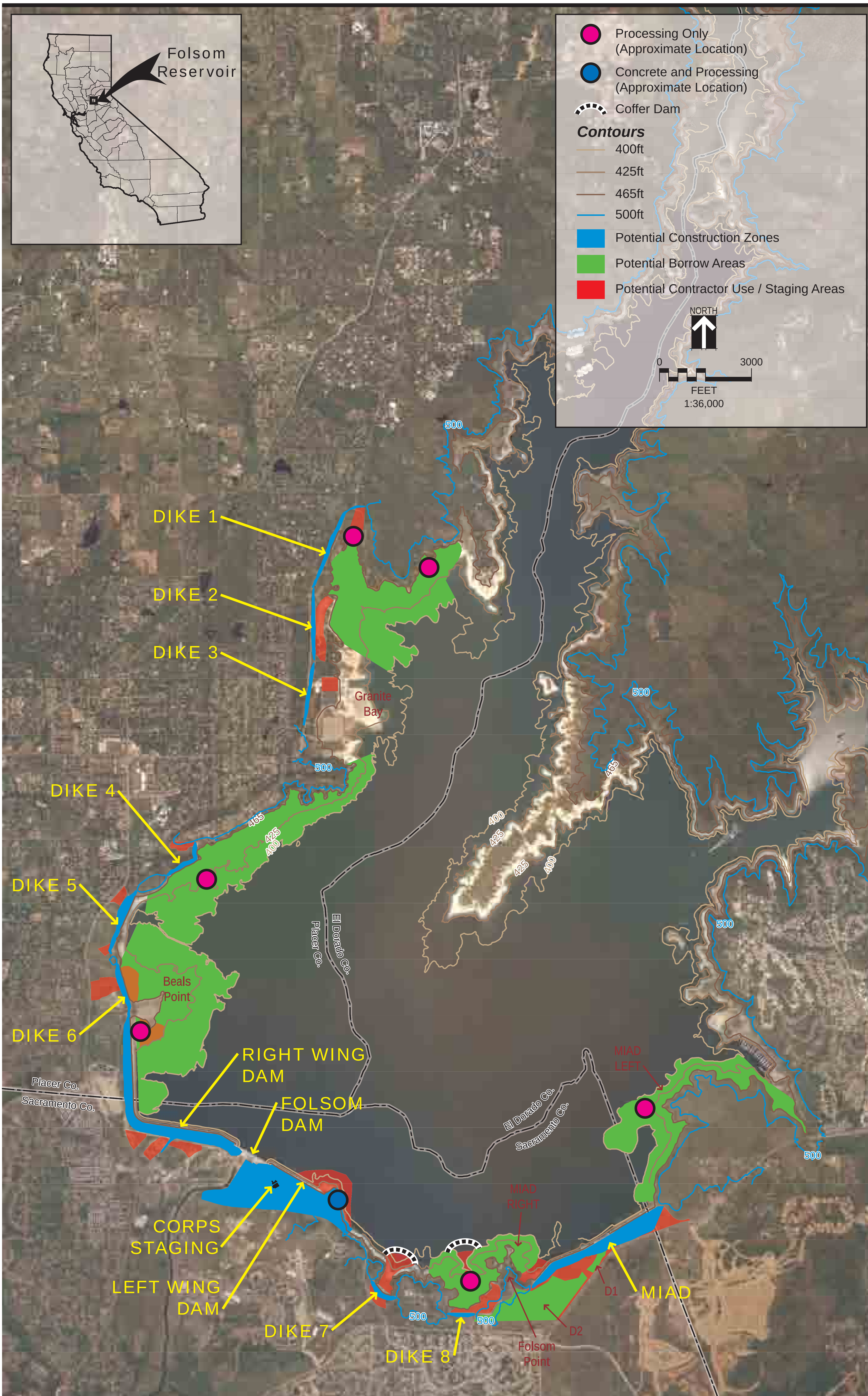

Figure 2-5
Folsom DS/FDR EIS/EIR
Alternative 5

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The various components of the Folsom Facility are located along an 8-mile stretch of the western and southern edges of Folsom Reservoir. Facilities to the east of the LWD are separated from all other facilities to the west and north by the American River and the Main Concrete Dam.

Figure 1-1 provides a base map that illustrates the main features of the Folsom Facilities. The existing facilities include the Main Concrete Dam (Folsom Dam), wing dams, MIAD, and the eight dikes. Figures 2-1 through 2-5 show the basic nature and locations of the improvements to those main features as envisioned under each of five action alternatives, as overlaid on the base map. The following describes the color coding scheme used to identify improvements on the figures for the action alternatives.

The approximate alignment for the new Auxiliary Spillway and/or tunnel is outlined in orange. The proposed contractor work areas illustrating the maximum area of consideration for potential effects due to construction are shown in blue. Locations where earthen materials processing and concrete mixing (batch plants) could occur are shown with blue and red dots. Contractor use areas, which could include offices, parking, materials storage, and borrow material stockpiling, are identified by the fuchsia color. The maximum area of consideration for potential borrow sites, within and adjacent to the reservoir, are shown in green.

It is important to note that:

1) The proposed construction, contractor use areas and borrow areas are conservative estimates of the actual area that would be impacted by project construction. The outlined areas reflect the maximum project footprint that was analyzed for potential impacts to all resources. Once all of the potential features of the project have been optimized, the actual area impacted by the project would, in most cases, be much smaller than what was analyzed.

2) The borrow site locations reflect potential construction areas. Borrow would only be taken from these areas if the quantity of borrow material from the Auxiliary Spillway is inadequate for project purposes at the wing dams and dikes. If borrow material is actually required for construction, it is most likely that the only sites that would be developed are located at Folsom Point and MIAD (Alternatives 1, 2, and 3).

The features incorporated into the comprehensive range of alternatives listed in Table 2-10 were developed so that all viable joint and stand-alone dam safety and flood damage reduction alternatives retained during screening could be assessed for environmental effects within at least one alternative.

The two principle ways that alternatives achieve the joint dam safety and flood damage reduction objectives is either by increasing the facilities release capacity, where a higher volume of water is released sooner during an event, and/or if the alternative increases the facilities ability to contain inflows longer, and thereby safely pass the event. The structural modifications described in the proposed alternatives are designed to achieve these objectives.

