Construction for Destruction: Downriver Diversion Dam Modifications Required for Matilija Dam Decommissioning

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In a 2004 feasibility study, the U.S. Army Corps of Engineers (Corps) and Ventura County Watershed Protection District (VCWPD) recommended decommissioning Matilija Dam, a concrete arch dam originally constructed to a 60-metre height in 1948. A decade after its completion, the United States Bureau of Reclamation (USBR) constructed the Ventura River Project, comprising additional facilities designed to meet the growing water demand of Ventura County. Robles Diversion Dam, a 7-metre high by 160-metre long diversion structure located downstream of Matilija Dam, was built under the Ventura River Project to feed Lake Casitas, a water supply reservoir that serves as an integral part of the overall project.

Due to extreme sedimentation, Matilija Dam no longer serves its intended water supply and flood control purposes. In addition to the loss of storage capacity, other issues surround the dam, including adverse environmental impacts from its continued operation, seismic considerations, and structural concerns. These concerns led to the decision to decommission the dam as an essential step in rehabilitating key ecosystems in the Ventura River Catchment and reducing future risks to public safety. According to current estimates, 5 million cubic metres of sediment has accumulated behind the dam and will need to be removed in conjunction with the dam decommissioning; minimising the associated downstream impacts has been the subject of additional government studies.

The USBR determined through detailed hydrologic, hydraulic, and sediment transport analyses, including numerical and physical modelling, that the existing Robles Diversion Dam was not capable of passing the increased sediment load expected to result from the removal of Matilija Dam. To increase the sediment transport capacity across its spillway, the existing diversion dam requires modification. Under contract with the Corps, Tetra Tech and its subcontractors are completing the design plans for the Robles Diversion Dam modifications.

This paper presents unique aspects of the Robles Diversion Dam modifications, including sediment management procedures guided by numerical and physical model results and issues associated with the design of a rock ramp spillway and high-flow fishway, expansion of the existing spillway gate structure, and raising of the dam embankment. The rehabilitation efforts reduce impacts to the migration of endangered fish species and allow for the eventual removal of Matilija Dam, which is the ultimate goal in the effort to balance engineered structures with a natural river setting. When completed, the project will provide fish passage to the upper catchment for the first time in over sixty years.

Keywords: *Decommissioning, sedimentation, siltation, modification, fish passage, diversion*

Introduction

As an increasing number of dams around the world reach the end of their useful lives, jurisdictional agencies are facing difficult decisions regarding the future. Decisions affecting recommendations for decommissioning or recommissioning the structures are often governed by complex economic and environmental considerations. When decommissioning is undertaken in the form of dam removal, sediment management issues can largely govern the costs, particularly for large dams situated in high-yield basins. Large dam removal projects that involve substantial amounts of sediment accumulation often carry additional downstream implications that extend far beyond the immediate dam and reservoir area. These additional implications must be figured into the costs and impacts from the initial planning phases onwards.

The U.S. National Oceanic and Atmospheric Administration (NOAA) Fisheries Service has published a number of Biological Opinions indicating that the continued operation of specific dams and diversions, particularly in coastal tributaries, threatens migratory fish populations. As a predominant example, the Southern California Distinct Population Segment (DPS) of Steelhead Trout (*Oncorhynchus mykiss*) is at risk of extinction in the face of diminishing habitat. NOAA Fisheries designated the Southern California Steelhead DPS as endangered in 1997 and reaffirmed its endangered status in 2006. In its final designation, NOAA placed the Ventura River and other Southern California tributaries under Critical Habitat Status (2005).

In light of these designations, impassable manmade barriers in the affected catchments have come under particular scrutiny. The environmental pressures, coupled with concerns for public safety, have given rise to a number of studies to determine the viability of existing dams and reservoirs in coastal tributaries of Southern California.

In the case of Matilija Dam, construction of an effective fish ladder is impractical due to the size of the dam. The dam's removal would present an opportunity to restore fish passage and help to preserve an endangered species; however, any debris removal method involving natural downstream sluicing of the material also presents potential hindrances to fish passage, particularly at existing downstream fish passage facilities not designed to handle the excess sediment load. Upgrades to these facilities – which in this case involve the addition of a high-flow fishway, a rock ramp, and increased spillway capacity – are tied to the overall success of the decommissioning project.

Ventura River Basin

The Ventura River drains 600 square kilometres from the Topatopa Mountains to the Pacific Ocean. Approximately half the drainage area is U.S. Forest Service (USFS) land. The remaining catchment area comprises rural hills under public and private ownership, agricultural development, and urban areas that are concentrated in the lower catchment reaches.

