram (P&ID) is shown in Figure 5-8. Each customer would have some sort of control valve that they operate to regulate when flow to their system occurs. This may be a motor operated valve, a hydraulic-actuated globe valve, or other type of valve. Its primary function would be to open and close on demand by the customer's system. Flow would be metered by the SCADA system, and a second, GBRA-owned modulating valve at the delivery point would throttle the flow to the contractually established rate. When flow ceases because the customer's valve closes, the throttling valve would remain fixed until flow resumed. The customer's valve could be located adjacent to or remote from the delivery point meter and valve vault.



LEGEND

AI – ANALYSIS INDICATOR (CHLORINE RESIDUAL)
AIT – ANALYSIS INDICATOR TRANSMITTER
FIC – FLOW INDICATING CONTROLLER
FIT – FLOW INDICATING TRANSMITTER
FQI – FLOW TOTALIZING INDICATOR
FY – FLOW RELAY

* SAWS & BEXAR

MALCOLM PIRNIE

MALCOLM PIRNIE, INC

HDR

HDR Engineering, Inc.

GBRA - REGIONAL WATER SUPPLY PROJECT

TYPICAL CUSTOMER CONNECTION P&ID

Date: JUNE, 2000

Figure No: 5-8

The control strategy outlined above requires uninterrupted communication between the high service pump station, remote pump station, BMWD delivery point, and SAWS delivery point. A loss of communication will prevent the exchange of data required for proper operation of the overall system control logic. During short-duration communication failures of less than five to ten minutes, the isolated PLCs should continue to function based on the last data received. If communications remain down for a longer time, the isolated PLCs will need to begin a shut-down to prevent overflowing or draining the system.

5.5.2 Instrumentation

Instrumentation should be provided throughout the delivery system for monitoring and control. Providing the instrumentation will add significant programming flexibility to the system for future modification of the system control logic if conditions warrant changes. It will also provide warning of failures, such as major breaks, and valuable information regarding system performance for analysis.

Instruments that should be provided at each delivery point include a pressure transmitter and flowmeter. The pressure transmitters should be located upstream from the flowmeters and modulating valves. In addition, a discharge pressure transmitter and flowmeter should be provided at each pump station, and a level transmitter should be provided at the storage reservoir at the remote pump station. Last, a chlorine residual analyzer should be provided at the SAWS and BMWD delivery points as described previously.

5.5.3 SCADA System

The overall control of the proposed potable water treatment and transmission system as presently envisioned will be implemented via a SCADA system. In view of the complex system hydraulics and specific customer requirements, the SCADA system must be flexible, reliable, user friendly and effective over a large geographical area. The component architecture of such a SCADA system would be as shown on Figure 5-9.

5.5.3.1 System Architecture

The central component of this system, as shown, is the Programmable Logic Controller (PLC). The PLC's of this system will function as both a Remote Terminal Unit (RTU), a logic controller and as a redundant controller. A master redundant processor PLC will be located in

7. The customer must provide a minimum 20'x30' easement to locate delivery and control facilities, including an underground concrete valve vault, control/radio cabinet, antenna mast, and other required facilities.
8. The customer must provide electric service to control enclosure.
9. The customer must provide a license agreement for the GBRA to install a level transmitter and associated SCADA equipment and radio telemetry on and/or adjacent to the customer's tank. Furnish electrical power to the equipment.
10. The customer must have a Certificate of Convenience and Necessity.

A schematic showing the control valves, isolation valves, and delivery into the customer tank is presented in Figure 6-1. Figure 6-1 also shows the connection schematics for SAWS and BMWD, the two major out-of-district customers that have a special set of criteria due to their unique contractual relationship with the GBRA and special hydraulic considerations.

6.2.2 Pressure Reduction

Pressure-reducing facilities may be needed where the hydraulic grade line is more than 46 feet (20 psi) above the elevation of the discharge into the customer's water storage tank. The pressure-reducing method will either be a modulating globe valve (i.e., Cla-Valve or equal) or an orifice plate, depending on the transmission line pressure. The need for pressure reduction will depend on the specific hydraulic conditions for each customer and will be determined during facility design.

