MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

DAM REMOVAL CONCEPTS EVALUATION REPORT
MARCH 2016

Prepared for:
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Executive Summary

Since its construction in 1947, the 168-foot-high, arched concrete Matilija Dam has blocked the transport of an estimated 8 million cubic yards (mcy) of sediment from naturally moving downstream to the ocean. This has resulted in loss of almost all reservoir storage, downstream sand and gravel-sized materials necessary to promoting downstream wildlife habitat, and sediment needed to maintain beaches at Surfer's Point. The dam also prevents southern steelhead from reaching upper Matilija Creek.

In the early 2000's, Ventura County Watershed Protection District (VCWPD) and the US Army Corps of Engineers (USACE) evaluated several alternatives for dam removal to arrive at a preferred dam removal alternative (Alternative 4b) that involved slurrying an estimated 2 mcy of fine sediment from the Reservoir sub-area just upstream of the dam to a downstream disposal location. Subsequently, in 2009 and 2010, the Matilija Dam Fine Sediment Study Group (FSSG) was convened to evaluate temporary upstream disposal of the fine sediment as an alternative to downstream disposal which was associated with concern over cost, constructability, and impacts on habitat and visual appeal. VCWPD has since contracted with AECOM (formerly URS) and Stillwater Sciences (the Consultant Team) to evaluate a range of concepts, including those documented in previous studies as well as new concepts.

In coordination with the Management Team, the Technical Advisory Committee (TAC), and the Design Oversight Group (DOG), three concepts were chosen from six dam removal concepts previously screened by the Consultant Team (URS and Stillwater Sciences, 2014a, also provided as Attachment 3 to this report). The three concepts are primarily focused on alternative methods for managing the fine sediment accumulated in the Reservoir sub-area (the sediment deposits immediately upstream of the dam and dominated by fine sediment). The coarse sediment would be transported naturally from the reservoir for all three concepts. The purpose of this report is to document the technical components of each of the shortlisted dam removal concepts, the criteria developed to evaluate the concepts, the methods and metrics utilized to address or populate the criteria, and the associated evaluation results.

The transport of impounded fine sediments from the Matilija reservoir is associated with two discrete phases of erosion and transport. From an initial, un-channeled condition, Phase I erosion occurs while the fine sediments in the Reservoir and Delta sub-areas remain accessible to the flow, with anticipated suspended sediment concentrations as high as 106 mg/L. Phase II erosion occurs once fine sediment is no longer directly accessible to the flow and is associated with a declining rate of additional sediment input.

The three dam removal concepts are briefly summarized below:

- **Dam Removal Concept-1 (DRC-1) Containment Berm with High Flow Bypass:** This concept would involve removing the dam and building a temporary containment berm to temporarily hold the reservoir sediment in place, with a bypass tunnel to divert creek flow to North Fork (NF) Matilija Creek, until a high flow event occurs to erode a large portion of reservoir fine sediments. For DRC-1, sediment is released in high concentrations during Phase 1, followed by Phase II erosion at a declining rate.
- **Dam Removal Concept 2A/2B (DRC-2A/2B) Uncontrolled Orifices with Optional Gates:** This concept would involve boring tunnels at the base of the dam and then blasting open the

tunnels when a high flow event occurs to erode a large portion of reservoir fine sediments. Concept DRC-2B would include the installation of gates on the upstream end of the tunnel orifices if it were found that the large storm did not remove an adequate amount of the accumulated fine sediment from the reservoir. The gates would be closed to allow the reservoir to refill to minimize additional water quality impacts, until the next high flow event occurs. The dam would be removed when a sufficient amount of the accumulated fine sediment has been eroded from the reservoir. For DRC-2, sediment is released in high concentrations during Phase 1, followed by Phase II erosion at a declining rate.

- **Dam Removal Concept-3 (DRC-3) Temporary Upstream Storage of Fine Sediment:** This option would involve mechanical removal and temporary upstream storage of both fine and coarse sediment from a portion of the reservoir, creating a channel through the lower third of the reservoir approximately along the pre-dam creek alignment, at the pre-dam creek elevations. The dam would be removed when this earthwork is complete. While Phase I erosion is completely avoided due to the prior mechanical removal of much of the fine reservoir sediment, Phase II erosion would be similar to DRCs-1 and 2.

In order to evaluate how well the above concepts met the various project objectives, the following list of evaluation criteria were developed: steelhead passage and health, existing and post-project vegetation communities, implementation costs and risks, and water supply. The approach to evaluating the dam removal concepts involved quantitative and qualitative assessments of the evaluation criteria listed above, using relevant tools and empirical data available from analogous dam removals elsewhere. Several technical assessments, primarily outside the scope of specific evaluation criteria, were conducted to broaden the understanding of baseline and future conditions for resource areas pertinent to this study.

Evaluation of the three dam removal concepts based on the above criteria is briefly summarized below:

- **Steelhead Passage:** The time required to reach effective fish passage is primarily a function of the project construction duration and the waiting period for flushing. Closure of the gates installed for DRC-2B could cause further delays to fish passage depending on gate operation. DRC-3 has the potential to provide fish passage in the least amount of time, while DRC-2B has the risk of taking the longest time to allow passage.
- **Steelhead Health**: Both DRC-1 and DRC-2 result in the substantial, but likely not complete, loss of a year class of fish in Matilija Creek and the Ventura River, immediately following sediment flushing. This impact is avoided under DRC-3, which involves mechanically removing the majority of the accumulated fine sediments. Closing and re-opening of the gates under DRC-2B would likely result in additional fish mortality events during each subsequent gate opening.
- **Existing Vegetation Communities**: Among the six vegetation communities identified to be impacted by the dam removal concepts, the Riparian Woodland community would have the most acreage impacted. DRC-3 would have an overall greater impact (69 acres) on existing vegetation communities at the site compared to DRC-1 and DRC-2, due to the temporary sediment stockpiles remaining for a significant period of time after dam removal. DRC-1 has a slightly greater overall area of impact than DRC-2 (26 acres versus 20 acres).
- **Post-Project Vegetation Communities**: In general, DRC-1 and DRC-2 would have similar anticipated future vegetation communities. Due to the deeply incised channel in the lower reservoir, vegetation communities transition from more open water and riparian communities

under existing conditions to a mixture of riparian, oak woodland, and scrub/chaparral. For DRC-3, there would be less riparian vegetation relative to the other dam removal concepts, with an associated increase in mixed chaparral (in upstream sediment stockpile areas).

- **Range of Magnitude Construction Cost (ROMCC)**: The ROMCCs for DRCs-1, 2A, 2B, and 3 are $40.4 million (M), $18.5M, $20.4M, and $49.7M respectively, with the expected accuracy range being from 20% to 30% lower than the estimate to 30% to 50% higher than the estimate .
- **Risk Management**: Assumptions or components associated with each of the dam removal concepts may include some inherent risk, or may in some instances help to mitigate a risk associated with implementation. The dam removal concepts were evaluated and scored based on a variety of risks occurring in the following periods: construction, flood waiting period, and post-storm flush. DRCs-2A, 2B, and 3 have lower overall risk relative to DRC-1. The longer construction duration associated with DRC-3 (and associated exposure to weather delays) puts it at slightly higher risk relative to DRC-2A.
- **Water Supply**: A diversion disruption scenario that assumes Robles diversions are suspended for one large storm (while flushing is occurring) was completed to determine impact to surface water supply. Based on the assessment, the associated drop in Lake Casitas storage was approximately 4 to 6 %. This result would apply only to DRCs-1 and 2, which include diversion disruption during Phase I sediment transport. DRC-3 would have no significant impact on Lake Casitas storage. DRC-2B has the option to close the orifice and wait for another flush, potentially resulting in additional impacts to Robles diversions. Suspending diversions for three consecutive large storm events, which would be a more conservative assumption, could result in an associated drop in Lake Casitas storage of up to 15 %.

The dam removal concepts were ranked under each criterion, and then cumulatively. DRC-2A (without gate) ranks first overall, primarily due to having the lowest cost, risk, and impact to existing vegetation. DRC-3 ranks second, with its high impact to existing vegetation (large footprint), high cost, and lower long-term vegetation habitat benefit pulling it well below DRC-2A. DRC-2B ranks third primarily due to the harm that subsequent gate closure(s) could do to steelhead health and passage. DRC-1 ranks last given the selected criteria, primarily due to the fact that it carries the greatest risk, has a relatively high cost, and fails to positively distinguish itself in multiple categories.

Based on the evaluation in this report, up to two alternatives are anticipated to move forward into preliminary design at a future date.

1.0 Introduction

1.1 Project Background and Purpose

Since its construction in 1947, the 168-foot-high[1], arched concrete Matilija Dam has blocked the transport of nearly 8 million cubic yards (mcy) [2] of fine and coarse sediment, preventing it from naturally moving downstream to the ocean. This has resulted in loss of the reservoir's original function of water storage[3] for agricultural needs, and also loss of downstream sand and gravel-sized materials necessary to promote habitat for a variety of wildlife species, loss of sediment needed to maintain beaches at Surfer's Point, and increased erosion of the Ventura River streambed. The dam, with its non-functioning fish ladder, also prevents southern California steelhead (Oncorhynchus mykiss) from reaching upper Matilija Creek, which, prior to dam construction, was one of the most productive spawning and rearing habitats in the Ventura River system and provided important refugia habitat within the Los Padres National Forest. Without dam removal, an estimated total of 9 mcy of sediment will be trapped behind the dam before the entire natural sediment load of Matilija Creek begins to be carried over the dam, likely within the next three decades. While such a scenario would eventually begin to address sediment deprivation of the downstream reaches, leaving the dam in place would not address fish passage beyond the dam and impacts to upstream habitat.

In the early 2000's, Ventura County Watershed Protection District (VCWPD) and the US Army Corps of Engineers (USACE) evaluated several alternatives for dam removal and published a Final Environmental Impact Statement/Environmental Impact Report (EIS/R, USACE 2004). They arrived at a preferred alternative (Alternative 4b) that involved slurrying an estimated 2 mcy of fine sediment from the Reservoir sub-area just upstream of the dam to a downstream disposal location, removing the dam in one season, excavating a channel through the remaining coarse sediment, and protecting the lower seven feet of the channel banks with soil cement, while allowing 10-year and greater discharges to remove the accumulated sediments above the seven-foot level. At some future date, the soil cement would be removed, allowing the remaining accumulated sediment to be flushed through the river system. Alternative 4B was authorized for federal funding but did not move forward. Subsequently, in 2009 and 2010, the Matilija Dam Fine Sediment Study Group (FSSG) was convened to address concerns over cost, constructability, and habitat and visual impacts of the downstream disposal options for the fine sediment. In particular, they evaluated temporary upstream disposal of the fine sediment as an alternative solution.

VCWPD has since contracted with AECOM (formerly URS) and Stillwater Sciences (the Consultant Team) to evaluate a range of concepts including those documented in previous studies, concepts

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[1] The original height of the dam was 198 feet prior to two phases of notching in 1965 and 1977.

[2] The estimated volume is based on the difference between 2005 LiDAR and original topography before dam construction (Stillwater Sciences, 2014a). 6.8 mcy of sediment is distributed from downstream to upstream as about 2.4 mcy of silt and clay in what is termed the Reservoir sub-area, 3.2 mcy of sand, silt and clay, and gravel in what is termed the Delta sub-area, and 1.2 mcy of sand and gravel in what is termed the Upstream Channel sub-area. Using historical sediment deposition volumes to extrapolate beyond the last measurement in 2005 to 2014 results in an estimated 7.9 mcy total sediment presently deposited upstream of the dam.

[3] The original reservoir capacity of 7,018 acre-feet has been reduced to less than 500 acre-feet due to the combination of sedimentation and notching in 1965 and 1977.

developed by the FSSG, and new concepts. A shortlist of six dam removal concepts was identified and screened based on selected key criteria (URS and Stillwater Sciences, 2014a, also provided as Attachment 3 to this report) to arrive at the three concepts being evaluated in this report. Following the evaluation (in this report), up to two alternatives are anticipated to move forward into preliminary design at a future date.

The purpose of this report is to document the technical components of each of the shortlisted dam removal concepts, the criteria developed to evaluate the concepts, the methods and metrics utilized to address or populate the criteria, and the associated evaluation results. It should be noted that assessments and calculations included in this report are associated only with the dam removal components of the project, and do not include other project considerations (e.g., downstream flood mitigation, lost water diversion mitigation, operation and maintenance, etc.).

1.2 Previous Studies

The ***Task 2.1 Hydrologic Assessment*** memorandum (Stillwater Sciences 2014b, Attachment 1 in this report) summarizes hydrologic data and assessments that are relevant to sediment transport and flood analyses associated with any dam removal alternatives for Matilija Dam. The memorandum includes a characterization of the hydrology of the Matilija-Ventura watershed, with particular emphasis on the episodicity of extreme events, analysis of the Ventura River and Matilija Creek hydrographs over the full period of record, and development of hydrologic scenarios at a level of detail sufficient for screening of the initial options.

The ***Task 2.2 Sediment Characterization*** memorandum (Stillwater Sciences 2014a, Attachment 2 in this report) provides a broad characterization of key locations and sources of sediment that may influence the selection of dam removal options, and that are anticipated to be the primary sources of sediment loads into the Ventura River without Matilija Dam in place. The discussion includes sediment presently stored behind the dam as well as the on-going, “natural” sediment load of the watershed that drains to Matilija Creek and the Ventura River.

The ***Task 1.2 Initial Options Screening*** report (URS and Stillwater Sciences 2014a, Attachment 3 in this report) summarizes six initial options for dam removal primarily focused on methods for managing the removal of fine sediment accumulated in the reservoir area, selected from previously considered and newly developed concepts/alternatives. The report includes screening criteria for the initial options, methods and metrics utilized to address the criteria, and the screening results.

The ***Task 3.2 Hydrologic Assessment for Water Supply*** memorandum (URS and Stillwater Sciences 2014b, Attachment 4 in this report) provides an evaluation of the hydrologic conditions of the Ventura River watershed, water supply to Lake Casitas based on historical diversions by the Casitas Municipal Water District (CWMD) and stream gage data, and the impacts of shutting down the Robles diversion during high turbidity periods associated with the removal of Matilija Dam. Water levels in Lake Casitas were analyzed for three scenarios: without Robles diversion, without Robles diversion during one major storm, and without Robles diversion during three consecutive major storms.

The ***Task 3.3 Water Supply Mitigation Options*** report (AECOM 2016), which is being submitted concurrently with this report, presents and evaluates options to offset downstream water supply impacts in the Ventura River watershed, associated with the dam removal concepts considered in this report. Specific water supply impacts and options to offset the impacts, are identified for surface water suppliers such as CMWD and the City of Ventura, as well as groundwater providers such as the Ventura River Water District and Meiners Oaks Water District.

1.3 Summary of the Dam Removal Concepts

In coordination with the Management Team, the Technical Advisory Committee (TAC), and the Design Oversight Group (DOG), three concepts were chosen from six dam removal concepts screened by the Consultant Team (URS and Stillwater Sciences, 2014a). The three concepts are primarily focused on alternative methods for managing the fine sediment accumulated in the Reservoir sub-area (the sediment deposits immediately upstream of the dam and dominated by fine sediment). The coarse sediment would be transported naturally from the reservoir for all three concepts. The three dam removal concepts are briefly described below and in more depth in Section 3.0.

- Dam Removal Concept-1 (DRC-1) Containment Berm with High Flow Bypass: This concept would involve removing the dam and building a temporary containment berm to hold the reservoir sediment in place, with a bypass tunnel to divert creek flow to North Fork (NF) Matilija Creek, until a high flow event occurs to erode a large portion of reservoir fine sediments
- Dam Removal Concept 2A/2B (DRC-2A/2B) Uncontrolled Orifices with Optional Gates: This concept would involve boring tunnels at the base of the dam and then blasting open the tunnels when a high flow event occurs to erode a large portion of reservoir fine sediments. Concept DRC-2B would include the installation of gates on the upstream end of the tunnel orifices if it were found that the large storm did not remove an adequate amount of the accumulated fine sediment from the reservoir. The gates would be closed to allow the reservoir to refill to minimize additional water quality impacts, until the next high flow event occurs. The dam would be removed when a sufficient amount of the accumulated fine sediment has been eroded from the reservoir.
- Dam Removal Concept-3 (DRC-3) Temporary Upstream Storage of Fine Sediment: This option would involve mechanical removal to full depth and temporary upstream storage of both fine and coarse sediment from a portion of the reservoir, creating a channel through the lower third of the reservoir approximately along the pre-dam creek alignment, at the pre-dam creek elevations. The dam would be removed when this earthwork is complete.

1.4 Organization of this Report

This concepts evaluation report is organized as follows:

- **Section 1.0 Introduction**: provides the project background and purpose, and brief summaries of previous studies and the shortlisted dam removal concepts.
- **Section 2.0 Project Objectives and Evaluation Criteria**: summarizes the overall project objectives, along with brief descriptions of the evaluation criteria selected for the dam removal concepts evaluation.
- **Section 3.0 Concept Descriptions:** provides a detailed description of each dam removal concept with a focus on key engineered features and the approach to managing accumulated fine sediment and associated organic material in the reservoir.
- **Section 4.0 Technical Assessments:** describes technical assessments and information that are outside specific evaluation criteria quantification (which is included in Section 5), but ultimately are necessary as baseline information for quantifying criteria, as well as providing context for discussions throughout the report.
- **Section 5.0 Results and Discussion**: summarizes the methods and calculations completed to provide a quantitative or qualitative assessment of the various evaluation criteria.
- **Section 6.0 Evaluation Summary**: provides a summary of evaluation results with cumulative rankings.
- **Section 7.0 Statement of Limitations**: describes the limitations associated with the assessments and evaluations provided in the report.
- **Section 8.0 References**: provides a reference list for the sources cited throughout this report.

This concepts evaluation report includes the following appendices:

- **Appendix A – Dam Removal Concept Drawings**: drawings detailing the conceptual design for each of the dam removal concepts.
- **Appendix B – ROMCC & Schedule Details**: range of magnitude construction cost (ROMCC) estimates and schedules for each of the dam removal concepts.
- **Appendix C – Coarse Sediment Assessment**: summary report of coarse sediment model setup and preliminary results associated with the initial options considered for the removal of Matilija Dam.

2.0 Project Objectives & Evaluation Criteria

2.1 Project Objectives

In the January 2013 scope of work for dam removal and sediment transport developed by the TAC, project design objectives were refined and documented as shown below:

1. Biological Objectives:
    a. restore effective fish passage within one year after the dam is removed;
    b. minimize, to the degree feasible, ecological impacts of project implementation;
    c. restore aquatic/riparian/upland habitats in the reservoir area;
    d. encourage beach nourishment, as feasible.

2. Cost-Effectiveness Objectives:
    a. reduce cost/maximize cost-effectiveness;
    b. develop a feasible removal plan, within the context of the federally authorized Alternative 4b (presumably, if a proposed solution were similar enough to Alternative 4b, it may be possible to utilize previously authorized federal funds [tied to the authorized project], should those funds become available).

3. Sediment Transport and Water Quality Objectives:
    a. maximize mobilization of fine material during high flow events;
    b. reduce mobilization during low flows;
    c. minimize artificial or permanent stabilization material (e.g., riprap or soil cement) in the project area and environmentally sensitive areas;
    d. minimize project-related turbidity increases and nutrient inputs to Casitas reservoir;
    e. maintain existing level of safe supply of water to customers of all water districts.

These objectives are the basis of formulation of the current phase of technical work and this evaluation report.

2.2 Evaluation Criteria

Based on subsequent discussions with the TAC and the DOG, the objectives listed above were used to develop a refined list of evaluation criteria to allow for comparison of the shortlisted concepts developed and summarized in this report (Section 3). Certain objectives listed above are not included in the current evaluation because they are not significantly different between the three shortlisted concepts. Other objectives (e.g., context of the federally authorized Alternative 4b) were determined to be outside of the technical nature of this evaluation. In total, the objectives for steelhead passage and health, existing and post-project vegetation communities, implementation costs and risks, and water supply were judged to provide the clearest distinction between concepts, resulting in the following pertinent and manageable list of evaluation criteria (Table 2.2-1).

Table 2.2-1. Evaluation Criteria

	Evaluation Category	Evaluation Criteria Description
A.	**Biological Resources**	
	Steelhead Passage	Time to achieve steelhead passage through dam/reservoir area after project implementation
	Steelhead Health	Scale of severity of impacts of suspended sediment on steelhead
	Ecological Health	Acreage of vegetation communities impacted by actions at dam/reservoir
	Ecological Health	Acreage of future vegetation communities within reservoir area
B.	**Technical & Implementation**	
	Cost	Rough Order of Magnitude Construction Cost
	Risk Management	Inherent risk and/or flexibility to manage risk and react to unanticipated conditions
C.	**Sediment Transport & Water Quality**	
	Water Supply	Dry cycle percent reduction in Lake Casitas water storage levels and water quality impacts

The approach to evaluating the dam removal concepts involves quantitative and qualitative assessments of the various evaluation criteria listed above, using relevant tools and empirical data available from analogous dam removals elsewhere (Section 4). After the criteria are populated, the dam removal concepts can be ranked under each criterion, and then cumulatively (Section 6). The goal for the evaluation is to utilize the criteria and cumulative rankings to select those concepts that best meet the project objectives, given the anticipated funding constraints.

The following sections provide an overview of the evaluation criteria and the methods that were used to quantify these criteria for each dam removal concept.

2.2.1 Biological Resources

Criteria that are associated with existing and future biological resources at the project site include steelhead passage, steelhead health, impacts to existing vegetation communities, and anticipated post-project vegetation communities. While the criteria described below for steelhead passage and habitat inherently have a more watershed-wide perspective (steelhead passage to upstream watershed; steelhead health based on downstream suspended sediment concentrations), the assessment of vegetation impacts and benefits are limited to the general reservoir area. This was necessary to accommodate the available funding constraints for the evaluation. In general, while temporary downstream impacts to vegetation communities and wildlife habitat may be greater for those concepts that flush a significant amount of fine sediments, the long-term benefits of re-establishing more natural sediment continuity will be similar for all three dam removal concepts.

Each of the biological resources criteria are described in more detail below.

2.2.1.1 Steelhead Passage

The assessment of how quickly fish passage will be restored is based on the project construction duration, any “waiting period” associated with sediment flushing approaches that require a significantly large storm event, and the likely delay between the initial release of water through the dam site and the establishment of a fish-passable channel through the impounded sediment deposits. Other recent dam removal case studies, where fish passage was a key element of the project and thus monitored carefully, were also considered. Based on these considerations, implementation durations (in years from start of project construction) were estimated for each dam removal concept.

2.2.1.2 Steelhead Health

Section 4.4 provides a characterization of the effects of high suspended sediment concentrations (resulting from the various dam removal concepts) on salmonid health in the downstream channel of Matilija Creek and the Ventura River, based on Newcombe and Jensen's (1996) quantified index of "severity-of-ill-effects". Two refinements to this analysis could be added, but are not included in the present analysis:

1. Identification of the spatial and temporal distribution of each life stage in the watershed downstream of the dam, relative to expected areas of elevated suspended sediment. For each life stage, potential effects could be estimated by evaluating the predicted magnitude and duration of TSS concentrations.

2. Consideration of the proportion of the cohort predicted to be in the main stem during high suspended sediment events, including both spatial distribution (i.e., proportion of the life stage expected to be in the main stem compared to tributaries, and their proximity to the dam) and life-history timing (i.e., proportion of the population expected to be present during the period of effect). The absolute effects thus depend in part on the season in which a high-TSS event occurs and the status of the particular cohort.

For evaluating the *relative* differences between dam removal concepts, however, these variations in life-history stage(s) and affected locations are not included because all shortlisted concepts involve the same locations and period (i.e., wet-season) for dam removal and the release of sediment.

It is also important to note that all areas upstream of the impounded sediments and within tributaries that are outside of the influence of any flushed sediment will remain unchanged. For lower tributaries, this provides a certain level of stability for fish and other aquatic species, while newly accessible areas upstream of the reservoir (and impounded sediments) will provide significant long-term benefits for steelhead health and population.

2.2.1.3 Impact to Existing Vegetation Communities

A Geographic Information System (GIS)-based desktop analysis was conducted to identify existing vegetation communities within the project area. The GIS data used in the analysis were obtained from the Matilija Dam Giant Reed Removal project (Ecosystems Restoration Associates 2007).

A site visit was conducted on March 5, 2015, during which occurrence of these vegetation communities was ground-truthed and the presence of dominant species was confirmed. An overview of the field reconnaissance is provided in Section 4.1. The total number of acres of each vegetation community directly impacted by the project was then calculated in GIS using the area of impact associated with each dam removal concept.

Vegetation communities considered for impact evaluation include the following:

- Freshwater Marsh
- Riparian Scrub
- Riparian Woodland
- Oak Woodland
- Coastal Sage Scrub
- Mixed Chaparral

2.2.1.4 Post-Project Vegetation Communities

Post-project vegetation communities were developed based on an understanding of the vegetation currently existing at the site (as summarized in Section 4), as well as the anticipated topography and hydrology expected to exist after project implementation (as described in Section 3-Concept Descriptions). In addition, a guided natural succession restoration approach was developed to leverage existing communities that are anticipated to persist given post-project conditions, while guiding the transition of other communities through selective seeding and planting. A detailed description of the restoration approach is provided in Section 5.

2.2.2 Technical & Implementation Considerations

Criteria that are technical in nature and/or associated with project implementation include range of magnitude construction cost, risk management, and impacts to water supply. Each of these criteria is described in more detail below.

2.2.2.1 Range of Magnitude Construction Cost

The ROMCC estimates for the dam removal concepts are based on the descriptions of the concepts in Section 3. The ROMCCs are the costs directly associated with each dam removal concept and do not include the following:

- Acquisition of real estate
- Robles Diversion Dam improvements
- Downstream flood mitigation
- Foster Park improvements
- Loss of diversion mitigation costs
- Operation and maintenance costs

The ROMCCs also do not include other related project costs, such as engineering, environmental compliance/permitting, Owner's construction management oversight, and any post-construction activities.

2.2.2.2 Risk Management

Inherent risks exist with any dam removal scenario, regardless of the implementation strategy. The purpose of this criterion is to assess the ability to adjust, adapt, or manage risks for each concept during each phase of project implementation (as well as post-flush considerations).

2.2.3 Impact to Water Supply

Potential impacts due to the release of fine sediment following Matilija Dam removal are primarily associated with increased suspended sediment concentrations. If diversions were to occur during high-concentration events, the impacts could include:

- Increases in suspended sediment concentration causing operational difficulties for water diversion at Robles Diversion Dam; and
- High organic content of suspended sediment with associated high oxygen demand (OD), causing long-term water quality problems, if diverted to Lake Casitas.

Alternatively, if diversions were not to occur during periods of high TSS concentrations and/or high OD, the loss of the diversion volume could have short- or long-term impacts on the availability of water in Lake Casitas.

These impacts will be evaluated first by determining the likely order of magnitude of TSS and organic material concentrations during each stage of dam removal and sediment erosion for each concept (Section 4), and comparing those levels with the historical range under which diversions have taken place in the past. For those conditions beyond the historical range, the percent reduction in storage levels at Lake Casitas (which is a function of diversion shutdown associated with each concept) compared with current conditions/operations will be estimated, recognizing that dam removal would not occur at all unless a significant (~4-year) flood was projected to occur. This estimate will be based on a “typical” dry hydrologic cycle, as defined in URS and Stillwater Sciences (2014b).

A similar assessment (URS and Stillwater Sciences 2014b), assuming a “typical” wet hydrologic cycle (similar to a relatively wet period between 1993 and 1998 followed by a generally dry period through 2013), indicated that implementation of a dam removal option similar to DRCs-1 and 2 could occur without any significant effect on storage in Lake Casitas.

3.0 Concepts Descriptions

In coordination with the Management Team, the TAC, and the DOG, three concepts were chosen from six initial dam removal options screened by the Consultant Team (URS and Stillwater Sciences, 2014a). The three shortlisted concepts are primarily focused on methods for managing the fine sediment and organic material accumulated in the Reservoir sub-area. All three concepts involve natural transport of most or all of the coarse sediment, from the reservoir to the downstream reach.

The following descriptions and evaluation of the transport of fine sediment out of the impoundment area make reference to two discrete phases of erosion and transport, using terminology introduced in the Initial Options Screening Report (URS and Stillwater Sciences 2014a). From an initial, un-channeled condition (Figure 3.0-1a), "Phase I" erosion occurs while the fine sediments in the Reservoir and Delta sub-areas remain accessible to the flow (i.e., the flow is in direct contact with the fine sediment deposits) (Figure 3.0-1b) and "Phase II" erosion occurs once fine sediment is no longer directly accessible to the flow (Figure 3.0-1c).

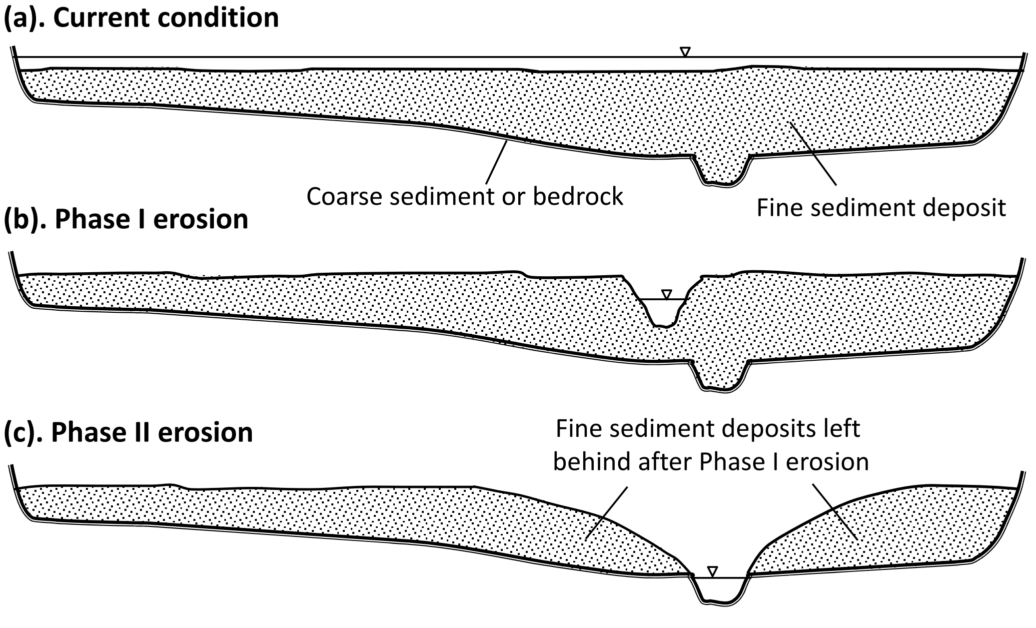

Figure 3.0-1. Sketches showing the two phases of fine sediment erosion. (a) Current, pre-incision condition; (b) Phase I erosion when fine sediment is directly accessible to the flow, presenting a virtually unlimited supply of sediment with transport limited only by the capacity and rate of discharge; and (c) Phase II erosion when fine sediment is no longer directly accessible to the flow.

During Phase I erosion, the high-energy flow powered by the large discharge and steep gradient will cut through the fine sediment deposits quickly. Net transport rates are limited only by the discharge of water. The maximum anticipated TSS concentration, estimated based on empirical data, could be as high as 10^6 mg/l. It is not anticipated that fine sediment cohesiveness would be a limiting factor for Phase I erosion given the extremely high forces associated with the flushing flow; future fine sediment characterization could help confirm this assumption. Fine sediment characterization for this site could be developed through a site geotechnical investigation during a future project planning phase. This data could be used to refine the channel evolution assessment, as well as develop a monitoring and adaptive management plan to address remaining fine sediment (post-flushing).

Phase II erosion will occur at rates more typical of fluvial erosion and transport, with a somewhat indeterminate but declining rate of additional sediment input from local mass failures of the bank, and sheet wash and rilling of the exposed upper surface of the fine sediment deposits adjacent to the incised channel. The likely rate(s) of these sediment-transport processes are evaluated in detail in Section 4.

The following sections provide detailed descriptions of the three shortlisted dam removal concepts being evaluated in this report. All drawings referred to in the following sections can be found in Appendix A.

3.1 Dam Removal Concept – 1: Containment Berm with High Flow Bypass

The primary objective of this dam removal concept would be to use one high flow event, having a minimum average daily flow of approximately 1,700 cubic feet per second (cfs)[4], to quickly erode and transport as much fine sediment and organic material as possible out of the reservoir and through the downstream reaches to the ocean. As described above, channelization and sediment transport during the high flow event would occur in two phases: Phase I sediment transport would occur as the channel cuts through the sediment resulting in the highest sediment loads during the high flow event, and Phase II sediment transport would occur as some sediment from the banks of the downcut channel and adjacent upland areas continue to erode. Channelization through the Reservoir sub-area would be allowed to form naturally through transport of coarse sediment to the downstream reaches over time. Fish passage during the channelization process may need to be monitored, and if necessary, construction equipment may need to be mobilized to maintain effective passage.

This dam removal concept is intended to minimize the duration and associated high turbidity impacts to downstream water diversions and ecology by concentrating the majority of fine sediment erosion and transport into a single storm event. Due to the uncontrolled nature of the sediment erosion and the large amounts of organic debris that may be present within/above the accumulated sediment, future consideration (i.e., additional studies or development of contingency plans) of high organic debris loads and associated flood control risk (during the fine sediment erosion process) would be necessary to avoid downstream impacts, likely limited to the relatively narrow reaches upstream of Robles Diversion Dam, especially at locations that are naturally confined by bedrock outcrops or valley walls.

In order to set the project up to “wait” for a high flow event, the dam would be removed, while flows smaller than the minimum high flow event would bypass the lower reservoir and dam site. The following major features would need to be implemented and are shown conceptually in Figure 3.1-1 and Drawing 1:

- Bypass Tunnel
- Upstream Temporary Cofferdam
- Temporary Containment Berm
- Single Season Dam Removal

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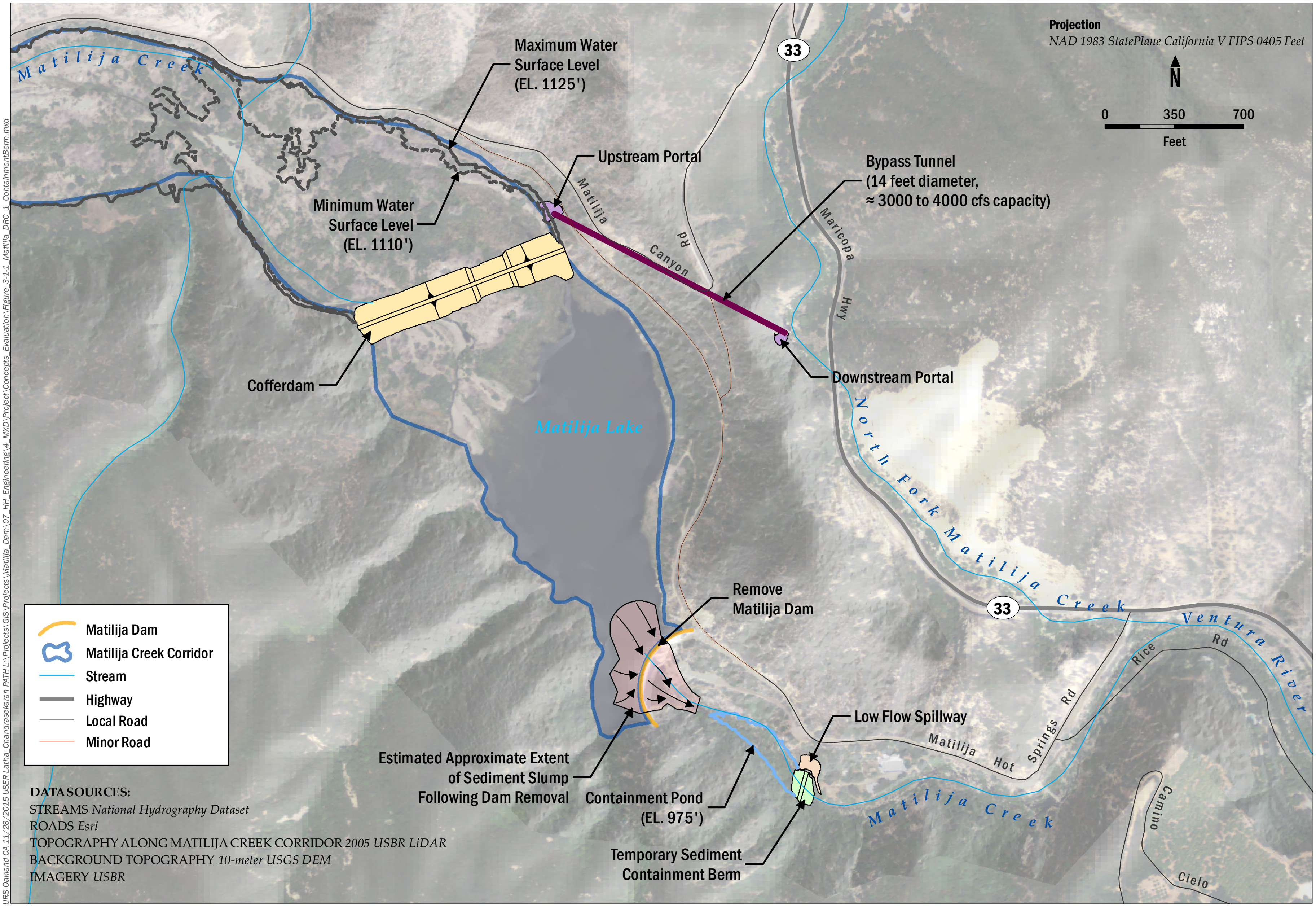
[4] The minimum high flow event on Matilija Creek that is assumed to be able to transport the large quantities of fine sediment over a short period of time is a storm having an average daily flow of at least 1,700 cfs, corresponding to a peak daily flow of about 3,000 cfs (Stillwater Sciences, 2014b). This is approximately a 4-year recurrence interval on Matilija Creek.



DATA SOURCES:
STREAMS *National Hydrography Dataset*
ROADS *Esri*
TOPOGRAPHY ALONG MATILIJA CREEK CORRIDOR *2005 USBR LiDAR*
BACKGROUND TOPOGRAPHY *10-meter USGS DEM*
IMAGERY *USBR*

URS Oakland CA 11/28/2015 USER Latha_Chandrasekaran PATH L:\Projects\GIS\Projects\Matilija_Dam\07_HH_Engineering\4_MXD\Project\Concepts_Evaluation\Figure_3-1-1_Matilija_DRC_1_ContainmentBerm.mxd

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FIGURE 3.1-1
Dam Removal Concept 1 - Containment Berm with High Flow Bypass

These major features are discussed in more detail below.

3.1.1 Bypass Tunnel

Prior to the high flow event, smaller flows would be routed around the reservoir to prevent them from eroding accumulated sediment that could cause repeated high turbidity impacts to the downstream reach. A flow bypass would be constructed to divert flows up to the peak flow (3,000 cfs) of the minimum high flow event, plus some additional flow capacity as a safety factor. The flow bypass could be accomplished by constructing either a series of bypass pipelines along the canyon valley to a point downstream of the temporary containment berm, or a bypass tunnel to connect into NF Matilija Creek.

Preliminary computations indicate that the pipelines would be more costly and difficult to construct; therefore, a bypass tunnel has been included for this dam removal concept.

The bypass could be aligned to transport flow from Matilija Creek (upstream of the fine sediment) to NF Matilija Creek as shown in plan and profile on Drawing 2. The conceptual design of the tunnel is a 14-foot-diameter horseshoe tunnel having a length of about 1,300 feet, a slope of about 0.9 percent, and an estimated capacity of 3,200 cfs. The topographic expression of NF Matilija Creek controls the location of the downstream portal and fixes the invert elevation of the downstream end of the tunnel at 1,098 feet. The invert elevation of the tunnel at the upstream end is 1,110 feet. Sediment transport would be initiated when a storm with a high enough peak flow to spill over the cofferdam occurs, at which time a gate installed near the upstream portal would be closed, so that the high flow event would be redirected over the cofferdam. This would cause a channel to be eroded through the cofferdam, allowing the high flow event to pass through the reservoir.

Geologically, the alignment of the tunnel passes through highly folded and faulted siltstone with interbeds of sandstone of the Juncal Formation from the middle to late Eocene period (Siang and Jones, 2006). The siltstone and sandstone layers are generally oriented perpendicular to the tunnel alignment and dip steeply to the northwest at about 60 to 70 degrees at the upstream portal and near vertical at the downstream portal. A landslide of unknown thickness has been mapped in the upstream portal (Siang and Jones, 2006). The thickness of this landslide deposit would need to be determined through a field investigation program to evaluate the impact on the feasibility of turning the tunnel under at this location.

Near-vertical bedding coupled with the likely fractured and seamy nature of the bedrock will result in potential unstable blocks and short stand-up time during excavation of the portals and the tunnel. The interbedded weak shale layers in the vicinity of the dam are susceptible to air slaking (Bechtel 1965), thus the shale layers exposed in the portal excavations and the tunnel are also likely to air slake. Based on these observations, early and carefully placed portal and tunnel support systems will be required to preserve ground stability and provide for worker safety. Support systems would likely include horizontal spiling in the roof of the tunnel to control block falls from the near vertical bedding and a combination of rock bolts and shotcrete.

The impact of the combined flows of Matilija Creek and NF Matilija Creek on the lower NF Matilija Creek channel prior to the high transport flow event was evaluated based on the historical record of flows for the two creeks. The estimated combined peak flow for a peak flow event in Matilija Creek of 3,000 cfs is 4,200 cfs. This flow is slightly greater than a 10-year event for NF Matilija Creek alone (3,857 cfs), based on prior studies along State Route 33 adjacent to Mossler Quarry (CWE 2012) downstream of the tunnel outlet. Thus, bank erosion due to the combined flows of Matilija and NF Matilija Creeks while waiting for the high flow transport event should not significantly increase bank erosion between the downstream portal of the tunnel and the confluence of the two creeks.

3.1.2 Upstream Temporary Cofferdam

A cofferdam would be constructed across the reservoir just upstream of the current pool at about Station 70+00 and just downstream of where Rattlesnake Canyon empties into the reservoir (see Drawing 1). This location is purposely placed as far downstream as possible to minimize both the length of the bypass tunnel and the volume of localized storm water flow that would pass over the fine sediment prior to occurrence of the high flow event. The cofferdam would divert Matilija Creek flows into the upstream tunnel portal (bypass entrance). The quality of the bypassed water would be similar to flows already seen at Robles Diversion and other downstream diversions.

The cofferdam would be constructed using alluvial materials available within the Reservoir sub-area that could be eroded during the high flow event. Conceptually as shown on Drawing 3, the cofferdam would have a length of about 1,100 feet, upstream and downstream slopes of 3H:1V, an overall height of about 30 feet, and a crest elevation of 1,130 feet. A 175-foot-wide by 5-foot-deep fuse plug with an invert elevation of 1,125 feet would be built into the cofferdam as shown on Drawing 3. The volume of water stored behind the cofferdam would range from approximately 160 acre-feet during summer low flows and up to 800 acre-feet for flood events that just approach the fuse plug elevation of 1,125 feet. The purpose of the fuse plug would be to control where the high flow event would cut through the cofferdam and potentially help control where the post-flush channel would develop in the reservoir sediment.

Overtopping and breaching of the cofferdam during the triggering flood event would result in a large, but short, increase in flows in the channel, as water impounded by the cofferdam are released. The higher additional flow would benefit the removal of reservoir sediment, but could result in significant downstream impacts. A simplified estimate of the additional flow that was performed assuming total breaching of the dam and evacuation of the water behind the cofferdam would occur in the range of 15 to 30 minutes. Based on these assumptions, the average additional flows might be in the range of 20,000 to 40,000 cfs, up to 7 to 13 times the peak flow for the minimum triggering storm event. Future design studies would need to include an analysis to better estimate the size and determine the impact of the flood wave that would accompany breaching of the 800 acre-foot pool behind the cofferdam, during initiation of sediment transport associated with the high flow event.

3.1.3 Temporary Containment Berm

A temporary containment berm would be constructed approximately 950 feet downstream of the dam and 2,200 feet upstream of the confluence of Matilija Creek and NF Matilija Creek as shown in Figure 3.1-1 and Drawing 4. Conceptually, the containment berm would have a length of about 150 feet, upstream and downstream slopes of 3H:1V, an overall height of about 20 feet, a crest elevation of 980 feet, and a capacity of 8 acre-feet at the spillway crest elevation of 975 feet. Materials for construction of the containment berm would be obtained from the alluvial deposits in the Matilija Reservoir area. The purpose of the containment berm is to allow the dam to be removed during the dry season while preventing fine sediment in the reservoir from moving too far downstream, thereby limiting initial downstream impacts.

The location of the containment berm has been selected so that the slumping sediment (shown with a slope varying between about 5H:1V and 7H:1V) would not impinge on the berm[5]. The height of the berm was selected to be high enough to control nuisance releases of sediment due to stormwater flows from the local watershed downstream of the cofferdam location, without creating an impoundment that would fall under the jurisdiction of the Division of Safety of Dams (DSOD) (although the dam removal plans would require DSOD approval). The containment berm would be designed to fail during the high transport event so as to not restrict the mobilization of the fine sediment.

The conceptual design also includes a small spillway sized to pass up to a 5-year storm event (115 cfs) associated with the local nuisance releases. The local nuisance watershed extends upstream only to the location of the high flow bypass upstream cofferdam, and to the top of the adjacent hillslopes to the west and east. This watershed totals approximately 300 acres, comprising the lower reservoir open water, the vegetated Delta sub-area sediment deposits, and the adjacent densely vegetated hillsides.

3.1.4 Single Season Dam Removal

The dam would be removed during the same season as construction of the bypass tunnel, cofferdam, and containment berm. It is desirable to remove the dam with as little fine sediment handling as possible, i.e., without dredging or excavating sediment upstream of the dam to access the dam for demolition, in order to minimize costs. The method of removal of the portion of the dam that is below the sediment that would require the least fine sediment handling is blasting. Removal of the portion of the dam above the fine sediment level could be done using either a hydraulic hoeram or blasting methods.

Dam demolition for DRC-1 would be performed in two phases: Phase I would remove the dam down to the sediment level (El. 1075 feet) using hydraulic hoeram to break up the concrete and Phase II would remove the remainder of the dam by blasting (see Drawing 4). Hydraulic hoeram methods would allow access to the upper portion of the abutments to be systematically stabilized with rock bolts if found to be necessary and would minimize the volume of concrete that might be buried in slumping sediment following blasting of the dam.

Conceptually, blasting of the portion of the dam below the reservoir sediment would involve drilling a series of lines of three near vertical 3-inch-diameter blast holes, every 5 feet along the crest of the dam. The blast holes would be drilled using compact track drills, given the narrow approximately 9-foot-wide dam crest. The conceptual blasting plan assumes a powder factor of 1.42 pounds per cubic yard of concrete. The number of blast holes is estimated to be 366, loaded with about 68,000 pounds of explosive. Blasting of the dam will generate ground vibration and air over-pressure. The closest infrastructure to the dam appears to be buildings associated with Matilija Hot Springs, located about 1,000 feet west of the dam. Ground vibration would be controlled by determining the maximum allowable charge per blasting

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[5] An assessment of the degree to which the sediment will slump and move downstream following removal of the dam by blasting would require further geotechnical and mud flow analyses, if this dam removal concept is carried forward. A review of some tailing dam failures suggest that sediment movement may have been limited to five to ten times the sediment height had the tailings ponds been dewatered prior to their failing.

delay. Conceptual level calculations limiting ground vibration at 1,000 feet to a conservative 0.5 inches/second at the nearest building suggests on the order of about 450 pounds of explosive/delay. It is not likely realistic that ground vibrations could be kept this low, given that the average line of blast holes might have between 550 to 600 pounds of explosive. Over-pressure is controlled by specifying a minimum amount of concrete burden between the blast holes and the downstream face of the dam.

Blasting of the dam would have the potential for contaminating surface and groundwater. Commercial explosives contain 70% to 94% ammonium nitrate by weight. Water can leach ammonia and nitrates from spilled or incompletely detonated explosive. The risks associated with such contamination are mitigated by specifying strict cleanup procedures for spills and the use of fixed-cartridge explosives.

The reservoir would be dewatered while the exposed section of the dam is removed prior to blasting. The concrete removed from the dam would be broken up and hauled to a recycling plant. After blasting of the remaining section of the dam, some of the concrete would be buried in the slumping sediment and would not be able to be removed and disposed of until after the high flow event. It is likely that some of the remaining concrete would be carried downstream during the high flow event.

3.1.5 Post-Flush Condition and Restoration

A possible alignment of the post-flush channel through the reservoir sediment following the high transport storm is shown on Drawing 5. The side slopes of the channel will vary through the reservoir, being as steep as 1.5H:1V on the outside of bends and as flat as perhaps 3H:1V in relatively straight reaches. The location of the channel alignment is anticipated to develop in the vicinity of the historic creek alignment, and is shown on Drawing 5. Also included on Drawing 5 are simulated flood inundation lines for the 25-year and 100-year flows of 25,500 cfs and 67,754 cfs (Stillwater Sciences 2014b), associated with the estimated post-flush channel profile.

Restoration following flushing would include grading the remnants of the cofferdam on either side of the post-flush channel to blend into the topography. The bypass tunnel could be abandoned by placement of 20-foot-long concrete plugs on the upstream and downstream ends. The tunnel between the plugs could be left unfilled. Alternatively, the tunnel between the plugs could be filled with controlled low strength material such as cellular concrete.

After the initial post-flush channel is formed, significant migration of this channel is not expected to occur because of the restriction of the historical erosion-resistant river banks and the substantial incision of the channel (over 50 feet throughout the Delta and Reservoir sub-areas). After the formation of the deeply incised channel, channel avulsion (i.e., the channel changing course and jumping to a different location, thus releasing more fine sediment through incision of a different channel) is not possible because it does not occur for deeply incised channels, such as those formed in the Reservoir sub-area following dam removal where the high banks restrict lateral movement of the flow. Although over the (very) long term, re-grading of the impounded sediment deposits by natural processes of bank erosion and channel migration would ultimately provide the opportunity for local channel aggradation and the potential for avulsions within the upstream channel deposits, this process is already active throughout the upper watershed wherever the channel is unconfined and would not represent an unusual event during any subsequent high flows that would be necessary for its initiation. The majority of the remaining accumulated sediment within the reservoir will persist until long after the acute impacts of dam removal have passed, and the associated existing vegetation communities will remain and slowly transition to adapt to a new and more natural water table and frequency of inundation.

Planting, hydroseeding, and irrigation will be completed to help facilitate this transition and support development of a diverse, native habitat. A summary of the restoration approach and associated re-vegetation effort is provided in Section 5, and anticipated post-project vegetation communities are shown on Drawing 6.

3.2 Dam Removal Concept – 2A: Uncontrolled Orifices/2B: Optional Gates

The objective of this dam removal concept (DRC-2A) would be to erode and transport as much fine sediment as possible from the reservoir, while minimizing costs and time associated with large bypass/containment structure construction and sediment removal. The fine sediment mobilization would be achieved by allowing flow through two uncontrolled orifices, whose opening would be coordinated to coincide with a sufficiently high flow event (as summarized for DRC-1). The orifices are sized to pass the minimum high flow event in an unpressurized condition and are located to maximize mobilization of the Reservoir sub-area sediments from the upstream face of the dam. However, if the unpressurized capacity of the orifice is exceeded, it could result in reduced reservoir sediment erosion and transport for the duration of the capacity exceedance[6]. The diameter and number of tunnels could be increased to increase the magnitude of the high flow event (something greater than a 4-year event) that could pass through the reservoir without choking the tunnels and forming a temporary reservoir.

Channelization through the Reservoir sub-area would be allowed to form naturally through transport of coarse sediment to the downstream reaches over time. Fish passage during the channelization process may need to be monitored, and if necessary, construction equipment may need to be mobilized to adaptively manage and maintain effective passage.

If, following the high flow event, a survey of the reservoir indicates a significant potential risk for further Phase I sediment transport during a future storm, a decision could be made to switch to DRC-2B, which would add gates at the upstream end of the orifices to allow for a second flushing during a future high flow event. Installation of the gates after the first high flow event, if determined to be needed, would allow flexibility to “wait” for another similar event to transport the remainder of the fine sediments, while allowing for cleaner downstream water diversions during the waiting period (as the reservoir fills up and spills). In this document, DRC-2B is evaluated as a separate concept to document the range of impacts associated with concepts that initially use uncontrolled orifices.

Similar to DRC-1, future consideration (i.e., additional studies and/or development of contingency plans) of high debris loads and associated flood control risk in the narrow reaches upstream of Robles Diversion Dam would be necessary during the fine sediment erosion process. In addition, a minor risk for plugging the orifices by debris during the fine sediment erosion process exists for DRC-2.

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[6] For the purposes of sizing the orifices, it has been assumed that development of a water surface that is 2 feet above the top of the orifice would not significantly reduce the ability of the orifice to transport sediment. At higher flows, the head over the top of the orifice and the size of the pool upstream of the orifice will increase, resulting in reduced velocities through the growing reservoir and decreased transport of sediment until the reservoir drains again on the descending limb of the high flow event.

The following major features would be implemented, and are shown conceptually in Figure 3.2-1 and Drawings 7 through 9:

- Installation and Operation of Uncontrolled Orifices
- Installation of Optional Gates (DRC-2B)
- Dam Removal

These major features are discussed in more detail below.

3.2.1 Installation and Operation of Uncontrolled Orifices

Installation of the orifice(s) could be completed without prior fine sediment handling, thereby keeping construction costs relatively low. In addition, the orifice construction method described below makes it unnecessary to construct a temporary containment berm and upstream diversion (since reservoir sediments are not directly exposed to storm flows prior to the high transport event).

Two twelve-foot diameter tunnels would be bored through the base of the dam from the downstream face up to a safe and stable distance (conceptually estimated to 10 feet) from the upstream face. The two tunnels sloping downstream at a 5 percent grade would conceptually have a combined maximum unpressurized capacity of about 3,300 cfs. A downstream system of walers or horizontal beams would be installed above and below the tunnels if structural stability analyses of the dam indicated the need for additional support to maintain the integrity of the arch.

The tunnels would be mined through the dam using drilling and concrete breaking, wire sawing methods, or possibly micro-blasting techniques. A probe hole would be drilled at each tunnel location to verify the exact location of the upstream face of the tunnel. Following drilling, each probe hole would be plugged with grout. A rock trap consisting of a pit excavated into the floor of the tunnels just downstream of the plugs would be considered to facilitate capture of debris from the plug blast.

The remaining 10 feet of concrete that would connect through to the upstream side of the dam would be set up for rapid mobilization of a controlled blasting operation. A series of blast holes would be drilled to within 1 to 1½ feet of the upstream face of the dam. The open holes would be plugged and secured until a high transport storm is approaching.

Two additional features would be included to aid in initiating and maintaining the flow of sediment-laden water through the conduits; a vertical hole from the crest of the dam into the top of each of the tunnels, and vertical, open large diameter pipes installed at the upstream face of the dam at each orifice location. The vertical hole would allow placement of a concussion charge into the tunnel to clear obstructions if they occur. A similar provision was in place at Condit Dam but was not needed, as the tunnel did not obstruct following the plug blast. The vertical, open, large-diameter (6-foot or larger) pipe would have a top elevation that would be above the sediment level and a bottom elevation just above the top of the orifices, such that water would flow down the pipe following the orifices being blasted open. The flow would act as a water jet that would assist in the erosion of sediment until a hole in the sediment at the face of the dam has developed, allowing water in the reservoir to have direct access to the orifices.

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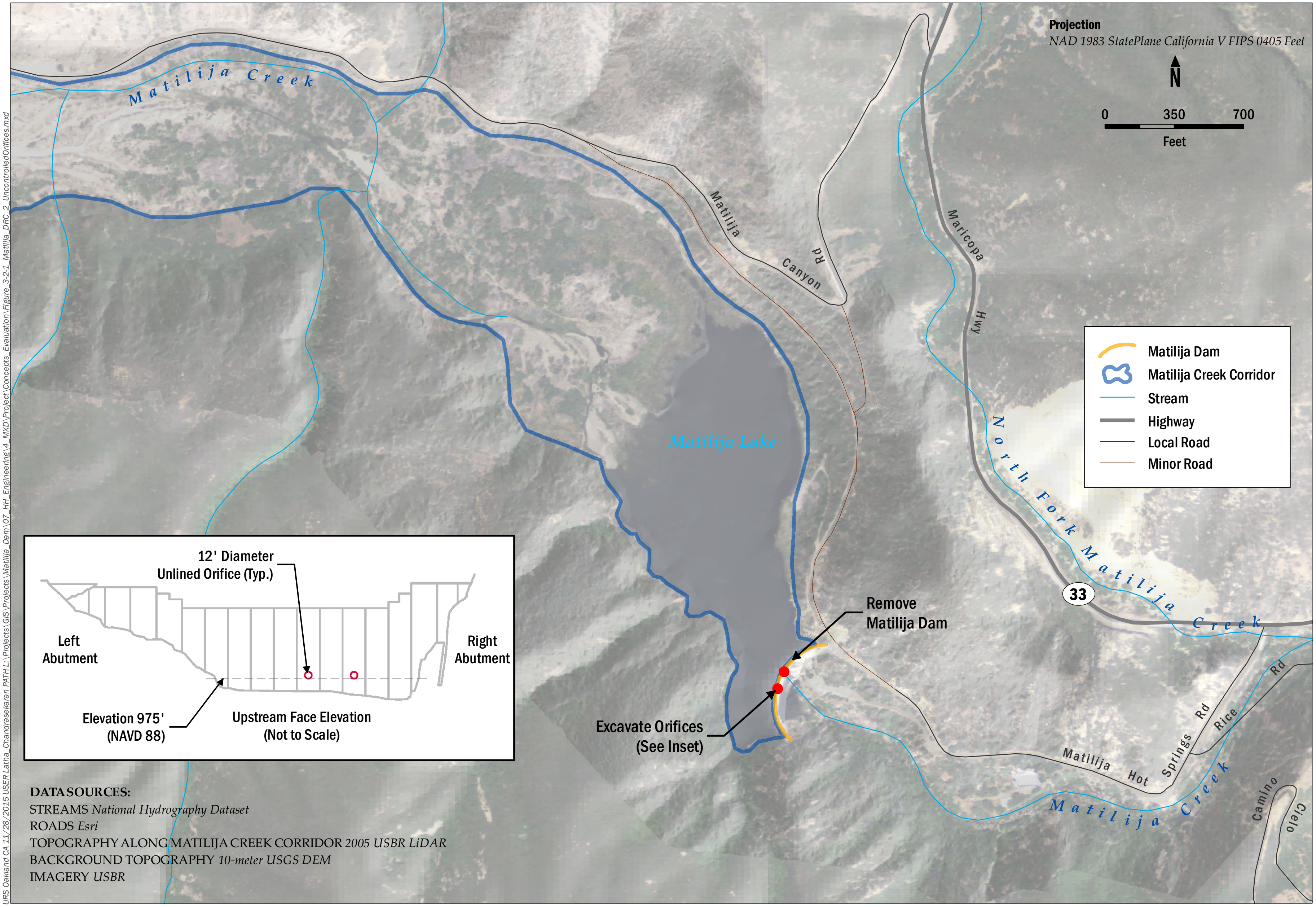

DATA SOURCES:
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FIGURE 3.2-1

Dam Removal Concept 2 - Uncontrolled Orifices with Optional Gates

A standby agreement would be in place with a contractor requiring the necessary products, blaster, and crew to execute the tunnel plug blasts within a certain time frame after notification. Ideally, the tunnel plugs would be detonated simultaneously as flows over Matilija Dam begin to increase during the high flow event allowing fine sediment to be flushed from the reservoir through the uncontrolled orifices.

3.2.2 Post-Flush Condition and Restoration

A possible alignment of the post-flush channel through the reservoir sediment following the high transport storm would mimic DRC-1, and is shown on Drawing 5. The side slopes of the channel might vary through the reservoir being as steep as 1.5H:1V on the outside of bends and as flat as perhaps 3H:1V in relatively straight reaches. The location of the channel alignment is anticipated to develop in the vicinity of the historic creek alignment, and is shown on Drawing 5. Also included on Drawing 5 are simulated flood inundation lines for the 25-year and 100-year flooding events associated with the estimated post-flush channel profile.

After the initial post-flush channel is formed, significant migration of this channel is not expected to occur because of the restriction of the historical erosion-resistant river banks and the substantial incision of the channel (over 50 feet throughout the Delta and Reservoir sub-areas). Therefore, the majority of the remaining accumulated sediment bank within the reservoir will persist, and the associated existing vegetation communities will remain and slowly transition to adapt to the new water table and frequency of inundation. Planting, hydroseeding and irrigation will be completed to help facilitate this transition and support development of a diverse, native habitat. A summary of the restoration approach and associated re-vegetation effort is provided in Section 5, and anticipated post-project vegetation communities are shown on Drawing 10.

3.2.3 Installation of Optional Gates (DRC-2B)

In the event that substantial fine sediment remained after the first high flow event, an assessment would be needed to determine if a portion could be permanently stabilized in place (naturally or by mechanical means), or whether additional creek flows or larger future high flow events would mobilize the remaining material causing some level of unacceptable downstream impact. Potentially, the upstream 3 to 5 feet of each orifice could be over-excavated to a diameter of 14 feet, steel sluice gate thimbles could be installed in the over-excavated tunnels, and gates could be installed on upstream side of dam (see Drawing 9). Either the existing outlet works (having an invert elevation of 1,025 feet) would be cleared of any remaining sediment and made operational or a new 6-foot-diameter penetration, with an invert elevation to be determined, would be constructed to maintain the reservoir at a lower level following closure of the gates, thereby increasing dam stability (by decreasing the hydraulic head on the dam structure) until the sufficient fine sediment has been evacuated and the dam can be removed.

Operationally, the sluice gates would remain in the closed position until a minimum high flow event is forecast. When the high flow event is forecast, downstream diversion facilities would be shut down and the sluice gates opened to dewater the reservoir. The initial opening could result in high concentrations of fine sediment discharging through the gates depending on how much additional sediment buildup occurs in the reservoir while waiting for the next minimum high flow event.

3.2.4 Dam Removal

Under this concept, the dam would be removed in a single phase in the dry season, following the determination that sufficient sediment was removed from behind the dam. Dam demolition would be by blasting similar to what was described for DRC-1. The concrete from the demolition would be broken up and hauled to a recycling plant.

3.3 Dam Removal Concept – 3: Temporary Upstream Storage of Fine Sediment

The objective of this dam removal concept is to provide a concept that has some similarity to the EIS/R Alternative 4b, but reduces the volume of excavated sediment and eliminates the need for a dredge-and-slurry system. These objectives are achieved by handling and temporary stabilization of a portion of the accumulated sediment within the reservoir and allowing limited release of a portion of the accumulated sediment. This could be accomplished by excavating a wide enough channel down to the pre-dam level from the dam to a point within the upstream reservoir that mobilization of fine sediment from the channel slopes would be no greater than during Phase II sediment transport for DRC-1 and DRC-2. The limited erosion of coarse sediment during Phase I would also be modestly further reduced due to the excavation of a pilot channel through the sediment to the upstream end of the reservoir. Excavated sediment would be temporarily stockpiled in storage areas upstream of the dam at elevations that would allow for inundation and potential transport during ten-year or greater storm events. The dam would be demolished and removed during the final season of channel excavation, with the goal of providing limited fish passage through the site immediately after dam removal.

The portion of the channel invert rising from the pre-dam surface to near the existing sediment level would be temporarily stabilized with erosion protection. The intent of the temporary stabilization would be to prevent downcutting of the channel and mobilization of fine sediment within the Delta sub-area of the reservoir during low flows until the minimum high flow event occurs, at which time a post-flush channel would develop through the remaining upstream sediment similar in size and location to DRC-1 and DRC-2.

The following major features would be implemented and are shown conceptually in Figure 3.3-1 and on Drawing 11:

- Channel Excavation
- Temporary Storages Areas
- Dam Removal

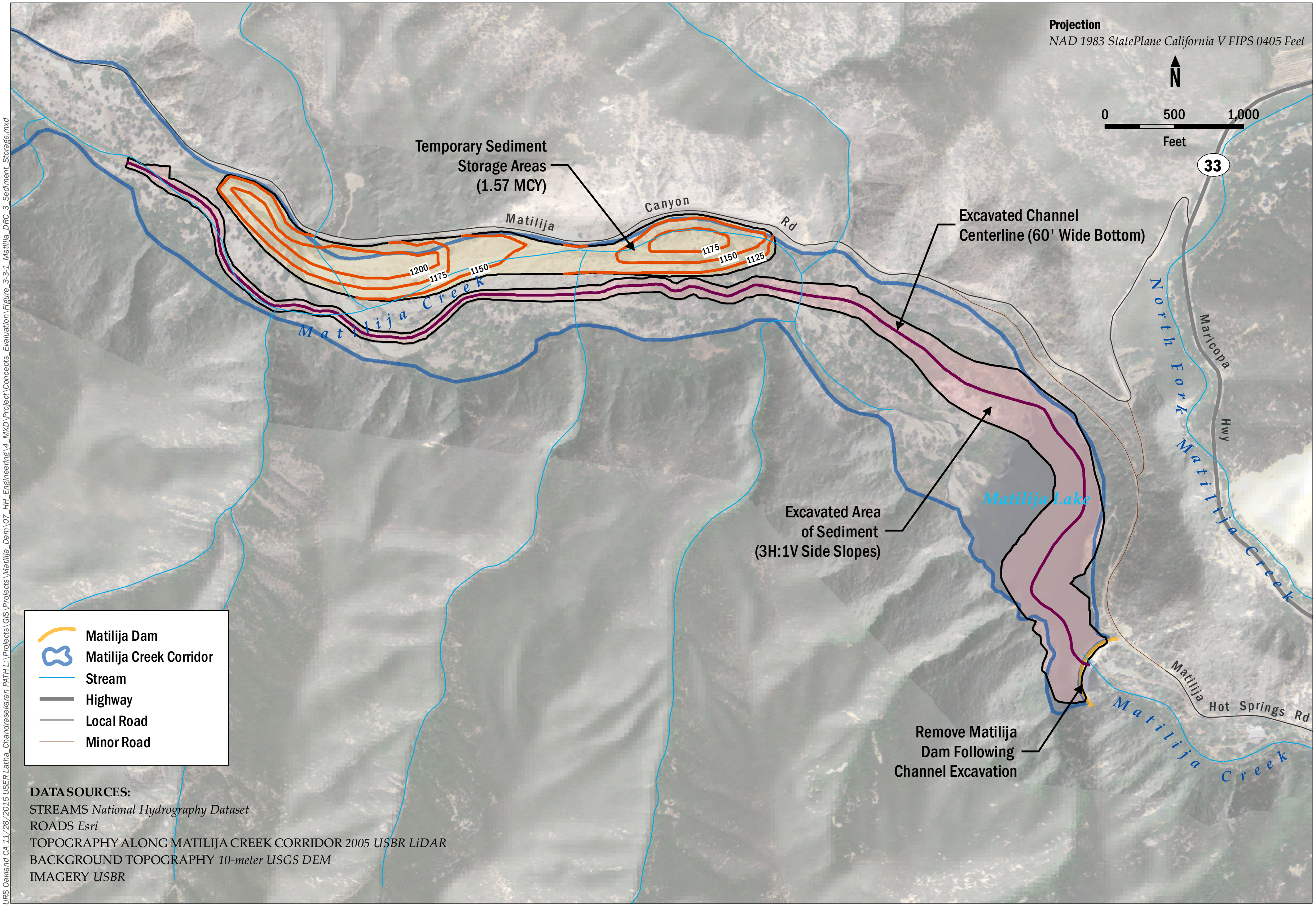

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FIGURE 3.3-1

Dam Removal Concept 3 - Temporary Upstream Storage of Fine Sediment

These major features are discussed in more detail below.

3.3.1 Channel Excavation

The channel excavation can be broken into three sections; a downstream section excavated to the pre-dam surface, a transition section, and an upstream pilot channel section. The downstream section (see Drawing 13), which would extend from the dam upstream to about Station 23+50, would be excavated along the pre-dam Matilija Creek thalweg. The channel bottom would be 60 feet wide, which is similar to anticipated width of the post-flush channel following Phase I transport of sediment for DRC-1 and DRC-2. The side slopes in the excavated sediment would be 3H:1V. The estimated in situ volume of sediment to be excavated from the downstream section is 1,230,000 cy.

Constructability of the excavated slopes was evaluated by comparing the characteristics of the sediment in Matilija Reservoir with that behind San Clemente Dam. The fine sediment at Matilija generally classifies as organic silt and is, more specifically, highly dilatant sandy silt interlayered with silts with low to no dilatancy. Observations during excavation of the fine organic sediment at San Clemente indicate that it was similarly interlayered. In general, the fine sediment at San Clemente is more plastic than the fine sediment at Matilija. Based on this comparison, and the experience of excavating the sediment at San Clemente using mechanical methods at slopes of 2.5H:1V, it is reasonable, in our opinion, to assume that 3H:1V slopes would be stable for excavation of the channel in the Matilija Reservoir sediment using the dewatering methods discussed below.

The alignment of the transition section and upstream pilot channel sections are located to the right (west) side of the temporary storage areas. The invert of the transition section would rise at a 5 percent grade between about Stations 23+50 and 34+50 to the invert elevation of the pilot channel that is capable of containing a 4-year storm event. The pilot channel would extend from Station 34+50 to near the upstream end of the accumulated sediment at about Station 98+20, as shown on Drawings 12 and 13. The in situ volumes to be excavated for the transition within the Delta sub-area and the pilot channel through the coarse sediment of the Upstream Channel sub-area are 460,000 cy and 120,000 cy, respectively.

The invert of the transition section would be protected from erosion for flows less than the minimum high flow event using riprap processed from materials on-site. Channel protection for the 5% sloped transition channel section was sized to be stable up to a peak flow of approximately 2,500 cfs. This flow is below the large sediment mobilization peak flow of 3,000 cfs, to increase the likelihood that the material will mobilize and allow flushing of the underlying sediments during the larger event. Using the California Department of Fish and Wildlife (CDFW) California Salmonid Stream Habitat Restoration Manual (2009), a D_{50} of 12 inches was estimated for the engineered streambed material. The riprap materials should be available on-site (as part of the upstream pilot channel excavation) based on our observations of the particle sizes of materials available at the upstream end of the reservoir.

Channel excavation would require dewatering of the reservoir. Dewatering the reservoir could be accomplished by installing a small cofferdam upstream of the remaining reservoir and a diversion pipe sized to divert summer flows from Matilija Creek around the excavation area. Once Matilija Creek is diverted, water stored in the reservoir would be pumped, run through a water treatment system, and released downstream of the dam. The diversion pipe would be installed at the sediment level along one of the canyon walls to a gated penetration through the dam. The diversion pipe would be pinned to the canyon walls where the sediment would be removed by the channel excavation. During precipitation seasons between channel excavation seasons, the downstream gate on the pipe would be shut and the pipe filled with water.

Channel excavation would also require dewatering of the sediment, to the extent practical. The fine sediment is likely to be difficult to dewater due to the fine-grained characteristics of the reservoir sediment (average 85 percent finer than 0.074 mm and 35 percent finer than 0.005 mm). Effective dewatering of this sediment typically requires vacuum wells or wellpoints installed at a relatively close spacing. However, dewatering will be more effective than indicated by the average gradations given that the sediment is interlayered silts and silty sands. Even after dewatering, the fine sediment would typically retain significant moisture, making these materials difficult to excavate and handle. Excavation will likely involve a repeating sequence of digging 10- to 15-foot deep trenches to allow for additional dewatering, followed by excavation down to near the trench invert. Excavated fine sediment would likely be moisture conditioned by a combination of mixing drier materials excavated from the pilot channel in the Delta and Upstream coarse sediment sub-areas with wet fine sediment and placement of the combined materials in thin lifts across the temporary storage areas for discing prior to compaction.

3.3.2 Temporary Storage Areas

Selection of temporary storage areas considered the storage sites that were included in Alternative 4b. Alternative 4b's "lower" storage sites would be utilized in DRC-3 by the fine sediment that will remain outside of the channel slopes following excavation. Storing any significant volume of additional material on top of these slopes of weak material would be challenging and was assumed to be infeasible. The two largest Alternative 4b upper storage sites were selected as the primary temporary storage areas for the excavated sediment. Since the footprints associated with these previously identified storage sites could not accommodate the entire volume of excavated sediment (assuming 3H:1V side slopes), the final temporary storage area shown on Drawings 11 and 14 extend slightly outside of these previously identified areas. The total capacity of the temporary storage areas is approximately 1,570,000 cy. The volume of sediment that would be excavated from the reservoir will shrink once it has been moisture-conditioned and compacted in the temporary storage areas. Shrinkage factors for the reservoir sediment, delta sediment, and coarse sediment are anticipated to be on the order of 0.7, 0.8, and 0.9, assuming a dry unit weight of 110 pounds per cubic foot after placement in the temporary storage areas. Thus, the total volume of sediment to be excavated 1,810,000 cy, will shrink to about 1,330,000 cy in the temporary storage area, 240,000 cy less than the storage area capacity.

The temporary sediment stockpiles would be constructed with base elevations that would be within the 10-year flood levels to allow for some degree of downstream sediment transport during storms exceeding a 10-year storm event. While long-term erosion of the temporary sediment stockpiles would be a continued source of sediment, the incremental increase in suspended sediment loads from the stockpiles during flooding would likely be small relative to the natural sediment load of Matilija Creek (see Section 4).

The top areas of the temporary sediment stockpiles would be temporarily stabilized with seeding and matting (if needed) to prevent overland and rill/gully erosion during smaller rainfall events.

3.3.3 Dam Removal

Following excavation of the channel, the dam would be removed in its entirety. The dam would likely be demolished using blasting methods similar to what was described for DRC-1, with the concrete being broken up and hauled to a recycling plant.

3.3.4 Post-Flush Condition and Restoration

A possible alignment of the post-flush channel through the reservoir sediment following the high transport storm is shown on Drawing 15. The side slopes of the channel might vary through the reservoir being as steep as 1.5H:1V on the outside of bends and as flat as perhaps 3H:1V in relatively straight reaches. The location of the channel alignment is anticipated to develop in the vicinity of the historic creek alignment, and is shown on Drawing 15. Also included on Sheet 15 are simulated flood inundation lines for the 25-year and 100-year flooding events associated with the estimated post-flush channel profile.

After the initial post-flush channel is formed, significant migration of this channel is not expected to occur because of the restriction of the historical erosion-resistant river banks and the substantial incision of the channel (over 50 feet throughout the Delta and Reservoir sub-areas). Therefore the majority of the remaining accumulated sediment bank within the reservoir will persist, and the associated existing vegetation communities will remain and slowly transition to adapt to the new water table and frequency of inundation. Planting, hydroseeding, and irrigation will be completed to help facilitate this transition and support development of a diverse, native habitat. However, the temporary sediment stockpiles would remain for an extended period of time after dam removal, as discussed in Section 3.3, and would result in the loss of existing riparian vegetation in that area. A summary of the restoration approach and associated re-vegetation effort is provided in Section 5, and anticipated post-project vegetation communities are shown on Drawing 16.

4.0 Technical Assessments

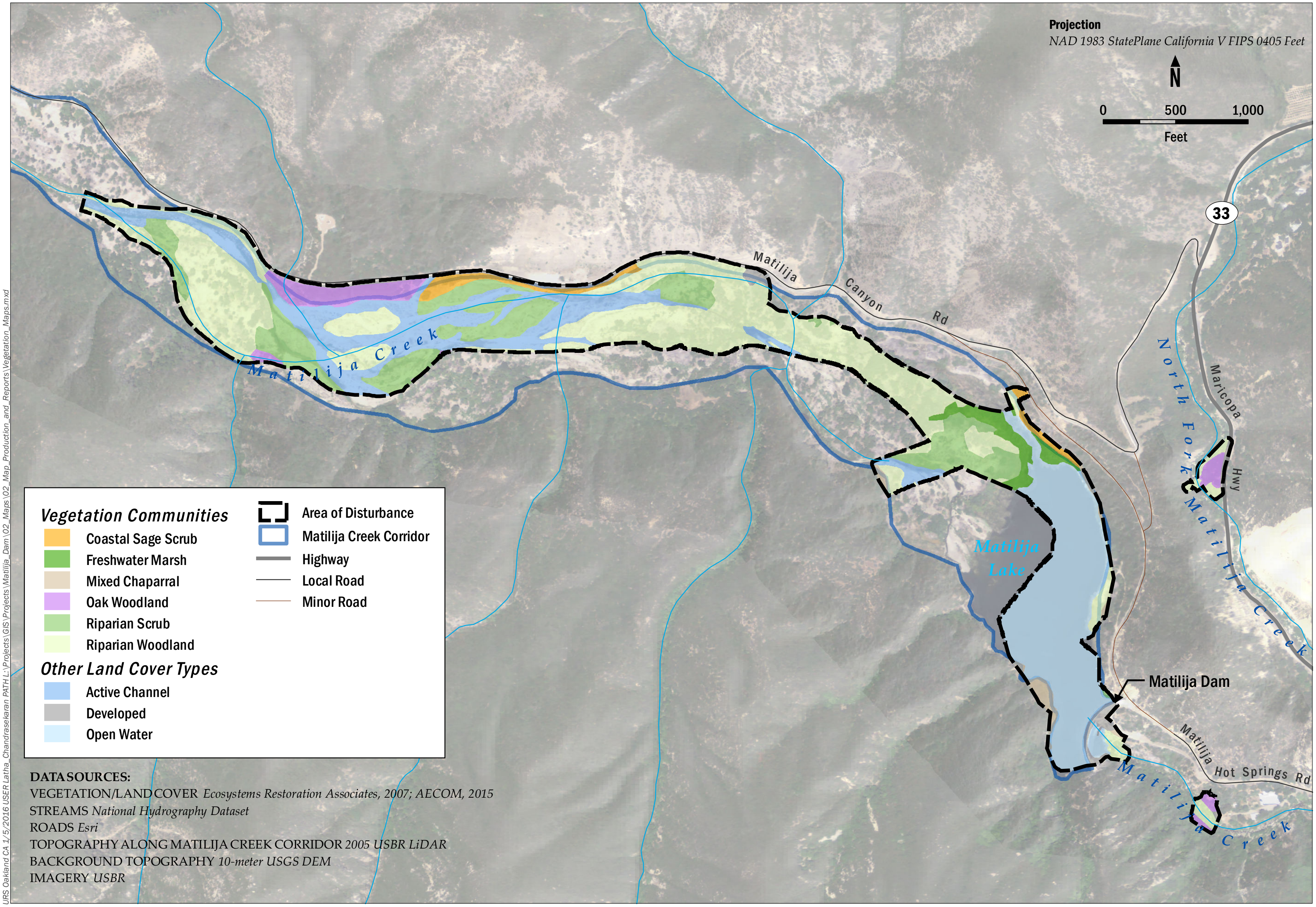
The section includes several technical assessments that help to broaden the understanding of baseline, and in some cases future conditions, for several resource areas pertinent to this report. The technical information presented in Section 4 remains primarily outside of specific evaluation criteria quantification (included in Section 5), but does serve as either a baseline or as input to assessments included in Section 5. Assessments included in Section 4 have been grouped into four primary categories:

1. Vegetation communities present at the project site
2. Erosion and transport of impounded sediments
3. Steelhead passage - dam removal case studies
4. Steelhead health downstream of the Matilija Dam site
5. Flushing flow waiting period

4.1 Vegetation Communities Present at the Project Site

The purpose of establishing and understanding the existing vegetation communities at the site is to provide a baseline for determination of impacts to existing biological resources associated with implementation of the various dam removal concepts, as well as to gain an understanding of the existing communities to inform the development of future post-project vegetation communities.

Data on existing vegetation communities within the project area were available from the Matilija Dam Giant Reed Removal project (Ecosystems Restoration Associates 2007), and are shown in Figure 4.1-1. A field reconnaissance was completed in March 2015 to confirm existing vegetation communities at the project site and to gain an overall understanding of existing biological conditions to be used during development of future post-project vegetation communities. Based on the field reconnaissance, Table 4.1-1 summarizes vegetation communities and dominant species that were observed at the site.



DATA SOURCES:
VEGETATION/LAND COVER *Ecosystems Restoration Associates, 2007; AECOM, 2015*
STREAMS *National Hydrography Dataset*
ROADS *Esri*
TOPOGRAPHY ALONG MATILIJA CREEK CORRIDOR *2005 USBR LiDAR*
BACKGROUND TOPOGRAPHY *10-meter USGS DEM*
IMAGERY *USBR*

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AECOM
Ventura County Watershed Protection District
Matilija Dam Removal, Sediment Transport, and Robles Mitigation Diversion
DAM REMOVAL CONCEPTS EVALUATION

FIGURE 4.1-1
Existing Vegetation Communities at the Project Site

Table 4.1-1. Vegetation Communities Present at the Project Site

Vegetation Community	Dominant Species
WETLAND	
Emergent Wetland (Fresh Water Marsh)	cattail, California bulrush, umbrella sedge, northern willow-herb, iris-leaved rush, water Cress, water speedwell, narrow-leaved willow, rushes, sedges
Riparian (Woodland & Scrub)	black cottonwood, white alder, western sycamore, *willows*
UPLAND	
Grassland	oat grasses, bromes, barleys, ryegrasses, and fescues
Oak Woodland	coast live oak, canyon live oak California black walnut, Mexican elderberry
Coastal Sage Scrub	California sagebrush, California buckwheat, black, white and purple sage, monkeyflower, prickly phlox, brickelbush, lemonadeberry
Mixed Chaparral	chamise, toyon, big pod ceanothus, laurel sumac, chaparral current, chaparral clematis, mountain mahogany, yerba santa, bush mallow

The following sections describe these communities in more detail.

4.1.1 Emergent Wetland (Fresh Water Marsh)

During the March 2015 field reconnaissance, it was determined that there are two types of emergent wetland in the project area: lake-edge (lacustrine), described in the Matilija Dam Giant Reed Removal report as fresh water marsh, which occurs along the perimeter of the Matilija Reservoir, and riverine, which occurs along the active channel of Matilija Creek both upstream and downstream of the dam and reservoir and is not described in the report. Emergent wetland is typically represented by erect, rooted, herbaceous plants growing directly from shallowly submerged soil. This vegetation consists of perennial plants that are present for most or all of the growing season (Cowardin et al.1979). The predominant plant genera making up the lacustrine emergent wetland habitat around Matilija Reservoir include *Schoenoplectus* [*Scirpus*], *Polygonum*, *Cyperus*, *Carex*, and *Juncus* species. The predominant herbaceous plant species, making up the riverine emergent wetlands along the Matilija Creek channel include a mixture of typical hydrophytic plant species including California bulrush (*Schoenoplectus californicus*) umbrella sedge (*Cyperus eragrostis*), northern willow-herb (*Epilobium ciliatum* ssp. *ciliatum*), iris-leaved rush (*Juncus xiphioides*), rabbitsfoot grass (*Polypogon monspeliensis*), water cress (*Rorippa nasturtium-aquatica*), cattail (*Typha domingensis*), and water speedwell (*Veronica anagallis-aquatica*). Saplings of mulefat (*Baccharis salicifolia*) and narrowleaf willow (*Salix exigua*) are also common.

Figure 4.1-2. Emergent Wetland dominated by California bulrush and cattail along the north end of Matilija Reservoir.

4.1.2 Riparian Woodland and Scrub

The type of riparian habitat that occurs in the project area is classified by Cowardin (1979) as Riverine Upper Perennial. It includes riverbank areas where the gradient and water velocity are high and floodplain development is low. Some water flows throughout the year, and a portion of the riparian habitat typically qualifies as jurisdictional wetland. The substrate consists of rock, cobbles, or gravel with occasional patches of sand. This habitat was observed in the flowing reaches of Matilija Creek above the reservoir and below the dam. The key species observed within the riparian wetland habitat are mulefat white alder, California sycamore, and several species of willow. Mulefat is an early seral species that occurs in, and along, stream and river channels with moderately coarse substrate. Typical secondary species might include mugwort (*Artemisia douglasiana*), scalebroom (*Lepidospartum squamatum*), and narrowleaf willow; however, in the project area, the riparian vegetation community is characterized by scattered, monotypic stands of mulefat interspersed among patches of bare, cobble-dominated ground. Mulefat thickets primarily occur in the northern terminus of the project area in the Matilija Creek channel bottom.

Because of coarse, well-drained cobbly soils in the middle and upper part of the former reservoir, many upland species from the adjacent coastal sage scrub and mixed chaparral vegetation communities grow on the variously elevated alluvial benches, protected by topography from regular inundation and form the flood alluvial scrub. This habitat, even though within the riparian areas, is dominated by upland species and is a transitional ecotone between the riparian and coastal sage scrub vegetation communities. Occasionally, this riparian ecotone may be subject to flooding or short-term inundation. Vegetation is dominated by scalebroom, California buckwheat (*Eriogonum fasiculatum*), yerba santa (*Eriodictyon* *crassifolium*), chaparral yucca (*Yucca whipplei*), white sage (*Salvia apiana*), prickly pear (*Opuntia littoralis*), and various other shrubs. Ground cover between shrubs is open with variable cover of native and alien annuals and herbaceous perennials. Flood alluvial scrub is limited to patches in the north end portion of the Matilija Reservoir where low-lying terraces occur adjacent to the active channel of Matilija Creek. Western sycamore (*Platanus racemosa*), arroyo (*Salix lasiolepis*) and narrowleaf willow, as well as white alder (*Alnus rhombifolia*) dominated riparian woodlands were observed in narrow patches along the creek above the reservoir and below the dam.

Figure 4.1-3. Riparian vegetation established on higher floodplain sediments within the upstream portion of Matilija Reservoir.

4.1.3 Grassland

A mixture of a native California annual grassland and ruderal grassland on shallow rocky soils was observed in small portions of the project area. Although species composition varies, both non-native and native annual grasses (genera including *Avena, Bromus, Hordeum, Lolium*, and *Vulpia*) typically dominate this plant community, while many native wildflowers, as well as naturalized annual forbs and invasive exotics, are important associates. The species observed in grassland areas were slender wild oat (*Avena barbata*), common oat (*A. sativa*), ripgut brome *(Bromus diandrus)*, soft chess (*B. hordeaceus*), Italian ryegrass (*Festuca* [*Lolium*] *multiflorum*), Mediterranean grass (*Schismus barbatus*), rattail fescue (*Festuca* [*Vulpia*] *myuros*), Bermuda grass (*Cynodon dactylon*), smilo grass (*Stipa* [*Piptatherum*] *miliacea* var. *miliacea*), summer mustard, (*Hirschfeldia incana*), tocalote (*Centaurea melitensis*), and bristly ox-tongue (*Picris echioides*), Mexican Tea (*Chenopodium ambrosioides* var. *ambrosioide*s), redstem filaree (*Erodium cicutarium*), sweet fennel (*Foeniculum vulgare*), lowland cudweed (*Gnaphalium luteo-album*), smooth cats-ear (*Hypochaeris glabra*), prickly wild lettuce (*Lactuca* *serriola*), white horehound (*Marrubium vulgare*), bur-clover (*Medicago polymorpha*), wild radishes (*Raphanus* spp), Russian thistle (*Salsola tragus*), windmill pink (*Silene gallica*), milk thistle (*Silybum marianum*), and sow-thistles (*Sonchus* spp).

Figure 4.1-4. Grassland habitats near Matilija Creek are sparse and seasonal. This locale is a riparian area that is lined with mulefat thickets in the background of the photo near the creek.

4.1.4 Oak Woodland

Oak woodlands are located away from the active, eroding channel scattered along the elevated terraces within the Matilija Creek floodplain. Coast live oak (*Quercus agrifolia*) is the most conspicuous tree within this community; however, Southern California black walnut (*Juglans californica*) and canyon live oak (*Quercus chrysolepis*) occur in scattered locations. Common understory species occurring within oak woodland include laurel sumac (*Malosma laurina*), skunkbush (*Rhus trilobata*), poison oak (*Toxicodendron diversilobum*), Mexican elderberry (*Sambucus mexicana*), and California bay (*Umbellularia californica*). The shrub stratum growing below the oak canopy typically includes many native species listed in the scrub section below. The associated ground layer species include those typical of the grassland community described above.

Figure 4.1-5. Coast live oak tree in Oak woodland community.

4.1.5 Coastal Sage Scrub

Scrub vegetation occupying the outer reaches of the Matilija Creek floodplain, and the lower portions of the slopes above, is predominantly coastal sage scrub. This community is dominated by drought-deciduous, low-growing, mostly soft-leaved, grayish-green, woody shrubs and subshrubs having evergreen or deciduous, non-leathery leaves, and growing from one to six feet tall, with a sparse herbaceous layer below. Scrub species form various canopy densities; they occupy shallow or heavy soils of dry, gentle to steep, moderately rocky, predominantly southern-facing slopes, generally occurring at lower elevations. Common species occurring within coastal sage scrub in the project area include: California sagebrush, California brickelbush (*Brickellia californica*), California bush sunflower (*Encelia californica*), morning-glories (*Calystegia* spp.), lanceleaf live-forever (*Dudleya lanceolata*), golden yarrow (*Eriophyllum confertiflorum* var. *confertiflorum*), green everlasting (*Gnaphalium californicum*), cudweed (*Gnaphalium canescens* ssp. *beneolens*), erect goldenaster (*Heterotheca sessiliflora* var. *fastigiata*), heart-leaved penstemon (*Keckiella cordifolia*), giant wildrye (*Leymus condensatus*), coast melic grass (*Melica imperfecta*), California buckwheat (*Eriogonum fasciculatum* var. *foliolosum*), (*Galium angustifolium ssp. angustifolium*), sawtooth goldenbush (*Hazardia squarrosa*), deerweed (*Acmispon glaber*) [*Lotus scoparius]*), laurel sumac, sticky monkeyflower, coast prickly pear, chaparral currant (*Ribes malvaceum*), white sage, chaparral nightshade (*Solanum xanthii* var. *xanthii*), chaparral yucca, chamise (*Adenostoma fasciculatum*), Mexican elderberry, and lemonadeberry (*Rhus integrifolia*).

Figure 4.1-6. Coastal sage scrub on slope adjacent to Forest Rte Road.

4.1.6 Mixed Chaparral

Chaparral is a shrubland vegetation type adapted to summer-dry Mediterranean climate. It includes shrubs with evergreen, leathery, dark green, sclerophyllous leaves, such as ceanothus, scrub oak, chamise, manzanita, and others. Smaller coastal scrub species may grow intermixed as associates. Chaparral within the project area occurs typically on moderate to steep west and south-facing slopes with dry, rocky, well-drained, shallow soils, becoming more abundant with higher elevations where temperatures are lower and moisture supplies are more ample. Many of the coastal sage scrub species described above also grow intermixed as associates with chaparral species. Large areas of chaparral were observed on the west facing, left high bank, both upstream and downstream of the Matilija Dam. The species observed were California sagebrush, coyote brush, hoaryleaf ceanothus (*Ceanothus crassifolius*), wedgeleaf ceanothus (*C. cuneatus*), bigpod ceanothus (*C. megacarpus* var. *megacarpus*), hairy ceanothus (*C. oliganthus* var. *oliganthus*), redheart (*C. spinosus)*, birchleaf mountain mahogany (*Cercocarpus betuloides* var. *betuloides*), thickleaf yerba santa (*Eriodictyon crassifolium* var. *nigrescens*), California buckwheat, toyon, Santa Cruz Island bush mallow, laurel sumac, hollyleaf redberry (*Rhamnus ilicifolia*), lemonadeberry, sugar bush (*Rhus ovata*), white sage, black sage, chaparral nightshade, and chaparral yucca. Laurel sumac, chamise, and bigpod ceanothus were observed alternately dominating the chaparral in the vicinity of Matilija Reservoir.

Figure 4.1-7. Chaparral on south-facing slope adjacent to Forest Route 5N13 Road leading to the north side of Matilija Dam.

4.2 Erosion and Transport of Impounded Sediments

The purpose of this section is to summarize key conclusions from previous work that focused on accumulated sediment mobilization and transport from Matilija Reservoir, and to use that work to gain a broader understanding of background suspended sediment and organic material conditions downstream of the reservoir. These prior conclusions can also be used to anticipate the incremental increases in suspended sediment and organic material associated with the various dam removal concepts being evaluated. This understanding will be applied in Section 5 to determine specific impacts of elevated concentrations of suspended sediment and organic material on biological resources and water supply.

A brief summary of the anticipated phases of channel evolution and sediment transport from the impoundment area is provided within the introduction to Section 3, and additional concept-specific details are provided in the subsequent concept descriptions and associated drawings. For all concepts, the channel geometry through the Reservoir and Delta sub-areas is assumed to be substantially established during the first large sediment mobilization event. Although the dynamics of channel evolution through the impounded sediment is complex and the actual alignment of the future post-flush channel is difficult to predict, it is reasonable to assume that the channel would develop in near proximity to the creek's historic alignment, given the fixed downstream location of the channel, and its cross-section would resemble the post-flush channel geometries shown on Drawing 5 (for DRCs-1 and -2) and Drawing 15 (for DRC-3). These cross-sections should provide an adequate representation of the channel even if the first large sediment mobilization event ends up being significantly larger than the minimum event (i.e., an average daily flow of at least 1,700 cfs, corresponding to a peak flow of about 3,000 cfs) being used for this assessment. This is particularly true through the Reservoir sub-area, because of the very high sediment transport capacity of the channel that will be incised into these deposits and the presence of erosion-resistant historical channel deposits encountered near the base of all three full-depth borings in this area (MDH-01, 02, and 15, see Section 4.2.2), which will constrain lateral channel erosion once the flow settles back into its historical alignment.

For purposes of concepts evaluation, the discussions below focus on accumulated fine sediment mobilization and transport, with the impacts being associated with increases in TSS and high organic concentrations within the downstream reach of Matilija Creek and the Ventura River relative to the background sediment load from the watershed as a whole. Coarse sediment will also mobilize and be transported under all three dam removal concepts presented in this report; but since the transport and downstream deposition of accumulated coarse sediment does not differ significantly between the three shortlisted dam removal concepts, coarse sediment transport and downstream deposition have not been identified as evaluation categories or criteria. Appendix C provides a full description of the coarse sediment modeling completed for a variety of dam removal and sediment management scenarios, including scenarios similar to those incorporated into DRCs 1, 2, and 3.

4.2.1 Suspended Sediment Concentrations

The magnitude and rates of fine-sediment release under the uncontrolled channel erosion (DRC-1 and DRC-2) and partially pre-excavated channel (DRC-3) concepts depend on the geometry of the channels assumed to be created through the deposits behind Matilija Dam and the grain-size distribution of those deposits. These assumptions are tabulated in Table 4.2-1 and coincide with the post-flush surfaces displayed on Drawings 5 and 15.

Using the average grain-size compositions of sediment in the three zones of deposition behind Matilija Dam (as compiled in Stillwater Sciences, 2014b, from data in the United States Bureau of Reclamation (BOR), 2006 [their Table 5.6]) and reproduced as Table 4.2-2 below, the channel geometries of Table 4.2-1 result in the calculated total volumes of excavated and eroded sediment and their component quantities of gravel, sand, and silt/clay presented in Table 4.2-3.

Table 4.2-1. Presumed channel geometries for purposes of calculated sediment volume

Channel Approach	DRC-1	DRC-2	DRC-3
Excavated channel	<none>		• Trapezoidal with 60-ft-wide base; 3H:1V side slopes
Eroded channel	Trapezoidal with 60-ft-wide base; 1.5H:1V average side slopes (1)		• Reservoir: none (all previously excavated) • Delta: partial incision through excavated channel (similar dimensions to DRC-1 & 2 eroded channel) • Upstream: full incision through excavated channel (similar dimensions to DRC-1 & 2 eroded channel)

(1) Actual channel side slopes may be highly variable, likely staying with the range of 1.5H:1V to 3H:1V

Table 4.2-2. Sediment gradation percentages (from BOR 2006, Table 5.6)

Sediment Deposit Sub-Area:	% Gravel (<2mm)	% Sand (0.0625-2 mm)	% Silt/Clay (<0.0625 mm)
Reservoir	0%	17%	83%
Delta	13%	54%	33%
Upstream Channel	78%	16%	6%

Table 4.2-3. Sediment volumes (in cubic yards) from channel erosion (determined for all concepts) and prior excavation (applicable to DRC-3 only)

Concept	Sub-area			Sediment Composition		
	Reservoir	Delta	Upstream	Gravel	Sand	Silt/Clay
DRC-1 and 2: Eroded Volume	950,000	500,000	390,000	370,000	490,000	980,000
DRC-3:						
Excavated Volume	1,230,000	460,000	110,000	150,000	470,000	1,180,000
Eroded Volume	-	173,000	311,000	265,000	143,000	76,000

URS and Stillwater Sciences (2014a) also estimated the annual average sediment yield of the watershed at Matilija Dam, independent of sediment that might be released during dam removal (Table 4.2-4), with the added caveat that sediment loads during a year with large storm(s) could be one or more orders of magnitude greater than these annual average amounts (Stillwater Sciences 2014a). These values can be used to determine the background rate of watershed sediment delivery, which provides a useful benchmark against which any additional sediment released by the erosion of the impounded deposits can be compared.

Table 4.2-4. Mass balance for the sediment load of Matilija Creek (Table A-1 of URS and Stillwater Sciences, 2014a)

Sediment Type	Average rate of deposition behind dam, 1947-2005 (cy/year)	Average downstream delivery, 1947-2005 (cy/year)	Average downstream delivery, post-dam (cy/year)
Coarse sediment (sand and gravel)	65,000	0 (assumed)	65,000
Fine sediment (silt and clay)	55,000	280,000	335,000

Although the average deposition rate of fine sediment behind the dam for the entire period 1947–2005 was 55,000 cy/yr (Table 4.2-4), the current rate is far less due to the diminishing trapping efficiency. By year 2020, for example, the sediment trapping efficiency for combined coarse and fine sediment will be only 14% (BOR 2006), indicating essentially no trapping of fines because coarse sediment constitutes this entire fraction of the combined sediment supply (see last column Table 4.2-4). Thus, the present flux of fine sediment being experienced downstream of the dam and into the Ventura River will not increase after the dam is removed (except for the immediate post-dam-removal period), because nearly all of the fine sediment load from the upper watershed is already moving over the dam.

As summarized in Section 3, prior dam removal projects have expressed two distinct "phases" of sediment transport associated with dam removal. Phase I includes the period of rapid incision of the flow through the deposits accumulated behind the dam (for DRC-1 and DRC-2), for which the supply of sediment is unlimited, and transport rates are determined solely by the discharge of water and the maximum concentration of sediment that the flow can carry. The transition to Phase II occurs when the flow has eroded completely through the accumulated sediments and no longer has direct access to the deposit; delivery of material is then restricted to mass failure of the banks or lateral erosion of the now-perched deposit by rills or gullies (which will occur under all three dam removal concepts).

Using assumed volumes of transported material similar to those in Table 4.2-3, URS and Stillwater Sciences (2014a, Appendix A) predicted a period of Phase I erosion lasting between about 10 hours (judged most likely) to no more than 1.5 days, by which time about 1 mcy of silt/clay would have been moved downstream. Phase I transport in Matilija Creek resulting from sediment flushing associated with DRC-1 and DRC-2 has predicted TSS concentrations on the order of 10^6 mg/l (URS and Stillwater Sciences 2014a). TSS concentrations downstream in the Ventura River during Phase I erosion will be somewhat less due to dilution (three-fold by discharge at gage 11118500 on the Ventura River relative to 11114495; see Stillwater Sciences 2014b), but very high TSS concentrations ($\geq 10^5$ mg/l) would nonetheless persist far downstream when Phase I transport is active. For purposes of subsequent analyses in this report, the duration of Phase I is assumed to be one day, with an acknowledged factor-of-2 range of uncertainty.

Estimating the magnitude and the effects of elevated (but not as extreme) TSS concentrations following the initial flush of fine sediments (i.e., Phase II erosion) is not as straightforward. The erosional processes that will contribute to Phase II are varied and, to some degree, stochastic in nature: stream banks will slump unpredictably, overland flow that causes sheet wash erosion and rilling will be highly episodic, and small lateral headcuts may create gullies that erode laterally into the reservoir deposits not removed by either Phase I erosion (DRC-1 and DRC-2) or mechanical excavation (DRC-3).

However, two recent dam removal projects, Condit Dam on the White Salmon River, WA (Wilcox et al. 2014) and Marmot Dam on the Sandy River, OR (Major et al. 2012, Cui et al. 2014), provide empirical guidance. Neither are perfect analogs for Matilija Dam: although both had a "compound" structure for the impounded deposits similar to the Matilija deposits, with coarser upstream deposits grading into and overlying finer downstream deposits, neither example spans as wide a range of grain sizes. The impounded deposits behind Condit Dam were almost entirely sand, silt and clay; those behind Marmot Dam were almost entirely sand and gravel (whereas Matilija deposits span the full range of grain sizes).

At Condit Dam, downstream TSS concentrations following dam removal fell below 10^4 mg/l after about one week, with an exponential reduction to 10^3 mg/l after about one month (Wilcox et al. 2014; Figure 4.2-1). At Marmot Dam, which is a closer analog to Matilija than Condit Dam based on the composition of the upstream deposits, the initial decline in TSS concentrations was much more rapid (Figure 4.2-2), with concentrations falling below 10^3 mg/l (the background condition) in less than a day (Major et al. 2012, Cui et al. 2014) despite a continually rising hydrograph (Figure 4.2-3). In the following two months, TSS concentrations downstream of the dam were elevated during successive storms, but only the immediately subsequent high-flow event (11/17-11/18) showed an increase in suspended sediment relative to the upstream gage (Figure 4.2-4). After that time, any Phase II contributions to the net sediment load was indiscernible from the background load.

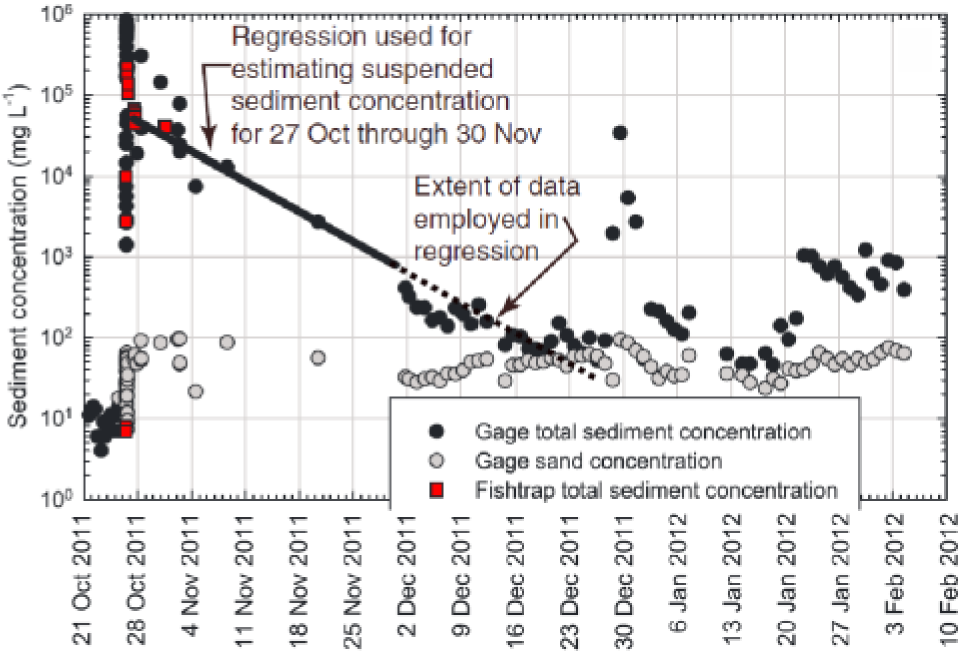

Figure 4.2-1. Figure 8b of Wilcox et al. (2014), showing the inferred exponential decline in suspended sediment concentrations downstream of Condit Dam following removal. Concentrations fell from >10^5 mg/l to 10^3 mg/l over about one month in this uniformly fine-grained system.

In both cases, the decline in TSS concentrations can be described by an exponential decline, which provides a mathematical framework to quantify anticipated TSS concentrations and to evaluate the sensitivity of the projected effects on water quality and biological resources to the assumed reductions in concentrations over time.

As discussed in URS and Stillwater Sciences (2014a), the decline of suspended sediment concentration during Phase II erosion following Matilija Dam removal should resemble Marmot Dam removal far more than the Condit Dam removal. Both Marmot and Matilija's upstream deposits are coarse sediment (mostly gravel and sand) with very small amount of fine sediment, while the entire Condit upstream deposit was fine sediment (sand and silt) that continued to contribute fine sediment for many weeks, while an erosional knick point migrated upstream through the full length of the impounded deposits. By assuming an exponential decay of sediment production in Phase II erosion, URS and Stillwater Sciences (2014a) predicted at most a few days of elevated Phase II erosion, after which either the fine sediment deposit would be depleted and transported downstream or the rate of fine sediment production would decrease to a sufficiently small value to pose no significant risk to fisheries or water supply. This analysis is consistent with the expectation that most of the Phase II sediment production will be produced by slumping of fine sediment remaining in the Reservoir subarea and adjacent to the channel, driven by dewatering. This process would extend the period of Phase II erosion at Matilija Dam relative to that seen in the exclusively coarse-grained deposits behind Marmot Dam; but once this process has slowed, the continued production of sediment by upstream channel erosion into the coarser upstream sediments should result in fine sediment production little different from that carried in the natural flow.

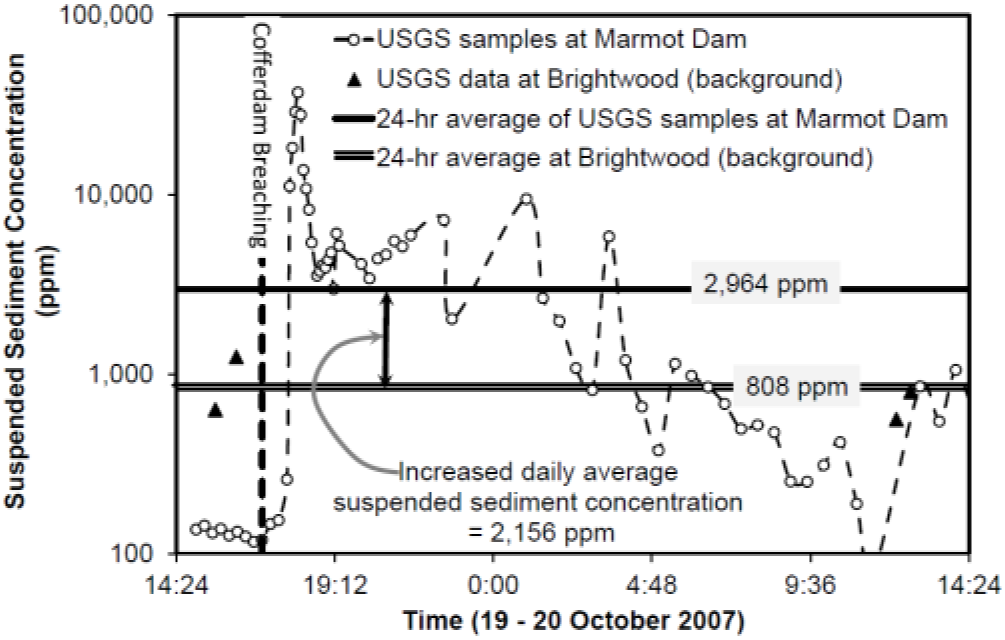

Figure 4.2-2. Figure 13 of Cui et al. (2014), showing the decline in suspended sediment concentrations downstream of Marmot Dam following removal. Concentrations fell to background levels ("Brightwood, ~10^3 mg/l) in no more than a day in this predominately coarse-grained system.

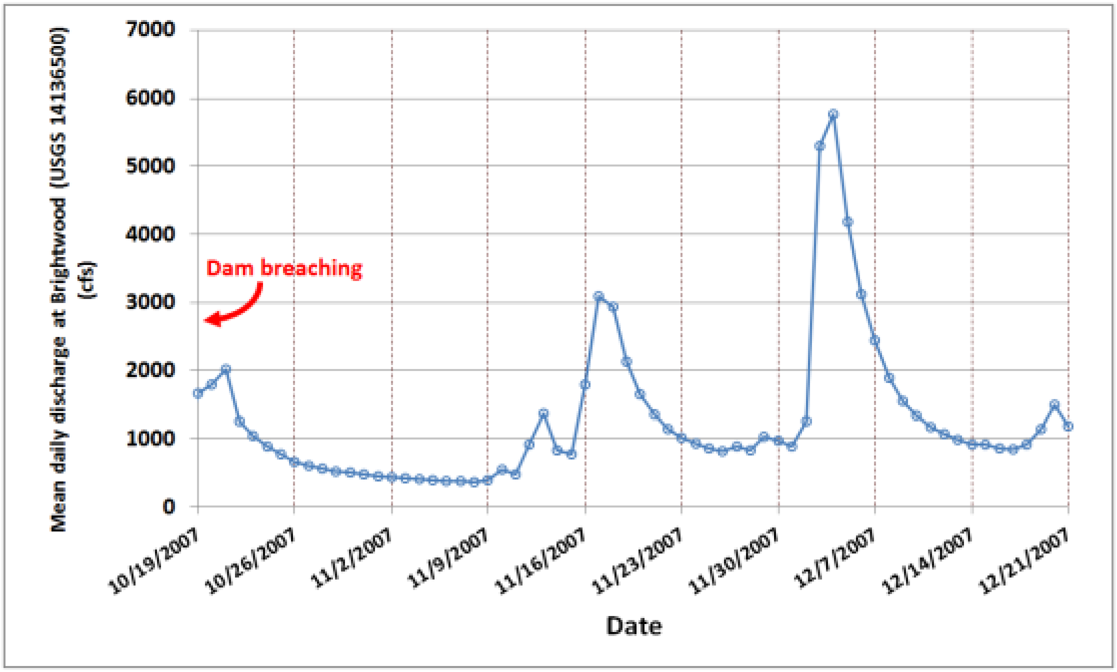

Figure 4.2-3. Discharge at USGS gage 14136500, immediately upstream of the reservoir behind Marmot Dam, in the days (individual data points) and weeks (vertical grid lines) following breaching.

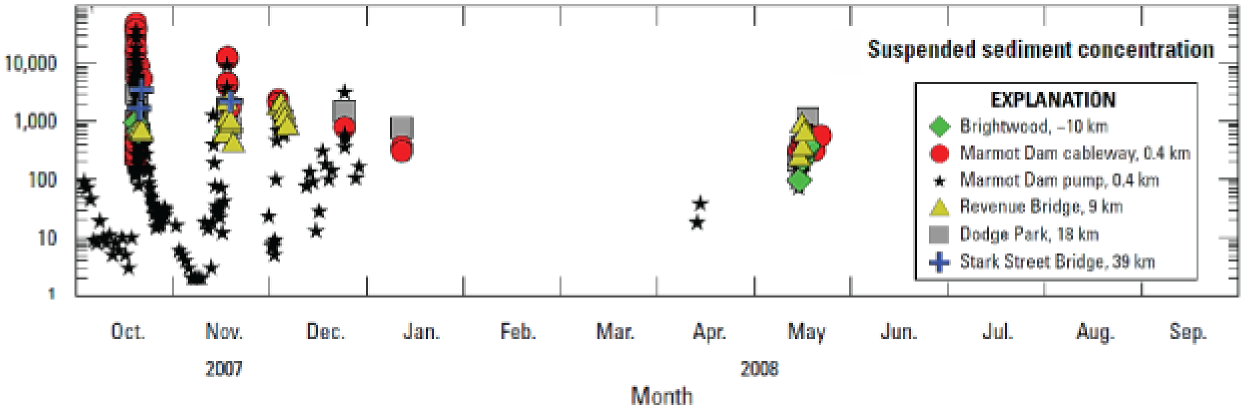

Figure 4.2-4. Figure 29B of Major et al. (2012), showing the pattern of suspended sediment concentrations upstream and downstream of Marmot Dam following removal. The initial, rapid decline in the first day following removal (Figure 4.2-2, and the near-vertical column of symbols in this graph in late October) was followed by subsequent pulses of high sediment, corresponding to the storm events recorded in Figure 4.2-3. Although the second storm (November 17/18) showed an order-of-magnitude increase in TSS concentrations downstream of the dam ("cableway" and "pump" sites) relative to the upstream site (Brightwood) and stations farther downstream (Revenue Bridge), by the time of the third (even larger) event in early December all available sites' data converge at values close to each other and at (or below) 1000 mg/l.

Among the three concepts, DRC-2 should have the highest Phase II suspended sediment concentration initially following dam removal, because the fine sediment deposit under this concept will have been saturated with water and the natural dewatering process is likely a major source of bank slumping. Fine deposits under DRC-1 and DRC-3 will already be at least partially dewatered by the time uncontrolled channel erosion begins, thus producing somewhat less (and likely near-equivalent to each other) sediment erosion volumes and rates. Once the primary dewatering of the fine deposits is finished for DRC-2, likely within a few days, all three concepts should experience similar levels of fine sediment erosion resulting from continued bank failures, although DRC-3's flatter constructed banks should contribute somewhat less than the others. Additional sediment generation from surface erosion off the remaining exposed fine deposits in the Reservoir sub-area will be similar for all concepts: the exposed surface covers about 12 acres for DRC-1 and 2, and 9 acres for DRC-3, but the latter has a commensurately greater area of side slopes adjacent to the channel.

Distinguishing sediment loads arising from dam removal from those that arise from the watershed naturally emphasizes the need to characterize not only the absolute differences between alternative dam removal concepts, but also their incremental effects on what is already a sediment-rich system during large storms. Reconstructing a "natural" TSS concentration prediction for Matilija Creek takes advantage of the 12 years (2002-2014) for which flow data from Matilija Creek at U.S. Geologic Survey (USGS) gage 11114495 are available. TSS concentrations in the channel upstream of the dam during this period can be predicted from Eqn. 4-1 (derived from the data presented in URS and Stillwater Sciences 2014a, Appendix A).

$$\text{TSS (mg/l)} = 154 \cdot Q^{0.67}\text{, where Q is mean daily discharge in cfs} \qquad \text{(Eqn. 4-1)}$$

This equation can be used to estimate background TSS concentrations originating from the non-impounded Matilija Creek watershed to better characterize the incremental impact of alternative dam removal concepts on downstream resources. When applied to the full 12-year record of gage 11114495 (2/15/2002 to the present), only two water years *lack* periods with predicted TSS concentrations greater than 10^3 mg/l, five years have periods with concentrations greater than 10^4 mg/l (i.e., almost bi-annual events), and no year exceeds 10^5 mg/l (Figure 4.2-5 and Table 4.2-5). In addition, TSS concentrations above 1,000 mg/l can persist for much if not all of the wet season on Matilija Creek (e.g., water years 2005, 2011).

Thus, based on the experiences from the removal of Marmot Dam and (to a lesser degree) Condit Dam, the period of Phase II erosion and elevated TSS concentrations of about 10^3 mg/l should last for several days up to about a week's worth of sediment-transporting flows. For purposes of subsequent analyses in this report, the duration of Phase II is assumed to be one week, with an acknowledged factor-of-2 range of uncertainty, after which elevated sediment levels will be indistinguishable from the watershed's natural TSS concentrations during high flows.

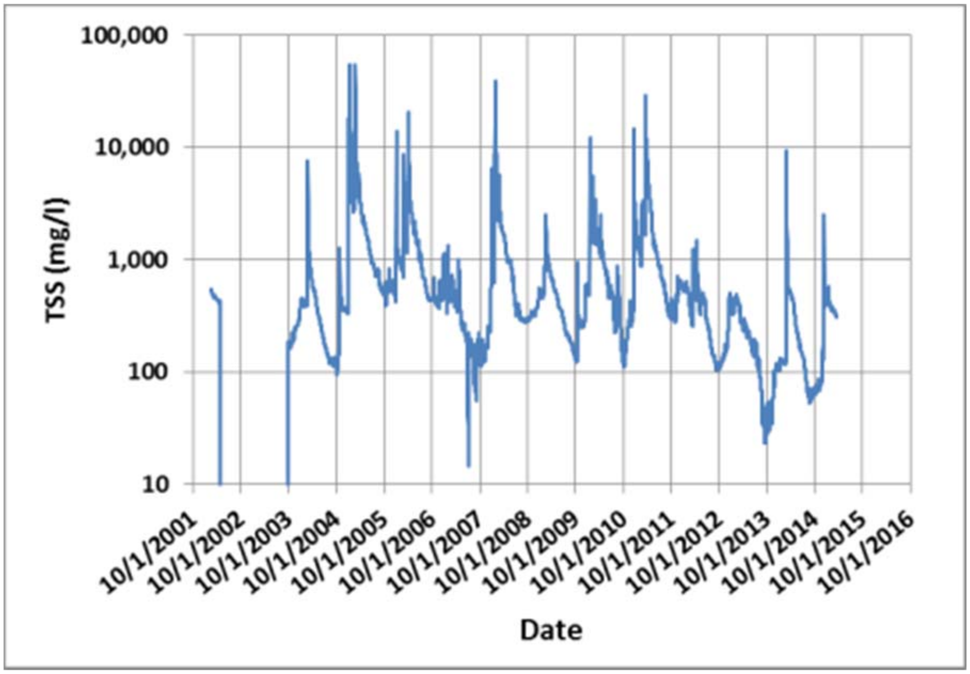

Figure 4.2-5. Time series of predicted TSS concentrations in Matilija Creek, using the full discharge record of USGS gage 11114495 and Equation 4-1. Water years are marked off by the vertical grid lines.

Table 4.2-5. Duration of TSS concentrations in Matilija Creek for the last 12 years, as graphed in Figure 4.2-5.

TSS (mg/l)	# days over full record	% of days
<1	524	11%
1-10	0	0%
10-100	282	6%
100-1000	3179	66%
1000-10,000	745	16%
10,000-100,000	46	1%

4.2.2 Organic Concentrations

Mobilization of reservoir sediments following removal of Matilija Dam may result in periods of hypoxia in Matilija Creek and the Ventura River due to organics contained within the sediments (USACE 2002), as well as chemical OD associated with unoxidized sulfide minerals or other reduced chemicals in the sediments (Allen et al. 1993, Simpson et al. 1998). The relatively low solubility of oxygen in water means that even low levels of microbial activity associated with the metabolism of organic matter will result in depletion of dissolved oxygen (DO) in the water column.

The acute concerns regarding ambient DO concentrations following dam removal are based on whether resulting DO in the downstream receiving waters would be suitable for aquatic life and sufficient to avoid impacts to Lake Casitas, if diverted. The instantaneous minimum acceptable water quality objective for

DO for warm, cold, and spawning designated beneficial uses is 5 mg/l, except when natural conditions cause lesser concentrations (e.g., LARWQCB 2013). Insufficient analyses have been conducted to establish a credible minimum threshold for suitable DO levels for Lake Casitas diversion, but given the opportunity for additional aeration in the five miles of open diversion channel and the substantial dilution that occurs once that water reaches the lake, the 5 mg/l criterion associated with instream beneficial uses is likely very conservative with respect to lake water quality impacts. The 5 mg/l criterion will be used as the critical threshold for all evaluations.

Sediment OD is typically determined by laboratory sediment core incubations, whereby mass additions in native water are conducted at controlled temperatures and using standard techniques (e.g., APHA 2005) with repeat measurements of DO over time to estimate milligram OD per milligram of TSS. While empirical determinations have not been undertaken for the sediment impounded behind Matilija Dam, previous dam removal studies on the Klamath River can inform an estimate of Matilija sediment OD, given knowledge of organic matter content as the primary driver of OD. The organic content of fine sediments from two Klamath River reservoirs (45 samples, typical core depth 4–5 feet with deepest core at approximately 20 feet) ranged from 0.3–8% with an average of 5% (BOR 2011). The OD of these sediments was found to average 0.0035 mg OD/mg TSS (Stillwater Sciences 2011, although earlier studies have reported organic contents up to nearly three times greater in the Klamath River reservoirs[7]).

By way of comparison, the organic content of sediments impounded behind Matilija Dam were evaluated by USACE (2002), who reported on tests for total organic carbon (TOC) of 39 samples from 15 borings (Table 4-2.6). These samples were widely distributed across the upstream, delta, and reservoir deposits behind the dam and the sampled intervals ranged from 8.8 to 85 feet below the surface. Within the reservoir deposit itself (borings MDH-1-01 to 7-01 and 15-01, located in Figures 4.2-6 and 4.2-7), TOC ranged from 0.8 to 5.1%, with an average of 1.8%. None of these borings penetrated through the methane-bearing strata noted in USACE (2002), and so zones of indeterminately higher organic content may be present in that zone, which comprises the lower one-third to one-half of the sediment thickness (Stillwater Sciences 2014a, their Figure 3) over approximately one-third of the area of the Reservoir sub-area. When averaged over the volume of sediment eroded under DRC-1 or 2, any such increment is not voluminous enough to greatly increase the overall estimate of organic content based on the data of Table 4.2-6 and so has been ignored. Future characterization studies of fine sediments, as discussed in Section 3.0, could help provide additional information concerning the location and material properties of organic sediments in the methane-bearing strata.

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[7] The OD analysis discussed below was based on the 45 samples of BOR (2011). Analysis of additional cores presented in GEC (2006) by Stillwater Sciences (2008), however, found significantly higher average organic contents: Iron Gate Reservoir = 6.9%; Copco 1 Reservoir = 14.6%; and J.C. Boyle Reservoir = 12.7%.

Table 4.2-6. Borings at Matilija Dam for which total organic carbon (TOC) was measured.

Sub-Area	Boring	Depth of sample (feet)	TOC (mg/kg)	TOC %
RESERVOIR SUB-AREA	MDH-01-01	28.3-33.3'	50900	5.09
		73.3-78.3'	11900	1.19
	MDH-02-01	23-28'	29000	2.9
		39.5-43'	22700	2.27
		63-68'	10500	1.05
	MDH-03-01	23.3-28.3'	27400	2.74
		38.3-43.3'	15100	1.51
		53.3-58.3'	10400	1.04
	MDH-04-01	13-18'	14800	1.48
	MDH-05-01	18-23'	13900	1.39
		48-53'	10300	1.03
	MDH-06-01	18-23'	16200	1.62
	MDH-07-01	21-23'	37500	3.75
	MDH-15-01	12-18'	12600	1.26
		18-28'	17700	1.77
		28-38'	22300	2.23
		38-48'	8500	0.85
		48-58'	10300	1.03
		58-68'	13600	1.36
		68-78'	12100	1.21
		78-85'	11900	1.19
DELTA SUB-AREA	MDH-08-01	8.8-10.8'	5500	0.55
		27.5-32.5'	14300	1.43
		47.5-52.5'	9100	0.91
	MDH-09-01	12.7-17.7'	3900	0.39
		32.7-37.7'	9600	0.96
		42.7-47.7'	8900	0.89
		52.7-55'	4300	0.43
	MDH-10-01	11.3-12.8'	4600	0.46
		22.8-27.8'	5000	0.5
		37.8-40.8'	5200	0.52
		47.8-52.8'	9630	0.963
	MDH-11-01	13-16.2'	4500	0.45
		23-24.5'	4300	0.43
		33-33.5'	4700	0.47
UP-STREAM CHANNEL SUB-AREA	MDH-12-01	23-24'	5400	0.54
	MDH-13-01	26.5-27.7'	8700	0.87
	MDH-14-01	13.5-18'	5700	0.57
		18-21.5'	5000	0.5

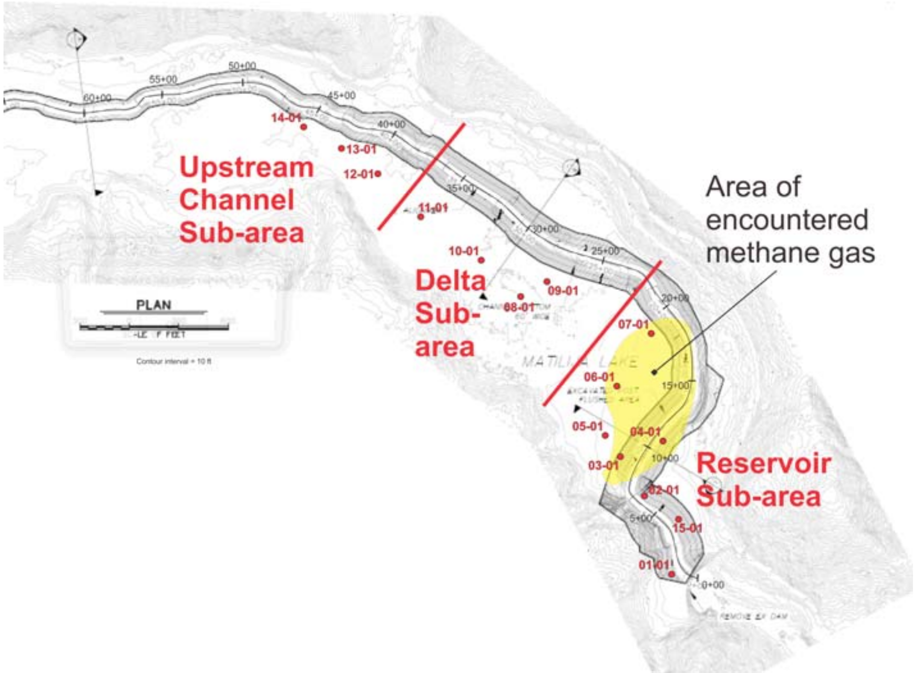


Figure 4.2-6. Overlay of the anticipated channel formed under DRC-1 and 2 with available boreholes (red circles) and the estimated area of methane gas production (from USACE 2002), given its presence in boreholes 3, 4, 6, and 7, and its absence elsewhere.

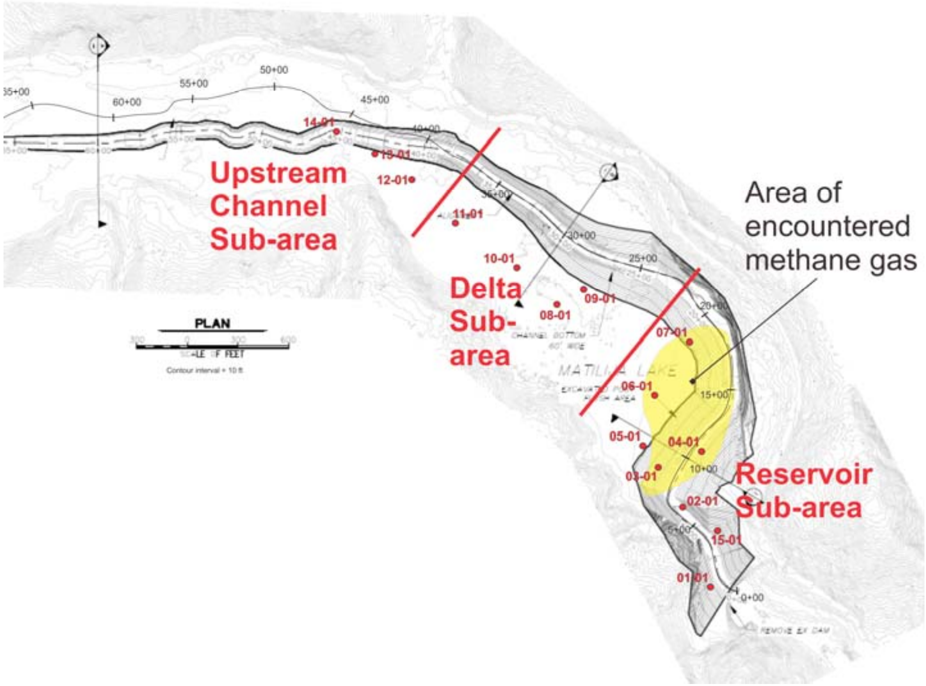


Figure 4.2-7. Map as for Figure 4.2-6 but showing the channel anticipated to develop under DRC-3.

Thus, OD of Klamath River reservoir sediments (5% average organic content) may be used as a conservative estimate of OD resulting from fine sediments following removal of Matilija Dam (1.8% organic content), by applying the same factor reported for the Klamath River reservoirs in Stillwater Sciences (2011) (0.0035 mg OD/mg TSS) to the predicted TSS concentrations in the Ventura River. A less conservative estimate can be made by proportional reduction of the predicted OD by the ratio of organic content in the two reservoir sediments (1.8:5.0, or about 36%). Given the potential for unsampled pockets of high-organic deposits within the Reservoir sub-area, the actual value probably lies between these extremes.

Under DRC-1 and DRC-2, about 1.8 mcy would be eroded from the impounded deposits under Phase I processes (Table 4.2-3), with voluminous sediment delivery and very high TSS concentrations. Most of this sediment will be eroded from the Reservoir sub-area, and about 60% (about 1 mcy) of the total is projected to be silt and clay. Applying the average Klamath sediment OD (i.e., 0.0035 mg OD/mg TSS) to the 1 mcy of fine sediment eroded during Phase I, projected TSS concentrations of greater than 10^5 mg/l would undoubtedly result in complete anoxia (OD > 100 mg/l) in the river downstream of the dam. Even with the two- to three-fold excess of TOC in Klamath sediments relative to Matilija sediments, the implications of this conclusion are unchanged (Table 4.2-7). However, Phase I transport is only anticipated to last for one day, with TSS concentrations that are so high as to be already lethal to salmonids and unsuitable for diversion to Lake Casitas, independent of OD.

Downstream recovery of DO to concentrations above 5 mg/l would eventually occur due to natural diffusive and advective processes affecting air–water exchange in the river. The distance to recovery is likely to be on the order of tens of miles, however, suggesting that Ventura River flows entering the Pacific Ocean will not be severely depleted, but that much of the upstream reach will have suffered severe or total anoxia (the dam-to-ocean distance is about 16 miles) during the hours immediately following dam removal.

Table 4.2-7. Calculation of minimum oxygen demand (OD) under Phase I transport for DRCs-1 and 2.

Value	Units	Reservoir	Source/basis for value
0.0035	mg OD/mg SSC dry weight	Klamath	fine sediment, 0.3-8% organics, 5% avg.
0.36	Reduction factor, [Matilija/Klamath] OD/mg	Matilija	fine sediment = 1.8% organics avg. (Table 4.2-6)
100,000	mg SSC dry weight/l	Matilija	minimum Phase I concentration
60%	Percent fines in eroded material	Matilija	Table 4.2-2
76	**mg OD/l**	**Matilija**	**Calculated result**

Under DRC-3, the sediment that would have undergone Phase I transport under other concepts will instead be excavated and removed from the active channel. The average TOC of these excavated sediments from the reservoir area is also 1.8%, but this material is anticipated to be transported only after months or years of stockpiling on the adjacent floodplain, during which time partial or total oxidation of the organics is likely to have occurred. Thus, DRC-3 avoids the one-time impact of high OD in Matilija Creek and the Ventura River, coincident with this concept's avoidance of very high (i.e., >10^5 mg/l) TSS concentrations.

As discussed above, the magnitude of Phase II erosion and associated levels of TSS concentrations are anticipated to be broadly similar for DRC-1, 2, and 3. Thus, their potential DO impacts are therefore broadly similar to one another and substantially less than that during Phase I of DRC-1 and 2, primarily due to sediment loads that are up to several orders of magnitude less than those of Phase I. Limited borehole data on the TOC content for those sediments adjacent to the channel through the Reservoir and Delta deposits and so likely to be eroded during Phase II suggest an average value of about 1.6% (Table 4.2-8), but the actual value would almost certainly be lower because the sediments will have been exposed to air prior to downstream transport. Nonetheless, Phase II erosion may still result in hypoxia immediately downstream of the dam for a period of a few days under all scenarios, particularly in the first week immediately following dam removal when TSS concentrations may exceed 10^4 mg/l TSS. As with Phase I, however, downstream recovery to DO concentrations above 5 mg/l would eventually occur due to natural channel reaeration. Since the inherent OD from Phase II sediments is likely to be one or more orders of magnitude lower than that of Phase I, the distance to full recovery is likely to be small (e.g., on the order of a mile or less) and maintain suitability for diversion to Lake Casitas.

By way of comparison, background OD in high-TSS winter flows in the Ventura River, into which this water will flow, is likely to be very low (<1 mg/l) due to primarily mineral forms of carbon typical of eroding hillslopes.

In summary (Table 4.2-9), very high OD during Phase I transport under DRC-1 and 2 is likely to create severely anoxic conditions in Matilija Creek and much, if not all, of the Ventura River during those hours immediately following dam removal for which suspended sediment concentrations will also be extraordinarily high. In the following week of (exponentially declining) Phase II transport, OD will fall rapidly to single-digit values given the rapid, orders-of-magnitude reduction in suspended sediment concentrations that are anticipated to occur. At these levels, the water should be rapidly re-oxygenated by downstream transport.

DRC-3 would avoid the day of intense anoxia immediately following dam removal and likely have a reduced level of background OD contribution during the following weeks of Phase II transport as well. However, the stockpiling of locally organic-rich sediment, particularly if not fully oxidized prior to further burial, would create some uncertainty for the magnitude of future OD during a subsequent sediment-mobilizing event. Under any dam removal alternative, however, the impacts of low DO in Matilija Creek during Phase II (and beyond) are likely to be minimal in extent and duration, and indiscernible in the Ventura River. Future transport of methane-generating organic sediment under any scenario would be restricted to those areas in the vicinity of borings 06-01 and 07-01 (Figures 4.2-6 and 4.2-7) and be of such incremental amounts as to be well-oxidized in transit to the Ventura River. Only a major avulsion could release significant new amounts of such material into Matilija Creek following Phase I, but the likelihood of such an event is negligible (see next section).