Matilija Creek joins the North Fork Matilija Creek to become the Ventura River approximately 25 kilometres from its mouth at the Pacific Ocean. The Matilija Dam and Robles Diversion Dam sites are located along the upper reaches of the Ventura River in Southern California. The location of the catchment relative to the State of California is shown in Figure 1.

Figure 1. Ventura River Catchment Overview

Annual rainfall in the Ventura River catchment averages 360 mm, and the river's discharge averages 17 gigalitres per year on an intermittent basis. The soils within the rugged and mountainous terrain of the catchment are highly erosive, and the drainage area provides a high sediment yield to the catchment's waterways. Sediment deposited at the Ventura River's mouth moves along the shoreline through littoral transport; the high sediment content of the Ventura River historically provided beach nourishment along the coast.

Historically, the river provided spawning grounds for salmonids and supported subsistence fishing by the native Chumash Indians (Latousek, 1995). Agricultural development of the Ventura River Basin began with the Spanish missions in the 1700's. In addition to a public desire for the implementation of flood control, demands for drinking water, irrigation, and industrial use sparked increasing development of the water resources. A number of wells and diversions were constructed within the catchment by various private and local public entities. Dam construction was initiated as agricultural wells ran dry from overuse; most notably, Matilija Dam was constructed by Ventura County in 1948.

Federal interests generated further development through the U.S. Bureau of Reclamation's Ventura River Project, which included storage dams, diversion dams, canals, pipeline distribution networks, pumping stations, and other features. The project was completed between 1956 and 1959 and included the construction of Robles Diversion Dam and Casitas Dam, which created Lake Casitas as the project's most visible feature. An area covering approximately 6,000 hectares of irrigable land is sustained by the project. The project's infrastructure is currently owned by USBR and operated in conjunction with local stakeholders.

Matilija Dam

Site Selection and Construction

In light of the decreasing groundwater table, the original dam site had been secured along Matilija Creek just upstream of the confluence with the North Fork Matilija Creek. The initial site selection for Matilija Dam was controversial as concerns over sedimentation were raised; however, construction proceeded under pressures to alleviate the water shortages. Construction of the concrete arch dam began in 1946. The dam was constructed to its designed, 60-metre height in 1948 at a cost of USD $4 million. Figure 2 shows the dam immediately following construction.

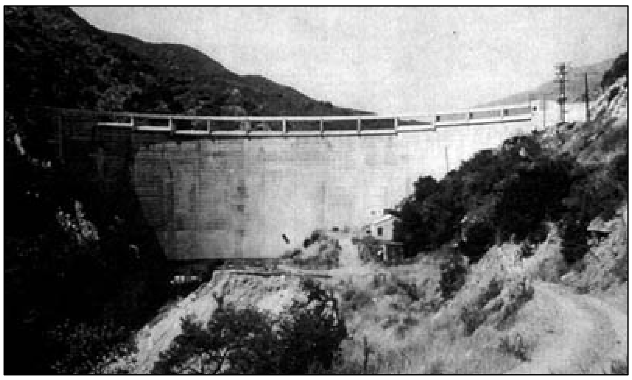

Figure 2. Matilija Dam in 1948

The concrete is 2.5 metres thick at the crest and 10.5 metres thick at the base with an overall width of 190 metres. The dam drains approximately 140 square kilometres of the Matilija Creek catchment. The 50-hectare, 9-gigalitre reservoir had filled with captured floodwaters by 1952.

Dam Issues

Sedimentation

By 1969, the dam was already virtually obsolete due to sedimentation. The current effective water storage capacity of the dam is approximately 0.5 gigalitres – a fraction of the designed capacity – and the storage is expected to diminish to essentially nil by 2020 (Corps 2004).

The additional pressures exerted by the sediment load, along with concerns regarding alkali-reactive aggregate, required the dam to be notched several times to reduce its capacity and the accompanying strain from hydrostatic and soil pressures. In its current configuration – accounting for the notching – Matilija Dam stands 51 metres high; the current reservoir capacity, excluding sedimentation losses, is approximately 5 gigalitres. Figures 3 and 4 show the present dam and reservoir.

Figure 3. Matilija Dam in 2004

Figure 4. Reservoir Siltation (photo by Paul Jenkins)

The USBR completed an Appraisal Investigations Report to investigate the volume, material properties, and potential toxicity of the sediment behind the dam (USBR 2000). Samples were taken of the sediment in the reservoir bottom and upstream delta area to determine the gradation and sediment quality. The sediment distribution was developed in a 3-dimensional model surface. The sediment volume behind the dam was estimated as approximately 5 million cubic metres; no significant levels of contamination were detected.