6.2.3 Remote Instrumentation

As described previously in Section 5.5, instruments that should be provided at each delivery point include a pressure transmitter and flowmeter. The pressure transmitters should be located upstream from the flowmeters and modulating valves.

6.2.4 Provisions for Future Connections

Connections made after initial construction must be made in accordance the adopted Customer Connection Criteria (Appendix E). If an existing tap is not available in proximity to a customer as determined by GBRA, GBRA will provide a tapped connection to the pipeline at the customer's expense.

Section 6
Customer Connection Design

6.1 Customer Connection Criteria

In order for the GBRA to evaluate requests for water purchase contracts to obtain water made available by the Regional Water System in western Comal and southeastern Kendall Counties, criteria for connections has been developed and is contained in Appendix E. The criteria stipulate the qualifications for an entity to obtain service from the system.

6.2 Delivery System Facilities

6.2.1 In-District Connection Design Criteria

Once a customer's service contract is approved, the following design criteria are proposed for the physical connection of the customer to the delivery system:

1. Existing pipeline taps installed during pipeline construction must be utilized where available. Pipeline taps will be installed on the pipeline for all customers identified at the time of design.
2. Minimum delivery volume is 100 acft per year delivered uniformly throughout the year (approximately 60 gpm) delivered through a minimum 2-inch diameter meter. With approval of GBRA, In-District public non-community customers could receive less water than this minimum.
3. Minimum pipeline diameter from the transmission pipeline to the customer's storage tank is 4 inches. The actual diameter required may be larger depending on the customer's commitment and will be determined by GBRA after an engineering review of the pipeline hydraulics.
4. Taps on the customer's approach main between the GBRA transmission pipeline and the customer's storage tank will not be allowed without written approval of the GBRA.
5. Water delivery must be made to a water storage tank through an air gap except for In-District public non-community customers, with approval of GBRA. A reduced-pressure zone backflow preventer is also required if the customer's tank is not located on a tract of land that is contiguous with the GBRA's easement for the flow meter and flow control valve.
6. Water storage capacity in conjunction with other water supplies (if any) must be shown to be sufficient to provide water supply at average day flow rates during outages of GBRA supplied water of up to 24 hours.

the water treatment plant. This PLC will contain logic that will coordinate and supervise the operation of the Water Treatment Plant distributed PLC's, the Raw Water Pump Station PLC and the Remote Pump Station PLC. This master PLC will also manipulate system data and transmit to the supervisory computer and the Operator Machine Interface (OMI) station. The PLC's at the Raw Water Pump Station and the Remote Pump Station will also be redundant processor equipped units. Operational logic for both these PLC's will include stand alone logic execution for each of the stations with full duplex logic exchange with the master PLC. Each of the customer metering and flow control sites will be equipped with a lower level PLC to serve as a communication device and execute control logic for the flow control equipment. The Host Computer/OMI will consist of a Personal Computer (PC) with Windows NT operating system running an OMI software such as Wonderware. Operator graphics, data archiving and report generation will be accomplished in this environment.

5.5.3.2 *Telemetry*

The overall geographic area encompassed by this project spans approximately 46 miles. To facilitate high speed, reliable information transmission, a licensed, full-duplex radio telemetry system similar to the existing GBRA facilities is envisioned. Buried fiber optic cable was considered the most reliable, but extremely high capital costs would be realized and is not cost effective. Spread spectrum radio and leased telephone are not considered reliable for this application.

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6.3 Customer-Owned Facilities

6.3.1 Approach Mains and Control Valves

The customer will own and maintain the approach main pipeline downstream of the GBRA's flowmeter and valve vault. In some cases, GBRA may elect to build or share in the cost of the approach main if GBRA determines that capacity in the pipeline is or will be required to serve other customers in the future. In this case, the approach main would become a system facility upon completion, and GBRA's flowmeter and valve vault would be located at the end of the system's approach main and the beginning of the customer's approach main. The customer will also own and operate the control valve that opens and closes to allow flow into their tank (note that this is separate from the flow modulating valve located at the delivery point and owned by the GBRA). Optionally and upon agreement between the customer and GBRA, the GBRA may operate the customer's control valve (or the GBRA's control valve in lieu of the customer control valve) through the GBRA's SCADA system. The customer's valve can be located anywhere on the approach main. The pipeline must deliver water directly to the customer's storage tank without any taps or branches between the delivery point and tank.