Optimization of the project measures, and potential “repackaging” of the alternatives, was an ongoing engineering review task being conducted at the time of development of this EIS/EIR. The five action alternatives (Alternatives 1 through 5) presented and evaluated in the Draft EIS/EIR represent a reasonable range of alternatives for the proposed Folsom DS/FDR project, based on the facts, circumstances, and information available at the time. It is very possible, however, that the final project identified in the Record of Decision, as determined through ongoing engineering reviews and concept refinements and through the results of the NEPA and CEQA review processes for this EIS/EIR, would recombine measures taken from two or more of the alternatives. Inasmuch as the analyses presented in this EIS/EIR evaluate, to varying degrees, the improvements currently envisioned under each alternative on both an individual basis and a collective basis (i.e., examining the impacts particular to the key components of each action alternative as well as disclosing the overall collective impacts of the alternative), it is likely that the environmental consequences of a potential hybrid alternative would have, to some degree, already been addressed within the Draft EIS/EIR. Any such "repackaging" of the alternatives would be examined in light of the analysis presented in this EIS/EIR to determine whether the potential associated environmental impacts have been sufficiently addressed and disclosed in accordance with the requirements of NEPA and CEQA. That review would determine the extent to which the components of the preferred alternative, be it one of the original five action alternatives or some combination thereof, have been sufficiently addressed so as to allow decision-makers to proceed with an approval action (i.e., issuance of a ROD). The review would also determine whether supplemental environmental documentation is necessary and, if so, define the nature, scope, and timing of such additional environmental review specific to those components that were not yet adequately addressed. This evaluation and determination process would be conducted in accordance with the requirements of NEPA and CEQA, as appropriate.

2.2.2 Corps Folsom Dam Flood Damage Reduction Related Alternatives

Table 2-11 presents a listing of projects, some of which are included under the Corps Folsom Dam Modification and Folsom Dam Raise Project Authorizations that are not a part of the Folsom DS/FDR EIS/EIR.

Table 2-11 Folsom Area Projects Addressed by Corps in Other Planning/Environmental Disclosure Documents		
Corps Project Feature	***Corps Project Activity***	***Documents***
Main Concrete Dam	Existing outlet modifications Addition of 2 new outlets	Folsom Dam Modification Environmental Assessment/Initial Study 2001 Folsom Dam Modification Limited Reevaluation Report, 2003 Folsom Dam Modification Environmental Assessment /Initial Study 2005
Ecosystem Restoration	Temperature Control Shutters	American River Watershed, California Long-Term Study, 2002
	Ecosystem Restoration	American River Watershed, California Long-Term Study, 2002
Miscellaneous	New Folsom Bridge and approach	American River Watershed, California Long-Term Study, 2002

As mentioned, the Folsom Dam Modification Project was authorized in the WRDA 1999. The authorized plan included the elements of the Folsom Modification Plan described in the 1996 SIR, as modified in the SAFCA Information Paper *Folsom Dam Modification Report*, *New Outlets Plan* of 1998. Because the project authorized in WRDA 1999 differed from the plan presented in the 1996 SIR, the Draft *Folsom Modification Project Environmental Assessment/Initial Study* (EA/IS) was prepared in 2001 (2001 EA/IS) to document environmental effects of the authorized elements. At the same time, additional studies were conducted, as directed by WRDA 1999, which were documented in the February 2002 *American River Watershed Long-Term Study Final Supplemental Plan Formulation Report/EIS/EIR* (2002 Long-Term Study).

The Folsom Modification Project originally authorized in the 1999 WRDA would enlarge the Folsom Dam outlet works and improve the use of surcharge storage space. On completion, the project would allow operators to evacuate flood storage space earlier in a flood event in anticipation of the need to store additional water in the reservoir to reduce downstream flood damages. In combination, the outlet and spillway modifications would achieve an objective release capacity of 115,000 cfs earlier than under without-project conditions.

To reconcile differences between the Folsom Dam modification elements presented in the 2001 EA/IS and the 2002 Long-Term Study, the *Folsom Dam Modification Project Limited Reevaluation Report and EA/IS* was prepared in 2003 (2003 LRR).

Proposed changes to the Folsom Modification Project that were identified in the 2003 LRR included the following:

- Construct two new upper tier river outlets (instead of constructing five new outlets)

- Enlarge the four existing upper tier outlets to 9 feet, 4 inches by 14 feet, and the four existing lower tier outlets to 9 feet, 4 inches by 12 feet (instead of enlarging all eight outlets to 6 feet by 12 feet)

- Construct the new stilling basin as previously authorized, but provide additional anchorage for the apron slab

Since preparation of the 2003 LRR, and completion of construction plans for those elements, additional studies and authorization of the Folsom Dam Raise Project have identified further changes to the Folsom Modification Project. Plans and specifications for the Folsom Modification Project were prepared in 2003 and 2004, and contractor bids were solicited in 2005. The returned bids were nearly three times higher than had previously been estimated. This new cost significantly exceeded the PL 99-662 Section 902 authorization and appropriations limit. The high bid estimates were largely due to costly non-standard construction methods that would need to be employed to safely enlarge the existing outlets without taking the reservoir out of service during the construction period. Consequently, dam operations and performance and alternate structural methods to achieve the flood protection provided by the outlet modifications were reexamined.

Subsequent studies to the 2003 LRR found that modification of the two outboard lower tier outlets was infeasible, and offered only a marginal increase in performance. The design was been further refined, consisting of enlarging six river outlets (four upper tier outlets and two lower tier outlets) and constructing two new outlets as a result of hydraulic, geotechnical and structural assessment associated with enlarging the two outside lower tier outlets. Environmental impacts of this plan would be less than disclosed in the 2001 EA/IS, 2003 LRR and 2005 EA/IS, since lower tier construction would be limited to two, rather than four, and thus debris removal and dredging limits would be confined to a smaller area and construction would be accomplished in a shorter amount of time.

