MITIGATED NEGATIVE DECLARATION

FOR

SALMONID RESTORATION FEDERATION
MARSHALL RANCH STREAMFLOW ENHANCEMENT PROJECT
SCH # 2019109088

September 2021

Lead Agency:
County of Humboldt

Lead Agency Contact:
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Attachment A: Basis of Design (BOD) Report for the Marshall Ranch Streamflow Enhancement Project, Humboldt County, California (Stillwater Sciences, September 2021)

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I. PROJECT INFORMATION

Date: September 2021

Project Title: Marshall Ranch Streamflow Enhancement Project

Lead Agency: County of Humboldt

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Current General Plan Designation: County of Humboldt APN 220-061-011-000

- Residential Agriculture (RA)

Current Zoning: County of Humboldt

- Unclassified (U)

Property Owners and Parcels:

Humboldt County				
Landowner	**Location**	**Parcel #**	**Contact**	**Phone**
The Marshall Ranch LLC	Briceland, CA	220-061-011	David Sanchez	707-223-3946

II. PROJECT DESCRIPTION

Note that the Project design and this associated Mitigated Negative Declaration (MND) have been revised from the versions that were circulated twice for public comment. An initial design iteration was completed in September 2019 and the MND was circulated for public comment, from November 1, 2019 to December 2, 2019. A second design iteration was completed in September 2020 and the MND was circulated for public comment, from October 29, 2020 to November 30, 2020 based on comments received from California Department of Fish and Wildlife, State Water Resources Control Board Division of Water Rights, and neighboring landowners. A third design iteration was completed in August 2021 (the current Project). Between the 2020 and 2021 design iterations, the size of the Project has been decreased from 15.3 to 10 million gallons, based on the future objective of developing a new 5.5-million-gallon project on nearby property owned by Lost Coast Forestlands (LCF). The Marshall Ranch and LCF Projects combined will generate the original target flow augmentation of 50 gallons per minute (gpm) during the 5-month dry season.

The 10-million-gallon Project is designed to provide 30 gpm of flow augmentation to Redwood Creek during the 5-month dry season. The current Project design addresses the three primary substantive community concerns raised during the CEQA public comment period for the 2020 project design:

1) **the risk of catastrophic pond failure has been drastically reduced by dividing storage into two ponds by reducing the original pond volume from 15.3 million gallons to 3.8 million gallons, with the second pond at 5.7 million gallons;**
2) **the current design approach allows for a separate but related flow enhancement project (i.e. future LCF project) that benefits upstream reaches of Redwood Creek with significant aquatic habitat value; and**
3) **the current design allows for filling of the pond and cooling of the outflow via passive gravity systems and does not rely on significant long-term energy use.**

The Salmonid Restoration Federation (SRF) plans to construct 10 million-gallons of off-stream water storage on the Marshall Ranch, adjacent to Redwood Creek, a tributary to the South Fork Eel River. Water storage is proposed in two ponds and five tanks designed to fill with rainwater (~3.5 million gallons) and water diverted from two Redwood Creek tributaries during the wet season (~6.5 million gallons). The project is located near the town of Briceland in southern Humboldt County as shown on Figure 1. This Project seeks to improve habitat for coho salmon (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*) in Redwood Creek, an important salmon-bearing tributary, by addressing the limiting factor of low summer streamflows. The storage facilities have been sited and designed to fill during the winter wet season and release their stored water directly to Redwood Creek during the five-month dry season providing increased flows of approximately 30 gallons per minute (gpm) along the 5.5-mile stream reach delineated in Figure 1. This flow augmentation will provide significant, measurable benefits in terms of dry season flow enhancement for coho salmon, steelhead, and other aquatic species.

Other ancillary project components include:

- Installation of one large wood habitat enhancement and bank stabilization structure in Redwood Creek to improve instream aquatic habitat along 80 feet of the Redwood Creek stream channel.
- Stabilization of two seasonal tributaries with approximately 10 rock-armor grade control structures, regrading, and riparian planting.

- Construction of a passive on-demand "cooling and filtration gallery" in an existing gully to provide treatment of the flow releases, as needed, to improve water quality and reduce temperature.
- Construction of an off-grid power system including a 1 KW solar array, battery bank, inverter, internet connection, and small control center building to support operations and monitoring capabilities.
- Upgrading access roads within the project area including three road/stream crossing upgrades, and gravel surfacing to provide year-round access.
- Riparian exclusion fencing for cattle.
- Installation of plumbing infrastructure including two fire hydrants to allow for a portion of the water stored in the tanks to be utilized for domestic, ranch, and fire suppression needs.

These project design features are described in detail in the Basis of Design Report and 90% Design Plans included as Attachment A of this MND.

This project is proposed on the Marshall Ranch ownership and integrated alongside a conservation easement encompassing the entire ranch that is managed by the California Rangeland Trust. This conservation easement guarantees that the ranch will not be subdivided and will be maintained for ranching activities and wildlife conservation. These restrictions will be especially beneficial in this region, where small subdivisions are frequently used for cannabis cultivation with detrimental impacts to water quality and supply, as well as fish and wildlife habitat.

An integral component of the project is the proposed diversion of water from Redwood Creek tributaries during the wet season that will be used to fill the off-stream storage ponds and tanks. The project team has applied for an Appropriative Water Right with the State Water Board Division of Water Rights (Application A033073) for a total yearly diversion of 20 acre-feet (~6.5 million gallons) with gravity diversions from two seasonal tributaries. The location of the proposed diversion structures via screened intake and gravity piping are shown on the project Site Plan on Figure 2. Of the total requested diversion amount, 19.25 acre-feet (6.25 million gallons) would be dedicated to flow enhancement for the benefit of fish and wildlife and 0.75 acre-feet (250,000 gallons) would be dedicated to domestic, stock watering and fire suppression uses which would allow the landowner to forbear diversion during the dry season.

The proposed water diversions from Redwood Creek tributaries during the wet season will be managed to minimize the impacts to instream resources (i.e. sufficient water will be left instream to meet the needs of aquatic habitat and senior diverters). A Water Availability Analyses (WAA) has been prepared by Stillwater Sciences and submitted to the State Water Board Division of Water Rights for review with the Appropriative Water Rights Application. The WAA is included in Attachment A of this MND as Appendix C of the BOD Report. From the WAA, the following diversion approach is proposed to minimize impacts to downstream aquatic habitat resources:

- Diversion season: December 15 to April 30.
- Diversion allowed when Redwood Creek mainstem at the Marshall Ranch is at or above 5 cubic feet per second (cfs).
- Diversion rate from the tributaries shall not exceed 10% of Redwood Creek mainstem flow at the Marshall Ranch.
- A minimum bypass flow of 5 gpm is required for each tributary.
- Cumulative diversion rates from the two tributaries will range from 75 to 200 gpm during the diversion season.

- 30 to 60 days of diversion needed to achieve 6.5 million gallons of diversion (20 ac-ft)

It is expected that ongoing collaboration between the project team and agency staff will result in agreed upon final diversion approach which will be defined in the approved Appropriative Water Rights documentation and Lake and Streambed Alteration Agreement.

After construction has been completed, extensive post-project monitoring and adaptive management will be implemented to ensure that the project is functioning as designed. This will be conducted through continued involvement of the Project's Technical Advisory Committee (TAC) including representatives from multiple state and federal agencies including Wildlife Conservation Board, California Department of Fish and Wildlife, NOAA Fisheries, State Water Resources Control Board, and North Coast Regional Water Quality Control Board.