6.3.2 Storage

The customer will own and maintain the water storage tank that this system delivers water into. Water storage capacity in conjunction with other water supplies available to the customer must be shown to be sufficient to provide water supply at average day flow rates during outages of GBRA-supplied water of up to 24 hours. Each customer will be required to allow the GBRA to install a level transmitter and associated SCADA equipment at each customer's tank. They will also be required to furnish electrical power for the GBRA's equipment. The GBRA will monitor the level in all customers' tanks to ensure that they are not overfilled and also to provide data for the GBRA's use.

6.3.3 Backflow Prevention and Cross Connection Control

As stated in the design criteria, a backflow preventer is required if the customer's tank is not located on a tract of land that is contiguous with the GBRA's easement for the flow meter and flow control valve. This protects the delivery system from possible contamination due to damage or breaks in the customer's approach main, which is more likely to occur in easements or right-of-way outside of the tank site. Backflow preventers must be of the reduced pressure zone type installed in accordance with engineering practice and prevailing standards. Annual inspection of the backflow preventer is required, and a copy of each inspection report must be filed with the GBRA.

6.3.4 Disinfection Compatibility

The results of the modeling to determine whether a disinfection booster station is required also provided DBP formation results. Because of long residence times and the level of available organic precursors remaining in conventionally treated Texas surface waters, chloramines is the secondary disinfectant of choice to minimize DBP formation in most transmission pipelines. Customers for this project currently use chlorine for secondary disinfection and would prefer not to change to chloramines. If a chloramine residual was used in the transmission pipeline, breakpoint chlorination would have to be performed in order for the customers to continue using chlorine as their secondary disinfectant. Based on discussions with water utilities whose customers combine chloraminated treated surface water with chlorinated supplies, there are more frequent taste and odor events, periodic depletion of chlorine residual in blending zones, and instances of excessive DBP formation when breakpoint chlorination occurs.

Upon review of the modeled DBP formation results based on the use of free chlorine and chloramines, GBRA and their customers established a water quality objective to minimize tastes and odors and avoid change in their current disinfection practices. This goal excludes the use of chloramines as a secondary disinfectant. Therefore, the blending, if required, of the transmitted water with that of the existing water sources for the customers should possess disinfection compatibility.

Section 7
Opinion of Probable Construction Cost

7.1 Delivery System Capital Costs

An opinion of probable cost was prepared for the one-time capital costs associated with construction of the project delivery system. The capital costs for the recommended delivery system are summarized in Table 7-1. A detailed account of each associated project component cost is included in Appendix F, Detailed Cost Estimates.

Table 7-1.
Summary of Recommended Delivery System Capital Costs

Item	Estimated Cost
WTP Pump Station	$ 1,339,000
Remote Pump Station	1,283,000
Bergheim Area Booster Pump Station	187,000
Treated Water Transmission Pipeline	22,577,000
Customer Connections/Valves/SCADA	730,000
Remote Storage Tanks	429,000
Total Construction Cost	$ 26,544,000

Costs for electrical feed connections required to service project facilities vary based on the specific location of the facility, the proximity of each proposed facility to an existing power supply line, and the policies of the providing local utility company. Specific costs for power connection to system facilities were not obtainable without a detailed location (address) of each facility. Development of these specific costs for power connection is applicable to and will be accomplished in final design. An estimated value for these costs has been incorporated into the miscellaneous electrical costs included in the Detailed Cost Estimates, Appendix F.

Total project costs for the project incorporate the capital costs for the entire project in addition to estimated costs for engineering and professional services, environmental studies and mitigation, land acquisition, and other costs. The overall total project costs are summarized in Section 7.2.