Table 4.2-8. Total organic carbon content of sediment encountered by borings and likely to be eroded under DRC-1 and 2 (note that Phase II erosion occurs for DRC-3 as well).

Sub-Area	Boring	Depth of sample (feet)	TOC %	Phase eroded
Reservoir Sub-Area	MDH-01-01	28.3-33.3'	5.09	I
		73.3-78.3'	1.19	I
	MDH-02-01	23-28'	2.9	I
		39.5-43'	2.27	I
		63-68'	1.05	I
	MDH-03-01	23.3-28.3'	2.74	I
		38.3-43.3'	1.51	I
		53.3-58.3'	1.04	I
	MDH-04-01	13-18'	1.48	I
	MDH-05-01	18-23'	1.39	II
		48-53'	1.03	II
	MDH-07-01	21-23'	3.75	II
	MDH-15-01	12-18'	1.26	I
		18-28'	1.77	I
		28-38'	2.23	I
		38-48'	0.85	I
		48-58'	1.03	I
		58-68'	1.36	I
		68-78'	1.21	I
		78-85'	1.19	I
Delta Sub-Area	MDH-09-01	12.7-17.7'	0.39	II

Table 4.2-9. Estimated oxygen demand (OD) in Matilija Creek and the Ventura River resulting from mobilization of Matilija Reservoir sediments following dam removal.

Phase I (DRCs-1 and 2 only)	Phase II (all concepts)	Units	Source
0.0012	0.0012	mg OD/mg TSS	Stillwater Sciences (2011) and this report
10^6–10^5	10^4–10^3	mg /l TSS	This report
60%	60%	percent fines in bulk material	This report
≥100	**10 to <1**	**mg OD/l**	

4.2.3 Avulsion

The analyses summarized above have all been conducted under the assumption that the primary channel of Matilija Creek through the impounded sediments remains generally fixed in location. This is a virtual certainty in the downstream reaches of the project area, insofar as the outlet location (at the present dam site) is fixed by bedrock outcrops and the depth of the incised channel will preclude out-of-bank shifts. In the upper part of the Upstream Channel sub-area, however, the channel is neither so deeply incised nor so laterally constrained that the potential for future avulsions (i.e., abrupt shifting to a new channel location, commonly by local in-channel deposition of coarse sediment during a flood and opportunistic occupation of an adjacent low area of the adjacent floodplain) can be ignored. However, the base level lowering of dam removal will generally result in channel degradation in this reach, which suppresses channel avulsion (i.e., while channel avulsion is still possible, the tendency will be much lower than under current conditions).

Past and existing conditions provide useful guidance for assessing the future risk of avulsion. The largest flood in the last 12 years (i.e., the period of record of gage 1114495) on Matilija Creek occurred on February 21, 2005 (8,780 cfs peak flow, between a 10 and 20- year flood; Stillwater Sciences 2014b). An aerial view of the floodplain (Figure 4.2-8) in the summer of 2006 shows the extent of avulsion and consequent braiding in the Upper Channel sub-area, largely confined to between about stations 95+00 and 45+00 (using the stationing of Appendix A, Drawing 5) and consistent with both modern topography (Drawing 5) and field evidence (Figure 4.2-9).

Following dam removal, however, the channel will be more deeply incised into the surrounding floodplain, either by the natural re-establishment of grade (DRC-1 and 2), or some combination of mechanical excavation and natural erosion (DRC-3). At station 60+00 (cross section A on Drawing 5) the magnitude of this incision is anticipated to be about 20 feet and will almost certainly maintain a confined channel that cannot avulse; at Station 85+00, however, the incision will be no more than about 5 feet and would surely permit some continued avulsion activity during a large flood.

Thus, future avulsion of the channel in the upper part of the Upstream Channel sub-area is potentially possible but less likely, compared to current conditions as discussed earlier. If avulsion in the Upstream Channel sub-area does occur as with the 2005 flood, any new avulsion channel will almost certainly rejoin the prior channel course before reaching the Delta sub-area at Station 37+00, most likely between 45+00 and 40+00, where an alluvial fan (left bank) and a bedrock ridge (right bank) confine the valley to no more than twice the width of the projected “canyon” of the incised Matilija Creek (Figure 4.2-8 and Drawings 5 and 13 of Appendix A). Thus, the risk of future, catastrophic release of fine sediment from a new avulsion channel eroding the reservoir deposits is judged to be negligible.

Figure 4.2-8. GoogleEarth© view of the Upper Channel sub-area (image date 8/12/2006; stationing [green numerals] from Drawing 5 of Appendix A). An alluvial fan is visible just north of 40+00; a bedrock ridge confines the valley on the right (south) bank about 300 feet upstream of this point. Station 60+00 (near the center of the image) is the location of cross-section A on Drawing 5, which projects about 20 feet of channel incision; Station 85+00 projects no more than about 5 feet of incision. The upstream-most location of observed braiding from airphotos (labeled) corresponds to the approximate upstream end of anticipated channel regrading (whether natural or mechanical) following dam removal.

Figure 4.2-9. Field view of the floodplain of Matilija Creek in the Upstream Channel sub-area, 60 m south of the present channel at about station 60+00 (Drawing 5), looking downvalley. Multiple braided channels give evidence to their frequent occupation, with the likelihood that one or more of them could become the main channel in the course of a very large flood.

4.3 Steelhead Passage – Dam Removal Case Studies

Analytical methods are ill-suited to predict the details of channel formation from initial headcutting and downcutting of the flow through the impounded sediments immediately following dam removal. Therefore, evaluation of the empirical data from prior dam removal projects is required to predict the morphology of the post-removal channel and its suitability for upstream fish passage. Among such recent projects, the Marmot Dam removal on the Sandy River is a particularly good analog to Matilija Creek (Table 4.3-1), particularly for understanding the likely development of the channel through the Delta and Upstream Channel sub-areas, primarily through the process of natural erosion for all three dam removal concepts. This example will serve as input to the evaluation of fish passage criteria (Section 5) for the three dam removal concepts summarized in this report.

Table 4.3-1. Comparison of characteristics governing initial sediment erosion and fish passage for Marmot Dam and Matilija Dam removal projects

Parameters Relevant to Fish Passage	Marmot Dam Removal	Matilija Dam Removal
Daily average discharge	1,840 cfs on day 1; 2,010 and 2,200 cfs the next two days	> 1,700 cfs
Approximate equilibrium channel gradient	0.01	0.017
Estimated effective channel width	~ 50 m	< 50 m
Deposit composition	Both with stratified deposits, see Figure 4.3-1 and Figure 4.3-2	
Coarse sediment grain-size distribution	Very similar, see Figure 4.3-3	

The daily average discharge in the Sandy River on the day of sediment erosion (i.e., the date of cofferdam breaching) was 1,840 cfs, which is only slightly higher than the design discharge of 1,700 cfs for DRC-1 and DRC-2. Hence, it is very likely that daily average discharge on the day of sediment erosion in Matilija Creek following Matilija Dam removal will be as high as or higher than that in the Sandy River. The overall geometry of delta and reservoir sediments behind Marmot Dam was similar to that behind Matilija Dam, and the approximate equilibrium channel gradient of the Sandy River is significantly flatter than that of Matilija Creek (Figures 4.3-1 and 4.3-2). In addition, the expected effective channel width through the impounded sediments behind Matilija Dam is expected to be narrower than the Sandy River. These factors can be integrated to form an empirically informed projection of the time required to establish fish passage through the impounded sediments.

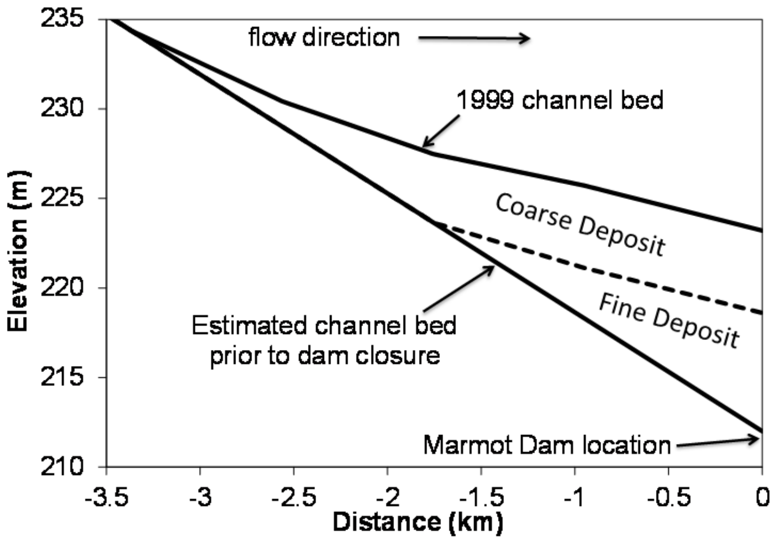


Figure 4.3-1. Profile of Marmot Dam sediment deposit, Sandy River, Oregon, modified from Cui and Wilcox (2008). Gradient of the pre-dam channel bed is 0.0066.

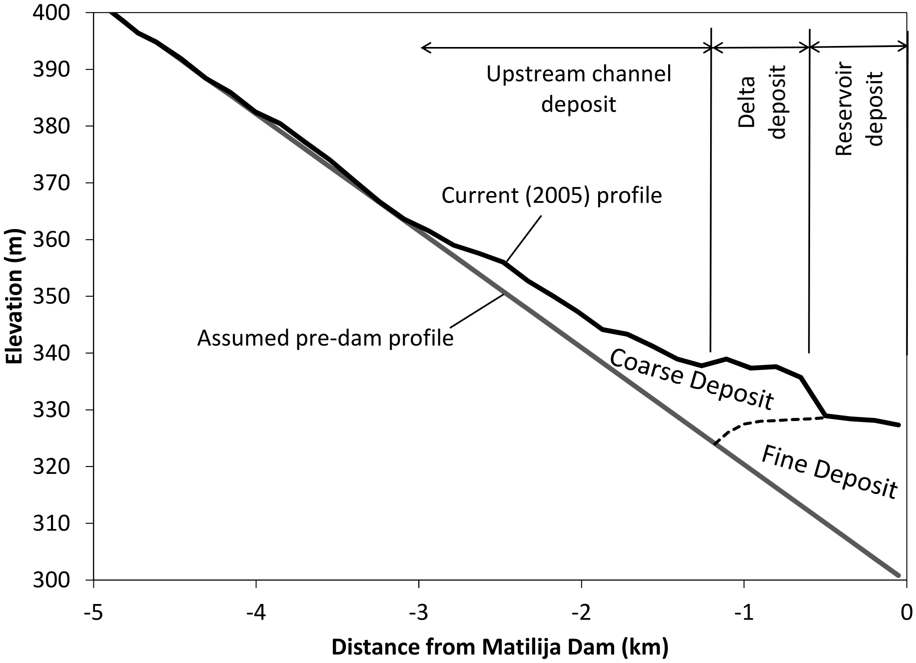


Figure 4.3-2. Profile of Matilija Dam sediment deposit. Gradient of the assumed pre-dam profile is about 0.02.

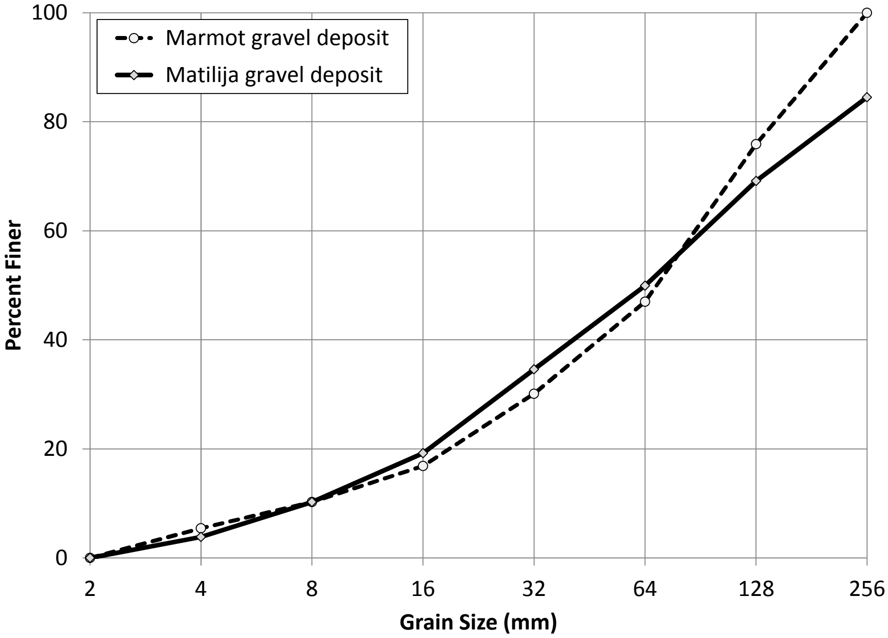


Figure 4.3-3. Comparison of grain size distribution of the gravel deposits in Marmot and Matilija reservoirs. Marmot gravel deposit grain size distribution was obtained from Stillwater Sciences (2000).

After dam removal, the Sandy River became visually similar to an undisturbed natural river only one night following the initiation of sediment erosion (Figures 4.3-4 and 4.3-5) and with observed upstream fish migration within three days following the initiation of sediment erosion (Cui et al. 2014). This suggests that physical conditions for the re-establishment of upstream fish passage should be very rapid in any similar system, including Matilija Creek, if the impounded deposits are allowed to erode naturally.

Figure 4.3-4. Photographs of the Sandy River Marmot Dam site (courtesy of Bruce McCammon) showing flow beginning to erode the cofferdam and the reservoir deposit.

Figure 4.3-5. Photographs of the Sandy River Marmot Dam site (courtesy of Jon Major) approximately 13 hours after breaching, at which time the river appeared to be close to its natural conditions (ignoring the concrete and steel bars and plates on-site)

The primary difference between these two settings is the existence of a proximal body of fine-grained sediments behind Matilija Dam, for which the process of initial channel formation at Condit Dam on the White Salmon River is a close (though not perfect) analog (with its 1.8 million m^3 sediment composed of 60% sand, 35% silt and clay, and 5% gravel; Wilcox et al. 2014). Although no direct observations were reported that speak directly to the attainment of fish passage through the impounded sediment, qualitative descriptions of observed sediment-delivery processes, the rapid drop-off in measured suspended sediment concentrations, and photographs of the evolving upstream channel all suggest that any potential physical barriers to fish passage had been obliterated by the time that Phase I erosion had ceased and access by fish through the turbid water downstream was even credible.

In addition to post-dam removal fish passage, water diversion from Matilija Creek into North Fork Matilija Creek through the bypass tunnel during the extended construction and waiting period for DRC-1 may alter fish passage conditions in North Fork Matilija Creek. Increased flow is likely to benefit adult steelhead upstream passage and juvenile rearing habitat in North Fork Creek in general, and may help reduce impacts of dam removal by increasing migration into, and refuge within, the North Fork prior to downstream impacts in the mainstem Matilija Creek. However, during high flow events there is a risk of decreased rearing suitability and fish passage conditions from high water velocities, which may occur under some conditions that would require more detailed hydraulic analysis if this alternative advances. If high flows appear to result in fish passage impediments during observed adult steelhead migration, capturing and transporting adults to suitable habitat might be necessary to avoid mortality.

4.4 Steelhead Health Downstream of the Matilija Dam Site

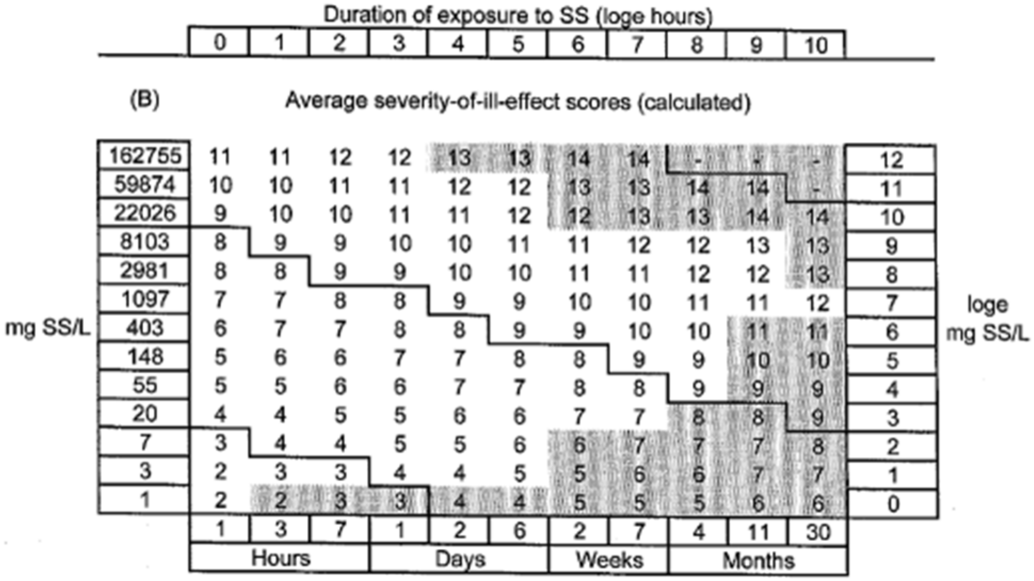
The purpose of this section is to:

1. Present a previously developed relationship between high suspended sediment concentrations and steelhead health,
2. Evaluate likely impacts to steelhead health under natural suspended sediment conditions, and
3. Discuss in general how increased sediment concentrations associated with dam removal may incrementally impact steelhead health.

This information will be considered in Section 5 during the detailed evaluation of steelhead health associated with the three dam removal concepts.

The effect of high TSS concentrations on salmonids is based on the work of Newcombe and Jensen (1996). Their summary results are presented below (Figure 4.4-1), where the "severity-of-ill-effect" scores ('severity scores') in each cell of the table are interpreted as follows: values between 1 and 3 are judged "behavioral responses"; 4-8 are "sub-lethal effects"; and 9-14 indicates potentially lethal effects: 9 = paralethal, 10 = 0-20% mortality, 11 = 20-40% mortality, 12 = 40-60% mortality, etc.

These data can be recast as continuous functions, which provides a basis to evaluate the relative trade-offs between the magnitude and the duration of the effects of high TSS concentrations (Figure 4.4-2).



Duration of exposure to SS (loge hours)

(B) Average severity-of-ill-effect scores (calculated)

mg SS/L	0	1	2	3	4	5	6	7	8	9	10	loge mg SS/L
162755	11	11	12	12	13	13	14	14	-	-	-	12
59874	10	10	11	11	12	12	13	13	14	14	-	11
22026	9	10	10	11	11	12	12	13	13	14	14	10
8103	8	9	9	10	10	11	11	12	12	13	13	9
2981	8	8	9	9	10	10	11	11	12	12	13	8
1097	7	7	8	8	9	9	10	10	11	11	12	7
403	6	7	7	8	8	9	9	10	10	11	11	6
148	5	6	6	7	7	8	8	9	9	10	10	5
55	5	5	6	6	7	7	8	8	9	9	9	4
20	4	4	5	5	6	6	7	7	8	8	9	3
7	3	4	4	5	5	6	6	7	7	7	8	2
3	2	3	3	4	4	5	5	6	6	7	7	1
1	2	2	3	3	4	4	5	5	5	6	6	0
	1	3	7	1	2	6	2	7	4	11	30	
	Hours			Days			Weeks		Months			

Figure 4.4-1. Fish Response to Suspended Sediments for Adult Salmonids (using the empirically generated model of Newcombe and Jensen, 1996)

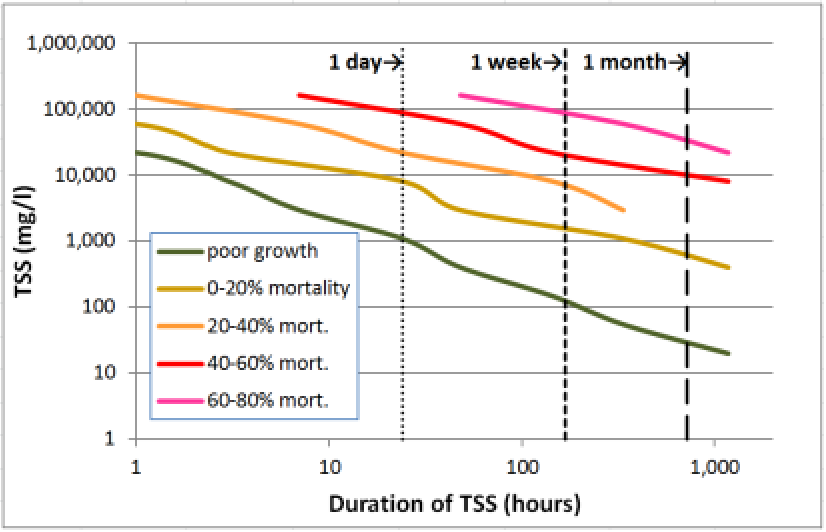


Figure 4.4-2. Table of effects from Newcombe and Jensen (1996), recast to show continuous boundaries between the cells of Figure 4.4-1 to simplify interpolation. Lines are drawn at the approximate "base" of each indicated category.

The background TSS concentrations in this naturally sediment-rich system are a likely cause of steelhead mortality and will persist independent of the differences in any alternative dam removal scenario. Applying Eqn. 4-1 to the full discharge record of gage 11114495 (Figure 4.2-5) predicts 12 high-TSS "events," which occur in 10 of the 12 water years that the gage has been operating (Figure 4.4-3). Each of these events would have had severe effects on any salmonids occupying the system by the criteria of Newcombe and Jensen (1996) (Figure 4.4-4), with significant mortality for adult and juvenile fish in the system at that time independent of any additional effects from the erosion of impounded sediments following dam removal. The Matilija system can obviously prove to be a challenging environment for steelhead to thrive. These conditions also stress the importance of tributary habitat, which provide refuge habitat from these natural events (and presumably would serve the same function following dam removal as well), because a nominally lethal, high-sediment condition in a channel with available refugia does not necessarily result in mortality for mobile organisms that have evolved under these conditions.

In addition, no study has been conducted on the behavior or tolerance of steelhead in the southern extreme of their range, where sediment loading is periodically and naturally extremely high, and there is some evidence that *O. mykiss* have a higher level of tolerance to sediment than other Oncorhynchus species (e.g., Sigler et al. 1984). Therefore, the analysis presented in this study can be considered a conservative evaluation, quite possibly overestimating the projected sediment level effects on O. mykiss in the Ventura River system (A. Spina, NMFS, written comm. 2015).

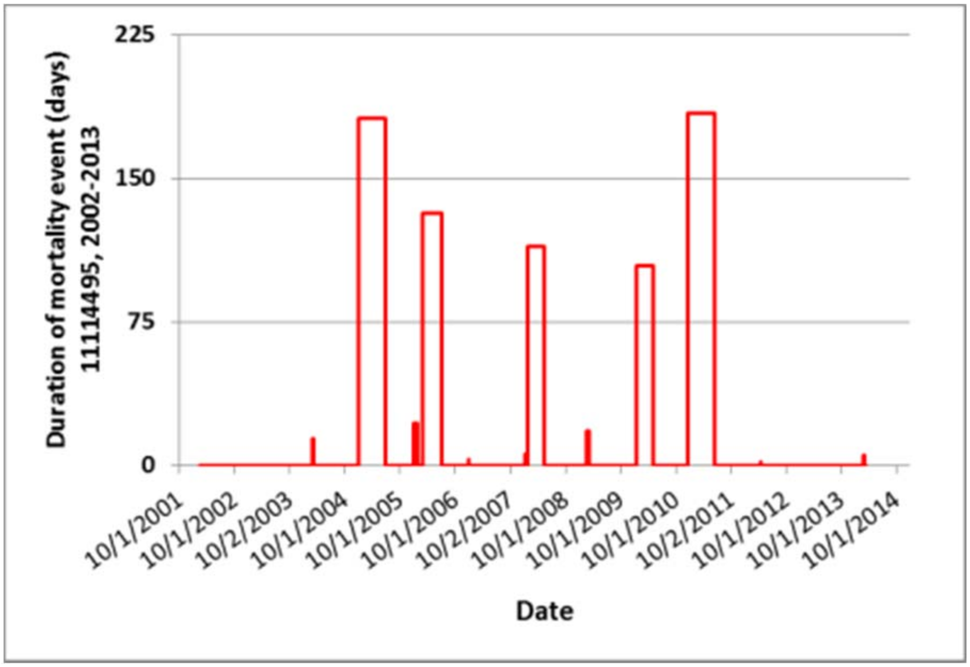


Figure 4.4-3. The flow record of Matilija Creek translated into periods of high fish mortality, using Equation 4-1 to translate flow into TSS. All dates without sufficient TSS to cause mortality plot along the x-axis; those of sufficient magnitude and duration are represented by the red bars, with a height that corresponds to the total duration of the event over which some degree of mortality is predicted.

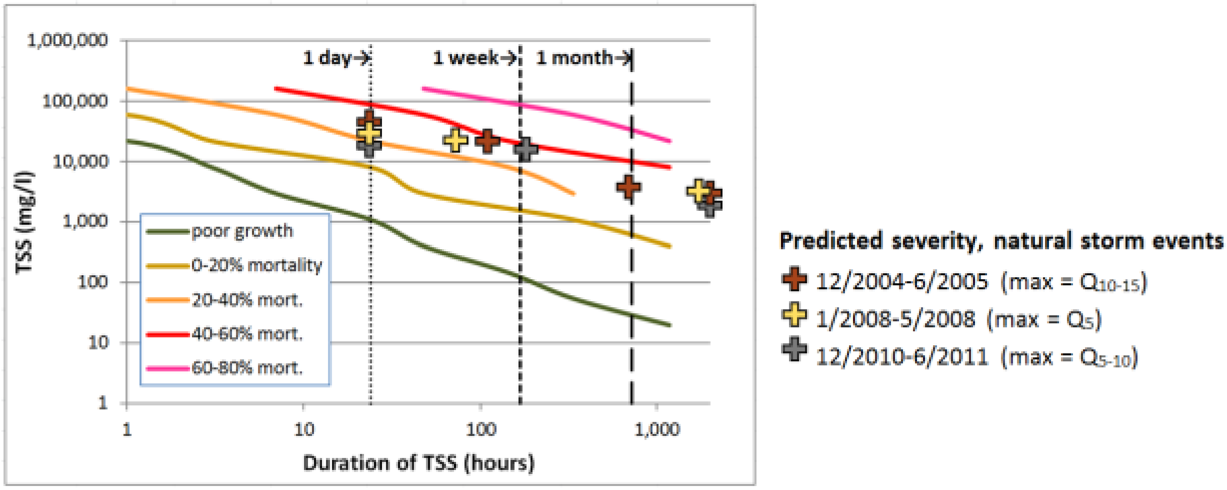


Figure 4.4-4. The three natural storm events on Matilija Creek from the 12-year gage record of 11114495 with the three most severe effects on fish mortality, plotted on the base of Figure 4.4-2. Predicted effects are plotted for three separate durations for each event, but all tend to fall in the same range (i.e., 20-40% mortality, corresponding to category "11" of Newcombe and Jensen 1996) regardless of the duration considered.

Had dam removal occurred during any of the five flow periods of greatest lethal effects in the last 12 years, natural TSS concentrations would have been greatly exceeded during Phase I (for DRC-1 and 2). Immediately following this, any of these flow periods each would have presumably seen an incremental increase in the severity of effects associated with Phase II erosion associated with an additional (and rapidly declining) ~10^4-10^3 mg/l suspended sediment over the anticipated one-week period of elevated Phase II erosion. This increment would not have resulted in any change in risk category and would barely change the magnitude of risk within that category, except perhaps for the first few days following dam removal.

As a further indication of the high natural sediment loads in this system, the shortest and least severe of the five events with significant predicted mortality (i.e., the 104 days from 1/18/2010 to 5/2/2010) had a peak discharge of 1,380 cfs on January 21st of that year, corresponding to about a 3-year discharge and so not reaching the recommended threshold for dam breaching of 3,000 cfs. Nonetheless, even without any additional contribution from Phase II erosion, this flow had a predicted maximum TSS concentration of about 12,000 mg/l, which yield severity scores of 10 for its one-day and 1-week TSS maxima, and a severity score of 11 for its one-month TSS level.

In summary, initial release of sediment during uncontrolled Phase I transport would be very short-lived (about one day) and quite lethal to any salmonids that remained in Matilija Creek, with declining but still very significant impacts in the mainstem Ventura River as flows become diluted. Subsequent transport events would be accompanied by naturally high sediment concentrations that are generally at or above those contributed by ongoing Phase II erosion. In the period immediately following dam removal, any such impacts would be of marginal incremental consequence relative to the broadly lethal consequences of Phase I. Over the subsequent week of discernable Phase II erosion impacts, empirical data from other dam removals (Section 4.2.1) suggest that chronic impacts would rapidly decline to levels substantially below those of the natural watershed sediment loads themselves.

The effect of each specific dam removal concept on steelhead health is discussed in more detail and given a severity score for evaluation in Section 5.

4.5 Flushing Flow Waiting Period

Two of the three dam removal concepts share a similar pattern for construction: removal of the dam (DRC-1) or construction of an orifice (DRC-2) during the dry season, followed by an indeterminate waiting period until a storm with a peak discharge of at least 3,000 cfs occurs during a subsequent wet season. This magnitude of flow has been determined to be sufficient to mobilize a substantial sediment load and to complete the process of Phase I erosion (Stillwater Sciences 2014b).

Given the highly episodic nature of storm events in southern California, the potential exists for many years' delay between the period of active construction and the final post-flush construction activities. Such a delay, given both its potential duration and its indeterminacy, could pose challenges for project management and funding. Therefore, this section offers a closer evaluation of the probability of delays between the initial and final stages of dam removal.

The Hydrologic Assessment memorandum (Stillwater Sciences 2014b) made a preliminary determination of the historical delays between successive "large" events, concluding that the intervals between them ranged from one (i.e., successive years) to ten years, with a median gap of three years. That analysis used average daily flows as the metric, with a threshold of either 5,000 cfs on the Ventura River at gage 11118500 (with a record spanning water years 1928-present) or 1,667 cfs on Matilija Creek as measured at gages 11115500 (1928-1988), 11114500 (1949-1969), and/or 11114495 (2002-present).

This section provides an assessment of the number of years of climate-driven delay that might be necessary following initial construction (dam removal for DRC-1, tunnel boring for DRC-2), using measured or reconstructed peak flows on Matilija Creek and based on the assumption that this construction phase would be completed during a single summer season. If a sufficiently high flow occurred during the water year immediately following construction, this would be considered a condition of "no delay."

Flows on Matilija Creek have been gaged for much, but not all, of the period from 1928 to the present, providing the raw data for the following analysis. The different periods of record, and how they are treated for this analysis, are as follows:

Table 4.5-1. Summary of Gage Records.

<table>
<tr><th colspan="2" rowspan="2">Water Year</th><th colspan="3">Matilija Creek gages</th><th>Ventura River gage</th><th rowspan="2">Data source(s) for Matilija Creek discharge</th></tr>
<tr><th>11115500</th><th>11114500</th><th>11114495</th><th>11118500</th></tr>
<tr><td colspan="2">1928-1947 (pre-dam)</td><td>X</td><td></td><td></td><td>X</td><td>11115500</td></tr>
<tr><td rowspan="4">Post-dam</td><td>1948-1969</td><td>X</td><td>X</td><td></td><td>X</td><td>Average of 11115500 and 11114500</td></tr>
<tr><td>1970-1988</td><td>X</td><td></td><td></td><td>X</td><td>11115500</td></tr>
<tr><td>1988-2001</td><td></td><td></td><td></td><td>X</td><td>transformed 11118500</td></tr>
<tr><td>2002-present</td><td></td><td></td><td>X</td><td>X</td><td>11114495</td></tr>
</table>

The data sources summarized in Table 4.5-1 are described in more detail as follows:

- 1928-1947: During this period, gage 11115500, located less than a mile downstream of the eventual dam site, was the only operational gage on Matilija Creek.
- 1948-1969: Gage 11114500, located a few miles upstream of the newly constructed Matilija Dam, began operating in June of 1948. The gage has a smaller drainage area (50.7 mi^2) than Gage11115500 (54.6 mi^2) but lies upstream of the potentially moderating effects of the dam. Comparison of the same-day record of these two gages during peak flow events >3000 cfs suggest no major differences between them with respect to the current analysis—in all cases, flows exceeding that threshold at one gage do so at the other as well (Figure 4.5-1). Most peak flows at 11115500 are slightly lower than at 11114500, suggesting a slight but generally negligible attenuation of large flood peaks by the dam (see also BOR 2006). The one exception, January 15 1952 (8800 cfs at 11114500, 3530 cfs at 11115500), may reflect the period of initial filling of the reservoir, but even that does not change the present evaluation since both discharges exceed 3000 cfs.
- 1970-1988: During this period, only gage 11115500 was operating on Matilija Creek. Being downstream of Matilija Dam, flows at this gage were potentially attenuated by its presence;

however, the 1948-1969 record indicates that any such influence was not significant for this analysis.

- 1988-2001: During this period, no gage was operating on Matilija Creek, and so peak flows must be determined by analogy to other operational gages, of which 11118500 on the Ventura River is most suitable by virtue of location and longevity. Over the full period of record, Stillwater Sciences (2014b) determined that average daily flows at Matilija Creek are approximately one-third that of the Ventura River. For the more limited (but more relevant) high-flow events on the two channels, the same relationship applies (Figure 4.5-2):

  Matilija Creek peak flow = 0.35 × [Ventura River peak flow]

  Using this equation, a peak discharge on the Ventura River must exceed 8,600 cfs to indicate a "major" event on Matilija Creek (i.e., peak flow >3,000 cfs).

- 2002-present: During this period, gage 11114495 has been operational upstream of the dam and has been used in the analysis with no corrections.

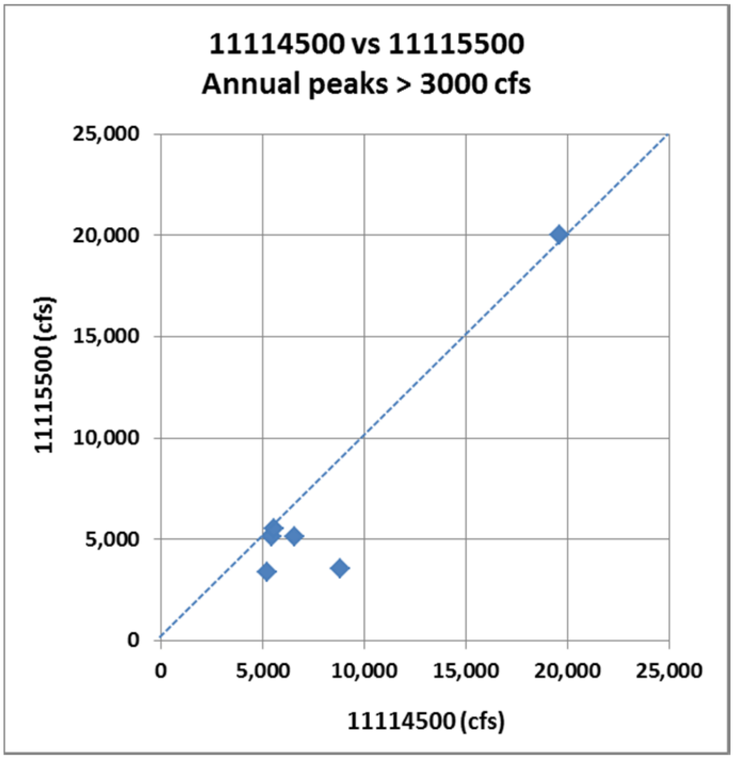


Figure 4.5-1. Comparison of same-day peak discharges for two simultaneously recording gages on Matilija Creek, 11114500 (upstream of dam) and 11115500 (downstream of dam). The period of overlapping records is water years 1948-1969, with peak discharges >3,000 cfs occurring in water years 1952, 1958, 1962, 1966, 1967, and 1969. Dashed line shows condition of perfect agreement.

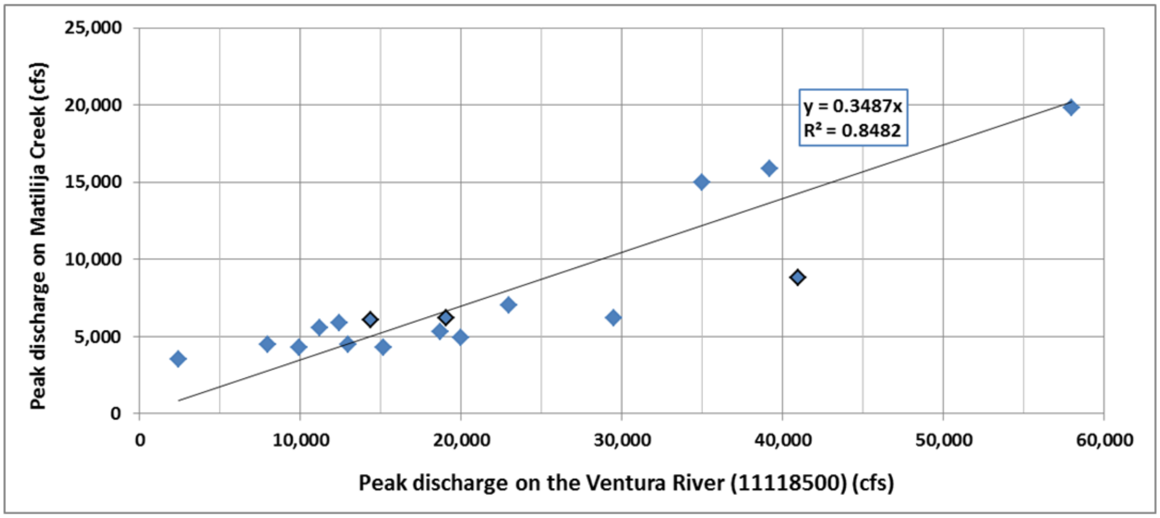


Figure 4.5-2. Relationship between peak discharges on the Ventura River at gage 11118500 and those on Matilija Creek. The three black-outlined points are from 2005-2011 at gage 11114495; all others are from gages 11114500 and/or 11115500.

With a synthesized, "complete" record of peak flows over 3,000 cfs on Matilija Creek from 1929 to the present, the frequency of such flows and the distribution of time between successive flows can be determined. The complete record through the end of water year 2015 is as plotted in Figure 4.5-3a. Figure 4.5-3b, plotted on the same time scale, shows the number of years of delay between any given summer (presumed to mark the completion of pre-dam-breaching construction) and arrival of a flow event >3,000 cfs. By this rationale, a delay of "0" years means that such a flow occurs in the water year immediately following; a delay of one year means that one entire year would be idle (plus, of course, whatever additional weeks or months pass before the actual event arrives).

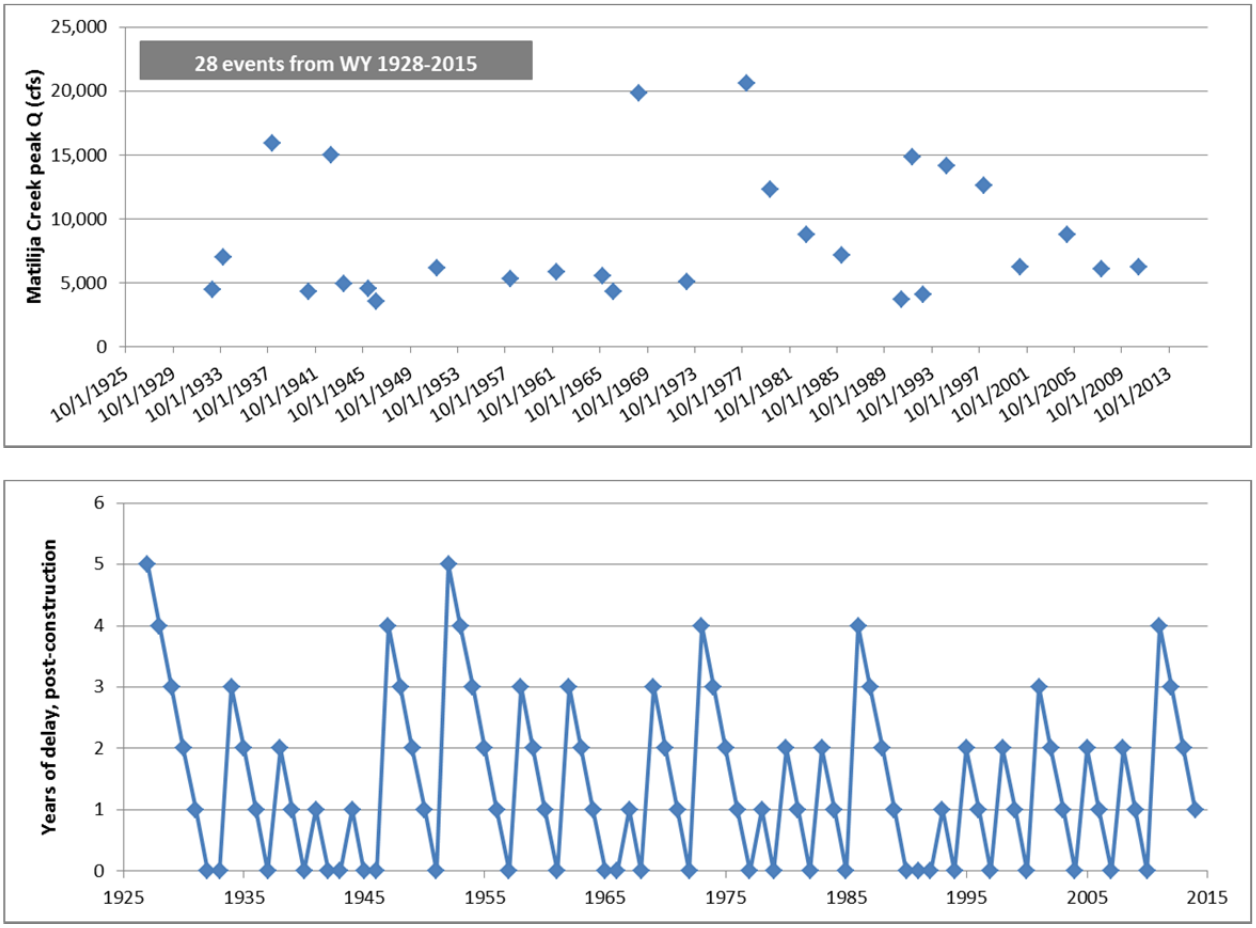


Figure 4.5-3. Top (a), the time series of all peak discharges >3,000 cfs on Matilija Creek since gaging in the watershed began in (water year) 1928. Bottom (b), the years of delay that would have occurred had pre-breaching construction been completed in the summer immediately preceding the indicated water year. So, for example, had construction been completed in the summer of 1983 (and so just "missing" the 3/1/1983 flood), final dam removal under DRC-1 or 2 would have had to wait two years for the flood of 2/14/1986. Had the initial phase of construction been completed in the summer of 1985, however, the same flow event would have resulted in a "0 year" delay.

The distribution of such delays is graphed in Figure 4.5-4. Regardless of the year of initial construction, no delay over the period of record is longer than five years; the median wait for a >3,000 cfs event on Matilija Creek is two years.

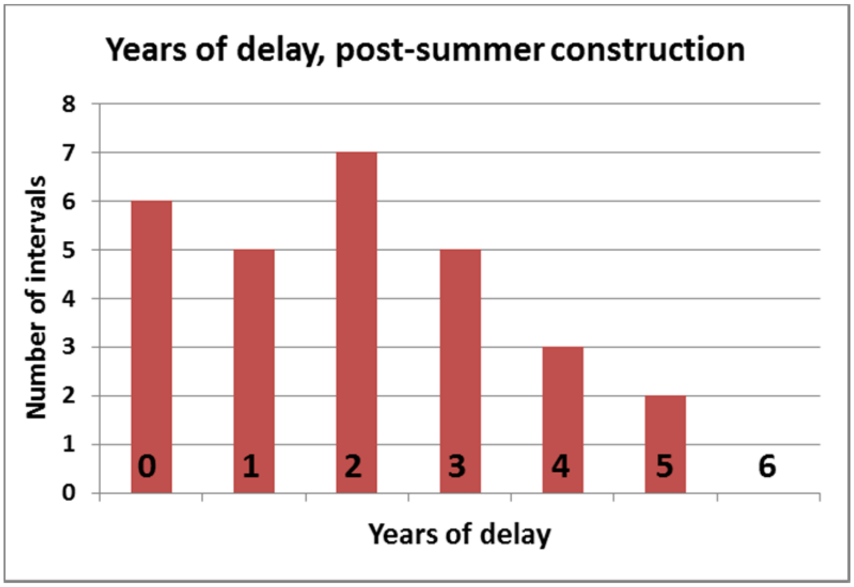


Figure 4.5-4. Distribution of delays over the period 1928-2011 (as of 2015, an additional 4-year delay associated with hypothetical summer 2011 construction has accrued but is not plotted).

5.0 Results & Discussion

5.1 Steelhead Passage through the Project Area

5.1.1 Project Implementation Duration (Construction and Flush Waiting Period)

Construction durations were estimated based on estimated quantities, labor, equipment application, and production required to implement each of the dam removal concepts. The estimated duration of construction also considered the logical sequence of work to permit concurrency of activities whenever possible. A detailed description of the consideration and key construction activities as they pertain to the schedule is provided in Appendix B, along with detailed schedule Gantt charts.

The range of overall project duration for each of the dam removal concepts was estimated assuming that the project is completed either just prior to a peak flow of 3,000 cfs (approximately a 4-year return event[8]) or just after such an event. A summary of the information provided in Appendix B is listed below for each concept:

1. DRC-1: A total of three construction seasons would be required (two prior to the large event and one following the large event). The estimated construction schedule is shown in Figure B-1. Construction duration for DRC-1, from start of construction to completion of dam removal would be in the range of three to six years depending on the timing of the high flow event that removes the sediment.
2. DRC-2A: A total of two construction seasons would be required (one prior to the large event and one following the large event). The estimated construction schedule for DRC-2A is shown in Figure B-2. Construction duration for DRC-2A, from start of construction to completion of dam removal would be in the range of two to five years depending on the timing of the high flow event that removes the sediment.
3. DRC-2B: A total of three construction seasons would be required (one prior to the large event, one after the first large event to install the gate, and one following the second large event). The estimated construction schedule for DRC-2B is shown in Figure B-3. Construction duration for DRC-2B, from start of construction to completion of dam removal would be in the range of three to nine years depending on the timing of the two high flow events that removes the sediment.
4. DRC-3: A total of two construction seasons would be required for DRC-3. The estimated construction schedule is shown in Figure B-4. Construction duration for DRC-3, from start of construction to completion dam removal would be two years. This would be followed by a waiting period of up to three additional years for the high flow event.

The construction schedules for DRC-1 and DRC-2 include a three-year waiting period for the large sediment mobilization event (since certain construction activities occur post-flush). A waiting period of

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[8] A 4-year return event is the minimum size storm considered to be large enough to move significant volumes of accumulated sediment from the reservoir area (Stillwater Sciences, 2014b), and corresponds to a peak flow of about 3,000 cfs on Matilija Creek. For the purposes of this evaluation, it assumed that 4-year or larger storms occur on an average interval of four years, although the reconstructed median wait time over the period of gaging on the Ventura River and its tributaries is only 2 years (see Section 4.5).

three years was selected to be conservative relative to the median wait time of two years summarized in Section 4.5. For DRC-3, construction in complete after two years, which would then be followed by a similar waiting period for a large sediment mobilization event (to further erode impounded sediments and improve fish passage). It is possible that some fish may be able to migrate upstream through the excavated channel (5% longitudinal slope for approximately 1,100 feet) prior to the sediment flushing event, if some fish-friendly elements are added to the channel.

Table 5.1-1 summarizes the construction durations provided in Appendix B.

Table 5.1-1. Project Implementation Durations for Each Dam Removal Concept

Dam Removal Concept	Implementation Duration (years)
DRC-1	3 to 6
DRC-2A	2 to 5
DRC-2B	3 to 9
DRC-3	2 to 5

5.1.2 Time to Fish Passage after Sediment Flushing

As summarized in Section 4.3, predicting the duration of impassable conditions following dam breaching is best accomplished by analogy to other dam removal projects where this parameter was monitored or otherwise can be evaluated. Following removal of Marmot Dam on the Sandy River, for example, upstream conditions became visually similar to an undisturbed natural river only one night following the initiation of sediment erosion; upstream fish migration was observed within three days following the initiation of sediment erosion under a discharge similar to the design discharge for DRCs-1 and 2 (Cui et al. 2014). This suggests that the re-establishment of upstream fish passage should be very rapid in any similar system, including Matilija Creek for which the grain-size distributions of the upstream sediment deposits are similar.

A variety of factors are likely to promote even more rapid channel erosion in Matilija Creek under DRC-1 and DRC-2 than in the Sandy River and, thus, even quicker re-establishment of upstream fish passage. The sediment deposits in the two impoundment areas are similar but the channel upstream of Matilija Dam is anticipated to be both steeper and narrower than that behind Marmot Dam. The grain size distributions of the coarse sediment deposits, which will govern the rate of sediment erosion in the two reservoirs, are particularly close in character (Figure 4.3-3). Based on these comparisons, re-establishment of physical conditions to allow upstream fish passage following initiation of sediment erosion for DRCs-1 and 2 should be very rapid (i.e., within a few days, and likely much less) and require no mechanical intervention.

In the unlikely contingency of gate installation and closure for DRC-2B, the establishment of fish passage will be dictated by how the gates are operated. Fish passage will most likely be available following the first day’s flush at all times that the gates are open and discharge is within the passage range, assuming that fish access to the downstream end of the tunnels is possible. Fish passage will obviously be blocked for as long as the gates are closed.

For DRC-3, fish passage will likely be fully established after the same flow event that initiates channel formation under DRC-1 and DRC-2, within the same time frame of no more than a few days but with slightly greater uncertainty. This uncertainty is associated with the engineered channel bed protection provided along the 1,100-foot transition section from pre-dam alluvium to the upstream pilot channel thalweg. The bed protection is included to limit or prevent high turbidity during a series of smaller flow events. The engineered bed material within the transition zone would be designed to mobilize and allow headcutting during the large flow event, resulting in the "passable" post-flush surface shown on Drawing 15. There is a risk, however, that the engineered channel bed material could cause temporary impediments to fish passage, either by failing to mobilize under the design event (and so allowing a 5% channel slope to persist) or by mobilizing and re-depositing farther downstream in a way that would temporarily impede passage.

5.1.3 Total Time to Fish Passage

In summary, physical conditions suitable for upstream fish passage in Matilija Creek will most likely be established within a few days following the initiation of sediment erosion for DRCs-1, 2A, and 3. Closure of the gates installed for DRC-2B could cause further delays to fish passage depending on gate operation. Therefore, the time required to reach effective fish passage will primarily be a function of the project implementation duration (Table 5.1-1) for all three concepts, because erosion of a fish-passable channel through the impounded sediments should be almost immediate. Any post-flush delays will be determined by the impacts of high suspended sediment downstream rather than any physical impediments to passage once the system can again be occupied by fish.

5.2 Steelhead Health

As summarized in Section 4.4, high flow events and associated high TSS concentrations are not infrequent in the Ventura River, and they almost surely have severe effects on the health of any steelhead that cannot find refuge in a less turbid tributary. For DRCs-1 and 2, the Phase I accumulated sediment flushing will have a significant increase in TSS (and thus severity of effect) for steelhead health, while Phase II transport for all three dam removal concepts will likely have an indiscernible incremental effect over baseline conditions. The sections below provide additional detail for each dam removal concept relative to their associated impact to steelhead health.

5.2.1 Impacts Under DRC-1

For DRC-1, Phase I transport in Matilija Creek, with predicted one-day TSS concentrations on the order of 10^6 mg/l, would likely result in the near-total loss of any steelhead remaining in the creek downstream of the dam (by reference to Figure 4.4-2). This is likely to be a rather small number of rearing juveniles, however, given the limited extent of accessible channel.

With the three-fold dilution of Matilija Creek in the Ventura River (based on flows at gage 1114495 relative to 11118500) and projected TSS concentrations of 10^6 mg/l in Matilija Creek, sediment concentrations during the day of Phase I erosion are projected to be up to several hundred thousand mg/l within the Ventura River. Historically, five dates on the Ventura River have measured TSS concentrations >10^5 mg/l (all in January/February 1969, a large discharge but not the largest flood of record), and so the magnitude of Phase I-generated TSS concentrations in the Ventura River would likely be in the range of the largest historical values. It would constitute a substantial mortality event (though not predicted to be 100%) for fish there (by reference to Figure 4.4-1, these conditions would likely receive a severity score of 12 or 13). Thus for Phase I transport, where TSS concentrations are likely to be in the range of 10^5-10^6 mg/l, even a day's duration would have substantial impact to both adults and rearing juveniles. Unavoidable uncertainties in predicting the exact magnitude and duration of Phase I-generated sediment in the Ventura River have virtually no effect on this predicted outcome, with at most a marginal change in severity score and mortality likely at or above 50%.

Given some uncertainties in the precise magnitude and rate of decline in TSS concentrations following the initial flush of fine sediments (i.e., Phase II transport) (Section 4.2.1), and a more varied range of effects on fish under conditions less severe than those of Phase I, projected impacts to steelhead are more equivocal, but insensitive across a wide range of plausible assumptions. Superimposing the additional sediment load from dam removal to background conditions in the watershed and applying the Newcombe and Jensen criteria, predicted conditions drop rapidly to a level of ~30% mortality of rearing juveniles and potentially adults, if present (Figure 5.2-1) (i.e., a severity score of 11). This outcome is almost completely independent of whether or not any Phase II erosion occurs at all.

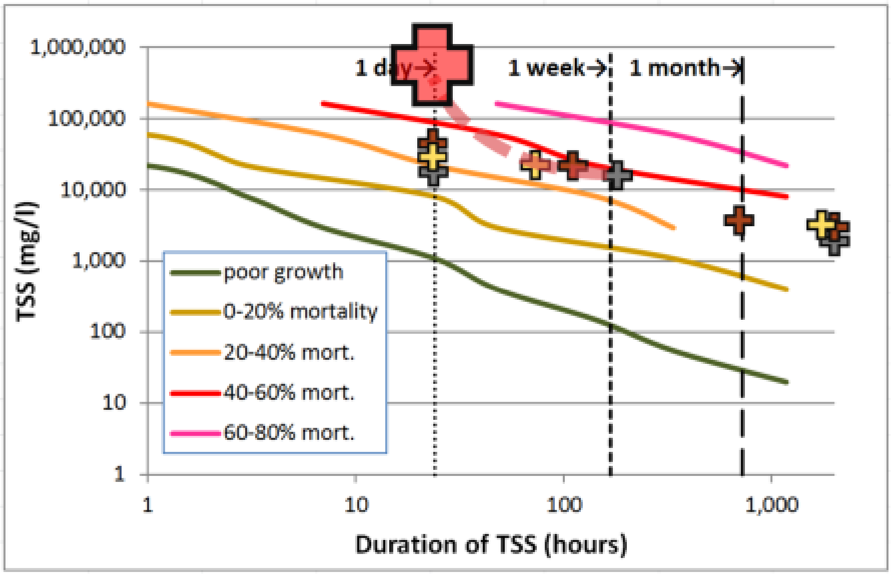


Figure 5.2-1. The effects of very high TSS concentrations during Phase I erosion under DRC-1 (red cross, sized to approximate the range of uncertainty) and the subsequent effects of declining Phase II transport (red dashed line), superimposed on conditions expressed by the three storms with the most severe effects on steelhead health during the 12-year operational period of gage 11114495 (from Figure 4.4-4). The incremental effects of the dam removal sediment load on storms of this magnitude will likely be indiscernable after a few days.

Although Phase II erosion has been considered separately from Phase I for purposes of characterizing TSS concentrations, these two processes will constitute one continuous event from the perspective of downstream biota. Their combined effect will likely represent a one-time, near-total loss of steelhead downstream that are unable to find refuge in unaffected tributaries.

5.2.2 Impacts Under DRC-2

Under the most likely scenario of a single-event opening of the tunnels and full drainage of the reservoir, the behavior of the sediments during Phase I of DRC-2A will be similar to DRC-1, and the impacts will be virtually identical. Under DRC-2A, sediments are likely to be more saturated at the time of dam removal than under DRC-1, and so the magnitude of Phase I erosion is likely to be modestly greater. In terms of biological impacts, however, these differences are insignificant - the events would be highly lethal to in-stream organisms in either case. If gates are installed and closed post-flush (DRC-2B), with the intent to re-open them during a later storm in a subsequent year, the impacts will be magnified. The consequences of very high TSS concentrations are essentially instantaneous, likely resulting in very high mortality for two independent years of aquatic organisms. The shorter duration of each individual event is not predicted to materially reduce their individual impacts.

5.2.3 Impacts Under DRC-3

Under DRC-3, Phase I erosion would be avoided altogether, and the one-time lethal effects of that release associated with the other alternatives would not occur. Phase II erosion is still likely, but its magnitude relative to DRCs-1 or 2 will depend on the primary mechanism(s) of sediment delivery. Equivalent areas of exposed sediment deposits will be available for sheet wash, rilling, and gullying under all alternatives; the only difference will be a likely reduction in the magnitude of any bank slumping given the flatter side slopes of DRC-3. The consequences of this difference between alternatives are unlikely to be large and quickly swamped by the magnitude of natural sediment loads originating from the watershed as a whole, as with the other alternatives. Thus, the severity of effects predicted in Figure 4.4-4 are likely to apply under this alternative, with natural mortality of ~30% a likely consequence of the natural sediment load of the watershed during "significant" (≥4-yr recurrence interval) flows and little to no incremental impacts from Phase II erosion after one week.

The potential consequences of stockpile erosion under DRC-3 in subsequent years are difficult to determine in any but qualitative terms. At one extreme, rapid undercutting during a very high discharge could potentially initiate landsliding of the stored material into the channel, with concentrations potentially intermediate between Phase I and Phase II concentrations for DRC-1 and that would approach or exceed that already contributed by the watershed, with potentially significant additional impacts on salmonid mortality. At minimum, elevated sediment delivery and in-stream concentrations are possible during larger storms (above 10-year) under this dam removal concept, given the extent of fine sediment stockpiles in close proximity to the channel, with modestly elevated concentrations likely to persist at sub-lethal levels for many years into the future. Slumped sediment could potential create a temporary barrier to fish passage, although the fine-grained nature of the material suggest that it would probably not persist for long under conditions of high flow in the channel.

5.2.4 Summary

As described above, there are two primary impacts to steelhead health in the project area and downstream in Matilija Creek and the mainstem of the Ventura River: (1) Phase I sediment loads for DRC-1 and DRC-2A, with a potential loss of a significant number of fish, including but not limited to steelhead, and other aquatic organisms in the project area and downstream in Matilija Creek and the mainstem of the

Ventura River immediately following dam release; and (2) natural sediment loads during all major floods, for which ongoing fish mortality is potentially significant but will not be appreciably altered or augmented by any of the dam-removal scenarios. Closing and re-opening of the gates under DRC-2B would likely result in near-equivalent Phase I mortality during each opening (depending on volume of accumulated sediment), thus potentially doubling the magnitude of steelhead impacts depending on conditions during each of the different years in which this occurs.

In summary, both DRC-1 and DRC-2 results in the substantial, but likely not complete, loss of a year class of fish in Matilija Creek and the Ventura River. This impact is avoided altogether under DRC-3. A variety of partial mitigation measures are likely feasible for DRC-1 and DRC-2, such as capturing and relocating migrating aquatic species upstream and downstream of the project site, plus the pre-project collection and relocation of native species within the project stream reach itself (coincident with this effort could be the elimination of non-native species, providing ancillary additional benefit). These potential actions are not included in Newcombe and Jensen’s (1996) analysis of the severity of effects (e.g., Figure 5.2-1), which are based on full exposure to the sediment load without recourse to refugia with lower sediment concentrations, and so those predictions almost certainly overstate the immediate biological impacts of the actual dam removal here.

Longer term concerns about the “legacy effects” of released sediment into the downstream channel network are also plausible, but recent experiences from other large-scale dam-removal projects suggest that such concerns are probably unfounded. Following the removal of Condit Dam, for example, downstream pool habitat decreased but suitable spawning habitat increased; and within a year of dam removal, 10% of the Chinook salmon run on the river had already found their way to spawn upstream of the dam site (Hatten et al. 2015). At an even larger scale, the Elwha River saw release of more than 10M tonnes of reservoir-impounded sediment following dam removal (East et al. 2015), but anadromous salmon returned to the system after less than a year and already have resulted in documented increases in marine-derived nutrients throughout the food web (Tonra et al. 2015).

Impacts to downstream channel geomorphology, biota, and water-supply and treatment infrastructure are similar for all alternatives, and they are all unlikely to be distinguishable from the effects of naturally high sediment loads during subsequent moderate and large floods.

5.3 Impact to Existing Vegetation Communities

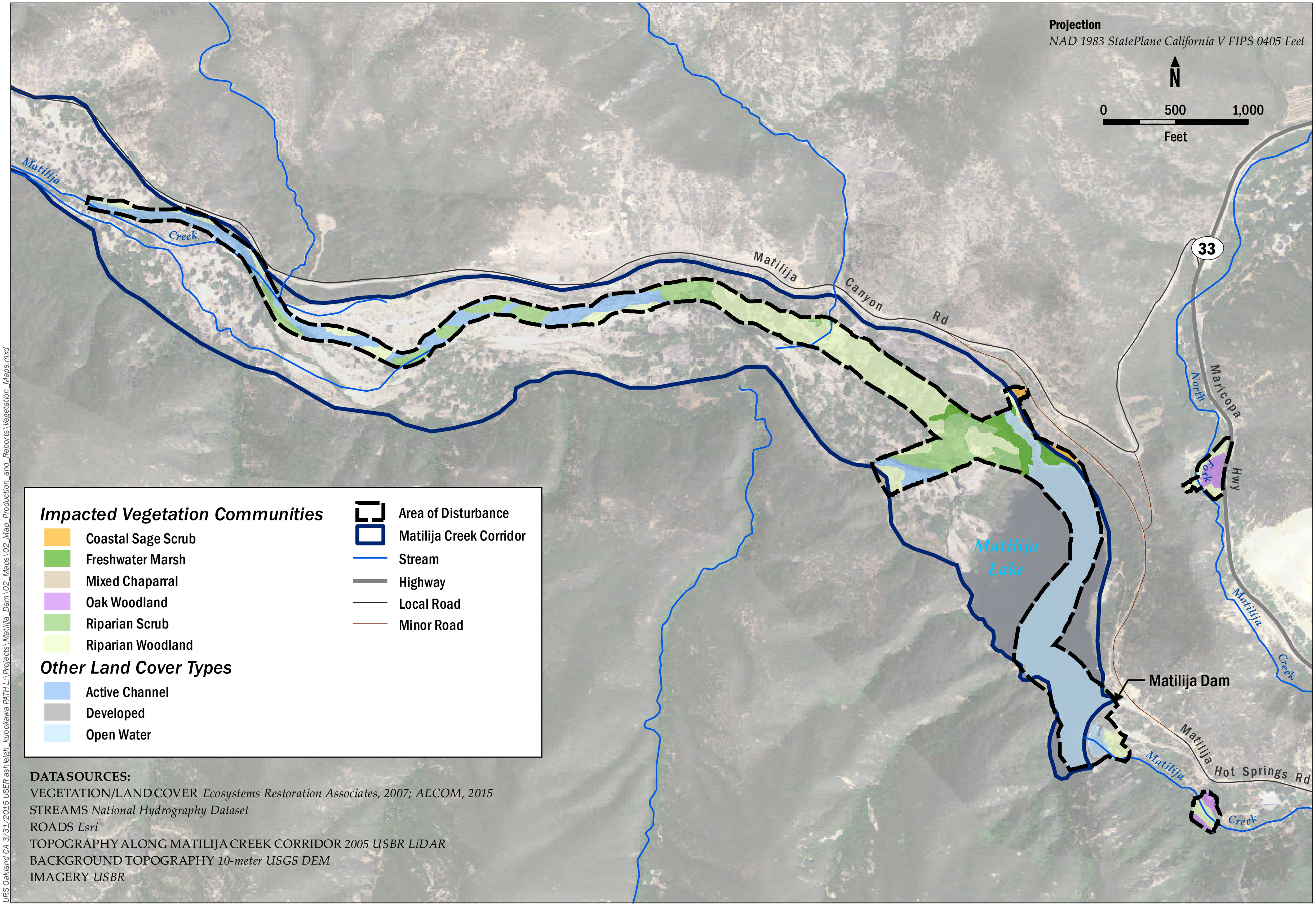
Figures 5.3-1 through 5.3-3 show the impact footprint and vegetation communities associated with each dam removal concept. The vegetation communities selected for this impact assessment are based on the GIS analysis and field reconnaissance described in Section 4.1.

Table 5.3-1 presents the total acres of each vegetation community that will be directly impacted by project activities.

Six vegetation communities would be impacted by the three dam removal concepts, as noted in Table 5.3-1. The Riparian Woodland community would have the most acreage impacted under all three dam removal concepts. However, the impacts in DRCs-1 and 2 are less than half of that measured for DRC-3 due to the temporary sediment stockpiles remaining for a significant period of time after dam removal. DRC-3 would also have a significantly greater impact on the Riparian Scrub and Oak Woodland communities, relative to the other dam removal concepts. Overall, DRC-3 would have a greater impact on existing vegetation communities at the site compared to DRC-1 and DRC-2, across all six vegetation communities. DRC-1 and DRC-2 would generally have similar impacts to existing vegetation, with DRC-1 having a slightly greater area of impact

Table 5.3-1. Impacts to Vegetation Communities by Concept

Vegetation Community	**Impacts (acres)**		
	DRC - 1	**DRC-2**	**DRC-3**
Mixed Chaparral	0.6	0.4	1.3
Freshwater Marsh	1.9	1.6	2.5
Oak Woodland	1.0	0.0	3.5
Riparian Scrub	7.2	5.7	15.5
Riparian Woodland	14.2	12.0	37.0
Coastal Sage Scrub	0.5	0.2	2.1
Total	25.5	19.6	69.0



DATA SOURCES:
VEGETATION/LAND COVER *Ecosystems Restoration Associates, 2007; AECOM, 2015*
STREAMS *National Hydrography Dataset*
ROADS *Esri*
TOPOGRAPHY ALONG MATILIJA CREEK CORRIDOR *2005 USBR LiDAR*
BACKGROUND TOPOGRAPHY *10-meter USGS DEM*
IMAGERY *USBR*

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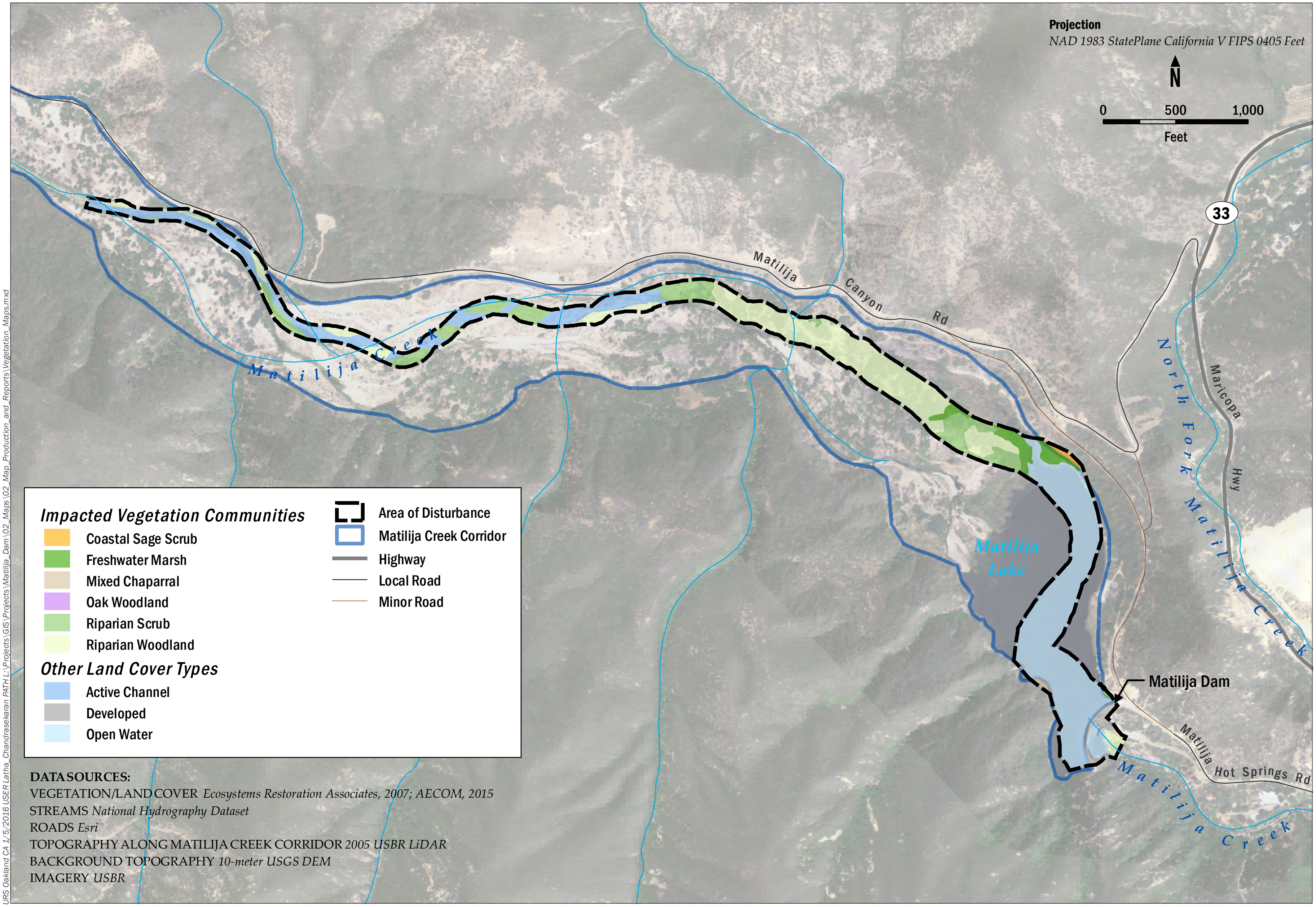
AECOM
Ventura County Watershed Protection District
Matilija Dam Removal, Sediment Transport, and Robles Mitigation Diversion
CONCEPTS EVALUATION

FIGURE 5.3-1
Dam Removal Concept 1 – Vegetation Community Impacts



DATA SOURCES:
VEGETATION/LAND COVER *Ecosystems Restoration Associates, 2007; AECOM, 2015*
STREAMS *National Hydrography Dataset*
ROADS *Esri*
TOPOGRAPHY ALONG MATILIJA CREEK CORRIDOR *2005 USBR LiDAR*
BACKGROUND TOPOGRAPHY *10-meter USGS DEM*
IMAGERY *USBR*

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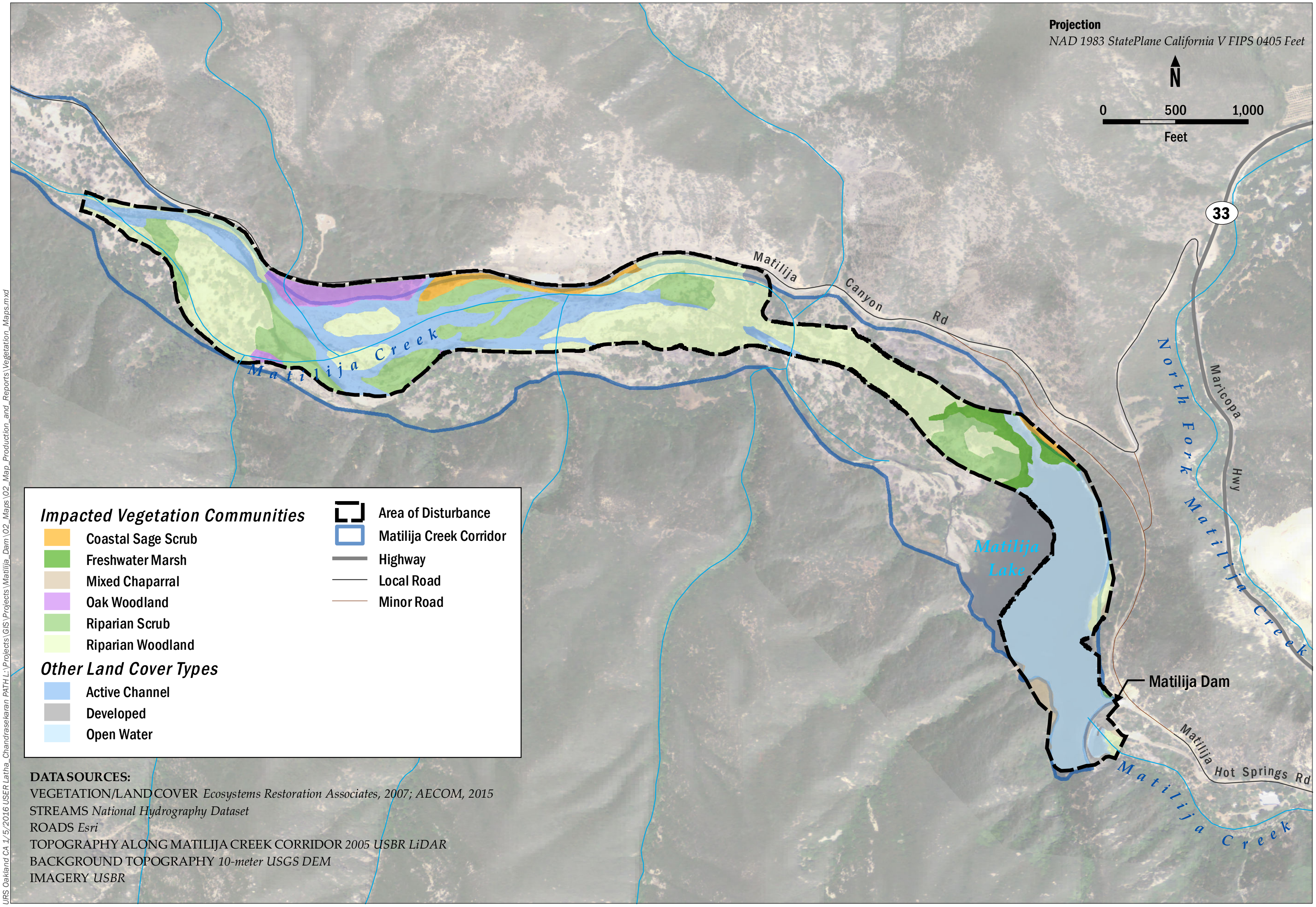
Ventura County Watershed Protection District
Matilija Dam Removal, Sediment Transport, and Robles Mitigation Diversion
DAM REMOVAL CONCEPTS EVALUATION

FIGURE 5.3-2
Dam Removal Concept 2 – Vegetation Community Impacts



DATA SOURCES:
VEGETATION/LAND COVER *Ecosystems Restoration Associates, 2007; AECOM, 2015*
STREAMS *National Hydrography Dataset*
ROADS *Esri*
TOPOGRAPHY ALONG MATILIJA CREEK CORRIDOR *2005 USBR LiDAR*
BACKGROUND TOPOGRAPHY *10-meter USGS DEM*
IMAGERY *USBR*

Ventura County Watershed Protection District
Matilija Dam Removal, Sediment Transport, and Robles Mitigation Diversion
DAM REMOVAL CONCEPTS EVALUATION

FIGURE 5.3-3
Dam Removal Concept 3 – Vegetation Community Impacts

5.4 Post-Project Vegetation Communities

The plan for restoring the project site will build off of the post-flush surfaces shown on Drawings 6, 10 and 16, along with the anticipated frequency of inundation.

Because of the desired and expected gradual channel evolution and natural geomorphological changes over the next several decades, the habitat restoration approach will be neither very intensive nor attempt to extensively stabilize the existing sedimentary deposits directly adjacent to the flushed channel. Restoration will primarily consist of limited restoration guidance, corrective support, and maintenance of the natural succession process. It will involve a combination of strict protection of the existing native upland and upper riparian vegetation within the floodplain, along with strategically located riparian re-vegetation. A methodical removal of invasive non-native vegetation will be an essential component of the restoration work in order to prevent the takeover of the disturbed areas by exotic plants.

Native upland vegetation and upper riparian vegetation consisting of a diversity of mixed chaparral, coastal sage scrub, oak woodland, and grassland species that is established on the floodplain will be carefully protected, where feasible, in areas indicated with crosshatched patterns on Drawings 6, 10 and 16. This vegetation will provide valuable parent habitat during the reshaping of the channel, and will serve as a source of native vegetation propagules. Because of the excessive drainage of the sedimentary soil forming the floodplain within the former reservoir area, riparian phraetophytic plants (obligate groundwater table connection plants) are growing in close proximity or mingled with upland sagebrush habitat species such as yucca, yerba santa, California buckwheat, prickly pear cactus, and others. These xeric plant species will likely survive even after a substantial drop in the groundwater table resulting from the removal of the dam structure and the subsequent deepening of the active channel. These surviving upland parent plants, along with the shaded microhabitat provided by the remnant phraetophytic vegetation, will aid in natural re-vegetation and transition of the perched riparian habitats to upland communities.

Existing lower riparian zone phraetophytic vegetation represented by species such as white alder, black cottonwood, western sycamore, mulefat, sandbar willow, arroyo willow, and other mesic species will be protected in non-disturbed areas between the proposed new channel and approximately the new 25-year flood event line. It is expected that this riparian wetland vegetation will not survive above the 25-year flood event line because of the depth to the groundwater table that will be likely in excess of 15 feet in the upstream reaches of the reservoir area. New successional vegetation types are expected to naturally develop in areas where riparian vegetation will not survive and their establishment will be expedited through introduction of upland vegetation seed collected in the adjacent areas.

The river banks of the newly formed Matilija Creek channel will be re-vegetated with phraetophytic riparian species between the Ordinary High Water Mark (OHWM) and a line following the 10-year flood event line in the upstream coarse gravel portion of the reservoir, and moving gradually up to the 50-year flood event line in the fine clayey sediments near the dam. This is the expected elevation range within which the riparian phraetophytes will be able to establish, with their roots reaching the groundwater table. In-stream steelhead rearing and spawning habitat features along with pole cuttings, willow fascine bundles and large woody materials will be incorporated into the newly formed banks and channel. The two riparian communities that will be restored on the banks of Matilija Creek will be herbaceous riparian and riparian scrub. Both of these communities include wetland plants such as mulefat, sandbar willow, mugwort, as well as a variety of rushes and sedges. These plants are relatively soft in terms of flood flow resistance, often rhizomatous, adaptable, and quick to reproduce in geomorphologically changing conditions. They will be able to re-establish on the evolving bank surfaces during the pulses of the high flow event that initiates channel erosion.

The third riparian community that commonly occurs in the project area, and throughout the Matilija Creek watershed, is the riparian woodland community that includes large trees such as white alder, western sycamore, black cottonwood, and others. Riparian woodland will only be restored along more stable tributary channels or areas not desired or expected to undergo additional significant erosion. To guide the natural succession process, pole cuttings of black cottonwood will be installed and white alder seed dispersed in these areas. Cottonwoods and alders are relatively short-lived and typically function as early successional, pioneer species. They will assist in creating a nursing habitat for later successional riparian woodland species such as western sycamore.

Upland habitats will be restored by dispersal of sage scrub and chaparral community plant species' seed on former floodplain areas and slopes rising from the valley floor into the existing hills. These native plant communities will integrate with the same existing native upland communities to provide continuity and natural transition into adjacent habitats. Upland plant communities will be different on south/west and north/east facing slopes because of the substantial difference in potential evapotranspiration and solar exposure. The south/west facing slopes will be seeded primarily with the sage scrub and chaparral species, while the north/east facing slopes will be restored as coast live oak woodland in most cases and sage scrub in transitional ecotone areas. The restored habitats will not be irrigated, however, seeding will be appropriately scheduled for the time of the year that best coincides with natural seed germination in the area, availability of sufficient precipitation, and lower daily temperatures.

A very important component of the guided succession/restoration process will be diligent control of invasive exotics. A large effort was recently exerted to eliminate widespread expanses of the aggressive exotic giant reedgrass (*Arundo donax*) throughout the Matilija Creek watershed. Only sporadic individuals were observed during the March 2015 site visit, and these will be eliminated as part of the follow-up of the weeding effort. Other invasive species that were observed in the project area and that could potentially quickly spread are fountain grass (*Pennisetum setaceum*), poison hemlock (*Conium maculatum*), fennel (Foeniculum vulgare), horehound (*Marrubium vulgare*), tree tobacco (*Nicotiana glauca*), and smilo grass (*Stipa* [*Piptatherum*] *miliacea*).

The following plant communities will be established in the project area through seeding, pole cutting, fascine bundle, and limited treepot container plant installation during the guided natural succession restoration work. They are presented in order of increasing distance from the stream's OHWM, the riparian wetland and mesic communities first, followed by the upland drought-resistant xeric communities:

1. Herbaceous Riparian: The herbaceous riparian community will be a diverse mix of wetland herbaceous species that typically colonize riparian banks along Matilija Creek. The seed mix will be dominated by sedges, and rushes such as umbrella sedge (*Cyperus eragrostis*), iris-leaved rush (*Juncus xiphioides*), deerbed sedge (*Carex praegracilis*), spreading rush (*Juncus patens*), brown-fruited rush (*Juncus phaeocephalus* var. *paniculatus*), toad rush (*Juncus bufonius* var. *bufonius*)

as well as herbaceous perennials such as mugwort (*Artemisia douglasiana*), spearmint (*Mentha spicata* var. *spicata*), and wetland grasses such as salt grass (*Distichlis spicata*).

2. Riparian Scrub: The riparian scrub will be dominated by large shrubs, particularly narrow-leaved willow (*Salix exigua*), arroyo willow (*Salix lasiolepis*), scalebroom (*Lepidospartum squamatum*), and mulefat (*Baccharis salicifolia*) that will be planted in some selected areas as pole cuttings. Co-dominant species that will be planted within the riparian scrub will include mugwort (*Artemisia douglasiana*), wild tarragon (*Artemisia dracunculus*), western goldenrod (*Euthamia occidentalis*), cocklebur (*Xanthium strumarium*), smooth scouring rush (*Equisetum laevigatum*), western goldenrod (*Euthamia occidentalis*), as well as a variety of wetland grasses, rushes, and sedges such as spreading rush (*Juncus patens*), creeping wildrye (*Leymus triticoides*), and those described above. Mulefat will be a keystone species because it prefers gravelly and sandy, alkaline soils that are present at the project site, and will intergrade well with the narrowleaf and sandbar willows.

3. Riparian Woodland: This community will be an important community in the riparian areas of the more stable tributary creek channels. California sycamore prefers riparian habitats with rocky soils, variable groundwater level, high stream velocities and requires year-round contact with the groundwater table. This community will consist of groupings of trees and a relatively dense, grass, rush and sedge-dominated herbaceous understory. California sycamore (*Platanus racemosa*) will be the dominant tree, with black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), narrowleaf (sandbar) willow (*Salix exigua*) and mulefat (*Baccharis salicifolia*) as associated species. The cottonwood, willow and mulefat will be planted as pole cuttings. White alder will be seeded along tributary creeks with known perennial flow, even if shallowly subsurface. The vegetation in understory and open areas between the trees will be seeded with a mix dominated by rushes, sedges, grasses and herbs, including spreading rush (*Juncus patens*), creeping wildrye (*Leymus triticoides*), blue wildrye (*Elymus glaucus*), and leafy bentgrass (*Agrostis pallens*).

4. Oak Woodland: This community will be planted on the north and east-facing slopes above Matilija Creek and the south bank rocky soil terraces that receive early afternoon shade from the mountain range to the south. Coast live oak and canyon live oak (*Quercus chrysolepis*) will be the dominant tree species. Associated tree species will include California bay (*Umbellularia californica*), and in more mesic areas near the toe of the steeper slopes, the big-leaf maple (*Acer macrophyllum*). These trees will be planted in the mesic or moisture conserving areas in the fall as small saplings from treepot 8 (T8) containers with a deep, well-developed root system to enhance the chances of their survival. Due to the dense evergreen canopy, the understory shrub layer of the oak woodland will include shade-tolerant poison oak (*Toxicodendron diversilobum*), California brome (*Bromus carinatus*), blue wildrye (*Elymus glaucus*), and needlegrasses (*Stipa* spp.)

5. Coastal Sage Scrub: The rockier and drier slopes on the south and west-facing slopes or flat exposed rocky areas will be planted with a mosaic of sage scrub that will, in some locations, progress to the chaparral community when shaded out by taller shrubs. This vegetation alliance will consist of the dominant shrubs California sagebrush (*Artemisia californica*), black sage

(*Salvia mellifera*), sticky monkeyflower (*Mimulus aurantiacus*), and sawtooth goldenbush (*Hazardia squarrosa*), California buckwheat, triangular fruited sedge (*Carex triquetra*), bush phlox (*Leptodactylon californicum*), California brickelbush (*Brickelia californica*), wedge-leaf goldenbush (*Ericameria cuneata*), thickleaf yerba santa (*Eriodictyon crassifolium* var. *nigrescens*), chaparral currant (*Ribes malvaceum*), white sage (*Salvia apiana*), chaparral nightshade (*Solanum xanthii var. xanthii*), and giant wildrye (*Leymus condensatus*).

6. Mixed Chaparral: This community will be planted on the steeper south and west facing slopes and it will be interspersed by the sage scrub community. The chaparral community will consist of dense shrubby cover and minor herbaceous ground cover. Shrub canopies will eventually overlap, producing a dense mosaic of shrubs with sparse open spaces in between. The dominant species will be chamise (*Adenostoma fasciculatum*), laurel sumac (*Rhus laurina*), toyon (*Heteromeles arbutifolia*), large-fruited ceanothus (*Ceanothus megacarpus*), mountain mahogany (*Cercocarpus betuloides*), holy-leaf cherry (*Prunus ilicifolia*), big-berry manzanita (*Arctostaphylos glauca*), chaparral clematis (*Clematis lasiantha*), and lemonadeberry (*Rhus integrifolia*).

Drawings 6, 10 and 16 show the vegetation communities that may establish over time for the three dam removal concepts. Table 5.4-1 summarizes the total acreages within the former reservoir area associated with each dam removal concept.

Table 5.4-1. Summary of Post-Project Vegetation Communities

Vegetation community	**Post-Project Acreage**		
	DRC-1	**DRC-2**	**DRC-3**
Herbaceous Riparian	7.4	7.4	7.9
Riparian Scrub	17.5	17.5	15.8
Riparian Woodland	26.3	26.3	14.4
Oak Woodland	21.5	21.5	28.9
Coastal Sage Scrub	59.2	59.2	53.6
Mixed Chaparral	22.1	22.1	39.3
Total	**154.0**	**154.0**	**159.9**

In general, DRC-1 and DRC-2 have identical anticipated future vegetation communities since the post-flush channel is the same for both. Due to the deeply incised channel in the lower reservoir, vegetation communities transition from more open water and riparian communities under existing conditions to a mixture of riparian, oak woodland, and scrub/chaparral. For DRC-3, due to the temporary sediment stockpiles remaining for an extended period of time after dam removal, there would be less riparian scrub and woodland relative to the other dam removal concepts, with an associated increase in mixed chaparral.

5.5 Range of Magnitude Construction Cost(ROMCC)

The ROMCCs include a 30 percent design contingency and a 15 percent allowance for construction-related changes, extra work, unforeseen conditions, or other unplanned costs after a construction contract is signed. A summary of the ROMCC, including the estimated construction costs for the major categories of work, is presented in Tables 5.5-2 through 5.5-5 for each dam removal concept. Additional ROMCC details are provided in Appendix B.

The ROMCC estimates are considered to be Class 5 estimates, as described by the Association for the Advancement of Cost Engineering (AACE, 2012):

> From AACE 2012: *"Class 5 estimates are generally prepared based on very limited information and subsequently have wide accuracy ranges. They are typically used for project concept screening. Typically, engineering is from 0% to 2% complete and the expected accuracy range is from 20% to 30% lower than the estimate to 30% to 50% higher than the estimate."*

For the purposes of the ROMCCs for the dam removal concepts, the accuracy range is assumed to be from 30 percent lower than the estimates to 50 percent higher than the estimates.

In developing the ROMCCs, major features and items were developed for each dam removal concept. The individual items comprising each feature in the ROMCC for each of the dam removal concepts are shown in Tables B-1 through B-3 in Appendix B, along with the quantities (where applicable) and unit costs for each item. The various design components of the dam removal concepts were developed in AutoCAD Civil 3D, using topographical data based on LiDAR data from Airborne 1 dated March 2005. In general, the quantities for the dam removal concepts were estimated using a combination of Civil 3D tools and simple hand calculation methods, given the conceptual level of design.

Construction costs were estimated with the use of a combination of previous cost estimate work by the USACE in 2004 and 2008 escalated to 2015, built-up unit prices, and statistical unit prices from published and internally developed and maintained historical databases factored for location, contractor markups, and other project-specific criteria. The logic, methods, and procedures used for developing these costs are typical for the construction industry. Various limitations need to be considered in the use of both built-up and statistical unit prices, such as the potential for changes in technology, methods, and construction applications; the impact of short-term economic cycles; and the time lag of reporting databases. Any estimate of unit prices is not intended to predict the outcome of hard dollar results from open and competitive bidding.

For comparison with the ROMCCs, the equivalent construction costs for Alternative 4b were taken from the 2004 and 2008 USACE cost estimates and escalated to March 2015 using cost trends published by the USACE and the BOR (see Table 5.5-1). A contingency of 25 percent was applied to the estimate as was done for the 2004 USACE estimates. It is noted that this is less than the sum of the design and construction contingencies used in the ROMCCs for the dam removal concepts.

Table 5.5-1. Summary of Alternative 4b Construction Costs

Project Categories	Construction Cost (2004 or 2008)	Construction Cost (2015)[c]
Mobilization[a]	$5,000,000	$7,000,000
Site Preparation[a]	$710,000	$990,000
Sediment Components[a]	$5,430,000	$7,600,000
Slurry System Components[a, b]	$11,620,000 + $37,860,000	$60,190,000
Dam Removal Components[a]	$10,440,000	$14,620,000
Subtotal		$90,400,000
Contingency (25%)		$22,600,000
Total		$113,000,000

a USACE 9/2004 estimate

b USACE 11/2008 estimate

c Based on USACE and BOR cost trends escalation factor from 9/2004 to 3/2015 = 1.40; from 11/2008 to 3/2015 = 1.16

A summary of the ROMCCs for DRCs-1 through 3 using the same project categories as those for Alternative 4b is shown below in Tables 5.5-2 through 5.5-5. The individual items comprising each feature in the ROMCC for all three dam removal concepts are included in Appendix B.

Table 5.5-2. Summary of DRC-1 Construction Costs

Project Categories	ROMCC (2015)	Low (-30%)	High (+50%)
Mobilization	$3,500,000		
Site Preparation	$11,800,000		
Sediment Components	$0		
Slurry System Components	$0		
Dam Removal Components	$9,200,000		
Site Restoration	$2,500,000		
Subtotal	$27,000,000		
Contingency (30%)	$8,100,000		
Subtotal	$35,100,000		
Construction Contingency (15%)	$5,300,000		
Total	$40,400,000	$28,300,000	$60,600,000

Table 5.5-3. Summary of DRC-2A Construction Costs

Project Categories	ROMCC (2015)	Low (-30%)	High (+50%)
Mobilization	$1,600,000		
Site Preparation	$900,000		
Sediment Components	$0		
Slurry System Components	$0		
Dam Removal Components	$8,000,000		
Site Restoration	1,900,000		
Subtotal	$12,400,000		
Contingency (30%)	$3,700,000		
Subtotal	$16,100,000		
Construction Contingency (15%)	$2,400,000		
Total	$18,500,000	$13,000,000	$27,800,000

Note – The ROMCC of each additional orifice would be $1,000,000.

Table 5.5-4. Summary of DRC-2B Construction Costs

Project Categories	ROMCC (2015)	Low (-30%)	High (+50%)
Mobilization	$1,800,000		
Site Preparation	$1,900,000		
Sediment Components	$0		
Slurry System Components	$0		
Dam Removal Components	$8,000,000		
Site Restoration	1,900,000		
Subtotal	$13,600,000		
Contingency (30%)	$4,100,000		
Subtotal	$17,700,000		
Construction Contingency (15%)	$2,700,000		
Total	$20,400,000	$14,300,000	$30,600,000

Note – The ROMCC of each additional orifice with gate would be $2,100,000.

Table 5.5-5. Summary of DRC-3 Construction Costs

Project Categories	ROMCC (2015)	Low (-30%)	High (+50%)
Mobilization	$4,400,000		
Site Preparation	$3,600,000		
Sediment Components	$15,000,000		
Slurry System Components	$0		
Dam Removal Components	$8,000,000		
Site Restoration	$2,200,000		
Subtotal	$33,200,000		
Contingency (30%)	$10,000,000		
Subtotal	$43,200,000		
Construction Contingency (15%)	$6,500,000		
Total	$49,700,000	$34,800,000	$74,500,000

5.6 Risk Management

The dam removal concepts have been evaluated based on the descriptions provided in Section 3, in addition to any assumptions provided throughout the various analyses and assessments included in Sections 4 and 5. However, assumptions or components associated with each of the dam removal concepts may include some inherent risk, or may in some instances help to mitigate a risk associated with implementation. This evaluation criterion is meant to capture how certain concepts either add or remove risk to the implementation process. Risk categories and associated risk management scores are provided in Table 5.6-1, along with considerations that led to the score.

Based on the risk categories and scoring presented below in Table 5.6-1, DRC-1 carries the highest risk for the following reasons:

1. During construction, DRC-1 matches DRC-3 for the highest risk. This is due to the risk of potential impacts due to weather, in addition to relying on geologic considerations not fully investigated to date (e.g. slumping sediment).

2. During the flush waiting period, DRC-1 has by far the highest risk of potential impacts to steelhead health, water quality, and public safety.

3. After sediment flushing, DRC-1 does not have the ability to adaptively manage unforeseen sediment conditions and therefore has the highest risk

DRCs-2A, 2B, and 3 have lower overall risk relative to DRC-1. The longer construction duration associated with DRC-3 (and associated exposure to weather delays) puts it at slightly higher risk relative to DRC-2A.

Table 5.6-1. Risk Management Scores* Summary

	Risk Category	DRC-1		DRC-2A		DRC-2B		DRC-3	
Construction	Geologic differing site condition	Potential for slumping sediment to extend further downstream than anticipated	-1	n/a	0	n/a	0	More difficult to excavate sediment than is expected due to the nature of the deposit	-1
	Late spring weather delays construction	One construction season could be impacted by late storms	-1	n/a	0	n/a	0	Two construction seasons could be impacted by late storms	-2
	Larger storm impacts construction	Potential to impact tunnel construction that extends through winter	-1	n/a	0	n/a	0	n/a	0
Waiting for Flood	Inadequate flow in Lower Matilija Creek impacts steelhead health	Lack of flow in lower Matilija Creek while waiting for flushing event could impact fish passage and health	-1	n/a	0	n/a	0	n/a	0
	Higher storm flows in NF Matilija negatively impact passage	Risk of decreased rearing suitability and fish passage conditions from high water velocities	-2	n/a	0	n/a	0	n/a	0
	Poor water quality due to increased turbidity during low flows impacts steelhead health	If sediment fills in ponding area behind containment berm, subsequent smaller storms could have increased turbidity from adjacent hillslope runoff	-1	n/a	0	n/a	0	n/a	0
	Public safety	Tunnel entryway could attract and be accessible to public, creating an access safety concern	-2	n/a Orifice opening can be blocked and locked to prevent access	0	n/a Orifice opening can be blocked and locked to prevent access	0	n/a	0
	Seismic event causes failure	Seismic event could lower cofferdam to allow smaller storms to access sediment	-1	n/a	0	n/a	0	n/a	0
	Coordination error when minimum high flow event predicted	Potential for coordination error that could prevent closing of tunnel entrance, thereby not maximizing flush event	-1	Potential for coordination error with explosives crew that could prevent orifice opening	-1	Potential for coordination error with explosives crew that could prevent orifice opening	-1	n/a	0

	Risk Category	DRC-1		DRC-2A		DRC-2B		DRC-3	
Post-Storm Flush	High turbidity risk due to minimum storm not eroding expected sediment volume	No means to adapt to unforeseen flushing results	-2	No means to adapt to unforeseen flushing results	-2	Installed gate could be closed to prevent subsequent storm turbidity, or wait for another large storm	2	Partially mitigates risk by excavating channel and protecting against significant erosion during smaller storms	1
	Storm magnitude less than predicted	Cofferdam does not breach	0	No ability to close tunnel so high TSS would occur without benefit of full flush. Subsequent small and intermediate events would cause additional impacts from high TSS	-2	No ability to close tunnel so high TSS would occur without benefit of full flush. Gate would prevent future high TSS events until full flush is initiated	-1	Channel protection would not erode so no additional impact	0
	Turbidity at low flow greater than anticipated	No means to adapt to unforeseen chronic turbidity	-1	No means to adapt to unforeseen chronic turbidity	-1	Installed gate could be closed (see above)	1	Partially mitigates risk by protecting channel (see above)	1
	Fish passage impaired or delayed	n/a	0	Dam would be removed to provide passage	2	If gates are installed/closed, passage could be prevented	-2	Channel protection could redistribute to impede passage	-1
	Public safety	Large flood wave caused by cofferdam breach	-1	n/a	0	n/a	0	n/a	0
	Seismic event causes failure	n/a	0	n/a	0	n/a	0	Temporary sediment stockpiles could fail, temporarily blocking channel	-1

***Scoring:** (-2) adds significant risk; (-1) adds some risk; (0) does not add or mitigate risk; (1) mitigates some risk; (2) mitigates significant risk

5.7 Water Supply

Evaluating the potential impacts to water supply is focused on CMWD's diversions at their Robles diversion facility, and any associated loss of water storage in Lake Casitas. Robles Diversion Dam is located on the Ventura River near Ventura, California at approximately river mile (RM) 14.2, and supplies water to Lake Casitas via the Robles-Casitas Canal. The normal maximum diversion is approximately 500 cfs, during the rainy season (December through February). The existing diversion dam is a low rock weir with a gated spillway, canal diversion headworks, and a fish passage facility located on the right abutment.

The CMWD supplies water to approximately 70,000 customers in Western Ventura County and to approximately 5,200 acres of agricultural land that are primarily composed of tree crops. The CMWD was formed in 1952 and the Ventura River project was authorized by Congress in 1956. The project included the Robles diversion facility on the Ventura River, the Robles-Casitas Canal, and Casitas Dam. Construction of Casitas Dam was completed in November 1958 and the reservoir spilled for the first time in 1978.

Section 4.2 provides an overview of mobilization and transport of the impounded sediment behind Matilija Dam for each dam removal concept. Results focus on anticipated concentrations of TSS and organic material and the duration of higher than baseline concentrations during the two primary phases of erosion. To evaluate the impact to water supply, it is assumed that diversions at the CMWD Robles diversion facility will be suspended during periods when TSS and organic material concentrations are significantly higher than typical conditions during floods on the Ventura River (when diversions have historically occurred). The sections below provide some background information on historic Robles diversions and associated stream TSS concentrations, as well as results for the water quality criteria selected for the evaluation of the dam removal concepts.

5.7.1 Historical Robles Diversions

CMWD has maintained records on the timing and volume of water diversions from the Ventura River for many years, but the data do not include information on turbidity or TSS concentrations. However, sufficient information exists to infer the likely TSS concentrations during diversion events, and to evaluate whether there has been an empirical threshold above which diversions have been judged to be problematic and so avoided.

Figure 5.7-1 shows the silt rating curve for the Ventura River at Foster Park (USGS gage 11118500), eight miles downstream of Robles Diversion, which is the closest location for which suspended sediment data are available. The highlighted zone, covering discharges greater than 10,000 cfs, are invariably associated with silt concentrations of at least 3000 mg/l, ranging as high as 20,000 mg/l and with a best-fit regression value of 6000 mg/l. This six-fold spread is rather narrow for such data; "Indeed, the time series of the residuals about either regression curve shown that the concentration of suspended sediment at a given stream flow has been remarkably consistent in spite of significant changes in the drainage basin, i.e., major fires, water and land development" (BOR 2006, p. 120). At 10,000 cfs, suspended sand (not shown) increases the total TSS concentration by about one-third over those reported here for silt alone (BOR 2006, Figure 5.23).

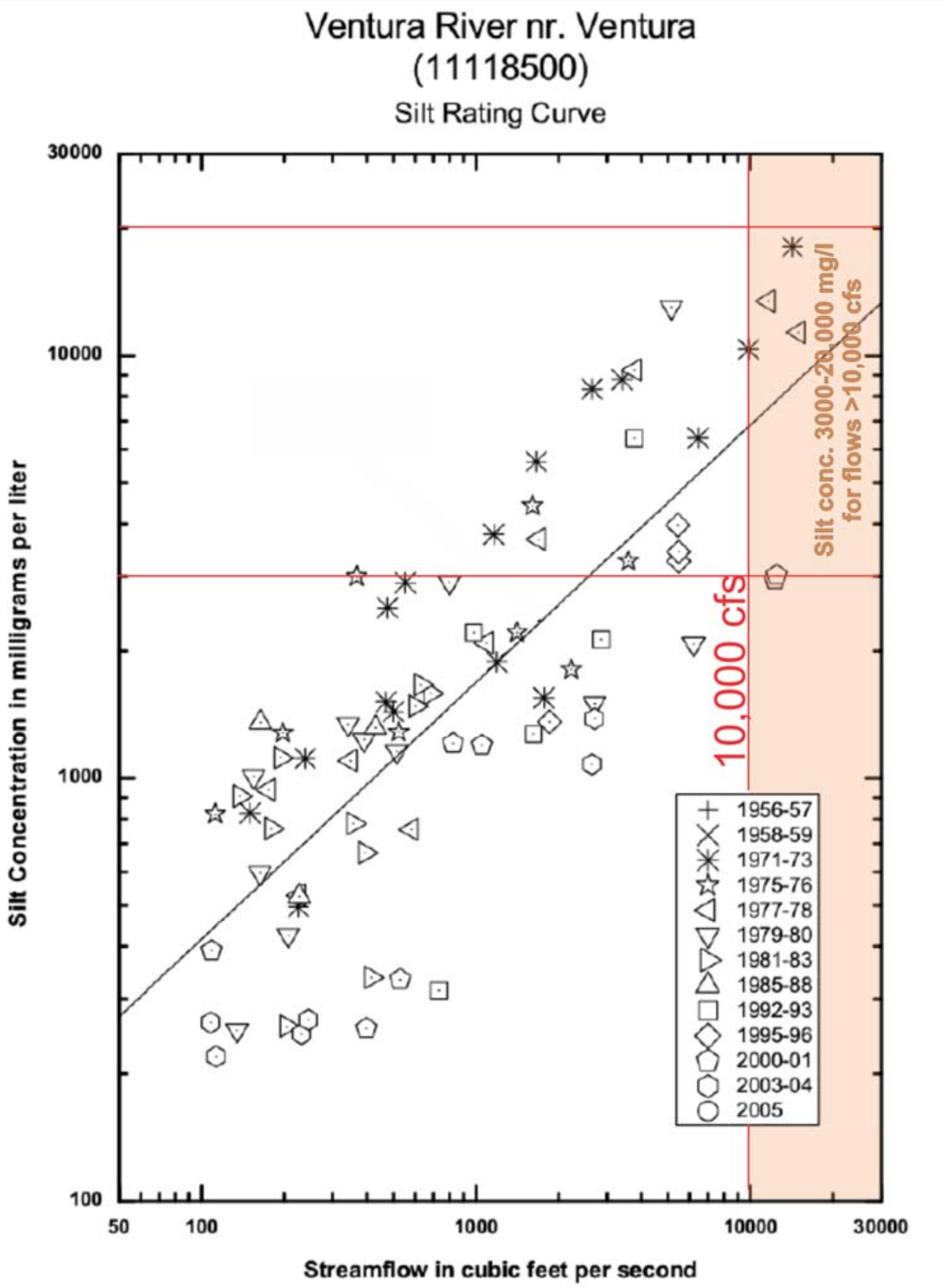


Figure 5.7-1. Figure 5.22 of BOR (2006), showing the measured relationship between measured (instantaneous) discharge and silt concentration.

During the 21-year period for which diversion records from Lake Casitas are available (1993-2003), seven days had average daily discharges greater than 10,000 cfs (likely corresponding to instantaneous discharges about three times larger; Stillwater Sciences 2014b). According to the available records, diversion occurred on six of these seven dates, during which the flow rates were at or near full capacity of the diversion canal (Figure 5.7-2). Despite the absence of direct measurement, reference to Figure 5.7-1 suggests that TSS values at Foster Park were at minimum about 4,000 mg/l (silt + sand) and more likely somewhat greater than 10,000 mg/l, given the greater average daily flows during most of these diversion events and the even higher instantaneous flows that would have occurred during the course of each day. Although not necessarily identical, suspended sediment concentrations are likely quite similar at Robles Diversion under these conditions. If an upper limit exists for feasible operation of Robles Diversion, therefore, it almost certainly exceeds 10,000 mg/l at Foster Park and likely approaches several times this value.

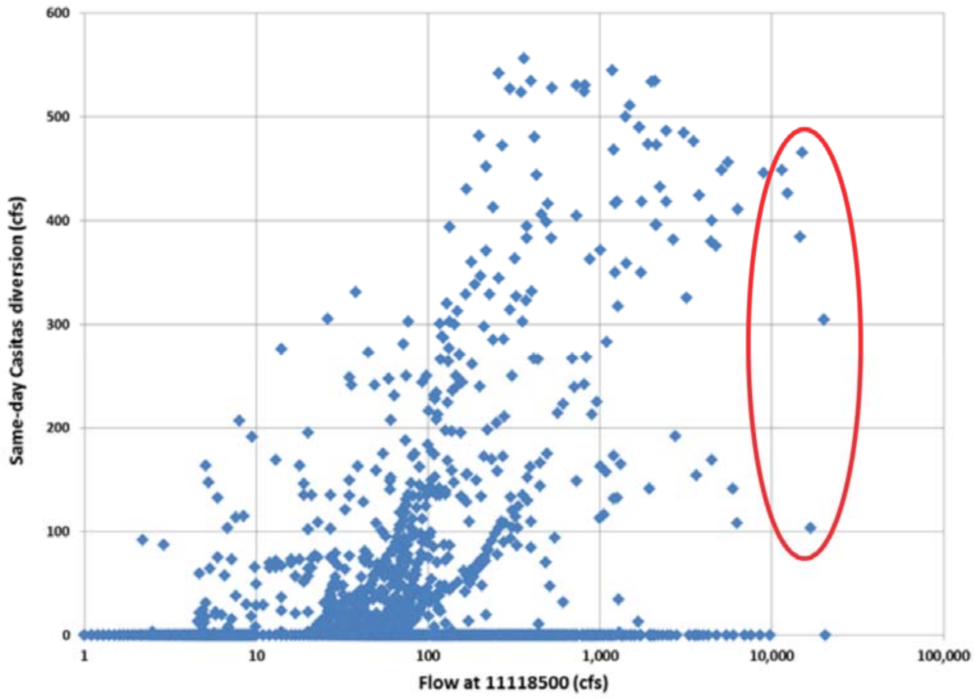


Figure 5.7-2. Plot of average daily discharges in the Ventura River at Foster Park (USGS gage 11118500) (x axis) against the reported diversions for the same date into Lake Casitas (y axis). The six dates with discharges >10,000 cfs are highlighted; only on one other such date was water not diverted.

5.7.2 Water Supply Criteria Results

In general, the results from Section 4.2 indicate that for DRCs-1 and 2, elevated (above baseline) TSS concentrations (up to $10^{\hat{}6}$ mg/l) and organic concentrations will persist for up 1 day for Phase I erosion, while more modestly elevated TSS (i.e., above $10^{\hat{}4}$ mg/l) concentrations for Phase II erosion could persist for up to a week. For DRC-3, Phase I impacts will be avoided, while Phase II impacts will be broadly equivalent to those of the other two concepts. This is generally consistent with the results of the fine sediment assessment completed by URS and Stillwater Sciences (2014a, Appendix A), which estimates approximately 7 days for initial options similar to DRCs-1 and 2, and minimal impact (a broadly accurate characterization of Phase II impacts) for initial options similar to DRC-3.

Based on these results, it is possible to apply the diversion disruption scenarios summarized in URS and Stillwater Sciences (2014b), which analyzed the impact to storage levels in Lake Casitas, if diversions were suspended for one to three storms of significance. The analysis was based on historical creek and water system data including the following:

- Ventura River data from USGS gage 11118500
- Matilija Creek data for February 15, 2002 through December 31, 2013 from USGS gage 11114495
- Matilija Creek data for January 1, 1993 through February 14, 2002 calculated based on Ventura River data and a ratio of average daily flows of 0.34:1 (Matilija Creek:Ventura River) (ratio based on Stillwater 2014a).
- NF Matilija Creek data from VCWPD gage 604.
- Water Elevation in Lake Casitas (feet)
- Storage in Casitas Reservoir (acre-feet)
- Inflow from tributaries entering into the Casitas Reservoir (acre-feet)
- Precipitation at Casitas Reservoir (acre-feet)
- Inflow from diversion at Robles-Casitas Canal (acre-feet)
- Outflow from Casitas Reservoir to Main Distribution System (acre-feet)
- Outflow from Casitas Reservoir through spillway (acre-feet)
- Outflow from Casitas Reservoir to the downstream Coyote Creek channel (acre-feet)
- Evaporation from Casitas Reservoir (acre-feet)

A diversion disruption scenario that assumes Robles diversions are suspended for one large storm (Scenario 2 from URS and Stillwater Sciences 2014b) is generally consistent with the periods of greatly elevated TSS and organic material for Phase I summarized above for DRC-1 and 2. The analysis was completed for three different storms (as shown in Table 5.7-1) that occurred during relatively dry periods.

Table 5.7-1. Events with average daily flow >2000 cfs in Matilija Creek (from URS and Stillwater Sciences, 2014b)

Date (Event Start)	Date (Event Peak)	Matilija Creek Average Daily Flow >2000 (Event Peak) (cfs)	Lake Casitas Elevation (Event Start) (feet)	Lake Casitas Capacity (Event Start) (percent)	Robles Diversion (Event Total) (acre-feet)
1/9/1995	1/10/1995	5,727 [a]	557.7	90%	1,175
3/2/1995	3/11/1995	3,324 [a]	567.6	101%	0
2/2/1998	2/3/1998	5,114 [a]	560.5	93%	4,859
2/14/1998	2/23/1998	7,023 [a]	568.2	101%	0
2/24/2001	3/5/2001	4,193 [a]	550.6	83%	10,008
12/28/2004	1/9/2005	5,950 [b]	528.4	64%	15,435
2/11/2005	2/21/2005	5,940 [b]	552.9	86%	13,180
1/23/2008	1/27/2008	3,560 [b]	549.2	82%	9,212
3/20/2011	3/20/2011	2,350 [b]	546.0	79%	13,536

[a] Average daily flow calculated as 0.3409 x Ventura River average daily flow.

[b] Data from gage 11114495.

Gray rows indicate storms with the greatest potential impact on Lake Casitas storage levels if diversions had been suspended.

For the three storms analyzed, the associated drop in Lake Casitas storage was approximately 4 to 6 % of the total reservoir capacity (see Figure 5.7-3). This result would apply only to DRCs-1 and 2, while DRC-3 would have no significant impact on Lake Casitas storage, because no suspension of diversions is anticipated during the period of Phase II erosion under any concept. DRC-2B has the flexibility to close the orifice and wait for another flush, potentially resulting in additional impacts to Robles diversions.

A more conservative approach would be to assume that diversions would require disruption during more than one storm event. Although the arguments presented in Sections 4 and 5 do not support this approach, suspending diversions for three consecutive large storm events could result in an associated drop in Lake Casitas storage of up to 15 % (URS and Stillwater Sciences, 2014b).

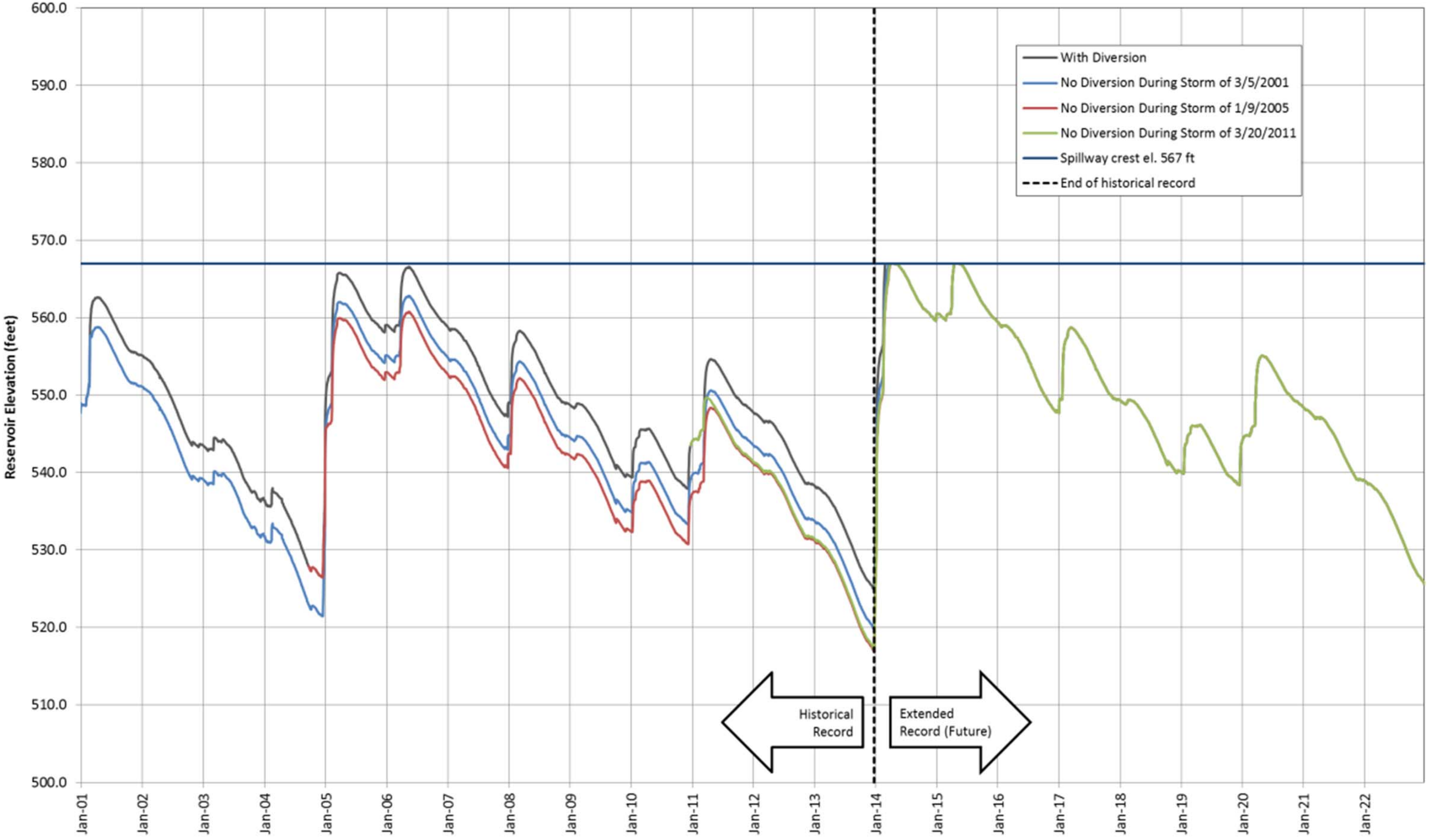


Figure 5.7-3. Comparison of storage (a) with regular diversion, (b) no diversion for the storm of 3/5/2001, (c) no diversion for the storm of 1/9/2005, and (d) no diversion for the storm of 3/20/2011

6.0 Evaluation Summary

Table 6.0-1 summarizes the evaluation scores for the selected criteria, as well as overall scores and ranks for each dam removal concept (Rank 1 = least cost, shortest duration, and least impact). In addition, other considerations are noted as follows for each of the concepts:

- DRC-2A (without gate) ranks first overall, primarily due to having the lowest cost, risk, and impact to existing vegetation. In addition, it does not rank last in any category.
- DRC-3 ranks second, with its high impact to existing vegetation (large footprint), high cost, and lower long-term vegetation habitat benefit placing it below DRC-2A in overall score.
- DRC-2B ranks third, primarily due to the harm that subsequent gate closure(s) could do to steelhead health and passage, and the potential for the longest implementation duration.
- DRC-1 ranks third given the selected criteria, primarily due to the fact that it only ranks first in one of the criteria, generally failing to significantly differentiate itself from the other concepts, while carrying the greatest risk and relatively high cost.

For context, the following list attempts to provide a qualitative comparison of the dam removal concepts to Alternative 4b (recommended plan) from the EIS/R (USACE 2004):

1. Alternative 4b would provide upstream passage past the dam and reservoir area immediately after the three-year construction period, and implementation is not dependent on any given storm event. This may result in a shorter time frame compared to the current dam removal concepts, which each likely require a waiting period after initial construction to flush sediment, prior to achieving complete fish passage. There is a risk associated with Alternative 4b that the upstream material stockpiles could fail or the engineered channel substrate could redistribute in a way that would temporarily block passage.
2. For steelhead health, Alternative 4b would theoretically perform similar or better than the current dam removal options. Alternative 4b removes more of the impounded sediments from the reservoir area, but temporarily places them at downstream locations adjacent to the Ventura River. The initial Phase I flush would certainly be lower in terms of TSS concentrations, but long-term risk of stockpile mobilization could be a consideration.
3. Alternative 4b would have significantly more impact to existing vegetation communities relative to the current dam removal concepts. This is due to the large Alternative 4b project footprint within and upstream of the reservoir, as well as at the downstream temporary sediment disposal areas.
4. Alternative 4b would likely perform worse than the current dam removal alternatives when considering post-project vegetation communities. This is primarily due to the replacement of floodplain habitat with sediment stockpiles in multiple storage areas.
5. The ROMCC for Alternative 4b is significantly higher than the current dam removal alternatives.

6. The risks associated with Alternative 4b could be similar to DRC-3, since both are removing a portion of the more problematic fine, organic rich sediments and placing them in temporary stockpiles. However, Alternative 4b relies on a slurry operation that has its own risks, one of which is being able to procure enough process water to create slurry that can be pumped.
7. For water supply, Alternative 4b would likely perform similarly to DRC-3, since they have a similar approach to dealing with the fine, organic rich impounded sediment.

Table 6.0-1. Evaluation Summary for Dam Removal Concepts

DRC	Steelhead Passage		Steelhead Health		Impact to Existing Vegetation Communities		Post Project Vegetation Communities		Range of Magnitude Construction Cost (ROMCC)				Risk Management		Water Supply		Total Evaluation Score and Rank	
									(-30%)	Estimate	(+50%)							
DRC-1	Longer possible time (relative to DRC-2A and 3) to fish passage at 6 years from project start	3	Phase I impact could lead to severity score* up to 13	2	~25 total acres of impact	2	~50 acres of wetland & riparian and ~100 acres of upland restored (given anticipated topography and hydrology)	1	$28,300,000	$40,400,000	$60,600,000	3	Has the highest risk during construction period, flush waiting period, and post-construction	4	Significant incremental increase in TSS and organic material during Phase I, with slightly less increased anticipated for Phase II: diversion shutdown could result in 4%-6% drop in Lake Casitas storage	2	Total Score Rank is **Fourth** • Highest risk throughout implementation process • Longest time to fish passage • Scores best in only one category, and worst in two categories	17
DRC-2A	2 to 5 years	2	Phase I impact could lead to severity score up to 13	3	~20 total acres of impact	1	~50 acres of wetland & riparian and ~100 acres of upland restored (given anticipated topography and hydrology)	1	$13,000,000	$18,500,000	$27,800,000	1	Slightly higher risk than DRC-2B due to inability to control turbidity should impounded sediments not mobilize during initial flush	3	Similar to DRC-1	2	Total Score Rank is **First** • Lowest cost, risk, and impact to existing vegetation • Scores worst in only one category	13
DRC-2B	3 to 9 years includes two waiting periods for high flows to flush sediments	4	Initial Phase I impact could lead to severity score up to 13; The gate will result in additional impact for second flush	4	~20 total acres of impact	1	~50 acres of wetland & riparian and ~100 acres of upland restored (given anticipated topography and hydrology). Subsequent gate closure could delay vegetation establishment	2	$14,300,000	$20,400,000	$30,600,000	2	Lowest risk throughout implementation process	1	Similar to DRC-1	2	Total Score Rank is **Third** • Relatively low cost, risk, and impact to existing vegetation • Scores worst in two categories	16
DRC-3	2 to 5 years, with some passage possible prior to large event	1	Minimal Phase I impact; Phase II could lead to severity score of 11	1	~69 total acres are highest impact to existing vegetation (37 acres of riparian woodland impacted)	3	~40 acres of wetland & riparian and ~120 acres of upland restored. Replacement of existing riparian with upland is less favorable from a permitting perspective	3	$34,800,000	$49,700,000	$74,500,000	4	Slightly higher risk than DRC-2A due to longer construction duration leaving concept susceptible to unforeseen weather impacts	2	Minimal Phase I and II impact to water supply diversions	1	Total Score Rank is **Second** • Scores best for steelhead and water supply • Scores worst for vegetation impact, future vegetation, and cost	15

***Severity score is associated with impact of suspended sediment concentrations on steelhead health based on work by Newcombe and Jensen (1996), see Section 4.4**

7.0 Statement of Limitations

The services presented herein were conducted in a manner consistent with the standard of care ordinarily applied as the state of practice in the profession in developing the dam removal concepts and their associated construction costs, given the amount of existing site and design information available at the time of preparation of this report. No other warranties, either expressed or implied, are included or intended in this document.

This report is conceptual or preliminary in nature and is not to be used as the sole basis for final design or construction, or as a basis for major capital decisions. Further detailed design should be performed prior to such decisions.

Some background information, design bases, and other data used by the Consultant Team in preparing this report have been furnished by the BOR, CMWD, Ventura County, and/or third parties. AECOM and Stillwater Sciences have relied on this information as furnished, and are neither responsible for nor have confirmed the accuracy of this information.

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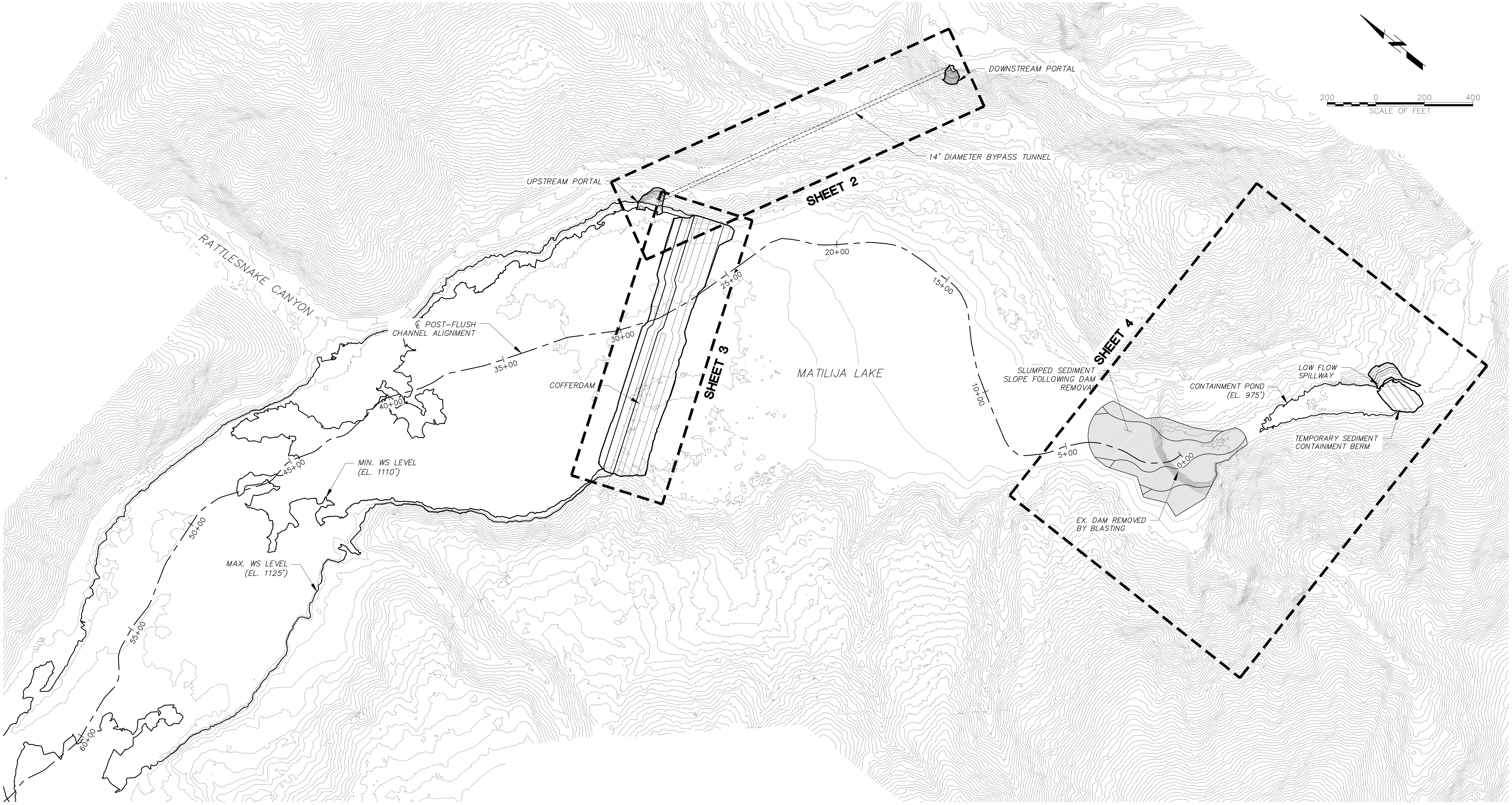
MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

DAM REMOVAL CONCEPTS EVALUATION REPORT

MARCH 2016

APPENDIX A: DAM REMOVAL CONCEPT DRAWINGS



NOTES:
1. *PROJECT COORDINATE SYSTEM IS NAD83, CALIFORNIA STATE PLANE ZONE 5.*
2. *PROJECT VERTICAL DATUM IS NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88).*
3. *TOPOGRAPHY IS BASED ON LIDAR DATA FROM AIRBORNE 1 IN U.S. SURVEY FEET, DATED MARCH 2005.*
4. *EXISTING TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS.*
5. *PROPOSED TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS.*

PLOT DATE: 6/23/15

SAVE DATE: 3/28/15 LATHA_CHANDRASEKARAN A:\MATILIJADAM_03124235\5000 TECHNICAL\5001CAD\05_CAD\C3D_CONCEPTS_EVALUATION\02_SHEETS\C_SHEET-1.DWG

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1333 BROADWAY, SUITE 500
OAKLAND, CA 94612
PHONE: (510) 893 3600
FAX: (510) 874 3268

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– DRAWN
– CHECKED

PROJECT MANAGER DATE
DEPUTY DIRECTOR DATE
DISTRICT DIRECTOR DATE

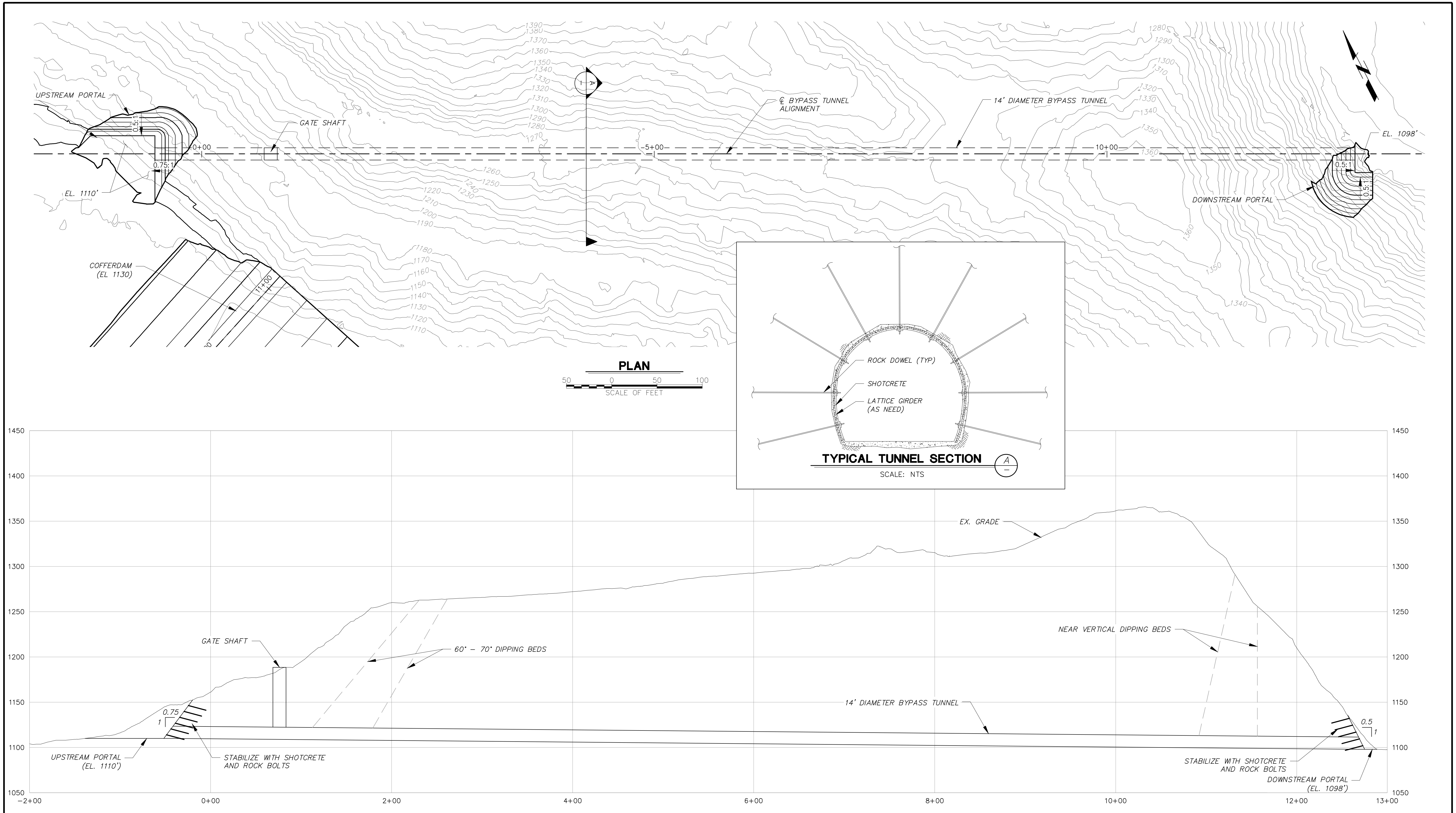
COUNTY OF VENTURA
PUBLIC WORKS AGENCY
WATERSHED PROTECTION DISTRICT

SPEC. NO. –
PROJ. NO. –

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

DAM REMOVAL CONCEPT 1 – GENERAL ARRANGEMENT PLAN

SHEET 1
OF 16
DRAWING NO.



PLAN

TYPICAL TUNNEL SECTION (A)

SCALE: NTS

℄ BYPASS TUNNNEL PROFILE

SCALE: HORZ: 1" = 50'
VERT: 1" = 50'

NOTES:

1. EXISTING TOPOGRAPHY IS SHOWN AT 10–FOOT CONTOUR INTERVALS.
2. PROPOSED TOPOGRAPHY IS SHOWN AT 10–FOOT CONTOUR INTERVALS.
3. FOLLOWING LARGE FLOW EVENT, PLACE 20–FOOT WIDE CONCRETE PLUG AT BOTH ENDS OF TUNNEL.