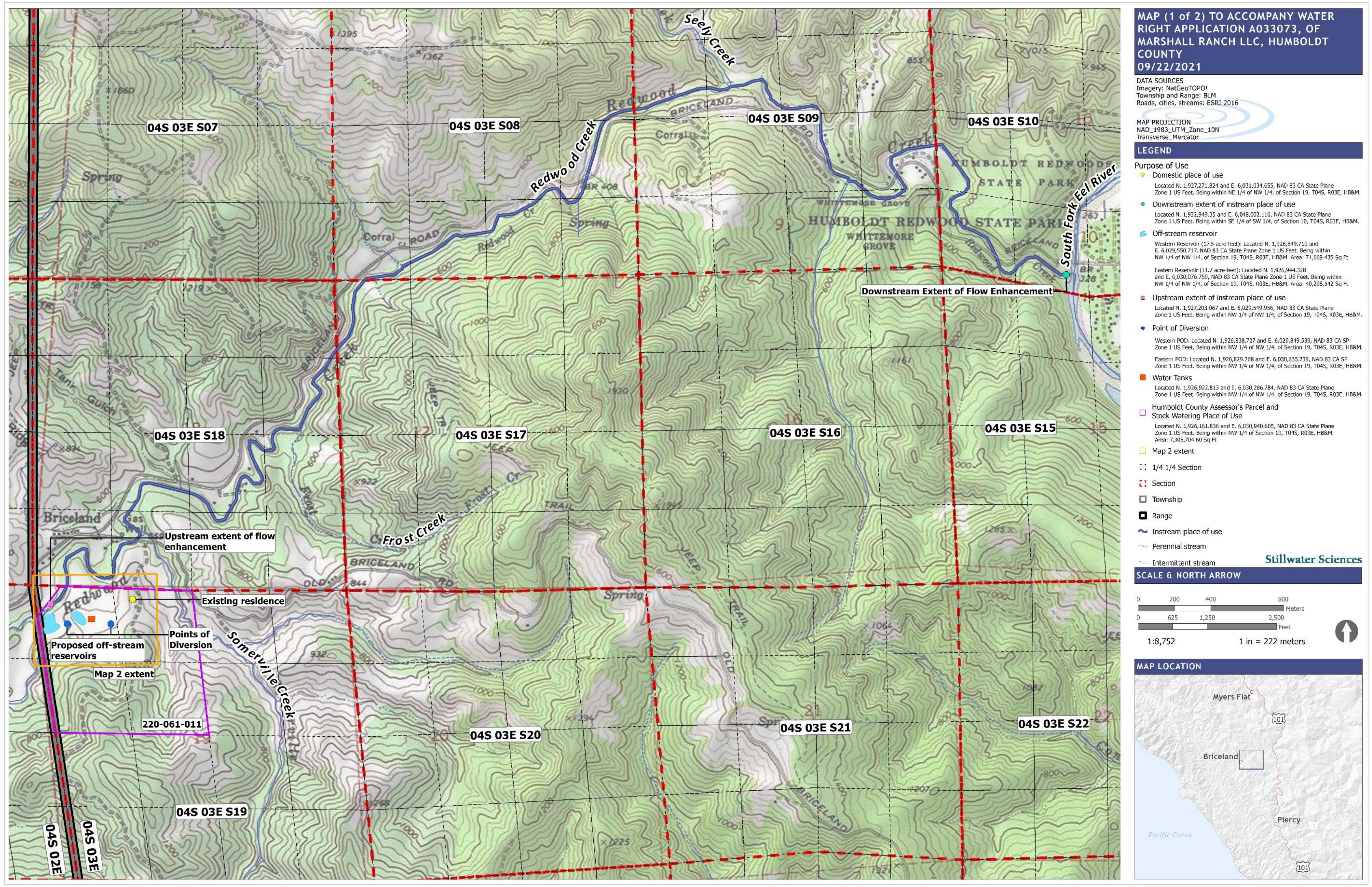

Figure 1: Project Overview Map

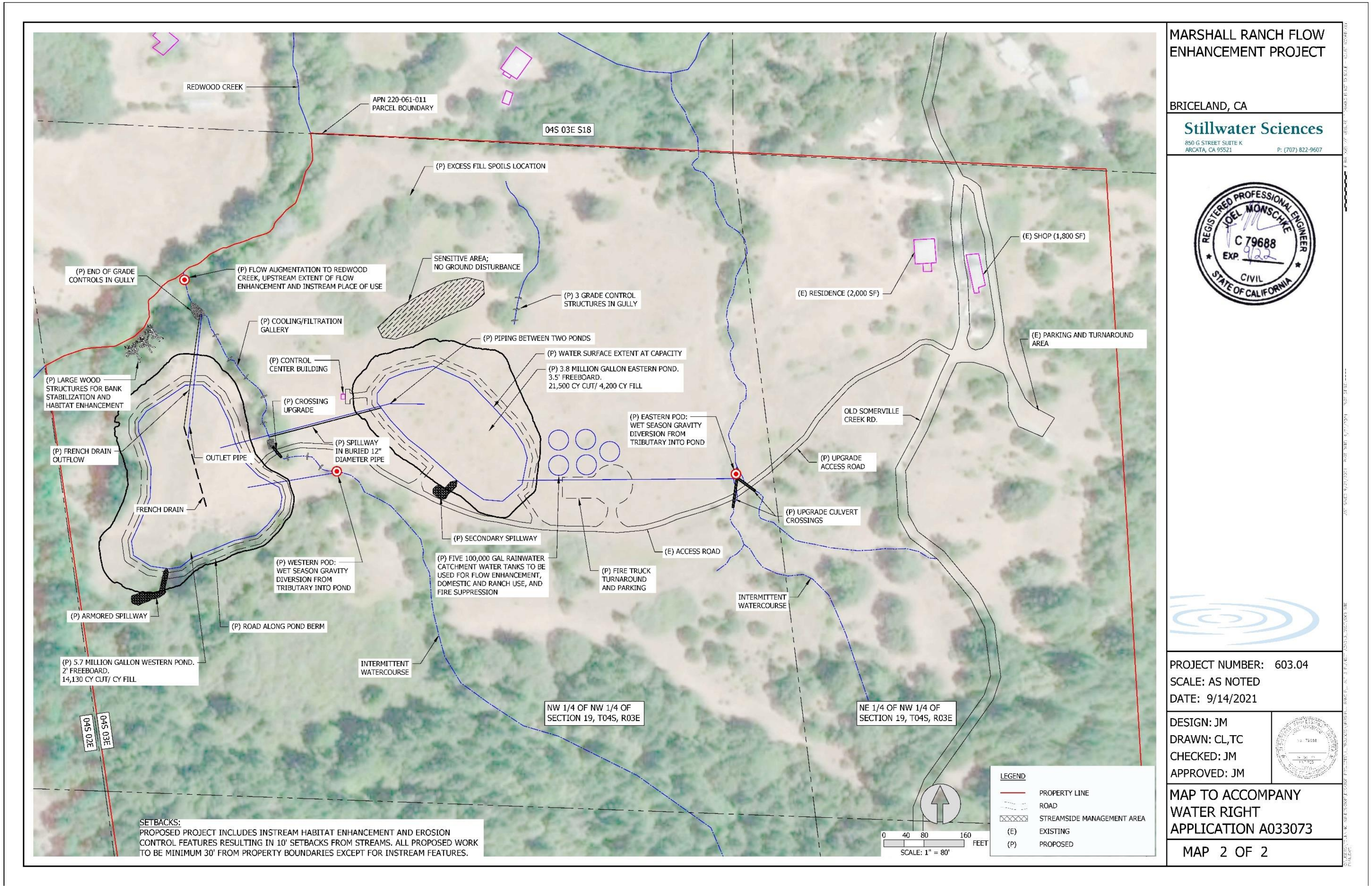

Figure 2: Project Site Plan

Background: The South Fork Eel River is one of five priority watersheds selected for flow enhancement projects in California by the State Water Resources Control Board (SWRCB) and California Department of Fish and Wildlife (CDFW) as part of the California Water Action Plan effort (SWRCB 2019). Redwood Creek is a critical tributary to the South Fork Eel River (NMFS, 2014) that historically supported coho and chinook salmon (*Oncorhynchus tshawytscha*) and steelhead.

Coho salmon stocks in the South Fork Eel River Watershed may have historically constituted one of the largest populations of the species in California (NMFS, 2014). However, their population has experienced a precipitous decline, with an approximately 1,200% reduction observed between the 1930s and 1991 (BLM et al. 1996, Brown and Moyle 1991). Today, the population is threatened, with the National Marine Fisheries Service assigning a moderate risk of extinction to the Southern Oregon and Northern California Evolutionarily Significant Unit (SONCC ESU). This ESU is currently listed as threatened under the federal Endangered Species Act (ESA) and the California Endangered Species Act (CESA).

Numerous factors are responsible for the declines in coho salmon abundance, and many of these limiting factors are also impacting Chinook salmon and steelhead, which are also severely reduced in abundance relative to historical population estimates. Land use practices including logging and road systems have greatly increased winter runoff resulting in decreased groundwater storage and historically low summer streamflows. Widespread removal of large wood from streams has also decreased groundwater storage through channel incision and loss of floodplain connectivity, and resulted in fewer and shallower instream pools that are of insufficient size to withstand drought. Cannabis cultivation has also expanded in the last 15 years, which has resulted in increased water diversions that have affected area watercourses and summer stream flows. Industrial logging practices combined with fire suppression have resulted in overly dense even-aged forests with higher evapotranspiration rates, which significantly contribute to lower dry season flows. The problems of reduced groundwater storage and increased evapotranspiration are intensified during longer dry seasons which have become the norm during the past decade.

SRF has been conducting low flow monitoring in Redwood Creek during the past nine dry seasons. Monitoring results paint a dire picture with dry season flows in Redwood Creek mainstem typically measuring between 0 and 5 gallons per minute during the driest part of the year in late summer and early fall. Over the last several years, the dry conditions have lasted into November due to the late onset of rainfall.

There are several examples analogous to this Project where stored water is used to directly augment dry-season streamflow. Flow releases from two different agricultural ponds and one municipal groundwater well to tributaries of the Russian River in Sonoma County demonstrate encouraging results. As described in Ruiz et al. (2019), the Sonoma project began in 2015 and is ongoing. Data show that flow augmentations in all years from 2015 – 2018, appreciably increased wetted habitat and increased stream water dissolved oxygen downstream from the flow release points. While modest compared to winter flows, these augmentations have the potential to increase pool connectivity and improve water quality. A foundational hypothesis for this Project, that increased pool connectivity will bolster over-summer salmonid survival, is supported by the work of Obedzinski, Pierce, Horton, and Deitch (2018). Their study found that days of disconnected surface flow showed a strong negative correlation with juvenile coho salmon survival rate in four tributaries to the Russian River. Provided this evidence, it is anticipated that the Project's release of approximately 30 GPM into Redwood Creek throughout the dry season can result in significant habitat benefit.

Surrounding Land Uses: The lands surrounding the project consist of private holdings, small-family farms, forests used for timber production, and conserved lands owned by federal and state agencies, non-profits, and sustainable forestry landowners. The proposed pond construction site is an ancient fluvial terrace primarily covered by grassland utilized for livestock grazing. The grassland is flanked to the east and west by intermittent drainages hosting corridors of bigleaf maple forest. These drainages are incised and actively eroding, exporting deleterious fine sediment to Redwood Creek. Redwood Creek also exhibits anthropogenic degradation as it is incised and lacks large wood relative to historical conditions (CDFW 2014). Over the last several years, Redwood Creek has experienced completely dry conditions at two of the four mainstem Redwood Creek flow gages downstream from the proposed flow enhancement site (Stillwater Sciences, 2021). Flow conditions in 2021 are the lowest since monitoring began in 2013.

Project Consistency with Local and Regional Plans: The Project addresses many of the goals and policies included in the Humboldt County General Plan's Water Resources Element:

- WR-G2 - Water Resource Habitat**.** River and stream habitat supporting the recovery and continued viability of wild, native salmonid and other abundant cold water fish populations supporting a thriving commercial, sport, and tribal fishery.
- WR-G9 - Restored Water Quality and Watersheds. All water bodies de-listed and watersheds restored, providing high quality habitat and a full range of beneficial uses and ecosystem services.
- WR-P23 - Watershed and Community Based Efforts. Support the efforts of local community watershed groups to protect, restore, and monitor water resources and work with local groups to ensure decisions and programs take into account local priorities and needs.
- WR-P25 - State and Federal Watershed Initiatives. Support implementation of state and federal watershed initiatives such as the Total Maximum Daily Loads (TMDLs), the North Coast Regional Water Quality Control Board's (NCRWQCB) Watershed Management Initiative, the National Marine Fisheries Services and Department of Fish and Game coho recovery plans and the California Non-Point Source Program Plan.
- WR-IMP19 - Coordinate and Support Watershed Efforts. Seek funding and work with land and water management agencies, community-based watershed restoration groups, and private property owners to implement programs for maintaining and improving watershed conditions that contribute to improved water quality and supply.

The Project also addresses the following goals, policies and standards in the Humboldt County General Plan's Biological Resources Element:

- BR-G1. Threatened and Endangered Species. Sufficient recovery of threatened and endangered species to support de-listing.
- BR-G3. Benefits of Biological Resources. Protect fish and wildlife habitats on a sustainable basis to generate long-term public, economic and environmental benefits.
- BR-P12. Agency Review. The County shall request the California Department of Fish and Wildlife, as well as other appropriate trustee agencies and organizations, to review plans for development within Sensitive Habitat, including Streamside Management Areas. The County shall request NOAA Fisheries or U.S. Fish and Wildlife Service to review plans for development within critical habitat if the project includes federal permits or federal

funding. Recommended mitigation measures to reduce impacts below levels of significance shall be considered during project approval, consistent with CEQA.

- BR-S2. Agency Consultation. For discretionary projects with potential to impact critical, or sensitive habitats, the County will seek specific recommendations from the appropriate agencies, as applicable to the specific project location, class of development, or natural resource involved.
- BR-S6. Development within Stream Channels. Development within stream channels may be approved where consistent with Policy BR-P4, Development within Stream Channels, and is limited to the following projects:
    A. Fishery, wildlife, and aquaculture enhancement and restoration projects.
    H. Bank protection, provided it is the least environmentally damaging alternative.
- BR-S7. Development within Streamside Management Areas. Development within Streamside Management Areas may be approved where consistent with Policy BR-P6, Development within Streamside Management Areas, and shall be limited to the following uses:
    A. Development permitted within stream channels per BR-S6, Development within Stream Channels.

Additionally, the project also addresses the goals of important statewide and federal plans. The project directly addresses the goals of the California Water Action Plan (SWRCB, 2019) and will ensure the restoration of critically important habitat. The Project supports the following actions: 1) Restoration of degraded stream ecosystems to assist in natural water management and improved habitat; 2) Enhancement of water flows in stream systems statewide; 3) Expansion of water storage capacity and improvement of groundwater management; and 4) Management and preparation for dry periods.

The Project addresses Goal B of the WCB Strategic Plan (WCB, 2014): Work with partners to restore and enhance natural areas, create viable habitat on working lands, manage adaptively, and ensure long-term ecosystem health and strategic direction. It also addresses goal B.1: Invest in projects and landscape areas that help provide resilience in the face of climate change, enhance water resources for fish and wildlife and enhance habitats on working lands. The Project includes a collaborative team of partners, will improve habitat on adjacent sustainable forestry working land, will include adaptive management, and will help ensure long - term ecosystem health and resilience to climate change related drought as well as intensified rainfall events.

The Project also aligns with Goal 2 of the State Wildlife Action Plan (CDFW, 2015) – Enhance Ecosystem Conditions, and Goal 3 – Enhance Ecosystem Functions and Processes: Maintain and improve ecological conditions vital for sustaining ecosystems in California. Most specifically, the project improves the hydrologic regime and increases water quantity and availability vital for sustaining ecosystems.

NOAA Fisheries has prioritized a list of recovery actions for coho salmon in the South Fork Eel River Population chapter of their SONCC Recovery Plan (NMFS, 2014). The proposed strategy universal to the top 10 priority actions is listed as "Improve flow timing or volume." Additionally, Redwood Creek is repeatedly identified as a "stream where coho would benefit immediately," and is regarded as a high priority tributary with high habitat value in the South Fork Eel River watershed. While specific action items for this strategy primarily focus on diversion reduction to improve flows, the Project's reservoir surely utilizes the same strategy to accomplish a common goal. Additionally, components of the project do align with specific action items in the recovery plan including increased channel complexity, decreased water temperature, increased dissolved oxygen, and reduced sediment delivery.

Other Public Agencies Whose Approval Is Required (permits, financing approval, or participation agreement): California Wildlife Conservation Board, U.S Army Corps of Engineers, National Marine Fisheries Service, U. S. Fish and Wildlife Service, North Coast Regional Water Quality Control Board, State Water Resources Control Board, California Department of Fish and Wildlife.

The Project aims to secure implementation funding from the CA Wildlife Conservation Board (WCB) Proposition 1 Streamflow Enhancement Program. The Project may also in the future secure funding from other sources including (but not limited to) State Coastal Conservancy (SCC) Proposition 1, California Department of Fish and Wildlife (CDFW) Fisheries Restoration Grant Program (FRGP), Department of Water Resources (DWR) Proposition 1, and CDFW and WCB Proposition 68 Programs. These projects are subject to review under the California Environmental Quality Act (CEQA) (Pub. Resources Code, § 21000 et seq.).

While the implementation may be funded by different sources over several years, the planning and permitting of the entire Project is currently funded by the WCB and SCC Proposition 1 funds. This Initial Study and MND describe and analyze the potential significant impacts of all Project treatments at all sites. Individual restoration activities will require additional environmental permitting from CDFW, State Water Resources Control Board (SWRCB), North Coast Regional Water Quality Control Board (NCRWQCB), and federal agencies. These individual restoration activities will also include monitoring and analysis of outcomes. Construction is expected to be completed during one dry season, likely 2022 or 2023, depending on availability of implementation funds as well as contract and permit execution dates.

Have California Native American tribes traditionally and culturally affiliated with the project area requested consultation pursuant to Public Resources Code section 21080.3.1? If so, is there a plan for consultation that includes, for example, the determination of significance of impacts to tribal cultural resources, procedures regarding confidentiality, etc.?