7.2 Overall Project Costs

The overall project costs are reported for delivery system costs (this report) and for raw water intake and treatment costs from the Contract A report. Facility costs included from the Contract A report are:

- Raw water intake;
- Raw water pump station;
- Raw water pipeline; and
- Water treatment plant.

7.2.1 Annual Costs

Annual costs for the project include consideration for the annual debt service, debt service coverage, operations and maintenance costs of system facilities, power cost, and purchase of stored water from GBRA.

7.2.1.1 Annual Debt Service

The annual debt service for the project is the total project cost annualized over the debt period of the project. A finance factor of 0.0782, corresponding to an interest rate of 6 percent over a period of 25 years was used. This finance rate is based on non-taxable municipal bond finance terms.

7.2.1.2 Debt Service Coverage

The debt service coverage cost was calculated in accordance with the contract and financing requirement.

7.2.1.3 O&M Cost

The annual costs for operations and maintenance of system facilities were evaluated for the pump stations, WTP facility, transmission pipeline equipment, and storage facilities. The resulting annual costs are tabulated for each facility in Tables 7-2 through 7-5.

7.2.1.4 Annual Power Cost

The annual power costs were estimated by considering the required power at each operating facility and converting to cost using a purchase rate of $0.06 per kilowatt-hour (kWh). The water supply system is assumed to operate at an annual flow rate of 10 MGD (10,527 acft/yr). The resulting values are tabulated in Tables 7-2 through 7-5.

Table 7-2.
Cost Estimate Summary
Base Project – 10 MGD Membrane WTP
(Costs are mid-2001 dollars)

Item	Estimated Cost
Capital Costs	
Lake Intake and Raw Water Pump Station	$3,000,000
Raw Water Pipeline and Storage Tank	4,224,000
Water Treatment Plant (Membrane)	18,272,000
WTP Pump Station	1,339,000
Remote Pump Stations	1,469,000
Treated Water Transmission Pipeline	22,577,000
Customer Connections/Valves/SCADA	1,280,000
Remote Storage Tanks	429,000
Total Capital Costs	**$52,590,000**
Engineering and Other Professional Fees	$4,994,000
Environmental Studies and Mitigation	320,000
Land Acquisition	3,888,000
Reserve Account and Financing Costs	1,602,000
Interest During Construction	4,760,000
Total Project Cost	**$68,154,000**
Annual Costs	
Annual Debt Service (6 percent for 25 years)	$5,330,000
Annual Debt Service Coverage	533,000
Annual Operation and Maintenance:	
Water Treatment Plant	1,324,000
Pump Stations	85,000
Transmission Facilities	151,000
Storage Facilities	10,000
Annual Power Cost	1,237,000
Purchase of Stored Water[1]	676,000
Total Annual Cost	**$9,346,000**
Annual Water Delivery (acft)	**10,527**
Unit Cost of Water ($ per acft)	**$888**
Unit Cost of Water ($ per 1,000 gal)	**$2.72**

[1] Cost of stored water purchased from GBRA is currently $61 per acft. Quantity purchased includes 5 percent allowance for treatment and transmission losses.

Table 7-3.
Cost Estimate Summary
Phased Expansion from 10 MGD to 15 MGD Membrane WTP
(costs are mid-2001 dollars)

Item	Estimated Cost
Capital Costs	
Raw Water Intake Expansion	$219,000
Water Treatment Plant Expansion (Membrane)	5,635,000
WTP Pump Station Expansion	497,000
Remote Pump Stations Expansion	306,000
Total Capital Costs	**$6,757,000**
Engineering and Other Professional Fees	$811,000
Environmental Studies and Mitigation	0
Land Acquisition	0
Reserve Account and Financing Costs	0
Interest During Construction	612,000
Total Project Cost	**$8,180,000**
Annual Costs	
Annual Debt Service for Base Project (10 MGD)[1]	$5,330,000
Annual Debt Service for Expansion to 15 MGD (6 percent for 25 years)	640,000
Annual Debt Service Coverage, incl. Base Project	597,000
Annual Operation and Maintenance for 15 MGD[2]	
Water Treatment Plant	1,854,000
Pump Stations	119,000
Transmission Facilities	151,000
Storage Facilities	10,000
Annual Power Cost[2]	2,085,000
Purchase of Stored Water[3]	1,027,000
Total Annual Cost	**$11,813,000**
Annual Water Delivery (acft)	**16,000**
Unit Cost of Water ($ per acft)	**$738**
Unit Cost of Water ($ per 1,000 gal)	**$2.27**