Most recently, a gated Auxiliary Spillway has been identified as a viable “functionally equivalent” alternative to outlet modifications. The Auxiliary Spillway is anticipated to be less costly than modifying the Main Concrete Dam outlets because it would not entail the construction risk associated with the outlet modifications. In addition, the material excavated from the Auxiliary Spillway site could be used for static and seismic dam safety improvements proposed by Reclamation.

As authorized, the Folsom Dam Raise Project included modifications to the LL Anderson Dam Spillway for dam safety purposes. Modifications to the LL Anderson

Dam, a non federal, privately-owned and operated dam, located on the Middle Fork of the American River at French Meadows Reservoir, upstream of the Folsom Facility, would involve enlarging the spillway to allow safe passage of the Probable Maximum Flood (PMF). These improvements would reduce the risk of impacts to Folsom Dam of a potential failure of LL Anderson Dam. However, since the initial authorization, modifications to LL Anderson Dam have been dropped from further consideration in the Folsom DS/FDR Action. The Federal Energy Regulatory Commission (FERC) and the owner/operator of the dam (Placer County Water Agency) have agreed to resolve the dam safety issues as a separate project.

2.2.3 Relationship of Safety of Dams and Flood Damage Reduction to the Joint Federal Project

As presented in Chapter 1, Reclamation and the Corps have separate missions related to the function of Folsom Reservoir based upon their federal authorizations. Reclamation is focused on water delivery, power generation, and related programs including dam safety, while the Corps is focused on flood control and flood damage reduction. One overlapping issue for dam safety and flood damage reduction is management of the hydrology of the American River watershed. Reclamation’s dam safety concerns focus on preventing overtopping of the dam structures during a major flood event. The Corps’ mission focus is flood damage reduction, which is achieved by controlling releases from the reservoir at levels that maintain the integrity of the downstream levees

Congress has requested that Reclamation and the Corps develop a common solution to the overlapping issues related to Dam Safety and Flood Damage Reduction. Both agencies have identified that a gated Auxiliary Spillway would address both agencies concerns, which is now referred to as the “Joint Federal Project” (JFP). Separate stand-alone dam safety and flood damage reduction alternatives to be independently implemented concurrently by each agency are explicitly distinct form the joint effort although they collectively are analyzed within this EIS/EIR to address the potential cumulative effects at the Folsom Facility. When used in this document, JFP refers specifically to the following:

> The JFP at Folsom Dam and Reservoir would consist of six new 23-ft X 33-ft submerged tainter gates at invert 368 ft combined with a concrete lined Auxiliary Spillway approximately 170 ft wide and 1700 ft in length. Gate dimensions and invert elevation may be optimized during design to maximize performance and/or reduce costs. To achieve the objective of expedited feasibility level design, optimization of the spillway design would focus, to the extent feasible, upon varying the invert elevation of the new tainter gates, but if necessary, may include varying the dimensions of the gates, approach channel or Auxiliary Spillway. The optimization process would endeavor to improve upon the flood damage reduction objective of at least 1/200 year

flood protection while continuing to preserve and expedite completion of the dam safety objective of safely passing the PMF.

Additional features may be added to the JFP at a later point in the development of the project, if the features are mutually determined to be necessary by participating agencies in order to (1) achieve a minimum 1/200 year flood protection, or (2) as incrementally justified through appropriate analysis and evaluation. Potential additional features may include a raise of up to 3.5 feet for all embankments, or modification or replacement of the existing service gates or emergency spillway gates. Any additions to the JFP, as justified, would be for flood damage reduction purposes only.

Most of the remaining Folsom DS/FDR actions would be implemented separately as stand-alone modifications, by each agency, depending upon their respective Safety of Dams and flood damage reduction authorities. The appropriate level of environmental documentation would be completed before any features not fully described and evaluated in this document are constructed.

2.2.4 Description of the Engineering Measures

This section describes measures that increase the capability of the Folsom Facility to address Safety of Dams hydrologic, seismic, and static concerns, and to better manage floods in order to safely pass the PMF, and lesser floods up to a 1 in 200 year event. This section also describes supplemental measures to provide an integrated security system that includes appropriate physical security components and electronic security systems to provide a complete and useable protection system for the Folsom Facility. These engineering measures include several different structural modification alternatives to upgrade the overall system. It is important to note that the engineering measures described in this section represent the full range of improvements to the Folsom Facility that are reflected in different degrees and combinations within the five action alternatives currently being considered for the Folsom DS/FDR Project. Table 2-10 in the preceding section provides a summary of which measures are included in which action alternative(s), and Sections 2.4 through 2.8, which follow later in this chapter, provide a detailed description of how each action alternative includes a specific combination of measures. The discussion provided below in this section describes the basic nature, design, function, and construction characteristics of each of the measures contemplated within the range of action alternatives. This comprehensive description of all the measures is intended help the reader better understand how the characteristics of each of the action alternatives compare and contrast, and also helps set the context for understanding how the construction characteristics associated with each alternative relate to the impacts discussion presented in Chapter 3.

The Folsom facilities to be addressed by one or more of the proposed structural modification alternatives includes the Main Concrete Dam, the RWD and LWD, the MIAD, and Dikes 1 through 8 (See Figure 1-1). The concrete dam and earthen wing dams serve to impound water associated with the main stem of the American River. MIAD serves to dam water within the historic Blue Ravine river channel, while the earthen dikes serve to contain water at low spots in the topography during periods when the reservoir is at or near capacity.

Not all of the proposed structural modification alternatives are applicable to all Folsom facility structures. Although the alternatives may be similar in nature from structure to structure, each structure is unique unto itself and requires distinct consideration. For example, construction of shear keys or post tensioned anchors would only be applicable to the Main Concrete Dam since it is the only concrete structure. All of the earthen structures, however, could have static and seismic elements that would be similar to all earthen embankment dams/dikes, with slight unique variations due to unique consideration applicable to an individual structure. The basic details of the proposed structural modification alternatives are provided in the text below.