A letter requesting AB-52 Tribal Consultation was sent to Bear River Band of the Rohnerville Rancheria on November 20, 2020. The county received no response. A Cultural Resources Investigation was also completed, the results of which are confidential. The project sponsor has coordinated with the Bear River Band of the Rohnerville Rancheria and incorporated mitigation measures into the project.

CEQA Requirement:

The Project is subject to the requirements of the California Environmental Quality Act (CEQA). The Lead Agency is the County of Humboldt (County), per CEQA Guidelines Section 21067. The purpose of this Initial Study (IS) is to provide a basis for determining whether to prepare an Environmental Impact Report (EIR) or a Negative Declaration. This Initial Study is intended to satisfy the requirements of CEQA (Public Resources Code, Div 13, Sec 21000-21177) and the State CEQA Guidelines (California Code of Regulations, Title 14, Sec 15000-15387).

CEQA encourages lead agencies and applicants to modify their projects to avoid potentially significant adverse impacts (CEQA Section 20180[c][2] and State CEQA Guidelines Section 15070[b][2]).

Section 15063(d) of the State CEQA Guidelines states that an IS shall contain the following information in brief form:

1) A description of the project including the project location
2) Identification of the environmental setting
3) Identification of environmental effects by use of a checklist, matrix, or other method, provided that entries on a checklist or other form are briefly explained to provide evidence to support the entries
4) Discussion of means to mitigate significant effects identified
5) Examination of whether the project would be consistent with existing zoning, plans, and other applicable land use controls
6) The name of the person or persons who prepared and/or participated in the IS

The Finding: Although the projects may have the potential to cause minor short-term impacts on soil, vegetation, wildlife, water quality, and aquatic life, the measures that shall be incorporated into the project will lessen such impacts to a level that is less than significant (see initial study and environmental impacts checklist).

Basis for the Finding: Based on the initial study, it was determined there would be no significant adverse environmental effects resulting from implementing the proposed project. The project is designed to provide environmental benefit by enhancing and maintaining quality salmonid spawning and rearing habitat in the project area and downstream through augmentation of dry season stream flows.

Humboldt County finds that implementing the proposed projects will have no significant environmental impact. Therefore, this mitigated negative declaration is filed pursuant to the California Environmental Quality Act (CEQA), Public Resources Code § 21080 (c2). This proposed mitigated negative declaration consists of all of the following:

III. ENVIRONMENTAL FACTORS POTENTIALLY AFFECTED:

The environmental factors checked below would be potentially affected by this project, involving at least one impact that is a **"Potentially Significant Impact"** as indicated by the checklist on the following pages.

☐ Aesthetics
☐ Agricultural and Forestry Resources
☐ Air Quality
☒ Biological Resources
☒ Cultural Resources
☐ Energy
☒ Geology/Soils
☐ Greenhouse Gas Emissions
☐ Mineral Resources
☒ Hazards/Hazardous Materials
☐ Land Use/Planning
☒ Noise
☒ Hydrology/Water Quality
☐ Population/Housing
☐ Public Services
☐ Recreation
☐ Transportation/Traffic
☒ Tribal Cultural Resources
☒ Utilities/Service
☒ Mandatory Findings of Significance

An explanation for all checklist responses is included, and all answers take into account the whole action involved, including off-site as well as on-site; cumulative as well as project-level; indirect as well as direct; and construction as well as operational impacts. In the checklist the following definitions are used:

> "**Potentially Significant Impact**" means there is substantial evidence that an effect may be significant.
> "**Potentially Significant Unless Mitigation Incorporated**" means the incorporation of one or more mitigation measures can reduce the effect from potentially significant to a less than significant level.
> "**Less Than Significant Impact**" means that the effect is less than significant and no mitigation is necessary to reduce the impact to a lesser level.
> "**No Impact**" means that the effect does not apply to the Project, or clearly will not impact nor be impacted by the Project.

DETERMINATION: (To be completed by the Lead Agency on the basis of this initial evaluation)

- ☐ I find that the proposed project **could not** have a significant effect on the environment, and a **Negative Declaration** will be prepared.
- ☑ I find that although the proposed project could have a significant effect on the environment, there will not be a significant effect in this case because revisions in the project have been made by or agreed to by the project proponent. A **Mitigated Negative Declaration** will be prepared.
- ☐ I find that the proposed project **may** have a significant effect on the environment, and an **Environmental Impact Report** (EIR) is required.
- ☐ I find that the proposed project **may** have a "potentially significant impact" or "potentially significant unless mitigated" impact on the environment, but at least one effect 1) has been adequately analyzed in an earlier document pursuant to applicable legal standards, and 2) has been addressed by mitigation measures based on the earlier analysis as described on attached sheets. An **Environmental Impact Report** is required, but it must analyze only those effects that remain to be addressed.
- ☐ I find that although the proposed project could have a significant effect on the environment, because all potentially significant effects (a) have been analyzed adequately in an earlier **EIR** or **Negative Declaration** pursuant to applicable standards, and (b) have been avoided or mitigated pursuant to that earlier **EIR** or **Negative Declaration**, including revisions or mitigation measures that are imposed upon the proposed project, nothing further is required.

Joshua Dorris

Signature

10/08/2021

Date

Joshua Dorris, Planner

For Humboldt County Planning
and Building Department

EVALUATION OF ENVIRONMENTAL IMPACTS

1) A brief explanation is required for all answers except "No Impact" answers that are adequately supported by the information sources a lead agency cites in the parentheses following each question. A "No Impact" answer is adequately supported if the referenced information sources show that the impact simply does not apply to projects like the one involved (e.g., the project falls outside a fault rupture zone). A "No Impact" answer should be explained where it is based on project-specific factors as well as general standards (e.g., the project will not expose sensitive receptors to pollutants, based on a project-specific screening analysis).

2) All answers must take account of the whole action involved, including offsite as well as onsite, cumulative as well as project-level, indirect as well as direct, and construction as well as operational impacts.

3) Once the lead agency has determined that a particular physical impact may occur, then the checklist answers must indicate whether the impact is potentially significant, less than significant with mitigation, or less than significant. "Potentially Significant Impact" is appropriate if there is substantial evidence that an effect may be significant. If there are one or more "Potentially Significant Impact" entries when the determination is made, an EIR is required.

4) "Negative Declaration: Less Than Significant With Mitigation Incorporated" applies where the incorporation of mitigation measures has reduced an effect from "Potentially Significant Impact" to a "Less Than Significant Impact." The lead agency must describe the mitigation measures, and briefly explain how they reduce the effect to a less than significant level (mitigation measures from Section XVII, "Earlier Analyses," may be cross-referenced).

5) Earlier analyses may be used where, pursuant to the tiering, program EIR, or other CEQA process, an effect has been adequately analyzed in an earlier EIR or negative declaration. Section 15063(c)(3)(D). In this case, a brief discussion should identify the following:

   a) Earlier Analysis Used. Identify and state where they are available for review.

   b) Impacts Adequately Addressed. Identify which effects from the above checklist were within the scope of and adequately analyzed in an earlier document pursuant to applicable legal standards, and state whether such effects were addressed by mitigation measures based on the earlier analysis.

   c) Mitigation Measures. For effects that are "Less Than Significant with Mitigation Measures Incorporated," describe the mitigation measures which were incorporated or refined from the earlier document and the extent to which they address site-specific conditions for the project.

6) Lead agencies are encouraged to incorporate into the checklist references to information sources for potential impacts (e.g., general plans, zoning ordinances). Reference to a previously prepared or outside document should, where appropriate, include a reference to the page or pages where the statement is substantiated.

7) Supporting Information Sources: A source list should be attached, and other sources used or individuals contacted should be citied in the discussion.

8) This is only a suggested form, and lead agencies are free to use different formats; however, lead agencies should normally address the questions from this checklist that are relevant to a project's environmental effects in whatever format is selected.

9) The analysis of each issue should identify:

    a) the significance criteria or threshold used to evaluate each question; and
    b) the mitigation measure identified, if any, to reduce the impact to less than significance.

I. AESTHETICS: Except as provided in Public Resources Code Section 21099, would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Have a substantial adverse effect on a scenic vista?	☐	☐	X	☐
b) Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway?	☐	☐	☐	X
c) In non-urbanized areas, substantially degrade the existing visual character or quality of public views of the site and its surroundings? (Public views are those that are experienced from a publicly accessible vantage point). If the project is in an urbanized area, would the project conflict with applicable zoning and other regulations governing scenic quality?	☐	☐	X	☐
d) Create a new source of substantial light or glare which would adversely affect day or nighttime views in the area?	☐	☐	X	☐

Discussion:

(a) Less Than Significant Impact: The project will not have a significant effect on a scenic vista. Such an impact will not occur because the project will not be readily visible from Briceland Road or any other heavily traveled local roadway. The project has been designed with consideration of maintaining low visibility and will serve to restore to the watershed to a more natural condition with water flowing in Redwood Creek during the dry season offsetting human consumptive use.

(b) No Impact: The project will not damage scenic resources such as trees, rock outcroppings, and historic buildings within a state scenic highway. Such an impact will not occur because the project is not located in the vicinity of a state scenic highway.

(c) Less Than Significant Impact: The project will not substantially degrade the existing visual character or quality public views of the sites and their surroundings because there are no publicly accessible vantage points overlooking the project site. Access to the site is via a private drive and any overlooking locations are within the Marshall Ranch or adjacent private properties. Adjacent neighbors may experience some degraded visual character due to installation of the project. However, through careful planning and design, the natural character of the site will be maintained to the greatest extent practical while still achieving the project objectives. Final berm grading will be blended in with natural topographic features. In addition, planting of native trees, shrubs and other vegetation will be performed at all sites where vegetation has been removed or fill has been placed. It is also important to consider that the overall goal of this project is to enhance dry season flows in Redwood Creek which will restore the natural character of a significant portion of the watershed.

(d) Less Than Significant Impact: The project will not create a new source of substantial light which would adversely affect day or nighttime views in the area of the worksites. Such an impact will not occur because the restoration project does not require installation of artificial lighting. It is possible that some glare may be created by the small 1 KW solar array. However, any receptors of glare created by the solar panels would be expected to occur to the south of the project area based on the southern orientation of the panels. The land to the south of the project is almost entirely large parcels utilized for ranching and timber and there are no residences located to the south of the project. Also, the size of the solar array has been drastically reduced to a ~100 SF footprint in the current project design. Therefore, the project would have a less than significant impact.

II. Agriculture and Forestry Resources. In determining whether impacts to agricultural resources are significant environmental effects, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997) prepared by the California Dept. of Conservation as an optional model to use in assessing impacts on agriculture and farmland. In determining whether impacts to forest resources, including timberland, are significant environmental effects, lead agencies may refer to information compiled by the California Department of Forestry and Fire Protection regarding the state's inventory of forest land, including the Forest and Range Assessment Project and the Forest Legacy Assessment project; and forest carbon measurement methodology provided in Forest Protocols adopted by the California Air Resources Board. Would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to non-agricultural use?			X	
b) Conflict with existing zoning for agricultural use, or a Williamson Act contract?			X	
c) Conflict with existing zoning for, or cause rezoning of, forest land (as defined in Public Resources Code section 12220(g)), timberland (as defined by Public Resources Code section 4526), or timberland zoned Timberland Production (as defined by Government Code section 51104(g))?				X
d) Result in the loss of forest land or conversion of forest land to non-forest use?				X
e) Involve other changes in the existing environment which, due to their location or nature, could result in conversion of Farmland, to non-agricultural use or conversion of forest land to non-forest use?			X	

Discussion:
The project is located on land that is zoned by Humboldt County as Residential Agriculture and periodically used for grazing livestock. Fish and wildlife management are allowable uses on this zoning.

(a) Less than Significant Impact: The Farmland Mapping and Monitoring Program has not mapped farmlands in Humboldt County. Per the county GIS the Natural Resource Conservation Service draft 2014 soil update maps the 1.5 acre area where the lower terrace (western) pond is proposed as Prime Farmland if Irrigated and the rest of the project site as Not Prime farmland. The 1.5 acre area would be converted from periodic seasonal cattle grazing to non-agricultural use. As this area is currently periodically grazed and not considered prime agricultural land, and it represents a small percentage of the overall ranch, the the project would have a less than significant impact.

(b) Less than Significant Impact: The site is currently zoned U, Unclassified, which allows General Agriculture as a principle permitted use. The site is periodically used for grazing livestock. Fish and wildlife management (one of the primary purposes of the project) is an allowable use on this zoning. The site is not under a Williamson Act (WA) contract and the proposed project would not interfere with the ability to place the site into a WA contract or preserve.

(c) No Impact: The project is zoned as Unclassified and as such will not conflict with existing zoning for, or cause rezoning of, forestland, timberland, or timber zoned Timberland Production.

(d) No Impact: No trees will be removed, and no loss or conversion of forest land will occur.

