Briones Reservoir - Inlet/Outlet Tower: Evaluation of Retrofit Options Final Report

Prepared for

EBMUD

East Bay Municipal Utility District

by

JACOBS ASSOCIATES

Engineers/Consultants

San Francisco, California

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REGISTERED PROFESSIONAL ENGINEER
JOHANNES VAN GREUNEN
No. C 52885
Exp.: 12/31/10
CIVIL
STATE OF CALIFORNIA

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1. INTRODUCTION

This report presents the conceptual retrofit design of the Briones Reservoir Inlet/Outlet Tower (Tower). The work was performed for the East Bay Municipal Utility District (the District) as a subconsultant to Geomatrix Consultants of Oakland. As a prior part of the study, the seismic performance of the existing Tower was evaluated by Quest Structures, Inc. (Quest) and presented in a separate report. The dynamic analyses performed by Quest showed that the existing Tower is structurally deficient and could suffer significant damage during a major earthquake. The proposed retrofit alternatives for the existing Tower and possible new designs are discussed and evaluated in this report. Preliminary cost estimates were performed and cost comparisons of the most feasible alternatives are also presented.

1.1. Description of the Tower

The Briones Tower is located approximately two hundred and fifty yards upstream of the embankment of the Briones Reservoir and was constructed in 1965. The Briones Reservoir is one of the essential storage elements of the District water supply system. The Tower is used to feed water intermittently to the Orinda water treatment plant and used mainly as a backup reservoir.

The inlet-outlet works consist of the Tower and the inlet-outlet tunnel connected to its base. The Tower is a freestanding, vertical reinforced concrete structure located upstream of the toe of the dam embankment. The Tower is 230 feet high with 60-inch butterfly valves at 7 levels operated by hydraulic lines from a platform at the top of the Tower. The internal diameter of the Tower varies from 20 feet at the base to 10 feet at the top while the wall thickness varies from 16 inches at the base to 9 inches at the top. The Tower is founded on claystone, silty claystone, and minor sandstone of an unnamed sedimentary and volcanic rock unit (Tus). Several short, minor fractures or zones of sheared and crushed rock were observed in the Tower foundation excavation that range from ½ to 3 inches thick. Most of these shears were healed or filled with calcite, and none were observed to cross the entire width of the foundation (Marliave, 1964).

During normal operations, only certain of the Tower valves and the vault shut-off valve are open with the outflow in the tunnel being controlled by the Briones draft valve at the Briones Center. The inlet-outlet works are generally operated by drafting up to 85 MGD (132 cfs) from the reservoir or pumping up to 45 MGD (70 cfs) into the reservoir. Under emergency conditions the flow could be as high as 521 cfs, which translates into a flow velocity of 11.8 feet per second (fps) in the tunnel that frames into the base of the Tower. The tunnel is lined with a reinforced concrete final lining except for the section through the embankment, which is reinforced with a steel lining to prevent leakage of water due to the weak rock encountered in this reach.

1.2. Seismic Hazard

The Tower was analyzed by Quest for response to both the Maximum Credible Earthquake (MCE) and Maximum Design Earthquake (MDE) level ground motions – the response spectra are shown in Tables 1 and 2 and Figures 1 and 2 respectively.

The MCE corresponds to a 1000 year return period event. The District established the MDE as a ground motion having a 10 percent probability of exceedance in 50 years (a 475 year return period). Both the MDE and MCE were estimated by Geomatrix Consultants.

The US Army Corps of Engineers (USACE) Engineer Manual EM 1110-2-2400 recommends outlet works to be designed considering both the MDE and OBE (Operating Basis Earthquake). The OBE is defined as a ground motion having a 50 percent probability of exceedance in 100 years (a 144 year return period). The seismic forces calculated for each of the MDE and OBE ground motions have to be factored for design. Load factors recommended by EM 1110-2-2400 are 1.1 and 1.5 for the MDE and OBE respectively. Due to the smaller load factors used for the MDE (which is a more severe earthquake and therefore has higher seismic demands) the factored seismic demands for the MDE and OBE are generally close. For our preliminary design only the MDE with the associated load factors recommended by EM 1110-2-2400 were used. For the final design the response spectrum for an OBE level event should be established and the design verified for that level of design event.

Table 1: MDE Response Spectra at 5% Damping

Period	Spectral Acceleration, S_a (g)	
(sec)	Fault Normal	Fault Parallel
PGA	0.697	0.697
0.075	1.184	1.184
0.100	1.390	1.390
0.200	1.648	1.648
0.300	1.474	1.474
0.500	1.076	1.076
1.000	0.589	0.562
1.500	0.393	0.360
2.000	0.299	0.261
3.000	0.197	0.148
4.000	0.141	0.096

Table 2: MCE Response Spectra at 5% Damping

Period	Spectral Acceleration, S_a (g)	
(sec)	Fault Normal	Fault Parallel
PGA	0.748	0.748
0.050	0.999	0.999
0.075	1.233	1.233
0.100	1.426	1.426
0.150	1.685	1.685
0.200	1.788	1.788
0.300	1.721	1.721
0.400	1.569	1.569
0.500	1.387	1.387
0.750	1.117	1.024
1.000	0.960	0.800
1.500	0.740	0.526
2.000	0.606	0.382
3.000	0.448	0.228
4.000	0.351	0.153

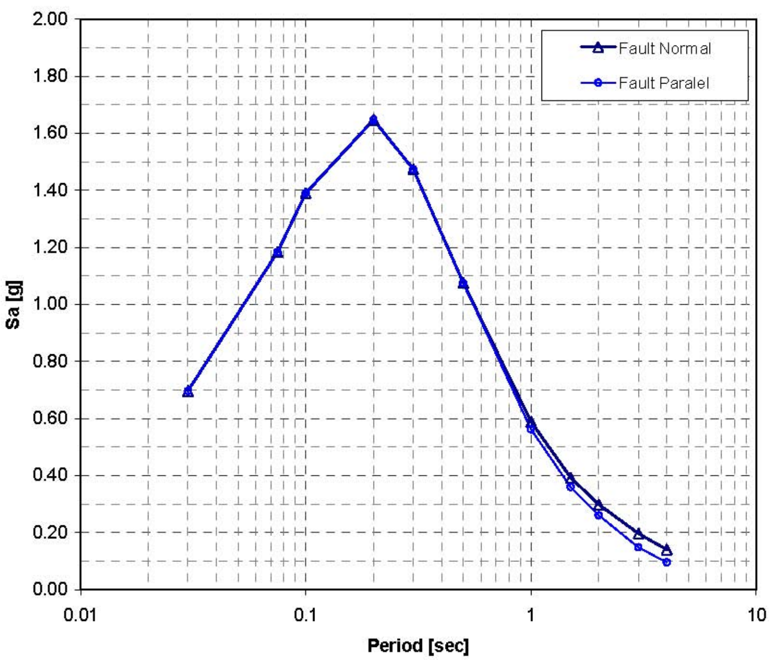


Figure 1: MDE Acceleration Response Spectra at 5% Damping

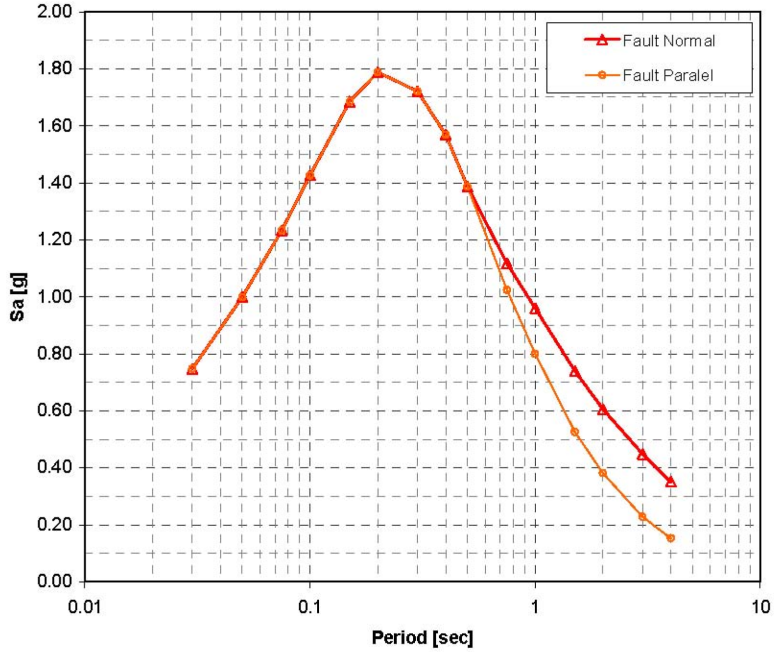


Figure 2: 84th Percentile MCE Acceleration Response Spectra at 5% Damping

1.3. Scope of Report

The retrofit evaluation of the Tower consisted of considering a range of possible retrofit options and performing conceptual design calculations to determine preliminary material properties and element sizes as discussed in Sections 2 and 3. The constructability of the alternatives was then evaluated and only those alternatives considered viable were selected for further preliminary design to provide enough information to do preliminary cost estimates as presented in Section 4.

2. RETROFIT OPTIONS CONSIDERED

2.1. General

Draining the reservoir was investigated (see the discussion at the end of this subsection), but it was concluded that it is not advisable to drain the reservoir for construction due to the role of the Briones Reservoir as a storage facility and operational considerations. This drastically limits the potential retrofit options that can be considered and practically rules out the option of using an external jacket for strengthening. To strengthen the existing Tower three possible designs were considered. Only one of these alternatives was considered a viable option. Two new inlet/outlet facilities were also investigated. Additionally, an alternative option of partially demolishing the existing Tower was investigated. The following potential retrofit and new options for the Briones Tower were considered:

1. Guyed Cables: Use guyed cables to stabilize the existing Tower.
2. External Supporting Piers and Frame: Buttressing of the Tower by addition of three external piers and supporting frames at three levels.
3. Reinforced Tower and Strengthened Foundation: Strengthening and stiffening of the base of the Tower, combined with internal strengthening of the Tower shaft.
4. New Connecting Tunnel and Sloping Inlet/Outlet: Replace the existing Tower with a new connecting tunnel and sloping inlet/outlet pipe. Connecting a new sloping inlet/outlet pipe into the existing tunnel was also investigated (4A).
5. New Posttensioned Precast Tower: Construct a new inlet/outlet tower over the existing tunnel consisting of a base structure and forming the tower with precast rings followed by vertical posttensioning.
6. Partial Demolition of Existing Tower: Demolishing the upper part of the existing Tower and replacing it with a steel shaft.

The feasibility of draining the Briones Reservoir to allow construction of a retrofit scheme in the dry was evaluated for Options 3 and 4 above, resulting in significant cost savings as shown in Table 3 (Options 3B and 4B) and discussed in Section 4 below. The cost of refilling the reservoir is estimated to be of the order of $6 million. However, considering the risk of interruption to the District water supply system, without the availability of the backup storage provided by the Briones Reservoir and being dependent on supply through the pipelines, the potential cost saving is not considered relevant. Draining the reservoir is therefore not considered a realistic option and was not considered in any further detail.

2.2. Option 1: Guyed Cables

The initial scheme to retrofit the Tower was patterned after a guyed transmission tower utilizing a set of cables tied to one elevation of the Tower. The initial layout of the guy cables was based on 2 pairs of tethers with the tethers in each group separated by 60° and each set separated 180° on center from the other. Eventually, this pattern was rearranged such that each tether was 90° apart from the others. The location and angle of inclination of the tethers were positioned to avoid the outlet tunnel and the Tower’s foundation. The cables would be anchored into the reservoir bed and attached to a collar which would be affixed to the exterior of the Tower at elevation 512 feet. The collar elevation was based on the practical limits of the bathysphere required to provide a working platform below the water level. The anchors would be located at a radius of 115 feet from the Tower centerline, resulting in a cable angle of 45 degrees. The normal operational level of the reservoir is 576 feet. See Appendix B1, Section 2 for further details of this scheme and the analyses performed to evaluate it.

A preliminary cost estimate indicated that the guyed cable scheme could be a cost effective option. Therefore, Option 1A with two levels of cables was investigated by Quest as documented in Appendix B3. This analysis showed that a retrofit scheme using two levels of cables would also not provide adequate support to the existing Tower.

The guyed cables approach would require a substantial amount of diving work. Alternatively, a bathysphere type structure would have to be built around the Tower and anchored into the reservoir bed to provide a dry work area for the construction of the collar and the anchoring of the tethers to the Tower. Several barges would be required for the installation of the bathysphere and tethers; including a barge capable of setting the anchors in the reservoir bed. Underwater work at depths of 200 feet by divers would be required to attach the tethers to the anchors in the reservoir bed.

This design scheme resulted in heavy cables which did not adequately stabilize the Tower and provide the required reduction in demand on the existing Tower structure. Due to the technical deficiency of the design, combined with concerns about constructability and long term durability and maintenance of the cables this option was not pursued further.

2.3. Option 2: External Supporting Piers and Frame

The second scheme was an attempt to buttress the Tower with three external support shafts connected to each other and the existing Tower with a steel framing system as shown in the sketches on Drawing SK-6, Appendix A. The support shafts consist of three 10-foot diameter drilled piers spaced 120° on a 37-foot radius. The piers were positioned to avoid the foundation and the outlet tunnel. The piers would be socketed into the reservoir floor and rise approximately 201 feet above the floor. Three levels of trusses at elevations 448, 523, and 572 feet were positioned to avoid the inlet valves. Each level of trusses consists of a horizontal steel truss, spanning between piers to buttress the Tower. A saddle would be required at each truss to Tower interface to distribute the forces encountered during a seismic event.

The buttress approach would require a casing oscillator deployed from a barge to socket the shafts into the rock of the reservoir floor. Each shaft would require permanent casing from the surface to facilitate the concreting operation and to serve as an attachment surface for steel framing. Significant underwater work performed by divers would be required to install the framing. The stiffness provided by the buttress structure, coupled with the added mass, was determined to be insufficient when compared to that of the Tower and consequently the embedment of the piers was not designed. This option was discarded not only because of its technical shortcomings, but also due to concerns about both constructability and cost.

2.4. Option 3: Reinforced Tower and Strengthened Foundation

A third scheme was developed to reinforce the Tower by adding an interior lining. However, due to the forces and reactions at the base of the Tower, the need to strengthen the foundation was apparent. To minimize the impact of the overturning moment, additional ballast was required. Dredging of the foundation's overburden and adding a 60-foot high tremie pour atop the existing foundation would provide the needed ballast and would at the same time stiffen the foundation and shorten part of the Tower shaft. Details of this option are shown on Drawing SK-1, Appendix A.

The valve aperture at elevation 382.5 feet would need to be extended through the tremie pour to maintain its functionality. The vertical opening of the Tower would be reduced by installing an 8-foot diameter pipe vertically throughout the height of the Tower. This vertical riser would be connected to the outlet tunnel as well as all of the valves along the height of the Tower. The riser would provide an unimpeded path for the water to flow from the reservoir into the outlet tunnel.

Vertical reinforcement as well as hoop steel would be placed within the annular space between the vertical pipe and the Tower's existing walls, which would be backfilled with concrete. An added benefit of the exterior tremie pour at the Tower base is raising the plane of the Tower/footing interface and encapsulating the lower part of the Tower shaft. This reduces the height of the shaft and therefore the bending moment and shear that the cantilevered Tower must resist. This also allows for the development of the vertical reinforcement in the concrete lining below the top of footing plane versus the anchoring of the vertical bars in the existing foundation. The design would need to accommodate the valve actuators that are currently supported on the interior face of the Tower wall. The pipe connecting the valve aperture to the vertical pipe could be sized to accommodate the valve's actuator.

During construction the contractor will need to develop his work process to allow for the District's emergency response efforts in the event of an emergency in the existing water supply network. This would entail opening the valves within 48 hours and providing a flow path from the inlet valves through the Tower to the outlet tunnel. The construction sequence is anticipated to be:

- Excavate the material backfilled over the existing foundation under water.
- Divers would be required to assemble and set the forms for the foundation tremie pour. A multi-plate corrugated pipe approximately 60 feet in diameter would serve as the form.
- Tremie the foundation concrete by using a floating slick line to deliver the concrete to the Tower which is approximately 250 yards from the shore.
- The existing valves would need to be temporarily sealed to provide a dry work area within the Tower for the installation of the interior pipe, reinforcement and other work.
- Remove platform at top of Tower, platforms and ladders.
- Install the reinforcing cage and interior pipe, which will act as the interior form, and pour new concrete inner lining in lifts.
- Reinstall ladders and other equipment.
- Reinstall the platform.

2.5. Option 4: New Connecting Tunnel and Sloping Inlet/Outlet

A fourth option that consists of replacing the existing Tower with a sloping inlet/outlet pipe embedded into the reservoir bank was investigated. In addition, a new tunnel would be required to connect the new sloping pipe with the existing tunnel. The new tunnel would be mined from an approximately 280-foot deep, 30-foot diameter access shaft on the south shore of the reservoir as shown on Drawing SK-2, Appendix A. A short tunnel would extend from the shaft to connect into the existing tunnel, while another tunnel would connect into a shaft below the sloping pipe. Additional details are shown on Drawings SK-3 and SK-4, Appendix A. The anticipated construction sequence would be:

- Assemble and weld together the sloping pipe including the inlets and valves on shore.
- Excavate the sloped trench in the reservoir bank under water and sink the shaft a minimum of 5 feet into competent rock. Grouting of the surrounding rock may be required to reduce the risk of water inflows when making the future connection from the tunnel.
- Float or barge the inlet pipe into position and sink it into the sloped trench.
- Tremie the concrete backfill around the sloping pipe and then dewater the pipe.
- In a parallel operation the access shaft would be excavated and the tunnels mined.
- Make the connection into the sloping pipe from the tunnel by raising the shaft into the concrete plug installed previously.
- The final approximately 20 feet of tunnel excavation and connection into the existing tunnel would be made during an outage where the existing Tower valves would be closed and the existing tunnel dewatered.
- Demolish the existing Tower in part or completely. The bottom inlet could be retained as part of a reduced existing Tower.

As an additional alternative, connecting the new sloping inlet/outlet pipe directly into the existing tunnel was suggested by the District. This option would consist of connecting the sloping inlet to the existing tunnel through a vertical shaft approximately 100 feet downstream of the existing Tower. The anticipated construction sequence for this revised Option 4 would be:

- On shore, assemble and weld together the sloping pipe, including the inlets, valves, and the first section of the shaft connection sealed with a blind flange.
- Excavate the sloped trench in the reservoir bank under water and excavate the shaft to expose the existing tunnel up to its invert slab. Grouting of the surrounding rock at this shaft area may be required to reduce the risk of water inflows when making the future connection from the tunnel.
- Float or barge the inlet pipe into position and sink it into the shaft and sloped trench.

- Tremie the concrete backfill by using a floating slick line to deliver the concrete into the shaft, creating a concrete plug between the existing tunnel and the shaft flange, and around the sloping pipe. The sloping pipe is then dewatered.
- During an outage where the existing Tower valves are closed and the existing tunnel dewatered, make the connection into the sloping pipe from the tunnel by raising the shaft into the concrete plug and shaft section installed previously.
- Demolish the existing Tower in part or completely. The bottom inlet could be retained as part of a reduced existing Tower

This revised Option 4, connecting directly into the existing tunnel, proved to be substantially less expensive than the original scheme and cost estimates for this option only is presented in Section 4.

2.6. Option 5: New Posttensioned Precast Tower

This option consists of constructing a new tower straddling the existing tunnel and is shown in Drawing SK-5, Appendix A. This new tower will use a foundation of the same size and construction as the retrofitted foundation of Option 3. The tower itself, with internal and external diameters of 10 and 18.67 feet respectively, would then be assembled from a series of 12-foot high precast rings. The valves will be built into each second ring. In the lower part of the tower all the cells in the rings will be filled with concrete. As the demands decrease towards the top of the tower the number of cells filled with concrete will decrease. Finally the assembled rings will be posttensioned to form the final tower shaft. The construction sequence would be:

- Excavate the in-situ material over the existing tunnel at the new tower location under water to width and depth required for the new foundation.
- Divers would be required to assemble and set the forms for the foundation tremie pour. A multi-plate corrugated pipe approximately 60 feet in diameter would serve as the form. Install the internal 10 foot diameter pipe and duct loops for the posttensioning cables.
- Tremie the foundation concrete by using a floating slick line to deliver the concrete to the new tower location, which would be approximately 240 yards from the shore.
- Precast the tower rings in a precast yard or on site and float or barge them out to the location of the new tower. Lower each ring down to assemble the tower shaft.
- Place reinforcing in cells and place concrete either under water or in the dry if cells can be adequately sealed to achieve that.
- Thread the cables through the ducts in the precast rings and looped through the foundation. Posttension both ends at the top of the tower.

- Dewater the interior of the tower and connect into the existing tunnel during an outage where the existing Tower valves can be closed and the existing tunnel is dewatered.
- Install valve actuators, ladders, and other equipment, including the platform and railing at the top of the tower.
- Demolish the existing Tower in part or completely. The bottom inlet could be retained as part of a reduced existing Tower.

2.7. Option 6: Partial Demolition of the Existing Tower

As an additional alternative it was considered to demolish the upper part of the existing Tower and replace it with a steel shaft as shown in the attached Drawing SK-7, Appendix A, to maintain current operational capacity. The analysis of this modified existing Tower was performed by Quest and is described in Appendix B2. The Tower height was reduced by approximately 88 feet and therefore there is a substantial reduction in mass. However, this also results in a relative stiffening the remaining part of the Tower, resulting in a shorter period of vibration for the system. The net result is that the response is moved up the response spectrum curve, resulting in higher accelerations and therefore almost the same level of shear and bending moment in the remaining part of the tower. Since the results indicated that the Tower would have to be strengthened this option was not investigated further.

During discussions with the District the option of demolishing the Tower to a level where the remaining section of the existing shaft would have adequate structural capacity was discussed as a minimum cost solution. This would entail demolishing the Tower and installing a closure slab to maintain the ability to shut the intake valves and dewater the Tower and tunnel. The hydraulic controls for the remaining valves would be rerouted along the reservoir bed to a location on shore. This option would limit the operational capacity of the Tower significantly. Demolishing the Tower to elevation 451 feet would mean that only the lowest 3 inlet valves will remain. Demolishing the Tower to elevation 426 feet, the most likely scenario, would mean that only the lowest 2 inlet valves will remain. Access to the interior of the Tower and valves would only be through the tunnel after valve closure, dewatering the tunnel and providing adequate ventilation for the confined area of tunnel and Tower. Access to the outside of the valves would be provided by diving deeper than 100 feet unless the reservoir is partly drained.

3. PRELIMINARY DESIGNS

Preliminary analysis and design calculations were performed for all of the retrofit and new concepts. The results of these investigations are summarized below

3.1. Option 1: Guyed Cables

One level of tethers

Several cable diameters were investigated, but a 4-inch diameter cable was the basis for the analysis performed by Quest. The analysis is explained and results are provided in the attached report, "Seismic Evaluation of Retrofit Options for Briones Outlet Tower", attached as Appendix B1.

A review of the results indicates that a 4-inch diameter cable is not sufficient to resist the tension loads. While larger diameter cable is available, the support provided by the cables is insufficient because of the limited moment capacity and shear capacity of the existing Tower. The anchoring of the guy cables at Elevation 512 feet results in a concentration of shear that exceeds the allowable capacity. As an example, at Elevation 540 feet, the shear demand is 1700 kips for the MCE, while the capacity is approximately 950 kips; reference page 21 of Quest's report. Moment capacity is consistently less than the demand for the MCE case as shown on page 20 of Quest's report.

Two levels of tethers

As discussed in the report by Quest, "Seismic Evaluation of Guy-Wires with Two Support Levels" attached in Appendix B3, adding another level of tethers did not support the Tower significantly better than the one level of tehers.

Based on the moment and shear demand, further strengthening of the Tower would be required, including the thickening of the Tower and the addition of reinforcement to resist shear and moment. The analyses performed have shown that using guyed cables to strengthen and support the existing Tower is not a feasible retrofit option.

3.2. Option 2: External Supporting Piers and Frame

The 10-foot diameter piers selected for the buttress shafts are considered the practical limits for this design concept due to availability of equipment and cost. A preliminary analysis was performed for the buttressed scheme as shown in Drawing SK-6, Appendix A. For design purposes, an arbitrary 1000 kip load was applied to each elevation of the buttressing frame. The preliminary analysis indicates that the vertical piers are too slender for their height. Based on the preliminary analysis, the Tower is stiffer than the pier framing system. The magnitude of the bending moment in the piers is such that the amount of reinforcement needed in the piers exceeds the maximum allowable percentage of steel for a reinforced beam/column. Therefore, this option was not pursued further in greater detail.

3.3. Option 3: Reinforced Tower and Strengthened Foundation

Details of this option are shown on Drawing SK-1, Appendix A. The ballasting of the foundation with the tremie concrete mitigates the overall flexural and shear demand on the Tower by reducing the cantilevered length of the Tower. In addition, the impact of the overturning moment on the foundation is negated by the ballasting of the footing, resulting in a reduction of the eccentricity on the footing. A preliminary review of the outlet tunnel indicates that the additional ballast will not have a detrimental effect on its structural integrity.

Quest has performed an analysis of this proposal as presented in Appendix B1. Based on the retrofitted design, the retrofitted moment capacity of the structure will be greater than the bending moment acting on the structure from the maximum design earthquake (MDE). The MCE event results in a 40% overstress when the maximum moment is compared to the corresponding maximum capacity of the structure. For an MCE occurrence, the allowable Demand vs. Capacity ratio is 2, thus the retrofitted design has sufficient capacity for the estimated bending moments.

3.4. Option 4: New Connecting Tunnel and Sloping Inlet

The preliminary design of this option was based on the design for the new Lenihan Dam outlet tunnel in Santa Clara County, currently under construction. Since detailed contour information is not available the concept for the new sloping inlet/outlet, shafts and tunnel was laid out as shown in Drawings SK-2 to 4, Appendix A. Shaft and tunnel size and design, and steel tunnel lining thickness were based on similar projects Jacobs Associates have recently designed.

Connecting directly into the existing tunnel proved to be considerably less costly than a new shaft and tunnel. Therefore, only cost estimates for the revised Option 4, the alternative connecting directly into the existing tunnel, were developed.

3.5. Option 5: New Posttensioned Precast Tower

The concept for the new tower straddling the existing tunnel is shown in Drawing SK-5, Appendix A. Since it was not possible to perform a detailed analysis for this option an estimate was made based on the following: Both the mass and stiffness of the precast ring tower would fall somewhere in between that of the existing Tower and the reinforced Tower proposed for Option 3. The results from the analyses for the existing Tower model (Quest, 2006) and for the Option 3 retrofitted model (Appendix B1) for both shear and bending moment were averaged and used to perform the preliminary design. Providing the required shear capacity is one of the critical elements of tower design. The cells of the precast rings, which can be filled with concrete to provide continuity between the rings, play an important role to provide the required shear capacity. In the top rings this additional shear capacity is not required and the added mass of the concrete filled cells are therefore avoided. Benefits of the posttensioning is the added shear capacity due to the prestress of the shaft and the reduction in reinforcing steel because of the higher tensile strength of the tendons.

3.6. Option 6: Partial Demolition of the Existing Tower

The concept for this option consists of partial demolition of the existing Tower and is shown on Drawing SK-7, Appendix A. The analysis performed by Quest is documented in Appendix B2. Preliminary sizing of the steel shaft and platform was done, but no preliminary design or cost estimate was performed since the analysis showed that the option was not viable.

No analysis, design or cost estimates were performed for the more extensive demolition option discussed in the last paragraph of Section 2.7 above.

4. COST ANALYSIS AND COMPARISON

4.1. General

Preliminary cost estimates have been performed for the options that are considered viable and constructable and are summarized in Table 3. Details of the cost estimates for each option are presented in Appendix C. All of the cost estimates include an Owner's contingency of 40%, which is deemed appropriate for this preliminary level of design effort. For the cost estimates it has been assumed that the material excavated from the reservoir bottom by dredging and concrete resulting from demolition of the existing tower can be deposited on the reservoir floor. The estimated additional costs of hauling the dredged material off site were estimated and included for each option.

Table 3: Summary of Estimated Construction Cost for Retrofit Alternatives

Retrofit/New Alternative	Estimated Preliminary Cost (million)
Option 3: Reinforced Tower and Foundation	$29.9
Option 3A: Reinforced Tower and Foundation (partially drained)	$25.2
Option 3B: Reinforced Tower and Foundation (drained)	$15.8
Option 4: New Sloping Inlet into Existing Tunnel	$39.1
Option 4A: New Sloping Inlet into Existing Tunnel (partially drained)	$26.1
Option 4B: New Sloping Inlet into Existing Tunnel (drained)	$17.3
Option 5: New Posttensioned Tower	$41.9
Option 5A: New Posttensioned Tower (partially drained)	$28.2

4.2. Constructability Review

To aid in developing the preliminary cost estimates the District engaged the services of a local contractor, Vortex Marine Construction, Inc. (Vortex). Based on discussions with Vortex it became clear that there is a significant difference between underwater work in water up to a depth of 100 feet versus working at depths beyond 100 feet and up to 230 feet, as would be required for this project. The rates for underwater work provided by Vortex are attached in Appendix C and were used to develop the cost estimates for the undrained (3, 4 and 5) and partially dewatered (3A, 4A and 5A) options.

4.3. Discussion

The original options, 3, 4 and 5 considered construction on the Tower with the reservoir full. Because of the high cost of the undrained underwater work additional options, 3A, 4A, and 5A were developed, assuming partial dewatering and refilling the reservoir to allow construction in water not exceeding 100 feet in depth.

Options 3B and 4B, considering the reservoir fully drained and including the cost of refilling the reservoir, were ruled out due to the unacceptably high risk to the District supply system and are shown for completeness only (see the discussion in Section 2.1).

Undrained Options

Option 3, strengthening of the existing Tower, is the lowest estimated cost option at a cost of $29.9 million. The advantage of this option is that the work is fairly well defined since it consists of strengthening an existing structure and the risk is therefore also more limited. The disadvantage of this option is working around the existing valves and having to be able to provide the District with operational functionality at 48 hour notice during most of the construction period.

The estimated construction cost of the new sloping inlet pipe of Option 4 is approximately 31% higher than that of Option 3. The advantage of this option is that it is all new construction which can take place without interfering with the operation of the existing inlet/outlet works. The risk associated with this option is the shaft excavation up to the existing tunnel and the connection of the shaft to the existing tunnel. These activities will occur under the full reservoir head and the permeability of the rock mass and potential for groundwater inflows could require pre-excavation grouting and impact the work.

The estimated construction cost of the new posttensioned tower of Option 5 is approximately 40% higher than that of Option 3. The advantage of this option is that it is all new construction which can take place without interfering with the operation of the existing inlet/outlet works. The risk associated with this option is the under water excavation of the foundation around the existing tunnel.

Partially Dewatered Options

Option 3A, strengthening of the existing Tower, is again the lowest estimated cost option at a cost of $25.2 million. The reduction in estimated cost due to partial dewatering is approximately 16% compared to Option 3.

The estimated construction cost of the new sloping inlet pipe of Option 4A is approximately 4% higher than that of Option 3A.

The estimated construction cost of the new posttensioned tower of Option 5A is approximately 12% higher than that of Option 3A.

When partial dewatering is considered the estimated cost of Options 3A and 4A are roughly equal. In this case the new sloping inlet would be the preferred choice since it provides a new inlet/outlet facility with very low seismic vulnerability.

5. CONCLUSIONS

Six potential retrofit options have been investigated and the three most viable conceptual designs for the retrofit or replacement of the Briones Outlet Tower have been identified. The three most feasible alternatives have been discussed; preliminary designs performed, and estimated construction cost comparisons presented. Since it is not considered advisable to drain the reservoir for Tower retrofit construction, work will be performed from barges and divers will have to be employed for all alternatives. If partially draining the reservoir is acceptable, the cost of underwater work is significantly reduced and more options are cost effective.

Based on the preliminary designs and cost estimates presented, the strengthening of the existing structure, Option 3, appears to be the most economical alternative to retrofit the Briones Tower. There are operational benefits to constructing new inlet/outlet works and if the replacement of the existing valves and actuators are considered, the difference in estimated cost between Options 3 and 4 would be significantly less.

Preliminary designs for the most feasible Options 3, 4 and 5 have been performed. During the final design all of these options should be analyzed and designed in more detail to optimize the designs and make a more detailed comparison of not only the cost, but also constructability, operational functionality, seismic vulnerability and long term performance issues.

6. REFERENCES

Quest Structures, Inc. (2007), “Seismic Evaluation of Briones Outlet Tower.”

USACE (2003), EM 1110-2-2400 “Structural Design and Evaluation of Outlet Works.”

APPENDIX A: DRAWINGS

As-Built Drawings

Drawing No. 4404-G-1: Outlet Tower Plan & Elevations

Drawing No. 4404-G-2: Outlet Tower Sections

Drawings Showing Retrofit Options

Drawing No. SK-1 Option 3: Elevations, Sections and Details

Drawing No. SK-2 Option 4: General Plan

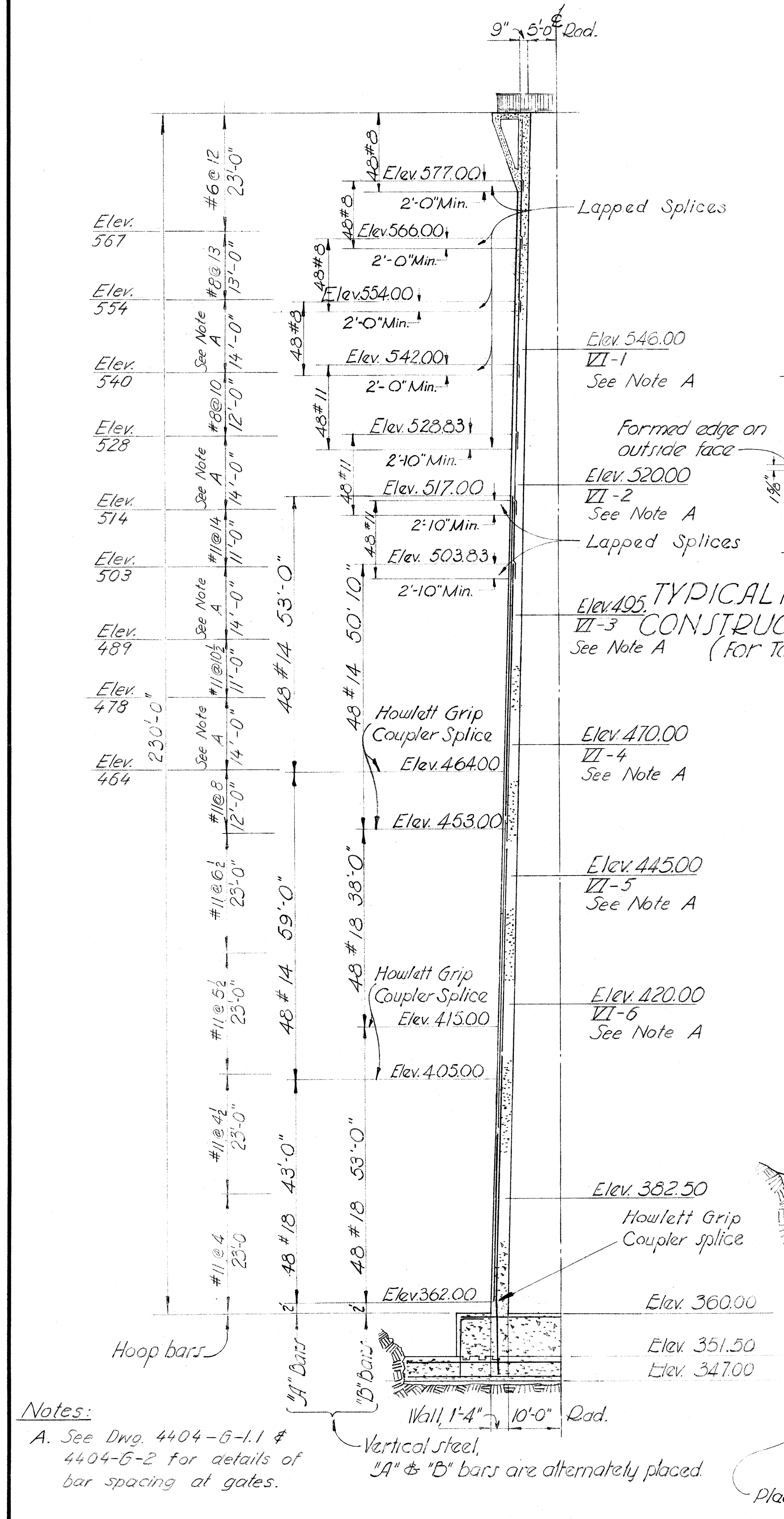
Drawing No. SK-3 Option 4: Section along Inclined Pipe

Drawing No. SK-4 Option 4 Details

Drawing No. SK-5 Option 5: Elevation and Details

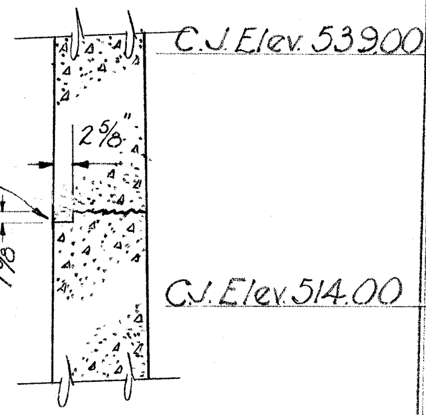
Drawing No. SK-6 Option 2: External Supporting Piers and Frame

Drawing No. SK-7 Option 6: Partial Demolition of Existing Tower

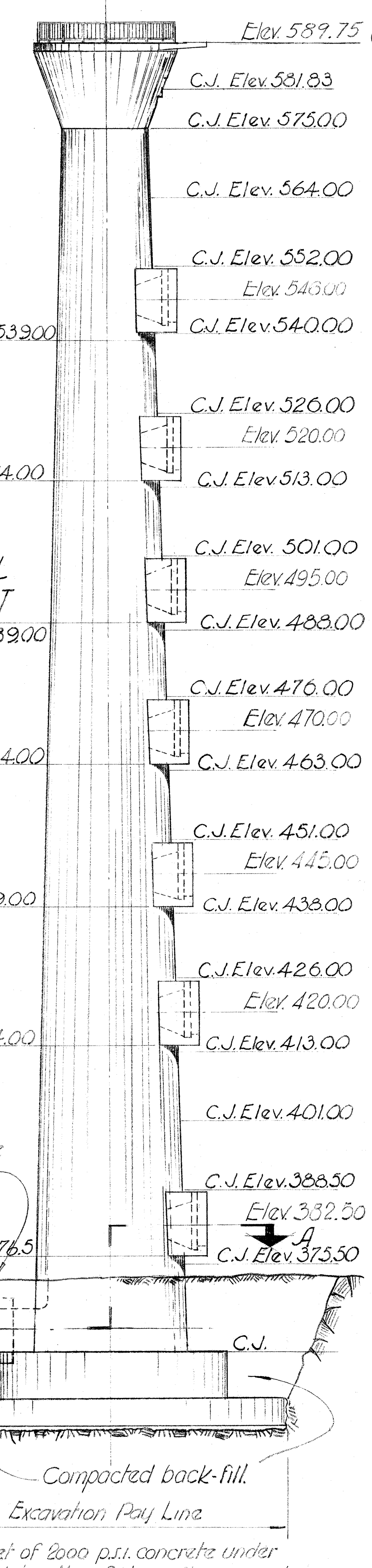


Notes:
A. See Dwg. 4404-G-1.1 & 4404-G-2 for details of bar spacing at gates.

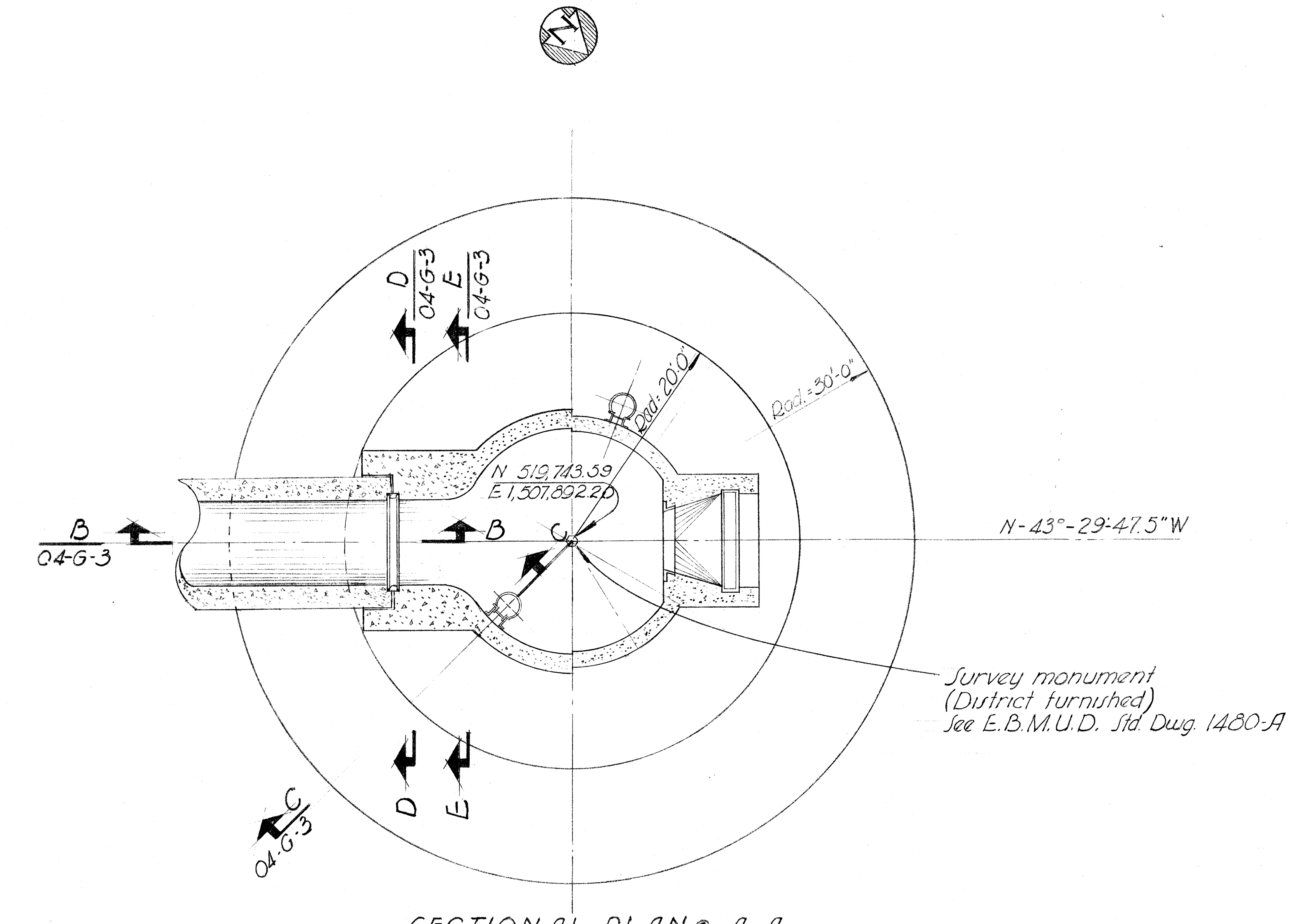
TYPICAL WALL REINFORCING
1/16" = 1'-0"



TYPICAL HORIZONTAL CONSTRUCTION JOINT
(For Tower)



EAST ELEVATION
1/16" = 1'-0"



SECTIONAL PLAN @ A-A
1/8" = 1'-0"

GENERAL NOTES

1. Unless otherwise noted, all ferrous metals (except stainless steel & reinforcing bars) below elev 581.00 in Outlet Tower & elev. 602.50 in Valve Access shaft shall be coated with tarset. Coating shall be shop applied wherever practicable & touched up in the field.
2. All reinforced concrete construction shall be in accordance with section 3 of the specifications.
3. Concrete shall have a minimum compressive strength of 3000 p.s.i. @ 28 days unless otherwise noted.
4. Reinforcing steel shall be deformed bars of intermediate grade.
5. Reinforcing bars in unformed surfaces against ground shall have 3" concrete cover. All other bars shall have 2" cover unless noted otherwise.
6. Spliced bars shall lap a minimum of 24 bar diameters but not less than 12"
7. Right angled hooks shall have a radius of bend of 4 bar diameters plus an extension of 12 bar diameters
8. All exposed corners shall be chamfered 3/4"
9. All structural steel shall be in accordance with the current A.I.S.C. Specifications & A.S.T.M. Spec. A-7
10. All exposed structural steel & embedded steel members shall be galvanized as outlined in the specifications unless otherwise noted.
11. For water-stops see specifications.
12. Verify all equipment dimensions with Vendors Drawings or existing equipment.

OUTLET TOWER NOTES

1. All concrete above elevation 360.00 shall develop f'_c of 4000 p.s.i in 28 days. Below elev. 360.00 conc. shall develop f'_c of 3000 p.s.i in 28 days unless noted.
2. All splices in hoop bars shall be staggered 120°
3. Minimum cover of reinforcing shall be 2" unless noted.
4. All anchor bolts & other embedded metal must be kept 2" minimum clear of all reinforcing steel & have no metal to metal contact with reinforcing steel
5. Welds in reinforcing steel where shown shall develop full strength of the bar.
6. For locations of pipe supports & electrical inserts see Dwgs 04-G-8, 04-G-10, 04-G-11, & 04-G-13.
7. No vertical contruction joints shall be allowed unless shown on dwg's.
8. Elevations indicated by (S) were established from precise level survey of June 1965. Ref. EBMUD precise level volumes 65, 139, 146, 147 & F.B. 3449-A.

GRAPHIC SCALES
1/8" = 1'-0": 0 5 10 15 20
1/16" = 1'-0": 0 10 20 30 40

REGISTERED PROFESSIONAL ENGINEER — WILLIAM BERTELL — No. 6109 — CIVIL — STATE OF CALIFORNIA

NO.	DATE	REVISION		
1	1-15-65	Revised As-Built	T.G.	

KAISER ENGINEERS
DIVISION OF HENRY J. KAISER COMPANY
OAKLAND CALIFORNIA

APPROVED — CHIEF ENGINEER R.E. No. 969

DESIGNED BY	P.R. FLORENCE
DRAWN BY	E.A. O'DELL
CHECKED BY	E.F. NIELSEN
CORROSION CHECK BY	
PROJECT ENGR.	
MANAGER DESIGN ENGRG.	
MANAGER WATER PROD. & DIST.	

EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND, CALIFORNIA

BRIONES DAM
OUTLET TOWER
PLAN & ELEVATIONS

STRUCTURE OR ZONE DESIGNATION	521
SCALE	As shown
DATE	3-4-63

4404-G-1

DIETERICH-POST CLEARPRINT 1000 H

NO.	DATE	REVISION		
1	1-19-65	Revised As-Built	T.G.	

KAISER ENGINEERS
DIVISION OF HENRY J. KAISER COMPANY
OAKLAND CALIFORNIA

APPROVED J. McCosta CHIEF ENGINEER R. E. No. 969

DESIGNED BY P.P. FLORENCE
DRAWN BY E.A. O'DELL
CHECKED BY E.F. NIELSEN
CORROSION CHECK BY
PROJECT ENGR. W. H. Ball 3-4-60
MANAGER DESIGN ENGRG.
MANAGER WATER PROD. & DIST.

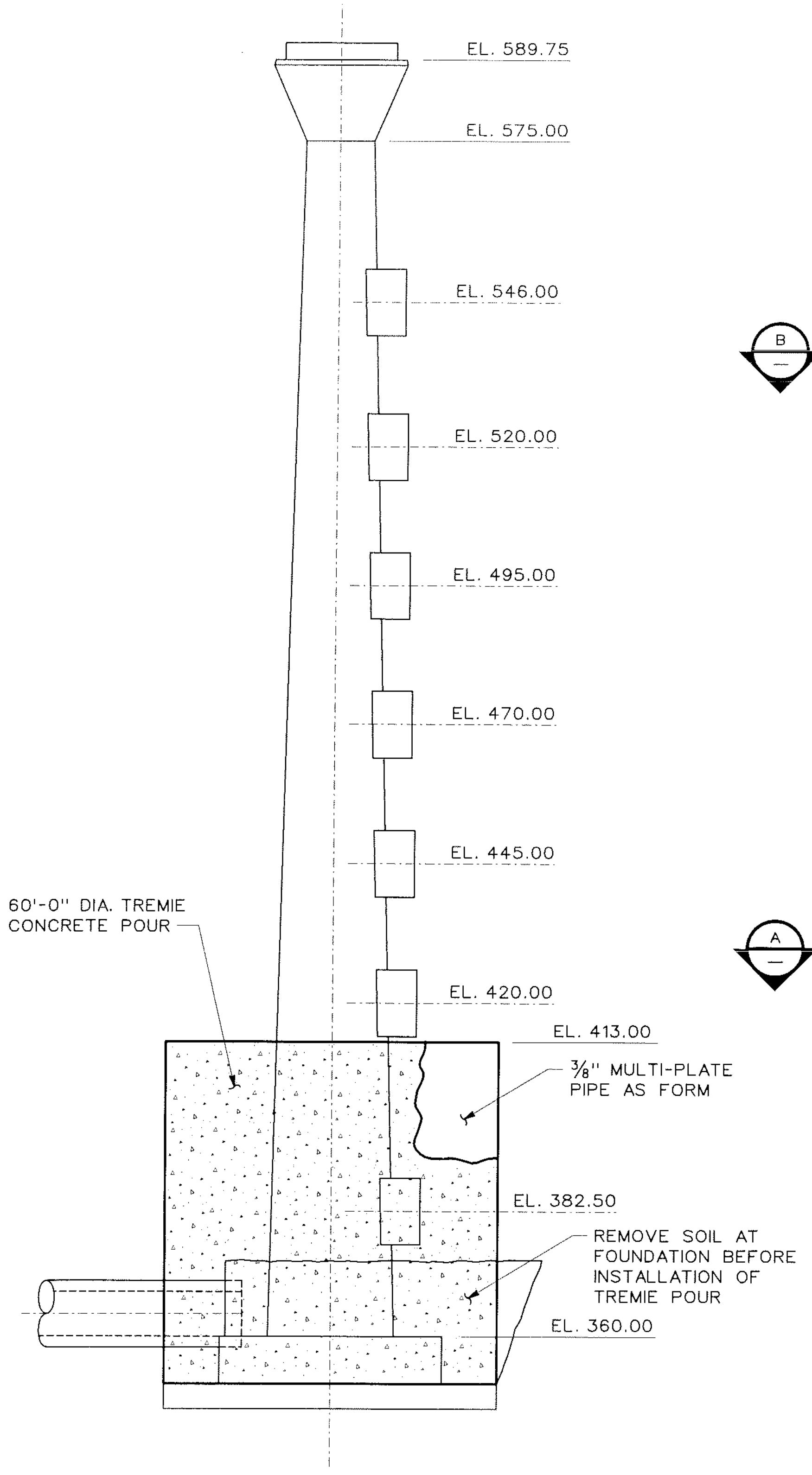
EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND, CALIFORNIA

BRIONES DAM
OUTLET TOWER
SECTIONS

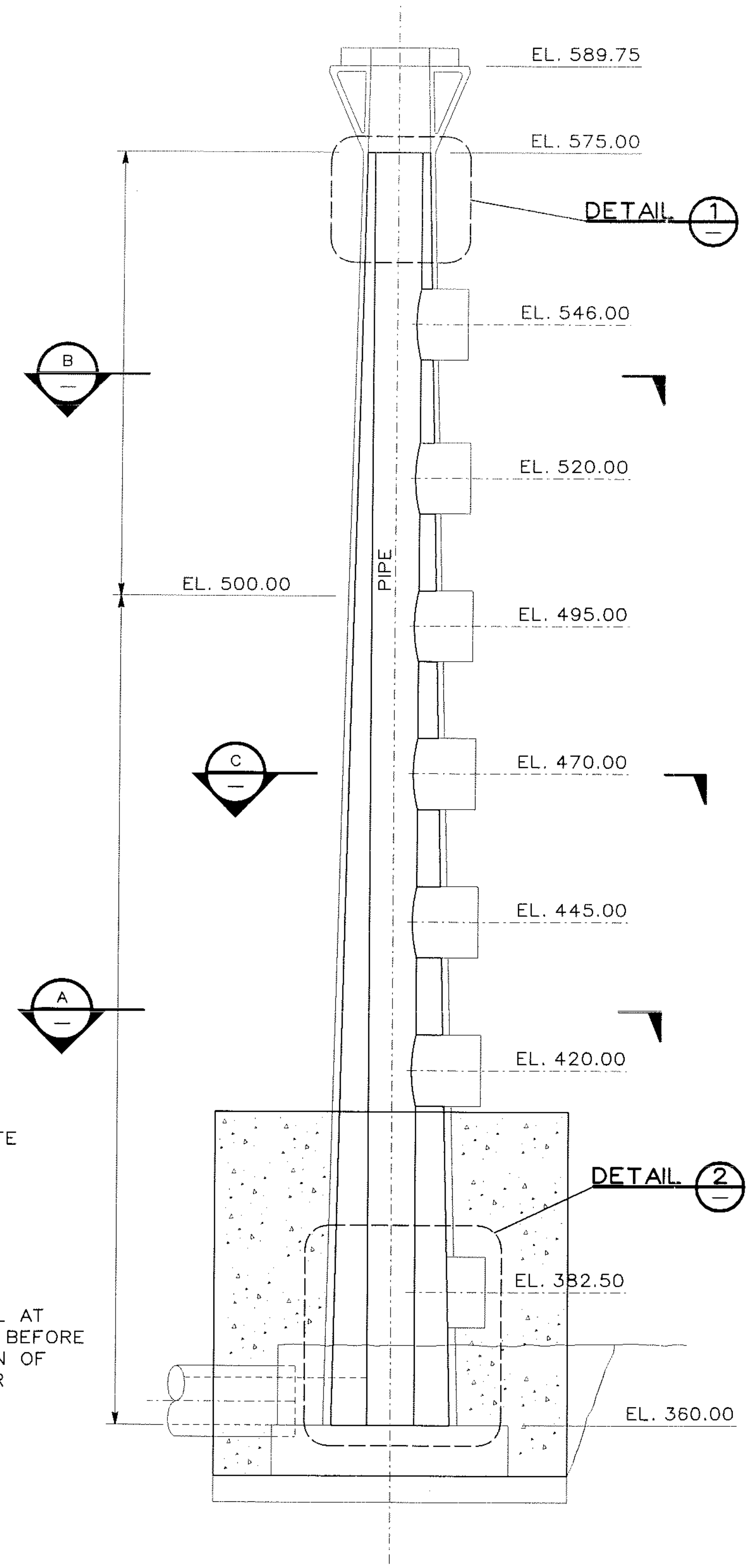
STRUCTURE OR ZONE DESIGNATION 521
SCALE As shown
DATE 3-4-60

4404-G-2

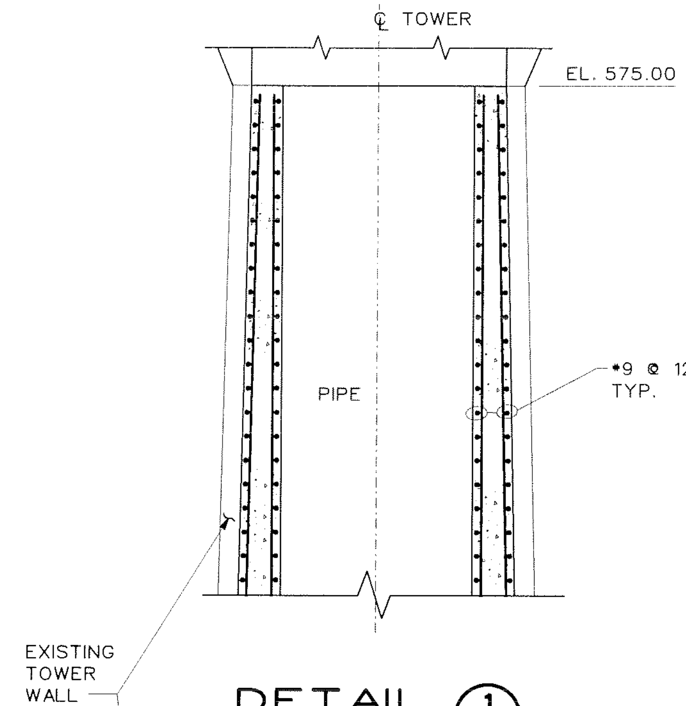
DIETERICH-POST CLEARPRINT 1000 H



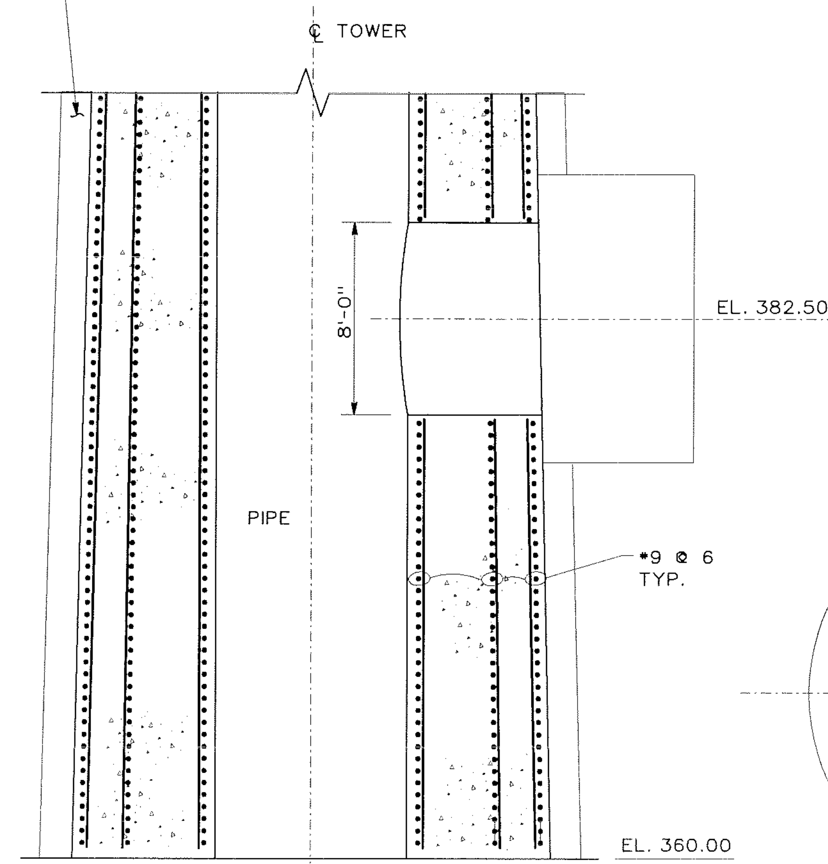
ELEVATION OF TOWER
SCALE: 1/16"-1'-0"



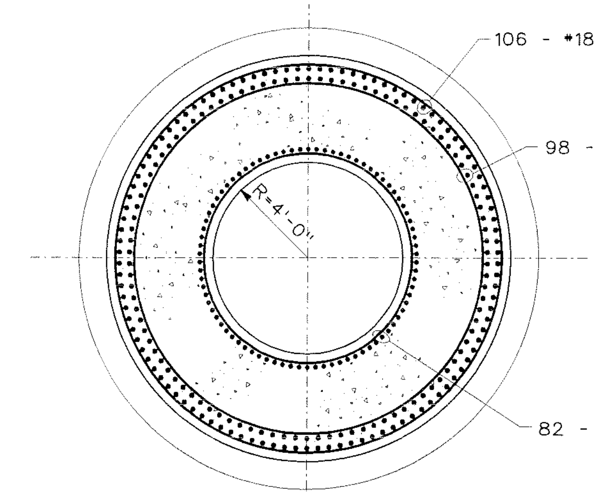
SECTION THROUGH TOWER
SCALE: 1/16"-1'-0"



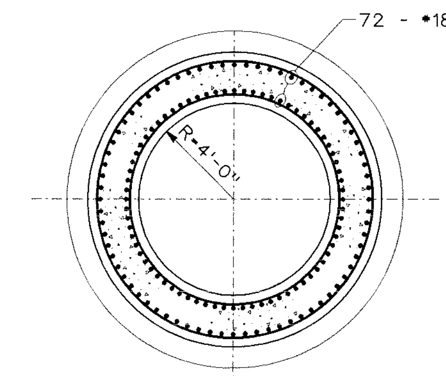
DETAIL 1
SCALE: 1/4"-1'-0"



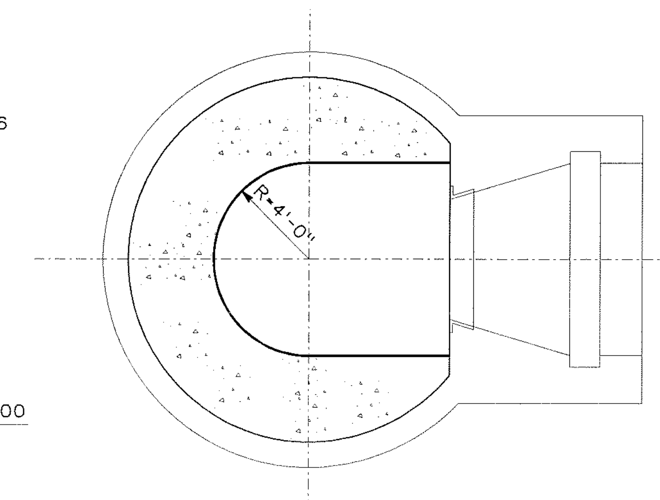
DETAIL 2
SCALE: 1/4"-1'-0"



SECTION A
SCALE: 1/4"-1'-0"



SECTION B
SCALE: 1/4"-1'-0"



SECTION C
SCALE: 1/4"-1'-0"

REBAR NOT SHOWN FOR CLARITY

DESCRIPTION	BY	CK.	APP.	DATE	DESCRIPTION	BY	CK.	APP.	DATE

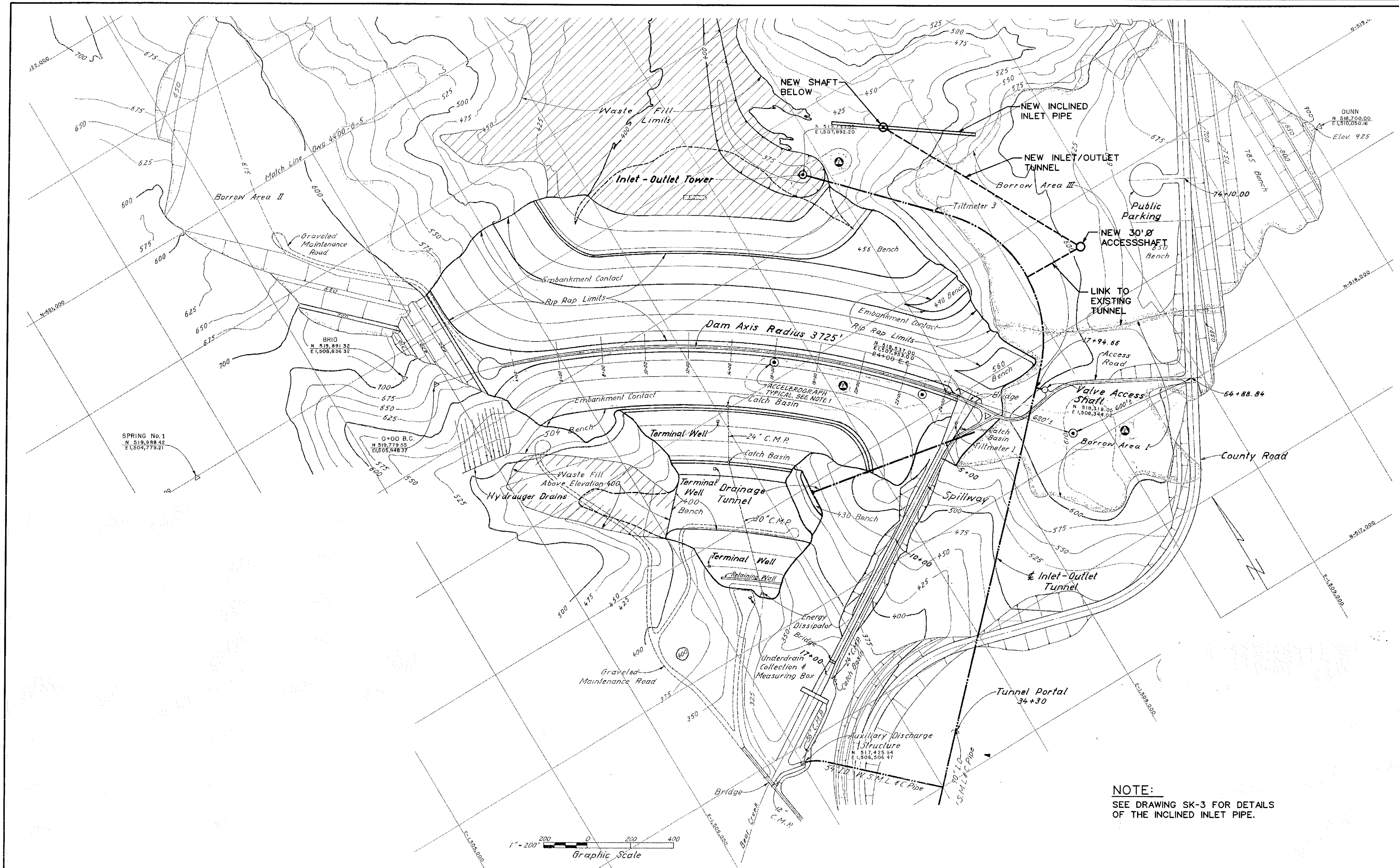
DRAWN BY	D. HALL	05-08
CHECKED	M. HOLLERAN	05-08
APPROVED		

JACOBS ASSOCIATES
Engineers/Consultants

EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND, CALIFORNIA

BRIONES DAM INLET/OUTLET TOWER RETROFIT
OPTION 3: ELEVATIONS, SECTIONS AND DETAILS

SCALE	AS NOTED
JOB NUMBER	3876.1
DRAWING NUMBER	SK-1
REV.	0



NOTE:
SEE DRAWING SK-3 FOR DETAILS OF THE INCLINED INLET PIPE.