Ventura Beach is a popular surfing destination. Replenishment of beach sands transported through littoral drift decreased significantly following construction of the dam, resulting in a net sediment deficit near the Ventura River mouth. The Corps sediment transport modelling efforts (2006) were inconclusive regarding the amount of coastal erosion attributable to the dam. Figure 5 shows erosion at Ventura Beach following a storm.

Figure 5. Ventura Beach

Fisheries Impacts

In 1949, just one year following construction, fish kills related to high temperatures in the stagnant water of the reservoir were recorded. A fish ladder constructed in 1956 proved ineffective, and Matilija Dam remained essentally impassable to migrating fish. The number of steelhead migrating to spawning grounds in the upper Ventura River catchment decreased from an estimated 5,000 in 1940 to several dozen in 2000 (NOAA 2005).

Figure 6. Existing Fish Ladder at Matilija Dam

Dam Removal

In light of the sedimentation and fisheries concerns, government studies of removal scenarios were undertaken with mounting public support. As shown in Figure 7, a demonstration section was removed in 2000 to test the feasibility of various demolition techniques. Preliminary studies focused on the costs associated with various sediment disposal options, which involved various combinations of natural conveyance, in-place stabilisation, or removal of sediments by conveyor belt, truck, or sluice pipe.

Figure 7. Concrete removal in 2000

A feasibility study completed by the Corps (2004) presented various alternative combinations for dam and sediment removal with their associated costs. In the preferred alternative, the reservoir fines are to be removed by slurry pipe and deposited on the downstream floodplains. A channel will be created through the reservoir deposits, and the material removed from this excavation will be placed and stabilised on the channel banks. Figure 8 shows the original bed, the current sediment level, and a future conditions rendering of the reservoir area.

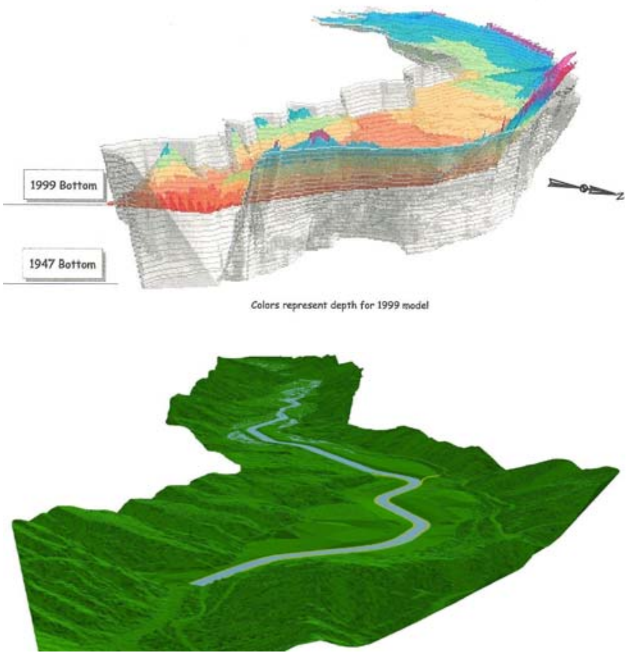

Figure 8. Pre- (above) and post-project (below)

The USBR completed a one-dimensional sediment transport analysis of the reservoir system under existing and post-project conditions using GSTAR (Generalised Sediment Transport Model for Alluvial Rivers) software in conjunction with HEC-RAS (USBR 2006). The model quantified the sediment transport trends anticipated under the preferred alternative. The feasibility study concluded that the additional sediment transport resulting from the dam removal would impact downstream facilities, including rendering existing levee heights inadequate for flood control, reducing the diversion capacity for water supply to Lake Casitas, and blocking fish passage through the Robles Diversion Dam fishway.

Robles Diversion Dam

History

Robles Diversion Dam was constructed in 1958 as part of the Ventura River Project. A diversion canal was concurrently constructed from the diversion point to Lake Casitas, which had been formed by the construction of Casitas Dam along Coyote Creek under the Ventura River project. During the wet season, Robles Diversion Dam diverts water from the Ventura River into Lake Casitas in the adjacent subcatchment through a gravity flow system. A conduit system comprising 50 kilometres of pipe conveys flows from Lake Casitas to the population centres downstream. A USD $9 million fishway was added in 2004. Figure 9 shows an aerial view of the diversion dam with the fishway under construction.