(e) Less Than Significant Impact: The project will not involve other changes in the existing environment, which due to their location or nature, could result in significant conversion of farmland to non-agricultural use. The site is not considered important farmland. Fisheries habitat restoration actions either are away from, or are compatible with, existing agricultural uses. The proposed ponds are located in an open grassland and will utilize some of the space that could be used for periodic grazing. However, it represents a very small percentage of the overall ranch ownership. Additionally, the project design will allow for future cattle grazing within portions of the project footprint, (following several years of revegetation) and will also enhance water availability for livestock while reducing livestock impacts to watercourses via riparian fencing.

III. Air Quality. Where available, the significance criteria established by the applicable air quality management or air pollution control district may be relied upon to make the following determinations. Would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Conflict with or obstruct implementation of the applicable air quality plan?			X	
b) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient air quality standard?			X	
c) Expose sensitive receptors to substantial pollutant concentrations?			X	
d) Result in other emissions (such as those leading to odors) adversely affecting a substantial number of people?				X

Discussion:
Humboldt County is designated as ‘in attainment’ for all National Ambient Air Quality Standards (NAAQS or federal standards). Humboldt County is designated as ‘in attainment’ for all California Ambient Air Quality Standards (CAAQS or State standards) pollutants except PM_{10}. The North Coast Unified Air Quality Management District (NCUAQMD) has not formally adopted significance thresholds that would apply to projects such as this. For construction emissions, the NCUAQMD has indicated that construction emissions are not considered regionally significant for projects that will be of relatively short duration (less than one year) (NCUAQMD 2015).

Impacts related to construction dust are considered significant if dust is allowed to leave the site (NCUAQMD 2015). Construction activities are subject to Rule 104 (Prohibitions) Section D (Fugitive Dust Emission). Pursuant to Section D, the handling, transporting, or open storage of materials in such a manner, which allows or may allow unnecessary amounts of particulate matter to become airborne, shall not be permitted. Reasonable precautions shall be taken to prevent particulate matter from becoming airborne, including, but not limited to: 1) covering open bodied trucks when used for transporting materials likely to give rise to airborne dust; and 2) the use of water during the grading of roads or the clearing of land.

(a) Less than significant: The construction portion of the project will last for less than one year (June 1 to November 1). During this period, the project will comply with Rule 104, Section D and cover open body trucks hauling materials off site and use water during the grading of roads, excavation, and land clearing.

(b) Less than significant: Humboldt County is in attainment of all air quality standards, except PM_{10}. The project will comply with Rule 104, Section D and cover open body trucks hauling materials off site and use water during the grading of roads, excavation, and land clearing. Therefore, the project will not result in a cumulatively considerable net increase of any criteria pollutant for which the project region is in non-attainment under applicable federal or state ambient air quality standards.

(c) Less than significant: The project will not expose sensitive receptors to substantial pollutant concentrations. Such an impact will not occur because the project will not increase pollutant concentrations and is designed to operate utilizing solar energy. There is the potential for fugitive dust to travel off site and expose neighbors. However, the project will comply with Rule 104, Section D and cover open body trucks hauling materials off site and use water during the grading of roads, excavation, and land clearing. Therefore, it is not expected that sensitive receptors would be exposed to substantial concentrations of PM_{10}.

(d) No Impact: The project will not create other emissions (such as objectionable odors) affecting a substantial number of people.

IV. Biological Resources. Would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?		X		
b) Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, and regulations or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?		X		
c) Have a substantial adverse effect on federally protected wetlands (including, but not limited to, marsh, vernal pool, coastal, etc.) through direct removal, filling, hydrological interruption, or other means?				X
d) Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites?		X		
e) Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?				X
f) Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan?				X

Discussion:

Special-status species are defined in this ISMND as those that are:

- listed as endangered or threatened, rare, or proposed/candidates for listing under the ESA and/or CESA;
- designated by CDFW as a Species of Special Concern;
- have a California Rare Plant Rank (CRPR) of 1, 2, 3 or 4; and/or
- have a state ranking of S1, S2, or S3 (critically imperiled, imperiled, or vulnerable, respectively) on CDFW's California Sensitive Natural Communities List (CDFW 2018a).

An in-depth review of the project site and surrounding area was conducted using desktop and field reviews (Appendix F of the BOD Report). The desktop review included querying the following resources:

- The U.S. Fish and Wildlife Service (USFWS) online Information for Planning and Consultation (IPaC),
- The California Native Plant Society's (CNPS) online Inventory of Rare and Endangered Vascular Plants of California,
- CDFW's California Natural Diversity Database (CNDDB),
- CDFW's CNDDB northern spotted owl viewer, and

- National Marine Fisheries Service's (NMFS) California Species List Tools database (NMFS 2019).

The desktop review generated a list of special status plant and wildlife species with potential to inhabit the project area (Tables 1 and 2). The field review was conducted on 3 May 2019 and was used to assess habitat for the species on the list, determine their potential to be present, and identify what project-related effects on these species would occur, if any. Please see Appendices F and I of the BOD report in Attachment A for more detailed information.

Table 1. Special status plant species with the potential to be present in or around the Project Area.

Scientific name (common name)	**Status (Federal, State, CRPR[1])**	**Habitat association[2]**	**Source**	**Likelihood of occurrence**
Astragalus agnicidus (Humboldt County milk-vetch)	None/CE/1B.1	Openings, disturbed areas, and sometimes roadsides in broadleafed upland forest and north coast coniferous forest; 390–2,625 ft. Blooming period: April–September	CNPS, CDFW	**Moderate:** Broadleafed upland and north coast coniferous forest habitats present within Project area. Two occurrences within 5–10 mi of the Project area.
Coptis laciniata (Oregon goldthread)	None/None/4.2	Mesic meadows and seeps and streambanks in north coast coniferous forest; 0–3,280 ft. Blooming period: (February) March–May (September–November)	CNPS, CDFW	**Moderate:** North coast coniferous forest habitat present within Project area. Two occurrences within 5–10 mi of the Project area.
Erythronium oregonum (giant fawn lily)	None/None/2B.2	Sometimes serpentinite, rocky, openings in cismontane woodland and meadows and seeps; 325–3,775 ft. Blooming period: March–June (July)	CNPS, CDFW	**Moderate:** Cismontane woodland habitat present within Project area. No ultramafic soils mapped or observed in Project area. One occurrence is within 5–10 mi of the Project area.
Erythronium revolutum (coast fawn lily)	None/None/2B.2	Mesic, streambanks, bogs and fens, broadleafed upland forest, and north coast coniferous forest; 0–5,250 ft. Blooming period: March–July (August)	CNPS, CDFW	**Moderate:** Broadleafed upland and north coast coniferous forest habitats present within Project area. Two occurrences within 5–10 mi of the Project area.
Gilia capitata subsp. *pacifica* (Pacific gilia)	None/None/1B.2	Coastal bluff scrub, openings in chaparral, coastal prairie, and valley and foothill grassland; 15–	CNPS, CDFW	**Moderate:** Chaparral and valley and foothill grassland habitats present within Project

Scientific name (common name)	Status (Federal, State, CRPR[1])	Habitat association[2]	Source	Likelihood of occurrence
		5,465 ft. Blooming period: April–August		area. Multiple occurrences within 5–10 mi of the Project area.
Montia howellii (Howell's montia)	None/None/2B.2	Vernally mesic, sometimes roadsides in meadows and seeps, north coast coniferous forest, and vernal pools; 0–2,740 ft. Blooming period: (February) March–May	CNPS, CDFW	**Moderate:** North coast coniferous forest habitat present within Project area. Two occurrences within 5–10 mi of the Project area.
Piperia candida (white-flowered rein orchid)	None/None/1B.2	Sometimes serpentinite in broadleafed upland forest, lower montane coniferous forest, and north coast coniferous forest; 95–4,300 ft. Blooming period: (March) May–September	CNPS, CDFW	**Moderate:** Broadleafed upland, lower montane coniferous, and north coast coniferous forest habitats present within Project area. No ultramafic soils mapped or observed in Project area. Multiple occurrences within 1 mi of the Project area.
Usnea longissima (Methuselah's beard lichen)	None/None/4.2	On tree branches, usually on old growth hardwoods and conifers in broadleafed upland forest and north coast coniferous forest; 160–4,790 ft. Blooming period: N/A (lichen)	CNPS, CDFW	**Moderate:** Broadleafed upland and north coast coniferous forest habitats present within Project area. Multiple occurrences within 5–10 mi of the Project area.

Table 2. Special status wildlife species with the potential to be present in or around the Project Area.

Species name	Status[1] Federal/ State	Distribution and habitat associations	Location of suitable habitat in Project area	Likelihood of occurrence
Fish				
Oncorhynchus kisutch (Coho salmon – southern Oregon/ northern California coast Evolutionarily Significant Unit)	FT, CH/ST	Spawn in coastal streams and large mainstem rivers (i.e., Klamath/Trinity rivers) in riffles and pool tails-outs and rear in pools ≥ 3 ft deep with overhead cover with high levels oxygen and temperatures between 50–59°F.	Suitable habitat occurs in the South Fork Eel River and Redwood Creek.	**High**: Present in Redwood Creek.
Oncorhynchus tshawytscha (Chinook salmon – California Coastal ESU*)*	FT, CH/None	Wild coastal, spring, and fall-run Chinook found in streams and rivers between Redwood Creek, Humboldt County to the north and the Russian River, Sonoma County to the south.	Suitable habitat occurs in the South Fork Eel River and Redwood Creek.	**High**: Present in Redwood Creek.
Oncorhynchus mykiss (Steelhead – northern California coast Distinct Population Segment)	FT, CH/None	Inhabits small coastal streams to large mainstem rivers with gravel-bottomed, fast-flowing habitat for spawning. However, habitat criteria for different life stages (spawning, fry rearing, juvenile rearing) are can vary significantly.	Suitable habitat occurs in the South Fork Eel River and Redwood Creek.	**High**: Present in Redwood Creek.
Entosphenus tridentatus (Pacific lamprey)	None/SSC	Similar to anadromous salmonids, inhabits coastal streams and rivers with gravel-bottomed, fast-flowing habitat for spawning. Ammocoetes rear in backwater areas with sand, silt, and organic material for 4 to 10 years before migrating to the ocean.	Suitable habitat is present and spawning/rearing occurs in the South Fork Eel River. Spawning and rearing habitat is likely to occur in Redwood Creek.	**High:** Suitable habitat present.

Species name	Status[1] Federal/ State	Distribution and habitat associations	Location of suitable habitat in Project area	Likelihood of occurrence
		Amphibians		
Rana boylii (Foothill yellow-legged frog, North Coast Clade)	None/SSC	Associated with partially shaded, shallow streams, and riffles with rocky substrate. Some cobble-sized substrate required for egg laying. Adults move into smaller tributaries after breeding.	Suitable habitat is present and breeding occurs in the South Fork Eel River. Observed in Redwood Creek downstream of Project area.	**High**: Suitable habitat present.
Taricha rivularis (Red-bellied newt)	None/SSC	Ranges from southern Humboldt to Sonoma counties. Found in streams during breeding season. Moist habitats under woody debris, rocks, and animal burrows.	Suitable habitat is present and sightings have occurred in the Mattole River, approximately 5 mi west of the Project area.	**High**: Habitat present in the Project area.
		Birds		
Strix occidentalis caurina (Northern spotted owl)	FT/ST	Typically found in large, contiguous stands of mature and old-growth coniferous forest with dense multi-layered structure.	Suitable foraging habitat is present within the Project area. Habitat within the Project area is unsuitable for nesting. The closest activity center is over 1.7 mi to the south-southeast of the Project area.	**Moderate**: Suitable foraging habitat exists in the Project area.
Asio otus (Long-eared owl)	None/SSC	Distributed throughout North America. Recorded in north coast from Bald Hills, Humboldt County to Willits, Mendocino County. In Humboldt County, nest in mixed stands of conifers and oaks with edges and openings such as meadows or prairies.	Suitable nesting and foraging habitat present in the Project area.	**High**: Habitat present in the Project area.
		Reptiles		
Emys marmorata (Western pond turtle)	None/SSC	Ponds, marshes, rivers, streams, and irrigation ditches with abundant vegetation, and either rocky or muddy bottoms, in woodland forest and	Suitable habitat occurs in the South Fork Eel River. Ponds that may contain western	**Moderate.** May occur in neighboring ponds.