2.2.4.1 Auxiliary Spillway

The current dam spillway and outlets do not have sufficient discharge capacity for managing the predicted PMF and lesser event flood inflows above a 1 in 100 year event. The Folsom Facility has insufficient capacity to safely pass the PMF event, and therefore Reclamation has proposed structural modification alternatives to address increasing discharge capability and/or increasing storage during extreme flood events above the 1 in 200 year event up to the PMF. The Folsom Facility currently can safely release flood flows above 115,000 cfs and below 160,000 cfs for a duration which provides a level of protection provided by downstream levees associated with a 1 in 100 year event. Proposed Flood Damage Reduction structural modification alternatives address increasing discharge capability and/or increasing storage (reservoir surface elevation of 388.6 ft) for extreme flood events above the existing conditions. The proposed features would be able to safely release flood flows above 115,000 cfs and below 160,000 cfs for a longer duration equivalent to a 1 in 200 year event level.

Various combinations of Auxiliary Spillways (fuseplug, fusegate, gated), tunnels and potential dam raises have been considered to address overtopping of the dam during extreme flood events and increase the duration lesser events can be held to releases of 160,000 cfs or below. A new Auxiliary Spillway is the major feature being considered to address the dam safety hydrologic risk of safely passing part or the entire PMF event. One goal of this new structure would be potentially achieving a greater than 1- in 200-year flood protection objective.

The Auxiliary Spillway design alternatives increase the flood control capability of the Folsom Facility by increasing the outflow capacity at lower lake levels, resulting in reduced maximum pool elevations when large flood events occur and proper reservoir operations are followed. The purpose of the Auxiliary Spillway would be to provide better hydrologic control of the reservoir capacity during large flood events. Based on reservoir levels and anticipated and observed reservoir inflows, the Auxiliary Spillway would be used to safely and quickly lower the reservoir level to withstand the expected storm runoff.

In general, all Auxiliary Spillway alternatives would consist of the construction of new spillway on the south abutment and downstream of the LWD. It would include an approach channel on the water side of the control section, a control structure section consisting of either a segmented earthen fuseplug control structure or a gated control structure and a discharge chute to convey water to the river. Beyond the control section, the discharge chute would lead to an energy dissipating structure and exit channel that would channel spillway flows to the river. The principle differences in the various spillways are the type of control structure, the depth and width of the channel, and the length of the approach channel.

Concrete for construction of the Auxiliary Spillway would be produced at an onsite batch plant, with cement and aggregate hauled to the site from Sacramento area commercial suppliers. The discharge chute linings would be either a short lined-chute option, constructed in the upper portion of the spillway, or a fully-lined chute option constructed completely to the river discharge point. The spillway chute would be lined either with roller compacted concrete, or structural, formed, and poured concrete.

The spillway would be constructed in phases to obtain an interim ability to safely pass the PMF as expeditiously as possible followed by incremental phases to achieve the full flood damage reduction objectives.

The Auxiliary Spillway would be constructed by excavating an elongated trench in the area adjacent to and below the LWD. Decomposed granite and surficial soils would be removed and stockpiled using standard construction equipment. The underlying competent rock foundation would be excavated using standard drill and blast techniques. Material excavated from the trench would be utilized as borrow material for the raising and strengthening of earthen structures, particularly MIAD. Excess material would be permanently stockpiled on site.

The spillway chute when complete would convey the spillway discharge to the American River channel without impact to the LWD. It is expected that the excavation of the approach and discharge chutes would be done in multiple stages. The initial stages would include removing common material and some excavation of the rock. A rock plug and/or cofferdam would be used to close off the partially excavated spillway during construction and could be used to partially pass a large flood event should one occur during construction. Subsequent stages would involve excavation of the approach and discharge chutes to the final grade, and the Auxiliary Spillway control structure would be completed. It is anticipated that blasting would be used as the primary means of rock excavation. Construction of the approach channel to the spillway gates could involve underwater blasting, dredging, and barging of material from within the reservoir to the shoreline, where the material would be stockpiled. It is anticipated that the material excavated from the approach chute would be put to beneficial use.

The Auxiliary Spillway would be controlled by either an earthen fuseplug control structure that would meet the dam safety objectives of passing the PMF or submerged tainter gates that would meet both dam safety and flood control objectives. Features of the fuseplug Auxiliary Spillway and tainter gate spillway are provided in the following sections.

2.2.4.2 Fuseplug Auxiliary Spillway

A control structure consisting of an earthen fuseplug embankment sections would serve as the Auxiliary Spillway control on an interim basis or permanent basis. On an interim basis, the fuseplug Auxiliary Spillway would address Reclamation’s Safety of Dams objective while flood damage reduction elements are being designed and constructed. The fuseplug control structure could serve on a permanent basis if it were to be determined through future analysis that flood damage reduction objectives were met by another alternative or indefinitely deferred. The spillway would be principally excavated and constructed as described above. The fuseplug section would consist of a zoned embankment with an impervious core, an internal coarse shell zone, and erosion protection material would be placed on the upstream face of the fuseplug. The fuseplug control structure would be designed with multiple segments to allow for the progressive passage of smaller floods up to the PMF flow, without affecting the complete fuseplug control structure. The fuseplug embankment sections would be segmented with concrete divider walls to insure that no single segments operational flows would exceed downstream levee capacity. The fuseplug embankment sections would be designed to erode in a controlled manner when the reservoir elevation exceeds the elevation of a pilot channel (by approximately 1 foot) and would be 2 feet below the fuseplug embankment crest.

The fuseplug Auxiliary Spillway alternative with the largest width is identified in Alternative 1. A mostly unlined rock approach channel would extend from the control structure into the reservoir. The last 150 ft of the approach channel would be lined with roller compacted concrete. The 520-ft wide, 400-ft long approach channel would convey water to the control structure. The spillway would have a 520-ft wide control structure at the upstream end of a 1,100-ft long, 520- to 300-ft wide roller-compacted concrete-lined channel. This channel would lead to a 1,700-ft unlined channel discharging into the American River. This alternative fully passes the PMF but provides limited achievement of flood damage reduction objectives. Since the fuseplug alone does not meet the dual objectives, the fuseplug alternative could be implemented on an interim basis as flood elements are further designed and constructed. A fuseplug could also be implemented on a permanent basis if it were to be determined through future analysis that flood damage reduction objectives were better met by other alternative combinations or indefinitely deferred. A smaller fuseplug control structure (approximately 400 feet wide) is considered under Alternative 2 in conjunction with an underlying tunnel and dam raise to achieve both dam safety and flood damage reduction objectives.