DESCRIPTION	BY	CK.	APP.	DATE	DESCRIPTION	BY	CK.	APP.	DATE
REVISIONS					REVISIONS				

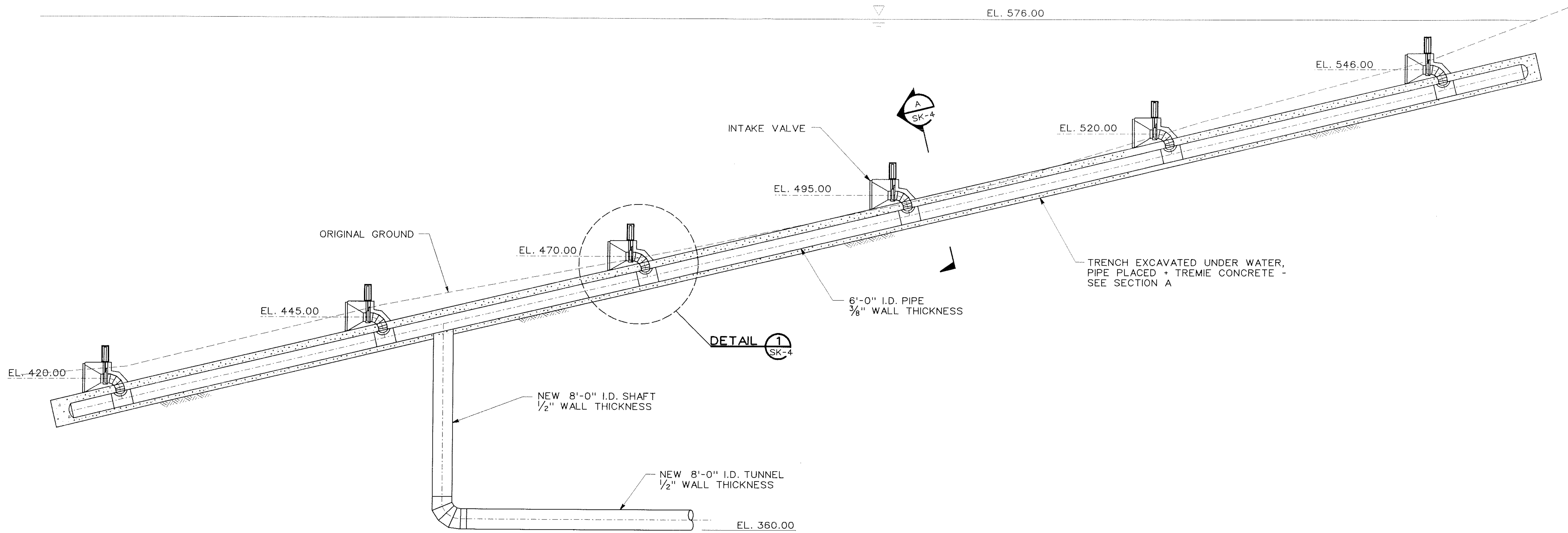
DRAWN BY	D. HALL	05-08
CHECKED	J.V. GREUNEN	05-08
APPROVED		

JACOBS ASSOCIATES
Engineers/Consultants

EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND, CALIFORNIA

BRIONES DAM INLET/OUTLET TOWER RETROFIT
OPTION 4: GENERAL PLAN

SCALE 1" = 200'-0"
JOB NUMBER 3876.1
DRAWING NUMBER SK-2
REV. 0



SECTION ALONG INCLINED PIPE

SCALE: 1"=20'-0"

DESCRIPTION	BY	CK.	APP.	DATE	DESCRIPTION	BY	CK.	APP.	DATE

REVISIONS

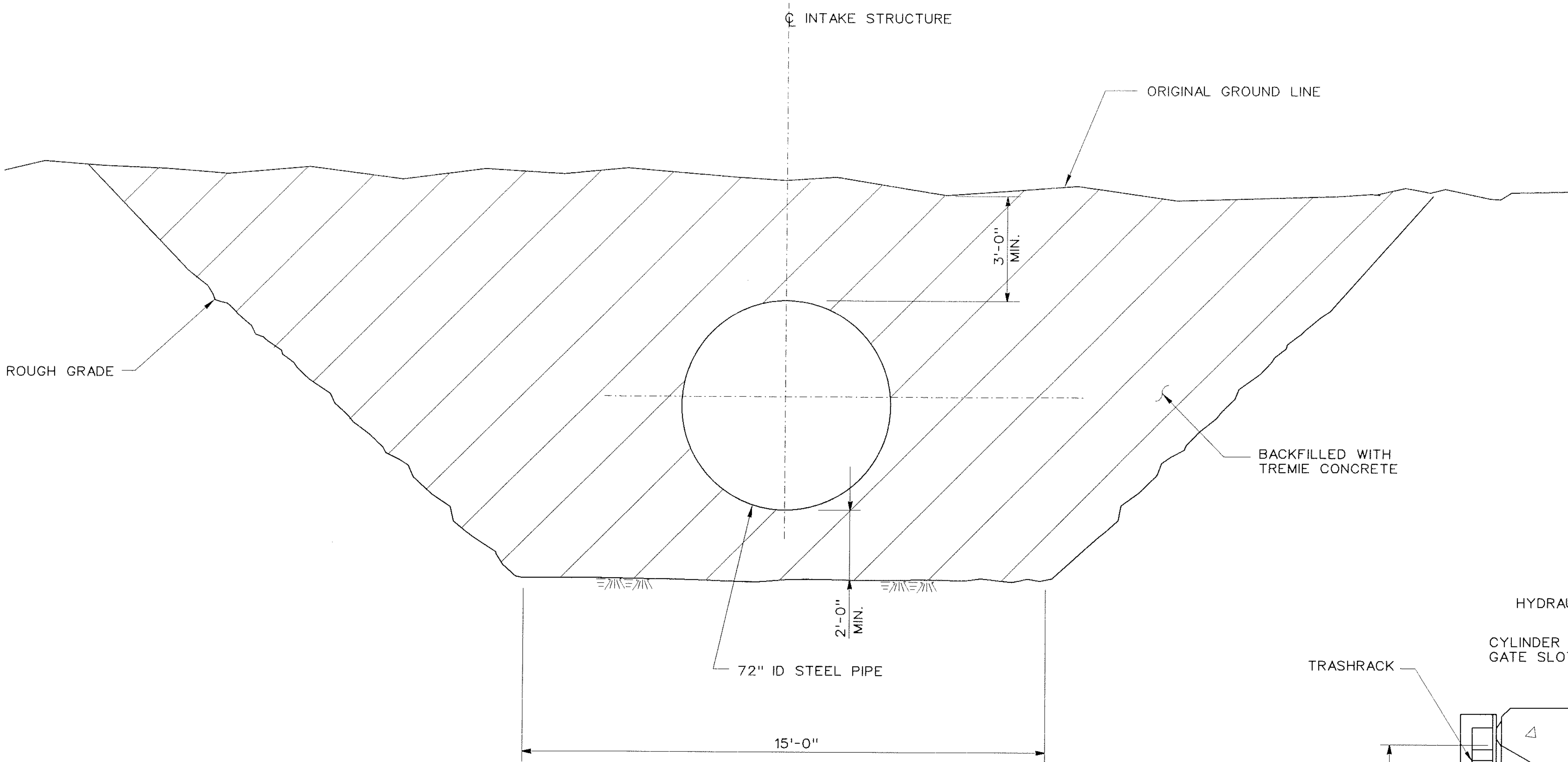
DRAWN BY	D. HALL	05-08
CHECKED	J.V. GREUNEN	05-08
APPROVED		

JACOBS ASSOCIATES
Engineers/Consultants

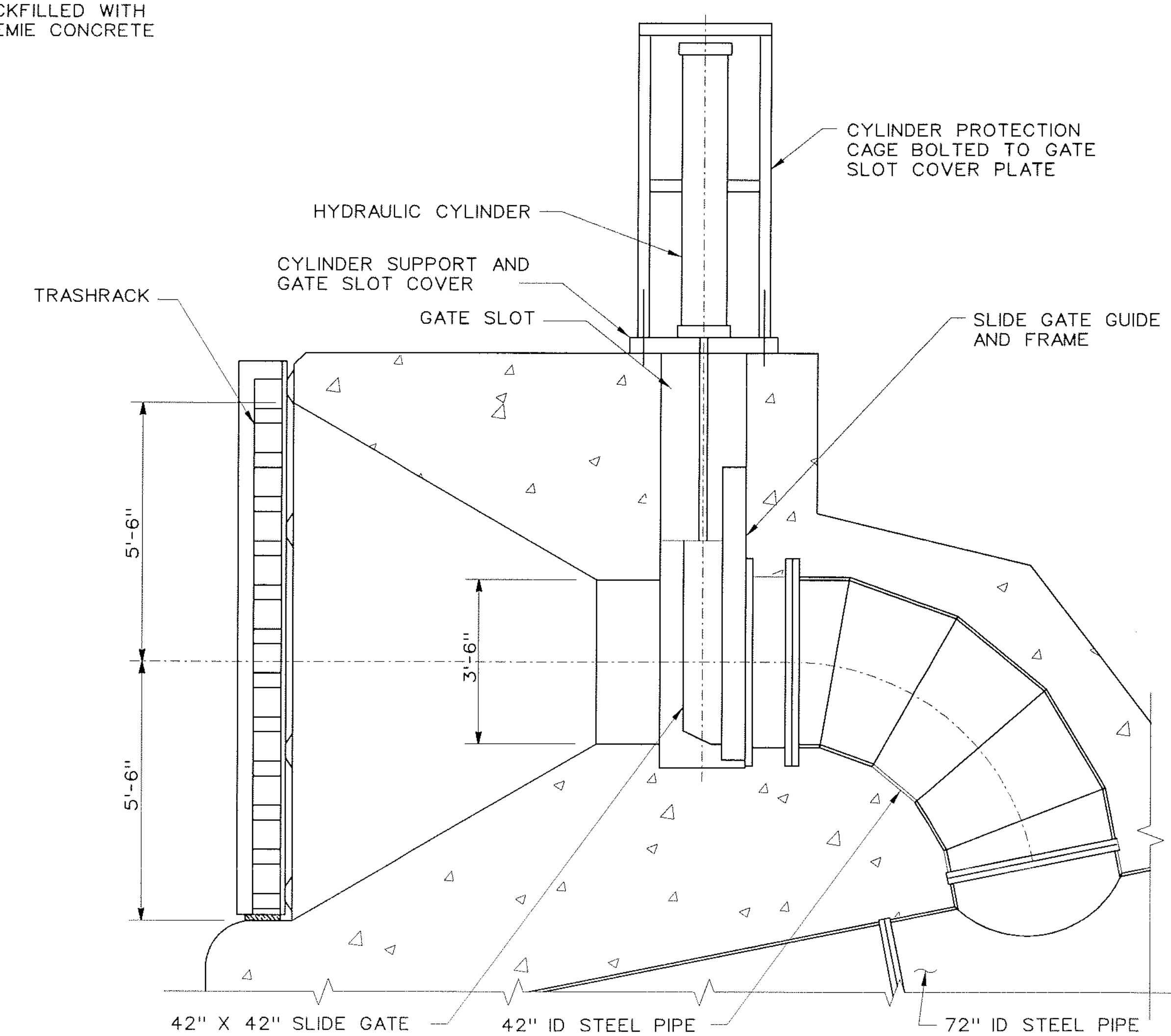
EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND, CALIFORNIA

BRIONES DAM INLET/OUTLET TOWER RETROFIT
OPTION 4: SECTION ALONG INCLINED PIPE

SCALE AS NOTED
JOB NUMBER 3876.1
DRAWING NUMBER SK-3
REV. 0



SECTION A / SK-3
SCALE: 1/23"-1'-0"



DETAIL 1 / SK-3
SCALE: ½"-1'-0"

DESCRIPTION	BY	CK.	APP.	DATE	DESCRIPTION	BY	CK.	APP.	DATE
REVISIONS					REVISIONS				

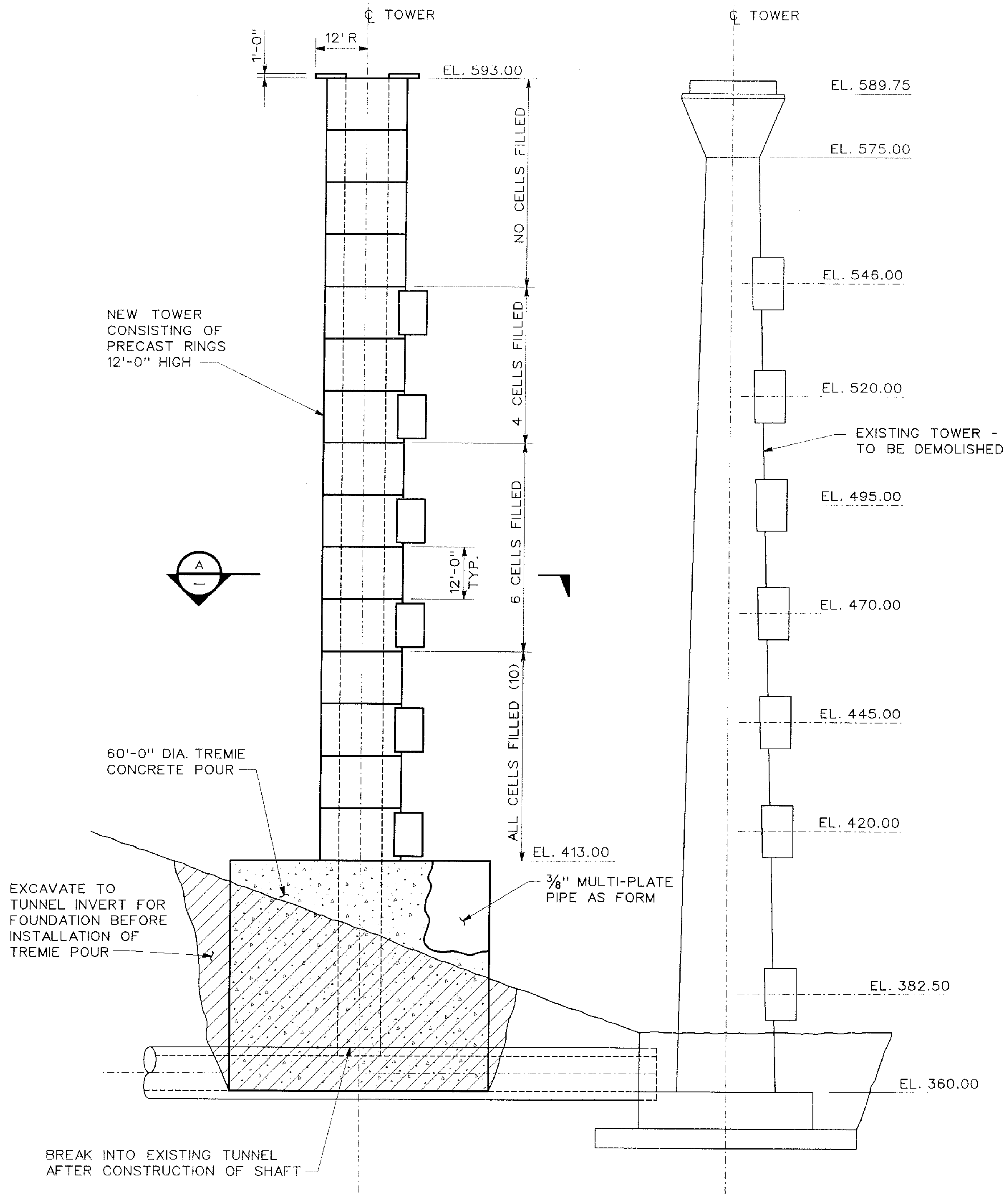
DRAWN BY	D. HALL	05-08
CHECKED	J.V. GREUNEN	05-08
APPROVED		

JACOBS ASSOCIATES
Engineers/Consultants

EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND, CALIFORNIA

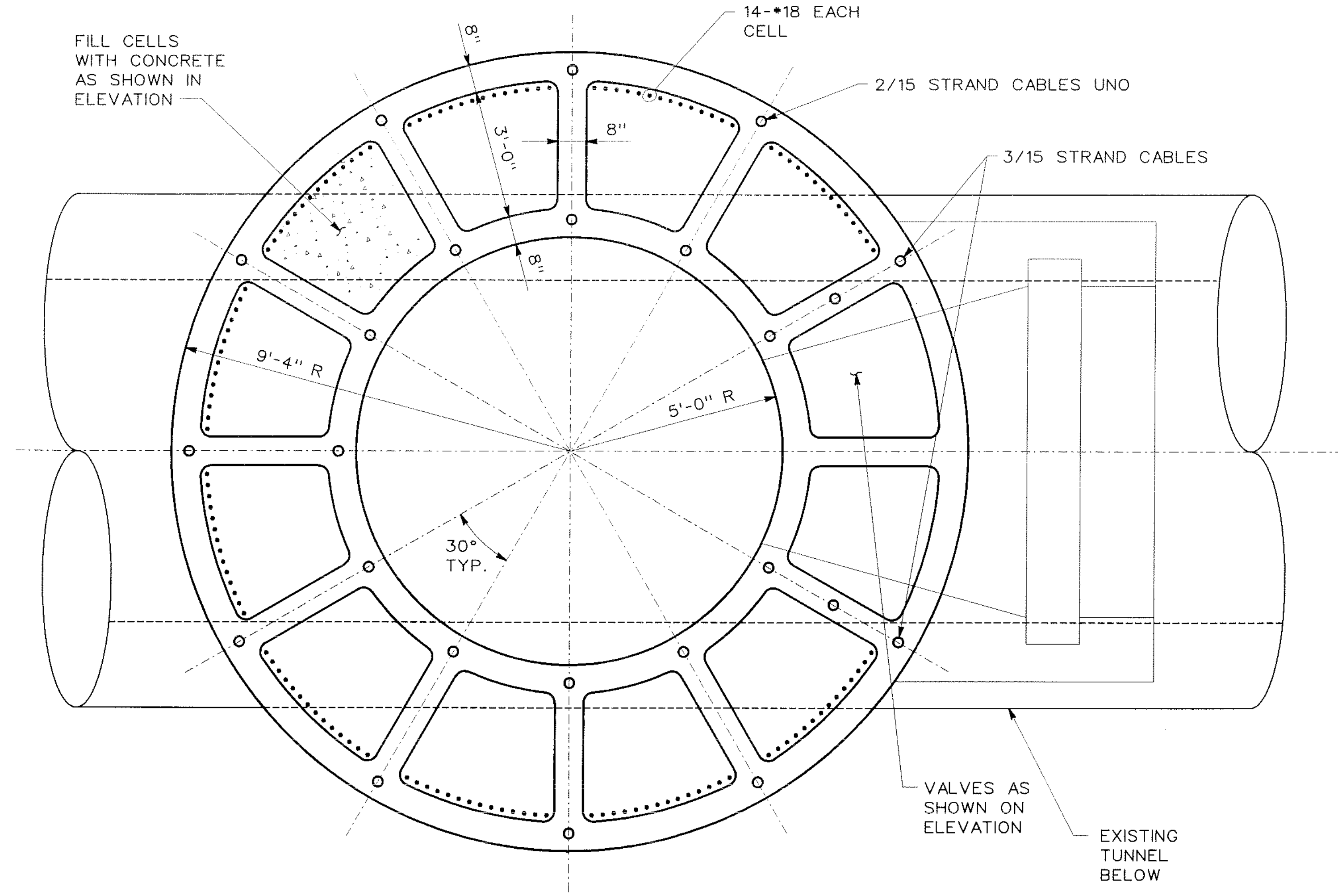
BRIONES DAM INLET/OUTLET TOWER RETROFIT
OPTION 4: DETAILS

SCALE AS NOTED
JOB NUMBER 3876.1
DRAWING NUMBER SK-4
REV. 0



ELEVATION OF TOWERS

SCALE: 1/16"=1'-0"



SECTION (A)

SCALE: 1/2"=1'-0"

NOTE:

CABLES LOOPED IN FOUNDATION THREADED AND STRESSED AFTER ALL RINGS HAVE BEEN PLACED.

REVISIONS: DESCRIPTION	BY	CK.	APP.	DATE	REVISIONS: DESCRIPTION	BY	CK.	APP.	DATE

DRAWN BY	D. HALL	05-08
CHECKED	J.V. GREUNEN	05-08
APPROVED		

JACOBS ASSOCIATES

Engineers/Consultants

EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND, CALIFORNIA

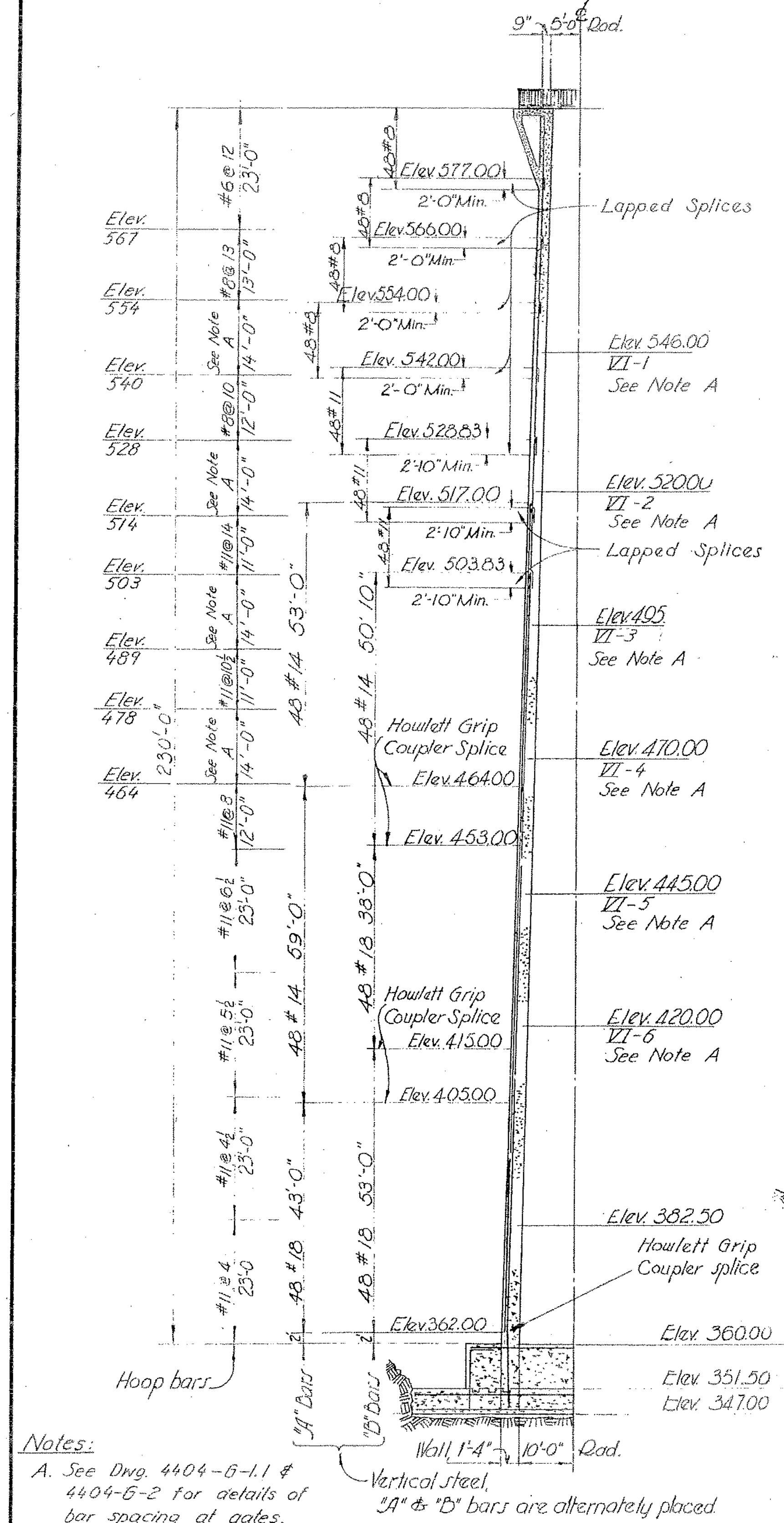
BRIONES DAM INLET/OUTLET TOWER RETROFIT
OPTION 5: ELEVATION AND DETAILS

SCALE: AS NOTED

JOB NUMBER: 3876.1

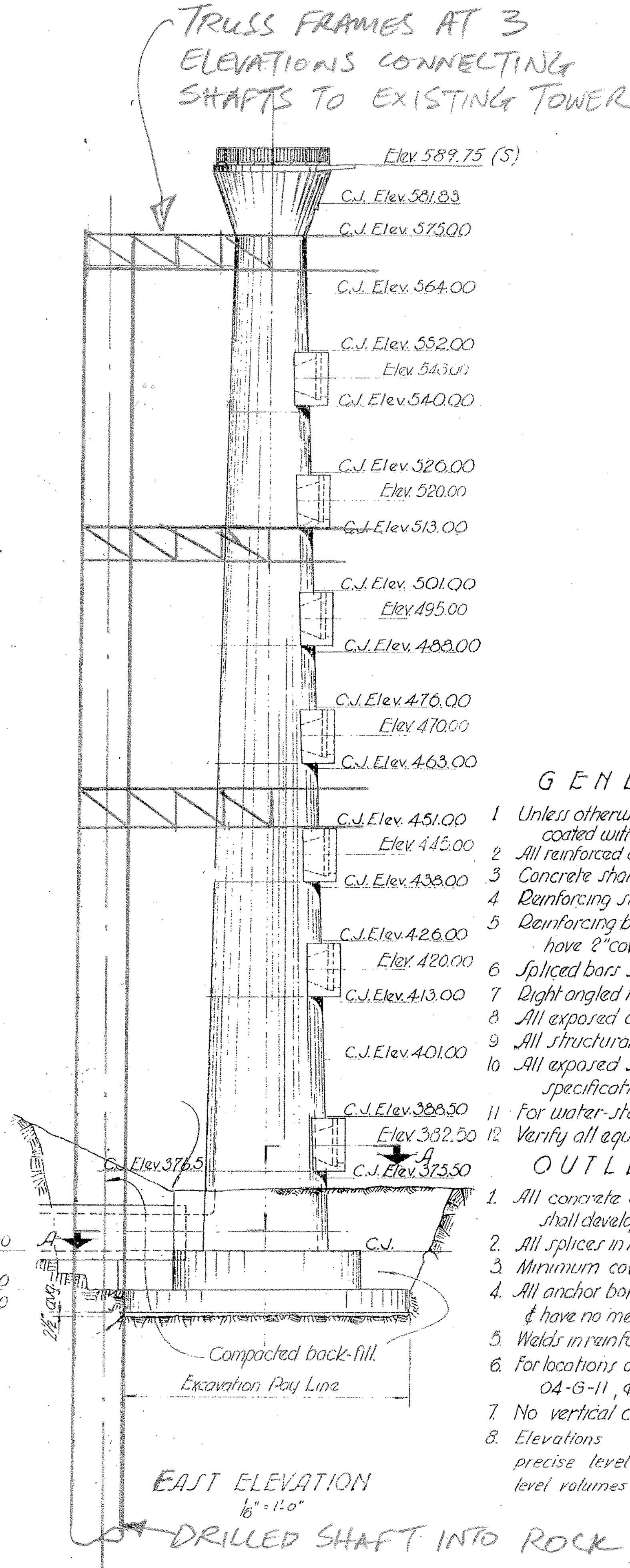
DRAWING NUMBER: SK-5

REV.: 0

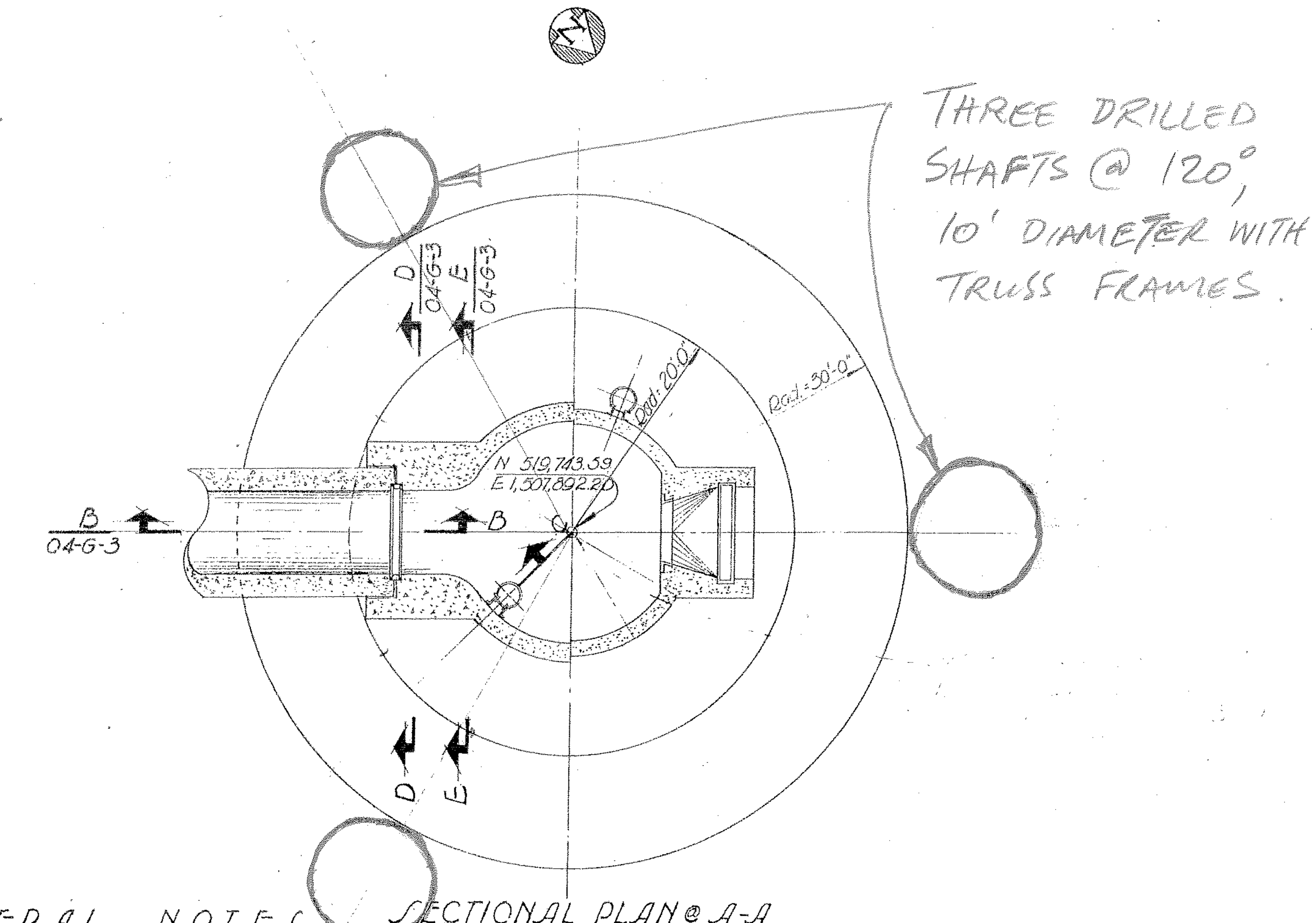


Notes:
A. See Dwg. 4404-G-1.1 & 4404-G-2 for details of bar spacing at gates.

TYPICAL WALL REINFORCING
1/16" = 1'-0"



EAST ELEVATION
1/16" = 1'-0"



SECTIONAL PLAN @ A-A
1/8" = 1'-0"

GENERAL NOTES

1 Unless otherwise noted, all ferrous metals (except stainless steel & reinforcing bars) below elev 581.00 in Outlet Tower & elev. 602.50 in Valve Access shaft shall be coated with tarset. Coating shall be shop applied wherever practicable & touched up in the field.
2 All reinforced concrete construction shall be in accordance with section 3 of the specifications.
3 Concrete shall have a minimum compressive strength of 3000 p.s.i. @ 28 days unless otherwise noted.
4 Reinforcing steel shall be deformed bars of intermediate grade.
5 Reinforcing bars in unformed surfaces against ground shall have 3" concrete cover. All other bars shall have 2" cover unless noted otherwise.
6 Spliced bars shall lap a minimum of 24 bar diameters but not less than 12"
7 Right angled hooks shall have a radius of bend of 4 bar diameters plus an extension of 12 bar diameters
8 All exposed corners shall be chamfered 3/4"
9 All structural steel shall be in accordance with the current A.I.S.C. Specifications & A.S.T.M. Spec. A-7
10 All exposed structural steel & embedded steel members shall be galvanized as outlined in the specifications unless otherwise noted.
11 For water-stops see specifications.
12 Verify all equipment dimensions with Vendors Drawings or existing equipment.

GRAPHIC SCALES
1/8" = 1'-0": 1 0 5 10 15 20
1/16" = 1'-0": 1 0 10 20 30 40

OUTLET TOWER NOTES

1. All concrete above elevation 360.00 shall develop f'_c of 4000 p.s.i in 28 days. Below elev. 360.00 conc. shall develop f'_c of 3000 p.s.i in 28 days unless noted.
2. All splices in hoop bars shall be staggered 120°
3. Minimum cover of reinforcing shall be 2" unless noted.
4. All anchor bolts & other embedded metal must be kept 2" minimum clear of all reinforcing steel & have no metal to metal contact with reinforcing steel
5. Welds in reinforcing steel where shown shall develop full strength of the bar.
6. For locations of pipe supports & electrical inserts see Dwgs 04-G-8, 04-G-10, 04-G-11, & 04-G-13.
7. No vertical construction joints shall be allowed unless shown on dwg's.
8. Elevations indicated by (S) were established from precise level survey of June 1965. Ref. EBMUD precise level volumes 65, 139, 146, 147 & F.B. 3449-A.

REGISTERED PROFESSIONAL ENGINEER — WILLIAM BENTVELL — No. 6109 — CIVIL — STATE OF CALIFORNIA

NO.	DATE	REVISION		
5	1-15-65	Revised As-Built	T.G.	

KAISER ENGINEERS
DIVISION OF HENRY J. KAISER COMPANY
OAKLAND CALIFORNIA

APPROVED ______ CHIEF ENGINEER R. E. No. 989

DESIGNED BY	P.R. FLORENCE
DRAWN BY	E.A. O'DELL
CHECKED BY	E.F. NIELSEN
CORROSION CHECK BY	
PROJECT ENGR.	3-4-60
MANAGER DESIGN ENGRG	
MANAGER WATER PROD. & DIST.	

EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND, CALIFORNIA

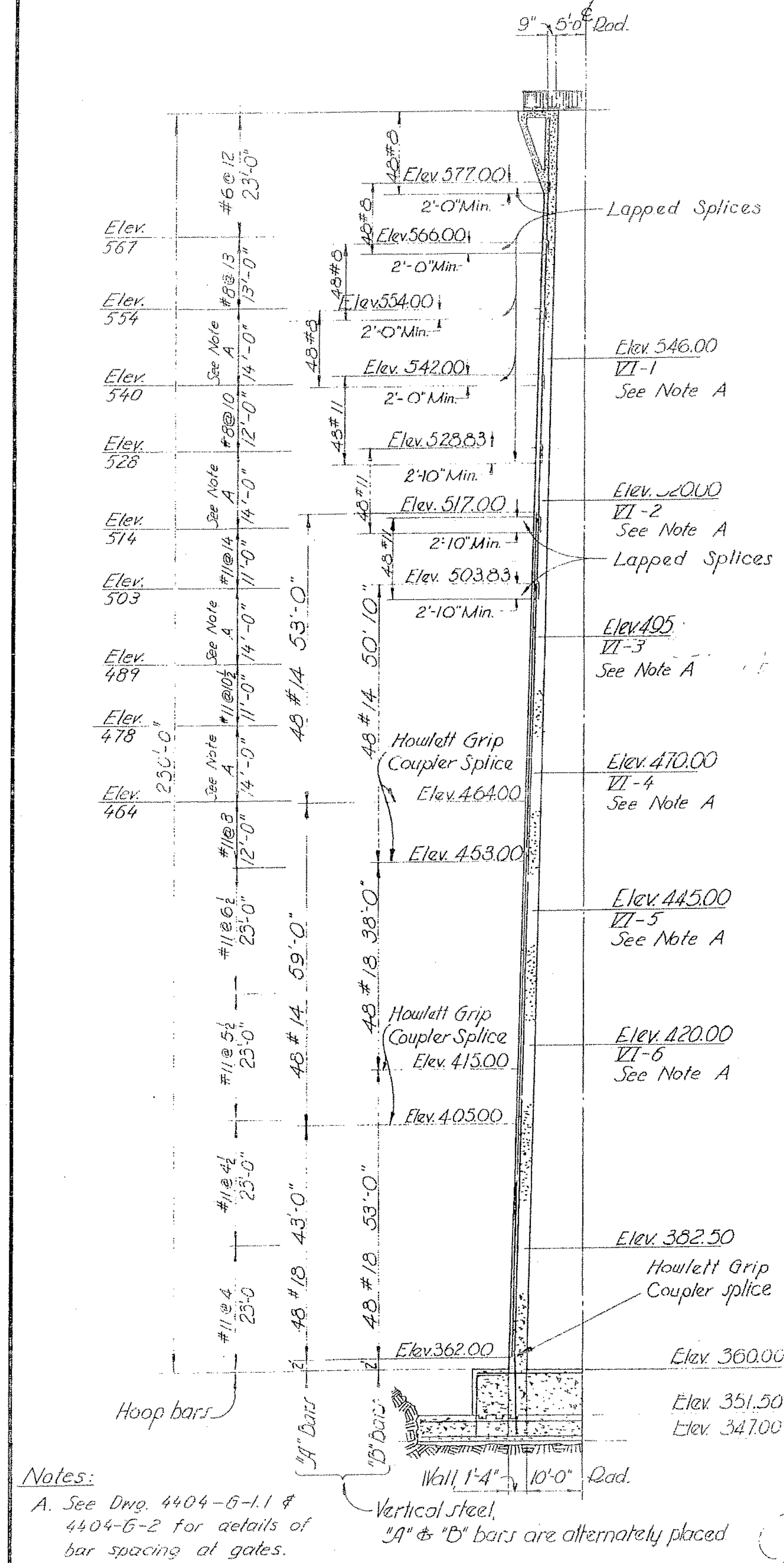
BRIONES DAM
OUTLET TOWER
PLAN & ELEVATIONS

STRUCTURE OR ZONE DESIGNATION	521
SCALE	As shown
DATE	3-4-60

4404-G-1

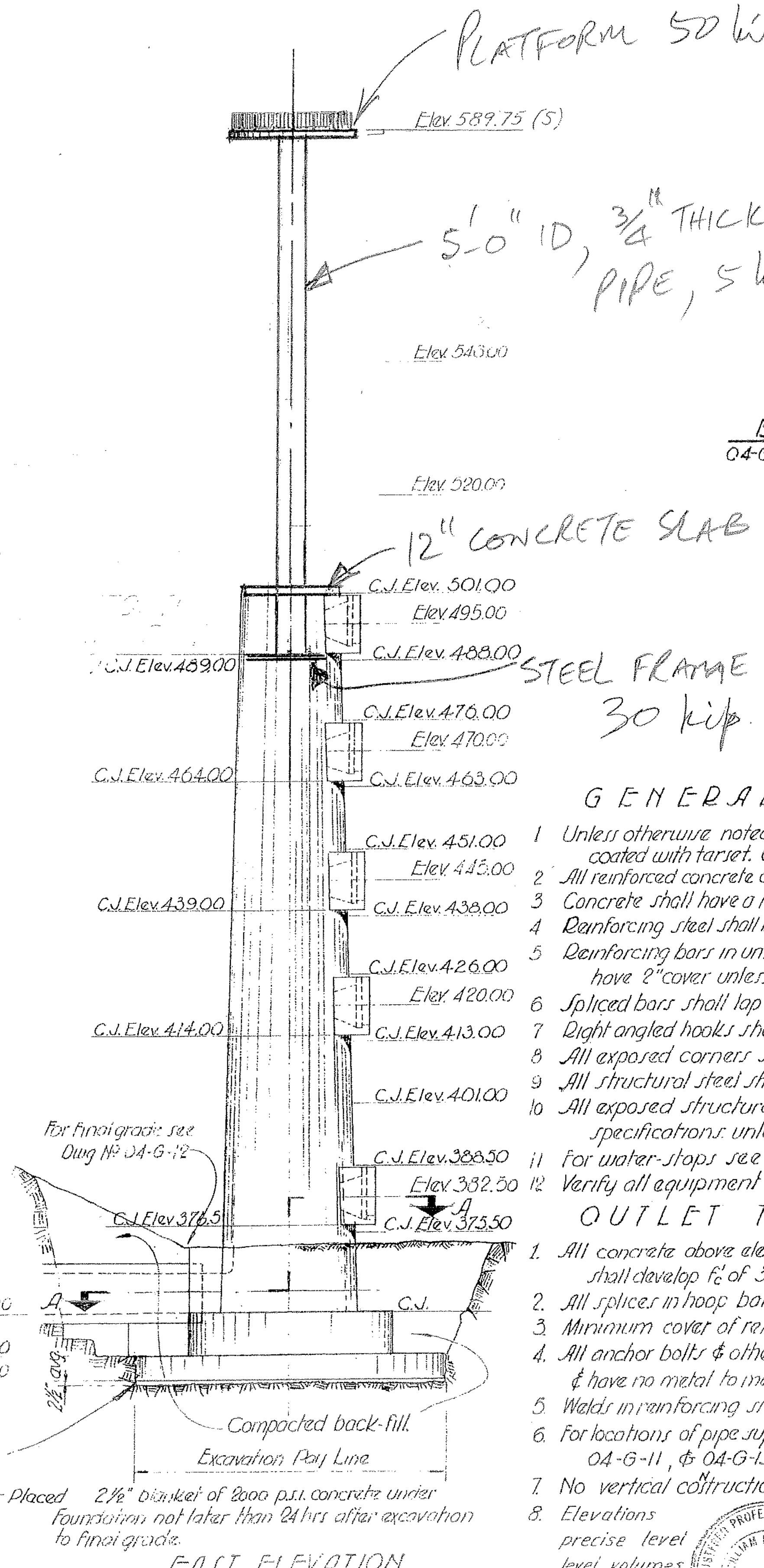
DIETERICH-POST CLEARPRINT 1000 H

OPTION 2: EXTERNAL SUPPORTING PIERS AND FRAME SK-6

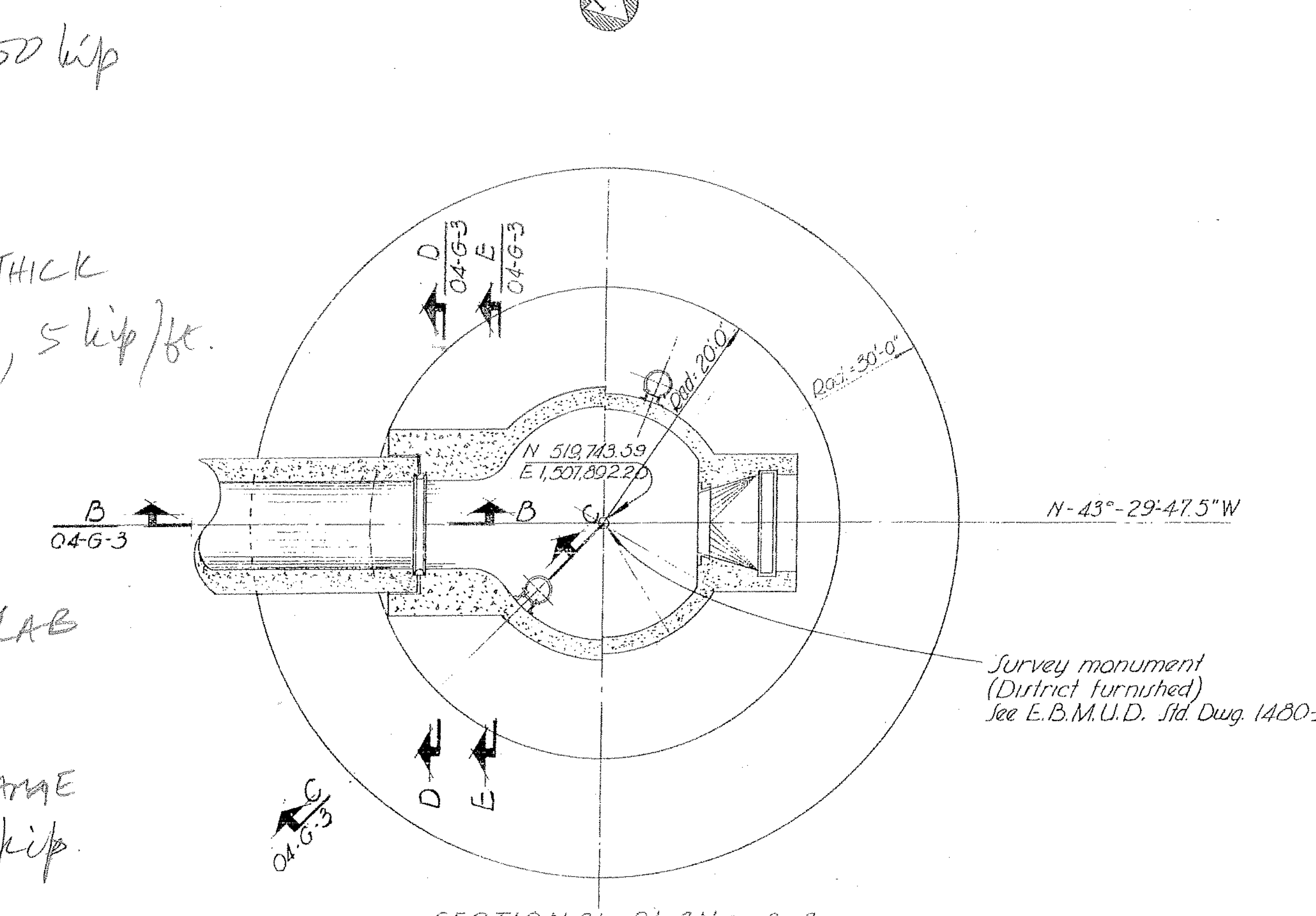


Notes:
A. See Dwg. 4404-G-1.1 & 4404-G-2 for details of bar spacing at gates.

TYPICAL WALL REINFORCING
1/16" = 1'-0"



EAST ELEVATION
1/16" = 1'-0"



SECTIONAL PLAN @ A-A
1/8" = 1'-0"

GENERAL NOTES

1. Unless otherwise noted, all ferrous metals (except stainless steel & reinforcing bars) below elev 581.00 in Outlet Tower & elev. 602.50 in Valve Access shaft shall be coated with tarset. Coating shall be shop applied wherever practicable & touched up in the field.
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9. All structural steel shall be in accordance with the current A.I.S.C. Specifications & A.S.T.M. Spec. A-7
10. All exposed structural steel & embedded steel members shall be galvanized as outlined in the specifications unless otherwise noted.
11. For water-stops see specifications.
12. Verify all equipment dimensions with Vendors Drawings or existing equipment.

GRAPHIC SCALES
1/8" = 1'-0": 0, 5, 10, 15, 20
1/16" = 1'-0": 0, 10, 20, 30, 40

OUTLET TOWER NOTES

1. All concrete above elevation 360.00 shall develop f'_c of 4000 p.s.i in 28 days. Below elev. 360.00 conc. shall develop f'_c of 3000 p.s.i in 28 days unless noted.
2. All splices in hoop bars shall be staggered 120°
3. Minimum cover of reinforcing shall be 2" unless noted.
4. All anchor bolts & other embedded metal must be kept 2" minimum clear of all reinforcing steel & have no metal to metal contact with reinforcing steel
5. Welds in reinforcing steel where shown shall develop full strength of the bar.
6. For locations of pipe supports & electrical inserts see Dwgs 04-G-8, 04-G-10, 04-G-11, & 04-G-13.
7. No vertical construction joints shall be allowed unless shown on dwg's.
8. Elevations indicated by (S) were established from precise level survey of June 1965. Ref. EBMUD precise level volumes 65, 139, 146, 147 & F.B. 3449-A.

KAISER ENGINEERS
DIVISION OF HENRY J. KAISER COMPANY
OAKLAND CALIFORNIA

APPROVED [signature] CHIEF ENGINEER R.E. No. 969

DESIGNED BY	P.D. FLORENCE
DRAWN BY	E.A. O'DELL
CHECKED BY	E.F. NIELSEN
CORROSION CHECK BY	
PROJECT ENGR.	[signature] 3460
MANAGER DESIGN ENGRG.	[signature]
MANAGER WATER PROD. & DIST.	[signature]

EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND, CALIFORNIA

BRIONES DAM
OUTLET TOWER
PLAN & ELEVATIONS

NO.	DATE	REVISION		
1	1-15-65	Revised As-Built	T.G.	[initials]

STRUCTURE OR ZONE DESIGNATION: 521
SCALE: As shown
DATE: 3-4-65

~~4404-G-1~~

[Stamp: REGISTERED PROFESSIONAL ENGINEER, WILLIAM BESTWELL, No. 6199, CIVIL, STATE OF CALIFORNIA]

OPTION 6: PARTIAL DEMOLITION OF EXISTING TOWER   SK-7

APPENDIX B1: SEISMIC EVALUATION OF RETROFIT OPTIONS FOR BRIONES OUTLET TOWER

SEISMIC EVALUATION OF RETROFIT OPTIONS FOR BRIONES OUTLET TOWER

Final Report

Prepared for

East Bay Municipal Utility District
375 11th Street
Oakland, CA 94607

By

Quest Structures, Inc.
3 Altarinda Road, Suite 203
Orinda, CA 94563

September 12, 2008

Table of Contents

1. INTRODUCTION

The most recent seismic evaluation of Briones Tower (Quest, 2007) concluded that the tower would suffer significant damage and could overturn or become unstable when subjected to ground motions at the level of the maximum design earthquake (MDE) or the maximum credible earthquake (MCE). The MDE was estimated probabilistically and was chosen by the East Bay Municipal Utility District (District) as a ground motion having a 10 percent probability of exceedance in 50 years (a return period of 475 years). The MCE was estimated deterministically as an M_w 7.25 event on the nearby Hayward-Rogers Creek Fault.

Subsequently, Jacobs Associates of San Francisco was contracted to develop remediation schemes to strengthen the tower with Quest Structures to conduct seismic evaluation of the remediation alternatives. This report presents the results of seismic analyses carried out by Quest Structures for two remediation schemes consisting of a guy-wire support and a concrete infill scheme proposed by Jacobs Associates.

This report was prepared by Quest Structures for the District under a subcontract to Geomatrix Consultants of Oakland, California.