Figure 9. Robles Fish Ladder under Construction

Current Configuration

Dam and spillway

The existing drainage area upstream of the diversion is approximately 200 square kilometres, and the 100-year peak discharge is approximately 770 cubic metres per second (cms). The existing diversion dam consists of an 8-meter high by 100-metre wide, in-channel, rock-filled embankment with impervious core and bypass structure. The normal operating depth is 4 metres. The diversion control structure comprises a single-leaf overshot gate and electronically controlled hoist assembly.

The existing spillway capacity is approximately 170 cms, and the existing diversion canal capacity is approximately 15 cms. The bypass and diversion include a gate-controlled bypass structure for the Ventura River (one 3-metre by 3-metre radial gate and three 5-metre by 3-metre radial gates) and a gate-controlled canal diversion structure with a debris barrier (three 4-metre by 3-metre radial gates).

Figure 10. Robles Diversion Dam in 2008

Robles Diversion Dam is currently owned and operated by the Casitas Municipal Water District (CMWD). Robles operates under a highly regulated diversion schedule, affected by the highly variable river flows, large sediment loads, downstream water rights and minimum flow requirements for fish passage.

Fishway

Because Matilija Dam represents a complete fish passage barrier just upstream of the Robles structure, the benefits of providing fish passage through the diversion dam are limited so long as Matilija Dam remains in place; the original diversion structure was thus constructed without providing for fish passage. Environmental pressures continued to mount, however. At this time, federal officials estimate that only about 100 adult steelhead remain in the Ventura River Catchment. In light of the federal listing of the steelhead trout as endangered, fish passage facilities providing both juvenile and adult passage were constructed in 2004, and environmental flow criteria were implemented to provide passage of adult and juvenile steelhead around the diversion dam. As shown in Figure 11, the existing fish screen applies a chevron-configuration, vertical plate design with travelling brush mechanisms and adjustable velocity distribution baffles.

Figure 11. Fish screen and cleaning brushes

The 100-metre vertical slot fish ladder was constructed to convey nominal flows with an auxiliary bypass pipeline to introduce supplemental “attraction” flows at the fishway entrance. The fishway also includes a bio-monitoring and trapping facility, a low-flow exit channel to prevent stranding, and a high-flow exit channel to prevent fall-back. The operational sequences and routines of the facility control system incorporate video monitoring, and results are published online.

Sedimentation Concerns

As determined by the feasibility study (Corps 2004), the increased sediment load resulting from the removal of Matilija Dam would negatively affect the operation of Robles Diversion Dam by clogging the existing fishway. In order to assess various measures to mitigate for these concerns, hydrologic, hydraulic, and sediment transport relations were investigated by the USBR (2006). This study compared historical operations to future with-project scenarios and concluded that the anticipated sediment load ran the risk of rendering the newly constructed fishway ineffective. Additional studies were undertaken to refine viable options in further detail. Functional limitations of the 2006 GSTAR-1D model that was used to model sediment transport through the upstream reservoir prevented characterisation of the sediment distribution within the reservoir and suitable application to the Robles Diversion Dam.

Numerical Modelling

Due to the complex hydraulic conditions at Robles, a two-dimensional sediment transport model (SRH-2D) was applied as an alternative (Lai and Greiman 2008). The model was used to determine the interaction of flows and bed load sediments. A high-flow bypass (HFB) spillway was proposed to enhance sediment movement through the diversion pool, thereby reducing the impacts of elevated bed load levels resulting from the anticipated sediment deposition. The results of optimisation efforts indicated that the HFB could provide significant reductions in total sediment deposition.

Physical Model Study

A 1:20 Froude-scale model of the proposed facility was tested by the USBR to verify the numerical modelling results. The physical model determined the interaction of flows and base load sediments near the diversion dam under Matilija Dam removal scenarios with varying hydrologic conditions (Mefford et al. 2008). Modelling was conducted at the USBR Water Resources Research Laboratory (WRRL) in Denver, Colorado. Models were analysed with and without the HFB in place and with varying locations for the proposed bypass.

The fishway exit became inundated by sediment during all model tests, resulting in a recommendation for a secondary fishway to provide fish passage during HFB operation. Guide walls were also recommended to reduce flow contractions that occurred on the outside walls of service spillway bays. Modifications to the stilling pool and spillway were also made in order to hold the hydraulic jump within the basin. Results between the numerical and physical modelling scenarios agreed reasonably well. Both predicted an approximately reduction of 50% of deposited sediments with the HFB in place. The refinements made to the physical and numerical models were incorporated into design recommendations for project features that will alleviate the impacts anticipated from the removal of Matilija Dam. The Corps retained Tetra Tech, Inc. to complete the design of the Robles Diversion Dam modifications and to develop the plans and specifications.