1 From Table 7-2.
2 Includes costs for Base Project.
3 Cost of stored water purchased from GBRA is currently $61 per acft. Quantity purchased includes 5 percent allowance for treatment and transmission losses.

Table 7-4.
Cost Estimate Summary
Base Project – 10 MGD Conventional WTP
(costs are mid-2001 dollars)

Item	Estimated Cost
Capital Costs	
Lake Intake and Raw Water Pump Station	$3,000,000
Raw Water Pipeline and Storage Tank	4,224,000
Water Treatment Plant (Conventional)	18,331,000
WTP Pump Station	1,339,000
Remote Pump Stations	1,469,000
Treated Water Transmission Pipeline	22,577,000
Customer Connections/Valves/SCADA	1,280,000
Remote Storage Tanks	429,000
Total Capital Costs	**$52,649,000**
Engineering and Other Professional Fees	$4,994,000
Environmental Studies and Mitigation	320,000
Land Acquisition	3,888,000
Reserve Account and Financing Costs	1,602,000
Interest During Construction	4,760,000
Total Project Cost	**$68,213,000**
Annual Costs	
Annual Debt Service (6 percent for 25 years)	$5,334,000
Annual Debt Service Coverage	533,000
Annual Operation and Maintenance	
Water Treatment Plant	1,191,000
Pump Stations	85,000
Transmission Facilities	151,000
Storage Facilities	10,000
Annual Power Cost	1,214,000
Purchase of Stored Water[1]	676,000
Total Annual Cost	**$9,194,000**
Annual Water Delivery (acft)	**10,527**
Unit Cost of Water ($ per acft)	**$873**
Unit Cost of Water ($ per 1,000 gal)	**$2.68**

[1] Cost of stored water purchased from GBRA is currently $61 per acft. Quantity purchased includes 5 percent allowance for treatment and transmission losses.

Table 7-5.
Cost Estimate Summary
Phased Expansion from 10 MGD to 15 MGD Conventional WTP
(costs are mid-2001 dollars)

Item	Estimated Cost
Capital Costs	
Raw Water Intake Expansion	$219,000
Water Treatment Plant Expansion (Conventional)	6,404,000
WTP Pump Station Expansion	497,000
Customer Connections/Valves/SCADA	100,000
Remote Pump Stations Expansion	306,000
Total Capital Costs	**$7,526,000**
Engineering, Contingencies, and Legal Costs	$903,000
Environmental Studies and Mitigation	0
Land Acquisition	0
Reserve Account and Financing Costs	0
Interest During Construction	680,000
Total Project Cost	**$9,109,000**
Annual Costs	
Annual Debt Service for Base Project (10 MGD)[1]	$5,334,000
Annual Debt Service for Expansion to 15 MGD (6 percent for 25 years)	712,000
Annual Debt Service Coverage, incl. Base Project	605,000
Annual Operation and Maintenance for 15 MGD[2]	
Water Treatment Plant	1,667,000
Pump Stations	119,000
Transmission Facilities	151,000
Storage Facilities	10,000
Annual Power Cost[2]	2,053,000
Purchase of Stored Water[3]	1,027,000
Total Annual Cost	**11,678,000**
Annual Water Delivery (acft)	**16,000**
Unit Cost of Water ($ per acft)	**$730**
Unit Cost of Water ($ per 1,000 gal)	**$2.24**

1 From Table 7-4.
2 Includes costs for Base Project.
3 Cost of stored water purchased from GBRA is currently $61 per acft. Quantity purchased includes 5 percent allowance for treatment and transmission losses.