2. OPTION-1: GUY-WIRE ALTERNATIVE

The guy-wire retrofit option consisted of four steel wire ropes connected to the tower at El. 512 ft at one end and anchored to the reservoir floor at the other end (Figures 2-1 and 2-3). The anchors are to locate at a radius of 115 feet from the tower centerline. The steel wires are to be 2.5, 3.25, or 4 inches in diameter. The guy wires were initially arranged at a 60-degree angle (Figure 2-2), but later at a 90-degree angle between the wires to preserve the symmetry (Figure 2-3). Initial analyses indicated that the 2.5-inch and 3.25-inch diameter wires had inadequate capacity. The final analysis reported here was carried out using the 4-in diameter wires.

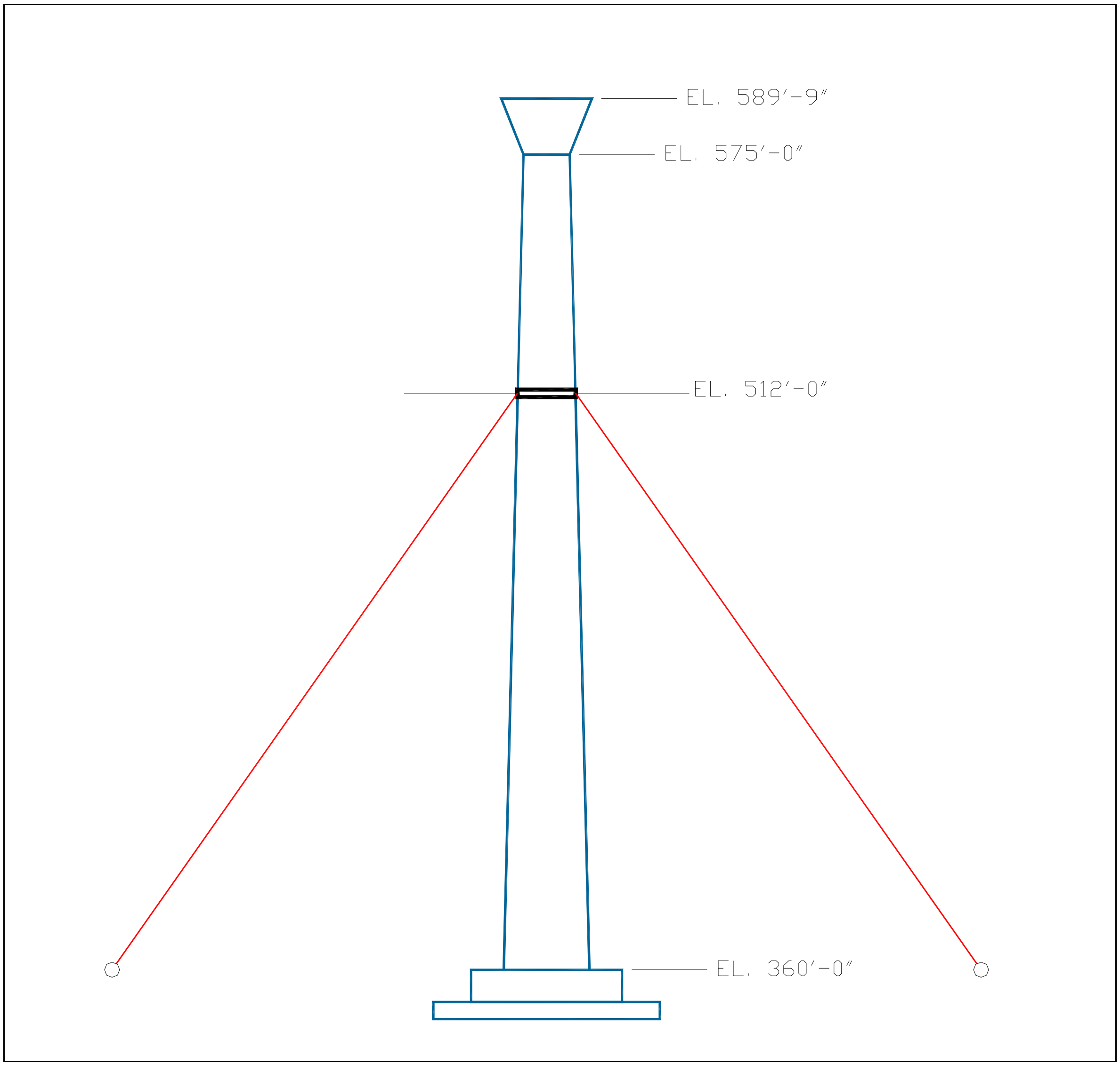


Figure 2-1. Elevation view of proposed guy-wire retrofit option

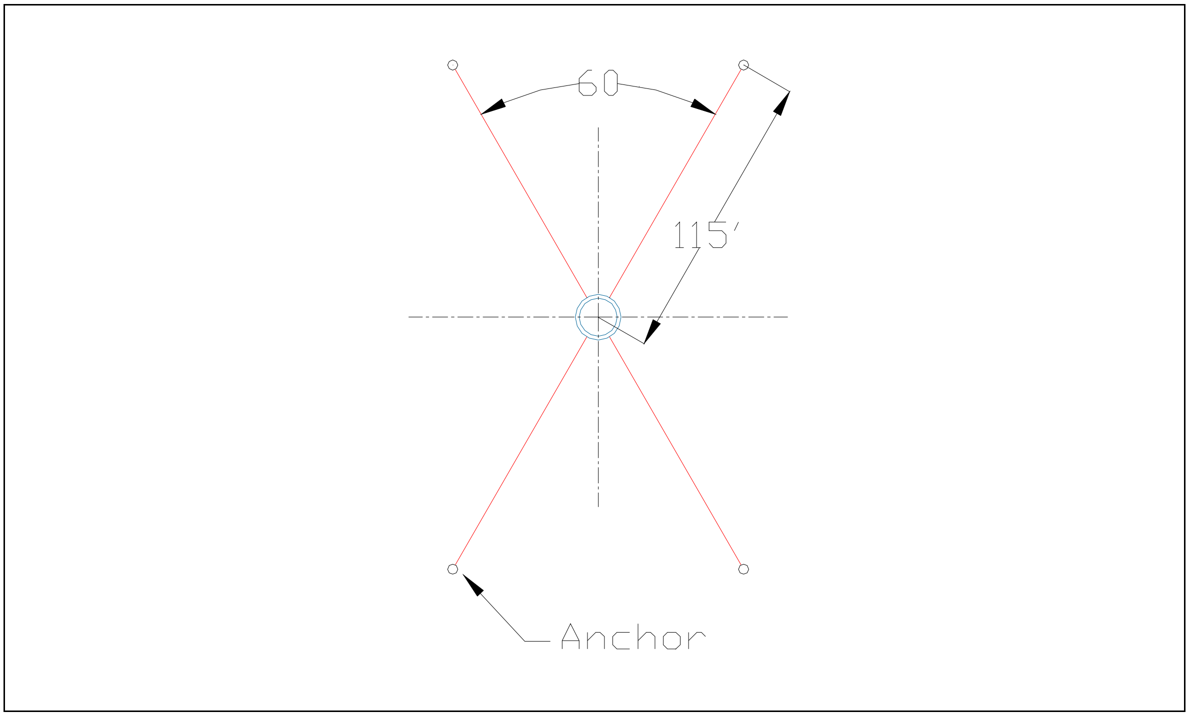


Figure 2-2. Plan view with guy-wires at 60 degrees.

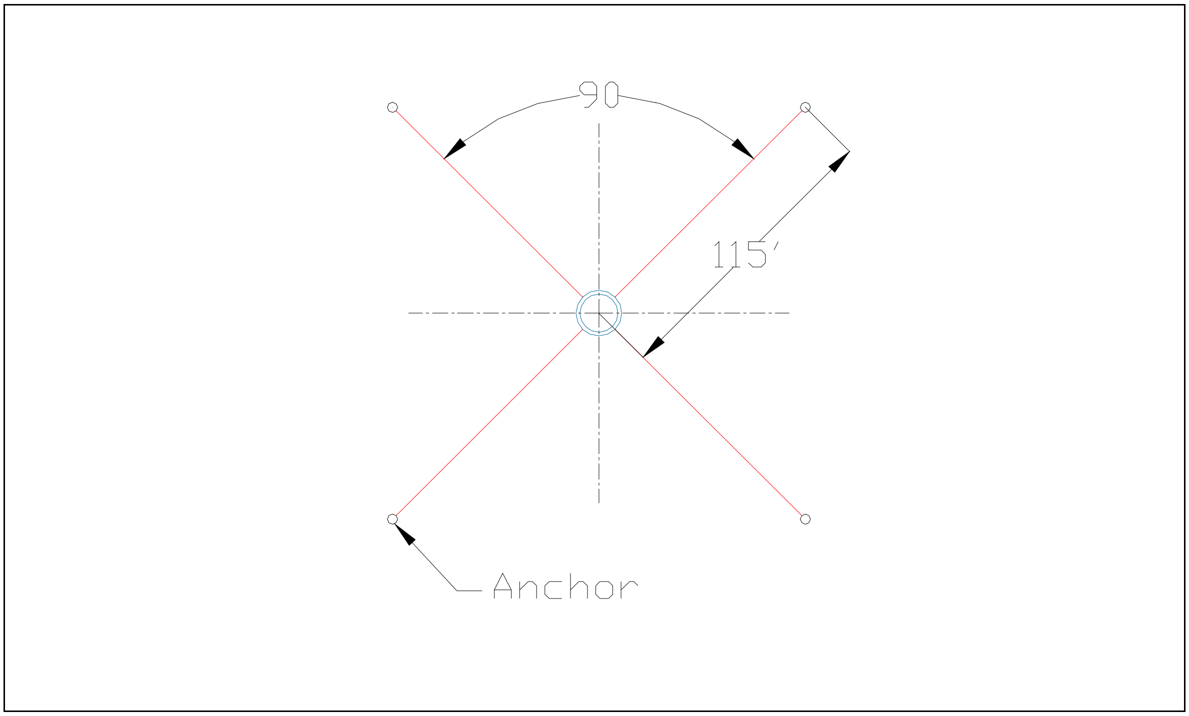


Figure 2-3. Plan view with guy-wires at 90 degrees.

2.1 Finite Element Model

The SAP2000 model from the 2007 study (Quest, 2007) was used, except that nonlinear elements were used to model the guy-wires and also the bottom section of the tower where the plastic hinging was expected to occur. The hollow circular shaft was represented by linear beam elements with axial, bending, and shear deformations. The model included 17 nodal points and 16 beam elements spanning from the bottom elevation at 360 ft to top elevation at 589.75 ft, corresponding to elevation of the operating platform. The beam elements were developed based on the shaft nominal section geometry. A nonlinear joint element was included at the base of the shaft to model nonlinear behavior at this location. The nonlinear joint element was represented by a nonlinear moment-curvature relationship discussed in Section 2.3. The guy-wires were modeled using cable elements with the catenary behavior under their self-weight. The cable elements include both the tension-stiffening and large-deflections nonlinearity. Figure 2-4 displays the model with extruded beam elements shown in blue and cable elements shown as green lines. Figure 2-5 shows a plan view of the model with the guy-wires installed at 90 degrees.

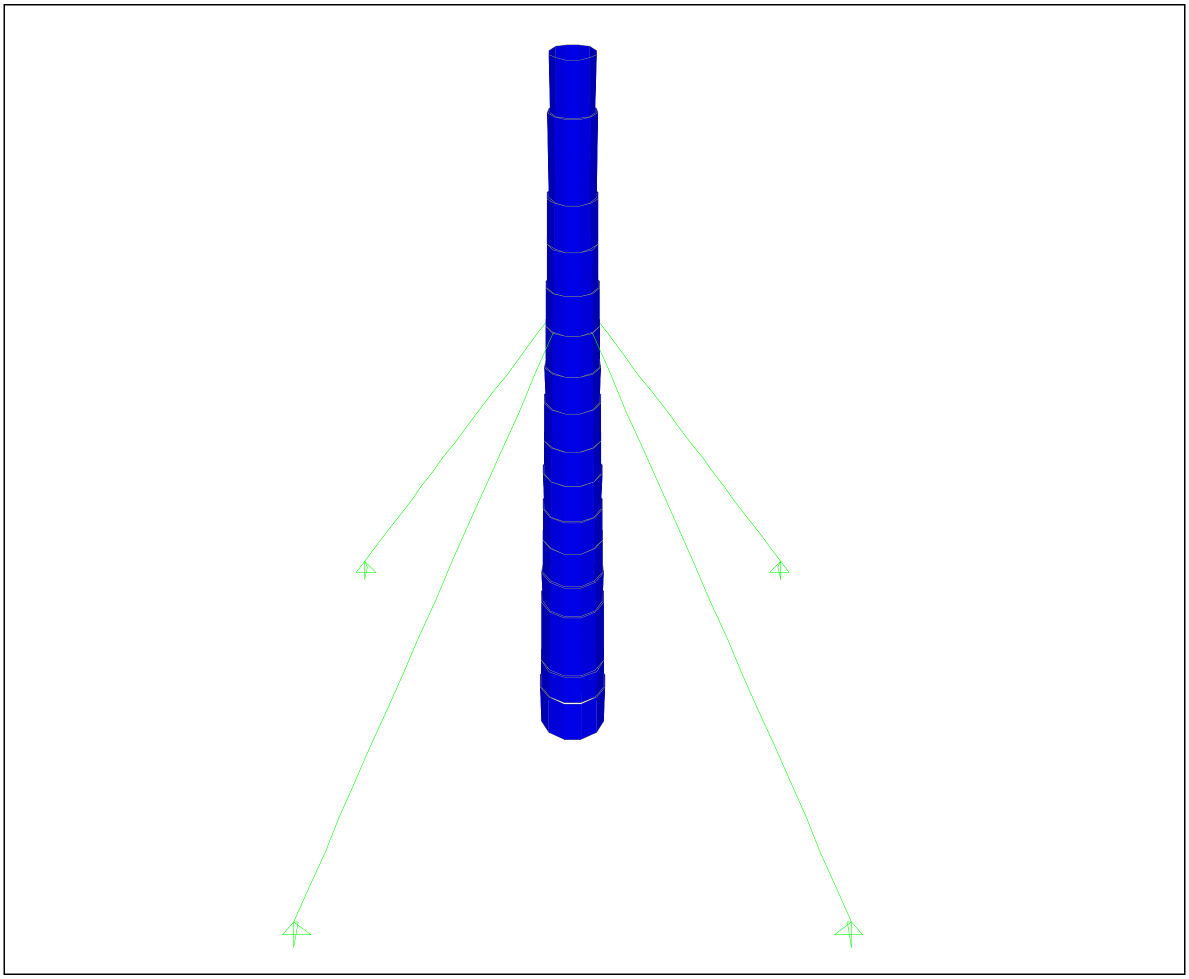


Figure 2-4. Finite element model of tower with guy wires

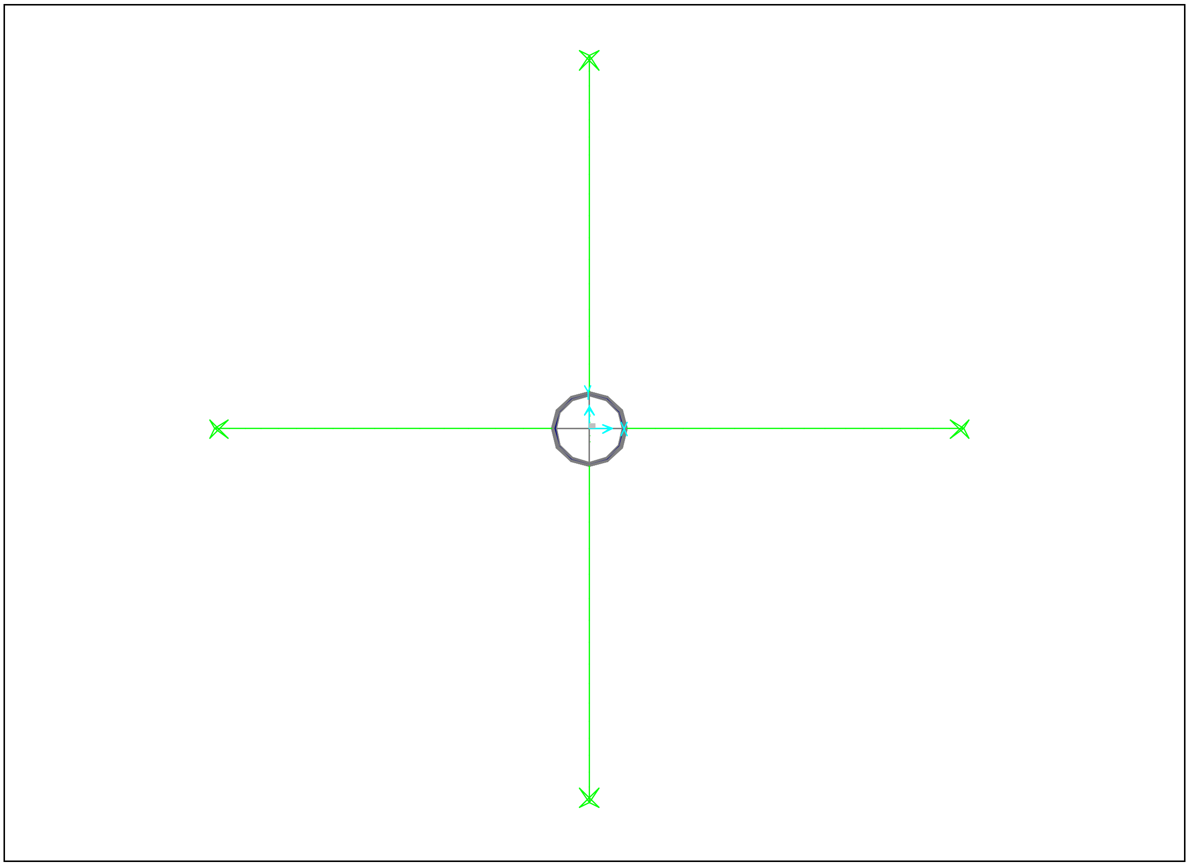


Figure 2-5. Plan view of the model with guy-wires installed at 90 degrees.

2.2 Evaluation Loads

Evaluation loads consisted of the dead weight, water, and seismic loads. These are fully described in the 2007 report (Quest, 2007).

2.2.1 Dead Loads

The dead loads due to weight of the concrete were determined using a unit weight of 150 pcf.

2.2.2 Water Loads

The water loads were estimated for the reservoir water level at El. 576 ft, just below the spilling elevation. The tower is normally full, thus the elevation of inside water is also at 576 ft. The net hydrostatic pressures acting on the inside and outside surfaces of the circular shaft are zero.

2.2.3 Hydrodynamic Loads

The inside and outside water inertia loads due to seismic excitation were accounted for by added-mass terms following the Goyal and Chopra's procedure (1989).

2.2.4 Seismic Loads

The seismic input for the 2007 linear and equivalent-linear (post-elastic) seismic analyses of the tower consisted of the site-specific response spectra for the MDE and MCE ground motions developed by Geomatrix Consultants (Quest, 2007). The estimated peak horizontal ground accelerations for these events are 0.70g and 0.75g, respectively. However, the seismic input for the nonlinear analysis of the tower with guy wires required acceleration time histories. This was accomplished by using the acceleration time histories that had been developed for the Sobrante Outlet Tower, except that they were scaled to the level of Briones response spectra. This approach seems reasonable considering that Sobrante Tower is located only a few miles from Briones Tower and that the seismic load for both towers is controlled by similar seismic sources.

Figures 2-6 and 2-7 compare spectra for the fault-normal and fault-parallel acceleration time histories with the target fault-normal and fault-parallel MDE response spectra. The spectrum-matched acceleration time histories for the MDE ground motion are displayed in Figure 2-8.

Figures 2-9 and 2-10 compare spectra for the fault-normal and fault-parallel acceleration time histories with the target fault-normal and fault-parallel MCE response spectra. The corresponding spectrum-matched acceleration time histories for the MCE ground motion are given in Figure 2-11.

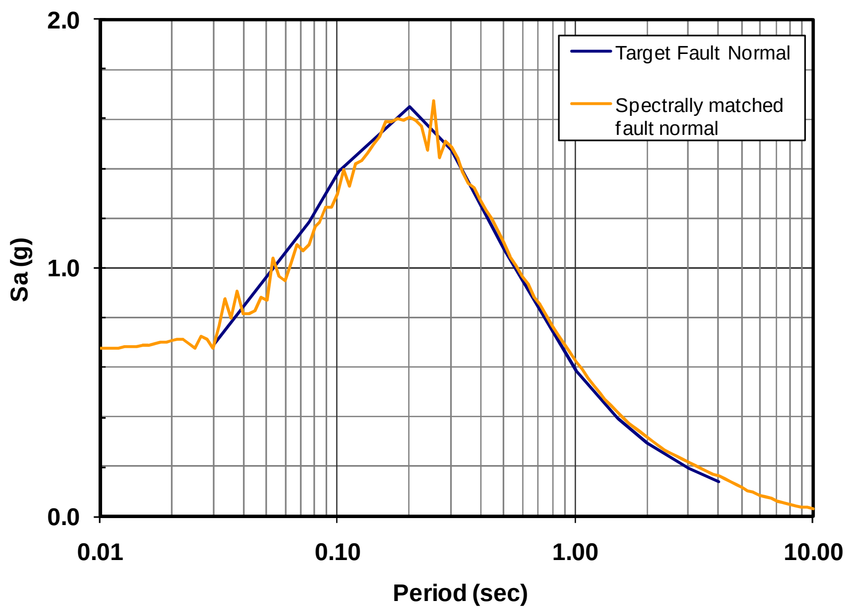


Figure 2-6. Comparison of spectrum for fault normal acceleration time history with target fault normal MDE response spectrum (damping).

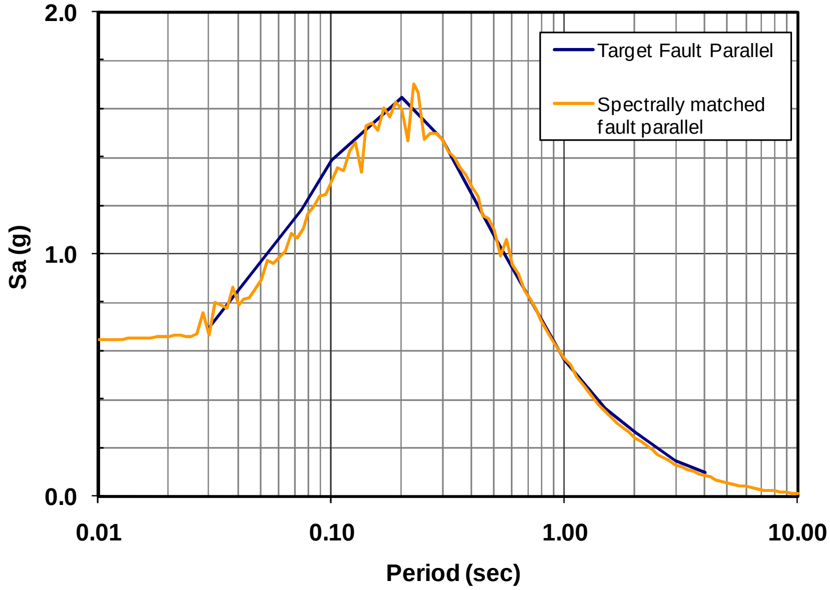


Figure 2-7. Comparison of spectrum for fault parallel acceleration time history with target fault parallel MDE response spectrum (5% damping).

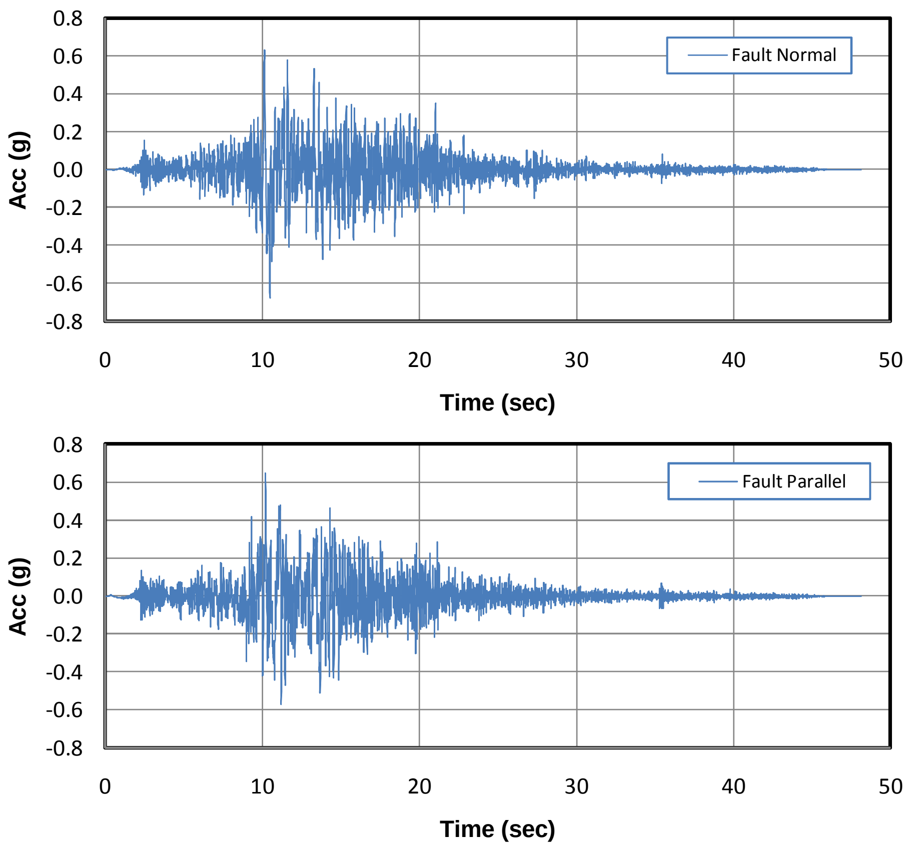


Figure 2-8. MDE fault-normal and fault-parallel spectrum-matched acceleration time histories.

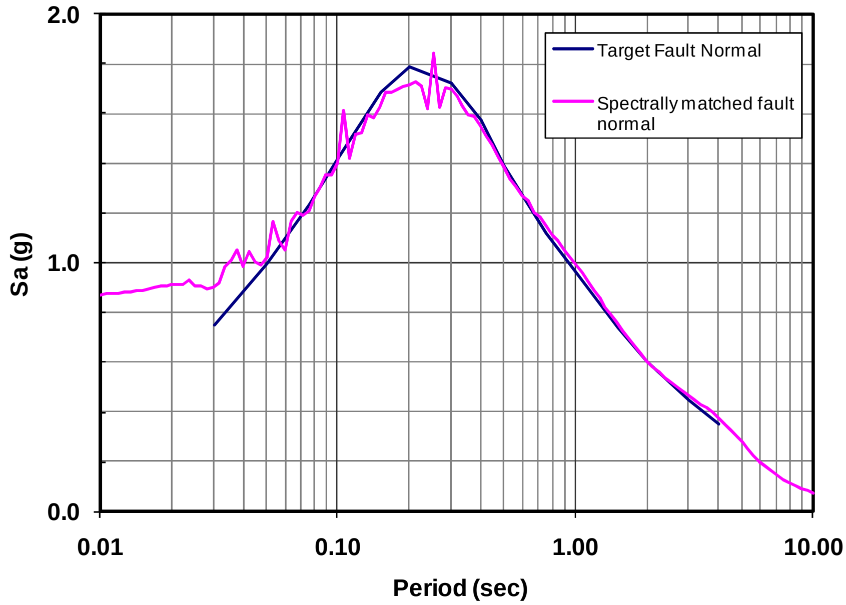


Figure 2-9. Comparison of spectrum for fault-normal acceleration time history with target fault-normal MCE spectrum (5% damping).

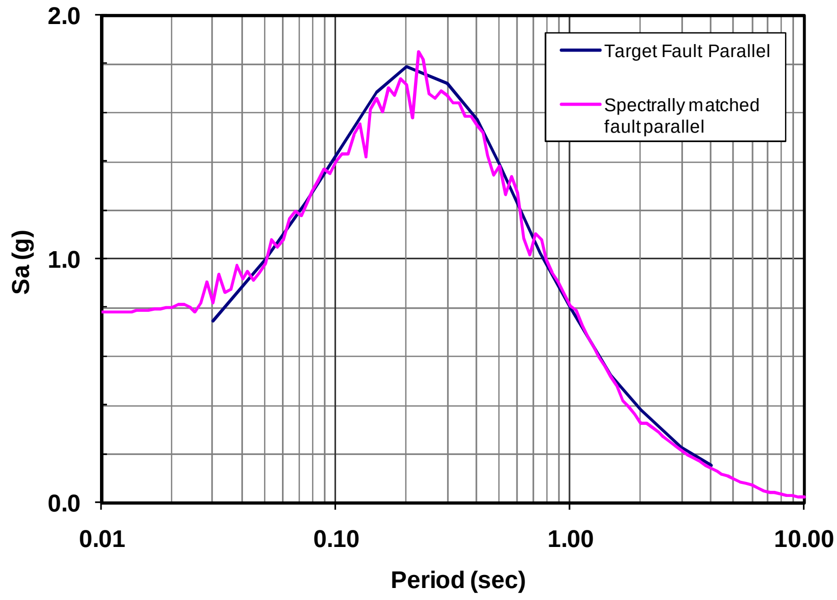


Figure 2-10. Comparison of spectrum for fault-parallel acceleration time history with target fault-parallel MCE spectrum (5% damping).

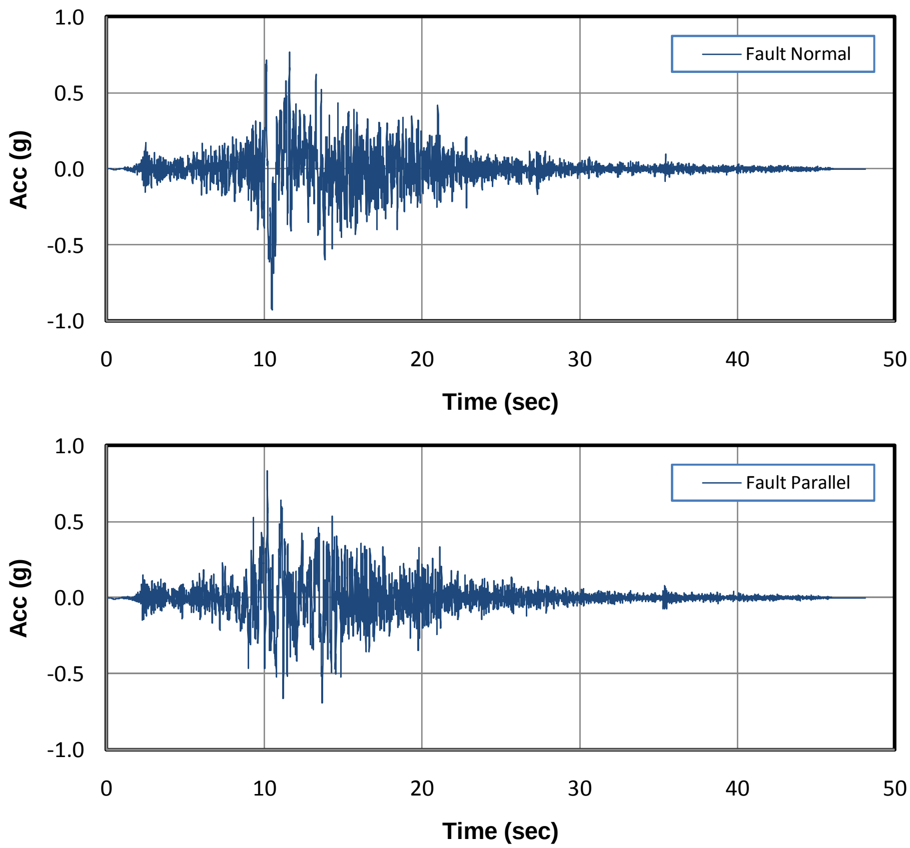


Figure 2-11. MCE fault-normal and fault-parallel spectrum-matched acceleration time histories.

2.3 Moment-Curvature Relationship

The moment-curvature (M-Phi) relationship for the nonlinear joint element at the bottom of the tower was estimated using the computer program M-Phi developed for the US Army Corps of Engineers (Ehsani and Marine, 1994). This program computes the moment and the corresponding curvature values for a specified reinforced-concrete cross section from typical stress-strain models for concrete and reinforcing steel. Figure 2-12 shows one such M-Phi relationship for the bottom section of Briones Tower. This figure shows that there is a reduction in the moment values immediately following the cracking of the concrete (i.e., kink on the graph), while the curvature increases. This behavior is common for sections that have large concrete area in tension. Also shown on this figure is the nominal section moment capacity estimated using the ACI procedure.

The concrete multi-linear pivot hysteretic plasticity model available in SAP2000 was used to represent the nonlinear joint element. Input parameters for this plasticity model were defined consistent with the moment-curvature relationship computed for the bottom section.

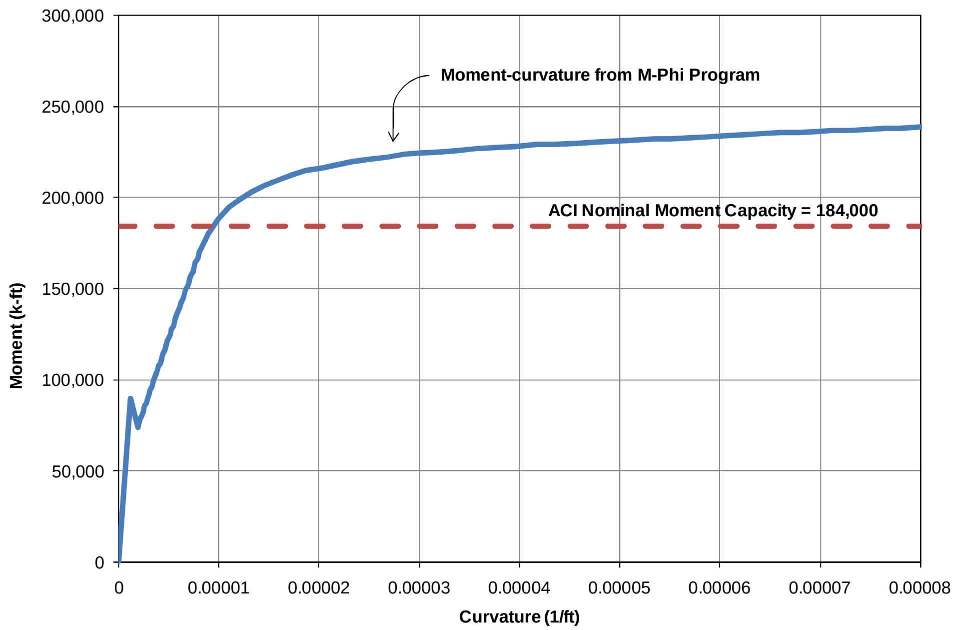


Figure 2-12. Moment curvature relationship for bottom section of tower.

2.4 Analysis Results

The finite-element model described in section 2.1 was analyzed using the step-by-step nonlinear time history method. Both horizontal components of the ground motions were applied as the seismic input but the effects of the vertical component were ignored. Considering that circular cross sections are subjected to the resultant shear and moment caused by two horizontal components of the ground motion, the maximum shear and moment should be estimated for the combined effects of the horizontal components. This can be done by applying both horizontal components simultaneously and determining the resultant shear and moment at each time step, from which the maximum resultant shear moment can then be obtained. However, in this study a simpler approach was taken, in which each horizontal component of ground motion was applied separately but was multiplied by 1.3 to account for the two-component excitation. The factor of 1.3 was selected consistent with the customary 30% rule used for building structures. This way the resultant shear and moment time histories are computed directly and then searched to obtain the maximum values. The results reported in the following sections are for the 1.3 times the fault normal and 1.3 times the fault parallel components applied separately.

2.4.1 Displacement Histories

Figures 2-13 and 2-14 show the time histories of the maximum displacements at the top of tower due the MDE and MCE ground motions, respectively. The results indicate that the top of tower moves in the range of 1.75 to 2.8 ft when subjected to the MDE and in the range of 2 to 3.2 ft in the case of the MCE excitation.

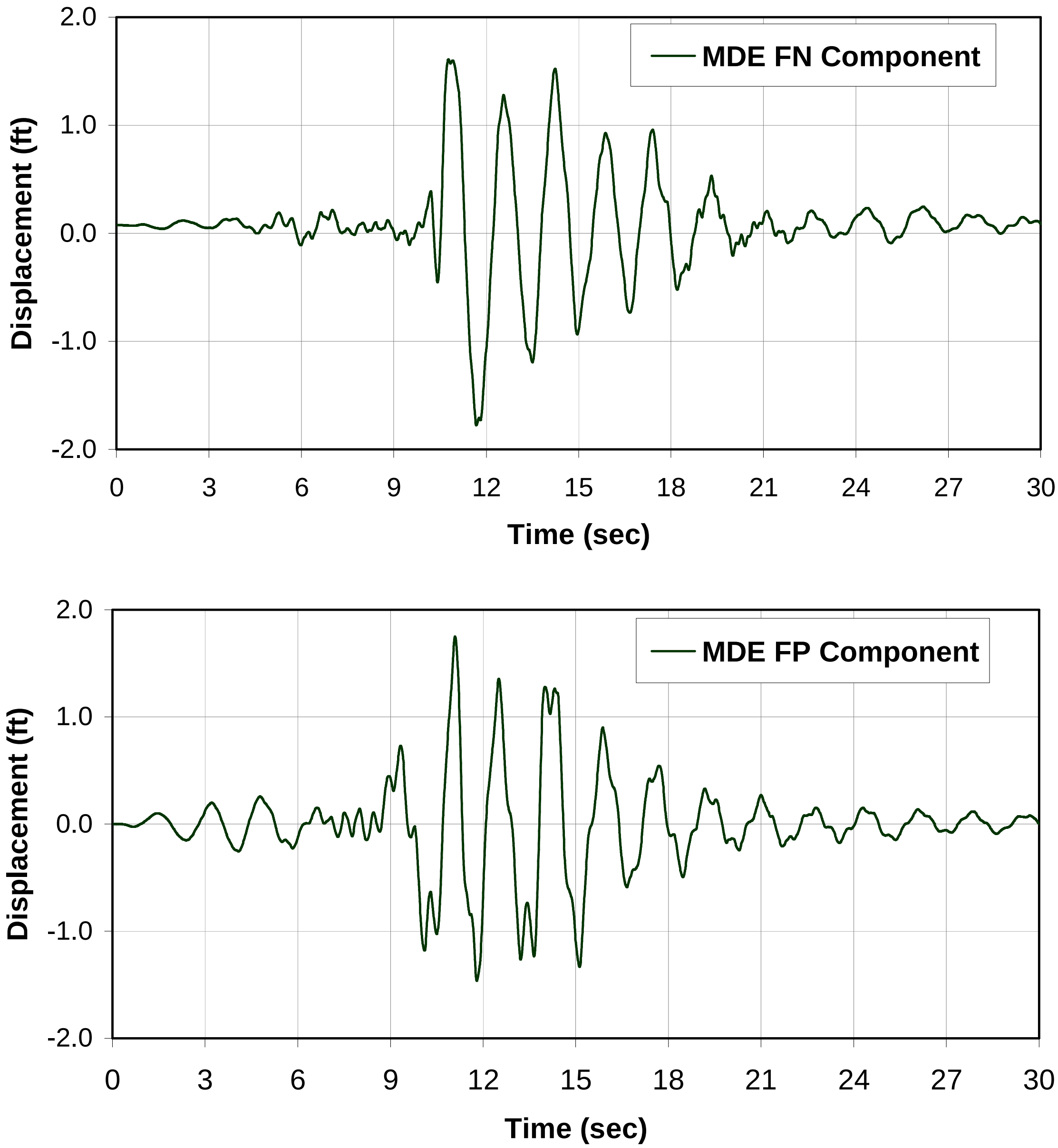
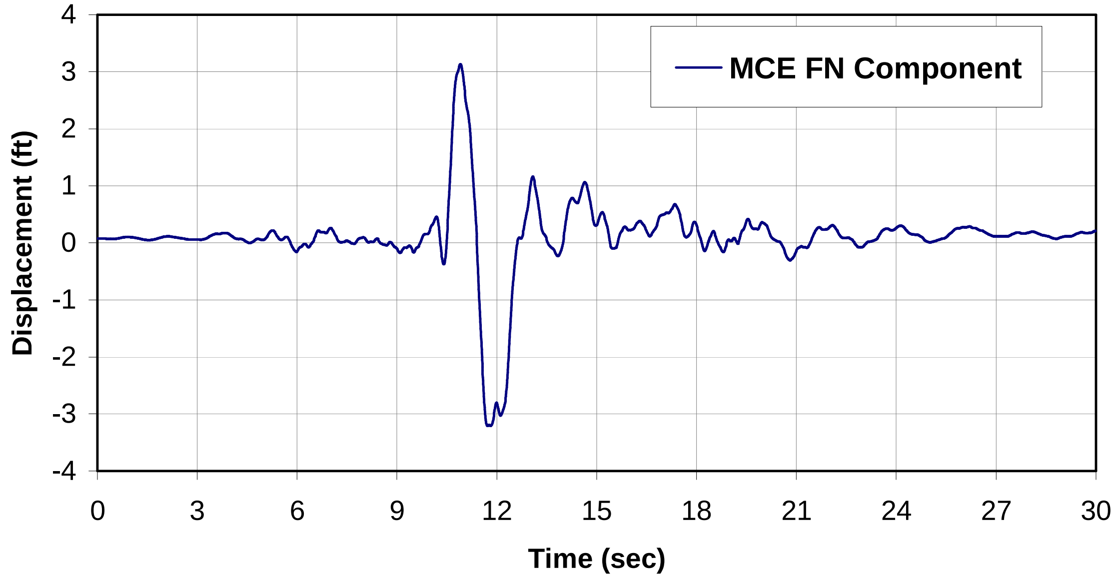


Figure 2-13. Maximum displacement histories due to MDE



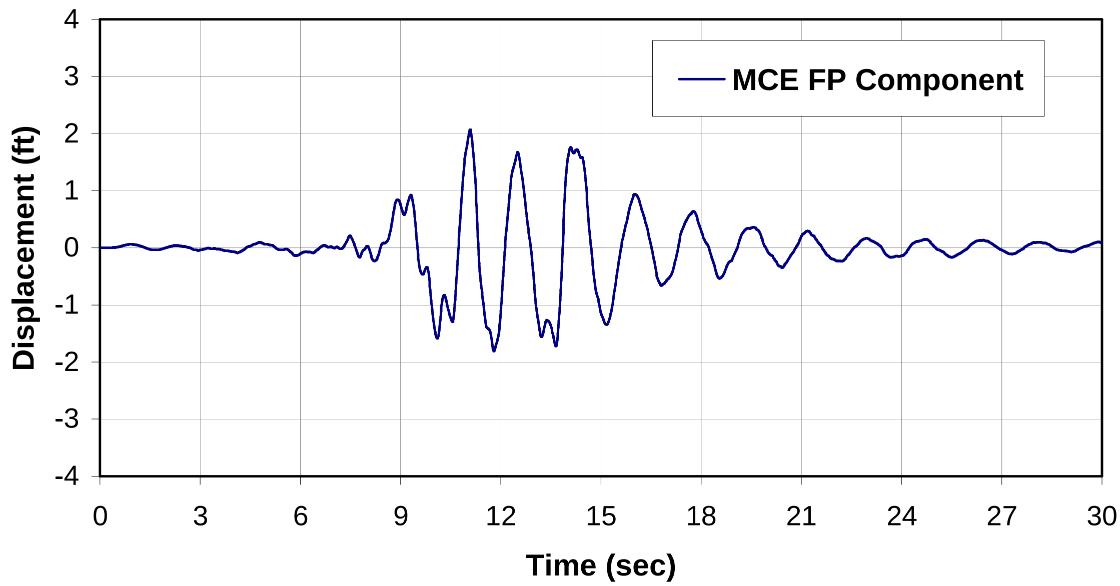


Figure 2-14. Maximum displacement time histories due to MCE

2.4.2 Force and moment histories

Figures 2-15 and 2-16 exhibit axial force histories for guy wires due to the MDE and MCE ground motions, respectively. As expected the wires experience tensile forces only. The maximum wire tension reaches 800 kips for the MDE and over 1,600 kips for the MCE. The ultimate capacity of the 4-in-diameter wires is about 2,000 kips. Using a factor of safety of 2, they will be designed for an allowable tension value of only 1,000 kips. On this basis, the 4-in-diameter works are adequate for the MDE but not the MCE.

Figures 2-17 and 2-18 show time histories of the maximum moments at the base of the tower for the MDE and MCE, respectively. As expected, the maximum moments at the base of the tower are limited to the moment capacity of the nonlinear joint set to 225,000 k-ft in accordance with the M-Phi results (also see Figure 2-12). The magnitudes of moments at higher elevations are discussed below in Section 2.4.3.

Figures 2-19 and 2-20 display time histories of the maximum shear forces at the base of the tower for the MDE and MCE, respectively. The results show that the maximum base shear is less than the base shear capacity (6,000 kips) for both the MDE and MCE ground motions. Comparison of shear demands with shear capacities at higher elevations are discussed below in Section 2.4.3.

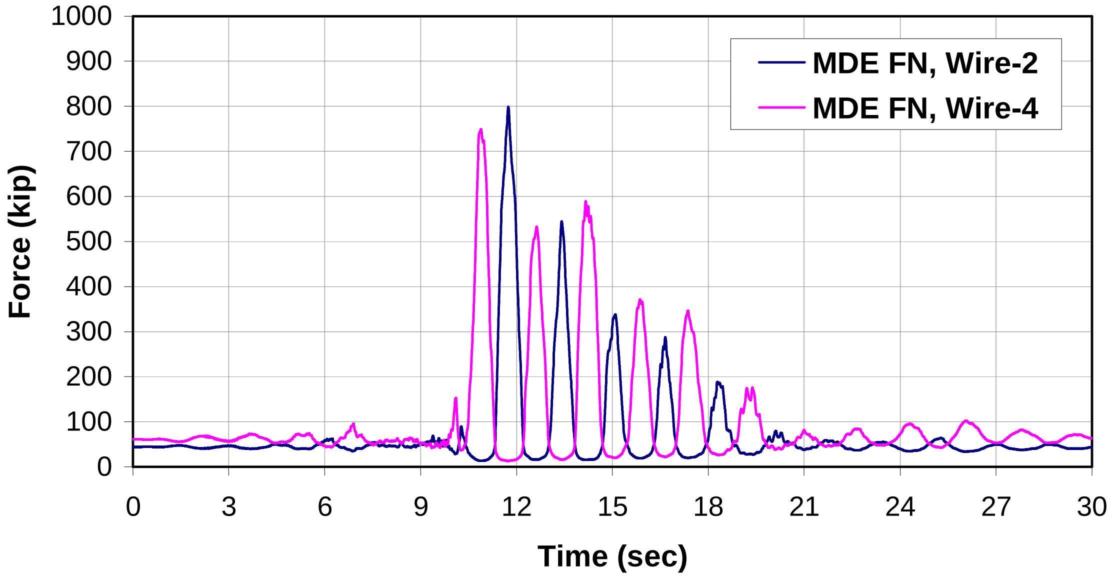
2.4.3 Evaluation of Results

Figure 2-21 compares moment demands with moment capacities along the entire height of the tower for the MDE excitation. The results indicate that moment demands remain below the M-Phi moment capacities at elevations below 450 ft but exceed moment capacities above this elevation. Note that the M-Phi moment capacities are generally 25 percent higher than those obtained using the ACI procedure, because the ACI moment capacity is based on nominal yield strength while the M-Phi moment capacity beyond the yield point takes advantage of the steel strain-hardening. The results suggest that the nonlinear response behavior and the guy wires have helped to reduce moments in the lower portion of the tower but not in the upper portion. This indicates that the tower could still experience significant cracking and yielding in its upper half.

Figure 2-22 provides a comparison of the moment demands with moment capacities for the MCE excitation. The results clearly indicate that moment demands exceed moment capacities along the entire height of the tower, except at the bottom where the cracking and yielding were permitted. The results suggest that the concrete cracking and steel yielding will not be limited to the bottom of the tower, a condition for which the guy wires could have secured the tower from overturning. Spread of cracking and yielding to higher elevations diminishes the benefit of guy wires as stabilizers.

Figures 2-23 and 2-24 compare shear demands with shear capacities for the MDE and MCE, respectively. The results show that the shear demands remain below the shear capacities at elevations below the guy-wire connection, but exceed the capacities above this elevation.

Overall, the results suggest that the guy-wire bracing concept is not feasible, because significant cracking would still spread along the height of the tower. The guy-wires option would have worked if the damage was limited to the bottom of the tower.



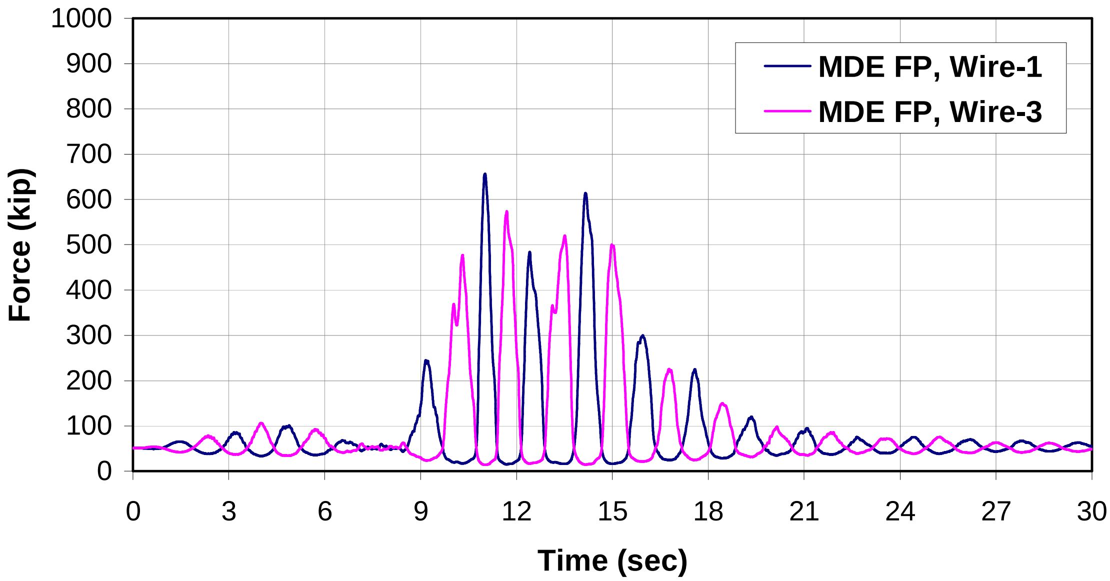


Figure 2-15. Time histories of guy-wires tensile forces due to MDE.

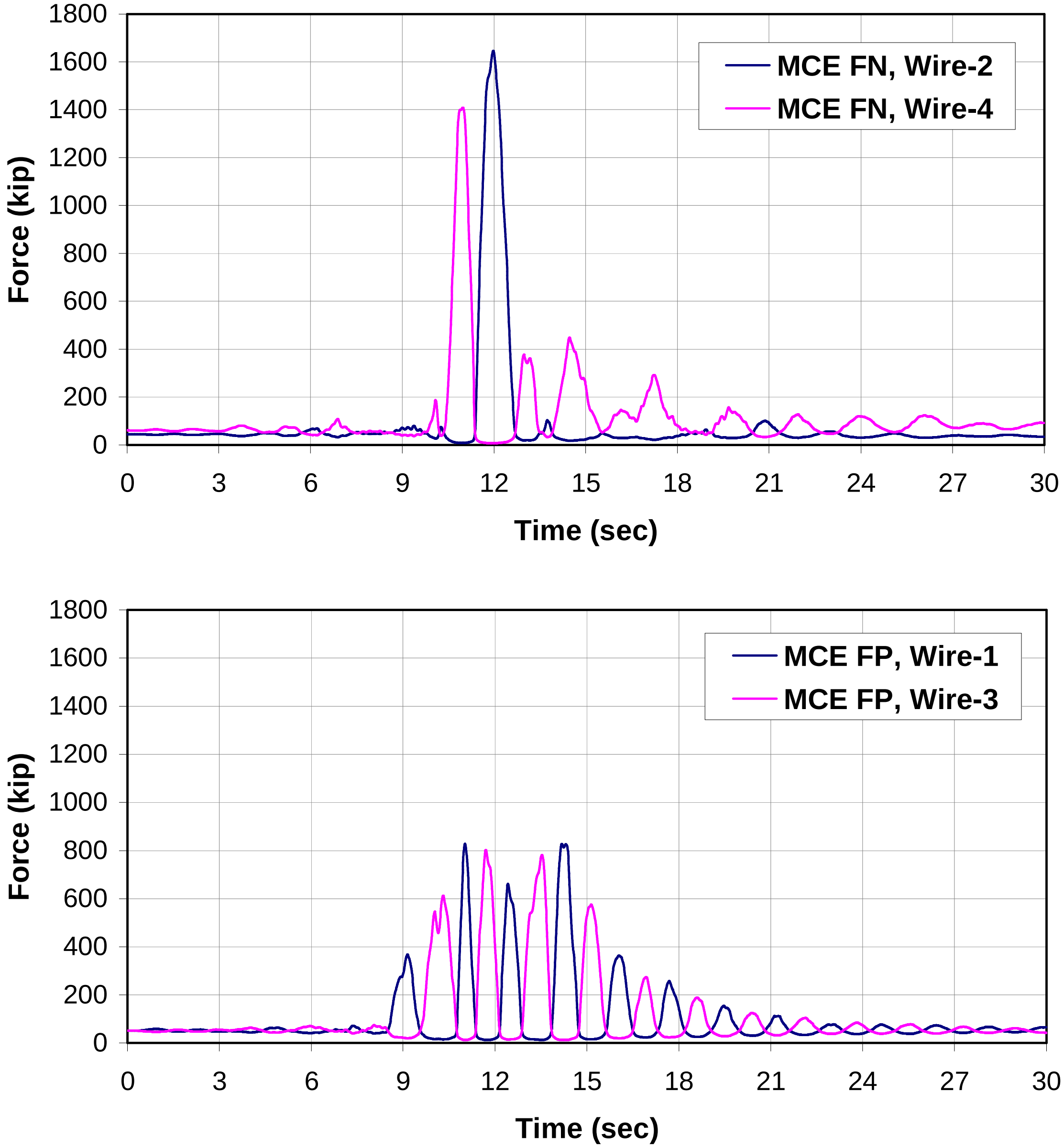
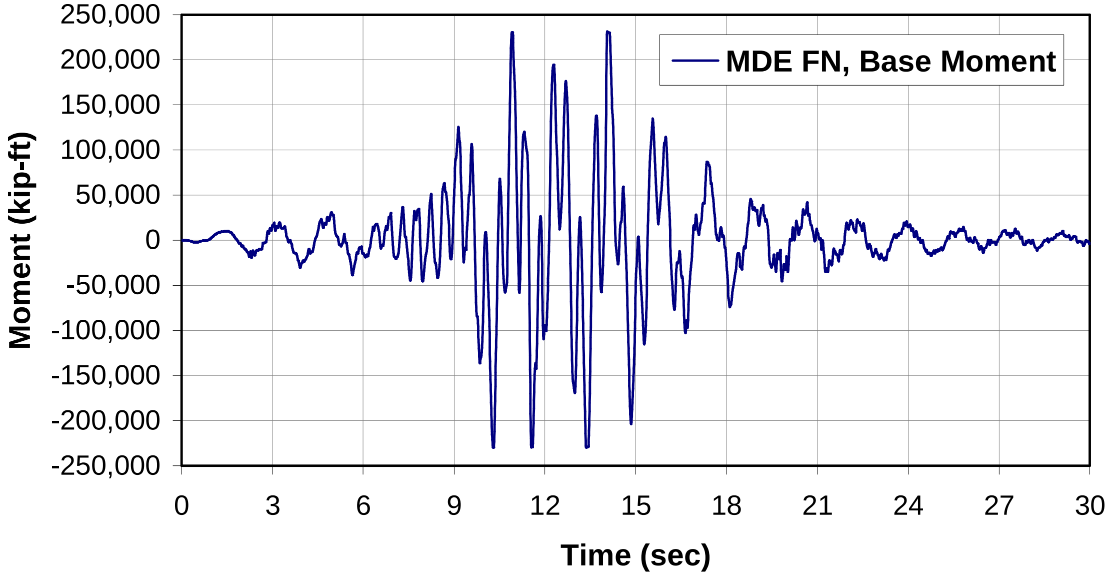


Figure 2-16. Time histories of guy-wires tensile forces due to MCE.