A-2

PLOT DATE: 6/25/15

SAVE DATE: 6/25/15 LATHA_CHANDRASEKARAN A:\MATILIJADAM_03124235\5000 TECHNICAL\5001CAD\05_CAD\C3D_CONCEPTS_EVALUATION\02_SHEETS\C_SHEET-2.DWG

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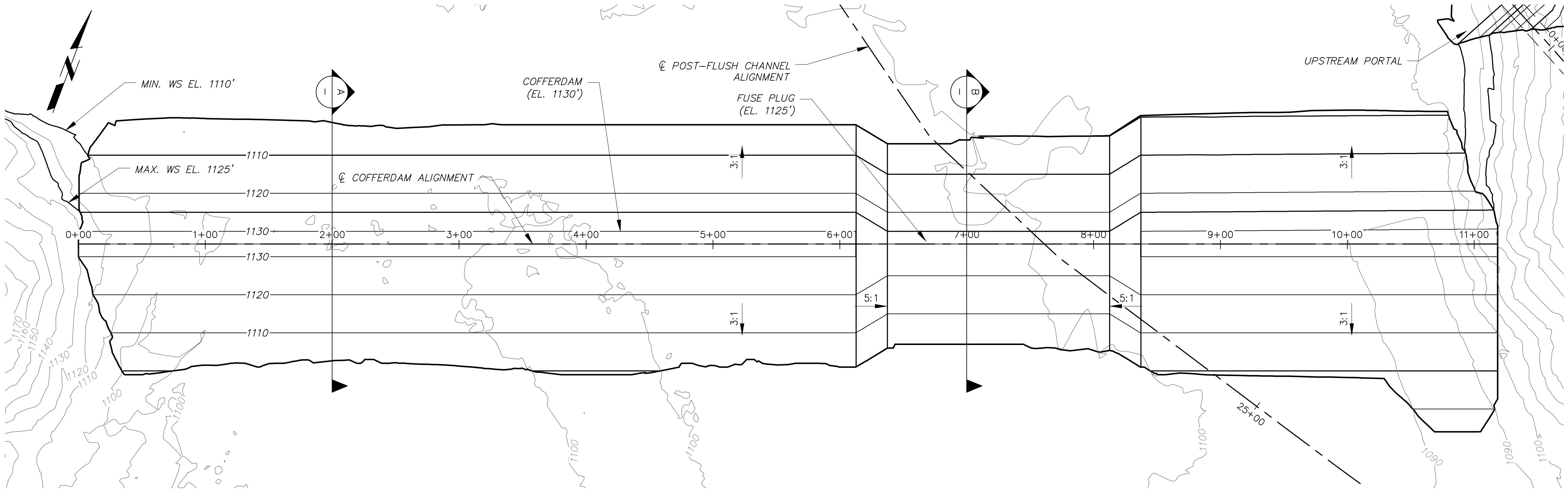
WATERSHED PROTECTION DISTRICT

SPEC. NO. –
PROJ. NO. –

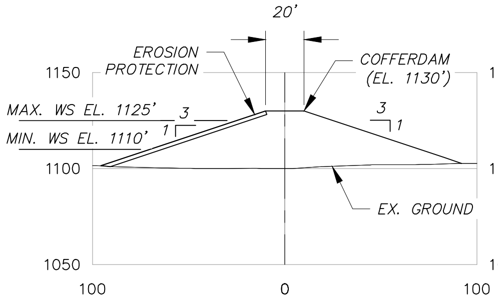
MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT
DAM REMOVAL CONCEPT 1 – 14' DIAMETER BYPASS TUNNEL
PLAN, PROFILE, AND DETAILS

SHEET 2 OF 16
DRAWING NO.



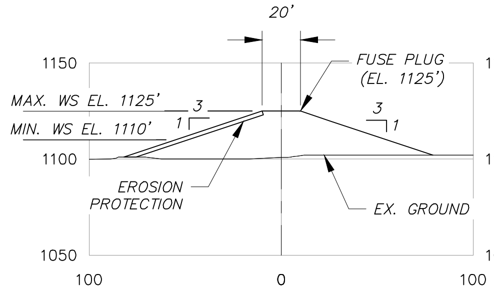
PLAN

50 0 50 100
SCALE OF FEET



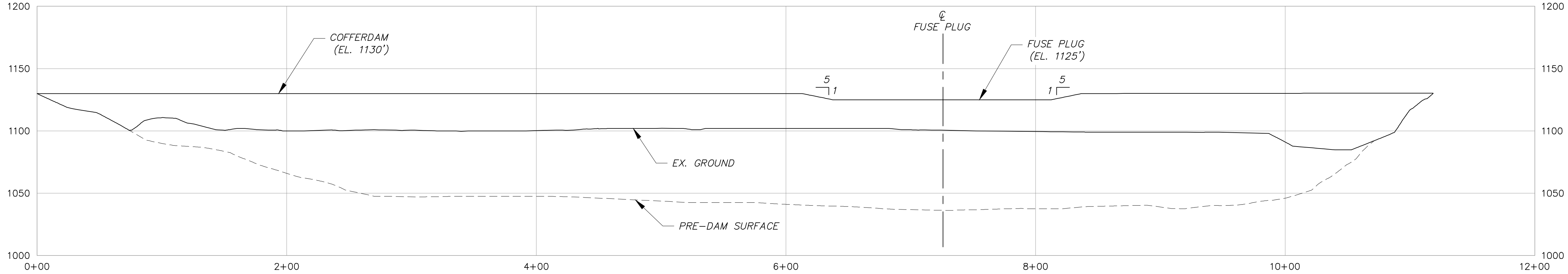
COFFERDAM (A/–)

SCALE: HORZ: 1" = 50'
VERT: 1" = 50'



FUSE PLUG (B/–)

SCALE: HORZ: 1" = 50'
VERT: 1" = 50'



℄ COFFERDAM PROFILE

SCALE: HORZ: 1" = 50'
VERT: 1" = 50'

NOTES:
1. EXISTING TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS.
2. PROPOSED TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS.

A-3

PLOT DATE: 3/28/15

SAVE DATE: 3/28/15 LATHA_CHANDRASEKARAN A:\MATILIJADAM_03124235\5000 TECHNICAL\5001CAD\05_CAD\C3D_CONCEPTS_EVALUATION\02_SHEETS\C_SHEET-3.DWG

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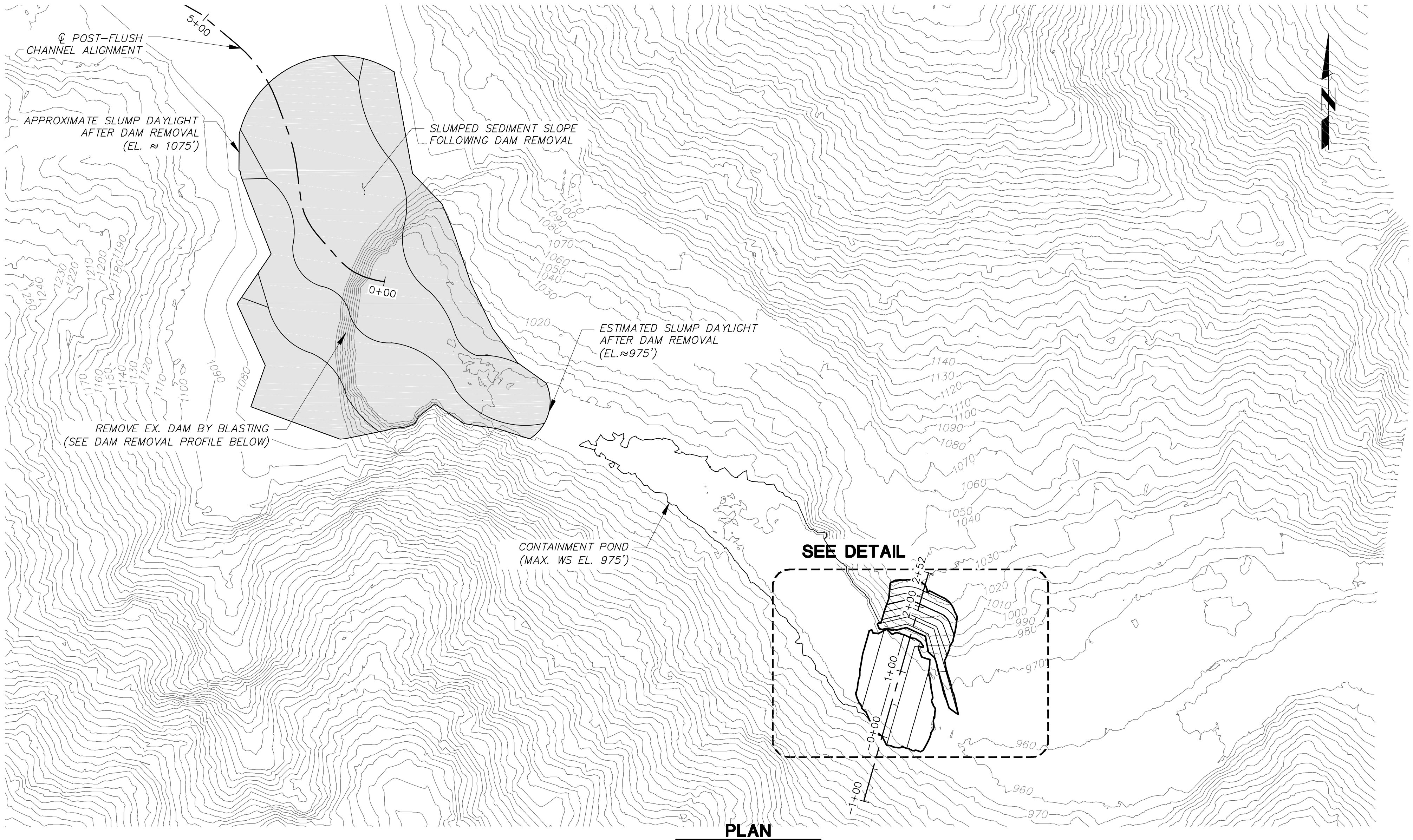
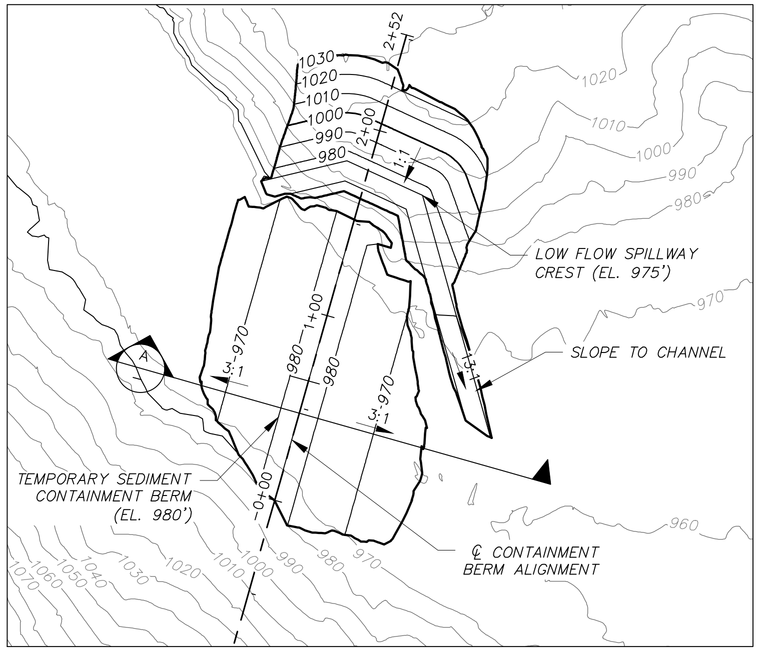
MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT
DAM REMOVAL CONCEPT 1 – COFFERDAM
PLAN, PROFILE, AND DETAILS

SHEET 3
OF 16
DRAWING NO.



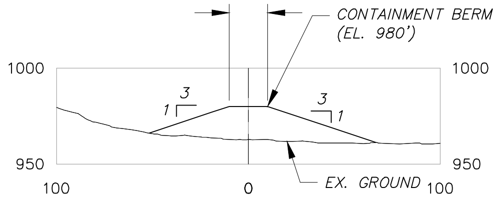
PLAN

100 0 100 200
SCALE OF FEET



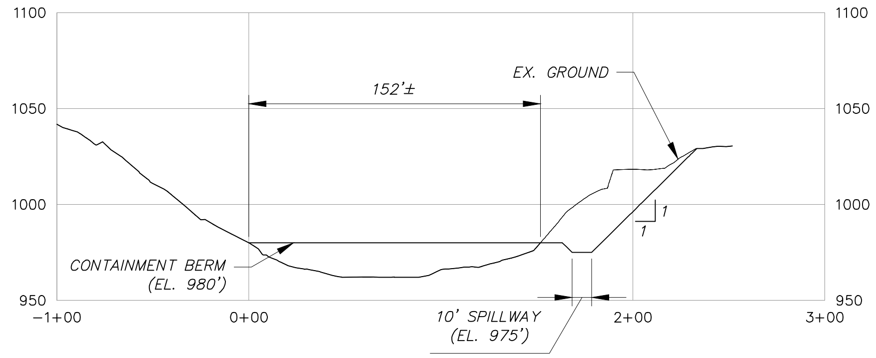
CONTAINMENT BERM AND SPILLWAY DETAIL

50 0 50 100
SCALE OF FEET



SECTION A - CONTAINMENT BERM (A/–)

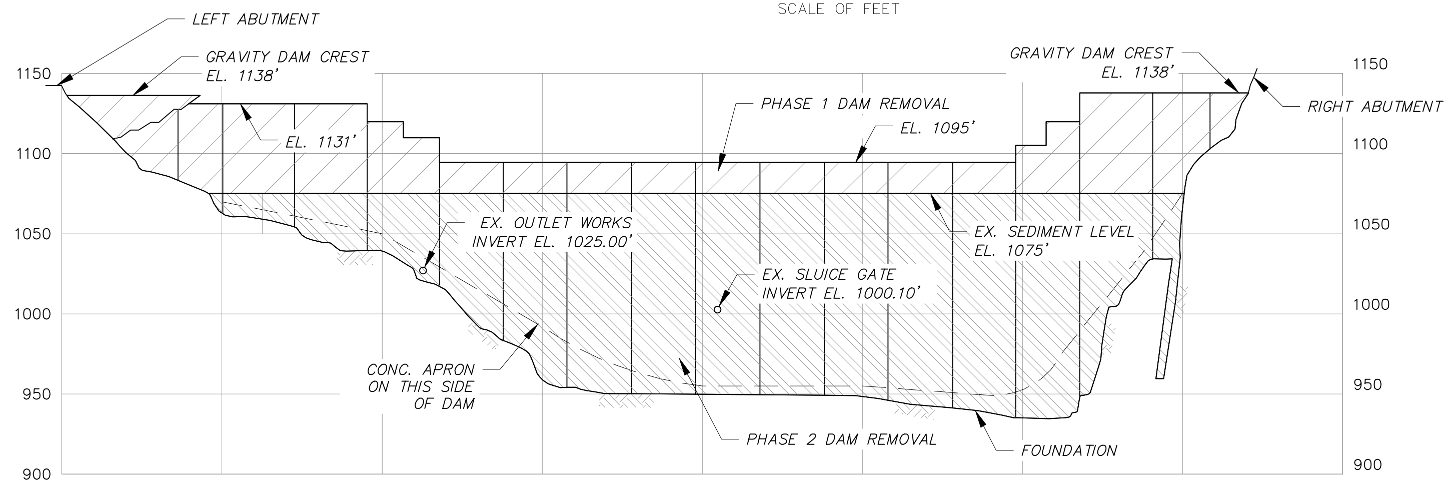
SCALE: HORZ: 1" = 50'
VERT: 1" = 50'



℄ CONTAINMENT BERM PROFILE

SCALE: HORZ: 1" = 50'
VERT: 1" = 50'

NOTES:
1. EXISTING TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS.
2. PROPOSED TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS.
3. PERFORM STAGE 1 DAM REMOVAL DURING CONSTRUCTION OF BYPASS TUNNEL.
4. STAGE 2 DAM REMOVAL FOLLOWS COMPLETION OF BYPASS TUNNEL, COFFERDAM, AND CONTAINMENT BERM.
5. DEWATER RESERVOIR PRIOR TO STAGE 2 DAM REMOVAL.



DAM REMOVAL PROFILE

SCALE: HORZ: 1" = 60'
VERT: 1" = 60'

A-4

PLOT DATE: 3/29/15

SAVE DATE: 3/29/15 LATHA_CHANDRASEKARAN A:\MATILIJADAM_03124235\5000 TECHNICAL\5001CAD\05_CAD\C3D_CONCEPTS_EVALUATION\02_SHEETS\C_SHEET-4.DWG

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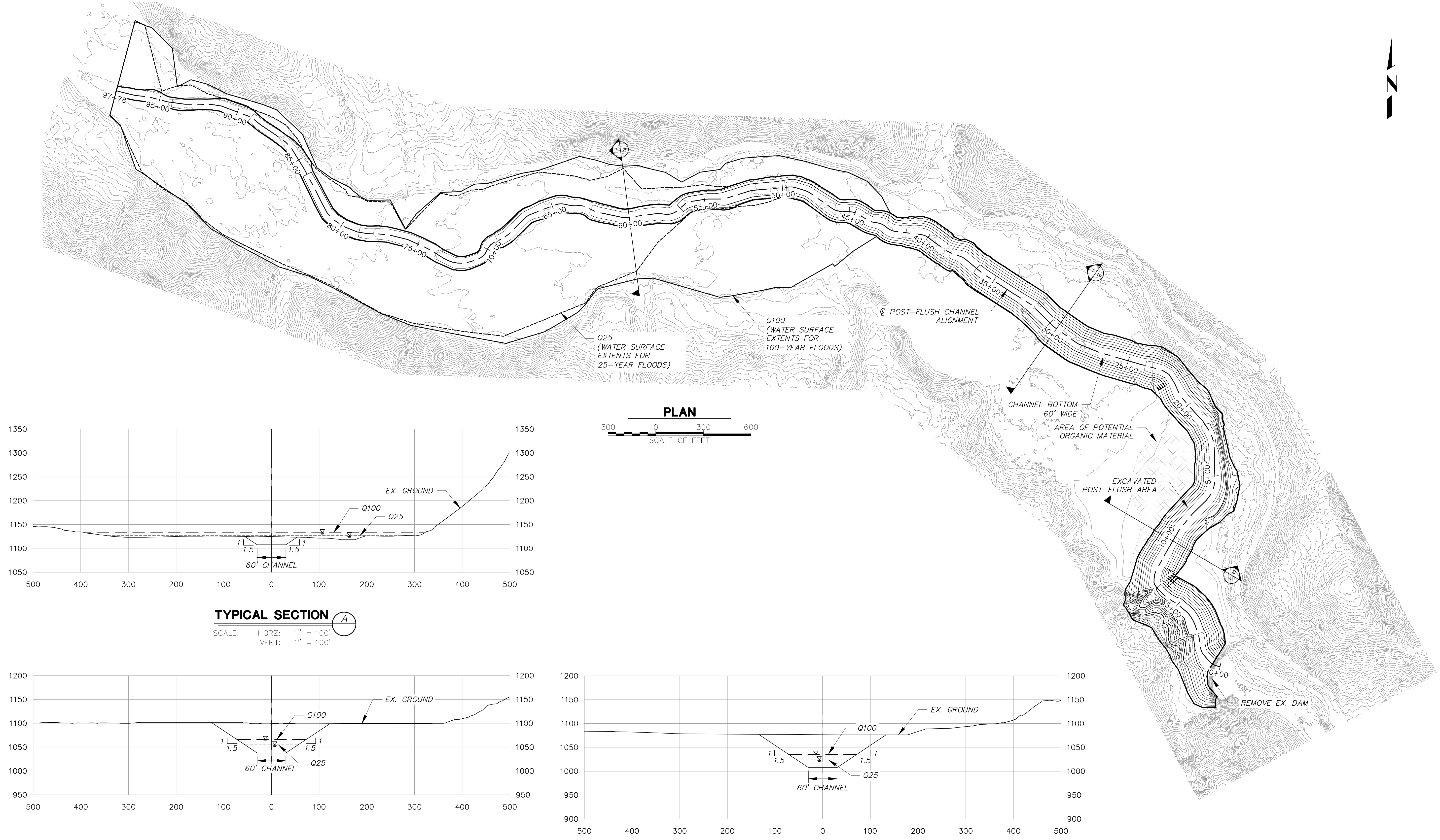
PROJ. NO. –

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT
DAM REMOVAL CONCEPT 1 – CONTAINMENT BERM
PLAN, PROFILE, AND DETAILS

SHEET 4
OF 16
DRAWING NO.



PLAN

TYPICAL SECTION A

SCALE: HORZ: 1" = 100'
VERT: 1" = 100'

TYPICAL SECTION B

SCALE: HORZ: 1" = 100'
VERT: 1" = 100'

TYPICAL SECTION C

SCALE: HORZ: 1" = 100'
VERT: 1" = 100'

NOTES:
1. EXISTING TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS.
2. PROPOSED TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS FOR THE POST-FLUSH CHANNEL.

A-5

PLOT DATE: 3/29/15

SAVE DATE: 3/29/15 LATHA_CHANDRASEKARAN A:\MATILIJADAM_03124235\5000 TECHNICAL\5001CAD\05_CAD\C3D_CONCEPTS_EVALUATION\02_SHEETS\C_SHEET-5.DWG

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WATERSHED PROTECTION DISTRICT

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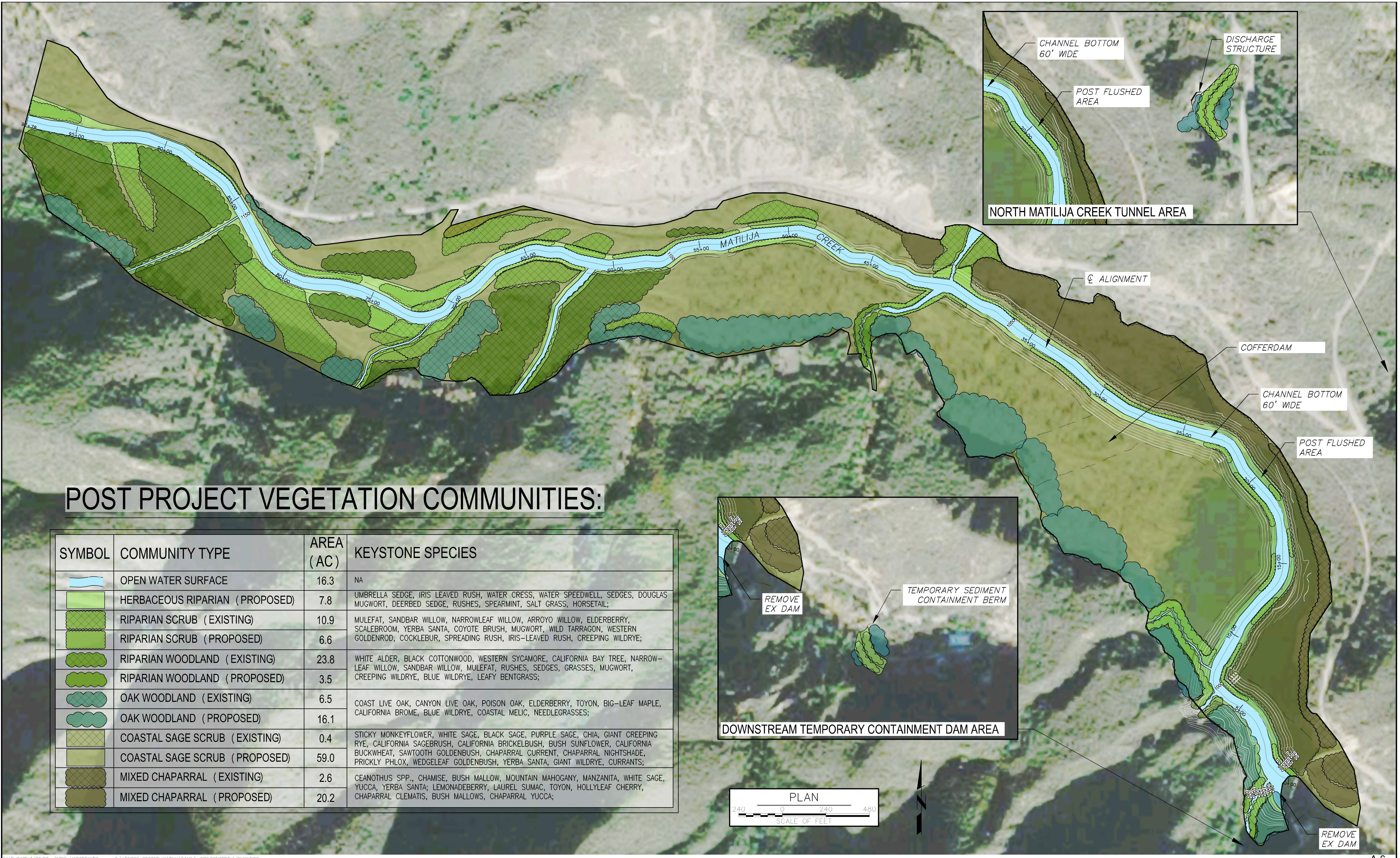
MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT
DAM REMOVAL CONCEPT 1 – POST-FLUSH CHANNEL

SHEET 5 OF 16
DRAWING NO.



POST PROJECT VEGETATION COMMUNITIES:

SYMBOL	COMMUNITY TYPE	AREA (AC)	KEYSTONE SPECIES
🟦	OPEN WATER SURFACE	16.3	NA
🟩	HERBACEOUS RIPARIAN (PROPOSED)	7.8	UMBRELLA SEDGE, IRIS LEAVED RUSH, WATER CRESS, WATER SPEEDWELL, SEDGES, DOUGLAS MUGWORT, DEERBED SEDGE, RUSHES, SPEARMINT, SALT GRASS, HORSETAIL;
▨	RIPARIAN SCRUB (EXISTING)	10.9	MULEFAT, SANDBAR WILLOW, NARROWLEAF WILLOW, ARROYO WILLOW, ELDERBERRY, SCALEBROOM, YERBA SANTA, COYOTE BRUSH, MUGWORT, WILD TARRAGON, WESTERN GOLDENROD, COCKLEBUR, SPREADING RUSH, IRIS-LEAVED RUSH, CREEPING WILDRYE;
🟩	RIPARIAN SCRUB (PROPOSED)	6.6	
▨	RIPARIAN WOODLAND (EXISTING)	23.8	WHITE ALDER, BLACK COTTONWOOD, WESTERN SYCAMORE, CALIFORNIA BAY TREE, NARROW-LEAF WILLOW, SANDBAR WILLOW, MULEFAT, RUSHES, SEDGES, GRASSES, MUGWORT, CREEPING WILDRYE, BLUE WILDRYE, LEAFY BENTGRASS;
🟩	RIPARIAN WOODLAND (PROPOSED)	3.5	
▨	OAK WOODLAND (EXISTING)	6.5	COAST LIVE OAK, CANYON LIVE OAK, POISON OAK, ELDERBERRY, TOYON, BIG-LEAF MAPLE, CALIFORNIA BROME, BLUE WILDRYE, COASTAL MELIC, NEEDLEGRASSES;
🟩	OAK WOODLAND (PROPOSED)	16.1	
▨	COASTAL SAGE SCRUB (EXISTING)	0.4	STICKY MONKEYFLOWER, WHITE SAGE, BLACK SAGE, PURPLE SAGE, CHIA, GIANT CREEPING RYE, CALIFORNIA SAGEBRUSH, CALIFORNIA BRICKELBUSH, BUSH SUNFLOWER, CALIFORNIA BUCKWHEAT, SAWTOOTH GOLDENBUSH, CHAPARRAL CURRENT, CHAPARRAL NIGHTSHADE, PRICKLY PHLOX, WEDGELEAF GOLDENBUSH, YERBA SANTA, GIANT WILDRYE, CURRANTS;
🟩	COASTAL SAGE SCRUB (PROPOSED)	59.0	
▨	MIXED CHAPARRAL (EXISTING)	2.6	CEANOTHUS SPP., CHAMISE, BUSH MALLOW, MOUNTAIN MAHOGANY, MANZANITA, WHITE SAGE, YUCCA, YERBA SANTA; LEMONADEBERRY, LAUREL SUMAC, TOYON, HOLLYLEAF CHERRY, CHAPARRAL CLEMATIS, BUSH MALLOWS, CHAPARRAL YUCCA;
🟫	MIXED CHAPARRAL (PROPOSED)	20.2	

PLOT DATE: 3/30/15

SAVE DATE: 3/30/15 CHRIS_HARGREAVES G:\VENTCO_RESTOR_MATILIJADAM\6-WIP\CONCEPT 1 PLAN.DWG

A-6

	REVISION DESCRIPTION	APP.	DATE
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PROJECT MANAGER DATE
DEPUTY DIRECTOR DATE
DISTRICT DIRECTOR DATE

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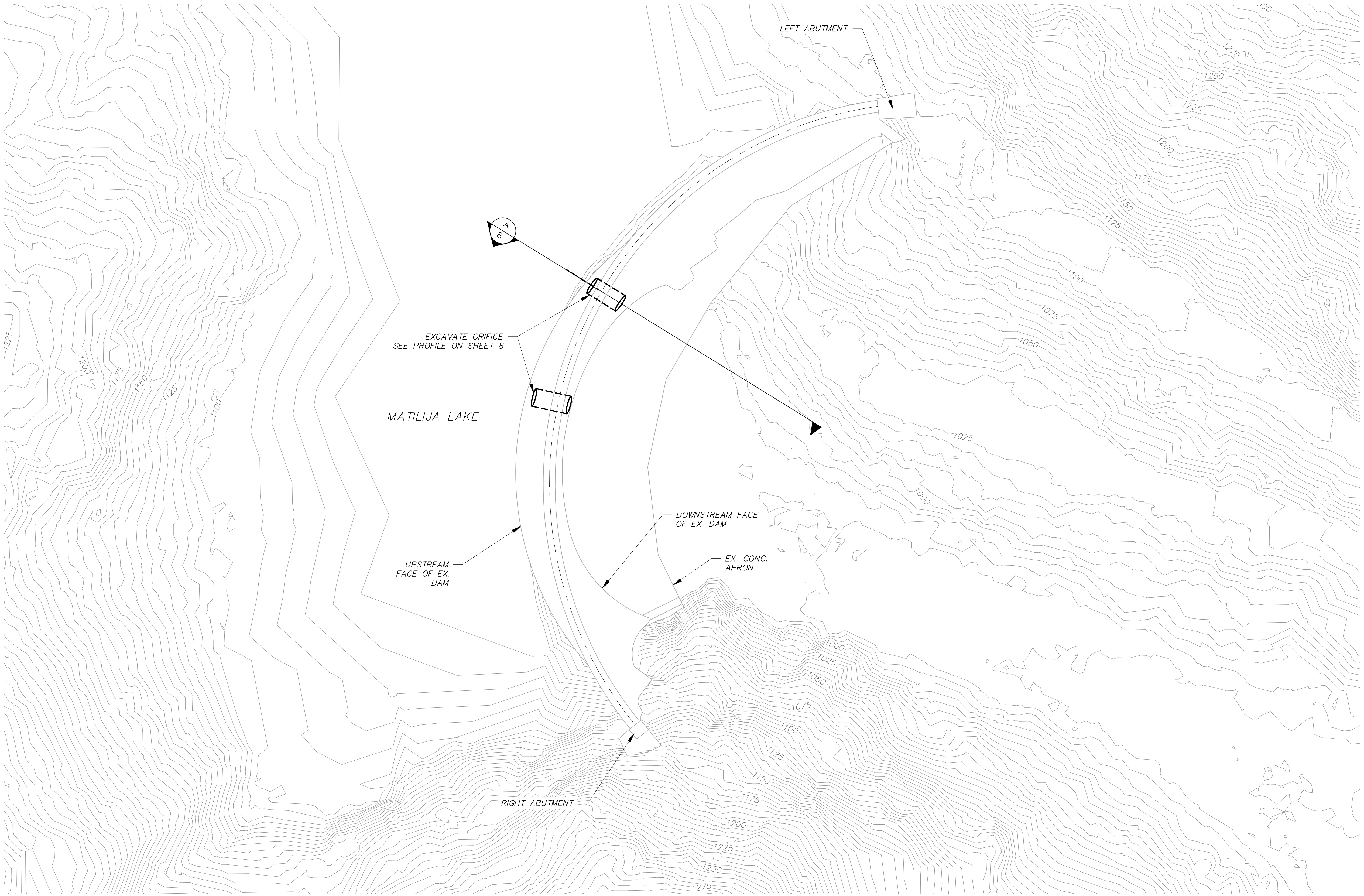
PUBLIC WORKS AGENCY
WATERSHED PROTECTION DISTRICT

SPEC. NO. –
PROJ. NO. –

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT,
AND ROBLES DIVERSION MITIGATION PROJECT
DAM REMOVAL CONCEPT 1 – POST PROJECT
VEGETATION COMMUNITIES

SHEET 6
OF 16
DRAWING NO. C-1



NOTES:

1. *PROJECT COORDINATE SYSTEM IS NAD83, CALIFORNIA STATE PLANE ZONE 5.*
2. *PROJECT VERTICAL DATUM IS NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88).*
3. *TOPOGRAPHY IS BASED ON LIDAR DATA FROM AIRBORNE 1 IN U.S. SURVEY FEET, DATED MARCH 2005.*
4. *EXISTING TOPOGRAPHY IS SHOWN AT 10–FOOT CONTOUR INTERVALS.*

PLAN

40 0 40 80
SCALE OF FEET

A-7

PLOT DATE: 3/29/15

SAVE DATE: 3/29/15 LATHA_CHANDRASEKARAN A:\MATILIJADAM_03124235\5000 TECHNICAL\5001CAD\05_CAD\C3D_CONCEPTS_EVALUATION\02_SHEETS\C_SHEET–7.DWG

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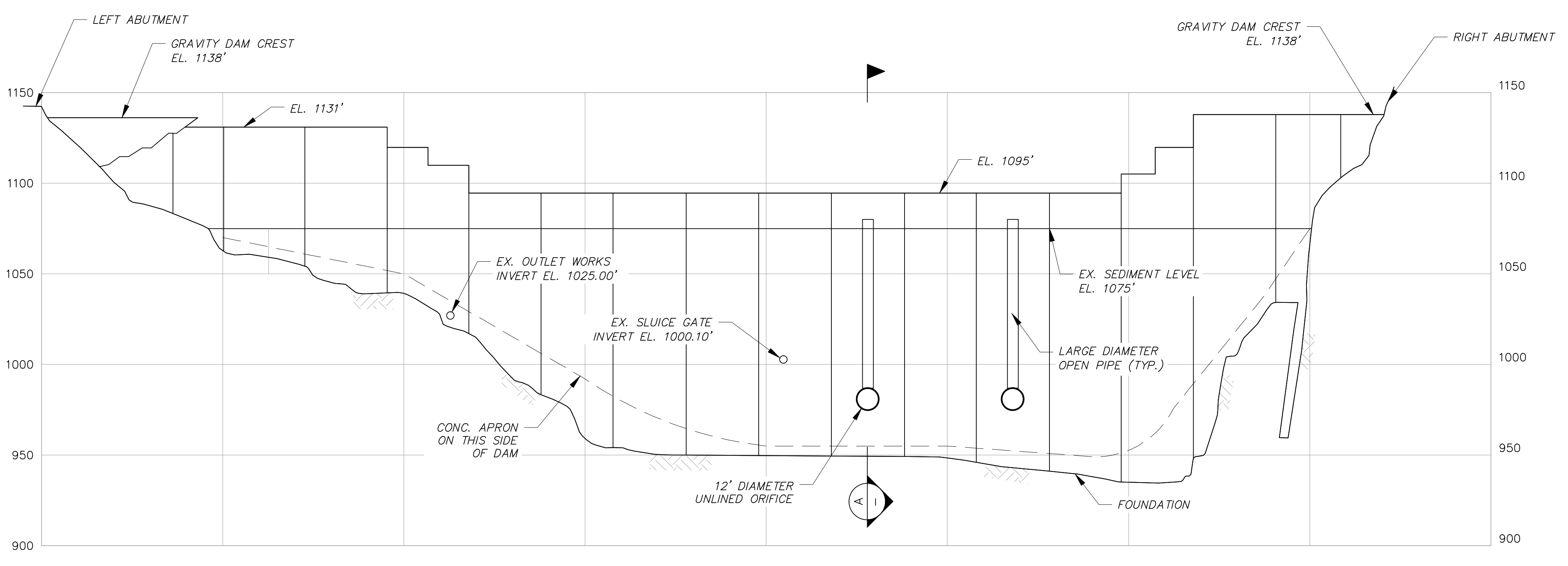
WATERSHED PROTECTION DISTRICT

SPEC. NO. –
PROJ. NO. –

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT,
AND ROBLES DIVERSION MITIGATION PROJECT

DAM REMOVAL CONCEPT 2 – GENERAL ARRANGEMENT PLAN

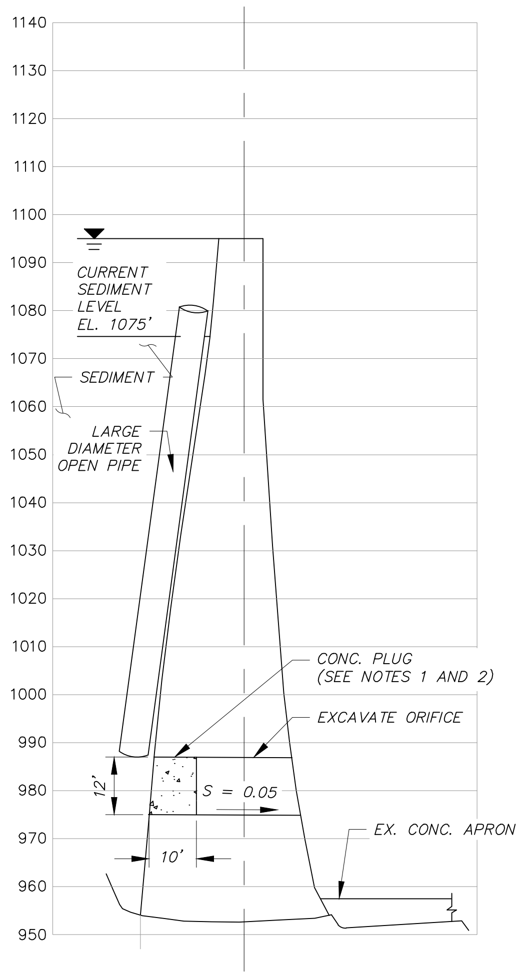
SHEET 7
OF 16
DRAWING NO.



UPSTREAM ELEVATION OF DAM

(ALONG CL OF TOP ARCH RING)

SCALE: HORZ: 1" = 40'
VERT: 1" = 40'



SECTION A

SCALE: HORZ: 1" = 20'
VERT: 1" = 20'

NOTES:

1. PREPARE CONCRETE PLUG FOR REMOVAL BY DRILLING BLAST HOLES.
2. REMOVE PLUG BY LOADING BLAST HOLES WHEN 4-YEAR RETURN OR GREATER STORM IDENTIFIED AND BLAST AS STORM FLOWS BEGIN TO PASS OVER DAM CREST.
3. DAM REMOVAL TO BE PERFORMED DURING DRY SEASON FOLLOWING PLUG REMOVAL, UNLESS IT IS DETERMINED THAT OPTIONAL GATES ARE TO BE INSTALLED.
4. SEE SHEET 9 FOR OPTIONAL GATES.

PLOT DATE: 6/23/15

SAVE DATE: 6/23/15 LATHA_CHANDRASEKARAN A:\MATILIJADAM_03124235\5000 TECHNICAL\5001CAD\05_CAD\C3D_CONCEPTS_EVALUATION\02_SHEETS\C_SHEET-8.DWG

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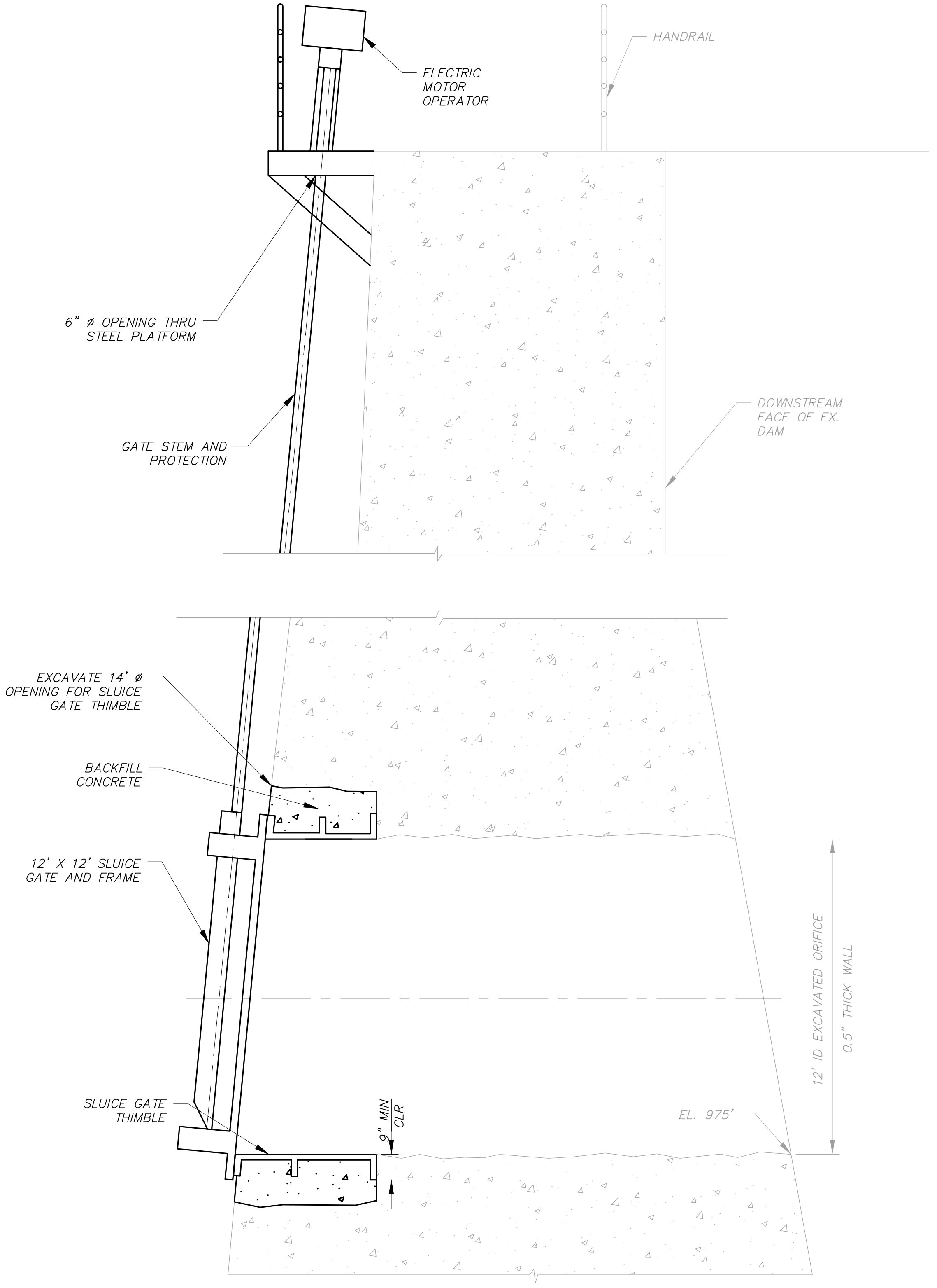
MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

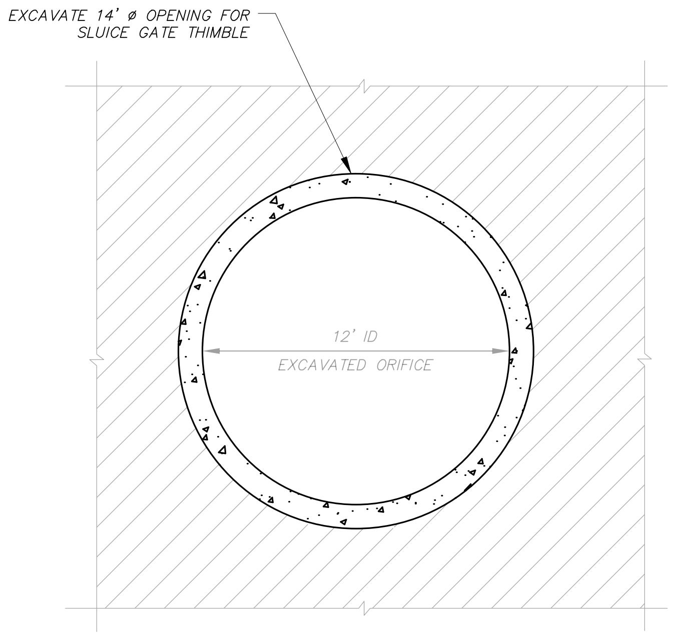
DAM REMOVAL CONCEPT 2A – DAM PROFILE AND SECTION

SHEET 8 OF 16
DRAWING NO.



SECTION A (OPTIONAL GATE)

SCALE: NTS



EXCAVATION FOR SLUICE GATE THIMBLE
(LOOKING DOWNSTREAM)

SCALE: 1" = 4'

A-9

PLOT DATE: 6/23/15

SAVE DATE: 3/31/15 LATHA_CHANDRASEKARAN A:\MATILIJADAM_03124235\5000 TECHNICAL\5001CAD\05_CAD\C3D_CONCEPTS_EVALUATION\02_SHEETS\C_SHEET-9.DWG

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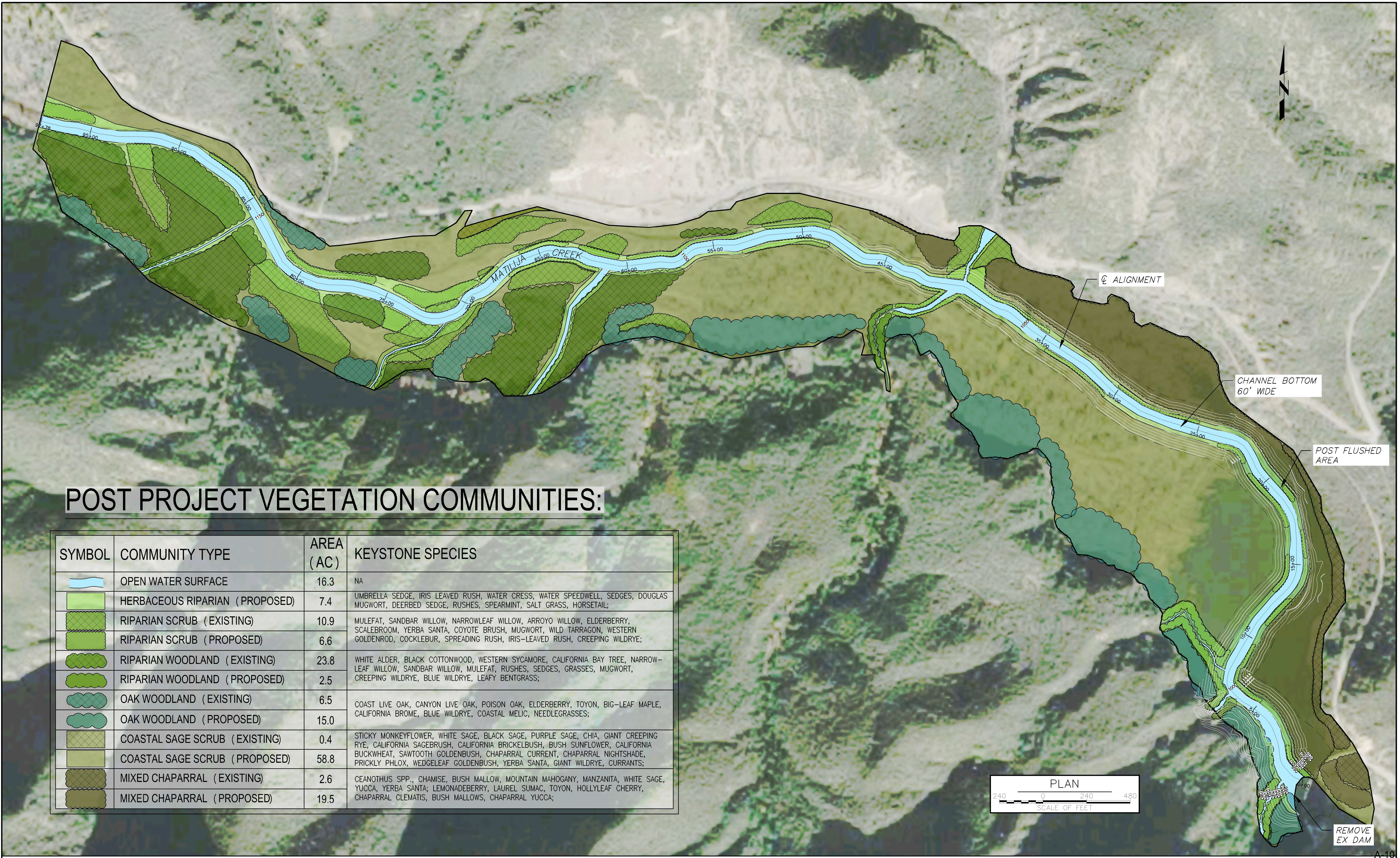
MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

DAM REMOVAL CONCEPT 2B – OPTIONAL GATE DETAILS

SHEET 9
OF 16
DRAWING NO.



POST PROJECT VEGETATION COMMUNITIES:

SYMBOL	COMMUNITY TYPE	AREA (AC)	KEYSTONE SPECIES
🟦	OPEN WATER SURFACE	16.3	NA
🟩	HERBACEOUS RIPARIAN (PROPOSED)	7.4	UMBRELLA SEDGE, IRIS LEAVED RUSH, WATER CRESS, WATER SPEEDWELL, SEDGES, DOUGLAS MUGWORT, DEERBED SEDGE, RUSHES, SPEARMINT, SALT GRASS, HORSETAIL;
▨	RIPARIAN SCRUB (EXISTING)	10.9	MULEFAT, SANDBAR WILLOW, NARROWLEAF WILLOW, ARROYO WILLOW, ELDERBERRY, SCALEBROOM, YERBA SANTA, COYOTE BRUSH, MUGWORT, WILD TARRAGON, WESTERN GOLDENROD, COCKLEBUR, SPREADING RUSH, IRIS-LEAVED RUSH, CREEPING WILDRYE;
🟩	RIPARIAN SCRUB (PROPOSED)	6.6	
▨	RIPARIAN WOODLAND (EXISTING)	23.8	WHITE ALDER, BLACK COTTONWOOD, WESTERN SYCAMORE, CALIFORNIA BAY TREE, NARROW-LEAF WILLOW, SANDBAR WILLOW, MULEFAT, RUSHES, SEDGES, GRASSES, MUGWORT, CREEPING WILDRYE, BLUE WILDRYE, LEAFY BENTGRASS;
●	RIPARIAN WOODLAND (PROPOSED)	2.5	
▨	OAK WOODLAND (EXISTING)	6.5	COAST LIVE OAK, CANYON LIVE OAK, POISON OAK, ELDERBERRY, TOYON, BIG-LEAF MAPLE, CALIFORNIA BROME, BLUE WILDRYE, COASTAL MELIC, NEEDLEGRASSES;
●	OAK WOODLAND (PROPOSED)	15.0	
▨	COASTAL SAGE SCRUB (EXISTING)	0.4	STICKY MONKEYFLOWER, WHITE SAGE, BLACK SAGE, PURPLE SAGE, CHIA, GIANT CREEPING RYE, CALIFORNIA SAGEBRUSH, CALIFORNIA BRICKELBUSH, BUSH SUNFLOWER, CALIFORNIA BUCKWHEAT, SAWTOOTH GOLDENBUSH, CHAPARRAL CURRENT, CHAPARRAL NIGHTSHADE, PRICKLY PHLOX, WEDGELEAF GOLDENBUSH, YERBA SANTA, GIANT WILDRYE, CURRANTS;
🟩	COASTAL SAGE SCRUB (PROPOSED)	58.8	
▨	MIXED CHAPARRAL (EXISTING)	2.6	CEANOTHUS SPP., CHAMISE, BUSH MALLOW, MOUNTAIN MAHOGANY, MANZANITA, WHITE SAGE, YUCCA, YERBA SANTA; LEMONADEBERRY, LAUREL SUMAC, TOYON, HOLLYLEAF CHERRY, CHAPARRAL CLEMATIS, BUSH MALLOWS, CHAPARRAL YUCCA;
●	MIXED CHAPARRAL (PROPOSED)	19.5	

PLOT DATE: 3/30/15

SAVE DATE: 3/23/15 CHRIS_HARGREAVES G:\VENTCO_RESTOR_MATILIJADAM\6-WIP\CONCEPT 2 PLAN.DWG

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DISTRICT DIRECTOR DATE

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PUBLIC WORKS AGENCY
WATERSHED PROTECTION DISTRICT

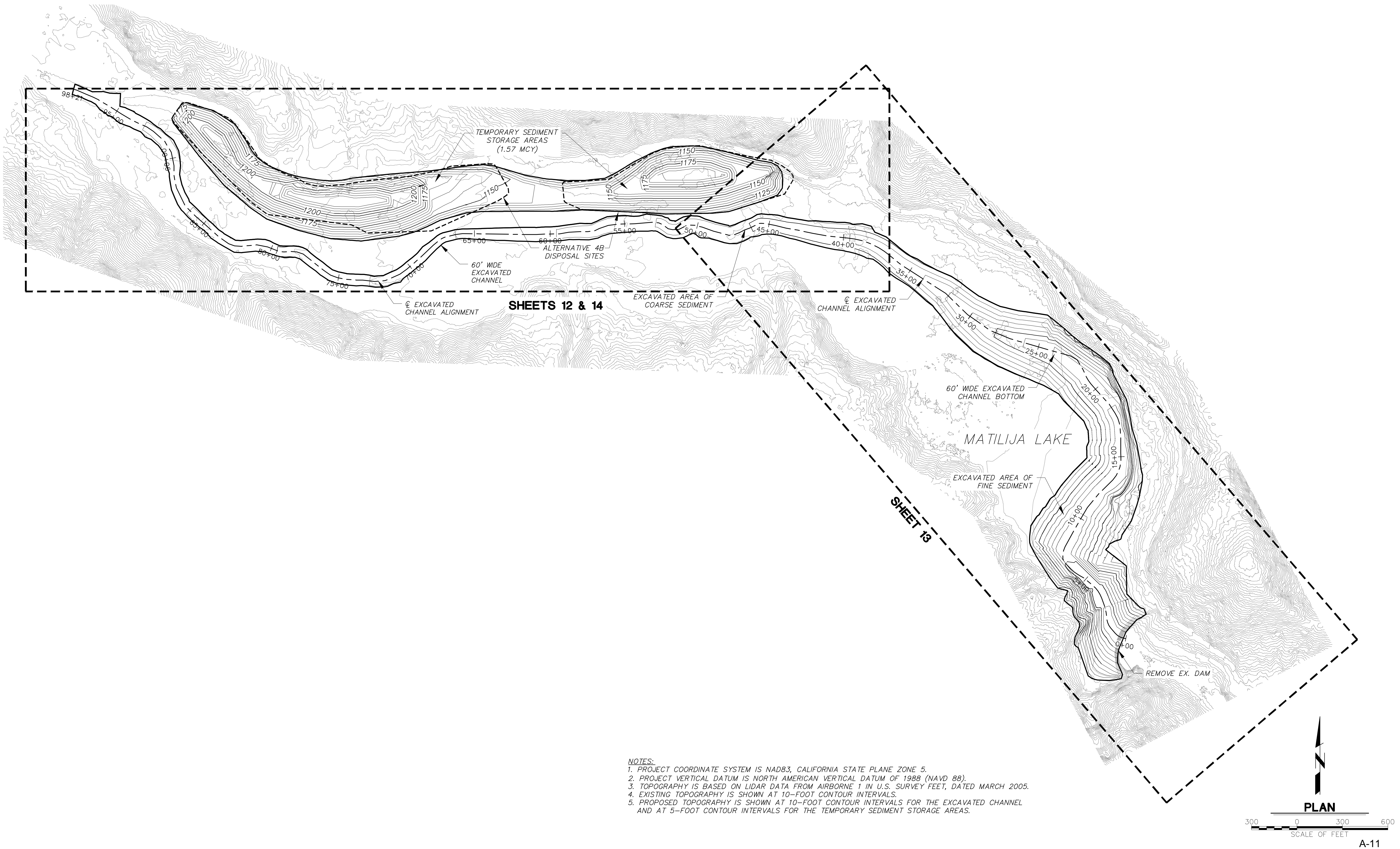
SPEC. NO. –

PROJ. NO. –

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT,
AND ROBLES DIVERSION MITIGATION PROJECT
DAM REMOVAL CONCEPT 2 – POST PROJECT
VEGETATION COMMUNITIES

SHEET 10 OF 16

DRAWING NO. C-2



NOTES:
1. PROJECT COORDINATE SYSTEM IS NAD83, CALIFORNIA STATE PLANE ZONE 5.
2. PROJECT VERTICAL DATUM IS NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88).
3. TOPOGRAPHY IS BASED ON LIDAR DATA FROM AIRBORNE 1 IN U.S. SURVEY FEET, DATED MARCH 2005.
4. EXISTING TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS.
5. PROPOSED TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS FOR THE EXCAVATED CHANNEL AND AT 5-FOOT CONTOUR INTERVALS FOR THE TEMPORARY SEDIMENT STORAGE AREAS.

PLAN

A-11

PLOT DATE: 3/31/15

SAVE DATE: 3/31/15 LATHA_CHANDRASEKARAN A:\MATILIJADAM_03124235\5000 TECHNICAL\5001CAD\05_CAD\C3D_CONCEPTS_EVALUATION\02_SHEETS\C_SHEET-11.DWG

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△	REVISION DESCRIPTION	APP.	DATE

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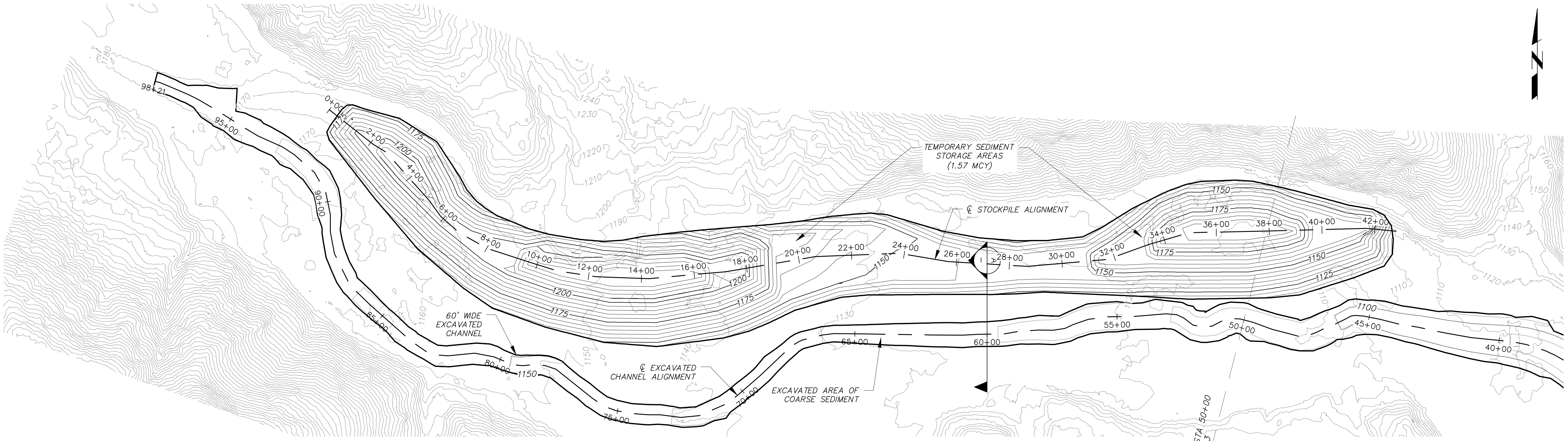
PUBLIC WORKS AGENCY
WATERSHED PROTECTION DISTRICT

SPEC. NO.
–
PROJ. NO.
–

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

DAM REMOVAL CONCEPT 3 – GENERAL ARRANGEMENT PLAN

SHEET 11
OF 16
DRAWING NO.

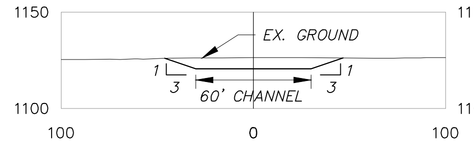


<u>NOTES:</u>

1. EXISTING TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS.
2. PROPOSED TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS FOR THE EXCAVATED CHANNEL AND AT 5-FOOT CONTOUR INTERVALS FOR THE TEMPORARY SEDIMENT STORAGE AREAS.

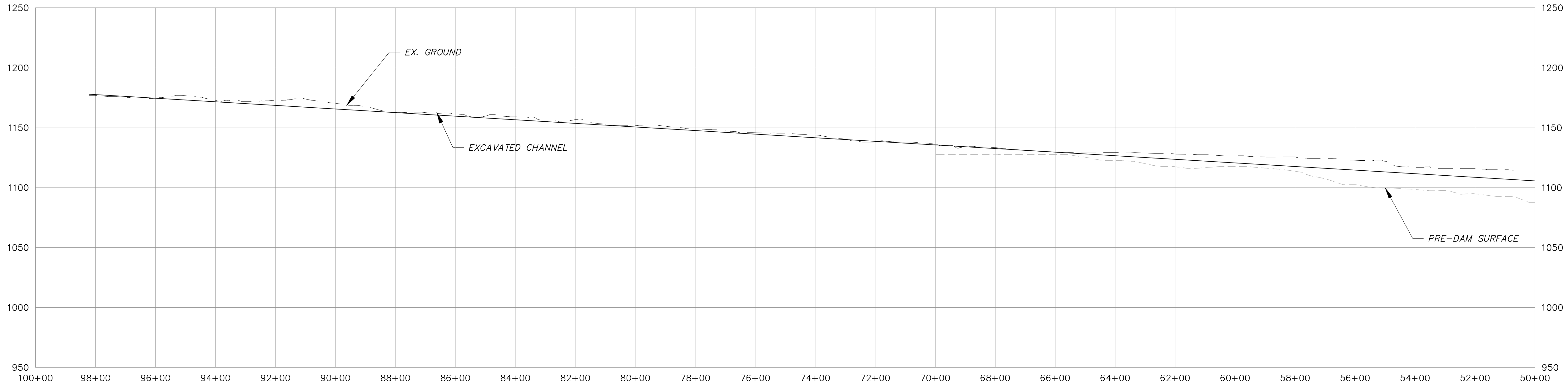
PLAN

200 0 200 400
SCALE OF FEET



TYPICAL SECTION (A)

SCALE: HORZ: 1" = 50'
VERT: 1" = 50'



℄ CHANNEL PROFILE

SCALE: HORZ: 1" = 200'
VERT: 1" = 50'

A-12

PLOT DATE: 3/29/15

SAVE DATE: 3/29/15 LATHA_CHANDRASEKARAN A:\MATILIJADAM_03124235\5000 TECHNICAL\5001CAD\05_CAD\C3D_CONCEPTS_EVALUATION\02_SHEETS\C_SHEET-12.DWG

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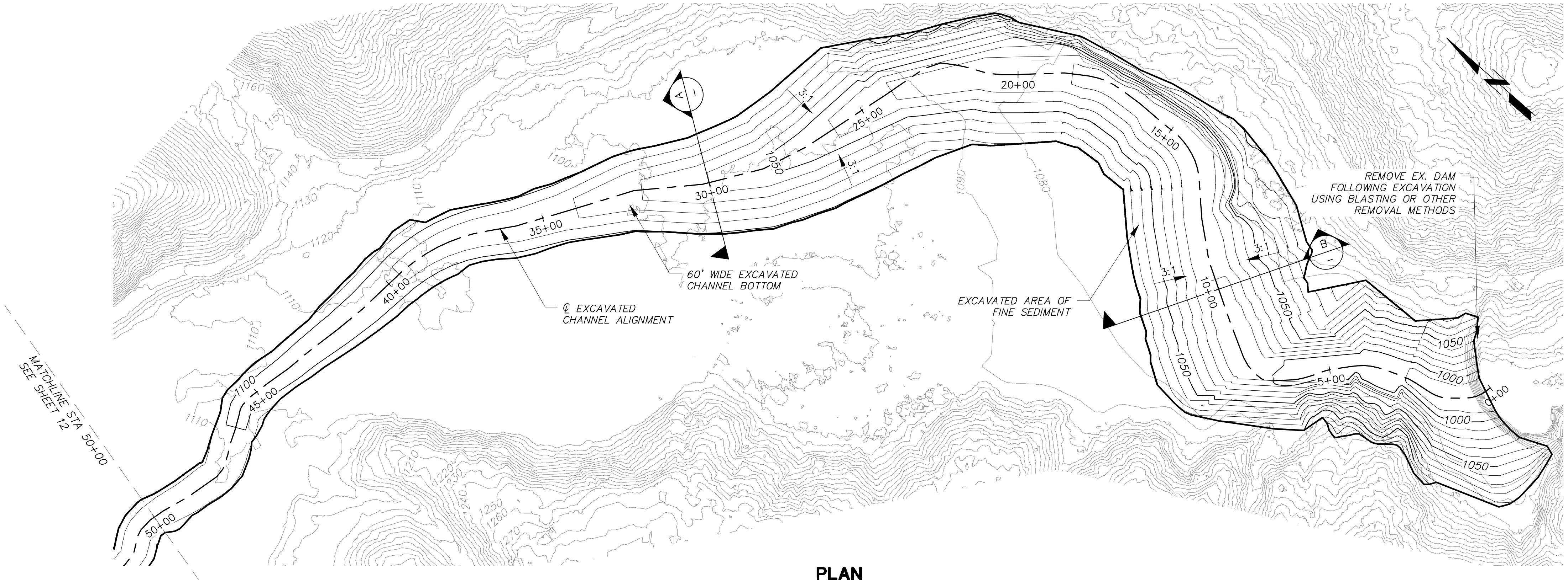
DISTRICT DIRECTOR DATE

COUNTY OF VENTURA
PUBLIC WORKS AGENCY
WATERSHED PROTECTION DISTRICT

SPEC. NO. –
PROJ. NO. –

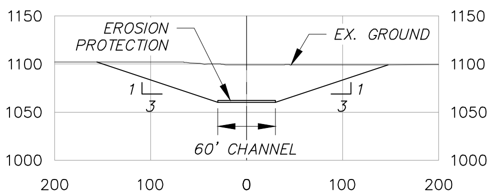
MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT
DAM REMOVAL CONCEPT 3 – EXCAVATED CHANNEL
PLAN, PROFILE, AND SECTION

SHEET 12 OF 16
DRAWING NO.



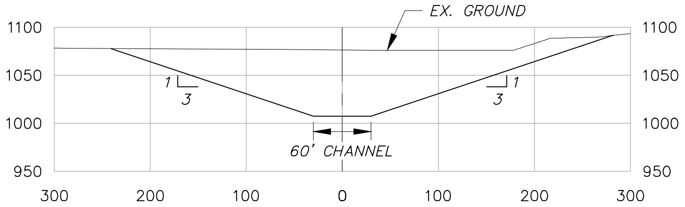
PLAN

NOTES:
1. EXISTING TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS.
2. PROPOSED TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS FOR THE EXCAVATED CHANNEL.



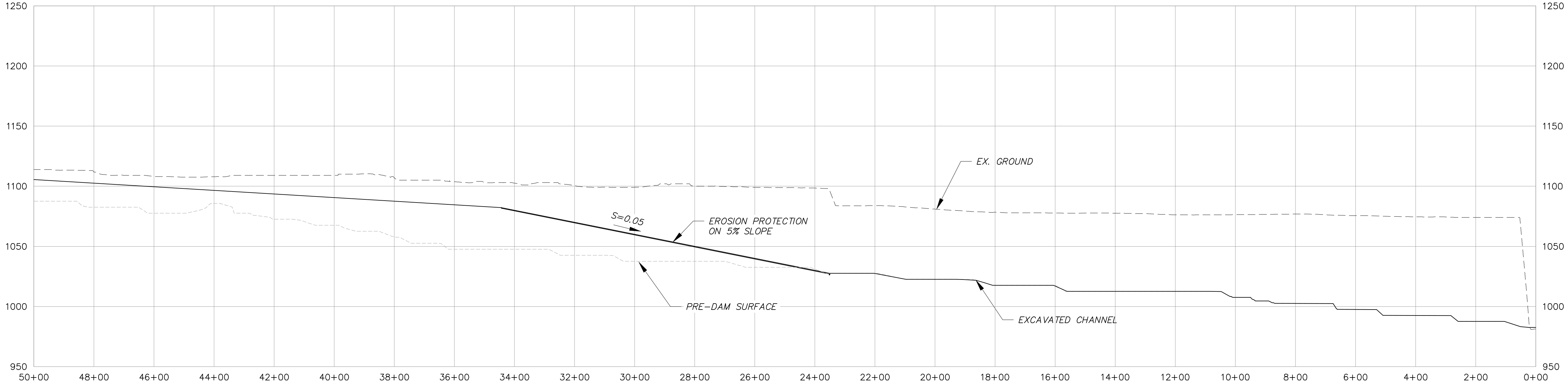
TYPICAL SECTION A

SCALE: HORZ: 1" = 100'
VERT: 1" = 100'



TYPICAL SECTION B

SCALE: HORZ: 1" = 100'
VERT: 1" = 100'



℄ EXCAVATED CHANNEL

SCALE: HORZ: 1" = 200'
VERT: 1" = 50'

A-13

PLOT DATE: 3/29/15

SAVE DATE: 3/29/15 LATHA_CHANDRASEKARAN A:\MATILIJADAM_03124235\5000 TECHNICAL\5001CAD\05_CAD\C3D_CONCEPTS_EVALUATION\02_SHEETS\C_SHEET-13.DWG

△	REVISION DESCRIPTION	APP.	DATE
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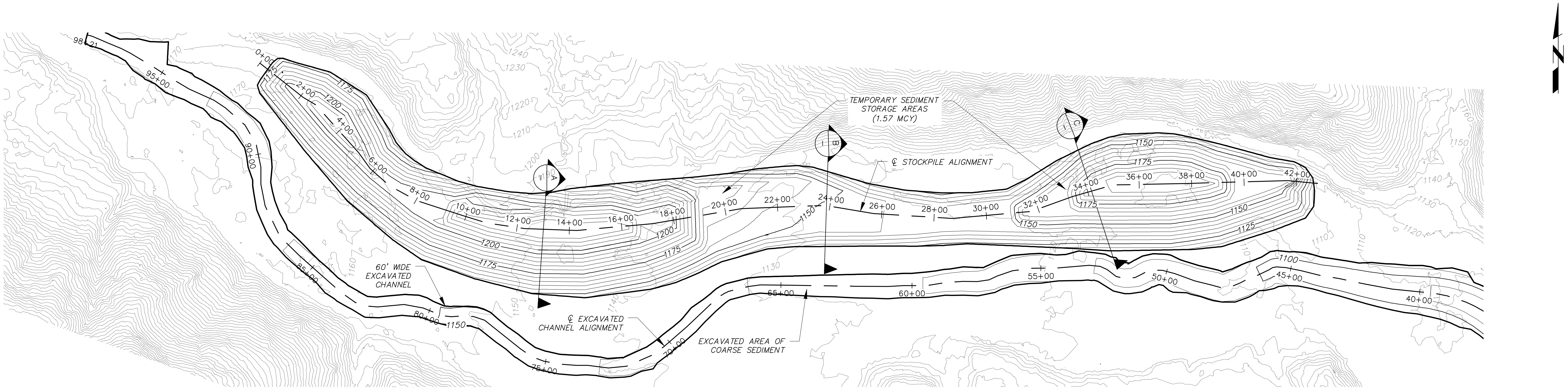
DEPUTY DIRECTOR DATE
DISTRICT DIRECTOR DATE

COUNTY OF VENTURA
PUBLIC WORKS AGENCY
WATERSHED PROTECTION DISTRICT

SPEC. NO. –
PROJ. NO. –

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT
DAM REMOVAL CONCEPT 3 – EXCAVATED CHANNEL
PLAN, PROFILE, AND SECTIONS

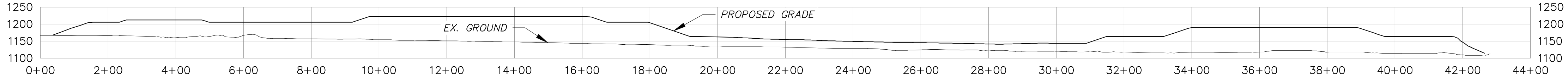
SHEET 13
OF 16
DRAWING NO.



PLAN

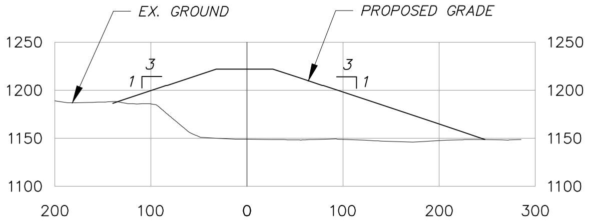
200 0 200 400
SCALE OF FEET

NOTES:
1. EXISTING TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS.
2. PROPOSED TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS FOR THE EXCAVATED CHANNEL AND AT 5-FOOT CONTOUR INTERVALS FOR THE TEMPORARY SEDIMENT STORAGE AREAS.



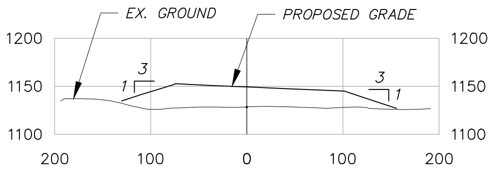
℄ STOCKPILE PROFILE

SCALE: HORZ: 1" = 200'
VERT: 1" = 200'



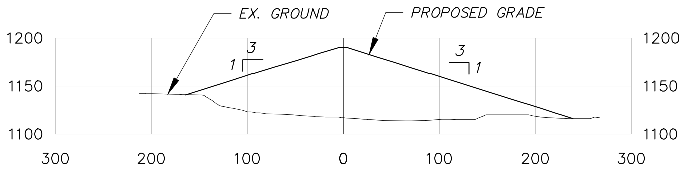
SECTION A

SCALE: HORZ: 1" = 100'
VERT: 1" = 100'



SECTION B

SCALE: HORZ: 1" = 100'
VERT: 1" = 100'



SECTION C

SCALE: HORZ: 1" = 100'
VERT: 1" = 100'

A-14

PLOT DATE: 3/29/15

SAVE DATE: 3/28/15 LATHA_CHANDRASEKARAN A:\MATILIJADAM_03124235\5000 TECHNICAL\5001CAD\05_CAD\C3D_CONCEPTS_EVALUATION\02_SHEETS\C_SHEET-14.DWG

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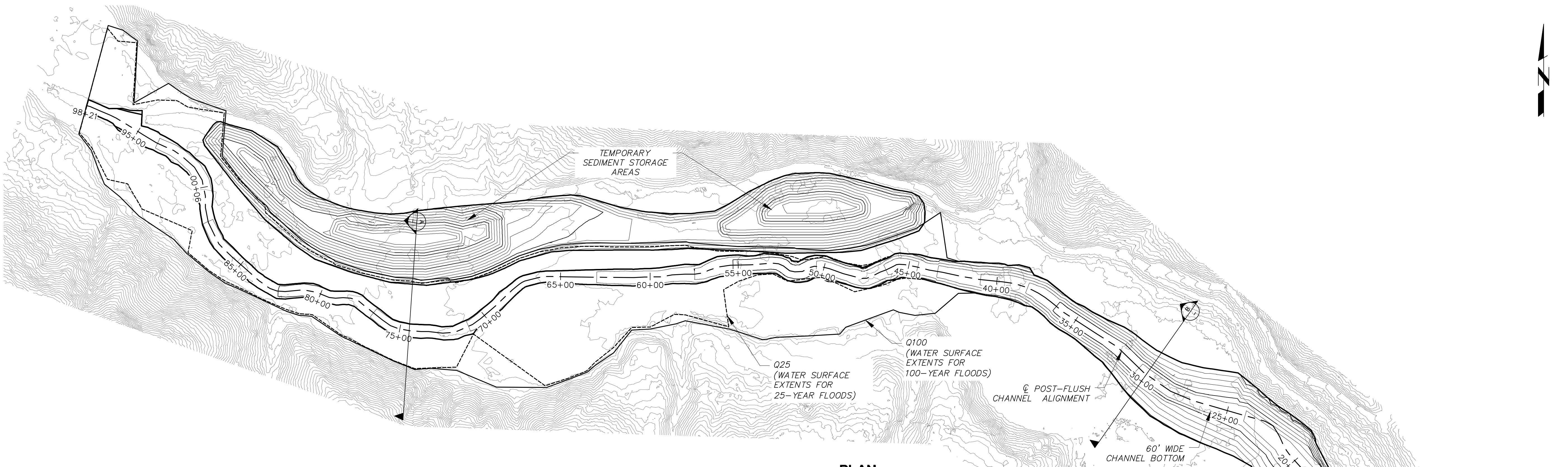
DISTRICT DIRECTOR DATE

COUNTY OF VENTURA
PUBLIC WORKS AGENCY
WATERSHED PROTECTION DISTRICT

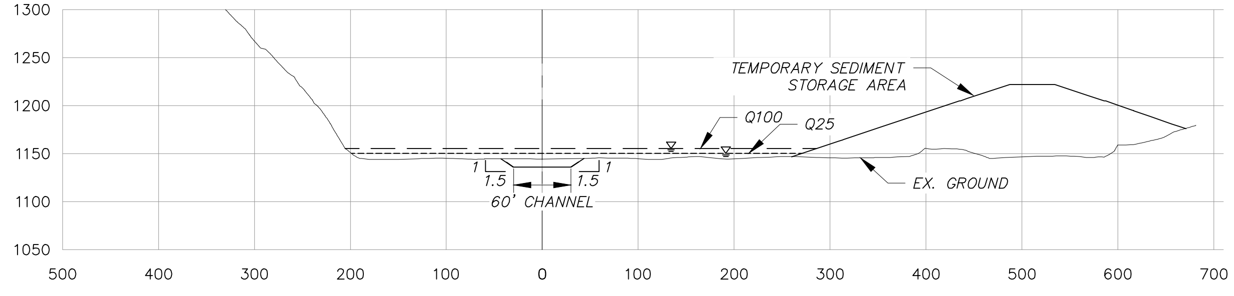
SPEC. NO. –
PROJ. NO. –

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT
DAM REMOVAL CONCEPT 3 – TEMPORARY SEDIMENT STORAGE AREAS
PLAN, PROFILE, AND SECTIONS

SHEET 14
OF 16
DRAWING NO.

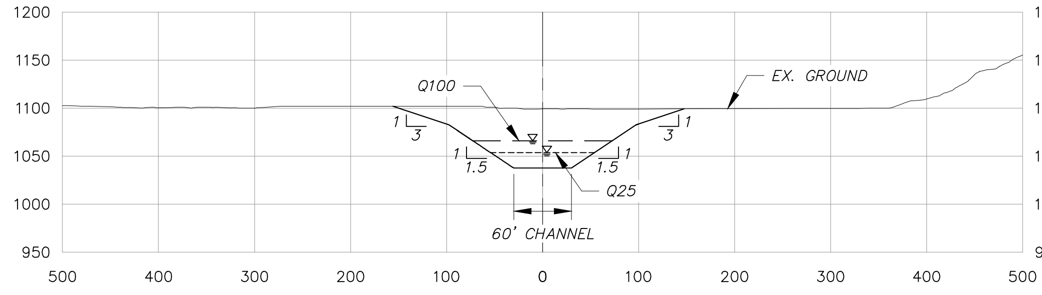


PLAN



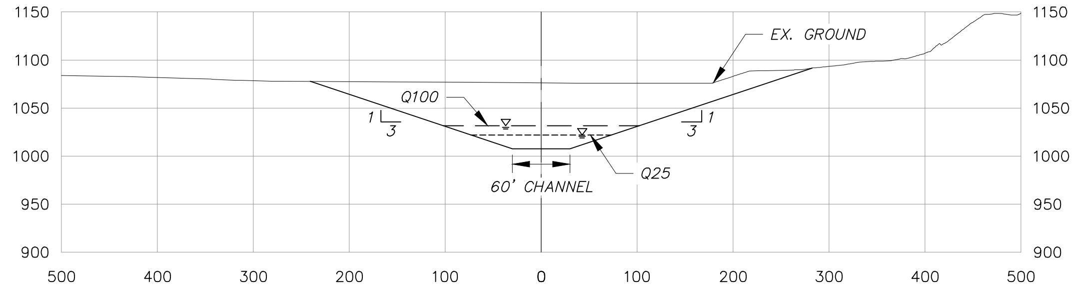
TYPICAL SECTION (A)

SCALE: HORZ: 1" = 100'
VERT: 1" = 100'



TYPICAL SECTION (B)

SCALE: HORZ: 1" = 100'
VERT: 1" = 100'



TYPICAL SECTION (C)

SCALE: HORZ: 1" = 100'
VERT: 1" = 100'

NOTES:
1. EXISTING TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS.
2. PROPOSED TOPOGRAPHY IS SHOWN AT 10-FOOT CONTOUR INTERVALS FOR THE POST-FLUSH CHANNEL AND AT 5-FOOT CONTOUR INTERVALS FOR THE TEMPORARY SEDIMENT STORAGE AREAS.

A-15

PLOT DATE: 3/29/15

SAVE DATE: 3/29/15 LATHA_CHANDRASEKARAN A:\MATILIJADAM_03124235\5000 TECHNICAL\5001CAD\05_CAD\C3D_CONCEPTS_EVALUATION\02_SHEETS\C_SHEET-15.DWG

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DISTRICT DIRECTOR DATE

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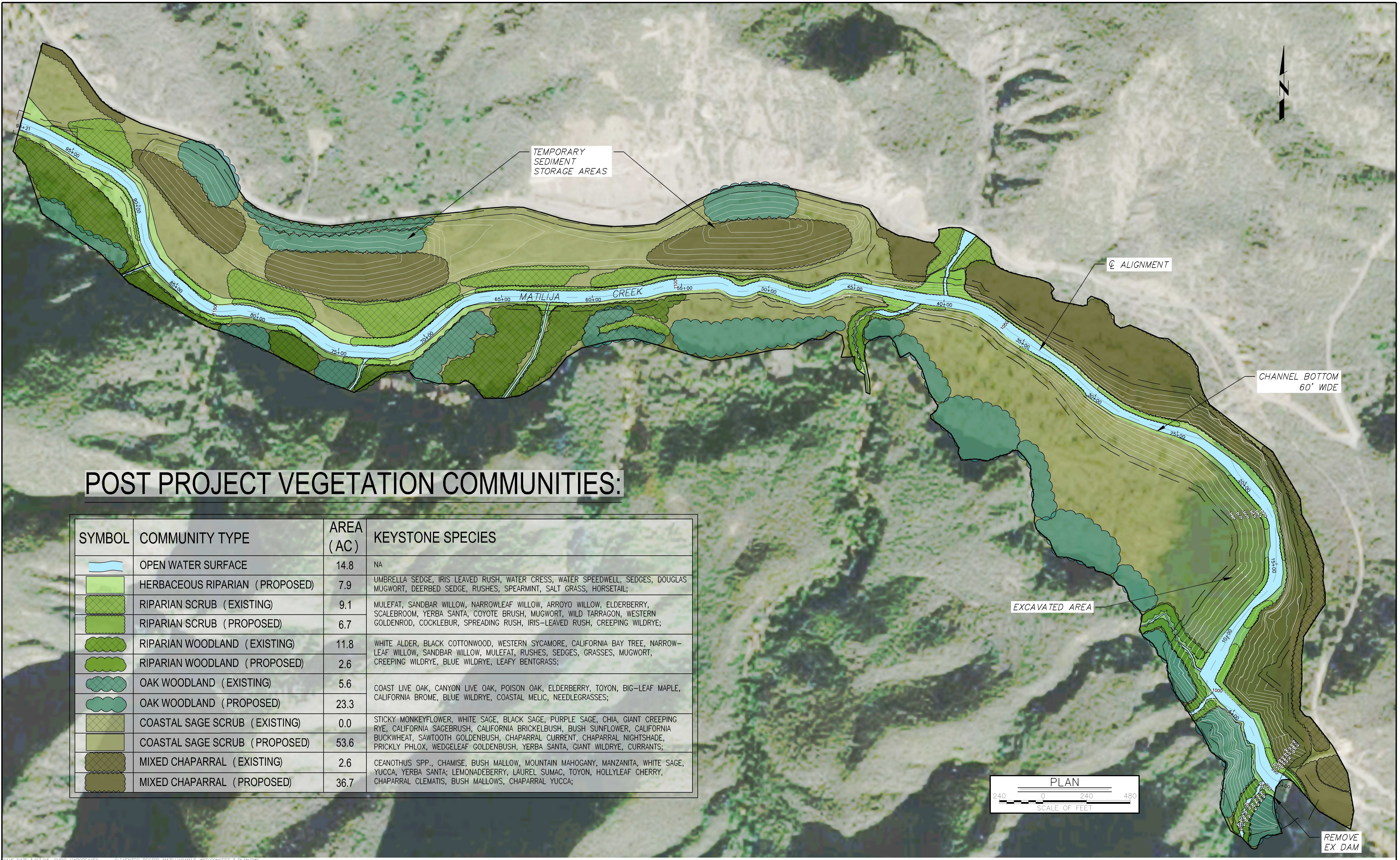
WATERSHED PROTECTION DISTRICT

SPEC. NO. –
PROJ. NO. –

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

DAM REMOVAL CONCEPT 3 – POST-FLUSH CHANNEL

SHEET 15
OF 16
DRAWING NO.



POST PROJECT VEGETATION COMMUNITIES:

SYMBOL	COMMUNITY TYPE	AREA (AC)	KEYSTONE SPECIES
🟦	OPEN WATER SURFACE	14.8	NA
🟩	HERBACEOUS RIPARIAN (PROPOSED)	7.9	UMBRELLA SEDGE, IRIS LEAVED RUSH, WATER CRESS, WATER SPEEDWELL, SEDGES, DOUGLAS MUGWORT, DEERBED SEDGE, RUSHES, SPEARMINT, SALT GRASS, HORSETAIL;
▨	RIPARIAN SCRUB (EXISTING)	9.1	MULEFAT, SANDBAR WILLOW, NARROWLEAF WILLOW, ARROYO WILLOW, ELDERBERRY, SCALEBROOM, YERBA SANTA, COYOTE BRUSH, MUGWORT, WILD TARRAGON, WESTERN GOLDENROD, COCKLEBUR, SPREADING RUSH, IRIS-LEAVED RUSH, CREEPING WILDRYE;
🟩	RIPARIAN SCRUB (PROPOSED)	6.7	
▨	RIPARIAN WOODLAND (EXISTING)	11.8	WHITE ALDER, BLACK COTTONWOOD, WESTERN SYCAMORE, CALIFORNIA BAY TREE, NARROW-LEAF WILLOW, SANDBAR WILLOW, MULEFAT, RUSHES, SEDGES, GRASSES, MUGWORT, CREEPING WILDRYE, BLUE WILDRYE, LEAFY BENTGRASS;
🟩	RIPARIAN WOODLAND (PROPOSED)	2.6	
▨	OAK WOODLAND (EXISTING)	5.6	COAST LIVE OAK, CANYON LIVE OAK, POISON OAK, ELDERBERRY, TOYON, BIG-LEAF MAPLE, CALIFORNIA BROME, BLUE WILDRYE, COASTAL MELIC, NEEDLEGRASSES;
🟩	OAK WOODLAND (PROPOSED)	23.3	
▨	COASTAL SAGE SCRUB (EXISTING)	0.0	STICKY MONKEYFLOWER, WHITE SAGE, BLACK SAGE, PURPLE SAGE, CHIA, GIANT CREEPING RYE, CALIFORNIA SAGEBRUSH, CALIFORNIA BRICKELBUSH, BUSH SUNFLOWER, CALIFORNIA BUCKWHEAT, SAWTOOTH GOLDENBUSH, CHAPARRAL CURRENT, CHAPARRAL NIGHTSHADE, PRICKLY PHLOX, WEDGELEAF GOLDENBUSH, YERBA SANTA, GIANT WILDRYE, CURRANTS;
🟩	COASTAL SAGE SCRUB (PROPOSED)	53.6	
▨	MIXED CHAPARRAL (EXISTING)	2.6	CEANOTHUS SPP., CHAMISE, BUSH MALLOW, MOUNTAIN MAHOGANY, MANZANITA, WHITE SAGE, YUCCA, YERBA SANTA; LEMONADEBERRY, LAUREL SUMAC, TOYON, HOLLYLEAF CHERRY, CHAPARRAL CLEMATIS, BUSH MALLOWS, CHAPARRAL YUCCA;
🟩	MIXED CHAPARRAL (PROPOSED)	36.7	

PLOT DATE: 3/30/15
SAVE DATE: 3/23/15 CHRIS_HARGREAVES G:\VENTCO_RESTOR_MATILIJADAM\6-WIP\CONCEPT 3 PLAN.DWG

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△	REVISION DESCRIPTION	APP.	DATE

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DISTRICT DIRECTOR DATE

COUNTY OF VENTURA
PUBLIC WORKS AGENCY
WATERSHED PROTECTION DISTRICT

SPEC. NO. –
PROJ. NO. –

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT,
AND ROBLES DIVERSION MITIGATION PROJECT
DAM REMOVAL CONCEPT 3 – POST PROJECT
VEGETATION COMMUNITIES

SHEET 16
OF 16
DRAWING NO. C-3

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

DAM REMOVAL CONCEPTS EVALUATION REPORT

MARCH 2016

APPENDIX B: ROUGH ORDER OF MAGNITUDE CONSTRUCTION COST & SCHEDULE DETAILS

TABLE B-1

Project: Matilija Dam Removal, Sediment Transport, & Robles Diversion Mitigation
Task 1.3: Concept Evaluation
DRAFT Rough Order of Magnitude Cost Estimate (Class 5)
Date: 5/28/2015
Detailed Breakdown: DRC-1 - Containment berm with high flow bypass

Line Item #	Line Item	Quantity	Unit	Unit cost	Amount	Notes
1	**Mobilization/Demobilization (15%)**				**$ 3,522,651**	
	Mobilization/Demobilization (15%)	1	LS	$ 3,522,651	$ 3,522,651	Moblization and Demoblization (15% of Direct Construction Cost associated with Items not including Mob/Demob)
2	**Site Preparation**				**$ 257,456**	
	Clear & grub general staging areas and access roads	1.0	acre	$ 5,320	$ 5,320	Price escalated from USACE September 2004
	Clear & grub portal areas	2.4	acre	$ 5,320	$ 12,768	Price escalated from USACE September 2004
	Clear & grub containment berm area	1.0	acre	$ 5,320	$ 5,320	Price escalated from USACE September 2004
	Clear & grub cofferdam area	6.4	acre	$ 5,320	$ 34,048	Price escalated from USACE September 2004
	Downstream portal preparation (grading, temporaily covering/bridging NF Matilija)	1	LS	$ 200,000	$ 200,000	Allowance
3	**Build bypass**				**$ 9,650,000**	
	Upstream Portal	1	ea	$ 150,000	$ 150,000	Assumed size stabilized with 12-foot dowel @ 10x10 spacing and shotcrete; used historic prices
	Downstream Portal	1	ea	$ 480,000	$ 480,000	Assumed size stabilized with 12-foot dowel @ 10x10 spacing and shotcrete; used historic prices
	Tunnel and Gate Shaft	1,370	ft	$ 6,000	$ 8,220,000	Based on historic price per foot and a relatively recent bid for 12-foot-diameter tunnels
	Sluice gate	1	ea	$ 300,000	$ 300,000	From Searsville, purchase and installation
	Erosion protection for NF Matilija Creek	1	LS	$ 500,000	$ 500,000	Allowance
4	**Build DS containment berm**				**$ 203,175**	
	Excavation for containment berm	2,500	cy	$ 12.00	$ 30,000	Cost based on crew/equipment/material buildup
	Excavation for spillway	4,100	cy	$ 12.00	$ 49,200	Cost based on crew/equipment/material buildup
	Fill for containment berm	7,500	cy	$ 14.50	$ 108,750	Cost based on crew/equipment/material buildup
	Erosion protection (processed from coarse alluvium at u/s end of reservoir)	420	cy	$ 36.25	$ 15,225	Cost based on crew/equipment/material buildup (process $21.75/cy + $14.5/cy placement)
5	**Build US cofferdam**				**$ 1,421,000**	
	Excavate and place fill	118,500	cy	$ 10.25	$ 1,214,625	Cost based on crew/equipment/material buildup
	Erosion protection (processed from coarse alluvium at u/s end of reservoir)	6,500	cy	$ 31.75	$ 206,375	Cost based on crew/equipment/material buildup (process $21.5/cy + $10.25/cy placement)
6	**Dewatering**				**$ 263,900**	
	Dewater reservoir	500	ac-ft	$ 247.80	$ 123,900	Price escalated from USACE September 2004
	Fish rescue and relocation	1	LS	$ 140,000.00	$ 140,000	Price escalated from USACE September 2004
7	**Remove dam**				**$ 9,174,810**	
	Remove fish traps and control house	1	LS	$ 70,560.00	$ 70,560	Price escalated from USACE September 2004
	Hoeram dam down to El. 1075 feet	9,350	cy	$ 160.00	$ 1,496,000	Cost based on crew/equipment/material buildup
	Drill & blast remaining dam to stream channel (17,500 cy left below stream invert)	45,700	cy	$ 40.00	$ 1,828,000	Intact volume, Cost based on crew/equipment/material buildup
	Process for hauling	55,050	cy	$ 10.00	$ 550,500	Intact volume, Cost based on crew/equipment/material buildup
	Haul to recycling plant	55,050	cy	$ 50.00	$ 2,752,500	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	82,575	cy	$ 30.00	$ 2,477,250	Rubble volume, Searsville price
8	**Site Restoration**				**$ 2,514,000**	
	Remove remaining cofferdam	94,000	cy	$ 6.00	$ 564,000	Unit rate assumed to be half of unit rate to construct
	Site Restoration	1	LS	$ 1,950,000.00	$ 1,950,000	Assumed not required for naturally formed slopes in reservoir area
	Subtotal				**$ 27,006,992**	
	Design & Unit Cost Contingency (30%)				$ 8,102,098	

TABLE B-1

	Total Direct Construction Cost				$ 35,109,090	
	Construction Contingency (15%)				$ 5,266,363	
	Total Construction Cost				**$ 40,375,453**	
	Low Side of Class 5 Estimate Range (-30%)				**$ 28,262,817**	
	High Side of Class 5 Estimate Range (+50%)				**$ 60,563,180**	

TABLE B-2A

Project: Matilija Dam Removal, Sediment Transport, & Robles Diversion Mitigation
Task 1.3: Concept Evaluation
DRAFT Rough Order of Magnitude Cost Estimate (Class 5)
Date: 5/28/2015
Detailed Breakdown: DRC-2A - Uncontrolled orifices

Line Item #	Line Item	Quantity	Unit	Unit cost	Amount	Notes
1	**Mobilization/Demobilization (15%)**				**$ 1,614,287**	
	Mobilization/Demobilization (15%)	1	LS	$ 1,614,287	$ 1,614,287	Moblization and Demoblization (15% of Direct Construction Cost associated with Items not including Mob/Demob)
2	**Site Preparation**				**$ 7,412**	
	Clear & grub general staging areas and access roads	1.0	acre	$ 7,412	$ 7,412	RSMeans Heavy Construction (2007) - page 205 (1.148 Location Factor)
3	**Excavate tunnels through dam**				**$ 851,690**	
	Excavate and place fill for working platforms	4,170	cy	$ 12.00	$ 50,040	Cost based on crew/equipment/material buildup
	Drill & break out concrete	210	cy	$ 2,770.00	$ 581,700	Price from Searsville
	Haul to recycling plant	210	cy	$ 50.00	$ 10,500	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	315	cy	$ 30.00	$ 9,450	Rubble volume, Searsville price
	Remove final plug	1	LS	$ 200,000.00	$ 200,000	Cost based on crew/equipment/material buildup to drill and blast plugs + $75,000 standby allow.
4	**Remove dam**				**$ 8,052,810**	
	Remove fish traps and control house	1	LS	$ 70,560.00	$ 70,560	Price escalated from USACE September 2004
	Drill & blast dam down to stream channel (17,500 cy left below stream invert)	55,050	cy	$ 40.00	$ 2,202,000	Intact volume, Cost based on crew/equipment/material buildup
	Process for hauling	55,050	cy	$ 10.00	$ 550,500	Intact volume, Cost based on crew/equipment/material buildup
	Haul to recycling plant	55,050	cy	$ 50.00	$ 2,752,500	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	82,575	cy	$ 30.00	$ 2,477,250	Rubble volume, Searsville price
5	**Site Restoration**				**$ 1,850,000**	
	Site Restoration	1	LS	$ 1,850,000.00	$ 1,850,000	Assumed not required for naturally formed slopes in reservoir area
	Subtotal				**$ 12,376,199**	
	Design & Unit Cost Contingency (30%)				$ 3,712,860	
	Total Direct Construction Cost				$ 16,089,059	
	Construction Contingency (15%)				$ 2,413,359	
	Total Construction Cost				**$ 18,502,418**	
	Low Side of Class 5 Estimate Range (-30%)				**$ 12,951,693**	
	High Side of Class 5 Estimate Range (+50%)				**$ 27,753,627**	

TABLE B-2B

Project: Matilija Dam Removal, Sediment Transport, & Robles Diversion Mitigation
Task 1.3: Concept Evaluation
DRAFT Rough Order of Magnitude Cost Estimate (Class 5)
Date: 5/28/2015
Detailed Breakdown: DRC-2B - Uncontrolled orifices with gates

Line Item #	Line Item	Quantity	Unit	Unit cost	Amount	Notes
1	**Mobilization/Demobilization (15%)**				**$ 1,779,133**	
	Mobilization/Demobilization (15%)	1	LS	$ 1,779,133	$ 1,779,133	Moblization and Demoblization (15% of Direct Construction Cost associated with Items not including Mob/Demob)
2	**Site Preparation**				**$ 7,412**	
	Clear & grub general staging areas and access roads	1.0	acre	$ 7,412	$ 7,412	RSMeans Heavy Construction (2007) - page 205 (1.148 Location Factor)
3	**Excavate tunnels through dam**				**$ 851,690**	
	Excavate and place fill for working platforms	4,170	cy	$ 12.00	$ 50,040	Cost based on crew/equipment/material buildup
	Drill & break out concrete	210	cy	$ 2,770.00	$ 581,700	Price from Searsville
	Haul to recycling plant	210	cy	$ 50.00	$ 10,500	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	315	cy	$ 30.00	$ 9,450	Rubble volume, Searsville price
	Remove final plug	1	LS	$ 200,000.00	$ 200,000	Cost based on crew/equipment/material buildup to drill and blast plugs + $75,000 standby allow.
4	**Optional Gates**				**$ 1,098,974**	
	Build working platforms DS	2,000	cy	$ 12.00	$ 24,000	Cost based on crew/equipment/material buildup
	Build access for mid-level orifice	1	ea	$ 100,000.00	$ 100,000	Allowance
	Drill & break out concrete for gated orifices	10	cy	$ 2,770.00	$ 27,700	Price from Searsville recycling of concrete
	Drill and break out concrete for mid-level orifice	16	cy	$ 2,770.00	$ 44,320	Price from Searsville drilling, breaking out, hauling, recycling of concrete
	Haul to recycling plant	26	cy	$ 68.00	$ 1,768	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	39	cy	$ 30.41	$ 1,186	Rubble volume, Searsville price
	Purchase and install 12-foot-diameter sluice gates	2	ea	$ 400,000.00	$ 800,000	Price from Searsville estimate
	Purchase and install 6-foot-diameter sluice gates	1	ea	$ 100,000.00	$ 100,000	Ratio of price for 12-foot-diameter gates based on area of gate
5	**Remove dam**				**$ 8,052,810**	
	Remove fish traps and control house	1	LS	$ 70,560.00	$ 70,560	Price escalated from USACE September 2004
	Drill & blast dam down to stream channel (17,500 cy left below stream invert)	55,050	cy	$ 40.00	$ 2,202,000	Intact volume, Cost based on crew/equipment/material buildup
	Process for hauling	55,050	cy	$ 10.00	$ 550,500	Intact volume, Cost based on crew/equipment/material buildup
	Haul to recycling plant	55,050	cy	$ 50.00	$ 2,752,500	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	82,575	cy	$ 30.00	$ 2,477,250	Rubble volume, Searsville price
6	**Site Restoration**				**$ 1,850,000**	
	Site Restoration	1	LS	$ 1,850,000.00	$ 1,850,000	Assumed not required for naturally formed slopes in reservoir area
	Subtotal				**$ 13,640,019**	
	Design & Unit Cost Contingency (30%)				$ 4,092,006	
	Total Direct Construction Cost				$ 17,732,025	
	Construction Contingency (15%)				$ 2,659,804	
	Total Construction Cost				**$ 20,391,829**	
	Low Side of Class 5 Estimate Range (-30%)				**$ 14,274,280**	
	High Side of Class 5 Estimate Range (+50%)				**$ 30,587,743**	

TABLE B-3

Project: Matilija Dam Removal, Sediment Transport, & Robles Diversion Mitigation
Task 1.3: Concept Evaluation
DRAFT Rough Order of Magnitude Cost Estimate (Class 5)
Date: 5/28/2015
Detailed Breakdown: DRC-3 - Remove sediment for structure removal, temporary US storage of sediment

Line Item #	Line Item	Quantity	Unit	Unit cost	Amount	Notes
1	**Mobilization/Demobilization (15%)**				**$ 4,335,830**	
	Mobilization/Demobilization (15%)	1	LS	$ 4,335,830	$ 4,335,830	Moblization and Demoblization (15% of Direct Construction Cost associated with Items not including Mob/Demob)
2	**Site Preparation**				**$ 1,185,600**	
	Clear & Grub Staging Area and Access Roads	1.0	acre	$ 5,320	$ 5,320	Price escalated from USACE September 2004
	Clear & grub channel in delta, upstream coarse sediment, and temp. stockpile areas	79.0	acre	$ 5,320	$ 420,280	Price escalated from USACE September 2004
	Diversion system	1	LS	$ 760,000	$ 760,000	Allowance (assumes 6,500-foot-long 48-inch HDPE with a dam penetration)
3	**Dewatering**				**$ 2,492,120**	
	Dewater reservoir - 1st season	500	ac-ft	$ 247.80	$ 123,900	Price escalated from USACE September 2004
	Install mid-level orifice - 1st season					
	Build access for mid-level orifice	1	ea	$ 100,000.00	$ 100,000	Allowance
	Drill and break out concrete for mid-level orifice	16	cy	$ 2,770.00	$ 44,320	Price from Searsville drilling, breaking out, hauling, recycling of concrete
	Purchase and install 6-foot-diameter sluice gates	1	ea	$ 100,000.00	$ 100,000	Ratio of price for 12-foot-diameter gates based on area of gate
	Dewater reservoir - 2nd season	500	ac-ft	$ 247.80	$ 123,900	Price escalated from USACE September 2004
	Dewater sediment	1	LS	$ 2,000,000.00	$ 2,000,000	Allowance
4	**Excavate channel**				**$ 14,975,000**	
	Excavate and stockpile fine sediment	1,230,000	cy	$ 7.20	$ 8,856,000	Cost based on crew/equipment/material buildup
	Access roads for fine sediment excavation	10,000	lf	$ 40.00	$ 400,000	Est. 2,000 lineal feet of 40-foot-wide 2-foot-thick access roads at 5 levels for fine sediment ex.
	Excavate and stockpile delta area sediment	460,000	cy	$ 9.40	$ 4,324,000	Cost based on crew/equipment/material buildup
	Excavate and stockpile coarse sediment	120,000	cy	$ 8.60	$ 1,032,000	Cost based on crew/equipment/material buildup
	Erosion protection for channel	12,100	cy	$ 30.00	$ 363,000	Cost based on crew/equipment/material buildup (process $20/cy + $10/cy placement)
5	**Remove dam**				**$ 8,052,810**	
	Remove fish traps and control house	1	LS	$ 70,560.00	$ 70,560	Price escalated from USACE September 2004
	Drill & blast dam down to stream channel (17,500 cy left below stream invert)	55,050	cy	$ 40.00	$ 2,202,000	Intact volume, Cost based on crew/equipment/material buildup
	Process for hauling	55,050	cy	$ 10.00	$ 550,500	Intact volume, Cost based on crew/equipment/material buildup
	Haul to recycling plant	55,050	cy	$ 50.00	$ 2,752,500	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	82,575	cy	$ 30.00	$ 2,477,250	Rubble volume, Searsville price
6	**Site Restoration**				**$ 2,200,000**	
	Site Restoration	1	LS	$ 2,200,000.00	$ 2,200,000	Historic unit rate; assumes placed in fall/winter without irrigation.
	Subtotal				**$ 33,241,360**	
	Design & Unit Cost Contingency (30%)				$ 9,972,408	
	Total Direct Construction Cost				$ 43,213,767	
	Construction Contingency (15%)				$ 6,482,065	
	Total Construction Cost				**$ 49,695,832**	
	Low Side of Class 5 Estimate Range (-30%)				**$ 34,787,083**	
	High Side of Class 5 Estimate Range (+50%)				**$ 74,543,749**	

Estimated Construction Duration

Durations of construction were estimated based on quantities of work and equipment application and production assumed to handle the work estimated to implement each of the dam removal concepts. The estimated duration of construction also considered the logical sequence of work allowing for concurrency of activities where possible. The following general assumptions were used in estimating construction duration:

- Mobilization for construction during months prior to the in-channel construction window
- No unusual weather delays
- Work performed five days per week, up to two shifts per day
- 9 hours of production are assumed for each 10-hour shift
- Night work is assumed to be allowed
- Saturdays are assumed to be a contingency for maintenance and make-up activities
- No overly restrictive constraints on trucking materials into the site
- A diversion and in-channel construction window of May 15 to October 31

DRC-1 – Containment Berm with High Flow Bypass

In general, DRC-1 would require that the bypass tunnel, upstream cofferdam, and downstream containment berm be in place prior to removal of the dam. Construction of the bypass tunnel would begin during the first season of construction from the downstream end and would continue through the winter season, being completed early in the in-channel construction window during the second season of construction. Following construction of the upstream cofferdam, also early in the in-channel construction season of the second construction season, flows from Matilija Creek would be diverted through the bypass tunnel allowing dewatering of the reservoir and the commencement of demolition of the dam down to the sediment level of 1075 feet using excavators with hoerams working from the dam crest to break the concrete.

The portion of the dam below Elevation 1075 feet would be demolished by blasting following completion of the downstream construction berm. It is anticipated that blasting of the dam would result in pile of rubble that would be covered or mixed with sediment that would slump downstream of the reservoir. To the extent possible, the concrete rubble would be broken up using excavators with hoerams, loaded into highway legal dump trucks, and hauled to a concrete recycling plant located approximately 30 miles away.

The project would then wait for the minimum high flow event to occur. Some portion of the remaining concrete would likely be carried downstream by the high flow event. A portion of the cofferdam and all of the containment berm would be eroded and carried downstream. Concrete rubble and any portions of the dam remaining at the dam site above the invert of Matilija Creek would be removed, broken up, loaded, and hauled to the recycling plant during the in-channel construction window following the large event. Restoration of the reservoir area including leveling and reshaping the remaining cofferdam to have a more natural appearance and planting of the remaining sediment would also occur during the in-channel construction window following the large event.

Some of the key production rates assumed in the construction schedule include:

- Bypass tunnel mining – 10 lf/day
- Cofferdam construction – 2,400 cy/shift, single shift
- Dam removal to El. 1075 feet by conventional methods – 108 cy/day, double shift
- Dam removal to stream invert – Drilling blast holes – 400 lf/shift, double shift
- Demolished concrete processing and removal – 180 cy/shift, double shift

A total of three construction seasons would be required; two prior to the large event and one following the large event. The estimated schedule for construction is shown on Figure B-1. Construction duration for DRC-1, from start of construction to completion of removal of the dam would be in the range of three to six years depending on the timing of the high flow event that removes the sediment.

DRC-2 – Uncontrolled Orifices/Optional Gates

Initial construction activities for this dam removal concept would include filling of the plunge pool area up to Elevation 975 feet to form a construction platform from which the orifices would be excavated through the base of the dam. The orifices are assumed to be constructed by excavating though the concrete in four-foot long increments using a combination of drilling and hydraulic breaking. A series of four-foot deep holes would be drilled around the perimeter of orifice and within the concrete mass inside the perimeter. The concrete would then be broken out from inside the perimeter. Using this method, each orifice would be excavated to within about 8 feet of the upstream face of the dam. A series of blast holes would then be drilled to perhaps two to four feet of the upstream face of the dam in preparation for loading and blasting just prior to the large storm event that would be used to erode fine sediment from the reservoir. Demolition of the dam down to the Elevation 1105 feet using excavators with hoerams working from the dam crest to break the concrete would follow excavation of the orifices. Concrete rubble from resulting from the excavation of the orifices and conventional dam demolition activities would be loaded and hauled to a concrete recycling plant located approximately 30 miles away.

The project would then wait for the large flow event to occur. A decision-making process would need to be in place to determine when a predicted large storm would have enough certainty to give the go-ahead to load the pre-drilled blast holes and blast out the remaining plugs in the tunnels, initiating release of the fine sediment. Blasting of the plugs could be timed to occur during the beginning of the storm event. The dam would be removed during the dry season following the high flow event (assuming a decision was not made to install gates on the orifices) by drilling and blasting, breaking up the concrete rubble using excavators with hoerams, loading into highway legal dump trucks, and hauling to the concrete recycling plant. Restoration of the reservoir area including leveling of the remaining cofferdam and planting of the remaining sediment would also occur during the in-channel construction window following the large event

Some of the key production rates assumed in the construction schedule include:

- Mining of orifices – 4 lf/day
- Dam removal to El. 1105 feet by conventional methods – 108 cy/day, single shift
- Dam removal to stream invert – Drilling blast holes – 400 lf/shift, double shift
- Demolished concrete processing and removal – 180 cy/shift, double shift

A total of two construction seasons would be required; one prior to the large event and one following the large event. The estimated schedule for construction for DRC-2 is shown on Figure B-2. Construction duration for DRC-2, from start of construction to completion of removal of the dam would be in the range of two to five years depending on the timing of the high flow event that removes the sediment.

If a gate were to be added after the first flushing event (referred to as DRC-2B), there would likely be a second waiting period and subsequent flush, as shown on Figure B-3.

DRC-3 – Temporary Upstream Storage of Fine Sediment

Early activities for this dam removal concept would include mobilizing and setting up a water treatment system that would be used to handle water from draining the reservoir and water from dewatering wells and sump pumps located in the sediment excavation. A small cofferdam and temporary diversion system would be installed upstream of the reservoir area to divert summer flows from Matilija Creek around the excavation area. Dewatering wells that would extend through the fine sediment into the underlying alluvium through the reservoir area and shallower vacuum wells or wellpoints in the fine sediment would be installed and operated to draw the phreatic surface in the reservoir sediment down below the excavation grade. The fine sediment would not be anticipated to dewater significantly and would remain at a high moisture content.

Excavation and hauling of the fine sediment is assumed to be performed using excavators and articulated off-highway trucks during up to two in-channel construction seasons.[1] Where the excavated grade is found to be too weak to support the equipment, access roads and working platforms would be constructed using coarse alluvium from upstream. These same methods were successfully used to excavate wet fine sediment from the reservoir area behind San Clemente Dam for that dam removal project. Delta and upstream coarse sediment would also be excavated using excavators and, similar to the San Clemente Dam removal project, mixed with the wetter fine sediment to facilitate moisture conditioning and placement in the temporary stockpile areas.

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[1] Some additional sediment would be deposited during the rainy season between construction seasons. If a high flow event were to occur, a significant amount of sediment could fill the area excavated during the previous construction season.

The dam would be penetrated at elevations consistent with the amount of sediment that would be removed during each construction season to allow the reservoir to drain to near the excavated sediment level – thus minimizing the amount of dewatering that would be needed to restart excavation.

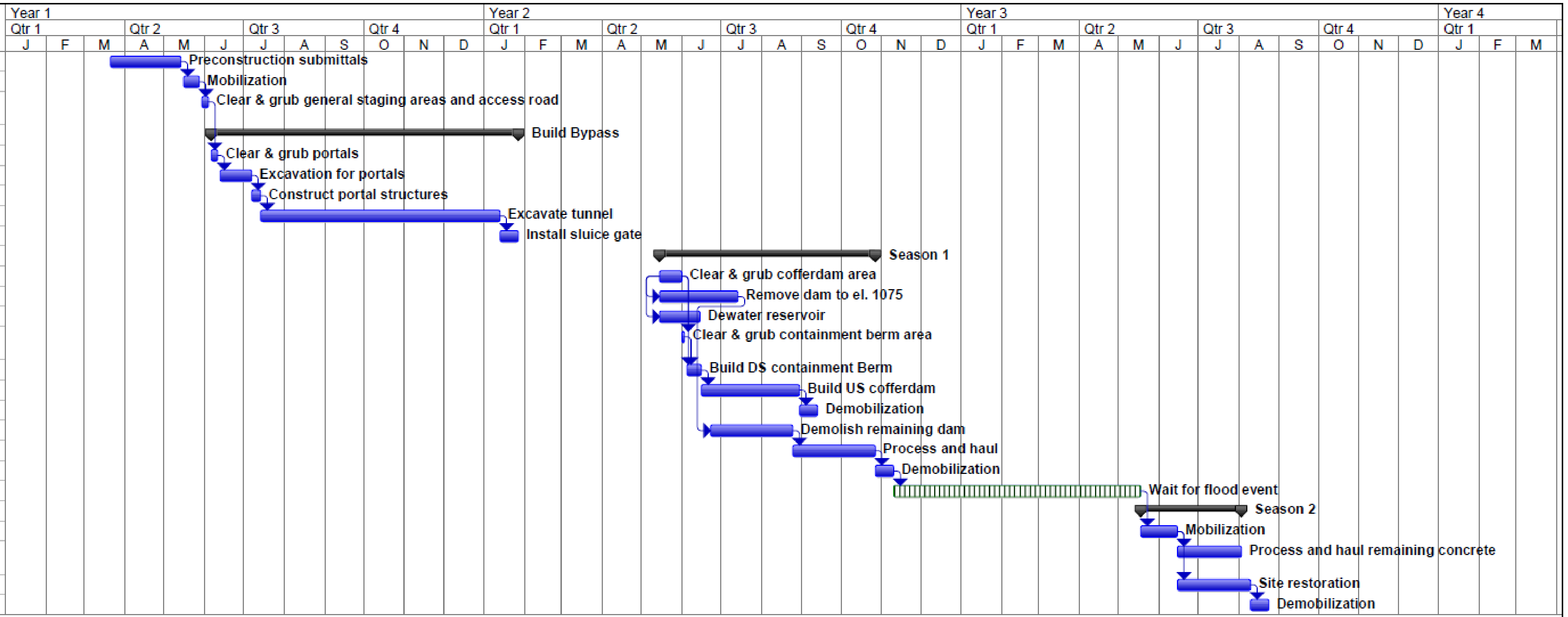
The dam would be removed down to the Matilija Creek invert during the last season of excavation by drilling and blasting, breaking up the concrete rubble using excavators with hoerams, loading into highway legal dump trucks, and hauling to the concrete recycling plant.

Some of the key production rates assumed in the construction schedule include:

- Fine sediment excavation – 5,700 cy/shift, double shift
- Delta and upstream coarse sediment – 3,000 cy/shift, double shift
- Dam removal to El. 1075 feet by conventional methods – 108 cy/day, single shift
- Dam removal to stream invert – Drilling blast holes – 400 lf/shift, double shift
- Demolished concrete processing and removal – 180 cy/shift, double shift

A total of two construction seasons would be required for DRC-3. The estimated schedule for construction is shown on Figure B-4. Construction duration for DRC-3, from start of construction to completion of removal of the dam would be two years.

ID	ℹ	Task Name	Duration
1	▦	Preconstruction submittals	40 days
2		Mobilization	10 days
3		Clear & grub general staging areas and access road	5 days
4		**Build Bypass**	**169 days**
5		Clear & grub portals	5 days
6		Excavation for portals	18 days
7		Construct portal structures	5 days
8		Excavate tunnel	131 days
9		Install sluice gate	10 days
10		**Season 1**	**119 days**
11	▦	Clear & grub cofferdam area	13 days
12	▦	Remove dam to el. 1075	44 days
13		Dewater reservoir	23 days
14		Clear & grub containment berm area	2 days
15		Build DS containment Berm	9 days
16		Build US cofferdam	53 days
17		Demobilization	10 days
18		Demolish remaining dam	45 days
19		Process and haul	45 days
20		Demobilization	10 days
21		Wait for flood event	135 days
22		**Season 2**	**55 days**
23		Mobilization	20 days
24		Process and haul remaining concrete	35 days
25		Site restoration	40 days
26		Demobilization	10 days



Project: DRC-1 Berm w/ bypass
Date: 6/19/15

Task	▬	Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	]
Unknown duration	▥	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Progress	▬
Split	┈	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Deadline	⇩
Milestone	◆	External Milestone	◆	Manual Task	▬	Start-only	[		

Project No.
26818945

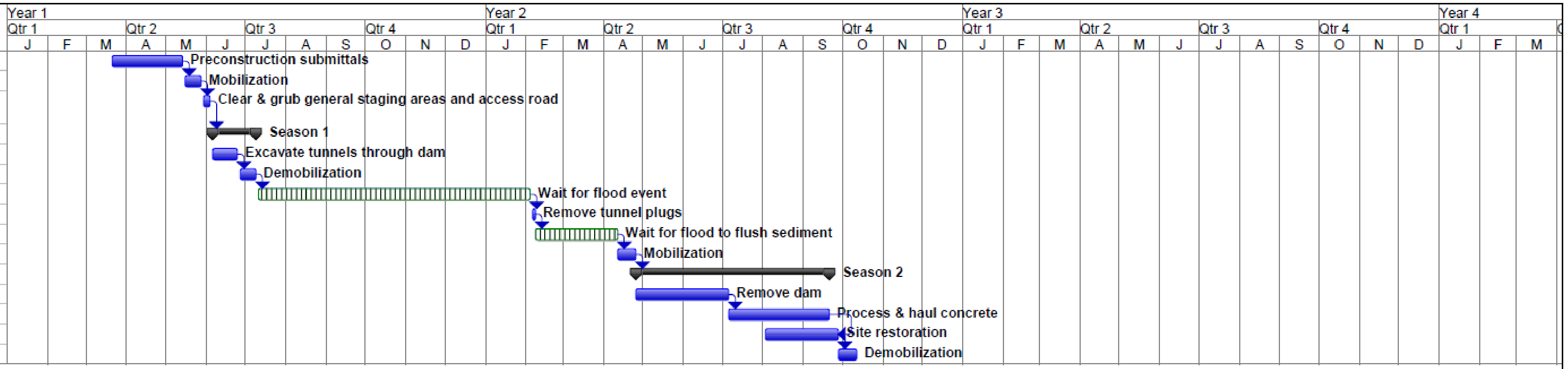
Matilija Dam Removal

URS

Estimated Construction Schedule
DRC-1: Containment Berm with High Flow Bypass

Figure
B-1

ID		Task Name	Duration
1	▦	Preconstruction submittals	40 days
2		Mobilization	10 days
3		Clear & grub general staging areas and access road	5 days
4		**Season 1**	**25 days**
5		Excavate tunnels through dam	15 days
6		Demobilization	10 days
7	▦	Wait for flood event	150 days
8		Remove tunnel plugs	2 days
9		Wait for flood to flush sediment	45 days
10		Mobilization	10 days
11		**Season 2**	**106 days**
12		Remove dam	51 days
13		Process & haul concrete	55 days
14		Site restoration	40 days
15		Demobilization	10 days

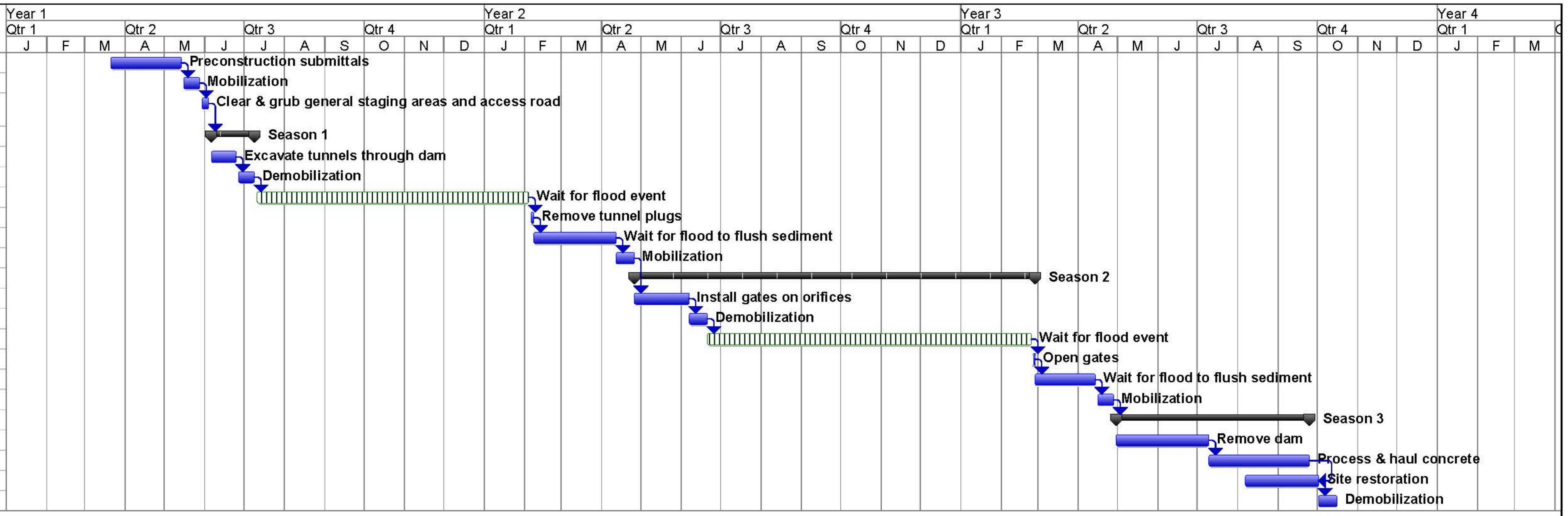


Project: DRC-2 Uncontrolled orifices
Date: 6/19/15

Task	▬	Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	]
Unknown duration	▥	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Progress	▬
Split	┈	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Deadline	⇩
Milestone	◆	External Milestone	◆	Manual Task	▬	Start-only	[		

Project No. 26818945	Matilija Dam Removal	Estimated Construction Schedule DRC-2: Uncontrolled Orifices
	URS	Figure B-2

ID	ℹ	Task Name	Duration
1	▦	Preconstruction submittals	40 days
2		Mobilization	10 days
3		Clear & grub general staging areas and access road	5 days
4		**Season 1**	**25 days**
5		Excavate tunnels through dam	15 days
6		Demobilization	10 days
7	▦	Wait for flood event	150 days
8		Remove tunnel plugs	2 days
9		Wait for flood to flush sediment	45 days
10		Mobilization	10 days
11		**Season 2**	**219 days**
12		Install gates on orifices	30 days
13		Demobilization	10 days
14		Wait for flood event	178 days
15		Open gates	1 day
16		Wait for flood to flush sediment	34 days
17		Mobilization	10 days
18		**Season 3**	**106 days**
19		Remove dam	51 days
20		Process & haul concrete	55 days
21		Site restoration	40 days
22		Demobilization	10 days



Project: DRC-2B Uncontrolled orifices
Date: 9/16/15

Task	▬	Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	⊐
Unknown duration	▥	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Progress	▬
Split	┈	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Deadline	⇩
Milestone	◆	External Milestone	◆	Manual Task	▬	Start-only	⊏		

Project No.
26818945

Matilija Dam Removal

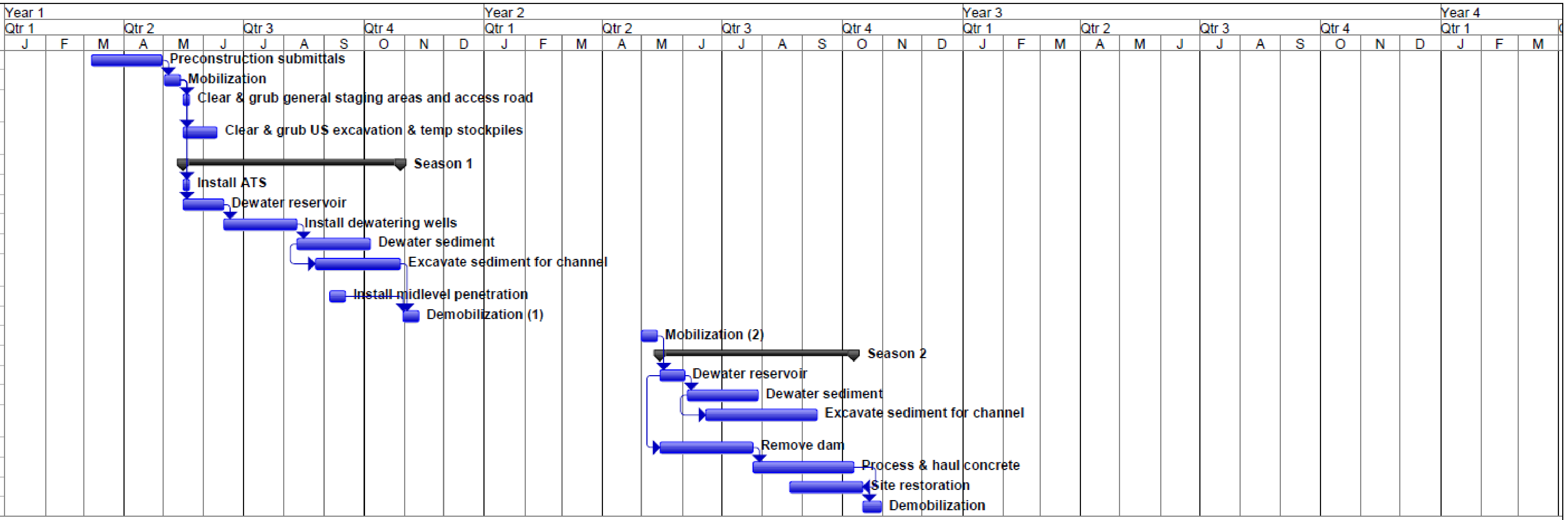
URS

Estimated Construction
Schedule DRC-2 Uncontrolled
Orifices w/ Gates

Figure

B-3

ID	ⓘ	Task Name	Duration
1	▦	Preconstruction submittals	40 days
2		Mobilization	10 days
3		Clear & grub general staging areas and access road	5 days
4		Clear & grub US excavation & temp stockpiles	20 days
5		**Season 1**	**120 days**
6		Install ATS	5 days
7		Dewater reservoir	23 days
8		Install dewatering wells	40 days
9		Dewater sediment	40 days
10		Excavate sediment for channel	47 days
11	▦	Install midlevel penetration	10 days
12		Demobilization (1)	10 days
13	▦	Mobilization (2)	10 days
14		**Season 2**	**106 days**
15		Dewater reservoir	15 days
16		Dewater sediment	40 days
17		Excavate sediment for channel	61 days
18		Remove dam	51 days
19		Process & haul concrete	55 days
20		Site restoration	40 days
21		Demobilization	10 days



Project: DRC-3 Temp US storage
Date: 6/26/15

Task	▬	Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	]
Unknown duration	▥	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Progress	▬
Split	┅	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Deadline	⇩
Milestone	◆	External Milestone	◆	Manual Task	▬	Start-only	[		

Project No.
26818945

Matilija Dam Removal

URS

Estimated Construction Schedule
DRC-3: Temporary Upstream Storage of Fine Sediment

Figure
B-4

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

DAM REMOVAL CONCEPTS EVALUATION REPORT

MARCH 2016

APPENDIX C: COARSE SEDIMENT TRANSPORT PRELIMINARY ANALYSIS

Stillwater Sciences

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TECHNICAL MEMORANDUM

DATE: March 2015

TO: Management Team, Matilija Dam Ecosystem Restoration Project

FROM: Derek Booth PhD PE PG, and Yantao Cui PhD, Stillwater Sciences

SUBJECT: Matilija Dam Removal, Sediment Transport, & Robles Diversion Mitigation Study Coarse Sediment Transport Preliminary Analysis, Task 2.4

Table of Contents

1 Introduction

The objective of this technical memorandum is to document the coarse sediment model setup and some preliminary results associated with the initial options being considered to removal Matilija Dam (URS/SWS 2014). These options are as follows:

- Initial Option (IO)-01 Containment Berm with High Flow Bypass: This option would involve removing the dam and building a temporary containment berm to hold the reservoir sediment in place until a high flow event occurs which would erode a large portion of reservoir fine sediments
- IO-02 Uncontrolled Orifices: This option would involve boring tunnels at the base of the dam and then blasting open the tunnels when a high flow event occurs, which would erode a large portion of reservoir fine sediments. The dam would be removed after this large sediment mobilization event
- IO-03 Gated Orifices: This option would bore tunnels and install gates on the upstream end of the tunnel orifices. The gates would then be opened when a high flow event occurs, which would erode a large portion of reservoir fine sediments. The gates could be subsequently closed and reopened during the following high flow event. The dam would be removed when a sufficient amount of the accumulated fine sediment has been eroded from the reservoir
- IO-04 Gated Notch(es): This option would involve installing a series of notches with gates over several phases, so that only incremental portions of the reservoir fines would be available for transport during each phase. Phases would continue until the dam is fully removed
- IO-05 Temporary Upstream Storage of Fine Sediment: This option would involve mechanical removal and temporary upstream storage of both fine and coarse sediment in a portion of the reservoir to create a channel along the pre-dam creek alignment at the pre-dam creek elevations. The dam would be removed when earthwork is complete
- IO-06 Downstream Slurry and Temporary Upstream Storage of Fine Sediment: This option would involve slurry dredging portions of reservoir fines to both downstream (for more organic material) and upstream temporary storage locations. A portion of the fine sediment would also be mechanically excavated and hauled to the upstream temporary storage areas. The dam would be removed when the slurry and mechanical excavation operations are complete

Two potential impacts from the release of coarse sediment have been recognized. First, channel aggradation downstream of the dam may result in increased risks for flooding. Second, increased sediment deposition in Robles diversion forebay may require more frequent sediment removal efforts. To counter these potential impacts, the project’s final EIS/EIR (ACOE 2004) identified a suite of mitigation measures to be implemented as part of the dam removal project, including: realigning levees and floodwalls to allow vegetative screening of flood-control improvements, screening levees and floodwalls with vegetation planting, and constructing a high-flow and sediment bypass structure at Robles Diversion Dam to help coarse sediment to move through the Robles forebay more quickly and to create a deep channel along the diversion intake. Finally, aggradation of the channel bed downstream of Matilija Dam is likely to affect instream fish habitat, both negatively and positively, for one to many years depending on location.

To better understand the potential impacts from coarse sediment release following dam removal, hypotheses of potential erosion and transport of coarse reservoir deposit have been developed based on research developed over the past two decades, and a DREAM-2 sediment transport model was developed to test those hypotheses and to better quantify the impacts. Potential impacts from coarse sediment deposit are discussed below in the next section. Development of DREAM-2 sediment transport model is discussed in Attachment A, and details of DREAM-2 model can be found in Cui et al. (2006a, 2006b).

2 Potential Impacts from the Release of Coarse Sediment

2.1 Related Research and Hypotheses

Theoretical, numerical, and field research over the past two decades on the evolution of sediment pulses in rivers (e.g., Lisle et al. 1997, 2001; Sutherland 2002; Cui et al. 2003a, 2003b, 2005; Cui and Parker 2005; Greimann et al. 2006; Sklar et al. 2009) and recent numerical predictions and observations of sediment transport following dam removal (e.g., Stillwater Sciences 2000; Cui and Wilcox 2008; Downs et al. 2009; Major et al. 2012; Cui et al. 2014) have provided the basis for predicting with reasonable confidence how the coarse sediment deposited in the Matilija Dam impoundment will move downstream following dam removal. According to the research results on sediment pulse evolution from these scientific studies, a generalized coarse sediment pulse in a gravel-bedded river evolves primarily by dispersion, meaning that the sediment pulse will gradually expand in place in both upstream and downstream directions[1] while decreasing its thickness at its apex, because of the high Froude number during flood events when the majority of the sediment is transported. In the case of a reservoir deposit as the specific source, the dispersion is entirely toward the downstream direction (Downs et al. 2009). Because the evolution of a coarse reservoir deposit is dominated by downstream dispersion, the reach of significant potential impact (i.e., the river reach where significant channel aggradation is expected) is usually limited to a relatively short distance downstream of the dam, in the case where the downstream channel begins in a quasi-equilibrium state (**Figure 1**): the farther away from the sediment pulse, the smaller magnitude of the potential sediment deposition as the sediments spread to a progressively larger area. This outcome has been confirmed by numerical simulations (Stillwater Sciences 2000; Cui et al. 2003b; Cui and Parker 2005; Cui and Wilcox 2008; Cui et al. 2008) and field observations (Sutherland et al. 2002; Major et al. 2012; Cui et al. 2014), including those after Marmot Dam removal on the Sandy River, Oregon, where the release of approximately 750,000 m^3 (approximately 1 million cubic yards) of sediment resulted in channel aggradation within 1.2 km (0.75 miles) downstream of the dam (**Figure 2**) but minimal (and largely undetectable) channel aggradation farther downstream. Note that the Sandy River is a steep gravel bedded river with high Froude numbers during sediment transport event, a condition shared by the Matilija Creek and Ventura River that favors a dispersive evolution for coarse sediment pulses (Lisle et al. 1997).