7.2.2 Purchase of Stored Water

The annual purchase of stored water from the GBRA is included in the overall annual cost for the project. The current value of $61 per acre-foot was used for this determination, as indicated in Tables 7-2 through 7-5.

7.2.3 Project Cost Summary

7.2.3.1 Base Project – Membrane WTP

Table 7-2 summarizes project costs for the Base Project (i.e., 10-MGD) with a membrane water treatment plant. Total capital cost for all project facilities is estimated to be $52,590,000. Total project cost, including engineering, land acquisition, financing, and interest during construction totals $68,154,000 (Table 7-2). Annual costs are reported in the lower half of Table 7-2, including debt service ($5,330,000), debt service coverage ($533,000), WTP O&M ($1,324,000), electric power ($1,237,000), and purchase of water ($676,000). Total annual cost is $9,346,000 (Table 7-2). For delivery of 10,527 acft/yr, the unit cost of water will be $888 per acft, or about $2.72 per 1,000 gallons.

7.2.3.2 Phased Project – Expansion to 15 MGD with Membrane WTP

Table 7-3 summarizes project costs for the expansion of the Base Project from 10 MGD to 15 MGD with a membrane water treatment plant. Costs shown in Table 7-3 are in mid-2001 dollars. Capital costs to expand project capacity to 15 MGD are $6,757,000, including expansion of the raw water intake, water treatment plant expansion, and pump station improvements. Total project cost to expand the system, including engineering, financing, and interest during construction totals $8,180,000 (Table 7-3). Annual costs for the expanded system as reported in the lower half of Table 7-3, are inclusive of costs for the base 10-MGD project. Debt service, O&M costs, power, purchase of water and other annual costs for the full 15 MGD system total $11,813,000 (Table 7-3), or about $2,467,000 more than the cost of the base 10 MGD project. For delivery of 16,000 acft/yr, the unit cost of water for the expanded system drops to $738 per acft, or about $2.27 per 1,000 gallons.

7.2.3.3 Base Project – Conventional WTP

Table 7-4 summarizes project costs for the Base Project (i.e. 10 MGD) with a conventional water treatment plant. Total capital cost for all project facilities is estimated to be

$52,649,000. Total project cost, including engineering, land acquisition, financing, and interest during construction totals $68,213,000 (Table 7-4). Annual costs are reported in the lower half of Table 7-4, including debt service ($5,334,000), debt service coverage ($533,000), WTP O&M ($1,191,000), electric power ($1,214,000), and purchase of water ($676,000). Total annual cost is $9,194,000 (Table 7-4). For delivery of 10,527 acft/yr, the unit cost of water will be $873 per acft, or about $2.68 per 1,000 gallons.

7.2.3.4 Phased Project – Expansion to 15 MGD with Conventional WTP

Table 7-5 summarizes project costs for the expansion of the Base Project from 10 MGD to 15 MGD with a conventional water treatment plant. Costs shown in Table 7-5 are in mid-2001 dollars. Capital costs to expand project capacity to 15 MGD are $7,526,000, including expansion of the raw water intake, water treatment plant expansion, and pump station improvements. Total project cost to expand the system, including engineering, financing, and interest during construction totals $9,109,000 (Table 7-5). Annual costs for the expanded system as reported in the lower half of Table 7-5, are inclusive of costs for the base 10-MGD project. Debt service, O&M costs, power, purchase of water and other annual costs for the full 15 MGD system total $11,678,000 (Table 7-5), or about $2,484,000 more than the cost of the base 10 MGD project. For delivery of 16,000 acft/yr, the unit cost of water for the expanded system drops to $730 per acft, or about $2.24 per 1,000 gallons.

7.3 Cost Allocation

Annual cost allocations for each major participant should consider expected expenditures within the first 10 years of system operation including:

- Raw water purchase;
- Firm annual commitment;
- Additional water; and
- Returnable water.

Cost allocation tables for each project participant will be prepared showing each of these cost elements.