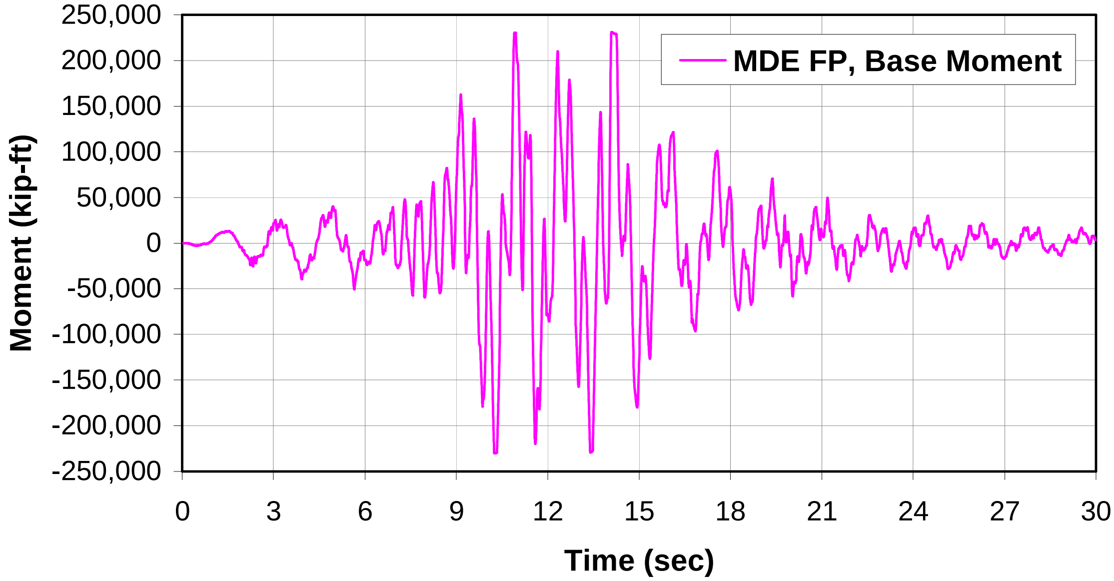
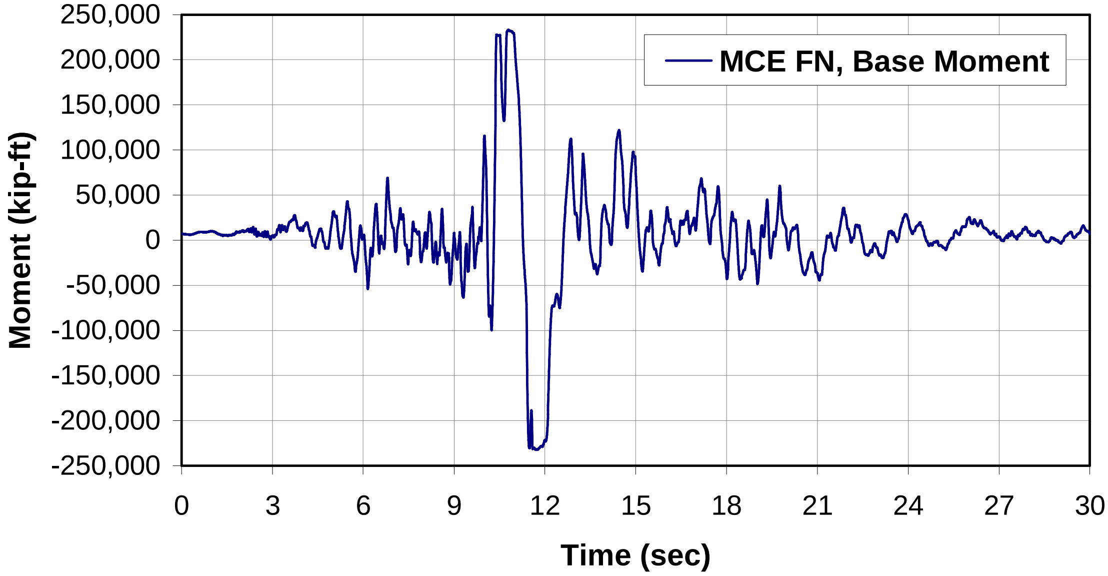


Figure 2-17. Time histories of maximum moments due to MCE.



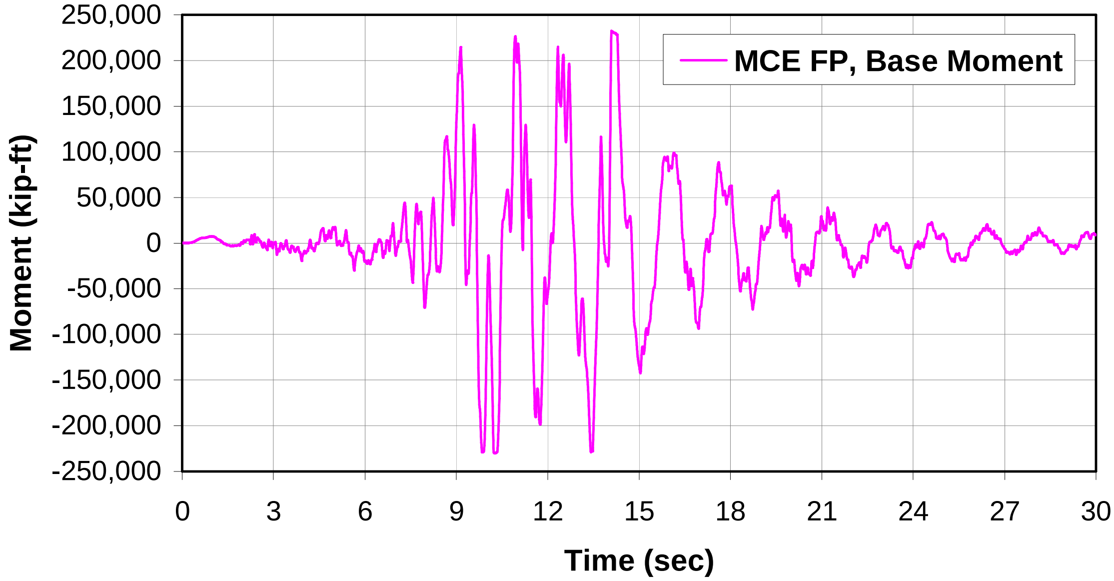


Figure 2-18. Time histories of maximum moments due to MCE.

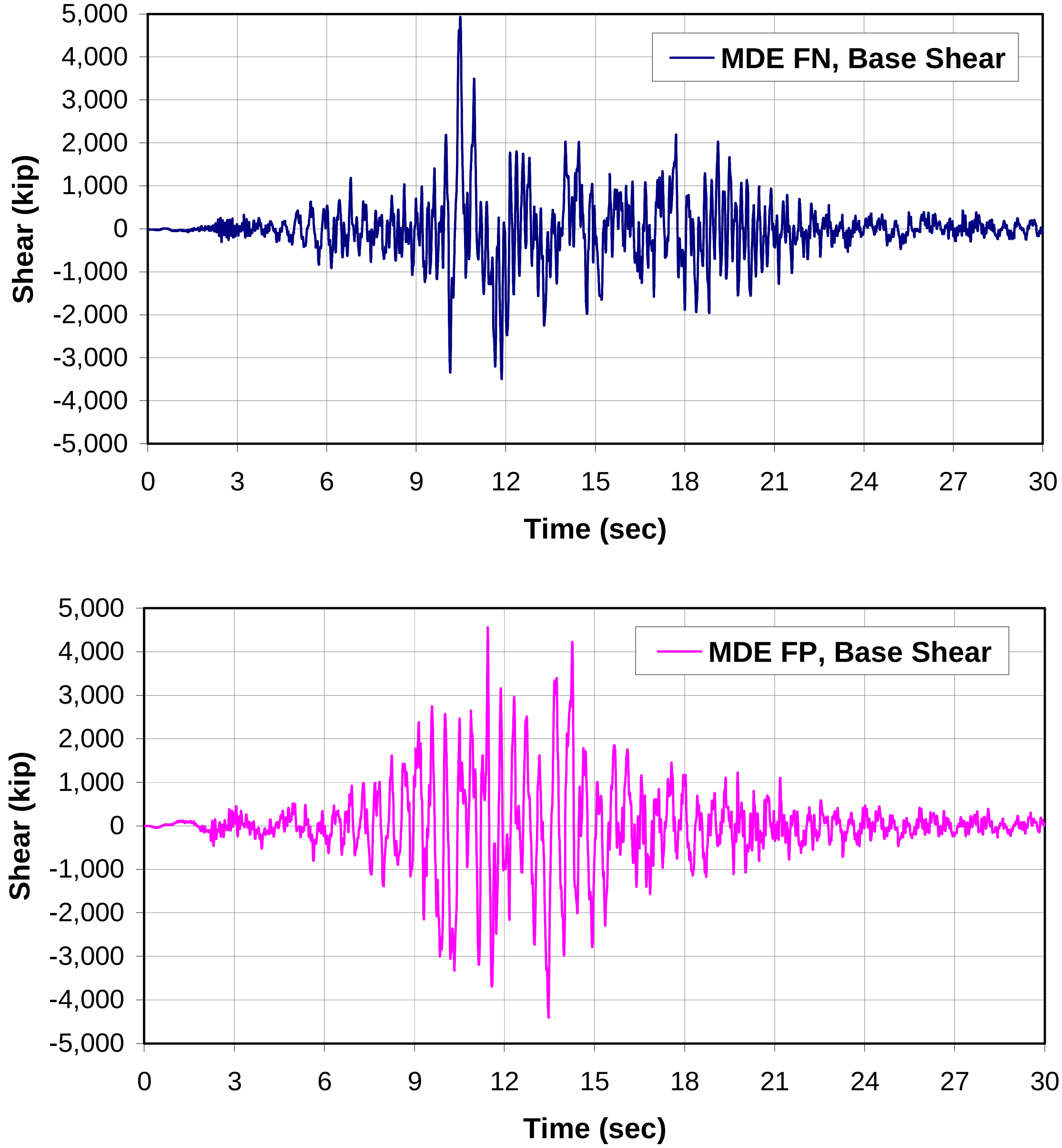


Figure 2-19. Time histories of base shears for MDE.

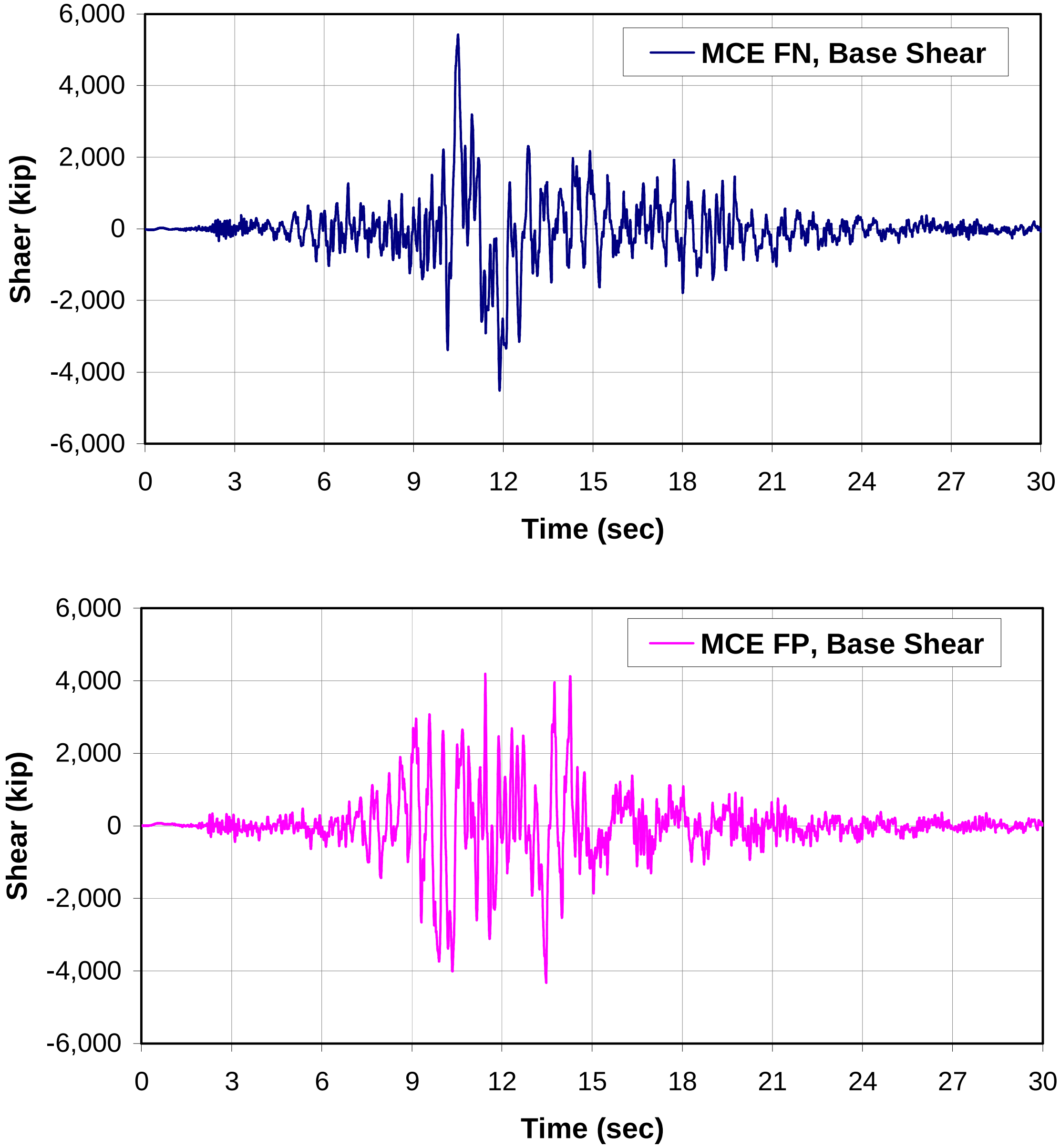


Figure 2-20. Time histories of base shear for MCE.

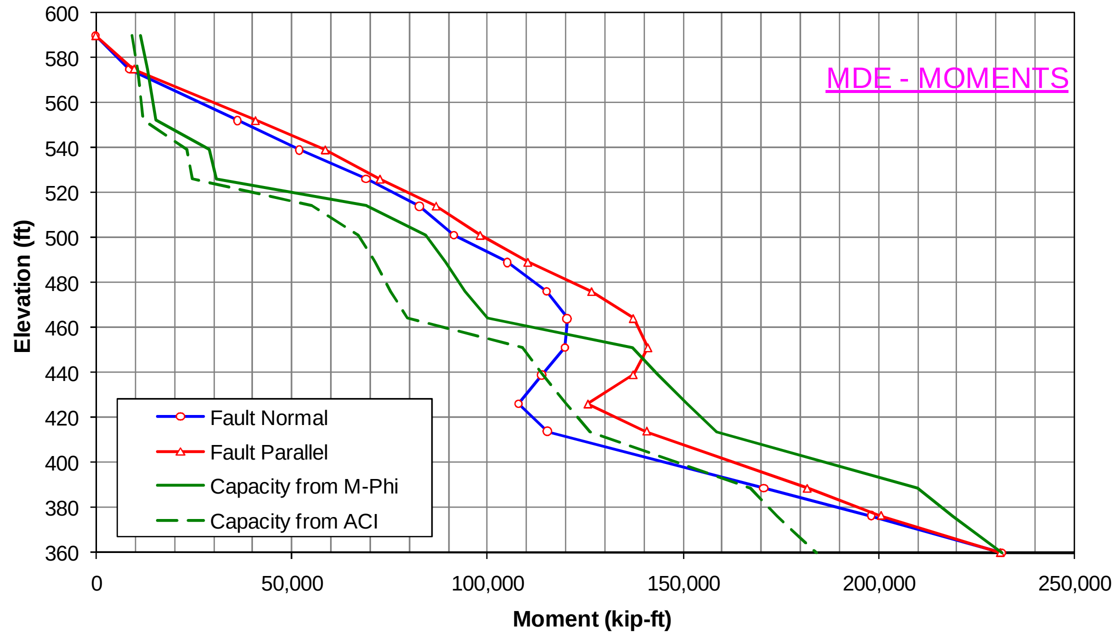


Figure 2-21. Comparison of moment demands with moment capacities for MDE.

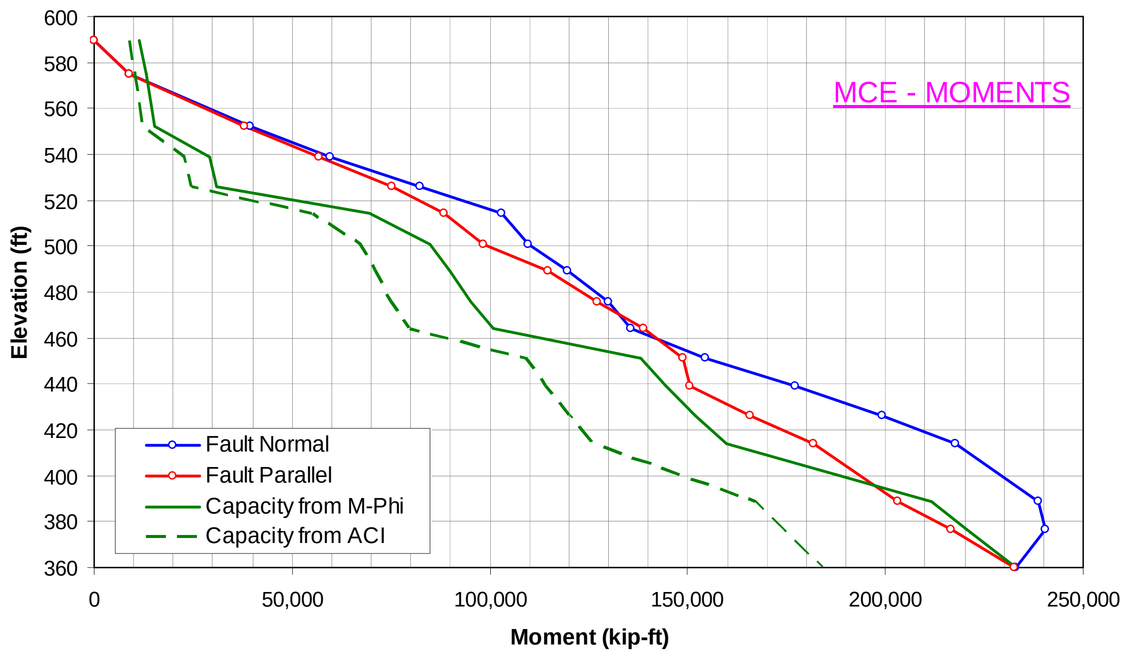


Figure 2-22. Comparison of moment demands with moment capacities for MCE.

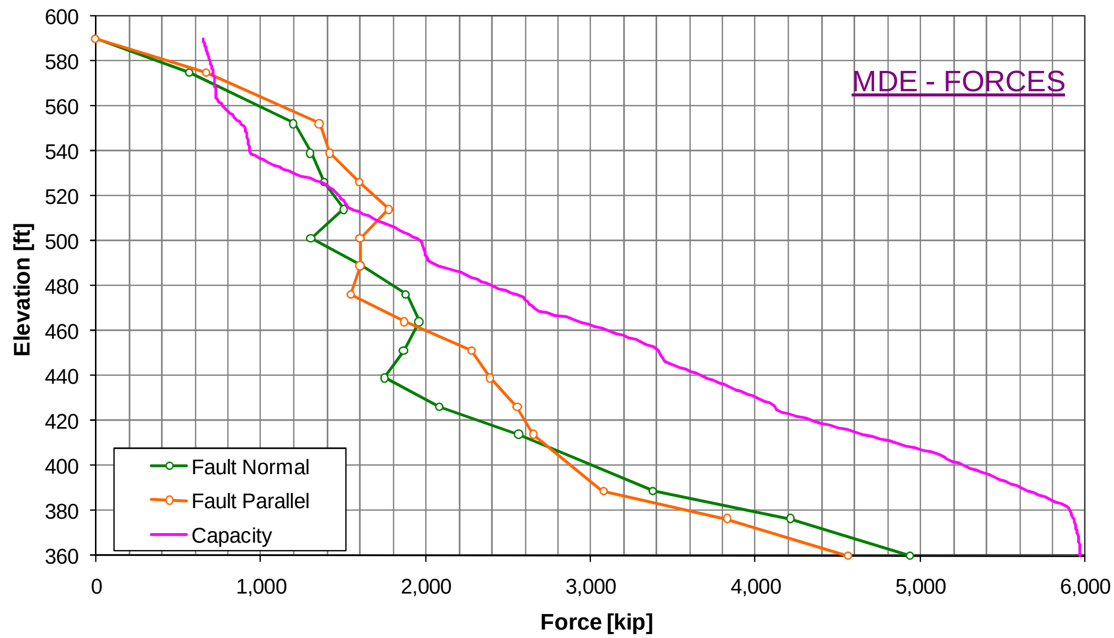


Figure 2-23. Comparison of shear demands with shear capacities for MDE.

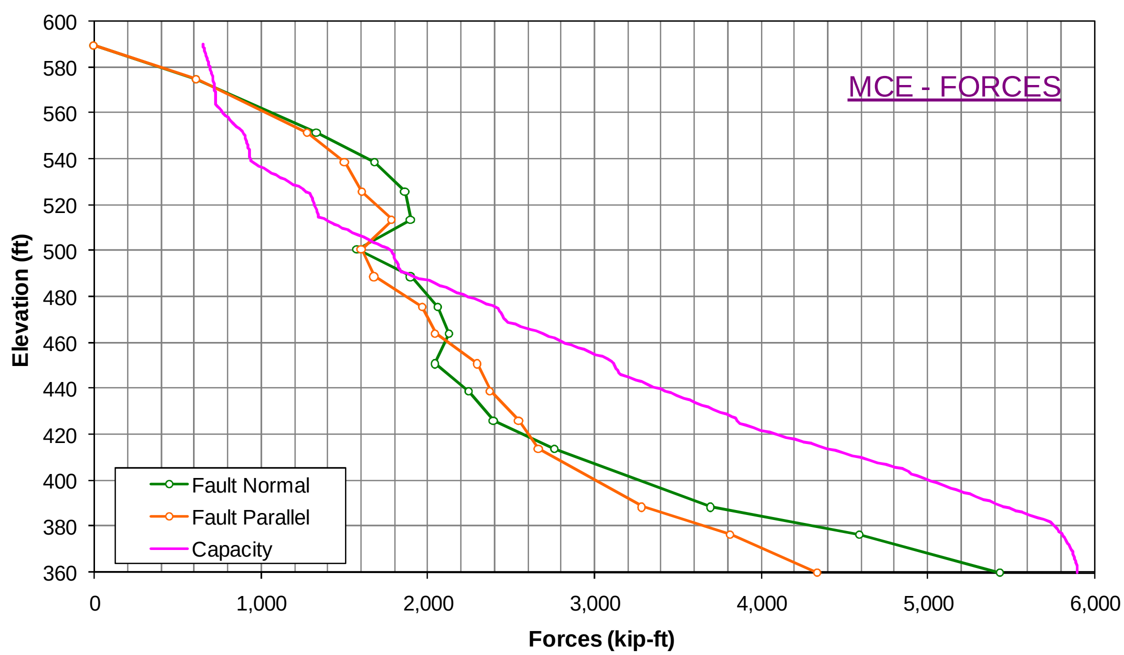


Figure 2-24. Comparison of shear demands with shear capacities for MCE.

3. OPTION-3: REINFORCED TOWER AND STRENGHTENED FOUNDATION

This retrofit option consists of two parts: an internal concrete infill, and an external concrete addition. The internal concrete infill is to thicken the existing shaft from the inside diameters of 20 ft at the bottom and 10 ft at the top to a uniform inside diameter of 8 ft from top to bottom using a reinforced concrete infill. The external concrete addition will use treme concrete to thicken the bottom portion of the tower from the footing at El. 347 ft up to El. 414 ft, just under the 2nd valve opening. The external concrete would limit tower deformations along the length of the added concrete and would also eliminate the need for anchoring the concrete-infill reinforcing-steel into the foundation rock.

3.1 Computer Model

The hollow circular shaft including the concrete infill was represented by linear beam elements with axial, bending, and shear deformations. The model included 17 nodes and 16 beam elements spanning from the bottom elevation of 360 ft to top elevation of 589.75 ft at the operating platform. The beam elements were developed based on the shaft nominal section geometry that included both the existing and the concrete infill. The added external treme concrete was also modeled using beam elements attached to the shaft as parallel elements. An outside diameter of 60 ft was assumed for the treme concrete.

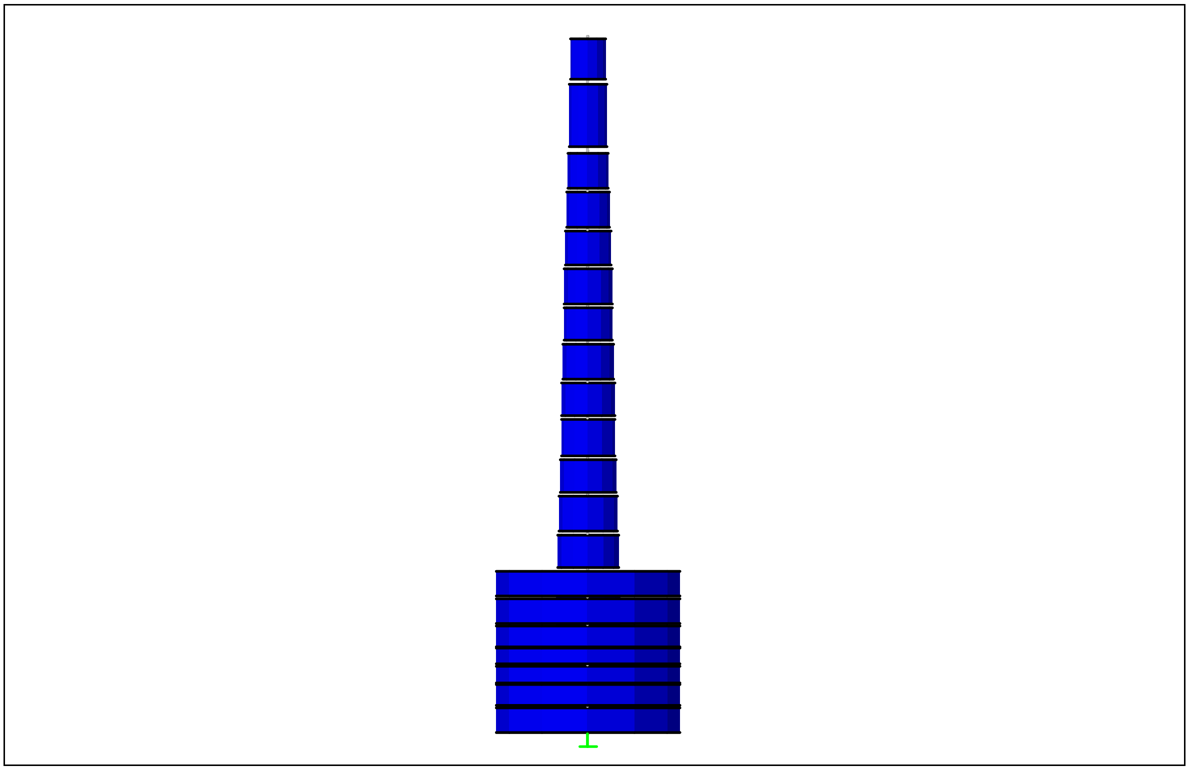


Figure 3-1. Finite element model of concrete infill option with external concrete addition.

3.2 Material Properties

The expected concrete material properties, established in the 2007 study (Quest, 2007), were used. These are summarized below.

Concrete Expected properties

Compressive strength	f_c	=	6,000	psi
Modulus of rupture	f_r	=	581	psi
Weight density	W_c	=	150	pcf
Modulus of elasticity	E_c	=	4,415,200	psi
Ultimate compressive strain	ε_c	=	0.003	

The expected yield strength of 46 ksi with a modulus of elasticity of 29,000 ksi and ultimate strain of 0.05 were assumed for the reinforcing steel.

3.3 Evaluation Loads

Evaluation loads consisted of the dead weight, water and seismic loads, as described below.

3.3.1 Dead Loads

The dead loads due to weight of the concrete were determined using a unit weight of 150 pcf.

3.3.2 Water Loads

The water loads were estimated for the reservoir water level at El. 576 ft, just below the spilling elevation. The tower is normally full, thus the elevation of inside water is also at 576 ft. The net hydrostatic pressures acting on the inside and outside surfaces of the circular shaft are zero.

3.3.3 Hydrodynamic Loads

The inside and outside water inertia loads due to seismic excitation were accounted for by added-mass terms following the Goyal and Chopra's procedure (1989).

3.3.4 Seismic Loads

The seismic input for evaluation of the concrete infill option consisted of two horizontal components of the site-specific MDE response spectra at 5% damping. The seismic performance of the tower was also checked against the seismic loads generated by the MCE. The MDE and MCE acceleration response spectra are fully described in the 2007 report (Quest, 2007). The estimated peak horizontal ground accelerations for these events are 0.70g and 0.75g, respectively.

3.4 Section Capacities

The flexural and shear section capacities were estimated following the procedures described in the 2007 study (Quest, 2007). The axial force-bending moment interaction diagrams were computed for the expected material properties using PCACOL computer program. Table 3-1 lists nominal moment capacities along the height of the tower for the existing tower, tower with concrete infill (composite section), and the concrete infill.

The section shear capacities were estimated in accordance with the US Army Corps of Engineers' EM1110-2-2400 and included contribution from the concrete and reinforcing steel. For this computation, however, only shear reinforcement associated with the existing concrete was considered. This is because shear reinforcements for the concrete infill were not available at the time of this computation. The estimated section capacities are thus conservative because they ignore contribution of the concrete-infill shear reinforcements. Table 3-2 summarizes section shear capacities along the height of the tower. In this table V_s is the shear contribution from the existing reinforcing steel and V_c from the existing and new concrete infill.

Table 3-1. Section moment capacities (also see Figure 3-3)

	Existing Section	Concrete Infill	Existing + Infill
ELEV. (ft)	M_N [k-ft]	M_N [k-ft]	M_N [k-ft]
589.75	9,000	108,000	117,000
575.00	10,400	203,600	214,000
552.00	12,000	229,000	241,000
539.00	22,900	240,100	263,000
526.00	24,400	255,600	280,000
514.00	55,000	261,000	316,000
501.00	67,000	274,000	341,000
489.00	71,000	289,000	360,000
476.00	75,000	305,000	380,000
464.00	79,500	318,500	398,000
451.00	109,000	330,000	439,000
439.00	114,000	348,000	462,000
426.00	120,000	363,000	483,000
414.00	126,000	381,000	507,000
388.50	167,000	418,000	585,000
376.50	174,000	429,000	603,000
360.00	184,000	450,000	634,000

Table 3-2. Section shear capacities (also see Figure 3-4)

ELEV. [ft]	Shear capacity (kip)		
	0.85Vs	0.85Vc	0.85(Vc+Vs)
589.75	249	813	1062
575.00	264	1016	1280
567.00	273	1131	1403
567.00	452	1131	1582
552.00	478	1356	1834
552.00	1129	1356	2485
540.00	1183	1562	2744
540.00	651	1562	2212
528.00	665	1668	2333
528.00	950	1668	2618
526.00	971	1777	2748
526.00	1918	1777	3695
514.00	1995	1984	3978
514.00	997	1984	2981
501.00	1039	2217	3256
501.00	1385	2217	3602
489.00	1436	2441	3877
476.00	1492	2692	4184
476.00	1958	2692	4650
464.00	2025	2933	4958
453.00	2086	3161	5247
453.00	2568	3161	5729
451.00	2582	3203	5785
439.00	2664	3461	6125
428.00	2740	3704	6444
428.00	3238	3704	6942
426.00	3254	3749	7003
414.00	3352	4023	7375
405.00	3425	4235	7659
405.00	4186	4235	8421
388.50	4350	4634	8983
382.50	4410	4782	9192
382.50	4961	4782	9743
376.50	5028	4933	9961
360.00	5212	5359	10571

3.5 Analysis Results

The linear-elastic response-spectrum method of analysis was used to evaluate the concrete-infill retrofit option. The model was first analyzed to obtain its vibration mode shapes and periods, which were then used to compute the maximum responses to the MDE and MCE ground motions. The modal responses were combined using the CQC method and directional responses were combined using the SRSS method.

3.5.1 Mode Shapes and Periods

Table 3-3 lists modal periods with individual and cumulative modal participation ratios for 48 modes. The results show that 100 percent participation was achieved in all three orthogonal directions. Note that the identical modes are obtained in the x and y directions, because the symmetric beam model was analyzed in three dimensions.

Figure 3-2 displays the first four mode shapes in “x” direction. These represent the first four cantilever bending modes, where the effects of the outside concrete addition in the lower part of the tower can be observed.

3.5.2 Maximum Shears and Moments

The moment demands, moment capacities, and moment demand-capacity ratios for the MDE and MCE are listed in Table 3-4. The moment demands for the MDE and MCE are compared with the section moment capacities in Figure 3-3. The results indicate that the MDE moments remain below the moment capacities at all elevations and that the maximum moment demand-capacity ratio is 0.9. This indicates that the response of the concrete-infill option to the MDE ground motion is within the linear-elastic range. Consequently, under the MDE, the concrete infill option should perform satisfactorily. The moment demand-capacity ratios for the MCE are mostly less than one, except in the lower portion of the tower between El. 408 to 468 ft. However, the maximum demand-capacity ratio in this region is limited to 1.4, which is less than the allowable value of 2 required by EM 1110-2-2400. Therefore, the flexural performance of the concrete infill is also acceptable for the MCE ground motion.

The shear demands and capacities along the height of the tower are compared in Figure 3-4. Note that the shear capacities are given separately for the reinforcing steel and the concrete as well as for the combined concrete and reinforcing steel. It is also important to note that only the existing shear reinforcing steel was considered in this study. It is anticipated that the concrete infill will include significant shear reinforcing steel and thus the actual shear capacities of the modified section would be significantly higher than the current estimate. The results show that the shear demands for the MDE are generally lower than the section shear capacities and thus the required shear demand-capacity of less than 1 is met. The shear demands for the MCE exceed the current estimates of the shear capacities, indicating that the concrete-infill should be designed with adequate shear reinforcement to make up for the difference. With the additional shear capacity provided by the concrete-infill, it can be concluded that the concrete infill option is a feasible alternative and can be designed to satisfy both the shear and flexural requirements for the MDE and MCE.

Table 3-3. Vibration periods and modal participation ratios.

MODE	PERIOD	INDIVIDUAL MODE (PERCENT)			CUMULATIVE SUM (PERCENT)		
	(SEC)	UX	UY	UZ	UX	UY	UZ
1	**1.1479**	**41.29**	**0.00**	**0.00**	**41.29**	**0.00**	**0.00**
2	1.1479	0.00	41.29	0.00	41.29	41.29	0.00
3	**0.2543**	**15.19**	**0.00**	**0.00**	**56.48**	**41.29**	**0.00**
4	0.2543	0.00	15.19	0.00	56.48	56.48	0.00
5	**0.1058**	**8.11**	**0.00**	**0.00**	**64.59**	**56.48**	**0.00**
6	0.1058	0.00	8.11	0.00	64.59	64.59	0.00
7	**0.0567**	**6.00**	**0.00**	**0.00**	**70.59**	**64.59**	**0.00**
8	0.0567	0.00	6.00	0.00	70.59	70.59	0.00
9	0.0524	0.00	0.00	49.71	70.59	70.59	49.71
10	0.0377	4.15	0.00	0.00	74.74	70.59	49.71
11	0.0377	0.00	4.15	0.00	74.74	74.74	49.71
12	0.0299	3.53	0.00	0.00	78.27	74.74	49.71
13	0.0299	0.00	3.53	0.00	78.27	78.27	49.71
14	0.0237	0.00	4.63	0.00	78.27	82.90	49.71
15	0.0237	4.63	0.00	0.00	82.90	82.90	49.71
16	0.0226	0.00	0.00	11.57	82.90	82.90	61.28
17	0.0191	0.00	3.79	0.00	82.90	86.69	61.28
18	0.0191	3.79	0.00	0.00	86.69	86.69	61.28
19	0.0160	3.82	0.00	0.00	90.50	86.69	61.28
20	0.0160	0.00	3.82	0.00	90.50	90.50	61.28
21	0.0142	0.00	0.00	5.94	90.50	90.50	67.22
22	0.0133	0.00	1.56	0.00	90.50	92.06	67.22
23	0.0133	1.56	0.00	0.00	92.06	92.06	67.22
24	0.0116	0.00	1.33	0.00	92.06	93.40	67.22
25	0.0116	1.33	0.00	0.00	93.40	93.40	67.22
26	0.0105	0.00	0.97	0.00	93.40	94.36	67.22
27	0.0105	0.97	0.00	0.00	94.36	94.36	67.22
28	0.0103	0.00	0.00	4.89	94.36	94.36	72.12
29	0.0095	0.00	0.65	0.00	94.36	95.01	72.12
30	0.0095	0.65	0.00	0.00	95.01	95.01	72.12
31	0.0085	0.00	0.43	0.00	95.01	95.44	72.12
32	0.0085	0.43	0.00	0.00	95.44	95.44	72.12
33	0.0081	0.00	0.00	5.42	95.44	95.44	77.53
34	0.0069	0.00	0.00	4.86	95.44	95.44	82.39
35	0.0064	0.00	0.00	4.78	95.44	95.44	87.18
36	0.0063	0.00	4.03	0.00	95.44	99.46	87.18
37	0.0063	4.03	0.00	0.00	99.46	99.46	87.18
38	0.0057	0.00	0.00	5.92	99.46	99.46	93.10
39	0.0050	0.00	0.00	2.02	99.46	99.46	95.11
40	0.0046	0.00	0.00	1.35	99.46	99.46	96.47
41	0.0042	0.00	0.00	0.43	99.46	99.46	96.90
42	0.0039	0.00	0.00	0.18	99.46	99.46	97.08
43	0.0037	0.00	0.00	0.07	99.46	99.46	97.15
44	0.0036	0.00	0.00	0.03	99.46	99.46	97.18
45	0.0031	0.00	0.54	0.00	99.46	100.00	97.18
46	0.0031	0.54	0.00	0.00	100.00	100.00	97.18
47	0.0027	0.00	0.00	2.23	100.00	100.00	99.42
48	0.0016	0.00	0.00	0.58	100.00	100.00	100.00

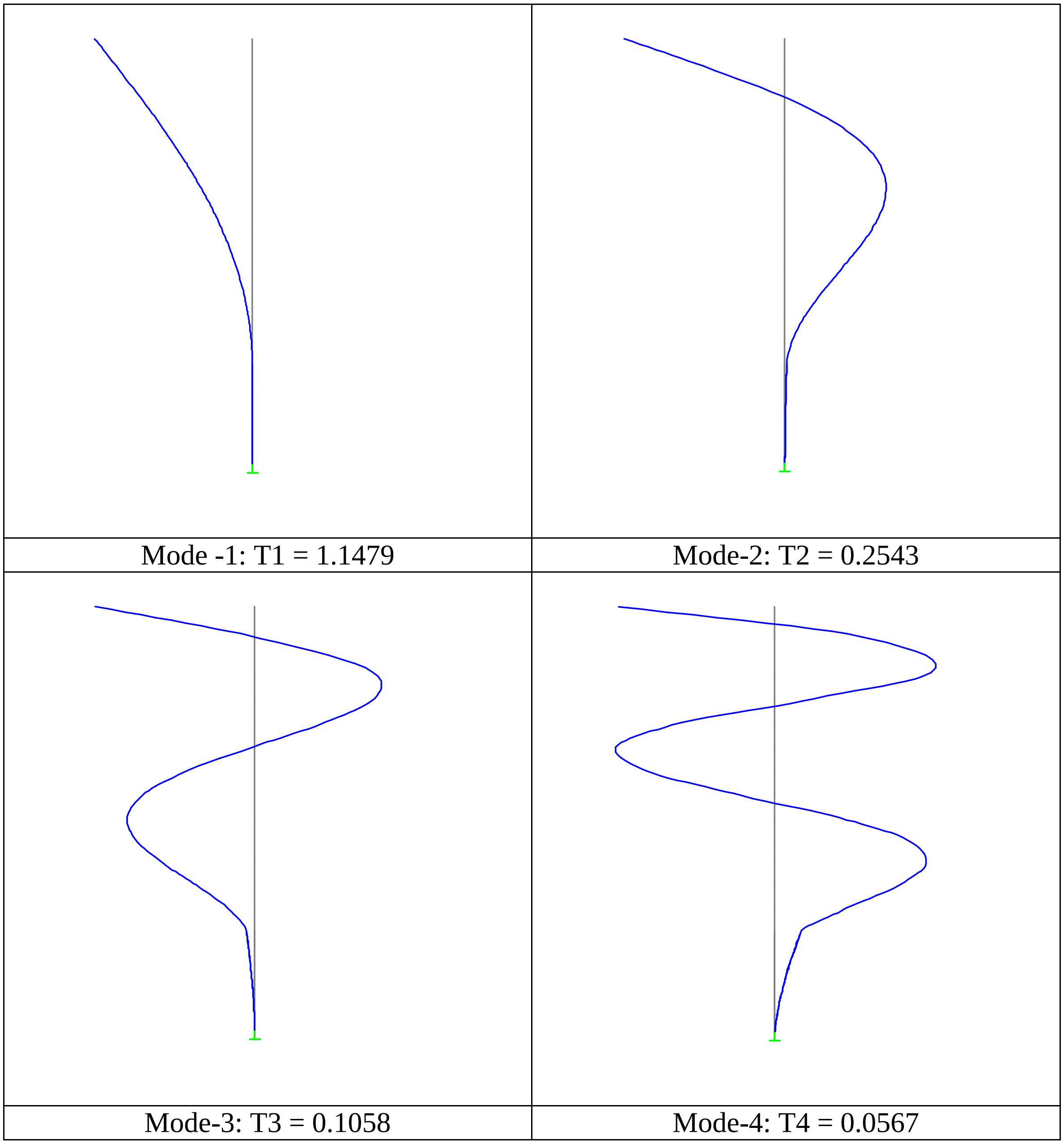


Figure 3-2. Deflected shape of first four modes

Table 3-4. Moment demand-capacity ratios

EL. (ft)	Moment Capacity	Moment Demands		Moment Demand-Capacity Ratio	
	M_N [k-ft]	MCE M [k-ft]	MDE M [k-ft]	MCE	MDE
589.75	117,000	0	0	0.0	0.00
575.00	214,000	20,290	16,973	0.1	0.08
552.00	241,000	79,099	62,648	0.3	0.26
539.00	263,000	118,063	89,827	0.4	0.34
526.00	280,000	159,074	115,230	0.6	0.41
514.00	316,000	200,767	140,114	0.6	0.44
501.00	341,000	247,987	166,733	0.7	0.49
489.00	360,000	296,318	194,581	0.8	0.54
476.00	380,000	351,986	227,068	0.9	0.60
464.00	398,000	409,250	262,788	1.0	0.66
451.00	439,000	475,125	305,643	1.1	0.70
439.00	462,000	541,643	351,529	1.2	0.76
426.00	483,000	616,332	404,579	1.3	0.84
414.00	507,000	689,500	458,341	1.4	0.90
388.50	585,000	16,362	11,521	0.0	0.02
376.50	603,000	18,445	12,941	0.0	0.02
360.00	634,000	23,740	16,863	0.0	0.03

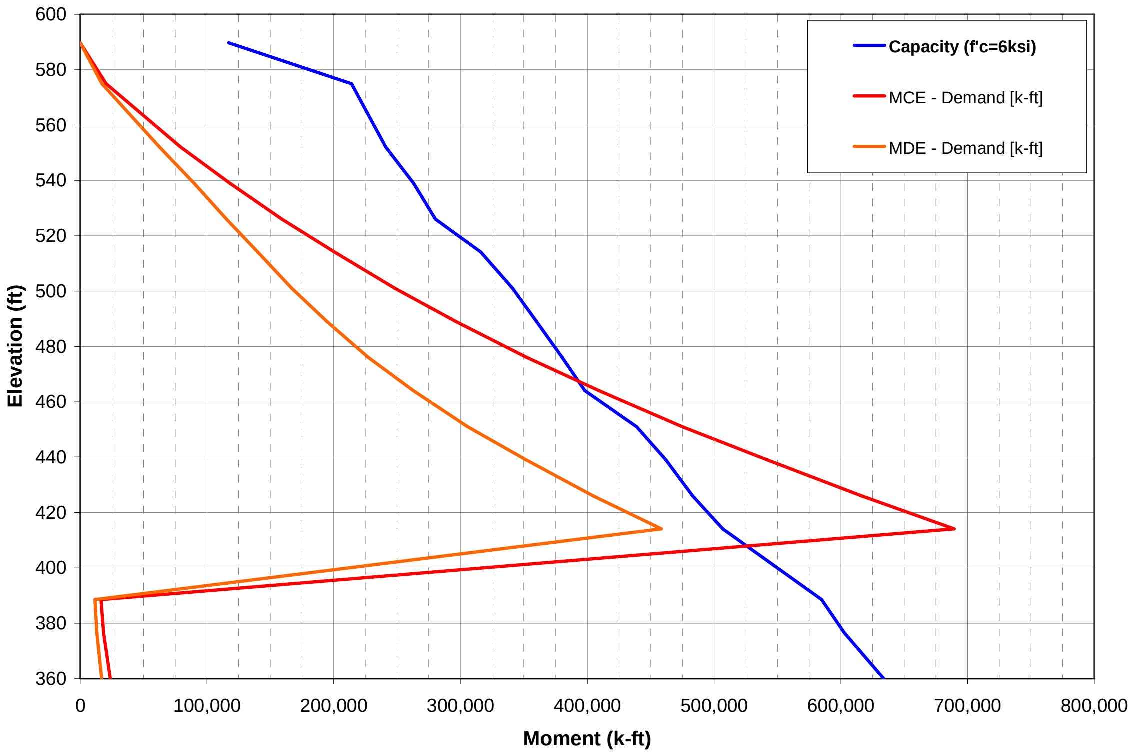


Figure 3-3. Comparison of MDE and MCE moment demands with section moment capacities.

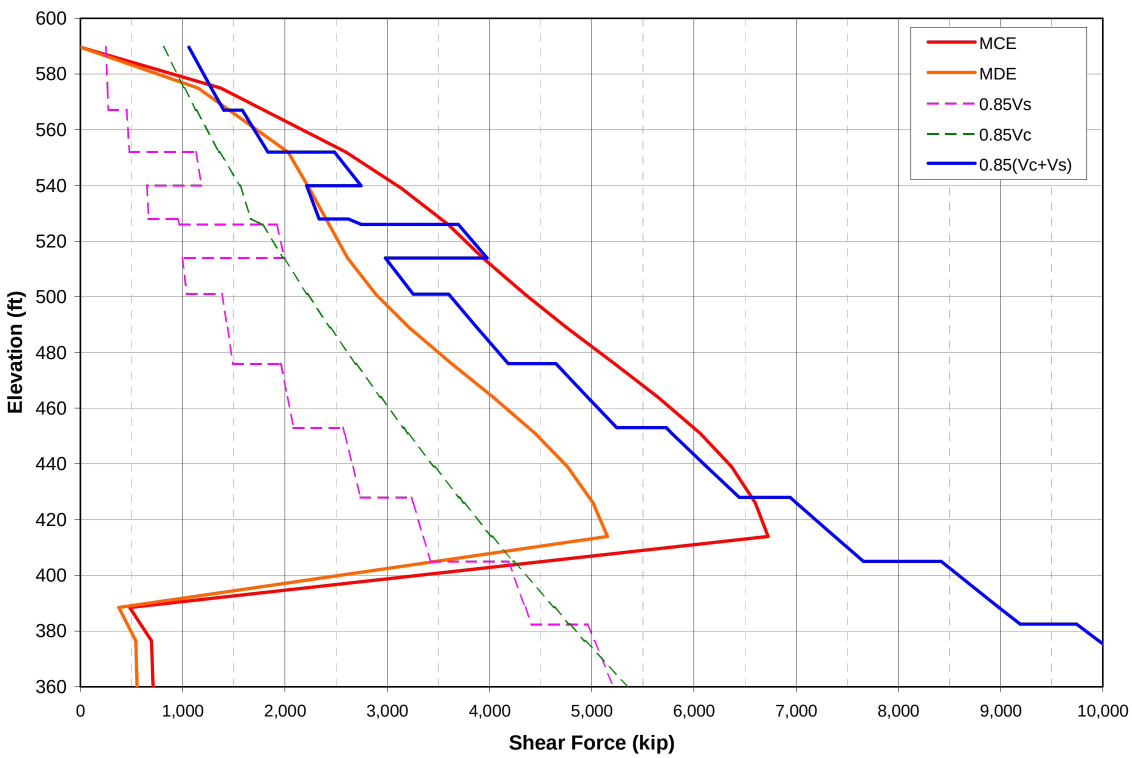


Figure 3-4. Comparison of MDE and MCE shear demands with section shear capacities.

4. CONCLUSION

The results of nonlinear time-history analyses indicate that the guy-wire support alternative is not feasible for stabilization of Briones Tower. This is because the tower would still experience tensile cracking along its height and could fail in shear at elevations above the guy wires.

The results of linear-elastic analyses suggest that the concrete infill alternative is a feasible alternative and can be designed to satisfactorily resist both shear and moment demands for the MDE and MCE ground motions.

5. REFERENCES

Ehsani M.R. and Marine M.E. (1994), “User’s Guide for Concrete Moment-Curvature Relationship (M-Phi),” prepared for US Army Corps of Engineers.

Goyal, A. and Chopra, A.K. (1989), “Earthquake Analysis and response of Intake-Outle Towers,” report No. UCB/EERC-89-04, Earthquake Engineering research Center, University of California, Berkeley, 1989.

Quest, 2007, “Seismic Evaluation of Briones Outlet Tower,” final report submitted to EBMUD, August 6, 2007.

APPENDIX B2: SEISMIC EVALUATION OF OPTION-6 ALTERNATIVE BRIONES OUTLET TOWER

SEISMIC EVALUATION OF OPTION-6 ALTERNATIVE BRIONES OUTLET TOWER

September 12, 2008

Prepared for

East Bay Municipal Utility District
375 11th Street
Oakland, CA 94607

By

Quest Structures, Inc.
3 Altarinda Road, Suite 203
Orinda, CA 94563

Seismic Evaluation of Option-6 Alternative Briones Outlet Tower

1. Description of Option 6 Alternative

Figure 1 shows the latest remedial alternative designated as Option 6. It involves cutting the top 1/3 of the tower and replacing it with a 5-foot-diameter and ¾-inch thick steel pipe. The pipe will be 88.75 ft long, rising from El. 501 to 589.75 ft with an access platform at the top. The steel pipe will be connected to the bottom concrete shaft using a steel frame and 12-inch concrete slab that caps the shaft.

2. Finite-element Model

Figure 2 displays SAP2000 models for the Option 6 alternative and the existing tower. The steel pipe for the Option 6 is indicated as red. The access platform and the anchoring steel frame were represented as lumped nodal lumped masses.

3. Seismic Analysis

The Option 6 model was analyzed for the gravity and the effects of MDE ground motion. The response-spectrum mode superposition method of analysis was used. The analysis included more than 40 modes to ensure 100% modal mass participation. The material properties for the concrete were the same as those reported previously. A damping ratio of 5% was used for all modes of vibration.

4. Mode Shapes and Periods

The lowest 6 mode shapes and periods for the Option 6 are presented in Figure 3. Mode-1 with a period of 1.65 sec corresponds to the fundamental bending mode of the steel pipe. Mode-2 with a period of 0.78 sec is the fundamental bending mode of the shortened concrete shaft. These can be compared with mode shapes and periods of the existing tower provided in Figure 4.

The important change to note is that the fundamental mode of the existing tower with the largest modal participation factor of 50% vibrates at a period of 1.78 sec, while the fundamental mode of the shortened concrete shaft in the Option 6 vibrates at 0.78 sec. The MDE spectral acceleration at 1.78 sec is 0.34g and at 0.78 sec is 0.806g. This indicates that although the remediated tower is approximately 30% lighter, the spectral acceleration for its primary mode with the largest participation factor is 2.37 times larger (0.806/0.34 = 2.37) than that for the heavier exiting tower. So the net effect is such that the base shear and moment for the retrofitted tower is about the same as that of the existing tower, as discussed next.

5. Results

The moment and shear results for Option 6 and the exiting tower are provided in Figures 5 and 6, respectively. Also provided in these figures for comparison are the moment and shear capacities.

The results show that the moments for Option 6 are equal or greater than those for the exiting tower in the bottom 20 feet of the shaft. This indicates that the lower part of the tower would still suffer significant damage even though the top 1/3 of the tower have been replaced by lighter steel pipe. This condition is more severe for the MCE excitation (not shown here). To make this option work the lower 20 to 50 feet of the tower should be strengthened.

The shears for Option 6 are even higher than those obtained for the exiting tower at elevations below 501 feet (i.e., for the entire concrete shaft). In particular, shear demands exceed the shear capacity in the embedded portion of the steel pipe (El. 489 to 501), thus requiring shear strengthening in this region.

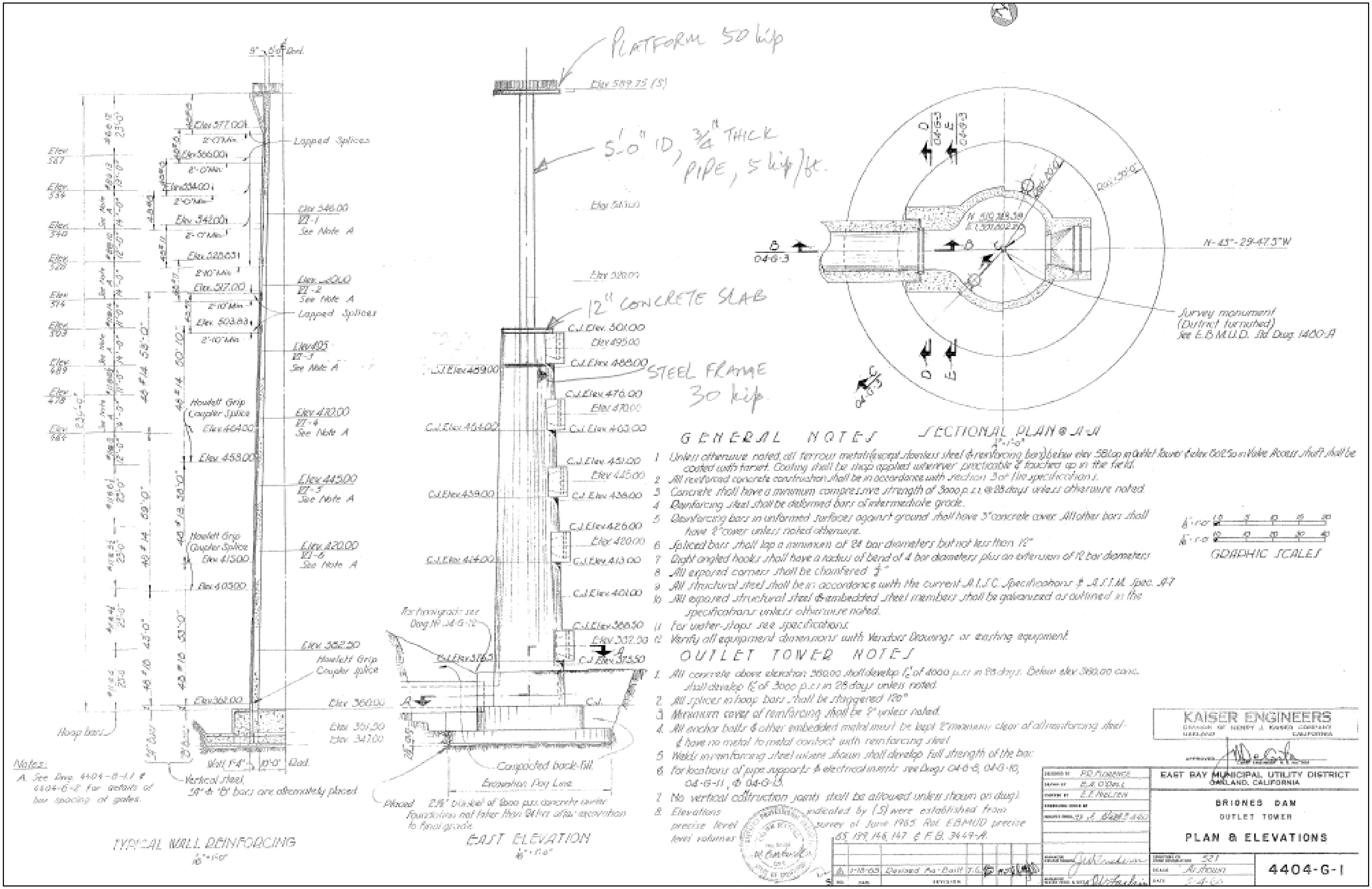
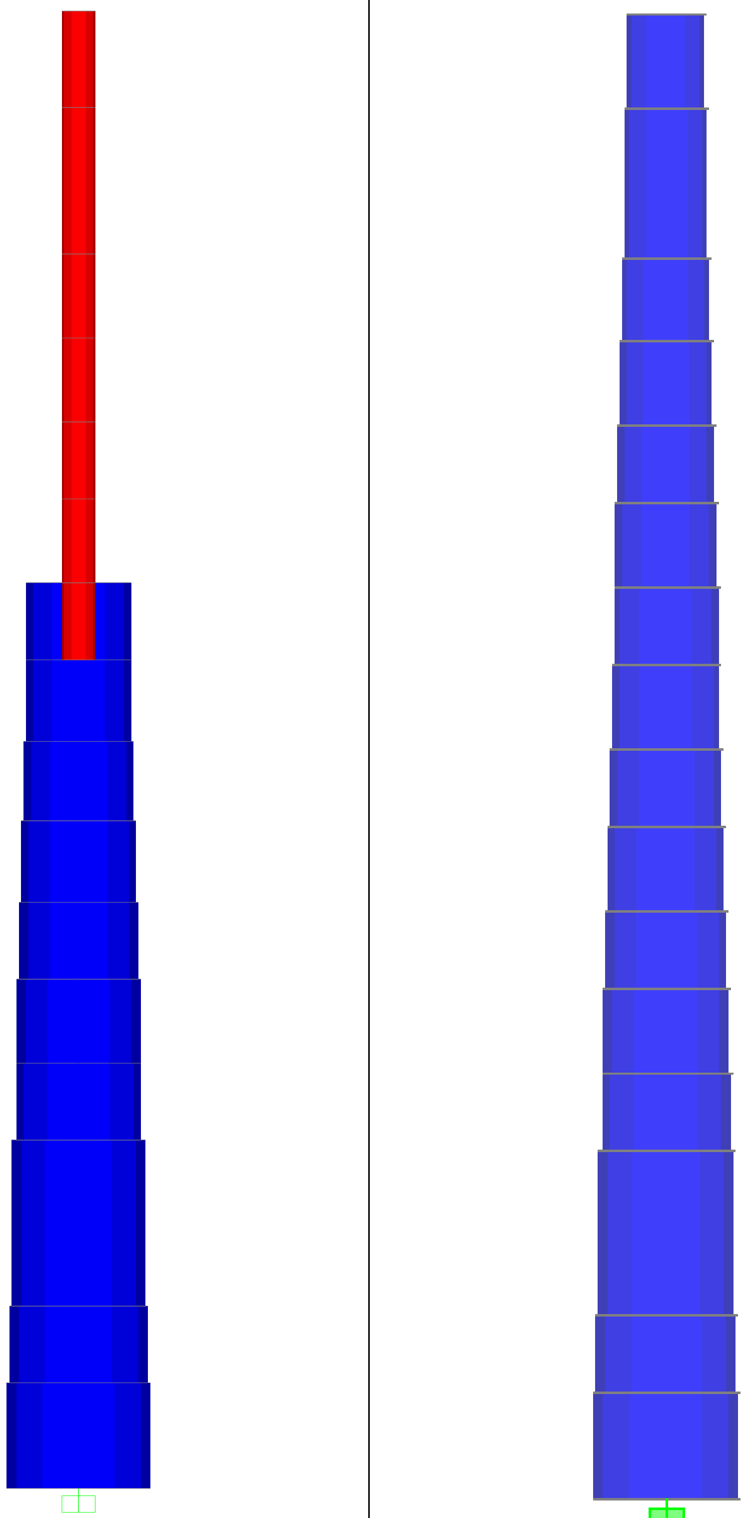


Figure 1. Proposed pipe retrofit option (Option 6).



a) Option-6 Model

b) Existing Tower Model

Figure 2. SAP2000 models of Option-6 and original towers.