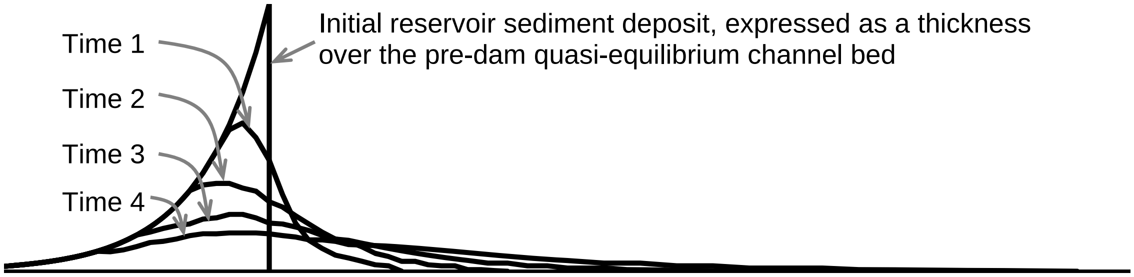

Figure 1. Illustration of the evolution of a coarse reservoir sediment deposit following dam removal, showing the deposit gradually disperse downstream and becomes progressively thinner. Sketch adopted from Downs et al. (2009).

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[1] The (counterintuitive) upstream dispersion of a sediment pulse occurs because of the deposition of sediment supplied from upstream, while sediment particles are always transported downstream. See one of the cited references for details.

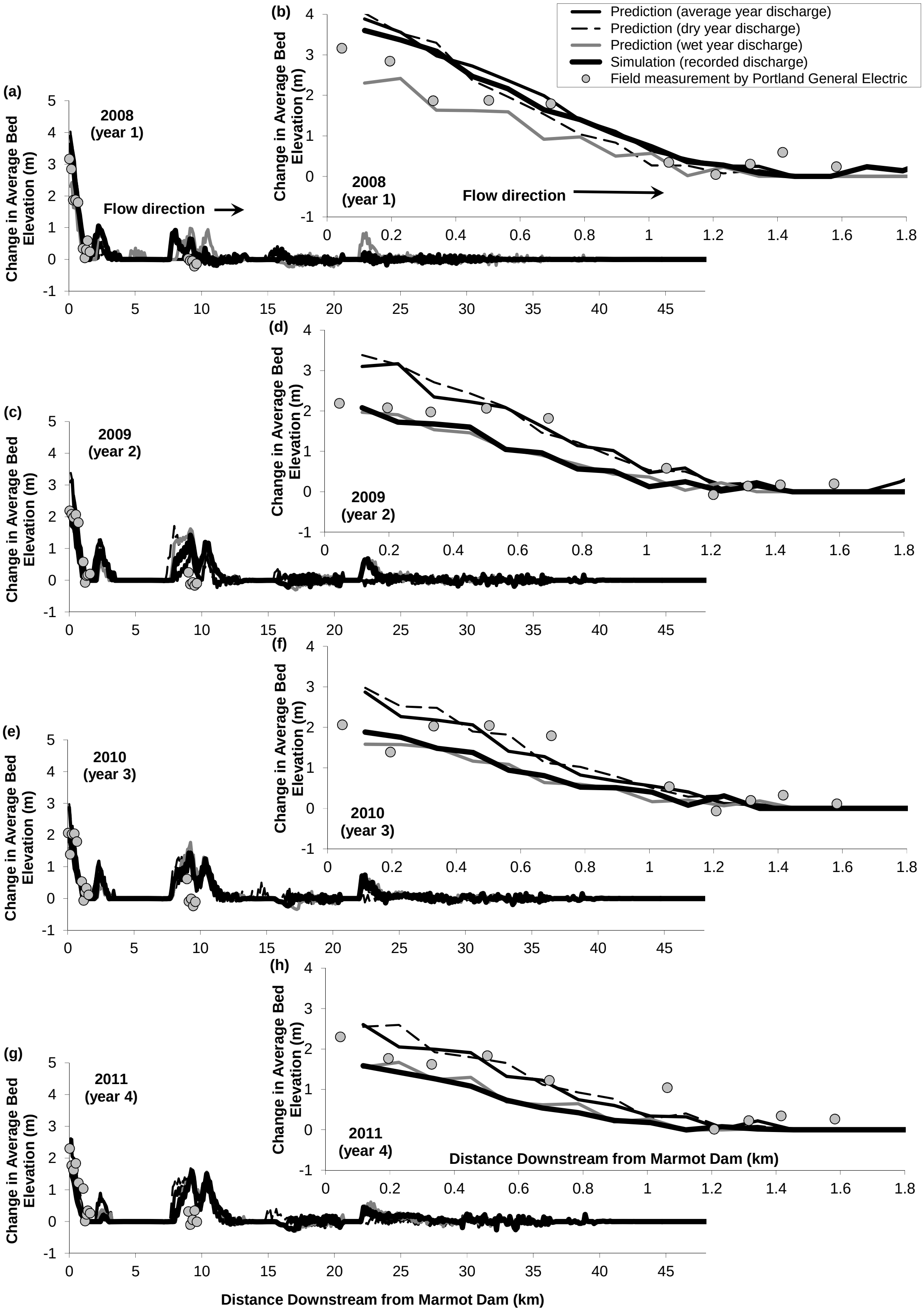

Figure 2. Simulated and observed channel aggradation in the Sandy River following Marmot Dam removal. Diagrams adapted from Cui et al. (2014).

2.2 Matilija Creek and Ventura River Considerations

Based on the knowledge obtained during research on sediment pulse evolution, and observations of sediment transport dynamics following Marmot Dam removal, coarse sediment deposition would occur within a short distance, likely only within a couple of kilometers, downstream of Matilija Dam following removal if the river is currently at a quasi-equilibrium state. The Matilija Creek and Ventura River, however, are not in quasi-equilibrium state that deserve further considerations. In particular, two pieces of the geomorphic history of the Matilija Creek and Ventura River have caused local non-equilibrium conditions that will affect coarse sediment transport and deposition following Matilija Dam removal, as discussed below.

First, the presence of Robles Diversion Dam, which is located at approximately 3.7 km (2.3 miles) downstream of Matilija Dam on the Ventura River, and the active sediment management at Robles forebay will have significant implications for coarse sediment dynamics following Matilija Dam removal. Constructed in the late 1950s, Robles Diversion Dam has an effective hydraulic height of 4 m (13 ft) (URS and Stillwater Sciences 2014), allowing up to 500 cfs of water to be diverted to Casitas Lake via a diversion canal. Casitas Municipal Water District (CMWD) regularly removes the sediment deposited in the Robles forebay. According to BOR (2006), an estimated 427,000 m^3 (559,000 cubic yards) (bulk volume) was removed during the 33-year period between 1966 and 1998, or approximately 256,000 m^3 solids (assuming a porosity of 0.4 for the removed sediment), which translates to approximately a 7,800 m^3/yr (solid) sediment removal rate, of which the majority was disposed of off-site, while some was disposed in the overflow channel downstream of the cutoff dam (Neil Cole, per. com., 6 June 2014). Only a small fraction of the sediment disposed of downstream of the cutoff dam likely has been released to the channel and transported downstream. In the absence of additional improvement to Robles Diversion Dam (such as the High Flow and Sediment Bypass Structure proposed in EIS/EIR), significantly more sediment deposition is expected to occur within the Robles forebay area following Matilija Dam removal, and significant additional sediment removal effort will be needed to keep the Robles diversion functioning due to the short-term release of the coarse sediment deposit from Matilija Dam impoundment, plus the long-term contribution of additional coarse sediment from the Matilija Creek watershed that has been blocked by the reservoir since dam construction (Stillwater Sciences 2014b) but would again be free to pass downstream once the dam is removed.

Second, significant channel degradation had occurred at two specific reaches of the Ventura River following the closure of Matilija Dam (BOR 2006): up to 2 m (6 ft) of channel degradation in the 2-km (1.2-mile) reach immediately downstream of Robles Diversion Dam (approximately 3.7 – 5.7 km downstream of Matilija Dam), and up to 3.3 m (10 ft) of channel degradation in a 7-km (4.4-mile) reach downstream of Coyote Creek confluence (approximately 16 - 23 km downstream of Matilija Dam). In addition to these two reaches with significant channel degradation, up to 1.5 m (4.5 ft) degradation had occurred within 1 km immediately downstream of the dam, and minor channel degradations have also been observed elsewhere along the Ventura River (BOR 2006).

Channel degradation immediately downstream of Matilija Dam was the result of coarse sediment trapping in the reservoir, which is expected to have minimal implications to the sediment deposition patterns following dam removal: channel aggradation is expected to occur in this reach irrespective of whether the channel had been degraded during the years of reservoir operation.

Channel degradation immediately downstream of Robles Diversion Dam is likely the result of the combined effect of Matilija Dam closure, which blocked virtually all coarse sediment supply from

Matilija Creek, and the ongoing sediment removal at Robles forebay that has removed some fraction of the coarse sediment supplied from the unimpeded contribution of North Fork Matilija Creek (Attachment A). It can be expected that some or all of the degraded channel bed in this short reach will recover following Matilija Dam removal if sediment is allowed to pass through Robles Diversion Dam (i.e., without additional sediment removal effort in the forebay).

Channel degradation downstream of Coyote Creek confluence is likely due primarily to the construction of Casitas Dam on Coyote Creek in 1958, which cut off all the coarse sediment supply to the Ventura River from that tributary while still delivering high flows when Casitas Lake is full[2]. Other potential factors contributing to the degradation downstream of Coyote Creek include: (a) the constriction of the channel caused by urbanization and Highway 33; (b) natural cycles of erosion and fill that occur in relatively short cycles in response to landslides and fire; and (3) increased runoff in the lower basin due to urbanization and oil drilling in the watershed (Blair Greimann, per. comm. March 2015). The closure of Matilija Dam and sediment removal in Robles forebay surely provided an additional influence. The sediment reduction from the upstream Ventura River is considered to be a relatively minor influence, however, compared to the impact from the construction of Casitas Dam because only minor channel degradation (generally within 1 m [3 ft]) has been observed just *upstream* of the Coyote Creek confluence. As a result, only minor recovery of the degraded channel bed is potentially possible in the reach downstream of Coyote Creek following Matilija Dam removal, even if sediment is allowed to pass freely through Robles Diversion Dam.

Other than the reach upstream of Robles Diversion Dam, the 2-km reach immediately downstream of the Robles Diversion Dam, and the potential minor effect to the 7-km reach downstream of Coyote Creek confluence, the deposition of coarse sediment from Matilija Dam impoundment following Matilija Dam removal is expected to be minimal, irrespective of how and when the dam is removed.

2.3 Preliminary Modeling of Coarse Sediment Transport

Three DREAM-2 model runs were conducted to validate the above hypotheses and to quantify the general magnitude and duration of channel aggradation following Matilija Dam removal. Details of DREAM-2 model can be found in Cui et al. (2006a, 2006b); description of development of DREAM-2 model in the Ventura River for Matilija Dam removal project is provided in Attachment A. These model runs are *not* intended to provide a full analysis of coarse-sediment dynamics for all selected alternatives; rather, they demonstrate some broad outcomes relevant to coarse-sediment management behind Matilija Dam.

DREAM-2 model runs were conducted for three scenarios, all of which used the daily discharge record between 10/1/1933 and 9/30/1983 as model input (**Figure 3**), with two different starting dates for the simulations to explore outcomes under alternative hydrological conditions when the dam might be removed. Each simulation runs for 50 years, starting on the day when dam is presumed to be removed (or when cofferdam breaches, e.g., 2/15/1941 for Runs 1 and 3, and 1/16/1952 for Run 2, chosen arbitrarily for demonstration purposes), up until 9/30/1983, with the discharge from 10/1/1933 to the day just before dam removal appended to the record to achieve a full 50-year simulation. The dates for dam removal in these simulations are selected arbitrarily, with the only criteria that there is a discharge of at least 1,000 cfs on the day of dam removal (or cofferdam breaching). Note that none of

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[2] Casitas is currently managed to minimize spilling, and hasn't spilled since 1998. The trapping of sediment, however, continues.

the three runs were conducted to simulate a specific dam removal alternative, and as such, the discharge on the day of dam removal for Run 2 does not meet the minimal discharge requirement of 1,700 cfs specified for several of the initial options. Instead, they are used collectively to validate the hypotheses discussed above and to provide a broad understanding of potential impact from coarse sediment release following Matilija Dam removal. Two of the runs, Runs 1 and 2, simulate the case of a one-time dam removal (IO-01, 02, 03, and 06 fall into this category), with the dam being removed during a relatively wet year for Run 1 and during a dry period for Run 2 (**Figure 3**, **Figure 4**, and **Figure 5**). Run 3 simulates progressive dam removal (IO-04 falls into this category) during a moderately wet period, with the dam being removed in four stages over a 5-year span (**Figure 3**). The modeling assumes existing conditions for hydraulic structures at Robles Diversion Dam (i.e., the High Flow and Sediment Bypass Structure is not constructed) and without sediment removal at Robles forebay.

These three model runs assumed that dam removal would result in the formation of a trapezoidal channel of 20-m (66 ft) base width and 35^o bank slope in the reservoir area. The 20-m base width and 35^o bank slope result in approximately a 25-m bankfull width (assuming a bankfull depth of approximately 2 m [6.5 ft]), which approximates the average active channel width in the Matilija Creek between Matilija Dam and North Fork Matilija Creek confluence (24 m) and is wider than the active channel width in Matilija Creek upstream of the reservoir influenced area (which is generally less than 17 m). The assumed channel geometry would result in a potential release of 1.0 million m^3 (1.3 million cubic yards) coarse and fine sediment, of which approximately 270,000 m^3 (350,000 cubic yards) would be coarse sediment.

Run 1 indicates that the reservoir deposit within the defined trapezoidal channel will be eroded quickly following dam removal, approaching the pre-dam bed profile within about two years (**Figure 6** and **Figure 7**). As expected with the hypotheses presented above, downstream sediment deposition occurs immediately downstream of the dam, in the reach upstream of Robles Diversion Dam, and in a short reach downstream of Robles Diversion Dam (**Figure 8** and **Figure 9**). Sediment deposition immediately downstream of Matilija Dam (at 0.54 km downstream of Matilija Dam, for example) is up to 4.8 m (16 ft) (**Figure 8**), which is eroded downstream relatively quickly, allowing the channel bed to recover to the pre-dam-removal condition in about a year (**Figure 10**). Sediment deposition between North Fork Matilija Creek confluence and Robles Diversion Dam (at 3 km downstream of Matilija Dam, for example) peaks shortly after dam removal and is up to 7.3 m (24 ft). Substantial sediment deposition persists in this reach for over two decades before beginning to decrease over time (**Figure 10**, at 2.14 km; and **Figure 11**), primarily due to the almost two decades of drought shortly after dam removal (**Figure 3**) using the February 1941 starting date for this model run. Results shown in **Figure 10** and **Figure 11** affirm the value of improved sediment bypass at Robles Diversion Dam, such as the EIS/EIR-recommended High Flow and Sediment Bypass Structure. If designed properly, a sediment bypass structure not only will reduce the amount of sediment deposition in the forebay area but also (and more importantly) will be able to sluice out a deep channel along the diversion intake, allowing the water diversion operation to function properly even if there is substantial amount of sediment deposition in the other areas of the forebay (note, however, that evaluation of the sediment bypass is not within the scope of work, and DREAM-2 model simulation does not provide enough details for such an evaluation due to its one-dimensional nature). Also as hypothesized, the 2-km reach immediately downstream of Robles Diversion Dam aggrades by an average of 2 m (6 ft) and up to 4 m (13 ft) at approximately 5.5 km downstream of Matilija Dam (**Figure 8**), recovering all of the depth the channel bed degraded since 1947. Minimal channel aggradation is predicted farther downstream, agreeing with our hypotheses discussed earlier.

Modeling results for Runs 2 and 3 (**Figure 12**/**Figure 13** and **Figure 14**/**Figure 15**, respectively) indicate that, although hydrological conditions during and after dam removal and the rate of dam removal (as in a progressive notching such as Run 3) affect the timing of sediment deposition, the overall patterns and magnitude of sediment deposition are similar to that of Run 1.

Based on comparisons of modeling results for the three runs, it is believed that depth and location of coarse sediment deposition downstream of the dam following dam removal is relatively insensitive to when or how the dam is removed, presuming that no coarse sediment is removed prior to dam removal (such as in the case of IO – 05). This conclusion is understandable because downstream sediment deposition is a relatively long-term process in Matilija Creek and Ventura River due to the rather sparse high flow events, whereas the details of when and how the dam is removed impose relatively short-term differences that become unimportant over time.

Based on hypothesis developed from past research discussed above, observations of past projects, and DREAM-2 modeling results, the potential impacts from the release of coarse sediment is considered to be quite similar for all the initial options except IO – 05, which removes a portion of the coarse sediment from the reservoir deposit prior to dam removal. Removing part of the coarse sediment in IO – 05 will reduce the short-term impact from coarse sediment deposition, but over the long term, the impact will be similar to other initial options because of the re-establishment of the natural, substantial coarse sediment load from Matilija Creek.

It should be noted that a major objective of coarse sediment removal for IO – 05 is to accelerate the process of establishing fish passage through the former reservoir area. This objective, however, is expected to be achieved for all the dam removal options based on the observations following Marmot Dam removal (Cui et al. 2014): fish passage will most likely be achieved quickly after a single moderate storm event following dam removal, due to the quick erosion of the reservoir deposit as illustrated in **Figure 6** for Run 1. Observations following Elwha River dam removal and Condit Dam removal also support the assessment that physical barrier for fish passage in the form of extremely steep slope or vertical head-cut following Matilija Dam removal will not occur.

In addition to the three runs discussed above, which assumed a 20-m width at the base of a trapezoidal channel to be eroded in the reservoir deposit, sensitivity runs were conducted by increasing the width from 20 to 25 m to release more sediment from the reservoir deposit. Increasing the width to 25 m for the sensitivity runs made the potential volume of reservoir sediment erosion more conservative, increasing the potential release of sediment by approximately 20% to 1.2 million m^3 (1.5 million cubic yards), among which approximately 390,000 m^3 (510,000 cubic yards) is coarse sediment that represents a 44% increase from the 20-m width runs. Results of these sensitivity test runs indicate that downstream sediment deposition is relatively insensitive to the amount of erosion of the reservoir deposit within a reasonable range (such as ±20%), as demonstrated by a comparison between **Figure 8**/**Figure 9** for Run 1 (20-m base width) and **Figure 16**/**Figure 17** for Run 1a (25-m base width). Note the implication of these results with regard to IO 5 is that unless a large quantity of potentially erodible coarse sediment is mechanically removed prior to dam removal, the downstream sediment deposition for IO 5 is likely only slightly smaller than the other initial options that do not call for any coarse sediment removal.

Another sensitivity run (Run 1b) was also conducted to examine if the construction of a sediment bypass structure on Robles Diversion Dam, which accelerates the sediment transport moving through the diversion dam, will result in increased sediment deposition farther downstream. This is achieved by assuming that a bypass structure will completely neutralize the effect of the existence of Robles Diversion Dam (i.e., as if the diversion dam is no longer in place). Simulated change in average bed elevation downstream of Robles Diversion Dam for Run 1b (**Figure 18**/**Figure 19**) is found to be very similar to that for Run 1 (**Figure 8**/**Figure 9**).

Results from Run 1b also illustrate the benefit of a sediment bypass structure in reducing the amount of sediment deposition upstream of Robles Diversion Dam (**Figure 20**). It should be noted, however, that the assumption used for Run 1b is the extreme optimal end of the possible effect of a sediment bypass structure, and the actual impact of any sediment bypass structure in reducing the amount of sediment deposition in the forebay would probably be far less than what was assumed in the modeling. As stated earlier, however, the benefit of a sediment bypass structure in sluicing a deep channel alongside the diversion intake that cannot be demonstrated with DREAM-2 model due to its one-dimensional nature.

Assuming the amount of mechanical sediment removal for IO – 05 is relatively small, the downstream deposition of coarse sediment is likely to result in long-term changes to fish habitat characteristics (both positive and negative) that are largely equivalent for all six alternatives. Potential negative impacts to fish habitats include loss of pool habitat, loss of side-channel habitat, burying of redds, increased frequency and depth of scour, and reduced permeability. Major potential positive impacts to fish habitats are the creation of new spawning habitat due to the deposition of gravel and improved existing spawning habitat due to the increased depth of gravel deposition. Coarse sediment deposition is not expected to negatively impact the upstream fish migration because (a) the increased channel gradient due to coarse sediment deposition will be minimal; and (b) thalweg will most likely persist even in the reach with high rate of sediment deposition based on observations following Marmot Dam removal (Cui et al. 2014) and other dam removal projects (such as Elwha River dam removal and Condit Dam removal).

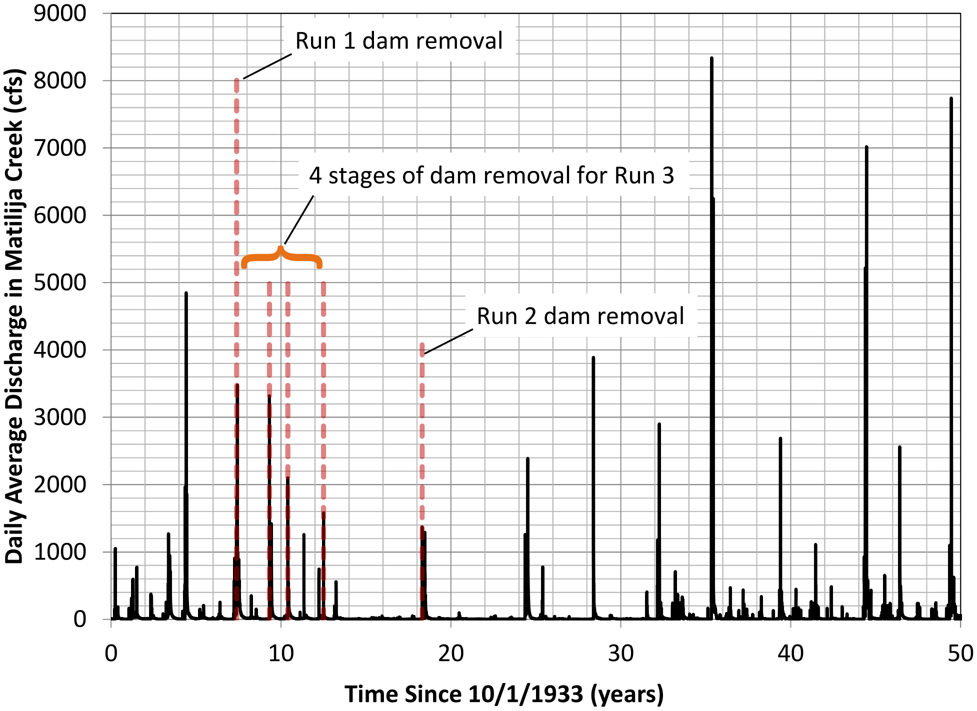

Figure 3. Daily average discharge in Matilija Creek for the period of 10/1/1933 through 9/30/1983 to be used as model input for DREAM-2 simulation. The red dashed lines indicate dates when the dam structure is removed and sediment is allowed to transport downstream. Source of discharge data are as follows: 10/1/1933 - 5/31/1948 at USGS #11115500; 6/1/1948 – 9/30/1969 at USGS # 11114500; and 10/1/1960 – 9/30/1983 at USGS #11115500.

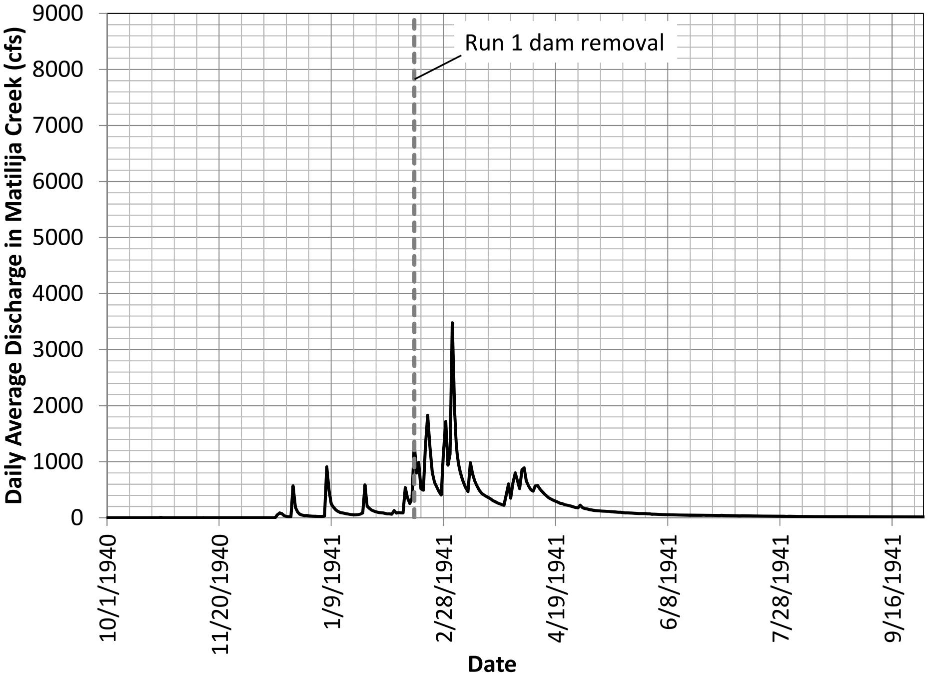

Figure 4. Detailed view of the daily average discharge in Matilija Creek during the water year of Matilija Dam removal for Run 1 and the first stage of dam removal for Run 3.

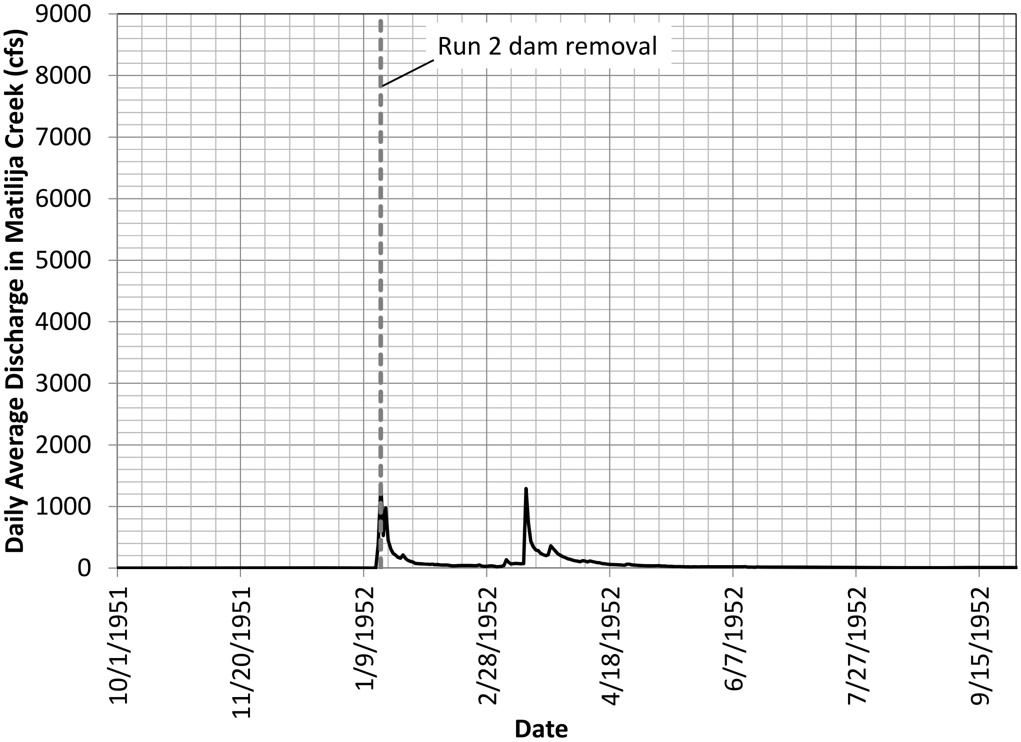

Figure 5. Detailed view of the daily average discharge in Matilija Creek during the water year of Matilija Dam removal for Run 2. Note that this simulation does not meet the criterion of a minimium 1,700 cfs discharge required for some of the initial alternatives.

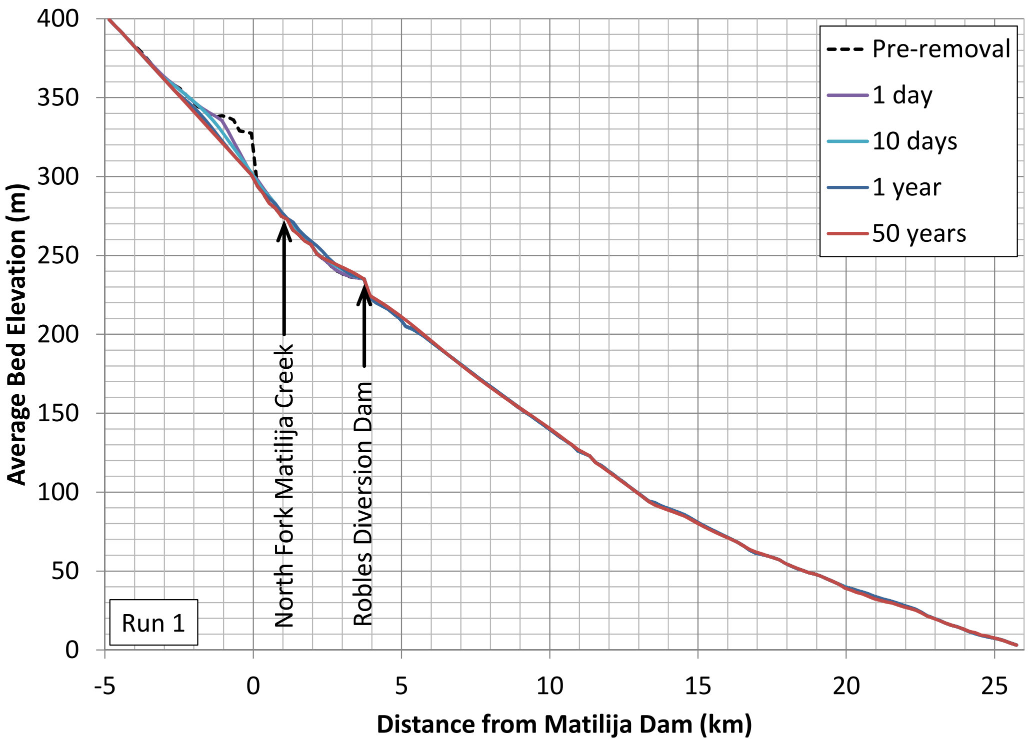

Figure 6. Simulated longitudinal profile for Run 1 with dam removal during a relatively wet period of time.

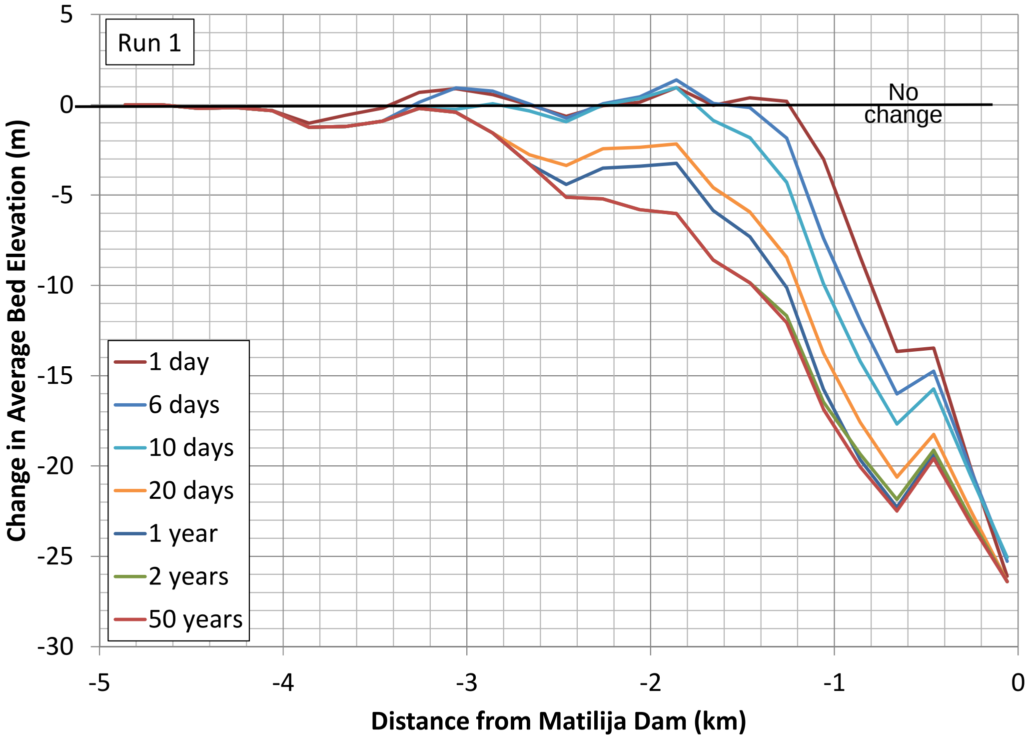

Figure 7. Simulated change in average bed elevation *upstream* of Matilija Dam (i.e. negative distance values on the x-axis, with Matilija Dam at distance = 0 km) following dam removal for Run 1, with dam removal occurring during a wet period.

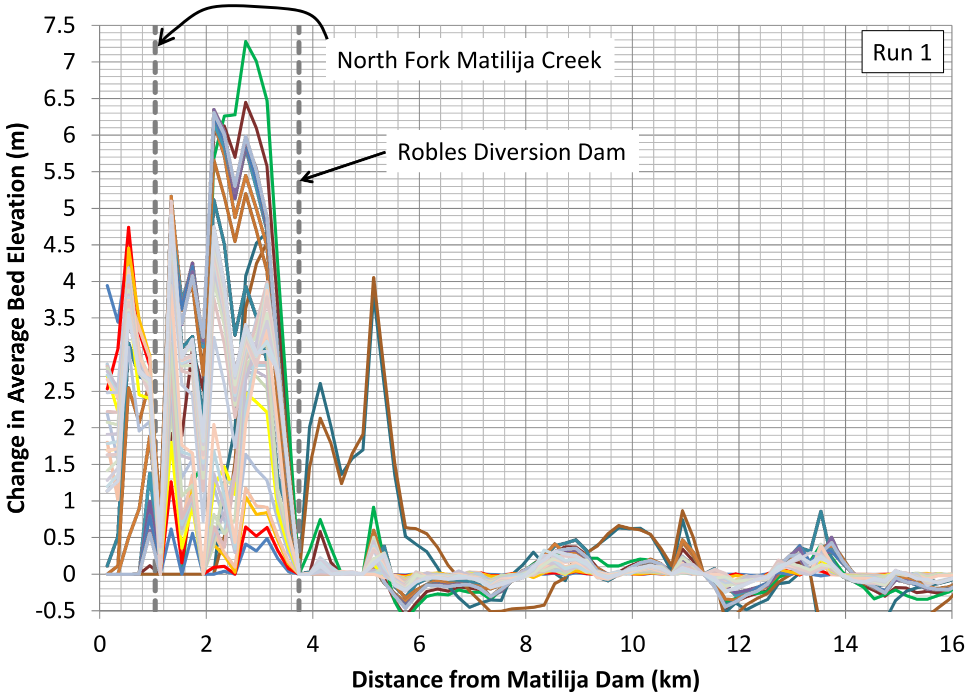

Figure 8. Simulated change in average bed elevation downstream of Matilija Dam following dam removal for Run 1, with dam removal occurring during a relatively wet year. Diagram presents selected monthly results over the 50-year simulation period and is intended to show only the general locations and magnitudes of maximum channel aggradation, rather than presenting the time-sequence of aggradation and degradation. See **Figure 10** for time variation of the channel bed at a few selected locations.

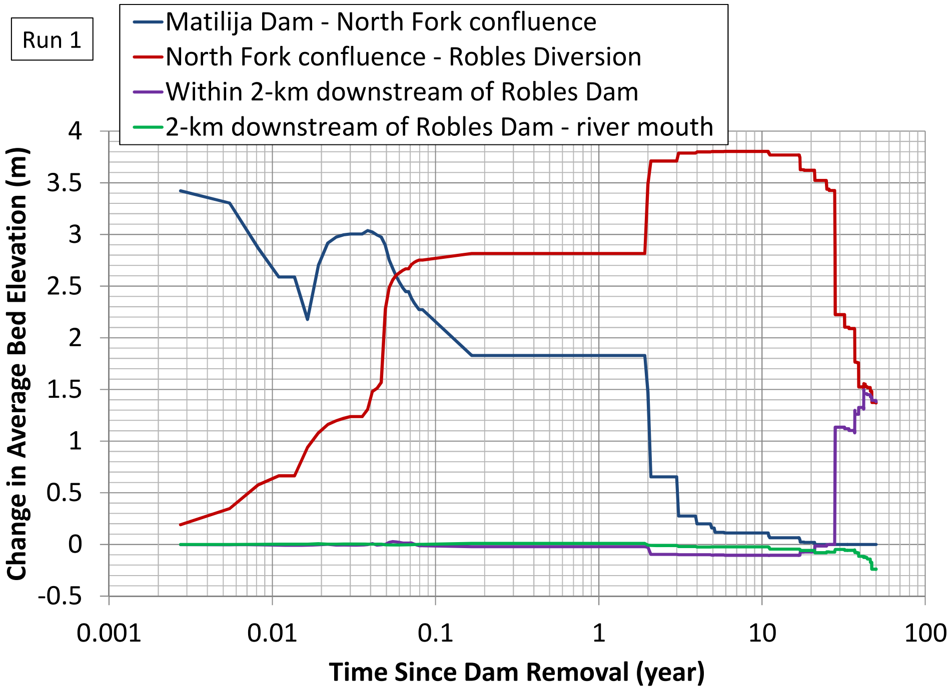

Figure 9. Simulated change in reach-average bed elevation downstream of Matilija Dam following dam removal for Run 1.

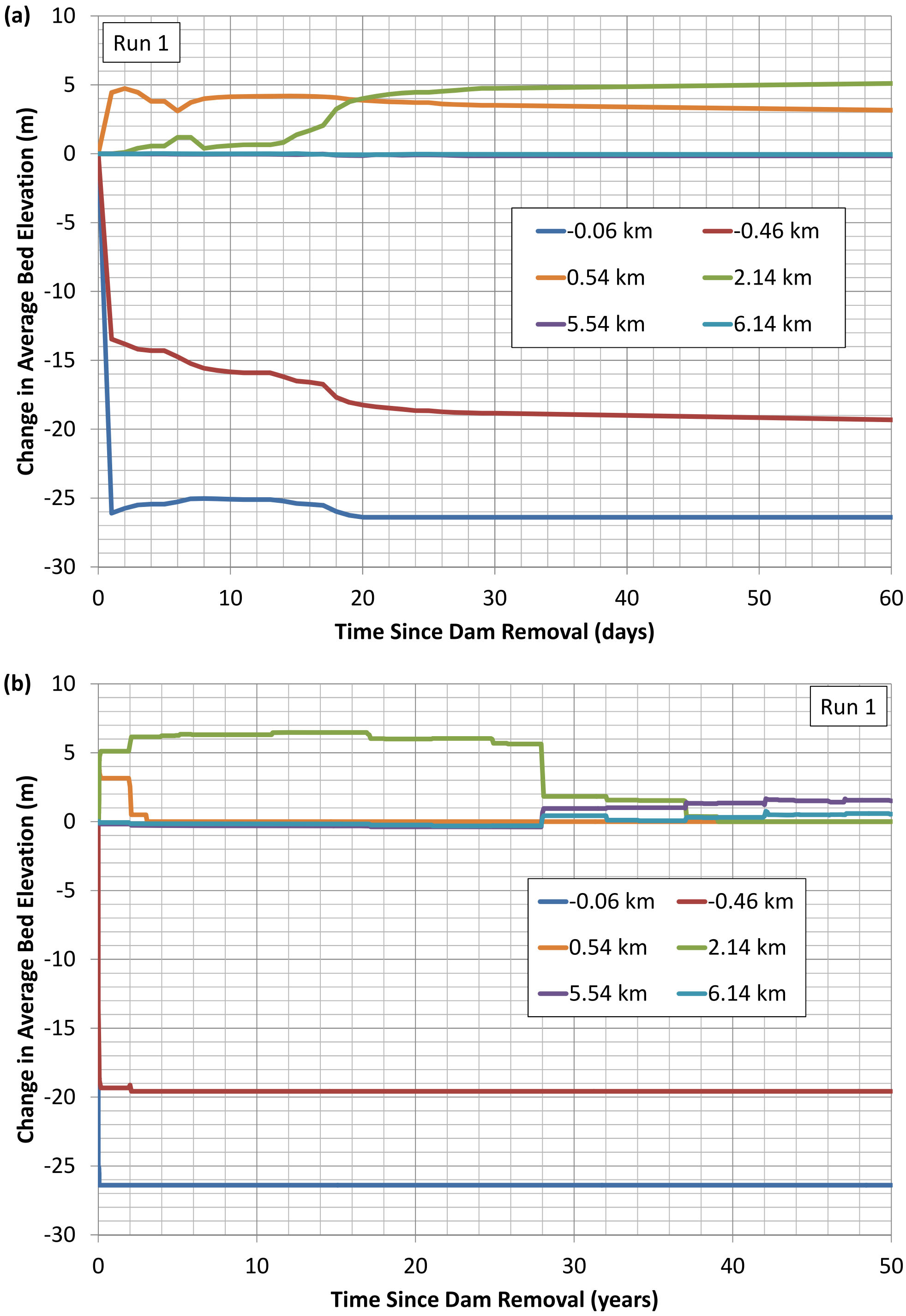

Figure 10. Simulated change in average bed elevation at selected locations following Matilija Dam removal for Run 1, with dam removal occurring during a wet period (2 upstream locations, 4 downstream locations). (a). Results within 60 days following dam removal, where the lines for 5.54 and 6.14 km almost overlay each other; (b). Results over the entire 50 years of simulation. The relative constancy of conditions for years 1–28 are primarily the reflection of the decadal droughts of the 1940's and 1950's that, a period of minimal rainfall that is included in this simulation period.

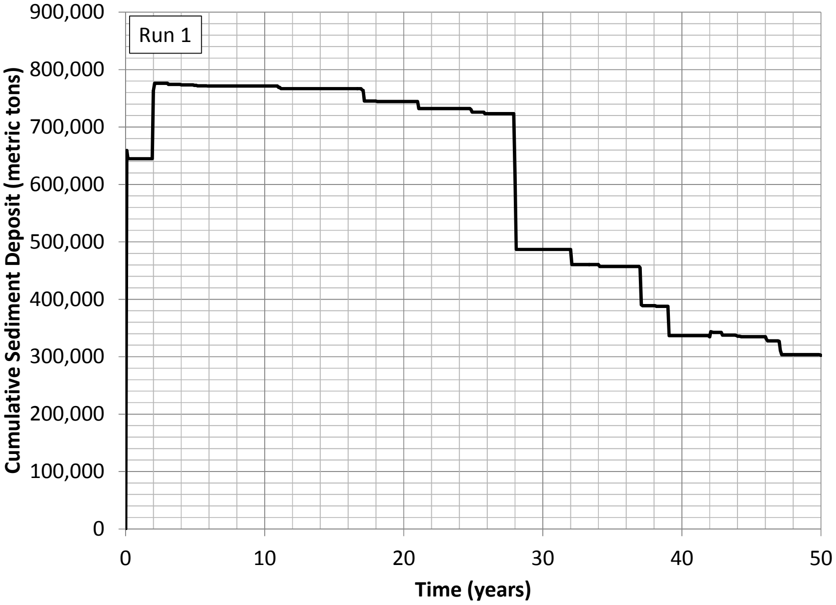

Figure 11. Simulated cumulative sediment deposit between North Fork Matilija Creek and Robles Diversion Dam following Matilija Dam removal for Run 1, assuming no improvement to Robles Diversion Dam and no sediment removal effort. Note the slow erosion before year 28 was due to the continued drought over that period of time, while the sudden decrease in sediment deposit around year 28 is due to an extremely high flow event (> 8,000 cfs daily average) as indicated in **Figure 3**.

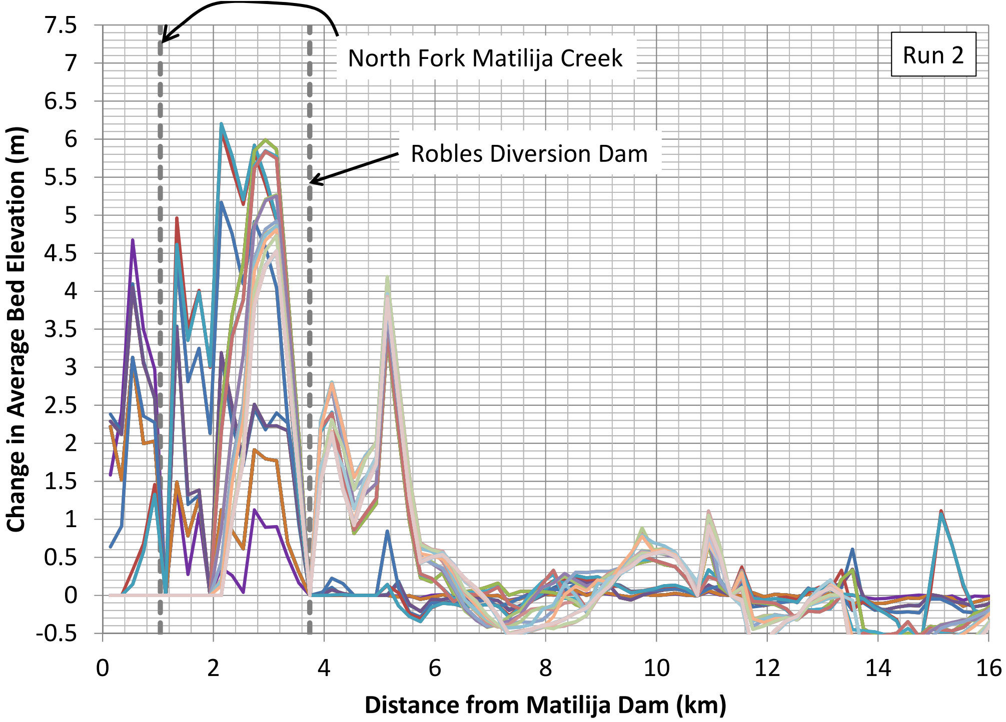

Figure 12. Simulated change in average bed elevation downstream of Matilija Dam following dam removal for Run 2, with dam removal occurring during a dry period. Diagram is intended to show the general area and magnitude of channel aggradation rather than presenting individual years.

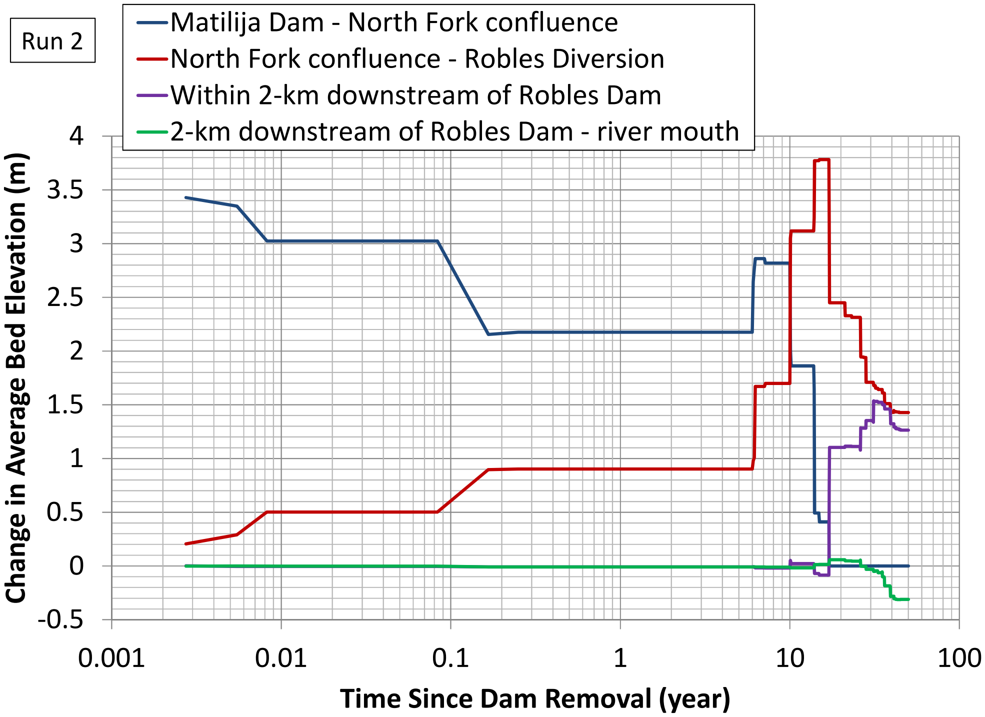

Figure 13. Simulated change in reach-average bed elevation downstream of Matilija Dam following dam removal for Run 2.

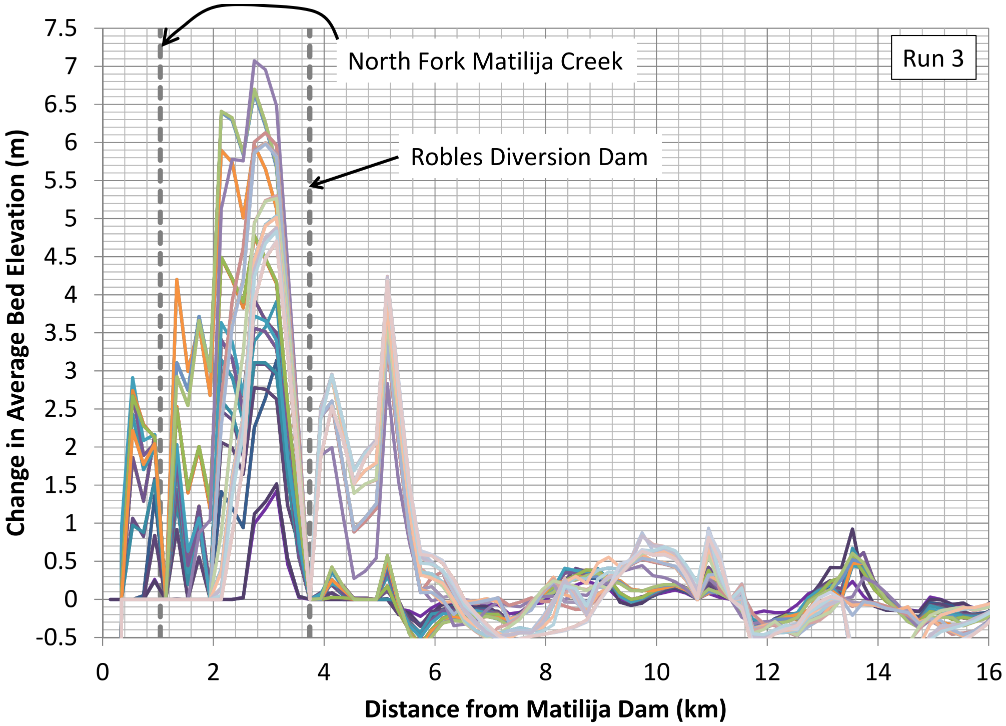

Figure 14. Simulated change in average bed elevation downstream of Matilija Dam following dam removal for Run 3, with dam notched in 4 stages over a 5-year period.

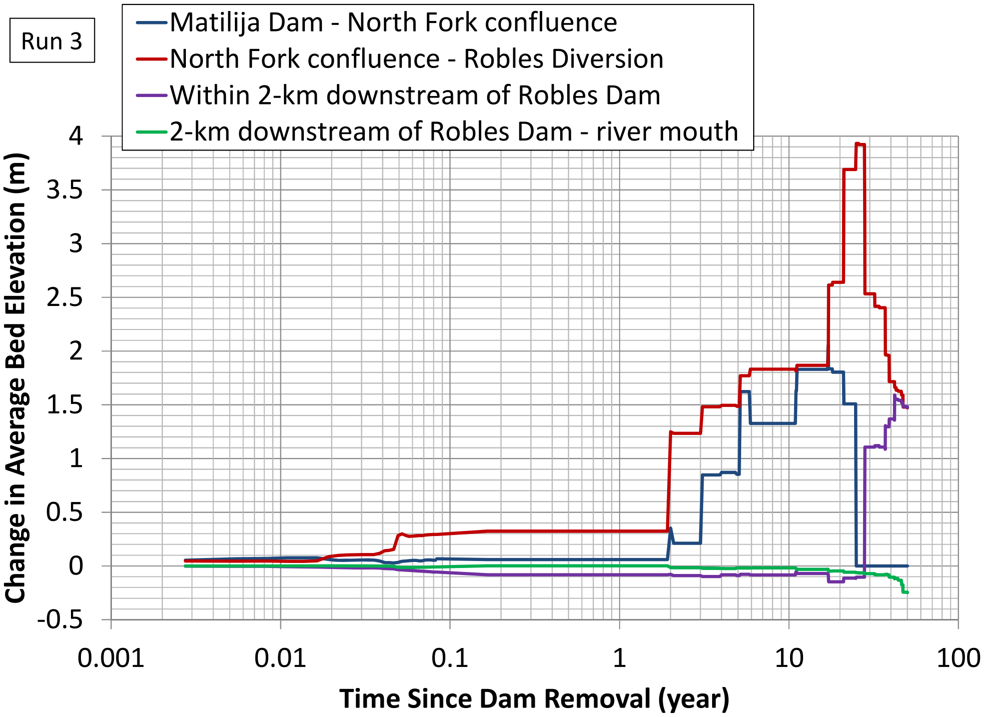

Figure 15. Simulated change in reach-average bed elevation downstream of Matilija Dam following dam removal for Run 3.

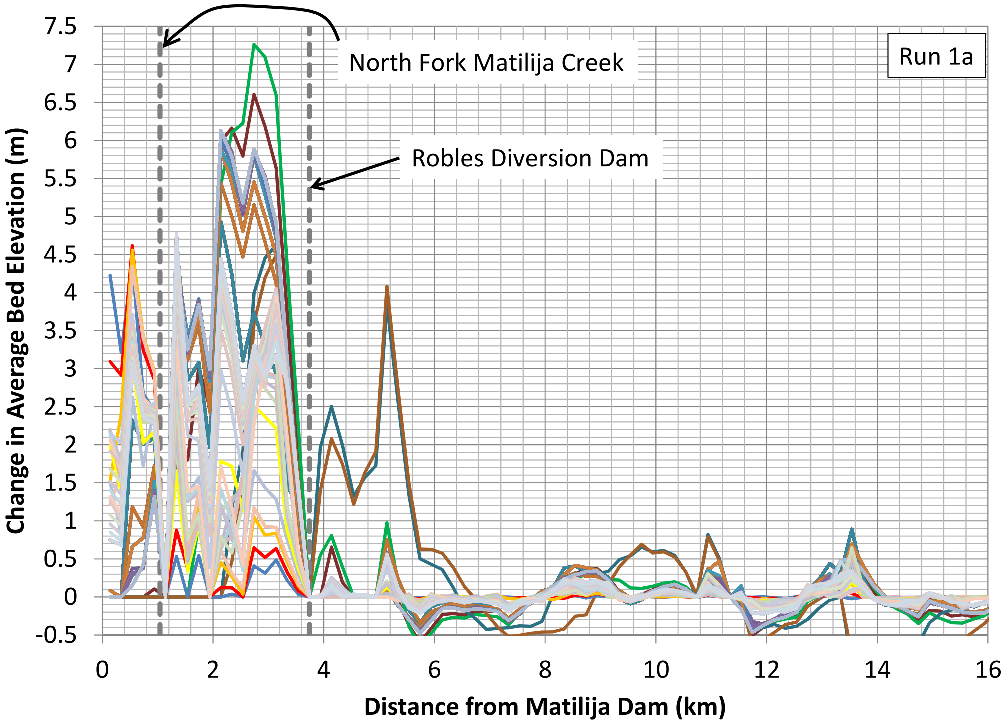

Figure 16. Simulated change in average bed elevation downstream of Matilija Dam following dam removal for Run 1a, which is identical to Run 1 (**Figure 8**) except that the channel width at the base of the trapezoidal channel to be formed in reservoir is increased from 20 m to 25 m.

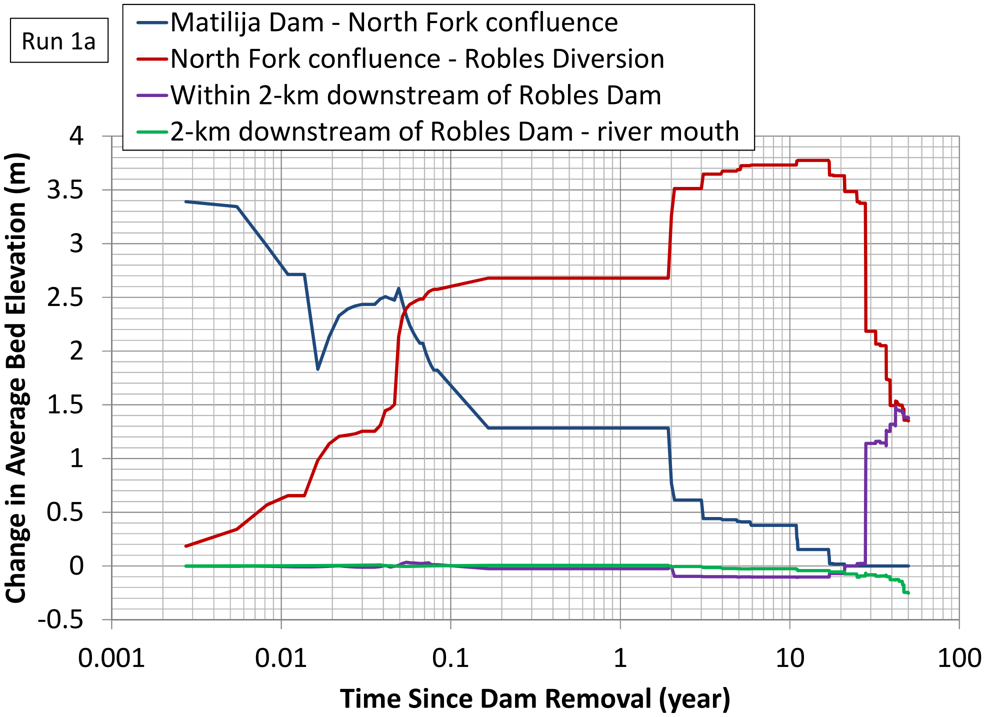

Figure 17. Simulated change in reach-average bed elevation downstream of Matilija Dam following dam removal for Run 1a.

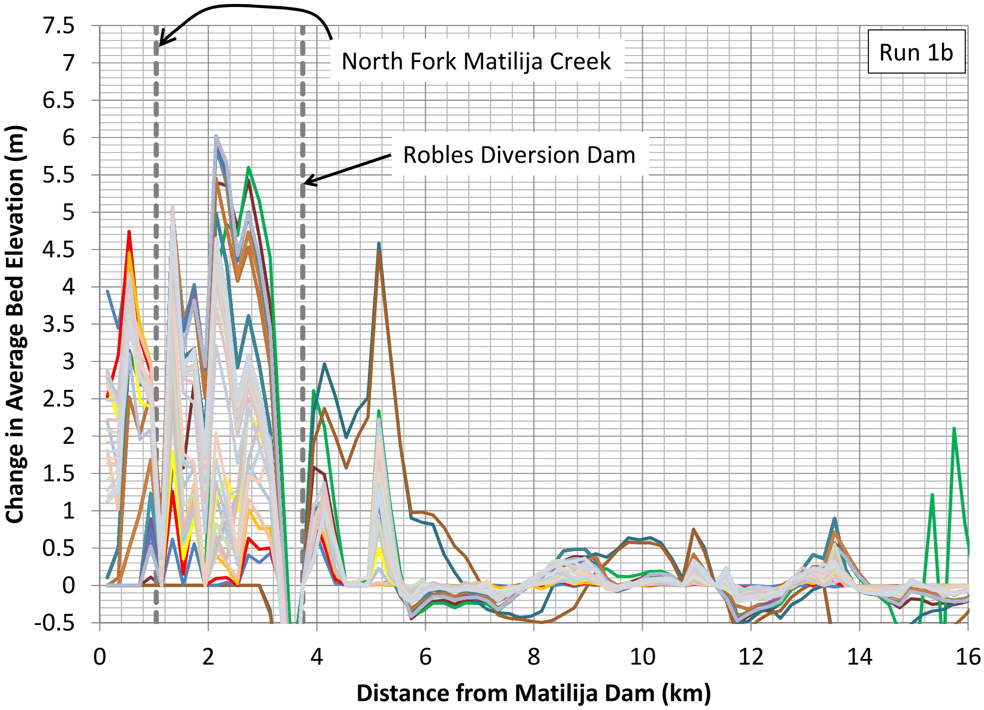

Figure 18. Simulated change in average bed elevation downstream of Matilija Dam following dam removal for Run 1b, which is identical to Run 1 (**Figure 8**), except that Robles the hydraulic effect of Diversion Dam is assumed to be no longer in place due to construction of a sediment bypass structure. Vertical scales (and magnitude of bed changes) are the same in both graphs.

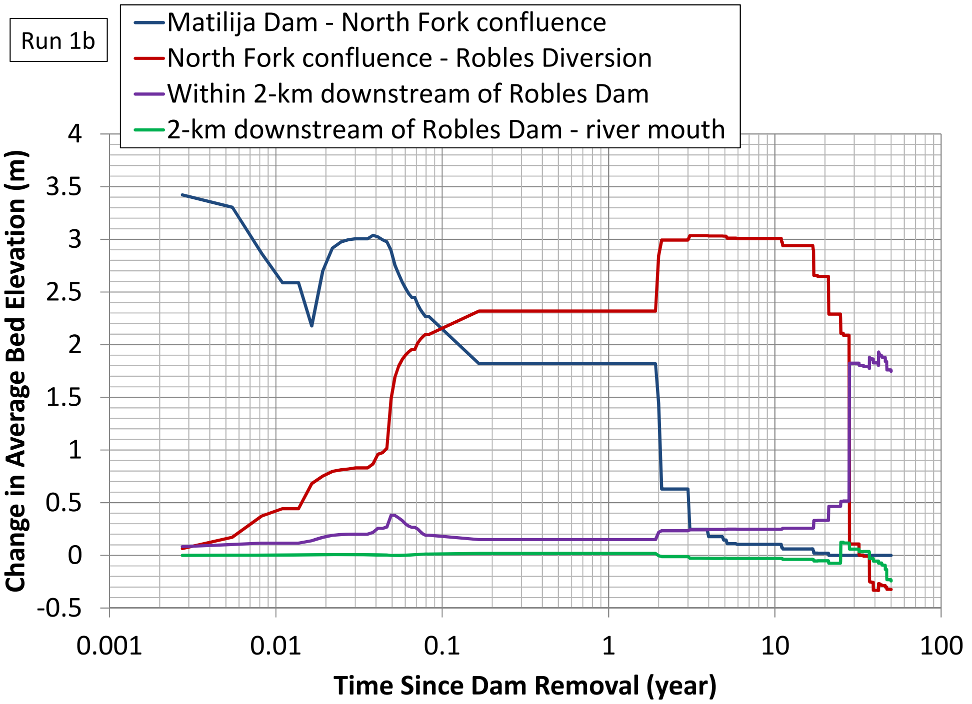

Figure 19. Simulated change in reach-average bed elevation downstream of Matilija Dam following dam removal for Runs 1b.

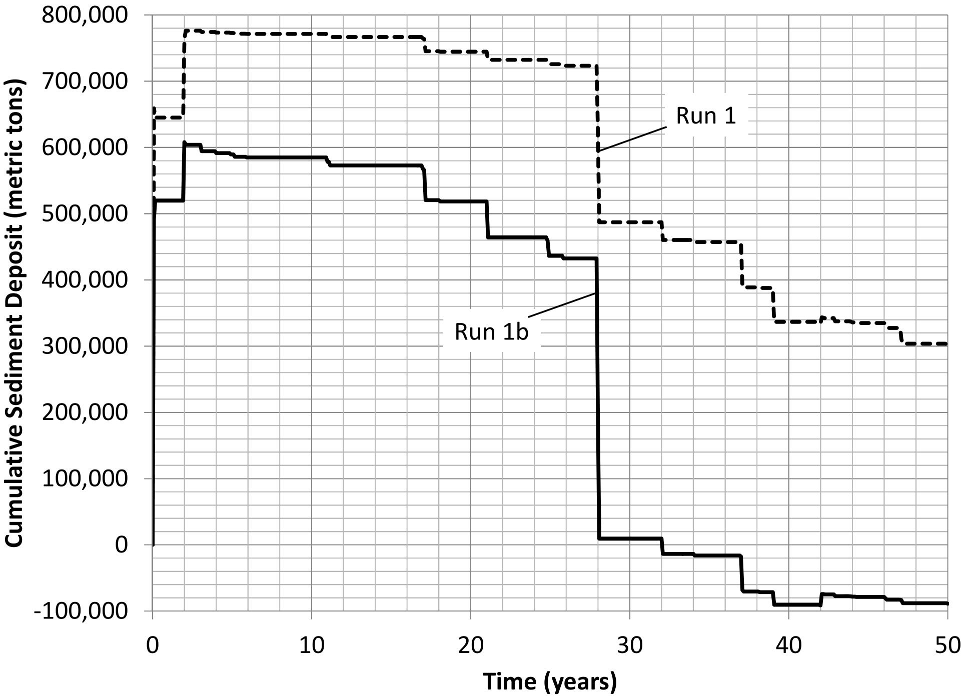

Figure 20. Simulated cumulative sediment deposit between North Fork Matilija Creek and Robles Diversion Dam for Runs 1 and 1b (which includes a sediment bypass structure on the dam). Note the sudden decrease in sediment deposit around year 28 is due to an extremely high flow event (> 8,000 cfs daily average) as indicated in **Figure 3**.

3 Discussions and Recommendations

Although there is 7 to 8 million cubic yards of sediment deposit in the Matilija Dam impoundment area (Stillwater Sciences 2014b), only approximately 350,000 cubic yards of coarse deposit (gravel and coarser) are likely going to be mobilized by natural erosion following dam removal.

As a comparison with past successful similar project, Marmot Dam removal on the Sandy River in Oregon was estimated to potentially mobilize 600,000 cubic yards (60% of the total 1,000,000 cubic yards of deposit) of coarse sediment once the river achieves its new equilibrium conditions (Cui and Wilcox 2008), and by the fourth year following dam removal, more than 72% of the anticipated erosion of the impoundment deposit had occurred (Stillwater Sciences 2012b). That is, the total coarse sediment mobilization following Matilija Dam removal that can potentially cause downstream channel aggradation will likely be less than 60% of that in the Sandy River following Marmot Dam removal. Note that coarse sediment deposit downstream of Marmot Dam occurred within approximately 1.2 km (less than 1 mile) downstream of Marmot Dam removal.

Here it is also useful to put the anticipated erosion of coarse sediment following Matilija Dam removal into a long-term perspective: the long-term average gravel supply in the Matilija Creek is estimated to be approximately 10,000 m^3/yr (solid), which translates to approximately 22,000 cubic yards (bulk volume) per year by assuming a porosity value of 0.4, meaning that the 350,000 cubic yards of coarse sediment release is equivalent to approximately 16 years of coarse sediment supply on a long-term averaged basis. Note that coarse sediment supply and transport is highly nonlinear (proportional to discharge to the 3rd power as discussed in Attachment A), and as a result, the 16 years sediment supply assessed on an annual averaged basis can potentially occur over a very short period during extreme flood events as demonstrated in **Figure 21**, where the coarse sediment transport during a single day on January 25, 1969 (with daily average discharge of 8,610 cfs) is estimated to be approximately 282,000 cubic yards (bulk volume), or approximately 80% of the anticipated coarse sediment erosion following dam removal.

Any coarse sediment removal prior to dam removal (such as IO-5) would reduce the amount of coarse sediment erosion and potentially reduce the amount of channel aggradation downstream of the dam. It should be noted, however, that the amount of mechanical removal do not automatically translates to the amount of reduction in sediment erosion, especially if the design for sediment erosion is more conservative (e.g., an excavated channel that is wider than naturally eroded channel or with side slopes more gentle than naturally eroded channel). Sensitivity test runs indicated that adding/reducing the amount of sediment by 20% does not significantly change the amount of downstream sediment deposition, indicating that unless a significant amount of coarse sediment is mechanically removed prior to dam removal, downstream sediment deposition for IO-5 will be similar to (i.e., only slightly smaller than) the other initial alternatives that do not require the removal of any coarse sediment. This realization is similar to the findings obtained during the study for Marmot Dam removal project, where modeling results indicated that dredging 15-30% of the reservoir deposit prior to dam removal would provide minimal reduction in downstream sediment deposition (Stillwater Sciences 2002).

Also note that the preliminary modeling results presented here do not consider the potential mitigation measures to Robles Diversion Dam such as the proposed construction of High Flow Sediment Bypass Structure or future sediment removal operations upstream of Robles Diversion Dam. It is recommended that additional studies be conducted to evaluate the potential flooding risks in the next phase of study with these measures in full consideration, with particular attention being paid to the reach between Matilija Dam and North Fork Matilija Creek confluence, where both residential housing constructed on the low lying floodplain and low rising narrow bridges can potentially be venerable to flood damage, especially if large amount of woody debris is released following dam removal.

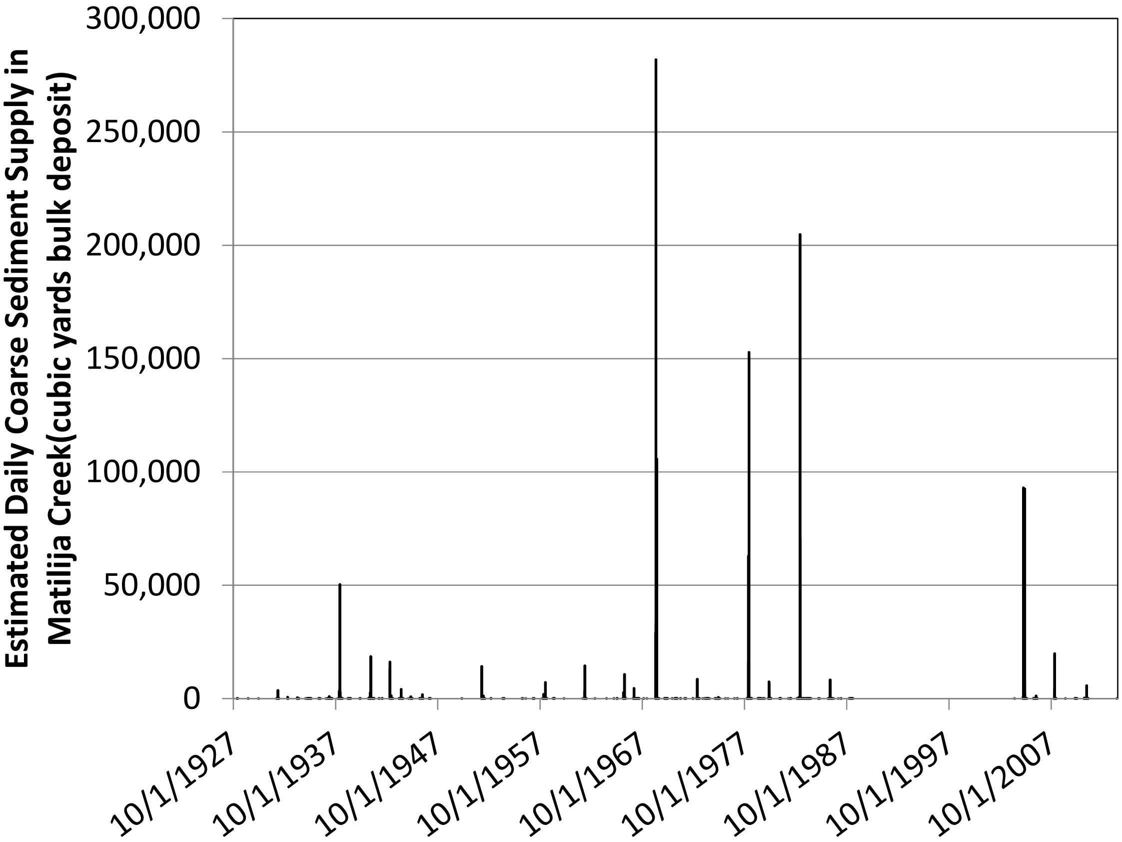

Figure 21. Calculated daily coarse sediment supply of the Matilija Creek using discharge records at USGS #11115500, USGS #11114500, and USGS #11114495 between WY 1928 and 2013, and assuming coarse sediment supply is proportional to discharge to the 3rd power (Attachment A), a long-term average supply rate of 10,000 m^3/yr (solid), and a porosity of 0.4.

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Attachment A: DREAM-2 Model Development for Matilija Dam Removal Project

This attachment discusses the most important input parameters used to setup DREAM-2 model, the zeroing process to prepare the model for dam removal modeling, and examinations of the model using field observations.

A.1 Overview of DREAM-2 Sediment Transport Model

DREAM-2 was one of the two Dam Removal Express Assessment Models (DREAM-1 and DREAM-2) initially developed for sediment transport simulation following dam removal (Cui et al. 2006a, 2006b). DREAM-1 and DREAM-2 models and their predecessors and sister models (i.e., early versions of the models and models that differ only in sediment transport equations, which were selected based on composition of sediment deposit) have been used for simulation of large sediment pulse movement in rivers, including sediment transport following dam removal for many projects. Example case studies include: mining waste disposal in Ok Tedi – Fly River system in Papua New Guinea (Cui and Parker 1999); Soda Springs Dam removal study on the North Umpqua River in Oregon (Stillwater Sciences 1999); Marmot Dam removal on the Sandy River, Oregon (Stillwater Sciences 2000; Cui and Wilcox 2008; Cui et al. 2014); Saeltzer Dam removal on Clear Creek, California (Stillwater Sciences 2001); landslide sediment evolution in the Navarro River, California (Sutherland et al. 2002; Cui and Parker 2005); Iron Gate, Copco 1, Copco 2, and J.C. Boyle Dam removal on the Klamath River, California and Oregon (Stillwater Sciences 2004; Stillwater Sciences 2008); Simpkins and Bloede Dam removal on the Patapsco River, Maryland (Stillwater Sciences 2010, 2014d, 2014e); Harvey Diversion Structure removal on Santa Paula Creek, California (Stillwater Sciences 2012a); and Freeman Dam removal on the Santa Clara River, California (Stillwater Sciences 2013). In addition to these practical projects, DREAM-1 and DREAM-2 models were also examined with flume experiments and proved to produce excellent results without or with minimal model calibrations (Cui et al. 2008). More details of the Dam Removal Express Assessment Models can be found in Cui et al. (2006a, 2006b).

DREAM-2 was designed for simulation of sediment transport dynamics in rivers following dam removal where at least the top layer of the sediment deposit in the reservoir is composed primarily of gravel and coarser sediment. It simulates the transport and deposition of gravel and sand and is applicable to rivers with any combination of gravel-bedded and bedrock reaches downstream of the dam. For flow parameter calculations, the DREAM-2 model applies a standard backwater equation. DREAM-2 model applies the surface-based bedload equation of Parker (1990) for calculating transport capacity of gravel and coarser sediment (i.e., particles coarser than 2 mm) and Brownlie's (1982) bed material equation for calculating transport capacity of sand-sized sediment (i.e., particles between 0.0625 and 2 mm). Sediment in the silt and clay range (i.e., particles finer than 0.0625 mm) is treated as wash load that is assumed unable to redeposit onto the channel bed once released into the water column following erosion of the sediment deposit upstream of the dam. Furthermore, the model assumes that the erosion of reservoir deposit is governed by the mobilization of gravel-sized and coarser particles, and thus eroding the deposit down to a given elevation by mobilizing gravel and coarser particles will simultaneously result in the release of all the finer particles (i.e., sand, silt and clay).

The model requires the following input parameters: a) initial channel profile, including the elevation of a non-erodible bed and the thickness of a layer of sediment deposit over the non-erodible bed; b) initial grain size distributions of the sediment deposit upstream and downstream of the modeled structure; c) channel cross-sections simplified as rectangles with widths equal to the active channel width; d) daily average water discharge values; e) the rate and grain size distribution of sediment supply; and, f) the downstream base-level control (i.e., either downstream water surface elevation or fixed bed elevation). Model output includes the evolution and the thickness of sediment deposits in reaches upstream and downstream of the structure, sediment fluxes, and daily-averaged total suspended sediment concentrations along the river in response to the specified water discharge and sediment supply conditions.

A.2 Longitudinal Profile and Active Channel Width

Longitudinal profile (**Figure 22** and **Figure 23**) and active channel width (**Figure 24**) are obtained from the HEC-RAS model provided by BOR (2006). Although the amount of sediment deposit upstream of Matilija Creek to date is projected to be higher than depicted with the 2005 profile shown in **Figure 22** due to continued sediment accumulation (Stillwater Sciences 2014b), the 2005 profile is used for model input for the following reasons: first, a reliable profile after 2005 does not exist; and second, increased sediment deposition can be accommodated in other ways more convenient than estimating a 2014 or future profile (such as by increasing the estimated channel width to be formed in the deposit following dam removal). The 0.8-km moving average channel widths presented in **Figure 24** are used for model input so as to smooth out some of the local variations to accommodate the reach-averaged nature of one-dimensional modeling.

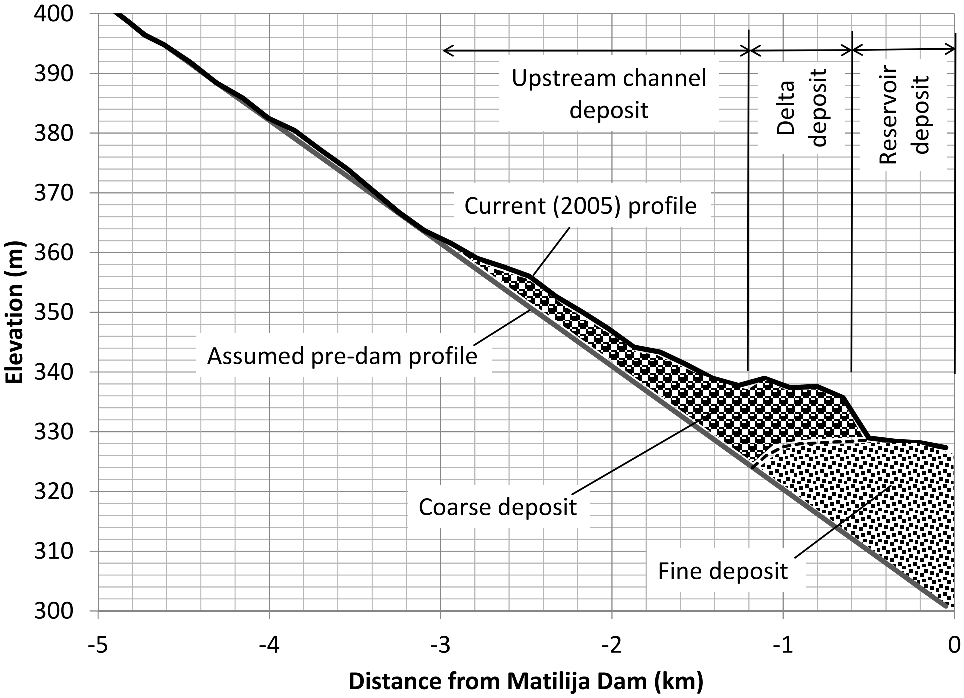


Figure 22. Longitudinal profile of the Matilija Creek upstream of Matilija Dam, showing the approximate location of the "reservoir", "delta", and "upstream channel" sub-areas defined in BOR (2006).

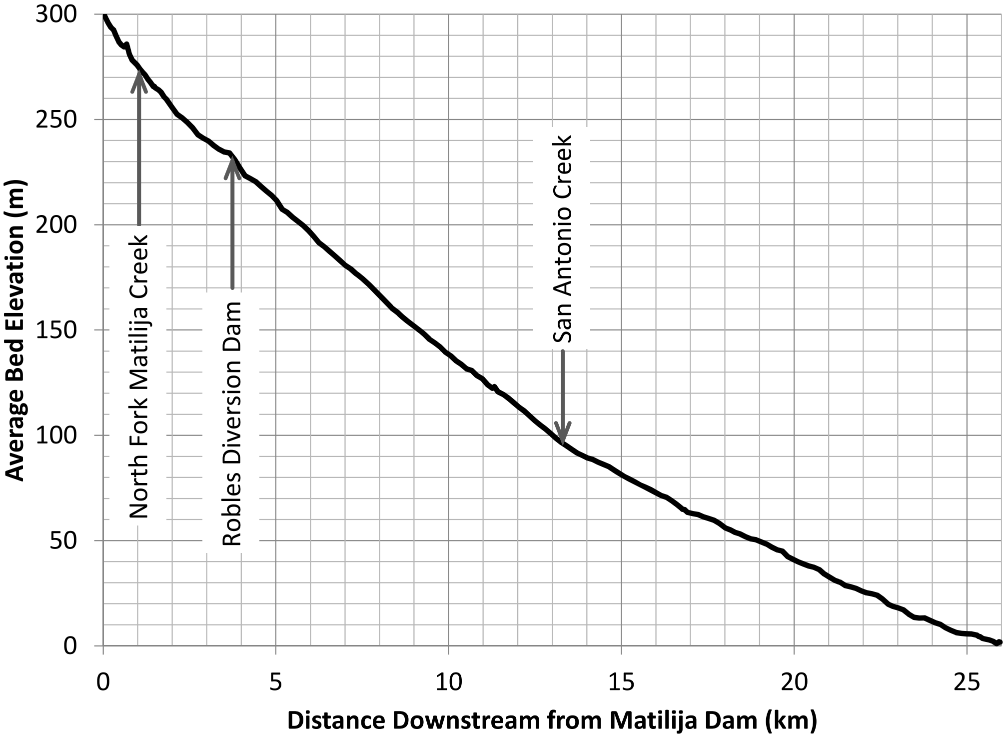


Figure 23. Longitudinal profile of Matilija Creek and the Ventura River downstream of Matilija Dam.

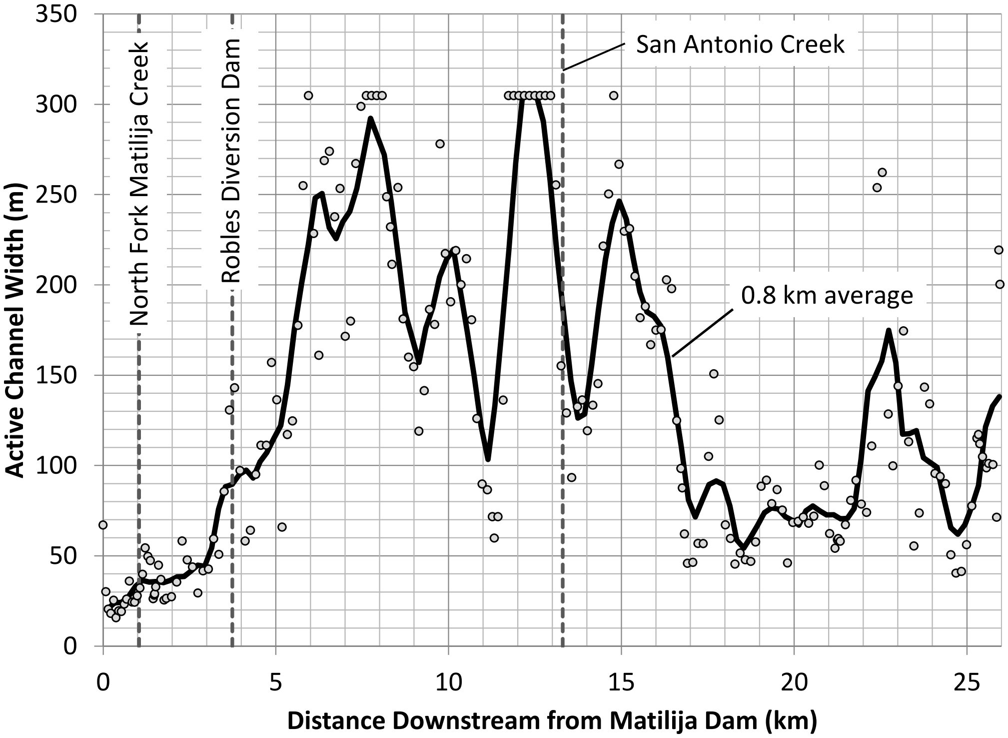


Figure 24. Active channel width of the Matilija Creek and Ventura River downstream of Matilija Dam, in which the symbols are obtained from the BOR (2006) HEC-RAS model, and the line represents the 0.8-km moving average of the symbols.

A.3 Matilija Creek and Ventura River Sediment Grain-Size Distribution

Information with regard to Matilija Creek and Ventura River surface grain size distribution of the Matilija Creek and Ventura River is based on data provided in Sections 5.3 of BOR (2006).

Surface gravel (particles > 2 mm) and sand grain size distributions collected by BOR (2006) are presented in **Figure 25** and **Figure 26**, respectively. Data presented in the two diagrams will be used for reference and further discussed below.

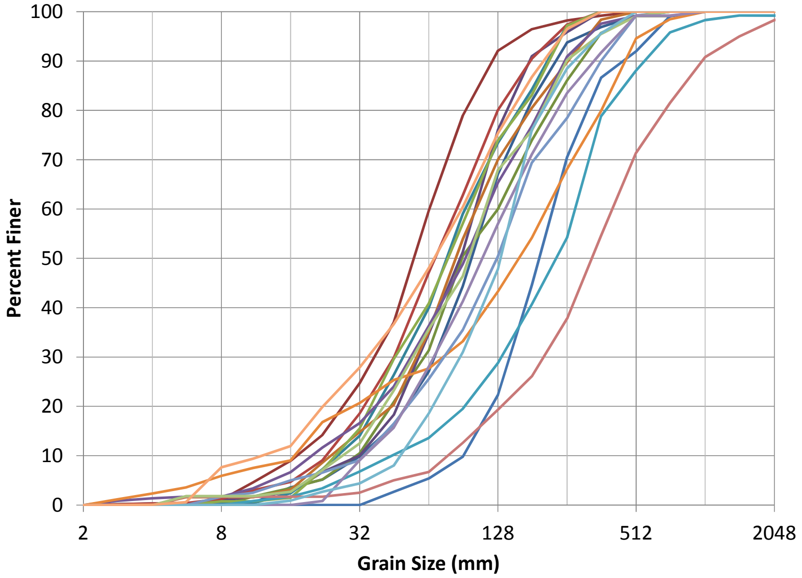


Figure 25. Surface gravel grain size distributions in Matilija Creek and Ventura River, based on pebble count data collected by BOR (2006).

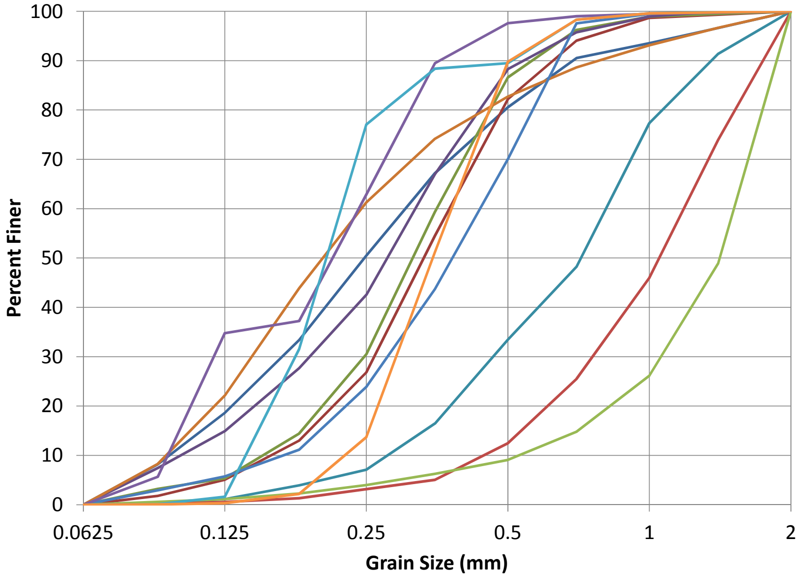


Figure 26. Surface sand grain size distribution in Matilija Creek and Ventura River, based on surface sample data collected by BOR (2006).

A.4 Abrasion Coefficient for Gravel Particles

Abrasion coefficient of gravel particles varies by three orders of magnitude in natural rivers (e.g., Attal and Lave 2009). For modeling purposes, volumetric abrasion coefficient (fraction of volume lost for transporting a unit distance) is assumed to be 0.02 km^{-1}, with the understanding that it can be adjusted during the zeroing process (discussed below in Section A.9), if it is determined an adjustment to the volumetric abrasion coefficient reproduces better existing channel longitudinal profile. Note that if the downstream fining due to selective transport following Matilija Dam closure is neglected and all the downstream fining is attributed to abrasion, field data (BOR 2006) suggest a volumetric abrasion coefficient of 0.108 km^{-1} (=3×0.036, in which the factor 3 is from Equation 1 below and 0.036 is the exponent in **Figure 27**) based on regression of surface gravel geometric mean grain sizes (**Figure 27**) and Sternberg's (1875) equation:

$$\frac{D}{D_0} = exp\left[-\frac{1}{3}\beta x\right] \qquad (1)$$

where D and D_0 denote geometric mean grain size at downstream and upstream locations; β denotes volumetric abrasion coefficient; and x denotes distance between the two locations.

Considering the contribution from selective transport as the result of Matilija Dam sediment trapping (i.e., channel bed downstream of and close to the dam became progressively coarser due to the reduced bedload supply), the volumetric abrasion coefficient of the Ventura River gravel has to be less than 0.108 km^{-1} (i.e., the 0.108 km^{-1} can be considered as the maximum possible value).

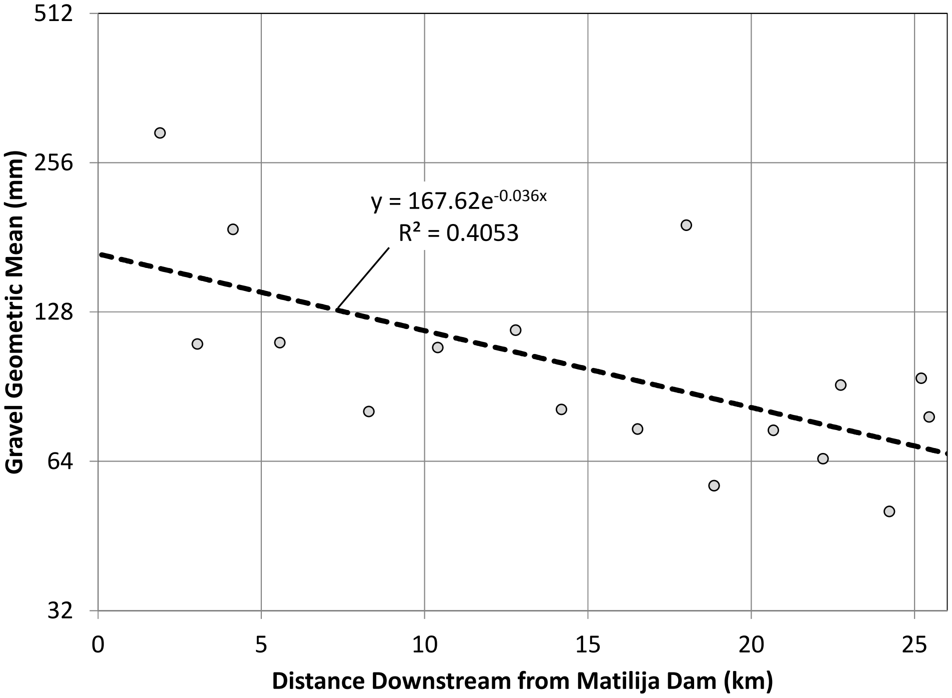


Figure 27. Surface gravel geometric mean grain size in Matilija Creek and Ventura River downstream of Matilija Dam (based on data provided in BOR 2006 shown in **Figure 25**).

A.5 Grain-Size Distribution of Matilija Dam Impoundment Deposits

Information with regard to Matilija Dam impoundment deposit is based on data provided in Sections 5.4 of BOR (2006) (**Table 1**).

In **Table 1**, the grain-size distributions for sediment deposits in "reservoir", "delta", and "upstream channel" sub-areas are copied directly from BOR (2006) (see **Figure 22** for definitions of reservoir, delta, and upstream channel sub-areas), while the grain-size distribution for the entire deposit was weighted average of the above three distributions using the deposit volume (last row in **Table 1**) as the weight for averaging. Grain size distributions in **Table 1** are also presented in **Figure 28**.

The application of DREAM-2 model requires a grain-size distribution to be broken into a gravel size distribution and a sand size distribution, and the full grain-size distribution is represented by the size distributions of gravel and sand in conjunction with fractions of gravel, sand, and silt/clay. A grain-size distribution for silt and clay is not required in DREAM-2 modeling as silt and clay particles are assumed to act as washload (i.e., they contribute to the overall suspended sediment concentration, but interact minimally with the channel bed once eroded from the reservoir deposit).

Table 2, **Table 3**, and **Table 4** break down the grain-size distributions to gravel, sand, and silt/clay based on the information presented in **Table 1**. Gravel and sand size distributions presented in **Table 2** and **Table 3** are also presented in **Figure 29** and **Figure 30**, respectively. For modeling purposes, the fine deposit delineated in **Figure 22** is assumed to be composed of 17% of sand and 83% of silt and clay, while the coarse deposit delineated in the same diagram is assumed to be composed of 78% gravel, 16% sand, and 6% silt and clay, and the gravel and sand distributions are those for the entire deposit presented in **Table 2**, **Table 3**, **Figure 29** and **Figure 30**.

The size distribution of the Matilija gravel deposit shown in **Figure 29** does not have the long tails (i.e., the fraction of sediment becomes increasingly smaller when the grain size becomes larger or becomes closer to sand size) normally found for natural sediment such as presented in **Figure 25**. This lack of tails in gravel size distribution is believed to be most likely due to the limitations of sediment sampling from reservoir deposits: samples are most likely skewed to the surface layer in the upstream channel deposit (and thus, skewed to the coarse particles) and skewed to the finer deposit in the reservoir deposit (and thus, skewed to the finer particles). As a result, minor modifications were made to the Matilija sediment deposit grain size distribution in reference to the surface pebble counts (**Figure 25**) for modeling purposes, as presented in **Figure 31**.

Comparison of the grain size distribution of the entire Matilija impoundment deposit presented in **Figure 32** with bed material sand grain size distributions presented in **Figure 26** indicated that the impoundment deposit sand grain size is generally finer than that of the bed material (**Figure 32**). While it is not certain whether the finer Matilija deposit sand grain size was an accurate representation of the field or due to limitations on sampling, the reservoir deposit sand grain size distribution is assumed to be identical to the average of BOR (2006) surface sand samples (i.e., the red thick line in **Figure 32**) as a conservative measure (i.e., a coarser grain size, and thus more likely to deposit on river bed) for modeling purposes. That is, the thick red lines in **Figure 31** and **Figure 32** are used as the gravel and sand portions of the Matilija impoundment deposit for modeling purposes.

Table 1. Grain-size distributions of Matilija Dam impoundment gravel deposit, based on data provided in Table 5.6 in BOR (2006).

Grain Diameter (mm)	*% Finer*			
	Reservoir	Delta	Upstream Channel	Entire Deposit
512	100	100	100	100
256	100	100	87.9	97.9
128	100	100	75.9	95.9
64	100	99.8	60.9	93.3
32	100	98.4	48.9	90.6
16	99.9	95.1	36.9	86.9
8	99.8	92.5	29.9	84.5
4	99.7	89.9	24.9	82.4
2	99.7	87.3	21.9	80.6
1	99.5	83.7	18.4	78.3
0.5	99	77.5	15.0	74.6
0.25	97.2	66.5	12.0	68.2
0.125	92.2	50.8	9.0	58.5
0.0625	82.8	33.2	6.0	46.2
0.03125	70.9	21.9	4.0	36.3
0.015625	57.3	14.5	2.0	27.6
0.007813	43.1	9.7	1.0	20.1
0.003906	30.1	5.3	0	13.2
0.001953	18	0	0	6.4
Total Bulk Volume in 2005 (m^3)	1,600,000	2,100,000	800,000	4,500,000

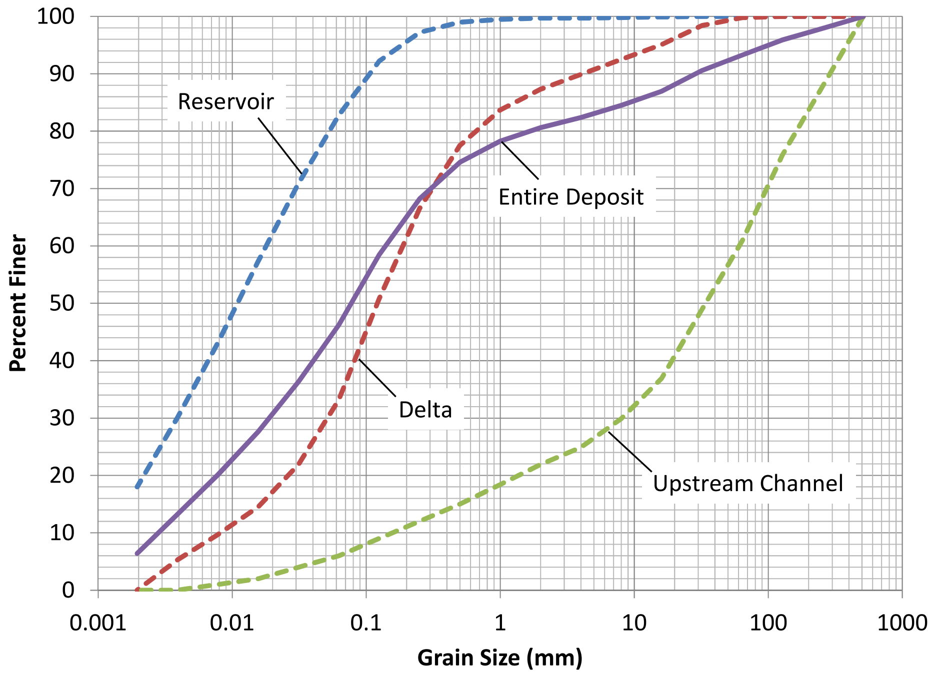


Figure 28. Grain-size distributions of Matilija Dam impoundment deposits, based on data provided in Table 5.6 in BOR (2006).

Table 2. Grain-size distributions of Matilija Dam impoundment gravel deposits, based on data provided in Table 5.6 in BOR (2006).

Grain Diameter (mm)	*% Finer*			
	Reservoir	Delta	Upstream Channel	Entire Deposit
512	100	100	100.0	100.0
256	100	100	84.5	89.4
128	100	100	69.1	78.9
64	100	98.4	49.9	65.3
32	100	87.4	34.6	51.4
16	66.7	61.4	19.2	32.6
8	33.3	40.9	10.2	19.9
4	0	20.5	3.8	9.0
2	0	0	0	0

Table 3. Grain size distributions of Matilija Dam impoundment sand deposits, based on data provided in Table 5.6 in BOR (2006).

Grain Diameter (mm)	*% Finer*			
	Reservoir	Delta	Upstream Channel	Entire Deposit
2	100	100	100	100
1	98.8	93.3	78.0	93.1
0.5	95.9	81.9	56.6	82.3
0.25	85.2	61.6	37.7	63.8
0.125	55.6	32.5	18.9	35.5
0.0625	0	0	0	0

Table 4. Gravel, sand, and silt/clay fractions in Matilija Dam impoundment deposits, based on data provided in Table 5.6 in BOR (2006).

Sediment	*Reservoir*	*Delta*	*Upstream Channel*	*Entire Deposit*
Gravel	0.00	0.13	0.78	0.19
Sand	0.17	0.54	0.16	0.34
Silt and clay	0.83	0.33	0.06	0.46

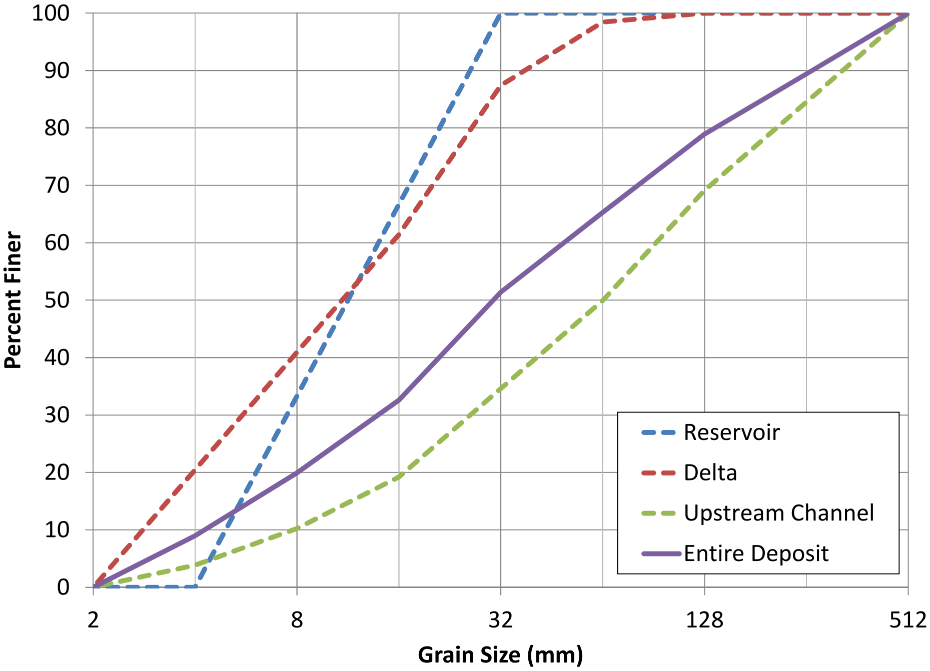


Figure 29. Grain-size distributions of gravel deposits in Matilija Dam impoundment, based on data provided in Section 5.4 in BOR (2006).

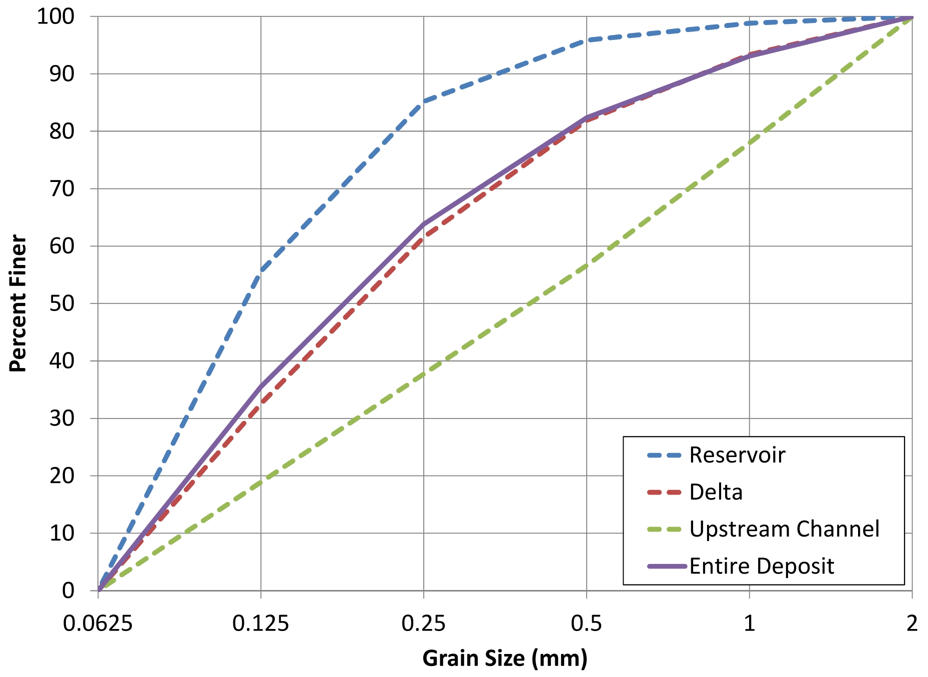


Figure 30. Grain-size distributions of the sand deposits in Matilija Dam impoundment, based on data provided in Section 5.4 in BOR (2006).

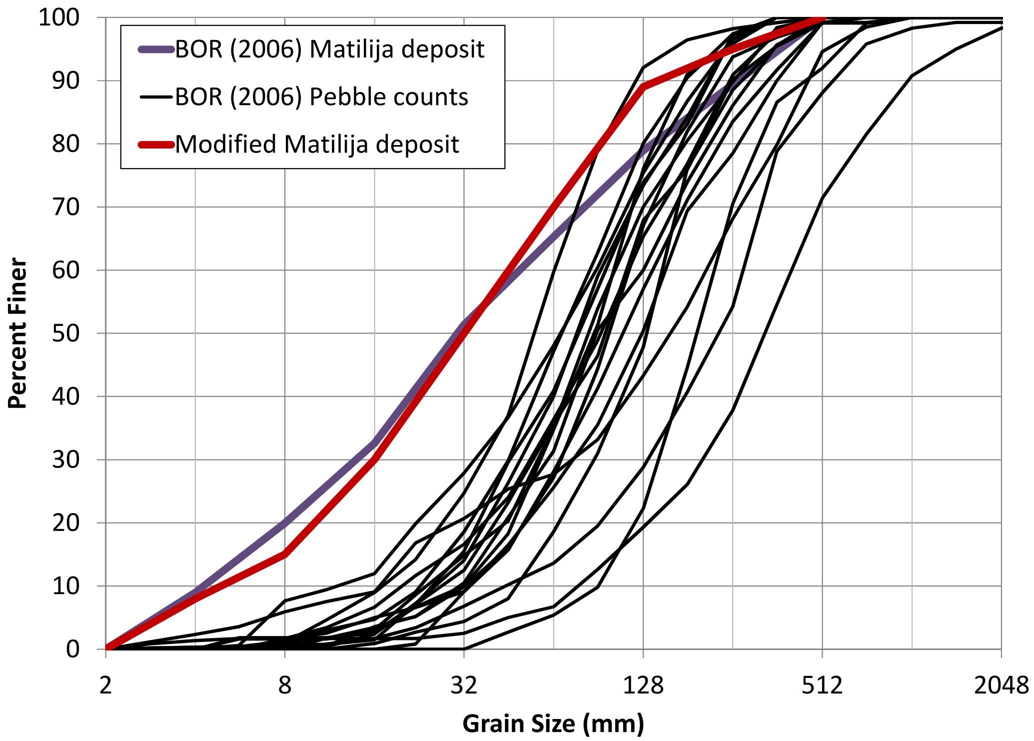


Figure 31. Slightly modification to the grain size distribution of Matilija impoundment gravel deposit based on the general shapes of the pebble counts in the Ventura River. The line for “BOR (2006) Matilija deposit” is directly from **Figure 28** for “entire deposit”.

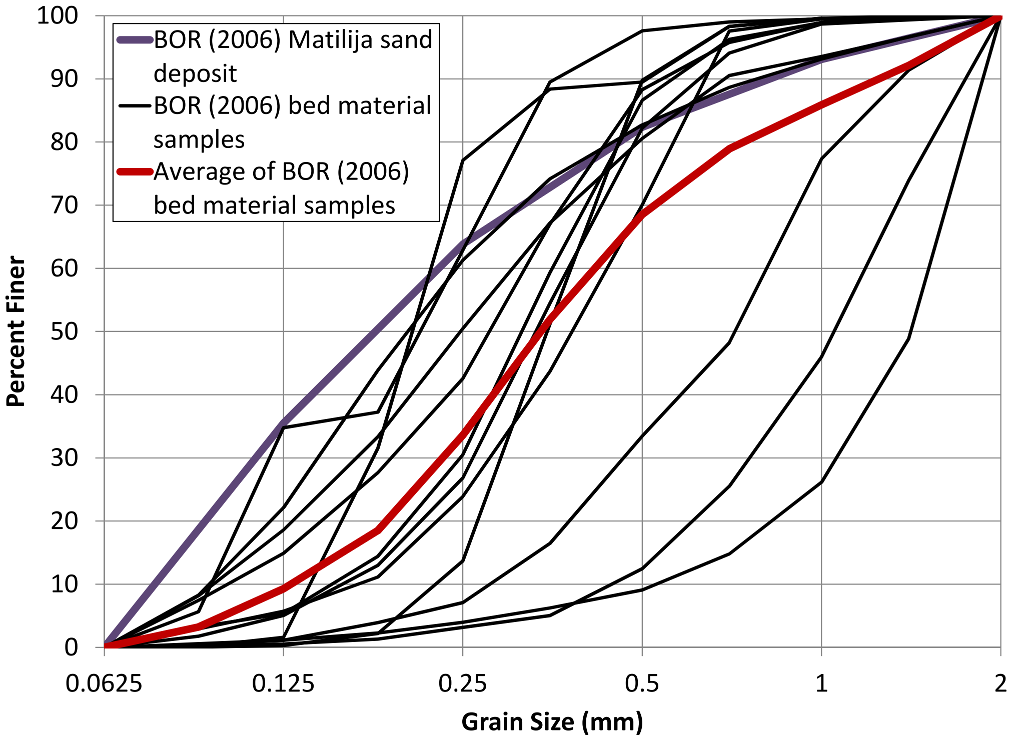


Figure 32. Comparison of sand grain size distribution of Matilija Dam impoundment deposit with bed material sand grain size distribution in Ventura River.

A.6 Grain-Size Distributions of Gravel and Sand Supply

Minimal gravel and sand load has escaped the Matilija Dam during the post-dam years (BOR 2006), and thus it is reasonable to assume that the average gravel and sand grain size distributions of the influx sediment is identical to the grain-size distributions of gravel and sand deposits. For initial modeling purposes, it was assumed that the gravel supply has a grain-size distribution identical to the gravel size distribution for "modified gravel deposit" in **Figure 31**, and sand supply has a grain-size distribution identical to the "average of BOR (2006) bed material samples" presented in **Figure 32**. Realizing that there are uncertainties associated with the grain-size distributions of the reservoir deposits, which were the basis of the assumed grain-size distribution of gravel supply, more adjustment to the grain-size distribution of the gravel supply was provided in the zeroing process, during which attempt was made to reproduce the observed longitudinal profile of the Matilija Creek and Ventura River (see details in Section A.9).

The silt/clay size distribution in the sediment supply is not needed for modeling purposes, as discussed earlier, because silt and clay particles are assumed to be transported as wash load and assumed to be unable to deposit onto the channel bed once they are supplied to the river or eroded from the reservoir deposit.

For modeling purposes, the grain-size distribution of gravel supply from the North Fork Matilija Creek is assumed to be identical to that from the Matilija Creek. The grain-size distribution of the gravel supply from San Antonio Creek was determined during the zeroing process (discussed below), and is known to be finer than that from the Matilija Creek based on reconnaissance-level field observations on May 29, 2014 during which it was observed that San Antonio Creek gravel-sized bed material is finer than the gravel deposit in Matilija Dam impoundment.

A.7 Discharge Records

We selected 50 years discharge record (WY 1934 – 1983) from the available discharge records to conduct the modeling. The discharge will be represented as follows (**Figure 33**):

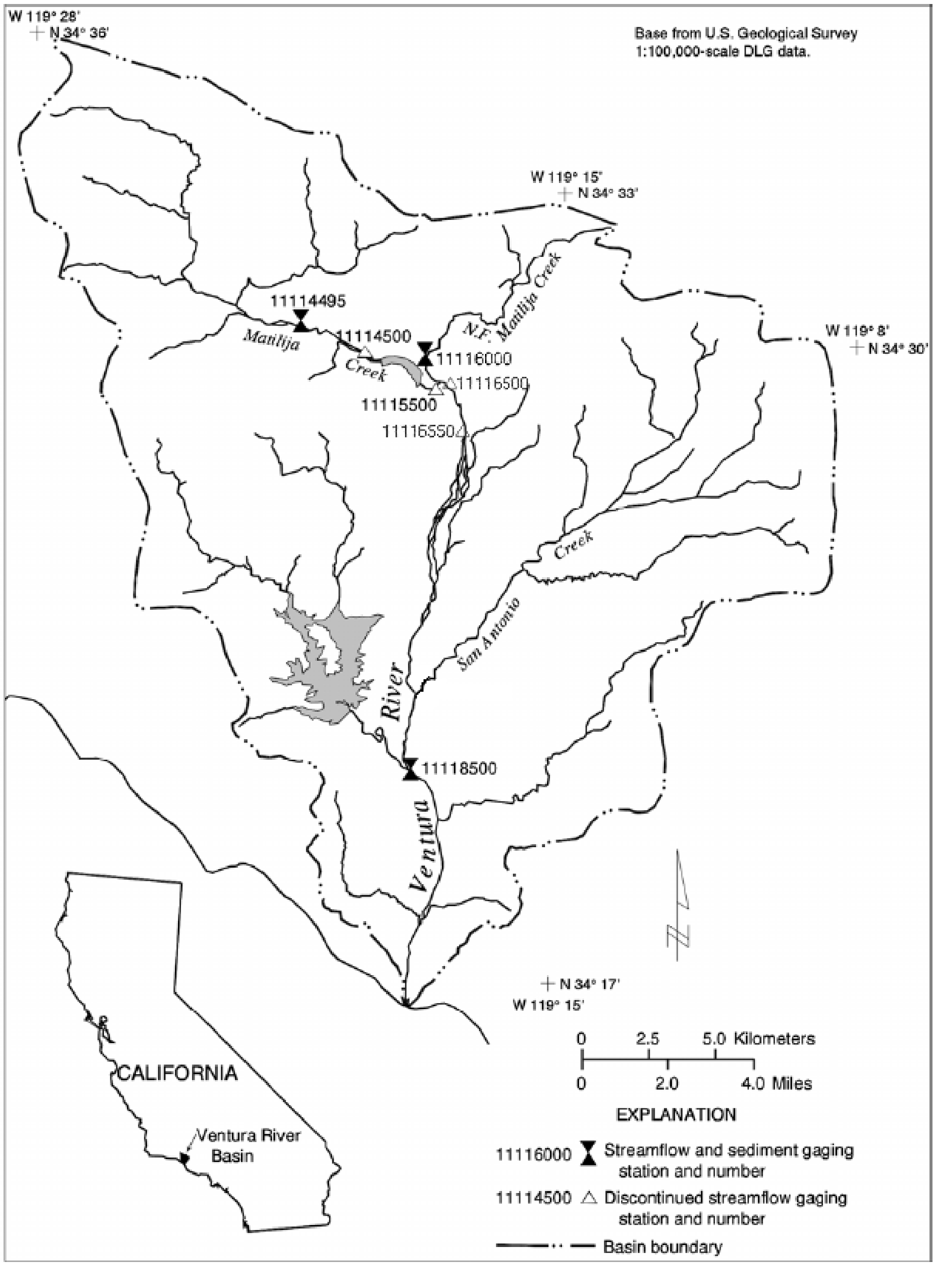


Figure 33. Map of stream gages in the Ventura River watershed (modified from Figure 2.1 of BOR 2006).

- Matilija Creek, represented with discharge recorded at USGS Station #11115500 (Matilija Creek at Hot Springs);
- Ventura River upstream of San Antonio Creek, represented by the sum of discharge at USGS Station 11115500 (Matilija Creek near Hot Springs) and USGS 11116000 (North Fork Matilija Creek at Hot Springs); and
- Ventura River downstream of San Antonio Creek, represented by discharge recorded at USGS Station #11118500 (Ventura River near Ventura).

Comparison of the available recorded discharge at USGS 11116500 (Ventura River near Meiners Oaks) with the sum of the recorded discharges in Matilija Creek and North Fork Matilija Creek indicates that using the sum of Matilija Creek and North Fork Matilija Creek discharge to represent discharge in the Ventura River between North Fork Matilija Creek confluence and San Antonio Creek confluence provide a good approximation for modeling purposes (**Figure 34**).

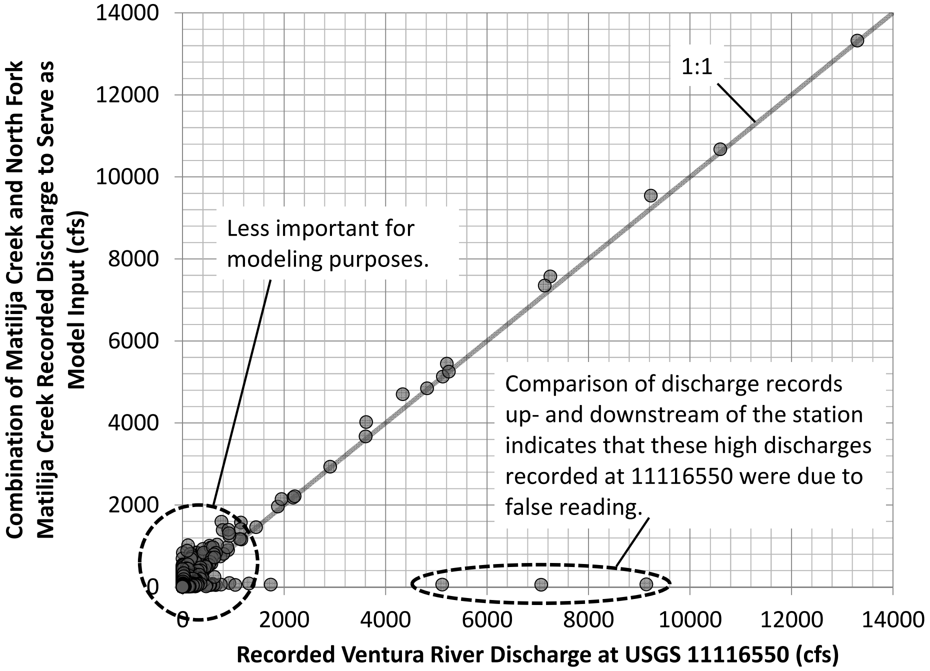


Figure 34. Comparison of discharge record at USGS 11116550 (Ventura River near Meiners Oaks) with the sum of recorded discharge in Matilija Creek and North Fork Matilija Creek for the period of WY 1959 – 1983.

A.8 Rates of Sediment Supply from Matilija Creek and Major Tributaries

Long-term average gravel and sand supply from Matilija Creek can be calculated based on the estimated volume of sediment deposit in Matilija Creek. It is estimated that minimal amounts of gravel and sand particles have escaped the entrapment of Matilija Dam, evidenced by the small fraction of sand in the reservoir sub-area sediment deposit (BOR 2006). According to the analysis by

Stillwater Sciences (2014b), there had been an estimated 5.2 million m^3 (6.8 million cubic yards) of sediment deposited in Matilija Dam impoundment as of 2005, that is, after approximately 58 years of reservoir operation following the dam closure in 1947. Using the amount of deposits in three different areas and the estimated density of sediment deposit provided in Stillwater Sciences (2014b), the long-term average supply rates from the Matilija Creek is estimated to be approximately 16,000 m^3/yr for sand (solid) and 10,000 m^3/yr for gravel (solid) respectively (**Table 5**).

First-order estimates of gravel and sand supply rates in North Fork Matilija Creek are obtained by assuming that sediment production rates per unit drainage area in the Matilija Creek and North Fork Matilija Creek sub-basins are identical, and as a result, long-term average rates of gravel and sand supply are proportional to the catchment area (**Table 5**).

First-order estimates of gravel and sand supply rates in San Antonio Creek are obtained based on BOR's (2006) assessment that gravel and sand supply rates from San Antonio Creek and North Fork Matilija Creek have a ratio of 5:3 (**Table 5**).

Table 5. Estimated rates of sediment supply from the Matilija Creek, North Fork Matilija Creek, and San Antonio Creek, in m^3/yr (solid).

	Gravel	*Sand*	*Silt/Clay*[a]	*Total*[b]	*Catchment*[c] *Area (km^2)*
Matilija Creek[d]	10,000	16,000	134,000	160,000	139.8
North Fork Matilija Creek[e]	2,850	4,570	42,580	50,000	39.9
San Antonio Creek[f]	4,750	7,620	167,630	180,000	157.4

a. Silt/clay supply rates estimated as total supply minus gravel and sand supply;
b. Total sediment supply estimated based on the assumption of 3,000 t/km^2/yr production rate (Stillwater Sciences 2014b);
c. Drainage area provided by BOR (unpublished document);
d. Gravel and sand supply rates based on volumes of gravel and sand deposits in Matilija Dam impoundment in 2005 provided in (Stillwater Sciences 2014b);
e. Gravel and sand supply rates estimated based on the assumption that sediment production rate in the Matilija Creek and North Fork Matilija Creek watersheds are identical;
f. Gravel and sand supply rates estimated based on the assumption that gravel and sand supply from San Antonio Creek and North Fork Matilija Creek have a ratio of 5:3 based on the analysis of BOR (2006), Table 5.16.

The estimated total sediment supply from the three sources in **Table 5** (390,000 m^3) compared remarkably well with the BOR (2006) estimate of total sediment load delivered to the ocean at equilibrium condition (i.e., no Matilija Dam) of 548,000 cubic yards, or 419,000 m^3 (Table 5.18 on page 137 in BOR 2006), because 20% of the sediment delivered to the ocean is likely contributed from other, smaller catchments.

A.9 Rating Curves for Sediment Supply

Gravel, sand, and silt/clay (wash load) supply rating curves can be expressed in the general form

$$Q_g = a_1 {Q_w}^{b_1}\ ;\ Q_s = a_2 {Q_w}^{b_2}\ ;\ Q_{si} = a_3 {Q_w}^{b_3} \qquad \text{(2a,b,c)}$$

in which Q_g, Q_s, and Q_{si} denote gravel, sand, and silt/clay transport rates, respectively; Q_w denotes water discharge; and a_1, b_1, a_2, b_2, a_3 and b_3 are coefficients.

The exponent for gravel transport b_1 should be almost identical in all watersheds of gravel-bedded rivers as demonstrated in Stillwater Sciences (2014a). The exponent b_1 derived by DREAM-2 modeling results in Alameda Creek, CA has a value of 3.08 (Stillwater Sciences 2014), and the b_1 value for the Trinity River derived from bedload sampling data has a value of 2.89 (**Figure 35**) (Gaeuman 2014). The study of Barry et al. (2004) indicate that, although b_1 values are somewhat correlated to the surface to subsurface characteristic grain size ratio, they are centered around a value of 3.0 with a range of between approximately 1.5 to 3.8. Here a b_1 value of 3.0 is used in all the sub-watersheds for modeling purposes.

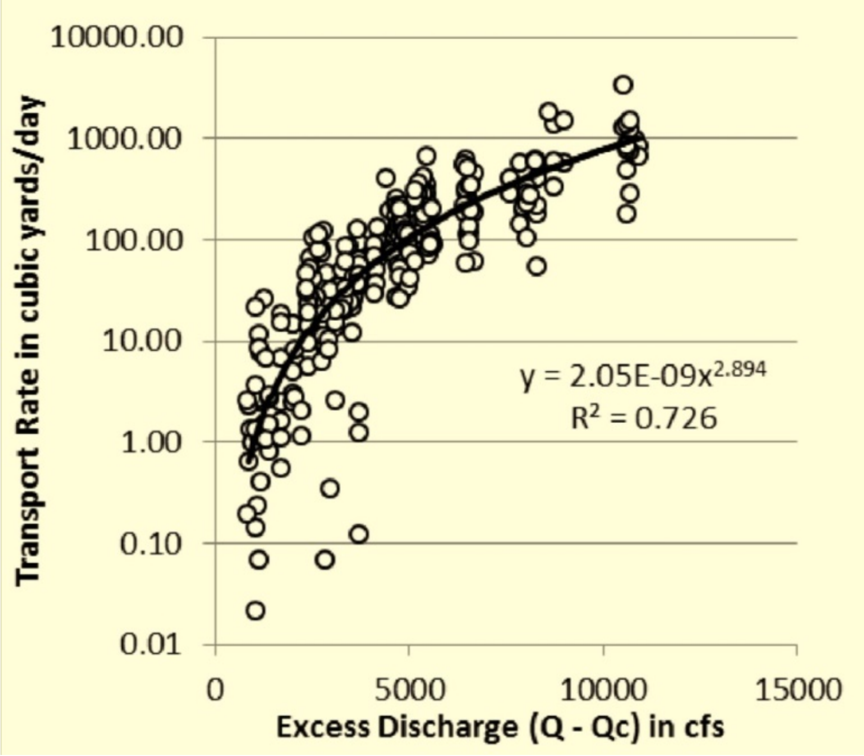


Figure 35. Gravel transport rating curve in the Trinity River, CA, showing gravel transport rate is approximately proportional to water discharge to the third power. This diagram is a reproduction from Gaeuman (2014).

The sand concentration – water discharge relations at North Fork Matilija Creek (**Figure 36**), San Antonio Creek (**Figure 37**), and Ventura River (**Figure 38**) provide the best estimate of the range of b_2 values (**Table 6**). For modeling purposes, the average b_2 value of 2.4 (the average of the three sub-watersheds) is applied in all the sub-watersheds.

Similarly, a b_3 value of 1.7 (**Figure 39**, **Figure 40**, **Figure 41**, and **Table 7**) is applied to all the sub-watersheds for modeling purposes.

Table 6. Exponent for sand transport rating curve b_2 at three USGS stations based on analysis of suspended sediment concentration data provided by BOR (2006).

	Exponent for sand transport rating curve b_2[a]
North Fork Matilija Creek (USGS #11116000)	2.2
San Antonio Creek (USGS #11117500)	2.7
Ventura River (USGS #11118500)	2.4
Average	2.4

a. Sediment transport rate = sediment concentration multiply discharge, and thus, the exponent for sand transport rating curve should equal to the exponent presented in **Figure 36**, **Figure 37**, and **Figure 38** plus 1.

Table 7. Exponent for silt transport rating curve b_3 at three USGS stations based on analysis of suspended sediment concentration data provided by BOR (2006).

	Exponent for silt transport rating curve b_3[a]
North Fork Matilija Creek (USGS #11116000)	1.5
San Antonio Creek (USGS #11117500)	1.9
Ventura River (USGS #11118500)	1.6
Average	1.7

a. Sediment transport rate = sediment concentration multiply discharge, and thus, the exponent for sand transport rating curve should equal to the exponent presented in **Figure 39**, **Figure 40**, and **Figure 41** plus 1.

Coefficients a_1, a_2, and a_3 in Equations (2a,b,c) are calculated within the model using the b_1, b_2, and b_3 values above in conjunction with the estimated long-term sediment supply rates (**Table 5**) and the long-term discharge record provided to the model. The so obtained a_1, a_2, and a_3 values for Matilija Creek, for example, are 9.1×10^{-8}, 3.2×10^{-6}, and 6.6×10^{-4}, respectively, when both water discharge and sediment supply rate are in m^3/s, resulting in sediment supply rating curves as shown in **Figure 42**.

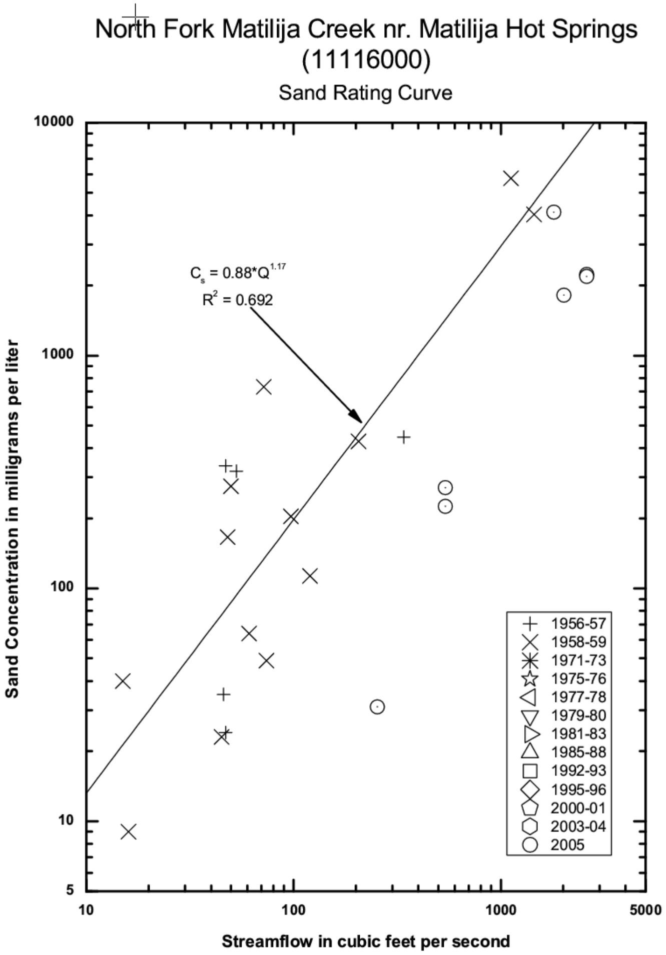


Figure 36. Sand transport rating curve at North Fork Matilija Creek near Ojai, CA. Diagram provided by BOR (2006).

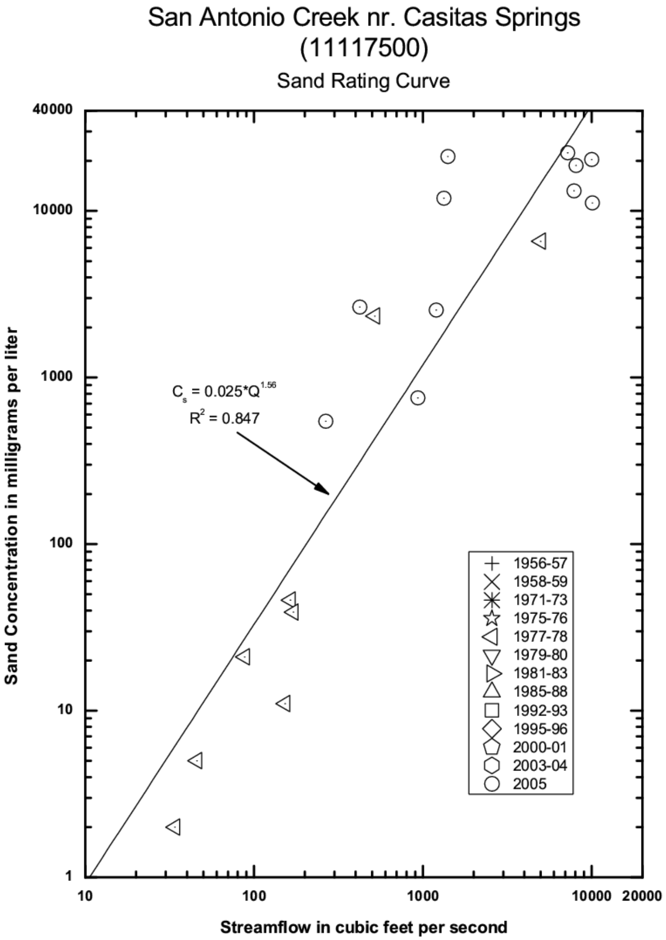


Figure 37. Sand transport rating curve for San Antonio Creek near Ojai, CA. Diagram provided by BOR (2006).

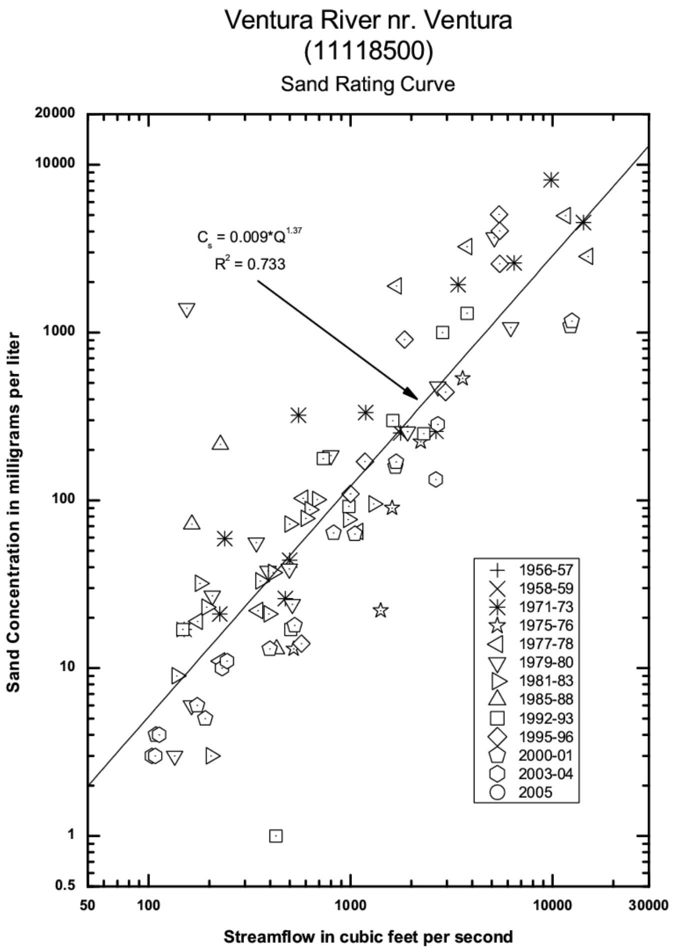


Figure 38. Sand transport rating curve in Ventura River near Ojai, CA. Diagram provided by BOR (2006).