Section 8
Schedule and Permitting

8.1 Project Schedule

Figure 8-1 presents a timeline schedule of the major work elements to implement the project. For a start date July/August 2000 to begin the control surveys, aerial photography, and limited final design, the design process can be completed in about 10 months (May 2001). Upon completion of the environmental permitting, the construction project is scheduled to be ready for bid advertisement in July 2001. Bidding and contract award could then be completed by September 2001 with the start in construction on October 2001. The right-of-way surveying and land acquisition would begin in parallel with final design and would finish during the early part of construction, as shown in Figure 8-1.

The amount of time required for construction is estimated to be about 14 months, which results in a completion date of November 2002. This construction schedule is based on two construction crews maintaining reasonably high installation rates of 500-feet per crew-day with allowance for mobilization and pipe delivery at project beginning and pipe testing and cleanup at the end. Delays due to material delivery or land acquisition will lengthen this schedule. It is expected that the hill country setting could present some construction challenges such as steep topography and variable hardness rock that could slow construction. It might be possible to accelerate the construction schedule slightly and shorten the construction time by 60 days by the addition of installation crews. However, the cost of the construction will likely increase to meet a fast track schedule and pipe material delivery time will become a limiting factor.

8.2 Permitting

8.2.1 Pre-Application Agency Coordination

8.2.1.1 Texas Natural Resource Conservation Commission — Edwards Aquifer Rules

On January 02, 2000, Mr. Scott Jecker of SWCA, Inc. Environmental Consultants (SWCA) contacted Mr. Tom Gutierrez with the Texas Natural Resource Conservation Commission (TNRCC) to determine if a permit would be required for construction of the proposed water distribution system. Mr. Gutierrez stated that, although the project would be located over the Edwards Aquifer, the project was exempt from permit requirements since the pipeline would be carrying water.

It should be noted that although the project is exempt from the permitting associated with the Edwards Aquifer Rules, a Storm Water Pollution Prevention Plan would need to be prepared for the project.

8.2.1.2 U. S. Army Corps of Engineers

By letter dated January 4, 2000, SWCA contacted the Regulatory Branch of the U.S. Army Corps of Engineers (USACE) Fort Worth District regarding the proposed project. By letter dated January 20, 2000 the USACE assigned project number 200000014 to the proposed project and advised SWCA that a Project Manager was assigned to the project. SWCA subsequently contacted USACE and requested a pre-application meeting to discuss the project. USACE advised that a pre-application meeting was not necessary and that we should follow the general guidance provided by the USACE on their web page. He said that the application would be processed under Nationwide Permit No. 12 (NWP 12).

8.2.1.3 Texas General Land Office

On March 1, 2000, SWCA contacted the Texas General Land Office (GLO) to determine if the proposed pipeline would cross any state-owned streams or lands. GLO determined that no state-owned lands or streams would be crossed by the pipeline. Therefore, no further coordination with the GLO will be necessary.

8.2.1.4 U. S. Fish and Wildlife Service

SWCA conducted a pre-application meeting at their offices in Austin, Texas on February 18, 2000 and staff from the U.S. Fish and Wildlife Service (USFWS) attended the meeting. USFWS initial reaction to the proposed project was that it did not appear to impact any areas of significance. USFWS requested that SWCA provide copies of the maps showing the pipeline routes under consideration. SWCA provided the route maps to the USFWS and SWCA contacted USFWS to obtain comments after reviewing the route maps. USFWS said that all portions of the project above Bulverde were in the Edwards Aquifer Contributing Zone and USFWS was not concerned with those portions of the project. However, the portions of the project that extended below Bulverde would be of potential concern. USFWS pointed out that the areas below Bulverde would be over the Edwards Aquifer Recharge Zone and would be in potential habitat for threatened and endangered species. Specifically, the project would be located within potential habitat for the black-capped vireo (*Vireo atricapillus*) and the golden-cheeked warbler (*Dendroica chrysoparia*). USFWS also pointed out that the project area south of Bulverde included karst features that may contain protected invertebrates.

8.2.1.5 Texas Parks and Wildlife Department

Staff from Texas Parks and Wildlife Department (TPWD) attended the pre-application meeting on February 18, 2000. TPWD stated that a Sand, Shell, Gravel, and Marl permit might be required for the project if any of the pipeline crosses state-owned streams. TPWD offered no specific comments on the project but stated that TPWD did not believe there would be any significant impacts. TPWD requested that SWCA provide copies of the proposed route maps for closer review.