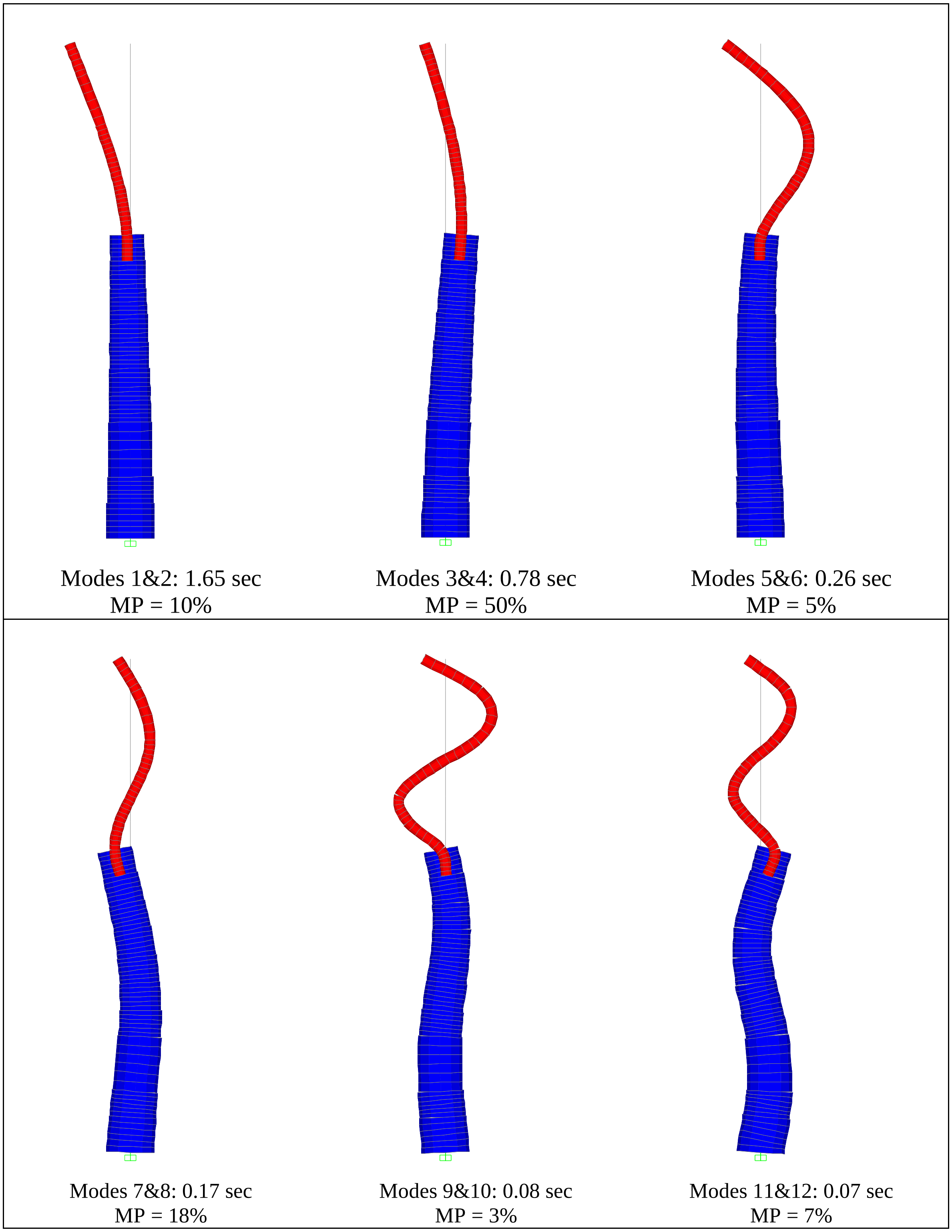


Figure 3. Mode shapes, periods, and modal participation factors for Option 6.

Note: Modes 1&2, 3&4, etc. refer to two similar modes in each of the two horizontal directions.

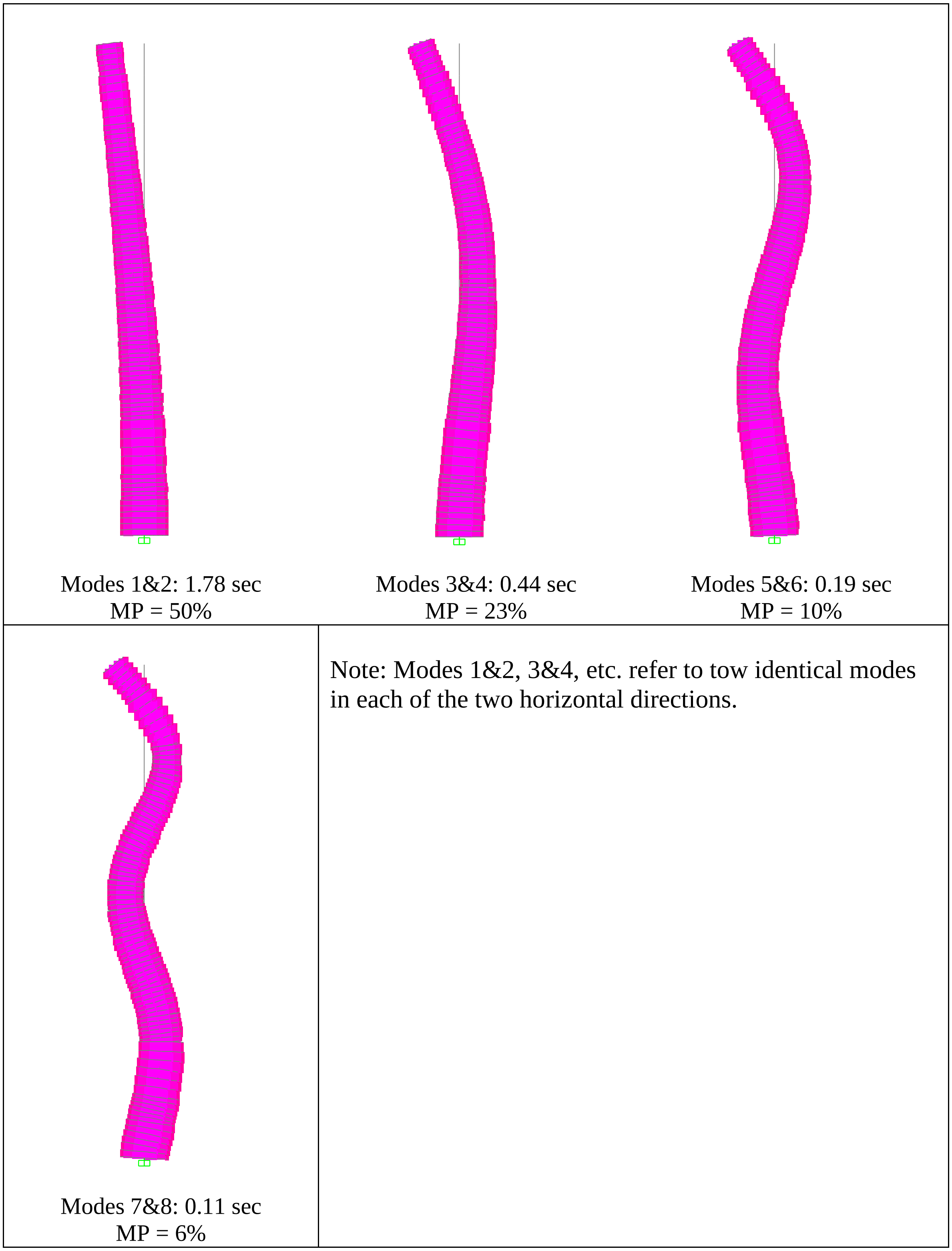


Figure 4. Mode shapes, periods, and modal participation factors for existing tower.

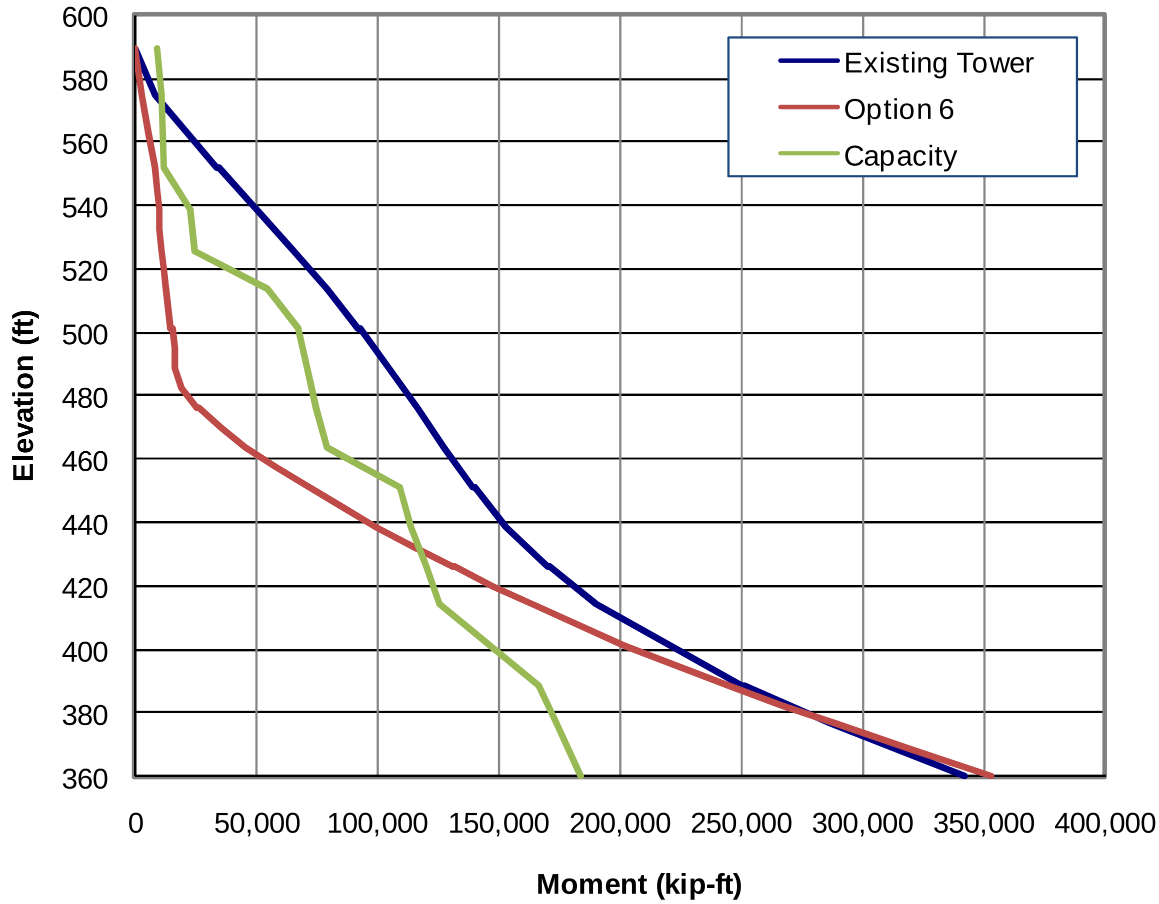


Figure 5. Comparison of MDE moment demands with moment capacity

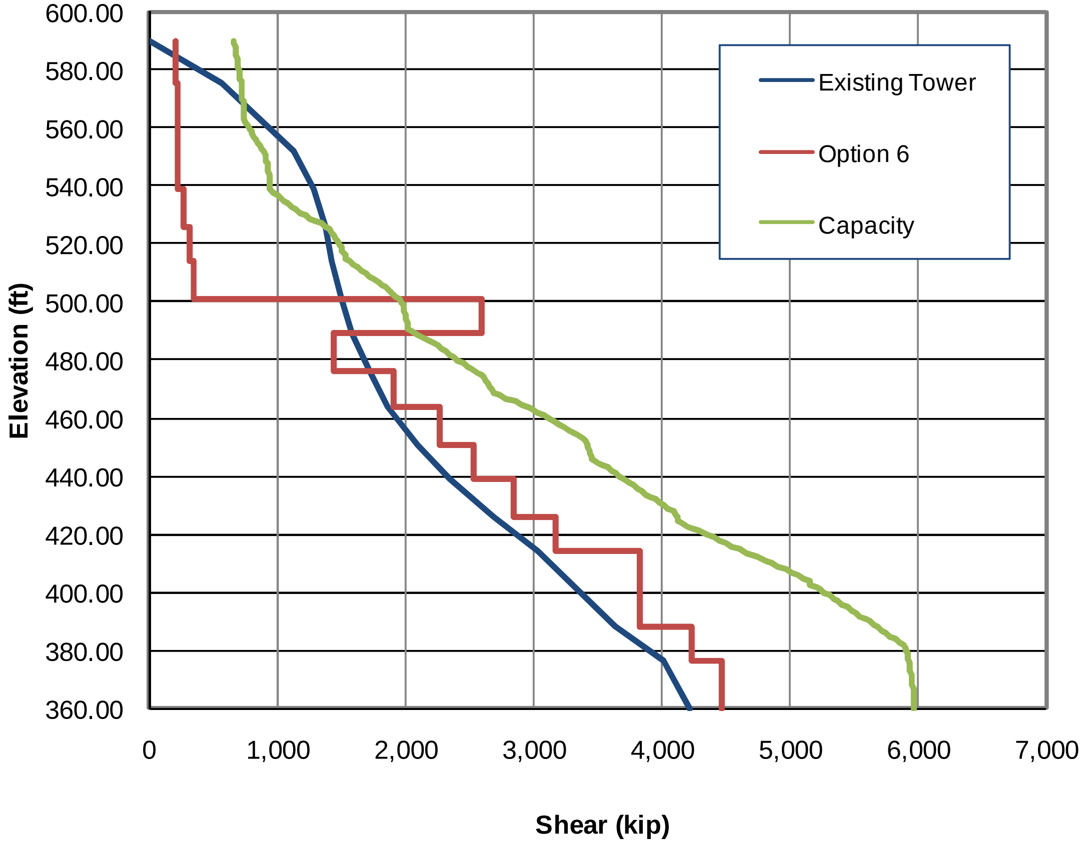


Figure 6. Comparison of MDE shear demands with shear capacity

APPENDIX B3: SEISMIC EVALUATION OF GUY-WIRES WITH TWO SUPPORT LEVELS

SEISMIC EVALUATION OF GUY-WIRES WITH TWO SUPPORT LEVELS (OPTION 1A)

BRIONES OUTLET TOWER

Final Report

Prepared for

East Bay Municipal Utility District
375 11th Street
Oakland, CA 94607

By

Quest Structures, Inc.
3 Altarinda Road, Suite 203
Orinda, CA 94563

March 27, 2009

Table of Contents

Seismic Evaluation of
Guy-wires with Two Support Levels
Briones Outlet Tower

1. DESCRIPTION OF GUY-WIRE SUPPORT ALTERNATIVE

Figure 1-1 is a sketch of a two-level guy-wire support alternative (Option 1A) proposed for stabilization of Briones Tower. It consists of two sets of four wires with two support levels at approximate elevations of 485 ft and 555 ft. The wires will use steel rings for connection to the tower and four hold down points for anchorage to the reservoir floor. The two levels of wires are tied to the same anchor, with an assumed 45 degrees angle for the upper level and a flatter angle for the lower wire. However, the anchorage point of the upper level wire could be 10 feet higher than that of the lower level wire.

2. FINITE-ELEMENT MODEL

The SAP2000 model is based on the same tower shaft idealization used previously (Quest, 2007), but also employs nonlinear elements to represent guy wires and plastic hinging at the base of the tower. The hollow circular shaft is represented by linear beam elements with axial, bending, and shear deformations. The model includes 17 nodal points and 16 beam elements spanning from the bottom elevation at 360 ft to the top elevation at 589.75 ft. The beam elements are based on the shaft nominal section geometry. A nonlinear joint element is included at the base of the shaft to model plastic hinging at this location. The nonlinear joint element uses a nonlinear moment-curvature relationship discussed previously (Quest, 2008). The guy-wires are modeled using cable elements with the catenary behavior under their self-weight. The cable elements include both the tension-stiffening and large-deflections nonlinearity. Figures 2-1 and 2-2 display the model with extruded beam elements shown in blue and cable elements shown as green lines.

3. EVALUATION LOADS

Evaluation loads consist of the dead weight, water, and seismic loads. These are fully described in the Quest 2007 report (Quest, 2007).

3.1 Dead Loads

The dead loads due to weight of the concrete were determined using a unit weight of 150 pcf.

3.2 Water Loads

The water loads were estimated for the reservoir water level at El. 576 ft, just below the spilling elevation. The tower is normally full, thus elevation of the inside water is also at 576 ft. The net hydrostatic pressures acting on the inside and outside surfaces of the circular shaft are zero.

3.3 Hydrodynamic Loads

The inside and outside water inertia loads due to seismic excitation were accounted for by added-mass terms following the Goyal and Chopra's procedure (1989).

3.4 Seismic Loads

The seismic input is the same as that used previously (Quest, 2007). It consists of the site-specific response spectra for the MDE and MCE ground motions developed by Geomatrix Consultants. The estimated peak horizontal ground accelerations for these events are 0.70g and 0.75g, respectively. However, the seismic input for the nonlinear analysis of the tower with guy wires required acceleration time histories. This was accomplished by using the acceleration time histories that had been developed for the Sobrante Outlet Tower, except that they were scaled to the level of Briones response spectra (Quest, 2008).

4. RESULTS OF ANALYSIS

The finite-element model described in section 2 was analyzed using the step-by-step nonlinear time history method. Both horizontal components of the ground motions were considered but each was applied separately plus the vertical component. Circular cross sections are subjected to the resultant shear and moment caused by both horizontal components of the ground motion. The maximum shear and moment therefore should be estimated for the combined effects of the horizontal components. This can be done by applying both horizontal components simultaneously and determining the resultant shear and resultant moment at each time step, from which the maximum resultant shear moment can then be obtained. However, in this study a simpler approach was taken, in which each horizontal component of ground motion was applied separately but was multiplied by 1.3 to account for the effects of two-component excitation. The factor of 1.3 was selected consistent with the customary 30% rule used for building structures. This way the resultant shear and moment time histories are computed directly and then searched to obtain the maximum values. The results reported in the following sections are for the 1.3 times the fault normal and 1.3 times the fault parallel components applied separately.

Two cases were analyzed: one with 2 ¼-inch wires, and another with 4-inch wires to investigate whether larger wires would improve the seismic performance of the tower.

4.1 Results for 2 ¼ inch Wires

4.1.1 Tower displacement

Figures 4-1 and 4-2 show the maximum displacement histories at the top of the tower for the MDE and MCE ground motions, respectively. The results indicate a maximum displacement of 1.8 ft for the MDE and 3.1 ft for the MCE. These are comparable with those estimated previously for the guy wires with one level support.

4.1.2 Wire axial forces

Figures 4-3 and 4-4 exhibit guy-wires axial-force histories for the MDE and MCE, respectively. As expected the wires experience tensile forces only. The maximum tension reaches the wire capacity of 600 kips for the MDE, and 700 kips for the MCE which is slightly higher than the capacity.

4.1.3 Tower base moment and shear

Figures 4-5 and 4-6 show the maximum moment histories at the base of the tower for the MDE and MCE, respectively. As expected, the maximum moments at the base of the tower are limited to the moment capacity of the nonlinear joint set to 225,000 kip-ft in accordance with previous study (Quest, 2008). The magnitudes of moments at higher elevations are discussed below in Section 4.1.4.

Figures 4-7 and 4-8 display the maximum shear force histories at the base of the tower for the MDE and MCE, respectively. The results show that the maximum base shear is just under the base shear capacity of 6,000 kips for both the MDE and MCE ground motions. Comparison of shear demands with shear capacities at higher elevations are discussed below in Section 4.1.4.

4.1.4 Evaluation of results

Figures 4-9 and 4-10 compare moment demands with moment capacities along the entire height of the tower for the MDE and MCE, respectively. The results indicate that the MDE moment demands exceed moment capacities above El. 450 ft and the MCE moments exceed the moment capacities at all elevations. This indicates that the tower could still experience significant cracking and yielding in its upper half. Spread of cracking and yielding to higher elevations diminishes the benefit of guy wires as the stabilizers.

Figures 4-11 and 4-12 compare shear demands with shear capacities for the MDE and MCE, respectively. The results show that the shear demands remain below the shear capacities at elevations below the lower level guy-wires, but exceed the capacities above this elevation.

Overall, the results suggest that the two-level guy-wires have improved the situation only slightly over the one-level guy-wires analyzed previously.

4.2 Results for 4-inch Wires

4.2.1 Tower displacement

Figures 4-13 and 4-14 show the maximum displacement histories at the top of the tower for the MDE and MCE ground motions, respectively. The results indicate a maximum displacement of 1.7 ft for the MDE and 3.0 ft for the MCE, only slightly less than those for the 2 ¼ inch wires.

4.2.2 Wire axial forces

Figures 4-15 and 4-16 exhibit the guy-wires axial-force histories for the MDE and MCE, respectively. The maximum wire tension for the MDE is well within the wire capacity of the MCE just reaches the capacity of 1000 kips.

4.2.3 Tower base moment and shear

Figures 4-17 and 4-18 show the maximum moment histories at the base of the tower for the MDE and MCE, respectively. As expected, the maximum moments at the base of the tower are limited to the moment capacity of the nonlinear joint set to 225,000 kip-ft.

Figures 4-19 and 4-20 display the maximum shear force histories at the base of the tower for the MDE and MCE, respectively. The results show that the maximum base shear is under the base shear capacity of 6,000 kips for both the MDE and MCE ground motions.

4.2.4 Evaluation of results

Figures 4-21 and 4-22 compare moment demands with moment capacities along the entire height of the tower for the MDE and MCE, respectively. The results indicate that the MDE moment demands exceed moment capacities above El. 460 and those of the MCE exceed the capacities at all elevations. The results suggest that the use of 4-inch diameter wires have not improved the situation over that of the 2 ¼ inch diameter wires.

Figures 4-23 and 4-24 compare shear demands with shear capacities for the MDE and MCE, respectively. The results show that the shear demands remain below the shear capacities at elevations below the lower level guy-wires, but exceed the capacities above this elevation.

5. CONCLUSION

Overall, the results indicate that neither the 2 ¼ inch nor the 4-inch diameter wires with 2 level attachments show any measureable performance improvement over the single-attachment guy wires analyzed previously (Quest, 2008).

6. REFERENCES

Goyal, A. and Chopra, A.K. (1989), "Earthquake Analysis and response of Intake-Outlet Towers," report No. UCB/EERC-89-04, Earthquake Engineering research Center, University of California, Berkeley, 1989.

Quest, 2007, "Seismic Evaluation of Briones Outlet Tower," final report submitted to EBMUD, August 6, 2007.

Quest, 2008, "Seismic Evaluation of Retrofit Options for Briones Outlet Tower," final report submitted to EBMUD, September 12, 2008.

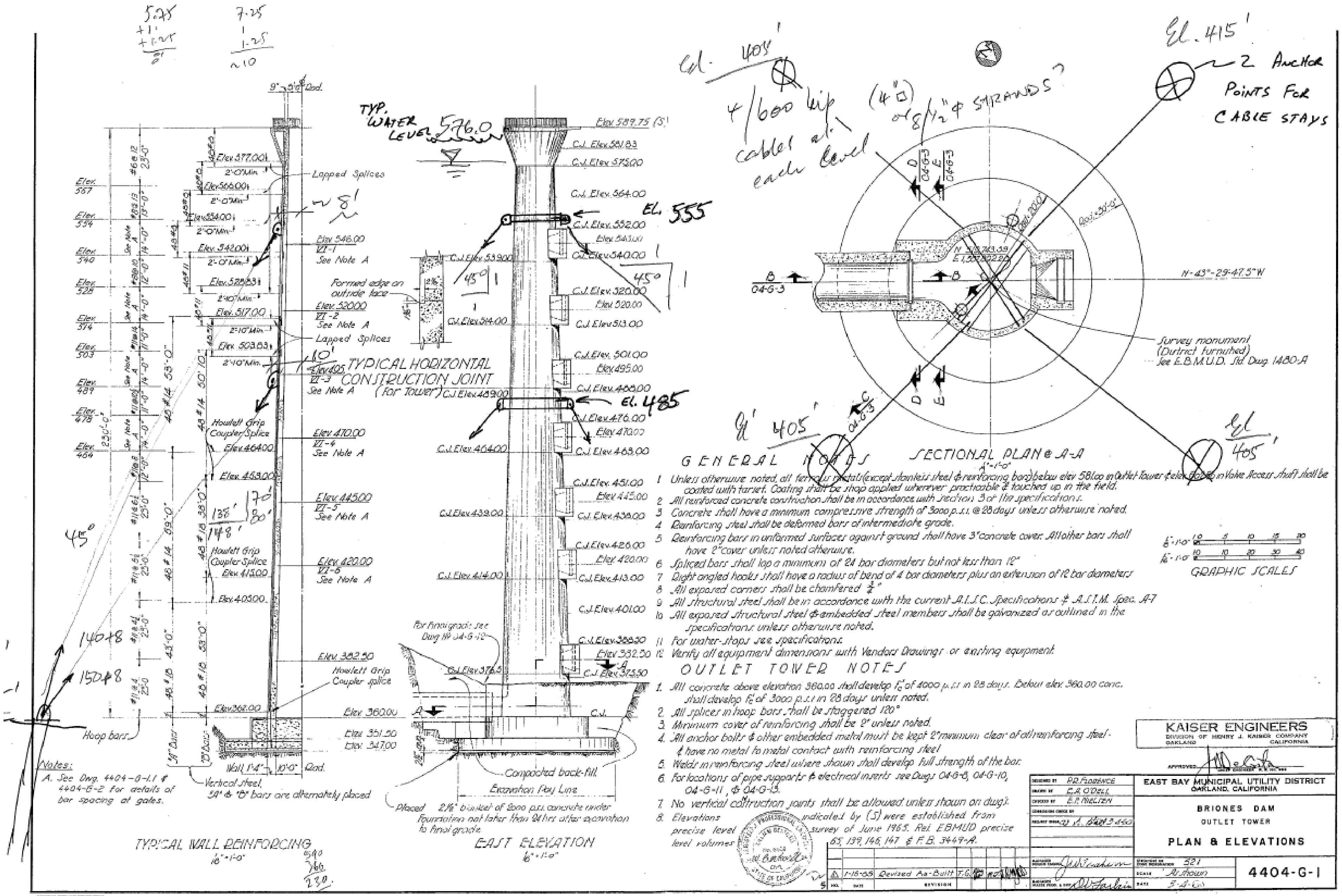


Figure 1-1: Sketch of guy wires alternative with 2 support levels.

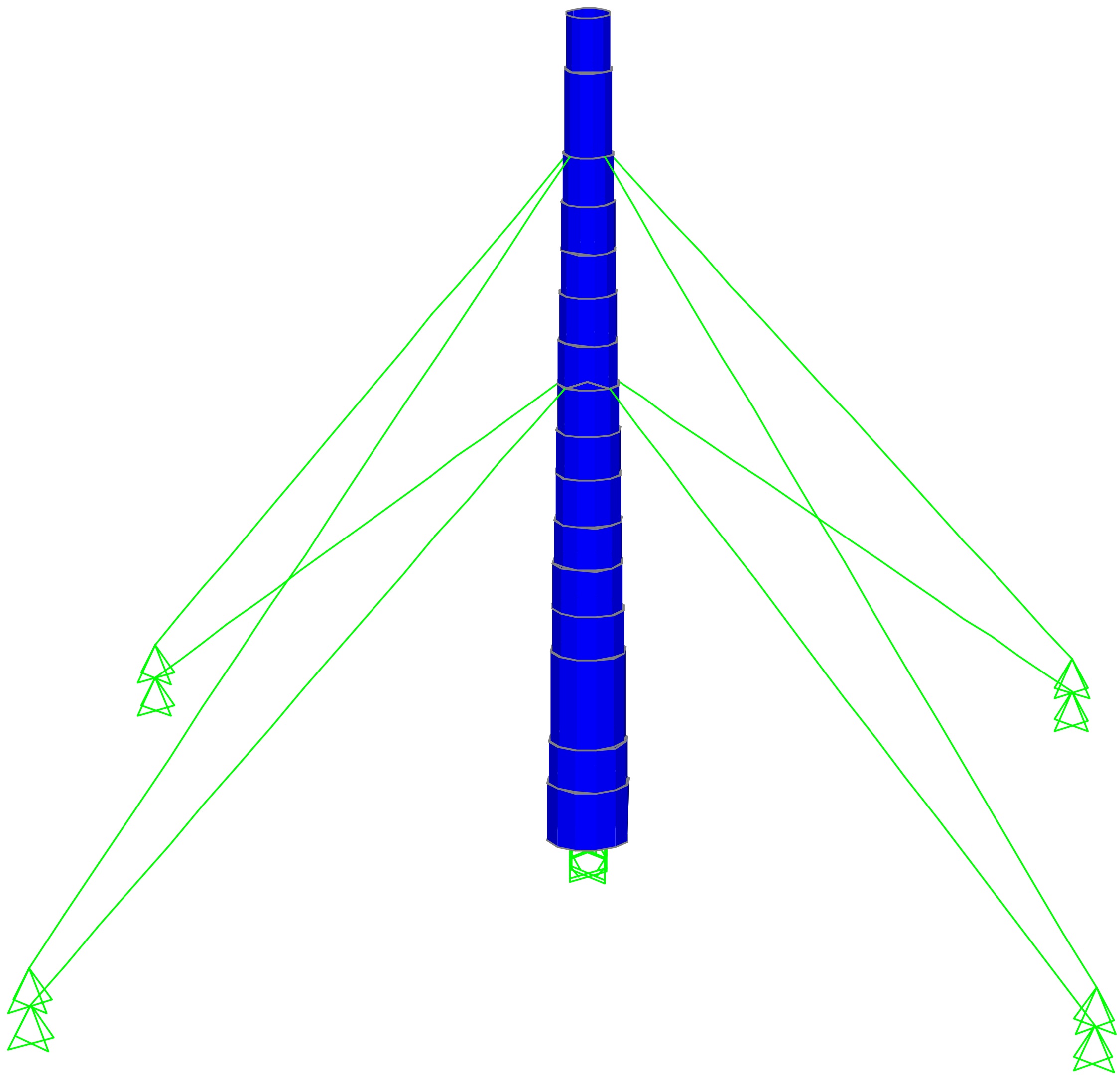


Figure 2-1: 3D view of finite-element model showing tower with 2 sets of guy wires.

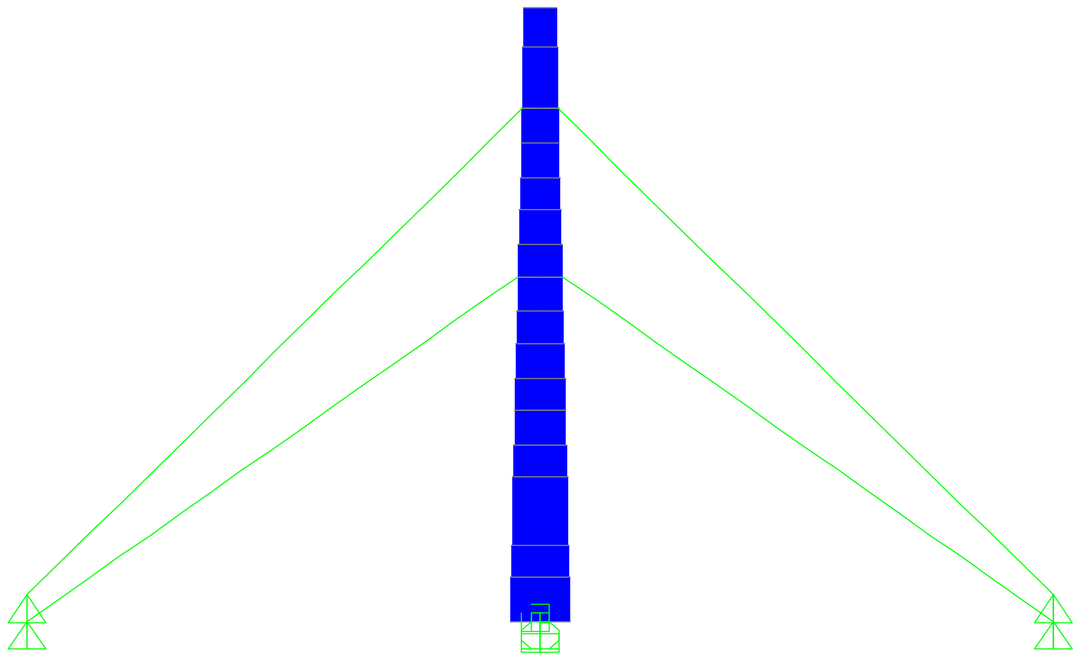
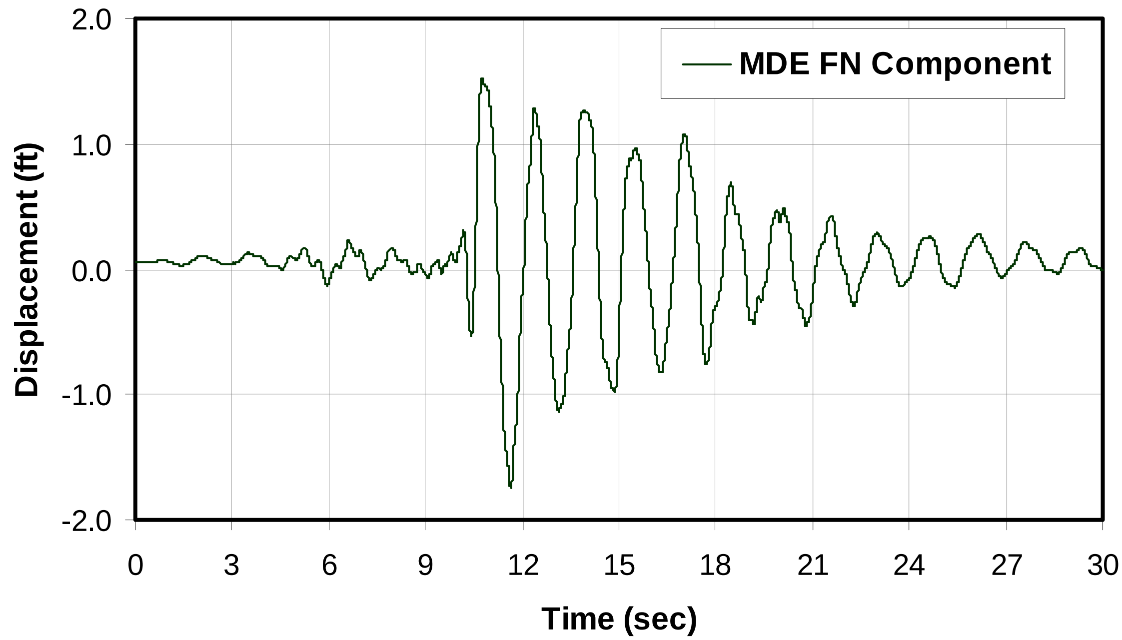


Figure 2-2: Elevation view of finite-element model.



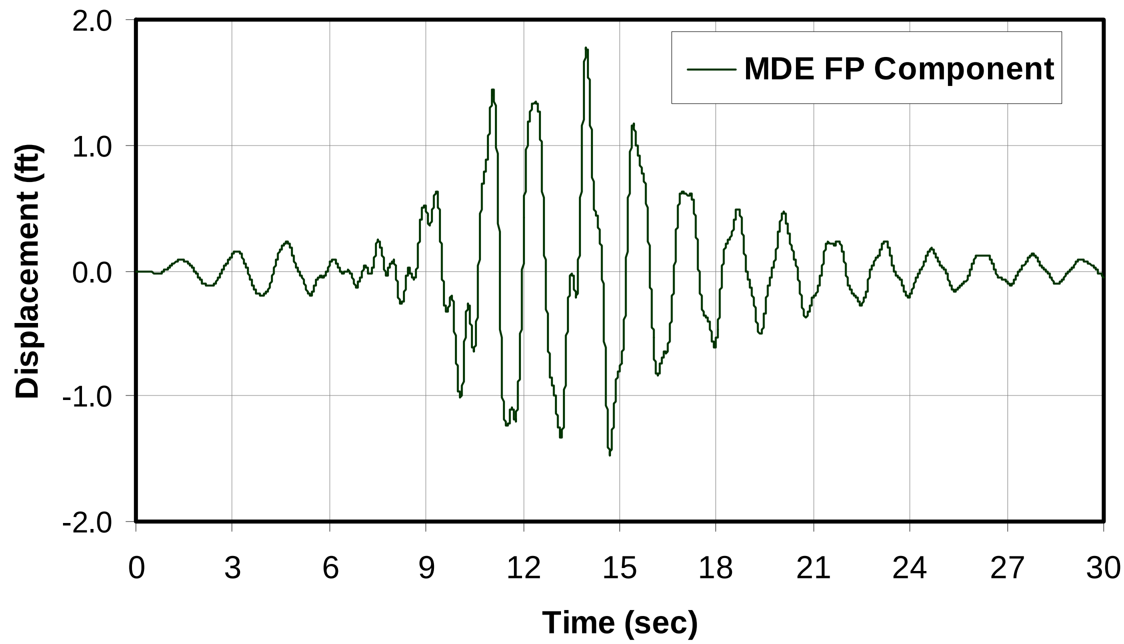


Figure 4-1: MDE displacement histories at top of tower (2-1/4 inch wires).

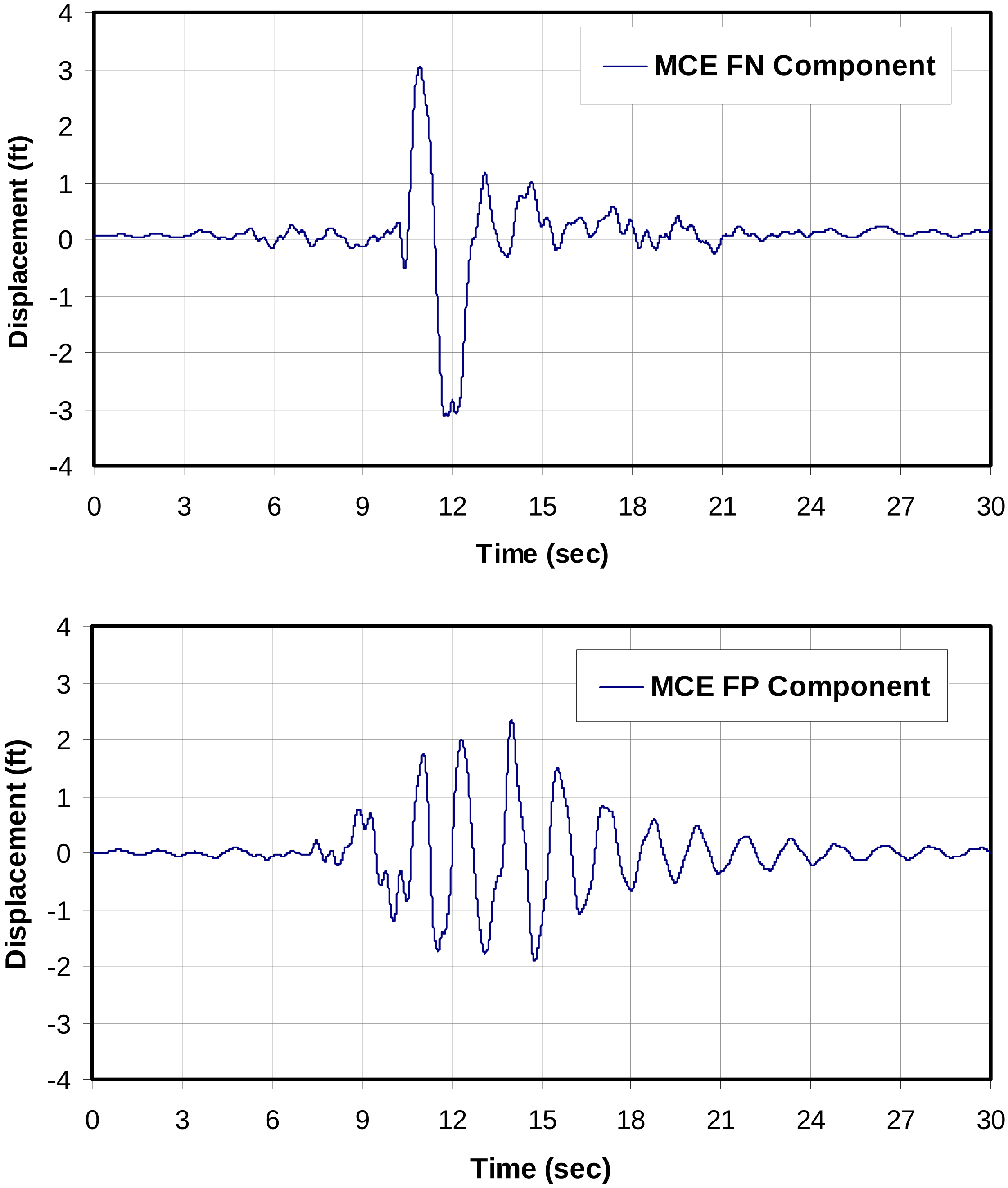
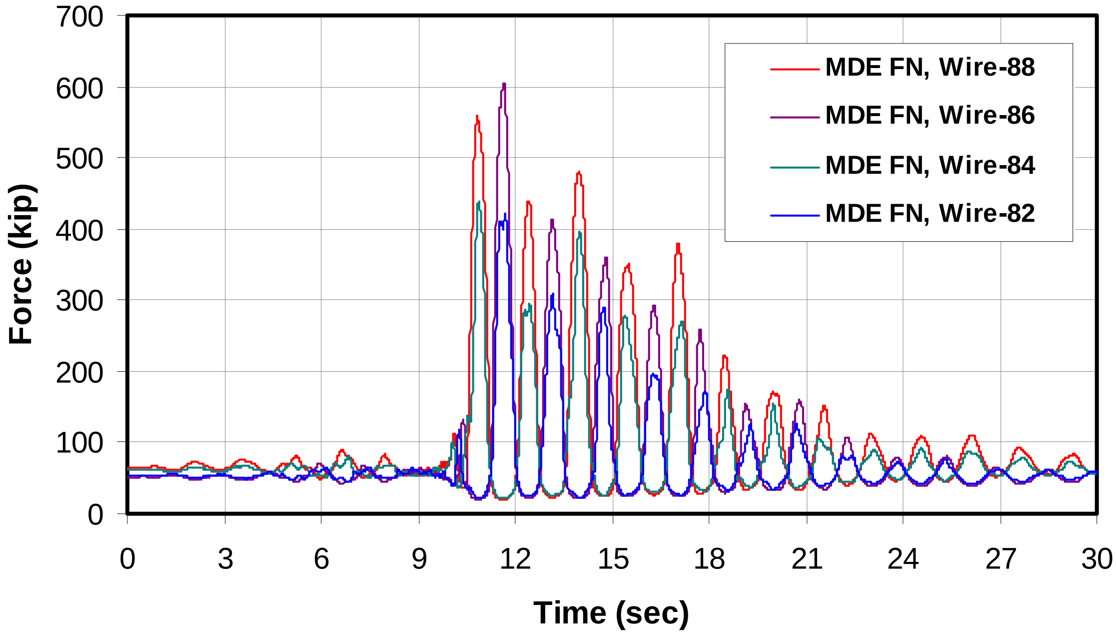


Figure 4-2: MCE displacement histories at top of tower (2-1/4 inch wires).



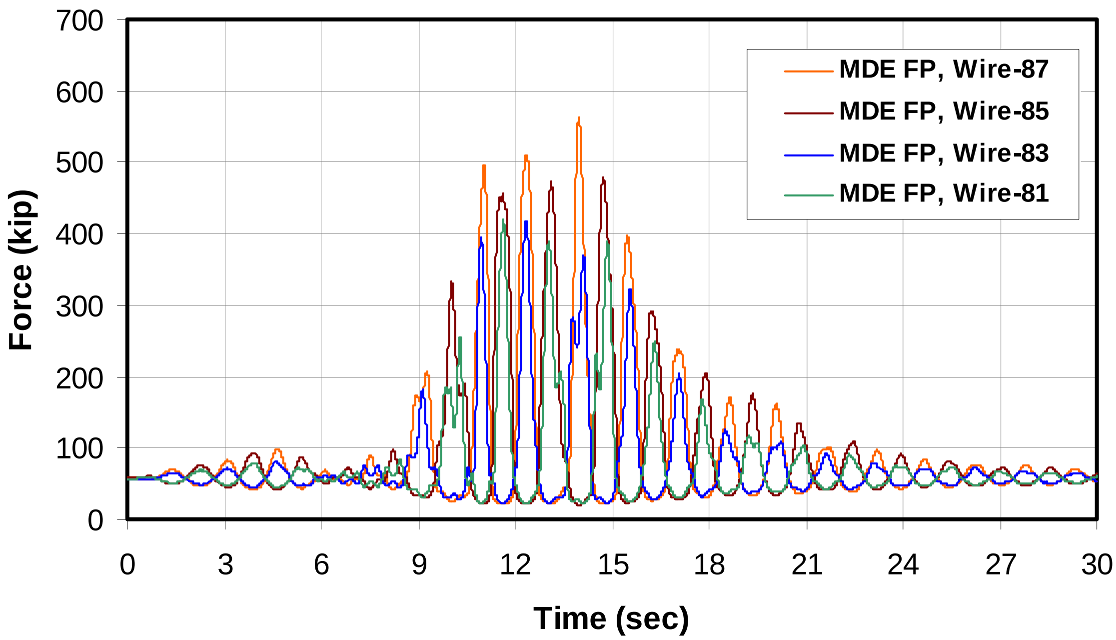


Figure 4-3: Time history of wire forces for MDE (2 ¼ inch wires).

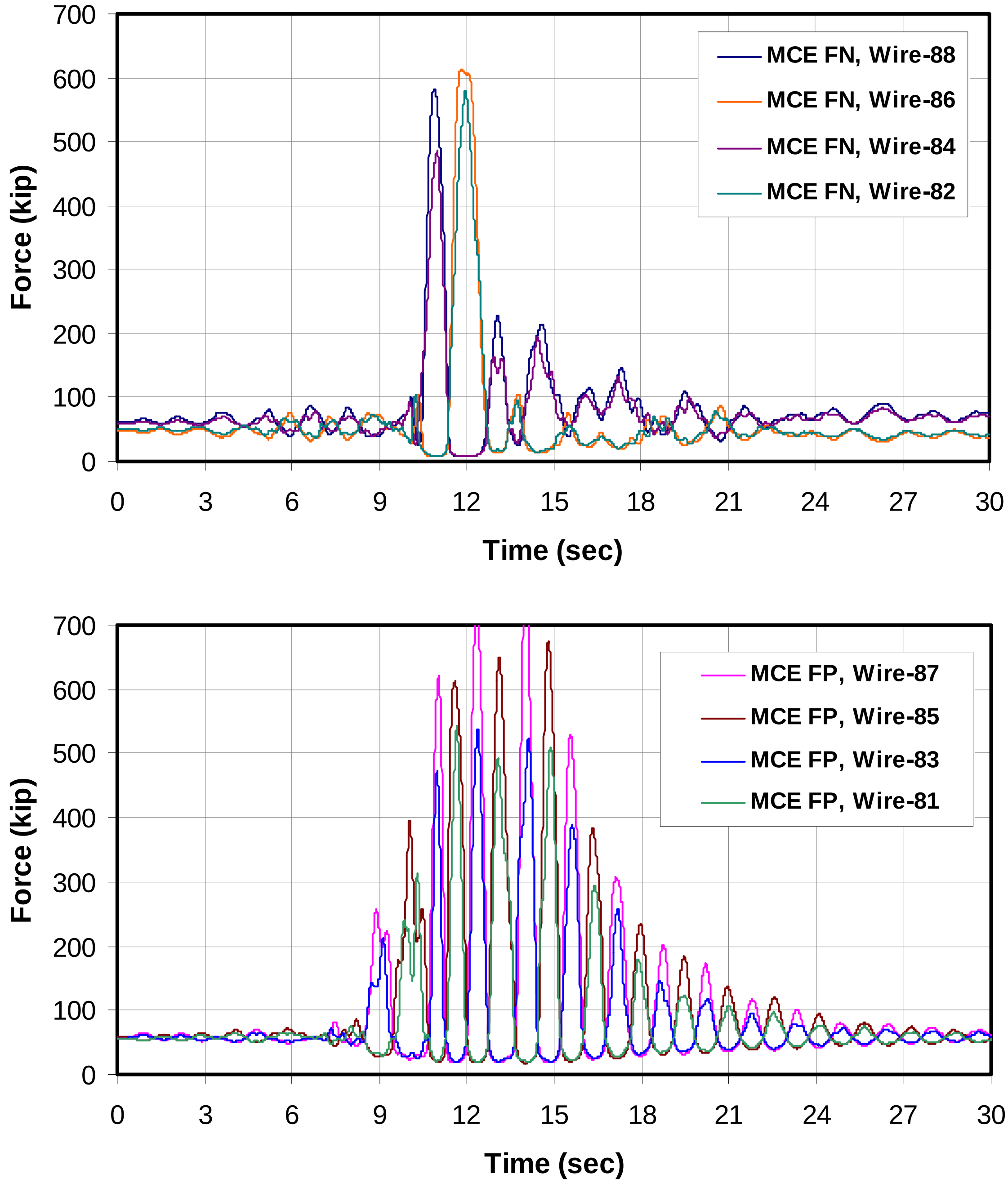
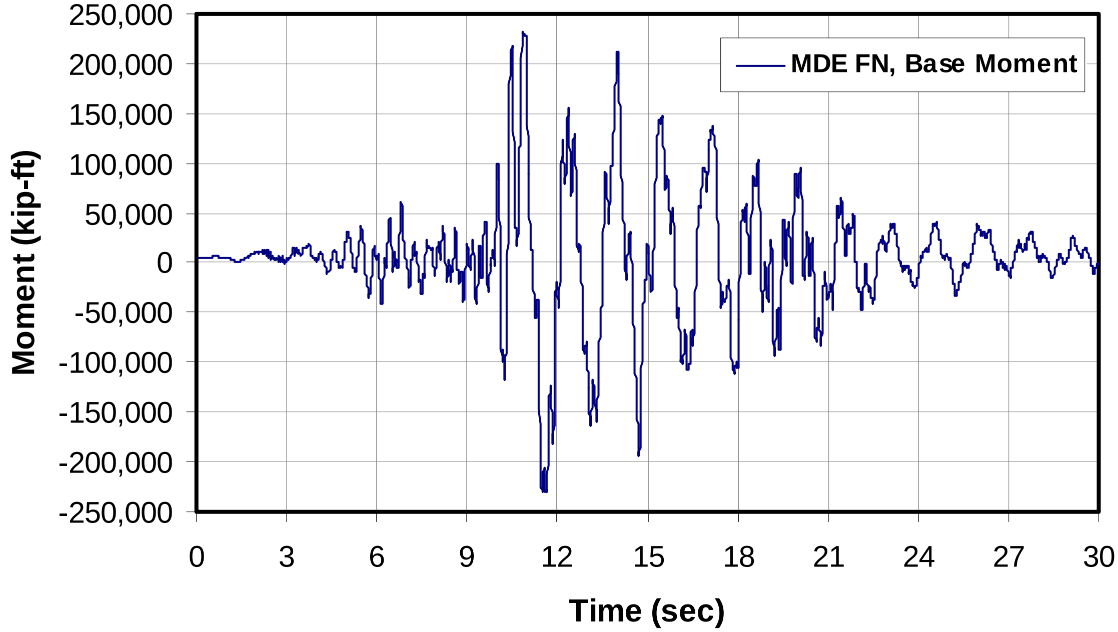


Figure 4-4: Time Histories of wire forces for MCE (2 ¼ inch wires).



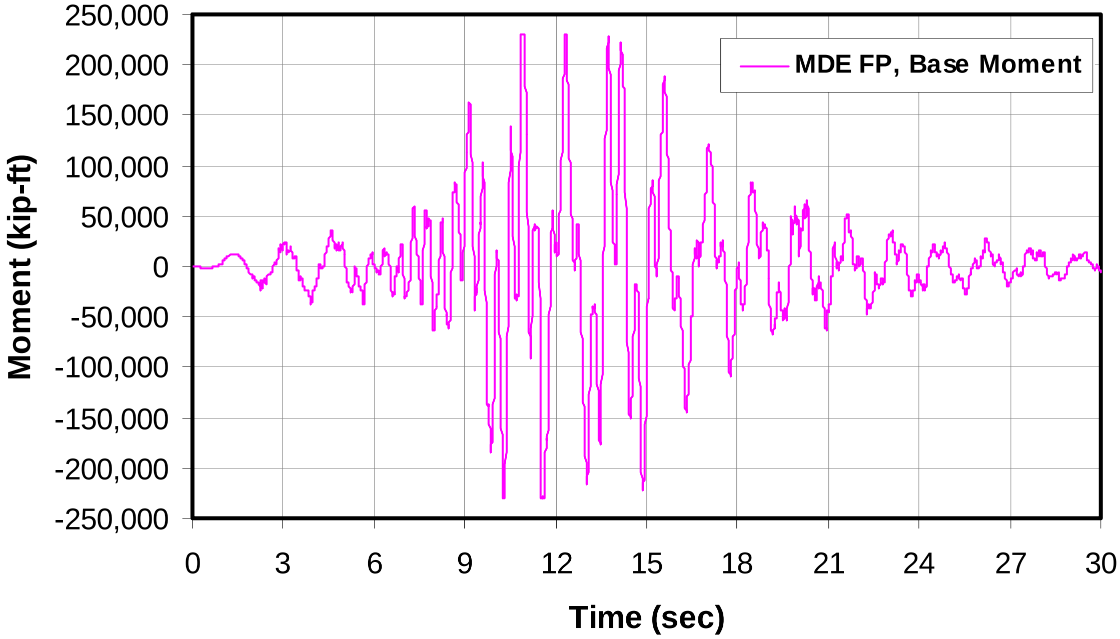


Figure 4-5: Time histories of maximum moments for MDE (2 ¼ inch wires).

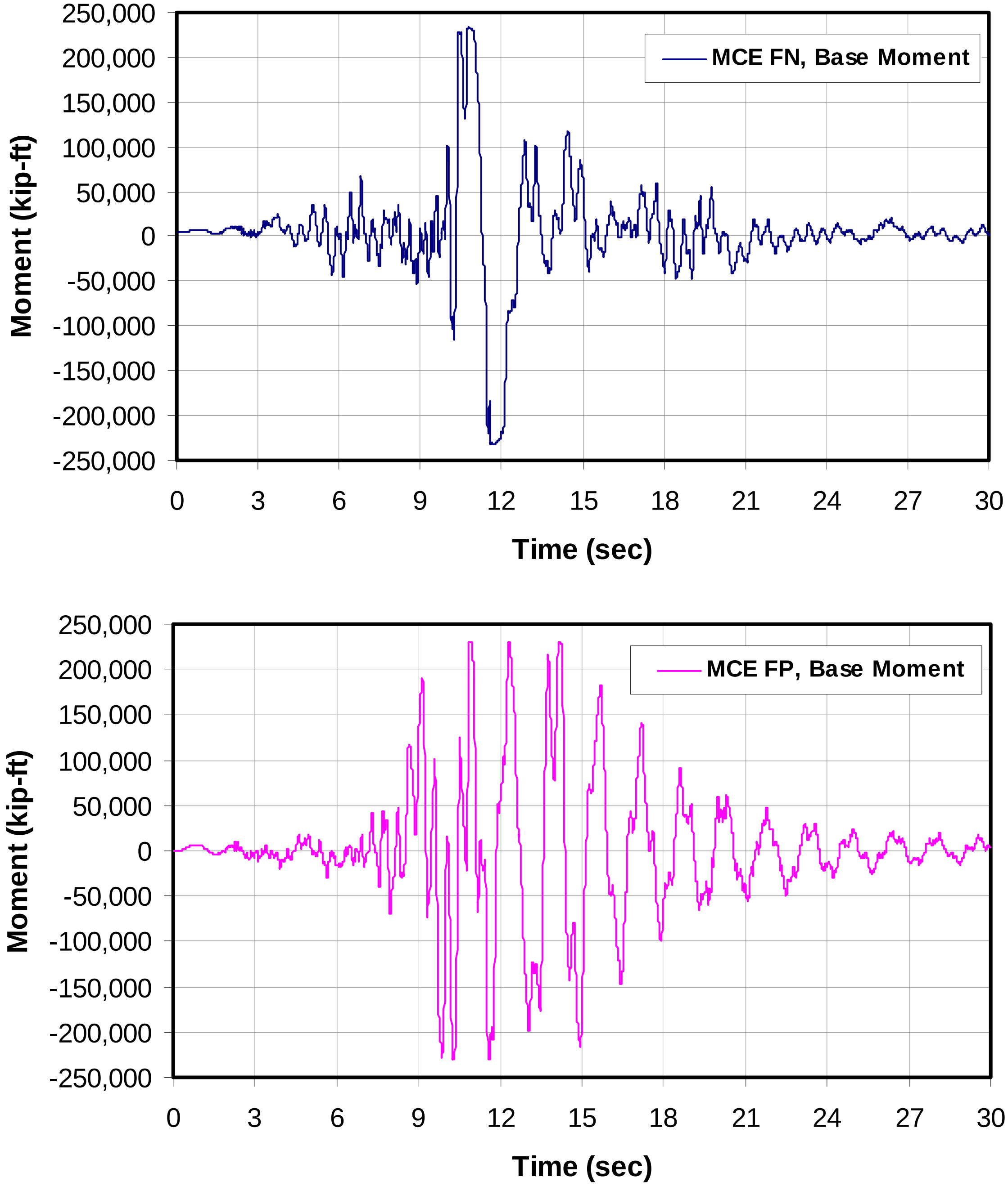


Figure 4-6: Time histories of maximum moments for MCE (2 ¼ inch wires).