Species name	Status[1] Federal/ State	Distribution and habitat associations	Location of suitable habitat in Project area	Likelihood of occurrence
		grasslands. Below 6,000 ft elevation. Basking sites are required. Egg-laying sites are located on suitable upland habitats (grassy open fields) up to 1,640 ft from water.	pond turtles are located on neighboring properties.	
		Mammals		
Arborimus pomo (Sonoma tree vole)	None/SSC	Associated nearly exclusively with Douglas-fir trees and occasionally grand fir trees within the north coast fog belt between the northern Oregon border and Sonoma County. Eats Douglas-fir needles exclusively.	Early to mid-seral Douglas-fir stands are present adjacent to the Project area, which could provide nesting and foraging habitat.	**High**: Recorded occupying timber stands adjacent to the Project area
Corynorhinus townsendii (Townsend's big-eared bat)	None/SSC, CT	Found throughout California in all but subalpine and alpine habitats. Roosts in cavernous habitats, usually in tunnels, caves, buildings, mines, and basal hollows of trees, but also rock shelters, preferentially close to water. Caves near water's edge are favored. Forages in riparian zone and follows creeks and river drainages on foraging bouts. Feeds primarily on moths. Drinks at stream pools.	Suitable foraging habitat throughout most of the Project area; however, barns, old buildings, and bridges for roosting are not present within the Project area.	**Moderate**: May be present in some of the barns and older structures adjacent to the Project area.
Antrozous pallidus (Pallid bat)	None/SSC	Found throughout California. Roosts in rock crevices, outcrops, cliffs, mines, and caves; trees (underneath exfoliating bark of pine and oak) and in basal hollows; and a variety of vacant and occupied structures (e.g., bridges) or buildings. Roost individually or in small to large colonies (hundreds of individuals). Feeds low to or on the ground in a variety of open habitats, primarily on ground-dwelling arthropods.	Suitable foraging habitat throughout most of the Project area, however, barns, old building, and bridges are not present within the Project area.	**Moderate**: May be present in some of the older structures adjacent to the Survey Area

Species name	Status[1] Federal/ State	Distribution and habitat associations	Location of suitable habitat in Project area	Likelihood of occurrence
		Forages most frequently in riparian zone, in open oak savannah, and open mixed deciduous forest. Drinks at stream pools.		

(a) Less Than Significant with Mitigation Incorporated: The project will not have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status in local or regional plans, policies, or regulations, or by the California Department of Fish and Wildlife (CDFW), National Oceanic and Atmospheric Administration (NOAA) or U.S. Fish and Wildlife Service (USFWS). All effects will be less than significant with the incorporation of the mitigation measures listed below and in Appendix F of the BOD Report.

Plants

No special-status plant species were observed during the protocol-level botanical survey conducted in the Project area on 4 May 2019 (see Appendix F of BOD Report). In addition, there are no records of special-status plant occurrences within the Project area based on the 2019 CDFW CNDDB queries and collection records in the Consortium of California Herbaria (ucjeps.berkeley.edu/consortium). As such, Project activities will have no impact on known special-status plant populations. However, the following design features are incorporated into the project description and discussed further in Appendix F of BOD Report.

- The Project footprint will be minimized to the extent possible.
- The ponds will be positioned to minimize impacts on existing vegetation to the extent possible.
- Ground disturbance and vegetation clearing and/or trimming will be confined to the minimum amount necessary to facilitate Project implementation.
- Heavy equipment and vehicles will use existing access roads to the extent possible.
- Construction materials will be stored in designated staging areas.
- Measures to prevent the spread of invasive weeds and sudden oak death pathogens will be taken, including, where appropriate, inspecting equipment for soil, seeds, and vegetative matter, cleaning equipment, utilizing weed-free materials and native seed mixes for revegetation, and proper disposal of soil and vegetation.
- Disturbed soils areas will be revegetated with native grasses and forbs. Please see the erosion control and revegetation sheet in the project design package.

Fish

Coho and Chinook salmon, steelhead, and Pacific lamprey are special-status fish species known to occur in Redwood Creek within to the Project area. Project-related impacts on these species could result from discharge of sediment from ponds and infiltration gallery construction, gully stabilization, instream habitat enhancement, contact with heavy equipment, and/or entrainment into dewatering pumps.

There would be long-term beneficial effects for fish and habitat resulting from the addition of large wood and water to the stream channel. The increase in wood structures would result in localized scour and help create pool and cover habitat for fish. The input of water during the summer and late fall would increase flow in Redwood Creek during the dry season. It is expected that coho salmon and steelhead will benefit from the augmentation of project water during the summer and fall months. Stabilization of the gullies on the property would reduce sediment input into Redwood Creek which has adverse effects on spawning and rearing habitat for fish.

The following measures, and those in Appendix I of the BOD Report, will be employed by the Project to avoid, minimize, or mitigate indirect sediment-related impacts on special-status fish species and their habitat.

BIO-1: The use of cofferdams will contain any turbid water produced during the Project within the work area, thereby avoiding impacts on downstream salmonids. Any turbid water within the confined work areas would be pumped to a receiving site outside the channel or to tanks. Any turbid water within the work area would be allowed to settle prior to removal of the cofferdams, thereby minimizing downstream effects on salmonids.

BIO-2: Discharge of sediment will be controlled and minimized with the implementation of best management practices (BMPs) on all disturbed soils that have the potential to discharge into area watercourses. Applicable BMPs include, but are not limited to, installation of silt fences, straw wattles, and placement of seed-free rice straw. BMPs will be installed at all access points to the work sites, which will minimize the potential for sediment delivery and deleterious effects on salmonids.

BIO-3 - All gully stabilization work will be conducted when the individual sites are dry (i.e. no surface water).

BIO-4: A June 15 – November 1 instream work window will be established to allow time for young-of-the-year salmonids to be very mobile and capable of avoiding injury. The work window will also allow downstream migration of smolts to be completed prior to any Project-related channel disturbance taking place. In addition, the work window coincides with the summer low-flow season during which flow in the creek will be at its summer base flow. Finally, the November 1 date will ensure all work is done prior to the rainy season and arrival of any upstream migrating adult salmonids.

BIO-5: Prior to the initiation of any instream work in areas with surface water, a qualified biologist will survey the site to determine fish presence. The biologist will implement an aquatic species removal and relocation plan to move any fish or amphibians that may be in work sites to suitable habitat downstream. Block nets will be installed to prevent fish from reentering the work area. Any fish remaining in the work area will be captured by hand, dip net, or as a last resort, using a backpack electrofisher. Cofferdams will be constructed in the channel at sites where streamflow is present. Water will then be diverted around the work area.

BIO-6: The Project will follow the Fish Screening Criteria for Salmonids (NMFS 1997), NOAA Restoration Center/Army Corps of Engineers programmatic biological opinion requirements.

Wildlife

Foothill yellow-legged frogs

The ponds and filtration gallery construction activities will take place in open meadow areas not utilized by foothill yellow-legged frogs. However, foothill yellow-legged could be affected by proposed activities that would take place within Redwood Creek and at gully stabilization sites.

Impacts on adult, juvenile, or larval frogs could occur through direct contact with heavy equipment or disturbed soil. Adverse impacts could occur from instream structure construction, dewatering of work areas, trampling of larvae during instream operations, contact with heavy equipment, and sediment discharge. The gully stabilization sites are not utilized by foothill yellow-legged frogs for breeding or larval rearing and impact on these life history stages would not occur at these locations.

The Project would result in the development of additional instream habitat, which should benefit foothill yellow-legged frogs by maintaining and potentially expanding the amount of instream habitat available for breeding and larval development in Redwood Creek.

The following mitigation measures, and those Appendix I of the BOD Report, will be employed to avoid or minimize effects on foothill yellow-legged frogs:

BIO-7: A foothill yello-legged frog egg mass survey will be conducted in May prior to the construction season to determine if breeding occurs within the Project reaches.

BIO-8: A visual observation survey of the project areas will be conducted within two weeks prior to the start of construction to determine if adult and juvenile foothill yellow-legged frogs are present in the Project area.

BIO-9: If foothill yellow-legged frogs are present, then a qualified CDFW-approved biologist will be present immediately prior to the start of construction to remove any frogs and relocate them in suitable habitat.

BIO-10: The Project manager or qualified designee will conduct daily morning inspections of the area slated for work to determine if amphibians entered the areas overnight. Any individuals will be captured and relocated prior to the start of the day's work.

Red-bellied newt

Adult and juvenile red-bellied newts would likely be occupying terrestrial areas during the operation period and could be affected by heavy equipment that collapses burrows or moves woody debris. Larval newts have the potential to be present in areas that could be affected by instream operations. Mitigation measure BIO 10, those in Appendix K of the BOD Report, and the following will be employed to avoid or minimize the potential for take of red-bellied newt:

BIO-11: Sufficient terrestrial woody debris will be left in place to maintain the habitat supporting viable population of red-bellied newt during operations within the riparian areas.

BIO-12: Prior to the initiation of any instream work in areas with surface water, a qualified biologist will survey the site to determine larval newt presence. If red-bellied newts are present, then a qualified CDFW-approved biologist will be present immediately prior to the start of operations to remove any individuals and relocate them in suitable habitat.

The Project will result in the development of additional instream habitat, which should benefit red-bellied newts by maintaining and potentially expanding the amount of instream habitat available for breeding and larval development.

Northern spotted owl

The closest northern spotted owl activity center to the Project is approximately 1.7 mi away from the Project area and recent surveys (i.e., within the last four years) have not documented nesting within this activity center (Appendix F of the BOD Report). Nesting habitat does not occur within the Project area or in the adjacent forest. The Project activities do not include removal of any trees that could provide habitat for owls. Therefore, there will not be any direct impacts on northern spotted owls or their habitat. However, there is the potential for construction-related noise to affect northern spotted owls that may be on adjacent properties or away from the Project area.

The potential for Project construction to indirectly impact nesting northern spotted owls was preliminary evaluated using USFWS (2006) guidelines. Owls can be affected by noise-related, visual, or physical disturbances, such as created by heavy equipment. USFWS (2006) identifies the distance that sound associated with different types of construction equipment is estimated to disturb northern spotted owls during the breeding season, relative to ambient noise levels. Most types of standard construction equipment (e.g., backhoes, bulldozers, construction vehicles, etc.) would require disturbance buffers of 330–1,320 ft from nesting spotted owl activity centers. No Project activities utilizing these types of equipment are expected to occur within 1,320 ft of a northern spotted owl nest. In addition, as stated above, recent surveys have not found nesting northern spotted owls with the closest known activity center (1.7 mi from the Project area). Therefore, project effects on northern spotted owls would be less than significant.

Long-eared owl

Long-eared owls have not been observed within 17 mi of the Project area (Appendix K of the BOD Report). However, this species nests in conifer and oak woodlands that are either open or are adjacent to grasslands, meadows, or shrublands. These habitats exist within the Project area, although no evidence of occupancy was observed during the field survey. Construction activities associated with the Project would not affect nesting or roosting habitat since no trees would be removed. However, potential foraging habitat could be affected due to the construction of the reservoir and infiltration gallery. In addition, construction noise may affect nesting owls.

The construction of the ponds will result in approximately 3.1 ac of grazed grassland area being permanently converted to open water and associated containment berm features. This conversion could affect the amount of foraging habitat available for long-eared owls. A preliminary estimate of available grasslands in the Briceland area conducted using satellite imagery showed approximately 470 ac of grassland (not including numerous small openings) within a one-mile radius of the Project area. The Project would convert approximately 0.7% of this area to reservoir, a relatively minor impact in consideration of the amount of suitable foraging habitat in the vicinity and the lack of evidence indicating species presence in and around the Project area.

The following conservation measure will be employed to avoid or minimize the potential for impacts on long-eared owls:

BIO-13: A pre-construction nesting bird survey will be conducted during the breeding season and within two weeks of the start of construction pursuant to CDFW Survey and Monitoring Protocols. Appropriate buffers will be established around all active nests within the Project area.

Sonoma tree vole

Suitable habitat for Sonoma tree voles is present in the timber stand adjacent to the Project area. The Project will not occur within the forest nor remove any trees; therefore, there will be no impact on this species.

Pallid bat

Suitable habitat for pallid bats is present in the timber stand adjacent to the Project area. The Project will not occur within the forest nor remove any trees or structures that could be occupied by this species; therefore, there will be no impact on pallid bat.

Townsend's big-eared bat

Suitable habitat for Townsend's big-eared bats is present in the timber stand adjacent to the Project area. The Project will not occur within the forest nor remove any trees or structures that could be occupied by this species; therefore, there will be no impact on Townsend's big-eared bat.

Western pond turtles

Redwood Creek, within the Project area has a relatively closed canopy, which would limit the basking opportunities for turtles. In addition, water flow during the summer months is very low or intermittent, which is not the preferred habitat for turtles. Finally, there are no ponds in the Project area that could contain this species. However, there is still the potential that turtles could be within the Project area at the start of construction.

The following mitigation measure, along with those in Appendix K of the BOD Report, will be employed to avoid or reduce impacts on western pond turtles to a less than significant level:

BIO-14: Prior to the initiation of any instream work in areas with surface water, a qualified biologist will survey the site to determine turtle presence. The biologist will capture and relocate any turtle that may be in work sites to suitable habitat downstream. Block nets will be installed to prevent turtles from reentering the work area.