The approach channel would have a trapezoidal cross-section, with a flat-bottom at elevation 435 ft. Both unconsolidated (soil and loose rock) and consolidated (bedrock) material would be excavated. For common excavation, it is anticipated that scrapers, bulldozers, and dump trucks would be used. For bedrock excavation, blasting would be required to breakup the material into adequate size for excavation. Blasting would occur above and below the reservoir water line. Within reservoir excavation would be accomplished by using a dragline. Within reservoir water quality impacts would be mitigated through sediment control actions.

2.2.4.3 Gated Spillway

Another option for the Auxiliary Spillway control section would be the use of mechanical gates (submerged tainter gates) housed in a concrete structure to meet both dam safety and flood damage reduction objectives. Overall, the gated Auxiliary Spillway is similar to other spillway alternatives and would consist of an approach channel on the waterside of the gate, a control structure consisting of six submerged tainter gates, and a concrete-line chute leading to an energy dissipating structure and exit channel. Concrete for construction of the spillway would be produced at an onsite batch plant, with cement and aggregate hauled to the site from Sacramento area commercial suppliers or onsite aggregate. The discharge chute would be fully lined with formed concrete and is inclusive of an energy-dissipating structure (stilling basin) at the river.

The 6 STG gated spillway as proposed in Alternative 3, would have a 190-ft wide control structure at the head of a 1,100-ft long, 190-ft wide concrete-lined channel. The approach channel would be similar to that of the fuseplug spillway, but would be excavated deeper into the bedrock to an elevation of 364 ft. This approach channel and gate would lead to a 1,700-ft concrete-lined channel discharging into the American River. The 6 STG gated Auxiliary Spillway has a discharge capacity of approximately 280,000 cfs at pool elevation 477 ft. Gate dimensions and invert elevation may be optimized during design to maximize performance and/or reduce costs. The gated sections would be designed to allow safe passage of more frequent, smaller flood events and maintain the capability of the structure to safely pass part of or all of the PMF without a dam raise of any height to prevent overtopping the other retention structures. A raise could be included if additional flood damage reduction benefits are incrementally justified as presented in Alternative 3. A smaller, narrower 4 STG spillway is proposed in Alternative 4 which would require a raise of 7 feet to meet both dam safety and flood damage reduction objectives.

The approach channel would have a trapezoidal cross-section, with a flat-bottom at elevation 364 ft. Both unconsolidated (soil and loose rock) and consolidated (bedrock) material would be excavated. For common excavation, it is anticipated that scrapers, bulldozers, and dump trucks would be used. For bedrock excavation, blasting would be required to breakup the material into adequate size for excavation. Blasting would occur above and below the reservoir water line. Within reservoir excavation would be accomplished by using a dragline. Within reservoir water quality impacts would be mitigated through sediment control actions.

2.2.4.4 Concrete Dam Structural Modifications

Foundation, Gate and Pier Improvements

Structural modifications to the existing Main Concrete Dam foundation, exiting gates and gate piers are being considered to reduce dam safety seismic risks. The existing concrete dam spillway gates are proposed for replacement under flood damage reduction objective dam raise options because structural members for the existing gates would be impacted during the passage of large flood releases. To address flood damage reduction objectives for dam raise options, replacement of the existing bridge over the spillway gates on top of the Main Concrete Dam would be raised or replaced.

2.2.4.5 Main Concrete Dam Seismic Improvement Options

The Main Concrete Dam was constructed of concrete monoliths that may have the potential to slide on horizontal lift lines within the dam during a large earthquake event. In addition, evaluation of the dam's original construction details and stability analysis indicates that the dam monoliths may slide along the dam-foundation contact during a large earthquake. Engineering options being considered to reduce the probability of Main Concrete Dam movement include upper and lower post tensioned anchors, shear keys, and a toe-block. Existing gate and gate pier reinforcement is also required to reduce dam safety seismic risks. Spillway pier reinforcement is comprised of bracing post tensioned anchors and/or pier wraps along with additional bracing or replacement of structural members to the existing spillway gates. No existing spillway bridge improvements are required with these modifications.

Post-Tensioned Anchors in Upper Portion of Dam (Upper Post tensioned anchors)

There are two monoliths on either end of the Main Concrete Dam (monoliths 1 and 28) that may require anchoring within the Main Concrete Dam to prevent earthquake induced sliding of the concrete blocks. Upper post tensioned anchors would be installed by boring vertical holes within the two monoliths and anchoring the monolith blocks with post tensioned anchors. The design calls for the post tensioned anchors to be 87.5 ft in length, anchored 25 ft below the lift line at approximate elevation 418. The design requires six post tensioned anchors for each monolith for a total of 24 post tensioned anchors. Figure 2-6 illustrates the post-tensioned tendon concept where the connection between concrete lift lines is reinforced.

Lower Post-tensioned anchors

There are eight dam monoliths requiring anchoring to mitigate potential earthquake induced sliding along the foundation contact. Lower post-tensioned anchors would be installed by drilling boreholes at 45-degree angles through the downstream face of the concrete dam monoliths blocks into underlying foundation (i.e., crossing the dam foundation contact). Steel post tensioned anchors passing through the monoliths into the foundation would be anchored into rock foundation with cement grout, which would tie the base of the concrete dam to the foundation. Figure 2-7 illustrates the post-tensioned concept where the connection between concrete and rock foundation is reinforced.

Post-tensioned tendon installation in the Main Concrete Dam would be limited to monoliths 15 through 22. Construction would be performed on work-platforms constructed on the downstream face of the Main Concrete Dam, including excavation of small blockouts on the downstream face of the concrete dam face for tendon installation, followed by drilling diagonally upstream through the monoliths into the foundation. Following drilling, post tensioned anchors would be installed, then anchored with cement grout, followed by tensioning. The remaining drill hole above the anchored portion would then be filled with grout. The blockouts would then be filled with concrete to conform with the original concrete dam face profile. Approximately 50,000 cubic yards of earthen material would be excavated from LWD to enable installation of post tensioned anchors into the lower portions of monoliths 20 through 22. This excavated material would be stockpiled and replaced after post tensioned anchors are installed. Water produced during drilling of the tendon holes would be captured, contained, and disposed of in accordance with the construction water quality permit.