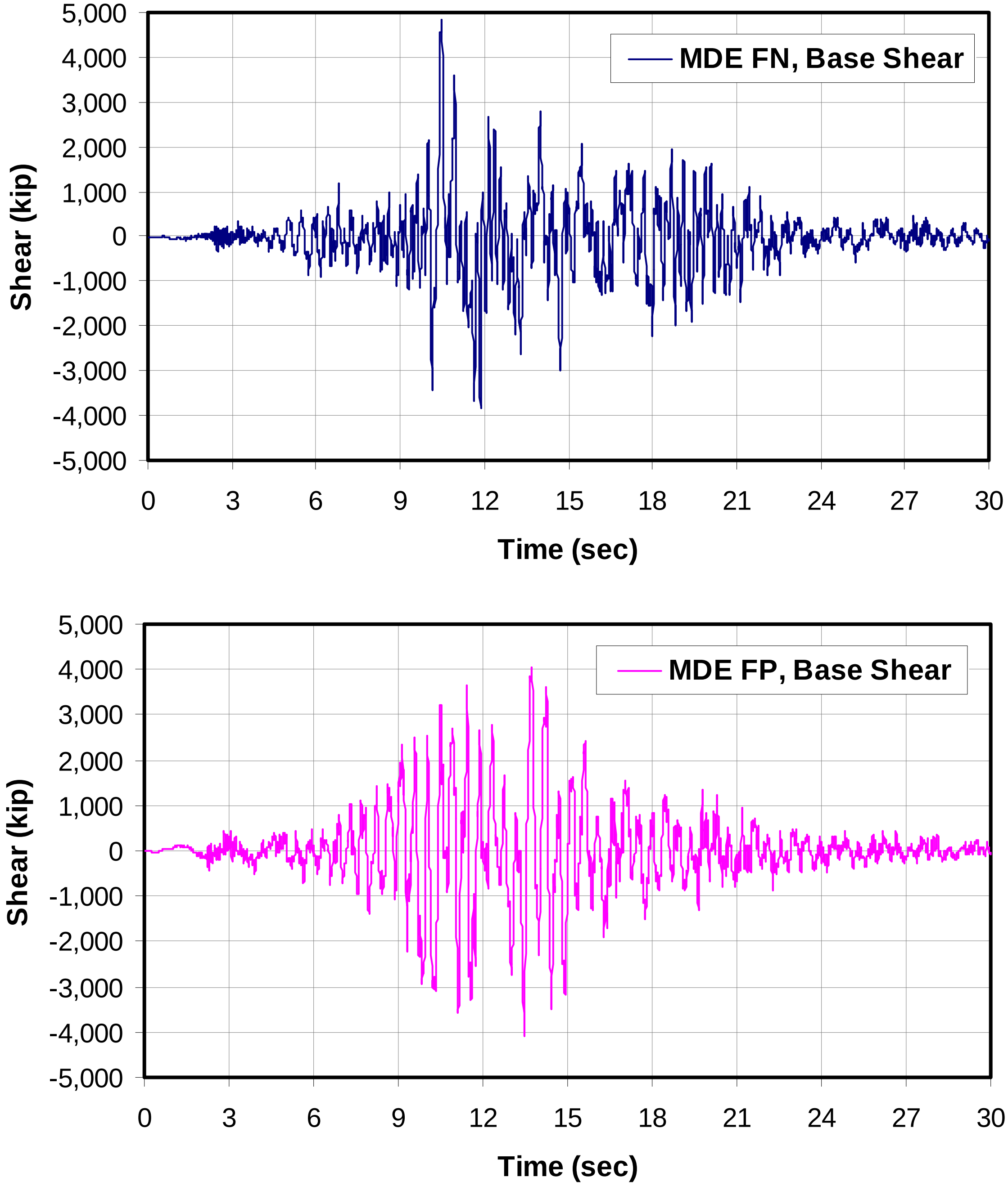


Figure 4-7: Time histories of base shear for MDE (2 ¼ inch wires).

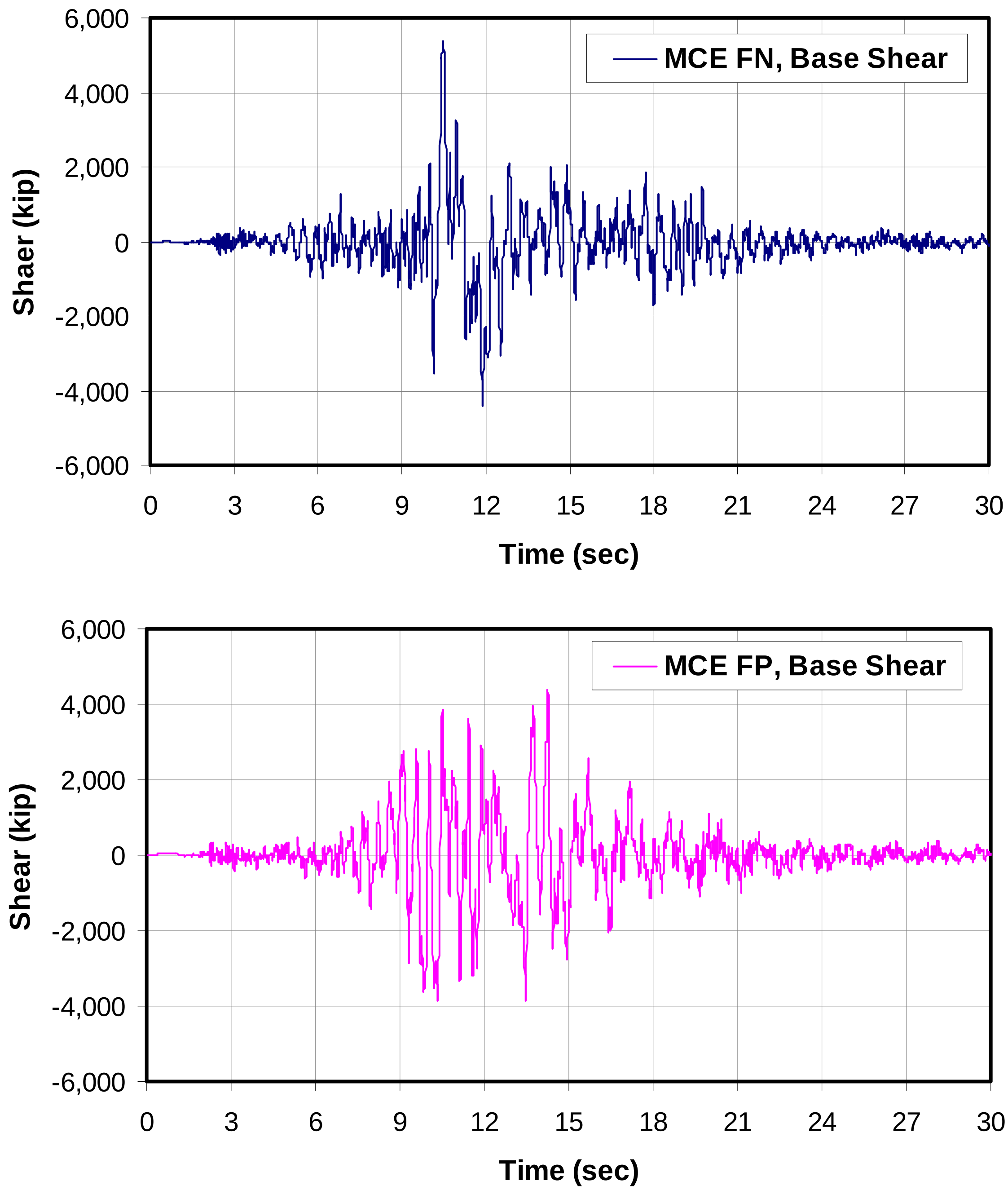


Figure 4-8: Time histories of base shear for MCE (2-1/4 inch wires).

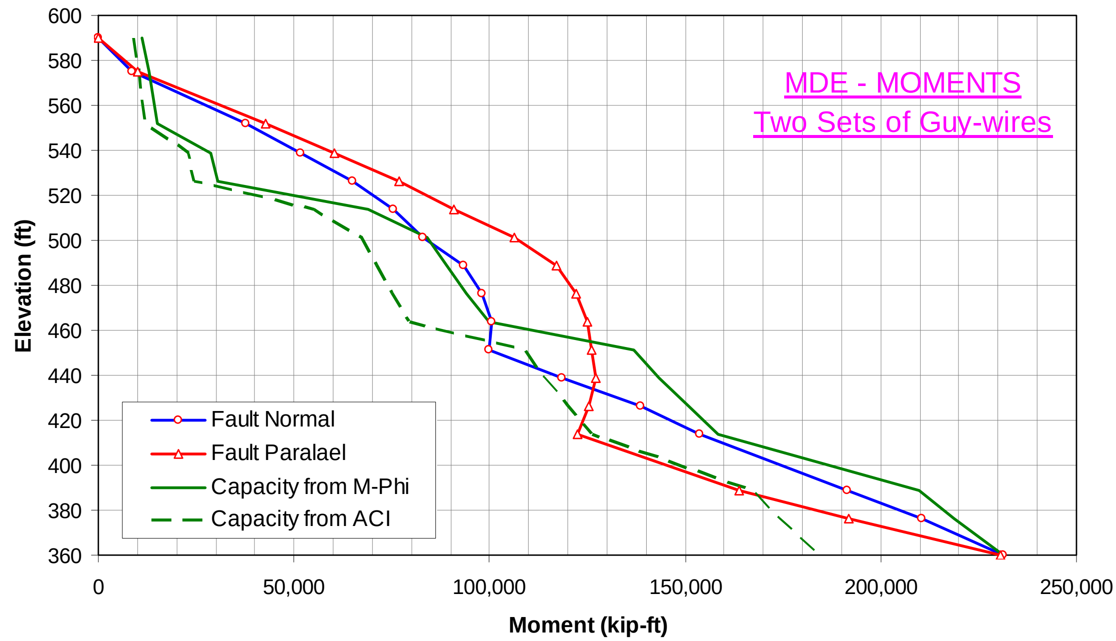


Figure 4-9: Comparison of MDE moment demands with moment capacities (2 ¼ inch wires).

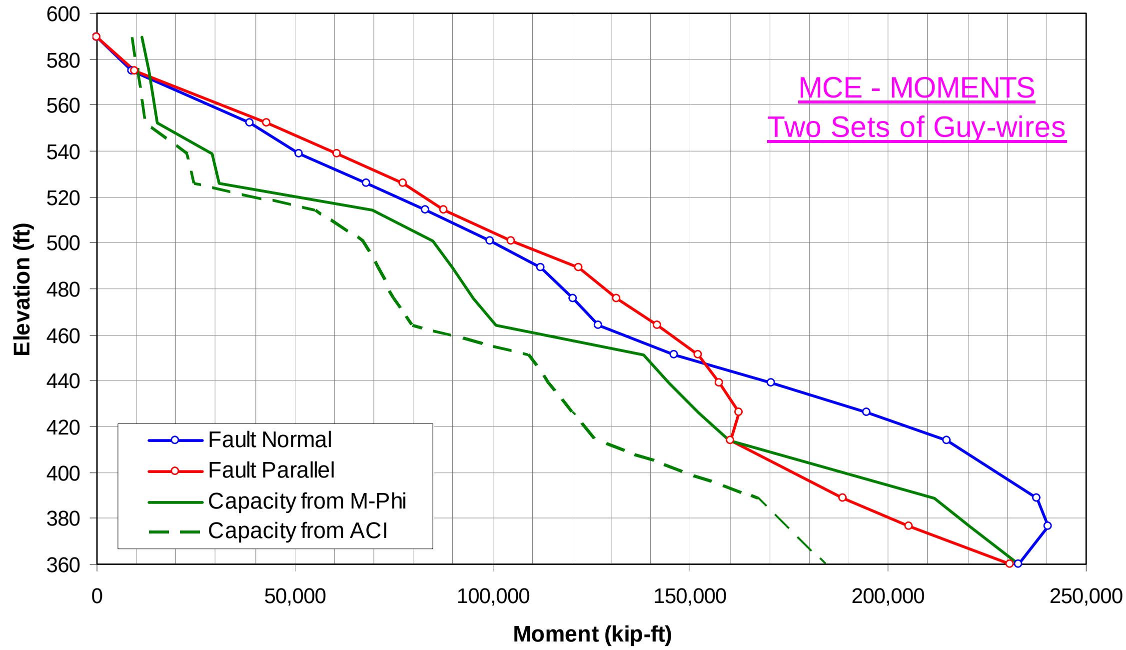


Figure 4-10: Comparison of MCE moment demands with moment capacities (2 ¼ inch wires).

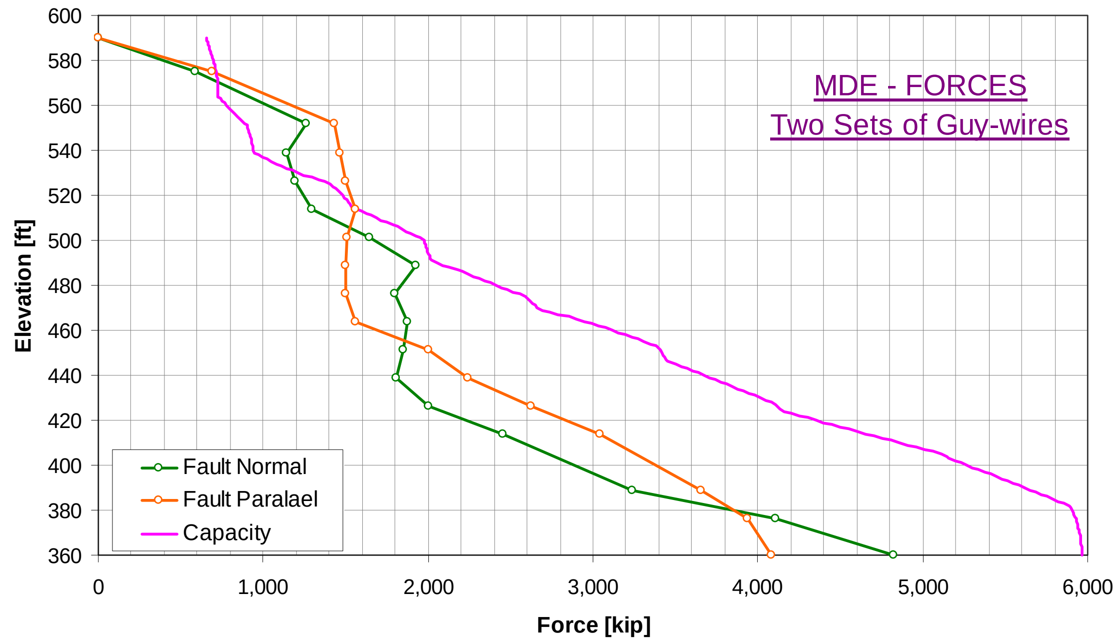


Figure 4-11: Comparison of MDE shear demands with shear capacities (2 ¼ inch wires).

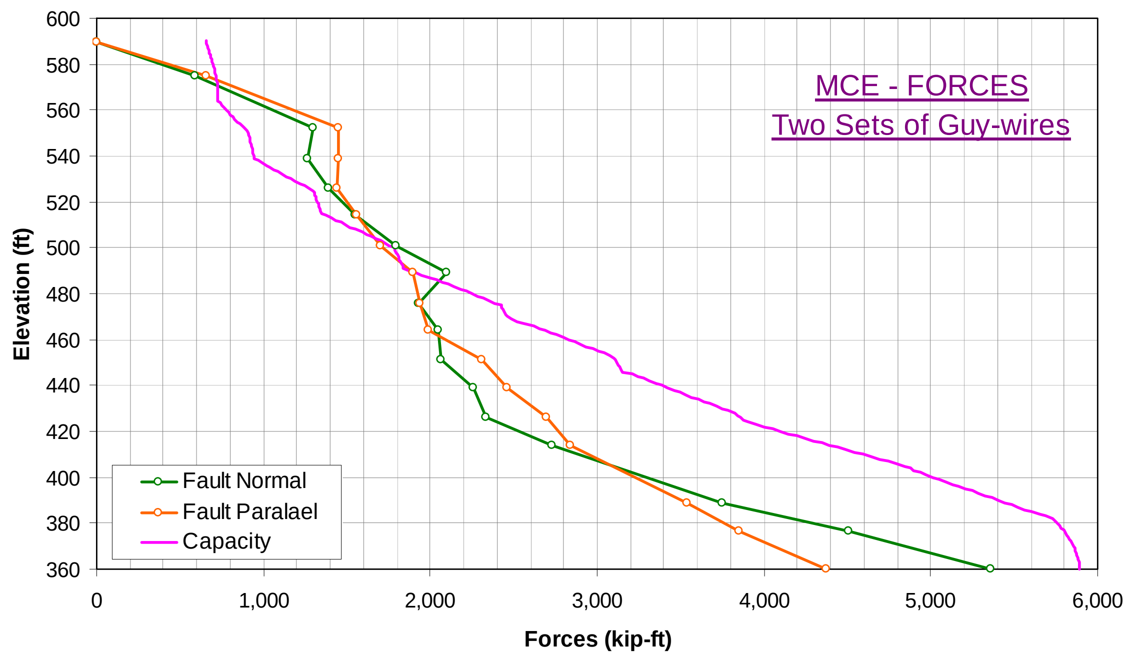


Figure 4-12: Comparison of MCE shear demands with shear capacities (2 ¼ inch wires).

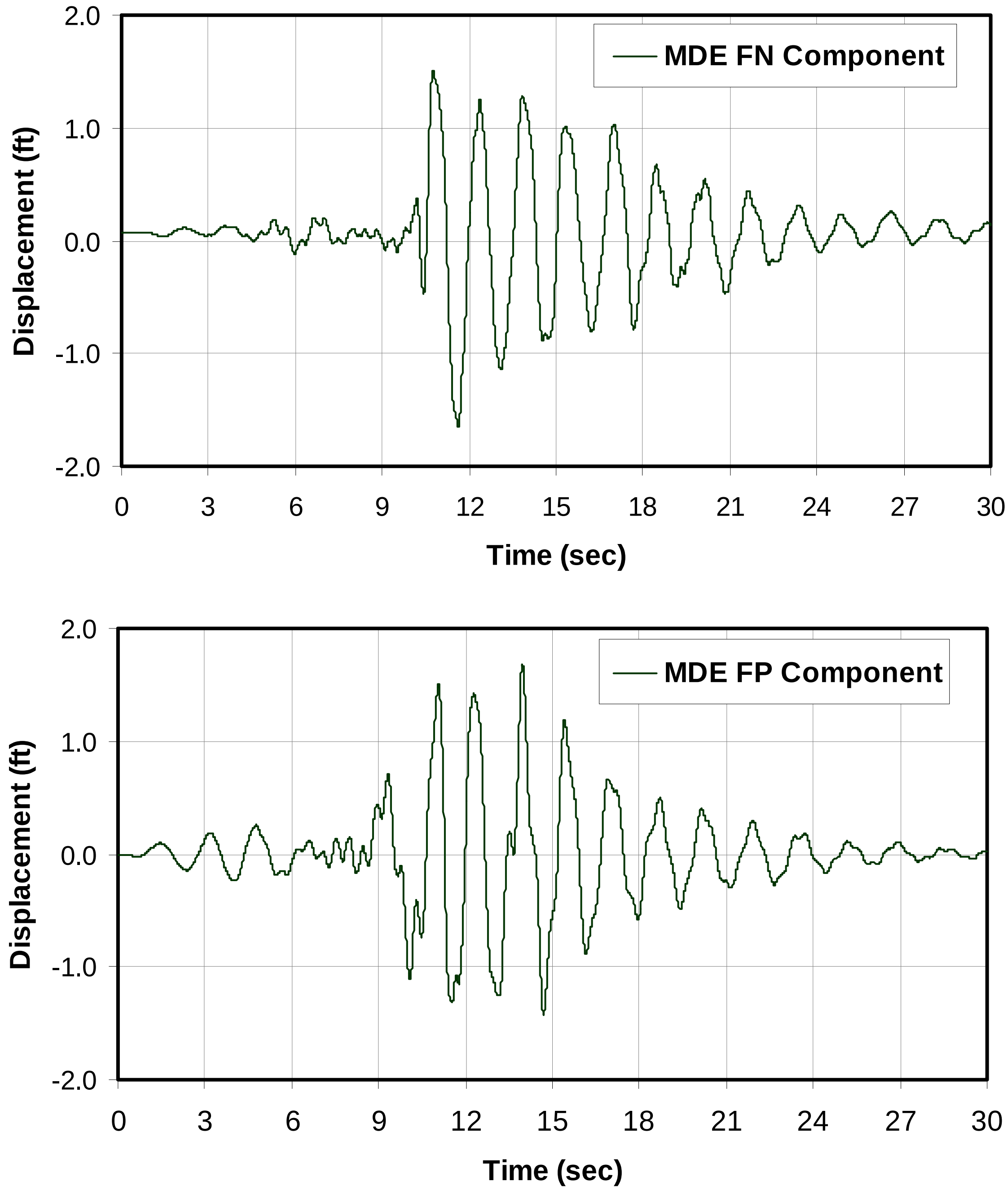


Figure 4-13: Displacement histories of top of tower for MDE (4-in wires).

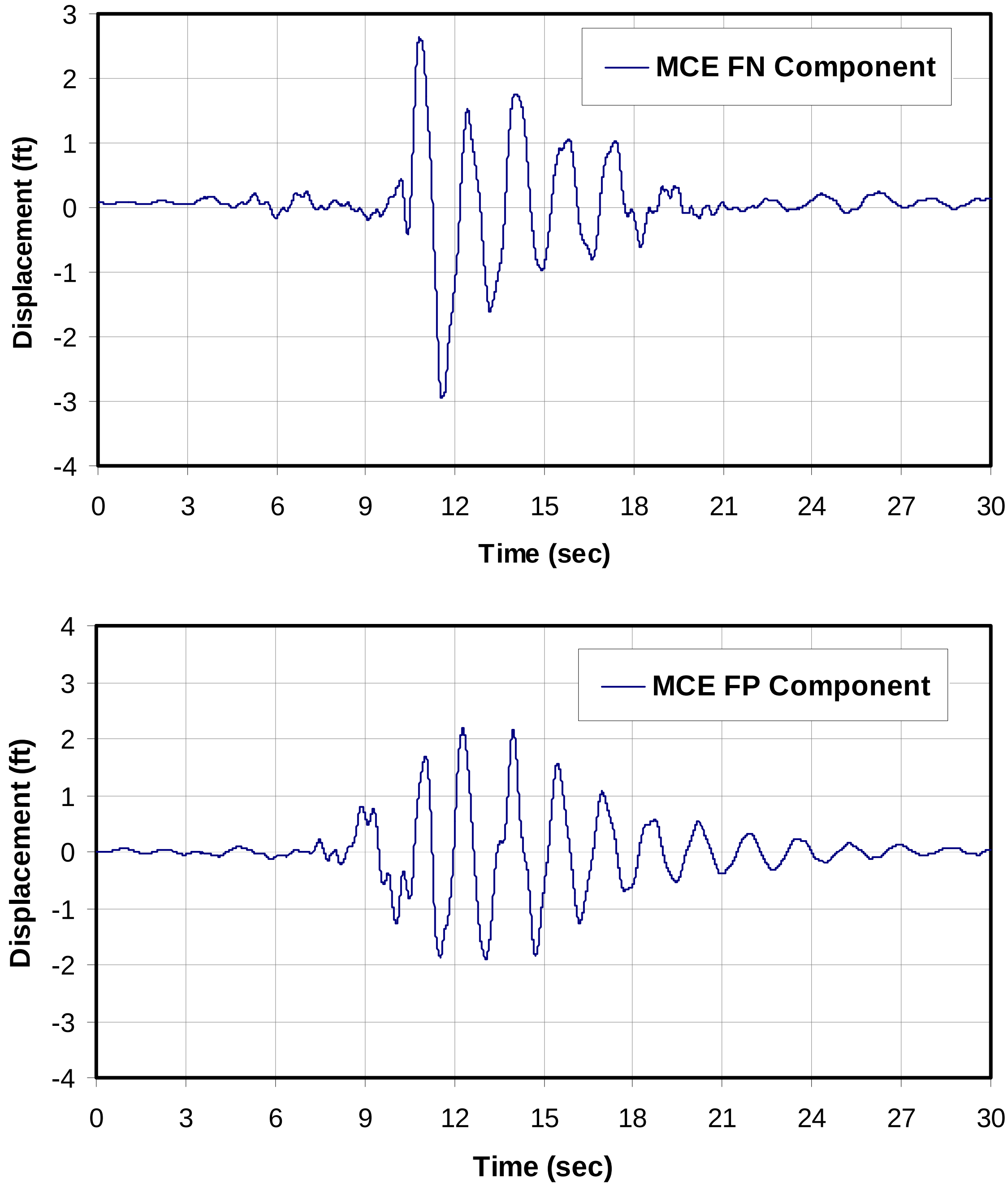


Figure 4-14: Top of tower displacement histories for MCE (4-inch wires).

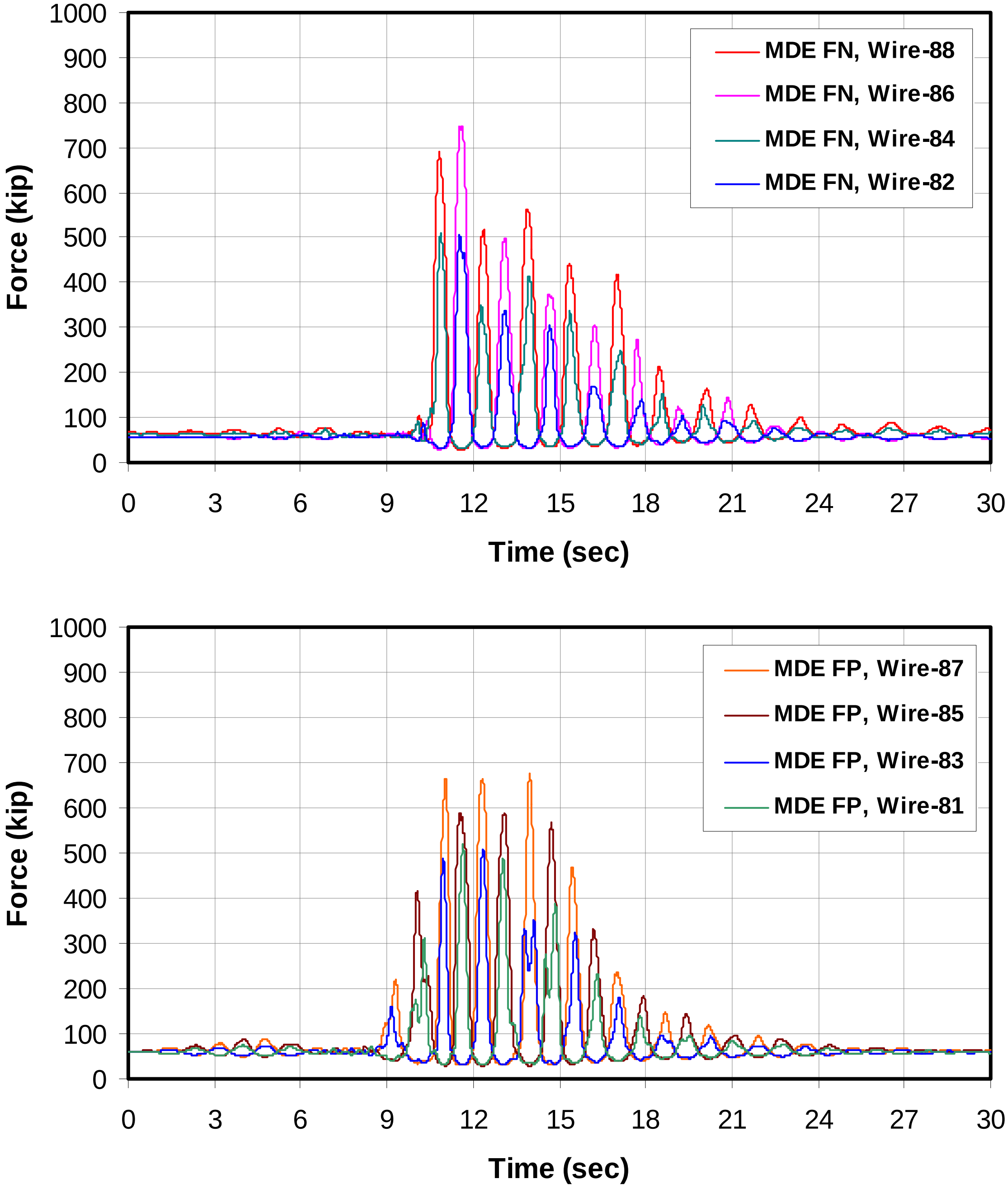


Figure 4-15: Time histories of wire forces for MDE (4-inch wires).

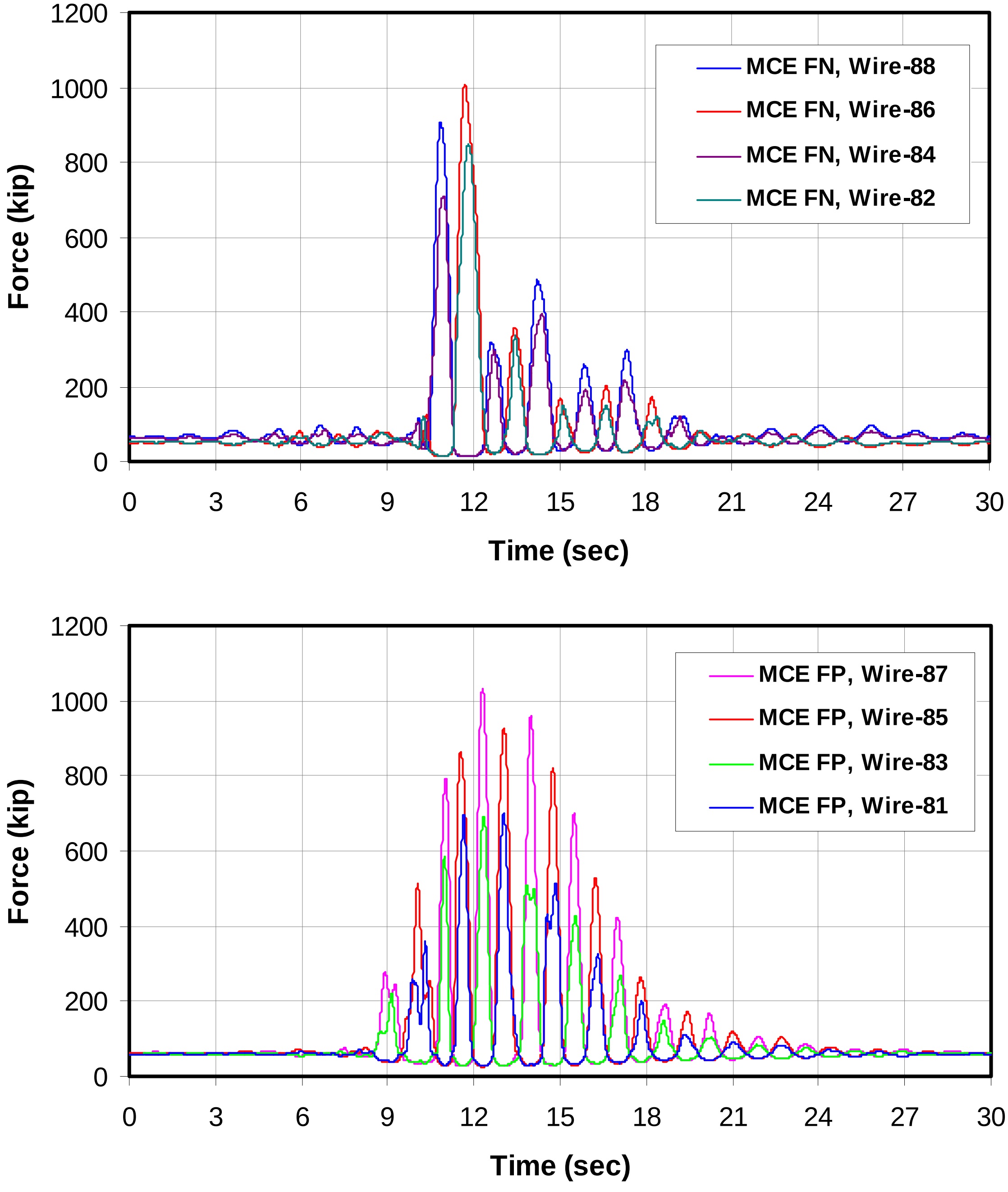


Figure 4-16: Time histories of wire forces for MCE (4-inch wires).

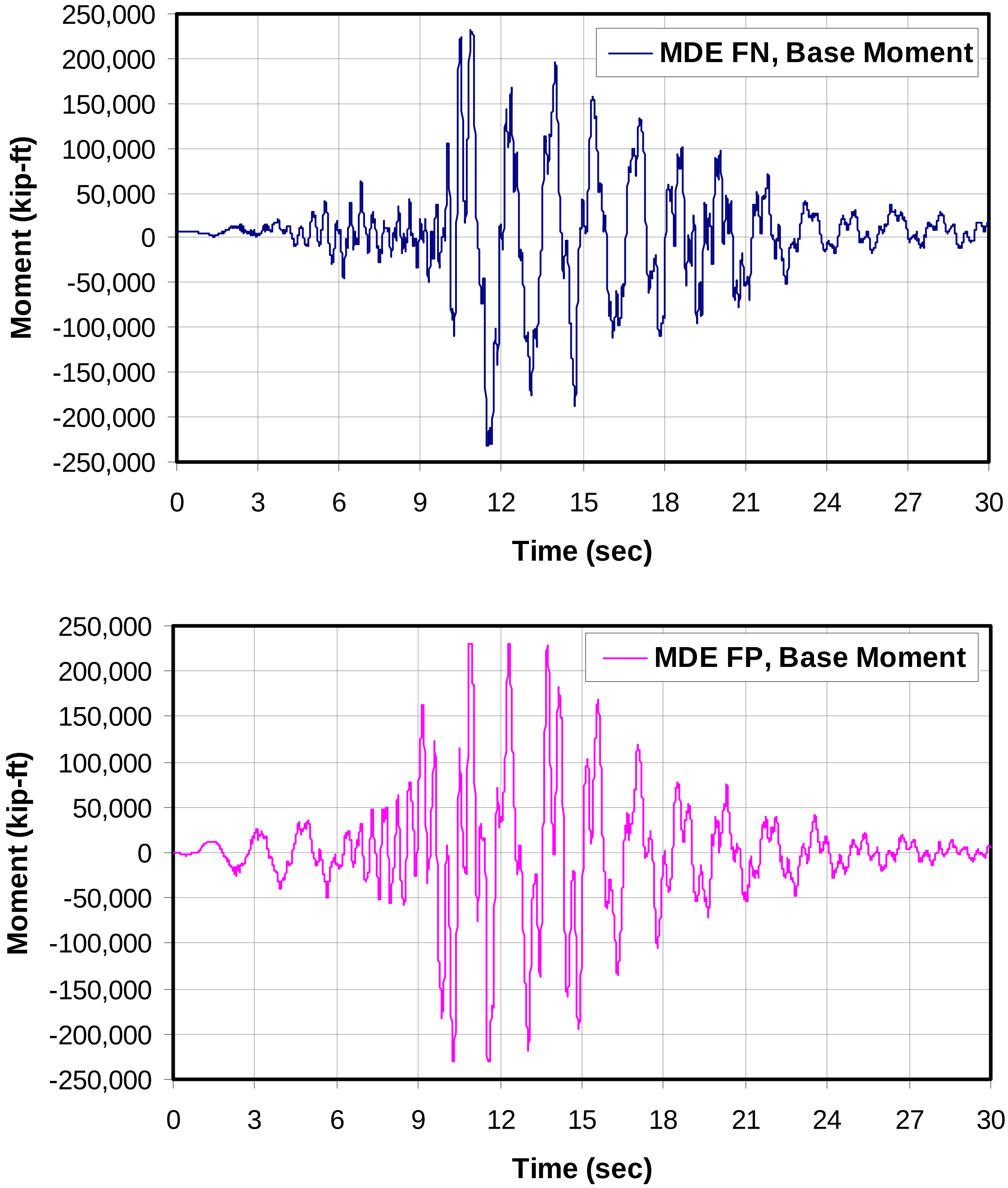


Figure 4-17: Time history of maximum moments for MDE (4-inch wires).

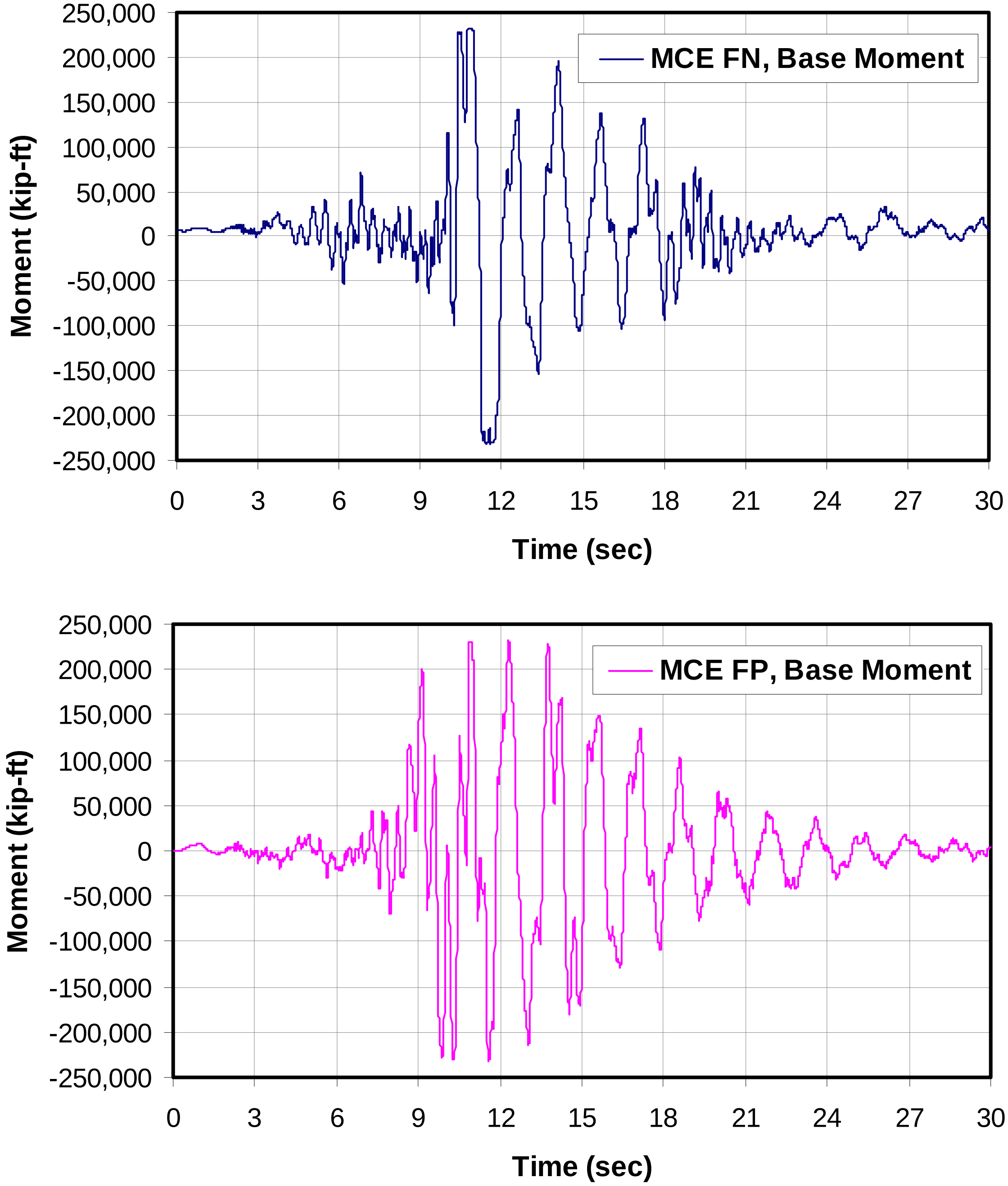


Figure 4-18: Time histories of maximum moments for MCE (4-inch wires).

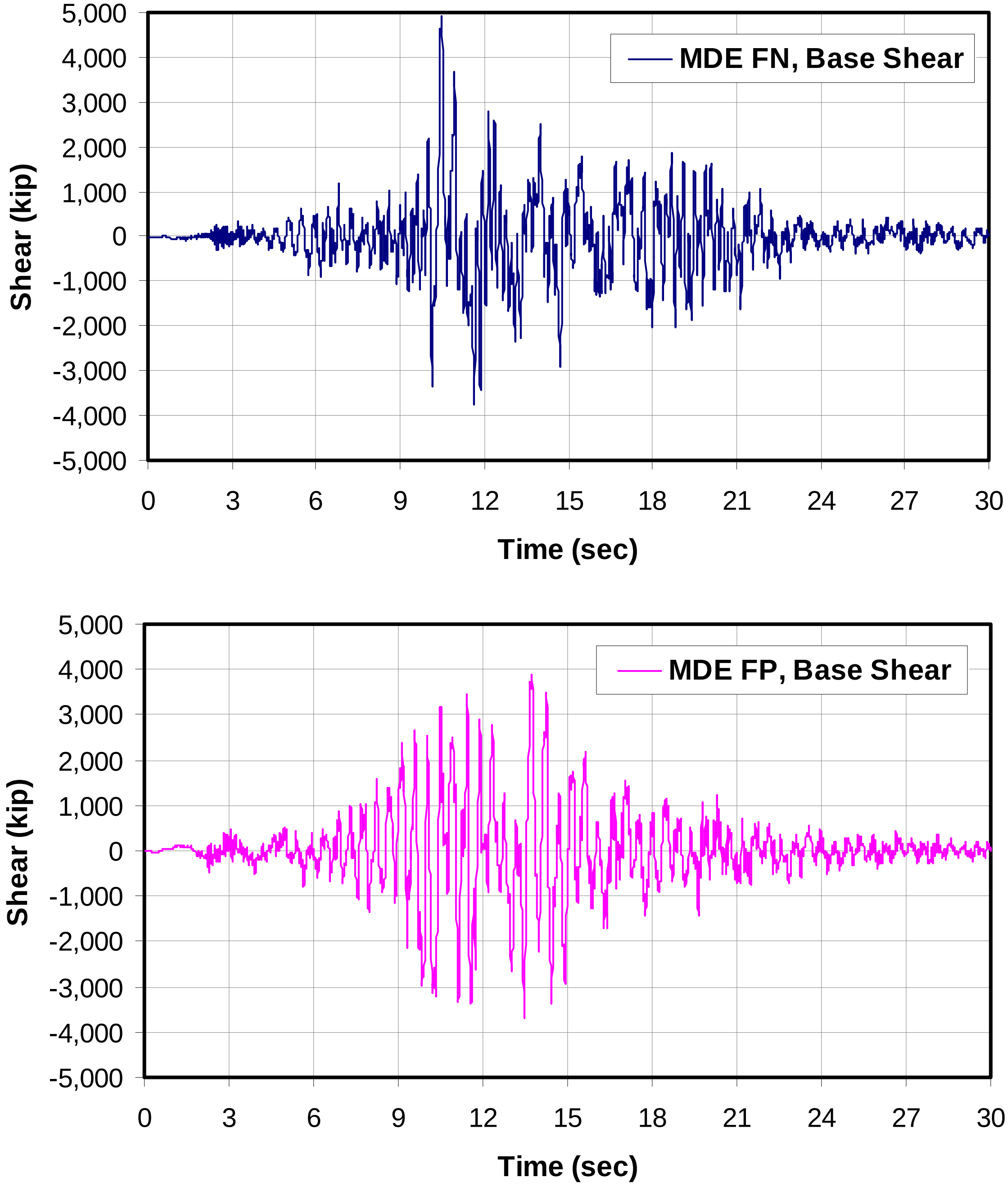
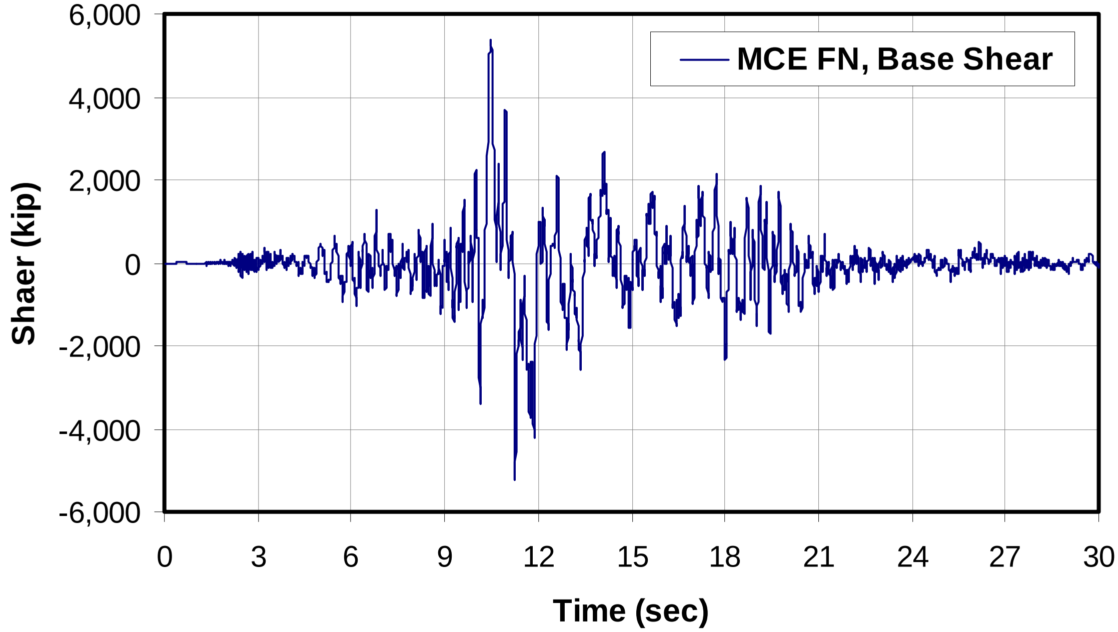


Figure 4-19: Time histories of base shear for MDE (4-inch wires).



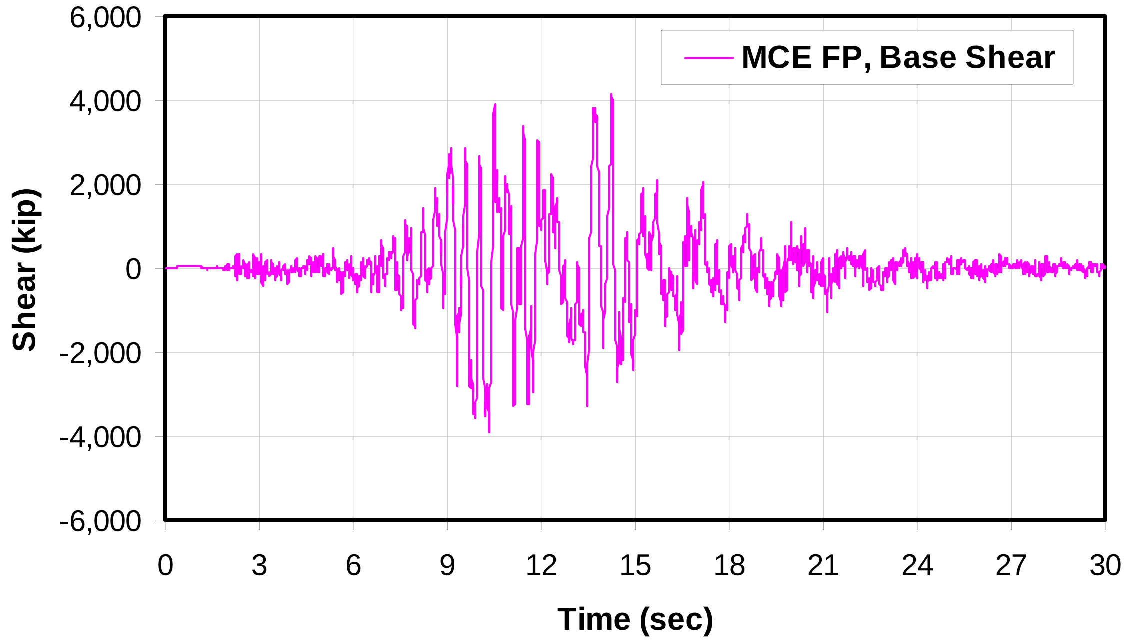


Figure 4-20: Time histories of base shear for MCE (4-inch wires).

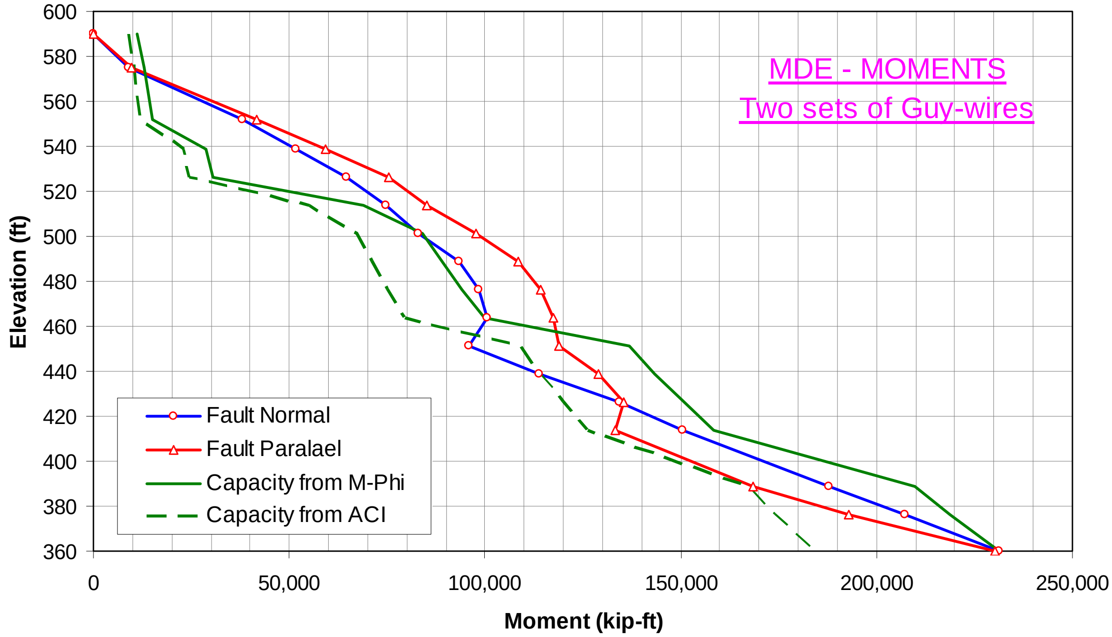


Figure 4-21: Comparison of MDE moment demands with moment capacities (4-inch wires).

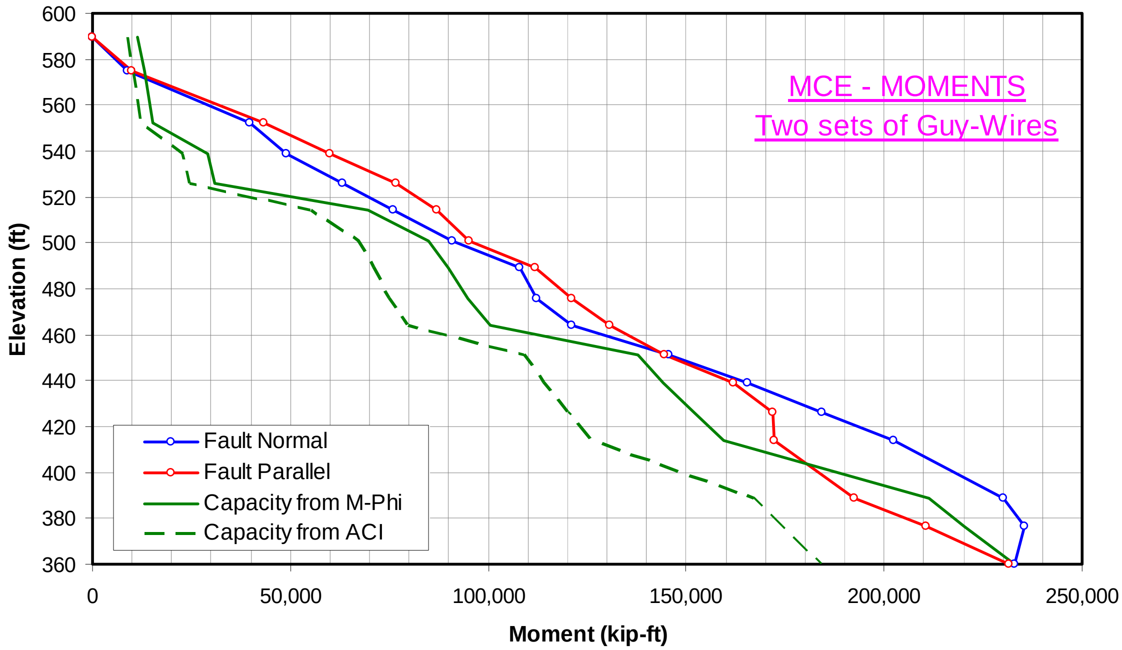


Figure 4-22: Comparison of MCE moment demands with moment capacities (4-inch wires).

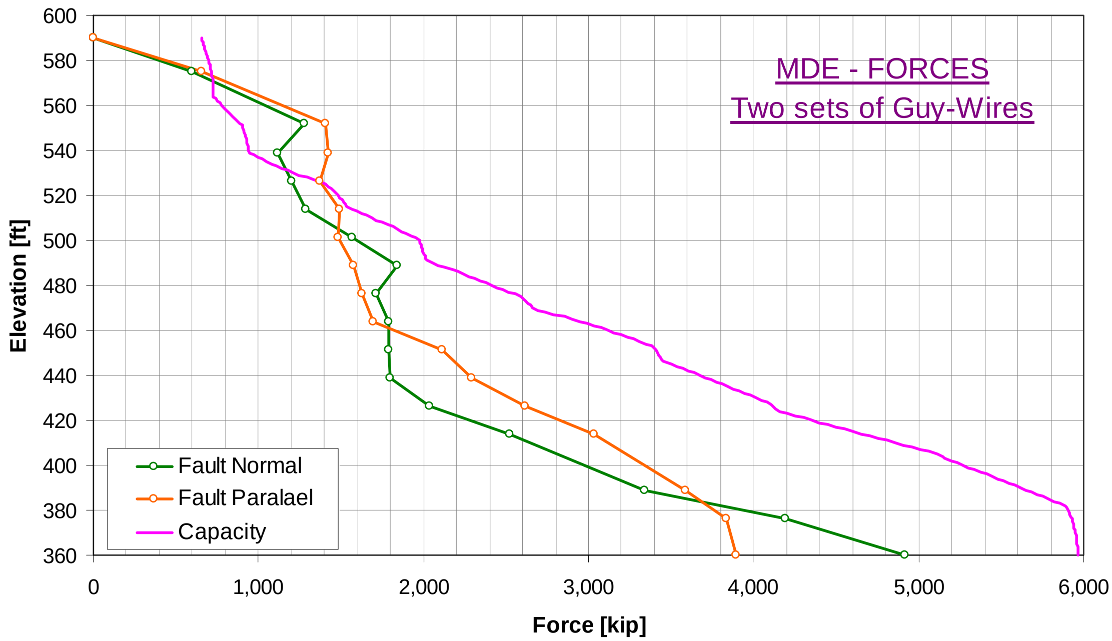


Figure 4-23: Comparison of MDE shear demands with shear capacities (4-inch wires).

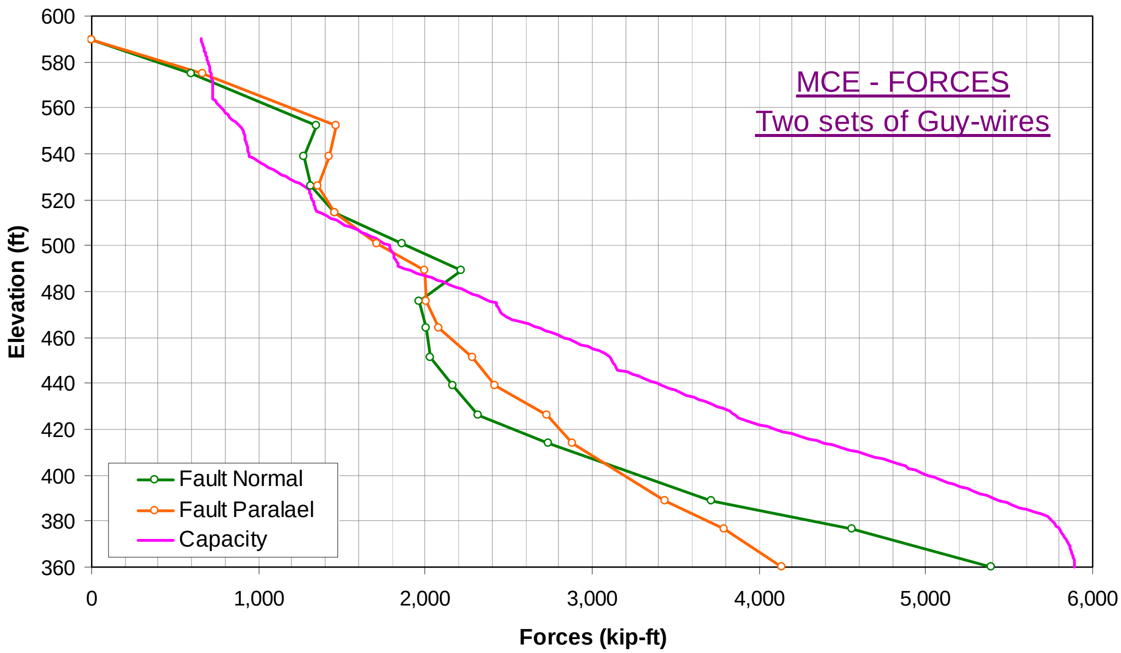


Figure 4-24: Comparison of MCE shear demands with shear capacities (4-inch wires).