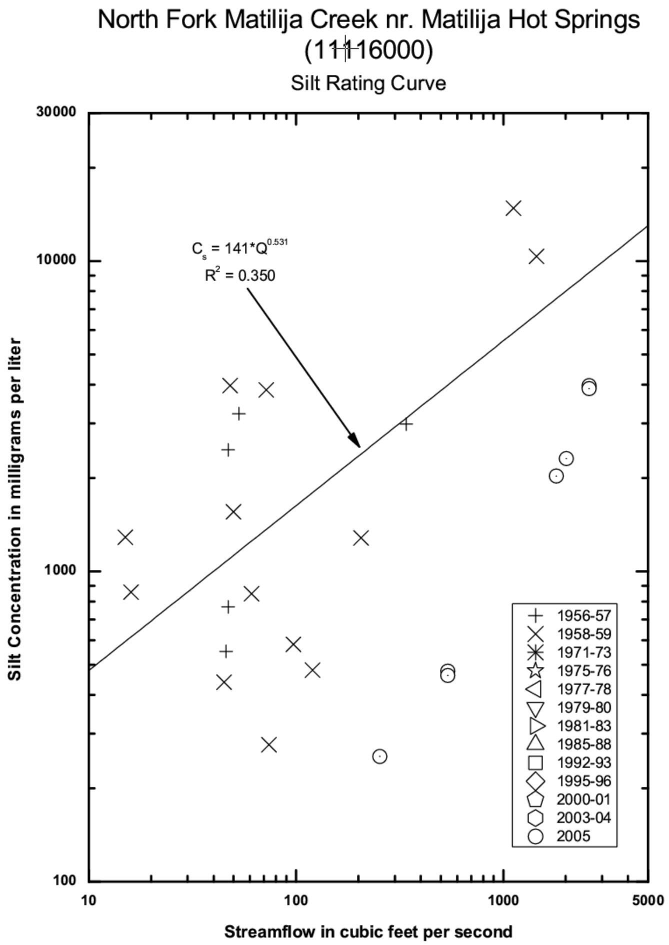


Figure 39. Silt transport rating curve at North Fork Matilija Creek near Ojai, CA. Diagram provided by BOR (2006).

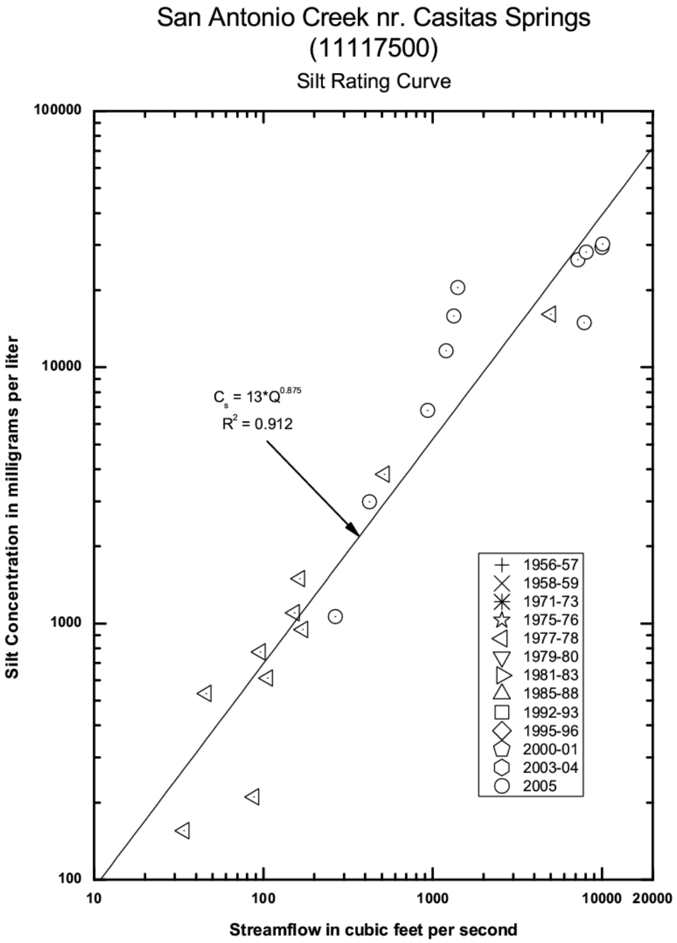


Figure 40. Silt transport rating curve for San Antonio Creek near Ojai, CA. Diagram provided by BOR (2006).

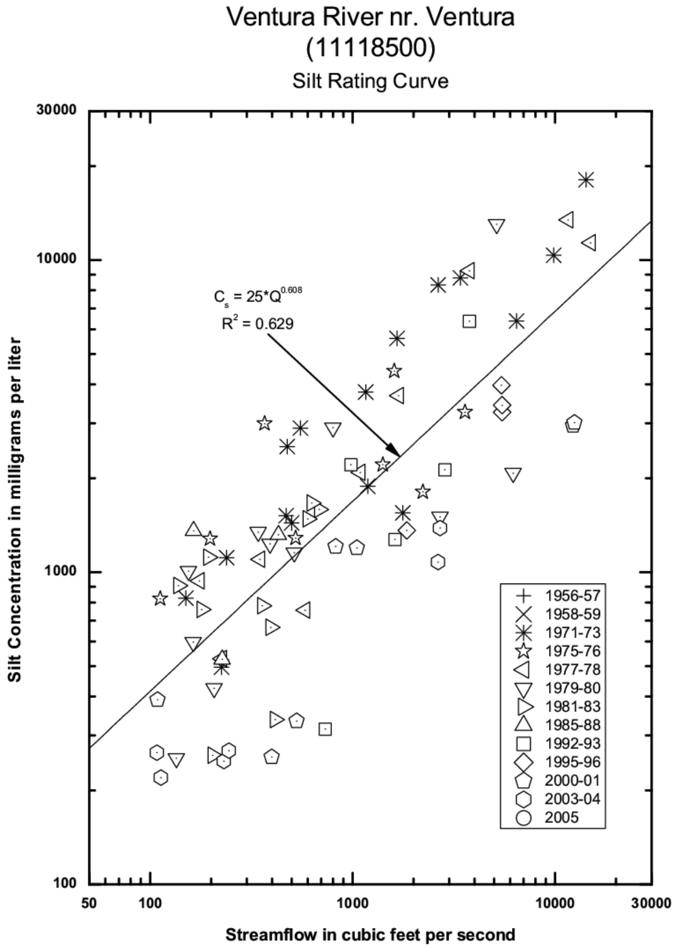


Figure 41. Silt transport rating curve in Ventura River near Ojai, CA. Diagram provided by BOR (2006).

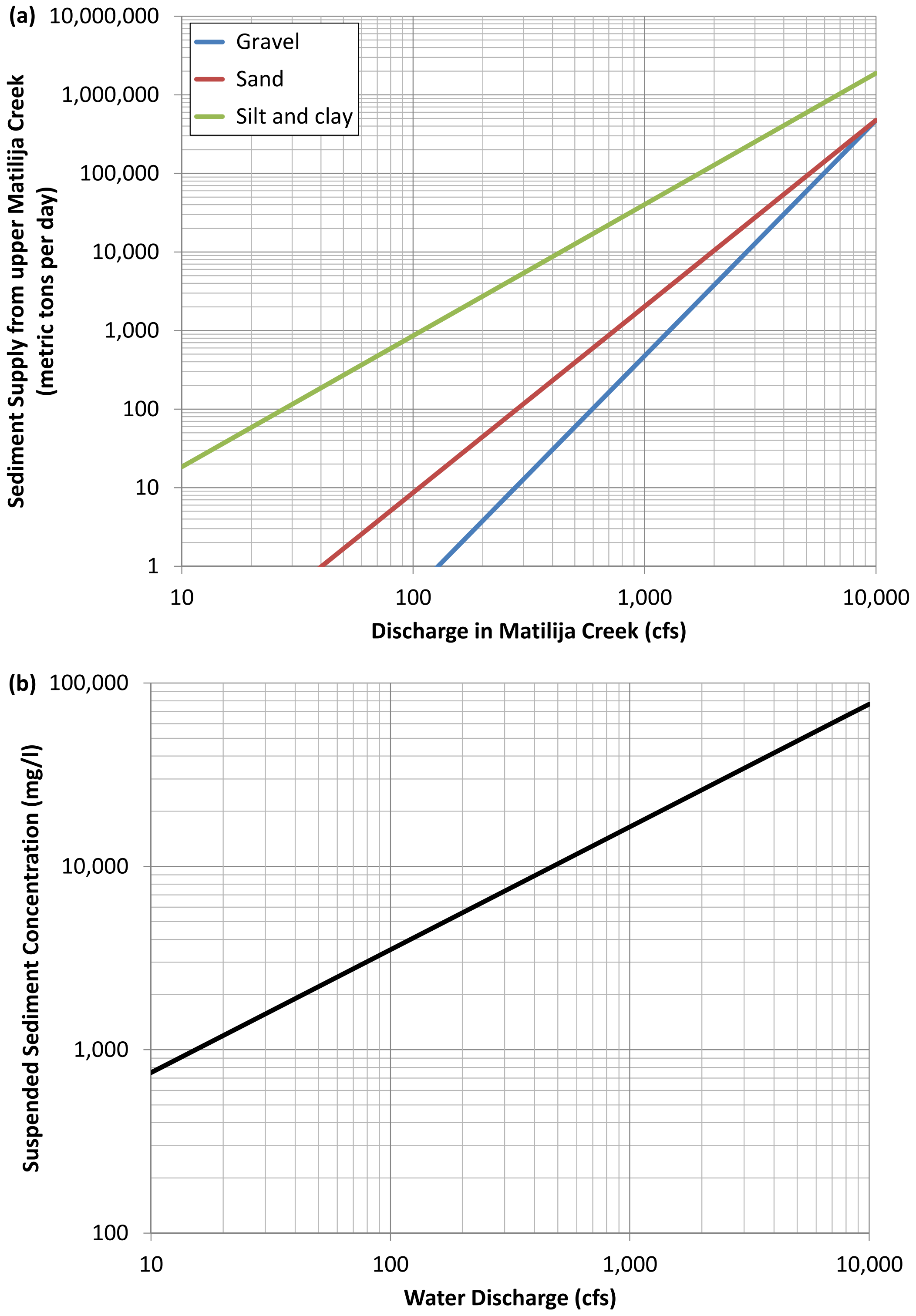


Figure 42. Derived sediment supply rating curves for the Matilija Creek. (a). Sediment supply; (b). suspended sediment concentration.

A.10 Model Zeroing Process

A zeroing process attempts to adjust input parameters so that the model reasonably reproduces the observed channel longitudinal profile downstream of the dam under the current conditions. In a previous dam removal study in the Sandy River, Oregon, it was assumed that the river is in a quasi-equilibrium state, where the river experiences minimal cumulative channel aggradation or degradation based on the fact that sediment had been passing through the dam for several decades (Stillwater Sciences 2000; Cui and Wilcox 2008; Cui et al. 2014). Upon finishing the zeroing process, the modeled quasi-equilibrium profile, which is similar but not identical to the observed longitudinal profile, is then used as the initial condition to model sediment transport dynamics following dam removal. The biggest advantage of applying such a zeroing process is that any channel aggradation/degradation simulated with the model can be interpreted as the direct result of dam removal.

Although a strict quasi-equilibrium assumption is not applicable in the Matilija Creek and the Ventura Creek because of the presence of Robles Diversion Dam, the sediment removal operation in Robles Diversion forebay, and because Matilija Dam is trapping 100% of the incoming gravel and sand load, the following zeroing process that considered the geomorphic history of the river due to the construction of Matilija Dam and the sediment removal operation at Robles Diversion Dam is conducted.

- It is assumed that the Matilija Creek and Ventura River were in a quasi-equilibrium state prior to the construction of Matilija Dam. This assumption allowed the model to run for a long time (2000 years) using the pre-dam construction sediment supply conditions to simulate a pre-dam quasi-equilibrium longitudinal profile (pre-dam profile hereafter). During this zeroing run the grain size distributions of the gravel supply from the Matilija Creek, North Fork Matilija Creek and San Antonio Creek were adjusted so that the simulated pre-dam profile is slightly higher than the observed profile in 2001. At the end of the 2000 year simulation, the simulated long-term channel aggradation or degradation at any point is limited to no more than 0.1 m per 100 years.

- Starting with the pre-dam profile, an 18-year simulation is then conducted to model the channel process between 1948 and 1965 after Matilija Dam construction and before Casitas Municipal Water District (CMWD) started to clean sediment from the Robles forebay. Base elevation at the current Robles Diversion Dam location was increased by 4 m (13 ft) in 1958, representing the construction of Robles Diversion Dam. Gravel and sand supply from the Matilija Creek is assumed to be zero during this period of time because of the trapping in Matilija Dam. This simulation produces a simulated profile at the beginning of 1966 (termed the "simulated 1966 profile" hereafter).

- Starting with the simulated 1966 profile, a 49-year simulation is then conducted to model the channel process between 1966 and 2014. During this period, the gravel and sand supply from the Matilija Creek remains zero because Matilija Dam continues to trap all the upstream gravel and sand load. Meanwhile, CMWD started to remove a significant amount of sediment from the Robles forebay area to keep the diversion working properly.

> According to BOR (2006), an estimated 559,000 cubic yards (bulk volume) was removed during the 33-year period between 1966 and 1998, or approximately 256,000 m^3 solid assuming a porosity of 0.4 for the removed sediment, which translates to approximately 7,800 m^3/yr (solid) of sediment removal rate. Note in **Table 5** the estimated long-term gravel and sand supply from North Fork Matilija Creek is approximately 7,420 m^3/yr (solid, 2,850 m^3/yr gravel, 4,570 m^3/yr sand), and no gravel or sand was supplied from Matilija Creek during this period of time. That is, the sediment removal operation at Robles Diversion Dam likely has been removing most, if not all, of the gravel and sand coming out of the North Fork Matilija Creek. Most of the removed sediments were disposed of offsite, while some are disposed in the overflow channel downstream of the cutoff dam (Neil Cole, per. com., 6 June 2014), of which only a small fraction, if any, was released to the channel and transported downstream. Because DREAM-2 model does not have a module to handle Robles Diversion Dam sediment removal, the sediment supply from North Fork Matilija Creek was reduced to serve as an approximation of the sediment removal effort at Robles forebay. Here it was assumed that the sediment placed in the overflow channel was not reached by the high flow during the period of 1966 and 2014, and as a result, assumed zero gravel and sand supply rates from the North Fork Matilija River for the modeling of this period (i.e., 1966 – 2014). The simulated 2014 profile was used to serve as the initial profile for the simulation of sediment transport process following Matilija Dam removal.

The simulated longitudinal profile of the river in 2014 is similar to the observed profile in 2001, and is slightly lower than the simulated 1947 (pre-dam) and 1965 (pre-Robles Dam sediment removal) profiles because of the trapping of sediment in Matilija Dam impoundment and removal of sediment from Robles forebay area (**Figure 43**). In producing the simulated 2014 profile shown in **Figure 43**, the model had adjusted the bed profile over a 2000+ year simulation as illustrated in **Figure 44**, where bed elevations asymptotically approaches a quasi-equilibrium profile over the first 2000 years simulation, followed by channel degradation after Matilija Dam closure.

To achieve the results presented in **Figure 43** and **Figure 44**, the grain size distributions of the gravel supply from the Matilija Creek, North Fork Matilija Creek and San Antonio Creek were adjusted by trial-and-error: choosing grain sizes of the gravel supply too fine would result in a simulated 1947 profile lower than the 2001 surveyed profile, and gravel grain sizes too coarse would result in a simulated 2014 profile higher than the 2001 surveyed profile. The selected final grain-size distributions of the gravel supply from the three sources obtained through trial-and-error are provided in **Figure 45**.

No further adjustment was applied to the early assumption of a volumetric abrasion coefficient of 0.02 km^{-1} during the zeroing process.

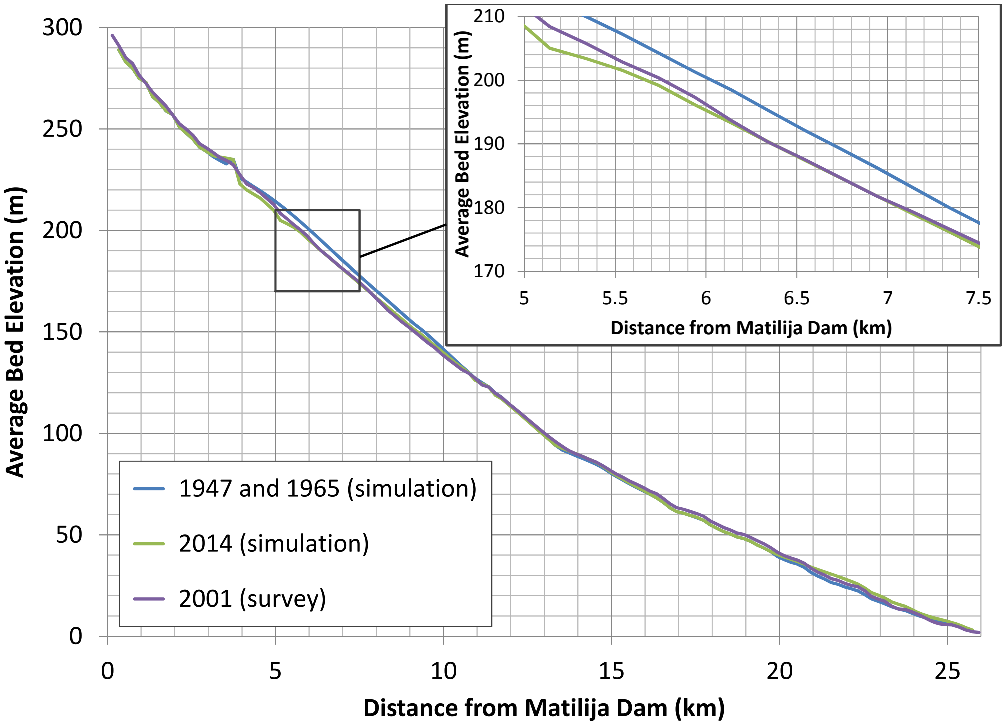


Figure 43. Comparison of simulated profiles in different years during the zeroing process in comparison with the 2001 survey data. Note the simulated 1947 and 1965 profiles almost completely overlap with each other.

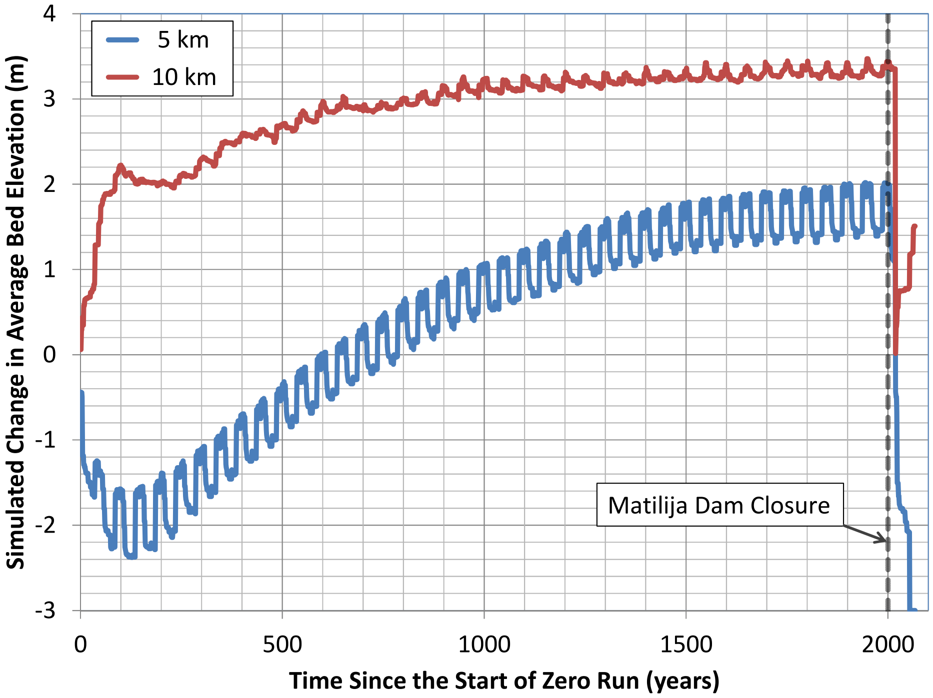


Figure 44. Simulated change in average bed elevation during the zeroing process at two locations, showing asymptotic approach to quasi-equilibrium state, followed by channel degradation after Matilija Dam closure. The periodicity shown in the results is an artifact of repeating 50-year flow record in the simulation.

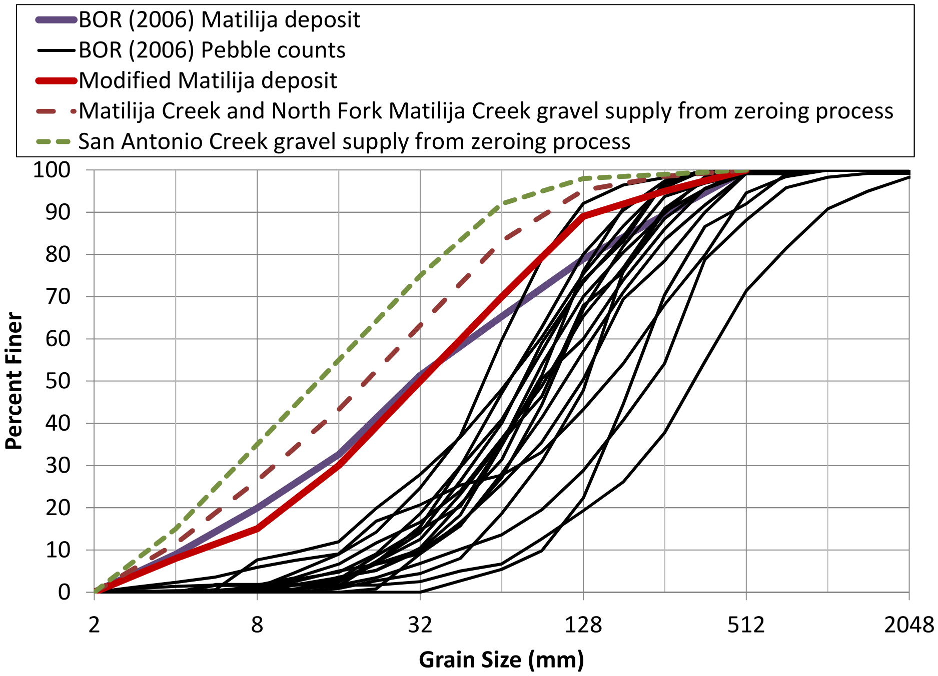


Figure 45. The assumed grain size distributions of gravel supply from Matilija Creek, North Fork Matilija Creek, and San Antonio Creek, obtained during zeroing process through trial-and-error and in reference with the estimated grain size distribution of the gravel deposit in Matilija Dam impoundment. Gravel grain size distributions for Matilija Dam deposit and Ventura River surface pebble counts are also shown in the diagram for comparison purposes.

Although the simulated bed profiles in **Figure 43** provided the general morphological responses of the river due to the construction of Matilija Dam and sediment removal at Robles forebay, they do not exactly match the survey data in 1970 and 2001 provided in BOR (2006). According to the two surveys, up to 2 m (6 ft) of channel degradation had occurred immediately downstream of Robles Diversion Dam, which was fairly closely reproduced by the model. There is also up to 3.3 m (10 ft) channel degradation observed approximately between 17 and 19 km downstream of Matilija Dam (BOR 2006), while the simulation produced less than 1 m (3 ft) of channel degradation. It is believed that the observed channel degradation in this reach (i.e., between 17 and 19 km downstream of Matilija Dam) was primarily geomorphic response of the river to the construction of Casitas Dam, which trapped all the bedload while still sending down high flows occasionally when Casitas Reservoir is full. The process from the tributary where Casitas Reservoir is located is not represented in the model.

The simulated 2014 profile was used as the initial profile for all the model runs presented in Section 2 of this technical memorandum.

A.11 References Cited in the Attachment

The references cited in this Attachment (and subsequent appendices) have been consolidated into the main document’s reference section (Section 4 of the main report).

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

DAM REMOVAL CONCEPTS EVALUATION REPORT

MARCH 2016

ATTACHMENT 1: HYDROLOGIC ASSESSMENT, TASK 2.1

Stillwater Sciences

2855 Telegraph Ave, Suite 400, Berkeley, CA 94705
phone 510.848.8098 fax 510.848.8398

TECHNICAL MEMORANDUM

DATE:	June 3, 2014
TO:	Management Team, Matilija Dam Ecosystem Restoration Project
FROM:	Derek Booth PhD PE PG, Stillwater Sciences
SUBJECT:	Matilija Dam Removal, Sediment Transport, & Robles Diversion Mitigation Study HYDROLOGIC ASSESSMENT, Task 2.1

1 INTRODUCTION

This memo summarizes hydrologic data, data sources, prior hydrologic investigations, and key attributes of flow conditions in Matilija Creek and the Ventura River that are anticipated to be relevant to evaluating alternatives for the removal of Matilija Dam. It includes preliminary identification of "hydrologic scenarios that will be utilized in the sediment transport and flood assessments, based primarily on the existing gage and rainfall records from the Ventura River watershed" (from the original Scope of Work for Task 2.1).

These analyses are not intended to be final, however, insofar as definition of suitable hydrologic scenarios (whether historical or synthetic) depends in part on the final choice of dam-removal scenarios and the detailed needs of the selected sediment-transport model. In addition, a variety of other hydrologic attributes and issues not directly anticipated by the original scope language are also likely to prove relevant in the evaluation, selection, and analysis of dam-removal scenarios, and so they are included in the following discussion as well.

Thus, the purpose of this document is three-fold:

1. Provide an overall characterization of the hydrology of the Matilija–Ventura watershed, with particular emphasis on the episodicity of extreme events that is likely to influence the selection of dam-removal scenarios.
2. Analyze the hydrograph of the Ventura River and Matilija Creek over the full period of record to identify other specific attributes of those records that are likely to affect the feasibility and implementation of one or more prospective dam-removal scenarios.
3. Generate (or otherwise identify) the scope-specified "hydrologic scenarios that will be utilized in the sediment transport and flood assessments," at a level of detail sufficient to support the screening of initial dam-removal options, and with the expectation of further refinements once the option(s) advancing to more detailed analysis have been determined. This topic is covered in the last section of the memo.

2 DATA SOURCES, TIME SPAN, AND PRIOR INVESTIGATIONS

Most of the data compiled and analyzed herein come from web-accessible flow data provided by the US Geological Survey. Data from the following gages have been compiled on an average daily flow basis (Table 1 and Figure 1). Additional gages have been operated in the watershed by the Ventura County Watershed Protection District, although their data have not been incorporated into the present analysis.

Table 1. USGS flow gages and dates of record in the Ventura River watershed.

Stream and Gage #	Lat.	Long.	Drainage area (mi^2)	Begin date	End date	Decades covered by gage record									
						1920	1930	1940	1950	1960	1970	1980	1990	2000	2010
Matilija Ck:															
11114495	34°30'10"	119°21'23"	47.8	2/15/2002	present									🟧	🟧
11114500	34°29'41"	119°19'48"	50.7	6/1/1948	9/30/1969			🟧	🟧	🟧					
11115500	34°28'58"	119°18'03"	54.6	10/1/1927	9/30/1988	🟧	🟧	🟧	🟧	🟧	🟧	🟧			
North Fk Matilija:															
11116000	34°29'33"	119°18'20"	15.6	10/1/1928	9/30/1983	🟧	🟧	🟧	🟧	🟧	🟧	🟧			
Matilija + N Fk Matilija:															
11116500	34°29'06"	119°17'50"	70.7	10/1/1911	6/30/1924	🟧									
Ventura River:															
11116550	34°27'54"	119°17'20"	76.4	6/1/1959	9/30/1988					🟧	🟧	🟧			
11118500	34°21'08"	119°18'27"	188	10/1/1929	present		🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧

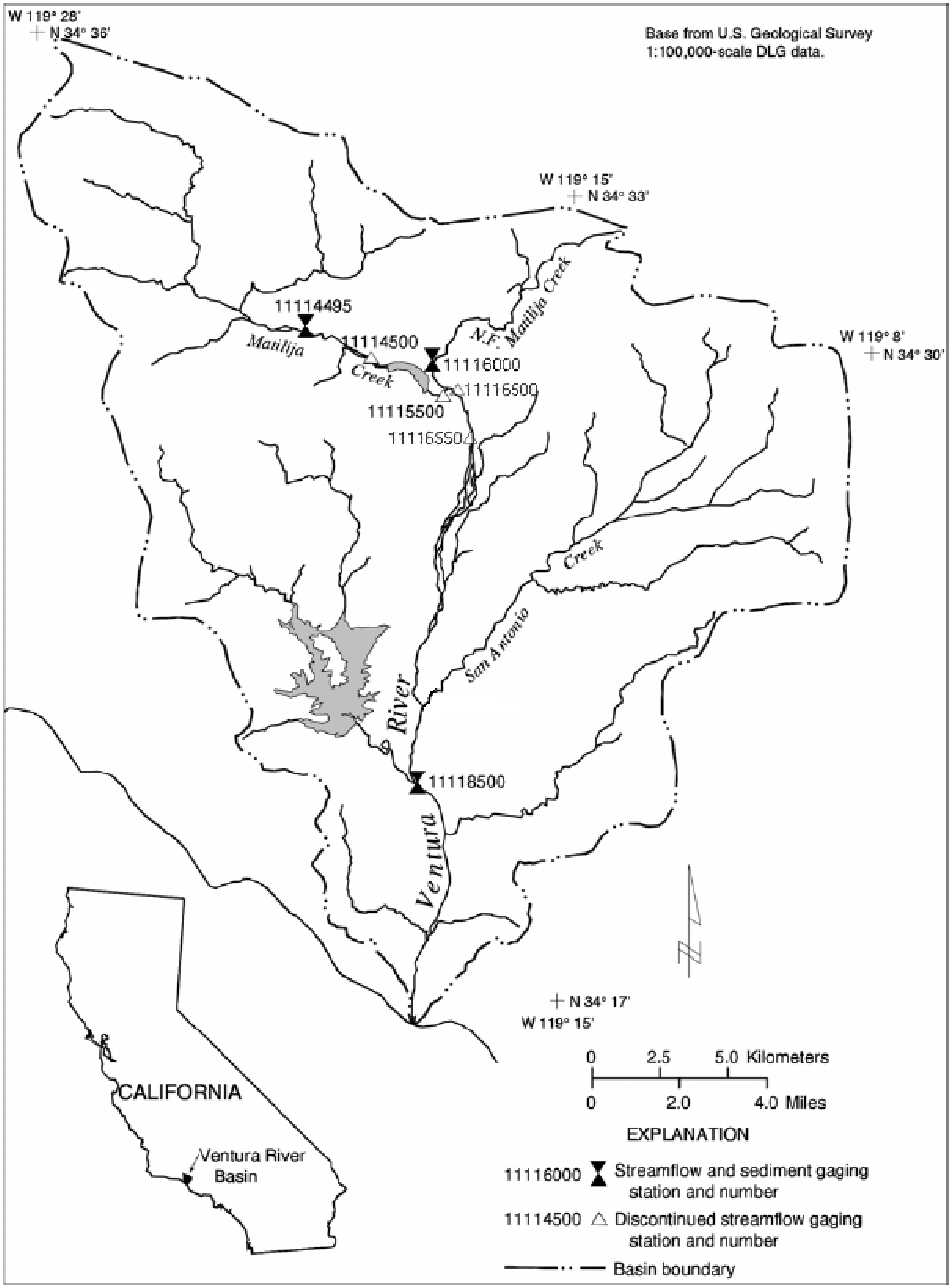


Figure 1. Map of stream gages in the Ventura River watershed considered in this analysis (modified from Figure 2.1 of BOR 2006).

In addition, peak annual instantaneous floods were compiled for the 7 gages listed in Table 1, and analyses of flood frequency and flow durations were compiled from Colorado State University's on-line *Environmental Risk and Management System* (www.erams.com/), which provides a convenient platform for analysis of the USGS gage data (or any other data series) using standard hydrologic tools (in particular, Bulletin 17B for flood-frequency analysis). Note, however, that BOR (2006, p. 42) warned that "It is expected that the distribution does not work well in this region of the county because of the peculiarities of the weather patterns." Adjustments have not been made at this stage in the analysis, pending a determination of whether or not they are important to the management issues now being explored.

Finally, individual Excel workbooks covering the years 1993–2013 were provided by the Casitas Water District, documenting daily reservoir, meteorological, and diversion data for this 21-year period. A subset of these data judged relevant to the characterization of watershed hydrology was extracted from these records; they were compiled and matched with USGS gage data for the corresponding dates.

These hydrologic data are readily accessible and thus have been the subject of multiple prior investigations. BOR (2006) devoted an entire chapter to the topic of hydrology, including flood-frequency analyses of multiple gages and compilation of daily average and extreme flow statistics, flow-duration curves, and Casitas diversions over the period 1991–2000. The following discussion, therefore, does not attempt to replicate this past work, but instead to augment it where the additional length of record (in particular, the floods of 2005 and 2010/2011, and the additional 13 years of Casitas diversion) yields materially expanded findings. Also discussed herein are aspects of the watershed hydrology that may have particular relevance for dam-removal alternatives currently or potentially under consideration, but that were not specifically addressed in BOR (2006).

One additional prior document, an informal 9-page memo prepared by Dr. Thomas Dunne of the Technical Advisory Committee in mid-2013 (referenced as Dunne 2013), has also been referenced in the preparation of the following text. It raises several potentially relevant points regarding the hydrology of the watershed that have not been heretofore explored in full, and it has provided the framework for several of the topics discussed below.

3 GENERAL FLOW REGIME OF THE VENTURA RIVER AND MATILIJA CREEK

The entire Ventura River system is strongly seasonal and highly episodic, with long periods of near-zero flow punctuated by moderate to extremely high discharges. This hydrologic behavior is common to much of the western Transverse Ranges and is driven by intense rainstorms over a generally steep catchment with rapid runoff response and minimal valley storage of floodwaters throughout most of the channel network (e.g., Warrick and Mertes 2009; Stillwater Sciences 2011). Hydrographs of the last twelve years (i.e., since operation of the current gage on Matilija Creek, USGS 11114495, a few miles upstream of Matilija Dam) illustrate this behavior well (Figure 2).

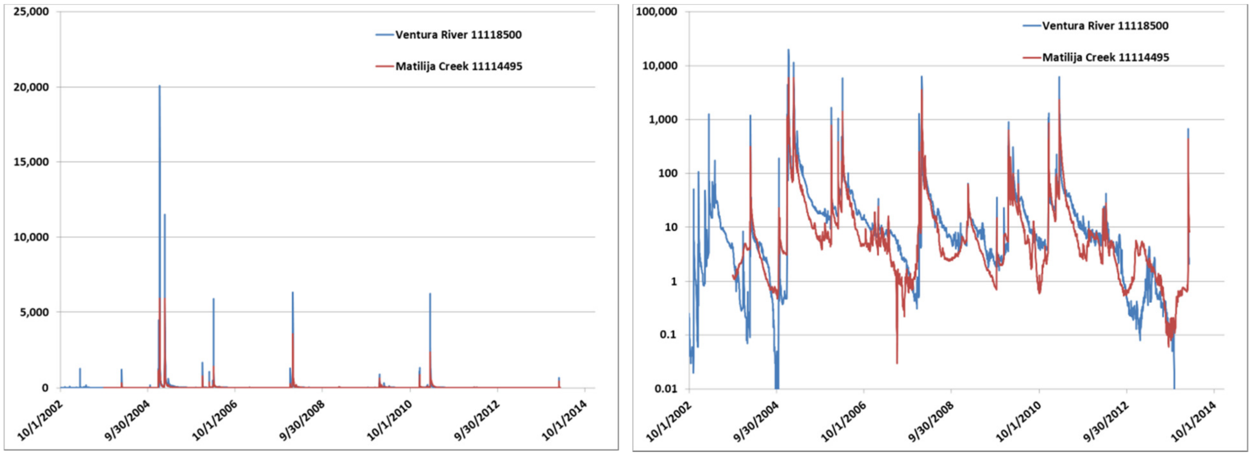


Figure 2. Hydrographs of the Ventura River and Matilija Creek for water years 2003 through mid-2014, expressed as cubic feet per second (cfs) on arithmetic (left) and log (right) scales. The former emphasizes the dramatic variability of this system, with individual flow events of typically a few days' to a few weeks' duration, separated by one to several years of very low flow; the latter shows that that flow is minimal but almost always non-zero in both channels at the gage locations. Both graphs also show the close correspondence of tributary (Matilija) and mainstem (Ventura) flows at the resolution of a daily time step.

Based on conversations with California Department of Fish and Wildlife (Dana McCanne, pers. comm., Environmental Scientist, South Coast Region Steelhead Monitoring Program, California Department of Fish and Wildlife, April 3, 2014), these 2003–2014 gage data are broadly representative of hydrologic behavior over the entire period of record. During most years the mainstem Ventura River is wet from the confluence of San Antonio Creek (about two miles upstream of 11118500) to the estuary. There is typically perennial flow from Matilija Creek (also see Figure 2, right panel), but a losing reach from the Camino Cielo road crossing, downstream of Matilija Dam, past the Robles Diversion, and continuing downstream as far as the confluence with San Antonio Creek results in dry riverbed conditions during portions of most years. Summer 2013 was unusually dry, and the mainstem Ventura River dropped to nearly unprecedented levels (Figure 2, right panel) but still with areas of wetted habitat. Under almost all less extreme conditions, there are typically measurable numbers of *O. mykiss* rearing in the mainstem.

4 ANALYSES

4.1 Data Quality

Gaging intermittent and multi-channel rivers of southern California has commonly proved to be challenging, particularly in unconfined reaches with mobile beds. Although Matilija Creek and the Ventura River are primarily gravel- and cobble-bedded over much of their length, and so not as highly mobile as (for example) the Santa Maria River (Booth et al. 2013; Stillwater Sciences and Kear Groundwater [2012], which included an extensive evaluation of gage data quality), a degree of caution is nonetheless warranted in working with any such data. For example, the 2013 annual Water-Data Report for gage 11114495 rates the data quality as "poor" (i.e., >15% divergence of recorded from actual); that of gage 11118500 rates the quality no better than "fair" (10–15% error; and worse at very low flows). Based on records from around the region, gaging of very high flows is also likely to carry significant errors (e.g., Booth et al. 2013).

Two USGS gages on Matilija Creek (11114500 and 11115500) operated simultaneously for 21 years (6/1/1948 through 9/30/1969), providing a limited opportunity to evaluate the consistency of these flow data. They lay on opposite sides of Matilija Dam, which BOR (2006) noted provides minimal attenuation of flows greater than about a 5-year return interval and likely even less influence following the dramatic shrinkage of the reservoir volume following the 1969 storms. Table 2.3 of BOR (2006) showed measured peak flows up- and downstream of the dam for 7 events, with the greatest attenuation being more than 2-fold for the earliest (1/15/1952). Comparison of the average daily flows for these two gages on this same date show even greater differences but less than 5% difference on the day following. In January 1969, differences in average daily flows between the two gages were typically less than 10%, not only for the very high-flow days (e.g., >3,000 cfs) but also for the intervening flows of only one to several hundred cfs. Low flows upstream and downstream of the dam track each other almost exactly through the rest of that water year (after which the upstream gage 11114500 was retired), a consistency suggesting that flow records are broadly accurate. These data also affirm BOR (2006)'s conclusion of minimal flow attenuation by the dam.

4.2 Relationship between Flows in Matilija Creek and the Ventura River

Evaluating the relationship between flows in these two channels is likely to be useful for future applications, because the natural transport of sediment out of the Matilija reservoir area will depend exclusively on flows in Matilija Creek (as presently measured at gage 11114495, and previously by gages 11114500 and 11115500) but will continue down the Ventura River only insofar as mainstem discharges (as represented here by measurements at gage 11118500) are also sufficiently high. The availability of historical flow data is greater on the Ventura River than on Matilija Creek, and so establishing a relationship may also enable the extrapolation of an extended record beyond that available for Matilija Creek.

The records of flows in these two channels overlap almost continuously from 1929 through to the present day, except for water years 1989–2001 (inclusive) when gage 11115500 had retired and gage 11114495 had not yet come into service, and they bracket the closure of Matilija Dam (1948). Thus, flows from 19 years pre-dam and more than 50 years post-dam are available for comparison. Inspection of these data (Figure 3) suggest that (1) on a daily average basis, flows in Matilija Creek below the dam are almost exactly one-third those in the mainstem Ventura River at gage 11118500, only modestly greater than the 25–29% fraction of the contributing watershed area; and (2) the presence of Matilija Dam has not significantly influenced the larger daily average flows that most strongly determine the correlations.

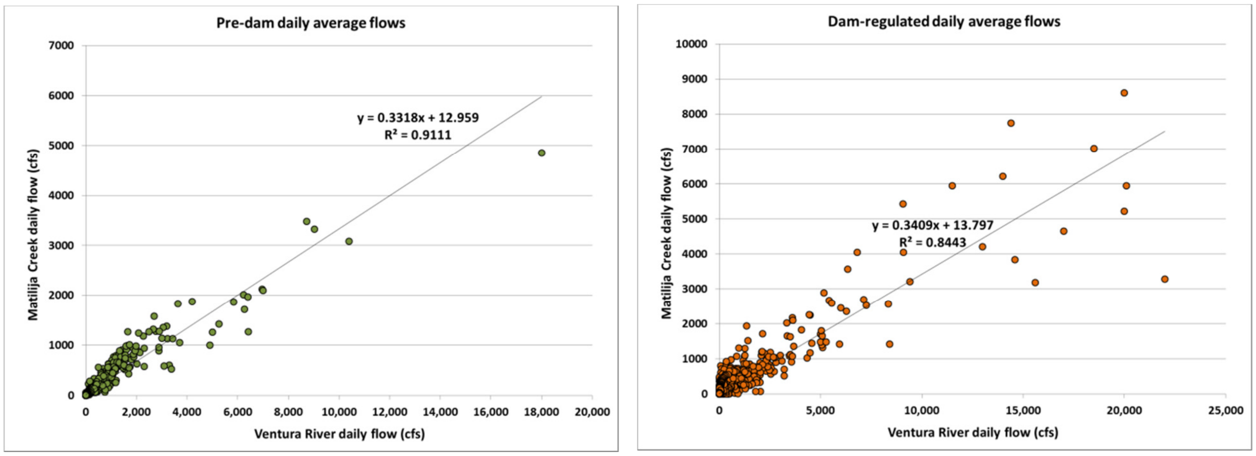


Figure 3. Same-day average flows for the Ventura River at gage 11118500 (x axis) and Matilija Creek (y axis) for the pre-dam (left) and dam-regulated (i.e., post- 4/14/1948) (right) periods. Correlations suggest a 3:1 ratio of flows and no significant systematic differences between the two periods.

4.3 Daily Average vs. Peak Instantaneous Flow

Given the availability of both daily average and annual maximum flow data, their relationship can be plotted and quantified. The value of such a relationship is that daily discharges are available throughout the period of record for all gages, but instantaneous values are only readily available for a single flow (the annual flood) each year. Dunne (2013) found that the ratio is about 35% at the 11118500 gage, a result that is confirmed here and plotted in Figure 4 (left panel). Albeit with much more limited data, the ratio of average to peak flows for Matilija Creek at gage 11114495 is 57%.

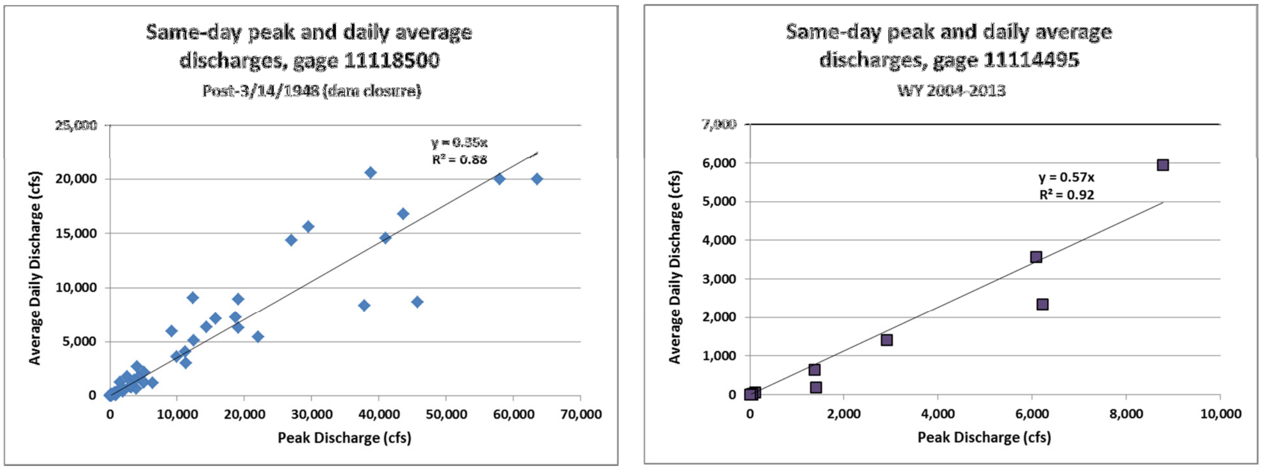


Figure 4. Same-day peak and daily average flows for the annual flood on the Ventura River (left, gage 11118500) and Matilija Creek (right, gage 11114495) for the dam-regulated period. Correlations suggest an average daily flow of about 35% of the same-day instantaneous peak flow on the Ventura River (but with a range from 19-73% for individual events >10,000 cfs) and 57% on Matilija Creek.

4.4 Historical Levels of Significant Sediment Transport

Detailed sediment-transport modeling is reported in BOR (2006) and more will be accomplished as part of the Matilija Dam Removal, Sediment Transport, and Robles Diversion Mitigation Study (of which this memo is a part). There is no intention here to replicate prior efforts or anticipate the potential range of future work; however, initial screening of alternatives will require some knowledge of the general flow levels at which significant sediment movement has historically occurred under present conditions of watershed sediment delivery and sediment sequestration in Matilija Lake. Dunne (2013) judged that moving a significant suspended load (i.e., greater than a few thousands or tens of thousands of tons/day) since 1948 has required a flood peak in the Ventura River at gage 11118500 of ≥15,000 cfs and an average daily flow of ≥5,000 cfs. This conclusion is corroborated by the plot of average daily discharge vs. measured daily suspended sediment loads at 11118500 (Figure 5, as reported on the USGS National Water Information System) over the period of sediment measurements (2/26/1969 through 9/27/1986, with a 4-year gap in reported sediment measurements during WYs 1981–1984).

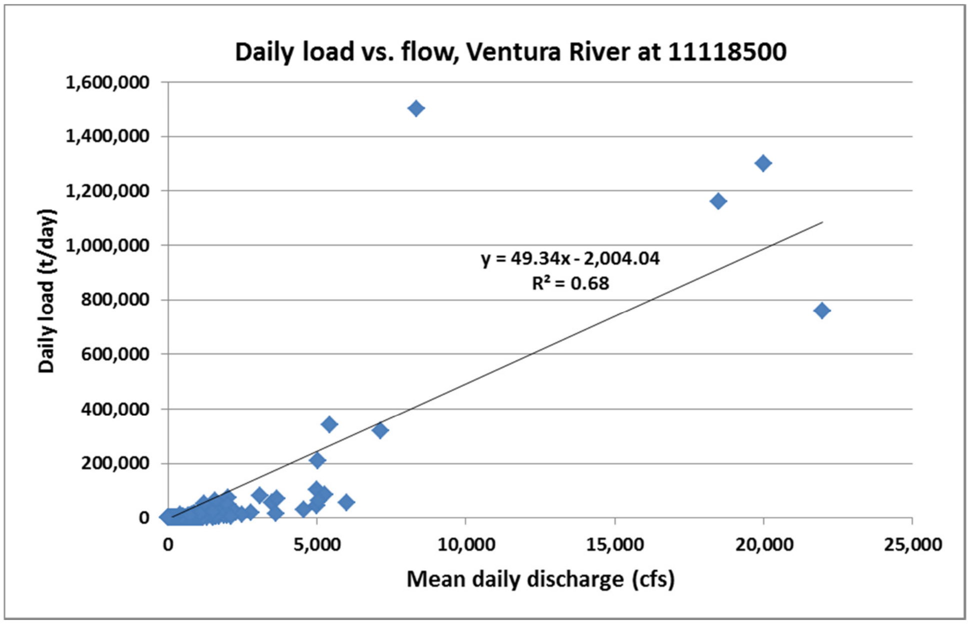


Figure 5. Comparison of mean daily (water) discharges and daily suspended sediment loads on the Ventura River at gage 11118500 for the period 1969-1989. The highest reported value (1.5M tons) occurred on 2/16/1980, although the peak flow was only the fourth largest in the record of simultaneous sediment-flow measurements.

From an inspection of these data, daily suspended sediment loads increase substantially as average daily flows increase beyond about 5,000 cfs—flows at or above this discharge have not "guaranteed" significant transport (i.e., in excess of 100,000 tons/day), but all flows that do carry loads at or above this value have exceeded this discharge. By reference to Figure 4, this correlates with a peak *instantaneous* discharge of about 14,000 cfs, which in turn corresponds to about a 4-year discharge (Figure 6).

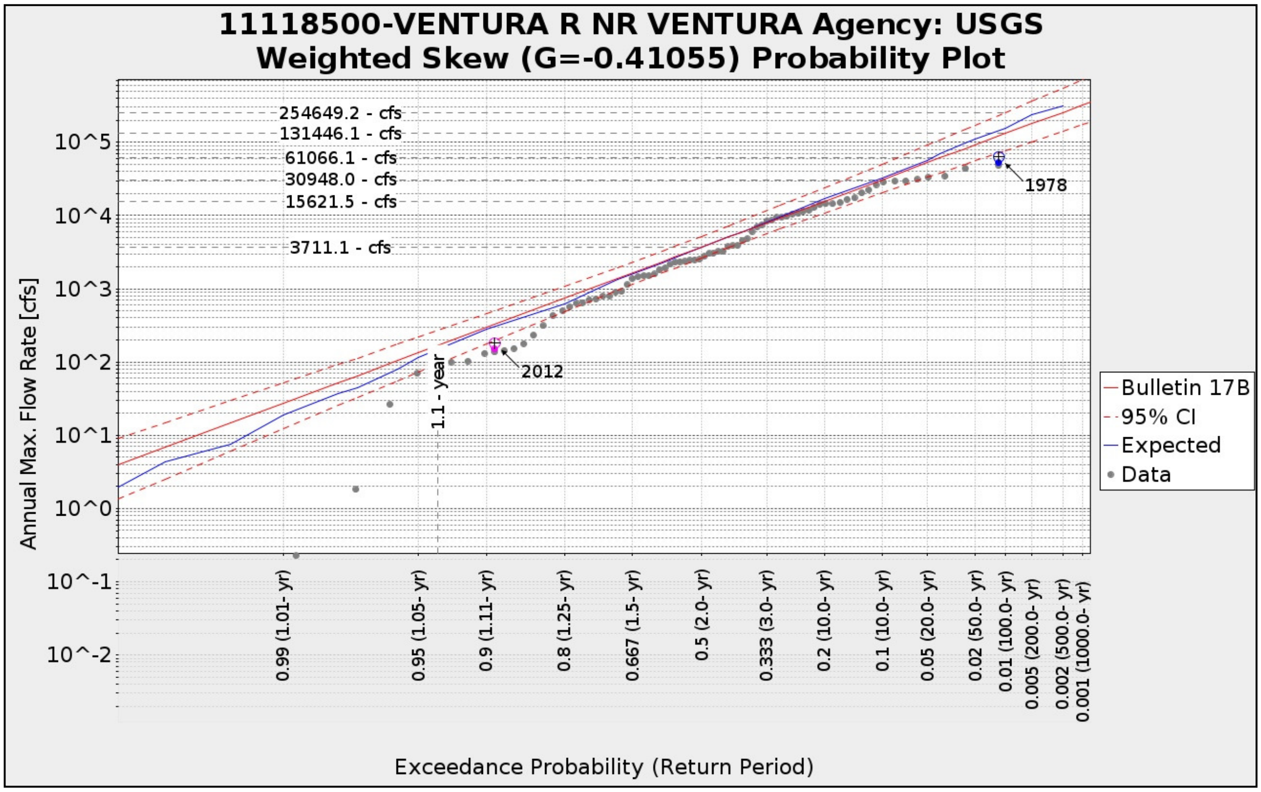


Figure 6. Flood-frequency graph for the Ventura River at 11118500, from www.erams.com. Note the incorrect label for the 0.2 exceedance flood (labeled “10-yr”, should be “5-yr”). The minimum flow historically associated with significant suspended sediment transport (see text), 14,000 cfs, is about a 4-year recurrence.

Some corroboration of this discharge value is available from the record of sediment clean-out at the Robles Diversion Dam, from data reported by the Casitas Water District (Table 2).

Table 2. Reported removal of sediment accumulated at the Robles Diversion Dam (from BOR 2006, their Table 1.5).

Year	Amount of Sediment Removed (yd^3)	Max. preceding peak (cfs)
1966	30,000	11,200
1969	Data Not Available	58,000
1973	50,000	15,700
1978	91,000	63,600
1980	71,000	37,900
1983	57,000	27,000
1986	30,000	22,100
1991	20,000	11,300
1993	Data Not Available	12,500
1995	35,000	43,700
1998	35,000	38,800

With one exception, these years correspond exactly to those years that experienced one to several days of average daily flows ≥5,000 cfs at the Ventura River gage (11118500). That exception is 1991, showing the smallest removal amount on this table and whose highest average daily flows of the year were 2,370 and 2,990 cfs. There is only one year (1992) with a 5,000-cfs flow exceedence that is *not* represented in this list, and its sediment may have been included in the "unavailable" 1993 removal data. These data suggest that the concept of a "threshold" is not absolute based on the historical record but may be a useful construct for planning purposes.

Somewhat more tenuously, the relationships displayed in Figure 3 and Figure 4 suggest that a 5,000-cfs daily average flow on the Ventura River will likely correlate with a flow about 1/3 of this magnitude on Matilija Creek, and that this average daily flow on Matilija Creek will in turn be associated with an instantaneous peak flow about 75% higher—in other words, an instantaneous flow of about 3,000 cfs at gage 11114495. Perhaps just fortuitously, this is *also* about a 4-year recurrence on Matilija Creek (Figure 7).

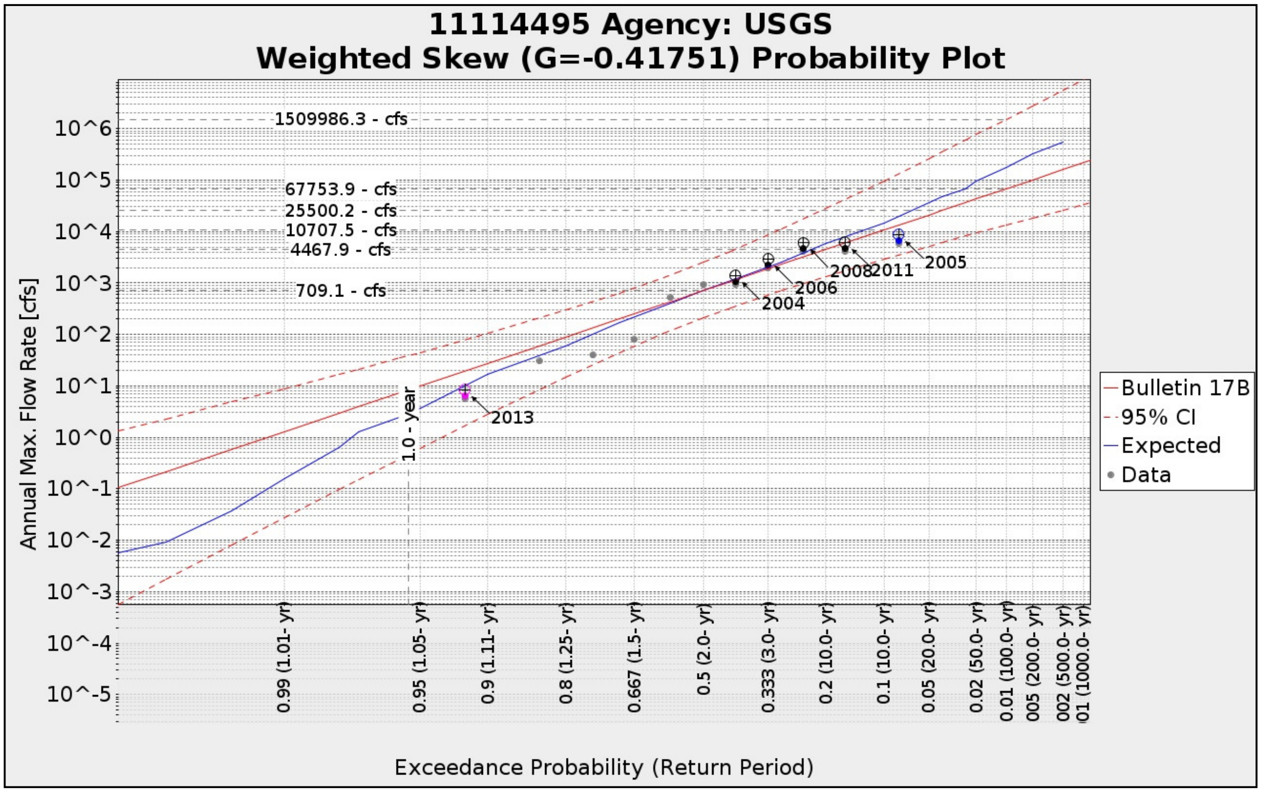


Figure 7. Flood-frequency graph for Matilija Creek at 11114495, from www.erams.com. Note the incorrect label for the 0.2 exceedance flood (labeled "10-yr", should be "5-yr"). By analog to the Ventura River data (Figure 6), the minimum flow in Matilija Creek historically associated with significant sediment transport is about 3,000 cfs, a 4-year recurrence.

4.5 Flow Episodicity

The value of identifying a flow threshold for significant sediment transport, however crude, is in the ability to consider the frequency at which sediment-transporting events might be anticipated in a post-dam flow and sediment regime. This historically based analysis, however, suffers from one potential limitation that may require further (re)analysis once transport modeling begins in earnest: the empirical measurement of sediment transport is a function of both transport capacity and sediment supply, and the latter is likely to be dramatically altered under most potential dam-removal scenarios. Thus, the current presumption of a threshold of significant transport at a 4-year event may be overly conservative with respect to the channel's ability to transport sediment in a post-dam regime. At this stage in the analyses, however, exploring the consequences of such an assumption is nonetheless instructive.

A "4-year event" means that over a long period of record, about one-quarter of the years will express such a flood. However, the prior record of flows on this system suggests that the variability in time between such events can be quite high. This variability was noted by both BOR (2006) and Dunne (2013), but it is sufficiently critical to the planning of alternative removal scenarios that the key points will be summarized here as well.

Analysis of the average daily flows for the Ventura River (gage 11118500) and Matilija Creek (various gages, with an absence of any data from 1989 through 2001) reveal 26 water years with at least one event that meets the minimum flow criteria for "significant" sediment transport (i.e., average daily flow ≥5,000 cfs at 11118500 and/or one-third of that amount [1,667 cfs] in Matilija Creek). In all but two instances both criteria were met, and so the distinction between them is not critical for planning purposes. This averages to slightly more frequent than a 1-in-4-year occurrence, but the actual gaps between such events vary widely: from 10 years (from 1/15/1952 to 2/9/1962) to as little as 1 year (most recently, from 2005 to 2006, although the 2006 event on 4/4/2006 was one of the two instances where the Ventura River exceeded its threshold [5,930 cfs] but Matilija Creek did not [1410 cfs]). Overall, the pattern of such presumed significant sediment-transporting events is erratic (Figure 8), with some modest suggestion of more frequent high flows in recent years as previously noted by BOR (2006).

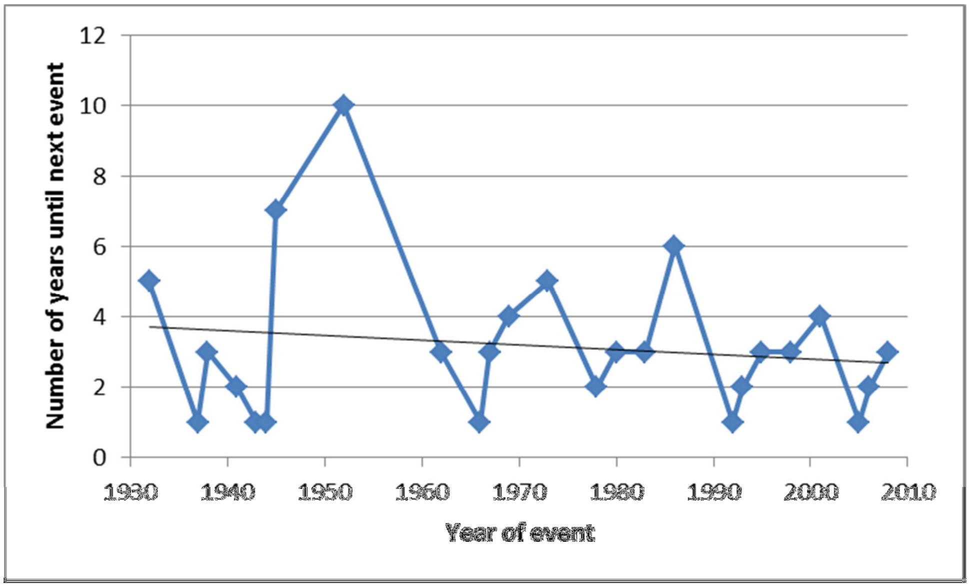


Figure 8. Time series of "events" (average daily flow of ≥5,000 cfs at 1118500 and/or ≥1,667 cfs in Matilija Creek) plotted on the y-axis as the number of years until the next year with at least one such event. Multiple events within the same water year are ignored. Solid line suggests a linear trend of slightly decreasing duration between successive water years with one or more events, but this pattern is strongly influenced by the dry period of the late 1940's and 1950's and is not evident over the last 50 years.

On average, 3 to 4 “non-transporting” years have passed between years with sufficient flow to move a significant sediment flow through the channel network.

4.6 Correlation of High-flow Periods with ENSO Index

Given extended, multi-year periods of dry or nearly dry conditions in the channel network, any dam-removal scenarios that require advance planning would benefit from an “early warning” of likely wet weather—not just on the scale of a few days to a week or so (i.e., weather forecasting), but rather with sufficient time to mobilize equipment and personnel (i.e., many weeks or months). To that end, the well-recognized association of wet winters in southern California with the El Niño phase of the Southern Oscillation was explored for its potential utility in predicting upcoming seasons of high flow on the Ventura River. For every water year, the corresponding value of the Oceanic Niño Index (ONI) averaged over the period October/November/December was calculated, on the assumption that these months would have the best chance of showing a correlation between the Index and same-year rainfall. Data were downloaded from the Nation Weather Service’s Climate Prediction Center (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml) and plotted against the annual peak discharge at gage 11118500 (Figure 9).

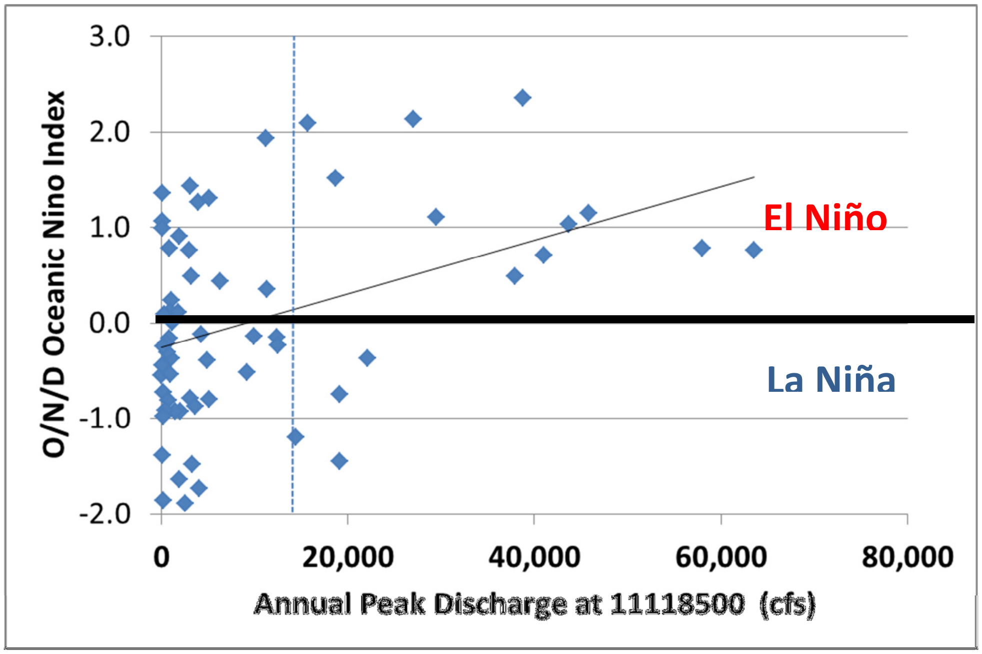


Figure 9. Annual peak discharge on the Ventura River at gage 11118500 plotted against the averaged value of the Oceanic Niño Index for the months of October, November, and December at the beginning of the corresponding water year (data range 1950-2011). “El Niño” conditions are associated with positive values of this index; La Niña conditions with negative values. The dashed vertical line marks 14,000 cfs, the presumptive peak discharge required for “significant” sediment transport (see text); the thin gray line marks the linear trend of the entire data set.

From inspection of these data, there is no fully predictive discrimination of “wet” and “dry” years that the ONI provides, although the nine wettest years all are presaged by positive values of the index. When the index was positive in the autumn, 11 of 29 years (38%) had a significant sediment-transporting event. In contrast, those years with negative ONI values have had a significant transport event in only 4 of 33 years (12%). Thus, significant transport is three times more likely in years with a positive autumn index—but this has still only occurred a bit more than 1/3 of the time.

A similar (and even stronger) relationship has been noted in the nearby Santa Clara River (Figure 10). Moderate to strong El Niño years do not *guarantee* high flows, but they do significantly raise the probability of them occurring.

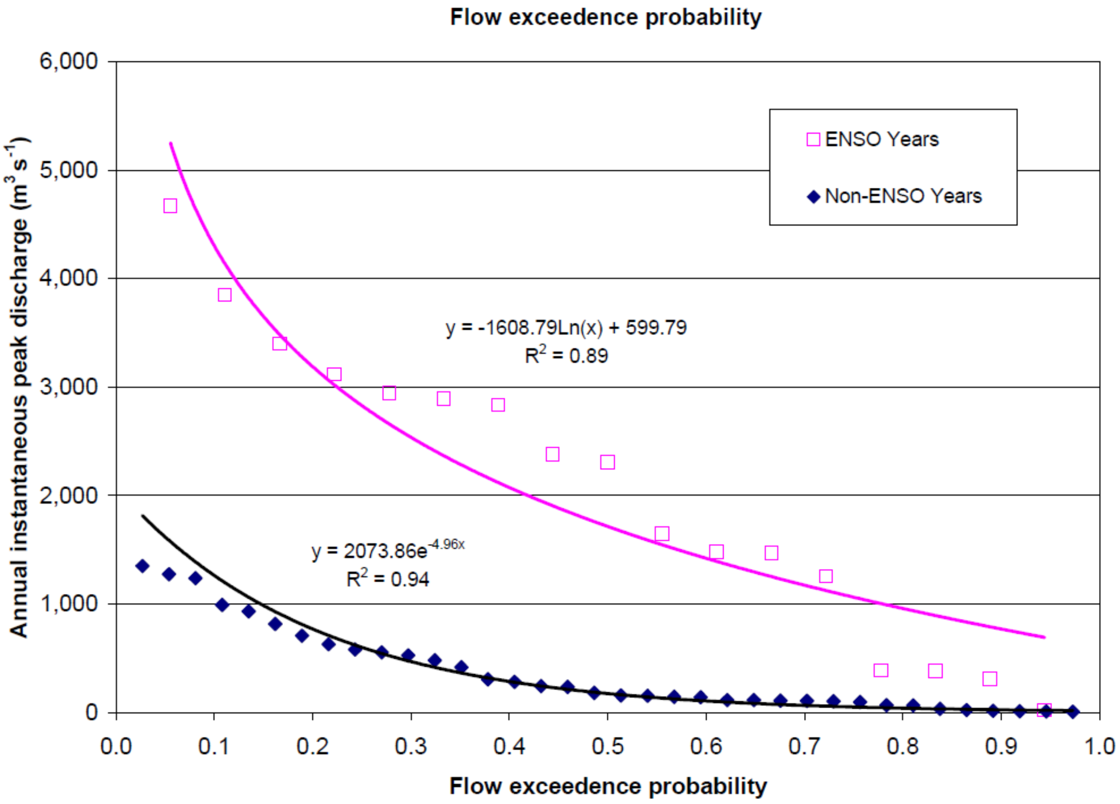


Figure 10. Flow exceedance for El Niño/non-El Niño years for the Lower Santa Clara River at Montalvo (USGS 11114000) from WY 1950-2005 (Figure 4-5 of Stillwater Sciences 2011).

5 HYDROLOGIC SCENARIOS FOR SEDIMENT TRANSPORT CALCULATIONS

Owing to the extreme episodicity of both flows and sediment movement in the Ventura River watershed, a hydrologic time series for use in sediment-transport modeling must emphasize two basic elements: (1) the character of “typical” and “extreme” sediment-transporting events, with typical durations of a few days to at most a few weeks (see Figure 2 and discussion below); and (2) the duration of quiescent intervals between each such event. The second element is addressed above in the section “Flow episodicity,” and so this section emphasizes the character of typical and extreme flow events that are associated with the movement of sediment.

Choosing "typical" and "extreme" flow conditions can follow a variety of alternative approaches. BOR (2006), for example, noted that "The hydrology is such that an average year is atypical. It is more likely that the annual discharge is greater or less than the average" (p. 45). It identified "wet" (1969), "dry" (1948), and "average" (1991) years for flows at Matilija Creek gage 11115500, considering both average and maximum daily discharges relative to minima and maxima over the period of record (for the dry and wet years) and the arithmetic mean of flows relative to the average flow for each year (Figures 2.9 and 2.10 in BOR 2006). For purposes of identifying representative full-year hydrographs, no substantive changes need be made to this analysis; and at this stage in the overall project, BOR's (2006) recommendations for the choice of full-year hydrographs are accepted without modification.

A closer look at the 1969 record provides further support for following BOR's (2006) choice of this water year as representative of a "wet" year, given the Scope of Work's specification for defining a "50-year event." The plotting position for the annual flood of 1969 is the closest approximation to a 50-year event in the record (see Figure 6, being the second-largest discharge over 80 years). As with all of the highest peak discharges recorded at gage 11118500, however, the magnitude of this peak is significantly below the eRAMS projection of flood magnitude for this recurrence. Even the flood of record over the past 80 years at this gage (63,600 cfs on 2/10/1978) lies below a projected 25-year recurrence, suggesting that the upper tail of the distribution at this gage is not well-represented by the Bulletin 17B methodology (see also BOR 2006, p. 42). This is likely true of the flood-frequency distribution on Matilija Creek as well, wherein the corresponding peak discharge for 1969 (20,000 cfs at gage 11115500, the flood of record over the 34-year lifetime of this gage) rates as less than a 20-year discharge as calculated by Bulletin 17B (and also as implemented by eRAMS), based on either the full gage 11115500 record or the shorter (but more current) record of 11114495 (Figure 7).

In the context of sediment transport for dam removal, however, the analysis of representative hydrographs can benefit from an expanded focus on typical and extreme *events* rather than full-year hydrographs. Such events are defined as having likely initiated some degree of significant sediment transport in the mainstem Ventura River by virtue of average daily flows ≥5,000 cfs (see above, based on the record of measured suspended sediment loads at the gage) and/or reported sediment removal at the Robles Diversion (presumably reflecting some significant degree of bedload transport). For purposes of identifying such events, the full record of daily average flows at gage 11118500 was filtered to identify all instances of at least one average daily discharge exceeding 2,000 cfs (as a conservative, inclusive threshold), and including all contiguous days before and after this ≥2,000 cfs value with a discharge of at least 200 cfs, in order to capture the "tails" of the peak flow event. Years with multiple such "events" separated by brief intervals of low flow were generally plotted as multiple events, but any such discrimination is somewhat arbitrary (and ultimately irrelevant for any future analyses using a continuous flow series). The raw data are graphed in Figure 11.

A concept within the overall strategy of sediment-transport modeling that may influence the final selection of hydrologic years for model input is that some scenarios may include human control on when to initiate a post-dam removal sediment transport event. For example, an upstream cofferdam might be constructed and maintained following dam removal to prevent the erosion of reservoir deposit during relatively small flows until the discharge in Matilija Creek reaches a designed threshold that breaches the cofferdam. Under such a design concept, the "dry" year would be selected to the year with the smallest storm event with a discharge exceeding the designed threshold discharge for cofferdam breaching, and "average" and "dry" years would need to be adjusted accordingly. These considerations are acknowledged but not presently included in the current analysis.

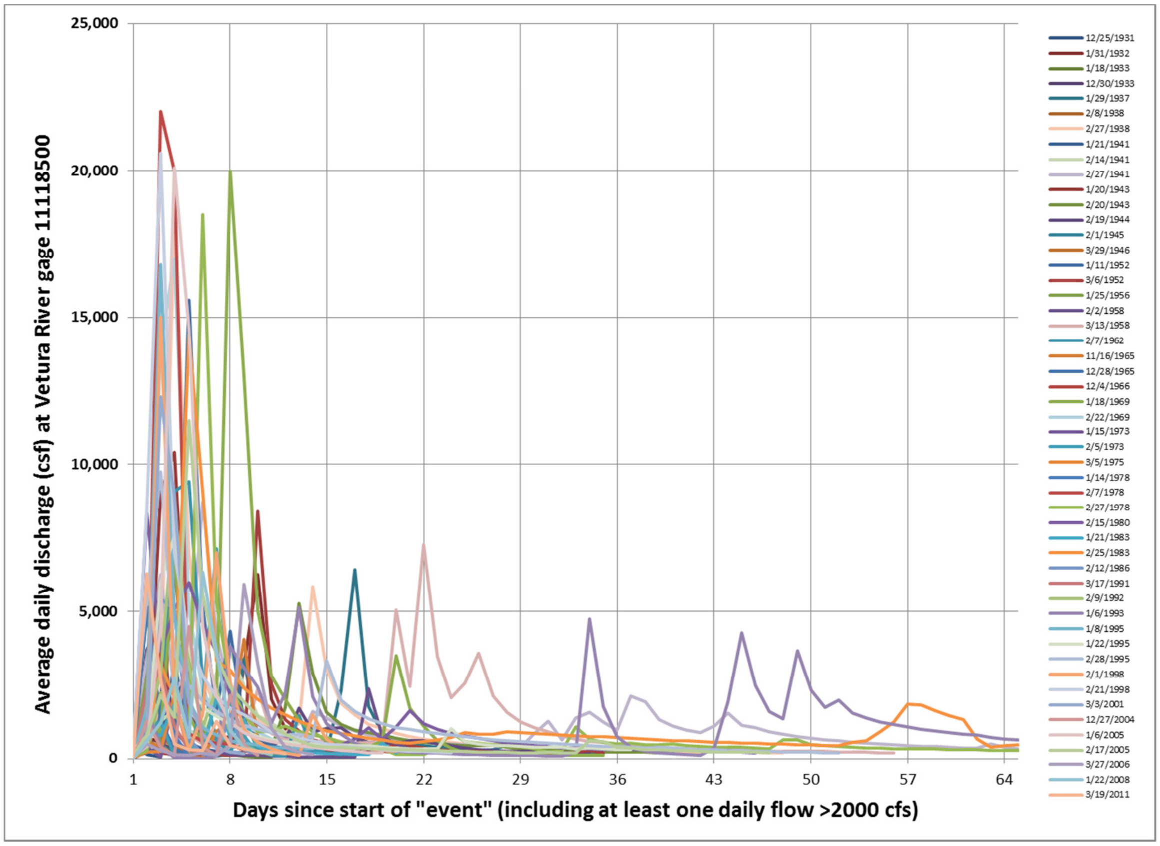
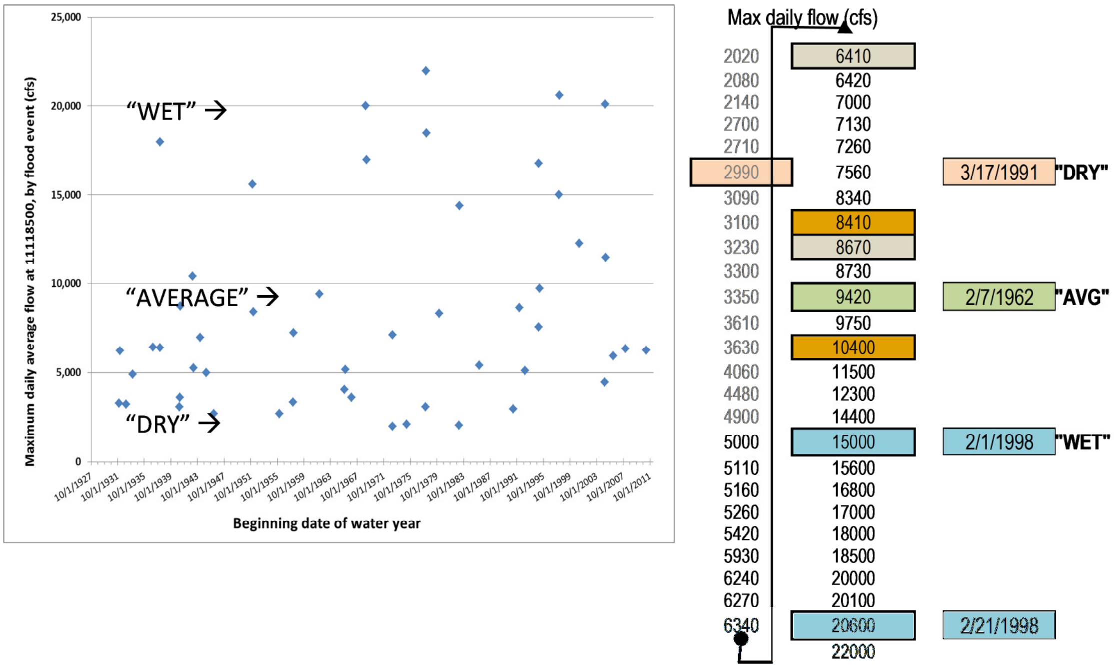


Figure 11. Hydrographs of all flow events on the Ventura River at gage 11118500 for the entire period of record. An "event" is defined as a continuous period of flows including at least one daily average flow >2,000 cfs; the graphed period is extended both prior to and following that >2,000 cfs discharge to include all "adjacent" days with flows above 200 cfs. Starting dates of individual events using this definition are listed at right. Termination of a graphed event is somewhat arbitrary but generally was set at the first day below 200 cfs.

Although the aggregated data suggest the general duration of any given "event" (as defined) lasts for typically 1-2 weeks, there is too much variability for any such generalization to be useful. In order to better identify representative examples, these data were considered in two ways (broadly akin to the analysis in BOR 2006, but considering individual events rather than whole-year records): in comparison with the "average" magnitude and duration of the entire population of events, and in comparison to the extremes of this distribution (both wet and dry). To simplify the identification of broadly representative events, the entire population of maximum daily flows for all events was plotted (Figure 12, left panel) and also tabulated in rank order (Figure 12, right panel; note that the list of maximum daily flows has been wrapped into two columns for efficiency of presentation). The hydrograph of the three events that appear to capture average and extreme conditions most representatively are graphed in Figure 13. For comparative purposes, Figure 13 also graphs the maximum event for gage 11118500 during BOR's "wet" year (1969; BOR's "dry" year [1949] had a maximum discharge of less than 1 cfs for the entire year and does not show at this scale; the maximum flow that occurred during BOR's "average" year [1991] is also shown, but here as inclusive of a typical "dry" sediment-transporting *event*).



2020	6410		
2080	6420		
2140	7000		
2700	7130		
2710	7260		
2990	7560	3/17/1991	"DRY"
3090	8340		
3100	8410		
3230	8670		
3300	8730		
3350	9420	2/7/1962	"AVG"
3610	9750		
3630	10400		
4060	11500		
4480	12300		
4900	14400		
5000	15000	2/1/1998	"WET"
5110	15600		
5160	16800		
5260	17000		
5420	18000		
5930	18500		
6240	20000		
6270	20100		
6340	20600	2/21/1998	
	22000		

Figure 12. Determination of "wet," "average," and "dry" flow events over the period of record on Ventura River gage 11118500. Flow periods lacking at least one maximum daily discharge above 2,000 cfs were excluded. Data are graphed on the left, with the suggested magnitude of "dry," "average," and "wet" flows. The plotted values are tabulated in rank order on the right (listed in two columns, which should be read from the bottom of the left column to the top of the adjacent column). On these two columns, the following flows are highlighted: pale red (2,990 cfs), the lowest flow with evidence of sediment transport at Robles Diversion (i.e., sediment removal occurred that year); gray, the *median* maximum flow based on the full (i.e., all >2,000 cfs) (6,410 cfs) and truncated (i.e., only those >5,000 cfs) (8,670 cfs) list of events; and brown, the *average* maximum flow based on the limited (8,410 cfs) and truncated (10,400 cfs) list of events. Based on these considerations, the designated "dry," "average," and "wet" events were selected as indicated on the right side of the figure; note that the latter is composed of two nominally separated but time-contiguous periods of extended high flow in February 1998.

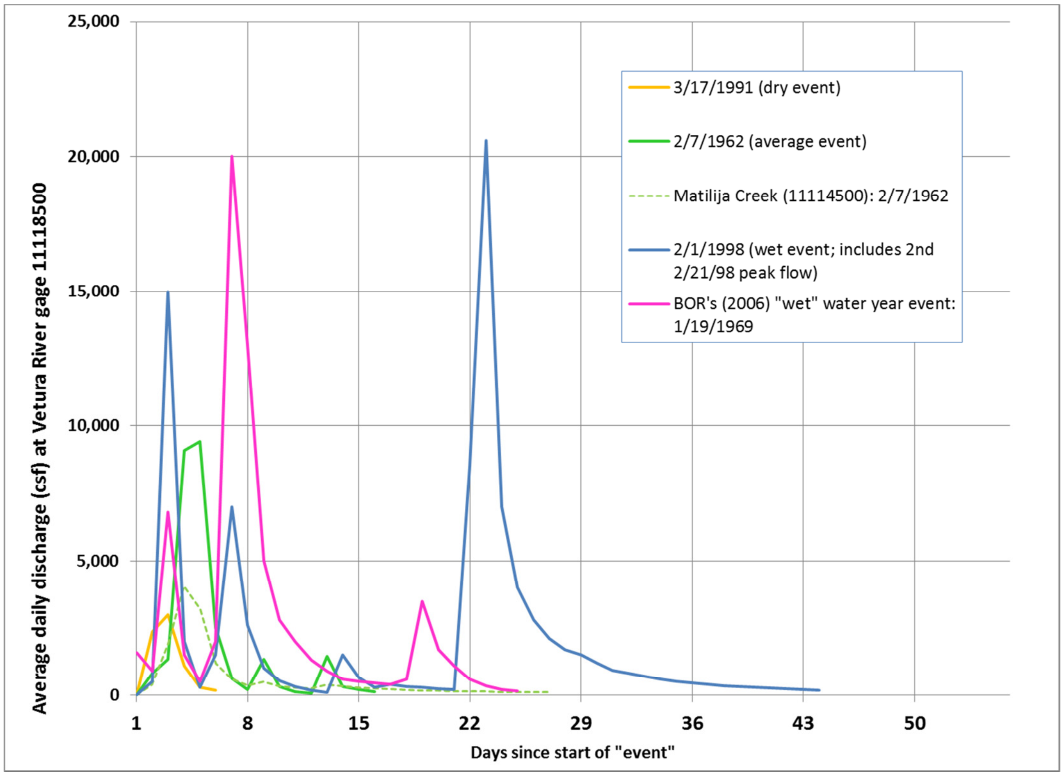


Figure 13. Hydrographs of the representative flow events identified in Figure 12. For comparison, the same-day flows for the "average" event on Matilija Creek (gage 11114500) are also plotted, showing the typical ~1:3 ratio with peak flows with the Ventura River and close correspondence in timing (Matilija gages were not operational during the "dry" and "wet" events). The period that includes maximum daily flows during BOR's (2006) "average" year is plotted as the 3/17/1991 event; BOR's "wet" water year (1969) is dominated by the 1/19/1969 event and a subsequent, near-equivalent 17,000-cfs flow five weeks later (not plotted).

Interestingly, Water Year 1991 (which includes the representative "dry" event above) was identified by BOR (2006) as an "average year" with respect to mean annual flow. These results are not contradictory; BOR considered the entire population of annual flows, for which WY 1991 falls almost exactly on the average (their Figure 2.10), whereas this event-based analysis has been truncated to remove all years without at least one day's flow above 2,000 cfs. This eliminates 49 of 84 years from further consideration, under the assumption that there is little value in constructing hydrographs for future sediment-transport scenarios for a virtually dry river.

These representative years (from BOR 2006) and representative events (above) constitute the initial recommendation of daily hydrographs to be used for subsequent sediment-transport modeling. The average daily flow data are available for each scenario for both the Ventura River (gage 11118500) and Matilija Creek (gages 11114500, 11115500, and/or 11114495, depending on date), and this level of temporal resolution is anticipated to be sufficient for upcoming modeling events (note, however, that BOR 2006, p. 167 offers an alternative perspective). Model set-up and initial runs under subsequent tasks of the overall project, as well as the particular choice of dam removal alternatives to explore, will most likely modify these initial choices of representative scenarios; complete flow records are available to support any such modifications that may be necessary.

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MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

DAM REMOVAL CONCEPTS EVALUATION REPORT

MARCH 2016

ATTACHMENT 2: SEDIMENT CHARACTERIZATION, TASK 2.2

Stillwater Sciences

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TECHNICAL MEMORANDUM

DATE: June 3, 2014

TO: Management Team, Matilija Dam Ecosystem Restoration Project

FROM: Joel Monschke PE, Derek Booth PhD PE PG, and Yantao Cui PhD, Stillwater Sciences

SUBJECT: Matilija Dam Removal, Sediment Transport, & Robles Diversion Mitigation Study
WATERSHED AND IMPOUNDMENT-AREA SEDIMENT CHARACTERIZATION, Task 2.2

1 INTRODUCTION

The purpose of this memo is to broadly characterize key locations and sources of sediment that may influence the selection of dam-removal scenarios, and that are anticipated to be the primary sources of sediment loads into the Ventura River without Matilija Dam in place. The discussion is divided into two sections, reflecting the scope of work for this subtask: the characterization of sediment presently stored behind the dam itself, and the ongoing, "natural" sediment load of the watershed that drains to Matilija Creek and the Ventura River. For the first component (reservoir sediment), the analyses and findings are based largely on previously published borehole data supplemented by topography and a field visit in March 2014. For the second component (watershed sediment yield), prior analogous studies of watershed sediment yields in various nearby watersheds in the western Transverse Ranges have been compiled and analyzed to characterize the likely rates, volumes, and episodicity of the watershed sediment load, formulated and presented to provide necessary input parameters for the sediment transport modeling of subsequent subtasks.

2 CHARACTERIZATION OF SEDIMENT BEHIND MATILIJA DAM

2.1 Summary

In order to characterize and quantify the sediment stored behind the Matilija Dam, existing data and topography from 1947 and 2005 were reviewed and analyzed. Two different methods were used to characterize reservoir sediment: the first provides a general overview of the volumes of coarse- and fine-grained deposits behind the dam, while the second method more precisely subdivides the sediment into three size classes (gravel, sand, and silt/clay). Based on these analyses, there were approximately 6.9 million cubic yards of sediment stored behind the Matilija Dam as of 2005, comprising approximately 3.0 million cubic yards of silt and clay, 2.2 million cubic yards of sand, and 1.7 million cubic yards of gravel, cobble, and boulders. These volumes are consistent with the U.S. Bureau of Reclamation's (BOR) estimate of 5.9 million cubic yards of stored sediment in 2000 (BOR, 2000). This difference in sediment volume is likely a consequence of additional sediment delivered into the reservoir between 2000 and 2005 (of which the likely majority would have been deposited during 2005 storm events). Using a straight-line extrapolation from these data, we estimate that there is currently (2014) about 7.9M yd^3 of sediment stored behind the dam.

If further refinement of the sediment volume is ultimately needed, ground surveys could be conducted to field-check the LiDAR data and additional boreholes could be drilled to more accurately determine the pre-reservoir valley topography. In addition, a new aerial survey could be conducted that would accurately depict 2014 conditions. However, at this stage of the overall project the sediment volume calculations should be sufficiently accurate to determine the feasibility of conceptual restoration alternatives and to provide sediment modeling input data.

Following is a discussion of the steps taken to characterize the Matilija Reservoir sediments for this study.

2.2 Topographic Data

Total sediment volumes stored in Matilija Reservoir were calculated using AutoCAD Civil3D (CAD) by comparing two topographic data sets from 2005 and 1947. 2005 topography was based on the LiDAR-generated “upper_matilija_tin_2005”. The LiDAR aerial survey was performed by Airborne1 in March 2005 (BOR, 2006; additional information on the LiDAR data included therein). The vertical datum for the LiDAR data is NAVD88 and the horizontal datum is NAD83 CA State Plane Zone 5. One-foot contour data were extracted from the GIS file and imported into CAD. The LiDAR data covering the area upstream of Matilija Dam, however, did not appear to be fully processed to determine a “bare earth” surface. In addition, data covering the area where reservoir water was present did not have accurate contours. Therefore, additional processing of the LiDAR data was completed to remove vegetation from the Matilija Reservoir “delta” area. Elevation data were also incorporated from borehole logs reported in the Geotechnical Report (USACE and BOR, 2004) to determine appropriate reservoir sediment levels wherever the impounded lake may have interfered with the LiDAR data collection.

1947 topography was based on the TIN surface titled “historic_topography_1947_navd88”. This TIN was developed based on the CAD file provided by BOR with 5-foot contour intervals. The contours were based on a hard copy scan of pre-dam topography; although any such transcription is not likely to meet survey-quality standards, it is the best available pre-reservoir topography of the study area. The vertical and horizontal datums were re-projected from NGVD29 and NAD27 (in the original data file) to NAVD88 and NAD83, respectively.

The 1947 topography lacked accurate contours covering the stream reach immediately upstream of the dam for approximately 500 feet. The topography in this area was reconstructed using elevations at three locations: 1) the elevation at the dam, based on the 2005 LiDAR topography from the downstream channel; 2) the elevation approximately 330 feet upstream from the dam, based on the Borehole 15 “bottom of hole” elevation; and 3) the elevation approximately 500 feet upstream from the dam, tied into the existing 1006-foot elevation contour from the 1947 topography. The slopes were assumed to be constant between these three known locations and a channel width of 40 feet was used, based on upstream channel widths taken from the 1947 topography. The channel was generally reconstructed along the center of the valley. These reconstructed new contour lines, at 10-foot intervals, are shown on Figure 1.

Following these changes, a series of cross sections along the length of the reservoir were drawn in CAD to compare the 1947 and 2005 topography. From these sections, an appropriate boundary for the 1947 topography was determined that best tied in with the 2005 topography along the lateral extents of the reservoir. A cut/fill analysis was then performed in CAD to determine the elevation differences between the 1947 and 2005 surfaces, thus defining the volume of the sediment wedge behind the Matilija Dam. The results of this analysis are also displayed on Figure 1 (page 8, below).

2.3 Sensitivity Analysis

The sediment volume calculations are not highly sensitive to the horizontal alignment between the 1947 and 2005 surfaces (i.e., as long as they are aligned within +/- 15 feet, calculated sediment volumes do not change by more than one percent). In addition, the minor reconstruction of topography immediately upstream of the dam led to an increase of only 20,000 cubic yards of stored sediment (0.3%). In contrast, the calculated sediment volumes were quite sensitive to vertical changes across large portions of the study area. Removing obvious vegetation from the LiDAR data and correcting for the reservoir sediment levels decreased the predicted sediment volumes by approximately 200,000 cubic yards (about 3%). Even more extreme, changing the vertical datum of the 1947 topography from NGVD29 to NAVD88 decreased the predicted sediment volume by approximately 500,000 cubic yards (about 7%). Further refinement of the sediment volume, if necessary, would require field-checking of the LiDAR data, additional boreholes, and/or a new aerial survey.

2.4 Borehole Analysis

Data from the borehole logs in the Geotechnical Report (USACE and BOR, 2004) were used to determine the elevation of the top of the sediment within the Matilija Reservoir and to double-check the elevation of the 1947 and 2005 topography. First, the borehole locations from USACE and BOR (2004) were digitized into CAD. Next, the elevations at the top and bottom of each borehole were compared to both the 2005 LiDAR and 1947 topography. Overall, there was very strong consistency between the borehole data and CAD surfaces: within +/- 1.5 feet at most borehole locations and no more than +/- 4 feet at a few outliers.

In addition to checking the surface elevations, the borehole logs were also used to characterize the grain-size distribution of the reservoir sediments themselves. First, a longitudinal profile was created in CAD that spanned the length of the Matilija Creek channel covered by the LiDAR data, drawn down the center of the valley and intersecting nearby borehole locations where feasible, but in all cases seeking to minimize the horizontal distance over which the borehole data would need to be projected onto the profile. The 1947 and 2005 ground surfaces were projected onto the profile in CAD (Figure 2; alignment shown on Figure 1).

The textural data from the boreholes were subdivided into two categories based on the narrative descriptions on the logs: 1) fine-grained sediments consisting of clay, silt, and sand; and 2) coarse-grained sediments consisting of gravel, cobble and boulders. The coarse-grained sediment deposits also included a fine-grained component, with sand and some silt filling the voids between larger particles. These data were projected onto the longitudinal profile (Figure 3), based on the location of the boreholes. The textural categories were manually digitized based on the elevations from the borehole logs. After all data were added to the profile, inferred contacts between predominantly fine and predominantly coarse sediment deposits were interpolated in the areas between boreholes.

In the northern portion of the “reservoir” area, three boreholes (04-01, 06-01, and 07-01) all terminated at less than 40’ depth (and thus spanned only about one-half of the total thickness of the accumulated sediments at the boring locations) because of methane gas. Based on the position in the sediment pile relative to the dam and the characteristics of the overlying and adjacent sediment, the underlying material is almost certainly dominated by clay, silt, and/or sandy silt, and it is so included in the calculated volumes of "fine" sediment, recognizing that is must also include with sufficient organic material to generate appreciable methane. This material may pose an additional hazard for certain dam-removal alternatives, particularly those that involve mechanical excavation of reservoir sediment in this area.

2.5 Determining Sediment Gradation and Volumes

Two different approaches were used to calculate sediment volumes and size gradations in the Matilija Reservoir. The first approach utilized the sediment profile shown on Figure 3, which broadly distinguishes between coarse and fine deposits. The second approach utilized the reservoir sediment gradation table (Table 5.6, BOR, 2006) to more precisely define the sediment volumes within each of the three size classes ("gravel," "sand," and "silt/clay") that may be required for future sediment modeling input data. The methodologies used for each approach are described below.

2.5.1 Approach 1 – Determine volume of fine versus coarse sediment deposits

The percentages of "fine" and "coarse" sediment, broadly distinguished, were determined using data from the Matilija Reservoir sediment profile (Figure 3). The two-dimensional fractions of fine sediments (i.e., silt, clay, and some associated sand) versus coarse sediments (i.e., gravel and coarser, plus an indeterminate amount of associated sand-sized sediment) were calculated in CAD, with a result of 34% coarse sediment and 66% fine sediment. These percentages were then applied to the total sediment volume of 6.8 million cubic yards, assuming that lateral variability of the grain-size distribution followed that of the centerline profile. This results in an estimate of approximately 2.3 million cubic yards of "coarse" sediment deposits and 4.5 million cubic yards of "fine" sediment deposits. There is no basis to presume uniform lateral variability, and it is likely that the marginal deposits are somewhat finer than those of the centerline reflecting greater dispersion of finer particles. Thus, the estimate of 4.5 million yards of fine sediment deposits is likely conservative (i.e., low) relative to the actual fine sediment volumes in the reservoir as of 2005, with a likely increase of 10-15% over the following nine years (see below).

2.5.2 Approach 2 – Determine volume of gravel, sand, and silt/clay size classes

To provide input data for the sediment modeling phase of the project, a second analysis was performed that divided reservoir sediments into three numerically defined size classes: 1) gravel [>2 mm]; 2) sand [0.0625–2 mm]; and 3) silt/clay [<0.0625 mm]. The data source for this approach was Table 5.6 from BOR (2006), which was assembled using borehole data from USACE and BOR (2004). Based on this table, the percentages of each sediment gradation size class within the three reservoir sub-areas were determined (Table 1; see Figure 1 for longitudinal location of each sub-area). The data from Table 1 are also shown on the bottom of the sediment profile on Figure 3 to display the spatial context of sediment gradations.

Table 1. Sediment gradation percentages (determined from BOR 2006, Table 5.6).

Sediment Deposit Sub-Area:	% Gravel (>2 mm)	% Sand (0.0625–2 mm)	% Silt/Clay (<0.0625 mm)
Reservoir	0%	17%	83%
Delta	13%	54%	33%
Upstream Channel	78%	16%	6%

CAD was used to determine the overall sediment volume change of the deposits behind the dam; within each of the three sub-areas, we assumed the same distribution of sediment amongst the three sub-areas as reported in BOR (2006, Table 5.6) and their sediment-size percentages listed in Table 1. These results are tabulated in Table 2.

Table 2. Sediment gradation volumes.

Sediment Deposit Sub-Area	Total Volume Sediment (as of 2005)	Volume Gravel (>2 mm)	Volume Sand (0.0625 - 2 mm)	Volume Silt/Clay (<0.0625 mm)
	(all values in cubic yards)			
Reservoir	2,420,000*	0	410,000	2,010,000*
Delta	3,230,000	420,000	1,740,000	1,070,000
Upstream Channel	1,150,000	900,000	180,000	70,000
Total Volume	6,800,000*	1,320,000	2,330,000	3,150,000*
Total Percent	100%	19%	35%	46%

*Inferred deposition of silt/clay in the Reservoir sub-area during the period 2002–2005 but not "seen" by the LiDAR or 2001 boreholes should raise these amounts by ~160,000 yd^3 (see below).

In summary, calculations indicate that sediments stored behind the Matilija Dam as of 2005included 3.3 million cubic yards of silt and clay, 2.3 million cubic yards of sand, and 1.3 million cubic yards of gravel, cobbles, and boulders.

2.5.3 Reservoir Sub-Area Sediment Deposition between 2001 and 2005, and post-2005

The 2005 sediment volume within the Reservoir sub-area is likely higher than the volume determined through the analysis described above. This is due to the fact that borehole data from 2001 was used to supplement LiDAR data where reservoir water prevented LiDAR data collection. Thus, the volume calculations for the Reservoir sub-area (only) do not include deposition from 2005 storm events (or from any subsequent deposition), presumed to be overwhelmingly silt/clay. The following general analysis was used to estimate sediment deposition in the Reservoir sub-area between 2002 and 2005 to be consistent with the date of LiDAR data collection.

The Reservoir sub-area covers approximately 1.3 million square feet, so every foot of sediment deposition produces a volume increase of approximately 50,000 cubic yards. From Figure 5.11 in the 2006 BOR Report, sediment depths near the dam increased approximately 0.8 feet per year between 1986 and 1999, a period that had numerous high peak discharges. Applying this rate for the period of 2002 to 2005 (which also assumes constant trap efficiency) would produce an additional 3.2 feet of sediment depth and 160,000 cubic yards of additional fine sediment deposition in the Reservoir sub-area, increasing the total sediment volume by 2.4%.

There are no data available to directly calculate the volume of sediment presently (2014) behind Matilija Dam, but the variety and general consistency of prior measurements provide a remarkably consistent estimate. Using the estimates (both inferred and surveyed) from BOR (2006, Table 5.4), our calculation of 2005 volumes using topography differences (and post-2001 subaqueous sedimentation), and a straight-line extrapolation that appears warranted given the general regulatority of the data (Figure 4), we estimate that approximately **7.9M yd^3 of sediment** is currently impounded behind Matilija Dam.

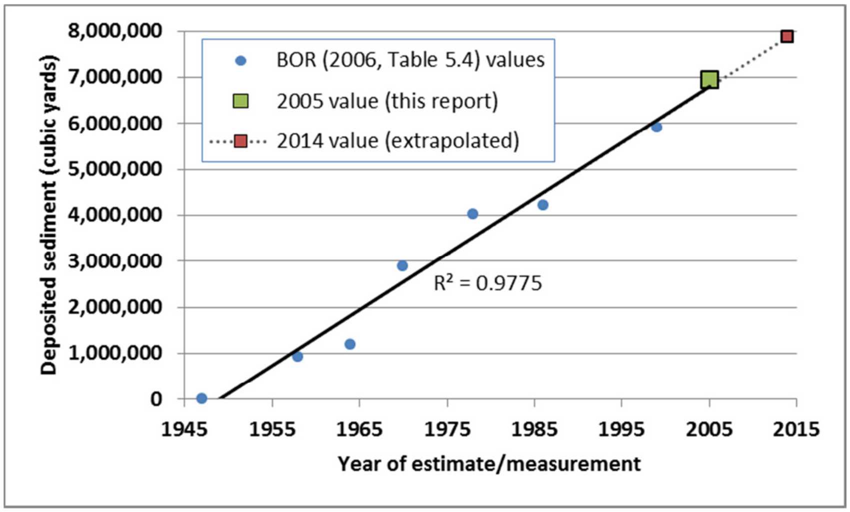


Figure 4. Historically inferred, measured, and extrapolated sediment volumes behind Matilija Dam (data sources as noted).

2.6 Bulk Density Calculation

According to BOR (2006), the Matilija Reservoir sediments have a computed average bulk density of 71 lb/ft^3 and a measured average bulk density of 73 lb/ft^3 (approximately 0.99 ton/yd^3). Although not explicitly stated in BOR (2006), these bulk density values appear to apply to the "reservoir sub-area" and not the bulk density for all of the stored sediment behind the dam. BOR (2006) also stated that the bulk density of sand and gravel within the reservoir is 97 lb/ft^3 (1.3 tons/yd^3), a value that is likely applicable to the upstream channel sub-area.

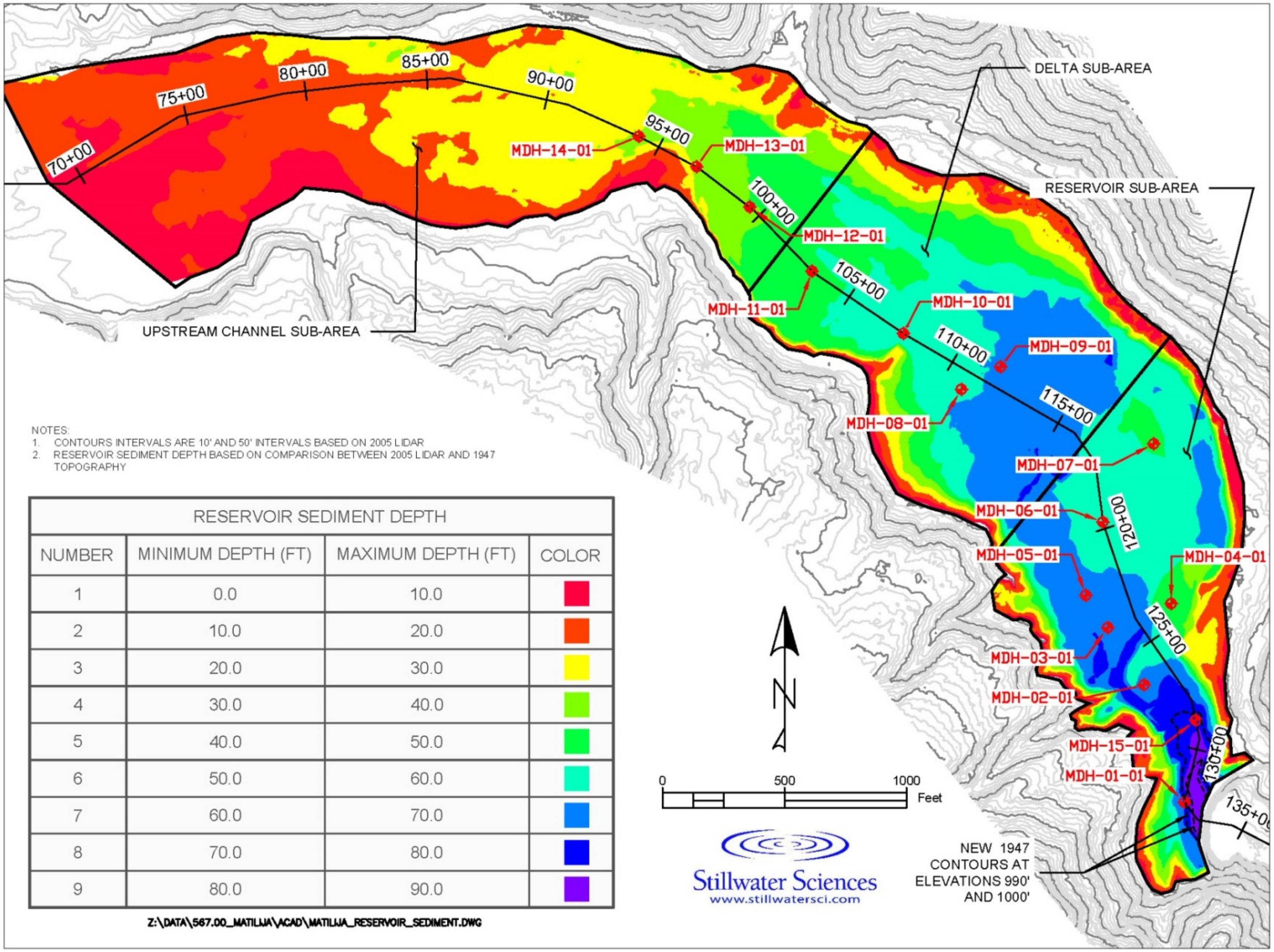
The bulk density values presented by BOR (2006) lie within the range of average reservoir sediment bulk densities from recent publications, including 60 lb/ft^3 (0.81 ton/yd^3) (Minear and Kondolf, 2007) and 106 lb/ft^3 (1.43 ton/yd^3) (Lavé and Burbank, 2004). In addition, these bulk densities also lie within the range of densities of reservoir-deposited sediments listed in ASCE Sediment Engineering Manual 54 for clay/silt mixtures, which range from 40 to 84 lb/ft^3 (0.53 to 1.14 ton/yd^3); sand, ranging from 84 to 99 lb/ft^3 (1.14 to 1.34 ton/yd^3); and poorly sorted sand and gravel, ranging from 94 to 129 lb/ft^3 (1.28 to 1.74 ton/yd^3). Table 3 summarizes the estimated bulk densities in each of the three sub-areas, showing different density units for comparison with other studies. These values are primarily taken from BOR (2006), with densities inferred for the delta sub-area. If more precise bulk densities are subsequently required, additional field data collection and laboratory testing will be needed.

Table 3. Sediment bulk density by sub-area.

Sediment Deposit Sub-Area	Bulk Density (lbs/ft^3)	Bulk Density (tons/yd^3)	Bulk Density (tonnes/m^3)
Reservoir	73	1.0	1.2
Delta	86	1.2	1.4
Upstream Channel	97	1.3	1.6

2.7 Upstream Sediment Wedge

The longitudinal profile shown on Figure 2 suggests that additional sediment has been deposited between Stations 40+00 and 70+00, upstream from the historic extent of the reservoir. This region is not included in the sediment volume calculations presented above, but that sediment has likely been deposited in this reach as a result of downstream aggradation, which has lowered the gradient and reduced the creek's sediment transport capacity. Based on field observation of the surface deposits, the sediments within this area are likely coarse-grained throughout, with a total volume of 100,000 to 150,000 cubic yards based on simple geometric calculations. These sediments will have minimal implications for the preliminary period of sediment release but will likely lead to a modest increase in medium- to long-term coarse-grained sediment transport in Matilija Creek. As the main reservoir sediments are eroded and the downstream channel gradient is steepened, these upstream accreted sediments are likely to mobilize as well.



RESERVOIR SEDIMENT DEPTH			
NUMBER	MINIMUM DEPTH (FT)	MAXIMUM DEPTH (FT)	COLOR
1	0.0	10.0	🟥
2	10.0	20.0	🟧
3	20.0	30.0	🟨
4	30.0	40.0	🟩
5	40.0	50.0	🟩
6	50.0	60.0	🟦
7	60.0	70.0	🟦
8	70.0	80.0	🟦
9	80.0	90.0	🟪

Figure 1. Plan view of Matilija Reservoir sediment deposits and borehole locations.

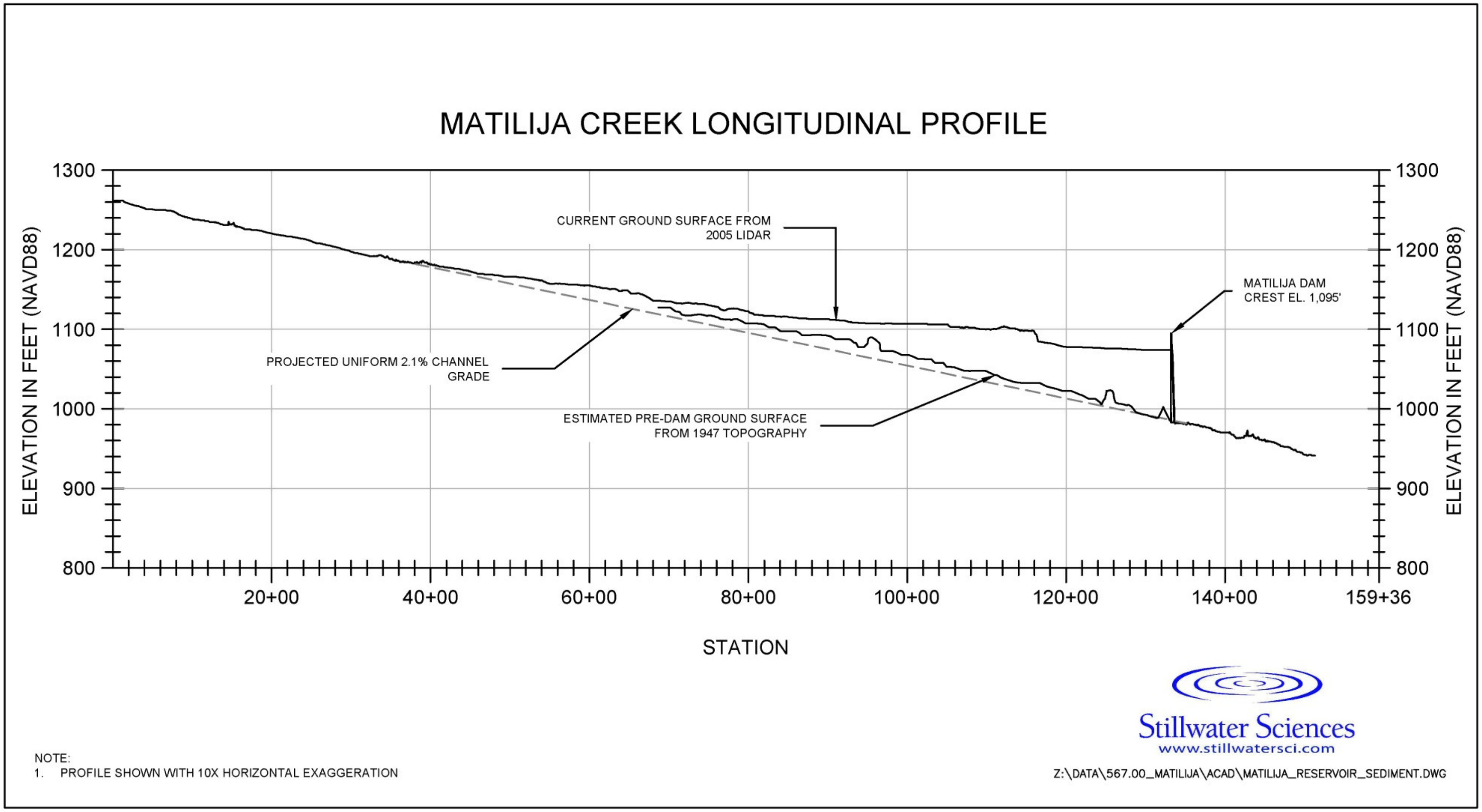


Figure 2. Matilija Creek longitudinal profile.

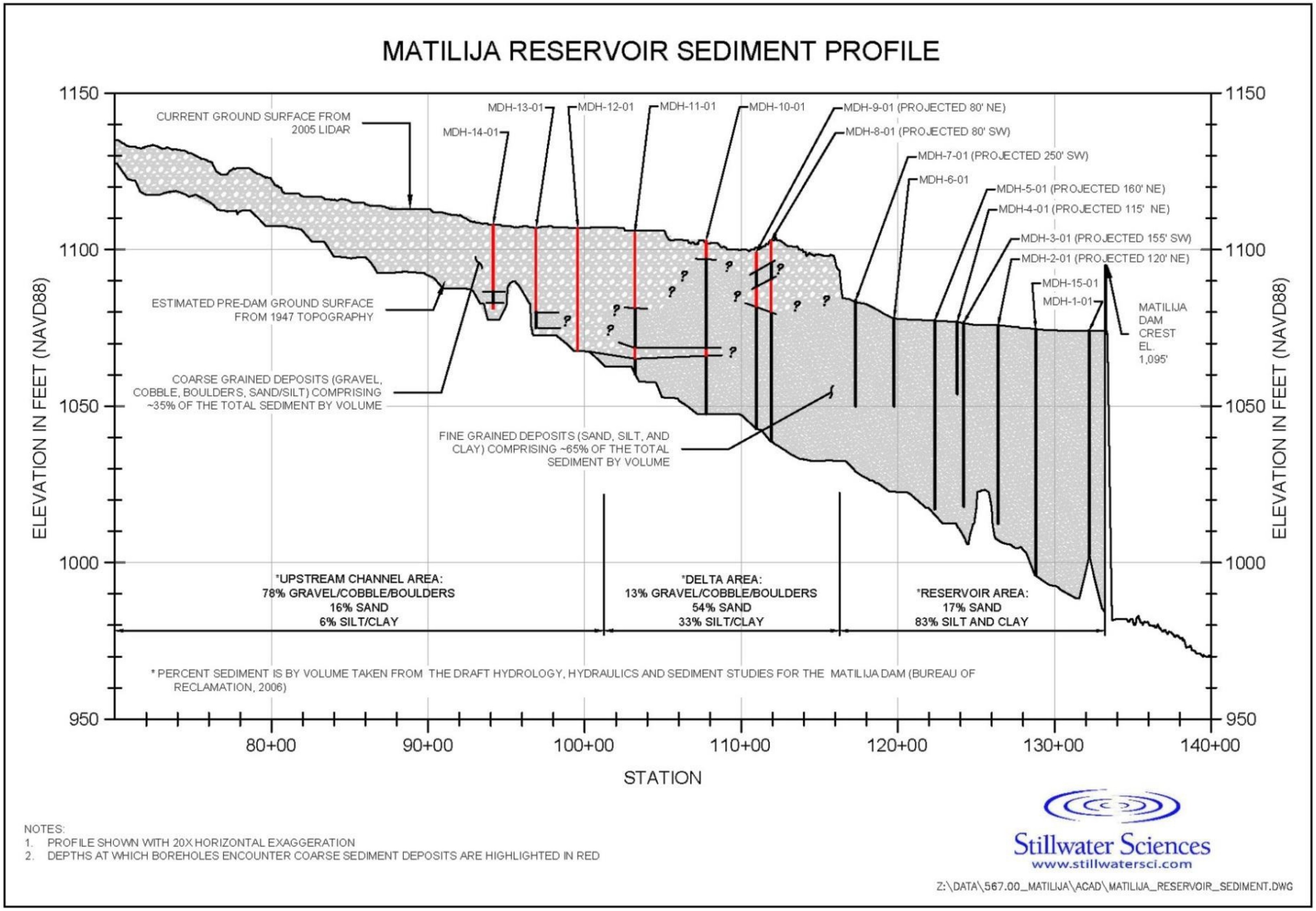
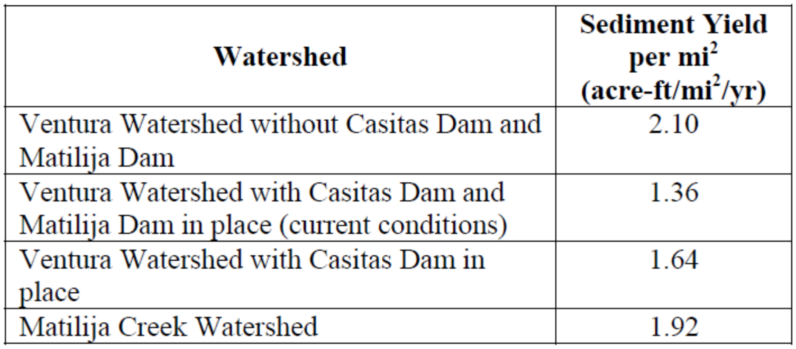


Figure 3. Matilija Reservoir sediment deposit profile.

3 CHARACTERIZATION OF WATERSHED-DERIVED SEDIMENT

In addition to the sediment already stored behind Matilija Dam, the overall watershed is a highly productive source of sediment during storm events. The magnitude of watershed sediment yield was discussed extensively in BOR (2006, particularly Section 5.5 of that report). For the present effort, no attempt is made to duplicate or review that discussion, but rather to augment those data with additional studies conducted since that time with likely relevance to sediment delivery from the watersheds of Matilija Creek and the Ventura River.

Table 5.14 of BOR (2006) reports the following estimates of watershed sediment yield:



Watershed	Sediment Yield per mi^2 (acre-ft/mi^2/yr)
Ventura Watershed without Casitas Dam and Matilija Dam	2.10
Ventura Watershed with Casitas Dam and Matilija Dam in place (current conditions)	1.36
Ventura Watershed with Casitas Dam in place	1.64
Matilija Creek Watershed	1.92

By way of comparison, sediment yield in the adjacent Sespe Creek watershed (Booth et al., 2014) was calculated from both measured suspended sediment in Sespe Creek (at USGS gage 11113000 from 1966 through 1978), and by analogy to debris basin records and geologically determined rates of uplift and erosion (Lavé and Burbank, 2004; Warrick and Mertes, 2009). They found yields to be about 2,600 tonnes/km^2/year (using the units of that study), or about 1 mm/yr of landscape lowering (equivalent to the first entry on the table above of 2.10 acre-ft/mi^2/yr, which is attributed to Brownlie and Taylor 1981). Given the preponderance of steep, relatively highly-erosive lithologies in the watershed of Matilija Creek relative to those in Sespe Creek, this value is likely a lower bound on the long-term average rate of watershed sediment production, but the overall correspondence of these disparate values given typically broad uncertainties in their calculation (Reid and Dunne 1996) suggest that seeking greater precision in any such estimate is unlikely to be fruitful.

By analogy to the annual reconstruction of Sespe Creek sediment loads (Stillwater Sciences 2010, Figure 3.2; reproduced below as Figure 4), the annual average load is exceeded (by up to 16-fold) in a single storm or set of storms that exceed about a 5-year recurrence interval (i.e., 17 of 81 years).

Conversion of these measures of mass (as originally reported in the cited literature) into a volume of water-transported sediment (as is commonly measured in spatial analyses of reservoir deposits) requires a density conversion, as discussed in the previous section. For purposes of the following discussion a mid-range value of 1.4 tonnes/m^3 (Table 3) is assumed.

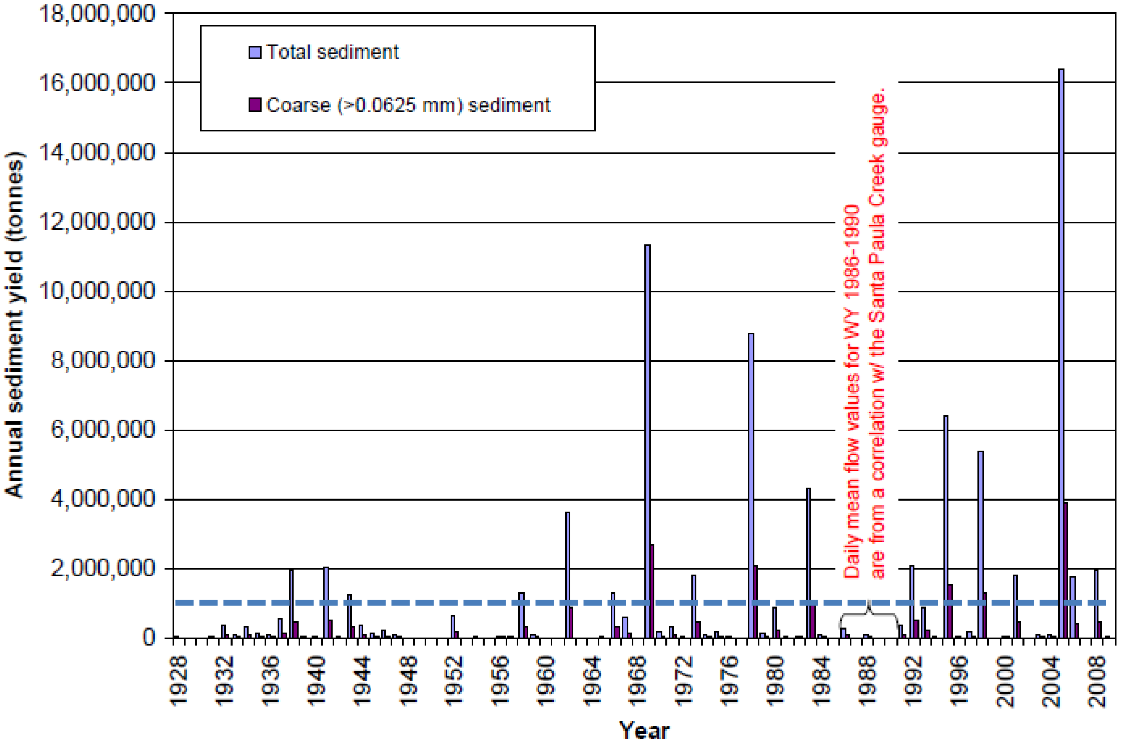


Figure 4. Calculated total sediment yield (i.e., suspended load + bedload) and coarse-only (>0.0625 mm) sediment load for Sespe Creek at Fillmore (USGS gage 11113000). Dashed blue line is the average annual sediment yield calculated from these data (990,000 tonnes/year). The year of greatest sediment yield (2005) had an annual load more than 16 times the average; other major sediment-yielding years produce two to more than ten times the long-term average value. From Stillwater Sciences (2010, their Figure 3.2).

Assuming an annual average sediment from the watershed draining to Matilija Dam of 3,000 tonnes/km^2/year (an extrapolated estimate based on Sespe Creek findings, and equivalent to single-digit precision of BOR's [2006] estimate of yield to the dam), the average annual sediment yield from the upstream watershed is about 400,000 tonnes per "average" year (about 400,000 yd^3), and thus potentially more than 5M yd^3 of transported sediment during a truly exceptional year. Even with the dam in place, the fraction of silt and clay in the sediment load (see BOR 2006, Table 5.6) coupled with the current trapping efficiency of the dam (about 45% for fines; BOR 2006, Table 5.4) suggest that at least 100,000 yd^3 per year of fine sediment are moving down the Ventura River past Robles Diversion. This represents about one-third of the total annual load of fines presently estimated to be delivered to the Pacific Ocean (BOR 2006, Table 5.15) from this relatively steep and erodible fraction of the total watershed (i.e., 54 of 226 mi^2, or about 24%).

In summary, watershed sediment yields during major sediment-transporting events are of the same magnitude as the volume of sediment presently stored behind Matilija Dam. Predicted transport volumes out of the reservoir area following dam removal during major events are likely to be augmented by a similar amount of "new" sediment from the contributing watershed, both from Matilija Creek and the North Fork Matilija Creek, together with the even larger watershed entering the Ventura River downstream of Robles Diversion. Estimates of watershed sediment yield also suggest that sediment management at the Robles Diversion, however problematic during the period of reservoir sediment releases following dam removal, will pose an ongoing challenge of nearly equivalent magnitude in the post-dam era during all subsequent high-flow years, even after the reservoir sediment has been fully evacuated.

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MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

DAM REMOVAL CONCEPTS EVALUATION REPORT

MARCH 2016

ATTACHMENT 3: INITIAL OPTIONS SCREENING REPORT

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

DRAFT INITIAL OPTIONS SCREENING REPORT

SEPTEMBER 9, 2014

Prepared for:
Ventura County Watershed Protection District

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Stillwater Sciences

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A	Fine Sediment Assessment
B	ROMCC & Schedule Details
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1.0 Purpose and Background

The purpose of this report is to document the technical components of each initial option, the screening criteria developed at the May 2014 Technical Advisory Committee (TAC) Meeting, the methods and metrics utilized to address or populate the criteria, and the associated screening results. It should be noted that assessments and calculations included in this report are associated only with the dam removal components of the project, and do not include other project considerations (e.g. downstream flood mitigation, lost water diversion mitigation, operation and maintenance, etc.).

1.1 Project Background

Since its construction in 1947, the 168-foot high[1], arched concrete Matilija Dam has blocked the transport of an estimated 6,800,000 cubic yards[2] (cy) of fine and coarse sediment from naturally moving downstream to the ocean. This has resulted in loss of the reservoir's original function of water storage[3] for agricultural needs, and limited flood control, loss of downstream sand and gravel sized materials necessary to promoting habitat for a variety of wildlife species, loss of sediment needed to maintain beaches at Surfer's Point, and increased erosion of the Ventura River streambed. The dam, with its non-functioning fish ladder, also prevents southern steelhead from reaching upper Matilija Creek, which prior to dam construction, was the most productive spawning and rearing habitat in the Ventura River system. Without dam removal, an estimated total of 9,000,000 cubic yards of sediment will be trapped behind the dam before the natural full annual sediment load of Matilija Creek begins to be carried over the dam in approximately 2040. While such a scenario would eventually begin to address sediment deprivation of the downstream reaches, leaving the dam in place would not address fish passage beyond the dam and impacts to upstream habitat.

In the early 2000's, Ventura County Watershed Protection District (VCWPD) and the US Army Corps of Engineers (USACE), evaluated several alternatives for dam removal and published a Final Environmental Impact Statement/Environmental Impact Report (EIS/R, USACE 2014). They arrived at a preferred alternative (Alternative 4b) that involved slurrying an estimated 2,100,000 cy of fine sediment from the reservoir area just upstream of the dam to a downstream disposal location, removing the dam in one season, excavating a channel through the remaining coarse sediment, and protecting the lower seven feet of the channel banks with soil cement to allow 10-year and greater storm events to remove the accumulated sediments above the seven-foot level. At some future date, the soil cement would be removed, allowing the remaining accumulated sediment to be flushed through the river system.

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[1] The original height of the dam was 198 feet prior to two phases of notching in 1965 and 1977.

[2] The estimated volume is based on the difference between 2005 LiDAR and original topography before dam construction (Stillwater Sciences, 2014a). The 6.8 mcy of sediment is distributed from downstream to upstream as about 2.4 mcy of silt and clay in what is termed the reservoir sub-area, 3.2 mcy of sand, silt and clay, and gravel in what is termed the delta area, and 1.2 mcy in what is termed the upstream channel area. Using historical sediment deposition volumes to extrapolate beyond the last measurement in 2005 to 2014 results in an estimated 7.9 mcy total sediment deposited upstream of the dam.

[3] The original reservoir capacity of 7,018 acre-feet has been reduced to less than 500 acre-feet due to the combination of sedimentation and notching in 1965 and 1977.

Subsequently, in 2009 and 2010, the Matilija Dam Fine Sediment Study Group (FSSG) was convened and temporary upstream disposal of the fine sediment was considered to address concerns over cost and constructability of the downstream disposal options for the fine sediment.

VCWPD has since contracted with URS and Stillwater Sciences (the Consultant Team) to evaluate a range of concepts including those documented in previous documents, concepts developed by the FSSG, and new concepts. A short list of six initial options was identified and is screened (in this report) based on selected key criteria. Following the screening process, up to four alternatives will move forward into the evaluation phase, which would use a wide range of criteria to compare the selected alternatives.

1.2 Summary of the Initial Options

In coordination with the Management Team, the TAC, and the Design Oversight Group (DOG), six initial options were selected from a long list of previously considered concepts/alternatives and new concepts developed by the Consultant Team. The six initial options are primarily focused on methods for managing the removal of fine sediment accumulated in the reservoir area. All options would involve dam removal and five of the six options involve natural transport of coarse sediment from the reservoir. The six initial options are briefly described below and in more depth in Section 2.0.

- Initial Option (IO)-01 Containment Berm with High Flow Bypass: This option would involve removing the dam and building a temporary containment berm to hold the reservoir sediment in place until a high flow event occurs which would erode a large portion of reservoir fine sediments
- IO-02 Uncontrolled Orifices: This option would involve boring tunnels at the base of the dam and then blasting open the tunnels when a high flow event occurs, which would erode a large portion of reservoir fine sediments. The dam would be removed after this large sediment mobilization event
- IO-03 Gated Orifices: This option would bore tunnels and install gates on the upstream end of the tunnel orifices. The gates would then be opened when a high flow event occurs, which would erode a large portion of reservoir fine sediments. The gates could be subsequently closed and reopened during the following high flow event. The dam would be removed when a sufficient amount of the accumulated fine sediment has been eroded from the reservoir
- IO-04 Gated Notch(es): This option would involve installing a series of notches with gates over several phases, so that only incremental portions of the reservoir fines would be available for transport during each phase. Phases would continue until the dam is fully removed
- IO-05 Temporary Upstream Storage of Fine Sediment: This option would involve mechanical removal and temporary upstream storage of both fine and coarse sediment in a portion of the reservoir to create a channel along the pre-dam creek alignment at the pre-dam creek elevations. The dam would be removed when earthwork is complete
- IO-06 Downstream Slurry and Temporary Upstream Storage of Fine Sediment: This option would involve slurry dredging portions of reservoir fines to both downstream (for more organic material) and upstream temporary storage locations. A portion of the fine sediment would also be mechanically excavated and hauled to the upstream temporary storage areas. The dam would be removed when the slurry and mechanical excavation operations are complete

2.0 Screening Approach

In order to make informed decisions concerning which of the short-listed full dam removal methods/approaches warrant further development and evaluation, construction duration and cost were identified as two key screening criteria by the TAC during a workshop in May 2014. After further consideration by the Consultant Team, accumulated fine sediment mobilization (and associated downstream impact) was added as a third criterion, for consideration during screening.

The approach to screening initial options involves quantification of fine sediment mobilization and associated downstream impact, construction cost and construction duration for each initial option. After criteria are populated, initial options can be ranked under each criterion, and then cumulatively. The goal for screening is to utilize the criteria and cumulative rankings, along with consideration of the spread of criteria values between initial options, to select those initial options that best meet the project objectives and funding constraints.

The sections below provide an overview of the three screening criteria and the methods that were used to quantify these criteria for each initial option.

2.1 Fine Sediment Mobilization & Associated Downstream Impact

Potential impacts due to the release of fine sediment following Matilija Dam removal are primarily associated with increased suspended sediment concentrations. These impacts include:

a) Both short-term and long-term increases in suspended sediment concentration, which will negatively impact aquatic biota, injuring or killing fish or other aquatic animals and plants
b) Increases in suspended sediment concentration that may cause operational difficulties for water diversion at Robles Diversion Dam
c) Potentially high organic content in suspended sediment, which could cause long-term water quality problems if diverted to Casitas Lake

In addition to the potential impact due to high suspended sediment concentrations, there have been previous concerns over the potential for fine sediment infiltrating into the alluvium of the river bed in downstream reaches that could result in decreased conductivity for groundwater wells and infiltration galleries. The United States Bureau of Reclamation (BOR; 2006, p. 202), however, had previously concluded that silt and clay will not enter into the groundwater aquifer, which is consistent with recent research (Wooster et al. 2008; Cui et al. 2008), which finds that interaction of silt and clay with the coarse channel bed will be limited to the surface layer, and any fine sediment deposited on the surface can be washed clean once there is a high flow event. The shallow infiltration of fine sediment into gravel deposit is also in agreement with field observations such as Frostick et al. (1984) and Beschta and Jackson (1979). While some early literature suggested a deeper infiltration of fine sediment into a coarse deposit that could potentially impact the aquifer, Cui et al. (2008) have pointed out the flawed assumption employed in their theoretical analysis and the limitation in their flume experiment; replacing their flawed assumption with a correct one yields conclusions in agreement with those of others.

As a result, an assessment of fine sediment mobilization and potential downstream impacts will focus on the potential impact from high suspended sediment concentration, with some preliminary considerations of high organic carbon concentration in the surface waters. For screening purposes, these impacts will be summarized using the following metrics:

1. Anticipated number of days and storm events that high suspended sediment concentrations may cause downstream impacts to diversions at Robles and aquatic resources. For this screening analysis, the estimated duration is provided for comparison purposes only. Further refinement of the fine sediment downstream impact duration will be provided in a subsequent phase of work.

The fine sediment assessments are summarized within the main body of this report, and detailed further in Appendix A.

2.2 Construction Duration

Durations of construction were estimated based on quantities of work and equipment application and production assumed to handle the work estimated to implement each of the initial options. The estimated duration of construction also considered the logical sequence of work allowing for concurrency of activities where possible. The following general assumptions were used in estimating construction duration:

- Mobilization for construction during months prior to the in-channel construction window
- No unusual weather delays
- Work performed five days per week, up to two shifts per day
- 9 hours of production are assumed for each 10-hour shift
- Night work is assumed to be allowed
- Saturdays are assumed to be a contingency for maintenance and make-up activities
- No overly restrictive constraints on trucking materials into the site
- A diversion and in-channel construction window of May 15 to October 31

The range for overall project duration for each of the initial options was estimated assuming that the project is completed either just prior to a 4-year return event[4] or is completed just after a 4-year return event. For initial options that require more than one high flow event to complete removal of the dam, it is assumed that each subsequent large storm event would occur at a 4-year interval.