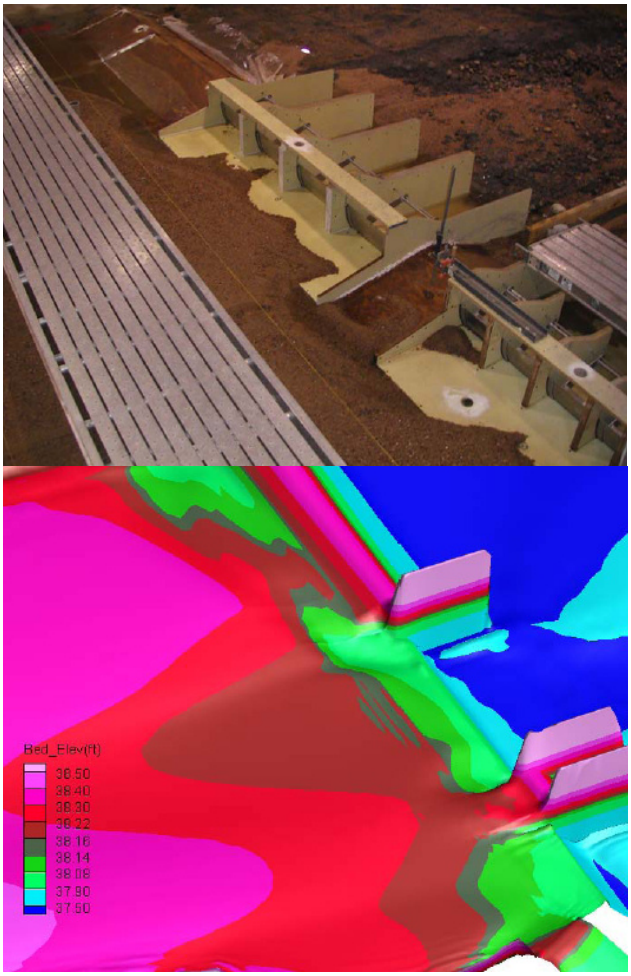

Figure 12. Physical and numerical modelling results

Design Features

Sediment Passage Features

The current design proposed the construction of a HFB spillway consisting of four 10-metre wide by 4-metre high tainter gates, stilling basin, and a high-flow fishway. Additionally, the existing dam embankments are to be raised and an armoured rock ramp spillway provided for the embankment. The current design protects the diversion structure against failure in the 100-year event and is a sediment mitigation component of the overall Matilija Dam removal project. The design modifications to Robles are based upon the selected alternative in the Corps feasibility report (2004), with the only deviations from the selected alternative being the addition of the fish bypass and the rock ramp spillway.

The addition of the HFB increases the spillway capacity from approximately 170 cms (less than the 10-year return period) to almost 540 cms (20-year return period). With the rock ramp spillway operating, the total diversion dam capacity will increase to 770 cms (equivalent to a 100-year return period level of protection).

Fish Passage Features

The Streaming Flow Fishway is designed to allow migration of the endangered Steelhead Trout (*O. mykiss*) during high-flow events. To increase operating efficiency of the diversion structure and fishway, the existing embankment will be raised by approximately 60 cm. The existing gates are 3 metres in height; a 60 cm extension will be connected to the existing gates to increase their depth capacity. A concrete sill will be placed across the crest of the raised embankment to control the weir elevation and the forebay depth. A rock ramp will be placed approximately 120 metres downstream of the existing spillway structure and the proposed HFB structure. The ramp is designed to protect the downstream channel and focus the outlet flows into a single stream. This will assist in preventing stranding of fish as they migrate upstream. Figure 13 shows the existing and proposed elevation.

Design Details

Hydrology and hydraulics

As determined in the hydrologic modelling efforts (USBR 2006), the 100-year design discharge for the Ventura River at the Robles Diversion Dam is approximately 770 cms. The hydrologic and hydraulic analyses for the project include rainfall-runoff modelling for the with-project conditions, numerical sedimentation analysis, and a physical hydraulic and sediment model of the baseline and with-project condition. Although the site does have a high groundwater table during the rainy season, susceptible to seasonal variations and flows, construction activities are anticipated during the dry season, and groundwater is not anticipated at the proposed construction depths. Further details are presented in the Design Documentation Report (DDR) (Corps 2009).