APPENDIX C: PRELIMINARY COST ESTIMATES

Option 3: Dredge around Tower, Tremie Anchor Concrete, Stiffen Interior w/ Reinforced Concrete

Option 3A: PARTIALLY DEWATERED - Dredge around Tower, Tremie Anchor Concrete, Stiffen Interior w/ Reinforced Concrete

Option 3B: DEWATERED - Excavate Around Tower, Anchor Concrete, Stiffen Exterior w/ Reinforced Concrete

Option 4: Dredge over Existing Tunnel, Install Lakebed Piping, Connect to Existing Tunnel

Option 4A: PARTIALLY DEWATERED - Dredge over Existing Tunnel, Install Lakebed Piping, Connect to Existing Tunnel

Option 4B: DEWATERED - Excavate over Existing Tunnel, Install Lakebed Piping, Connect to Existing Tunnel

Option 5: Dredge over Existing Tunnel, Tremie Anchor Concrete, Install Precast Tower Spools and Posttension

Option 5A: PARTIALLY DEWATERED - Dredge over Existing Tunnel, Tremie Anchor Concrete, Install Precast Tower Spools and Posttension

Vortex Estimate for Diving Work

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Option 3 - Dredge Around Tower, Tremie Anchor Concrete, Stiffen Interior w/ reinforced Concrete
No Dewatering

Item	Description	Quantity		Hrs/Shift	Shifts/Day	Days		Unit Cost		Item Cost
1	Mobilization	1	LS	10	1	10				$706,000
2	Dredge for Tremied Anchor Concrete	1	LS	10	1	11				$2,143,000
3	Install formwork and bracing for Anchor Concrete	1	LS	10	1	20				$4,478,000
4	Tremie Base Anchor Concrete	1	LS	10	1	6				$2,128,000
5	Dewater & Clean Tower	1	LS	10	1	13				$684,000
6	FRP Tunnel Transition	1	LS	10	1	11				$284,000
7	FRP to valve at El. 382.5	1	LS	10	1	11				$265,000
8	FRP to El. 399	1	LS	10	1	7				$188,000
9	FRP to valves at El. 420, 445, 470, 495	1	LS	10	1	44				$1,377,000
10	FRP to valve at El. 520	1	LS	10	1	12				$228,000
11	FRP to valves at El. 546	1	LS	10	1	11				$240,000
12	FRP to El. 589.75	1	LS	10	1	12				$252,000
13	Permanent Access into Tower	1	LS	10	1	20				$1,045,000
14	Demobilization	1	LS	10	1	10				$426,000
						198	Days			
						9.9	Months			$14,444,000
15	Supervision	1	LS			9.9	Mo	$62,020	Mo	$614,000
16	General Operations	1	LS			9.9	Mo	$111,010	Mo	$1,099,000
17	General Requirements 10% of Direct	10	%							$1,445,000
18	Home Office - 4-% of Direct	4	%							$578,000
	Subtotal									$18,180,000
19	Profit - 15% total	15%								$2,727,000
20	Bond, Taxes, & Insurance	2	%							$419,000
	Total (2008 Dollars)									$21,326,000
21	Escalation Excluded - Recommend 5% per year									
22	Contingency & Escalation	40%								$8,531,000
	Total Unescalated Construction Cost with Contingency									$29,857,000
	Excludes Design Costs, CM Costs, and Owner Soft Costs									

Assume Dredging material deposited on reservoir floor. Assume $250,000 additional to total unescalated cost if off-hauled.
Assume Valve controls, actuators, piping, etc do not have to be relocated or removed, and partially encased in Concrete.

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3 - Dredge Around Tower, Tremie Anchor Concrete, Stiffen Interior w/ reinforced Concrete
No Dewatering

Item	Description	Quantity	Hrs/Shift	Shifts/Day	Days		Unit Cost	LF	Item Cost
1	Mobilization	1 LS	10	1	10				$706,000
	Move in cranes, barges, office, formwork, materials, etc								
1	Mobilize Plant & Equip	1 LS				1	600000		$600,000
2	Setup Plant & Equip (8 men)	10 Day	100 mhr/day		10	1000	72 $/hr	1.05	$75,600
3	Receive Materials	20 Day	20 mhr/day			400	72 $/hr	1.05	$30,240
2	Dredge for Tremied Anchor Concrete	1 LS	10	1	11				$2,143,000
	Dredge around base of tower for tremie concrete, 10-hr shift, 1 shift per day, 250 CY/day								
1	Dredger - Subcontractor	2512 CY				2512	100 $/cy		$251,200
2	Divers	11 Days	80 mhr/day			880	157200 $/day		$1,729,200
3	100 T Crane	11 Days				110	250 $/hr		$27,500
4	Barge & Tug	11 Days				110	340 $/hr	1.05	$39,270
5	Labor	11 Days	100 mhr/day		11	1100	72 $/hr		$79,200
6	Decompression chamber	11 Days				264	62.5 $/hr		$16,500
7	Muck Disposal - on lake bed								
3	Install formwork and bracing for Anchor Concrete	1 LS	10	1	20				$4,478,000
	Install 60-ft diameter "formwork" and Brace, 10-hr shifts, 1 shift per day, divers - 3sf/mh								
1	Divers	20 Days	160 mhr/day			3200	179625 $/day		$3,592,500
2	100 T Crane	20 Days				200	250 $/hr		$50,000
3	Barge & Tug	20 Days				200	340 $/hr		$68,000
4	Decompression chamber	20 Days				480	62.5 $/hr		$30,000
5	Labor	20 Days	100 mhr/day		20	2000	72 $/hr	1.05	$151,200
6	Form material	60 LF				60	9430 $/LF		$565,800
7	Bracing	1 LS				1	20000 LS		$20,000
4	Tremie Base Anchor Concrete	1 LS	24	1	6				$2,128,000
	Setup concrete operation & tremie concrete, 50 CY/hr								
1	Divers	6 Days	192 mhr/day			1152	157200 $/day		$943,200
2	100 T Crane	6 Days				144	250 $/hr		$36,000
3	Barge & Tug	6 Days				144	340 $/hr		$48,960
4	Decompression chamber	6 Days				144	62.5 $/hr		$9,000
5	Concrete pump & piping	5500 CY				5500	10 $/cy		$55,000
6	Tremie Concrete	6 Days	240 mhr/day		6	1440	72 $/hr	1.5	$155,520
7	Concrete	5500 CY				5500	140 $/cy		$770,000
8	Concrete Overtime fees	3667 CY				3667	30 $/cy		$110,010
5	Dewater & Clean Tower	1 LS	10	1	13				$684,000
	Dewater tower, clean interior, and remove unnecessary appurtenances (ladders, etc)								
1	Dewater tower & seal intakes	3 Days	100 mhr/day		3	300	72 $/hr	1.05	$22,680

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3 - Dredge Around Tower, Tremie Anchor Concrete, Stiffen Interior w/ reinforced Concrete
No Dewatering

Item	Description	Quantity	Hrs/Shift	Shifts/Day	Days		Unit Cost	LF	Item Cost
2	Divers	3 Days	80 mhr/day			240	157200 $/day		$471,600
3	Barge & Tug	13 Days				130	250 $/hr		$32,500
4	100 T Crane	13 Days				130	340 $/hr		$44,200
5	Decompression chamber	2 Days				48	62.5 $/hr		$3,000
6	Clean interior walls	5 Days	100 mhr/day		5	500	72 $/hr	1.05	$37,800
7	Remove unnecessary Appurtenances	5 Days	100 mhr/day		5	500	72 $/hr	1.05	$37,800
8	Man cage	13 Days				130	2 $/hr		$260
9	Ventilation	13 Days				130	10 $/hr		$1,300
10	Generator	13 Days				130	15 $/hr		$1,950
11	Intake Seal Covers	6 ea					5000 ea		$30,000
6	FRP Tunnel Transition		10	1	11				$284,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish Tunnel transition, 11 LF Pour								
1	Plant support for Reinforcing	4 Days	50 mhr/day		4	200	72 $/hr	1.05	$15,120
2	Install Special Formwork at Transition	3 Days	100 mhr/day		3	300	72 $/hr	1.05	$22,680
3	Install Vertical formwork	2 Days	100 mhr/day		2	200	72 $/hr	1.05	$15,120
4	Pour Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
5	Strip forms & patch Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
6	Reinforcing Bars furnish & install	11 LF	4786 lbs/LF			52646	1.5 $/lb		$78,969
7	Concrete	11 LF	5 CY/LF			55	140 $/cy		$7,700
8	Transition Formwork	1 LS				1	10000 LS		$10,000
9	Shaft Formwork - 25-ft Purchase	1 LS				1	50000 LS		$50,000
10	Barge & Tug	11 Days				110	340 $/hr		$37,400
11	100 T Crane	11 Days				110	250 $/hr		$27,500
12	Concrete pump & piping	55 CY				55	10 $/cy		$550
13	Man cage	11 Days				110	2 $/hr		$220
14	Ventilation	11 Days				110	10 $/hr		$1,100
15	Generator	11 Days				110	15 $/hr		$1,650
7	FRP to valve at El. 382.5		10	1	11				$265,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top of valve at El. 382.5, 15 LF Pour								
1	Plant support for Reinforcing	4 Days	50 mhr/day		4	200	72 $/hr	1.05	$15,120
2	Install Special Formwork at Transition	3 Days	100 mhr/day		3	300	72 $/hr	1.05	$22,680
3	Install Vertical formwork	2 Days	100 mhr/day		2	200	72 $/hr	1.05	$15,120
4	Pour Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
5	Strip forms & patch Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
6	Reinforcing Bars furnish & install	15 LF	4786 lbs/LF			71790	1.5 $/lb		$107,685
7	Concrete	15 LF	5 CY/LF			75	140 $/cy		$10,500
8	Transition Formwork	1 LS				1	10000 LS		$10,000
9	Barge & Tug	11 Days				110	250 $/hr		$27,500

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3 - Dredge Around Tower, Tremie Anchor Concrete, Stiffen Interior w/ reinforced Concrete
No Dewatering

Item	Description	Quantity	Hrs/Shift	Shifts/Day	Days		Unit Cost	LF	Item Cost
10	100 T Crane	11 Days				110	340 $/hr		$37,400
11	Concrete pump & piping	75 CY				75	10 $/cy		$750
12	Man cage	11 Days				110	2 $/hr		$220
13	Ventilation	11 Days				110	10 $/hr		$1,100
14	Generator	11 Days				110	15 $/hr		$1,650
8	FRP to El. 399		10	1	7				$188,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top of valve at El. 382.5, 13 LF Pour								
1	Plant support for Reinforcing	3 Days	50 mhr/day		3	150	72 $/hr	1.05	$11,340
2	Install Special Formwork at Transition	0 Days	100 mhr/day		0	0	72 $/hr	1.05	$0
3	Install Vertical formwork	2 Days	100 mhr/day		2	200	72 $/hr	1.05	$15,120
4	Pour Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
5	Strip forms & patch Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
6	Reinforcing Bars furnish & install	13 LF	4786 lbs/LF			62218	1.5 $/lb		$93,327
7	Concrete	13 LF	5 CY/LF			65	140 $/cy		$9,100
8	Transition Formwork	0 LS				0	10000 LS		$0
9	Barge & Tug	7 Days				70	340 $/hr		$23,800
10	100 T Crane	7 Days				70	250 $/hr		$17,500
11	Concrete pump & piping	65 CY				65	10 $/cy		$650
12	Man cage	7 Days				70	2 $/hr		$140
13	Ventilation	7 Days				70	10 $/hr		$700
14	Generator	7 Days				70	15 $/hr		$1,050
9	FRP to valves at El. 420, 445, 470, 495		10	1	44				$1,377,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top of valves 4 Pours @ 25 LF								
1	Plant support for Reinforcing	16 Days	50 mhr/day		16	800	72 $/hr	1.05	$60,480
2	Install Special Formwork at Transition	12 Days	100 mhr/day		12	1200	72 $/hr	1.05	$90,720
3	Install Vertical formwork	8 Days	100 mhr/day		8	800	72 $/hr	1.05	$60,480
4	Pour Concrete	4 Days	100 mhr/day		4	400	72 $/hr	1.05	$30,240
5	Strip forms & patch Concrete	4 Days	100 mhr/day		4	400	72 $/hr	1.05	$30,240
6	Reinforcing Bars furnish & install	100 LF	4786 lbs/LF			478600	1.5 $/lb		$717,900
7	Concrete	100 LF	5 CY/LF			500	140 $/cy		$70,000
8	Transition Formwork	4 Ea				4	10000 Ea		$40,000
9	Barge & Tug	44 Days				440	340 $/hr		$149,600
10	100 T Crane	44 Days				440	250 $/hr		$110,000
11	Concrete pump & piping	500 CY				500	10 $/cy		$5,000
12	Man cage	44 Days				440	2 $/hr		$880
13	Ventilation	44 Days				440	10 $/hr		$4,400
14	Generator	44 Days				440	15 $/hr		$6,600

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3 - Dredge Around Tower, Tremie Anchor Concrete, Stiffen Interior w/ reinforced Concrete
No Dewatering

Item	Description	Quantity	Hrs/Shift	Shifts/Day	Days		Unit Cost	LF	Item Cost
10	FRP to valve at El. 520		10	1	12				$228,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top of valve at El. 520, 26 LF pour w/ 1-ft dutchman								
1	Plant support for Reinforcing	4 Days	50 mhr/day		4	200	72 $/hr	1.05	$15,120
2	Install Special Formwork at Transition	3 Days	100 mhr/day		3	300	72 $/hr	1.05	$22,680
3	Install Vertical formwork	3 Days	100 mhr/day		3	300	72 $/hr	1.05	$22,680
4	Pour Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
5	Strip forms & patch Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
6	Reinforcing Bars furnish & install	26 LF	1200 lbs/LF			31200	1.5 $/lb		$46,800
7	Concrete	26 LF	5 CY/LF			130	140 $/cy		$18,200
8	Transition Formwork	1 LS				1	10000 LS		$10,000
9	Dutchman Formwork	1 LS				1	2000 LS		$2,000
10	Barge & Tug	12 Days				120	340 $/hr		$40,800
11	100 T Crane	12 Days				120	250 $/hr		$30,000
12	Concrete pump & piping	130 CY				130	10 $/cy		$1,300
13	Man cage	12 Days				120	2 $/hr		$240
14	Ventilation	12 Days				120	10 $/hr		$1,200
15	Generator	12 Days				120	15 $/hr		$1,800
11	FRP to valves at El. 546		10	1	11				$240,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top of valve at EL 546 1 Pour @ 25 LF								
1	Plant support for Reinforcing	4 Days	50 mhr/day		4	200	72 $/hr	1.05	$15,120
2	Install Special Formwork at Transition	3 Days	100 mhr/day		3	300	72 $/hr	1.05	$22,680
3	Install Vertical formwork	2 Days	100 mhr/day		2	200	72 $/hr	1.05	$15,120
4	Pour Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
5	Strip forms & patch Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
6	Reinforcing Bars furnish & install	25 LF	1200 lbs/LF			30000	1.5 $/lb		$45,000
7	Concrete	25 LF	5 CY/LF			125	140 $/cy		$17,500
8	Transition Formwork	4 LS				4	10000 LS		$40,000
9	Barge & Tug	11 Days				110	340 $/hr		$37,400
10	100 T Crane	11 Days				110	250 $/hr		$27,500
11	Concrete pump & piping	125 CY				125	10 $/cy		$1,250
12	Man cage	11 Days				110	2 $/hr		$220
13	Ventilation	11 Days				110	10 $/hr		$1,100
14	Generator	11 Days				110	15 $/hr		$1,650
12	FRP to El. 589.75		10	1	12				$252,000

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3 - Dredge Around Tower, Tremie Anchor Concrete, Stiffen Interior w/ reinforced Concrete
No Dewatering

Item	Description	Quantity	Hrs/Shift	Shifts/Day	Days		Unit Cost	LF	Item Cost
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top at EL 589.75, 2 pours @ 20LF each								
1	Plant support for Reinforcing	4 Days	50 mhr/day		4	200	72 $/hr	1.05	$15,120
2	Install Special Formwork at Transition	0 Days	100 mhr/day		0	0	72 $/hr	1.05	$0
3	Install Vertical formwork	4 Days	100 mhr/day		4	400	72 $/hr	1.05	$30,240
4	Pour Concrete	2 Days	100 mhr/day		2	200	72 $/hr	1.05	$15,120
5	Strip forms & patch Concrete	2 Days	100 mhr/day		2	200	72 $/hr	1.05	$15,120
6	Reinforcing Bars furnish & install	40 LF	1200 lbs/LF			48000	1.5 $/lb		$72,000
7	Concrete	40 LF	5 CY/LF			200	140 $/cy		$28,000
8	Transition Formwork	0 LS				0	10000 LS		$0
9	Barge & Tug	12 Days				120	340 $/hr		$40,800
10	100 T Crane	12 Days				120	250 $/hr		$30,000
11	Concrete pump & piping	200 CY				200	10 $/cy		$2,000
12	Man cage	12 Days				120	2 $/hr		$240
13	Ventilation	12 Days				120	10 $/hr		$1,200
14	Generator	12 Days				120	15 $/hr		$1,800
13	Permanent Access into Tower		10	1	20				$1,045,000
	Provide New ladder into shaft								
1	Furnish Ladder	1 LS				1	25000		$25,000
2	Install Ladder	10 Days	100 mhr/day		10	1000	72 $/hr	1.05	$75,600
3	Furnish Hoisting system w/ workdeck & New Cover	1 LS				1	750000		$750,000
4	Install Hoisting system	10 Days	100 mhr/day		10	1000	72 $/hr	1.05	$75,600
5	Barge & Tug	20 Days				200	340 $/hr		$68,000
6	100 T Crane	20 Days				200	250 $/hr		$50,000
14	Demobilization		10	1	10				$426,000
	Demobilize cranes, barges, office, formwork, materials, etc								
1	Demobilize Plant & Equip	1 LS				1	300000 LS		$300,000
2	Tear down Plant & Equip (8 men)	10 Day	100 mhr/day		10	1000	72 $/hr	1.05	$75,600
3	Restoration	1 LS				1	50000 LS		$50,000

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3 - Dredge Around Tower, Tremie Anchor Concrete, Stiffen Interior w/ reinforced Concrete
No Dewatering

Item	Description	Quantity		Months		Unit Cost		Item Cost
1	Supervision	1	LS	9.9	Mo	$62,020	Mo	$614,000
1	Project Manager	1	Ea	9.9		13000	Mo	$128,700
2	Project Superintendent	1	Ea	9.9		12000	Mo	$118,800
3	Walker	3	Ea	9.9		10000	Mo	$99,000
4	Project Engineer	1	Ea	9.9		10000	Mo	$99,000
5	Office Manager	1	Ea	9.9		8000	Mo	$79,200
6	Field Engineer	2	Ea	9.9		9000	Mo	$89,100
2	General Operations	1	LS	9.9	Mo	$111,010	Mo	$1,099,000
1	Office	1	Ea	9.9		450		$4,455
2	Change House	1	Ea	9.9		450		$4,455
3	Shop Containers	4	Ea	9.9		100		$3,960
4	Power supply	1	Ea	9.9		400		$3,960
5	Lights	1	Ea	9.9		100		$990
6	Phones	1	Ea	9.9		250		$2,475
7	Computers	1	Ea	9.9		250		$2,475
8	Copier	1	Ea	9.9		200		$1,980
9	Water	1	Ea	9.9		200		$1,980
10	Sewer	1	Ea	9.9		200		$1,980
11	Access Road	1	LS	1		20000	LS	$20,000
12	Vehicles	6	Ea	9.9		900		$53,460
13	CAT 950 FEL	1	Ea	9.9		10000		$99,000
14	Forklift	1	Ea	9.9		4000		$39,600
15	RT30 Crane	1	Ea	9.9		12000		$118,800
16	Living Costs	6	Ea	9.9		2000		$118,800
17	Travel	1	Ea	9.9		1000		$9,900
18	Insurance	1	LS	1		500000	LS	$500,000
19	Permits	1	LS	1		10000	LS	$10,000
20	Consultants	1	LS	1		50000	LS	$50,000
21	Legal	1	LS	1		50000	LS	$50,000

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3A - Dredge Around Tower, Tremie Anchor Concrete, Stiffen Interior w/ reinforced Concrete
Partial Dewater to 100 ft

Item	Description	Quantity	Hrs/Shift	Shifts/Day	Days	Unit Cost	Item Cost
1	Mobilization	1 LS	10	1	10		$706,000
2	Dredge for Tremied Anchor Concrete	1 LS	10	1	11		$960,000
3	Install formwork and bracing for Anchor Concrete	1 LS	10	1	20		$1,980,000
4	Tremie Base Anchor Concrete	1 LS	10	1	6		$1,483,000
5	Dewater & Clean Tower	1 LS	10	1	13		$361,000
6	FRP Tunnel Transition	1 LS	10	1	11		$284,000
7	FRP to valve at El. 382.5	1 LS	10	1	11		$265,000
8	FRP to El. 399	1 LS	10	1	7		$188,000
9	FRP to valves at El. 420, 445, 470, 495	1 LS	10	1	44		$1,377,000
10	FRP to valve at El. 520	1 LS	10	1	12		$228,000
11	FRP to valves at El. 546	1 LS	10	1	11		$240,000
12	FRP to El. 589.75	1 LS	10	1	12		$252,000
13	Permanent Access into Tower	1 LS	10	1	20		$1,045,000
14	Demobilization	1 LS	10	1	10		$426,000
					198 Days		
					9.9 Months		$9,795,000
15	Supervision	1 LS			9.9 Mo	$62,020 Mo	$614,000
16	General Operations	1 LS			9.9 Mo	$111,010 Mo	$1,099,000
17	General Requirements 10% of Direct	10 %					$980,000
18	Home Office - 4-% of Direct	4 %					$392,000
	Subtotal						$12,880,000
19	Profit - 15% total	15%					$1,932,000
20	Bond, Taxes, & Insurance	2 %					$297,000
	Total (2008 Dollars)						$15,109,000
21	Escalation Excluded - Recommend 5% per year						
22	Contingency & Escalation	40%					$6,044,000
	Dewater Costs to 100 LF						$4,000,000
	Total Unescalated Construction Cost with Contingency						$25,153,000
	Excludes Design Costs, CM Costs, and Owner Soft Costs						

Assume Dredging material deposited on reservoir floor. Assume $250,000 additional to total unescalated cost if off-hauled.
Assume Valve controls, actuators, piping, etc do not have to be relocated or removed, and partially encased in Concrete.

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3A - Dredge Around Tower, Tremie Anchor Concrete, Stiffen Interior w/ reinforced Concrete
Partial Dewater to 100 ft

Item	Description	Quantity	Hrs/Shift	Shifts/Day	Days		Unit Cost	LF	Item Cost
1	Mobilization	1 LS	10	1	10				$706,000
	Move in cranes, barges, office, formwork, materials, etc								
	1 Mobilize Plant & Equip	1 LS				1	600000		$600,000
	2 Setup Plant & Equip (8 men)	10 Day	100 mhr/day		10	1000	72 $/hr	1.05	$75,600
	3 Receive Materials	20 Day	20 mhr/day			400	72 $/hr	1.05	$30,240
2	Dredge for Tremied Anchor Concrete	1 LS	10	1	11				$960,000
	Dredge around base of tower for tremie concrete, 10-hr shift, 1 shift per day, 250 CY/day								
	1 Dredger - Subcontractor	2512 CY				2512	100 $/cy		$251,200
	2 Divers	11 Days	80 mhr/day			880	49600 $/Day		$545,600
	3 100 T Crane	11 Days				110	250 $/hr		$27,500
	4 Barge & Tug	11 Days				110	340 $/hr	1.05	$39,270
	5 Labor	11 Days	100 mhr/day		11	1100	72 $/hr		$79,200
	6 Decompression chamber	11 Days				264	62.5 $/hr		$16,500
	7 Muck Disposal - on lake bed								
3	Install formwork and bracing for Anchor Concrete	1 LS	10	1	20				$1,980,000
	Install 60-ft diameter "formwork" and Brace, 10-hr shifts, 1 shift per day, divers - 3sf/mh								
	1 Divers	20 Days	160 mhr/day			3200	54750 $/Day		$1,095,000
	2 100 T Crane	20 Days				200	250 $/hr		$50,000
	3 Barge & Tug	20 Days				200	340 $/hr		$68,000
	4 Decompression chamber	20 Days				480	62.5 $/hr		$30,000
	5 Labor	20 Days	100 mhr/day		20	2000	72 $/hr	1.05	$151,200
	6 Form material	60 LF				60	9430 $/LF		$565,800
	7 Bracing	1 LS				1	20000 LS		$20,000
4	Tremie Base Anchor Concrete	1 LS	24	1	6				$1,483,000
	Setup concrete operation & tremie concrete, 50 CY/hr								
	1 Divers	6 Days	192 mhr/day			1152	49600 $/Day		$297,600
	2 100 T Crane	6 Days				144	250 $/hr		$36,000
	3 Barge & Tug	6 Days				144	340 $/hr		$48,960
	4 Decompression chamber	6 Days				144	62.5 $/hr		$9,000
	5 Concrete pump & piping	5500 CY				5500	10 $/cy		$55,000
	6 Tremie Concrete	6 Days	240 mhr/day		6	1440	72 $/hr	1.5	$155,520
	7 Concrete	5500 CY				5500	140 $/cy		$770,000
	8 Concrete Overtime fees	3667 CY				3667	30 $/cy		$110,010
5	Dewater & Clean Tower	1 LS	10	1	13				$361,000
	Dewater tower, clean interior, and remove unnecessary appurtenances (ladders, etc)								
	1 Dewater tower & seal intakes	3 Days	100 mhr/day		3	300	72 $/hr	1.05	$22,680

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3A - Dredge Around Tower, Tremie Anchor Concrete, Stiffen Interior w/ reinforced Concrete
Partial Dewater to 100 ft

Item	Description	Quantity	Hrs/Shift	Shifts/Day	Days		Unit Cost	LF	Item Cost
2	Divers	3 Days	80 mhr/day			240	49600 $/Day		$148,800
3	Barge & Tug	13 Days				130	250 $/hr		$32,500
4	100 T Crane	13 Days				130	340 $/hr		$44,200
5	Decompression chamber	2 Days				48	62.5 $/hr		$3,000
6	Clean interior walls	5 Days	100 mhr/day		5	500	72 $/hr	1.05	$37,800
7	Remove unnecessary Appurtenances	5 Days	100 mhr/day		5	500	72 $/hr	1.05	$37,800
8	Man cage	13 Days				130	2 $/hr		$260
9	Ventilation	13 Days				130	10 $/hr		$1,300
10	Generator	13 Days				130	15 $/hr		$1,950
11	Intake Seal Covers	6 ea					5000 ea		$30,000
6	FRP Tunnel Transition		10	1	11				$284,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish Tunnel transition, 11 LF Pour								
1	Plant support for Reinforcing	4 Days	50 mhr/day		4	200	72 $/hr	1.05	$15,120
2	Install Special Formwork at Transition	3 Days	100 mhr/day		3	300	72 $/hr	1.05	$22,680
3	Install Vertical formwork	2 Days	100 mhr/day		2	200	72 $/hr	1.05	$15,120
4	Pour Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
5	Strip forms & patch Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
6	Reinforcing Bars furnish & install	11 LF	4786 lbs/LF			52646	1.5 $/lb		$78,969
7	Concrete	11 LF	5 CY/LF			55	140 $/cy		$7,700
8	Transition Formwork	1 LS				1	10000 LS		$10,000
9	Shaft Formwork - 25-ft Purchase	1 LS				1	50000 LS		$50,000
10	Barge & Tug	11 Days				110	340 $/hr		$37,400
11	100 T Crane	11 Days				110	250 $/hr		$27,500
12	Concrete pump & piping	55 CY				55	10 $/cy		$550
13	Man cage	11 Days				110	2 $/hr		$220
14	Ventilation	11 Days				110	10 $/hr		$1,100
15	Generator	11 Days				110	15 $/hr		$1,650
7	FRP to valve at El. 382.5		10	1	11				$265,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top of valve at El. 382.5, 15 LF Pour								
1	Plant support for Reinforcing	4 Days	50 mhr/day		4	200	72 $/hr	1.05	$15,120
2	Install Special Formwork at Transition	3 Days	100 mhr/day		3	300	72 $/hr	1.05	$22,680
3	Install Vertical formwork	2 Days	100 mhr/day		2	200	72 $/hr	1.05	$15,120
4	Pour Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
5	Strip forms & patch Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
6	Reinforcing Bars furnish & install	15 LF	4786 lbs/LF			71790	1.5 $/lb		$107,685
7	Concrete	15 LF	5 CY/LF			75	140 $/cy		$10,500
8	Transition Formwork	1 LS				1	10000 LS		$10,000
9	Barge & Tug	11 Days				110	250 $/hr		$27,500

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3A - Dredge Around Tower, Tremie Anchor Concrete, Stiffen Interior w/ reinforced Concrete
Partial Dewater to 100 ft

Item	Description	Quantity	Hrs/Shift	Shifts/Day	Days		Unit Cost	LF	Item Cost
10	100 T Crane	11 Days				110	340 $/hr		$37,400
11	Concrete pump & piping	75 CY				75	10 $/cy		$750
12	Man cage	11 Days				110	2 $/hr		$220
13	Ventilation	11 Days				110	10 $/hr		$1,100
14	Generator	11 Days				110	15 $/hr		$1,650
8	FRP to El. 399		10	1	7				$188,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top of valve at El. 382.5, 13 LF Pour								
1	Plant support for Reinforcing	3 Days	50 mhr/day		3	150	72 $/hr	1.05	$11,340
2	Install Special Formwork at Transition	0 Days	100 mhr/day		0	0	72 $/hr	1.05	$0
3	Install Vertical formwork	2 Days	100 mhr/day		2	200	72 $/hr	1.05	$15,120
4	Pour Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
5	Strip forms & patch Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
6	Reinforcing Bars furnish & install	13 LF	4786 lbs/LF			62218	1.5 $/lb		$93,327
7	Concrete	13 LF	5 CY/LF			65	140 $/cy		$9,100
8	Transition Formwork	0 LS				0	10000 LS		$0
9	Barge & Tug	7 Days				70	340 $/hr		$23,800
10	100 T Crane	7 Days				70	250 $/hr		$17,500
11	Concrete pump & piping	65 CY				65	10 $/cy		$650
12	Man cage	7 Days				70	2 $/hr		$140
13	Ventilation	7 Days				70	10 $/hr		$700
14	Generator	7 Days				70	15 $/hr		$1,050
9	FRP to valves at El. 420, 445, 470, 495		10	1	44				$1,377,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top of valves 4 Pours @ 25 LF								
1	Plant support for Reinforcing	16 Days	50 mhr/day		16	800	72 $/hr	1.05	$60,480
2	Install Special Formwork at Transition	12 Days	100 mhr/day		12	1200	72 $/hr	1.05	$90,720
3	Install Vertical formwork	8 Days	100 mhr/day		8	800	72 $/hr	1.05	$60,480
4	Pour Concrete	4 Days	100 mhr/day		4	400	72 $/hr	1.05	$30,240
5	Strip forms & patch Concrete	4 Days	100 mhr/day		4	400	72 $/hr	1.05	$30,240
6	Reinforcing Bars furnish & install	100 LF	4786 lbs/LF			478600	1.5 $/lb		$717,900
7	Concrete	100 LF	5 CY/LF			500	140 $/cy		$70,000
8	Transition Formwork	4 Ea				4	10000 Ea		$40,000
9	Barge & Tug	44 Days				440	340 $/hr		$149,600
10	100 T Crane	44 Days				440	250 $/hr		$110,000
11	Concrete pump & piping	500 CY				500	10 $/cy		$5,000
12	Man cage	44 Days				440	2 $/hr		$880
13	Ventilation	44 Days				440	10 $/hr		$4,400
14	Generator	44 Days				440	15 $/hr		$6,600

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3A - Dredge Around Tower, Tremie Anchor Concrete, Stiffen Interior w/ reinforced Concrete
Partial Dewater to 100 ft

Item	Description	Quantity	Hrs/Shift	Shifts/Day	Days		Unit Cost	LF	Item Cost
10	FRP to valve at El. 520		10	1	12				$228,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top of valve at El. 520, 26 LF pour w/ 1-ft dutchman								
1	Plant support for Reinforcing	4 Days	50 mhr/day		4	200	72 $/hr	1.05	$15,120
2	Install Special Formwork at Transition	3 Days	100 mhr/day		3	300	72 $/hr	1.05	$22,680
3	Install Vertical formwork	3 Days	100 mhr/day		3	300	72 $/hr	1.05	$22,680
4	Pour Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
5	Strip forms & patch Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
6	Reinforcing Bars furnish & install	26 LF	1200 lbs/LF			31200	1.5 $/lb		$46,800
7	Concrete	26 LF	5 CY/LF			130	140 $/cy		$18,200
8	Transition Formwork	1 LS				1	10000 LS		$10,000
9	Dutchman Formwork	1 LS				1	2000 LS		$2,000
10	Barge & Tug	12 Days				120	340 $/hr		$40,800
11	100 T Crane	12 Days				120	250 $/hr		$30,000
12	Concrete pump & piping	130 CY				130	10 $/cy		$1,300
13	Man cage	12 Days				120	2 $/hr		$240
14	Ventilation	12 Days				120	10 $/hr		$1,200
15	Generator	12 Days				120	15 $/hr		$1,800
11	FRP to valves at El. 546		10	1	11				$240,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top of valve at EL 546 1 Pour @ 25 LF								
1	Plant support for Reinforcing	4 Days	50 mhr/day		4	200	72 $/hr	1.05	$15,120
2	Install Special Formwork at Transition	3 Days	100 mhr/day		3	300	72 $/hr	1.05	$22,680
3	Install Vertical formwork	2 Days	100 mhr/day		2	200	72 $/hr	1.05	$15,120
4	Pour Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
5	Strip forms & patch Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
6	Reinforcing Bars furnish & install	25 LF	1200 lbs/LF			30000	1.5 $/lb		$45,000
7	Concrete	25 LF	5 CY/LF			125	140 $/cy		$17,500
8	Transition Formwork	4 LS				4	10000 LS		$40,000
9	Barge & Tug	11 Days				110	340 $/hr		$37,400
10	100 T Crane	11 Days				110	250 $/hr		$27,500
11	Concrete pump & piping	125 CY				125	10 $/cy		$1,250
12	Man cage	11 Days				110	2 $/hr		$220
13	Ventilation	11 Days				110	10 $/hr		$1,100
14	Generator	11 Days				110	15 $/hr		$1,650
12	FRP to El. 589.75		10	1	12				$252,000

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3A - Dredge Around Tower, Tremie Anchor Concrete, Stiffen Interior w/ reinforced Concrete
Partial Dewater to 100 ft

Item	Description	Quantity	Hrs/Shift	Shifts/Day	Days		Unit Cost	LF	Item Cost
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top at EL 589.75, 2 pours @ 20LF each								
1	Plant support for Reinforcing	4 Days	50 mhr/day		4	200	72 $/hr	1.05	$15,120
2	Install Special Formwork at Transition	0 Days	100 mhr/day		0	0	72 $/hr	1.05	$0
3	Install Vertical formwork	4 Days	100 mhr/day		4	400	72 $/hr	1.05	$30,240
4	Pour Concrete	2 Days	100 mhr/day		2	200	72 $/hr	1.05	$15,120
5	Strip forms & patch Concrete	2 Days	100 mhr/day		2	200	72 $/hr	1.05	$15,120
6	Reinforcing Bars furnish & install	40 LF	1200 lbs/LF			48000	1.5 $/lb		$72,000
7	Concrete	40 LF	5 CY/LF			200	140 $/cy		$28,000
8	Transition Formwork	0 LS				0	10000 LS		$0
9	Barge & Tug	12 Days				120	340 $/hr		$40,800
10	100 T Crane	12 Days				120	250 $/hr		$30,000
11	Concrete pump & piping	200 CY				200	10 $/cy		$2,000
12	Man cage	12 Days				120	2 $/hr		$240
13	Ventilation	12 Days				120	10 $/hr		$1,200
14	Generator	12 Days				120	15 $/hr		$1,800
13	Permanent Access into Tower		10	1	20				$1,045,000
	Provide New ladder into shaft								
1	Furnish Ladder	1 LS				1	25000		$25,000
2	Install Ladder	10 Days	100 mhr/day		10	1000	72 $/hr	1.05	$75,600
3	Furnish Hoisting system w/ workdeck & New Cover	1 LS				1	750000		$750,000
4	Install Hoisting system	10 Days	100 mhr/day		10	1000	72 $/hr	1.05	$75,600
5	Barge & Tug	20 Days				200	340 $/hr		$68,000
6	100 T Crane	20 Days				200	250 $/hr		$50,000
14	Demobilization		10	1	10				$426,000
	Demobilize cranes, barges, office, formwork, materials, etc								
1	Demobilize Plant & Equip	1 LS				1	300000 LS		$300,000
2	Tear down Plant & Equip (8 men)	10 Day	100 mhr/day		10	1000	72 $/hr	1.05	$75,600
3	Restoration	1 LS				1	50000 LS		$50,000

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3A - Dredge Around Tower, Tremie Anchor Concrete, Stiffen Interior w/ reinforced Concrete
Partial Dewater to 100 ft

Item	Description	Quantity	Months	Unit Cost	Item Cost
1	Supervision	1 LS	9.9 Mo	$62,020 Mo	$614,000
1	Project Manager	1 Ea	9.9	13000 Mo	$128,700
2	Project Superintendent	1 Ea	9.9	12000 Mo	$118,800
3	Walker	3 Ea	9.9	10000 Mo	$99,000
4	Project Engineer	1 Ea	9.9	10000 Mo	$99,000
5	Office Manager	1 Ea	9.9	8000 Mo	$79,200
6	Field Engineer	2 Ea	9.9	9000 Mo	$89,100
2	General Operations	1 LS	9.9 Mo	$111,010 Mo	$1,099,000
1	Office	1 Ea	9.9	450	$4,455
2	Change House	1 Ea	9.9	450	$4,455
3	Shop Containers	4 Ea	9.9	100	$3,960
4	Power supply	1 Ea	9.9	400	$3,960
5	Lights	1 Ea	9.9	100	$990
6	Phones	1 Ea	9.9	250	$2,475
7	Computers	1 Ea	9.9	250	$2,475
8	Copier	1 Ea	9.9	200	$1,980
9	Water	1 Ea	9.9	200	$1,980
10	Sewer	1 Ea	9.9	200	$1,980
11	Access Road	1 LS	1	20000 LS	$20,000
12	Vehicles	6 Ea	9.9	900	$53,460
13	CAT 950 FEL	1 Ea	9.9	10000	$99,000
14	Forklift	1 Ea	9.9	4000	$39,600
15	RT30 Crane	1 Ea	9.9	12000	$118,800
16	Living Costs	6 Ea	9.9	2000	$118,800
17	Travel	1 Ea	9.9	1000	$9,900
18	Insurance	1 LS	1	500000 LS	$500,000
19	Permits	1 LS	1	10000 LS	$10,000
20	Consultants	1 LS	1	50000 LS	$50,000
21	Legal	1 LS	1	50000 LS	$50,000

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3B - Dewatered - Excavate Around Tower, Anchor Concrete, Stiffen Exterior w/ reinforced Concrete

Item	Description	Quantity		Hrs/Shift	Shifts/Day	Days		Unit Cost		Item Cost
1	Mobilization	1	LS	10	1	10				291000
2	Excavate for Anchor Concrete	1	LS	10	1	2				$18,000
3	Install formwork and bracing for Anchor Concrete	1	LS	10	1	10				$530,000
4	Pour Anchor Concrete	1	LS	10	1	11				$921,000
5	Clean Tower	1	LS	10	1	5				$53,000
6	Purchase special formwork	1	LS	10	1	0				$134,000
7	FRP to valves at El. 420, 445, 470, 495	320.4379	cy	10	1	48		$3,435.92	cy	$1,101,000
8	FRP to valve at El. 520	69.16161	cy	10	1	12		$3,383.38	cy	$234,000
9	FRP to valve at El. 546	62.08338	cy	10	1	12		$3,479.19	cy	$216,000
10	FRP to El. 589.75	90.70916	cy	10	1	16		$3,792.34	cy	$344,000
11	Demobilization	1	LS	10	1	10				$211,000
						136	Days			
						6.2	Months			$4,053,000
12	Supervision	1	LS			6.2	Mo	$62,118	Mo	$384,000
13	General Operations	1	LS			6.2	Mo	$150,279	Mo	$929,000
14	General Requirements 10% of Direct	10	%							$406,000
15	Home Office - 4-% of Direct	4	%							$163,000
	Subtotal									$5,935,000
16	CAT 960 FEL	15%								$890,250
17	Bond, Taxes, & Insurance	2	%							$137,000
	Total (2008 Dollars)									$6,963,000
18	Escalation Excluded - Recommend 5% per year									
19	Contingency & Escalation	40%								$2,785,200
	Reservoir Dewatering cost									$6,000,000
	Total Unescalated Construction Cost with Contingency									$15,748,200
	Excludes Design Costs, CM Costs, and Owner Soft Costs									

Assume Excavated material deposited on reservoir floor. Assume $250,000 additional if off-hauled.
Assume valves, controls, actuators, piping, etc have no associated work.
Assume Valve @ El. 382.5 is totally encased.
Assume existing valve outlets partially encased in "stiffening" concrete

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3B - Dewatered - Excavate Around Tower, Anchor Concrete, Stiffen Exterior w/ reinforced Concrete

Item	Description	Quantity		Hrs/Shift		Shifts/Day	Days		Unit Cost		LF	Item Cost
1	Mobilization	1	LS	10		1	10					$291,000
	Move in cranes, barges, office, formwork, materials, etc											
	1 Mobilize Plant & Equip	1	LS					1	200000			$200,000
	2 Setup Plant & Equip (8 men)	10	Day	96	mhr/day		10	800	72	$/hr	1.05	$60,480
	3 Receive Materials	20	Day	20	mhr/day			400	72	$/hr	1.05	$30,240
2	Excavate for Tremied Anchor Concrete	1	LS	10		1	2					$18,000
	Excavate around base of tower for tremie concrete, 10-hr shift, 1 shift per day, 1300 CY/day											
	1 D8 Dozer for spreading muck	2	Days					20	200	$/hr		$4,000
	2 Labor	2	Days	60	mhr/day		2	120	72	$/hr	1.05	$8,640
	3 Cat 375 Excavator	2	Days					20	250	$/hr		$5,000
	4 Muck Disposal - on lake bed											
3	Install formwork and bracing for Anchor Concrete	1	LS	10		1	10					$530,000
	Install 60-ft diameter "formwork" and Brace, 10-hr shifts, 1 shift per day, - 7sf/mh											
	1 Labor	10	Days	120	mhr/day		10	1200	72	$/hr	1.05	$90,720
	2 100 T Crane	10	Days					100	250	$/hr		$25,000
	3 Form material	60	LF					60	4735	$/LF		$284,100
	4 Bracing	1	LS					1	20000	LS		$20,000
	5 Crane Mats	100	ea					10000	5	$/hr		$50,000
	6 Reinforcing Bar dowels furnish & install	20	LF	1976.8	lbs/LF			39535.38	1.5	$/lb		$59,303
	CAT 960 FEL											
4	Pour Anchor Concrete	1	LS	10		1	11					$921,000
	Setup concrete operation & pump concrete, 50 CY/hr											
	1 Pump Concrete	11	Days	120	mhr/day		11	1320	72	$/hr	1.05	$95,040
	2 100T Crane	11	Days					110	250	$/hr		$27,500
	3 Concrete pump & piping	5500	CY					5500	10	$/cy	1.05	$55,000
	4 Concrete	5500	CY					5500	125	$/cy		$687,500
	5 Crane Mats	100	ea					11000	5	$/hr		$55,000
5	Clean Tower Exterior	1	LS	10		1	5					$53,000
	Clean exterior of tower											
	1 Clean Exterior walls	5	Days	96	mhr/day		5	480	72	$/hr	1.05	$36,288
	2 100 T Crane	5	Days					50	250	$/hr		$12,500
	3 Man cage	5	Days					50	2	$/hr		$100

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3B - Dewatered - Excavate Around Tower, Anchor Concrete, Stiffen Exterior w/ reinforced Concrete

Item	Description	Quantity		Hrs/Shift		Shifts/Day	Days		Unit Cost		LF	Item Cost
4	Generator	5	Days					50	15	$/hr		$750
5	Crane Mats	100	ea					500	5	$/hr		$2,500
6	Form Purchase			10		1	0					$134,000
	Adjustible Conical Shaft Form purchase - 25 LF	25	LF					25	4000	$/LF		$100,000
	Shatf form Bracing 3 ea. For 8 pours	24	Ea					1380	1	$/lb		$33,120
7	FRP to valves at El. 420, 445, 470, 495			10		1	48					$1,101,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top of valves 4 Pours @ 25 LF											
1	Plant support for Reinforcing	16	Days	50	mhr/day			800	72	$/hr	1.05	$60,480
2	Install Special Formwork at Transition	12	Days	120	mhr/day		12	1440	72	$/hr	1.05	$108,864
3	Install Vertical formwork	8	Days	120	mhr/day		8	960	72	$/hr	1.05	$72,576
4	Pour Concrete	4	Days	120	mhr/day		4	480	72	$/hr	1.05	$36,288
5	Strip forms & patch Concrete	4	Days	120	mhr/day		4	480	72	$/hr	1.05	$36,288
6	Cure time - 3 days per pour						12					
7	Reinforcing Bars furnish & install	100	LF	1976.8	lbs/LF		8	197676.9	1.5	$/lb		$296,515
8	Concrete	100	LF	3.2044	CY/LF			320.4379	125	$/cy		$40,055
9	Transition Formwork	4	Ea					4	10000	Ea		$40,000
11	100 T Crane	48	Days					480	250	$/hr		$120,000
12	Concrete pump & piping	320.4379	CY					320.4379	10	$/cy		$3,204
13	Man cage	48	Days					480	2	$/hr		$960
15	Generator	48	Days					480	15	$/hr		$7,200
16	Crane Mats	100	ea					48000	5	$/hr		$240,000
17	Form Hoist System	8	ea					3840	10	$/hr		$38,400
8	FRP to valve at El. 520			10		1	12					$234,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top of valve at El. 520, 26 LF pour w/ 1-ft dutchman											
1	Plant support for Reinforcing	4	Days	50	mhr/day			200	72	$/hr	1.05	$15,120
2	Install Special Formwork at Transition	3	Days	120	mhr/day		3	360	72	$/hr	1.05	$27,216
3	Install Vertical formwork	2	Days	120	mhr/day		2	240	72	$/hr	1.05	$18,144
4	Pour Concrete	1	Days	120	mhr/day		1	120	72	$/hr	1.05	$9,072
5	Strip forms & patch Concrete	1	Days	120	mhr/day		1	120	72	$/hr	1.05	$9,072
6	Cure time - 3 days per pour						3					
7	Reinforcing Bars furnish & install	26	LF	820.49	lbs/LF		2	21332.76	1.5	$/lb		$31,999
8	Concrete	26	LF	2.6601	CY/LF			69.16161	125	$/cy		$8,645
9	Transition Formwork	1	LS					1	10000	LS		$10,000

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Briones Dam Inlet/Outlet Tower Retrofit

Option 3B - Dewatered - Excavate Around Tower, Anchor Concrete, Stiffen Exterior w/ reinforced Concrete

Item	Description	Quantity		Hrs/Shift		Shifts/Day	Days		Unit Cost		LF	Item Cost
10	Dutchman Formwork	1	LS					1	2000	LS		$2,000
11	100 T Crane	12	Days					120	250	$/hr		$30,000
12	Concrete pump & piping	69.16161	CY					69.16161	10	$/cy		$692
13	Man cage	12	Days					120	2	$/hr		$240
14	Generator	12	Days					120	15	$/hr		$1,800
14	Crane Mats	100	ea					12000	5	$/hr		$60,000
15	Form Hoist System	8	ea					960	10	$/hr		$9,600
9	FRP to valve at El. 546			10		1	12					$216,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top of valve at EL 546 1 Pour @ 25 LF											
1	Plant support for Reinforcing	4	Days	50	mhr/day			200	72	$/hr	1.05	$15,120
2	Install Special Formwork at Transition	3	Days	120	mhr/day		3	360	72	$/hr	1.05	$27,216
3	Install Vertical formwork	2	Days	120	mhr/day		2	240	72	$/hr	1.05	$18,144
4	Pour Concrete	1	Days	120	mhr/day		1	120	72	$/hr	1.05	$9,072
5	Strip forms & patch Concrete	1	Days	120	mhr/day		1	120	72	$/hr	1.05	$9,072
6	Cure time - 3 days per pour						3					
7	Reinforcing Bars furnish & install	25	LF	510.65	lbs/LF		2	12766.33	1.5	$/lb		$19,149
8	Concrete	25	LF	2.4833	CY/LF			62.08338	125	$/cy		$7,760
9	Transition Formwork	1	LS					1	10000	LS		$10,000
11	100 T Crane	12	Days					120	250	$/hr		$30,000
12	Concrete pump & piping	62.08338	CY					62.08338	10	$/cy		$621
13	Man cage	12	Days					120	2	$/hr		$240
14	Crane Mats	100	ea					12000	5	$/hr		$60,000
15	Form Hoist System	8	ea					960	10	$/hr		$9,600
10	FRP to El. 589.75			10		1	16					$344,000
	Install Reinforcing steel, Form, Pour, Strip, and Finish to top at EL 589.75, 2 pours @ 20LF each											
1	Plant support for Reinforcing	4	Days	50	mhr/day			200	72	$/hr	1.05	$15,120
2	Install Special Formwork at Transition	0	Days	120	mhr/day		0	0	72	$/hr	1.05	$0
3	Install Vertical formwork	4	Days	120	mhr/day		4	480	72	$/hr	1.05	$36,288
4	Pour Concrete	2	Days	120	mhr/day		2	240	72	$/hr	1.05	$18,144
5	Strip forms & patch Concrete	2	Days	120	mhr/day		2	240	72	$/hr	1.05	$18,144
6	Cure time - 3 days per pour						6					
7	Reinforcing Bars furnish & install	40	LF	510.65	lbs/LF		2	20426.13	1.5	$/lb		$30,639
8	Concrete	40	LF	2.2677	CY/LF			90.70916	125	$/cy		$11,339
9	Transition Formwork	0	LS					0	10000	LS		$0

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3B - Dewatered - Excavate Around Tower, Anchor Concrete, Stiffen Exterior w/ reinforced Concrete

Item	Description	Quantity		Hrs/Shift	Shifts/Day	Days		Unit Cost		LF	Item Cost
11	100 T Crane	16	Days				160	250	$/hr		$40,000
12	Concrete pump & piping	90.70916	CY				90.70916	10	$/cy		$907
13	Man cage	16	Days				160	2	$/hr		$320
14	Crane Mats	100	ea				16000	10	$/hr		$160,000
15	Form Hoist System	8	ea				1280	10	$/hr		$12,800
11	Demobilization			10	1	10					$211,000
	Demobilize cranes, barges, office, formwork, materials, etc										
1	Demobilize Plant & Equip	1	LS				1	100000	LS		$100,000
2	Tear down Plant & Equip (8 men)	10	Day	96	mhr/day	10	800	72	$/hr	1.05	$60,480
3	Restoration	1	LS				1	50000	LS		$50,000

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Briones Dam Inlet/Outlet Tower Retrofit
Option 3B - Dewatered - Excavate Around Tower, Anchor Concrete, Stiffen Exterior w/ reinforced Concrete

Item		Description	Quantity		Months		Unit Cost		Item Cost
1		Supervision	1	LS	6.2	Mo	$62,118	Mo	$384,000
	1	Project Manager	1	Ea	6.2		13000	Mo	$80,364
	2	Project Superintendent	1	Ea	6.2		12000	Mo	$74,182
	3	Walker	1	Ea	6.2		10000	Mo	$61,818
	4	Project Engineer	1	Ea	6.2		10000	Mo	$61,818
	5	Office Manager	1	Ea	6.2		8000	Mo	$49,455
	6	Field Engineer	1	Ea	6.2		9000	Mo	$55,636
2		General Operations	1	LS	6.2	Mo	$150,279	Mo	$929,000
	1	Office	1	Ea	6.2		450		$2,782
	2	Change House	1	Ea	6.2		450		$2,782
	3	Shop Containers	4	Ea	6.2		100		$2,473
	4	Power supply	1	Ea	6.2		400		$2,473
	5	Lights	1	Ea	6.2		100		$618
	6	Phones	1	Ea	6.2		250		$1,545
	7	Computers	1	Ea	6.2		250		$1,545
	8	Copier	1	Ea	6.2		200		$1,236
	9	Water	1	Ea	6.2		200		$1,236
	10	Sewer	1	Ea	6.2		200		$1,236
	11	Access Road	1	LS	1.0		20000	LS	$20,000
	12	Vehicles	6	Ea	6.2		900		$33,382
	13	CAT 960 FEL	1	Ea	6.2		10000		$61,818
	14	Forklift	1	Ea	6.2		4000		$24,727
	15	RT30 Crane	1	Ea	6.2		12000		$74,182
	16	Scaffold stair tower	1	ea	6.2		1000		$6,182
	17	Living Costs	6	Ea	6.2		2000		$74,182
	18	Travel	1	Ea	6.2		1000		$6,182
	19	Insurance	1	LS	1.0		500000	LS	$500,000
	20	Permits	1	LS	1.0		10000	LS	$10,000
	21	Consultants	1	LS	1.0		50000	LS	$50,000
	22	Legal	1	LS	1.0		50000	LS	$50,000

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Briones Dam Inlet/Outlet Tower Retrofit
Option 4A - Dredge Over existing tunnel, Install Lakebed Piping, Connect to existing Tunnel - No Dewatering

Item	Description	Quantity		Hrs/Shift	Shifts/Day	Days		Unit Cost		Item Cost
1	Mobilization	1	LS	10	1	10				$706,000
2	Dredge for Tremied Saddle & Lakebed Concrete	1	LS	10	1	29				$5,703,000
3	Install formwork and bracing for Tunnel "Saddle" Cor	1	LS	10	1	20				$4,036,000
4	Tremie Saddle Concrete	1	LS	10	1	3				$742,000
5	Install Lakebed piping, connect to new tunnel Riser F	1	LS	10	1	20				$5,131,000
6	Tremie Lake bottom Pipe Encasement	1	LS	10	1	6				$2,165,000
9	Make piping connection to Existing tunnel	1	LS	10	1	10				$161,000
11	Plug & demolish existing tower	1	LS	10	1	9				$595,000
12	Demobilization	1	LS	10	1	10				$426,000
						132	Days			
						6.6	Months			$19,665,000
13	Supervision	1	LS			6.6	Mo	$62,121	Mo	$410,000
14	General Operations	1	LS			6.6	Mo	$143,636	Mo	$948,000
15	General Requirements 10% of Direct	10	%							$1,967,000
16	Home Office - 4-% of Direct	4	%							$787,000
	Subtotal									$23,777,000
17	Profit - 15% total	15%								$3,567,000
18	Bond, Taxes, & Insurance	2	%							$547,000
	Total (2008 Dollars)									$27,891,000
19	Escalation Excluded - Recommend 5% per year									
20	Contingency & Escalation	40%								$11,157,000
	Total Unescalated Construction Cost with Contingency									$39,048,000
	Excludes Design Costs, CM Costs, and Owner Soft Costs									

Assume Dredging material deposited on reservoir floor. Assume $300,000 additional to total unescalated cost if off-hauled.
Assume Demolished Tower to remain on reservoir floor.