Specific details related to construction duration for each of the initial options are discussed in Section 3, and detailed schedule Gantt charts are located in Appendix B.

2.3 Range of Magnitude Construction Costs

2.3.1 Approach Summary

The range of magnitude construction cost (ROMCC) estimates for the initial options are based on the descriptions of the options in Section 3.0. The ROMCCs are only for the construction costs directly associated with each initial option and do not include the following costs:

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[4] A 4-year return event is the minimum size storm considered to be large enough to move significant volumes of sediment from the reservoir area (Stillwater Sciences, 2014b)

- Fine grading and habitat restoration of any of the channel slopes that are formed by either natural or mechanical sediment transport (if determined to be needed)
- Acquisition of real estate
- Robles Diversion Dam improvements
- Downstream flood mitigation
- Foster Park improvements
- Loss of diversion mitigation costs
- Operation and maintenance costs.

The ROMCCs also do not include other related project costs, such as engineering, environmental compliance/permitting, Owner's construction management oversight, and any post-construction phase activities.

The ROMCCs include a 30 percent design contingency and a 15 percent allowance for construction related changes, extra work, unforeseen conditions, or other unplanned costs after a construction contract is signed. A summary of the ROMCC, including the estimated construction cost for the major categories of work are presented in Section 3 for each initial option, and additional ROMCC details are provided in Appendix B.

The ROMCC estimates are considered to be Class 5 estimates, as described by the Association for the Advancement of Cost Engineering (AACE, 2012), as follows:

> From AACE 2012: *"Class 5 estimates are generally prepared based on very limited information and subsequently have a wide accuracy ranges. They are typically used for project concept screening. Typically, engineering is from 0% to 2% complete and the expected accuracy range is from 20% to 30% lower than the estimate to 30% to 50% higher than the estimate."*

For the purposes of the ROMCCs for the initial options, the accuracy range is assumed to be from 30 percent lower than the ROMCC to 50 percent higher than the ROMCC.

In developing the ROMCCs, major features and items were developed for each initial option. The individual items comprising each feature in the ROMCC for each initial option are shown in Tables B-1 through B-6 in Appendix B, along with the quantities (where applicable) and unit costs for each item. In general, quantities for the initial options were developed using the average end area method and other simple hand calculation methods given the conceptual level of design.

Construction cost was estimated with the use of a combination of previous cost estimate work by the USACE in 2004 and 2008 escalated to 2014, built-up unit prices, and statistical unit prices from published and internally developed and maintained historical databases factored for location, contractor markups, and other project-specific criteria. Logic, methods, and procedures used for developing costs are typical for the construction industry. Various limitations need to be considered in the use of both built-up and statistical unit prices. These limitations include the potential for changes in technology, methods, and construction applications; the impact of short-term economic cycles; and the time-lag of reporting databases. Any estimate of unit prices is not intended to predict the outcome of hard dollar results from open and competitive bidding.

2.3.2 Alternative 4B Cost Comparison

For comparison with the ROMCCs, the equivalent construction costs for Alternative 4b were taken from the 2004 and 2008 USACE cost estimates and escalated to July 2014 using cost trends published by the USACE and the United States BOR. A contingency of 25 percent was applied to the estimate as was done for the 2004 USACE estimates. It is noted that this is less than the sum of the design and construction contingencies used in the ROMCCs for the initial options.

Table 1. Summary of Alternative 4b Construction Costs

Project Categories	Construction Cost (2004 or 2008)	Construction Cost (2014)[c]
Mobilization[a]	$5,000,000	$7,090,000
Site Preparation[a]	$710,000	$1,010,000
Sediment Components[a]	$5,430,000	$7,700,000
Slurry System Components[a, b]	$11,620,000 + $37,860,000	$61,460,000
Dam Removal Components[a]	$10,440,000	$14,800,000
Subtotal		$92,060,000
Contingency (25%)		$23,015,000
Total		$115,075,000

a USACE 9/2004 estimate
b USACE 11/2008 estimate
c Based on USACE and BOR cost trends escalation factor from 9/2004 to 7/2014 = 1.418; from 11/2008 to 7/2014 = 1.188

3.0 Screening Results

3.1 Initial Option – 01: Containment Berm with High Flow Bypass

3.1.1 Initial Option Description

The primary objective of this initial option would be to use one high flow event, having a minimum peak average daily flow of approximately 1,700 cfs[5], to quickly erode and transport as much fine sediment as possible out of the reservoir and through the downstream reaches to the ocean. This initial option is intended to lessen the implementation duration and associated high turbidity impacts to downstream water diversions and ecology, by concentrating the majority of fine sediment erosion into a single storm event. Due to the uncontrolled nature of the sediment erosion and the large amounts of debris that may be present within/above the accumulated sediment, future consideration of high debris loads and associated flood control risk (during the fine sediment erosion process) would be necessary.

In order to set the project up to "wait" for a high flow event, the dam would need to be removed and flows smaller than the high flow event would need to bypass the reservoir. The following major features would need to be implemented and are shown conceptually in Figure 1:

- Flow bypass system around reservoir fine sediment
- Temporary containment berm downstream of the dam
- Single-phase dam removal

Major features are discussed in more detail below.

3.1.1.1 Flow Bypass System

Prior to the high flow event, smaller event flows would be routed around the reservoir to prevent them from eroding accumulated sediment that would cause repeated high turbidity impacts to the downstream reach. A flow bypass would be constructed to divert flows up to the high transport flow event of 3,000 cfs peak flow, plus some additional flow capacity as a safety factor. The flow bypass could be accomplished by constructing either a bypass pipeline along the canyon valley to a point downstream of the temporary containment berm, or a bypass tunnel to connect into North Fork (NF) Matilija Creek. Preliminary computations indicate that a pipeline would be more costly and difficult to construct; therefore, a bypass tunnel has been included for this initial option.

Conceptually, the capacity of a 14-foot-diameter horseshoe tunnel would be between 3,000 and 4,000 cfs. The bypass could be aligned to transport flow from Matilija Creek (upstream of the fine sediment) to NF

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[5] The minimum size event on Matilija Creek that is assumed to be able to transport the large quantities of fine sediment over a short period of time is a storm having an average daily flow of about 1,700 cfs or greater and peak daily flows of about 3,000 cfs or greater (Stillwater, 2014b).

Matilija Creek as shown on Figure 1. Due to the existing bank erosion issues along NF Matilija Creek, slope protection improvements to accommodate the additional flow may be necessary.[6]

A cofferdam would be constructed across the reservoir just upstream of the current pool at about Station 114+00 (Stillwater, 2014b). This location is purposely placed as far downstream as possible to minimize the length of the bypass tunnel, as well as the volume of localized storm water flow that would be able to pass over the fine sediment prior to occurrence of the high flow event. The cofferdam would divert Matilija Creek flows into a tunnel portal (bypass entrance), located downstream of the outlet of Rattlesnake Canyon. The tunnel portal could include a gate or control structure at the entrance that could be closed during the high transport flow so that no portion of the flow would bypass the reservoir fine sediments. The bypass tunnel would connect into NF Matilija Creek, and the bypassed flows would flow into the NF Matilija Creek and subsequently into the Ventura River. The quality of the bypassed water would be similar to flows already seen at Robles Diversion and other downstream diversions. An assessment would be needed to confirm that the additional flow to NF Matilija Creek does not have significant adverse impacts during the period when the bypass would be in operation.

The cofferdam would be constructed using alluvial materials available within the reservoir area that would be able to be eroded during the high flow event. When the high flow event is forecast, the bypass tunnel would be closed so that the entire high transport flow volume passes over the cofferdam and downstream into the reservoir, to maximize fine sediment mobilization.

In the event that substantial fine sediment remained after the first large event, an assessment would be needed to determine if a portion could be permanently stabilized in place (naturally or by mechanical means), or whether additional creek flows or larger future storm events would mobilize the remaining material, causing some level of downstream impact.

3.1.1.2 Temporary Containment Berm

A temporary containment berm, less than 25 feet in height, would be constructed between 500 and 1,000 feet downstream of the dam to hold fine sediment that would slump from the reservoir once the dam is removed. The purpose of the containment berm is to allow the dam to be removed during the dry season and to prevent fine sediment in the reservoir from moving too far downstream, thereby limiting initial downstream impacts. The location of the berm would be upstream of the confluence of Matilija Creek and NF Matilija Creek.

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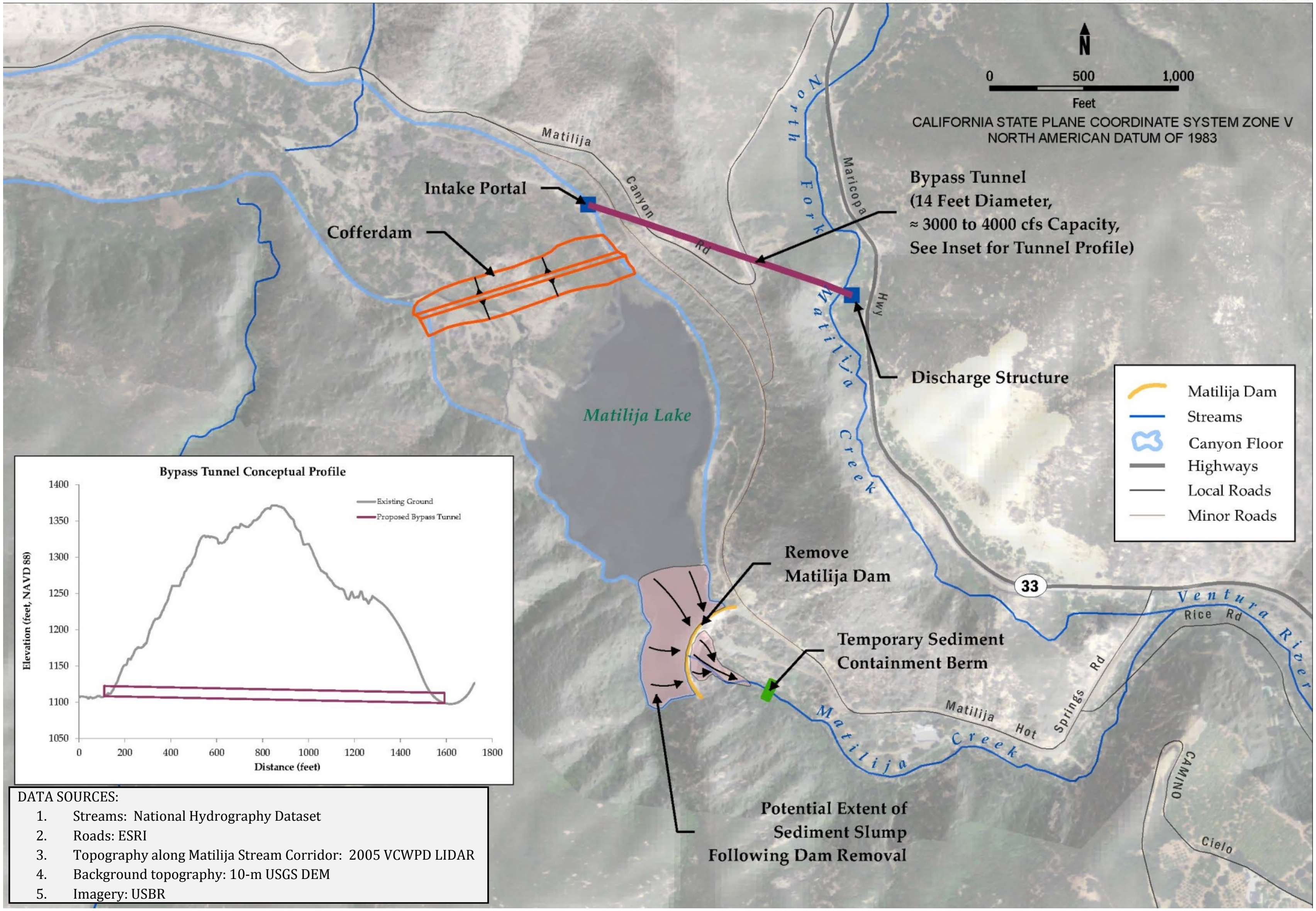
[6] Caltrans is preparing designs for bank stabilization project to protect Highway 33 in this area, which may be able to accommodate the additional flow, but design criteria for that project would need to be reviewed. The preliminary cost estimates here include bank stabilization measures for NF Matilija Creek.



DATA SOURCES:
1. Streams: National Hydrography Dataset
2. Roads: ESRI
3. Topography along Matilija Stream Corridor: 2005 VCWPD LIDAR
4. Background topography: 10-m USGS DEM
5. Imagery: USBR

Figure 1. Initial Option 01 – Containment Berm with High Flow Bypass

The containment berm would be constructed far enough downstream such that the slumping sediment would not impinge on the berm[7]. The berm would be high enough to control nuisance releases of sediment due to storm water flows from the local watershed downstream of the cofferdam location without creating an impoundment that would fall under the jurisdiction of the Division of Safety of Dams (DSOD) (although the dam removal plans would require DSOD approval). The containment berm would be designed to fail during the high transport event so as to not restrict the mobilization of the fine sediment.

3.1.1.3 Single-Phase Dam Removal

The dam would be removed at the end of the same season as construction of the containment berm and flow bypass system. It is desirable to remove the dam with as little fine sediment handling as possible, i.e. without dredging or excavating sediment upstream of the dam to access the dam for demolition, in order to minimize costs. The method of removal that would require the least fine sediment handling and has the lowest cost is blasting. The reservoir would be dewatered while the exposed section of the dam is removed prior to blasting. The concrete would be broken up and hauled to a recycling plant. After blasting of the remaining section of the dam, some of the concrete would be buried in the slumping sediment and would not be able to be removed and disposed of until after the high flow event.

Channelization through the reservoir area would be allowed to form naturally through transport of coarse sediment to the downstream reaches over time. Fish passage during the channelization process may need to be monitored. Where necessary, construction equipment may need to be mobilized following large events to dislodge debris jams or boulders that block fish passage.

3.1.2 Fine Sediment Mobilization

Under this scenario, fine sediment deposits within the reservoir and delta sub-areas (see Figure 2) will be redistributed downstream and be blocked by a containment berm once the dam is removed. Following the breaching of the cofferdam during the designed high flow event, both the cofferdam and the containment berm will be quickly washed out, thus initiating the release of fine and coarse sediment downstream.

There are two phases for the erosion of fine sediment deposit in the reservoir and delta sub-areas following breaching of the cofferdam, as discussed in further detail in Appendix A. Phase I erosion is initiated when the fine sediments in the reservoir and delta sub-areas are accessible to the flow (i.e., the flow is in direct contact with the fine sediment deposits) (Figure 3b), and Phase II erosion would occur subsequent to the first large flow peak, when fine sediment is no longer accessible to the flow (Figure 3c).

During Phase I erosion, the high-energy flow powered by the large discharge and steep gradient will cut through the fine sediment deposit quickly. Erosion during this phase will be governed by rapid gullying, followed by collapsing of banks and mass wasting, with the sediment generated from these processes being carried by the flow downstream.

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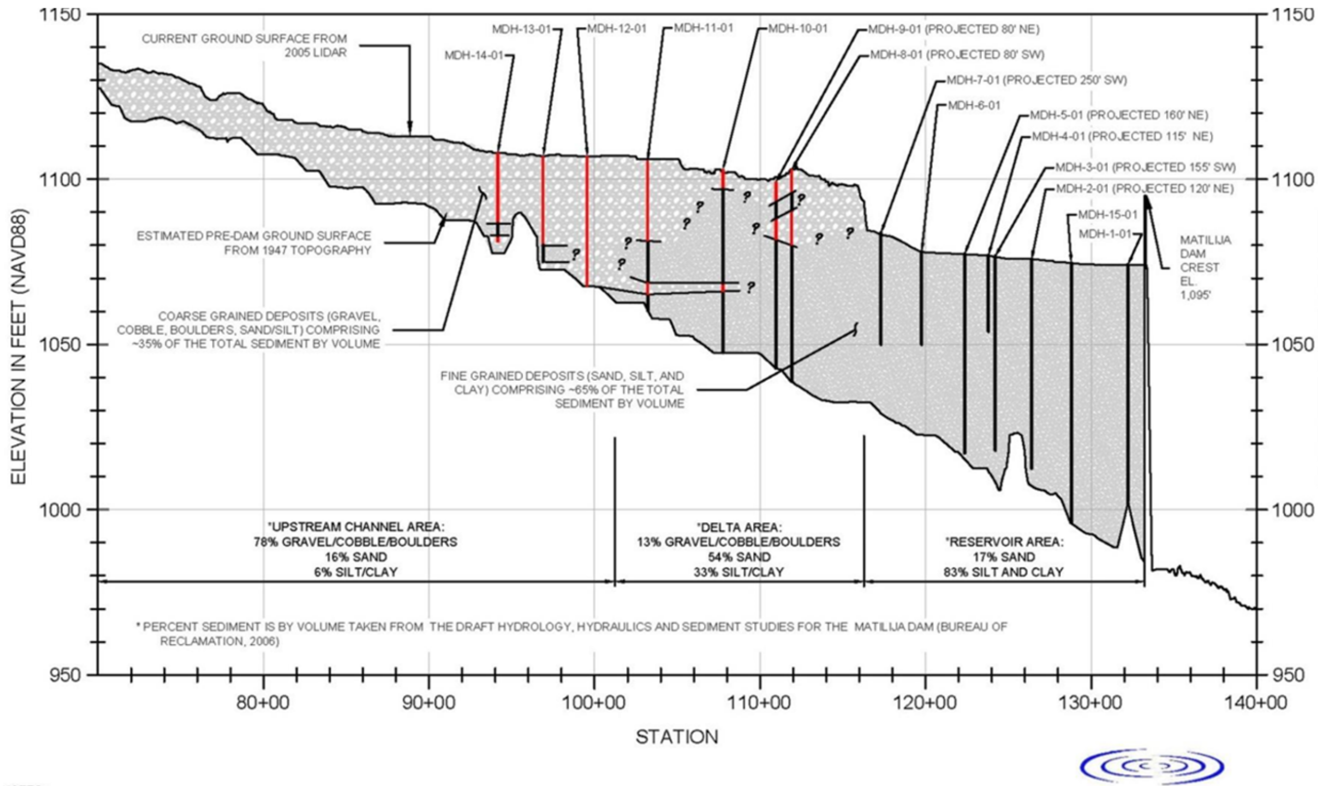
[7] The degree to which the sediment will slump and move downstream following removal of the dam by blasting would require further geotechnical and mud flow analyses if this initial option is carried forward. A review of some tailing dam failures suggest that sediment movement may have been limited to five to ten times the sediment height had the tailings ponds been dewatered prior to their failing.



NOTES:
1. PROFILE SHOWN WITH 20X HORIZONTAL EXAGGERATION
2. DEPTHS AT WHICH BOREHOLES ENCOUNTER COARSE SEDIMENT DEPOSITS ARE HIGHLIGHTED IN RED

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Figure 2. Matilija Reservoir sediment profile, showing the general distributions of gravel, sand and silt/clay deposits in three regions: upstream channel, delta, and reservoir sub-area. Diagram reproduced from Stillwater Sciences (2014b).

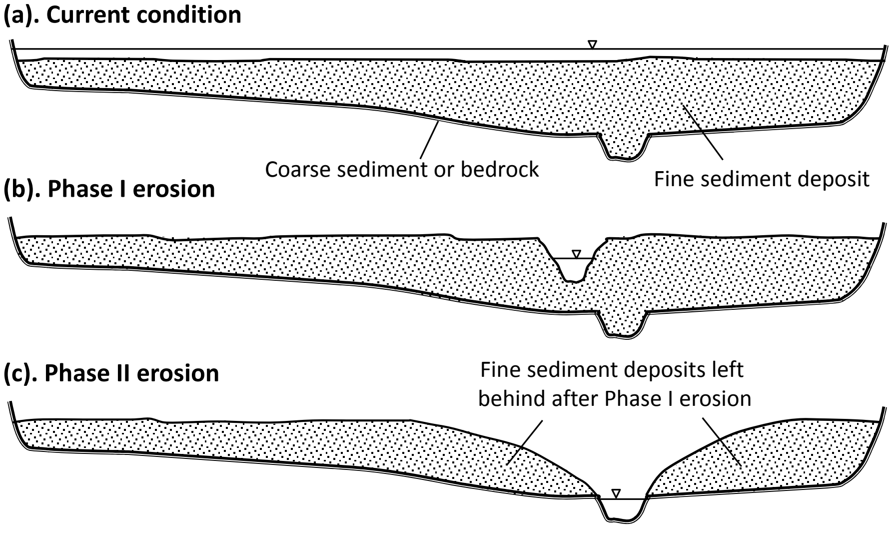

Figure 3. Sketches showing the two phases of fine sediment erosion. (a). Current condition; (b). Phase I erosion when fine sediment is directly accessible to the flow, presenting a virtually unlimited supply of sediment with transport limited only by the capacity and rate of discharge; and (c). Phase II erosion when fine sediment is no longer directly accessible to the flow.

Phase I erosion will likely erode only a portion of the fine sediment deposit from the reservoir area, because of a large deposit to channel width ratio, as illustrated in Figure 3b. Erosion will create a channel down through the fine sediment that may be on the order of 60 to 100 feet wide at the base of the channel with marginally stable side slopes on the order of 2 Horizontal:1 Vertical (2H:1V). The highest suspended sediment concentrations will occur during Phase I. Based on assessments of shear stress, creek flow carrying capacity and suspended sediment concentrations summarized in Appendix A, a conservative but plausible estimate of the duration of Phase I erosion for IO-01 is 13.5 hours (see Table A-4, Appendix A; assumes a suspended sediment carrying capacity of 500,000 mg/l and fine sediment erosion mass of 1.17 million metric tons).

Following the end of Phase I erosion, the remaining fine sediment deposits will no longer be accessible to the flow, and as a result the suspended sediment concentration in the river will decrease in time. Fine sediment erosion during the initial stage of Phase II erosion will primarily be the result of a mass wasting process that delivers fine sediment to the active channel, with sediment from high above the water surface slumping into the channel to be carried downstream by the flow. Based on the assessment summarized in Appendix A, a plausible maximum duration of potential impact due to Phase II mass wasting is approximately six days (see Table A-5, Appendix A; assumes a discharge of 500cfs at the end of Phase II, and a Phase II fine sediment erosion mass of 1.66 million metric tons).

Future high flow events equal to or greater than the initial high flow event would be likely to continue Phase II sediment transport that would only incrementally increase suspended sediment loads in comparison to the suspended sediments loads that typically occur in Matilija Creek. Therefore, a conservative duration of total fine sediment mobilization downstream impact (Phase 1 plus Phase II mass wasting) would be approximately seven days (i.e. no more than the first seven days of large storm event). This duration is approximate and is provided for comparison purposes only. Further refinement of the fine sediment downstream impact duration will be provided in a subsequent phase of work.

As mentioned previously, the minimum size event on Matilija Creek that is assumed to be able to transport large quantities of fine sediment over a short period of time is a storm having an average daily flow of about 1,700 cfs or greater and peak daily flows of about 3,000 cfs or greater (Stillwater, 2014b). A storm of this magnitude would be the design storm for IO-01. A review of recent storm data (2002-2014) reveals that storms meeting these general criteria do in fact typically have high flow durations that exceed the estimated Phase I erosion duration summarized above (see Figure 4).

As expected, all relatively large storms during this period of record have high flow durations that easily surpass the estimated Phase I erosion duration. A summary of the relevant storm data is listed below:

- 12/31/2004 storm: 2,780 cfs peak; 1,170 cfs maximum average daily flow; 28-hour duration above 1,000 cfs
- 1/9/2005 storm: 8,360 cfs peak; 5,950 cfs maximum average daily flow; 108- hour duration above 1,000 cfs
- 2/21/2005 storm: 8,780 cfs peak; 5,940 cfs maximum average daily flow; 137- hour duration above 1,000 cfs
- 4/4/2006 storm: 2,910 cfs peak; 1,410 cfs maximum average daily flow; 15- hour duration above 1,000 cfs

- 1/27/2008 storm: 6,080 cfs peak; 3,560 cfs maximum average daily flow; 85- hour duration above 1,000 cfs
- 3/20/2011 storm: 6,220 cfs peak; 2,350 cfs maximum average daily flow; 25- hour duration above 1,000 cfs

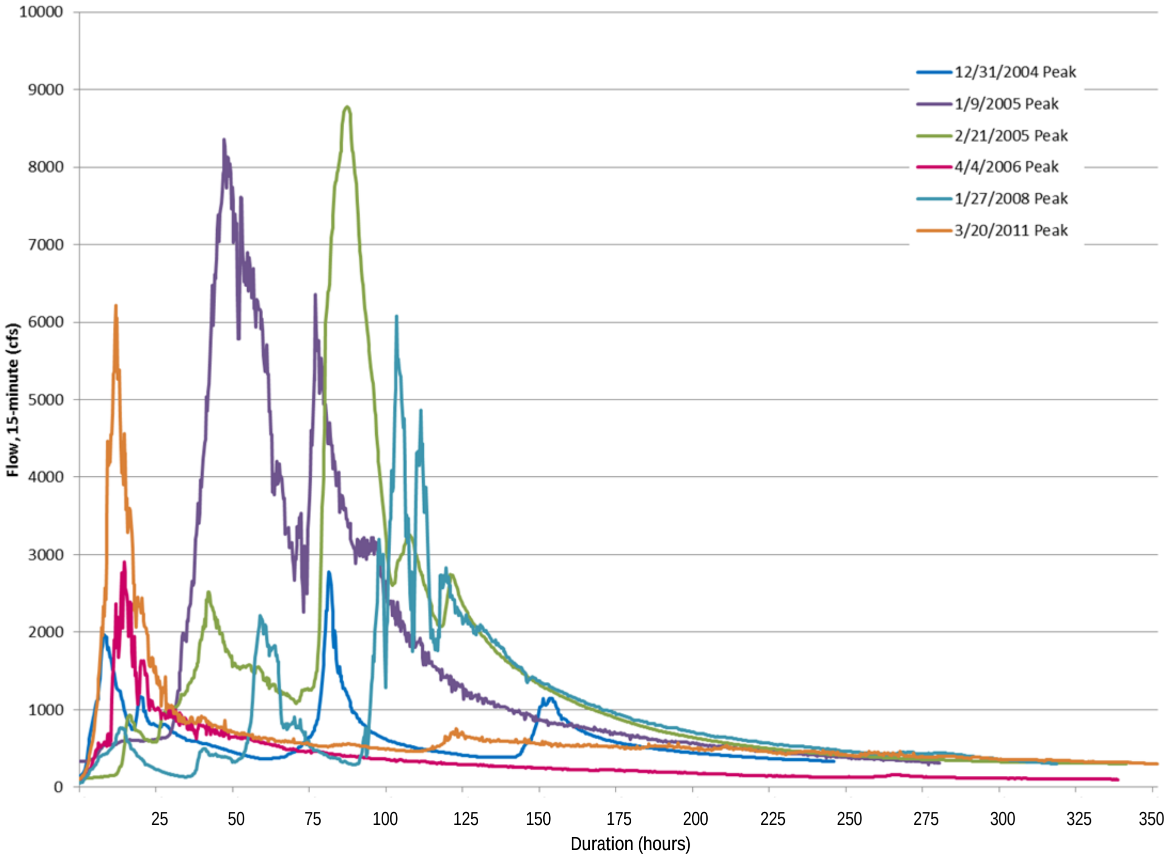

Figure 4. 15-minute data storm data for Matilija Creek (USGS Gage #11114495) for 2004-2011

For the estimated duration of downstream fine sediment impacts described above, it is anticipated that diversions at Robles would need to be suspended. In addition, there is a high likelihood of short-term impact to aquatic resources during the impact duration, which are described in more detail in Appendix A.

3.1.3 Construction Duration

In general, IO-01 would require that the bypass tunnel, upstream cofferdam, and downstream containment berm be in place prior to removal of the dam. Construction of the bypass tunnel would begin during the first season of construction from the downstream end and would continue through the winter season, being completed early in the in-channel construction window during the second season of construction. Following construction of the upstream cofferdam, also early in the in-channel construction season of the second construction season, flows from Matilija Creek would be diverted through the bypass tunnel allowing dewatering of the reservoir and the commencement of drilling blast holes in Matilija Dam.

The dam would be demolished by blasting following construction of the downstream construction berm. It is anticipated that blasting of the dam would result in pile of rubble that would be covered or mixed with sediment that would slump downstream of the reservoir. To the extent possible, the concrete rubble would be broken up using excavators with hoerams, loaded into highway legal dump trucks, and hauled to a concrete recycling plant located approximately 30 miles away.

The project would then wait for the large event to occur. Some portion of the remaining concrete would likely be carried downstream by the high flow event. Concrete rubble and any portions of the dam remaining at the dam site above the invert of Matilija Creek would be removed, broken up, loaded, and hauled to the recycling plant during the in-channel construction window following the large event.

A total of three construction seasons would be required; two prior to the large event and one following the large event. The estimated schedule for construction is shown on Figure B-1 in Appendix B. Construction duration for IO-01, from start of construction to completion of removal of the dam would be in the range of three to six years depending on the timing of the high flow event that removes the sediment.

3.1.4 Range of Magnitude Construction Cost

A summary of the ROMCC for IO-1 using the same Project Categories as those for Alternative 4b in Section 2.3.2 is shown below in Table 2. The individual items comprising each feature in the ROMCC for IO-1 are shown in Table B-1 in Appendix B.

Table 2. Summary of Initial Option-01 ROM Construction Costs

Project Categories	Construction Cost (2014)	Low (-30%)	High (+50%)
Mobilization	$4,300,000		
Site Preparation	$13,400,000		
Sediment Components	$0		
Slurry System Components	$0		
Dam Removal Components	$9,700,000		
Subtotal	$27,400,000		
Contingency (30%)	$8,200,000		
Subtotal	$35,600,000		
Construction Contingency (15%)	$5,300,000		
Total	$40,900,000	$28,700,000	$61,400,000

3.2 Initial Option – 02: Uncontrolled Orifices

3.2.1 Initial Option Description

The objective of this initial option would be to erode and transport as much fine sediment as possible from the reservoir, while minimizing costs and time associated with large bypass/containment structure construction and sediment removal. The fine sediment mobilization would be achieved by allowing flow through one or more uncontrolled orifices, whose opening would be coordinated to coincide with a high transport storm (as summarized in IO-01). The orifices would be sized and located to maximize mobilization of the reservoir and delta area sediments; however, if the unpressurized capacity[8] of the orifice is exceeded, it could result in reduced reservoir sediment erosion and transport for the duration of the capacity exceedence. Although lower sediment mobilization would be expected if the orifice unpressurized capacity is exceeded, a secondary benefit would be some level of flood protection (while the dam and orifices remain in place) due to the peak flow attenuation behind the orifice/dam for flows above design capacity.

Similar to IO-01, future consideration of high debris loads and associated flood control risk and the potential for plugging the orifices (during the fine sediment erosion process) would be necessary.

The following major features would be implemented, and are shown conceptually in Figure 5:

- Installation and operation of uncontrolled orifices
- Dam removal

Major features are discussed in more detail below.

3.2.1.1 Installation and Operation of Uncontrolled Orifices

Installation of the orifice(s) could be completed without prior fine sediment handling, thereby keeping construction costs relatively low. In addition, the orifice construction method described below makes it unnecessary to construct a temporary containment berm and upstream diversion (since reservoir sediments are not directly exposed to storm flows prior to the high transport event).

Two or three tunnels would be bored through the base of the dam from the downstream face up to a safe and stable distance from the upstream face (see Appendix C for as-built drawings of the dam structure). Twelve-foot-diameter tunnels would conceptually have a maximum open channel capacity in the range of 1,200-1,400 cfs, thus two- and three-tunnel arrangements would allow for open channel releases of 2,400-2,800 cfs and 3,600-4,200 cfs, respectively. A downstream system of walers or horizontal beams would be installed above and below the tunnels if structural stability analyses of the dam indicated the need for additional support to maintain the integrity of the arch. The remaining several feet of concrete that would connect through to the upstream side of the dam would be set up for rapid mobilization of a controlled blasting operation. During the first high flow event, the remaining concrete would be blasted, and fine sediment would be flushed from the reservoir through the uncontrolled orifices.

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[8] The orifices will provide the most benefit for sediment transport when they operate in an unpressurized, open channel condition. Once that capacity is exceeded, the reservoir will begin to refill and trap sediment until the reservoir drains again on the descending limb of the storm event.

In the event that substantial fine sediment remained after the first large event, an assessment would be needed to determine if a portion could be permanently stabilized in place (naturally or by mechanical means), or whether additional creek flows or larger future storm events would mobilize the remaining material causing some level of downstream impact. Although not included at this phase, a future refinement to this initial option could consider installing orifice gates (on upstream dam face) after the first large storm, to provide flexibility in dam operation prior to removal.

3.2.1.2 Dam Removal

Following the initial evacuation of fine sediment, the dam would be removed in its entirety. The dam would likely be demolished using blasting methods with the concrete being broken up and hauled to a recycling plant.

Channelization through the reservoir area would be allowed to form naturally through transport of coarse sediment to the downstream reaches over time. Fish passage during the channelization process may need to be monitored. Where necessary, construction equipment may need to be mobilized following large events to dislodge debris jams or boulders that block fish passage.

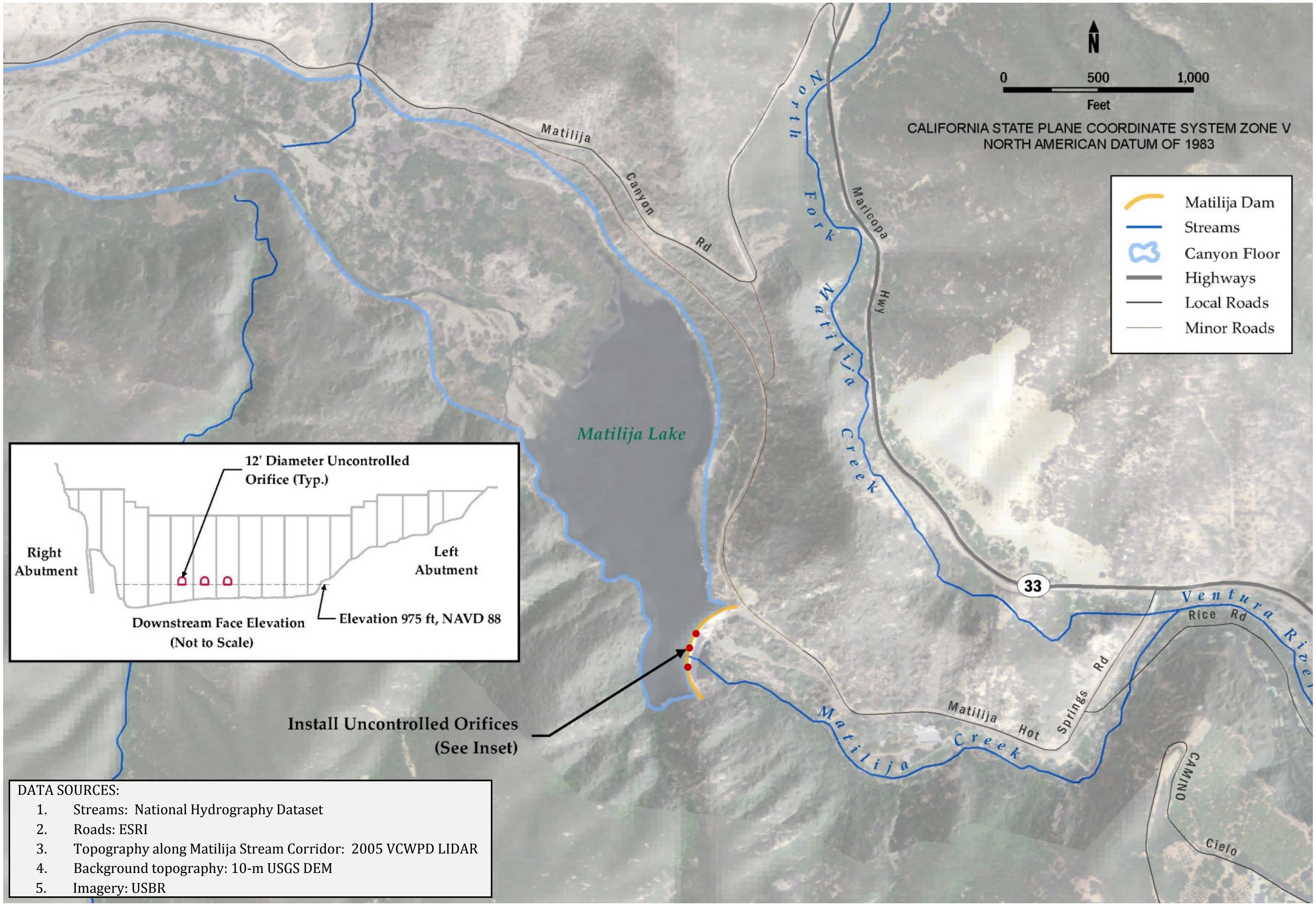

Figure 5. Initial Option 02 – Uncontrolled Orifices

3.2.2 Fine Sediment Mobilization

Fine sediment transport dynamics following the opening of the tunnel for IO-02 is similar to that of IO-01 discussed above, when in-stream flow is below the tunnels' capacity under open channel flow conditions. If water discharge exceeds the tunnels' capacity under open channel flow conditions, however, reservoir pool level would rise, resulting in decreased fine sediment erosion or even complete termination of the erosion process, depending on the pool level. If that were to happen, erosion of fine sediment would resume during the receding limb of the flow event, again, similar to that discussed for IO-01 above. It is anticipated that the combined duration of sediment-eroding flow (i.e., high flow that does not exceed the tunnels' capacity) will exceed what is needed to accomplish Phase I erosion.

Similar to IO-01, a conservative duration of downstream impact associated with total fine sediment mobilization (Phase I plus Phase II mass wasting) would be approximately seven days (i.e. no more than the first seven days of large storm event). This duration is approximate and is provided for comparison purposes only. Further refinement of the fine sediment downstream impact duration will be provided in a subsequent phase of work.

As mentioned previously, the minimum size event on Matilija Creek that is assumed to be able to transport large quantities of fine sediment over a short period of time is a storm having an average daily flow of about 1,700 cfs or greater and peak daily flows of about 3,000 cfs or greater (Stillwater, 2014b). A storm of this magnitude would be the design storm for the IO-02 orifices. A review of recent storm data (2002-2014) reveals that storms meeting these general criteria do in fact typically have high flow durations that exceed the estimated Phase I erosion duration summarized above (see Figure 4). For IO-02, the durations summarized below do not include the duration of each storm when the orifice capacity is exceeded.

As expected, all relatively large storms during this period of record have high flow (between 1,000 cfs and 3,000 cfs) durations that surpass the estimated Phase I erosion duration. A summary of the relevant storm data is listed below:

- 12/31/2004 storm: 2,780 cfs peak; 1,170 cfs maximum average daily flow; 28- hour duration between 1,000 cfs and 3,000 cfs
- 1/9/2005 storm: 8,360 cfs peak; 5,950 cfs maximum average daily flow; 68- hour duration between 1,000 cfs and 3,000 cfs
- 2/21/2005 storm: 8,780 cfs peak; 5,940 cfs maximum average daily flow; 117- hour duration between 1,000 cfs and 3,000 cfs
- 4/4/2006 storm: 2,910 cfs peak; 1,410 cfs maximum average daily flow; 15- hour duration between 1,000 cfs and 3,000 cfs
- 1/27/2008 storm: 6,080 cfs peak; 3,560 cfs maximum average daily flow; 76- hour duration between 1,000 cfs and 3,000 cfs
- 3/20/2011 storm: 6,220 cfs peak; 2,350 cfs maximum average daily flow; 18- hour duration between 1,000 cfs and 3,000 cfs

For the estimated duration of downstream fine sediment impacts described above, it is anticipated that diversions at Robles would need to be suspended. In addition, there is a high likelihood of short-term impact to aquatic resources during the impact duration, which are described in more detail in Appendix A.

3.2.3 Construction Duration

Initial construction activities for this initial option would include filling of the plunge pool area up to Elevation 975 feet to form a construction platform from which the orifices would be excavated through the base of the dam. The orifices are assumed to be constructed by excavating though the concrete in four-foot long increments using a combination of drilling and hydraulic breaking. A series of four-foot deep holes would be drilled around the perimeter of orifice and within the concrete mass inside the perimeter. The concrete would then be broken out from inside the perimeter. Using this method, each orifice would be excavated to within about 8 feet of the upstream face of the dam. A series of blast holes would then be drilled to perhaps two to four feet of the upstream face of the dam in preparation for loading and blasting just prior to the large storm event that would be used to erode fine sediment from the reservoir. Concrete rubble from resulting from the excavation of the orifices would be loaded and hauled to a concrete recycling plant located approximately 30 miles away.

The project would then wait for the large flow event to occur. A decision-making process would need to be in place to determine when a predicted large storm would have enough certainty to give the go-ahead to load the pre-drilled blast holes and blast out the remaining plugs in the tunnels, initiating release of the fine sediment. Blasting of the plugs could be timed to occur during the beginning of the storm event. The dam would be removed by drilling and blasting, breaking up the concrete rubble using excavators with hoerams, loading into highway legal dump trucks, and hauling to the concrete recycling plant.

A total of two construction seasons would be required; one prior to the large event and one following the large event. The estimated schedule for construction is shown on Figure B-2 in Appendix B. Construction duration for Initial Option 2, from start of construction to completion of removal of the dam would be in the range of two to five years depending on the timing of the high flow event that removes the sediment.

3.2.4 Range of Magnitude Construction Cost

A summary of the ROMCC for IO-2 using the same Project Categories as those for Alternative 4b in Section 2.3.2 is shown in Table 3. The individual items comprising each feature in the ROMCC for IO-2 are shown in Table B-2 in Appendix B.

Table 3. Summary of Initial Option-02 ROM Construction Costs

Project Categories	Construction Cost (2014)	Low (-30%)	High (+50%)
Mobilization	$2,100,000		
Site Preparation	$1,200,000		
Sediment Components	$0		
Slurry System Components	$0		
Dam Removal Components	$9,600,000		
Subtotal	$12,900,000		
Contingency (30%)	$3,800,000		
Subtotal	$16,700,000		
Construction Contingency (15%)	$2,500,000		
Total	$19,200,000	$13,500,000	$28,900,000

3.3 Initial Option – 03: Gated Orifices

3.3.1 Initial Option Description

The objective of this initial option would be to erode and transport fine sediment from the reservoir using a similar approach as described for IO-02, while providing flexibility through gating the orifice(s), which would allow refilling and spilling of a partial reservoir during lower flows to provide cleaner water for downstream diversion. This option has similar benefits to IO-02 with regard to lower construction cost and duration, while providing greater flexibility (through use of the gates) to potentially minimize downstream impacts (water supply and ecological) through use of the gates. Closure of the gates after the first high transport event would allow flexibility to “wait” for another similar event to transport the remainder of the fine sediments, while allowing for cleaner downstream water diversions during the waiting period (as the reservoir fills up and spills).

The following major features would be implemented and are shown conceptually in Figure 6:

- Installation and operation of gated orifices
- Removal of dam

Major features are discussed in more detail below.

3.3.1.1 Installation and Operation of Gated Orifices

Two or three large diversion sluice gates would be installed with invert elevations at about 975 feet (stream channel invert). Twelve-foot diameter gates would conceptually have a maximum open channel capacity in the range of 1,200-1,400 cfs, thus two- and three-gate arrangements would allow for open channel releases of 2,400-2,800 cfs and 3,600-4,200 cfs, respectively. Unlike construction of IO-02, installation of the gates would require either excavation of sediment away from the face of the dam or installation of a sheet pile or other type of cofferdams to provide access to the upstream face of the dam. Excavation of approximately 300,000 cy of sediment would require dewatering the reservoir and sediment[9] to the extent possible. Dewatering would not be required for cofferdam installation, except within the cofferdams themselves. However, the curved upstream face of the dam would be problematic in designing cofferdams that would be able to fit against the dam.

After creating access to the upstream dam face, the tunnels for the gated orifices would be mined through the dam using drilling and concrete breaking, wire sawing methods, or possible micro-blasting techniques. Steel liners would be installed in the tunnels, and gates with trash racks would be installed on upstream side of dam. A downstream system of walers or horizontal beams would be installed above and below the tunnels if structural stability analyses of the dam indicate the need for additional support to maintain the integrity of the arch. The cofferdams would be removed after orifice construction and gate installation is complete.

Operationally, the sluice gates would remain in the closed position until a storm having the potential to be greater than a daily average of 1,700 cfs is forecast. When the storm is forecast, downstream diversion facilities would be shut down and the sluice gates opened to dewater the reservoir. The initial opening would result in very high concentrations of fine sediment discharging through the gates. Large storm flows that do not exceed the open channel capacity of the gates would be the most effective in transporting the fine sediment out of the reservoir to the ocean. When inflows exceed the open channel capacity of the gates, the reservoir would begin to impound, thereby reducing velocities and the effectiveness of sediment removal.

On the tail of the storm, once flows have dropped to a flow that is yet to be determined (possibly in the range of 200 to 400 cfs), the gates could be closed so the reservoir could refill as deemed necessary. With the addition of a six-foot diameter gated mid-level penetration, downstream water diversions could restart once flows begin spilling through the mid-level orifice because a partial impoundment would lessen turbidity. The mid-level orifice would be installed at the same time as the gated orifices. Following the initial high transport storm, the mid-level penetration would also be used to maintain the reservoir at a lower level, thereby increasing dam stability (by decreasing the hydraulic head on the dam structure) until the fine sediment has been evacuated and the dam can be removed.

A possible future refinement to this option could be to consider installing the gates after the first large storm mobilizes a significant volume of the fine sediments. This could reduce the effort associated with upstream excavation discussed above for gate installation.

3.3.1.2 Dam Removal

Following the high flow storm event that is judged to have sufficiently removed the fine sediment from upstream of the dam, the dam would be removed using blasting methods with the concrete being broken up and hauled to a recycling plant.

Channelization through the reservoir area would be allowed to form naturally through transport of coarse sediment to the downstream reaches. Fish passage during the channelization process may need to be

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[9] Dewatering of the reservoir sediment is likely to be limited due to the fine-grained characteristics of the reservoir sediment (average 85 percent finer than 0.074 mm and 35 percent finer than 0.005 mm).

monitored. Where necessary, construction equipment may need to be mobilized following large events to dislodge debris jams or boulders that block fish passage.

3.3.2 Fine Sediment Mobilization

Fine sediment transport dynamics following the opening of the tunnels/gates for IO-03 is similar to that of IO-02 discussed previously. Similar to IO-02, a conservative duration of downstream impact associated with total fine sediment mobilization (Phase I plus Phase II mass wasting) would be approximately seven days (i.e. no more than the first seven days of large storm event). All relatively large storms during the period 2002-2014 have high flow (between 1,000 cfs and 3,000 cfs) durations that surpass the estimated Phase I erosion duration. This duration is approximate and is provided for comparison purposes only. Further refinement of the fine sediment downstream impact duration will be provided in a subsequent phase of work.

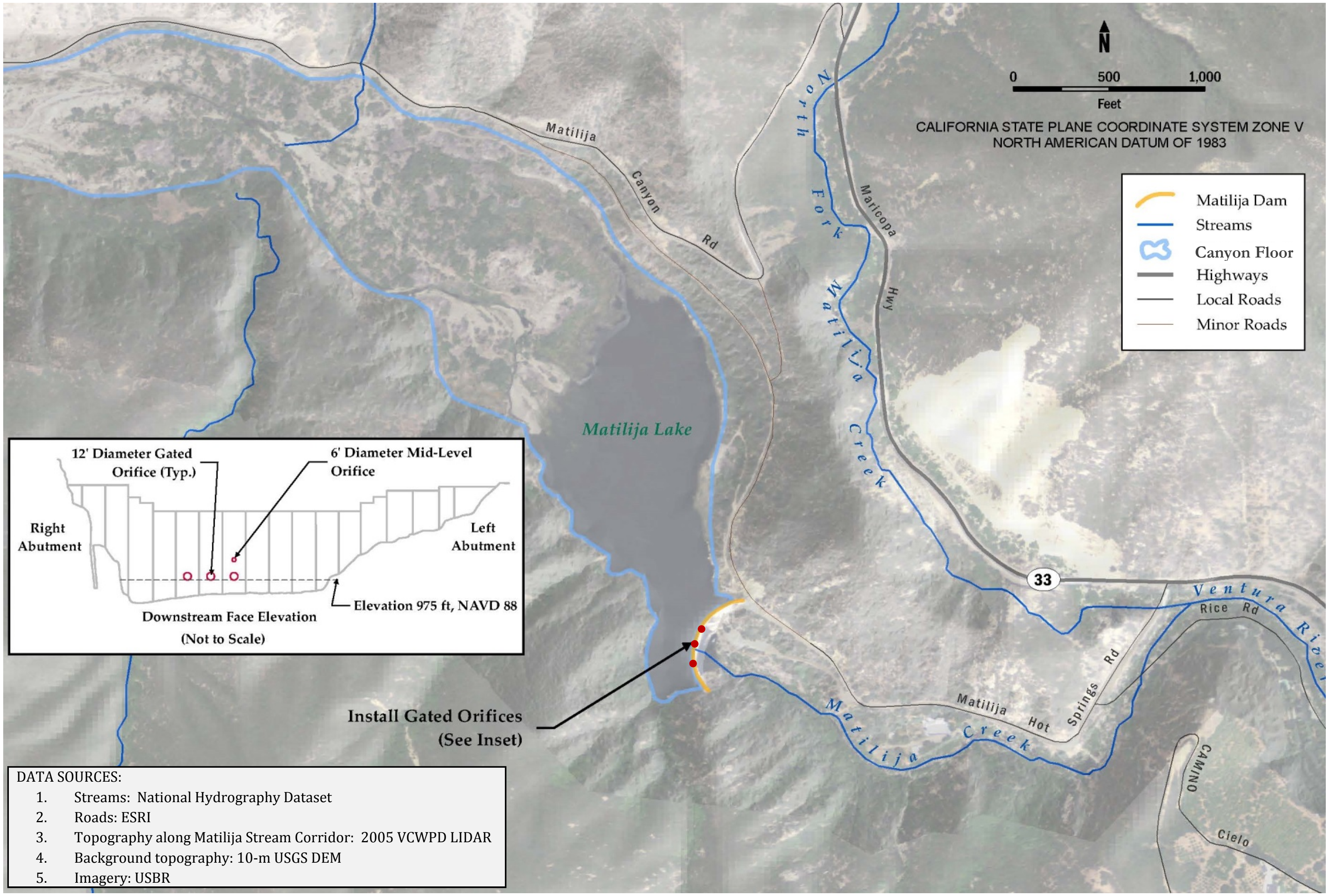
For the estimated duration of downstream fine sediment impacts described above, it is anticipated that diversions at Robles would need to be suspended. In addition, there is a high likelihood of short-term impact to aquatic resources during the impact duration, which are described in more detail in Appendix A.

3.3.3 Construction Duration

Early activities for this initial option would include mobilizing and setting up a water treatment system that would be used to handle water from draining the reservoir and water from dewatering wells and sump pumps located in the sediment excavation. A small cofferdam and temporary diversion system would be installed in the upstream reservoir area to divert summer flows from Matilija Creek around the sediment excavation area. Dewatering wells that would extend through the fine sediment into the underlying alluvium near the upstream face of the dam and shallower vacuum wells or wellpoints in the fine sediment would be installed and operated to draw the phreatic surface in the reservoir sediment down below the excavation grade. The fine sediment would not be anticipated to dewater significantly and would remain at a high moisture content.

Excavation and hauling of the 300,000 cy of fine sediment required to expose the upstream face of the dam is assumed to be performed using excavators and articulated off-highway trucks. Where the excavated grade is found to be too weak to support the equipment access, roads and working platforms would be constructed using coarse alluvium from upstream. These methods are currently being used to excavate fine sediment from the reservoir area of the Carmel River Reroute and Dam Removal Project. Sediment removal would be performed during two shifts each day so that sufficient time would be available at the end of the construction season to install the gates on the upstream side of the orifices.

Construction sequencing for excavation of the orifices for this initial option would be the same as for IO-02, except that the orifices would be tunneled all the way through the dam. The holing through of the orifices would be timed to coincide with completion of excavation of the sediment from the upstream face of the dam. Following completion of installation of the gates, the reservoir would be allowed to refill.



DATA SOURCES:

1. Streams: National Hydrography Dataset
2. Roads: ESRI
3. Topography along Matilija Stream Corridor: 2005 VCWPD LIDAR
4. Background topography: 10-m USGS DEM
5. Imagery: USBR

Figure 6. Initial Option 03 – Gated Orifices

The project would then wait for the large event to occur. A decision-making process would need to be in place to determine when a predicted large storm would have enough certainty to give the go-ahead to open the gates, drain the reservoir, and allow as much of the storm as possible to flow through the orifices in an unpressurized condition. The dam would then be removed by drilling and blasting, breaking up the concrete rubble using excavators with hoerams, loading into highway legal dump trucks, and hauling to the concrete recycling plant during the in-channel season following the large storm event.

A total of two construction seasons would be required; one prior to the large event and one following the large event. The estimated schedule for construction is shown on Figure B-3 in Appendix B. Construction duration for IO-03, from start of construction to completion of removal of the dam would be in the range of two to five years assuming that Phase I erosion of the fine sediment occurs during the first single large event. In the event that it was determined that it would be desirable to maintain the dam in place and await a second large storm, the construction duration would increase to a total of six to nine years.

3.3.4 Range of Magnitude Construction Cost

A summary of the ROMCC for IO-3 using the same Project Categories as those for Alternative 4b in Section 2.3.2 is shown in Table 4. The individual items comprising each feature in the ROMCC for IO-3 are shown in Table B-3 in Appendix B.

Table 4. Summary of Initial Option-03 ROM Construction Costs

Project Categories	Construction Cost (2014)	Low (-30%)	High (+50%)
Mobilization	$3,300,000		
Site Preparation	$4,200,000		
Sediment Components	$2,900,000		
Slurry System Components	$0		
Dam Removal Components	$9,600,000		
Subtotal	$20,000,000		
Contingency (30%)	$6,000,000		
Subtotal	$26,000,000		
Construction Contingency (15%)	$3,900,000		
Total	$29,900,000	$20,900,000	$44,800,000

There is a risk that excavation of the reservoir sub-area sediment by mechanical means might prove to be infeasible following additional geotechnical characterization and analyses. In that case, sediment would need to be removed from the face of the dam using slurry dredging methods. The slurry material would be transported to an upstream staging area, run through a rapid dewatering system[10], and hauled and placed in a temporary upstream storage area. The additional cost of slurry dredging of the sediment over mechanical removal of the sediment for this initial option including contingencies would be $3,200,000.

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[10] Rapid dewatering systems are available that pass a dredged slurry stream through a desanding unit, flocculating unit, and units that remove free and secondary water from the fines resulting in a stackable fill.

3.4 Initial Option – 04: Gated Notch(es)

3.4.1 Initial Option Description

The objective of this initial option would be to erode and transport fine sediment from the reservoir and complete the dam removal through a series of phased notches. Phasing the notches allows for limiting the total volume of fine sediment that can be sluiced during each phase, with the perceived benefit of limiting downstream impacts. Although this would decrease suspended sediment concentrations during high flow events relative to IO-01, IO-02 and IO-03, phasing would likely result in a longer overall duration of increased turbidity and associated downstream water supply and ecological impacts, because multiple events would be required to remove the fine sediment.

Gating the notches is proposed to allow refilling and spilling of the reservoir during lower flows to provide cleaner water for diversion. Elimination of the gates could be considered as a cost-saving measure.

This initial option is anticipated to have a longer implementation duration relative to previously discussed options, and although the first phase construction cost would likely be lower than IO-03 (since access to the lower portions of the dam would not be required), it would require multiple mobilization, demobilization, and dewatering activities (for subsequent phases of notching).

The following major features would be implemented and are shown conceptually in Figure 7:

- Installation and operation of gated notches
- Removal of dam in five phases

Major features are discussed in more detail below.

3.4.1.1 Installation and Operation of Gated Notches

Initial notching of the dam would include installation of two 80-foot wide by 15-foot high notches in the dam. The two 80-foot-wide notches would conceptually have a depth of flow over the notch of approximately 6 feet during a 5-year storm event (7,090 cfs; BOR 2006) and 12.5 feet during a 100-year storm event (21,600 cfs; BOR 2006). At the same time the notches are being installed, portions of the dam at the right and left abutments above the top of notch elevations would be demolished as shown on Figure 7. The invert of the initial notches would be at or slightly below the current sediment level. Dam removal for notching would be completed by controlled demolition methods (i.e. wire sawing and hoe ram). A reinforced concrete frame would be constructed in the notches for receiving a 12-foot-high bladder or similar type of gate.

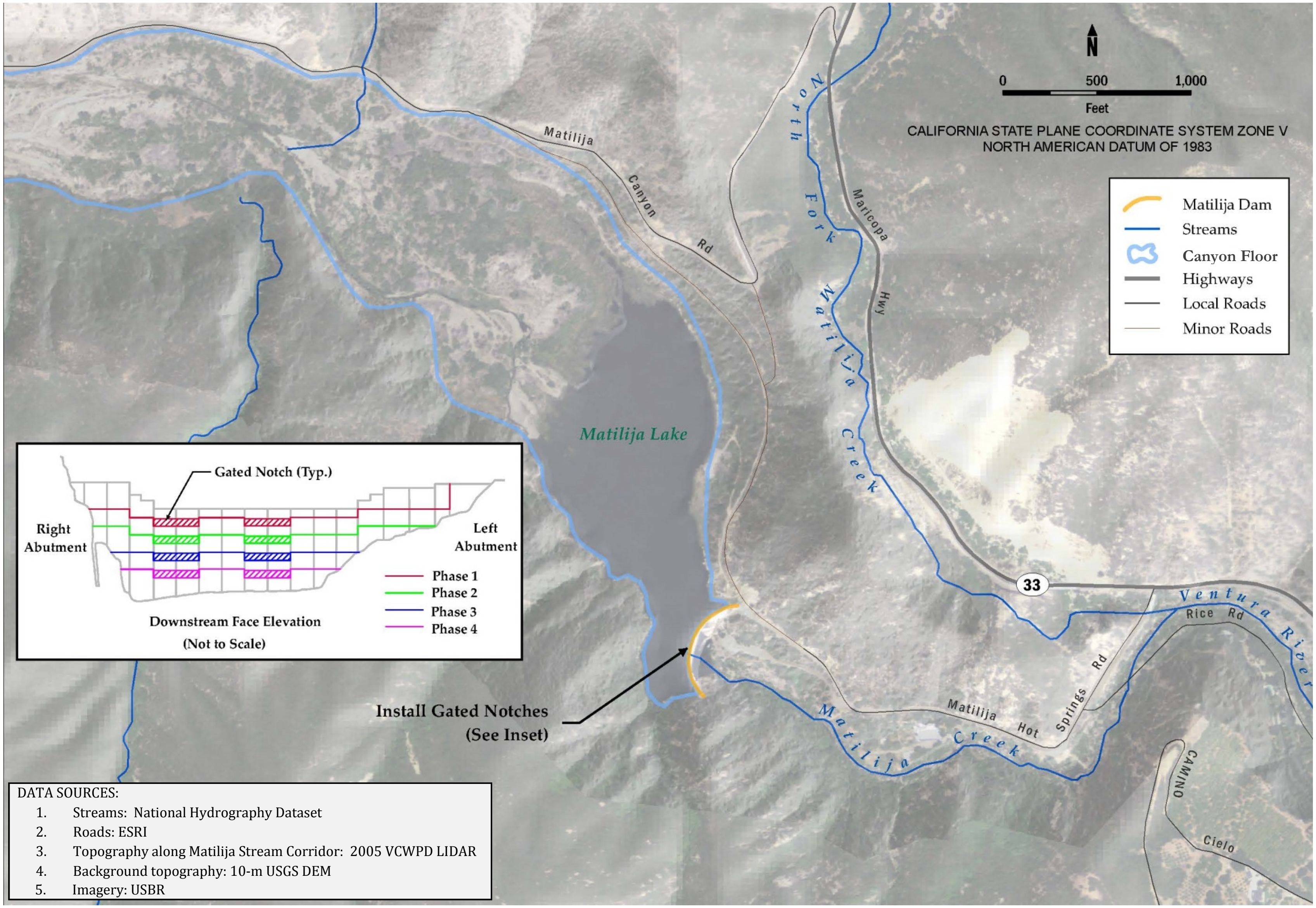
Construction of the initial notches and each successive notch would require dewatering of the reservoir prior to construction.

Operationally, the gated notches would remain in the raised (closed) position until a storm having the potential to be greater than a daily average flow of 1,700 cfs is forecast. Downstream diversions would be shut down and both gates lowered (opened) simultaneously ahead of the storm. Once storm flows have peaked and dropped back down to some level to be determined (possibly in the range of 200 to 400 cfs), the gates could be raised so the reservoir could refill and downstream diversions be restarted.

Construction of subsequent phases of notches would be initiated following a determination that a sufficient volume of the reservoir sediment had eroded from above the invert elevation of the current notch (i.e., the notch phases would be event-based). Flows across the notches will scour or pre-excavate a portion of the reservoir sediment just upstream of the notch(es). Depending on the depth of scour some additional sediment excavation may be required to expose the upstream dam face down to the invert level for installation of the next phase’s notches.

The fifth and final phase of dam removal would use blasting or hoe-ram methods. Concrete removed during each of the phases would be broken up and hauled to a recycling plant.

Channelization through the reservoir area would be allowed to form naturally through transport of coarse sediment to the downstream reaches. Fish passage during the channelization process may need to be monitored. Where necessary, construction equipment may need to be mobilized following large events to dislodge debris jams or boulders that block fish passage.



DATA SOURCES:
1. Streams: National Hydrography Dataset
2. Roads: ESRI
3. Topography along Matilija Stream Corridor: 2005 VCWPD LIDAR
4. Background topography: 10-m USGS DEM
5. Imagery: USBR

Figure 7. Initial Option 04 – Gated Notch(es)

3.4.2 Fine Sediment Mobilization

Sediment erosion dynamics following the opening of the gates on the notches is similar to that for IO-01, except that lesser amounts of sediment are eroded during each stage. The suspended sediment concentration during sediment erosion following the opening of the gates is expected to be extremely high, but lower than that for IO-01 due to the reduced energy gradient of the flow, resulting in overall longer duration of sediment erosion compared to IO-01.

High suspended sediment concentration as a result of mass wasting following the fifth stage of dam removal is still expected, but the suspended sediment concentration and duration of mass wasting is expected to be significantly lower and shorter compared to IO-01 because much of the mass wasting should have already occurred during the first four stages of notching.

Note that fine sediment in the reservoir sub-area can potentially be buried by coarse sediment during the later stages of notching for this initial option, which may result in a decreased magnitude of suspended sediment concentration, but longer duration for sediment flushing. The potentially increased duration of high suspended sediment concentration under the condition of fine sediment burial, however, should still not exceed a full day based on the experiences during Marmot Dam removal, where substantially higher suspended sediment concentrations compared to background conditions lasted only about 10 hours.

Although suspension of water diversion at Robles is likely needed for only a few hours during each gate opening event, water diversion suspension should be assumed to last a full day during each of the first four stages of notching and potentially the first week of the storm event for the fifth stage (to be comparable to IO-01). Therefore, a conservative duration of downstream impact associated with total fine sediment mobilization (Phase I plus Phase II mass wasting) would be approximately eleven days over multiple years. All relatively large storms during the period 2002-2014 have high flow (between 1,000 cfs and 3,000 cfs) durations that surpass the estimated Phase I erosion duration. This duration is approximate and is provided for comparison purposes only. Further refinement of the fine sediment downstream impact duration will be provided in a subsequent phase of work.

For the estimated duration of downstream fine sediment impacts described above, it is anticipated that diversions at Robles would need to be suspended. In addition, there is a potential for more long-term impacts to aquatic resources since the impact duration extends over multiple years. These impacts are described in more detail in Appendix A.

3.4.3 Construction Duration

Early activities for each of the notching phases for this initial option would be similar to IO-3. These would include mobilizing and setting up a water treatment system that would be used to handle water from draining the reservoir and water from sump pumps located in the sediment excavation. A small cofferdam and temporary diversion system would be installed in the upstream reservoir area to divert summer flows from Matilija Creek around the sediment excavation area at the upstream face of the dam. Excavation and hauling of the fine sediment from the face of the dam is assumed to be performed using excavators and articulated off-highway trucks. The volume of sediment excavation is assumed to be about 2,000 cy for the first notching phase and between 18,000 and 20,000 cy for each of the following notching phases. Where the excavated grade is found to be too weak to support the equipment, access roads and working platforms would be constructed using coarse alluvium from upstream. These methods are currently being used to excavate fine sediment from the reservoir area of the Carmel River Reroute and Dam Removal Project.

For each phase of notching, the portion of the dam above the notch would be demolished using a combination of wire sawing and drill and blast methods. For each phase following the initial notching phase, gates within the notches would be salvaged for reuse. The base of the portion of the dam being removed would be wire sawed and the dam above the wire saw cut would be drilled and blasted. The outline of the notches would be cut by wire saw and the concrete within the notch removed. The concrete rubble would be broken up using excavators with hoerams, loaded into highway legal dump trucks, and hauled to the concrete recycling plant. A reinforced concrete frame for the gates would be constructed within the notches and the gates installed using a crane from the downstream side of the dam. Following completion of installation of the gates the reservoir would be allowed to refill.

The project would then wait for the large event for each phase of notching to occur. A decision-making process would need to be in place to determine when a predicted large storm would have enough certainty to give the go-ahead to lower the gates to allow the storm to flow through the notches unimpeded.

The remaining portions of the dam above the Matilija Creek invert would be removed by drilling and blasting, breaking up the concrete rubble using excavators with hoerams, loading into highway legal dump trucks, and hauling to the concrete recycling plant during the in-channel season following the large storm event that passes the last phase of notching.

A total of five construction seasons would be required; one prior to each of four successive large events and one following the last large event. The estimated schedule for construction is shown on Figure B-4 in Appendix B. Construction duration for IO-04, from start of construction to completion of removal of the dam would be in the range of fourteen to seventeen years. Projects with fewer notches would require less time with a two- notch project requiring an estimated six to nine years and a three-notch project requiring ten to thirteen years for completion.

3.4.4 Range of Magnitude Construction Cost

A summary of the ROMCC for IO-4 using the same Project Categories as those for Alternative 4b in Section 2.3.2 is shown in Table 5. The individual items comprising each feature in the ROMCC for IO-4 are shown in Table B-4 in Appendix B.

Table 5. Summary of Initial Option-04 ROM Construction Costs

Project Categories	Construction Cost (2014)	Low (-30%)	High (+50%)
Mobilization	$3,500,000		
Site Preparation	$1,400,000		
Sediment Components	$600,000		
Slurry System Components	$0		
Dam Removal Components	$16,100,000		
Subtotal	$21,600,000		
Contingency (30%)	$6,400,000		
Subtotal	$28,000,000		
Construction Contingency (15%)	$4,200,000		
Total	$32,200,000	$22,600,000	$48,400,000

A sub-alternative to IO-4 would be to implement the notching plan without gates. Removal of the gates from this option, including contingencies, would reduce the construction cost by $3,900,000.

3.5 Initial Option – 05: Temporary Upstream Storage of Fine Sediment

3.5.1 Initial Option Description

The objective of this initial option would be to eliminate the need for a dredge-and-slurry system (associated with EIS/R Alternative 4b) by limiting release of accumulated sediment through partial handling and temporary stabilization within the reservoir. This could be accomplished by excavating a wide enough channel down to the pre-dam level from the dam to a point within the upstream reservoir that mobilization of sediment from the channel slopes would be no greater than during Phase II sediment transport for IO-1, IO-2, and IO-3. The excavated sediment would be temporarily stored in the reservoir area at elevations that would allow for transport during a three-year to ten-year or greater storm event. The dam would be demolished and removed during the same season the channel excavation is completed, such that fish passage would be restored through the site immediately after construction (in comparison to the other initial options, which require “waiting” for a large event to transport the majority of accumulated sediment and establish a fish passage channel).

The intent of the temporary stabilization would be to prevent frequent mobilization of fine sediment during low flows, and wait for a larger high transport storm to mobilize as much of the accumulated sediment as possible in one event.

The following major features would be implemented and are shown conceptually in Figure 8:

- Channel excavation
- Removal of dam

Major features are discussed in more detail below.

3.5.1.1 Channel Excavation

A channel would be excavated along the pre-dam Matilija Creek thalweg with the channel bottom being approximately 100 feet wide. The channel alignment will be refined in a future phase of work to maximize it's function and stability. The side slopes in the fine sediment (between the dam and roughly Station 101+00) would be about 5H:1V, while the side slopes in the coarse sediment (roughly upstream of Station 101+00) would be 3H:1V. This channel configuration is likely wider than might occur during Phase I sediment transport for IO-1, IO-2, and IO-3. Channel excavation would require dewatering of the reservoir as well as dewatering of the sediment to the extent possible. The fine sediment is likely to be difficult to dewater due to the fine-grained characteristics of the reservoir sediment (average 85 percent finer than 0.074 mm and 35 percent finer than 0.005 mm). Effective dewatering of this sediment typically requires vacuum wells or wellpoints placed at a relatively close spacing. Even after dewatering, the fine sediment would typically retain significant moisture, making these materials difficult to excavate and handle. Following excavation, the fine sediment would be laid out in thin lifts in a drying area to be moisture conditioned by discing. The moisture conditioned fine sediment would then be transported again and placed in the temporary storage areas.

Selection of temporary storage areas for this initial option first considered the storage sites that were included in Alternative 4b. The Alternative 4b lower storage sites would be utilized in IO-5 by the fine sediment that will remain outside of the channel slopes following excavation. Storing any significant volume of additional material on top of these slopes of weak material would be challenging and was assumed to be infeasible. The total capacity of the two largest Alternative 4b upper storage sites, assuming 3H:1V side slopes, was determined to range between 0.7 mcy to 1.3 mcy depending on the top elevation of the storage sites (see Figure 9).

Because the upper sites alone do not have sufficient capacity to accommodate the excavated sediments from IO-05, additional storage areas are required, either across the channel or upstream of the reservoir (see Figure 10). For this reason, the USA storage sites[11] were also considered. The combination of Alternative 4b upstream storage sites and USA sties similarly was not sufficient to dispose of the total IO-05 excavated sediment volume.

In order to limit overall disposal site footprints, the USA sites were sized as shown on Figure 8, to have a capacity approximately equal to the excavated material volume of materials for IO-5. Temporary storage areas would be constructed with base elevations that would be within the 3-year to 10-year flood levels to allow for downstream sediment transport during storms exceeding a 3-year to 10-year storm event. While long term erosion of the temporary storage areas would be a source of sediment, the incremental increase in suspended sediment loads from the storage areas during flooding would be small.

The top areas of the temporary sediment storage areas would be temporarily stabilized with seeding and matting (if needed) to prevent overland and rill/gully erosion during smaller rainfall events.

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[11] The USA sites are upstream storage areas that were proposed by the USACE in 2008 as alternative storage areas to the Alternative 4b Baldwin Road Disposal Area sites.

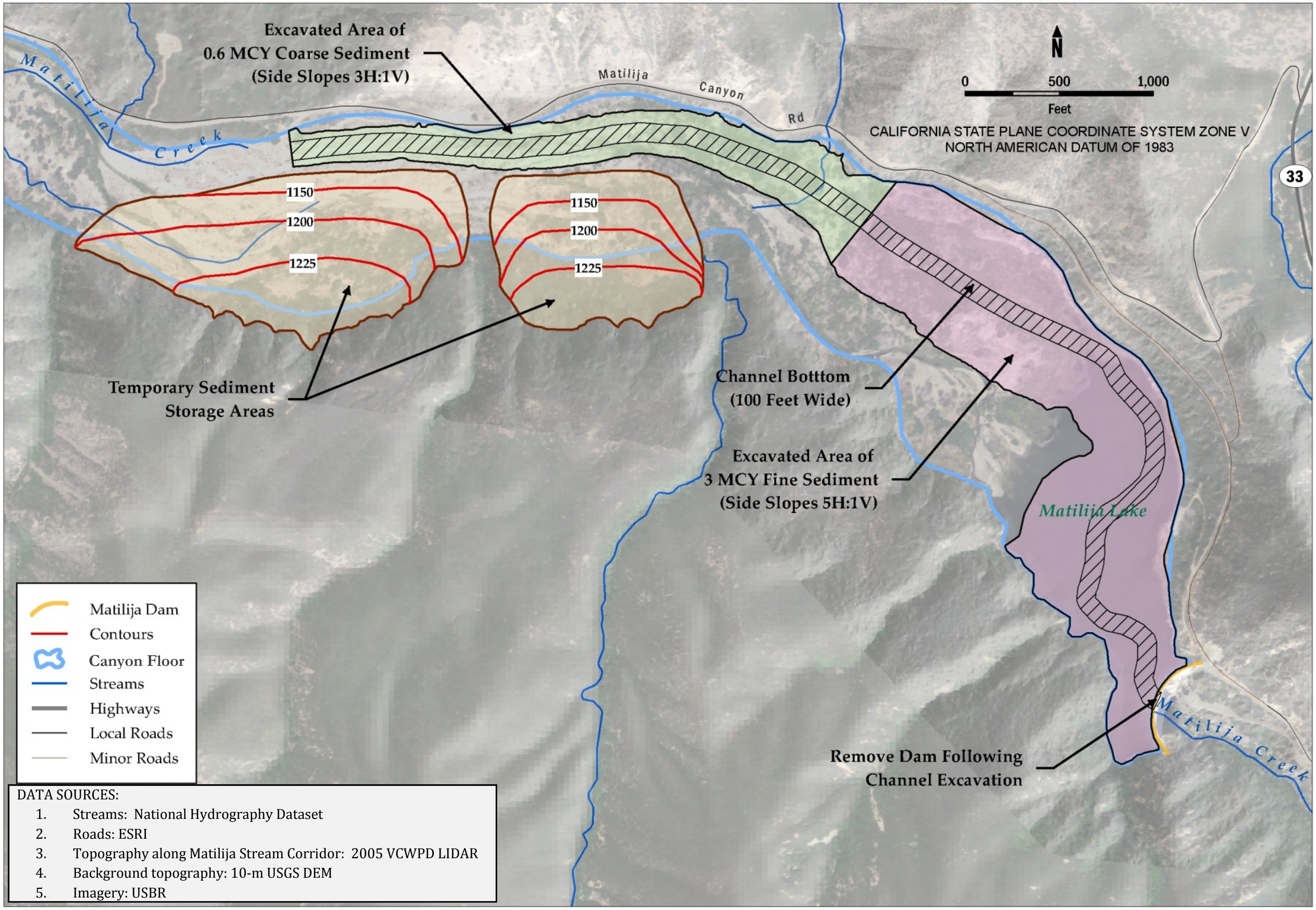

Figure 8. Initial Option 05 – Temporary Upstream Storage of Fine Sediment

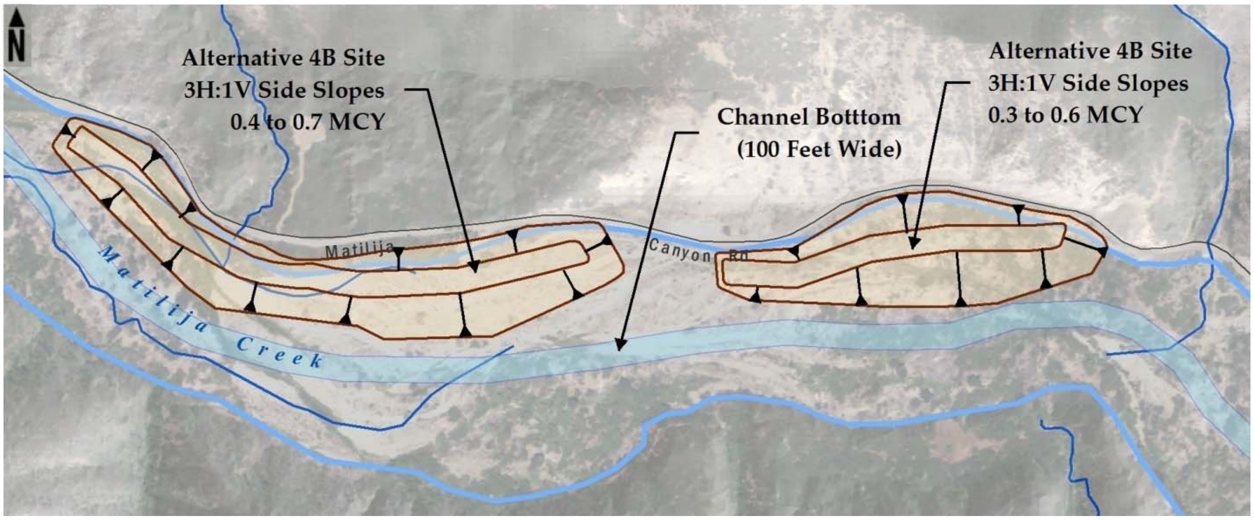

Figure 9. Upstream Storage Areas from Alternative 4b

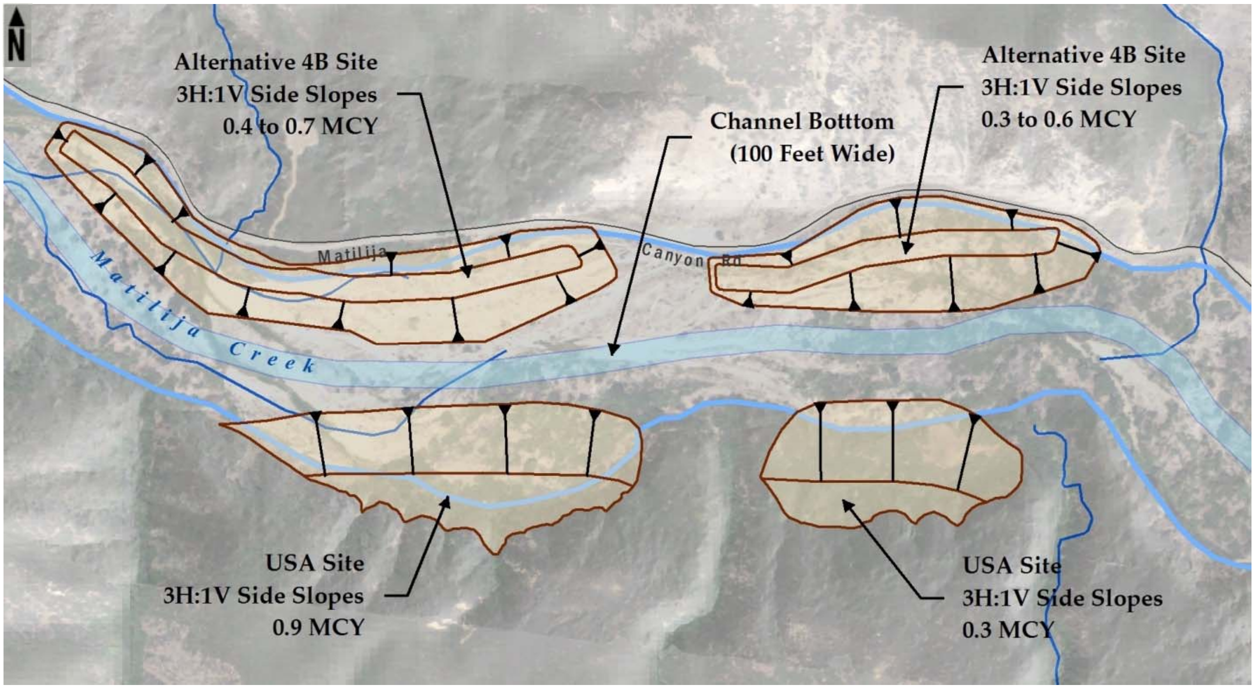

Figure 10. Combination of Upstream Storage Areas from Alternative 4b and USA

3.5.1.2 Dam Removal

Following excavation of the channel, the dam would be removed in its entirety. The dam would likely be demolished using blasting methods with the concrete being broken up and hauled to a recycling plant.

3.5.2 Fine Sediment Mobilization

Under this initial option the majority of the fine sediment subject to Phase I erosion would be removed from the reservoir deposit, and thus suspended sediment concentrations following dam removal are expected to be substantially lower than the previous initial options during the first high flow event. High suspended sediment concentration is still expected following dam removal when the discharge in the creek is low (i.e., a few cfs), because some erodible sediment would be left in the reservoir despite the best excavation efforts. If the fine sediment placed in temporary upstream storage can be released during a 10-year or greater storm event as planned, the suspended sediment concentration may be increased substantially for short periods of times during the storm event while the excess fine sediment is being delivered to the river by mass wasting. Averaged over the entire storm event, however, the increase in suspended sediment concentration should be relatively mild compared to the background conditions (assuming sediment erosion does occur only during a 10-year or greater storm event) because loads will already be high given the high sediment yield from the upper Matilija Creek watershed (420,000 metric tons per year on a long-term averaged basis, of which most is delivered in large, decadal to multi-decadal storms).

Impacts to Robles diversion associated with fine sediment mobilization are expected to be minimal, while there will likely be short-term impacts to downstream aquatic resources (see discussion in Appendix A).

3.5.3 Construction Duration

Early activities for this initial option would include mobilizing and setting up a water treatment system that would be used to handle water from draining the reservoir and water from dewatering wells and sump pumps located in the sediment excavation. A small cofferdam and temporary diversion system would be installed upstream of the reservoir area to divert summer flows from Matilija Creek around the excavation area. Dewatering wells that would extend through the fine sediment into the underlying alluvium through the reservoir area and shallower vacuum wells or wellpoints in the fine sediment would be installed and operated to draw the phreatic surface in the reservoir sediment down below the excavation grade. The fine sediment would not be anticipated to dewater significantly and would remain at a high moisture content.

Excavation and hauling of the fine sediment is assumed to be performed using excavators and articulated off-highway trucks during three in-channel construction seasons[12] working two shifts a day. Where the excavated grade is found to be too weak to support the equipment, access roads and working platforms would be constructed using coarse alluvium from upstream. These methods are currently being used to excavate fine sediment from the reservoir area of the Carmel River Reroute and Dam Removal Project. Coarse sediment would be excavated using scrapers. Excavation of the sediment is assumed to be performed during two shifts each day given the large volume required to be removed.

The dam would be penetrated at elevations consistent with the amount of sediment that would be removed during each construction season to allow the reservoir to drain to near the excavated sediment level – thus minimizing the amount of dewatering that would be needed to restart excavation.

The dam would be removed down to the Matilija Creek invert during the last season of excavation by drilling and blasting, breaking up the concrete rubble using excavators with hoerams, loading into highway legal dump trucks, and hauling to the concrete recycling plant.

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[12] Some additional sediment would be deposited during the rainy season between construction seasons. If a high flow event were to occur, a significant amount of sediment could fill the area excavated during the previous construction season.

A total of three construction seasons would be required for this initial option. The estimated schedule for construction is shown on Figure B-5 in Appendix B. Construction duration for IO-05, from start of construction to completion of removal of the dam would be three years.

3.5.4 Range of Magnitude Construction Cost

A summary of the ROMCC for IO-5 using the same Project Categories as those for Alternative 4b in Section 2.3.2 is shown in Table 6. The individual items comprising each feature in the ROMCC for IO-5 are shown in Table B-5 in Appendix B.

Table 6. Summary of Initial Option-05 ROM Construction Costs

Project Categories	**Construction Cost (2014)**	**Low (-30%)**	**High (+50%)**
Mobilization	$8,200,000		
Site Preparation	$3,200,000		
Sediment Components	$29,400,000		
Slurry System Components	$0		
Dam Removal Components	$9,700,000		
Subtotal	$50,500,000		
Contingency (30%)	$15,100,000		
Subtotal	$65,600,000		
Construction Contingency (15%)	$9,900,000		
Total	$75,500,000	$52,800,000	$113,200,000

There is a risk that excavation of the reservoir sub-area sediment by mechanical means might prove to be infeasible following additional geotechnical characterization and analyses. In that case, excavation of about 1.7 mcy of sediment from the reservoir sub-area would need to be removed using slurry dredging methods. The slurry material would be transported to an upstream staging area, run through a rapid dewatering system, and hauled and placed in a temporary upstream storage area. The additional cost of slurry dredging of the sediment over mechanical removal of the sediment for this initial option, including contingencies, would be $26,000,000.

3.6 Initial Option – 06: Downstream Slurry and Temporary Upstream Storage of Fine Sediment

3.6.1 Initial Option Description

The objective of this initial option would be to remove the fine sediment using a combination of phased slurry dredging, mechanical excavation, and natural transport that reduces costs relative to dredging and drying all fine sediment at the Baldwin Road Disposal Area (BRDA) sites located about five miles downstream of the dam. The apparently most organic-laden portion of the fine sediment (where methane gas was encountered during drilling in 2001) would be slurry dredged and transported by slurry pipeline down to BRDA to avoid this organic material entering the Robles diversion and Lake Casitas. A starter channel through the remaining fine sediment downstream of the area of organic-rich sediment would be slurry dredged and transported to temporary upstream storage areas at elevations that would allow for transport during a 10-year or greater storm event. A starter channel upstream of the organic-rich sediment would be mechanically excavated and also hauled to temporary upstream storage areas. The dam would be demolished during the final season of sediment excavation.

The following major features would be implemented and are shown conceptually in Figure 11:

- Fine sediment removal
- Channel excavation in delta sub-area sediment
- Removal of dam

Major features are discussed in more detail below.

3.6.1.1 Fine Sediment Removal

A portion of the fine sediment in the reservoir and delta sub-areas would be removed by a combination of slurry dredging (roughly 1.4 million cubic yards (MCY) or 870 acre-feet), mechanical removal (roughly 0.4 MCY or 250 acre-feet), and the remainder by natural transport. Fine sediment removal in the reservoir sub-area would be by slurry dredging. Conceptually, slurry operations would be performed during the dry season over two years with approximately 700,000 cy (430 acre-feet) of sediment being removed each year. Dredging would start at the beginning of the in-channel construction season to take advantage of end of the rainy season flows in Matilija Creek to slurry dredge an initial 90,000 cy (55 acre-feet) of sediment from the reservoir. After inflows have dropped to minimum required release levels, the approximate 500 acre-feet of water storage remaining behind the dam would be used to slurry dredge an estimated 375 acre-feet of sediment[13]. Slurry from the dredging operation would be processed through a high density thickener at the BRDA sites resulting in a thicker pumpable paste and through a rapid dewatering system at the temporary upstream storage areas that would produce stackable sediment. Water recovered from both the thickening process and rapid dewatering process would be pumped back to the reservoir for reuse. The storage capacity of the reservoir at the beginning of dredging during the second

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[13] The estimated in-situ volume of sediment dredged assumes slurry of 12 to 15 percent solids by volume, a rapid dewatering system to thicken the slurry to a similar in-situ condition of about 45 percent solids by volume, and a 25 percent loss of water return from the dewatering process during dredging.

season would increase due to sediment removed during the previous season[14]. However, the reservoir storage level for dredging in any season might require adjustment based on considerations of the dredging equipment being used and dewatering of a portion of the reservoir for mechanical channel excavation.

Sediment from the organic rich area (roughly 1.0 MCY or 620 acre-feet) would be transported via pipeline to the high density thickener located at BRDA Site 1, and subsequently pumped for temporary disposal at BRDA Sites 1 and 2. Sediment from downstream of the organic rich area (roughly 0.4 MCY or 250 acre-feet) would be transported upstream via pipeline to a rapid dewatering process area, and subsequently dewatered and hauled by truck for temporary disposal in upstream storage areas. In the temporary upstream storage areas, the dewatered slurry would be spread, further moisture conditioned, mixed with sediment from the channel excavation in the delta sub-area, and nominally shaped and compacted to blend into the topography.

During the first year of construction, a gated penetration would be constructed in the dam that would facilitate lowering the reservoir level following each of the two seasons of dredging from the current notch invert of 1,095 feet to a lower level consistent with the dredged sediment level. During the wet season, the gate would be closed and the reservoir allowed to refill and spill, to maximize the water available for dredging following the wet season.

3.6.1.2 Channel Excavation in delta sediment

Channel excavation through the delta sub-area sediment using mechanical excavation would occur during the latter half of each construction season with slurry dredging. Dewatering of these sediments would be facilitated by lowering of the reservoir due to loss of water during the dredging operation throughout the season. Excavated delta sediment materials would be mixed with dried fine sediment and placed in temporary storage areas in the upstream reservoir. Temporary storage areas would be shaped and integrated into the natural landscape but would be subject to mobilization during 10-year or greater storm events. The channel through the delta sub-area would have a grade that is steeper than the grade of the sediment upstream and the channel through the reservoir sub-area downstream to the dam and would be temporarily stabilized using coarse alluvial materials containing gravel, cobbles, and boulders from the upstream end of the reservoir area to prevent mobilization of underlying fine sediments during low flows.

Channelization through the upstream portion of the reservoir area would be allowed to form naturally through transport of coarse sediment to the downstream reaches. Fish passage during the channelization process may need to be monitored. Where necessary, construction equipment may need to be mobilized following large events to dislodge debris jams or boulders that block fish passage.

3.6.1.3 Dam Removal

Following excavation of the organic rich fine sediment and channels in the remaining reservoir and delta sub-area sediment, the dam would be removed in its entirety. The dam would likely be demolished using blasting methods, with the concrete being broken up and hauled to a recycling plant.

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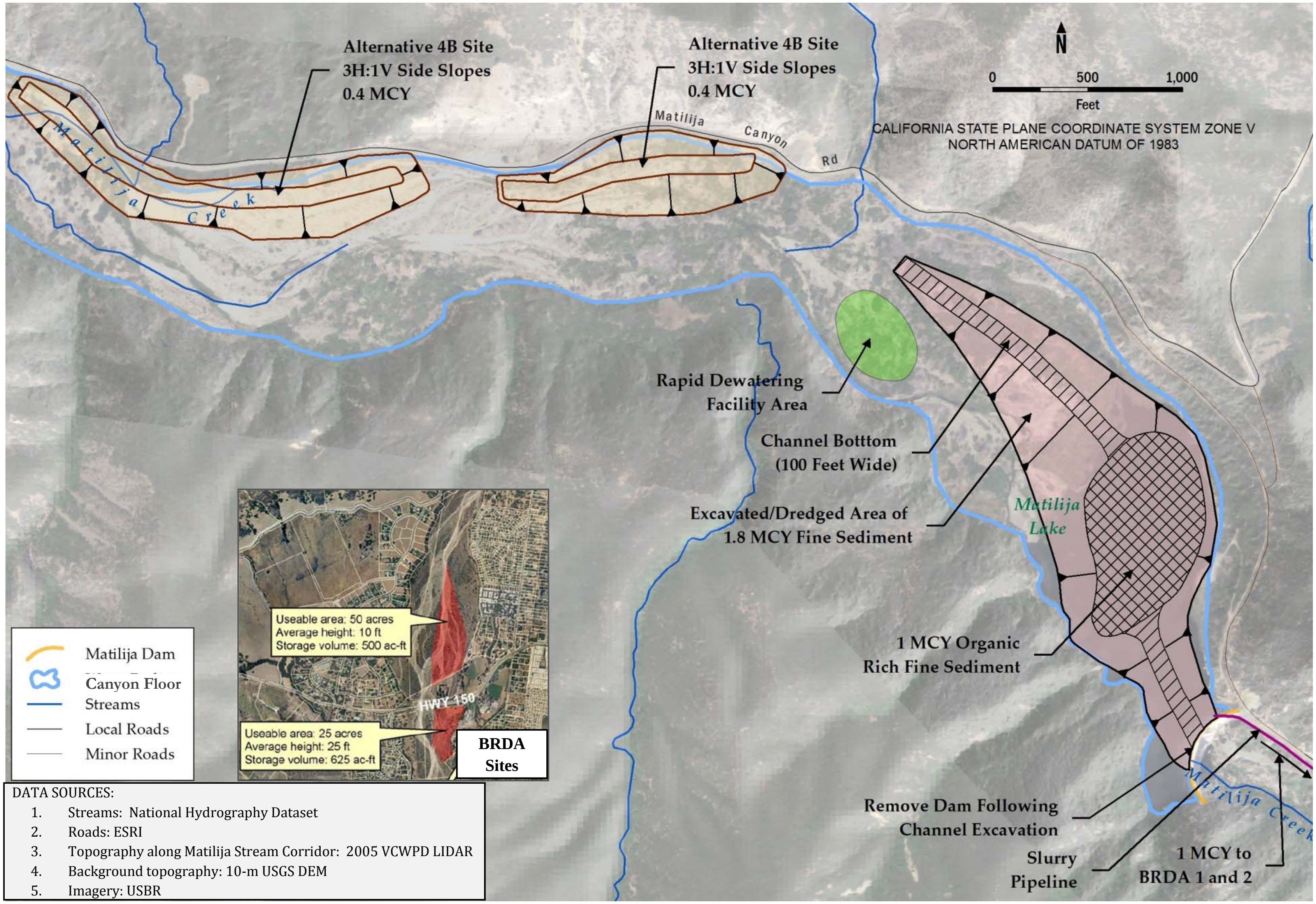
[14] Some additional sediment would be deposited during the rainy season between construction seasons. If a high flow event were to occur, a significant amount of sediment could fill the area dredged during the first construction season.



DATA SOURCES:

1. Streams: National Hydrography Dataset
2. Roads: ESRI
3. Topography along Matilija Stream Corridor: 2005 VCWPD LIDAR
4. Background topography: 10-m USGS DEM
5. Imagery: USBR

Figure 11. Initial Option 06 – Downstream Slurry and Temporary Upstream Storage of Fine Sediment

3.6.2 Fine Sediment Mobilization

Under this initial option the majority of the fine sediment subject to Phase I erosion would be removed from the reservoir deposit, and thus suspended sediment concentrations following dam removal are expected to be substantially lower than the previous initial options during the first high flow event. High suspended sediment concentration is still expected following dam removal when the discharge in the creek is low (i.e., a few cfs), because some erodible sediment would be left in the reservoir despite the best excavation efforts. If the fine sediment placed in temporary upstream storage can be released during a 10-year recurrence storm event or greater as planned, the suspended sediment concentration may be increased substantially for short periods of time during the storm event while the excess fine sediment is being delivered to the river by mass wasting. Averaged over the entire storm event, however, the increase in suspended sediment concentration should be relatively mild compared to the background conditions because loads will already be high given the high sediment yield from the upper Matilija Creek watershed (420,000 metric tons per year on a long-term averaged basis, of which most is delivered in large, decadal to multi-decadal storms).

Impacts to Robles diversion associated with fine sediment mobilization are expected to be minimal, while there will likely be short-term impacts to downstream aquatic resources (see discussion in Appendix A).

3.6.3 Construction Duration

The initial in-channel construction season for this initial option would be used to prepare the BRDA Sites 1 and 2 and the temporary upstream storage sites for excavation activities during the following year. Site preparation activities would include clearing of the pipeline corridor and containment pond areas, construction of the slurry and recaptured water pipelines from the dam to the BRDA sites, and construction of the containment dikes at the BRDA sites. The temporary upstream storage areas would also be cleared and a small cofferdam and temporary diversion system would be installed in the upstream reservoir area to divert summer flows from Matilija Creek around the delta sediment excavation area into the reservoir pool.

Dredging of the fine sediment from the reservoir area would commence at the beginning of the in-channel construction season during the second and third years of construction and would continue until the water level in the reservoir drops to the point where dredging operations can no longer continue.

Excavation of the fine sediment from the delta area is assumed to be performed using large excavators and articulated off-highway trucks later in each season after the reservoir water level has dropped due to loss of water from the dredging operation. Where the excavated grade is found to be too weak to support the equipment, access roads and working platforms would be constructed using coarse alluvium from upstream. These methods are currently being used to excavate fine sediment from the reservoir area of the Carmel River Reroute and Dam Removal Project. Armoring of the invert and sides of the portion of the channel through the delta area would follow excavation of the channel.

The dam would be removed down to the Matilija Creek invert during the last season of excavation by drilling and blasting, breaking up the concrete rubble using excavators with hoerams, loading into highway legal dump trucks, and hauling to the concrete recycling plant.

A total of three construction seasons would be required for this initial option. The estimated schedule for construction is shown on Figure B-6 in Appendix B. Construction duration for IO-06, from start of construction to completion of removal of the dam would be three years.

3.6.4 Range of Magnitude Construction Cost

A summary of the ROMCC for IO-6 using the same Project Categories as those for Alternative 4b in Section 2.3.2 is shown in Table 7. The individual items comprising each feature in the ROMCC for IO-06 are shown in Table B-6 in Appendix B.

Table 7. Summary of Initial Option-06 ROM Construction Costs

Project Categories	Construction Cost (2014)	Low (-30%)	High (+50%)
Mobilization	$8,200,000		
Site Preparation	$1,700,000		
Sediment Components	$5,500,000		
Slurry System Components	$25,000,000		
Dam Removal Components	$9,700,000		
Subtotal	$50,100,000		
Contingency (30%)	$15,000,000		
Subtotal	$65,100,000		
Construction Contingency (15%)	$9,800,000		
Total	$74,900,000	$52,400,000	$112,400,000

4.0 Results Summary

Table 8 summarizes the screening scores for construction cost, construction duration (from mobilization for the first construction season through completion of full dam removal), fine sediment mobilization, as well as overall scores and ranks for each initial option (1 = least cost, shortest duration, and least impact). In addition, risks and other considerations are noted for each of the initial options.

As shown in Table 8, IO-02 has the lowest estimated construction cost at about $19M, with dam removal activities as the primary cost driver. IO-03 had the second lowest estimated construction cost, with dam removal and gate material/installation as the primary drivers. IO-01 had a relatively higher estimated cost than IO-04 due to the effort associated with the bypass tunnel construction. IO-05 and IO-06 have the highest estimated construction cost at about $75M. The highest cost options were typically driven by the estimated cost associated with removal (excavation or dredging) and placement of accumulated sediment.

IO-02 and IO-03 have the shortest estimated construction duration at two to five years. The actual construction activities associated with these two initial options would occur over two separate construction seasons, with the period in between being a function of storm frequency. IO-04 has the highest estimated construction duration at fourteen to seventeen years, which is a function of having to wait for multiple large storms which would need to be separated by dry season construction activities.

IO-05 would have the lowest downstream impact associated with fine sediment mobilization and relatively low risks of high suspended sediment loads entering the downstream creek/river system. This is due to the fact that the majority of the accumulated fine sediments is removed from the active river channel and either temporarily or permanently stored within the creek valley, causing only incremental increases in suspended sediment during large storms. IO-06 has a similarly low effect on downstream suspended sediment concentrations, but has the additional risk of buried fines being exposed and mobilized during lower flows.

IO-01, IO-02 and IO-03 have similar scores for fine sediment mobilization since these three initial options utilize one large storm to mobilize the majority of the accumulated fine sediment. Their scores shown in Table 8 are a function of the risks associated with each option.

IO-04 has the highest impact due to elevated suspended sediment concentrations occurring over multiple storms and notching phases.

Overall, IO-02 and IO-03 rank relatively higher than other initial options considering unweighted rankings in the three screening categories. The higher estimated cost associated with IO-03 relative to IO-02 is offset by the ability to include trash racks and the flexibility provided by the gates to close the dam orifice.

IO-04 ranks relatively lower than other initial options considering rankings in the three screening categories. This is due to the significantly longer construction duration relative to other initial options, and the relatively higher downstream impacts associated with elevated suspended sediment concentrations.

Table 8. Summary of Results for Screening of Initial Options

Initial Option	Range of Magnitude Construction Cost (ROMCC)[1]				Construction Duration		Fine Sediment Mobilization & Associated Downstream Impacts		Total Screening Score and Risks/Comments	
	(-30%)	Estimate	(+50%)							
IO-01	$28,700,000	$40,900,000	$61,400,000	4	3 to 6 years	3	Approximately 7 days of elevated suspended sediment concentrations during 1 high flow event • Associated downstream impacts to Robles diversion and aquatic resources • Most effective of the full natural transport options (IO-1 through IO-4)	3	Total Score Rank is **Third** Risks: • Large storm event breaches cofferdam but is smaller/shorter than expected leading to greater water quality problems until next large storm • Uncertainty associated with increased erosion resistance due to the loss of water content in fine sediments while waiting for the designated high-flow event	10
IO-02	$13,500,000	$19,300,000	$28,900,000	1	2 to 5 years	1	Approximately 7 days of elevated suspended sediment concentrations during 1 high flow event • Associated downstream impacts to Robles diversion and aquatic resources • Flows greater than orifice capacity would result in less sediment removal than same storm in IO-01 • Possible that debris could block tunnels reducing effectiveness	5	Total Score Rank is **First** Risks: • Timing of blasting of plug with storm would require significant coordination and would involve some level of risk • Large storm is smaller/shorter than expected leading to greater water quality problems until next storm	7
IO-03	$20,900,000 • Add $3,200,000 to estimate if dredging used to excavate sediment in front of dam instead of mechanical excavation	$29,900,000	$44,800,000	2	2 to 5 years • Construction duration would be 6 to 9 years a second high flow event was selected to pass through the reservoir before dam removal	1	Approximately 7 days of elevated suspended sediment concentrations during 1 high flow event • Associated downstream impacts to Robles diversion and aquatic resources • Some flows on descending limb could be diverted • Flows greater than orifice capacity result in less sediment removal than IO-01 • Gate allows for flexibility to re-create reservoir and wait for another large storm to mobilize additional fine sediment • Well-designed trash racks could make IO-03 less susceptible to blockage than IO-02, but debris blockage is still a risk	4	Total Score Rank is **First** Risks: • Additional sediment will be trapped in the reservoir during seasons between construction completion and large storm events when gates are opened	7
IO-04	$22,600,000 • Remove $3,900,000 from estimate if notches are not gated	$32,200,000	$48,400,000	3	14 to 17 years	6	Approximately 11 days of elevated suspended sediment concentrations over 4 high flow events • Associated downstream impacts to Robles diversion and aquatic resources • Some flows on descending limb could be diverted	6	Total Score Rank is **Sixth** Risks: • Longer overall implementation duration for greater risk of drought and associated implementation delay	15
IO-05	$52,800,000 • Add $26,000,000 to estimate if dredging used to excavate sediment in front of dam instead of mechanical excavation	$75,500,000	$113,200,000	6	3 years • Late storms could delay channel excavation resulting in an additional year of construction	5	Minimal increase in suspended sediment concentrations • Minimal downstream impacts to Robles diversion and aquatic resources • Wide excavated channel with upstream temporary disposal should result in only incremental increases in suspended sediment	1	Total Score Rank is **Fifth** Risks: • Mechanical removal of fine sediments may be problematic, increasing costs by an estimated 34 percent. • Additional sediment will be trapped in the reservoir during multiple season construction	12
IO-06	$52,400,000	$74,900,000	$112,400,000	5	3 years	4	Minimal increase in suspended sediment concentrations • Minimal downstream impacts to Robles diversion and aquatic resources • Majority of fine sediments removed with a portion placed upstream for temporary disposal; incremental increases in suspended sediment • Risks associated with steeper channel excavation and potential for mobilization of underlying fine sediment during low flows	2	Total Score Rank is **Fourth** Risks: • Additional sediment will be trapped in the reservoir during multiple season construction • Steeper channel excavation and potential for mobilization of underlying fine sediment during low flows	11

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[1] For comparison, Alternative 4B construction costs for similar components was approximately $115M

5.0 Limitations

The services presented herein were conducted in a manner consistent with the standard of care ordinarily applied as the state of practice in the profession in developing the initial options and their associated construction costs, given the amount of existing site and design information available at the time of preparation of this report. No other warranties, either expressed or implied, are included or intended in this document.

This report is conceptual or preliminary in nature and is not to be used as the sole basis for final design or construction, or as a basis for major capital decisions. Further preliminary detailed design should be performed prior to such decisions.

Some background information, design bases, and other data have been furnished to URS by the U.S. BOR, CMWD, Ventura County and/or third parties, which URS has used in preparing this report. URS has relied on this information as furnished, and is neither responsible for nor has confirmed the accuracy of this information.

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MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

INITIAL OPTIONS SCREENING REPORT

APPENDIX A: FINE SEDIMENT ASSESSMENT

SEPTEMBER 9, 2014

Table of Contents

A1.0 Objective & Background

A1.1 Objective

The objective of this technical appendix is to provide an understanding of fine sediment transport through the Ventura River system, and to analyze potential impacts from fine sediment erosion and transport from Matilija Reservoir following Matilija Dam removal for the six initial options summarized in the main report.

Potential impacts due to the release of fine sediment following Matilija Dam removal are primarily associated with increased suspended sediment concentrations. These impacts include:

- Both short-term and long-term increases in suspended sediment concentration, which may negatively impact aquatic biota, injuring or killing fishes or other aquatic animals and plants
- Increases in suspended sediment concentration that may cause operational difficulties for water diversion at Robles Diversion Dam
- Potentially high organic content in suspended sediment, which could cause long-term water quality problems if diverted to Casitas Lake.

These potential impacts are discussed in detail for each of the six initial options in the sections below.

In addition to the potential impact due to high suspended sediment concentrations, there have been previous concerns with the potential for fine sediment infiltrating into the alluvium of the river bed in downstream reaches that could result in decreased conductivity for groundwater wells and infiltration galleries. BOR (2006, p. 202), however, concluded that silt and clay will not enter into the groundwater aquifer, which is consistent with recent research (Wooster et al. 2008; Cui et al. 2008), which finds that interaction of silt and clay with the coarse channel bed will be limited to the surface layer, and any fine sediment deposited on the surface can be washed clean once there is a high flow event. The shallow infiltration of fine sediment into gravel deposit is also in agreement with field observations such as Frostick et al. (1984) and Beschta and Jackson (1979). While some early literature suggested a deeper infiltration of fine sediment into a coarse deposit that could potentially impact the aquifer, Cui et al. (2008) have pointed out the flawed assumption employed in their theoretical analysis and the limitation in their flume experiment; replacing their flawed assumption with a correct one yields conclusions in agreement with those of others. As a result, this appendix will be focused only on the potential impact from high suspended sediment concentration in the water column, with some preliminary considerations of high organic carbon concentration in the surface waters.

A1.2 Background

As discussed in Stillwater Sciences (2014a), the entire Ventura River system is strongly seasonal and highly episodic, with long periods of low flow punctuated by moderate to extremely high discharges. Presently, measurable flow is commonly experienced in both systems, as summarized in Figure A-1. Individual years (2002-2014, for both graphed gages) are shown by faint gray lines, while the 12-year average is highlighted by the blue line. Low but non-zero flows occur more than 90% of the time in both systems; in particular, flows of sufficient magnitude to facilitate fish passage are nearly ubiquitous on Matilija Creek.

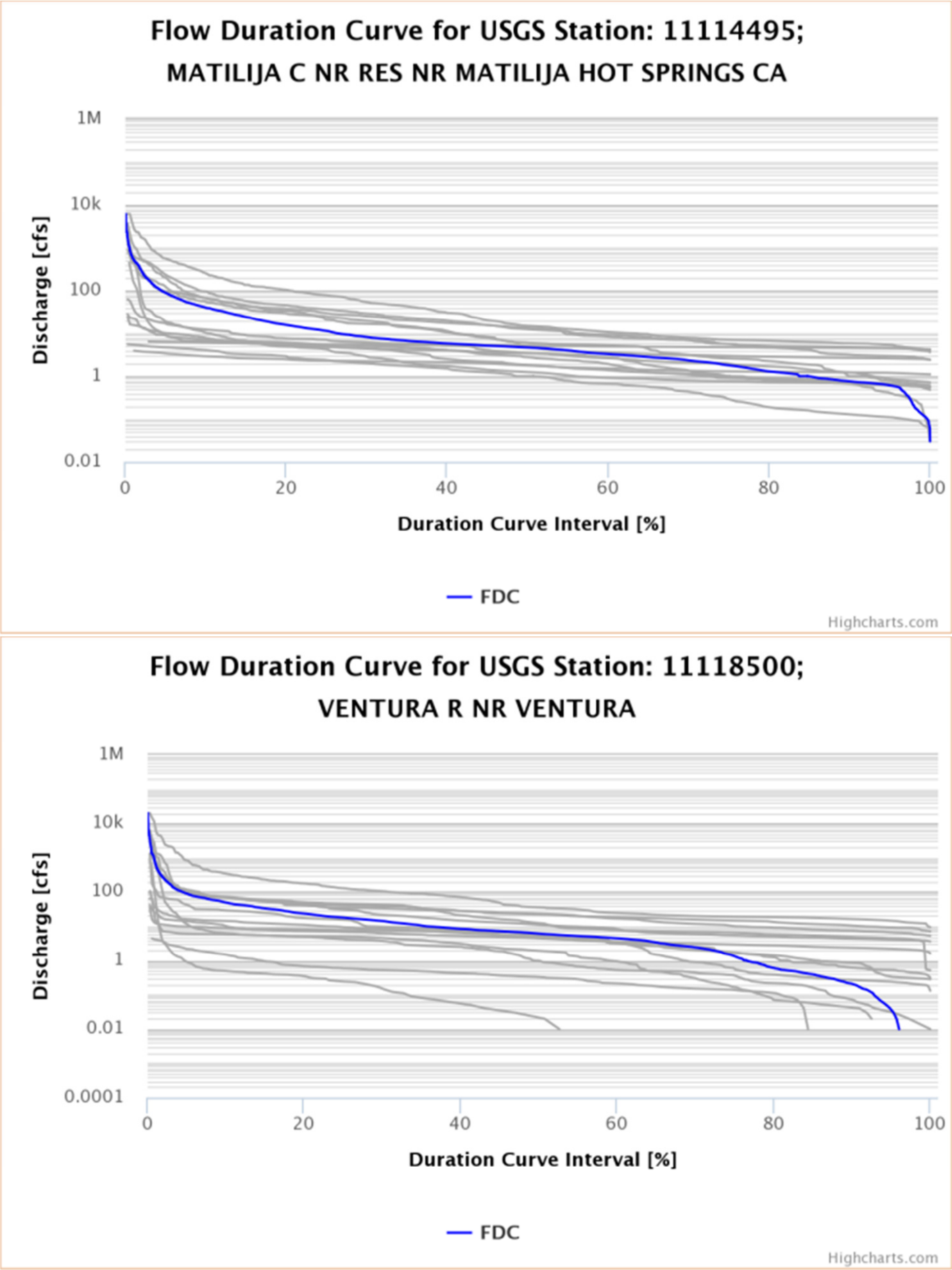

Figure A-1. Flow-duration curves for Matilija Creek (left) and Ventura River (right), as graphed by Colorado State University's on-line Environmental Risk and Management System (www.erams.com/)

Sediment delivery from the watershed of Matilja Creek is high, with the total average rate on the order of 400,000 cubic yards (cy)/year (yr), and with potentially more than 5-10 times that volume delivered in an exceptional year (of which five have likely occurred since the mid-20th century; Stillwater Sciences, 2014b). BOR (2006) echoes prior estimates that 90% or more of that watershed-delivered material is silt-sized and finer, travelling in suspension.

Roughly one-third of the total sediment load has been trapped behind Matilija Dam, based on the long-term rate of sediment accumulation in the reservoir (about 120,000 cy/yr; see Figure 4 of Stillwater Sciences 2014b), of which approximately 54% of the sampled deposit is sand and gravel, and 46% is silt-sized and smaller (Table 2, Stillwater Sciences 2014b; data from BOR 2006). This yields the values in the left-hand column of Table A-1.

Assuming that the trap efficiency of the reservoir is (and always has been) 100% for coarse sediment, then the rate of coarse sediment flux in the post-dam era (right-hand column, Table A-1) must equal that calculated from the accumulated sediment (left-hand column, Table A-1). Given a total watershed bulk sediment delivery rate of 400,000 cy/yr, the rate of fine-sediment delivery is over 335,000 cy/yr, indicating a [fine sediment]:[total sediment] ratio of 84%, reasonable for such steep terrain but nonetheless slightly lower than "typical" expected values. These values also indicate that the overall trap efficiency of the reservoir for fine sediment has been 16% when averaged over the entire history of the dam—likely higher initially, and approaching zero at present.

In summary, these considerations yield the following mass balance for the sediment load of Matilija Creek, expressed in bulk volumes of sediment as averaged over the period 1947–2005 (Table A-1).

Table A-1: Mass Balance for the Sediment Load of Matilija Creek

	Average rate of deposition behind dam, 1947-2005 (cy/yr)	Average downstream delivery, 1947-2005 (cy/yr)	Average downstream delivery, post-dam (cy/yr)
Coarse sediment (sand and gravel)	65,000	0 (assumed)	65,000
Fine sediment (silt and clay)	55,000	280,000	335,000

Between the period 1947-2005 and the post-dam period, there will be an approximate 20% increase in fine sediment load going downstream on average over 59 years. However, since the reservoir is currently trapping very little fine sediment, the post-dam period should be fairly consistent with the most recent conditions. Thus, there will likely be minimal increase in fine sediment load in a post-dam-removal future. In contrast, the increased flux of coarse sediment would be substantial, and likely exceed that of the present contribution from the North Fork Matilija Creek by several-fold.

Presently, suspended sediment concentrations on the mainstem Ventura River are commonly in the range of 1,000 mg/L (see Figure A-2) during flows commonly associated with diversion (i.e., 100 to nearly 1,000 cfs, accounting for well more than half of the total diverted volume 1993-2013); conversely, diversion is less common during discharges above several thousand cfs, associated with concentrations at or above about 8,000 mg/L. Between about 1,000 cfs and 3,000 cfs, the data are insufficient to resolve whether diversion operations have been dependent on the observed level of suspended sediment.

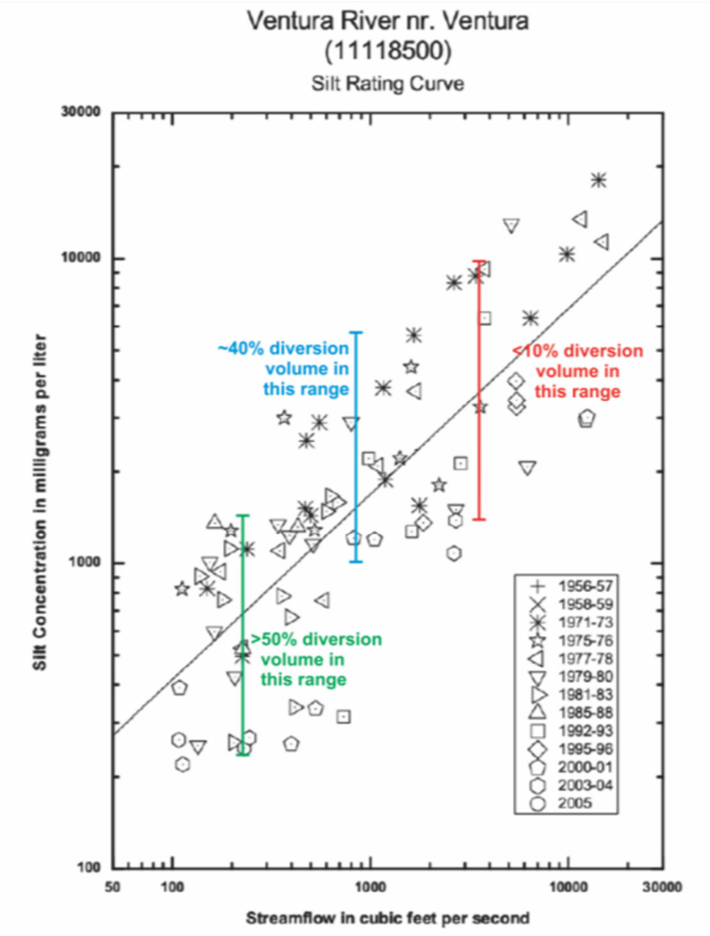

Figure A-2. Measured silt concentrations, an approximate surrogate for suspended sediment concentrations, measured at the Ventura River gage 11118500 over a range of low to moderate flows (highest plotted discharge ≈ 5-yr recurrence). Discharge values for the labeled >50% and <10% diversions taken from Figure A-1, above; data scatter reflects the order-of-magnitude variability typical of measured suspended-sediment rating curves. Graph reproduced from BOR (2006, Figure 5.22).

A2.0 Potential Impacts from the Release of Fine Sediments

The release of fine sediment in the reservoir and delta sub-areas (composed of 87% silt + clay and 13% sand, which will be transported downstream primarily as suspended load) following Matilija Dam removal is strongly related to when and how the dam is removed. Potential impacts from the release of fine sediment are discussed separately for each of the six initial options below, with IO-01 discussed in more detail and subsequent initial options discussed comparatively with previous discussed initial options. For each initial option, a discussion of fine sediment transport dynamics is discussed first, followed by discussions of the likely impacts due to high fine-sediment concentrations, including an extremely conservative estimate of suggested impact durations for planning purposes. A brief discussion of the uncertainties associated with sediment transport dynamics for each initial option is also provided.

A2.1 Initial Option - 01: Containment Berm with High Flow Bypass

A2.1.1 Fine Sediment Transport Dynamics

Under this scenario, fine sediment deposit within the "reservoir" and "delta" sub-areas (Figure A-3) will be redistributed downstream and temporarily held by a containment berm once the dam is removed. Following the breaching of the cofferdam during the designed high flow event, both the cofferdam and the containment berm will be quickly washed out, similar to the erosion of the cofferdam constructed for Marmot Dam removal project (Figure A-4), thus initiating the release of fine and coarse sediment downstream.

There are two phases for the erosion of fine sediment deposit in the reservoir and delta sub-areas following breaching of the cofferdam, as discussed below: "Phase I" erosion, when the fine sediments in the reservoir and delta sub-areas are accessible to the flow (i.e., the flow is in direct contact with the fine sediment deposits) (Figure A-5b); and "Phase II" erosion, when fine sediment is no longer accessible to the flow (Figure A-5c).

During Phase I erosion, the high-energy flow powered by the large discharge and steep gradient will cut through the fine sediment deposit quickly. The critical shear stress estimated for the reservoir deposit, using the diagram provided in Pant (2013) with a bulk density of 1.2 metric tons per cubic meter (Stillwater Sciences 2014b), is slightly below 0.1 Pa. In contrast, the estimated shear stress under a 1,700 cfs flow in Matilija Reservoir following dam removal is at least 73 Pa, almost three orders of magnitude higher than the estimated critical shear stress. Clearly, the flow will be able to erode the fine sediment without difficulty.

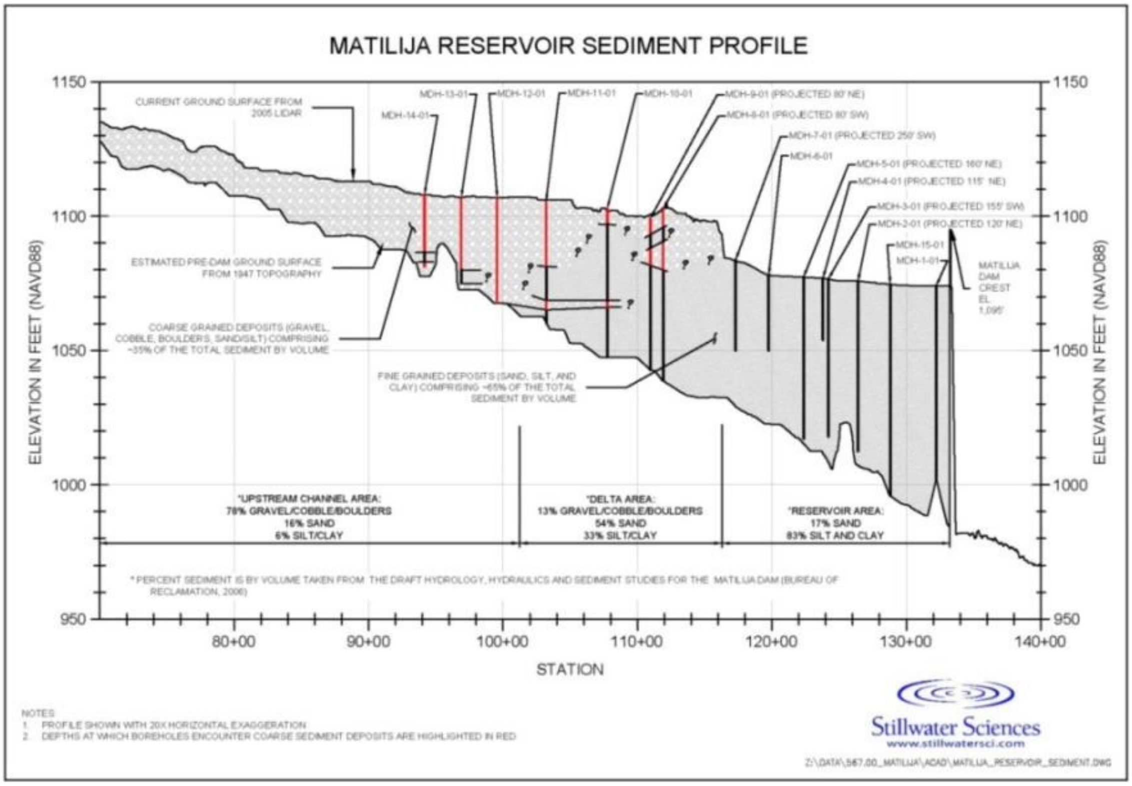

Figure A-3. Matilija Reservoir sediment profile, showing the general distributions of gravel, sand and silt/clay deposits in three regions: upstream channel, delta, and reservoir area. Diagram reproduced from Stillwater Sciences (2014b).

Figure A-4. Photograph of Marmot sediment deposit erosion approximately 20 min after the cofferdam was breached at a discharge of approximately 50 m^3/s (1,750 cfs), showing the quick erosion of the cofferdam and the sediment deposit. The arrow points to the remaining portions of the cofferdam; flow direction is towards the camera (image courtesy of Bruce McCammon and US Forest Service).

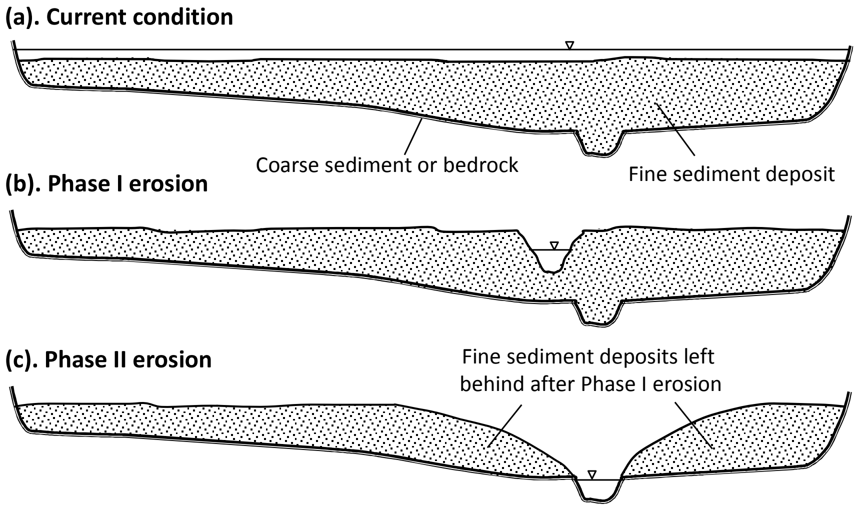

Figure A-5. Sketches showing the two phases of fine sediment erosion. (a) Current condition; (b) Phase I erosion when fine sediment is directly accessible to the flow, presenting a virtually unlimited supply of sediment with transport limited only by the capacity and rate of discharge; and (c) Phase II erosion when fine sediment is no longer directly accessible to the flow.

The typical excess shear stress-based equations commonly used for calculation of sediment transport capacity is valid only for transport processes due to surface erosion, while the Phase I erosion will not be a surficial process. Instead, the Phase I erosion of fine sediment will be governed by rapid gullying, followed by collapsing of banks and mass wasting, with the sediment generated from these processes being carried by the flow downstream. The more reasonable relationships used to estimate the Phase I fine sediment erosion are a suite of empirical and semi-empirical equations developed in the former Soviet Union and in China (as summarized in Chien and Wan 1991).

Test application of these relationships to the Phase I erosion under 1,700 cfs discharge with four different equations yield a wide range of potential suspended sediment concentrations, from quite plausible (and observed) values of 1.4×10^6 mg/L to outrageously large and impossible values of more than 3×10^9 mg/L. [1] Because of the discrepancies in equations, the evaluation here relies on a relationship originally developed by Chang (1963) that has been supported by sufficient field and experimental data (Figure A-6). It predicts that suspended sediment concentration is a function of dimensionless parameter $V^3/(gHv_s)$, in which V denotes average flow velocity, g denotes acceleration of gravity, H denotes water depth, and vs denotes settling velocity of sediment particles. Under 1,700 cfs flow, a conservative estimate of parameter $V^3/(gHv_s)$ is 6.65×10^5 (see Section A4.0 for details), which is out of the range of field and experimental data

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[1] It is very likely that the unit for some of these equations were incorrectly assigned when the equations were translated from Russian to Chinese, resulting in values that are more than three orders of magnitude larger than possible.

presented in Figure A-6. Assuming an extrapolation of the field and experimental data to a higher range is valid, the suspended sediment concentration during Phase I erosion for IO-01 is estimated to be on the order of 1000 g/l, or 1×10^6 mg/L. [2]

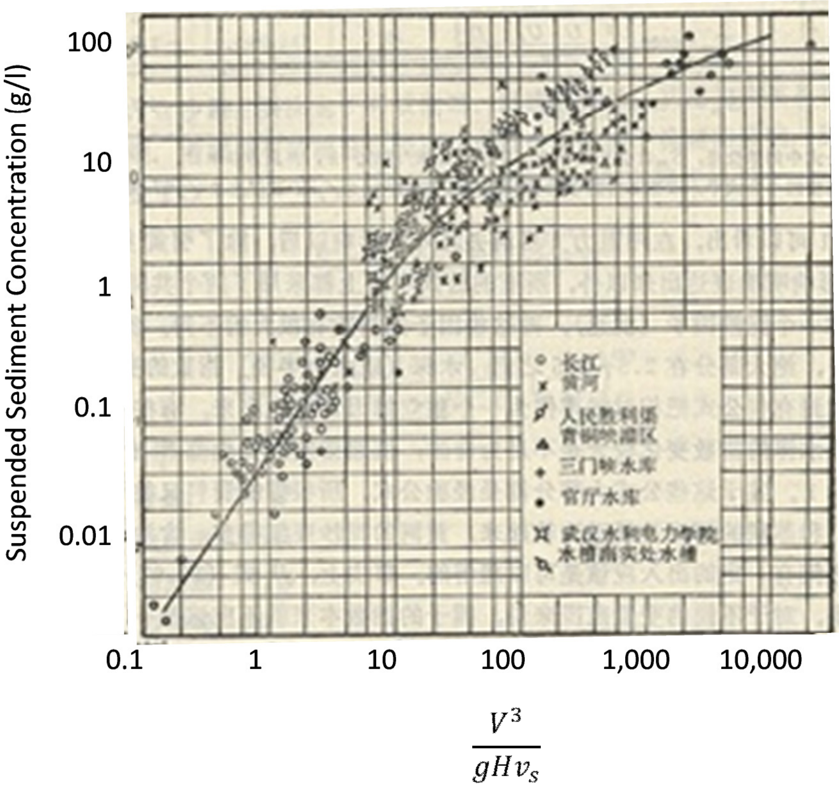

Figure A-6. Relation quantifying suspended sediment concentration and dimensionless parameter V^3/(gHvs), originally presented in Chang (1963) and summarized in Chien and Wan (1991). Figure legend provides the source of the data, including (from top to bottom): the Yangtze River, Yellow River, People's Victory Canal, Qingtong Gorge Irrigation District, Sanmen Gorge Reservoir, Guanting Reservoir, flume data from Wuhan Institute of Water Conservancy, and flume data from Nanjing Water Conservancy Research Institute.

Although the values of V^3/(gHv$_s$) for the data presented in Figure A-6 fall far short of levels needed to yield suspended sediment concentrations approaching 1×10^6 mg/L, measured suspended sediment concentrations in excess of 1×10^6 mg/L occur regularly in the Yellow River basin in China under natural conditions (Table A-2). The highest measured natural suspended sediment concentration in the Yellow River basin was recorded as 1,570,000 mg/L (Chien 1989). These observations indicate that a suspended sediment concentration close to or higher than 1×10^6 mg/L during Phase I erosion as extrapolated using the data in Figure A-6 is not far-fetched. Field observations during sediment sluicing in Hengshan Reservoir, Shanxi Province, China over the period 1974-1982 (Table A-3) (Qi et al. 2010) also indicate that a 1×10^6 mg/L suspended

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[2] Although Chang (1963) and Chien and Wan (1991) did present the equation, the values of its two parameters were not provided. As a result, the diagram provided in the reference and shown in Figure A-7 is used to determine the suspended sediment concentration.

sediment concentration is reasonable. Note in Table A-3 the suspended sediment concentration during Hengshan Reservoir sediment sluicing not only reached 1×10^6 mg/L range but also was sustained at high levels for more than 24 hours, with the mean suspended sediment concentration over the duration of the sluicing in excess of 400,000 mg/L in all the sluicing events except one (215,000 mg/L during 7/24/1982 sluicing event). The relatively low mean suspended sediment concentration during the July 24, 1982 sluicing event, however, was likely the result of previous sluicing events that occurred less than two month earlier (May 28 and 29, 1982), with potential additional contribution from the higher discharge during the sluicing (13.7 m^3/s, the highest among all the sluicing events) that might have elevated the pool level and thus reduced the erosion power of the flow.

In addition to data and theory from China, observations of two dam removal projects here in the United States should also shed light on suspended sediment transport during IO-01 erosion. The first relevant dam removal project is Condit Dam on the White Salmon River in Washington, which was removed in October 2011 by blasting open a 5-m wide hole near the base of the dam to drain the reservoir and release the 1.8 million m^3 of sediment. Measured suspended sediment concentration in the White Salmon River downstream of Condit Dam reached 850,000 mg/L shortly after the opening of the hole near the base of the dam (Wilcox et al. 2014). Sediment deposit in Condit Reservoir is similar to Matilija Reservoir in that both have a fine (silt and clay) bottomset deposit (i.e., the reservoir and delta sub-area deposits in case of Matilija Reservoir). As a result, the bottomset deposit erosion from Condit Reservoir during dam removal should provide us with useful information on the potential erosion and transport of reservoir and delta sub-area sediment deposit following Matilija Dam removal. The topset deposits (the upstream channel sub-area deposit in the case of Matilija Reservoir) for the two cases, however, are completely different: the Condit topset deposit was composed primarily of sand-sized particles (60%) with a high fraction of silt and clay (35%), while the majority of the Matilija topset deposit is gravel (78%) and sand (16%), plus a very smaller fraction of silt and clay (6%). The contrast between the topset deposits between the two cases will result in substantially different suspended sediment concentration during Phase II erosion, as discussed below.

Table A-2. List of the number of days when daily average suspended sediment concentration exceeded 400,000 mg/L in the Yellow River basin during the period of 1962 – 1971. Table translated from Chien (1989).

Region	**River**	**Station**	**Number of occurances with daily avearge suspended sediment concentration in the range of**				**Total number of occurances > 400,000 mg/l**	**Maximum Instantaneous (mg/l)**	**Calendar Year Maximum Occurred**
			400,000 - 600,000 mg/l	600,000 - 800,000 mg/l	800,000 - 1,000,000 mg/l	> 1,000,000 mg/l			
He-Long Region, West Bank Tributaries	Huang-Pu-Chuan	Huang-Pu	22	18	12	4	56	1,480,000	1967
	Ku-Ye-He	Wen-Jia-Chuan	19	11	4	1	35	1,500,000	1964
	Wu-Ding-He	Shuan-Kou	34	19	3		56	1,290,000	1966
	Qing-Jian-He	Yan-Chuan	39	45	8	1	93	1,150,000	1964
	Yan-Shui	Gan-Gu-Yi	35	34	4	1	74	1,210,000	1963
	Wu-Lan-Mu-Lun-Chuan	Wang-Dao-Heng-Ta	3	3	3	1	10	1,510,000	1966
	Xiao-Li-He	Li-Jia-He	21	30	23	2	76	1,220,000	1963
He-Long Region, East Bank Tributaries	Zhu-Jia-Chuan	Hou-Gu Villiage	39	46	4		89	1,260,000	1964
	Lan-Yi-He	Pei-Jia-Chuan	20	4			24	923,000	1967
	Qiu (Jiao)-Shui-He	Lin-Jia-Ping	60	9			69	960,000	1965
	San-Chuan-He	Hou-Da-Chen	21	1			22	819,000	1969
	Xin-Shui-He	Da-Ning	22				22	741,000	1966
Mainstem Wei River	Wei River	Qiu-Jia-Xia	17	4			21	939,000	1966
	Wei River	Nan-He-Chuan	29	4			33	811,000	1963
	Wei River	Hua-Xian	16	2			18	753,000	1968
Tributary to Wei River	San-Du-He	Gan-Gu-Yi	61	31			92	980,000	1969
	Hu-Lu-He	Qin-An	37	4			41	905,000	1968
Jing-He River Basin	Jing-He	Yang-Jia-Ping	34	1			35	875,000	1970
	Jing-He	Zhang-Jia-Shan	36	17			53	1,040,000	1963
	Huan-Jiang	Hong-De	57	82	74	1	214	1,130,000	1970
	Pu-He	Mao-Jia-He	49	10			59	992,000	1965
Luo-He River	Luo-He River	Fu-Tou	57	46	7		110	1,090,000	1967

Table A-3. Suspended sediment concentration in Tangyu River downstream of Hengshan Dam in Shanxi Province, China during Hengshan Reservoir sediment sluicing between 1974 and 1982. Table translated from Qi et al. 2010.