Bullfrogs

The construction and operations of the pond has the potential to create habitat for bullfrogs and subsequently impact native species. The following avoidance and minimization measures will be incorporated in the project design, monitoring and maintenance plan. In order to avoid bullfrogs from infesting the project sites the following strategies will be implemented:

a) Landowner and resident education is one of the most important strategies, as people have been known to intentionally introduce bullfrogs to local bodies of water as a source of food.

b) Monitoring of project sites will also be very important as early detection, before populations can get established, is a key component of control. Monitoring will be conducted as per Exhibit A in Appendix I of the BOD Report: Bullfrog Monitoring and Management Plan prepared by CDFW.

c) If needed, the off-channel ponds may be drained. David Manthorne, CDFW Senior Environmental Scientist recommends draining of ponds if invasive bullfrogs are present to interrupt their life cycle (CDFW Compliance Guidance). According to research by Doubledee et al, 2007, "*Bullfrogs*, *Disturbance Regimes*, *and the Persistence of California Red-Legged Frogs* ", draining of ponds can be effective for bullfrog management if draining occurs at least every 2 years.

d) If annual monitoring shows that bullfrogs are present, active measures will be taken in consultation with CDFW and will follow the methods described in Exhibit A of BOD Appendix I: Bullfrog Monitoring and Management Plan

(b) Less than Significant: The project will not have a substantial adverse effect on any riparian habitat or other sensitive natural communities identified in local or regional plans, policies and regulations, or by CDFW or USFWS.

One sensitive natural community, *Acer macrophyllum* Forest Alliance (S3), was observed within the Project area (Appendix F of the BOD Report). This alliance comprised the riparian forest (also under CDFW preliminary jurisdictional throughout the Project area) adjacent to Redwood Creek and its tributaries in the Project area. Some minor disturbance is anticipated within this natural community during the instream habitat enhancement and gully stabilization Project activities. Installation of the off-channel ponds will not affect this sensitive natural community, as it will replace a portion of the annual/perennial grassland in the Project area. Also, it is expected that the gully stabilization work will provide groundwater storage benefits, which could enhance riparian vegetation in those locations.

Some minor disturbance is expected where proposed instream structures are keyed into the stream banks. Riparian vegetation will be reestablished where construction activities disturb existing plants, and additional native plants will be planted to enhance the riparian vegetation. Mitigation measures to minimize impacts on riparian habitat are found in Appendix I of the BOD Report and include:

BIO-15: Planting of seedlings shall begin after December 1, or when sufficient rainfall has occurred to ensure the best chance of survival of the seedlings, but in no case after April 1.

BIO-16: Any disturbed banks shall be fully restored upon completion of construction. Revegetation shall be done using native species. Planting techniques can include seed casting, hydroseeding, or live planting methods using the techniques in Part XI of the California Salmonid Stream Habitat Restoration Manual.

BIO-17: Disturbed and compacted areas shall be re-vegetated with native plant species. The species shall be comprised of a diverse community structure that mimics the native riparian corridor. Planting ratio shall be 2:1 (two plants to every one removed). Unless otherwise specified, the standard for success is 80 percent survival of plantings or 80 percent ground cover for broadcast planting of seed after a period of 3 years.

BIO-18: To ensure that the spread or introduction of invasive exotic plants shall be avoided to the maximum extent possible, equipment shall be cleaned of all dirt, mud, and plant material prior to entering a work site. When possible, invasive exotic plants at the work site shall be removed. Areas disturbed by project activities will be restored and planted with native plants.

BIO-19: Mulching and seeding shall be done on all exposed soil which may deliver sediment to a stream. Soils exposed by project operations shall be mulched to prevent sediment runoff and transport. Mulches shall be applied so that not less than 90% of the disturbed areas are covered. All mulches, except hydro-mulch, shall be applied in a layer not less than two (2) inches deep. Where feasible, all mulches shall be kneaded or tracked-in with track marks parallel to the contour, and tackified as necessary to prevent excessive movement. All exposed soils and fills, including the downstream face of the road prism adjacent to the outlet of culverts, shall be reseeded with a mix of native grasses common to the area, free from seeds of noxious or invasive weed species, and applied at a rate which will ensure establishment.

BIO-20: If erosion control mats are used in re-vegetation, they shall be made of material that decomposes. Erosion control mats made of nylon plastic, or other non-decomposing material shall not be used.

BIO-21: If riparian vegetation is to be removed with chainsaws, the Permittee shall use saws that operate with vegetable-based bar oil.

(c) No impact: The project will not have a substantial adverse effect on federally protected wetlands as defined by § 404 of the Clean Water Act as there are no USACE jurisdictional wetlands within the project area. Two small state jurisdictional isolated wetlands have been mapped on the parcel but will not be disturbed as the result of any proposed project. The wetlands are located in the northeastern portion of the site approximately 300 feet from the project area. The project actions will have either no effect on wetlands or will be beneficial to wetlands.

(d) Less Than Significant Impact with Mitigation Incorporated: The instream construction portion of the project that requires the installation of cofferdams and dewatering of the work area will temporarily affect migration of fish between habitat units. However, this disruption in the ability of fish to migrate will only occur during the brief instream construction period. In addition, the instream part of the project is timed to begin after the downstream salmonid smolt migration has ceased. The project would end prior to the start of the upstream migration season for adult salmonids.

Once completed, the project will result in a substantial improvement in the ability of juvenile fish to migrate between habitat units during the dry season. This is due to the discharge of project water from the ponds into Redwood Creek. It is expected that the augmented flow will help maintain a single thread channel and connectivity between habitat units that is currently lacking during dry years. In addition, the project includes the installation of an instream habitat structure designed to create pool and cover habitat. This will improve the rearing habitat in Redwood Creek. These design features and implementation of the mitigation measures **BIO-4, -5, and -6** described above and in Appendix I of the BOD Report will reduce impacts to a less than significant level.

(e) No Impact: The project will not conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance. Such an impact will not occur because project actions are designed to restore and enhance biological resources. The Humboldt County Streamside Management Area Ordinance requires a Special Permit for all activities within Streamside Management Areas. This project has been submitted to the Humboldt County Planning Department with a Special Permit application as needed to allow for the project activities within the Streamside Management Areas. The Project supports goals, policies and standards in the Humboldt County General Plan's Bioloigcal Element including sufficient revcovery of threatened and endangered species to support delisting (BR-G1), protect fish and wildlife habitats on a sustainable basis to generate long-term public, economic and environmental benefits (BR-G3), fishery, wildlife, and aquaculture enhancement and restoration projects (BR-S6), and consulting with appropriate agencies on projects with potential to impact critical, or sensitive habitats (BR-S2).

(f) No Impact: The project will not conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or State habitat conservation plan. Such a conflict will not occur because the project restoration actions will not have a significant adverse impact on any species or habitat. Project actions are designed to restore the natural character of the fish and wildlife habitat at the project work sites. The project specifically supports the California Salmon, Steelhead Trout and Anadromous Fisheries Program Act (Fish and Game Code § 6900 et. seq.).

V. Cultural Resources. Would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Cause a substantial adverse change in the significance of a historical resource as defined in §15064.5?		X		
b) Cause a substantial adverse change in the significance of an archaeological resource pursuant to §15064.5?		X		
c) Disturb any human remains, including those interred outside of formal cemeteries?		X		

Discussion:

(a) Less Than Significant with Mitigation Incorporated: The project will not cause a substantial adverse change in the significance of a historical resource as defined in CEQA Guidelines § 15064.5.

Resources identified during site-specific surveys will be protected before ground-disturbing activities are permitted at a site. Ground disturbance will be required to implement the project at some work sites that have the potential to affect historical resources, this potential impact will be minimized to a less than significant level through implementation of the protective measures presented below and in Appendix E of the BOD Report. As a result, any potentially significant impacts will be avoided or mitigated to below a level of significance.

CR-1: Cultural resources on the site will be protected by the Permittee through implementation of the following protective measures before work can proceed:

a) The archaeological site boundary as identified in the Cultural Resources Investigation, shall be clearly marker during project implementation. Boundary markers such as flagging, stakes, fencing, or other highly visible barrier should be used.

b) The area containing the archaeological site shall be completely excluded from ground disturbing activities. The proposed path of the pond intake pipeline and primary spillway have been rerouted to avoid ground disturbance to the identified sensitive area.c) Spoils from pond excavation may be placed directly on the existing archaeological site surface, however, no grading or scarifying shall be conducted. Heavy equipment shall not enter the archaeological site unless atop a sufficient layer of fill, such that the underlying soil is not displaced.

d) All ground-disturbing activities and placement of fill material within the known archaeological site shall be monitored by a professional archaeologist familiar with specific project conditions. A monitoring plan should be developed and used to guide monitoring and discovery protocol.

e) In the event additional archaeological material is encountered during project implementation or during future site monitoring efforts, all work shall stop in the area of the find and the discovery protocol initiated as described below in MM CR-3.

CR-2: The Permittee shall ensure that the implementation contractor or responsible party is aware of these site-specific conditions, and shall inspect the work site before, during, and after completion of the action item.

CR-3: Inadvertent Discovery of Cultural Resources - If cultural resources are encountered during construction activities, all onsite work shall cease in the immediate area and within a 50-foot buffer of the discovery location. A qualified archaeologist will be retained to evaluate and assess the significance of the discovery, and develop and implement an avoidance or mitigation plan, as appropriate. For discoveries known or likely to be associated with Native American heritage (prehistoric sites and select historic period sites), the tribes listed in Section 6.2 and those that the County has on file shall also be contacted immediately to evaluate the discovery and, in consultation with the project proponent, the County, and consulting archaeologist, develop a treatment plan in any instance where significant impacts cannot be avoided. Prehistoric materials which could be encountered include obsidian and chert debitage or formal tools, grinding implements, (e.g., pestles, handstones, bowl mortars, slabs), locally darkened midden, deposits of shell, faunal remains, and human burials. Historic archaeological discoveries may include nineteenth century building foundations, structural remains, or concentrations of artifacts made of glass, ceramics, metal or other materials found in buried pits, wells or privies.

(b) Less Than Significant with Mitigation Incorporated: The project will not cause a substantial adverse change in the significance of an archaeological resource pursuant to CEQA Guidelines § 15064.5. While ground disturbance will be required to implement the project at some work sites that have the potential to affect archaeological resources, this potential impact will be avoided through implementation of the protective measures described above and presented in Appendices E and I of the BOD Report for all work sites. Resources identified during site-specific surveys will be protected before ground-disturbing activities are permitted at a site and an archeological monitor will be present during excavation in critical areas. As a result, mitigation measures will ensure that any potentially significant impacts are avoided or mitigated to below a level of significance.

(c) Less Than Significant with Mitigation Incorporated: The project is highly unlikely to disturb any human remains, including those interred outside of formal cemeteries. While ground disturbance will be required to implement the project at some work sites that have the potential to affect these resources, this potential impact will be avoided through implementation of the protective measures presented in Appendix E of the BOD Report for all work sites. Resources identified during site-specific surveys will be protected before ground-disturbing activities are permitted at a site and an archeological monitor will be present during excavation in critical areas.

CR-4: Inadvertent Discovery of Human Remains - If human remains are discovered during project construction, work shall stop at the discovery location, within 20 meters (66 feet), and any nearby area reasonably suspected to overlie adjacent human remains (Public Resources Code, Section 7050.5). The county coroner shall be contacted to determine if the cause of death must be investigated. If the coroner determines that the remains are of Native American origin, it is necessary to comply with state laws relating to the disposition of Native American burials, which fall within the jurisdiction of the Native American heritage Commission (NAHC) (Public Resources Code, Section 5097). The coroner will contact the NAHC. The descendants or most likely descendants of the deceased will be contacted, and work shall not resume until they have made a recommendation to the landowner or the person responsible for the excavation work for means of treatment and disposition, with appropriate dignity, of the human remains and any associated grave goods, as provided in Public Resources Code, Section 5097.98.

CR-5: Procedures for treatment of an inadvertent discovery of human remains:

a) Immediately following discovery of known or potential human remains all ground-disturbing activities at the point of discovery shall be halted.

b) No material remains shall be removed from the discovery site, a reasonable exclusion zone shall be cordoned off.

c) The property owner shall be notified and the Permittee Project Manager shall contact the county coroner.

d) The Permittee shall retain the services of a professional archaeologist to immediately examine the find and assist the process.

e) All ground-disturbing construction activities in the discovery site exclusion area shall be suspended.

f) The discovery site shall be secured to protect the remains from desecration or disturbance, with 24-hour surveillance, if prudent.

g) Discovery of Native American remains is a very sensitive issue, and all project personnel shall hold any information about such a discovery in confidence and divulge it only on a need-to-know basis, as determined by the CDFW.

h) The coroner has two working days to examine the remains after being notified. If the remains are Native American, the coroner has 24 hours to notify the NAHC in Sacramento (telephone 916/653-4082).

i) The NAHC is responsible for identifying and immediately notifying the Most Likely Descendant (MLD) of the deceased Native American.

j) The MLD may, with the permission of the landowner, or their representative, inspect the site of the discovered Native American remains and may recommend to the landowner and Permittee means for treating or disposing, with appropriate dignity, the human remains and any associated grave goods. The descendants shall complete their inspection and make recommendations or preferences for treatment with 48 hours of being granted access to the site (Public Resource Code, Section 5097.98(a)). The recommendation may include the scientific removal and non-destructive or destructive analysis of human remains and items associated with Native American burials.

k) Whenever the NAHC is unable to identify a MLD, or the MLD identified fails to make a recommendation, or the landowner or his/her authorized representative rejects the recommendation of the MLD and mediation between the parties by the NAHC fails to provide measures acceptable to the landowner, the landowner or his/her authorized representatives shall re-inter the human remains and associated grave offerings with appropriate dignity on the property in a location not subject to further subsurface disturbance in accordance with Public Resource Code, Section 5097.98(e).

l) Following final treatment measures, the Permittee shall ensure that a report is prepared that describes the circumstances, nature and location of the discovery, its treatment, including results of analysis (if permitted), and final disposition, including a confidential map showing the reburial location. Appended to the report shall be a formal record about the discovery site prepared to current California standards on DPR 523 form(s). Permittee shall ensure that report copies are distributed to the appropriate California Historic Information Center, NAHC, and MLD.