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Briones Dam Inlet/Outlet Tower Retrofit
Option 4A - Dredge Over existing tunnel, Install Lakebed Piping, Connect to existing Tunnel - No Dewatering

Item	Description	Quantity		Hrs/Shift		Shifts/Day	Days		Unit Cost			Item Cost
1	Mobilization	1	LS	10		1	10					$705,840
	Move in cranes, barges, office, formwork, materials, etc											
1	Mobilize Plant & Equip	1	LS					1	600000			$600,000
2	Setup Plant & Equip (8 men)	10	Day	100	mhr/day		10	1000	72	$/hr	1.05	$75,600
3	Receive Materials	20	Day	20	mhr/day			400	72	$/hr	1.05	$30,240
2	Dredge for Tremied Saddle & Lakebed Concrete	1	LS	10		1	29					$5,702,640
	Dredge over existing tunnel for tremie concrete & Lakebed Piping, 10-hr shift, 1 shift per day, 250 CY per day											
1	Dredger - Subcontractor	7100	CY					7100	100	$/cy		$710,000
2	Divers	29	Days	80	mhr/day			2320	157200	$/day		$4,558,800
3	100 T Crane	29	Days					290	250	$/hr		$72,500
4	Barge & Tug	29	Days					290	340	$/hr		$98,600
5	Labor	29	Days	100	mhr/day		29	2900	72	$/hr	1.05	$219,240
6	Decompression chamber	29	Days					696	62.5	$/hr		$43,500
7	Muck Disposal - On lake bed											
3	Install formwork and bracing for Tunnel "Saddle"	1	LS	10		1	20					$4,035,850
	Install 20-ft and 8-ft diameter "formwork", Pipe, and Brace, 10-hr shifts, 1 shift per day											
1	Divers	20	Days	160	mhr/day			3200	179625	$/day		$3,592,500
2	100 T Crane	20	Days					200	250	$/hr		$50,000
3	Barge & Tug	20	Days					200	340	$/hr		$68,000
4	Decompression chamber	20	Days					480	62.5	$/hr		$30,000
5	Labor	20	Days	100	mhr/day		20	2000	72	$/hr	1.05	$151,200
6	Form material 20-ft diameter	20	LF					20	4720	$/LF		$94,400
7	8-ft Diameter Pipe Saddle	25	LF					25	850	$/LF		$21,250
8	Bracing	1	LS					1	20000	LS		$20,000
9	Reinforcing Steel for "Saddle"	20	LF	500	lb/lf			10000	0.85	$/lb		$8,500
4	Tremie Saddle Concrete	1	LS	24		1	3					$741,642
	Setup concrete operation & tremie concrete, 2 days of tremie, 2 days of setup											
1	Divers	3	Days	192	mhr/day			576	150	$/hr		$86,400
2	100 T Crane	3	Days					30	157200	$/day		$471,600
3	Barge & Tug	3	Days					30	340	$/hr		$10,200
4	Plant support for setup	1	Days	240	mhr/day		1	240	72	$/hr	1.05	$18,144
5	Concrete pump & piping	700	CY					700	10	$/cy		$7,000
6	Tremie Concrete	2	Days	240	mhr/day		2	480	72	$/hr	1.05	$36,288
7	Reinforcing steel	0	lf	0	lb/lf			0	0.85	$/lb		$0

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Briones Dam Inlet/Outlet Tower Retrofit
Option 4A - Dredge Over existing tunnel, Install Lakebed Piping, Connect to existing Tunnel - No Dewatering

Item	Description	Quantity	Hrs/Shift	Shifts/Day	Days		Unit Cost		Item Cost
8	Concrete	700 CY				700	140 $/cy		$98,000
9	Concrete Overtime fees	467 CY				467	30 $/cy		$14,010
5	Install Lakebed piping, connect to new tunnel Riser Pipe		10	1	20				$5,130,700
	Load piping on barge, lower & install								
1	Divers	20 Days	80 mhr/day		20	1600	179625 $/day		$3,592,500
2	100 T Crane	20 Days				200	250 $/hr		$50,000
3	Barge & Tug	20 Days				200	340 $/hr		$68,000
4	Labor	20 Days	100 mhr/day			2000	72 $/hr	1.05	$151,200
5	Intake Piping - 6-ft ID 3/8-in Wall	640 LF				640	850 $/LF		$544,000
6	Intake Piping - 8-ft x 6-ft Tee 1/2-in Wall	10 LF				1	25000 Ea		$25,000
7	Valves, operators, & protection	7 Ea				7	100000 Ea		$700,000
6	Tremie Lake bottom Pipe Encasement		24	1	6				$2,164,361
	Setup concrete operation & tremie concrete, 2 days of setup, 50 cy/hr								
1	Divers	6 Days	192 mhr/day			1152	157200 $/day		$943,200
2	100 T Crane	6 Days				60	250 $/hr		$15,000
3	Barge & Tug	6 Days				60	340 $/hr		$20,400
4	Plant support for setup	1 Days	108 mhr/day		2	108	72 $/hr	1.05	$8,165
5	Concrete pump & piping	6500 CY				6500	10 $/cy		$65,000
6	Tremie Concrete	4 Days	240 mhr/day		4	960	72 $/hr	1.05	$72,576
7	Concrete	6500 CY				6500	140 $/cy		$910,000
8	Concrete Overtime fees	4334 CY				4334	30 $/cy		$130,020
9	Make piping connection to Existing tunnel		10	1	10				$160,074
	Dewater Tower, break into existing Tunnel, Form & place Transition								
1	Dewatering Labor	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
2	Break into existing tunnel	5 Days	100 mhr/day		5	500	72 $/hr	1.05	$37,800
3	Plant support for Reinforcing	2 Days	40 mhr/day			80	72 $/hr	1.05	$6,048
4	Install custom formwork	2 Days	100 mhr/day		2	200	72 $/hr	1.05	$15,120
5	Pump Concrete	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
6	Strip & remove formwork, and patch	1 Days	100 mhr/day		1	100	72 $/hr	1.05	$7,560
7	Barge & Tug	10 Days				100	340 $/hr	1.05	$35,700
8	Reinforcing steel furnish & install	2684 lbs				2684	1.5 $/lb		$4,026
9	Custom formwork	1 LS				1	10000 LS		$10,000
10	Concrete	10 CY				10	140 $/cy		$1,400
11	100 T crane	10 Days				100	250 $/hr		$25,000

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Briones Dam Inlet/Outlet Tower Retrofit
Option 4A - Dredge Over existing tunnel, Install Lakebed Piping, Connect to existing Tunnel - No Dewatering

Item		Description	Quantity	Hrs/Shift	Shifts/Day	Days		Unit Cost		Item Cost
	12	Mancage	10 Days				100	2 $/hr		$200
	13	Dewatering pumps	10 Days				100	10 $/hr		$1,000
	14	Ventilation fans	10 Days				100	10 $/hr		$1,000
	15	Concrete Pump & piping	10 CY				10	10 $/cy		$100
11		Plug & demolish existing tower		10	1	9				$594,548
		Implode tower onto lake bed								
	1	Plug formwork	1 LS							
	2	Install Formwork & pump Concrete	5 Days	100	mhr/day	5	500	72 $/hr	1.05	$37,800
	3	Concrete	20 CY				20	140 $/cy		$2,800
	4	100 T Crane	9 Days				90	250 $/hr		$22,500
	5	Barge & Tug	9 Days				90	340 $/hr		$30,600
	6	Concrete Pump & piping	20 CY				20	10 $/cy		$200
	7	Supporting Labor	9 Days	100	mhr/day		900	72 $/hr	1.05	$648
	8	Demo Existing tower Subcontractor	1 LS			4	1	500000 Ea		$500,000
12		Demobilization		10	1	10				$425,600
		Demobilize cranes, barges, office, formwork, materials, etc								
	1	Demobilize Plant & Equip	1 LS				1	300000 LS		$300,000
	2	Tear down Plant & Equip (8 men)	10 Day	100	mhr/day	10	1000	72 $/hr	1.05	$75,600
	3	Restoration	1 LS				1	50000 LS		$50,000

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Briones Dam Inlet/Outlet Tower Retrofit
Option 4A - Dredge Over existing tunnel, Install Lakebed Piping, Connect to existing Tunnel - No Dewatering

Item		Description	Quantity		Months		Unit Cost		Item Cost
1		Supervision	1	LS	6.6	Mo	$62,000	Mo	$409,200
	1	Project Manager	1	Ea	6.6		13000	Mo	$85,800
	2	Project Superintendent	1	Ea	6.6		12000	Mo	$79,200
	3	Walker	3	Ea	6.6		10000	Mo	$66,000
	4	Project Engineer	1	Ea	6.6		10000	Mo	$66,000
	5	Office Manager	1	Ea	6.6		8000	Mo	$52,800
	6	Field Engineer	2	Ea	6.6		9000	Mo	$59,400
2		General Operations	1	LS	6.6	Mo	$143,555	Mo	$947,460
	1	Office	1	Ea	6.6		450		$2,970
	2	Change House	1	Ea	6.6		450		$2,970
	3	Shop Containers	4	Ea	6.6		100		$2,640
	4	Power supply	1	Ea	6.6		400		$2,640
	5	Lights	1	Ea	6.6		100		$660
	6	Phones	1	Ea	6.6		250		$1,650
	7	Computers	1	Ea	6.6		250		$1,650
	8	Copier	1	Ea	6.6		200		$1,320
	9	Water	1	Ea	6.6		200		$1,320
	10	Sewer	1	Ea	6.6		1000		$6,600
	11	Access Road	1	LS	1		20000	LS	$20,000
	12	Vehicles	6	Ea	6.6		900		$35,640
	13	CAT 950 FEL	1	Ea	6.6		10000		$66,000
	14	Forklift	1	Ea	6.6		4000		$26,400
	15	RT30 Crane	1	Ea	6.6		12000		$79,200
	16	Living Costs	6	Ea	6.6		2000		$79,200
	17	Travel	1	Ea	6.6		1000		$6,600
	18	Insurance	1	LS	1		500000	LS	$500,000
	19	Permits	1	LS	1		10000	LS	$10,000
	20	Consultants	1	LS	1		50000	LS	$50,000
	21	Legal	1	LS	1		50000	LS	$50,000

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Briones Dam Inlet/Outlet Tower Retrofit
Option 4A - Dredge Over existing tunnel, Install Lakebed Piping, Connect to existing Tunnel - Partial Dewatering to 100 ft

Item	Description	Quantity		Hrs/Shift	Shifts/Day	Days		Unit Cost		Item Cost
1	Mobilization	1	LS	10	1	10				$706,000
2	Dredge for Tremied Saddle & Lakebed Concrete	1	LS	10	1	29				$2,583,000
3	Install formwork and bracing for Tunnel "Saddle" Cor	1	LS	10	1	20				$1,539,000
4	Tremie Saddle Concrete	1	LS	10	1	3				$419,000
5	Install Lakebed piping, connect to new tunnel Riser F	1	LS	10	1	20				$2,634,000
6	Tremie Lake bottom Pipe Encasement	1	LS	10	1	6				$1,519,000
9	Make piping connection to Existing tunnel	1	LS	10	1	10				$161,000
11	Plug & demolish existing tower	1	LS	10	1	9				$595,000
12	Demobilization	1	LS	10	1	10				$426,000
						132	Days			
						6.6	Months			$10,582,000
13	Supervision	1	LS			6.6	Mo	$62,121	Mo	$410,000
14	General Operations	1	LS			6.6	Mo	$143,636	Mo	$948,000
15	General Requirements 10% of Direct	10	%							$1,059,000
16	Home Office - 4-% of Direct	4	%							$424,000
	Subtotal									$13,423,000
17	Profit - 15% total	15%								$2,014,000
18	Bond, Taxes, & Insurance	2	%							$309,000
	Total (2008 Dollars)									$15,746,000
19	Escalation Excluded - Recommend 5% per year									
20	Contingency & Escalation	40%								$6,299,000
	Dewater to 100 ft									$4,000,000
	Total Unescalated Construction Cost with Contingency									$26,045,000
	Excludes Design Costs, CM Costs, and Owner Soft Costs									

Assume Dredging material deposited on reservoir floor. Assume $300,000 additional to total unescalated cost if off-hauled.
Assume Demolished Tower to remain on reservoir floor.

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Briones Dam Inlet/Outlet Tower Retrofit
Option 4A - Dredge Over existing tunnel, Install Lakebed Piping, Connect to existing Tunnel - Partial Dewatering to 100 ft

Item	Description	Quantity		Hrs/Shift		Shifts/Day	Days		Unit Cost			Item Cost
1	Mobilization	1	LS	10		1	10					$705,840
	Move in cranes, barges, office, formwork, materials, etc											
1	Mobilize Plant & Equip	1	LS					1	600000			$600,000
2	Setup Plant & Equip (8 men)	10	Day	100	mhr/day		10	1000	72	$/hr	1.05	$75,600
3	Receive Materials	20	Day	20	mhr/day			400	72	$/hr	1.05	$30,240
2	Dredge for Tremied Saddle & Lakebed Concrete	1	LS	10		1	29					$2,582,240
	Dredge over existing tunnel for tremie concrete & Lakebed Piping, 10-hr shift, 1 shift per day, 250 CY per day											
1	Dredger - Subcontractor	7100	CY					7100	100	$/cy		$710,000
2	Divers	29	Days	80	mhr/day			2320	49600	$/day		$1,438,400
3	100 T Crane	29	Days					290	250	$/hr		$72,500
4	Barge & Tug	29	Days					290	340	$/hr		$98,600
5	Labor	29	Days	100	mhr/day		29	2900	72	$/hr	1.05	$219,240
6	Decompression chamber	29	Days					696	62.5	$/hr		$43,500
7	Muck Disposal - On lake bed											
3	Install formwork and bracing for Tunnel "Saddle"	1	LS	10		1	20					$1,538,350
	Install 20-ft and 8-ft diameter "formwork", Pipe, and Brace, 10-hr shifts, 1 shift per day											
1	Divers	20	Days	160	mhr/day			3200	54750	$/day		$1,095,000
2	100 T Crane	20	Days					200	250	$/hr		$50,000
3	Barge & Tug	20	Days					200	340	$/hr		$68,000
4	Decompression chamber	20	Days					480	62.5	$/hr		$30,000
5	Labor	20	Days	100	mhr/day		20	2000	72	$/hr	1.05	$151,200
6	Form material 20-ft diameter	20	LF					20	4720	$/LF		$94,400
7	8-ft Diameter Pipe Saddle	25	LF					25	850	$/LF		$21,250
8	Bracing	1	LS					1	20000	LS		$20,000
9	Reinforcing Steel for "Saddle"	20	LF	500	lb/lf			10000	0.85	$/lb		$8,500
4	Tremie Saddle Concrete	1	LS	24		1	3					$418,842
	Setup concrete operation & tremie concrete, 2 days of tremie, 2 days of setup											
1	Divers	3	Days	192	mhr/day			576	150	$/hr		$86,400
2	100 T Crane	3	Days					30	49600	$/day		$148,800
3	Barge & Tug	3	Days					30	340	$/hr		$10,200
4	Plant support for setup	1	Days	240	mhr/day		1	240	72	$/hr	1.05	$18,144
5	Concrete pump & piping	700	CY					700	10	$/cy		$7,000
6	Tremie Concrete	2	Days	240	mhr/day		2	480	72	$/hr	1.05	$36,288
7	Reinforcing steel	0	lf	0	lb/lf			0	0.85	$/lb		$0

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Briones Dam Inlet/Outlet Tower Retrofit
Option 4A - Dredge Over existing tunnel, Install Lakebed Piping, Connect to existing Tunnel - Partial Dewatering to 100 ft

Item	Description	Quantity		Hrs/Shift		Shifts/Day	Days		Unit Cost			Item Cost
8	Concrete	700	CY					700	140	$/cy		$98,000
9	Concrete Overtime fees	467	CY					467	30	$/cy		$14,010
5	Install Lakebed piping, connect to new tunnel Riser Pipe			10		1	20					$2,633,200
	Load piping on barge, lower & install											
1	Divers	20	Days	80	mhr/day		20	1600	54750	$/day		$1,095,000
2	100 T Crane	20	Days					200	250	$/hr		$50,000
3	Barge & Tug	20	Days					200	340	$/hr		$68,000
4	Labor	20	Days	100	mhr/day			2000	72	$/hr	1.05	$151,200
5	Intake Piping - 6-ft ID 3/8-in Wall	640	LF					640	850	$/LF		$544,000
6	Intake Piping - 8-ft x 6-ft Tee 1/2-in Wall	10	LF					1	25000	Ea		$25,000
7	Valves, operators, & protection	7	Ea					7	100000	Ea		$700,000
6	Tremie Lake bottom Pipe Encasement			24		1	6					$1,518,761
	Setup concrete operation & tremie concrete, 2 days of setup, 50 cy/hr											
1	Divers	6	Days	192	mhr/day			1152	49600	$/day		$297,600
2	100 T Crane	6	Days					60	250	$/hr		$15,000
3	Barge & Tug	6	Days					60	340	$/hr		$20,400
4	Plant support for setup	1	Days	108	mhr/day		2	108	72	$/hr	1.05	$8,165
5	Concrete pump & piping	6500	CY					6500	10	$/cy		$65,000
6	Tremie Concrete	4	Days	240	mhr/day		4	960	72	$/hr	1.05	$72,576
7	Concrete	6500	CY					6500	140	$/cy		$910,000
8	Concrete Overtime fees	4334	CY					4334	30	$/cy		$130,020
9	Make piping connection to Existing tunnel			10		1	10					$160,074
	Dewater Tower, break into existing Tunnel, Form & place Transition											
1	Dewatering Labor	1	Days	100	mhr/day		1	100	72	$/hr	1.05	$7,560
2	Break into existing tunnel	5	Days	100	mhr/day		5	500	72	$/hr	1.05	$37,800
3	Plant support for Reinforcing	2	Days	40	mhr/day			80	72	$/hr	1.05	$6,048
4	Install custom formwork	2	Days	100	mhr/day		2	200	72	$/hr	1.05	$15,120
5	Pump Concrete	1	Days	100	mhr/day		1	100	72	$/hr	1.05	$7,560
6	Strip & remove formwork, and patch	1	Days	100	mhr/day		1	100	72	$/hr	1.05	$7,560
7	Barge & Tug	10	Days					100	340	$/hr	1.05	$35,700
8	Reinforcing steel furnish & install	2684	lbs					2684	1.5	$/lb		$4,026
9	Custom formwork	1	LS					1	10000	LS		$10,000
10	Concrete	10	CY					10	140	$/cy		$1,400
11	100 T crane	10	Days					100	250	$/hr		$25,000

Briones Dam Inlet/Outlet Tower Retrofit
Option 4A - Dredge Over existing tunnel, Install Lakebed Piping, Connect to existing Tunnel - Partial Dewatering to 100 ft

Item	Description	Quantity		Hrs/Shift	Shifts/Day	Days		Unit Cost			Item Cost
12	Mancage	10	Days				100	2	$/hr		$200
13	Dewatering pumps	10	Days				100	10	$/hr		$1,000
14	Ventilation fans	10	Days				100	10	$/hr		$1,000
15	Concrete Pump & piping	10	CY				10	10	$/cy		$100
11	Plug & demolish existing tower			10	1	9					$594,548
	Implode tower onto lake bed										
1	Plug formwork	1	LS								
2	Install Formwork & pump Concrete	5	Days	100	mhr/day	5	500	72	$/hr	1.05	$37,800
3	Concrete	20	CY				20	140	$/cy		$2,800
4	100 T Crane	9	Days				90	250	$/hr		$22,500
5	Barge & Tug	9	Days				90	340	$/hr		$30,600
6	Concrete Pump & piping	20	CY				20	10	$/cy		$200
7	Supporting Labor	9	Days	100	mhr/day		900	72	$/hr	1.05	$648
8	Demo Existing tower Subcontractor	1	LS			4	1	500000	Ea		$500,000
12	Demobilization			10	1	10					$425,600
	Demobilize cranes, barges, office, formwork, materials, etc										
1	Demobilize Plant & Equip	1	LS				1	300000	LS		$300,000
2	Tear down Plant & Equip (8 men)	10	Day	100	mhr/day	10	1000	72	$/hr	1.05	$75,600
3	Restoration	1	LS				1	50000	LS		$50,000

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Briones Dam Inlet/Outlet Tower Retrofit
Option 4A - Dredge Over existing tunnel, Install Lakebed Piping, Connect to existing Tunnel - Partial Dewatering to 100 ft

Item	Description	Quantity		Months		Unit Cost		Item Cost
1	Supervision	1	LS	6.6	Mo	$62,000	Mo	$409,200
1	Project Manager	1	Ea	6.6		13000	Mo	$85,800
2	Project Superintendent	1	Ea	6.6		12000	Mo	$79,200
3	Walker	3	Ea	6.6		10000	Mo	$66,000
4	Project Engineer	1	Ea	6.6		10000	Mo	$66,000
5	Office Manager	1	Ea	6.6		8000	Mo	$52,800
6	Field Engineer	2	Ea	6.6		9000	Mo	$59,400
2	General Operations	1	LS	6.6	Mo	$143,555	Mo	$947,460
1	Office	1	Ea	6.6		450		$2,970
2	Change House	1	Ea	6.6		450		$2,970
3	Shop Containers	4	Ea	6.6		100		$2,640
4	Power supply	1	Ea	6.6		400		$2,640
5	Lights	1	Ea	6.6		100		$660
6	Phones	1	Ea	6.6		250		$1,650
7	Computers	1	Ea	6.6		250		$1,650
8	Copier	1	Ea	6.6		200		$1,320
9	Water	1	Ea	6.6		200		$1,320
10	Sewer	1	Ea	6.6		1000		$6,600
11	Access Road	1	LS	1		20000	LS	$20,000
12	Vehicles	6	Ea	6.6		900		$35,640
13	CAT 950 FEL	1	Ea	6.6		10000		$66,000
14	Forklift	1	Ea	6.6		4000		$26,400
15	RT30 Crane	1	Ea	6.6		12000		$79,200
16	Living Costs	6	Ea	6.6		2000		$79,200
17	Travel	1	Ea	6.6		1000		$6,600
18	Insurance	1	LS	1		500000	LS	$500,000
19	Permits	1	LS	1		10000	LS	$10,000
20	Consultants	1	LS	1		50000	LS	$50,000
21	Legal	1	LS	1		50000	LS	$50,000

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Briones Dam Inlet/Outlet Tower Retrofit
Option 4B - Dewater Reservoir, Excavate Over Existing Tunnel, Install Lakebed Piping, Connect to Existing Tunnel

Item	Description	Quantity		Hrs/Shift	Shifts/Day	Days		Unit Cost		Item Cost
1	Mobilization	1	LS	10	1	10				$506,000
2	Dredge for Saddle & Lakebed Concrete	1	LS	10	1	15				$196,000
3	Install formwork and bracing for Tunnel "Saddle" Concret	1	LS	10	1	10				$245,000
4	Pour Saddle Concrete	1	LS	10	1	4				$160,000
5	Install Lakebed piping, connect to new tunnel Riser Pipe	1	LS	10	1	21				$1,516,000
6	Pour Lake bottom Pipe Encasement	1	LS	10	1	15				$1,256,000
9	Make piping connection to Existing tunnel	1	LS	10	1	9				$115,000
11	Plug & demolish existing tower	1	LS	10	1	9				$595,000
12	Demobilization	1	LS	10	1	10				$326,000
						118	Days			
						5.9	Months			$4,915,000
13	Supervision	1	LS			5.9	Mo	$62,034	Mo	$366,000
14	General Operations	1	LS			5.9	Mo	$154,915	Mo	$914,000
15	General Requirements 10% of Direct	10	%							$492,000
16	Home Office - 4-% of Direct	4	%							$197,000
	Subtotal									$6,884,000
17	Profit - 15% total	15%								$1,033,000
18	Bond, Taxes, & Insurance	2	%							$159,000
	Total (2008 Dollars)									$8,076,000
19	Escalation Excluded - Recommend 5% per year									
20	Contingency	40%								$3,231,000
	Dewater Reservoir									$6,000,000
	Total Unescalated Construction Cost with Contingency									$17,307,000
	Excludes Design Costs, CM Costs, and Owner Soft Costs									

Assume Excavated material deposited on reservoir floor. Assume $300,000 additional to total unescalated cost if off-hauled.
Assume Demolished Tower to remain on reservoir floor.

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Briones Dam Inlet/Outlet Tower Retrofit
Option 4B - Dewater Reservoir, Excavate Over Existing Tunnel, Install Lakebed Piping, Connect to Existing Tunnel

Item	Description	Quantity		Hrs/Shift		Shifts/Day	Days		Unit Cost			Item Cost
1	Mobilization	1	LS	10		1	10					$505,840
	Move in cranes, office, formwork, materials, RipRap,etc											
	1 Mobilize Plant & Equip	1	LS					1	400000			$400,000
	2 Setup Plant & Equip (8 men)	10	Day	100	mhr/day		10	1000	72	$/hr	1.05	$75,600
	3 Receive Materials	20	Day	20	mhr/day			400	72	$/hr	1.05	$30,240
2	Dredge for Saddle & Lakebed Concrete	1	LS	10		1	15					$195,720
	Excavate over existing tunnel for concrete & Lakebed Piping, 10-hr shift, 1 shift per day, 500 CY per day											
	1 Excavation Qty	7100	CY					7100				
	2 D8 Dozer for spreading muck	15	Days					150	200	$/hr		$30,000
	3 100 T Crane	15	Days					150	250	$/hr		$37,500
	4 Cat 375 Excavator	15	Days					150	250	$/hr		$37,500
	5 Labor	15	Days	80	mhr/day		15	1200	72	$/hr	1.05	$90,720
	6 Muck Disposal - On lake bed											
3	Install formwork and bracing for Tunnel "Saddle"	1	LS	10		1	10					$244,750
	Install 20-ft and 8-ft diameter "formwork", Pipe, and Brace, 10-hr shifts, 1 shift per day											
	1 100 T Crane	10	Days					100	250	$/hr		$25,000
	2 Labor	10	Days	100	mhr/day		10	1000	72	$/hr	1.05	$75,600
	3 Form material 20-ft diameter	20	LF					20	4720	$/LF		$94,400
	4 8-ft Diameter Pipe Saddle	25	LF					25	850	$/LF		$21,250
	5 Bracing	1	LS					1	20000	LS		$20,000
	9 Reinforcing Steel for "Saddle"	20	LF	500	lb/lf			10000	0.85	$/lb		$8,500
4	Pour Saddle Concrete	1	LS	10		1	4					$159,250
	Setup concrete operation & tremie concrete, 2 days of pour, 2 days of setup											
	1 100 T Crane	4	Days					40	250	$/hr		$10,000
	2 Plant support for setup	2	Days	100	mhr/day		2	200	72	$/hr	1.05	$15,120
	3 Concrete pump & piping	700	CY					700	10	$/cy		$7,000
	4 Tremie Concrete	2	Days	100	mhr/day		2	200	72	$/hr	1.05	$15,120
	5 Concrete	700	CY					700	140	$/cy		$98,000
	6 Concrete Overtime fees	467	CY					467	30	$/cy		$14,010
5	Install Lakebed piping, connect to new tunnel Riser Pipe			10		1	21					$1,515,770

Briones Dam Inlet/Outlet Tower Retrofit
Option 4B - Dewater Reservoir, Excavate Over Existing Tunnel, Install Lakebed Piping, Connect to Existing Tunnel

Item	Description	Quantity		Hrs/Shift	Shifts/Day	Days		Unit Cost			Item Cost
	Install Pipe bedding & install Pipe										
1	D8 Dozer for spreading muck	1	Days			1	10	200	$/hr		$2,000
2	100 T Crane	21	Days				210	250	$/hr		$52,500
3	Labor	20	Days	120	mhr/day	20	2400	72	$/hr	1.05	$181,440
4	Intake Piping - 6-ft ID 3/8-in Wall	640	LF				640	850	$/LF		$544,000
5	Intake Piping - 8-ft x 6-ft Tee 1/2-in Wall	10	LF				1	25000	Ea		$25,000
6	Valves, operators, & protection	7	Ea				7	100000	Ea		$700,000
7	Bedding	361	cy				361	30	$/cy		$10,830
6	Pour Lake bottom Pipe Encasement			10	1	15					$1,255,920
	Setup concrete operation & pour concrete, 2 days of setup, 50 cy/hr										
1	100 T Crane	15	Days				150	250	$/hr		$37,500
2	Plant support for setup	2	Days	100	mhr/day	2	200	72	$/hr	1.05	$15,120
3	Concrete pump & piping	6500	CY				6500	10	$/cy		$65,000
4	Pour Concrete	13	Days	100	mhr/day	13	1300	72	$/hr	1.05	$98,280
5	Concrete	6500	CY				6500	140	$/cy		$910,000
6	Concrete Overtime fees	4334	CY				4334	30	$/cy		$130,020
9	Make piping connection to Existing tunnel			10	1	9					$114,094
	Break into existing Tunnel, Form & place Transition										
1	Break into existing tunnel	5	Days	100	mhr/day	5	500	72	$/hr	1.05	$37,800
2	Plant support for Reinforcing	2	Days	40	mhr/day		80	72	$/hr	1.05	$6,048
3	Install custom formwork	2	Days	100	mhr/day	2	200	72	$/hr	1.05	$15,120
4	Pump Concrete	1	Days	100	mhr/day	1	100	72	$/hr	1.05	$7,560
5	Strip & remove formwork, and patch	1	Days	100	mhr/day	1	100	72	$/hr	1.05	$7,560
6	Reinforcing steel furnish & install	2684	lbs				2684	1.5	$/lb		$4,026
7	Custom formwork	1	LS				1	10000	LS		$10,000
8	Concrete	10	CY				10	140	$/cy		$1,400
9	100 T crane	9	Days				90	250	$/hr		$22,500
10	Mancage	9	Days				90	2	$/hr		$180
11	Dewatering pumps	9	Days				90	10	$/hr		$900
12	Ventilation fans	9	Days				90	10	$/hr		$900
13	Concrete Pump & piping	10	CY				10	10	$/cy		$100
11	Plug & demolish existing tower			10	1	9					$594,548
	Implode tower onto lake bed										

JACOBS ASSOCIATES
Engineers/Consultants

Briones Dam Inlet/Outlet Tower Retrofit
Option 4B - Dewater Reservoir, Excavate Over Existing Tunnel, Install Lakebed Piping, Connect to Existing Tunnel

Item	Description	Quantity		Hrs/Shift	Shifts/Day	Days		Unit Cost			Item Cost
	1 Plug formwork	1	LS								
	2 Install Formwork & pump Concrete	5	Days	100	mhr/day	5	500	72	$/hr	1.05	$37,800
	3 Concrete	20	CY				20	140	$/cy		$2,800
	4 100 T Crane	9	Days				90	250	$/hr		$22,500
	5 Barge & Tug	9	Days				90	340	$/hr		$30,600
	6 Concrete Pump & piping	20	CY				20	10	$/cy		$200
	7 Supporting Labor	9	Days	100	mhr/day		900	72	$/hr	1.05	$648
	8 Demo Existing tower Subcontractor	1	LS			4	1	500000	Ea		$500,000
12	Demobilization			10	1	10					$325,600
	Demobilize cranes, barges, office, formwork, materials, etc										
	1 Demobilize Plant & Equip	1	LS				1	200000	LS		$200,000
	2 Tear down Plant & Equip (8 men)	10	Day	100	mhr/day	10	1000	72	$/hr	1.05	$75,600
	3 Restoration	1	LS				1	50000	LS		$50,000

JACOBS ASSOCIATES
Engineers/Consultants

Briones Dam Inlet/Outlet Tower Retrofit
Option 4B - Dewater Reservoir, Excavate Over Existing Tunnel, Install Lakebed Piping, Connect to Existing Tunnel

Item		Description	Quantity		Months		Unit Cost		Item Cost
1		Supervision	1	LS	5.9	Mo	$62,000	Mo	$365,800
	1	Project Manager	1	Ea	5.9		13000	Mo	$76,700
	2	Project Superintendent	1	Ea	5.9		12000	Mo	$70,800
	3	Walker	3	Ea	5.9		10000	Mo	$59,000
	4	Project Engineer	1	Ea	5.9		10000	Mo	$59,000
	5	Office Manager	1	Ea	5.9		8000	Mo	$47,200
	6	Field Engineer	2	Ea	5.9		9000	Mo	$53,100
2		General Operations	1	LS	5.9	Mo	$154,880	Mo	$913,790
	1	Office	1	Ea	5.9		450		$2,655
	2	Change House	1	Ea	5.9		450		$2,655
	3	Shop Containers	4	Ea	5.9		100		$2,360
	4	Power supply	1	Ea	5.9		400		$2,360
	5	Lights	1	Ea	5.9		100		$590
	6	Phones	1	Ea	5.9		250		$1,475
	7	Computers	1	Ea	5.9		250		$1,475
	8	Copier	1	Ea	5.9		200		$1,180
	9	Water	1	Ea	5.9		200		$1,180
	10	Sewer	1	Ea	5.9		1000		$5,900
	11	Access Road	1	LS	1		20000	LS	$20,000
	12	Vehicles	6	Ea	5.9		900		$31,860
	13	CAT 950 FEL	1	Ea	5.9		10000		$59,000
	14	Forklift	1	Ea	5.9		4000		$23,600
	15	RT30 Crane	1	Ea	5.9		12000		$70,800
	16	Living Costs	6	Ea	5.9		2000		$70,800
	17	Travel	1	Ea	5.9		1000		$5,900
	18	Insurance	1	LS	1		500000	LS	$500,000
	19	Permits	1	LS	1		10000	LS	$10,000
	20	Consultants	1	LS	1		50000	LS	$50,000
	21	Legal	1	LS	1		50000	LS	$50,000

Briones Dam Inlet/Outlet Tower Retrofit
Option 5 - Dredge Over existing tunnel, Tremie Anchor Concrete, Install Precast tower spools & post tension - NO DEWATERING

Item	Description	Quantity		Hrs/Shift	Shifts/Day	Days		Unit Cost		Item Cost
1	Mobilization	1	LS	10	1	10				490720
2	Dredge for Tremied Anchor Concrete	1	LS	10	1	9				$1,849,440
3	Install formwork and bracing for Anchor Concrete	1	LS	10	1	14				$3,075,690
4	Tremie Anchor Concrete	1	LS	10	1	19				$4,193,726
5	Install reinforcing and precast spools	1	LS	10	1	30				$5,575,375
6	Tremie Concrete into Spool openings	1	LS	10	1	15				$2,677,200
7	Prefabricate Spools	1	LS	10	1	105				$1,370,638
8	Post-tensioning of new tower	1	LS	10	1	15				$589,400
9	Make piping connection to Existing tunnel	1	LS	10	1	12				$140,786
10	Plug & demolish existing tower	1	LS	10	1	9				$344,848
11	Demobilization	1	LS	10	1	10				$310,480
						248	Days			
						12.4	Months			$20,619,000
14	Supervision	1	LS			12.4	Mo	$62,000	Mo	$768,800
15	General Operations	1	LS			12.4	Mo	$98,106	Mo	$1,216,520
22	General Requirements 10% of Direct	10	%							$2,062,000
23	Home Office - 4-% of Direct	4	%							$825,000
	Subtotal									$25,492,000
24	Profit - 15% total	15%								$3,824,000
25	Bond, Taxes, & Insurance	2	%							$587,000
	Total (2008 Dollars)									$29,903,000
26	Escalation Excluded - Recommend 5% per year									
27	Contingency & Escalation	40%								$11,962,000
	Total Unescalated Construction Cost with Contingency									$41,865,000
	Excludes Design Costs, CM Costs, and Owner Soft Costs									

Assume Dredging material deposited on reservoir floor. Assume $250,000 additional if off-hauled.

Briones Dam Inlet/Outlet Tower Retrofit
Option 5 - Dredge Over existing tunnel, Tremie Anchor Concrete, Install Precast tower spools & post tension - NO DEWATERING

Item	Description	Quantity		Hrs/Shift		Shifts/Day	Days		Unit Cost			Item Cost
1	Mobilization	1	LS	10		1	10					$490,720
	Move in cranes, barges, office, formwork, materials, etc											
	1 Mobilize Plant & Equip	1	LS					1	400000			$400,000
	2 Setup Plant & Equip (8 men)	10	Day	100	mhr/day		10	800	72	$/hr	1.05	$60,480
	3 Receive Materials	20	Day	20	mhr/day			400	72	$/hr	1.05	$30,240
2	Dredge for Tremied Anchor Concrete	1	LS	10		1	9					$1,849,440
	Dredge over existing tunnel for tremie concrete Anchor, 10-hr shift, 1 shift per day, 350 CY per day											
	1 Dredger - Subcontractor	3000	CY					3000	100	$/cy		$300,000
	2 Divers	9	Days	80	mhr/day			720	157200	$/day		$1,414,800
	3 100 T Crane	9	Days					90	250	$/hr		$22,500
	4 Barge & Tug	9	Days					90	340	$/hr		$30,600
	5 Labor	9	Days	100	mhr/day		9	900	72	$/hr	1.05	$68,040
	6 Decompression chamber	9	Days					216	62.5	$/hr		$13,500
	7 Muck Disposal - On lake bed											
3	Install formwork and bracing for Anchor Concrete	1	LS	10		1	14					$3,075,690
	Install 60-ft and 10-ft diameter "formwork" and Brace, 10-hr shifts, 1 shift per day											
	1 Divers	14	Days	160	mhr/day			2240	179625	$/day		$2,514,750
	2 100 T Crane	14	Days					140	250	$/hr		$35,000
	3 Barge & Tug	14	Days					140	340	$/hr		$47,600
	4 Decompression chamber	14	Days					336	62.5	$/hr		$21,000
	5 Labor	14	Days	100	mhr/day		14	1400	72	$/hr	1.05	$105,840
	6 Form material 60-ft diameter	60	LF					60	4735	$/LF		$284,100
	7 Form material 10-ft diameter	60	LF					60	790	$/LF		$47,400
	8 Bracing	1	LS					1	20000	LS		$20,000
4	Tremie Anchor Concrete	1	LS	10		1	19					$4,193,726
	Setup concrete operation & tremie concrete, 13 days of tremie, 2 days of reinforcing, 4 days for post-tensioning ducts											
	1 Divers	19	Days	80	mhr/day			1520	157200	$/day		$2,986,800
	2 100 T Crane	19	Days					190	250	$/hr		$47,500
	3 Barge & Tug	19	Days					190	340	$/hr		$64,600
	4 Plant support for Reinforcing	2	Days	100	mhr/day		2	200	72	$/hr	1.05	$15,120
	5 Plant support for post tensioning ducts	4	Days	100	mhr/day		4	400	72	$/hr	1.05	$30,240
	5 Concrete pump & piping	6108	CY					6108	10	$/cy		$61,080
	6 Tremie Concrete	13	Days	100	mhr/day		13	1300	72	$/hr	1.05	$98,280

7	Reinforcing steel	24	lf	1715	lb/lf		41160	0.85	$/lb		$34,986
8	Concrete	6108	CY				6108	140	$/cy		$855,120
5	Install precast spools and reinforcing			10	1	30					$5,575,375
	Install Reinforcing steel, and pre-cast spools, 15 spools @ 12-ft high, EL 413 to EL 593, rebar - 386 lb/mh										
1	Install Reinforcing bars - Divers	15	Days	80	mhr/day	15	1200	157200	$/day		$2,358,000
2	Pre-fabricate rebar cages	15	Days	100	mhr/day		1500	72	$/hr	1.05	$113,400
3	Install Precast Spools - Divers	15	Days	120	mhr/day	15	1800	157200	$/day		$2,358,000
4	Reinforcing Bars - purchase material	180	LF	2575	lbs/LF		463500	0.85	$/lb		$393,975
5	Barge & Tug	30	Days				300	340	$/hr		$102,000
6	Special Spool Floatation air bags	1	Ea				1	100000	Ea		$100,000
7	100 T Crane - On Barge	30	Days				300	250	$/hr		$75,000
8	100 T Crane - On Land	30	Days				300	250	$/hr		$75,000
6	Tremie Concrete into Spool openings			10	1	15					$2,677,200
	Tremie Concrete into Spool Openings from Surface of new Tower, 180 LF										
1	Divers	15	Days	80	mhr/day		1200	157200	$/day		$2,358,000
2	100 T Crane	15	Days				150	250	$/hr		$37,500
3	Barge & Tug	15	Days				150	340	$/hr		$51,000
4	Concrete pump & piping	782	CY				782	10	$/cy		$7,820
5	Tremie Concrete	15	Days	100	mhr/day	15	1500	72	$/hr	1.05	$113,400
6	Concrete	782	CY				782	140	$/cy		$109,480
7	Prefabricate Spools			10	1	105					$1,370,638
	Pre-fabricate spools on site, 15 spools, formwork - 16sf/mh, rebar - 132lb/mh										
1	Pre-fabricate rebar cages	45	Days	60	mhr/day	45	2700	72	$/hr	1.05	$204,120
2	Install formwork	45	Days	60	mhr/day	45	2700	72	$/hr	1.05	$204,120
3	Install Tensioning ductwork	45	Days	10	mhr/day		450	72	$/hr	1.05	$34,020
4	100 T Crane	105	Days				1050	250	$/hr		$262,500
5	Concrete pump & piping	520	CY				520	10	$/cy		$5,200
6	Pour Spools	15	Days	30	mhr/day	15	450	72	$/hr	1.05	$34,020
7	Reinforcing Bars - purchase material	180	LF	1986	lbs/LF		357480	0.85	$/lb		$303,858
8	New valves	6	Ea				6	25000	Ea		$150,000
9	Valve Control System	1	Ea				1	100000	Ea		$100,000
9	Concrete	520	CY				520	140	$/cy		$72,800
8	Post-tensioning of new tower			10	1	15					$589,400
	11 U shaped ducts - 400 LF each										
1	Post Tensioning Subcontractor	1	LS				350000	1	LS		$350,000

2	Labor - Support for post-tensioning	15	Days	100	mhr/day	15	1500	72	$/hr	1.05	$113,400
3	Barge & Tug	15	Days				150	340	$/hr		$51,000
4	100 T Crane - On Barge	15	Days				150	250	$/hr		$37,500
5	100 T Crane - On Land	15	Days				150	250	$/hr		$37,500
9	Make piping connection to Existing tunnel			10	1	12					$140,786
	Dewater Tower, break into existing Tunnel, Form & place Transition										
1	Dewatering Labor	1	Days	100	mhr/day	1	100	72	$/hr	1.05	$7,560
2	Break into existing tunnel	5	Days	100	mhr/day	5	500	72	$/hr	1.05	$37,800
3	Plant support for Reinforcing	2	Days	100	mhr/day	2	200	72	$/hr	1.05	$15,120
4	Install custom formwork	2	Days	100	mhr/day	2	200	72	$/hr	1.05	$15,120
5	Pump Concrete	1	Days	100	mhr/day	1	100	72	$/hr	1.05	$7,560
6	Strip & remove formwork, and patch	1	Days	100	mhr/day	1	100	72	$/hr	1.05	$7,560
7	Reinforcing steel furnish & install	2684	lbs				2684	1.5	$/lb		$4,026
8	Custom formwork	1	LS				1	10000	LS		$10,000
9	Concrete	30	CY				30	140	$/cy		$4,200
10	100 T crane	12	Days				120	250	$/hr		$30,000
11	Mancage	12	Days				120	2	$/hr		$240
12	Dewatering pumps	1	Days				10	10	$/hr		$100
13	Ventilation fans	12	Days				120	10	$/hr		$1,200
14	Concrete Pump & piping	30	CY				30	10	$/cy		$300
10	Plug & demolish existing tower			10	1	9					$344,848
	Implode tower onto lake bed										
1	Plug formwork	1	LS								
2	Install Formwork & pump Concrete	5	Days	100	mhr/day	5	500	72	$/hr	1.05	$37,800
3	Concrete	20	CY				20	140	$/cy		$2,800
4	100 T Crane	9	Days				90	250	$/hr		$22,500
5	Barge & Tug	9	Days				90	340	$/hr		$30,600
6	Concrete Pump & piping	50	CY				50	10	$/cy		$500
7	Supporting Labor	9	Days	100	mhr/day		900	72	$/hr	1.05	$648
8	Demo Existing tower Subcontractor	1	LS			4	1	250000	Ea		$250,000
11	Demobilization			10	1	10					$310,480
	Demobilize cranes, barges, office, formwork, materials, etc										
1	Demobilize Plant & Equip	1	LS				1	200000	LS		$200,000
2	Tear down Plant & Equip (8 men)	10	Day	100	mhr/day	10	800	72	$/hr	1.05	$60,480
3	Restoration	1	LS				1	50000	LS		$50,000

Briones Dam Inlet/Outlet Tower Retrofit
Option 5 - Dredge Over existing tunnel, Tremie Anchor Concrete, Install Precast tower spools & post tension - NO DEWATERING

Item	Description	Quantity		Months		Unit Cost		Item Cost
1	Supervision	1	LS	12.4	Mo	$62,000	Mo	$768,800
1	Project Manager	1	Ea	12.4		13000	Mo	$161,200
2	Project Superintendent	1	Ea	12.4		12000	Mo	$148,800
3	Walker	3	Ea	12.4		10000	Mo	$124,000
4	Project Engineer	1	Ea	12.4		10000	Mo	$124,000
5	Office Manager	1	Ea	12.4		8000	Mo	$99,200
6	Field Engineer	2	Ea	12.4		9000	Mo	$111,600
2	General Operations	1	LS	12.4	Mo	$98,106	Mo	$1,216,520
1	Office	1	Ea	12.4		450		$5,580
2	Change House	1	Ea	12.4		450		$5,580
3	Shop Containers	4	Ea	12.4		100		$4,960
4	Power supply	1	Ea	12.4		400		$4,960
5	Lights	1	Ea	12.4		100		$1,240
6	Phones	1	Ea	12.4		250		$3,100
7	Computers	1	Ea	12.4		250		$3,100
8	Copier	1	Ea	12.4		200		$2,480
9	Water	1	Ea	12.4		200		$2,480
10	Sewer	1	Ea	12.4		200		$2,480
11	Access Road	1	LS	1		20000	LS	$20,000
12	Vehicles	6	Ea	12.4		900		$66,960
13	CAT 950 FEL	1	Ea	12.4		10000		$124,000
14	Forklift	1	Ea	12.4		4000		$49,600
15	RT30 Crane	1	Ea	12.4		12000		$148,800
16	Living Costs	6	Ea	12.4		2000		$148,800
17	Travel	1	Ea	12.4		1000		$12,400
18	Insurance	1	LS	1		500000	LS	$500,000
19	Permits	1	LS	1		10000	LS	$10,000
20	Consultants	1	LS	1		50000	LS	$50,000
21	Legal	1	LS	1		50000	LS	$50,000

Briones Dam Inlet/Outlet Tower Retrofit
Option 5A - Dredge Over existing tunnel, Tremie Anchor Concrete, Install Precast tower spools & post tension - PARTIAL DEWATERING to 100 ft

Item	Description	Quantity		Hrs/Shift	Shifts/Day	Days		Unit Cost		Item Cost
1	Mobilization	1	LS	10	1	10				490720
2	Dredge for Tremied Anchor Concrete	1	LS	10	1	9				$881,040
3	Install formwork and bracing for Anchor Concrete	1	LS	10	1	14				$1,327,440
4	Tremie Anchor Concrete	1	LS	10	1	19				$2,149,326
5	Install reinforcing and precast spools	1	LS	10	1	30				$2,501,875
6	Tremie Concrete into Spool openings	1	LS	10	1	15				$1,063,200
7	Prefabricate Spools	1	LS	10	1	105				$1,370,638
8	Post-tensioning of new tower	1	LS	10	1	15				$589,400
9	Make piping connection to Existing tunnel	1	LS	10	1	12				$140,786
10	Plug & demolish existing tower	1	LS	10	1	9				$344,848
11	Demobilization	1	LS	10	1	10				$310,480
						248	Days			
						12.4	Months			$11,170,000
14	Supervision	1	LS			12.4	Mo	$62,000	Mo	$768,800
15	General Operations	1	LS			12.4	Mo	$98,106	Mo	$1,216,520
22	General Requirements 10% of Direct	10	%							$1,117,000
23	Home Office - 4-% of Direct	4	%							$447,000
	Subtotal									$14,720,000
24	Profit - 15% total	15%								$2,208,000
25	Bond, Taxes, & Insurance	2	%							$339,000
	Total (2008 Dollars)									$17,267,000
26	Escalation Excluded - Recommend 5% per year									
27	Contingency & Escalation	40%								$6,907,000
	Dewater to 100 ft									$4,000,000
	Total Unescalated Construction Cost with Contingency									$28,174,000
	Excludes Design Costs, CM Costs, and Owner Soft Costs									

Assume Dredging material deposited on reservoir floor. Assume $250,000 additional if off-hauled.

Briones Dam Inlet/Outlet Tower Retrofit
Option 5A - Dredge Over existing tunnel, Tremie Anchor Concrete, Install Precast tower spools & post tension - PARTIAL DEWATERING to 100 ft

Item		Description	Quantity		Hrs/Shift		Shifts/Day	Days		Unit Cost			Item Cost
1		Mobilization	1	LS	10		1	10					$490,720
		Move in cranes, barges, office, formwork, materials, etc											
	1	Mobilize Plant & Equip	1	LS					1	400000			$400,000
	2	Setup Plant & Equip (8 men)	10	Day	100	mhr/day		10	800	72	$/hr	1.05	$60,480
	3	Receive Materials	20	Day	20	mhr/day			400	72	$/hr	1.05	$30,240
2		Dredge for Tremied Anchor Concrete	1	LS	10		1	9					$881,040
		Dredge over existing tunnel for tremie concrete Anchor, 10-hr shift, 1 shift per day, 350 CY per day											
	1	Dredger - Subcontractor	3000	CY					3000	100	$/cy		$300,000
	2	Divers	9	Days	80	mhr/day			720	49600	$/day		$446,400
	3	100 T Crane	9	Days					90	250	$/hr		$22,500
	4	Barge & Tug	9	Days					90	340	$/hr		$30,600
	5	Labor	9	Days	100	mhr/day		9	900	72	$/hr	1.05	$68,040
	6	Decompression chamber	9	Days					216	62.5	$/hr		$13,500
	7	Muck Disposal - On lake bed											
3		Install formwork and bracing for Anchor Concrete	1	LS	10		1	14					$1,327,440
		Install 60-ft and 10-ft diameter "formwork" and Brace, 10-hr shifts, 1 shift per day											
	1	Divers	14	Days	160	mhr/day			2240	54750	$/day		$766,500
	2	100 T Crane	14	Days					140	250	$/hr		$35,000
	3	Barge & Tug	14	Days					140	340	$/hr		$47,600
	4	Decompression chamber	14	Days					336	62.5	$/hr		$21,000
	5	Labor	14	Days	100	mhr/day		14	1400	72	$/hr	1.05	$105,840
	6	Form material 60-ft diameter	60	LF					60	4735	$/LF		$284,100
	7	Form material 10-ft diameter	60	LF					60	790	$/LF		$47,400
	8	Bracing	1	LS					1	20000	LS		$20,000
4		Tremie Anchor Concrete	1	LS	10		1	19					$2,149,326
		Setup concrete operation & tremie concrete, 13 days of tremie, 2 days of reinforcing, 4 days for post-tensioning ducts											
	1	Divers	19	Days	80	mhr/day			1520	49600	$/day		$942,400
	2	100 T Crane	19	Days					190	250	$/hr		$47,500
	3	Barge & Tug	19	Days					190	340	$/hr		$64,600
	4	Plant support for Reinforcing	2	Days	100	mhr/day		2	200	72	$/hr	1.05	$15,120
	5	Plant support for post tensioning ducts	4	Days	100	mhr/day		4	400	72	$/hr	1.05	$30,240
	5	Concrete pump & piping	6108	CY					6108	10	$/cy		$61,080
	6	Tremie Concrete	13	Days	100	mhr/day		13	1300	72	$/hr	1.05	$98,280

	7 Reinforcing steel	24 lf	1715 lb/lf			41160	0.85 $/lb		$34,986
	8 Concrete	6108 CY				6108	140 $/cy		$855,120
5	Install precast spools and reinforcing		10	1	30				$2,501,875
	Install Reinforcing steel, and pre-cast spools, 15 spools @ 12-ft high, EL 413 to EL 593, rebar - 386 lb/mh								
	1 Install Reinforcing bars - Divers	15 Days	80 mhr/day		15	1200	54750 $/day		$821,250
	2 Pre-fabricate rebar cages	15 Days	100 mhr/day			1500	72 $/hr	1.05	$113,400
	3 Install Precast Spools - Divers	15 Days	120 mhr/day		15	1800	54750 $/day		$821,250
	4 Reinforcing Bars - purchase material	180 LF	2575 lbs/LF			463500	0.85 $/lb		$393,975
	5 Barge & Tug	30 Days				300	340 $/hr		$102,000
	6 Special Spool Floatation air bags	1 Ea				1	100000 Ea		$100,000
	7 100 T Crane - On Barge	30 Days				300	250 $/hr		$75,000
	8 100 T Crane - On Land	30 Days				300	250 $/hr		$75,000
6	Tremie Concrete into Spool openings		10	1	15				$1,063,200
	Tremie Concrete into Spool Openings from Surface of new Tower, 180 LF								
	1 Divers	15 Days	80 mhr/day			1200	49600 $/day		$744,000
	2 100 T Crane	15 Days				150	250 $/hr		$37,500
	3 Barge & Tug	15 Days				150	340 $/hr		$51,000
	4 Concrete pump & piping	782 CY				782	10 $/cy		$7,820
	5 Tremie Concrete	15 Days	100 mhr/day		15	1500	72 $/hr	1.05	$113,400
	6 Concrete	782 CY				782	140 $/cy		$109,480
7	Prefabricate Spools		10	1	105				$1,370,638
	Pre-fabricate spools on site, 15 spools, formwork - 16sf/mh, rebar - 132lb/mh								
	1 Pre-fabricate rebar cages	45 Days	60 mhr/day		45	2700	72 $/hr	1.05	$204,120
	2 Install formwork	45 Days	60 mhr/day		45	2700	72 $/hr	1.05	$204,120
	3 Install Tensioning ductwork	45 Days	10 mhr/day			450	72 $/hr	1.05	$34,020
	4 100 T Crane	105 Days				1050	250 $/hr		$262,500
	5 Concrete pump & piping	520 CY				520	10 $/cy		$5,200
	6 Pour Spools	15 Days	30 mhr/day		15	450	72 $/hr	1.05	$34,020
	7 Reinforcing Bars - purchase material	180 LF	1986 lbs/LF			357480	0.85 $/lb		$303,858
	8 New valves	6 Ea				6	25000 Ea		$150,000
	9 Valve Control System	1 Ea				1	100000 Ea		$100,000
	9 Concrete	520 CY				520	140 $/cy		$72,800
8	Post-tensioning of new tower		10	1	15				$589,400
	11 U shaped ducts - 400 LF each								
	1 Post Tensioning Subcontractor	1 LS				350000	1 LS		$350,000

2	Labor - Support for post-tensioning	15	Days	100	mhr/day	15	1500	72	$/hr	1.05	$113,400
3	Barge & Tug	15	Days				150	340	$/hr		$51,000
4	100 T Crane - On Barge	15	Days				150	250	$/hr		$37,500
5	100 T Crane - On Land	15	Days				150	250	$/hr		$37,500
9	Make piping connection to Existing tunnel			10	1	12					$140,786
	Dewater Tower, break into existing Tunnel, Form & place Transition										
1	Dewatering Labor	1	Days	100	mhr/day	1	100	72	$/hr	1.05	$7,560
2	Break into existing tunnel	5	Days	100	mhr/day	5	500	72	$/hr	1.05	$37,800
3	Plant support for Reinforcing	2	Days	100	mhr/day	2	200	72	$/hr	1.05	$15,120
4	Install custom formwork	2	Days	100	mhr/day	2	200	72	$/hr	1.05	$15,120
5	Pump Concrete	1	Days	100	mhr/day	1	100	72	$/hr	1.05	$7,560
6	Strip & remove formwork, and patch	1	Days	100	mhr/day	1	100	72	$/hr	1.05	$7,560
7	Reinforcing steel furnish & install	2684	lbs				2684	1.5	$/lb		$4,026
8	Custom formwork	1	LS				1	10000	LS		$10,000
9	Concrete	30	CY				30	140	$/cy		$4,200
10	100 T crane	12	Days				120	250	$/hr		$30,000
11	Mancage	12	Days				120	2	$/hr		$240
12	Dewatering pumps	1	Days				10	10	$/hr		$100
13	Ventilation fans	12	Days				120	10	$/hr		$1,200
14	Concrete Pump & piping	30	CY				30	10	$/cy		$300
10	Plug & demolish existing tower			10	1	9					$344,848
	Implode tower onto lake bed										
1	Plug formwork	1	LS								
2	Install Formwork & pump Concrete	5	Days	100	mhr/day	5	500	72	$/hr	1.05	$37,800
3	Concrete	20	CY				20	140	$/cy		$2,800
4	100 T Crane	9	Days				90	250	$/hr		$22,500
5	Barge & Tug	9	Days				90	340	$/hr		$30,600
6	Concrete Pump & piping	50	CY				50	10	$/cy		$500
7	Supporting Labor	9	Days	100	mhr/day		900	72	$/hr	1.05	$648
8	Demo Existing tower Subcontractor	1	LS			4	1	250000	Ea		$250,000
11	Demobilization			10	1	10					$310,480
	Demobilize cranes, barges, office, formwork, materials, etc										
1	Demobilize Plant & Equip	1	LS				1	200000	LS		$200,000
2	Tear down Plant & Equip (8 men)	10	Day	100	mhr/day	10	800	72	$/hr	1.05	$60,480
3	Restoration	1	LS				1	50000	LS		$50,000

Briones Dam Inlet/Outlet Tower Retrofit
Option 5A - Dredge Over existing tunnel, Tremie Anchor Concrete, Install Precast tower spools & post tension - PARTIAL DEWATERING to 100 ft

Item	Description	Quantity		Months		Unit Cost		Item Cost
1	Supervision	1	LS	12.4	Mo	$62,000	Mo	$768,800
1	Project Manager	1	Ea	12.4		13000	Mo	$161,200
2	Project Superintendent	1	Ea	12.4		12000	Mo	$148,800
3	Walker	3	Ea	12.4		10000	Mo	$124,000
4	Project Engineer	1	Ea	12.4		10000	Mo	$124,000
5	Office Manager	1	Ea	12.4		8000	Mo	$99,200
6	Field Engineer	2	Ea	12.4		9000	Mo	$111,600
2	General Operations	1	LS	12.4	Mo	$98,106	Mo	$1,216,520
1	Office	1	Ea	12.4		450		$5,580
2	Change House	1	Ea	12.4		450		$5,580
3	Shop Containers	4	Ea	12.4		100		$4,960
4	Power supply	1	Ea	12.4		400		$4,960
5	Lights	1	Ea	12.4		100		$1,240
6	Phones	1	Ea	12.4		250		$3,100
7	Computers	1	Ea	12.4		250		$3,100
8	Copier	1	Ea	12.4		200		$2,480
9	Water	1	Ea	12.4		200		$2,480
10	Sewer	1	Ea	12.4		200		$2,480
11	Access Road	1	LS	1		20000	LS	$20,000
12	Vehicles	6	Ea	12.4		900		$66,960
13	CAT 950 FEL	1	Ea	12.4		10000		$124,000
14	Forklift	1	Ea	12.4		4000		$49,600
15	RT30 Crane	1	Ea	12.4		12000		$148,800
16	Living Costs	6	Ea	12.4		2000		$148,800
17	Travel	1	Ea	12.4		1000		$12,400
18	Insurance	1	LS	1		500000	LS	$500,000
19	Permits	1	LS	1		10000	LS	$10,000
20	Consultants	1	LS	1		50000	LS	$50,000
21	Legal	1	LS	1		50000	LS	$50,000

VORTEX

17 December, 2008

Jacobs Associates
465 California Street, Suite 1000
San Francisco, CA 94104-1824

Re: Briones Reservior Preliminary Pricing – EBMUD

Attn: Mr. Troy Page

Troy,

We have worked out budgetary pricing for the portion of the EBMUD Briones Reservoir Project that you requested for the following activities:

Option 1 (235 ft of fresh water)

- Task A
  - Work shift 10 hours
  - 4 working divers in the water for at least 80% of shift time
  - 20 shifts of work
  - Provide all dive labor and equipment only (does not include barge or marine support)

  Cost per shift: **$ 179,625/Weekday**
  $ 242,000/Saturday
  $ 291,450/Sunday

- Task B
  - Work shift 24 hours
  - 2 working divers in the water for at least 80% of shift time
  - 6 shifts of work
  - Provide all dive labor and equipment only (does not include barge or marine support)

  Cost per shift: **$ 157,200/Weekday**
  $ 190,600/Saturday
  $ 232,200/Sunday

Option 2 (100 ft of fresh water)

- Task A
  - Work shift 10 hours (recommend other shift length for better pricing or efficiency)
  - 4 working divers in the water for at least 80% of shift time
  - 20 shifts of work
  - Provide all dive labor and equipment only (does not include barge or marine support)

Cost per shift: **$ 54,750/Weekday**
$ 75,800/Saturday
$ 91,250/Sunday

- Task B
  - Work shift 24 hours
  - 2 working divers in the water for at least 80% of shift time
  - 6 shifts of work
  - Provide all dive labor and equipment only (does not include barge or marine support)

Cost per shift: **$ 49,600/Weekday**
$ 60,800/Saturday
$ 73,600/Sunday

Please note that this is budgetary pricing only, based upon current prevailing wage rates for divers and tenders, and does not include costs for any marine support of the diving operations. We feel that efficiencies can be created when the work activities are more defined. Please feel free to contact me with any questions.

Regards,

VORTEX MARINE CONSTRUCTION, INC.

Blaise Fettig