Date of sluicing	Sluicing duration (hours)	Maximum discharge passing dam (m^3/s)	Mean discharge passing dam (m^3/s)	Maximum concentration (mg/L)	Average concentration over the duration of sluicing (mg/L)
7/28/1974	63.3	8.0	1.1	944,000	422,000
8/8/1979	26.0	54.4	4.9	1,200,000	622,000
8/9/1979	30.0	2.7	1.8	942,000	593,000
5/28/1982	31.5	33.0	1.1	1,320,000	837,000
5/29/1982	32.9	1.0	0.6	1,210,000	846,000
7/24/1982[a]	19.3	36.3	13.7	1,200,000	215,000

[a] This event occurred within two months of the May 1982 sediment sluicing events, which was likely a primary contributor to the significantly lower average suspended sediment concentration compared to other sluicing events; the significantly higher discharge (13.7 m3/s) might also have contributed to the lower suspended sediment concentration because the sluicing gate might not have been able to accommodate the flow as open channel flow, resulting in elevated reservoir pool level.

Based on information provided in Wilcox et al. (2014), the Condit Reservoir bottomset deposit was approximately 600 m long and 10 m deep, and our estimated post-removal channel width in the bottomset deposit area from a small-scale aerial photograph provided in Wilcox et al. (2014) is approximately 25 m, resulting in a total bulk volume of 150,000 m^3. According to the estimate of Wilcox et al. (2014), approximately 160,000 m^3 of sediment was evacuated from the reservoir area within 90 minutes following the opening of the hole at the base of the dam, meaning most, if not all, of the erodible bottomset sediment was eroded and transported downstream within less than 2 hours.

As shown in Figure A-7, suspended sediment concentration peaked to 850,000 mg/L during the short-period of bottomset sediment erosion then decreased approximately exponentially for about 7 weeks to reach a negligible level of 100 mg/L; after that, high suspended sediment concentration occurred only during high flow events.

The 850,000 mg/L suspended sediment concentration during bottomset deposit erosion provides additional confidence of the early estimate that suspended sediment concentration will likely be in the 10^6 mg/L range following cofferdam breaching for IO-01 of the Matilija Dam removal project. The seven-week long exponential decreasing suspended sediment concentration following Condit Dam removal was the result of the erosion of topset deposit that released the 35% silt and clay contained in that deposit. The topset deposit in Matilija Reservoir (upstream channel area) contains minimal amount of silt and clay (6%), and as a result, the increased suspended sediment concentration associated with its erosion will likely be minimal, as discussed below in comparison with observations during the Marmot Dam removal project.

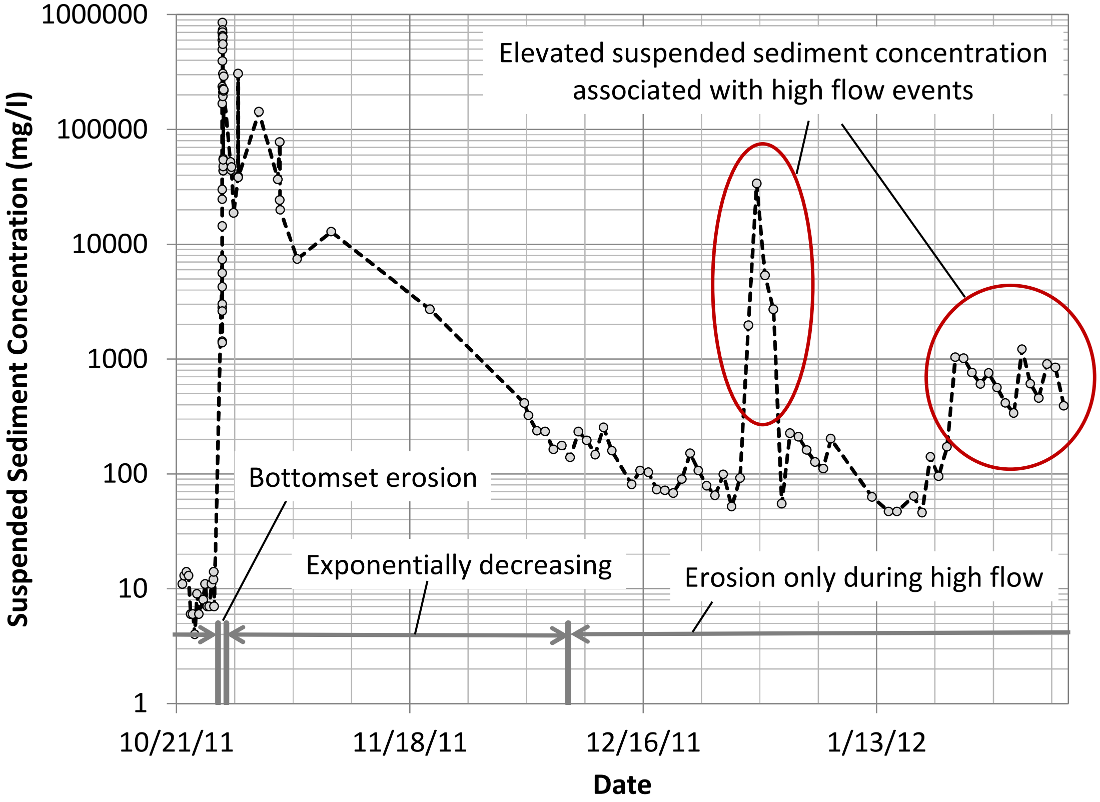

Figure A-7. Measured suspended sediment concentration in White Salmon River at approximately 2.3 km downstream of Condit Dam during Condit Dam removal, showing different phases of sediment erosion. Suspended sediment data was provided by Wilcox et al. (2014).

The second dam removal project that offers some insights relevant to Matilija is the Marmot Dam removal project (Figure A-4). Unlike the Matilija Reservoir deposit, the bottomset sediment deposit in the Marmot impoundment was composed primarily of sand-sized particles and was completely buried under an approximately 15-ft-thick coarse sediment deposit. Suspended sediment concentration peaked shortly after cofferdam breaching at approximately 37,000 mg/L (Cui et al. 2014). The increased suspended sediment concentration was most likely due to the erosion of the cofferdam, in conjunction with the erosion of some of the initially buried bottomset fine sediment. Suspended sediment concentration quickly receded after peaking, reaching the background level within about 10 hours following cofferdam breaching. Other than the 10-hour increase in suspended sediment concentration immediately after cofferdam removal, only one mild increase (by approximately 1,000 mg/L, with background concentration as high as 7,000 mg/L) was observed in the next high flow event.

It should be noted that the topset sediment deposit in the Marmot impound is very similar to that of the Matilija Reservoir[3], indicating that increased suspended sediment concentration due to erosion of upper channel sub-area reservoir deposit following Matilija Dam removal will be minimal.

Phase I erosion will likely erode only a portion of the fine sediment deposit from the reservoir area, because of a large deposit-to-channel-width ratio, as illustrated in Figure A-5. The widths of the reservoir deposit in the reservoir and delta sub-areas are on the order of 250 m (800 ft), while the average active channel width just downstream of Matilija Dam is approximately 24 m, suggesting that the pre-Matilija Dam main channel was on the order of about 24 m wide at its bankfull depth, or approximately 17 m at its base assuming a trapezoidal channel with a bank slope of 35^o and bankfull depth of 2 m. Measurements from aerial photographs in the Matilija Creek upstream of the reservoir influenced area indicate that a channel width on the order of 17 m is reasonable.

An assumed channel geometry with a bottom width of 20 m and a bank slope of 35^o, resulting in approximately a 25-m bankfull width, is applied below to estimate the duration of fine sediment erosion in Table A-4. In addition to a 20-m channel width with 35^o bank slope assumption, Table A-4 also provided evaluation on a more conservative 30-m channel width with 30^o bank slope assumption, and the most extreme case of eroding all the fine sediment contained in the reservoir and delta sub-areas.

Under the 20-m channel width with 35^o bank slope assumption, the Phase I fine sediment erosion will be accomplished in 10.2 hours assuming a 500,000 mg/L suspended sediment concentration or 6.0 hours assuming a 850,000 mg/L suspended sediment concentration (i.e., the same as Condit, which is slightly lower than the ~1,000,000 mg/L estimate from Figure A-6 as a conservative approach), eroding approximately 880,000 metric tons (960,000 cubic yards bulk volume) of sand and silt from the reservoir and delta sub-areas. Under the more conservative 30-m width with 30^o bank slope assumption, the Phase I fine sediment erosion will be accomplished in 13.5 hours assuming a 500,000 mg/L suspended sediment concentration or 8.0 hours assuming a 850,000 mg/L suspended sediment concentration, eroding approximately 1,170,000 metric tons (1,280,000 cubic yards bulk volume) of fine sediment from the reservoir deposit.

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[3] It is reported that Matilija Reservoir topset deposit (upstream channel sub-area deposit) contains 6% silt and clay (BOR 2006), which is common for gravel deposits in natural rivers (e.g., Shaw and Kellerhals 1982). No silt and clay is reported in Marmot impoundment topset deposit, not because the deposit did not contain any silt/clay-sized particles but because the sediment samples were obtained through underwater boring cores that lost all the silt/clay-sized particles during their retrieval (as observed by one of the authors of this technical memorandum).

Table A-4. Estimated duration for Phase I erosion assuming a 1,700 cfs discharge under various assumptions.

Suspended sediment concentration (mg/L)	Bottom width[a] (m)	Bank angle[a] (degrees)	Fine deposit erosion (metric tons)	Phase I erosion duration (hr)	Evaluation of presumed channel geometry
500,000	20	35	880,000	10.2	More likely scenario
	30	30	1,170,000	13.5	Conservative, but plausible
			2,830,000	32.7	Maximum[b]
850,000	20	35	880,000	6.0	More likely scenario
	30	30	1,170,000	8.0	Conservative, but plausible
			2,830,000	19.2	Maximum[b]

[a] Assumes a trapezoidal channel will form in the reservoir area, cutting through the existing deposit to reach the pre-dam bed.
[b] Assumes all the sand and silt deposit in reservoir and delta sub-areas are eroded during Phase I erosion.

To provide an absolute maximum estimate, eroding all of the 2.83 million metric tons (3,100,000 cubic yards bulk volume) of fine sediment deposited in the reservoir and delta sub-areas during Phase I erosion, which is an unlikely scenario, would require 32.7 hours assuming a 500,000 mg/L suspended sediment concentration or 19.2 hours assuming a 850,000 mg/L suspended sediment concentration. That is, under no combination of conditions does the Phase I erosion exceed 1.5 days (i.e., 36 hours). For comparison, the Phase I erosion for Condit Dam removal project (i.e., the period of bottomset deposit erosion) likely lasted less than 2 hours as discussed earlier (Figure A-7).

Following the end of Phase I erosion, the remaining fine sediment deposits will no longer be accessible to the flow, and as a result the suspended sediment concentration in the river will decrease with time. Fine sediment erosion during the initial stage of Phase II erosion will primarily be the result of mass wasting process that delivers fine sediment to the active channel, with sediment from high above the water surface slumping into the channel to be carried downstream by the flow. Additional contribution of fine sediment due to the erosion of topset deposit (i.e., upstream channel sub-area deposit) is expected to be minimal as discussed earlier.

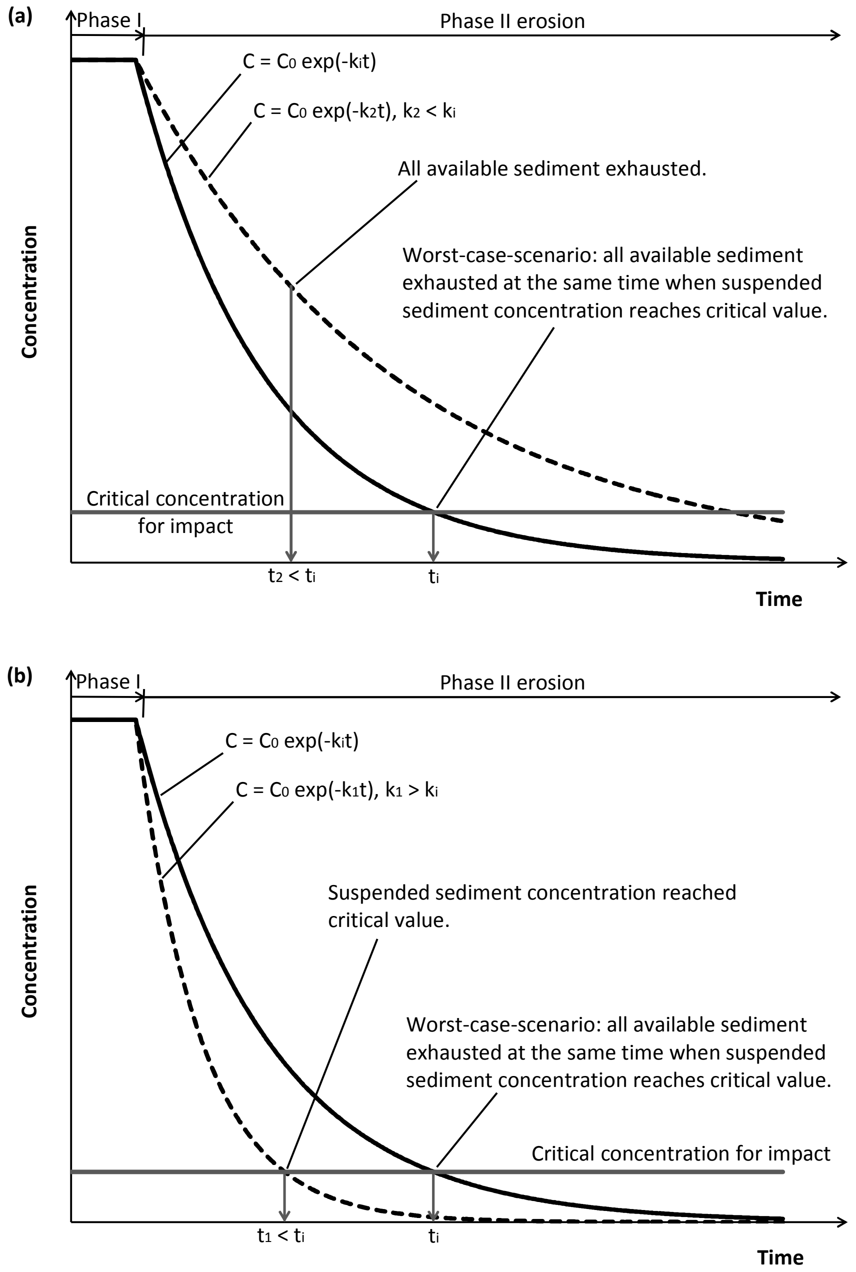
A maximum possible duration of early Phase II erosion (the period of mass wasting) can be assessed if mass wasting sediment production is assumed to be a smooth and internally cohesive decreasing function of time. Below we use an exponentially decaying function to conduct the assessment because it is the most internally consistent function that fits many natural processes. The measured suspended sediment concentration during Condit Dam removal shown in Figure A-7, for example, can be expressed nicely as an exponentially decaying function before it reached a negligible level of approximately 100 mg/L (i.e., between approximately October 26 and December 16, 2011).

Assume that the suspended sediment concentration following Phase I erosion can be expressed as $C = C_0 exp(-kt)$ under the assumption of a constant water discharge, in which C denotes suspended sediment concentration at time t; C_0 denotes Phase I suspended sediment concentration; t denotes time since the termination of Phase I erosion; and k is the exponential coefficient. The exponential coefficient k value determines how fast suspended sediment concentration decreases over time: a smaller k value means suspended sediment concentration decreases more slowly, and as a result, fine sediments are evacuated out of the reservoir area more quickly (Figure A-8a); and a larger k value means suspended sediment concentration decreases more quickly, reaching a relatively low (and presumably harmless) level over a shorter period of time even though fine sediment deposits are not evacuated out of the reservoir area as quickly as a lower k value (Figure A-8b). In other words, there must be a “highest impact” k value (denoted as k_i hereafter) that would result in the longest duration of impact (denoted as t_i hereafter): a k value higher than k_i would result in the suspended sediment concentration to become lower than the impact threshold over a time period shorter than t_i, and a k value lower than k_i would result in the exhaustion of all the erodible deposit over a time period shorter than t_i (Figure A-8).

Using this exercise and considering the possibility of a varying discharge after the conclusion of Phase I erosion (see detail in Section A5.0), it is found that the absolute maximum duration of impact due to mass wasting lasts for no more than 8 days (Table A-5), assuming a threshold suspended sediment concentration for impact of 1,000 mg/L, even if water discharge drops to tenth of the Phase I discharge of 1,700 cfs. Note the 1,000 mg/L threshold suspended sediment concentration is likely an extremely conservative estimate because background suspended sediment concentration likely exceeds this value by twenty-fold at 1,700 cfs (Figure A-9). Again, the 8-day maximum impact period was estimated based on the worst-case (and unlikely) scenario that a) all the post-Phase I fine sediments in reservoir and delta sub-areas are eroded by mass wasting; and b) the fine sediment erosion rate decreases exponentially in the least favorable way possible. The estimate is based on limitations on sediment volume and suspended sediment concentration (i.e., either run out of fine sediment, or suspended sediment concentration decreases to harmless level) instead of physics of sediment transport, implying that the actual mass wasting can range anywhere between a very short time (such as an hour or less) to maximum number of days of potential impact estimated above.

Table A-5. Calculated maximum potential impact duration due to mass wasting assuming an exponentially decaying fine sediment erosion rate, 1,700 cfs Phase I discharge, and 1,000 mg/L suspended sediment concentration threshold. The two duration values in the table are the results of two different Phase I concentration values (i.e., 850,000 and 500,000 mg/L).

Water discharge at the end of Phase II (cfs)	Phase I erosion (metric tons)	Maximum possible Phase II erosion (metric tons)	Maximum potential Phase II erosion duration (days)	Note
1,700	880,000	1,950,000	3.7/5.8	20-m/35◦ phase I channel
	1,170,000	1,660,000	3.2/5.0	30-m/30◦ phase I channel
	2,830,000	0	0.0	All fine eroded during Phase I erosion
500	880,000	1,950,000	4.4/7.0	20-m/35◦ phase I channel
	1,170,000	1,660,000	3.7/5.9	30-m/30◦ phase I channel
	2,830,000	0	0.0	All fine eroded during Phase I erosion
170	880,000	1,950,000	5.0/8.0	20-m/35◦ phase I channel
	1,170,000	1,660,000	4.2/6.8	30-m/30◦ phase I channel
	2,830,000	0	0.0	All fine eroded during Phase I erosion



FigureA-8. Illustration of the calculation of maximum potential duration for mass wasting.

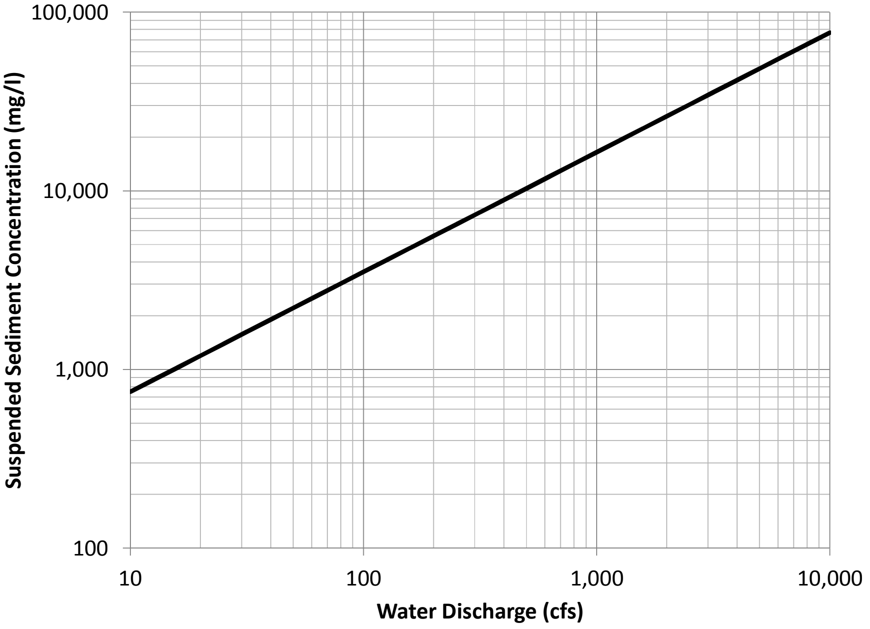


Figure A-9. Derived sediment supply rating curves for upper Matilija Creek. Derivation was based on fine sediment production rate presented in Table A-1 and the assumption that the rate of suspended sediment supply is proportional to water discharge to 1.7 power, where 1.7 was obtained from USGS gaging data in Ventura River, North Fork Matilija Creek and San Antonio Creek as reported in BOR (2006). Details of the derivation are presented in URS and Stillwater Sciences (in preparation).

Further narrowing down from the above estimated maximum impact duration for Phase II mass wasting erosion is offered by the observations of the Hengshan Reservoir sediment sluicing. One of their sluicing events was video-recorded and is posted on YouTube[4]; according to which mass wasting slowed down by 1:40 PM and virtually disappeared by 4:00 PM on the same day the sluicing started, indicating the duration of mass wasting was only a few hours (and certainly no more than 8 hours if it is assumed that sediment sluicing started at 8:00 AM, the official start of a working day in China)[5]. Note physically the mass wasting process is driven by the draining of water from the deposit under the influence of gravity, and having the majority of the water contained in the deposit drained within a few hours after being perched above the water table seems to be reasonable. Note also that the median size of Hengshan Reservoir deposit is 0.02 mm, while the Matilija reservoir and delta sub-area fine sediment deposits have a median size of 0.011 mm (BOR 2006). The finer deposit will make it more difficult to drain the water, and as a result, the duration of mass wasting following Matilija Dam removal will likely be longer than

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[4] Available at https://www.youtube.com/watch?v=BH6YdbSOu-w, accessed on August 2, 2014. Viewer needs to be cautious with the video clip as some of the narrative (in Chinese) is apparently inconsistent with the images being shown or values provided in Qi et al. (2010).

[5] The exact time of the day that the sluicing event began was not provided in the video, and as a result the exact duration of mass wasting cannot be determined.

what was observed during Hengshan Reservoir sediment sluicing. Even with the consideration of a potentially slower draining due to a finer deposit, the duration of mass wasting should not last for more than a few days, and more likely within a day (i.e., within approximately four times longer than what was observed during Hengshan Reservoir sediment sluicing).

In addition to mass wasting, subsequent Phase II high flow events (i.e., higher than the discharge that occurred during Phase I erosion) may also raise the water surface adequately to access some of the fine sediment, but the suspended sediment concentration associated with such events should be significantly lower than the Phase I erosion due to a combination of high discharge and much smaller amount of sediment erosion. Additionally, because the Ventura River is a high sediment-production basin (with a long-term average sediment supply on the order of 420,000 metric tons per year from the upper Matilija Creek, of which the vast majority is fine sediment), erosion of small amounts of former reservoir deposit after Phase I erosion is likely only a small fraction of the fine sediment carried naturally in the river, and thus is not expected to result in serious impacts. At a discharge of 110 m^3/s (4,000 cfs), for example, the silt and clay-sized sediment supply rate from the upper Matilija Creek is expected to be over 400,000 metric tons per day, which translates to a background suspended sediment concentration on the order of 40,000 mg/L (Figure A-9), far exceeding the likely rate of potential fine sediment erosion from the reservoir area after the Phase I erosion and the associated increase in suspended sediment concentration.

Some organic carbon contained in fine sediment deposit is expected to be released during the Phase I erosion. Following the termination of Phase I erosion, some organic carbon may remain in the fine sediment deposits (true for any dam-removal alternative that leaves the fine sediment in place for natural transport and allows a channel to form down to the base of the dam, i.e., all but IO-05 and 06), this material will be high above the water surface and should quickly oxidize once the deposit dries.

A2.1.2 Impacts due to High Suspended Sediment Concentration

For Robles diversion operation during the dam removal, a suspension of diversion operation during the first 24 hours following cofferdam breaching would be needed, and for planning purposes a reasonable, conservative assumption would be to suspend water diversion over the first week (i.e., 7 days) of the first high flow event.

There is a high likelihood of short-term impacts to aquatic resources under IO-01, including steelhead. Based on the analysis of Newcombe and Jensen (1996), exposure to fine sediment during Phase I with concentrations greater than 500,000 mg/L for a period of 5 hours or more would result in 80 to 100% mortality for exposed individuals. The initial release of Phase I sediment with flows greater than 1,700 cfs would probably occur during the potential upstream migratory period of adult steelhead. Any steelhead migrating upstream during the initial Phase I release would likely not survive. However, the relatively short duration of exposure reduces the likelihood that adults will be in the river during the release, since adults in the vicinity might find refuge habitat in tributaries or avoid entering the Ventura River during the release.

In addition, up to three cohorts of anadromous life-history rearing juveniles (age 0, age 1, and age 2) and more for resident life history would also suffer 80–100% mortality. Based on spatial distribution within the mainstem and tributaries, only a portion (albeit an unknown portion) would be impacted. The remaining portion of each cohort would presumably be rearing out of the mainstem and would therefore be unaffected. Overall, depending on exposure for adults, three to four generations of steelhead are likely to be directly affected by sediment release.

It is more challenging to predict the effects on fisheries resources of sediment released during the Phase II erosion, but it will be at lower concentrations than Phase I and may be similar to the background levels of suspended sediment that occur during high flow events under existing conditions (with measured concentrations on the Ventura River greater than 10,000 mg/L; BOR 2006, p. 131) when some diversion has historically occurred. A more detailed investigation of fisheries impacts will be conducted during the next phase of this project.

A2.1.3 Uncertainties Associated with the Option

The primary uncertainty associated with IO-01 is that the fine sediment in the reservoir and delta sub-areas will likely lose water content and gain strength during the period while waiting for the high flow event for cofferdam breaching. Significantly decreasing water content in the deposit can potentially make it more difficult to erode, and thus prolong the period of erosion. If the waiting period is more than a year, vegetation may also grow on the surface, which can further increase resistance to erosion. Because of the high water table upstream of the cofferdam just upstream of the delta sub-area, however, the majority of the fine sediment deposit will likely stay saturated, while only its surface layer will dry up.

Once the cofferdam is breached during a designed high flow event, initial incision of the fine sediment will likely occur along the weakest line of resistance, and once the flow gains access to the subsurface moist sediment it will cut down through the deposit relatively quickly (but still slower than the case of no dewatering). The rate of erosion will be governed by the erosion of the moist sub-surface sediment, with the tougher top layer falling into the flow in large chunks once the sediment underneath is eroded, as illustrated in Figure A-10. That is, the decreased erosion rate will likely be relatively minor once the flow breaks through the surface layer, which will likely occur rapidly under a 3,000 cfs peak flow and the exceptionally high channel gradient due to removal of the dam. The potential uncertainty associated with increased erosion resistance due to the loss of water content while waiting for the designated high-flow event could be easily managed with contingency plans such as mechanically breaking up the dried surface layer or using dynamite to strategically loosen up part of the deposits prior to the flood season, if determined to be necessary.

Another, relatively minor uncertainty associated with Initial Option – 01 is the uncertainty associated with the magnitude of suspended sediment concentration during the period of mass wasting described earlier (i.e., the early stage of Phase II erosion) which may last for a maximum of a few days. Because the rate of mass wasting is relatively independent of the magnitude of instream flow, a low instream flow during the period of mass wasting may result in an elevated suspended sediment concentration that can potentially impact downstream environment and water diversion.

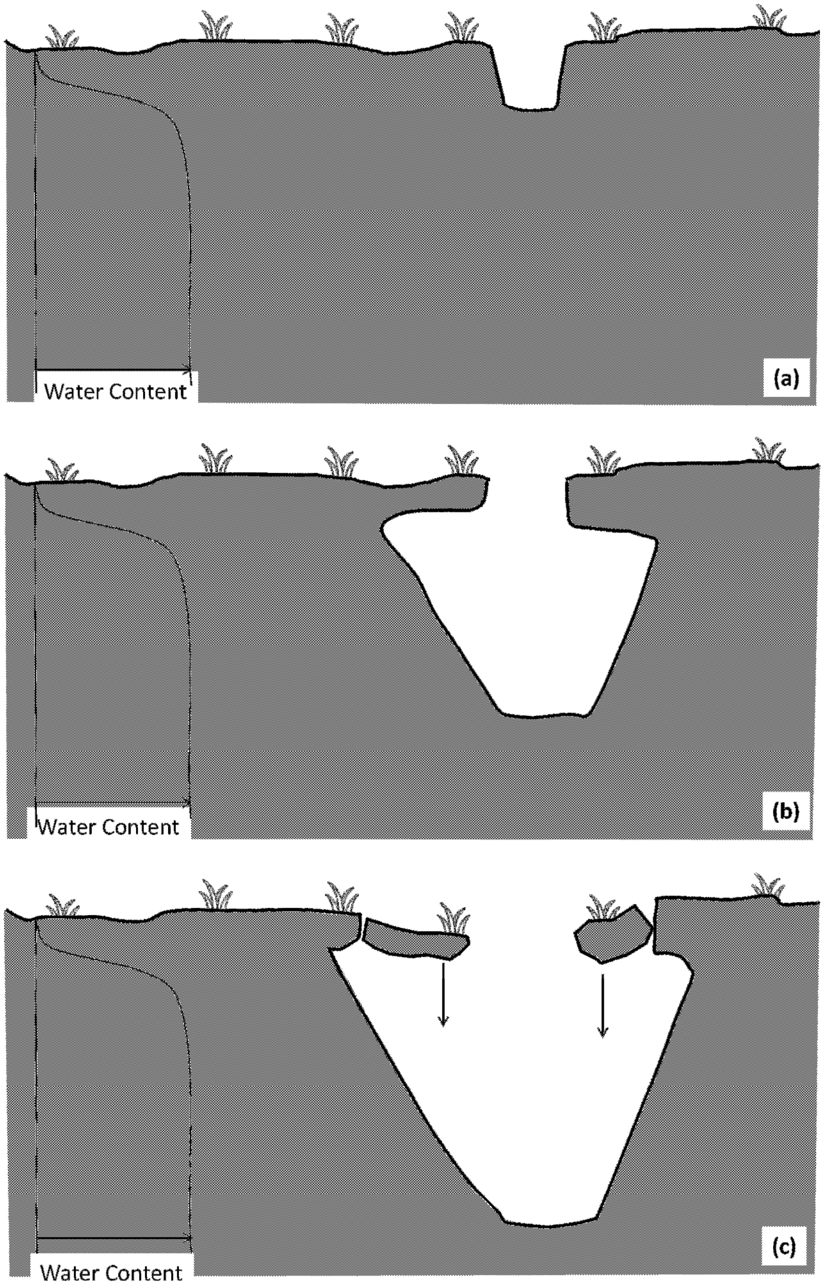

Figure A-10. Schematic sketch illustrating fine sediment erosion in case surface layer becomes dry and erosion resistant. (a). Surface erosion occurs through weak spot of the surface layer; (b) Rapid down cutting of the moist sub-surface sediment once the flow breaks through the surface layer; and (c). Continued subsurface erosion by deepening and widening of the channel with the surface sediment falling into the channel. Potential water content is provided on the left, where the high water table keeps the sediment moist in subsurface, while the surface layer is dry due to exposure to wind and sunlight.

A2.2 Initial Option – 02: Uncontrolled Orifices with Clean Water Diversion

A2.2.1 Fine Sediment Transport Dynamics

Fine sediment transport dynamics following the opening of the tunnel for IO-02 is similar to that of IO-01 discussed above when instream flow is below the tunnels' capacity under open channel flow conditions. If water discharge exceeds the tunnels' capacity under open channel flow conditions, however, reservoir pool level would rise, resulting in decreased fine sediment erosion or even complete termination of the erosion process, depending on the pool level. If that were to happen, erosion of fine sediment would resume during the receding limb of the flow event, again, similar to that discussed for IO-01 above. We expect the combined duration of sediment-eroding flow (i.e., high flow that does not exceed the tunnels' capacity) will exceed what is needed to accomplish Phase I erosion, as long as the daily average discharge in the river is above 1,700 cfs. The probability of that occurring (or not) can be quantified more precisely based on the historic hydrograph in the next stage of this project.

A2.2.2 Impacts due to High Suspended Sediment Concentration

Potential impact due to high suspended sediment concentration for IO-02 is similar to that of IO-01 discussed above, if water discharge remains below the tunnels' capacity. If water discharge exceeds the tunnels' capacity, however, the duration of impact to Robles Diversion is expected increase by an additional few hours (peak flow usually last for only a few hours) due to the reduced sediment erosion during the time of rising pool level. For planning purposes, impacts to Robles water diversion are assumed to be identical to those described under IO-01.

A2.2.3 Uncertainties Associated with the Option and Comparison with IO - 01

IO-02 is advantageous over IO-01 in that the water content in fine sediment deposits remains high prior to their erosion, which would help maintain high rate of fine sediment erosion and reduce the duration of impact. The major uncertainty of IO-02 is the reliability of weather forecasting—the target storm event has to be predicted in advance so that dynamite can be deployed while the discharge in the river is still low[6]. As a result, the duration of fine sediment impact may become longer if the actual discharge does not reach the designed value of 1,700 cfs (daily average). If only half of the designed discharge is realized (i.e., 850 cfs daily average discharge), for example, the expected duration would be twice as long as estimated for the 1,700 cfs, which translates to a maximum of 2 days of Phase I erosion instead of one day. The period of Phase II mass wasting is not expected to become longer even if water discharge is under-predicted, because mass wasting is driven by the draining of the deposit, a process independent of discharge.

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[6] Note the risks associated with the "prediction" of a future storm event for IO – 01 is significantly lower, as the cofferdam used for IO - 01 can be breached when the discharge actually achieves a reasonable value (such as 1,500 or 2,000 cfs).

A2.3 Initial Option – 03: Gated Orifices

A2.3.1 Fine Sediment Transport Dynamics

Sediment transport dynamics following the opening of the tunnel gates would be identical to that of IO-02. Similar to IO-02, it is expected that the combined duration of sediment-eroding flow (i.e., high flow that does not exceed the tunnels' capacity) will exceed what is needed to accomplish Phase I erosion, as long as the daily average discharge in the river is greater than 1,700 cfs. In the unlikely case that the duration of sediment-eroding flow is insufficient to accomplish all of the Phase I erosion, the tunnel gates could be closed; a subsequent high flow event would then complete the Phase I erosion.

Once the sluicing event is over, the gates should normally be kept open at least during moderately high and high flow events so that the incoming fine sediment can pass through the dam. Having the gates closed during subsequent high flow events may result in substantial fine sediment deposition in the reservoir area because of the high sediment yield in the basin, resulting in the need for yet another sluicing operation under Phase I transport conditions and a period of unnaturally high suspended-sediment events.

A2.3.2 Impacts due to High Suspended Sediment Concentration

Impact due to high suspended sediment concentration for IO - 03 is likely identical to that of IO-02.

A2.3.3 Uncertainties and Comparison with Other Initial Options

IO-03 is advantageous over IO-02 by eliminating the need for predicting the precise timing of a future high flow event for project implementation. Another potential advantage is that the gates can be closed if it becomes necessary; the most likely scenario, however, is that the gates would be opened only once and would not need to be closed. Similar to IO-02, IO-3 is advantageous over IO-01 in that fine sediment stays wet prior to erosion and that helps maintain high erosion rate following dam removal.

A2.4 Initial Option - 04: Gated Notch(es)

A2.4.1 Fine Sediment Transport Dynamics

Sediment erosion dynamics following the opening of the gates on the notches is similar to that for IO-01, except that lesser amounts of sediment are eroded during each stage. The suspended sediment concentration during sediment erosion following the opening of the gates is expected to be extremely high, but lower than that for IO-01 due to the reduced energy gradient of the flow, resulting in overall longer duration of sediment erosion compared to IO– 01 (i.e., during each notching stage high suspended sediment concentrations will last for more than one fifth of the duration listed in Table A-4, assuming equal amount of fine sediment is released during each stage). High suspended sediment concentration as a result of mass wasting following the fifth stage of dam removal is still expected, but the suspended sediment concentration and duration of mass wasting is expected to be significantly lower and shorter compared to IO-01 because much of the mass wasting should have already occurred during the first four stages of notching. Note that fine sediment in the reservoir sub-area can potentially be buried by coarse sediment during the later stages of notching for this initial option, which may result in a decreased magnitude of suspended sediment concentration but longer duration for sediment flushing. The potentially increased duration of high suspended sediment concentration under the condition of fine sediment burial, however, should still not exceed a full day based on the experiences during Marmot Dam removal, where substantially higher suspended sediment concentrations compared to background conditions lasted for only about 10 hours.

A2.4.2 Impacts due to High Suspended Sediment Concentration

Although suspension of water diversion at Robles is likely needed for only a few hours during each gate opening event, water diversion suspension should be assumed to last for a full day during each of the first four stages of notching and potentially for the first week of the storm event for the fifth stage (to be comparable to IO-01) for planning purposes due to logistic considerations (i.e., a resumption of water diversion may not occur if it becomes possible to do so at odd hours) and to be conservative (i.e., mass wasting may keep the suspended sediment at a high level for a week during the storm event for the last stage of notching).

Similar to effects described for IO-01 above, the predicted very high concentrations of fine sediment would likely result in nearly complete mortality of exposed steelhead. The implication of the timing of release and potential effects on adults are also similar to IO-01. However, at least five pulses of very high fine-sediment concentration would accompany the five gate opening events, and the completion of this sequence is likely to require up to several decades under the current rainfall regime to occur. Thus, multiple generations of steelhead—no less than seven, if the five events occur in successive years, and as many as 15, if the events are spaced three or more years apart—would suffer impacts due to very high suspended sediment concentrations under this option.

A2.4.3 Uncertainties Associated with the Option

Uncertainties associated with mass wasting following the conclusion of the storm event for the last stage of notching is still expected, but likely at a minimal level (and at most for a few days). Potential burial of fine sediment in the reservoir sub-area by coarse sediment in later stages of the notching may increase the duration of high suspended sediment concentration. The increased duration of high suspended sediment concentration due to fine sediment burial, however, is not expected to be more than a full day during each stage of notching.

A2.5 Initial Option - 05: Temporary Upstream Storage of Sediment

A2.5.1 Fine Sediment Transport Dynamics

Under this initial option the majority of the fine sediment subject to Phase I erosion would be removed from the reservoir deposit, and thus suspended sediment concentrations following dam removal are expected to be substantially lower than the previous initial options during the first high flow event. High suspended sediment concentration is still expected following dam removal when the discharge in the creek is low (i.e., a few cfs), because some erodible sediment would be left in the reservoir despite the best excavation efforts. If the fine sediment placed in temporary upstream storage can be released during a 10-year recurrence storm event or greater as planned, the suspended sediment concentration may be increased substantially for short periods of time during the storm event while the excess fine sediment is being delivered to the river by mass wasting. Averaged over the entire storm event, however, the increase in suspended sediment concentration should be relatively mild compared to the background conditions (assuming sediment erosion does occur only during 10-year event or higher) because loads will already be high given the high sediment yield from the upper Matilija Creek watershed (420,000 metric tons per year on a long-term averaged basis, of which most is delivered in large, decadal to multi-decadal storms).

A2.5.2 Impacts due to High Suspended Sediment Concentration

There is likely a period of low flow (e.g., a few cfs) following dam removal, during which the river will remain turbid as the flow erodes what is left from the newly excavated channel. Water diversion at Robles Diversion Dam, however, is unlikely to be affected by the project: the excavated channel would most likely become relatively clean before the discharge in the creek reaches 30 cfs (the minimal discharge at which Robles is allowed to divert water).

There is a potential for impacts to aquatic resources under IO-05, including steelhead. Based on the analysis of Newcombe and Jensen (1996) we would expect that exposure to lower concentrations of fine sediment under this option would have a lower impact, and direct mortality may not occur. However, sublethal impacts, including reduced growth rates, and physiological stress are still likely. Overall, depending on exposure for adults, at least three generations of steelhead are likely to experience sublethal impacts from sediment release, and possibly more if subsequent releases occur after additional spawning.

A2.5.3 Uncertainties Associated with the Option

The amount of sediment designed for mechanical removal from the reservoir exceeds what can be removed mechanically during one season. Removing sediment over multiple years increases the risk of this option because sediment deposition in the reservoir area would occur due to high sediment yield in the upper Matilija Creek basin (420,000 metric tons per year on a long-term averaged basis) and the increased sediment trapping efficiency following the formation of the dredging slot. Sediment supply from the upper Matilija Creek is non-linearly correlated with water discharge, so it is possible that sediment would deposit close to the pre-dredging level if a large storm event occurs before the dam is removed. Even if no large storm event occurs during the period of sediment removal, sediment deposition during the wet season will increase the amount of sediment that needs to be removed, making it difficult to estimate the true duration and cost of the removal operation.

A2.6 Initial Option - 06: Phased notching with Combination of Downstream Slurry and Upstream Temporary Storage of Fines

A2.6.1 Fine Sediment Transport Dynamics

Under this scenario the majority of the potentially erodible fine sediment deposit in the reservoir sub-area would be removed by slurry dredging prior to dam removal, and fine sediment in the delta sub-area left in place following fine sediment removal will be re-contoured and armored with boulders to ensure significant erosion would occur only when there is a significantly large flow event. Similar to IO-05, high suspended sediment concentration is still expected following dam removal when the discharge in the creek is low (i.e., a few cfs), because some erodible sediment would be left in the reservoir despite the best efforts at excavation. Once a high flow event occurs that breaks the armored surface in the delta sub-area, suspended sediment concentration will likely spike, but with a magnitude significantly lower than IO-01, 02, 03, and 04. The elevated suspended sediment duration during the erosion of the delta sub-area fine sediment is also expected to be short.

In addition to the high suspended sediment concentration as a result of delta sub-area fine sediment erosion, this alternative also has the same potential high suspended sediment concentration issue as IO-05 (i.e., uncertainties associated with the release of fine sediment stored in the upstream storage), depending on how much fine sediment is stored in the upstream storage area and how it is stored.

A2.6.2 Impacts due to High Suspended Sediment Concentration

Similar to IO-5, there is likely a period of low flow (e.g., a few cfs) following dam removal, during which the river will remain turbid as the flow erodes what is left from the newly excavated channel. By the time the discharge in the Ventura River reaches 30 cfs (the minimal discharge at which Robles is allowed to divert water), however, most of the fine sediment exposed on channel surface would have been eroded, and suspended sediment concentration would likely become adequately low to allow for Robles water diversion. Once water discharge becomes adequate to break the armor placed in delta sub-area, suspended sediment concentration will increase for a short period of time, during which Robles water diversion is unlikely affected because the majority of the high organic content sediment has been removed.

Similar to effects described for IO-05 above, the predicted lower concentrations of fine sediment from dredging efforts would likely result in sublethal effects to exposed steelhead.

A2.6.3 Uncertainties Associated with the Option

The amount of sediment that needs to be removed from the reservoir exceeds what can be removed mechanically during one season. As with Initial Option – 05, removing sediment in multiple years would increase the risk of this option because the amount of sediment deposition in the reservoir area during winter storm events may exceed the amount dredged in the previous dry season due to the high sediment yield in the upper Matilija Creek basin and the formation of the dredging slot that promotes sediment deposition.

The re-contouring of the delta sub-area and armoring of fine sediment deposit presents another risk: the armoring placed over the fine sediment deposit may be eroded during a discharge substantially lower than the intended discharge due to the high gradient following sediment excavation. If that occurs, it may result in a substantially longer period of high suspended sediment concentration that may negatively impact fisheries resources and Robles water diversion.

A3.0 Summary and Comparison of Potential Impacts for all Initial Options

Major findings with regard to fine sediment transport and potential impact for the six initial options are summarized in Table A-6 below. Potential impacts from coarse sediment dynamics are similar for all the initial options except IO-05, which has the least short-term impact from coarse sediment transport among all the initial options. Over the long-term, however, coarse sediment impacts are similar for all the six initial options.

Table A-6. Summary of the fine sediment findings for the six initial options

Initial Option	Description	Fine sediment dynamics	Impact due to high suspended sediment concentration	Uncertainties associated with fine sediment transport
01	**Containment berm with high flow bypass**	Initial (Phase I) erosion within about a day, followed by mass wasting for a few days, then only occasional erosion during high flow events.	Most likely one day suspension of water diversion at Robles; as a conservative approach, assume water loss during the first seven days of the first storm event following cofferdam breaching for planning purposes. Fisheries resources predicted to experience high mortality for exposed individuals, potentially including adults and certainly juveniles. Impacts are anticipated to be acute.	Major uncertainty is associated with the increased erosion resistance of the deposits following dewatering during the waiting period that potentially increases the duration of high suspended sediment concentration; likely easily manageable with contingency plans. Uncertainty during the period of mass wasting that can potentially last for a few days. Overall risk associated with this alternative is low because of the identification of contingency plans and the relatively short period of duration of impact.

Initial Option	Description	Fine sediment dynamics	Impact due to high suspended sediment concentration	Uncertainties associated with fine sediment transport
02	**Uncontrolled orifices with clean water diversion**	Similar to IO-01, with potential interruptions if instream flow exceeds the tunnels' design capacity, during which erosion of fine sediment would slow down or stop.	Water diversion loss at Robles is likely similar to IO-01 if instream flow following tunnel opening remains below tunnels capacity. More loss of water diversion at Robles may occur compared to IO - 01 if instream flow exceeds tunnels' capacity, but the duration of additional water loss should not exceed a few hours. Fisheries resources predicted to experience high mortality for exposed individuals, potentially including adults and certainly juveniles. Potential for acute and prolonged impacts.	Major risk associated with this initial option is the predictability of future high flow events. Overall risk associated with this alternative is low because the duration of impact is likely still within the acceptable range even if the future flow is somewhat under-predicted.
03	**Gated orifices**	Identical to IO - 02.	Impact to Robles water diversion for IO-03 is expected to be identical to IO-02. Fisheries resources predicted to experience high mortality for exposed individuals, potentially including adults and certainly juveniles. Potential for acute and prolonged impacts.	There are no major uncertainties for this initial option.
04	**Gated notch(es)**	Similar to IO - 01 during the first high flow event following each notching, but with slightly lower suspended sediment concentration and shorter duration.	Interruption to Robles water diversion is most likely four more days than IO – 01 due to the multiple releases during subsequent notching. Fisheries resources predicted to experience high mortality for exposed individuals, potentially including adults and certainly juveniles. Potential for acute and prolonged impacts, and could affect multiple generations.	Potential burial of fine sediment by coarse sediment in later stages of the notching may increase the duration of high suspended sediment concentration. The increased duration of high suspended sediment concentration, however, is not expected to be more than a full day even under a fine sediment burial scenario. The overall risk associated with this initial option is considered as low; but the certainty and magnitude of extended duration of impacts are very high.

Initial Option	Description	Fine sediment dynamics	Impact due to high suspended sediment concentration	Uncertainties associated with fine sediment transport
05	**Temporary upstream storage of sediment**	Suspended sediment is expected to be high during the period of low flow (i.e., a few cfs) after dam removal, but will likely become minimal when flow approaches the minimal instream flow allowed for water diversion (30 cfs). Short burst of high suspended sediment concentration is expected during events when the stored sediment is eroded in the future.	Minimal interruption to Robles water diversion is expected for this option. Fisheries resources predicted to experience sublethal effects for exposed individuals, potentially including adults and certainly juveniles. Potential for prolonged impacts.	It is possible that incoming sediment would deposit within the reservoir close to the pre-excavation level if a large storm event occurs before the dam is removed. Uncertainty associated with the erosion of the fine sediment stored upstream. The overall risk associated with this initial option is high, due to the need for excavation over multiple seasons.
06	**Phased notching with downstream slurry and upstream temporary storage of fines**	Suspended sediment is expected to be high during the period of low flow (i.e., a few cfs) after dam removal, but will likely become minimal when flow approaches the minimal instream flow allowed for water diversion (30 cfs). Short burst of high suspended sediment concentration is expected when high flow event breaks through the armor placed on top of fine sediment at delta sub-area. Short burst of high suspended sediment concentration is expected during events when the stored sediment is eroded in the future.	Minimal interruption to Robles water diversion is expected for this option. Fisheries resources predicted to experience sublethal effects for exposed individuals, potentially including adults and certainly juveniles. Potential for prolonged impacts.	It is possible that incoming sediment would deposit within the reservoir close to the pre-excavation level if a large storm event occurs before the dam is removed. Uncertainty associated with the initial erosion of what remains in the reservoir area after dam removal. Uncertainty associated with the erosion of the fine sediment stored upstream. The overall risk associated with this initial option is considered as high due to uncertainties associated with multi-year dredging and erosion of the remaining sediment in the delta sub-area.

A4.0 Supporting Material: Estimate of Parameters Relevant to Phase I Fine Sediment Erosion under 1,700 cfs Flow

Manning's Equation below is used to provide a rough estimate of water depth and flow velocity in the reservoir and delta sub-areas following dam removal:

$$V = \frac{1}{n} H^{2/3} S^{1/2} \tag{1a}$$

$$Q_w = VHB \tag{1b}$$

in which *V* denotes average velocity in meters per second; *n* denotes Mannings n; *H* denotes average water depth in meters; *S* denotes channel gradient; Q_w denotes water discharge in cubic meters per second; and B denotes average channel width.

Assuming a Manning's n value of 0.012, an average channel width of 25 m, a channel gradient of 0.023, and a discharge of 48 m^3/s (1,700 cfs), we obtain a velocity of 6.0 m/s and a depth of 0.32 m.

Note the 0.023 channel gradient is the average channel gradient just downstream of Matilija Dam and the actual channel gradient in the reservoir and delta sub-areas are likely substantially higher shortly after dam removal. As a result, the actual flow velocity is likely to be higher than the estimate and the water depth lower than the estimate.

The median size of the sediment deposit in the reservoir and delta sub-areas (excluding the coarse sediment cap in the delta sub-area) is approximately 0.011 mm (BOR 2006), and the settling velocity (v_s) associated with a 0.011 mm sediment particle is calculated to be 0.0001 m/s by assuming the drag force exerted to the particle while settling is perfectly balanced by the submerged weight of the particle (e.g., Vesilind et al. 1994), and from which we obtain

$$\frac{V^3}{gHv_s} = 6.65 \times 10^5 \tag{2a}$$

and

$$\tau_b = \rho g H S = 73\ Pa \tag{2a}$$

In which g denotes acceleration of gravity; τ_b denotes shear stress; and ρ denotes density of the flow. These parameters are often used to evaluate the suspended sediment carrying capacity (e.g., Chien and Wan, 1991).

A5.0 Supporting Material: Derivation of Equations to Quantify the Maximum Possible Duration of Impact of Phase II Erosion due to Mass Wasting

Under the condition of a constant water discharge, we can assume that suspended sediment concentration starts as C_0 and decreases exponentially over time:

$$C = C_0 exp(-kt) \tag{3a}$$

or

$$Q_s = Q_{s0} exp(-kt) \tag{3b}$$

where

$$Q_s = CQ_w;\ Q_{s0} = C_0 Q_{w0} \tag{3c,d}$$

in which C denotes suspended sediment concentration; k is exponential coefficient; t denotes time; Q_s denotes the rate of suspended sediment transport (and Q_{s0} is Q_s at $t = 0$).

Note equation (3a) is valid only under the condition of constant water discharge. Because mass wasting is independent of the water discharge in the creek, however, equation (3b) should be valid in case water discharge varies over time.

Based on equation (3b), the cumulative sediment transported at time t would be $M = \int_0^t Q_{s0} exp(-kt)dt$, or

$$M = \frac{C_0 Q_{w0}}{k}[1 - exp(-kt)] \tag{4}$$

in which Q_w denotes water discharge.

The time needed for suspended sediment concentration to reach a threshold value C_t is derived from equation (3b) with the aid of (3c) to obtain:

$$t_c = \frac{1}{k}\ln\left(\frac{Q_{w0}C_0}{Q_w C_t}\right) \tag{5}$$

in which t_c denotes the time needed for the suspended sediment concentration to reach the impact threshold concentration of C_t.

And from Equation (4) we obtain the time needed for all the available sediment to be transported:

$$t_m = -\frac{1}{k}\ln\left(1 - \frac{kM_t}{C_0 Q_{w0}}\right) \tag{6}$$

in which t_m denotes the time needed to transport all the sediment deposit; and M_t denotes the mass of all the deposit.

Note t_c decreases with increasing k value, while t_m increases with increasing k value, and the exponential coefficient k_i that would result in the longest impact is identified as the cross point between $t_c \sim k$ and $t_m \sim$ curves (i.e., when $t_c = t_m = t_i$), resulting

$$k_i = \frac{C_0 Q_{w0} - C_t Q_w}{M_t} \tag{7}$$

and

$$t_i = \frac{M_t}{C_0 Q_{w0} - C_t Q_w} \ln\left(\frac{Q_{w0} C_0}{Q_w C_t}\right) \tag{8}$$

in which t_i denotes maximum possible duration for potential impact.

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MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

INITIAL OPTIONS SCREENING REPORT

APPENDIX B: ROUGH ORDER OF MAGNITUDE CONSTRUCTION COST & SCHEDULE DETAILS

SEPTEMBER 9, 2014

TABLE B-1

Project: Matilija Dam Removal, Sediment Transport, & Robles Diversion Mitigation
Task 1.2: Initial Options Screening
DRAFT Rough Order of Magnitude Cost Estimate (Class 5)
Date: 8/5/2014
Detailed Breakdown: IO1 - Containment berm with high flow bypass

Line Item #	Line Item	Quantity	Unit	Unit cost	Amount	Notes
1	**Mobilization/Demobilization (15%)**				**$ 4,468,744**	
	Mobilization/Demobilization (15%)	1	LS	$ 4,468,744	$ 4,468,744	Moblization and Demoblization (15% of Direct Construction Cost associated with Items not including Mob/Demob)
2	**Site Preparation**				**$ 31,792**	
	Clear & grub general staging areas and access roads	1.0	acre	$ 5,388	$ 5,388	Price escalated from USACE September 2004
	Clear & grub containment berm area	1.0	acre	$ 5,388	$ 5,388	Price escalated from USACE September 2004
	Clear & grub cofferdam area	3.9	acre	$ 5,388	$ 21,015	Price escalated from USACE September 2004
3	**Build bypass**				**$ 12,300,000**	
	Portals	2	ea	$ 700,000	$ 1,400,000	Assumed size stabilized with 12-foot dowel @ 10x10 spacing and shotcrete; used historic prices
	Tunnel	1,600	ft	$ 6,000	$ 9,600,000	Based on historic price per foot and a recent bid for 12-foot-diameter tunnels
	Sluice gate	1	ea	$ 300,000	$ 300,000	From Searsville, purchase and installation
	Erosion protection for NF Matilija Creek	1	LS	$ 1,000,000	$ 1,000,000	Allowance
4	**Build DS containment berm**				**$ 66,720**	
	Excavate and place fill	5,560	cy	$ 12.00	$ 66,720	Cost based on crew/equipment/material buildup
5	**Build US cofferdam**				**$ 560,000**	
	Excavate and place fill	56,000	cy	$ 10.00	$ 560,000	Cost based on crew/equipment/material buildup
6	**Dewatering**				**$ 267,293**	
	Dewater reservoir	500	ac-ft	$ 250.99	$ 125,493	Price escalated from USACE September 2004
	Fish rescue and relocation	1	LS	$ 141,800.00	$ 141,800	Price escalated from USACE September 2004
7	**Remove dam**				**$ 9,690,832**	
	Remove fish traps and control house	1	LS	$ 71,467.20	$ 71,467	Price escalated from USACE September 2004
	Drill & blast	51,000	cy	$ 27.00	$ 1,377,000	Intact volume, Cost based on crew/equipment/material buildup
	Process for hauling	51,000	cy	$ 56.00	$ 2,856,000	Intact volume, Cost based on crew/equipment/material buildup
	Haul to recycling plant	51,000	cy	$ 60.00	$ 3,060,000	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	76,500	cy	$ 30.41	$ 2,326,365	Rubble volume, Searsville price
8	**Site Restoration**				**$ -**	
	Site Restoration	-	acre	$ -	$ -	Assumed not required for naturally formed slopes in reservoir area
	Subtotal				**$ 27,385,381**	
	Design & Unit Cost Contingency (30%)				$ 8,215,614	
	Total Direct Construction Cost				$ 35,600,995	
	Construction Contingency (15%)				$ 5,340,149	
	Total Construction Cost				**$ 40,941,144**	
	Low Side of Class 5 Estimate Range (-30%)				**$ 28,658,801**	
	High Side of Class 5 Estimate Range (+50%)				**$ 61,411,717**	

TABLE B-2

Project: Matilija Dam Removal, Sediment Transport, & Robles Diversion Mitigation
Task 1.2: Initial Options Screening
DRAFT Rough Order of Magnitude Cost Estimate (Class 5)
Date: 8/5/2014
Detailed Breakdown: IO2 - Uncontrolled orifices

Line Item #	Line Item	Quantity	Unit	Unit cost	Amount	Notes
1	**Mobilization/Demobilization (15%)**				**$ 2,099,293**	
	Mobilization/Demobilization (15%)	1	LS	$ 2,099,293	$ 2,099,293	Moblization and Demoblization (15% of Direct Construction Cost associated with Items not including Mob/Demob)
2	**Site Preparation**				**$ 7,412**	
	Clear & grub general staging areas and access roads	1.0	acre	$ 7,412	$ 7,412	RSMeans Heavy Construction (2007) - page 205 (1.148 Location Factor)
3	**Excavate tunnels through dam**				**$ 1,135,261**	
	Excavate and place fill for working platforms	4,170	cy	$ 12.00	$ 50,040	Cost based on crew/equipment/material buildup
	Drill & break out concrete	360	cy	$ 2,770.00	$ 997,200	Price from Searsville
	Haul to recycling plant	360	cy	$ 60.00	$ 21,600	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	540	cy	$ 30.41	$ 16,421	Rubble volume, Searsville price
	Remove final plug	1	LS	$ 50,000.00	$ 50,000	Allowance
4	**Remove dam**				**$ 9,622,931**	
	Remove fish traps and control house	1	LS	$ 71,467.20	$ 71,467	Price escalated from USACE September 2004
	Drill & blast	50,640	cy	$ 27.00	$ 1,367,280	Intact volume, Cost based on crew/equipment/material buildup
	Process for hauling	50,640	cy	$ 56.00	$ 2,835,840	Intact volume, Cost based on crew/equipment/material buildup
	Haul to recycling plant	50,640	cy	$ 60.00	$ 3,038,400	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	75,960	cy	$ 30.41	$ 2,309,944	Rubble volume, Searsville price
5	**Site Restoration**				**$ -**	
	Site Restoration	-	acre	$ -	$ -	Assumed not required for naturally formed slopes in reservoir area
	Subtotal				**$ 12,864,898**	
	Design & Unit Cost Contingency (30%)				$ 3,859,469	
	Total Direct Construction Cost				$ 16,724,367	
	Construction Contingency (15%)				$ 2,508,655	
	Total Construction Cost				**$ 19,233,022**	
	Low Side of Class 5 Estimate Range (-30%)				**$ 13,463,115**	
	High Side of Class 5 Estimate Range (+50%)				**$ 28,849,533**	

TABLE B-3

Project: Matilija Dam Removal, Sediment Transport, & Robles Diversion Mitigation
Task 1.2: Initial Options Screening
DRAFT Rough Order of Magnitude Cost Estimate (Class 5)
Date: 8/5/2014
Detailed Breakdown: IO3 - Gated orifices

Line Item #	Line Item	Quantity	Unit	Unit cost	Amount	Notes
1	**Mobilization/Demobilization (15%)**				**$ 3,260,328**	
	Mobilization/Demobilization (15%)	1	LS	$ 3,260,328	$ 3,260,328	Moblization and Demoblization (15% of Direct Construction Cost associated with Items not including Mob/Demob)
2	**Site Preparation**				**$ 387,412**	
	Clear & Grub Staging Area and Access Roads	1.0	acre	$ 7,412	$ 7,412	RSMeans Heavy Construction (2007) - page 205 (1.148 Location Factor)
	Diversion system	1	LS	$ 380,000	$ 380,000	Allowance (assumes 1,100-foot-long 48-inch HDPE with a dam penetration)
3	**Dewatering**				**$ 1,267,293**	
	Dewater reservoir	500	ac-ft	$ 250.99	$ 125,493	Price escalated from USACE September 2004
	Fish rescue and relocation	1	LS	$ 141,800.00	$ 141,800	Price escalated from USACE September 2004
	Dewater sediment	1	LS	$ 1,000,000.00	$ 1,000,000	Allowance
4	**US excavation**				**$ 2,860,000**	
	Fine sediment excavation	300,000	cy	$ 9.00	$ 2,700,000	Cost based on crew/equipment/material buildup
	Access roads for fine sediment excavation	4,000	lf	$ 40.00	$ 160,000	Est. 800 lineal feet of 40-foot-wide 2-foot-thick access roads at 5 levels within fine sediment ex.
5	**Excavate tunnels through dam**				**$ 2,588,784**	
	Build working platforms DS	4,170	cy	$ 12.00	$ 50,040	Cost based on crew/equipment/material buildup
	Build access for mid-level orifice	1	ea	$ 100,000.00	$ 100,000	Allowance
	Drill & break out concrete for gated orifices	380	cy	$ 2,770.00	$ 1,052,600	Price from Searsville recycling of concrete
	Drill and break out concrete for mid-level orifice	16	cy	$ 2,770.00	$ 44,320	Price from Searsville drilling, breaking out, hauling, recycling of concrete
	Haul to recycling plant	396	cy	$ 60.00	$ 23,760	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	594	cy	$ 30.41	$ 18,064	Rubble volume, Searsville price
	Purchase and install 12-foot-diameter sluice gates	3	ea	$ 400,000.00	$ 1,200,000	Price from Searsville estimate
	Purchase and install 6-foot-diameter sluice gates	1	ea	$ 100,000.00	$ 100,000	Ratio of price for 12-foot-diameter gates based on area of gate
6	**Remove dam**				**$ 9,616,141**	
	Remove fish traps and control house	1	LS	$ 71,467.20	$ 71,467	Price escalated from USACE September 2004
	Drill & blast	50,604	cy	$ 27.00	$ 1,366,308	Intact volume, Cost based on crew/equipment/material buildup
	Process for hauling	50,604	cy	$ 56.00	$ 2,833,824	Intact volume, Cost based on crew/equipment/material buildup
	Haul to recycling plant	50,604	cy	$ 60.00	$ 3,036,240	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	75,906	cy	$ 30.41	$ 2,308,301	Rubble volume, Searsville price
7	**Site Restoration**				**$ -**	
	Site Restoration	-	acre	$ -	$ -	Assumed not required for naturally formed slopes in reservoir area
	Subtotal				**$ 19,979,957**	
	Design & Unit Cost Contingency (30%)				$ 5,993,987	
	Total Direct Construction Cost				$ 25,973,945	
	Construction Contingency (15%)				$ 3,896,092	
	Total Construction Cost				**$ 29,870,036**	
	Low Side of Class 5 Estimate Range (-30%)				**$ 20,909,025**	
	High Side of Class 5 Estimate Range (+50%)				**$ 44,805,054**	

TABLE B-4

Project: Matilija Dam Removal, Sediment Transport, & Robles Diversion Mitigation
Task 1.2: Initial Options Screening
DRAFT Rough Order of Magnitude Cost Estimate (Class 5)
Date: 8/5/2014
Detailed Breakdown: IO4 - Gated notches

Line Item #	Line Item	Quantity	Unit	Unit cost	Amount	Notes
1	**Mobilization/Demobilization (15%)**				**$ 3,519,446**	
	Mobilization/Demobilization (15%)	1	LS	$ 3,519,446	$ 3,519,446	Moblization and Demoblization (15% of Direct Construction Cost associated with Items not including Mob/Demob)
2	**Site Preparation**				**$ 7,412**	
	Clear & Grub Staging Area and Access Roads	1.0	acre	$ 7,412	$ 7,412	RSMeans Heavy Construction (2007) - page 205 (1.148 Location Factor)
3	**Construct notches (1)**				**$ 4,286,244**	
	Remove fish traps and control house	1	LS	$ 71,467.20	$ 71,467	Price escalated from USACE September 2004
	Dewater reservoir	500	ac-ft	$ 350.99	$ 175,495	Assumed remaining reservoir storage; Price from USACE + allowance of $50,000 for sump pumping
	Fish rescue and relocation	1	LS	$ 141,800.00	$ 141,800	Price escalated from USACE September 2004
	Diversion system	1	LS	$ 240,000	$ 240,000	Allowance (assumes 400-foot-long 36-inch HDPE with a dam penetration)
	Excavate sediment	1,600	cy	$ 9.00	$ 14,400	Cost based on crew/equipment/material buildup
	Wire saw concrete	2,970	sf	$ 140.00	$ 415,800	Cost from Searsville estimate
	Drill & blast	5,900	cy	$ 45.00	$ 265,500	Intact volume, Cost based on crew/equipment/material buildup
	Process for hauling	5,900	cy	$ 56.00	$ 330,400	Intact volume, Cost based on crew/equipment/material buildup
	Haul to recycling plant	5,900	cy	$ 60.00	$ 354,000	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	8,850	cy	$ 30.41	$ 269,129	Rubble volume, Searsville price
	Purchase gates	2,400	sf	$ 800.00	$ 1,920,000	Cost from Searsville estimate, qty 2x 80ftx15ft
	Structural concrete for gates	100	cy	$ 1,200.00	$ 120,000	
	Install gates	120	hr	$ 331.00	$ 39,720	Cost from Searsville estimate
4	**Construct notches (2)**				**$ 1,907,625**	
	Dewater reservoir	1	LS	$ 50,000.00	$ 50,000	Allowance for sump pumping of area excavated into sediment
	Diversion system	1	LS	$ 240,000	$ 240,000	Assumed 400-foot-long 36-inch HDPE with a dam penetration
	Excavate sediment	19,800	cy	$ 9.00	$ 178,200	Cost based on crew/equipment/material buildup
	Access roads for fine sediment excavation	600	lf	$ 40.00	$ 24,000	Est. 300 lineal feet of 40-foot-wide 2-foot-thick access roads at 2 levels within fine sediment ex.
	Remove gates	60	hr	$ 331.00	$ 19,860	Half duration of installation
	Wire saw concrete	4,400	sf	$ 140.00	$ 616,000	Cost from Searsville estimate
	Drill & blast	3,000	cy	$ 45.00	$ 135,000	Intact volume, Cost based on crew/equipment/material buildup
	Process for hauling	3,000	cy	$ 56.00	$ 168,000	Intact volume, Cost based on crew/equipment/material buildup
	Haul to recycling plant	3,000	cy	$ 60.00	$ 180,000	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	4,500	cy	$ 30.41	$ 136,845	Rubble volume, Searsville price
	Structural concrete for gates	100	cy	$ 1,200.00	$ 120,000	
	Install gates	120	hr	$ 331.00	$ 39,720	Cost from Searsville estimate
5	**Construct notches (3)**				**$ 4,239,210**	
	Dewater reservoir	1	LS	$ 50,000.00	$ 50,000	Allowance for sump pumping of area excavated into sediment
	Diversion system	1	LS	$ 240,000	$ 240,000	Assumed 400-foot-long 36-inch HDPE with a dam penetration
	Excavate sediment	18,450	cy	$ 9.00	$ 166,050	Cost based on crew/equipment/material buildup
	Access roads for fine sediment excavation	600	lf	$ 40.00	$ 24,000	Est. 300 lineal feet of 40-foot-wide 2-foot-thick access roads at 2 levels within fine sediment ex.
	Remove gates	60	hr	$ 331.00	$ 19,860	Half duration of installation
	Wire saw concrete	5,940	sf	$ 140.00	$ 831,600	Cost from Searsville estimate
	Drill & blast	13,300	cy	$ 45.00	$ 598,500	Intact volume, Cost based on crew/equipment/material buildup
	Process for hauling	13,300	cy	$ 56.00	$ 744,800	Intact volume, Cost based on crew/equipment/material buildup
	Haul to recycling plant	13,300	cy	$ 60.00	$ 798,000	Intact volume, Cost based on crew/equipment/material buildup

TABLE B-4

	Recycle concrete	19,950	cy	$ 30.41	$ 606,680	Rubble volume, Searsville price
	Structural concrete for gates	100	cy	$ 1,200.00	$ 120,000	
	Install gates	120	hr	$ 331.00	$ 39,720	Cost from Searsville estimate
6	**Construct notches (4)**				**$ 4,695,482**	
	Dewater reservoir	1	LS	$ 50,000.00	$ 50,000	Allowance for sump pumping of area excavated into sediment
	Diversion system	1	LS	$ 240,000	$ 240,000	Assumed 400-foot-long 36-inch HDPE with a dam penetration
	Excavate sediment	17,600	cy	$ 9.00	$ 158,400	Cost based on crew/equipment/material buildup
	Access roads for fine sediment excavation	600	lf	$ 40.00	$ 24,000	Est. 300 lineal feet of 40-foot-wide 2-foot-thick access roads at 2 levels within fine sediment ex.
	Remove gates	60	hr	$ 331.00	$ 19,860	Half duration of installation
	Wire saw concrete	7,040	sf	$ 140.00	$ 985,600	Cost from Searsville estimate
	Drill & blast	14,800	cy	$ 45.00	$ 666,000	Intact volume, Cost based on crew/equipment/material buildup
	Process for hauling	14,800	cy	$ 56.00	$ 828,800	Intact volume, Cost based on crew/equipment/material buildup
	Haul to recycling plant	14,800	cy	$ 60.00	$ 888,000	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	22,200	cy	$ 30.41	$ 675,102	Rubble volume, Searsville price
	Structural concrete for gates	100	cy	$ 1,200.00	$ 120,000	
	Install gates	120	hr	$ 331.00	$ 39,720	Cost from Searsville estimate
7	**Remove remainder**				**$ 2,912,470**	
	Remove gates	60	hr	$ 331.00	$ 19,860	Half duration of installation
	Drill & blast	14,000	cy	$ 45.00	$ 630,000	Intact volume, Cost based on crew/equipment/material buildup
	Process for hauling	14,000	cy	$ 56.00	$ 784,000	Intact volume, Cost based on crew/equipment/material buildup
	Haul to recycling plant	14,000	cy	$ 60.00	$ 840,000	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	21,000	cy	$ 30.41	$ 638,610	Rubble volume, Searsville price
8	**Site Restoration**				**$ -**	
	Site Restoration	-	acre	$ -	$ -	Assumed not required for naturally formed slopes in reservoir area
	Subtotal				**$ 21,567,889**	
	Design & Unit Cost Contingency (30%)				$ 6,470,367	
	Total Direct Construction Cost				$ 28,038,255	
	Construction Contingency (15%)				$ 4,205,738	
	Total Construction Cost				**$ 32,243,994**	
	Low Side of Class 5 Estimate Range (-30%)				**$ 22,570,796**	
	High Side of Class 5 Estimate Range (+50%)				**$ 48,365,990**	

TABLE B-5

Project: Matilija Dam Removal, Sediment Transport, & Robles Diversion Mitigation
Task 1.2: Initial Options Screening
DRAFT Rough Order of Magnitude Cost Estimate (Class 5)
Date: 8/5/2014
Detailed Breakdown: IO5 - Remove sediment for structure removal, temporary US storage of sediment

Line Item #	Line Item	Quantity	Unit	Unit cost	Amount	Notes
1	**Mobilization/Demobilization (15%)**				**$ 8,235,071**	
	Mobilization/Demobilization (15%)	1	LS	$ 8,235,071	$ 8,235,071	Moblization and Demoblization (15% of Direct Construction Cost associated with Items not including Mob/Demob)
2	**Site Preparation**				**$ 1,034,808**	
	Clear & Grub Staging Area and Access Roads	1.0	acre	$ 5,388	$ 5,388	Price escalated from USACE September 2004
	Clear & grub upstream stockpile areas	50.0	acre	$ 5,388	$ 269,420	Price escalated from USACE September 2004
	Diversion system	1	LS	$ 760,000	$ 760,000	Allownace (assumes 6,500-foot-long 48-inch HDPE with a dam penetration)
3	**Dewatering**				**$ 2,125,493**	
	Dewater reservoir	500	ac-ft	$ 250.99	$ 125,493	Price escalated from USACE September 2004
	Dewater sediment	1	LS	$ 2,000,000.00	$ 2,000,000	Allowance
4	**Excavate channel**				**$ 29,200,000**	
	Excavate and stockpile fine sediment	3,000,000	cy	$ 9.00	$ 27,000,000	Cost based on crew/equipment/material buildup
	Access roads for fine sediment excavation	10,000	lf	$ 40.00	$ 400,000	Est. 2,000 lineal feet of 40-foot-wide 2-foot-thick access roads at 5 levels for fine sediment ex.
	Excavate and stockpile coarse sediment	600,000	cy	$ 3.00	$ 1,800,000	Cost based on crew/equipment/material buildup
	Erosion protection for channel	-	cy	$ -	$ -	
5	**Remove dam**				**$ 9,690,832**	
	Remove fish traps and control house	1	LS	$ 71,467.20	$ 71,467	Price escalated from USACE September 2004
	Drill & blast	51,000	cy	$ 27.00	$ 1,377,000	Intact volume, Cost based on crew/equipment/material buildup
	Process for hauling	51,000	cy	$ 56.00	$ 2,856,000	Intact volume, Cost based on crew/equipment/material buildup
	Haul to recycling plant	51,000	cy	$ 60.00	$ 3,060,000	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	76,500	cy	$ 30.41	$ 2,326,365	Rubble volume, Searsville price
6	**Site Restoration**				**$ 180,000**	
	Site Restoration of upstream stockpiles areas	50	acre	$ 3,600.00	$ 180,000	Historic unit rate; assumes placed in fall/winter without irrigation.
	Subtotal				**$ 50,466,205**	
	Design & Unit Cost Contingency (30%)				$ 15,139,861	
	Total Direct Construction Cost				$ 65,606,066	
	Construction Contingency (15%)				$ 9,840,910	
	Total Construction Cost				**$ 75,446,976**	
	Low Side of Class 5 Estimate Range (-30%)				**$ 52,812,883**	
	High Side of Class 5 Estimate Range (+50%)				**$ 113,170,464**	

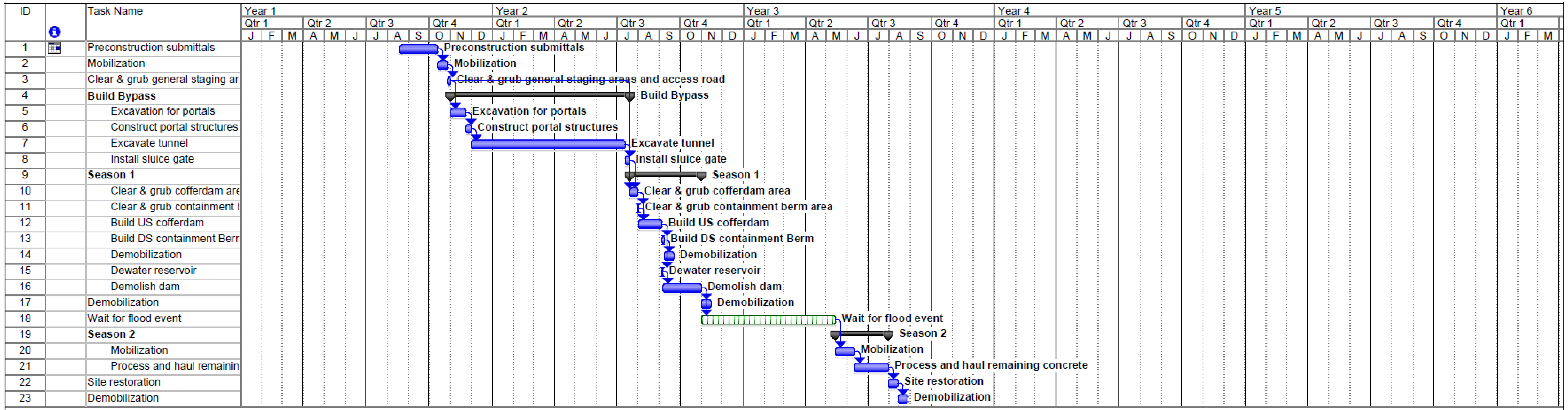
TABLE B-6

Project: Matilija Dam Removal, Sediment Transport, & Robles Diversion Mitigation
Task 1.2: Initial Options Screening
DRAFT Rough Order of Magnitude Cost Estimate (Class 5)
Date: 8/5/2014
Detailed Breakdown: IO6 - Phased notching w/ DS slurry and US storage

Line Item #	Line Item	Quantity	Unit	Unit cost	Amount	Notes
1	**Mobilization/Demobilization (15%)**				**$ 8,177,057**	
	Mobilization/Demobilization (15%)	1	LS	$ 8,177,057	$ 8,177,057	Moblization and Demoblization (15% of Direct Construction Cost associated with Items not including Mob/Demob)
2	**Site Preparation**				**$ 1,186,244**	
	Clear & Grub Staging Area and Access Roads	1.0	acre	$ 5,388	$ 5,388	Price escalated from USACE September 2004
	Clear & grub BRDA 1	50.0	acre	$ 5,388	$ 269,420	Price escalated from USACE September 2004
	Clear & grub BRDA 2	25.0	acre	$ 5,388	$ 134,710	Price escalated from USACE September 2004
	Pipeline ROW	19.5	acre	$ 5,388	$ 105,074	Price escalated from USACE September 2004
	Clear & grub US storage areas	30.0	acre	$ 5,388	$ 161,652	Price escalated from USACE September 2004
	Diversion system	1	LS	$ 510,000	$ 510,000	Allownace (Assumes 3,000-foot-long 48-inch HDPE with a dam penetration)
3	**Build starter dikes**				**$ 448,259**	
	BRDA1	34,235	cy	$ 10.00	$ 342,352	Built-up labor and equipment cost for IO-1 cofferdam
	BRDA2	10,591	cy	$ 10.00	$ 105,907	Built-up labor and equipment cost for IO-1 cofferdam
4	**Slurry Dredging**				**$ 24,577,851**	
	Pipelines to BRDA	1	LS	$ 8,812,100.00	$ 8,812,100	Price from USACE, see Qty calc sheet
	To BRDA	1,000,000	cy	$ 4.25	$ 4,254,000	Price from USACE
	To US storage areas	400,000	cy	$ 4.25	$ 1,701,600	Price from USACE
	Thickener at BRDA	1,000,000	cy	$ 2.73	$ 2,730,422	Price from USACE, per volume of in-place sediment
	Pump paste to disposal areas	1,000,000	cy	$ 0.76	$ 759,728	Price from USACE, per volume of in-place sediment
	Rapid dewatering at US storage area	400,000	cy	$ 9.00	$ 3,600,000	Price from Genesis, per volume of in-place sediment
	Placement and compaction of dewatered sediment at US storage	340,000	cy	$ 8.00	$ 2,720,000	Cost based on crew/equipment/material buildup from IO1 cofferdam, vol. is dewatered sediment
5	**Excavate channel**				**$ 5,400,000**	
	Excavate and stockpile delta area sediment	600,000	cy	$ 9.00	$ 5,400,000	Price from USACE
6	**Excavate tunnel through dam**				**$ 545,074**	
	Build access for mid-level orifice	1	ea	$ 100,000.00	$ 100,000	Assumed
	Drill & break out concrete for gated orifice	120	cy	$ 2,770.00	$ 332,400	Price from Searsville
	Haul to recycling plant	120	cy	$ 60.00	$ 7,200	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	180	cy	$ 30.41	$ 5,474	Rubble volume, Searsville price
	Purchase and install 6-foot-diameter sluice gates	1	ea	$ 100,000.00	$ 100,000	Ratio of price for 12-foot-diameter gates based on area of gate
7	**Remove dam**				**$ 9,668,198**	
	Remove fish traps and control house	1	LS	$ 71,467.20	$ 71,467	Price escalated from USACE September 2004
	Drill & blast	50,880	cy	$ 27.00	$ 1,373,760	Intact volume, Cost based on crew/equipment/material buildup
	Process for hauling	50,880	cy	$ 56.00	$ 2,849,280	Intact volume, Cost based on crew/equipment/material buildup
	Haul to recycling plant	50,880	cy	$ 60.00	$ 3,052,800	Intact volume, Cost based on crew/equipment/material buildup
	Recycle concrete	76,320	cy	$ 30.41	$ 2,320,891	Rubble volume, Searsville price
8	**Site Restoration**				**$ 108,000**	
	Site Restoration of upstream stockpiles areas	30	acre	$ 3,600.00	$ 108,000	Historic unit rate; assumes placed in fall/winter without irrigation.
	Subtotal				**$ 50,110,684**	

TABLE B-6

	Design & Unit Cost Contingency (30%)				$ 15,033,205	
	Total Direct Construction Cost				$ 65,143,889	
	Construction Contingency (15%)				$ 9,771,583	
	Total Construction Cost				**$ 74,915,472**	
	Low Side of Class 5 Estimate Range (-30%)				**$ 52,440,830**	
	High Side of Class 5 Estimate Range (+50%)				**$ 112,373,208**	



ID	ℹ	Task Name
1	▦	Preconstruction submittals
2		Mobilization
3		Clear & grub general staging ar
4		**Build Bypass**
5		Excavation for portals
6		Construct portal structures
7		Excavate tunnel
8		Install sluice gate
9		**Season 1**
10		Clear & grub cofferdam are
11		Clear & grub containment I
12		Build US cofferdam
13		Build DS containment Berr
14		Demobilization
15		Dewater reservoir
16		Demolish dam
17		Demobilization
18		Wait for flood event
19		**Season 2**
20		Mobilization
21		Process and haul remainin
22		Site restoration
23		Demobilization

Project: IO1 Berm w. bypass
Date: Tue 8/5/14

Task	▬	Split	┈	Milestone	◆	Project Summary	▬	External Milestone	◆
Unknown duration	▨	Progress	▬	Summary	▬	External Tasks	▬	Deadline	⇩

Project No.
26818945

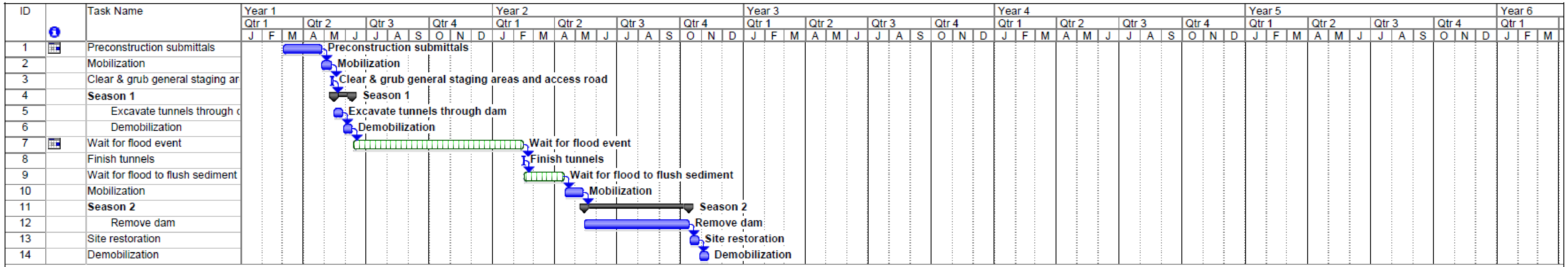
Matilija Dam Removal

URS

Estimated Construction Schedule
IO1 – Containment Berm with High Flow Bypass

Figure

B-1



ID	Task Name
1	Preconstruction submittals
2	Mobilization
3	Clear & grub general staging ar
4	**Season 1**
5	Excavate tunnels through d
6	Demobilization
7	Wait for flood event
8	Finish tunnels
9	Wait for flood to flush sediment
10	Mobilization
11	**Season 2**
12	Remove dam
13	Site restoration
14	Demobilization

Project: IO2 Uncontrolled orifices
Date: Tue 8/5/14

Task	▬	Split	┈	Milestone	◆	Project Summary	▬	External Milestone	◆
Unknown duration	▨	Progress	▬	Summary	▬	External Tasks	▬	Deadline	⇩

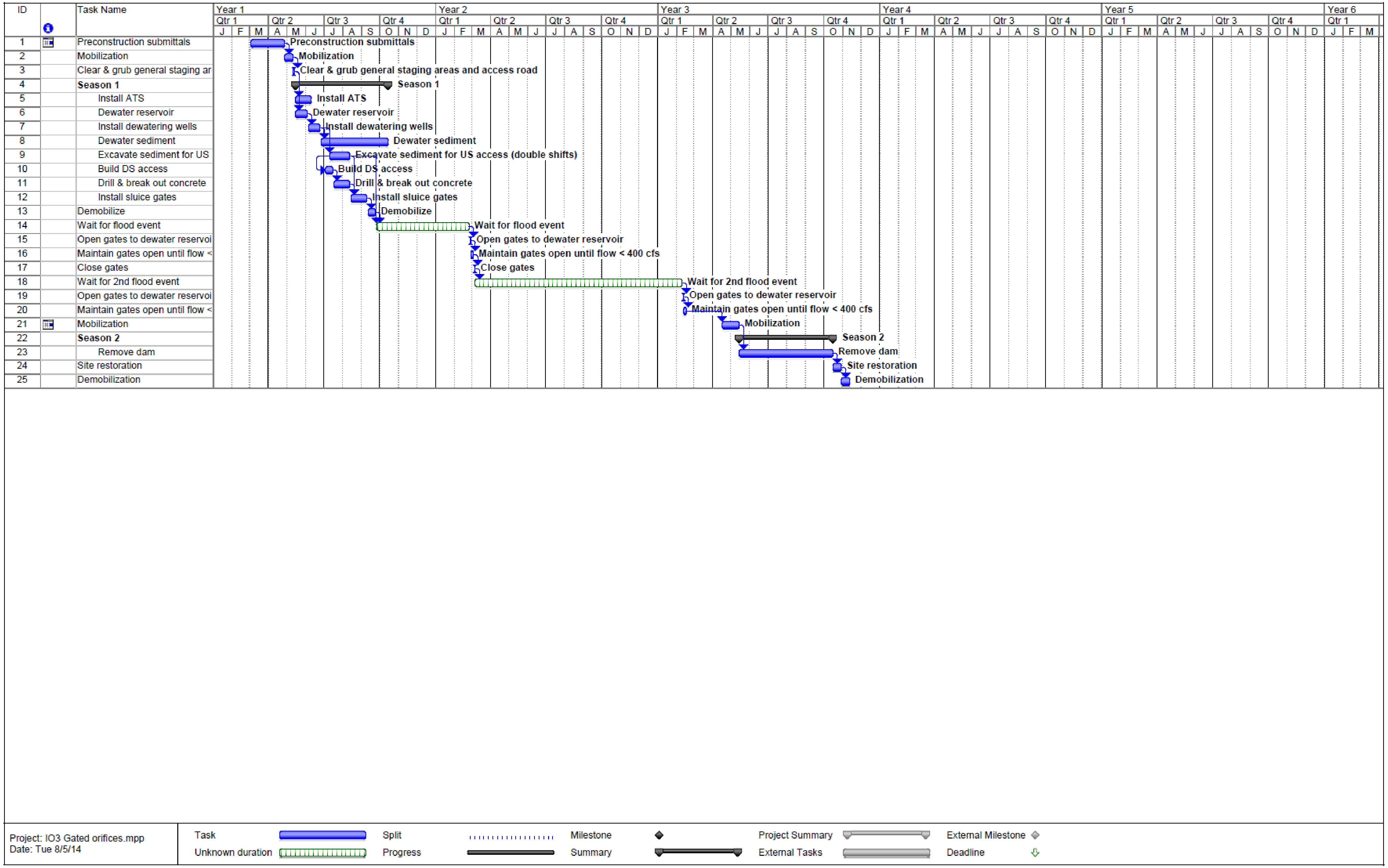
Project No.
26818945

Matilija Dam Removal

URS

Estimated Construction Schedule
IO2 – Uncontrolled Orifices

Figure
B-2

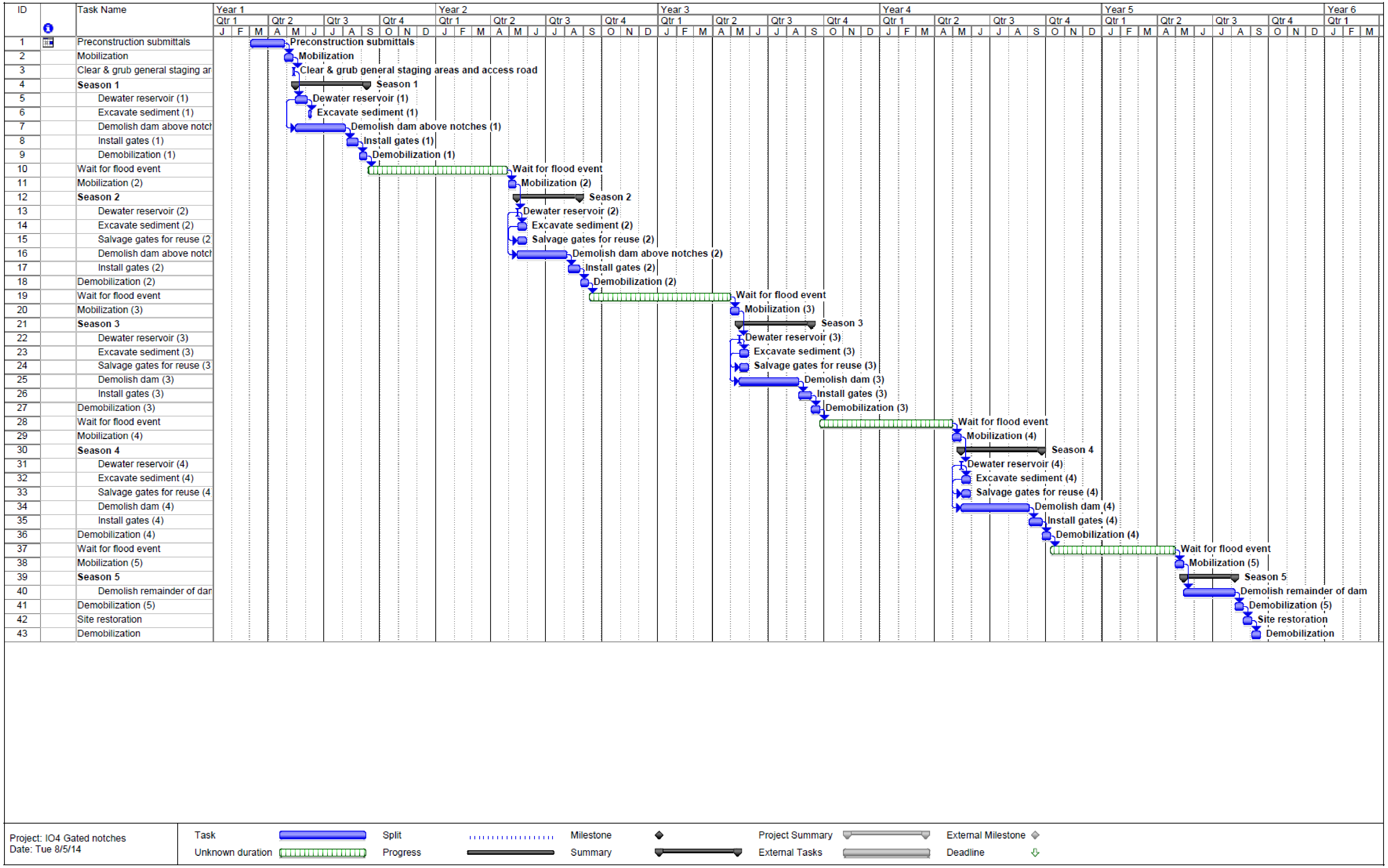


ID		Task Name
1		Preconstruction submittals
2		Mobilization
3		Clear & grub general staging ar
4		**Season 1**
5		Install ATS
6		Dewater reservoir
7		Install dewatering wells
8		Dewater sediment
9		Excavate sediment for US
10		Build DS access
11		Drill & break out concrete
12		Install sluice gates
13		Demobilize
14		Wait for flood event
15		Open gates to dewater reservoi
16		Maintain gates open until flow <
17		Close gates
18		Wait for 2nd flood event
19		Open gates to dewater reservoi
20		Maintain gates open until flow <
21		Mobilization
22		**Season 2**
23		Remove dam
24		Site restoration
25		Demobilization

Project: IO3 Gated orifices.mpp
Date: Tue 8/5/14

Project No. 26818945	Matilija Dam Removal	Estimated Construction Schedule IO3 – Gated Orifices	Figure B-3

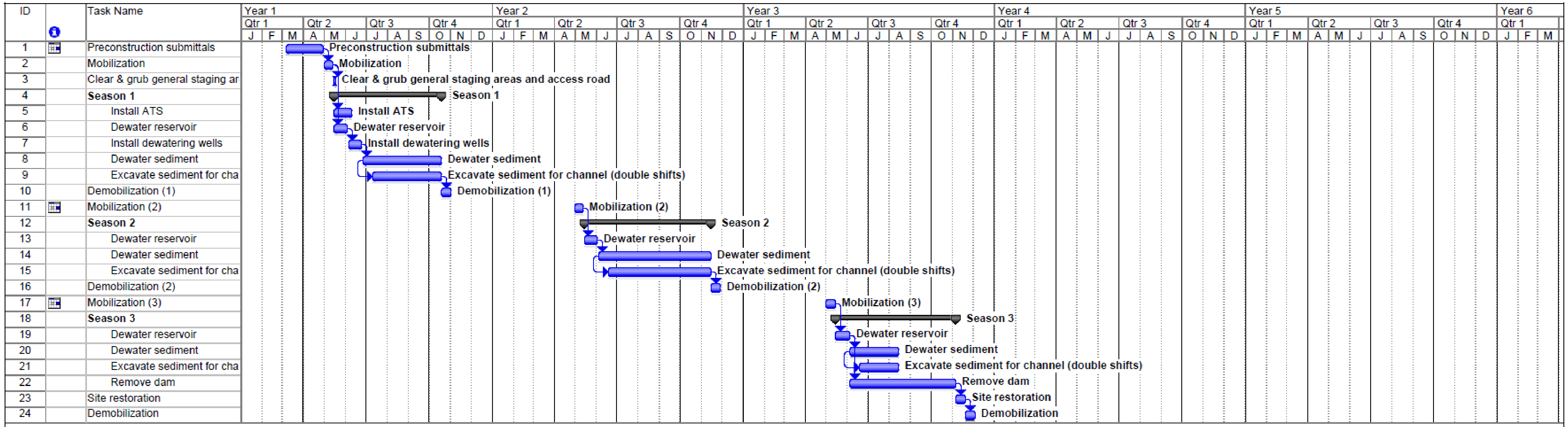
URS



ID	Task Name
1	Preconstruction submittals
2	Mobilization
3	Clear & grub general staging ar
4	**Season 1**
5	Dewater reservoir (1)
6	Excavate sediment (1)
7	Demolish dam above notcl
8	Install gates (1)
9	Demobilization (1)
10	Wait for flood event
11	Mobilization (2)
12	**Season 2**
13	Dewater reservoir (2)
14	Excavate sediment (2)
15	Salvage gates for reuse (2
16	Demolish dam above notcl
17	Install gates (2)
18	Demobilization (2)
19	Wait for flood event
20	Mobilization (3)
21	**Season 3**
22	Dewater reservoir (3)
23	Excavate sediment (3)
24	Salvage gates for reuse (3
25	Demolish dam (3)
26	Install gates (3)
27	Demobilization (3)
28	Wait for flood event
29	Mobilization (4)
30	**Season 4**
31	Dewater reservoir (4)
32	Excavate sediment (4)
33	Salvage gates for reuse (4
34	Demolish dam (4)
35	Install gates (4)
36	Demobilization (4)
37	Wait for flood event
38	Mobilization (5)
39	**Season 5**
40	Demolish remainder of dar
41	Demobilization (5)
42	Site restoration
43	Demobilization

Project: IO4 Gated notches
Date: Tue 8/5/14

Project No. 26818945	Matilija Dam Removal	Estimated Construction Schedule IO4 – Gated Notches
	URS	Figure B-4



ID	Task Name
1	Preconstruction submittals
2	Mobilization
3	Clear & grub general staging ar
4	**Season 1**
5	Install ATS
6	Dewater reservoir
7	Install dewatering wells
8	Dewater sediment
9	Excavate sediment for cha
10	Demobilization (1)
11	Mobilization (2)
12	**Season 2**
13	Dewater reservoir
14	Dewater sediment
15	Excavate sediment for cha
16	Demobilization (2)
17	Mobilization (3)
18	**Season 3**
19	Dewater reservoir
20	Dewater sediment
21	Excavate sediment for cha
22	Remove dam
23	Site restoration
24	Demobilization

Project: IO5 Temp US storage
Date: Tue 8/5/14

Task		Split		Milestone	◆	Project Summary		External Milestone	◇
Unknown duration		Progress		Summary		External Tasks		Deadline	⇩

Project No.
26818945

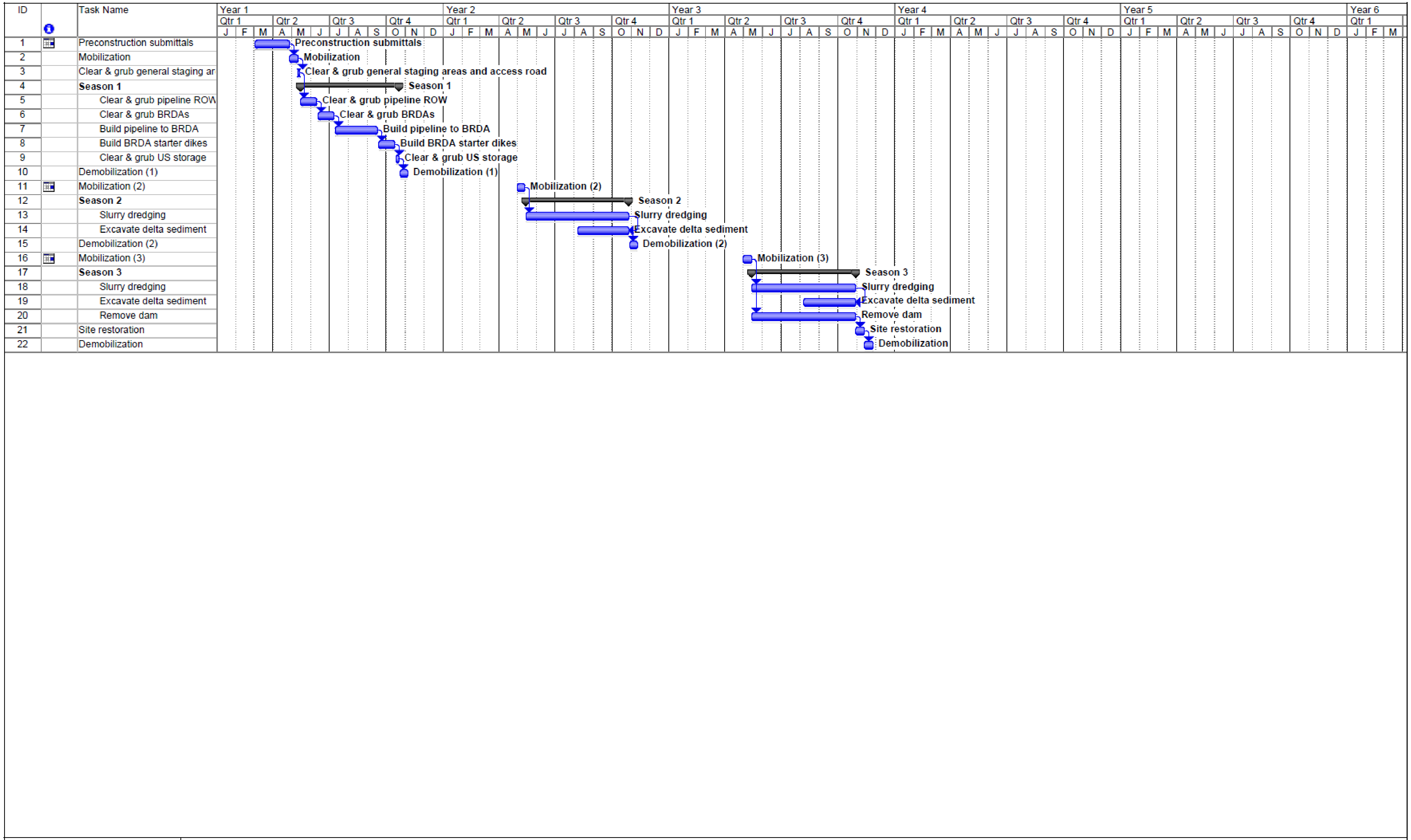
Matilija Dam Removal

URS

Estimated Construction Schedule
IO5 – Temporary Upstream Storage of Fine Sediment

Figure

B-5



ID		Task Name
1	▦	Preconstruction submittals
2		Mobilization
3		Clear & grub general staging ar
4		**Season 1**
5		Clear & grub pipeline ROW
6		Clear & grub BRDAs
7		Build pipeline to BRDA
8		Build BRDA starter dikes
9		Clear & grub US storage
10		Demobilization (1)
11	▦	Mobilization (2)
12		**Season 2**
13		Slurry dredging
14		Excavate delta sediment
15		Demobilization (2)
16	▦	Mobilization (3)
17		**Season 3**
18		Slurry dredging
19		Excavate delta sediment
20		Remove dam
21		Site restoration
22		Demobilization

Project: IO6 Slurry and temp storage
Date: Tue 8/5/14

Task	▬	Split	┈┈┈	Milestone	◆	Project Summary	▬	External Milestone	◇
Unknown duration	▭	Progress	━	Summary	▬	External Tasks	▬	Deadline	⇩

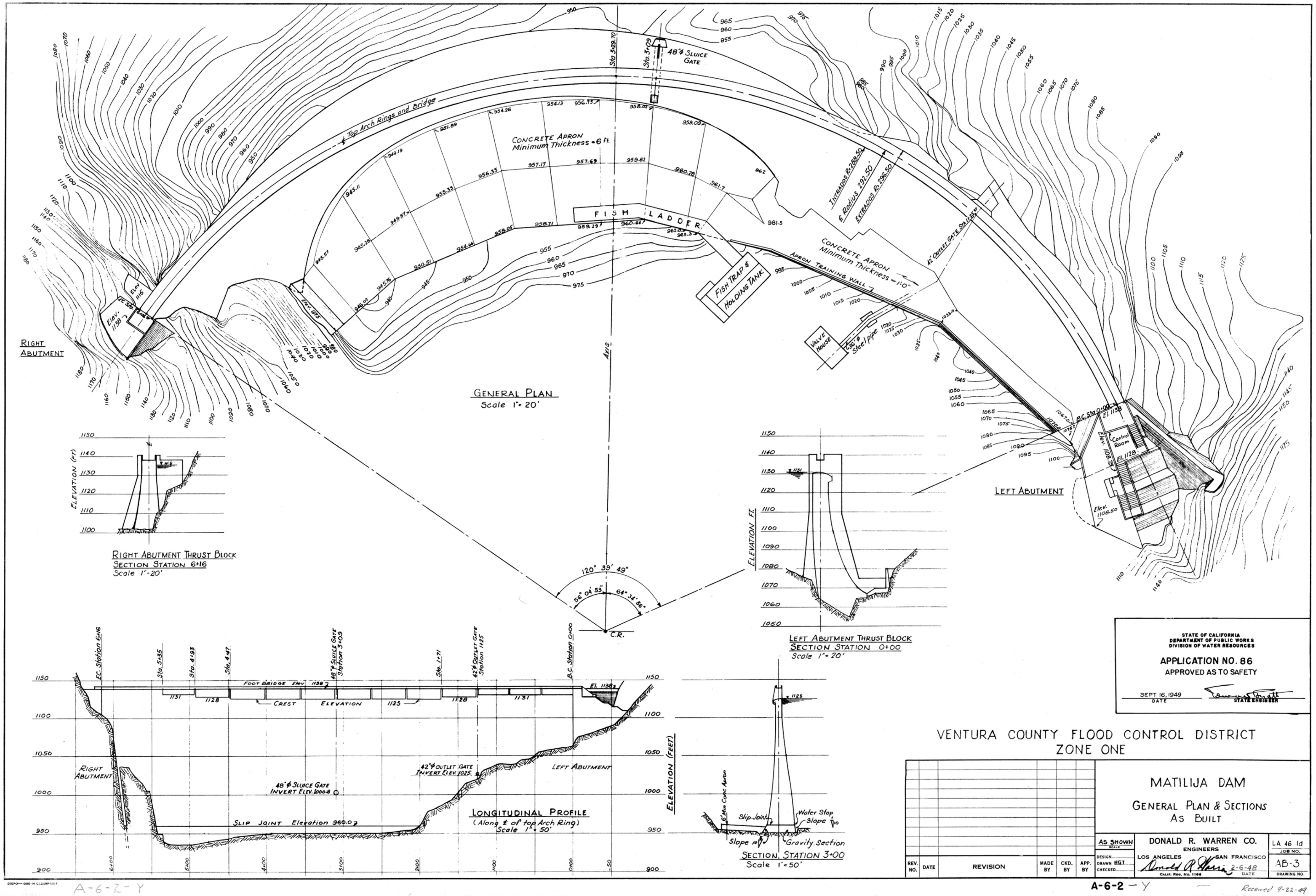
Project No. 26818945	Matilija Dam Removal	Estimated Construction Schedule IO6 – Downstream Slurry and Temporary Upstream Storage of Fine Sediment	Figure B-6
URS			

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

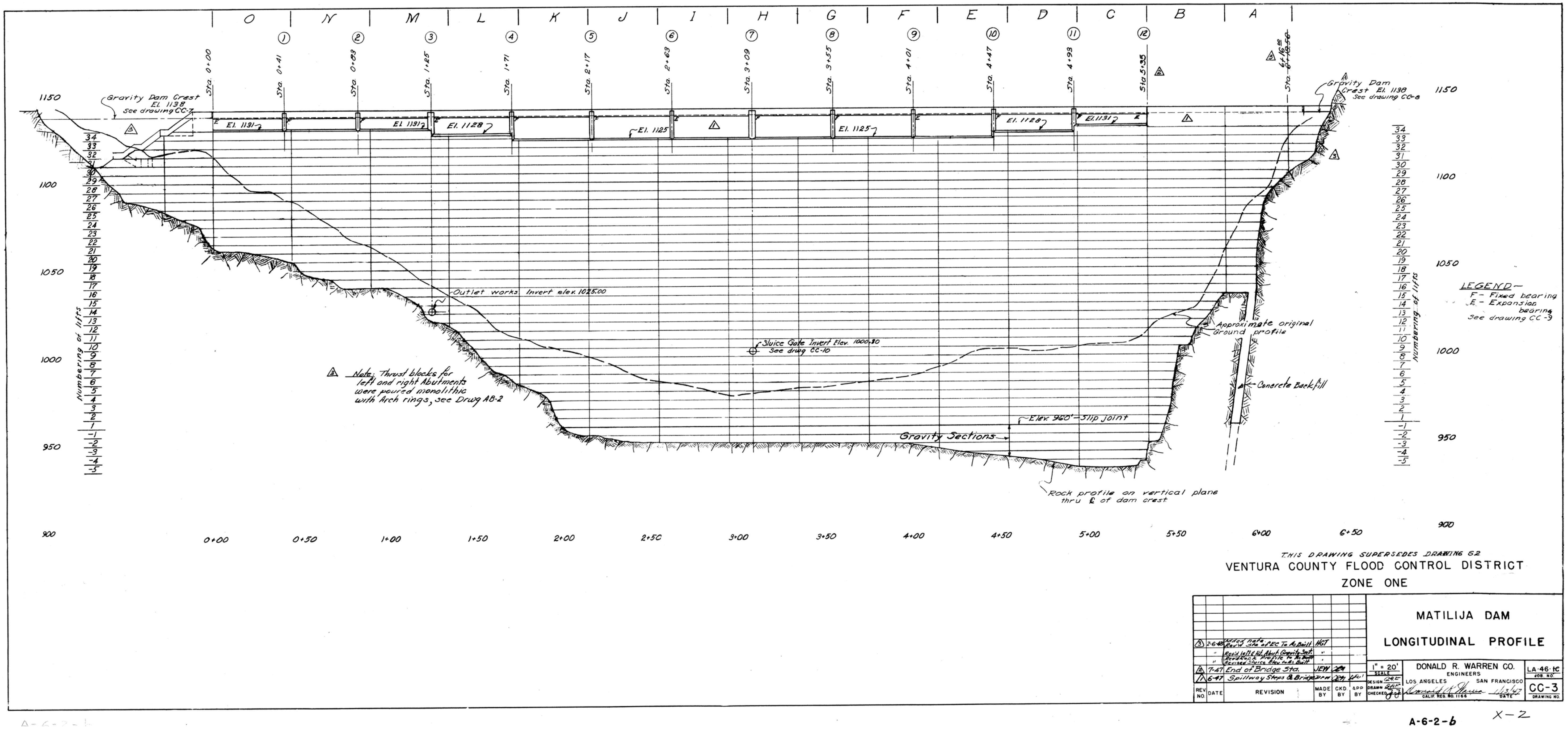
INITIAL OPTIONS SCREENING REPORT

APPENDIX C: MATILIJA DAM AS-BUILT INFORMATION

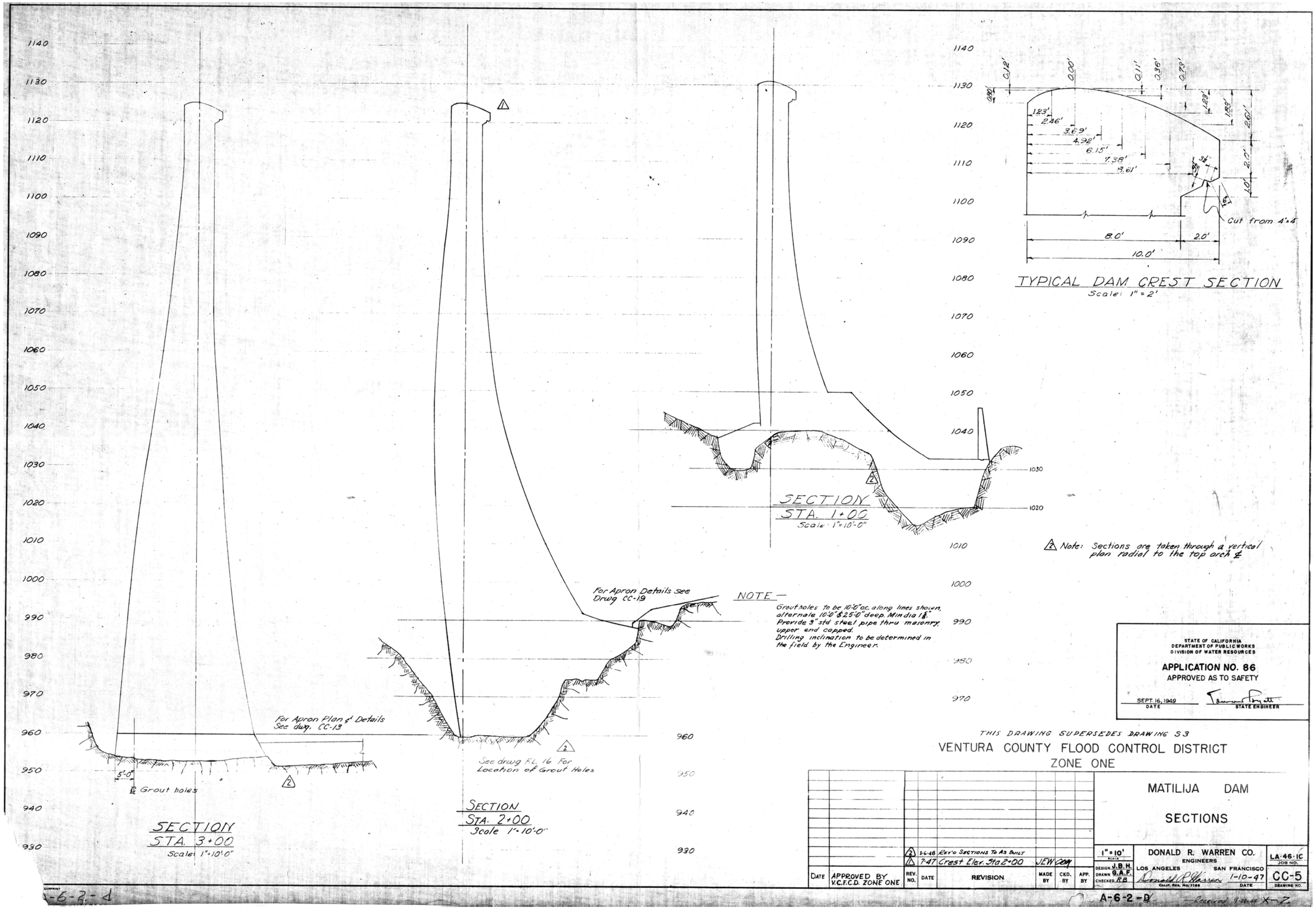
SEPTEMBER 9, 2014



Project No. 26818945	Matilija Dam Removal	Original Plan and Sections (1948, prior to notching)	Figure C-1
	URS		



Project No. 26818945	Matilija Dam Removal	Original Longitudinal Profile (1948, prior to notching)	Figure C-2
URS			



NOTE —
Grout holes to be 10'-0" o.c. along lines shown, alternate 10'-0" & 25'-0" deep. Min dia 1⅝".
Provide 3" std steel pipe thru masonry, upper end capped.
Drilling inclination to be determined in the field by the Engineer.

Note: Sections are taken through a vertical plan radial to the top arch ℄

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
APPLICATION NO. 86
APPROVED AS TO SAFETY
SEPT. 16, 1949 DATE
STATE ENGINEER

THIS DRAWING SUPERSEDES DRAWING S3

VENTURA COUNTY FLOOD CONTROL DISTRICT
ZONE ONE

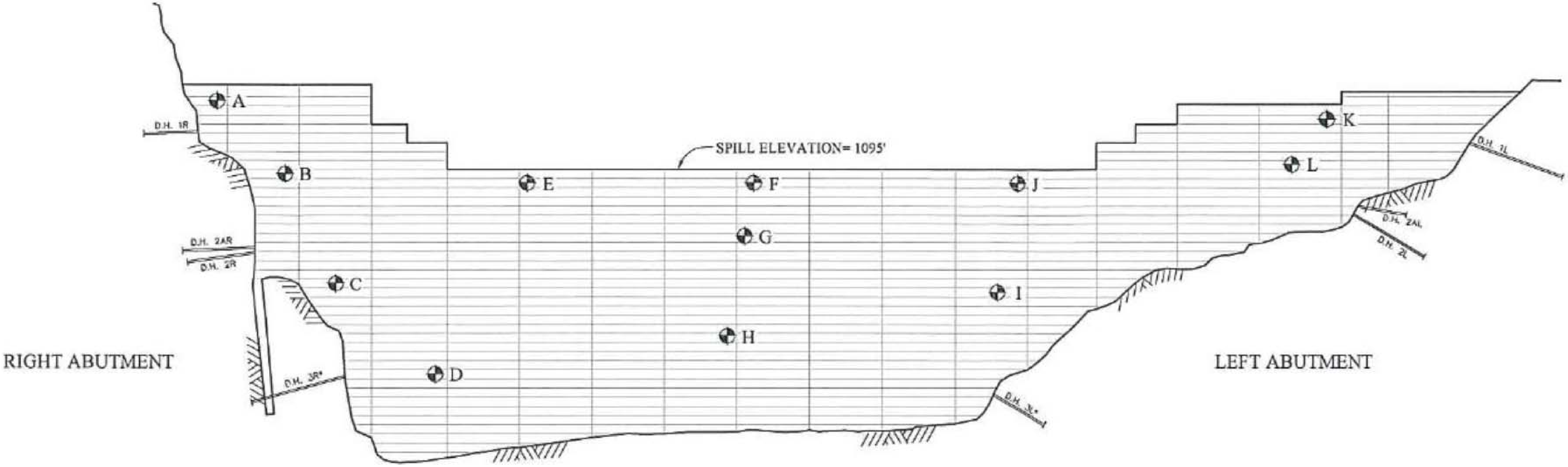
MATILIJA DAM
SECTIONS

DATE	APPROVED BY V.C.F.C.D. ZONE ONE	REV. NO.	DATE	REVISION	MADE BY	CKD. BY	APP. BY
		2	2-6-48	Rev'd Sections To As Built			
		1	7-47	Crest Elev. Sta 2+00	JEW		

SCALE 1" = 10'
DESIGN J.B.H.
DRAWN G.A.F.
CHECKED RB
DONALD R. WARREN CO.
ENGINEERS
LOS ANGELES SAN FRANCISCO
Donald R Warren
CALIF. REG. No. 1166
DATE 1-10-47
JOB NO. LA-46-IC
DRAWING NO. CC-5

A-6-2-D — Received 9-22-49 X-Z

Project No. 26818945	Matilija Dam Removal	Crown Cantilever Sections (1948, prior to notching)	Figure C-3
	URS		



* NOW ABANDONED

FACE ELEVATION

LOCATIONS OF TRIANGULATION TARGETS
AND STRAIN GAGE DRILL HOLES
NO SCALE

Source: Ventura County Flood Control District, Matilija Dam Horizontal Deformation, August 1991 Through September 2001, Sheet 1 of 5

Project No.
26818945

Matilija Dam Removal

URS

Currentl Elevation of Notched Crest and Downstream Face

Figure

C-4

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

DAM REMOVAL CONCEPTS EVALUATION REPORT

MARCH 2016

ATTACHMENT 4: HYDROLOGIC ASSESSMENT FOR WATER SUPPLY

URS Stillwater Sciences

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

HYDROLOGIC ASSESSMENT FOR WATER SUPPLY
SEPTEMBER 10, 2014

TABLE OF CONTENTS

1.0 PURPOSE & INTRODUCTION

The purpose of this memorandum is to evaluate hydrologic conditions of the Ventura River watershed for water supply, and to summarize our understanding of water supply and demand associated with Casitas Municipal Water District (CMWD), Lake Casitas, and the Robles diversion. The discussion is divided into two primary sections:

- A summary of our understanding of water supply and demand based on historical diversion and stream gage data
- An evaluation of alternative supply scenarios in an attempt to clarify the relative significance of the Robles diversion (compared to other sources to Lake Casitas Reservoir). Subsequently, an assessment of the impacts associated with scenarios that would limit the ability to divert at Robles Diversion Dam.

2.0 HISTORICAL WATER SUPPLY TO LAKE CASITAS

2.1 BACKGROUND

The CMWD supplies water to approximately 70,000 customers in Western Ventura County and to approximately 5,200 acres of agriculture land that are primarily composed of tree crops (citrus and avocado). The CMWD boundaries encompass the city of Ojai, Upper Ojai, the Ventura River Valley area, the city of Ventura to Mills Road, and the Rincon and beach area to the ocean and Santa Barbara County line (the Casitas Service District).

The CMWD was formed in 1952, and the Ventura River project was authorized by Congress in 1956. The project included the Robles diversion facility on the Ventura River, the Robles Canal, and Casitas Dam. Construction of Casitas Dam was completed in November 1958, and the reservoir spilled for the first time in 1978. Lake Casitas Reservoir has a capacity of approximately 254,000 acre-feet.

Robles Diversion Dam is located on the Ventura River near Ventura, California at approximately river mile (RM) 14.2, and supplies water to Lake Casitas via a canal (Figure 1). The normal maximum diversion is approximately 500 cubic feet per second (cfs). The existing diversion dam is a low rock weir with a gated spillway (Figure 2), canal diversion headworks and a fish passage facility located on the right abutment. The diversion weir has a hydraulic height of 13 feet.

The fish passage facility was adapted to the existing Robles Diversion Dam structures to provide the dual purposes of water diversions to Lake Casitas and to provide a migration corridor for steelhead trout (CMWD 2005).

Since water year 1960, Robles Diversion Dam has diverted water via the Robles-Casitas Canal to Lake Casitas. The canal enters Lake Casitas south of Highway 150 near where Santa Ana Creek enters the reservoir. The canal is concrete lined (typically 3 inches unreinforced). The canal prism is 7 feet wide at the bottom, approximately 27.5 feet wide at the top, has a design water depth of 5.6 feet and a freeboard of 15 inches. The canal is approximately 27,500 feet long with an additional boxed inverted siphon that is approximately 5,400 feet long. The capacity of the canal is 600 cfs. For the majority of its length, an access road parallels the canal and several small bridges provide locations for vehicles to cross over the canal.

Stored water in Lake Casitas is piped via the intake structure and tunnel through Casitas Dam directly into the water treatment facility located just downstream of the dam. The outlet works at the end of the tunnel divert up to 100 cfs to the water treatment plant and allow for emergency drawdown of the reservoir at a rate up to 570 cfs.

Inflows to Lake Casitas are from three sources: 1) diverted water from the Ventura River at Robles diversion, 2) direct capture of water from Coyote Creek, Santa Ana Creek, and other tributary streams, and 3) direct rainfall on the surface of the lake. Therefore, total inflow to the reservoir consists of direct runoff + precipitation + diversion.

Water leaves Lake Casitas through three pathways: 1) delivery of water through the conveyance system to meet local demand, 2) evaporation of water from the lake, and 3) water that goes over the spillway.[1] Therefore, total outflow from the reservoir includes demand + flow over the spillway + evaporation.

Annual water deliveries by the CMWD can vary considerably from year to year, primarily due to the large number of agricultural customers whose water needs can change significantly due to variations in weather and rainfall. Water deliveries can range from less than 15,000 acre-feet per year to greater than 23,000 acre-feet in a given year (CMWD 2014). Over the period from 1976 to 2002, residential water supply sales were relatively steady with a gradual increase from about 800 acre-feet per year to about 1,600 acre-feet per year over the period (CMWD 2004). During the same period, agricultural water sales varied significantly from year to year, inverse to the amount of precipitation, and ranged from about 4,000 acre-feet per year to about 10,600 acre-feet per year (CMWD 2004).

---

[1] Note that discharges to Coyote Creek downstream of the Casitas Dam were recorded for January 1993 through April 1996 and were on the order of 6 acre-feet per month during that period. Thereafter, no discharge to the creek was recorded. Due to the minimal amount of data, this component of water leaving Lake Casitas was ignored for this analysis.

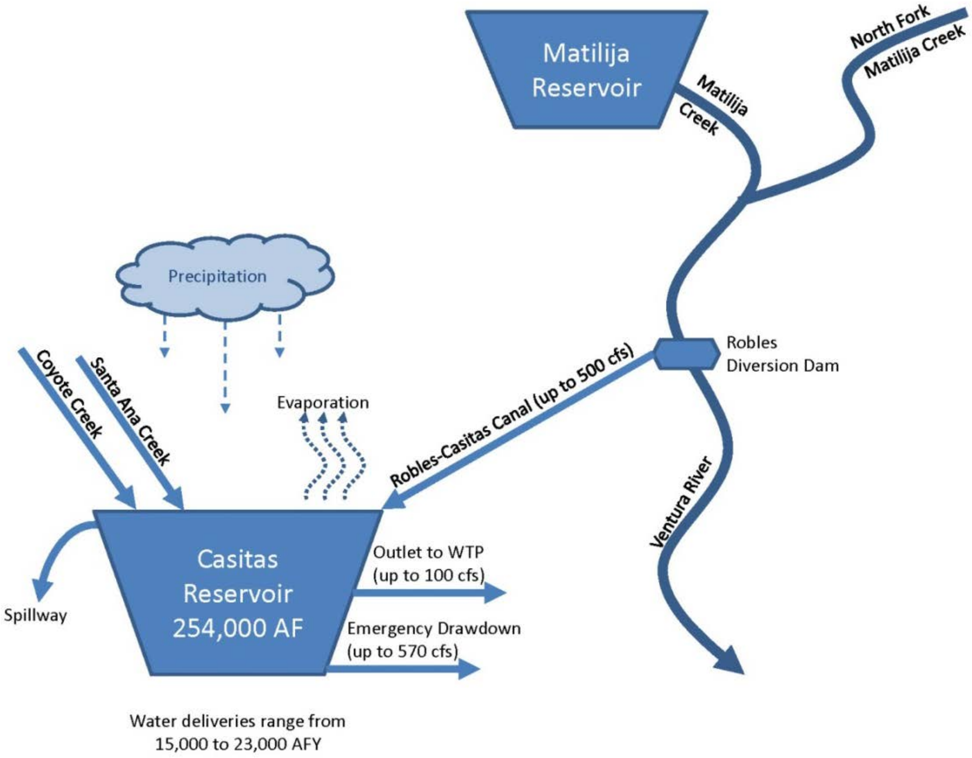


Figure 1: Lake Casitas and Robles Diversion (Location Map and Water Cycle Schematic)

Figure 2: Robles Diversion Dam

2.2 HISTORICAL WATER BALANCE DATA FOR LAKE CASITAS

CMWD provided mass balance spreadsheets that included the following data on a daily and monthly basis from 1993 to 2013:

- Water Elevation in Lake Casitas (feet)
- Storage in Casitas Reservoir (acre-feet)
- Inflow from tributaries entering into the Casitas Reservoir (acre-feet)
- Precipitation at Casitas Reservoir (acre-feet)
- Inflow from diversion at Robles-Casitas Canal (acre-feet)
- Outflow from Casitas Reservoir to Main Distribution System (acre-feet)
- Outflow from Casitas Reservoir through spillway (acre-feet)
- Outflow from Casitas Reservoir to the downstream Coyote Creek channel (acre-feet)
- Evaporation from Casitas Reservoir (acre-feet)

Figure 3 shows the variation of total inflow, total outflow, Robles diversion and reservoir elevation for the period of record from 1993 to 2013, which indicates that demand and inflow are offset in time (demand peaks in the summer and inflow peaks in the winter). Figure 4 shows the demand and evaporation from the Lake Casitas, which shows that demand and evaporation have consistent timing.

As shown in Figure 3, diversions occur during the precipitation season and, during the period of record, have ranged from zero (Water Years[2] 1999, 2002, 2007, and 2013) to greater than 20,000 acre-feet per month (Water Year 1993). The average monthly diversion (when they occur) was about 2,800 acre-feet per month from 1993 to 2013. The minimum reservoir level in the past 20 years was approximately El. 525 feet, which represents approximately 61% of the reservoir capacity. The maximum monthly total demand (releases to the Main Distribution System) is typically between 2,000 and 3,000 acre-feet.

The volume of water available in Lake Casitas to meet the water supply demand is managed under a safe annual yield concept. It is defined as the amount of water that the reservoir can yield for deliveries (consumption) without resulting in unacceptable negative impacts on the long-term water supply within the boundaries of the Casitas Service District. This is to ensure that that the water supply in the reservoir, when full, would extend through a period characterized by the most severe drought on record. The safe annual yield for Lake Casitas is 20,840 acre-ft with the operating criteria in the Robles Diversion Fish Passage Facility Project

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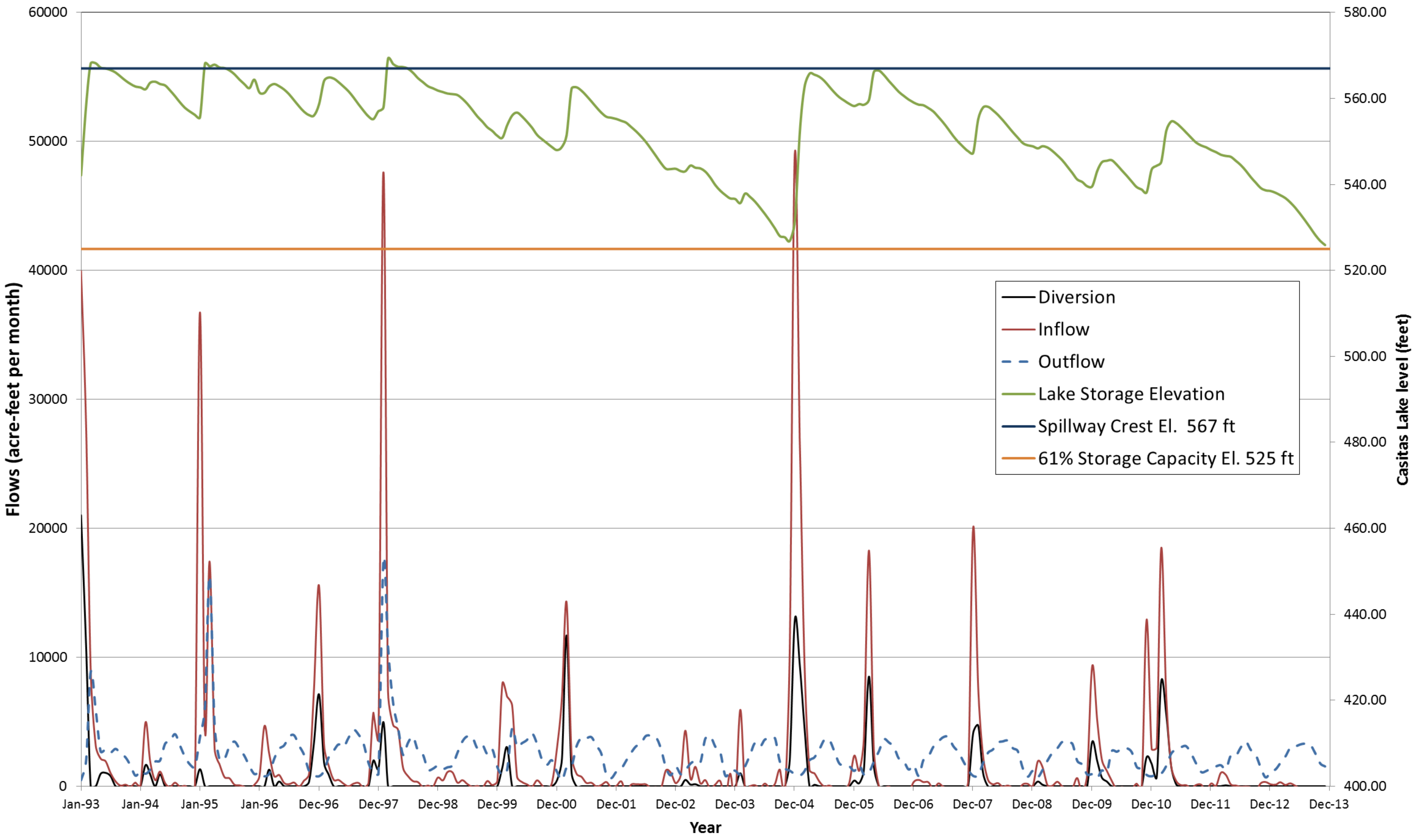
[2] Water Years start on October 1 of the previous year and end on September 30 of the cited year.

Biological Opinion and without Matilija Dam (CMWD 2004). The stage-storage and reservoir capacity levels in the lake are provided in Table 1.