To increase the high-flow diversion capacity of the Robles Diversion Dam, a rock ramp spillway is provided adjacent to the proposed HFB structure. To accommodate the steep (11.4%) gradient and provide variability in the flow paths, the rock ramp will be non-grouted, placed rip rap. The rock ramp spillway will have an embankment height of 2 metres, increasing the design capacity of the diversion structure system from 540 cms to 770 cms. The spillway is designed to convey flows up to 540 cms without damage to the ramp and up to 770 cms without damage to the diversion structure.

While the hydraulic design of the system protects the diversion dam and other components against catastrophic failure under 100-year return period conditions, the facility is not designed as a storage reservoir; Probable Maximum Flood (PMF) events were thus not considered in the design. The downstream Ventura River levees are being upgraded under a separate project to accommodate water surface increases resulting from additional sediment deposition; should a dam failure occur in a greater-than-design event, the additional overflow would be contained within the leveed riverbanks downstream at the urban centres.

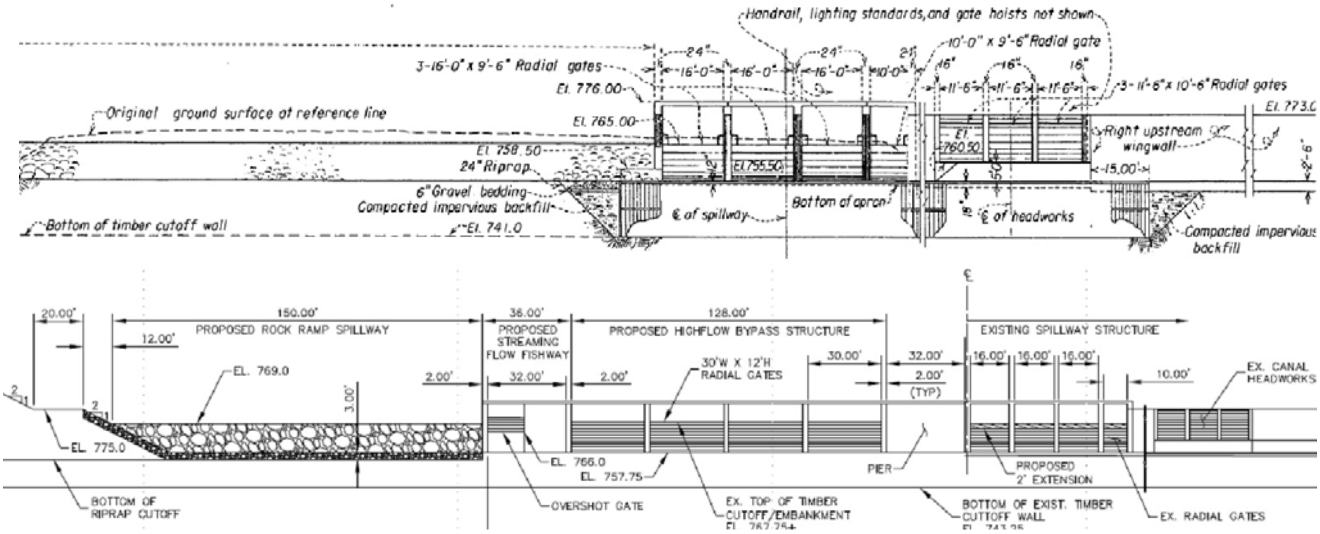

Figure 13. Existing Elevation (above) and Proposed Elevation (below)

Civil and geotechnical

An existing seasonal low-flow crossing will be removed and replaced with a concrete structure that will also serve as a grade control structure for the rock ramp channel. Existing all-weather maintenance and access roads will remain in place without modification. The embankment and maintenance access roads are designed to connect with the upstream limits of the levee improvements being undertaken as a separate project.

The rock ramp will join the existing river channel approximately 120 metres downstream of the diversion. The slope of the rock ramp will vary due to the difference in sill elevations of the existing stilling basin and the proposed basin. To account for this elevation difference, the rock ramp directly downstream of the existing structure will have a gradient of 1.5%. From the existing structure, the rock ramp gradient downstream of the HFB structure will be 2.0%. The gradient of the rock ramp is designed to maintain sediment passage downstream of the Robles Diversion structure.

It is expected that a majority of the excess material will be suitable for commercial use and will not require separate, off-site disposal The project site generally consists of bars of course-grained material (gravel, cobbles, and boulders) which have formed near the mid-channel both upstream and downstream of the diversion structure. The river channel is about 3 to 5 metres below the eastern and western banks. Additionally, due to the high ground water and presence of loose soils in the surface layers, the site is susceptible to liquefaction during a large earthquake event. Although site conditions allow for the possibility of liquefaction, the probability of liquefaction is low. Based upon the available engineering drawings, the existing diversion dam is a zoned earthfill and rockfill embankment. To help mitigate for potential seepage, a 5- to 6-metre deep trench of “compacted impervious backfill” was originally constructed upstream and downstream of a timber cutoff wall.