Shear Keys

Shear keys are another option to prevent the sliding of the concrete monoliths along the foundation contact (i.e., dam/foundation contact). For this option, 10-foot diameter tunnels would be excavated along the contact of the foundation and the base of the dam. The tunnels would be backfilled with reinforced concrete to provide the shear resistance along the contact sliding plane. Figure 2-8 illustrates the concept of the shear key.

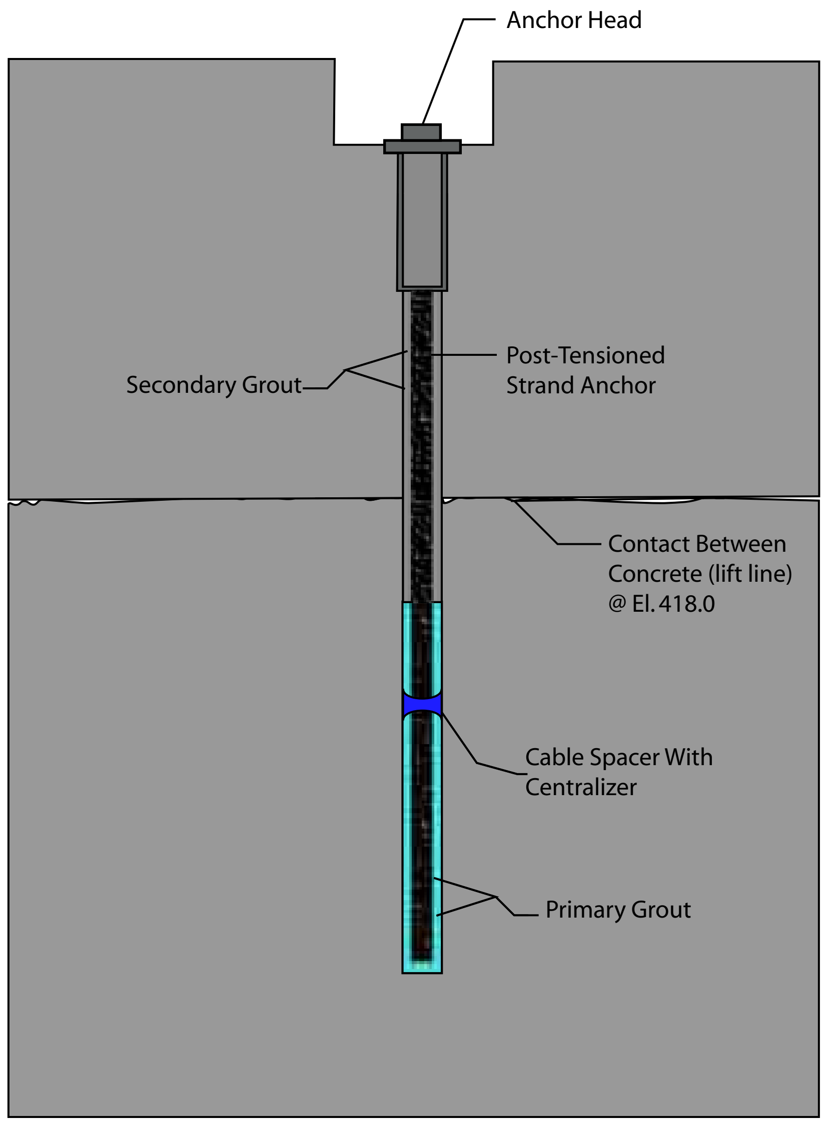

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Figure 2-6
Post-Tensioned Anchors Across Lift Line at El. 418.0