SWCA contacted TPWD to obtain any specific comments after reviewing the route maps. TPWD stated that a Sand, Shell, Gravel, and Marl permit will not be required based on the GLO's determination that no state-owned lands are crossed. TPWD had no specific comments regarding the proposed project.

8.2.1.6 Texas Historical Commission

SWCA archaeologists reviewed the Texas Historical Commission (THC) files contained at the Texas Archaeological Research Laboratory (TARL) to determine if any known archaeological sites had been recorded in or near the project area. SWCA found that each alternative route contained a combination of high, medium and low probability areas for the presence of archaeological sites.

Field investigations of the selected route will be required in support of the USACE permit application. The scope of these field investigations will be determined through close coordination with the USACE staff archaeologist once a preferred route is selected.

8.2.2 Environmental Screening

The preferred route and all alternative routes were screened for environmental constraints. National Wetland Inventory maps, aerial photography, soil survey maps, threatened and endangered species files, and archaeology files were reviewed. This was undertaken for the purposes of "grading" the possible routes, in terms of environmental resources.

From an environmental standpoint, all of the routes were essentially equal. The main area of concern is the southern distribution line, south of the town of Bulverde. The portion of the southern distribution line that is located around the town of Bulverde and south of Bulverde has the potential for containing threatened and endangered species. Golden-cheeked warblers, black-capped vireos and karst invertebrates are known to exist in the vicinity of the route. This area of the route is also in the Edwards Aquifer Recharge Zone. Being in the recharge zone could require that additional steps be taken to prevent subsurface siltation.

Appendix A
Technical Memorandum No. 1

To: File: 07081-033-036

From: Christianne Gaylord
(Registered in California, C57977)

Date: January 28, 2000 (Revised May 23, 2000)

HDR

Technical Memorandum

Subject: **Guadalupe-Blanco River Authority Regional Water System**
For Portions of Comal, Kendall, and Bexar Counties
HDR Project No. 07081-033-036
Technical Memorandum No. 1
Water Delivery System Hydraulic Design and Expansion Alternatives

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Purpose

The purpose of this technical memorandum (TM) is to present the hydraulic design alternatives evaluated for the Guadalupe-Blanco River Authority (GBRA) Regional Water System for portions of Comal, Kendall, and Bexar Counties. Evaluation of the hydraulic alternatives includes a comparison of the differential probable costs for alternative pipeline and pumping station scenarios as well as development and further evaluation of the preferred scenarios for future phasing options to deliver system capacities that may be made available in the system. In addition to comparison of quantitative differential costs, the qualitative factors influencing the feasibility of each alternative is evaluated and a single option for detailed consideration is recommended.

Preliminary Pipeline Route

Hydraulic evaluation has been performed using a representative pipeline route from the proposed water treatment plant (WTP) in the vicinity of Startz Hill to delivery points throughout the western Comal, Kendall and Bexar Counties, as depicted in Figure 1. The route varies within the portion between the water treatment plant and junction to Boerne, to reflect the most suitable route for each pipeline and pump station hydraulic design alternative, based on the particular gravity or pumped delivery scheme.

Ground Profile

The preliminary pipeline routes were superimposed on six USGS digital raster graphic (DRG) quadrangle sheets (Smithson Valley, Anhalt, Bulverde, Bergheim, Boerne, and Van Raub), and the ground profile was generated electronically.

Referring to Figure 1, the pipeline length along the Hwy 281/46 route is approximately 194,000 ft (37 miles). Similarly, the total pipeline length along the Smithson Valley Road alignment is approximately 212,000 ft (40 miles).

In addition, the alternate route along the transmission line alignment (deviating from Ammann Road) was generated to provide an assessment of ground conditions. Although this route was not used for detail study, it was determined that the route is plausible for all hydraulic design alternatives evaluated herein. All evaluated ground profiles are presented graphically in the Hydraulic Results section of this TM.