Notes: Inflow = Diversion + Surface Runoff + Precipitation; Outflow = Demand + Evaporation + Spill

Figure 3: Historical Diversion Monthly Data (1993-2013)

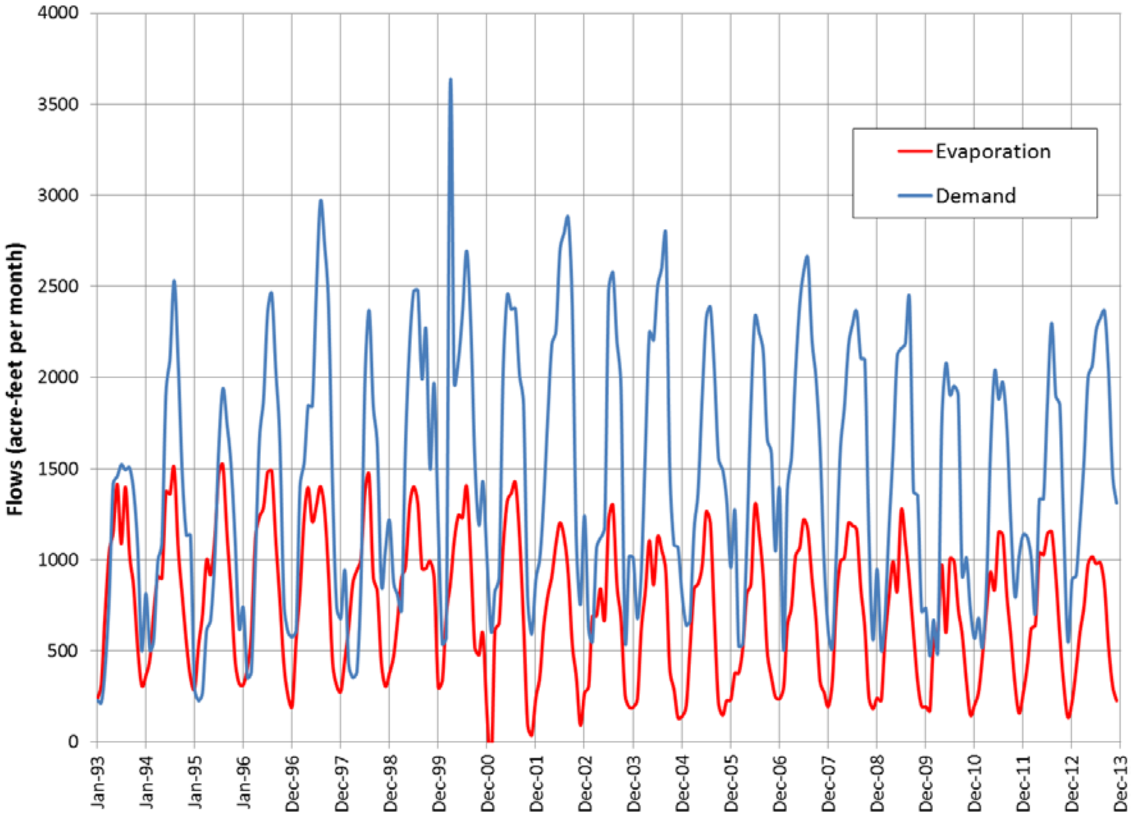


Figure 4: Monthly Variation of Demand and Evaporation from 1993 to 2013

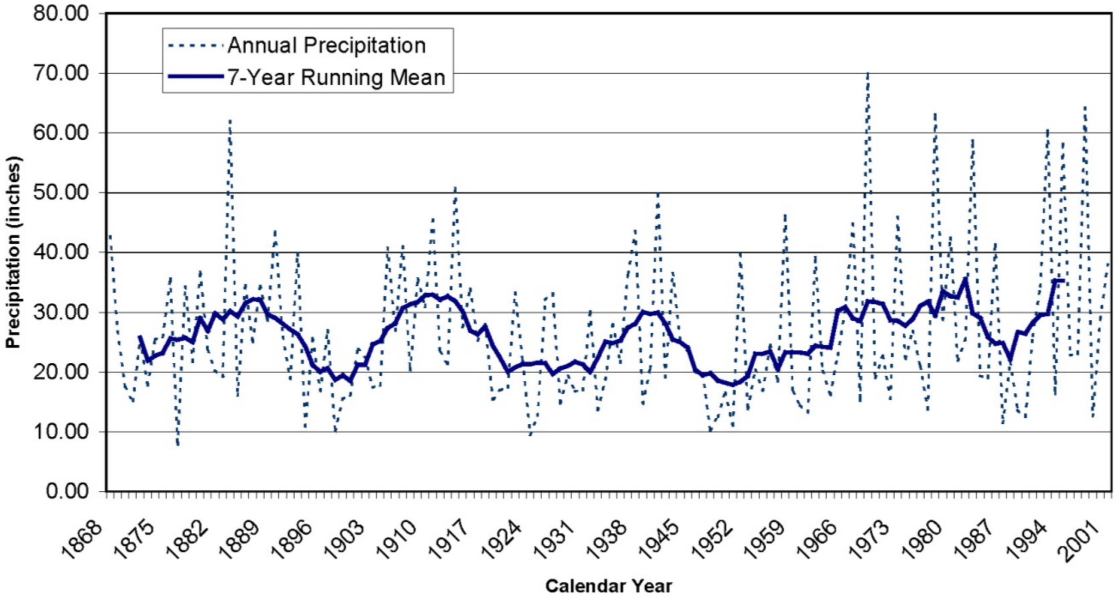
Table 1: Lake Elevation and Storage in Lake Casitas

Lake Elevation (feet)	Storage (acre-feet)	Storage Capacity (percent)	Lake Elevation (feet)	Storage (acre-feet)	Storage Capacity (percent)
380	9,560	3.8	**490**	94,878	37.4
390	13,082	5.2	**500**	109,916	43.3
400	17,250	6.8	**510**	126,649	49.9
410	22,101	8.7	**520**	144,906	57.1
420	27,669	10.9	**530**	165,020	65.0
430	34,084	13.4	**540**	186,804	73.5
440	41,402	16.3	**550**	210,262	82.8
450	46,690	19.6	**560**	235,411	92.1
460	59,025	23.2	**567**	254,002	100.0
470	69,496	27.4	**570**	262,208	103.2
480	81,444	32.1	**580**	290,693	114.4

Note – Spillway crest is at El. 567 feet.

2.3 HISTORICAL STREAM GAGE DATA

The long-term precipitation pattern for the Ventura River watershed, based on the Matilija Dam precipitation gage, exhibits a wet-dry year cycle (Figure 5; Entrix and CMWD 2002). The precipitation has fluctuated from wet year periods to dry year periods over approximately a 20-year cycle when viewed as a seven-year running mean (Entrix and CMWD 2002).



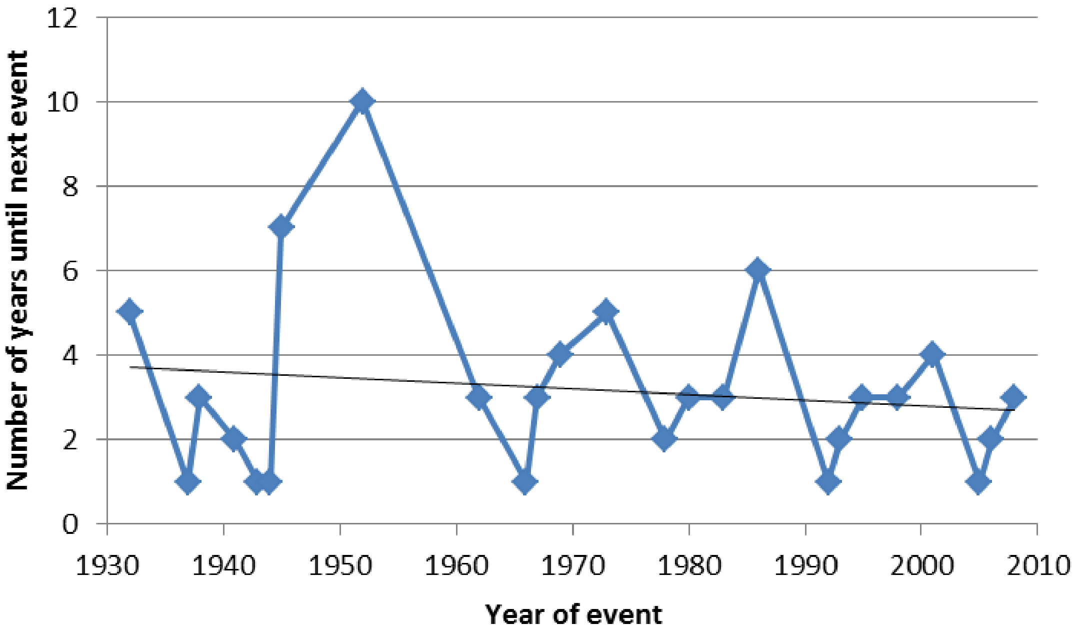
Source: Entrix and CMWD 2002.

Figure 5: Long-term precipitation pattern as recorded at the Matilija Gage 1868-2001

The Ventura River experiences large annual variations in peak flow magnitudes (BOR 2006):

- 1930s to 1940s: frequent flows
- 1940s to 1960s: less frequent and small magnitude flows except for 1969 flood
- Since 1970s: relatively frequent flows

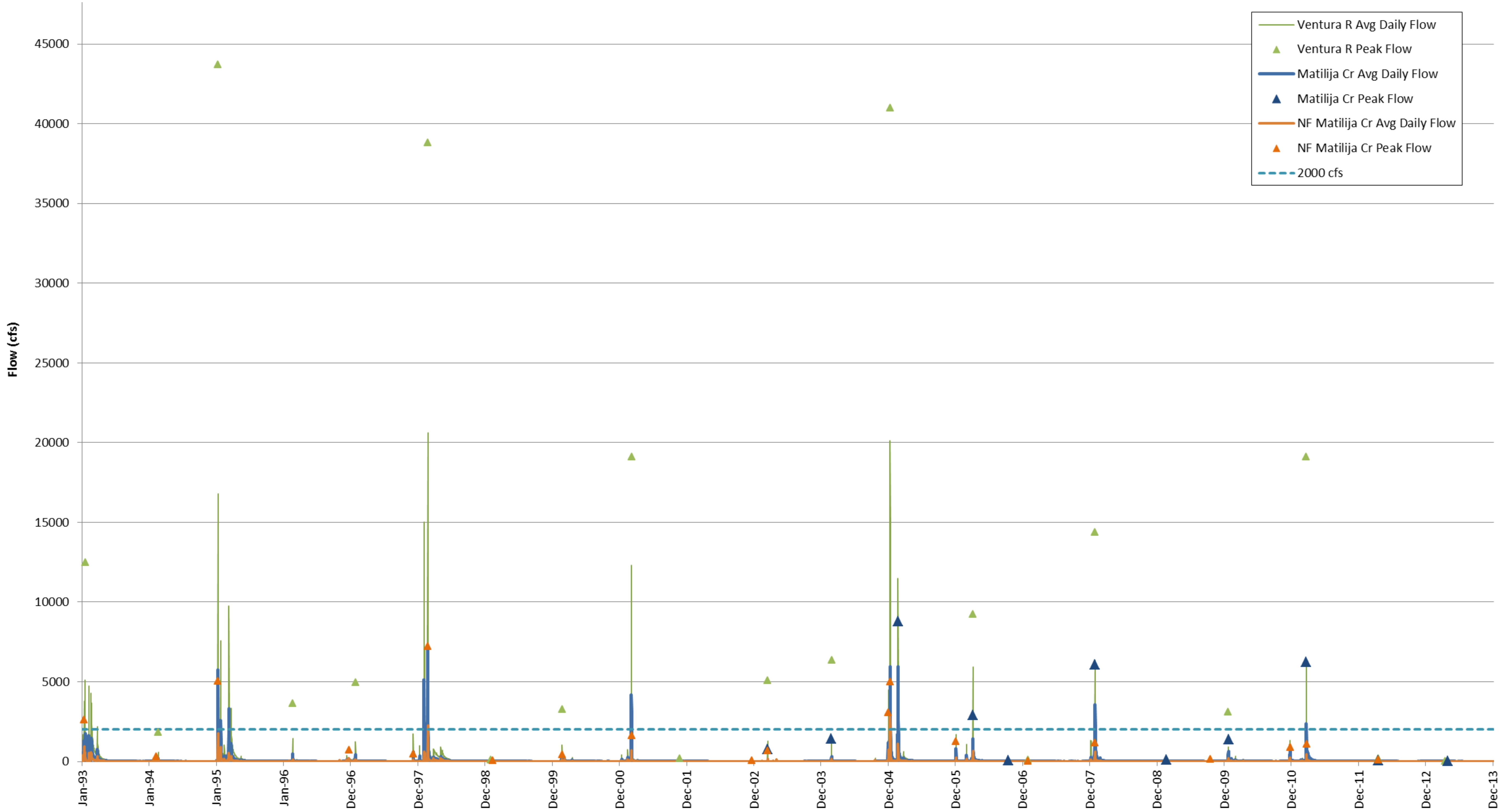
BOR 2006 notes that it is difficult to extrapolate the peak flow variation into the future and predict if a relatively wet period will continue or will enter into a relatively dry period. However, analysis of long-term trends in the flow record shows there is a typical pattern of oscillation between wet and dry periods suggesting a general 10- to 15-year cycle over the past 50 years (see Figure 6).



Source: Stillwater Sciences 2014.

Figure 6: Time series of "events" (average daily flow of ≥5,000 cfs at Ventura River gage (11118500) and/or ≥1,667 cfs in Matilija Creek) plotted on the y-axis as the number of years until the next year with at least one such event. Multiple events within the same water year are ignored. The black line suggests a linear trend of slightly decreasing duration between successive water years with one or more events, but this pattern is strongly influenced by the dry period of the late 1940's and 1950's and is not evident over the last 50 years.

Figure 7 shows the flows in the Ventura River, Matilija Creek, and North Fork Matilija Creek for the same period (1993 to 2013) as is available for the Lake Casitas water balance. Figure 7 shows that flows in these three reaches are intermittent, highly variable, and typically only occur for a few months in years when precipitation occurs. This figure also shows that peak flows are several times larger than the highest average daily flows, which indicates that the hydrology has a very flashy response to precipitation.



Source: Ventura River data from USGS gage 11118500. Matilija Creek data for Feb 15, 2002 through Dec 31, 2013 from USGS gage 11114495. Matilija Creek data for Jan 1, 1993 through Feb 14, 2002 calculated based on Ventura River data and a ratio of average daily flows of 0.3409:1 (Matilija Creek:Ventura River) (ratio based on Stillwater 2014). North Fork Matilija Creek data from Ventura County Watershed Protection District gage 604.

Figure 7: Matilija Creek, North Fork Matilija Creek, and Ventura River flows 1993 to 2013.

2.4 ROBLES DIVERSION

CMWD operates the Robles diversion facility to provide water supply to Lake Casitas. The operation is also managed to minimize the spill at Lake Casitas by stopping diversions at Robles diversion when the water elevation in Lake Casitas is within two feet of the spillway crest (elevation 565.0 feet) (Entrix and CMWD 2002). The reservoir has spilled in eight separate years since operations commenced. The first time it spilled was when it first filled in 1978. It subsequently spilled while the reservoir was full in 1979, 1980, 1983, 1986, 1993, 1995, and 1998. There were substantial flows in the Ventura River during many of these years. The likelihood of Lake Casitas spilling is low during years when reservoir volume is less than 200,000 acre-ft (79 percent full) at the start of the precipitation season (BOR 2000).

Figure 8 shows the cumulative runoff, precipitation and diversion into Lake Casitas for the 21-year period between 1993 and 2013. Table 2 provides the percentage of the respective cumulative contributions over the 21-year period and shows that the Robles diversion contributed a total of approximately 30.8 percent of the total cumulative inflows over that period. However, reservoir spills occurred in 1993, 1995 and 1998 during this period, for a total of approximately 75,800 acre-feet spilled compared to a total of at least[3] 41,560 acre-feet of Robles diversion inflow leading up to these spills. If management of the Robles diversion had avoided these spills by shutting down the Robles diversion as was done in 2005, the Robles diversion contribution to Lake Casitas would have been approximately 22.9 percent of total inflows (Table 3).

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[3] Prior to the 1993 spill that occurred from February to May, Robles diversions were made in both January and February that year. Additional Robles diversions that contributed to the 1993 spill may have occurred prior to January 1993, but data was not provided for the preceding years.

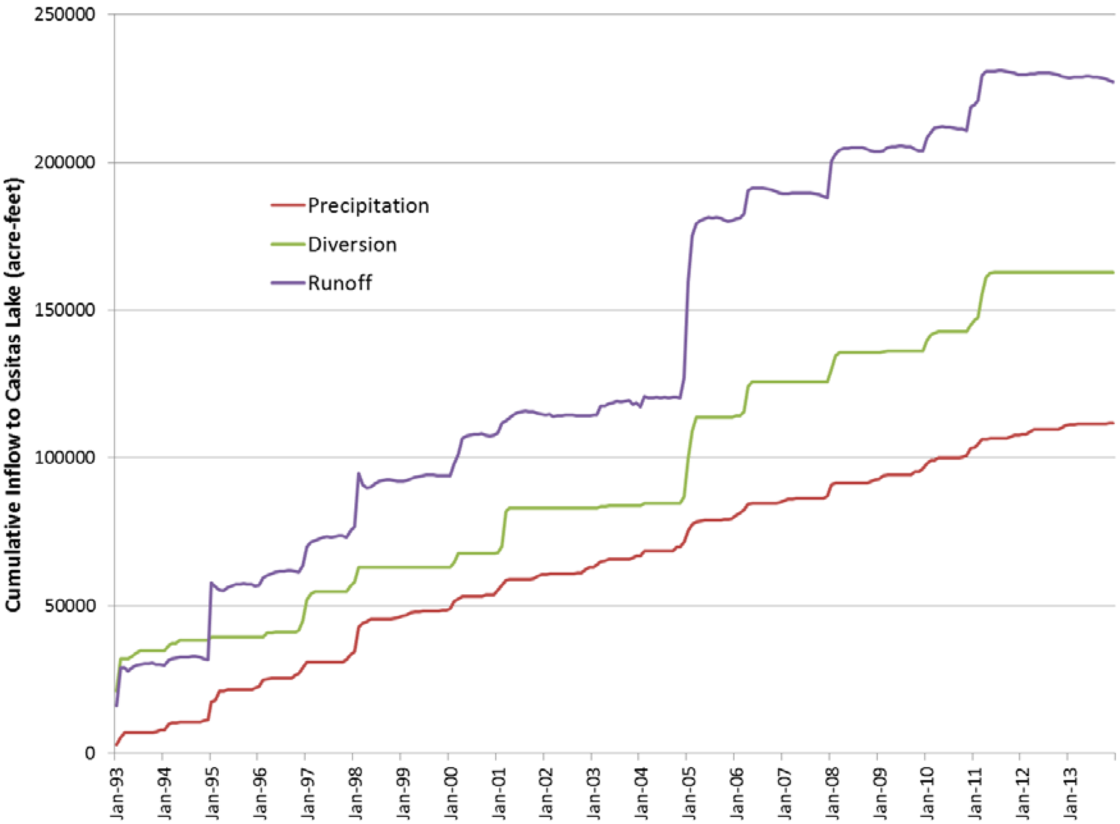


Figure 8: Cumulative precipitation, diversion and runoff to Lake Casitas (1993-2013)

Table 2: Cumulative Inflows into Lake Casitas (1993-2013).

Source	acre-feet	percent of total
Runoff from reservoir watershed[a]	253,717	48.0
Robles diversion	162,824	30.8
Direct precipitation	111,867	21.2

[a] Reservoir spills were subtracted from the cumulative runoff to create a more accurate understanding of the contribution of runoff to water supply.

Table 3: Cumulative Inflows into Lake Casitas (1993-2013) without diversions prior to spills.

Source	acre-feet	percent of total
Runoff from reservoir watershed [a]	295,278	55.9
Robles diversion	121,263	22.9
Direct precipitation	111,867	21.2

[a] Reservoir spills were subtracted from the cumulative runoff to create a more accurate understanding of the contribution of runoff to water supply.

2.4.1 ENVIRONMENTAL WATER REQUIREMENTS AT ROBLES

After the West Coast steelhead trout (*Oncorhynchus mykiss*) was listed as an endangered species, and in order to avoid potential liability under Section 9 of the Endangered Species Act, the Bureau of Reclamation consulted with the National Marine Fisheries Service and issued a biological opinion associated with diversion at Robles. The biological opinion describes diversion operations rules to provide flow through the fish ladder including base flows and a ramp down schedule following storm peaks.

2.4.2 SEDIMENTATION CONDITIONS AT ROBLES

Large amounts of sediment deposition occur at the Robles diversion during floods. In the Ventura River, the suspended material is mostly clays, silts, and sands, while the bed load is composed of gravels, cobbles, and boulders (BOR 2006). The diversion structure is not large enough to trap the suspended material transported by the river, but does trap a significant portion of the bed load. Based on sediment removal operations between 1966 and 1998, an average of 8 acre-feet per year of sediment (about 13,000 cubic yards) has been removed (BOR 2006).

3.0 DIVERSION DISRUPTION SCENARIOS

Diversions at Robles are an important source of water for Lake Casitas. It is anticipated that during the removal of Matilija Dam there will be some periods when the diversion may need to be shut down due to higher than normal suspended sediment loads or high organic carbon concentrations. To better understand the impacts to Lake Casitas during dam removal, three scenarios were modeled based on the 21-year historical record between 1993 and 2013:

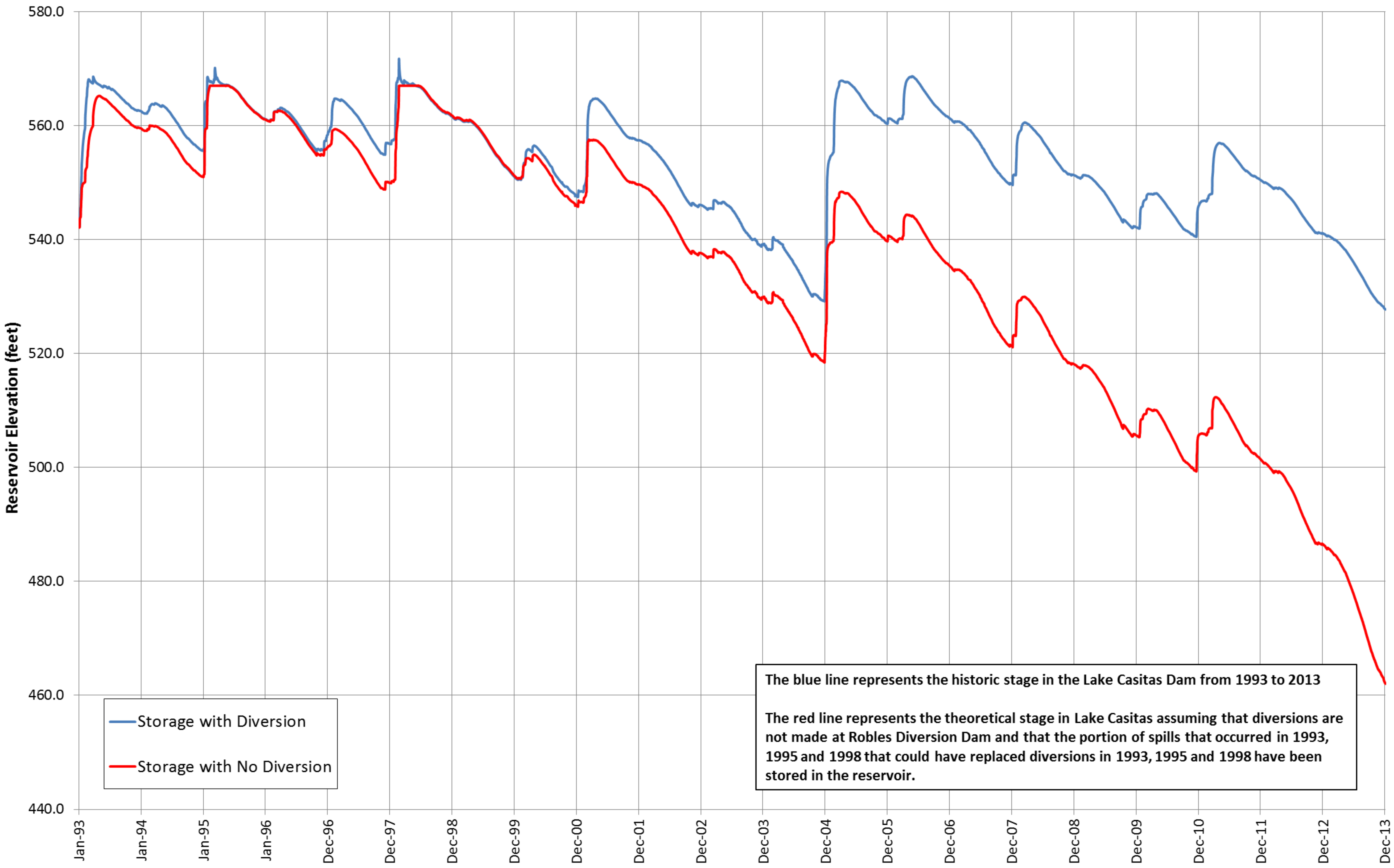
- Scenario 1 – Lake Casitas levels without Robles diversion
- Scenario 2 – Lake Casitas levels without Robles diversion during one major storm
- Scenario 3 – Lake Casitas levels without Robles diversion during three consecutive major storms

3.1 SCENARIO 1: LAKE CASITAS LEVELS WITHOUT ROBLES DIVERSION

Scenario 1 assumes diversions to Lake Casitas do not occur from 1993 through 2013 while all other conditions remain the same. Scenario 1 was developed to better understand the impact of Robles diversion on the storage in Lake Casitas. Using the daily data provided by CMWD, all diversions were ignored when calculating inflows to the reservoir. Periods when spilling had historically occurred were adjusted to avoid losing volume to the spill if the reservoir level was lower than the spillway crest elevation of 567.0 feet. Figure 9 shows historical Lake Casitas levels in blue and lake levels for Scenario 1 in red. Historical lake levels show spills occurring during 1993, 1995, and 1998. Subsequently, CMWD decided to limit the Robles diversion when the reservoir level was within 2 feet of the spillway crest. This decision resulted in the district avoiding spilling in 2005 and 2006 when precipitation was great enough to refill the reservoir after several dry years without the additional contribution from Robles diversion.

In general, the historical data can be broken into two broad periods: a relatively wet period between 1993 and 1998 followed by a generally dry period through 2013, although the outlying wet year of 2005 occurs during this overall generally dry period. During the wetter period, Scenario 1 indicates that diversions from Robles were not needed as inflows from the Lake Casitas watershed were still sufficient on their own to cause spilling. Without diversions from Robles during the entire period, Lake Casitas would only be 24 percent full compared to 63 percent full with diversions.

Based on this information, it is apparent that implementation of a Matilija dam removal option that releases large amounts of fine sediment (restricting or preventing Robles diversions) during a wet period similar to the early 1990’s could occur without having any significant effect on Lake Casitas storage. Whereas, implementation of a similar Matilija dam removal option during drier periods could have a significant, but likely temporary, impact on Lake Casitas storage volume as demonstrated in Scenarios 2 and 3 below.



The blue line represents the historic stage in the Lake Casitas Dam from 1993 to 2013

The red line represents the theoretical stage in Lake Casitas assuming that diversions are not made at Robles Diversion Dam and that the portion of spills that occurred in 1993, 1995 and 1998 that could have replaced diversions in 1993, 1995 and 1998 have been stored in the reservoir.

Note: For the “Storage with No Diversion” plot, the spills recorded in water years 1993, 1995, and 1998 were added back into reservoir storage. The reservoir tops out in 1995 and 1998 due to this additional volume.

Figure 9: Comparison of Lake Casitas levels 1993-2013 (a) with Diversion (i.e., actual) and (b) with No Diversion

3.2 SCENARIO 2: LAKE CASITAS LEVELS WITHOUT ROBLES DIVERSION DURING ONE MAJOR STORM

Scenario 2 assumes that one large storm (average daily flow >2,000 cfs in Matilija Creek) will be used to transport the majority of fine sediment out of Matilija reservoir, during which diversions would not be made at Robles.

Table 4 lists events in Matilija Creek where average daily flows were greater than 2,000 cfs for the period between 1993 and 2013, along with the Lake Casitas initial stage and capacity, and the Robles diversion associated with each storm event. Where gage data was not directly available for Matilija Creek, a ratio of 0.35 (Stillwater 2014) was used to convert average daily flows in Ventura River (gage 11118500) to average daily flows in Matilija Creek.

Table 4: Events with average daily flow >2000 cfs in Matilija Creek

Date (Event Start)	Date (Event Peak)	Matilija Cr Avg Daily Flow >2000 (Event Peak) (cfs)	Lake Casitas Elevation (Event Start) (ft)	Lake Casitas Capacity (Event Start) (percent)	Robles Diversion (Event Total) (acre-feet)
1/9/1995	1/10/1995	5,727 [a]	557.7	90%	1,175
3/2/1995	3/11/1995	3,324 [a]	567.6	101%	0
2/2/1998	2/3/1998	5,114 [a]	560.5	93%	4,859
2/14/1998	2/23/1998	7,023 [a]	568.2	101%	0
2/24/2001	3/5/2001	4,193 [a]	550.6	83%	10,008
12/28/2004	1/9/2005	5,950 [b]	528.4	64%	15,435
2/11/2005	2/21/2005	5,940 [b]	552.9	86%	13,180
1/23/2008	1/27/2008	3,560 [b]	549.2	82%	9,212
3/20/2011	3/20/2011	2,350 [b]	546.0	79%	13,536

[a] Average daily flow calculated as 0.3409 x Ventura River average daily flow.

[b] Data from gage 11114495.

Grey rows indicate storms with the greatest potential impact on Lake Casitas storage levels if diversions had been suspended.

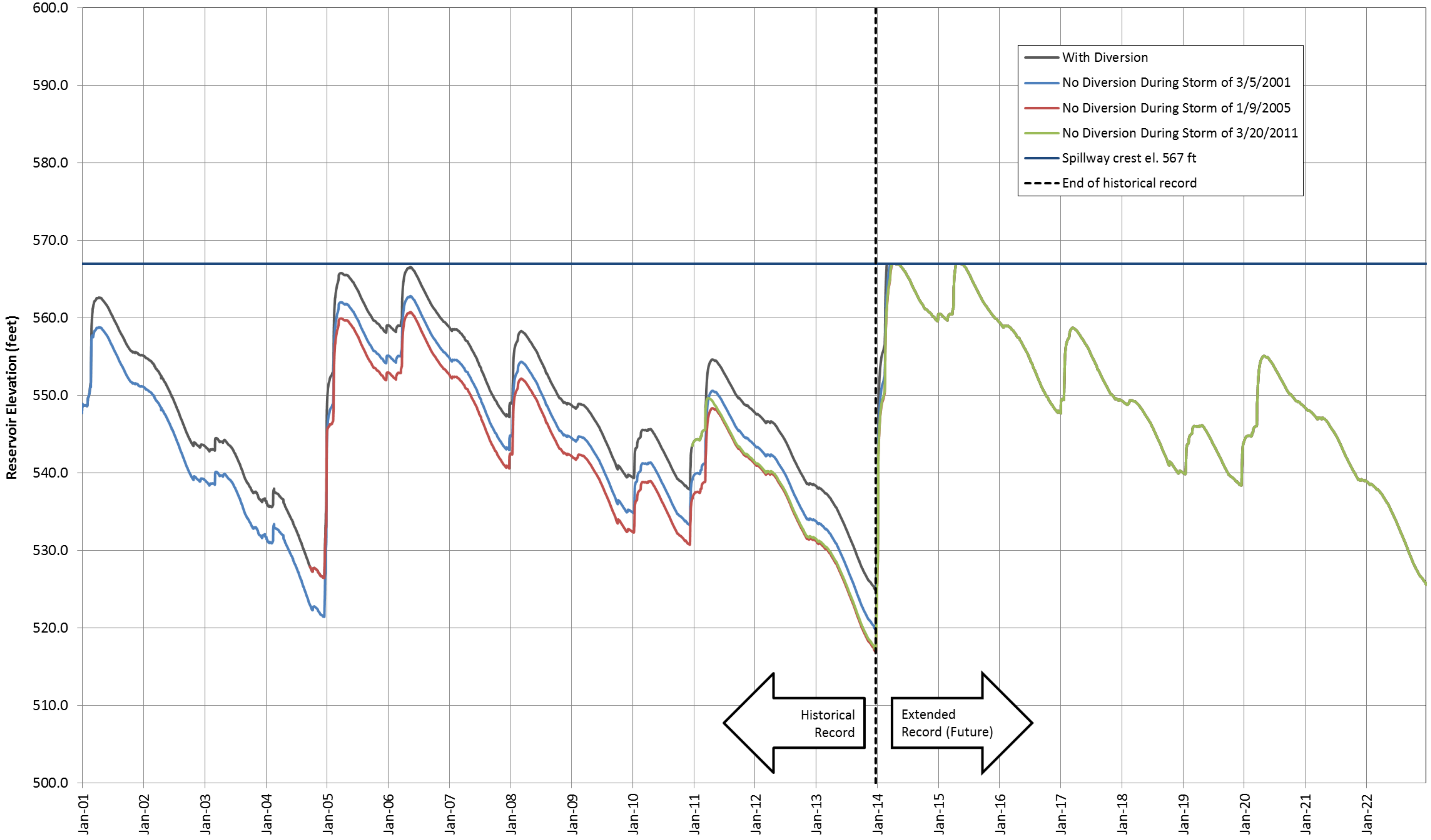
The worst case scenario event (i.e., where Lake Casitas storage is most impacted) would occur when the lake storage was at a minimum and diversion of flow into Lake Casitas was at a maximum. For the analysis, the storms that peaked on 3/5/2001, 1/9/2005, and 3/20/2011 were selected (grey rows in Table 4). The storms during the 1990s (wet period) were not selected because Scenario 1 demonstrated that diversions during wet periods are not necessary for maintaining storage in Lake Casitas.

A “gap analysis” was performed to show the impact on the water storage, assuming diversions are not made during the storm when flows in Matilija Creek exceed 50 cfs (Figure 10). The duration without the diversion is conservative, since the diversion could potentially resume after the sediment has been removed by the peak of the major storm allowing a greater portion of the tail of the storm to be diverted. As shown in Figure 10, by the end of the historical record (12/31/2013), the Lake Casitas storage capacity would drop approximately 4 percent, 6 percent, and 6 percent, respectively for the 3/5/2001, 1/9/2005, and 3/20/2011 storm events, compared to storage levels with diversion.

However, as shown in Figures 5 and 6, the Ventura River watershed experiences cycles of wet and dry periods. To understand the effect of the next wet cycle on the analysis, the record period from 12/26/2004 to 12/25/2013 was repeated at the end of the historical record, representing plausible future conditions from 2014 through 2022. This extended record includes a repeat of the historical 2005 storms in analysis year 2014, historical 2006 storms in analysis year 2015, etc.

The extended record also recognizes additional flows that could have been diverted at Robles during the 2005 storms but were not diverted due to the level in Lake Casitas approaching spilling. Total diversions during the 1/9/2005 and 2/21/2005 storms were approximately 15,435 and 13,180 acre-feet, respectively. Assuming flows at Robles are similar to the sum of Matilija Creek and North Fork Matilija Creek flows, the total potential diversions for the two storms could have been approximately 26,670 and 25,930 acre-feet. The calculated potential diversions account for the base flow and ramp down schedule from the Robles fish passage facility Biological Opinion.

In the extended record, potential diversions are assumed during the analysis year 2014 storms (historical 2005 storms) and historical diversions are assumed for the remainder of the extended record. As shown in Figure 10, all scenarios are able to capture sufficient water in analysis year 2014 to cause spilling at Lake Casitas. This means that diversions that are lost during a single storm event for dam removal will result in a temporary 4 to 6 percent drop in Lake Casitas storage that would be fully recovered during the next wet cycle.



Notes: Available historical record is 1/1/1993 to 12/31/2013. Extended record repeats the record from 12/26/2004 to 12/25/2013 at the end of the historical record to simulate the next wet period. Analysis year 2014 storms assume all potential diversions are captured. All the scenario plots are coincident after March 2014.

Figure 10: Comparison of storage (a) with regular diversion, (b) no diversion for the storm of 3/5/2001, (c) no diversion for the storm of 1/9/2005, and (d) no diversion for the storm of 3/20/2011

3.3 SCENARIO 3: LAKE CASITAS LEVELS WITHOUT ROBLES DIVERSION DURING THREE CONSECUTIVE MAJOR STORMS

Scenario 3 assumes that three large storms (each with average daily flow >2,000 cfs in Matilija Creek) will be used to transport the majority of fine sediment out of Matilija reservoir during which diversions would not be made at Robles. This scenario assumes that diversions would resume in between the three events during smaller storms (e.g., if gated orifices are used to control the release of fine sediment from Matilija reservoir or if smaller flows are able to pass through the reservoir area without eroding significant quantities of remaining fine sediment). This scenario may occur if one major storm (Scenario 2) is unable to clear all the fine sediment from Matilija reservoir.

Table 5 lists events in Matilija Creek where average daily flows were greater than 2,000 cfs for the period between 1993 and 2013 along with the Lake Casitas initial stage and capacity, the volume of diversion associated with each event, and the volume of diversion associated with the two consecutive prior events. Where gage data was not directly available for Matilija Creek, a ratio of 0.35 (Stillwater 2014) was used to convert average daily flows in Ventura River (gage 11118500) to average daily flows in Matilija Creek.

Table 5: Events with average daily flow >2000 cfs in Matilija Creek and three storm totals

Date (Event Start)	Date (Event Peak)	Matilija Cr Avg Daily Flow >2000 (Event Peak) (cfs)	Lake Casitas Elevation (Event Start) (ft)	Lake Casitas Capacity (Event Start) (percent)	Robles Diversion (Event Total) (acre-feet)	Robles Diversion (Three-Event Total) (acre-feet) [c]
1/9/1995	1/10/1995	5,727 [a]	557.7	90%	1,175	-
3/2/1995	3/11/1995	3,324 [a]	567.6	101%	0	-
2/2/1998	2/3/1998	5,114 [a]	560.5	93%	4,859	6,034
2/14/1998	2/23/1998	7,023 [a]	568.2	101%	0	4,859
2/24/2001	3/5/2001	4,193 [a]	550.6	83%	10,008	14,867
12/28/2004	1/9/2005	5,950 [b]	528.4	64%	15,435	25,443
2/11/2005	2/21/2005	5,940 [b]	552.9	86%	13,180	38,623
1/23/2008	1/27/2008	3,560 [b]	549.2	82%	9,212	37,827
3/20/2011	3/20/2011	2,350 [b]	546.0	79%	13,536	35,928

[a] Average daily flow calculated as 0.3409 x Ventura River average daily flow.

[b] Data from gage 11114495.

[c] The sum of diversions for this event plus the two prior events listed in the table.

Grey rows indicate the series of storms with the greatest potential impact on Lake Casitas storage levels if diversions had been suspended.

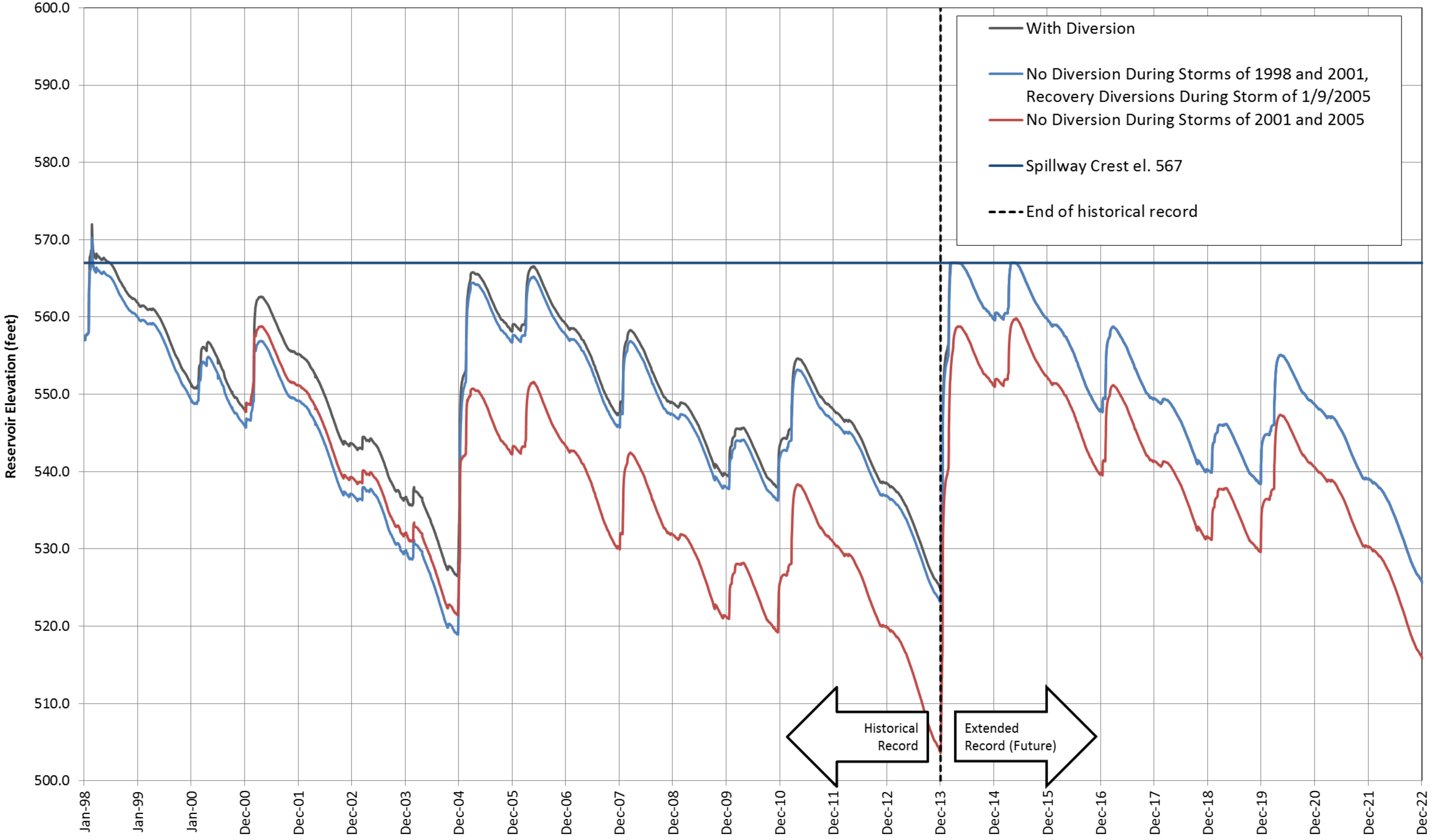
Rows outlined by the red box indicate the series of storms with an intermediate impact on Lake Casitas storage levels if diversions had been suspended.

The worst case scenario event (i.e., where Lake Casitas is most impacted) would be when the diversion of flow into Lake Casitas was at a maximum for the three consecutive events. For this analysis, the three storms that occurred in 2001 and 2005 were selected to show the worst case (grey rows in Table 5). The average storage capacity of the reservoir was 78 percent and the cumulative diversion was 38,623 acre-feet. The storms during the 1990s (wet period) represent a best case scenario and were not selected because Scenario 1 demonstrated that diversions during wet periods are not necessary for maintaining storage in Lake Casitas.

A “gap analysis” was performed to show the impact on the water storage, assuming diversions are not made during the three storms that occurred on 3/5/2001, 1/9/2005, and 2/21/2005 (Figure 11). The duration without diversion is conservative, since diversion could potentially resume after sediment has been removed by the peak of each major storm allowing a greater portion of the tail of each storm to be diverted. As shown in Figure 11, by the end of the historical record (12/31/2013), the Lake Casitas storage level would drop approximately 15 percent compared to storage levels with diversion.

A second set of three storms, judged to be intermediate between the best and worst case scenarios was also evaluated (red box in Table 5). The second set of storms (2/3/1998, 2/23/1998, and 3/5/2001) was assumed to have no diversions, and the 1/9/2005 storm was assumed to have the maximum potential diversion as discussed previously in Section 3.2. For this case, by the end of the historical record (12/31/2013), Lake Casitas returns to levels almost identical to the conditions with the continuous diversion.

Similar to Scenario 2, an extended record was added to the end of the historical record to represent a future wet period, and during the analysis year 2014 storms (historical 2005 storms), and the full potential diversions are taken rather than the historical diversions in all scenarios. For the remainder of the extended record, the historical diversions were used. As shown in blue in Figure 11, the intermediate case scenario (no diversions during the 1998 and 2001 storms followed by recovery diversions in the first 2005 event) is able to capture sufficient water in analysis year 2014 to cause spilling at Lake Casitas. This means that the next wet cycle would likely result in a full recovery at Lake Casitas. For the worst case scenario (i.e., no diversion during the 2001 and 2005 storms) shown in red, the next wet cycle as modeled would result in recovery of Lake Casitas to 91 percent of total storage capacity.



Notes: Available historical record is 1/1/1993 to 12/31/2013. Extended record repeats the record from 12/26/2004 to 12/25/2013 at the end of the historical record to simulate the next wet period. Analysis year 2014 storms assume all potential diversions are captured. The black and blue lines are coincident after March 2014.

Figure 11: Comparison of storage (a) with regular diversion, (b) No diversion for storms of 2/3/1998, 2/23/1998, and 3/5/2001 and storage recovery in 1/9/2005 storm, and (c) No diversion for storms of 3/5/2001, 1/9/2005, and 2/21/2005

4.0 CONCLUSIONS

The following are conclusions from the analyses summarized above, for consideration during refinement of Matilija dam removal options and discussions concerning associated mitigation for lost Robles diversions:

1. During the period of record available for this analysis, the Robles diversion provided approximately 31 percent of the inflow into Lake Casitas. This percentage would have been lower if diversions had been managed in some instances to prevent reservoir spilling.
2. There is a typical pattern of oscillation between wet and dry periods in the Ventura River watershed that has been on a roughly 10- to 15-year cycle for the past 50 years. Wet periods in the analyzed record are sufficient to refill Lake Casitas without any diversion at all.
3. Implementation of a dam removal project during a typical wet cycle as experienced in the 1993-1998 period that restricts diversions (allows diversion of a portion of storm or allows diversion between storms) or prevents diversions (no diversions throughout the period) would have little to no effect on water levels in Lake Casitas.
4. Implementation of a dam removal project during one of the typical dry cycles that suspends Robles diversions would significantly reduce water levels in Lake Casitas. If the suspension were limited to a few storms or less, it is probable that loss of storage capacity could be limited to between 4 and 15 percent and would persist only until the next wet cycle when those losses would be restored.

5.0 REFERENCES

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MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

DAM REMOVAL CONCEPTS EVALUATION REPORT

MARCH 2016

ATTACHMENT 5: DESIGN OVERSIGHT GROUP COMMENTS

- Casitas Municipal Water District Letter
- Surfrider Foundation, Ventura County Chapter – Matilija Coalition Letter
- NOAA National Marine Fisheries Service Letter
- Ojai Valley Sanitary District Email and Letter
- Stoecker Ecological Letter

CASITAS
Municipal Water District

October 22, 2015

RECEIVED
NOV 02 2015
WATERSHED PROTECTION DIST.

Mr. Tully Clifford
Ventura County Watershed Protection District
800 South Victoria Avenue
Ventura, CA 93003

RE: Matilija Dam, Sediment Transport, and Robles Diversion Mitigation Project
Draft Dam Removal Concepts Evaluation Report and Draft Water Supply Mitigation Concepts Evaluation Report

Dear Tully,

On behalf of the Casitas Municipal Water District, I would like to express our acknowledgement and appreciation for the commitment by the County of Ventura and the California State Coastal Conservancy to bring forward a new look at the Matilija Dam Ecosystem Restoration Project. The consultant team of AECOM (URS) and Stillwater Sciences has brought to this project their expertise and collaborative problem solving, resulting in a better understanding of how this project may be accomplished successfully.

The District hereby offers the following comments regarding the two reports:

Draft Dam Removal Concepts Evaluation Report

The Project Objectives and Evaluation Criteria stated in Section 2.0 are the cornerstones for the development and evaluation of each of the project alternatives. Most critical to the District is the minimizing of project impacts to water supply and water quality of the Ventura River system and Lake Casitas. The District concurs with the Report that DRC-2A and DRC-2B receive the most favorable rating of the three alternatives. DRC-2A and DRC-2B appear to offer the shortest time that would require a temporary suspension of diversions at Robles and provides for the implementation of adaptive management to the remaining fine sediment.

The Report discussions regarding the impact of the methane-bearing strata on the Ventura River and Lake Casitas have conclude that during the Phase I flush of the Matilija basin the impact of organic mass is "not voluminous to greatly increase the overall estimate of organic content based on the data of Table 4.2-6" (page 46, line 27). This conclusion appears to be reasonable while in the presence of a high flow condition and heavy sediment carrying capacity of the Phase I period. Of concern to the District is that portion of methane-bearing strata that could remain in the exposed embankment of the channel cut, as illustrated in Figures 4.2-6 and 4.2-7. The Report recognizes that the remaining channel walls could collapse into the channel during subsequent years. There appears to be a lack of data to support the determination of the degree of organic loading from the methane-bearing strata that could be introduced into post-dam removal stream flows or the determination that the methane-bearing strata would oxidize with exposure to air (Page 46, Line 22-25). Rather than debate this point further, it should be recognized that there are uncertainties with the content of the methane-bearing strata and whether the strata may avulse into the channel in subsequent years. Recognizing these uncertainties, there

5-1

should be a monitoring and adaptive management plan to address the remaining methane-bearing strata.

Draft Water Supply Mitigation Concepts Evaluation Report
The consultant team of AECOM (URS) and Stillwater Sciences has prepared a comprehensive evaluation of existing water supplies and listing of various mitigation options to either protect/treat or extend the life of the local water supplies water that could be affected by the Project. It is understood that what has been presented here are a wide variety of options that may or may not be considered for implementation upon the determination of appropriate justifications that warrant their implementation for the specific dam removal alternative project.

If you have any questions in regard to the above comments, please call me.

Sincerely,

Steven E. Wickstrum
General Manager

5-2

Surfrider Foundation
Ventura County Chapter – Matilija Coalition
PO Box 1028, Ventura, CA 93002
(805) 205-4953 **www.matilija-coalition.org**

October 17, 2015

Peter A. Sheydayi, P.E., D.WRE
Deputy Director, Design and Construction Division
Ventura County Watershed Protection District
800 S. Victoria Avenue Ventura, CA 93009-1610

RE: Matilija Dam Removal, Sediment Transport, and Robles Diversion Mitigation Project

Dear Mr. Sheydayi,

I am writing on behalf of the Matilija Coalition, an alliance of organizations, businesses and citizens committed to the removal of Matilija Dam and the restoration of the Ventura River. I have appreciated the opportunity to serve on the Technical Advisory Committee, as well as the consultant selection committee and the steering committee for the recently completed studies. Recognizing that there is still work to be done, I believe that the results of these studies provide a renewed opportunity to achieve our shared goals in an affordable and timely manner.

Comments on Project Alternatives:

The studies presented in the **Matilija Task 1.3 Draft Concepts Evaluation Report** benefit from information that was not available during the federal feasibility study of 2001-2004. Since then, several large dams have been removed from rivers on the west coast of the United States, and much has been learned. We now have real world examples demonstrating the power and resilience of riverine ecosystems to restore themselves, if given the chance. In every case, fish immediately migrated upstream of the former dam site, and downstream ecosystems absorbed and benefitted from the increased sediment transport. In no case were permanent negative impacts realized. And most notably, in the case of Condit Dam removal, we have witnessed the power of a single event to almost instantaneously reverse decades of negative impacts to a river through what was once predicted to result in "total biological annihilation."

The current studies apply this real world experience to demonstrate how the short-term impacts of a single sediment release will not permanently affect our local water supply. This provides a scientifically justified opportunity to take advantage of the energy of the Ventura River, saving tens of millions of dollars over mechanically moving and disposing of sediment, while significantly reducing the environmental footprint of the project.

1. ***Dam Removal Concept DRC-2:***

The analysis demonstrates that DRC-2, the low level orifice concept, provides the greatest benefits and least impact of the alternatives analyzed. This validates our previous comments, which have consistently advocated for natural transport of the sediments sequestered behind the dam. Because this is also the lowest cost approach, it is likely the most feasible from a funding standpoint.

2. *Dam Removal Concept DRC-3:*

DRC-3, the upstream sediment storage alternative essentially optimizes the "Alternative 4b" previously identified in the federal feasibility study completed in 2004, by eliminating the problematic slurry and disposal of fine sediments. However, the greater cost and increased impact caused by mechanical transport of a portion of the sediment make this less desirable than DRC-2.

3. *Dam Removal Concept DRC-1:*

DRC-1 as currently conceived is not a preferred option. The permanent and temporary impacts of constructing a tunnel through a geologically unstable ridge are unjustified for the cost. The multi-year dewatering of Matilija Creek and high discharges into N Fork Matilija Creek will cause undue stress to the aquatic ecosystem. There is also the potential for elevated risk to water supply and other downstream interests from temporary earthen cofferdams during intermediate storms.

We concur with the report's ranking of the alternatives, and support DRC-2 as the preferred alternative for achieving ecosystem restoration through dam removal.

Comments on Technical Assessments:

5.2 Steelhead Health

The comparative analysis uses steelhead health downstream of the Matilija Dam site as a parameter in evaluating the different alternatives. In some cases it assumes mortality of aquatic life downstream:

- *both DRC-1 and DRC-2 results in the substantial, but likely not complete, loss of a year class of fish in Matilija Creek and the Ventura River.*

This is a conservative conclusion, and while these dam removal alternatives will clearly create adverse downstream conditions, the report also states:

- *Matilija can obviously prove to be a challenging environment for steelhead to thrive; these conditions also stress the importance of tributary habitat, which provide refuge habitat from these natural events (and presumably would serve the same function following dam removal as well), **because a nominally lethal, high-sediment condition in a channel with available refugia does not necessarily result in mortality for mobile organisms that have evolved under these conditions**.*

In addition to the refugia value of tributaries such as the North Fork Matilija Creek and San Antonio Creek, a significant proportion of the native steelhead population resides in these tributaries as well as the headwaters upstream of the dam site. (see: **Steelhead Population and Habitat Assessment in the Ventura River / Matilija Creek Basin 2006-2012 FINAL REPORT (2015)**) So although there will certainly be impacts to downstream populations in the main stem of the Ventura River, decision makers should recognize that DRC-1 and DRC-2 will not result in the complete loss of the steelhead population. (One may even reasonably expect Phase I sediment release impacts to be similar to past geological events, hence within the evolutionary experience of the southern steelhead.)

Importantly, the study concludes that;

- *Phase II transport for all three dam removal concepts will likely have an indiscernible incremental effect over baseline conditions.*

The analyses clearly illustrate that, given the climate, geology, and naturally high sediment loads regularly experienced in the Ventura River, the future post-dam-removal fine sediment impacts will be within the natural range of turbidity for high flow events. This conclusion opens the way for implementation of cost-effective natural transport alternatives for dam removal without the previous fear of long-term downstream impacts.

Comments on Water supply mitigation:

The ***Matilija Task 3.2 Hydrologic Assessment for Water Supply*** study provides a comprehensive review of the contribution of Robles Diversion to Casitas Municipal Water District and the potential impacts of missed diversions on reservoir storage levels. This is also new information, which opens up opportunities above and beyond the assumptions made during the federal Feasibility process.

Most notably, the recent analysis revealed that diversions from the Ventura River at Robles have historically provided 23% of storage in Lake Casitas, in contrast to the prior assumption that Robles contributed fully 50% of supply. Furthermore, the analysis reveals that based on historic data, a single missed diversion event will only temporarily impact reservoir storage by 4-6%, and that this loss will be made up in the next flood event. While recognizing that this is only an estimate, this analysis provides a renewed perspective of the actual risk posed by utilizing natural transport to expedite dam removal. Most importantly, **it is now understood that a single missed diversion event is feasible**.

The ***Matilija Task 3.3 Water Supply Mitigation*** report presents a range of mitigation measures for water supply. However, based on the ***Task 3.2 Hydrologic Assessment for Water Supply*** analysis, it appears that water supply mitigation will not be necessary as a result of the project. Therefore, these measures should be considered part of a contingency plan rather than required mitigation for the project.

It is important to note that the impact of 4-6% reduction in storage is within the variability of diversion efficiency and conservation measures. The current operations are subject to fouling of fish screens, or even complete failure of the diversion dam (as in 1969), resulting in lost diversion opportunity. Also, current drought conservation efforts have successfully reduced demand by over 25%, demonstrating the feasibility of current and future conservation measures.

Moreover, this “loss” is not realized unless the lake runs dry and there is no supply to deliver to customers. Of relevance is the recent federal court decision regarding Robles Diversion, which determined that Casitas “…can establish a compensable injury when diversions resulting from the biological opinion criteria reduce the water project's safe yield to the point when deliveries are affected—i.e., to the point when use becomes constrained.” (Casitas v United States, 102 Fed.Cl. at 473 – http://caselaw.findlaw.com/us-federal-circuit/1623229.html#sthash.0DL3qkmC.dpuf) As demonstrated in the ***Hydrologic Assessment for Water Supply*** analysis, it is highly unlikely that the project will result in delivery constraints to water use.

In the course of discussion there has also been concern over the impacts of silt on other water supplies, specifically the City of Ventura water diversions at Foster Park and Meiners Oaks Water District wells in the upper basin.

4.2.1.2 Ventura Water - Our understanding is that the City no longer uses the surface diversion that was the original justification for “mitigation wells” in the federal Feasibility Study. Water diversions are currently served by a well field at this location.

4.2.2 Groundwater - This section does not mention Meiners Oaks Water District concerns that silt will plug groundwater wells.
During the recent meeting, the consultants referenced case studies that demonstrate minimal impacts to groundwater pumping from silt-laden surface flows. This information and studies should be included in the final report.

The ***Task 3.3 Water Supply Mitigation*** report identifies several contingency measures that would provide adequate assurance that water supply reliability will be maintained during the short period of sediment release and/or if silt affects downstream wells. These include using Casitas water as backup/replacement supply, backflushing wells if silt does pose a problem, and CMWD Water Treatment Plant System Modifications.

Aside from these immediate contingency measures, conservation provides the greatest opportunity to offset any additional loss of water supply and provides a long-term benefit to the watershed, assuming that the yield is not seen as a new or "surplus" supply to induce growth.

Recommendations:

1. Pursue DRC-2 as the least cost, least impact, greatest benefit project
2. Re-examine downstream mitigation components for further cost reduction
3. Use consensus as a path forward for funding
4. Assess non-federal funding options to piece together State and local resources
5. Develop a Ventura River Parkway and Restoration Plan to solidify public support for local funding initiative

1. Pursue DRC-2 as the least cost, least impact, greatest benefit project
Of the alternatives analyzed, the low-level orifice concept provides the greatest potential benefit with the least impact. Because this is also the lowest cost approach, it is likely the most achievable in a reasonable timeframe given the current funding constraints.

2. Re-examine downstream mitigation components for further cost reduction
Further cost reductions may be possible by re-examining previously identified mitigation measures. Additional analysis should be conducted to reevaluate the downstream project components, such as levees and water supply mitigation, for potential project cost reductions. For example, the flood control objectives of the proposed Meiners Oaks levee may be achieved with a buried floodwall, which would not only reduce the long-term O&M costs but also minimize the impacts associated with a standard levee design (i.e. fencing, pesticides, herbicides, aesthetics, public access, etc.)

3. Use consensus as a path forward for funding
In recent years it has been difficult to develop a path for funding the project. Although everyone has agreed that Matilija Dam needs to be removed, the lack of project consensus has been problematic. There is now an opportunity to build support around a more affordable least impact project that everyone can agree on.

4. Assess non-federal funding options to piece together State and local resources
Regardless of whether this is a federal or nonfederal project, it will likely require at least $40 million in non-federal monies. This will require a mix of State, local, and private funding.

5. Develop a Ventura River Parkway and Restoration Plan to solidify public support for local funding initiative
The Ventura River Parkway has a strong local constituency with the Friends of the Ventura River coalition of local organizations. Recent progress includes National Recreation Trail designation of the Ventura River/Ojai Valley bike path, acquisition and restoration of hundreds of acres of floodplain and adjacent upland, and a growing recreation trail network. Incorporating public amenities into a Ventura River Parkway and Restoration Plan that includes Matilija Dam removal will help solidify public support for a dedicated local funding initiative.

On behalf of the Matilija Coalition I would like to thank the Ventura County Watershed Protection District for its ongoing support of this project, and the California Coastal Conservancy for sponsoring these important studies. We anticipate that the stakeholder group will reach consensus on a path forward, and look forward to continued progress in the near future.

Sincerely,

A. Paul Jenkin

A. Paul Jenkin
Coordinator, Matilija Coalition
Ventura Campaign Coordinator, Surfrider Foundation
(805) 205-4953 pjenkin@surfrider.org

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
501 West Ocean Boulevard, Suite 4200
Long Beach, California 90802-4213

October 15, 2015

Tully Clifford, Director
Ventura County Watershed Protection District
800 So. Victoria Avenue,
Ventura, California 93003

RE: Matilija Dam Removal, Sediment Transport, and Robles Diversion Mitigation Project

Dear. Mr. Clifford:

NOAA's National Marine Fisheries Service has reviewed the two studies conducted by AECOM and Stillwater Sciences for the Ventura County Watershed Protection District (County) (Draft Dam Removal Concepts Evaluation Report, and Draft Water Supply Mitigation Concepts Evaluation Report, August 13, 2015) and hereby provides the County with preliminary comments on these two documents.

To begin with, we acknowledge the work of the County, consultants, and the various Matilija technical advisory groups in preparing these studies. These investigations have identified, at a conceptual level, a number of technically feasible, environmentally sound, and economically attractive alternatives for the removal of Matilija dam and the management of sediments, particularly fine sediments.

All three of the alternatives appear superior to the 4B alternative initially authorized by the Water Resources Development Act (WRDA) of 2007, in terms of costs, constructability, and environmental impacts and benefits. Of the three alternatives identified, Alternative DRC-2A and 2B (double bore holes) warrants further focused analysis, while potentially including elements of Alternative DRC-3 (temporary sediment storage). Based on the level of information and analysis provided in the studies, Alternative DRC-1 (bypass tunnel) has more components adding to the costs and uncertainties, making further development of that alternative a lower priority.

While the matrix of potential mitigation measures indicates that several actions might be feasible, the actual need for specific mitigation measures is not supported by the analysis; the retained options would be better characterized as "contingency" actions, pending the completion of an analysis that demonstrates they are in fact mitigations that address identified impacts. This should be the focus of follow-up design work.

Our detailed comments and suggested changes to the studies are contained in the enclosure. We hope these comments will be useful in finalizing both draft reports and provide guidance in taking the next steps in finalizing and implementing plans for the removal of Matilija Dam and the restoration of the Ventura River ecosystem.

If you have a question regarding these comments, please contact either Mark H. Capelli at (805) 963-6478 (mark.capelli@noaa.gov) or Brian L. Cluer at (707) 575-6061 (brian.cluer@noaa.gov).

Sincerely,

Anthony P. Spina
Chief, Southern California Branch
California Coastal Office

Enclosure

cc: Peter Shedaydi, Ventura County Watershed Protection District
Mary Larson, California Department of Fish Wildlife
Chris Dellith, U.S. Fish and Wildlife Service
Kevin Cooper, U.S. Forest Service
Kristi Klose, U.S. Forest Service
Steve Wickstrum, Casitas Municipal Water District
Darrel Buxton, U.S. Army Corps of Engineers
Sam Jenniches, California Coastal Conservancy
Administrative File: 151422SWR2002PR8272

COMMENTS OF NOAA'S NATIONAL MARINE FISHERIES SERVICE ON THE DRAFT DAM REMOVAL CONCEPTS EVALUATION REPORT AND THE DRAFT WATER SUPPLY MITIGATION CONCEPTS EVALUATION REPORT

October 14, 2015

Draft Dam Removal Concepts Evaluation Report

1.1 Project Background

Page 1

Lines 16-17. Suggest modifying the sentence to read "was one of the most productive steelhead spawning and rearing habitats in the Ventura River system, and provided important refugia habitat within the Los Padres National Forest."

Page 6

Lines 1-12. Suggest you modify the sentence to read "concerns over cost, constructability, and habitat and visual impacts, of the downstream disposal options for the fine sediment."

2.0 Project Objectives & Evaluation Criteria

Page 8.

2.1 Project Objectives

Line 13. Please clarify what is meant by "within the context of the federally authorized project." Alternatives DRC-1, DRC2A, and DRC-2B are substantially different from the 4B federally authorized project, and the consistency of Alternative 3 with the COE WRDA authorized project is unclear. It should also be noted that these new alternatives are not the COE WRDA authorized project covered by NMFS's Biological Opinion for the Matilija Dam Ecosystem Restoration Project.

The phrase "within the context of the federally authorize project" should be omitted to avoid any ambiguity and ensure consistency with a later statement that such an evaluation is not within the scope of the study plan.

3.0 Concept Descriptions

Page 13.

Lines 17-18. Please specify the nature and scope of "future fine sediment characterization" studies (either here or in some other part of the study); such studies should include characterization of where organic sediments are concentrated.

3.1 Dam Removal Concept 1: Containment Berm with High Flow Bypass

Page 14.

Line 7. Please also express the discharge of 1,700 cubic feet per second in terms of a flood-frequency return interval.

Page 15.

Figure 3.1.1

Please clarify how juvenile or adult steelhead would migrate around the downstream temporary sediment containment berm under varying flow conditions, or the timing of its removal or modification, to allow steelhead passage in conjunction with the upstream cofferdam.

3.3.1 Bypass Tunnel

Page 16.

Lines 10-19. Please explain how large sediment (boulders) or woody debris originating from upstream would be either kept out of the bypass tunnel or be removed to prevent the blockage of flows or the unplanned breaching of the cofferdam. The study notes that the vertical orientation of the geologic formation through which with the tunnel would be carved could potentially contribute to the sediment loading within the bypass tunnel. This is one of a number of uncertainties with Alternative DRC-1. Others include how the abandonment of the tunnel would be accomplished, and the management of the downstream temporary containment berm. We also note that during the during period the tunnel would be used to bypass Matilija Creek flows it would be accessible from both Matilija Canyon Road and Highway 33 and could be an attractive nuisance, and its subsequent sealing could result in visual impacts from the two public roadways.

3.1.3 Temporary Containment Berm

Page 18.

Line 5. A 5-year storm event is not 115 cfs as indicated; this return interval should be re-calculated.

Pages 17-18.

See comment above temporary containment Berm.

3.3 Dam removal Concept – 3: Temporary Upstream Storage of Fine Sediment

Page 24.

Lines 12-17. The temporarily stored sediments would be considerably above the new surface flows (and groundwater) level as a result of the pilot channel excavation. These would most likely result in conditions unconducive to the support of riparian vegetation. The situation could persist for some extended period (years or decades), resulting in the extended loss of the existing vegetation until the sediments had been eroded down to the pre-dam streambed elevation. This aspect of DRC-3 should be reflected in the brief discussion of impacts to existing vegetation communities.

4.0 Technical Assessments

Page 28.

Lines 6-9. The temporary storage of sediments in the reservoir area could persist for a number of years (perhaps decades). This impact extends beyond the existing vegetation to include future vegetation succession, and is therefore a long term effect which would delay or prevent the reestablishment of certain vegetation communities, particularly riparian. See comment above.

4.0 Technical Assessments

4.2 Erosion and Transport of Impoundment Sediments

4.2.2 Organic Concentrations

Page 46.

Lines 18-19. See comments above specifying the nature and scope of "future fine sediment characterization" studies.

4.4 Steelhead Health Downstream of the Matilija Dam Site

Pages 59-60.

Lines 1-8. The question of the lethal and sub-lethal effects on steelhead is complex. No study on the behavior or tolerance of steelhead in the southern extreme of their range, where sediment loading is periodically and naturally extremely high, have been conducted. However, *Oncorhynchus mykiss* have been shown to exhibit a higher level of tolerance to sediment than other *Oncorhynchus* species (See for example, T.C. Bjorum *In* Stoltz and Schnell (ed.) Trout (1991). The analysis presented in this study should therefore be considered conservative, in the sense that is may over-estimate the projected sediment level effects on *O.* mykiss in the Ventura River system.

Figures 4.4-1, 4.4-2 and 4.4-3 See comment above regarding sediment impacts on *O. mykiss.*

Lines 8-12. Matilija Creek itself is one of several tributaries to the Ventura River, with several sub tributaries (*e.g.*, Upper North Fork, Murrieta Creek).

5.0 Results and Discussion

5.1 Steelhead Passage through the Project Area

Page 67.

Lines 26-29. While the waiting period for a large sediment-mobilization event associated with alternative DRC-3 is similar to DRC-1 and DRC-2, the time for the complete evacuation of the temporarily stored and protected sediments would likely take much longer because of the storage of sediments dredged from the pilot channel, and the temporary erosion protection. See comment above.

5.2 Steelhead Health

5.2.1. Impacts Under DRC-1

Page 69.

Lines 19-22 See comments above regarding projected impacts of elevated sediments on steelhead.

5.2.3 Impacts Under DRC-3

Page 71.

Lines 13-21 As noted above the projected levels of elevated sediments (on a periodic basis) could be extended over a considerable period of time (multiple years) as a result of the temporary stock-piling of sediments within the reservoir area. This is a potentially significant difference between alternatives DRC-1 and DRC-2. See comment above.

5.2.4 Summary

Page 71.

Lines 24-25 Suggest changing the phrase "with a one-time loss of most if not all fish in the system" to "with a potential loss of a significant number of fish, including but not limited to steelhead, and other aquatic organisms in the project area and downstream in Matilija Creek and the mainstem of the Ventura River . . . ," See comments above regarding sediment impacts on steelhead.

5.7 Water Supply

5.7-2 Water Supply Criteria Results

Lines 13-15. Phase II impacts on riparian vegetation for DRC-3 could be extended over a considerable period of time (multiple years) as a result of the temporary stock-piling of sediments within the reservoir area. This alternative could result in extending impacts on water quality/supply and riparian vegetation. This is a potentially significant difference between alternatives DRC-1 and DRC-2. These impacts should be reflected the brief discussion on DRC-3 vegetation impacts, as well as in section 5.2.3. See comments above.

Page 90.

Lines 3-6. Please clarify what is meant by drop in storage by 15%. Is this 15% of the total potential storage capacity of the Casitas Reservoir, or a 15% reduction in what would have otherwise been diverted and stored without the projected disruption in diversions?

Draft Water Supply Mitigation Concepts Evaluation Report

1.0 Introduction

Page 3.

Lines 17-17. The need for specific mitigation measures is not supported by the analysis; the options would be better characterized as "contingency actions" and should be described as such, pending the completion of an analysis that demonstrates that they are in fact mitigations that address identified impacts. This should be the focus of follow-up design work. Also, as noted above, the new alternatives to which these mitigation concepts are intended to apply are not the COE WRDA authorized project covered by NMFS's Biological Opinion for the Matilija Dam Ecosystem Restoration Project.
See additional comments below regarding impacts on groundwater well field operations.

4.0 Potential Impacts to Providers

4.1 Increased Suspended Sediment

Page 17.

Lines 9-14. While the Phase II impacts of alternatives DRC-1, DRC-2, and DRC-3 are broadly equivalent, Phase II impacts on riparian vegetation within the reservoir area for DRC-3 could be extended over a considerable period of time (multiple years) as a result of the temporary stock-piling of sediments within the reservoir area. This is a potentially significant difference between alternatives DRC-1 and DRC-2 which do not involve temporary storage and erosion protection of sediments, and should be reflected in the brief discussion in section in 4.1. See comments above.

4.1.2 Groundwater

Page 18.

Lines 2-12. The finding that elevated suspended sediments in the Ventura River from the various removal alternatives would not adversely impact groundwater supplies (as a result of the infiltration into the aquifer) and related groundwater extraction operations is significant new information. We believe this finding obviates the need for some of the mitigations identified in the report, specifically new well heads at Foster Park. See additional comments below.

5.0 Mitigation Options

Page 21.

Line 1. Re-title this section "Contingency Options".

Page 21.

Lines 3-5. This section needs to further develop the option to avoid surface diversions when Phase I sediment impacts are expected. This would include, in addition to the deployment of the gates associated with DRC-2B, the potential manipulation of fine sediments between storm flows to facilitate their evacuation in subsequent storm events. Additionally, the need for any water supply mitigation during Phase II impacts should be clearly related to actual impacts The uncertainties in hydrology that may manifest during and shortly after dam removal is likely the greatest source of uncertainty in all of the alternatives. Further analyzing multiple possible hydrologic scenarios to refine dam removal timing and adaptive management measures would further reduce uncertainty in water supply and further identify the scale and type of potential mitigation needs.

5.1 Types of Mitigations

Page 21.

Table 5-1 Summary of Mitigation Alternative Types.

See comment above regarding new well heads at Foster Park.

5.3 Description and Evaluation of Mitigation Options

5.3.1 Diversion Replacement (Full or Partial)

Lines 6-8. All three of these options (Matilija Creek Diversion to Robles-Casitas Canal; North Fork Matilija Diver to Roble-Casitas Canal; Matilija Creek Diversion to North fork Matilija Diversion to Roble-Casitas Canal) could potentially adversely impacts steelhead as well as other aquatic organisms and riparian vegetation, and these potential impacts should be acknowledged in the environmental evaluation summaries.

5.3.1.1 Matilija Creek Diversion to Robles-Casitas Canal

Page 24.

Lines 29-30. See comment above regarding environmental impacts.

5.3.1.2 North Fork Matilija Creek Diversion to Robles-Casita Canal

Page 25.

Lines 16-17. See comment above regarding environmental impacts.

5.3.1.3 Matilija Creek Diversion to North Fork Matilija Creek Diversion to Robles-Casitas Canal

Lines 25-26. See comment above regarding environmental impacts.

Lines 8-9 See comment above regarding environmental impacts.

5.3.2.1 Infiltration Galleries

Page 27.

Lines 1-2 See comment above regarding environmental impacts.

5.3.2.5 New Well Heads at Foster Park

Page 30.

Lines 17-26. As noted above, the finding that elevated suspended sediments in the Ventura River from the various removal alternatives would not adversely impact groundwater supplies and related groundwater extraction operations obviates the need for the mitigations identified for the wells at Foster Park.

Lines 31-36. The installation and operation of new well heads at the Foster Park wells, with increased pumping capacity, could potentially adversely impact steelhead and designated steelhead critical habitat in the Ventura River. The magnitude, timing and duration of surface flows, and thus the quantity and quality of critical habitat, within the lower Ventura River could be affected by the operations of these wells to varying degrees, depending on the time of year, the amount of rainfall during the wet season, and the rate of withdrawals from the wells.

The principal potential adverse effect of well operations in the Foster Park area are the loss of summer rearing habitat for juvenile steelhead as well as other aquatic organisms. However, adverse effects could also occur to migrating adult steelhead, spawning steelhead, eggs and fry if flows are reduced to critical levels during adult steelhead migration and spawning.

Potentially all juvenile steelhead in the Ventura River watershed could use the Foster Park area at some point in their life cycle, either for rearing or as a migration corridor on their return to the ocean. Consequently, pumping from these wells has the potential to affect all juvenile steelhead in the watershed, and this has implications for the survival, abundance, productivity, and spatial structure of the Ventura River steelhead population.

Finally, recent studies and computer modeling of precipitation for Southern California over the next hundred years show a potential increase in weather extremes, and a slight to modest decrease in annual precipitation occurring by the year 2100 (see for example, Cayan, *et al.* 2007, Climate Change Scenarios for the California Region. *Climate Change* DOI 10,1007). This predicted decrease in the average annual rainfall is expected to result in a greater frequency of dry rainfall years, and an increased frequency and duration of dry hydrologic conditions in the Ventura River Watershed. The increased frequency of dry conditions resulting from climate change would be exacerbated by withdrawals from the Foster Park wells.

5.3.3.1 Water Re-Use

5.5.5.1.1 Ojai Valley Water Treatment Plant

Page 32.

Lines 29-32. The requirement that all effluent be discharged to the Ventura River to maintain aquatic habitat, including fish habitat, is also part of the Conditional Use Permit issued by the County of Ventura for the reconstruction of the Ojai Valley Waste Water Treatment Plant.

5.4 Evaluation Matrix

Page 44.

Table 5-1. Evaluation Mitigation Alternatives

The "New Well Heads at Foster Park" should be deleted; as noted above this type of mitigation is problematic because it does not mitigate an identified impact and it has potentially significant adverse impacts on aquatic resources, including, but not limited to steelhead. Additionally, the three diversion replacement mitigations are also problematic, and should not be pursued further. See comments above.

From: Jeff Palmer [mailto:Jeff.Palmer@ojaisan.org]
Sent: Thursday, September 17, 2015 9:27 AM
To: Sheydayi, Peter <Peter.Sheydayi@ventura.org>
Cc: Steve Wickstrum (swickstrum@casitaswater.com) <swickstrum@casitaswater.com>
Subject: Draft Matilija Dam Mitigation Report

Peter,

In reviewing the Draft report, there is a section regarding OVSD. I will be sending you a formal letter with comments, however, there are two areas of concern:

1. I didn't see any reference to any mitigation for our collection system facilities along the main stem of the Ventura River. We have extensive trunklines, manholes, metering stations, siphons, force mains and pump stations that all are within the impact area and could face significant impacts. Those facilities and locations need to be identified, studied and appropriate mitigations and funding sources identified prior to any project consideration.
2. The treatment plant DOES NOT provide title 22 water that meets State guidelines for reuse. There are significant issues related to permitting, environmental impacts and costs that also need to be identified prior to the Plant water being earmarked as a source of water.

Please feel free to contact me if you have any questions.

Jeff Palmer

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OJAI VALLEY SANITARY DISTRICT
A Public Agency
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September 23, 2015

Peter A. Sheydayi, P.E., D.WRE
Deputy Director, Design and Construction Division
Ventura County Watershed Protection District
800 S. Victoria Avenue Ventura, CA 93009-1610

Subject: Draft Dam Removal Concepts Evaluation Report, Dated August 13, 2015 and Matilija Dam Ecosystem Restoration Project, EIS, F5 Milestone Report Dated July 2004

Dear Peter:

On September 17, 2015, the DOG/TAC for the Matilija Dam Removal Project met to discuss the Dam Removal/Robles Mitigation Study by URS and Stillwater Sciences consultant team. The Ojai Valley Sanitary District (OVSD) Staff has reviewed the referenced studies both from 2004 and 2015 as it relates to existing sanitary sewer facilities downstream of the subject site.

OVSD provides sanitary sewer services to the unincorporated area along the Ventura River, south of the Robles Diversion Structure. The OVSD Treatment Plant is a modern tertiary treatment plant located at the mouth of the Ojai Valley, just southerly of Foster Park. OVSD has numerous facilities located along, under and adjacent to the Ventura River over Reach Nos. 3, 4 and 5, as shown on page 4-2 of the 2004 Study. These facilities include trunk lines, metering stations, manholes, pump stations, force mains and the treatment plant.

In reviewing both the 2004 and 2015 Studies and considering the infrastructure integrity, water quality, environmental and permitting issues that OVSD currently operates under, we have some concerns about the proposed Dam Removal alternatives and related hydraulic analysis, scour and river configuration analysis, floodplain change and mitigation measures outlined in your Studies. The 2015 Study appears to introduce new removal alternatives that have different and more potentially significant hydraulic impacts to the river south of the Robles Diversion. These new and more significant impacts need to be studied to determine more appropriate mitigation measures as it relates to impacts to the OVSD Collection System and Treatment Plant.

Your Studies suggests that the preparation of these updated studies is a step in determining the preferred removal option. From OVSD's perspective, the next step should be to update the Ventura River hydraulics analysis to determine the effects of creating an intentional significant "flushing" event to carry a significant amount of debris down the river to the ocean. The debris amounts considered, under natural conditions, would be carried over many events, possibly over many years. The intentional "flushing" event will attempt to do this in one event creating un-natural and artificially intense hydraulic flow conditions.

We believe that the following questions should be answered before any additional steps are taken.

1. What will the impacts be to the river and adjacent property from the Robles Diversion to the Treatment Plant and to the ocean?

2. How will the river hydraulics, grades, channel location and braiding, freeboard depth, and what scour depths result from the proposed plan?

3. How will the beneficial uses, environmental conditions and water quality be impacted and mitigated?

4. What protection measures are needed to protect the Sanitary Sewer System and Treatment Plant from impacts?

5. What are the costs associated with those impacts and protection measures?

6. What are the environmental and right of way impacts and costs of those mitigation measures?

7. At this time, there is no definitive review or conclusions regarding the answers to these questions.

Before any decision is made regarding the preferred plan, options, mitigations, costs or schedules, there must be a clear understanding of the project impacts and that: (1) the project alternatives will not degrade water quality or impact beneficial uses, (2) OVSD and our rate payers will not be unduly burdened by costs and liabilities, and (3) that OVSD facilities will not be put at risk by impacts related to the hydraulic silt flushing or dam removal related impacts.

We are more than willing to meet and discuss the project, our facilities and appropriate mitigation and protection issues.

Best Regards,

Jeff Palmer, P.E.
General Manager

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STOECKER ECOLOGICAL℠
NATURAL RESOURCE ASSESSMENT AND RESTORATION SERVICES

Tully Clifford, Director October 16, 2015
Ventura County Watershed Protection District
800 S. Victoria Ave.
Ventura, CA 93003

RE: Matilija Dam Removal and Sediment Management Alternatives

Dear Tully,

Thanks for receiving and compiling stakeholder comments on the recent dam removal and water supply concept reports from Stillwater Sciences and AECOM. The results of this study effort are highly encouraging and identify alternatives to effectively remove Matilija Dam while safeguarding water supplies, watershed health, and the public.

For reasons described in the reports, and the clear advantages from an ecological, risk, and cost standpoint, we support Alternative 2 (A or B). From a steelhead recovery and fish passage perspective, this "Condit-type" orifice dam removal and sediment transport strategy has been shown to be highly effective on Washington's White Salmon River. With the lowest cost of all three alternatives, Alternative 2 also make the potential for a locally led and funded project more feasible. Alternative 2 also appears to be acceptable, even preferable, to Casitas water interests and rapid transport of sediment to the coast with reduced long-term sedimentation risks. We support moving forward with final design planning efforts for Alternative 2A and 2B.

Alternative 3 is less attractive at roughly double the cost of 2A, with elevated engineered channel failure and fish passage risks, and reduced riparian restoration potential. Some level of temporary sediment storage, identified in this alternative, could be incorporated into final design planning and/or adaptation strategies for Alternative 2.

I agree with the report findings that Alternative 1 is the least attractive and with the highest risk. In fact, there are additional problems with this proposal not identified in the reports that I would like to see discussed briefly in the final draft and outlined below. I do not support Alternative 1 moving forward.

Alternatives 2A or 2B (and to a lesser degree Alternative 3) perform better than the previously authorized Alternative 4B from an economic, risk, and ecological perspective. I am also confident that the level of support from the public, permitting agencies and funders will be much great for Alternatives 2 or 3 than for the previous 4B concept. As noted in the additional comment section below, I also believe that a less expensive and potentially locally funded project has a greater likelihood of materializing than one that it dependent on approval by Congress. This political reality and risk needs to be considered as we select a preferred alternative.

Additional report comments and requests are included below. I hope these comments will help to finalize the reports, move us forward with a design alternative, and take the next steps towards permitting and implementing this historic project. On behalf of Patagonia, and representing them on the Matilija Technical Advisory Committee process, thank you for including us in this planning effort. We look forward to helping build the support needed to remove this dam.

Please let me know if you have any questions.

Sincerely,

Matt Stoecker

Matt Stoecker

Biologist
Stoecker Ecological
(650) 380-2965

Additional Report Comments and Requests

Alternative DRC-1

- There is no mention in the report that the proposed bypass tunnel, and increased flows to the N.F. Matilija Creek, present a serious risk to needed steelhead passage to (and refugia benefits from) this critical tributary during the construction impacts downstream. The report does mention the importance of tributary refuge habitat during construction projects in general, but does not include the importance of this specific tributary just downstream from identified impacts from this particular project. The rock quarry immediately downstream from the proposed bypass tunnel outlet has a long history of causing fish passage impediments due to rock slides, Highway 33 constrictions points, and the tricky hydraulics and drops in this narrow and modified reach. Adding potentially high Matilija Creek flows to this smaller tributary could produce excessive hydraulics and resume mobilization of the quarry rockslides and Highway 33 bank protection features. This has the potential to cause new migration impediments to steelhead seeking refuge from the downstream impacts of dam deconstruction. I request that the report identify this risk and note that NF Matilija Creek, below the bypass tunnel outlet, would also become part of an expanded "project construction site" area and experience additional construction impacts.

- Sections 4 and 5 describe DRC-1 and DRC-2 as having similar outcomes for steelhead health downstream with regards to TSS and anoxic conditions. It is important for the report to note that DRC-1 has significantly more risk than DRC-2 due to the likelihood that DRC-1 can result in reduced steelhead access to the NF Matilija Creek when this refuge is most critically needed during and following dam removal. Risking steelhead access to the only perennial, clear tributary downstream of the construction site, and during post removal sediment transport events, would be counter to ensuring steelhead survival during and after dam removal conditions. The same is true for rainbow trout upstream of the dam and other aquatic wildlife seeking refuge from dam removal conditions while migrating along the mainstem of Matilija Creek and upper Ventura River. I request that the report note this additional steelhead risk for DRC-1 and that it does not occur with DRC-2 or 3.

- The Costs and Risk section should include a brief mention of additional issues related to the DRC-1 bypass tunnel including the potential for needing to: 1) move quarry/Highway 33 bank protection boulders and ensure fish passage downstream of the outlet during and post project, 2) potential to have to transport fish if the tributary becomes impassable, and 3) potential spring or creek flow impacts from groundwater modifications caused by boring the tunnel.

DRC-3

- I request that the report identify post dam removal engineered channel risks with regards to potential fish passage blockages resulting from channel, bank, or sediment stockpile failures.

Political Reality

-While not discussed as a cost or risk in the report, at this stage in our planning efforts it would be irresponsible to not recognize the political reality that getting Congress to authorize any dam removal project effort at Matilija is unlikely. In fact, there are currently multiple high ranking congressman publically and adamantly opposed to allowing any federal funding for any dam removal projects nationally due to their ideology and defense of dams in their regions. Congressional authorization and funding for the widely supported Klamath dam removal effort is currently stalled because of these political tactics. For these reasons, I believe that binding the Matilija project to Congressional approval is likely to prevent the project from moving forward. Fortunately, with the dramatically lower price tag of Alternative 2 over the previous Alternative 4B, I believe the project can be more effectively led and funded locally with State, County, NGO, foundation, private, and even Federal support that does not require a vote in Congress (ie NOAA Fisheries grant funding).

Comparison to old Alternative 4b - Section 6.0 #1

-I believe the report language here overstates that Alternative 4b might achieve fish passage conditions faster than DRC-1, 2, or 3. A sentence should be added here identifying the potential for sediment stockpile and engineered channel mobility and chronic fish passage and/or turbidity problems (and the need for intervention) that may not be associated with DRC-2.

Project impacts to downstream wildlife

-It would be helpful if the report included a quick note that steelhead and other aquatic wildlife impacts can be reduced by 1) capturing and relocating migrating aquatic species upstream and downstream of the project site 2) encouraging and allowing upstream migrating fish and aquatic species to seek refuge in NF Matilija Creek 3) pre-project collection and relocation of native species (and elimination of non-native species) within the project stream reach. Collectively, these and other actions can reduce the negative construction impacts downstream that are outlined in the report and promote the rapid return and recolonization of aquatic species to the project site after construction.

MATILIJA DAM REMOVAL, SEDIMENT TRANSPORT, AND ROBLES DIVERSION MITIGATION PROJECT

DAM REMOVAL CONCEPTS EVALUATION REPORT

MARCH 2016

ATTACHMENT 6: COMMENT RESPONSE MATRIX

Matilja Dam Removal, Sediment Transport, and Robles Diversion Mitigation Project
DOG Comments on Draft Dam Removal Concepts Evaluation Report, dated 8/13/15

Comment Response Matrix

Item	Chapter/ Section	Page #	Line Number(s)	Reviewer Agency	Comments	Comment Reference	Response
1				Stoecker Ecological	For reasons described in the reports, and the clear advantages from an ecological, risk, and cost standpoint, we support Alternative 2 (A or B). Alternative 3 is less attractive at roughly double the cost of 2A, with elevated engineered channel failure and fish passage risks, and reduced riparian restoration potential. I agree with the report findings that Alternative 1 is the least attractive and with the highest risk. I do not support Alternative 1 moving forward. Alternatives 2A or 2B (and to a lesser degree Alternative 3) perform better than the previously authorized Alternative 4B from an economic, risk, and ecological perspective. **See Stoecker EXCERPT #1 from comment letter for detailed comments.**	Letter dated Oct 16, 2015	Noted.
2				Stoecker Ecological	DRC-1: There is no mention in the report that the proposed bypass tunnel, and increased flows to the N.F. Matilija Creek, present a serious risk to needed steelhead passage to (and refugia benefits from) this critical tributary during the construction impacts downstream. I request that the report identify this risk and note that NF Matilija Creek, below the bypass tunnel outlet, would also become part of an expanded "project construction site" area and experience additional construction impacts. **See Stoecker Excerpt #2 from comment letter for detailed comment.** **Same comment in email**	Letter dated Oct 16, 2015, Email dated Sep 11, 2015	A paragraph has been added at the end of Section 4.3 in acknowledgment of the potential issue that is raised here. The risk has also be added to Table 5.6-1 Risk Management Scores Summary, and the alternatives were scored accordingly. We do not concur that this risk warrants expanding the project construction site limits.
3	Sections 4 and 5			Stoecker Ecological	DRC-1: Sections 4 and 5 describe DRC-1 and DRC-2 as having similar outcomes for steelhead health downstream with regards to TSS and anoxic conditions. It is important for the report to note that DRC-1 has significantly more risk than DRC-2 due to the likelihood that DRC-1 can result in reduced steelhead access to the NF Matilija Creek when this refuge is most critically needed during and following dam removal. I request that the report note this additional steelhead risk for DRC-1 and that it does not occur with DRC-2 or 3. **See Stoecker Excerpt #3 from comment letter for detailed comment.** **Same comment in email, more detailed version in comment letter.**	Letter dated Oct 16, 2015, Email dated Sep 11, 2015	The tunnel will be dry when the dam is breached (since all the water's going through the reservoir area). Thus, it's not clear why DRC-1 would preclude refugia in the N Fork when the dam is breached.
4	Sections 5.5 and 5.6				DRC-1: The Costs and Risk section should include a brief mention of additional issues related to the DRC-1 bypass tunnel including the potential for needing to: 1) move quarry/Highway 33 bank protection boulders and ensure fish passage downstream of the outlet during and post project, 2) potential to have to transport fish if the tributary becomes impassable, and 3) potential spring or creek flow impacts from groundwater modifications caused by boring the tunnel. **Same comment in email.**	Letter dated Oct 16, 2015, Email dated Sep 11, 2015	Bank protection in NF Matilija is discussed in Section 3.1.1. Risk to fish passage in NF Matilija was addressed in response to comment #2. Low flow impacts in Matilija Creek (occurring pre-flush as flows are diverted into the bypass tunnel) are addressed in the risk management section (Section 5.6).
5	DRC-1			Stoecker Ecological	DRC-1: I think the report should note that there is potential for additional vegetation/riparian disturbance with this alternative due to bypassing flows into the NF Matilija Creek and anticipated issues with fish passage barrier mobility, bank/Highway 33 erosion, and potential need for intervention. The report should also note that NF Matilija Creek, below the bypass tunnel outlet, would become part of the "project site" area and experience the associated impacts.	Email dated Sep 11, 2015	Issues raised in this comment have been addressed in response to comments #s 2-4.
6	DRC-2A			Stoecker Ecological	DRC-2A: As with the report conclusions, this alternative is my preferred choice from an ecosystem, risk, and cost perspective.	Email dated Sep 11, 2015	Noted.
7	DRC-3			Stoecker Ecological	DRC-3: I request that the report identify post dam removal engineered channel risks with regards to potential fish passage blockages resulting from channel, bank, or sediment stockpile failures. **Same comment in email.**	Letter dated Oct 16, 2015, Email dated Sep 11, 2015	The risk of temporary passage issues associated with redistribution of engineered channel protection and/or sediment stockpile failure is considered in Table 5.6-1 (Risk Management Summary). See the "Post-Storm Flush" portion of the table.
8	DRC-3			Stoecker Ecological	DRC-3: The higher level of vegetation disturbance, less resulting riparian vegetation, and more than double the cost of DRC-2 is a big negative.	Email dated Sep 11, 2015	Noted.

Item	Chapter/ Section	Page #	Line Number(s)	Reviewer Agency	Comments	Comment Reference	Response
9				Stoecker Ecological	Political Reality: While not discussed as a cost or risk in the report, at this stage in our planning efforts it would be irresponsible to not recognize the political reality that getting Congress to authorize any dam removal project effort at Matilija is unlikely. Fortunately, with the dramatically lower price tag of Alternative 2 over the previous Alternative 4B, I believe the project can be more effectively led and funded locally with State, County, NGO, foundation, private, and even Federal support that does not require a vote in Congress (ie NOAA Fisheries grant funding). **See Stoecker Excerpt #4 from comment letter for detailed comment.**	Letter dated Oct 16, 2015	Noted. The Management Team's preference is to keep this report technical in nature and to refrain from including political challenges. Both federal and other funding opportunities are being investigated.
10	Section 6.0 #1			Stoecker Ecological	Comparison to old Alternative 4b: I believe the report language here overstates that Alternative 4b might achieve fish passage conditions faster than DRC-1, 2, or 3. A sentence should be added here identifying the potential for sediment stockpile and engineered channel mobility and chronic fish passage and/or turbidity problems (and the need for intervention) that may not be associated with DRC-2. **Same comment in email**.	Letter dated Oct 16, 2015, Email dated Sep 11, 2015	Language added to Section 6 to address comment. See last sentence in #1 of comparison numbered list.
11				Stoecker Ecological	Project impacts to downstream wildlife: It would be helpful if the report included a quick note that steelhead and other aquatic wildlife impacts can be reduced by 1) capturing and relocating migrating aquatic species upstream and downstream of the project site 2) encouraging and allowing upstream migrating fish and aquatic species to seek refuge in NF Matilija Creek 3) pre-project collection and relocation of native species (and elimination of non-native species) within the project stream reach. Collectively, these and other actions can reduce the negative construction impacts downstream that are outlined in the report and promote the rapid return and recolonization of aquatic species to the project site after construction. **Same comment in email with the following added:** In other words, describe that there are measures, and downstream tributary refuge, that can minimize the downstream steelhead (and other wildlife) health risks identified during the first few hours/days following dam removal.	Letter dated Oct 16, 2015, Email dated Sep 11, 2015	Agreed, suggested best management practices have been included at the end of Section 5.2.4 (Summary)
12	Section 3.0			Stoecker Ecological	Other Report Comments: Report maps (Fig. 3 section) incorrectly show N.F. Matilija Creek not crossing under Highway 33 downstream from where the bypass tunnel outlet. The creek occurs on the north side of H33 for most of this reach. This is a critical consideration due to the highly modified and constricted channel conditions, as noted above, and elevated flows from a bypass tunnel.	Email dated Sep 11, 2015	Figures have been updated.
13				Matilija Coalition	The studies presented in the Matilija Task 1.3 Draft Concepts Evaluation Report benefit from information that was not available during the federal feasibility study of 2001-2004. Since then, several large dams have been removed from rivers on the west coast of the United States, and much has been learned. We now have real world examples demonstrating the power and resilience of riverine ecosystems to restore themselves, if given the chance. This provides a scientifically justified opportunity to take advantage of the energy of the Ventura River, saving tens of millions of dollars over mechanically moving and disposing of sediment, while significantly reducing the environmental footprint of the project. **See Matilija Coalition EXCERPT #1 from comment letter for detailed comment.**	Letter dated Oct 17, 2015	Agreed. Many of our assessments are based on lessons learned or post flush monitoring data from other implemented dam removal projects (e.g. Condit, Marmot, etc.).
14				Matilija Coalition	DRC-2: The analysis demonstrates that DRC-2, the low level orifice concept, provides the greatest benefits and least impact of the alternatives analyzed. This validates our previous comments, which have consistently advocated for natural transport of the sediments sequestered behind the dam. Because this is also the lowest cost approach, it is likely the most feasible from a funding standpoint.	Letter dated Oct 17, 2015	Noted.
15	Project Alternatives			Matilija Coalition	DRC-3: DRC-3, the upstream sediment storage alternative essentially optimizes the “Alternative 4b” previously identified in the federal feasibility study completed in 2004, by eliminating the problematic slurry and disposal of fine sediments. However, the greater cost and increased impact caused by mechanical transport of a portion of the sediment make this less desirable than DRC-2.	Letter dated Oct 17, 2015	Noted.

Item	Chapter/ Section	Page #	Line Number(s)	Reviewer Agency	Comments	Comment Reference	Response
16	Project Alternatives			Matilija Coalition	DRC-1: DRC-1 as currently conceived is not a preferred option. The permanent and temporary impacts of constructing a tunnel through a geologically unstable ridge are unjustified for the cost. The multiyear dewatering of Matilija Creek and high discharges into N Fork Matilija Creek will cause undue stress to the aquatic ecosystem. There is also the potential for elevated risk to water supply and other downstream interests from temporary earthen cofferdams during intermediate storms.	Letter dated Oct 17, 2015	Noted. DRC-1 does score lowest of those investigated.
17	Project Alternatives			Matilija Coalition	We concur with the report's ranking of the alternatives, and support DRC-2 as the preferred alternative for achieving ecosystem restoration through dam removal.	Letter dated Oct 17, 2015	Noted.
18	Technical Assessments - 5.2 Steelhead Health			Matilija Coalition	The comparative analysis uses steelhead health downstream of the Matilija Dam site as a parameter in evaluating the different alternatives. In some cases it assumes mortality of aquatic life downstream. Although there will certainly be impacts to downstream populations in the main stem of the Ventura River, decision makers should recognize that DRC-1 and DRC-2 will not result in the complete loss of the steelhead population. The analyses clearly illustrate that, given the climate, geology, and naturally high sediment loads regularly experienced in the Ventura River, the future post-dam-removal fine sediment impacts will be within the natural range of turbidity for high flow events. This conclusion opens the way for implementation of cost-effective natural transport alternatives for dam removal without the previous fear of long-term downstream impacts. **See Matilija Coalition EXCERPT #2 from comment letter for detailed comment.**	Letter dated Oct 17, 2015	Noted. Most, if not all fish in Matilija Creek and Ventura River during the first few days following dam removal will likely be killed because of the extremely high TSS. The window of this killing, however, is going to be short (a few days), so hopefully not all the fish will be in the river at that time.
19				Matilija Coalition	Recommendation 1 - Pursue DRC-2 as the least cost, least impact, greatest benefit project: Of the alternatives analyzed, the low-level orifice concept provides the greatest potential benefit with the least impact. Because this is also the lowest cost approach, it is likely the most achievable in a reasonable timeframe given the current funding constraints.	Letter dated Oct 17, 2015	Noted.
20				Matilija Coalition	Recommendation 2 - Re-examine downstream mitigation components for further cost reduction: Further cost reductions may be possible by re-examining previously identified mitigation measures. Additional analysis should be conducted to reevaluate the downstream project components, such as levees and water supply mitigation, for potential project cost reductions. For example, the flood control objectives of the proposed Meiners Oaks levee may be achieved with a buried floodwall, which would not only reduce the long-term O&M costs but also minimize the impacts associated with a standard levee design (i.e. fencing, pesticides, herbicides, aesthetics, public access, etc.)	Letter dated Oct 17, 2015	While outside the scope of these studies (Tasks 1.3 and 3.3), we do agree that the proposed downstream flood improvement projects could be re-evaluated to reduce cost. This could be a future technical study.
21				Matilija Coalition	Recommendation 3 - Use consensus as a path forward for funding: In recent years it has been difficult to develop a path for funding the project. Although everyone has agreed that Matilija Dam needs to be removed, the lack of project consensus has been problematic. There is now an opportunity to build support around a more affordable least impact project that everyone can agree on.	Letter dated Oct 17, 2015	Noted.
22				Matilija Coalition	Recommendation 4 - Assess non-federal funding options to piece together State and local resources: Regardless of whether this is a federal or nonfederal project, it will likely require at least $40 million in non-federal monies. This will require a mix of State, local, and private funding.	Letter dated Oct 17, 2015	Noted.
23				Matilija Coalition	Recommendation 5 - Develop a Ventura River Parkway and Restoration Plan to solidify public support for local funding initiative: The Ventura River Parkway has a strong local constituency with the Friends of the Ventura River coalition of local organizations. Recent progress includes National Recreation Trail designation of the Ventura River/Ojai Valley bike path, acquisition and restoration of hundreds of acres of floodplain and adjacent upland, and a growing recreation trail network. Incorporating public amenities into a Ventura River Parkway and Restoration Plan that includes Matilija Dam removal will help solidify public support for a dedicated local funding initiative.	Letter dated Oct 17, 2015	Noted.

Item	Chapter/ Section	Page #	Line Number(s)	Reviewer Agency	Comments	Comment Reference	Response
24				Casitas Municipal Water District (CMWD)	The Project Objectives and Evaluation Criteria stated in Section 2.0 are the cornerstones for the development and evaluation of each of the project alternatives. Most critical to the District is the minimizing of project impacts to water supply and water quality of the Ventura River system and Lake Casitas. The District concurs with the Report that DRC-2A and DRC-2B receive the most favorable rating of the three alternatives. DRC-2A and DRC-2B appear to offer the shortest time that would require a temporary suspension of diversions at Robles and provides for the implementation of adaptive management to the remaining fine sediment.	Letter dated Oct 22, 2015	Noted.
25		46	22-25, 27	CMWD	It should be recognized that there are uncertainties with the content of the methane-bearing strata (on the Ventura River and Lake Casitas) and whether the strata may avulse into the channel in subsequent years. Recognizing these uncertainties, there should be a monitoring and adaptive management plan to address the remaining methane-bearing strata. **See Excerpt CMWD EXCERPT #1 from comment letter for detailed comment**	Letter dated Oct 22, 2015	Future fine sediment characterization studies, through site geotechnical investigations, could help estimate the amount of organic sediments in the methane-bearing strata, and could be the basis for a future monitoring and adaptive management plan. Report text has been updated in Section 3.0 and Section 4.2.2. As discussed in Section 4.2.3, and based on a review of past and existing channel conditions, the risk of a future, catastrophic release of fine sediment is judged to be negligible. A future characterization of fine sediment would provide a better estimate of existing conditions.
26				CMWD	The consultant team of AECOM (URS) and Stillwater Sciences has prepared a comprehensive evaluation of existing water supplies and listing of various mitigation options to either protect/treat or extend the life of the local water supplies water that could be affected by the Project. It is understood that what has been presented here are a wide variety of options that may or may not be considered for implementation upon the determination of appropriate justifications that warrant their implementation for the specific dam removal alternative project.	Letter dated Oct 22, 2015	Noted.
27				National Marine Fisheries Service (NMFS)	All three of the alternatives appear superior to the 4B alternative initially authorized by the Water Resources Development Act (WR.DA) of 2007, in terms of costs, constructability, and environmental impacts and benefits. Of the three alternatives identified, Alternative DRC-2A and 2B (double bore holes) warrants further focused analysis, while potentially including elements of Alternative DRC-3 (temporary sediment storage). Based on the level of information and analysis provided in the studies, Alternative DRC-1 (bypass tunnel) has more components adding to the costs and uncertainties, making further development of that alternative a lower priority.	Letter dated Oct 15, 2015	Noted.
28	1.1 Project Background	1	16-17	NMFS	Suggest modifying the sentence to read "was one of the most productive steelhead spawning and rearing habitats in the Ventura River system, and provided important refugia habitat within the Los Padres National Forest"	Letter dated Oct 15, 2015	Text updated as suggested.
29	1.1 Project Background	6	1-2	NMFS	Suggest you modify the sentence to read "concerns over cost, constructability, and habitat and visual impacts, of the downstream disposal options for the fine sediment"	Letter dated Oct 15, 2015	Text updated as suggested.
30	2.1 Project Objectives	8	13	NMFS	Please clarify what is meant by "within the context of the federally authorized project." Alternatives DRC-1, DRC2A, and DRC-2B are substantially different from the 4B federally authorized project, and the consistency of Alternative 3 with the COE WRDA authorized project is unclear. It should also be noted that these new alternatives are not the COE WRDA authorized project covered by NMFS's Biological Opinion for the Matilija Dam Ecosystem Restoration Project. The phrase "within the context of the federally authorize project" should be omitted to avoid any ambiguity and ensure consistency with a later statement that such an evaluation is not within the scope of the study plan.	Letter dated Oct 15, 2015	The purpose behind the referenced objective (although it did not get utilized in the evaluation documented in this report) was to consider benefits associated with utilization of federal funds, should they become available. The federal funds are tied to the Alternative 4B project description (federally authorized project), and discussions with the USACE have led the project stakeholders to believe a solution similar enough to Alt.4b may keep to door open to utilization of those federal funds. Since this is a previously documented project objective, we did not omit, but instead modified the text in Sections 1.1 and 2.1 to clarify.
31	3.0 Concept Descriptions	13	17-18	NMFS	Please specify the nature and scope of "future fine sediment characterization" studies (either here or in some other part of the study); such studies should include characterization of where organic sediments are concentrated.	Letter dated Oct 15, 2015	Fine sediment characterization could be developed through a geotechnical investigation during future project planning/design phases. This type of investigation could provide data on the location and characteristics of organic sediment. Text updated in Section 3.0 and Section 4.2.2 to clarify.

Item	Chapter/ Section	Page #	Line Number(s)	Reviewer Agency	Comments	Comment Reference	Response
32	3.1 Dam Removal Concept 1	14	7	NMFS	Please also express the discharge of 1, 700 cubic feet per second in terms of a flood-frequency return interval.	Letter dated Oct 15, 2015	1,700 cfs is the minimum average daily flow (not the peak), so we do not associate it with a recurrence interval. It does correspond (as noted in the footnote on that page) with a peak daily flow of approximately 3,000 cfs (close to a 4-year recurrence interval on Matilija Creek). Section 4.5 provides additional information on how long it may take to wait for an event of this magnitude.
33	3.1 Dam Removal Concept 1	15	Fig. 3.1.1	NMFS	Please clarify how juvenile or adult steelhead would migrate around the downstream temporary sediment containment berm under varying flow conditions, or the timing of its removal or modification, to allow steelhead passage in conjunction with the upstream cofferdam.	Letter dated Oct 15, 2015	The project does not provide steelhead passage during the project construction/implementation, which is when the berm would be in place. After the temporary containment berm fails during a high flow event, there would not be any impedance to steelhead passage in this area.
34	3.3.1 Bypass Tunnel	16	10-19	NMFS	Please explain how large sediment (boulders) or woody debris originating from upstream would be either kept out of the bypass tunnel or be removed to prevent the blockage of flows or the unplanned breaching of the cofferdam. The study notes that the vertical orientation of the geologic formation through which the tunnel would be carved could potentially contribute to the sediment loading within the bypass tunnel. This is one of a number of uncertainties with Alternative DRC-1. Others include how the abandonment of the tunnel would be accomplished, and the management of the downstream temporary containment berm. We also note that during the period the tunnel would be used to bypass Matilija Creek flows it would be accessible from both Matilija Canyon Road and Highway 33 and could be an attractive nuisance, and its subsequent sealing could result in visual impacts from the two public roadways.	Letter dated Oct 15, 2015	Boulders are currently not carried by flood flows into this portion of the reservoir. Blockage of the bypass tunnel with large woody debris would be prevented by installation of a log boom. The vertical orientation of the geology is noted as it pertains to the constructing of the bypass tunnel. The walls of the tunnel would be stabilized and would not contribute to sediment loading. Text added to Section 3.1.5 regarding tunnel abandonment. Table 5.6-1 address public safety risk associated with the tunnel openings. Last comment is noted, and would be addressed during detailed design.
35	3.1.3 Temporary Containment Berm	18	5	NMFS	A 5-year storm event is not 115 cfs as indicated; this return interval should be re-calculated.	Letter dated Oct 15, 2015	The 5-year storm of 115 cfs is associated only with local nuisance flows, not creek watershed. Local nuisance flow drainage area extends from containment berm upstream only to the location of the cofferdam and to the top of the adjacent hillslopes. The 5-year flow was estimated by comparison of the drainage area and 5-year flow corresponding to the larger watershed draining to Matilija Dam (Reference: USGS Water Resources Investigations 77-21).
36		17-18		NMFS	See comment above Temporary Containment Berm - Same comment as above	Letter dated Oct 15, 2015	See response to referenced comment
37	3.3 Dam Removal Concept 3	24	12-17	NMFS	The temporarily stored sediments would be considerably above the new surface flows (and groundwater) level as a result of the pilot channel excavation. These would most likely result in conditions unconducive to the support or riparian vegetation. The situation could persist for some extended period (years or decades), resulting in the extended loss or the existing vegetation until the sediments had been eroded down to the pre-dam streambed elevation. This aspect of DRC-3 should be reflected in the brief discussion of impacts to existing vegetation communities.	Letter dated Oct 15, 2015	Agreed. Impacts to existing riparian vegetation is assessed in Section 5.3. Table 5.3-1 indicates that DRC-3 impacts 37 acres of existing riparian woodland, compared to 12 acres for DRC-2 and 14 acres for DRC-1. Text also added to Section 3.3.4 to note the impacts.
38	3.3.4 Post-Flush Channel and Restoration	28	6-9	NMFS	The temporary storage of sediments in the reservoir area could persist for a number of years (perhaps decades). This impact extends beyond the existing vegetation to include future vegetation succession, and is therefore a long-term effect which would delay or prevent the reestablishment of certain vegetation communities, particularly riparian. See comment above.	Letter dated Oct 15, 2015	Long-term vegetation communities are address in Section 5.4. For this evaluation, it was assumed that the areas associated with the upstream sediment stockpiles would contain mixed chaparral vegetation communities for the foreseeable future. Therefore, DRC-3 has significantly less riparian and more chaparral over the long term, compared to DRC-1 and DRC-2. Text also added to the last paragraphs of Sections 5.3 and 5.4 to associate the impact of riparian habitat to the sediment stockpiles.
39	4.2.2 Organic Concentrations	46	18-19	NMFS	See comments above specifying the nature and scope of “future fine sediment characterization" studies.	Letter dated Oct 15, 2015	Fine sediment characterization could be developed through a geotechnical investigation during future project planning/design phases. This type of investigation could provide data on the location and characteristics of organic sediment. Text updated in Section 3.0 and Section 4.2.2 to clarify.

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40	4.4 Steelhead Health Downstream of the Matilija Dam Site	59-60	1 to 8	NMFS	The question of the lethal and sub-lethal effects on steelhead is complex. No study on the behavior or tolerance of steel head in the southern extreme of their range, where sediment loading is periodically and naturally extremely high, have been conducted. However, Oncorhynchus mykiss have been shown to exhibit a higher level of tolerance to sediment than other Oncorhynchus species (See for example, T.C. Bjorum In Stoltz and Schnell (ed.) Trout (1991). The analysis presented in this study should therefore be considered conservative, in the sense that is may over-estimate the projected sediment level effects on O. mykiss in the Ventura River system.	Letter dated Oct 15, 2015	This issue, and its associated uncertainties, have been added to the text (Section 4.4).
41	4.4 Steelhead Health Downstream of the Matilija Dam Site	59-60	Figures 4.4-1, 4.4-2, and 4.4-3	NMFS	See comment above regarding sediment impacts on O. mykiss	Letter dated Oct 15, 2015	This issue, and its associated uncertainties, have been added to the text (Section 4.4).
42		59-60	8-12	NMFS	Matilija Creek itself is one of several tributaries to the Ventura River, with several sub tributaries (e.g., Upper North Fork, Murrieta Creek).	Letter dated Oct 15, 2015	Noted.
43	5.1 Steelhead Passage through the Project Area	67	26-29	NMFS	While the waiting period for a large sediment-mobilization event associated with alternative DRC-3 is similar to DRC-1 and DRC-2, the time for the complete evacuation of the temporarily stored and protected sediments would likely take much longer because of the storage of sediments dredged from the pilot channel, and the temporary erosion protection. See comment above.	Letter dated Oct 15, 2015	Agreed, although we do not believe that future mobilization of the stored fine sediments will impeded passage. The risk of a catastrophic failure of these sediment stockpiles during a large earthquake, and any associated risk of temporary passage impediment, is addressed in Section 5.6. See Table 5.6-1 under "Post-Storm Flush, Seismic event causes failure". The risk of the temporary erosion protection redistributing in a way that would temporarily block passage is addressed in Table 5.6-1 under "Post-Storm Flush, Fish passage impaired or delayed".
44	5.2.1 Impacts under DRC-1	69	19-22	NMFS	See comments above regarding projected impacts of elevated sediments on steelhead	Letter dated Oct 15, 2015	This issue, and its associated uncertainties, have been added to the text (Section 4.4).
45	5.2.3 Impacts under DRC-3	71	13-21	NMFS	As noted above the projected levels of elevated sediments (on a periodic basis) could be extended over a considerable period of time (multiple years) as a result of the temporary stock-piling of sediments within the reservoir area. This is a potentially significant difference between alternatives DRC-1 and DRC-2. See comment above.	Letter dated Oct 15, 2015	For DRC-3, Phase I erosion impacts are avoided altogether. The temporary sediment stockpiles are constructed to allow for some degree of sediment transport during storms exceeding a 10-year storm event. During these infrequent and relatively high flow events, the incremental increase in TSS levels over background would be negligible. It is possible, though, that extreme storm events or seismic events could cause landsliding of the sediment stockpiles into the channel, resulting in TSS levels potentially intermediate between Phase 1 and Phase II erosion. This is the focus of discussion of the second paragraph of Section 5.2.3. The impact of a seismic event is identified as a risk in Table 5.6-1 (Risk Management Summary).
46	5.2.4 Summary	71	24-25	NMFS	Suggest changing the phrase "with a one-time loss of most if not all fish in the system" to "with a potential loss of a significant number of fish, including but not limited to steelhead, and other aquatic organisms in the project area and downstream in Matilija Creek and the mainstem of the Ventura River ... ," See comments above regarding sediment impacts on steelhead.	Letter dated Oct 15, 2015	Text updated as suggested.
47	5.7 -2 Water Supply Criteria Results	87	13-15	NMFS	Phase II impacts on riparian vegetation for DRC-3 could be extended over a considerable period of time (multiple years) as a result of the temporary stock-piling of sediments within the reservoir area. This alternative could result in extending impacts on water quality/supply and riparian vegetation. This is a potentially significant difference between alternatives DRC-1 and DRC-2. These impacts should be reflected the brief discussion on DRC-3 vegetation impacts, as well as in section 5.2.3. See comments above.	Letter dated Oct 15, 2015	See response to Comment 45. Mobilization of fine sediments from stockpiles during future large storms will not have a significant impact on water quality or water supply, since the incremental increase in suspended sediment concentrations will be negligible.

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48	5.7 -2 Water Supply Criteria Results	90	3-6	NMFS	Please clarify what is meant by drop in storage by 15%. Is this 15% of the total potential storage capacity of the Casitas Reservoir, or a 15% reduction in what would have otherwise been diverted and stored without the projected disruption in diversions?	Letter dated Oct 15, 2015	The 15% refers to the loss in storage capacity of Casitas Reservoir, which is (15% of 254,000 AF) 38,100 AF. This loss in storage capacity is associated with suspending diversions to Casitas Lake through the Robles Diversion Dam, over three consecutive, large storm events. Text added to report.
49				OVSD	OVSD has spent millions of dollars since the 1960's improving and maintaining the sanitary sewer system, upgrading the treatment plant, monitoring the conditions in the river and responding to the requirements of the Clean Water Act to improve the water quality of the Ventura River. The silt flushing options appear to potentially have significant impact on water quality and beneficial uses. The flushing effort will set back those efforts to improve the river. We would encourage evaluation of alternatives that do not have such significant water quality impacts.	Email from Jeff Palmer dated Sep 24, 2015	The analyses provided in the evaluation report indicate that primary impacts of fine sediment flushing include short-term impacts to downstream biological resources and surface water supply (Casitas will suspend diversions at Robles for a short period during flushing event). Approximately 980,000 cubic yards of fine silts and clays are anticipated to mobilize during the initial flushing event, and nearly all this material will flow fairly quickly through the river system to the ocean. The flushing event itself will not significantly impact downstream hydraulics, flooding, or OVSD's sanitary sewer system. Long-term hydraulic and flooding impacts (associated with coarse sediment moving downstream over time) are being addressed by proposed downstream flood improvements being designed and implemented separately.
50				OVSD	I didn't see any reference to any mitigation for our collection system facilities along the main stem of the Ventura River. We have extensive trunklines, manholes, metering stations, siphons, force mains and pump stations that all are within the impact area and could face significant impacts. Those facilities and locations need to be identified, studied and appropriate mitigations and funding sources identified prior to any project consideration.	Email from Jeff Palmer dated Sep 17, 2015	Since the impacts associated with flushing the accumulated fine sediments are limited to short-term increases in suspended sediment concentrations, and not downstream hydraulics or flooding, there is no anticipated impacts to OVSD's infrastructure.
51				OVSD	The treatment plant DOES NOT provide title 22 water that meets State guidelines for reuse. There are significant issues related to permitting, environmental impacts and costs that also need to be identified prior to the Plant water being earmarked as a source of water.	Email from Jeff Palmer dated Sep 17, 2015	Comment pertains to Task 3.3 Water Supply Offset Options Evaluation Report (AECOM, 2016). See comments response matrix associated with that report.
52				OVSD	The 2015 Study appears to introduce new removal alternatives that have different and more potentially significant hydraulic impacts to the river south of the Robles Diversion. These new and more significant impacts need to be studied to determine more appropriate mitigation measures as it relates to impacts to the OVSD Collection System and Treatment Plant. **See Excerpt OVSD #1 from comment letter for detailed comment**	Letter dated Sep 23, 2015	Since the impacts associated with flushing the accumulated sediments are limited to short-term increases in suspended sediment concentrations, and not downstream hydraulics or flooding, there is no anticipated impacts to OVSD's infrastructure.
53				OVSD	We believe that the following questions should be answered before any additional steps are taken. 1. What will the impacts be to the river and adjacent property from the Robles Diversion to the Treatment Plant and to the ocean? **See Excerpt OVSD #2 from comment letter for detailed comment**	Letter dated Sep 23, 2015	Flooding impacts associated with the dam removal project is covered through downstream flood improvement projects identified in the project EIS/EIR, which are being designed and implemented separately. Short term impacts from flushing accumulated sediments are primarily associated with surface water supply (Robles Diversion) and downstream biological resources (high suspended sediment concentrations negatively impacting fish and wildlife).
54				OVSD	2. How will the river hydraulics, grades, channel location and braiding, freeboard depth, and what scour depths result from the proposed plan?. **See Excerpt OVSD #2 from comment letter for detailed comment**	Letter dated Sep 23, 2015	The flushing of accumulated sediments, which is the focus of this study, does not alter river hydraulics, grades, channel location and braiding, freeboard depth, or scour depths. These issues were addressed in the certified EIS/R.
55				OVSD	3. How will the beneficial uses, environmental conditions and water quality be impacted and mitigated?. **See Excerpt OVSD #2 from comment letter for detailed comment**	Letter dated Sep 23, 2015	Water supply impacts associated with water quality, and potential mitigation options, are discussed in the Task 3.3 Water Supply Mitigation Options Evaluation (AECOM 2016). Environmental impacts are discussed in detail with regard to downstream biological resources (steelhead is primary species of concern) in Sections 4.4 and 5.2. Project impacts to other beneficial uses are covered in the certified EIS/R.

Matilja Dam Removal, Sediment Transport, and Robles Diversion Mitigation Project
DOG Comments on Draft Dam Removal Concepts Evaluation Report, dated 8/13/15

Comment Response Matrix

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56				OVSD	4. What protection measures are needed to protect the Sanitary Sewer System and Treatment Plant from impacts? . **See Excerpt OVSD #2 from comment letter for detailed comment.**	Letter dated Sep 23, 2015	See response to comment #50. Although we do not anticipate any significant impacts to OVSD infrastructure, specific locations of concern could be visited during final design to clarify OVSD concerns.
57				OVSD	5. What are the costs associated with those impacts and protection measures? . **See Excerpt OVSD #2 from comment letter for detailed comment**	Letter dated Sep 23, 2015	See response to comment #50. Although we do not anticipate any significant impacts to OVSD infrastructure, specific locations of concern could be visited during final design to clarify OVSD concerns.
58				OVSD	6. What are the environmental and right of way impacts and costs of those mitigation measures? . **See Excerpt OVSD #2 from comment letter for detailed comment**	Letter dated Sep 23, 2015	See response to comment #50. Although we do not anticipate any significant impacts to OVSD infrastructure, specific locations of concern could be visited during final design to clarify OVSD concerns.
59				OVSD	7. At this time, there is no definitive review or conclusions regarding the answers to these questions.. **See Excerpt OVSD #2 from comment letter for detailed comment**	Letter dated Sep 23, 2015	See response to comment #50. Although we do not anticipate any significant impacts to OVSD infrastructure, specific locations of concern could be visited during final design to clarify OVSD concerns.

Comment Letter Excerpts

Matilija Coalition EXCERPT #1	Letter dated Oct 17, 2015	The studies presented in the Matilija Task 1.3 Draft Concepts Evaluation Report benefit from information that was not available during the federal feasibility study of 2001-2004. Since then, several large dams have been removed from rivers on the west coast of the United States, and much has been learned. We now have real world examples demonstrating the power and resilience of riverine ecosystems to restore themselves, if given the chance. In every case, fish immediately migrated upstream of the former dam site, and downstream ecosystems absorbed and benefitted from the increased sediment transport. In no case were permanent negative impacts realized. And most notably, in the case of Condit Dam removal, we have witnessed the power of a single event to almost instantaneously reverse decades of negative impacts to a river through what was once predicted to result in "total biological annihilation." The current studies apply this real world experience to demonstrate how the short-term impacts of a single sediment release will not permanently affect our local water supply. This provides a scientifically justified opportunity to take advantage of the energy of the Ventura River, saving tens of millions of dollars over mechanically moving and disposing of sediment, while significantly reducing the environmental footprint of the project.
Matilija Coalition EXCERPT #2	Letter dated Oct 17, 2015	The comparative analysis uses steelhead health downstream of the Matilija Dam site as a parameter in evaluating the different alternatives. In some cases it assumes mortality of aquatic life downstream: . *both DRC-1 and DRC-2 results in the substantial, but likely not complete, loss of a year class of fish in Matilija Creek and the Ventura River.* This is a conservative conclusion, and while these dam removal alternatives will clearly create adverse downstream conditions, the report also states: . *Matilija can obviously prove to be a challenging environment for steelhead to thrive; these conditions also stress the importance of tributary habitat, which provide refuge habitat from these natural events (and presumably would serve the same function following dam removal as well),* ***because a nominally lethal, high-sediment condition in a channel with available refugia does not necessarily result in mortality for mobile organisms that have evolved under these conditions*** . In addition to the refugia value of tributaries such as the North Fork Matilija Creek and San Antonio Creek, a significant proportion of the native steelhead population resides in these tributaries as well as the headwaters upstream of the dam site. (see: **Steelhead Population and Habitat Assessment in the Ventura River / Matilija Creek Basin 2006-2012 FINAL REPORT (2015)**) So although there will certainly be impacts to downstream populations in the main stem of the Ventura River, decision makers should recognize that DRC-1 and DRC-2 will not result in the complete loss of the steelhead population. (One may even reasonably expect Phase I sediment release impacts to be similar to past geological events, hence within the evolutionary experience of the southern steelhead.) Importantly, the study concludes that; . *Phase II transport for all three dam removal concepts will likely have an indiscernible incremental effect over baseline conditions.* The analyses clearly illustrate that, given the climate, geology, and naturally high sediment loads regularly experienced in the Ventura River, the future post-dam-removal fine sediment impacts will be within the natural range of turbidity for high flow events. This conclusion opens the way for implementation of cost-effective natural transport alternatives for dam removal without the previous fear of long-term downstream impacts.
Matilija Coalition EXCERPT #3	Letter dated Oct 17, 2015	The ***Matilija Task 3.2 Hydrologic Assessment for Water Supply*** study provides a comprehensive review of the contribution of Robles Diversion to Casitas Municipal Water District and the potential impacts of missed diversions on reservoir storage levels. This is also new information, which opens up opportunities above and beyond the assumptions made during the federal Feasibility process. Most notably, the recent analysis revealed that diversions from the Ventura River at Robles have historically provided 23% of storage in Lake Casitas, in contrast to the prior assumption that Robles contributed fully 50% of supply. Furthermore, the analysis reveals that based on historic data, a single missed diversion event will only temporarily impact reservoir storage by 4-6%, and that this loss will be made up in the next flood event. While recognizing that this is only an estimate, this analysis provides a renewed perspective of the actual risk posed by utilizing natural transport to expedite dam removal. Most importantly, **it is now understood that a single missed diversion event is feasible.**

Matilija Coalition EXCERPT #4	Letter dated Oct 17, 2015	The ***Matilija Task 3.3 Water Supply Mitigation*** report presents a range of mitigation measures for water supply. However, based on the ***Task 3.2 Hydrologic Assessment for Water Supply*** analysis, it appears that water supply mitigation will not be necessary as a result of the project. Therefore, these measures should be considered part of a contingency plan rather than required mitigation for the project. It is important to note that the impact of 4-6% reduction in storage is within the variability of diversion efficiency and conservation measures. The current operations are subject to fouling of fish screens, or even complete failure of the diversion dam (as in 1969), resulting in lost diversion opportunity. Also, current drought conservation efforts have successfully reduced demand by over 25%, demonstrating the feasibility of current and future conservation measures. Moreover, this “loss” is not realized unless the lake runs dry and there is no supply to deliver to customers. Of relevance is the recent federal court decision regarding Robles Diversion, which determined that Casitas “…can establish a compensable injury when diversions resulting from the biological opinion criteria reduce the water project's safe yield to the point when deliveries are affected—i.e., to the point when use becomes constrained.” (Casitas v United States, 102 Fed.Cl. at 473 – http://caselaw.findlaw.com/us-federal-circuit/1623229.html#sthash.0DL3qkmC.dpuf) As demonstrated in the ***Hydrologic Assessment for Water Supply*** analysis, it is highly unlikely that the project will result in delivery constraints to water use.
Stoecker EXCERPT #1	Letter dated Oct 16, 2015	For reasons described in the reports, and the clear advantages from an ecological, risk, and cost standpoint, we support Alternative 2 (A or B). From a steelhead recovery and fish passage perspective, this “Condit-type” orifice dam removal and sediment transport strategy has been shown to be highly effective on Washington’s White Salmon River. With the lowest cost of all three alternatives, Alternative 2 also make the potential for a locally led and funded project more feasible. Alternative 2 also appears to be acceptable, even preferable, to Casitas water interests and rapid transport of sediment to the coast with reduced long-term sedimentation risks. We support moving forward with final design planning efforts for Alternative 2A and 2B. Alternative 3 is less attractive at roughly double the cost of 2A, with elevated engineered channel failure and fish passage risks, and reduced riparian restoration potential. Some level of temporary sediment storage, identified in this alternative, could be incorporated into final design planning and/or adaptation strategies for Alternative 2. I agree with the report findings that Alternative 1 is the least attractive and with the highest risk. In fact, there are additional problems with this proposal not identified in the reports that I would like to see discussed briefly in the final draft and outlined below. I do not support Alternative 1 moving forward. Alternatives 2A or 2B (and to a lesser degree Alternative 3) perform better than the previously authorized Alternative 4B from an economic, risk, and ecological perspective. I am also confident that the level of support from the public, permitting agencies and funders will be much great for Alternatives 2 or 3 than for the previous 4B concept. As noted in the additional comment section below, I also believe that a less expensive and potentially locally funded project has a greater likelihood of materializing than one that it dependent on approval by Congress. This political reality and risk needs to be considered as we select a preferred alternative.
Stoecker EXCERPT #2	Letter dated Oct 16, 2015	There is no mention in the report that the proposed bypass tunnel, and increased flows to the N.F. Matilija Creek, present a serious risk to needed steelhead passage to (and refugia benefits from) this critical tributary during the construction impacts downstream. The report does mention the importance of tributary refuge habitat during construction projects in general, but does not include the importance of this specific tributary just downstream from identified impacts from this particular project. The rock quarry immediately downstream from the proposed bypass tunnel outlet has a long history of causing fish passage impediments due to rock slides, Highway 33 constrictions points, and the tricky hydraulics and drops in this narrow and modified reach. Adding potentially high Matilija Creek flows to this smaller tributary could produce excessive hydraulics and resume mobilization of the quarry rockslides and Highway 33 bank protection features. This has the potential to cause new migration impediments to steelhead seeking refuge from the downstream impacts of dam deconstruction. I request that the report identify this risk and note that NF Matilija Creek, below the bypass tunnel outlet, would also become part of an expanded “project construction site” area and experience additional construction impacts.
Stoecker EXCERPT #3	Letter dated Oct 16, 2015	Sections 4 and 5 describe DRC-1 and DRC-2 as having similar outcomes for steelhead health downstream with regards to TSS and anoxic conditions. It is important for the report to note that DRC-1 has significantly more risk than DRC-2 due to the likelihood that DRC-1 can result in reduced steelhead access to the NF Matilija Creek when this refuge is most critically needed during and following dam removal. Risking steelhead access to the only perennial, clear tributary downstream of the construction site, and during post removal sediment transport events, would be counter to ensuring steelhead survival during and after dam removal conditions. The same is true for rainbow trout upstream of the dam and other aquatic wildlife seeking refuge from dam removal conditions while migrating along the mainstem of Matilija Creek and upper Ventura River. I request that the report note this additional steelhead risk for DRC-1 and that it does not occur with DRC-2 or 3.

Stoecker EXCERPT #4	Letter dated Oct 16, 2015	DRC-3 (Political Reality): While not discussed as a cost or risk in the report, at this stage in our planning efforts it would be irresponsible to not recognize the political reality that getting Congress to authorize any dam removal project effort at Matilija is unlikely. In fact, there are currently multiple high ranking congressman publically and adamantly opposed to allowing any federal funding for any dam removal projects nationally due to their ideology and defense of dams in their regions. Congressional authorization and funding for the widely supported Klamath dam removal effort is currently stalled because of these political tactics. For these reasons, I believe that binding the Matilija project to Congressional approval is likely to prevent the project from moving forward. Fortunately, with the dramatically lower price tag of Alternative 2 over the previous Alternative 4B, I believe the project can be more effectively led and funded locally with State, County, NGO, foundation, private, and even Federal support that does not require a vote in Congress (ie NOAA Fisheries grant funding).
OVSD EXCERPT #1		In reviewing both the 2004 and 2015 Studies and considering the infrastructure integrity, water quality, environmental and permitting issues that OVSD currently operates under, we have some concerns about the proposed Dam Removal alternatives and related hydraulic analysis, scour and river configuration analysis, floodplain change and mitigation measures outlined in your Studies. The 2015 Study appears to introduce new removal alternatives that have different and more potentially significant hydraulic impacts to the river south of the Robles Diversion. These new and more significant impacts need to be studied to determine more appropriate mitigation measures as it relates to impacts to the OVSD Collection System and Treatment Plant. Your Studies suggests that the preparation of these updated studies is a step in determining the preferred removal option. From OVSD's perspective, the next step should be to update the Ventura River hydraulics analysis to determine the effects of creating an intentional significant "flushing" event to carry a significant amount of debris down the river to the ocean. The debris amounts considered, under natural conditions, would be carried over many events, possibly over many years. The intentional "flushing" event will attempt to do this in one event creating un-natural and artificially intense hydraulic flow conditions.
OVSD EXCERPT #2		We believe that the following questions should be answered before any additional steps are taken. 1. What will the impacts be to the river and adjacent property from the Robles Diversion to the Treatment Plant and to the ocean? 2. How will the river hydraulics, grades, channel location and braiding, freeboard depth, and what scour depths result from the proposed plan? 3. How will the beneficial uses, environmental conditions and water quality be impacted and mitigated? 4. What protection measures are needed to protect the Sanitary Sewer System and Treatment Plant from impacts? 5. What are the costs associated with those impacts and protection measures? 6. What are the environmental and right of way impacts and costs of those mitigation measures? 7. At this time, there is no definitive review or conclusions regarding the answers to these questions. Before any decision is made regarding the preferred plan, options, mitigations, costs or schedules, there must be a clear understanding of the project impacts and that: (1) the project alternatives will not degrade water quality or impact beneficial uses, (2) OVSD and our rate payers will not be unduly burdened by costs and liabilities, and (3) that OVSD facilities will not be put at risk by impacts related to the hydraulic silt flushing or dam removal related impacts.
CMWD EXCERPT #1		The Report discussions regarding the impact of the methane-bearing strata on the Ventura River and Lake Casitas have conclude that during the Phase I flush of the Matilija basin the impact of organic mass is "not voluminous to greatly increase the overall estimate of organic content based on the data of Table 4.2-6" (page 46, line 27). This conclusion appears to be reasonable while in the presence of a high flow condition and heavy sediment carrying capacity of the Phase I period. Of concern to the District is that portion of methane-bearing strata that could remain in the exposed embankment of the channel cut, as illustrated in Figures 4.2-6 and 4.2-7. The Report recognizes that the remaining channel walls could collapse into the channel during subsequent years. There appears to be a lack of data to support the determination of the degree of organic loading from the methane-bearing strata that could be introduced into post-dam removal stream flows or the determination that the methane-bearing strata would oxidize with exposure to air (Page 46, Line 22-25). Rather than debate this point further, it should be recognized that there are uncertainties with the content of the methane-bearing strata and whether the strata may avulse into the channel in subsequent years. Recognizing these uncertainties, there should be a monitoring and adaptive management plan to address the remaining methane-bearing strata.

NMFS EXCERPT #1		The installation and operation of new well heads at the Foster Park wells, with increased pumping capacity, could potentially adversely impact steelhead and designated steelhead critical habitat in the Ventura River. The magnitude, timing and duration of surface flows, and thus the quantity and quality of critical habitat, within the lower Ventura River could be affected by the operations of these wells to varying degrees, depending on the time of year, the amount of rainfall during the wet season, and the rate of withdrawals from the wells. The principal potential adverse effect of well operations in the Foster Park area are the loss of summer rearing habitat for juvenile steelhead as well as other aquatic organisms. However, adverse effects could also occur to migrating adult steelhead, spawning steelhead, eggs and fry if flows arc reduced to critical levels during adult steelhead migration and spawning. Potentially all juvenile steelhead in the Ventura River watershed could use the Foster Park area at some point in their life cycle, either for rearing or as a migration corridor on their return to the ocean. Consequently, pumping from these wells has the potential to affect all juvenile steelhead in the watershed, and this has implications for the survival, abundance, productivity, and spatial structure of the Ventura River steelhead population. Finally, recent studies and computer modeling of precipitation for Southern California over the next hundred years show a potential increase in weather extremes, and a slight to modest decrease in annual precipitation occurring by the year 2100 (see for example, Cayan, et al. 2007, Climate Change Scenarios for the California Region. Climate Change DOI 10,1007). This predicted decrease in the average annual rainfall is expected to result in a greater frequency of dry rainfall years, and an increased frequency and duration of dry hydrologic conditions in the Ventura River Watershed. The increased frequency of dry conditions resulting from climate change would be exacerbated by withdrawals from the Foster Park wells.