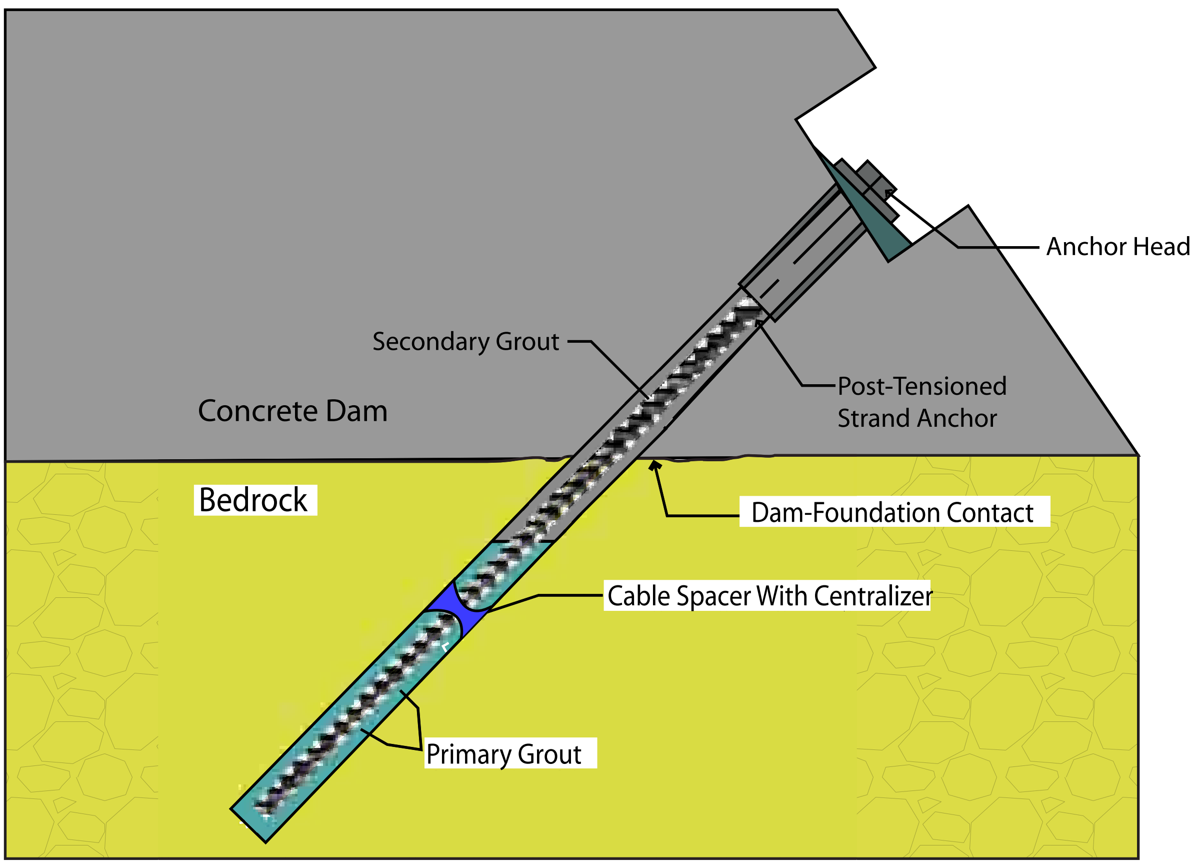
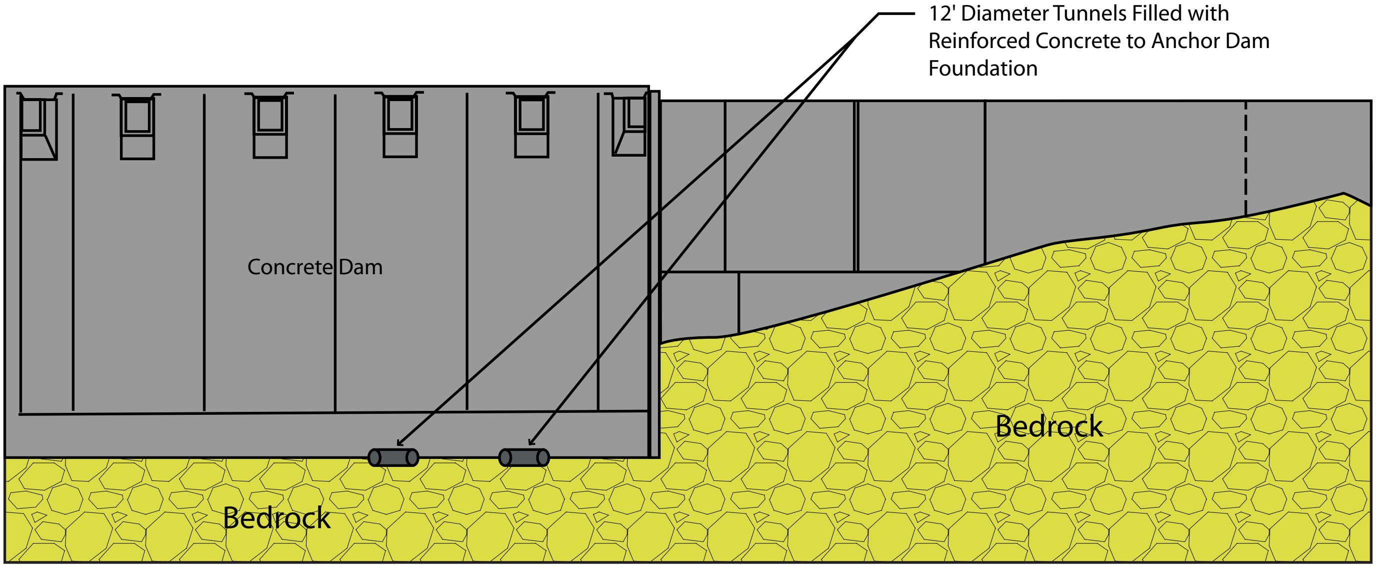


Figure 2-7
Post-Tensioned Anchors Across Foundation Contact



Shear Key Element Concept

Toe Block

A toe block is another option to prevent the sliding of the concrete monoliths along the contact. For this option, a toe block would be excavated along the downstream toe of the dam into the underlying rock foundation. The excavation would be backfilled with concrete to provide the shear resistance along the contact sliding plane.

For the installation of shear keys or toe blocks, the stilling basin would be dewatered, allowing access to the contact between the dam and its foundation. Excavation methods at the dam base would likely include controlled blasting in the foundation rock and mechanical methods for cutting into the concrete. Water used in installation of the shear keys and toe blocks would be captured, contained, and disposed of in accordance with the construction water quality permit.

Contraction Joint Shear Key

A contraction joint or vertical shear key is being considered for the anchoring the vertical contraction joints between dam monoliths 20-21, 21-22, and 22-23. The vertical shear keys would be 3-ft in diameter, vary in length between 100 and 140 ft, and receive vertical and horizontal reinforcement. The contraction joint shear keys would bisect each contraction joint in two locations on the downstream face of the dam and act to tie monoliths 21 and 22 to monoliths 20 and 23. Monoliths 15 through 22 are founded on the channel fault and could slide during a seismic event. The full base of monoliths 15 through 19 and half the base of monolith 20 would be anchored to the foundation. The vertical shear keys would bridge the unbonded vertical contraction joints and allow the adjacent monoliths to help anchor monoliths 21 and 22.

Drainage of Dam Foundation

Foundation drainage improvements could be used to reduce uplift pressures and reduce the risk of sliding of foundation wedge. To accomplish this, additional drains would be drilled from the existing dam drainage gallery between the spacing of the existing drains. Piezometers would be installed to monitor the uplift pressures within the foundation.

Gate and Pier Reinforcement

The spillway gate arms would be either be replaced or reinforced with welded steel plates and additional cross bracing to reduce the potential for a buckling failure during a large earthquake. Spillway piers would be braced with structural members and reinforced with steel wraps and tendons to inhibit pier lateral swaying during an earthquake and/or cable post tensioned anchors would be installed through the pier into the mass concrete of the dam to prevent shearing along the pier base. Also to prevent failure of the spillway piers during a seismic event, a steel plate would be wrapped around the downstream portion of the pier and cross anchored with bolts.

This band, or pier wrap, would carry the gate trunnion stress placed on it should a large magnitude earthquake occur.

2.2.4.6 Existing Stilling Basin

The existing stilling basin was designed so that it could contain hydraulic jump action for flows up to 200,000 cfs and prevent major damage during the existing spillway design flood. Flows above 200,000 cfs would result in hydraulic jump further downstream. Since total releases from the Main Concrete Dam, with existing Auxiliary Spillway, could be increased from the original design discharge of 567,000 cfs maximum to 920,000 under this project, modifications to the stilling basin are warranted. To address this concern, the existing stilling basin would be extended 50-75-ft. downstream as incrementally justified for flood damage reduction.