The values provided in the DDR (Corps 2009) are based upon the properties of the in-situ soils, comparison of engineering properties of soil with similar materials from previous investigations, and engineering judgment. These values are used for calculation of the earth pressure on the structures and retaining walls and slope stability of the embankment fills.

Subsurface investigations were performed to support the design. The equivalent earth fluid pressure was provided by the geotechnical engineer. The analysis assumed active earth pressure was applied to the upstream face of the spillway dam from the top of the seepage barrier to the bottom of the upstream foundation shear key. It was also assumed that the soil downstream of the spillway may not be present; the soil was thus not included in the analysis. Hydrostatic uplift pressures were determined by the geotechnical engineer using the flow net analysis to account for the seepage barrier in front of the dam.

The Operational Basis Earthquake (OBE) is the design earthquake that represents ground motions for which the essential structures and critical components of the system are expected to sustain no permanent damage, and the normal structures and non-critical components incur either minor or no permanent damage. “Critical” components and equipment are defined as those whose malfunction could interfere with the safe and continuous operation of the dam. Under the OBE earthquake loading, the structural response of the spillway shall remain essentially elastic under this earthquake loading.

The Maximum Design Earthquake (MDE) is the design earthquake in which normal structures may suffer permanent offsets, although no collapse may occur. Damage consisting of cracking, reinforcement yield, and major spalling of concrete is possible. These conditions may require closure of the spillways to repair the damage. The foundations must have sufficient capacity to withstand the earthquake loading without any damage. The peak response in the structure may be inelastic, but shall not exceed the prescribed residual deformations. Walls shall remain stable for the normal loading condition under the permanently deformed state. Essential structures may exhibit some visible damage, but shall be limited to narrow flexural cracking of concrete and the onset of yielding in steel. These earthquake design requirements were applied to each of the structural and mechanical components of the project.

Structural, mechanical, and electrical

SAP2000, Version 12 (Plus), was used for the structural modelling and analysis of the existing and new tainter gates. For the existing gate analysis an additional 2-foot extension was provided to account for the increased embankment elevation. The analysis was provided to confirm that the existing structure could accommodate the increased water surface elevation and associated loading. The following forces were considered in the analysis:

- Hydrostatic
- Gravity
- Ice load
- Mud and debris
- Gate lifting loads
- Impact
- Side-seal friction loads
- Trunnion pin friction loads
- Earthquake
- Wave

A 3-D model of existing and new tainter gates was created using frame and shell elements of SAP2000. Figure 14 shows the general layout of a gate with the loading diagram. The frame members' demand to capacity ratios (DCRs) were determined from the SAP2000 finite element analysis. It was determined that the Load Combination that included the factored dead, mud, ice, hydrostatic and seismic loads governed. Existing tainter gate trunnions were checked against the allowable bearing pressure of 35 MPa for the unfactored load combination that produces maximum reaction at the trunnion. The calculations showed that the maximum induced bearing pressure at the trunnion is 17 MPa, which is well within the allowable limit of 35 MPa.

The existing control system is to be retained and reused. The existing control panel does not have sufficient space on the enclosure front for new control and indicating devices; therefore, a new controls panel is provided and integrated with the existing control system. There appears to be sufficient capacity in the existing control system hardware for control and monitoring of the new tainter gates. Several options were considered related to the generator system. The selected option is to reconfigure the existing generator; the existing generator would still only provide 60kW of standby power; therefore, interlocks would be required that would prevent all systems from operating on the generator concurrently, but with selectability (such as a manual transfer switch between new gate motors and the existing system) such that at any given time, a predetermined block of equipment can be operated on the generator.