VI. Energy. Would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Result in potentially significant environmental impact due to wasteful, inefficient, or unnecessary consumption of energy resources, during project construction or operation?			X	
b) Conflict with or obstruct a state or local plan for renewable energy or energy efficiency?				X

Discussion:

(a) Less Than Significant: The Project will not result in the wasteful, inefficient, or unnecessary consumption or energy resources during construction or operations. The construction contractors will be using heavy equipment as effectively as possible to reduce fuel and labor costs and generation of greenhouse gasses. In addition, the operation of the Project will utilize an off-grid energy system powered by solar panels.

(b) No impact: The Project will not conflict with or obstruct a state or local plan for renewable energy or energy efficiency. The Project includes the installation of an off-grid energy system powered by solar panels.

VII. Geology and Soils. Would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving:				
i) Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42.				X
ii) Strong seismic ground shaking?				X
iii) Seismic-related ground failure, including liquefaction?			X	
iv) Landslides?			X	
b) Result in substantial soil erosion or the loss of topsoil?		X		
c) Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse?			X	
d) Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial direct or indirect risks to life or property?			X	
e) Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater?				X
f) Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?				X

Discussion:

(a) No Impact and Less Than Significant Impact:

(i) There are no earthquake faults on the project site. The nearest fault (Briceland Fault) is located over 4,000 ft to the northeast and is not considered active (CGS 2018). The project site is not located in an Earthquake Fault Zone (CGS 2018). The nearest active fault is the San Andreas fault, which is approximately 9.5 miles southwest of the project site. Therefore, there would be no impact.

(ii) The project would not result in strong seismic ground shaking or involve construction of features that would be at risk of structural failure due to strong seismic ground shaking. Therefore, there would be no impact.

(iii) The project's geotechnical report (Appendix B of the BOD Report) described that the materials beneath the upper terrace (where eastern pond will be located) have clay skins and iron and manganese accumulations, and is therefore too old and well cemented to be susceptible to liquefaction. The lower terraces (western pond and fill placement location) was described as having a low to moderate potential for liquefaction under sustained ground shaking. Within this portion of the project area, excavated fill from the pond sites will be placed and recontoured with gentle slopes that do not pose a substantial adverse risk. No human habitation structures are being proposed on these sites. Therefore, there would be a less than significant impact.

(iv) The geotechnical report stated that the project sites are on planar, generally level ground and that mass wasting is unlikely to affect the areas that would be under construction. In addition, the pond design contains multiple safety features as described in the BOD Report that would further limit the potential for failure. Therefore, there would be a less than significant impact.

(b) Less Than Significant impact With Mitigation Incorporated: The project will not result in substantial soil erosion or the loss of topsoil. Such an impact will not occur because the Project is designed to contribute to an overall reduction in gully erosion. Existing roads will be used to access work sites wherever possible. The potential for substantial soil loss associated with pond construction will be avoided through implementation of the design features and mitigation measures presented in Appendix I of the BOD Report.

GEO-1: Work sites shall be winterized at the end of each day to minimize the eroding of unfinished excavations when significant rains are forecasted. Winterization procedures shall be supervised by a professional trained in erosion control techniques and involve taking necessary measures to minimize erosion on unfinished work surfaces. Winterization includes the following: smoothing unfinished surfaces to allow water to freely drain across them without concentration or ponding; compacting unfinished surfaces where concentrated runoff may flow with an excavator bucket or similar tool, to minimize surface erosion and the formation of rills; and installation of culverts, silt fences, and other erosion control devices where necessary to convey concentrated water across unfinished surfaces, and trap exposed sediment before it leaves the work site.

GEO-2: Effective erosion control measures shall be in-place at all times during construction. Construction shall not begin until all temporary erosion controls (i.e., straw bales or silt fences that are effectively keyed-in) are in place down slope or down stream of project activities within the riparian area. Erosion control measures shall be maintained throughout the construction period. If continued erosion is likely to occur after construction is completed, then appropriate erosion prevention measures shall be implemented and maintained until erosion has subsided.

GEO-3: An adequate supply of erosion control materials (gravel, straw bales, shovels, etc.) shall be maintained onsite to facilitate a quick response to unanticipated storm events or emergencies.

GEO-4: Upon project completion, all exposed soil present in and around the project site shall be stabilized within 7 days. Soils exposed by project operations shall be mulched to prevent sediment runoff and transport. Mulches shall be applied so that not less than 90% of the disturbed areas are covered. All mulches, except hydro-mulch, shall be applied in a layer not less than two (2) inches deep. Where feasible, all mulches shall be kneaded or tracked-in with track marks parallel to the contour, and tackified as necessary to prevent excessive movement. All exposed soils and fills, including the downstream face of the road prism adjacent to the outlet of culverts, shall be reseeded with a mix of native grasses common to the area, free from seeds of noxious or invasive weed species, and applied at a rate which will ensure establishment.

(c) Less Than Significant impact: To minimize the risk of the project interacting with or creating geologic instabilities, geomorphic mapping of the greater project area and a geotechnical investigation of the site were conducted. Geomorphic mapping identified one dormant, one suspended, and one active landslide area, all of sufficient distance and topographic isolation to pose less than significant hazards to project infrastructure. Grade control structure installation in the west and central tributaries and a bank stabilization structure to be installed in Redwood Creek will serve to enhance geologic stability in the project area. Comprehensive results of the geomorphic and geotechnical investigations as well as Slope Stability Analyses are included in the Basis of Design Report in Attachment A. Additionally, best practices for construction will be maintained, including adherence to detailed compaction specifications as well as construction oversight by senior geotechnical and engineering staff.

Geotechnical Investigation Report (Appendix B of Basis of Design Report in Attachment A)

Geotechnical Investigation was performed by SHN with the purpose to evaluate the geotechnical conditions relative to the proposed water storage basins and associated infrastructure. The assessment focused on the geologic suitability of the site (exposure to geohazards and potential to influr5ence site geologic conditions) and general geotechnical conditions.

The scope of the investigation included reviewing available geologic and subsurface information; overseeing the advancement of geotechnical borings and excavation of soil test pits; percolation testing; performing laboratory testing on selected soil samples; and providing engineering geologic and geotechnical recommendations to aid in project planning, design, and construction.

Geologists from SHN conducted site visits on August 27 and 28, 2018, to oversee the advancement of three exploratory geotechnical borings and oversee the excavation of four soil test pits and two percolation pits. SHN conducted a supplemental geotechnical investigation in October 2020 that consisted of drilling two additional borings to further characterize the subsurface conditions in support of a slope stability analysis that was conducted by Stillwater Sciences. The exploration locations (borings and test pits) were chosen based on the initial locations of the proposed water storage basins and plumbing infrastructure to assess sub-surface soil and groundwater conditions, and infiltration rates. The project has since evolved with two proposed storage basins.

The assessment evaluated potential Geologic hazards common to the local area including seismic ground shaking, surface fault rupture, seismically induced ground deformation (liquefaction, coseismic compaction, and lateral spreading), slope stability and flooding.

Conclusions Relative to Geologic Hazards

The project appears associated with a low exposure to geologic hazards. What low risk is associated with the site has been mitigated through development of an extremely conservative design plan. The proposed storage basins are designed as a largely below-grade, lined structures with modest embankments, and large setbacks from adjacent slopes. The proposed embankments are designed with a low permeability cut-off trench extending into the underlying bedrock in order to reduce lateral groundwater flow through the terrace deposits.

The primary geologic hazards at the site are seismic shaking and landsliding. Seismic shaking is a regional hazard and is regularly mitigated through standard engineering design.

The risk of impacts associated with existing landslide hazard is negligible, due to the large setback of infrastructure from vulnerable slopes and the low permeability of the subsurface materials at the site. The potential for sliding along the "bedrock interface" (that is, the slightly dipping contact between the bedrock abrasion surface and the overlying terrace deposits) is negligible.

Conclusions and Recommendations

Based on the results of the field and laboratory investigation, it is SHN's opinion the project is feasible from a geohazard and geotechnical standpoint, if SHN's recommendations are implemented during design and construction.

Supplemental Geotechnical Investigations and Slope Stability Analyses (Appendix B of Basis of Design Report in Attachment A)

During October and November 2020, three significant activities were conducted to further characterize subsurface conditions and assess stability of the proposed Project. These included the following:

1) Supplemental Geotechnical Investigation consisting of two additional boreholes led by SHN
2) Shear Wave Velocity Analyses conducted by Dr. Dimitrios Zekkos
3) Slope Stability Analyses conducted by Dr. Adda Athanasopoulos-Zekkos

Supplemental Geotechnical Investigation

Drilling of two additional boreholes was conducted in October 2020 and overseen by SHN geologist Paul Sundberg. The key finding from this investigation is that there is an incline in the bedrock-soil interface downslope from the pond which will increase stability of the proposed pond.

Shear Wave Velocity Analyses

Shear wave velocity analyses were conducted to further characterize subsurface conditions in areas where boreholes do not exist. Field testing consisted of the measurement of surface wave velocities at four locations at the Project site (Figures 1 and 2 of Appendix B of the BOD). One of the locations was selected to be adjacent to a new borehole to relate shear wave velocities to specific subsurface soil/rock conditions, while the remaining were conducted in areas where subsurface data does not exist. Field measurements were performed under the direction of Dr. Dimitrios Zekkos on October 25, 2020 with the assistance of Parker Blunts and Brittany Russo. Analyses were conducted with the assistance of Dr. George Zalachoris. The report documents the field testing and was prepared by Dr. Dimitrios Zekkos, and Dr. George Zalachoris with reviews and feedback by Dr. Adda Athanasopoulos-Zekkos.

The analysis utilized an array of sensers to measure shear wave velocities within the subsurface soil profile – varying soil and rock types have different shear wave velocity signatures. Data collection was focused adjacent to and just downslope from the proposed pond berm as well as one data collection point in the vicinity of the proposed deflector berm on the lower terrace. This analysis is further described in Appendix B of the BOD.

Slope Stability Analyses

Slope stability analyses were performed to assess the landslide hazard at the project site. Analyses were conducted under the direction of Dr. Adda Athanasopoulos-Zekkos with the assistance of Dr. George Zalachoris. The report (Appendix C of BOD) documents the analytical results and was prepared by Dr. Adda Athanasopoulos-Zekkos and Dr. George Zalachoris. These analyses incorporated data from the geotechnical investigations and shear wave velocity analyses. Results are summarized on page 7 of the report in Appendix C of the BOD and are generally consistent with Stillwater Sciences' and SHN's previous findings.

The analyses considered two earthquake scenarios including a ~9.0 magnitude subduction zone earthquake and a ~7.0 magnitude earthquake along the San Andreas Fault. These two scenarios are described on Figure 17 in Appendix C. However, the nearest subduction zone fault is located ~25 km from the site, so a maximum ground motion equivalent to a 7.8 magnitude earthquake is expected at the site based on standard Seismic Design Code Specifications for a seismic event with a return period of 2,475 years.

The Analyses determined that the proposed pond and berm sites would experience displacements of less than one inch during this earthquake scenario, but more significant displacements of up to several feet are possible along the steeper slope downgradient from the proposed pond. The pond and berm developments are not expected to have a significant effect on the seismic stability of the slopes.

(d) Less Than Significant Impact : Expansive soils shrink and swell in response to soil moisture levels and generally have a large clay component. Geomorphic and Geotechnical investigation suggests that there are clay soils onsite that have low to medium plasticity and have a potential for expansion and contraction. This project proposes earthen fills and hydraulic appurtenances that will be designed to withstand soil expansion and contraction. In addition, the engineered fills will have liquid limits of less than 40 and a plasticity index of less than 15. Additionally, the pond design has been modified from a soil liner to a High-density Polyethylene (HDPE) liner to reduce risks associated with expansive soil. Therefore, the potential for substantial direct or indirect risks to life or property from this project being located on expansive soils is less than significant.