2.2.4.7 Embankment Raises (Dikes and Wing Dams)

Various combinations of raise heights in conjunction with increased outlet capacity modifications, Auxiliary Spillways (fuseplug, fusegate, gated), and tunnels and have been considered to avoid overtopping the dam during extreme flood events and increase the duration lesser events can be held to 160,000 cfs or below. The existing Main Concrete Dam has a parapet wall 4.0 ft above the crest elevation of the remaining embankment dams/dikes of 480.5. Some minor modifications to gaps along this parapet wall would be needed for raises of 4 feet or less. Significant dam modifications would be required for raises greater than 4 feet.

To temporarily increase the capacity of the reservoir and improve flood damage reduction, all earthen structures could be raised through the placement of additional earthen material, construction of concrete walls, or a combination of the two measures, along the crest of the facilities. The purpose of the raises would be to:

1) Small heights of less than 4 feet to accommodate resurfacing, security and/or crest hardening or small freeboard requirements following other embankment/dike structural modifications or under both safety of dams, security and flood damage reduction objectives as incrementally justified.

2) To provide additional freeboard or surcharge capacity up to greater heights of 7 ft under flood damage reduction objectives as incrementally justified.

3) A maximum raise height of 17 ft was analyzed as an alternative to contain the PMF without any increased discharge capacity from any combination of new or existing spillway, tunnel, and gate or existing outlet modifications. Additional modifications would be required to achieve flood damage reduction objectives.

Several options exist for the raising of existing dikes and wing dams. Embankment raise are described below.

Conventional Earthfill Raise.
The earthfill dikes (Dikes 1 through 8), LWD, RWD, and MIAD would be raised and strengthened using earthen materials similar to their current construction. The cores of the existing dam/dike embankments consist of decomposed granite and have performed well since construction. Soil material required for the dam/dike raises would include shell material (impervious soil and miscellaneous shell soil), coarse filter (slope protection bedding), and slope protection (riprap). Installed within the downstream shell would be a filter zone (see Section 2.2.4.).

The materials for the shell would be produced locally at borrow sites developed on Reclamation property. The materials for filters would most likely be hauled to the site from local commercial sources or produced onsite by processing granitic borrow material obtained during the Auxiliary Spillway excavation or an alternate onsite location. Shell and filter production would involve screening and crushing of excavated rock to sizes meeting the specifications for each of the project sites. Standard earth moving equipment would be used to excavate the material, haul it to processing sites, and then place the material at the project sites.

Earthfill raises would only involve the modification of the crest and downstream face of the structure (see Figure 2-9). Necessary seismic and static elements would also be incorporated into the overall design. An earthfill raise would be accomplished first by stripping a nominal 2-ft of existing cover from the downstream face prior to placement of new material. Stripping would most likely involve the pushing of material down the slope of the embankment by a bulldozer. At the bottom of the embankment, the material would be picked up by a bottom scraper hauler and transported to the storage site.

The material to be replaced on the downstream side would not be required to be impermeable and could be constructed of local materials. Following removal of the 2-ft layer, the raise would be accomplished by building up the downstream slope and raising dam/dike crests through the placement of appropriate soil materials developed at the borrow sites. The existing dam/dike crest would be excavated as necessary to key the new impermeable fill material to impermeable core of the existing embankment. The upstream (reservoir side) face and crest would not be altered below the point of the raise; upstream and downstream erosion protection would be extended to the crest height of the new raise. A slope stability analysis would be conducted to optimize the slope of the downstream dam/dike face.

Placement of additional earthen material would serve two primary functions: (1) the material could be used to raise the elevation of the structures, providing additional hydrologic control and temporary flood storage capacity, and (2) the material would provide additional mass to the existing earthen structures improving their static capabilities.

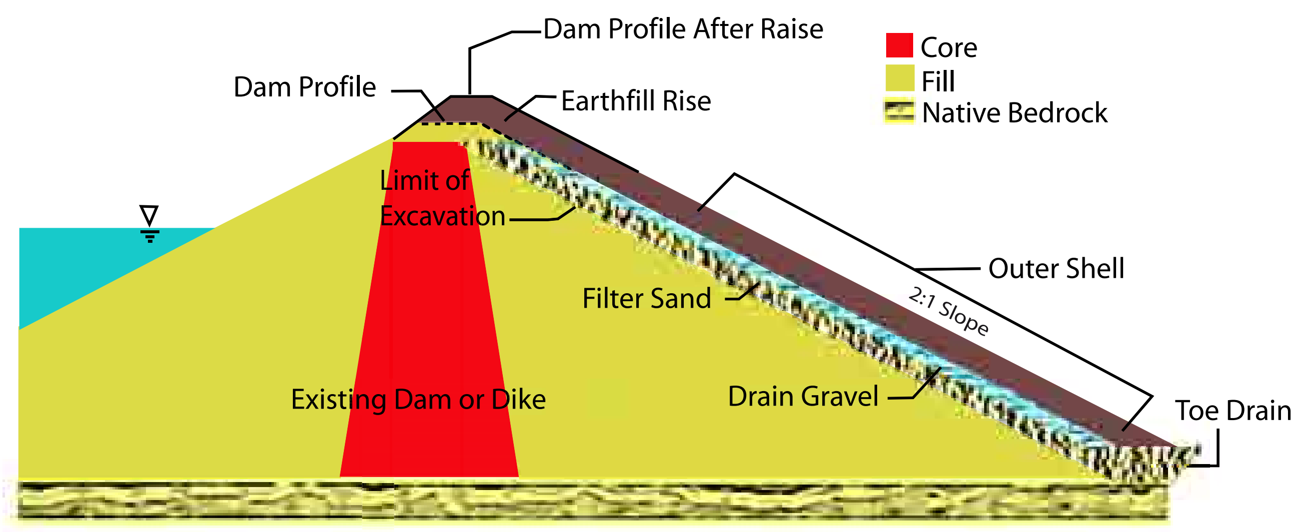


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Figure 2-9
Typical Dike Raise