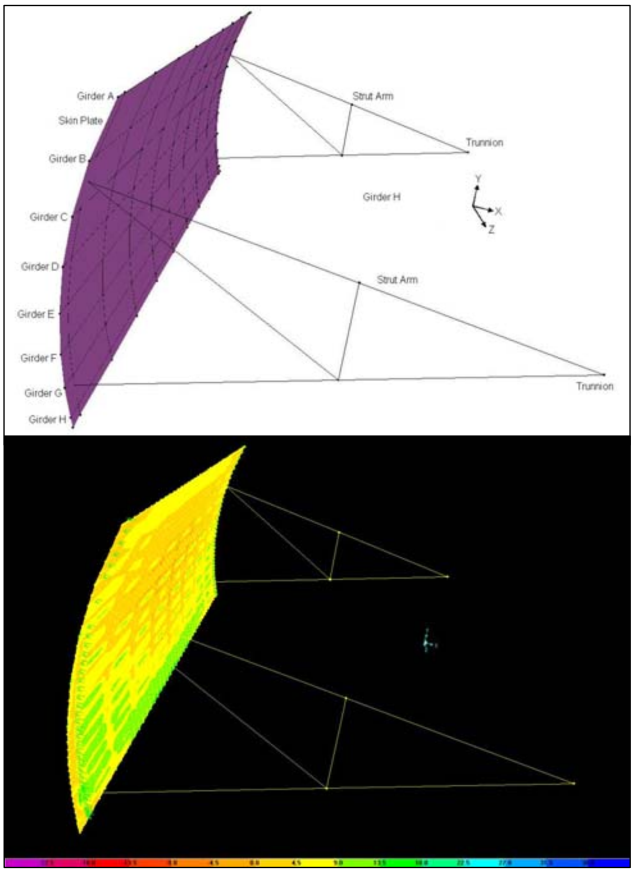

Figure 14. Tainter gate layout and skin plate shell

The existing gate leaves and operating equipment were analysed to determine if they would be adequate for the raised reservoir elevation. The structural and mechanical components were evaluated against Corps of Engineers requirements. Under the current design, the structural members, skin plate, and hoisting equipment meet the requirements. The existing gates will thus be provided with a 60cm skin plate extension along the top of the tainter gate, with the extension welded onto the outside of the existing skin plate.

Implementation and Monitoring

Construction of the Robles Diversion Dam modifications is anticipated in 2011, allowing for removal of Matilija Dam to begin in 2012. The removal of Matilija Dam would constitute one of the largest dam removal projects to date in the United States. Several other dams in the United States – Elwha Dam in Washington State being the most prominent among them – are likewise slated for removal along a similar timeline. The science on natural and induced habitat recovery following dam removal is notably sparse. Substantial monitoring efforts on the post-project river system will be implemented in order to improve the available science and guide future decisions related to dam removal efforts.

Application

These dam removal projects have potentially widespread applications to similar systems in Australia and worldwide. In Australia, Chanson and James documented siltation rates in over twenty fully silted reservoirs (1999).

Most of these dams are smaller than the Matilija dam; however, the general lessons learnt in the removal of the Matilija Dam and the associated upgrades to downstream infrastructure may be applied to many of the dams in the study. Chanson and James also documented reservoir siltation rates worldwide (1998). Each reservoir in their study is unique, and several factors are presented as influencing the siltation rates. Some siltation rates were exacerbated following bush fire conditions in the catchment, for example, a concept that currently bears some relevance to Victorian catchments in particular.

Conclusions

The complex issues involved in the decommissioning of the now defunct Matilija Dam have resulted in a decommissioning cost that is several orders of magnitude higher than the original construction cost. The widespread impacts of the decommissioning process serve as an example of the intertwined complexities of large engineering projects, with a reminder to account for these items in any future planning studies that are undertaken. Chanson concludes that "fully-silted reservoirs stand as a source of embarrassment for scientists and for the public. Each reservoir failure must be a valuable teaching and pedagogic tool to heighten the awareness of students, professionals, local authorities, and the public." (Chanson 1998).

The U.S. Society of Dams, in their policy statement on decommissioning, state that "each situation is different and must be considered on a case by case basis. Once a decision has been reached that decommissioning may be the best alternative, the actual dam removal must be carefully planned, giving full attention to the economic and environmental consequences of such removal. The incorporation of proper environmental protections must be an integral part of the removal. Planning for the removal process must include input by all affected stakeholders.

"Decommissioning of dams is a reality that engineers and dam owners will be facing more and more in the next few decades. It is time to gather and begin to exchange ideas now. Costs associated with decommissioning can be many times the cost of repairs and upgrades. Much can be learned from reviewing the decision process from decommissioning case studies."

The projects at Matilija Dam and Robles Diversion Dam restore steelhead access to a combined 70 kilometres of spawning and rearing habitats that have been unavailable to the species for over half a century, while maintaining the level of service to downstream consumers of the Ventura River Project. The projects apply "hard" engineering solutions to create a viable, more natural system. These projects will also begin addressing threats that have impaired the catchment-specific hydrologic and sediment regimes, a critical step in providing riverine habitat conditions and characteristics that are consistent with the life history and habitat requirements of steelhead and many other species on the river.

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