(e) No Impact: The project will not create any sources of wastewater requiring a septic system.

(f) No Impact: There are no unique paleontological resources or sites or unique geologic features in the Project area.

VIII. Greenhouse Gas Emissions. Would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Generate greenhouse gas emissions, either directly or indirectly, that may have a significant impact on the environment?			X	
b) Conflict with an applicable plan, policy or regulation adopted for the purpose of reducing the emissions of greenhouse gases?				X

Discussion:

(a) Less Than Significant Impact: The project will emit greenhouse gases (GHG) primarily through the burning of fuel to operate vehicles and heavy equipment during the construction phase of the project.

Construction and operational emissions were estimated using the CalEEMod (version 2016.3.2). CalEEMod is a statewide land use emissions computer model designed to provide a uniform platform for government agencies, land use planners, and environmental professionals to quantify potential criteria pollutant and GHG emissions associated with both construction and operation of a variety of land use projects. The model quantifies direct emissions from construction and operations (including vehicle use), as well as indirect emissions, such as GHG emissions from energy use, solid waste disposal, vegetation planting and/or removal, and water use.

The model was developed in collaboration with the air districts in California. Default data (emission factors, trip lengths, meteorology, source inventory, etc.) have been provided by the various California air districts to account for local requirements and conditions. The model is an accurate and comprehensive tool for quantifying air quality impacts from land use projects throughout California. The model can be used for a variety of situations where an air quality analysis is necessary or desirable such as CEQA documents. Input data and full results from CalEEMod is included in Attachment B of this MND.

The North Coast Unified Air Quality Management District (NCUAQMD) has not identified or recommended any GHG standards or thresholds of significance for the evaluation of construction projects. NCUAQMD has issued a rule stating that stationary sources emitting less than 25,000 tons per year of CO2 equivalent are exempt from compliance determination. Utilizing stationary source compliance rules is not recommended for the evaluation of projects subject to CEQA review and therefore we look to other jurisdictions that have developed thresholds, namely other California air districts, to show the emissions associated with this project in a state-wide context. These thresholds are as follows:

- South Coast Air Quality Management District (SCAQMD): SCAQMD's GHG Working Group has proposed a significance screening level of 3,000 metric tons CO2 equivalent (MT CO2e) per year for residential and commercial projects (SCAQMD 2015).
- Bay Area Air Quality Management District (BAAQMD) has adopted a project-level, operational threshold of significance that requires compliance with a qualified GHG reduction strategy or similar plan, maximum annual emissions of 1,100 MT CO2e per year or less, or achievement of a GHG efficiency rate of no more than 4.6 MT CO2e per

service population per year (BAAQMD 2017). BAAQMD has not adopted a project-level threshold of significance for construction-related GHG emissions.

- Sacramento Metro Air Quality Management District (SMAQMD) has adopted construction and operational GHG thresholds of 1,100 MT CO2e per year for land development and construction projects (SMAQMD 2015).

In the absence of NCUAQMD thresholds, the GHG emissions from this project will be compared to the SMAQMD threshold of 1,100 MT CO2e per year for construction emissions. This is because the SMAQMD has updated their guideline to account for the SB 32 2030 targets for GHG emissions. While utilized for comparative purposes, significance of the project's potential impact is ultimately based on its long-term interaction with the state's GHG reduction goals as stated in California Air Resources Board's (CARB) 2017 Scoping Plan.

When considering the project's long-term interaction with the state's GHG reduction goals, it is critical to consider the increasing contribution that wildfires have on California's greenhouse gas emissions. Between January 1, and September 18, 2020, fires in California burned through 3.4 million acres and generated an estimated 91 million MT CO2e, or ~26.8 MT CO2e per acre burned (Alberts 2020). These emissions are 25% more than California's annual emissions from fossil fuels. Considering that wildfires are becoming a major source of GHG emissions, this project will almost certainly result in a net reduction of GHG emissions over the life of the project due to the project objective of providing long-term water supply for fire suppression.

The project would emit GHG emissions during construction from off-road equipment, worker vehicles, and any hauling that may occur. Construction emissions would be generated from the exhaust of equipment, the exhaust of construction hauling trips, and worker commuter trips. The construction phases include site preparation, site grading, and building construction. CalEEMod inputs and results are included as Attachment B of this MND. Note that the CalEEMod analyses was conducted for the previous iteration of the project design, so for the current design, the original estimated emissions of 713 MT CO2e for the 15.3-million-gallon project is being reduced to 466 MT CO2e for the 10-million-gallon project based on a 65% of reduction in overall project size. This predicted emissions of 466 MT CO2e is below the SMAQMD construction threshold of 1,100 MT CO2e per year.

Based on the current project design, there will be no long term GHG emissions. Note that the previous design iteration did estimate long-term GHG emissions of 4 MT CO2e per year for operations of a pump and water chiller but those project components have been eliminated from the project design.

In summary, GHGs emitted by this proposed project fall below typical state thresholds for construction projects. Additionally, long term GHG emission from fire suppression benefits are likely to far offset the construction GHG emissions. Based on estimated GHG emission from 2020 wildfires in CA (Alberts 2020), 26.8 MT CO2e per acre burned were produced by the fires. Therefore, if the project prevents approximately 27 acres of wildfire, that will offset the construction related GHG emissions. Based on fire history and climatic trends, it is highly likely that this project will help prevent far greater than 27 acres of wildfire over the 50+ year lifespan of the project. Based on these factors, the project-generated GHG emissions will have a less than significant impact on the environment.

(b) No impact: The project will not conflict with any applicable plan, policy or regulation adopted for the purpose of reducing the emissions of greenhouse gases. GHG emissions in California are regulated under several state-wide measures, most prominently the California Global Warming Solutions Act of 2006, widely known as Assembly Bill (AB) 32, which requires the CARB to develop and enforce regulations for the reporting and verification of statewide GHG emissions and sets limits on state emissions with a mandate to reduce GHG emissions to 1990 levels by 2020. AB 32 has been followed up by additional legislation and orders mandating efficiency-based thresholds:

- SB 32 requires statewide GHG emissions to 40 percent below 1990 levels by 2030
- B-30-15 provides an interim 2030 goal with the ultimate goal of reducing emissions by 80 percent below 1990 levels by 2050. The B-30-15 interim 2030 emission reduction goal is consistent with SB 32 and represents ‘substantial progress’ towards the 2050 emissions reduction goal.
- EO S-03-05 directs the state to reduce GHG emissions to 80 percent below 1990 levels by 2050.

Locally, the NCUAQMD maintains air quality conditions in Humboldt County and administers a series of air pollution reduction programs, including open burning permits, grants, permitting of stationary sources, emission inventory and air quality monitoring, and planning and rule development. The NCUAQMD adopted Rule 111 in 2015, which evaluates stationary sources subject to NSR and Title V permitting. Pursuant to Rule 111, stationary sources emitting less than 25,000 tons per year of CO2 equivalent are exempt from compliance determination.

The Humboldt County General Plan commits to concrete actions to further reduce countywide GHG emissions. The County is currently preparing a Climate Action Plan (CAP). Although not yet finalized, the County is suggesting GHG reduction targets of 40 percent below 1990 levels by 2030, and 60 percent below 1990 levels by 2040.

As previously described, this project will generate GHG emissions during the construction phase, but all long-term operations will be powered by renewable energy. Furthermore, the project will provide a dry season water source to combat wildfires in the region which is expected to offset the construction GHG emissions. In summary, this project does not conflict with any plan, policy, or regulation adopted for the purpose of reducing the emissions of greenhouse gases.

IX. Hazards and Hazardous Materials. Would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?		X		
b) Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?		X		
c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within one-quarter mile of an existing or proposed school?				X
d) Be located on a site which is included on a list of hazardous materials sites complied pursuant to Government Code Section 65962.5 and, as a result, would it create a significant hazard to the public or the environment?				X
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project result in a safety hazard or excessive noise for people residing or working in the project area?				X
f) Impair implementation of, or physically interfere with an adopted emergency response plan or emergency evacuation plan?				X
g) Expose people or structures, either directly or indirectly, to a significant risk of loss, injury or death involving wildland fires?		X		

Discussion:

(a-b) Less Than Significant with Mitigation Incorporated: The project will not create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials. The only hazardous materials that would be used on site are fuels, lube oil, coolant, and hydraulic fluid associated with the routine maintenance and operation of heavy equipment. Any potential significant hazard associated with the accidental release of petroleum and coolant products used with equipment during construction will be minimized through implementation of the mitigation measures below and described in more detail in Appendix K of the BOD Report. As a result, mitigation measures will ensure that any potentially significant impacts are avoided or mitigated to below a level of significance.

HAZ-1: Heavy equipment that will be used in these activities will be maintained according to a maintenance and repair schedule and will be inspected for leakage of coolant and petroleum products and repaired, if necessary, before work is started.

HAZ-2: When operating vehicles in wetted portions of the stream channel, or where wetland vegetation, riparian vegetation, or aquatic organisms may be destroyed, the responsible party shall, at a minimum, do the following:

a) All equipment shall be cleaned to remove external oil, grease, dirt, or mud. Wash sites shall be located in upland locations so that dirty wash water does not flow into the stream channel or adjacent wetlands;
b) Check and maintain on a daily basis any vehicles to prevent leaks of materials that, if introduced to water, could be deleterious to aquatic life, wildlife, or riparian habitat;
c) Take precautions to minimize the number of passes through the stream and to avoid increasing the turbidity of the water to a level that is deleterious to aquatic life; and
d) Allow the work area to rest to allow the water to clear after each individual pass of the vehicle that causes a plume of turbidity above background levels, resuming work only after the stream has reached the original background turbidity levels.

HAZ-3: All equipment operators shall be trained in the procedures to be taken should an accident occur. Prior to the onset of work, the Permittee shall prepare a Spill Prevention/Response plan to help avoid spills and allow a prompt and effective response should an accidental spill occur. All workers shall be informed of the importance of preventing spills. Operators shall have spill clean-up supplies on site and be knowledgeable in their proper deployment.

HAZ-4: All activities performed in or near a stream will have absorbent materials designed for spill containment and cleanup at the activity site for use in case of an accidental spill. In an event of a spill, work shall cease immediately. Clean-up of all spills shall begin immediately. The responsible party shall notify the State Office of Emergency Services at 1-800-852-7550 and the CDFW immediately after any spill occurs and shall consult with the CDFW regarding clean-up procedures.

HAZ-5: All fueling and maintenance of vehicles and other equipment and staging areas shall occur outside of Streamside Management Areas and place fuel absorbent mats under pump while fueling. The USACE and the CDFW will ensure contamination of habitat does not occur during such operations. Prior to the onset of work, the Permittee shall prepare a plan to allow a prompt and effective response to any accidental spills. All workers will be informed of the importance of preventing spills and of the appropriate measures to take should a spill occur.

HAZ-6: Location of staging/storage areas for equipment, materials, fuels, lubricants, and solvents, will be located outside of the streams high water channel and associated riparian area. The number of access routes, number and size of staging areas, and the total area of the work site activity shall be limited to the minimum necessary to complete the restoration action. To avoid contamination of habitat during restoration activities, trash will be contained, removed, and disposed of throughout the project.

HAZ-7: Petroleum products, fresh cement, and other deleterious materials shall not enter the stream channel.

HAZ-8: Stationary equipment such as motors, pumps, generators, compressors, and welders, located within the dry portion of the stream channel or adjacent to the stream, will be positioned over drip-pans.

(c) No Impact: The project will not emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within one-quarter mile of an existing or proposed school. Such impact is avoided because the project will not create any feature that will emit hazardous substances.

(d) No Impact: The project worksites are not located on any site that is included on a list of hazardous materials sites compiled pursuant to Government Code Section 65962.5**.**

(e) No Impact: No project work site is located within an airport land use plan or within two miles of a public airport or public use airport.

(f) No Impact: The project will not impair implementation of, or physically interfere with, an adopted emergency response plan or emergency evacuation plan. The project has no effect on access. The project will include road upgrades and installation of firefighting infrastructure including hydrants and a pond suitable for helicopter and ground-based water withdrawals.

(g) Less Than Significant with Mitigation Incorporated: The project will not expose people or structures directly or indirectly to a significant risk of loss, injury, or death involving wild land fires. At work sites requiring the use of heavy equipment, there is a small risk of an accidental spark from equipment igniting a fire. Firefighting equipment (bulldozer, excavator, fire extinguishers, and hand tools) will be on site during construction. The project's pond will be suitable and available for use by helicopter or ground-based firefighting efforts. In addition, fire hydrants will be installed to assist in more localized firefighting efforts. The potential for accidental fire will be reduced to a less than significant level through implementation of the project design and mitigation measures presented in Appendix K of the BOD Report.

HAZ-9: All internal combustion engines shall be fitted with spark arrestors.

HAZ-10: The Permittee shall have an appropriate fire extinguisher(s) and firefighting tools (shovel and axe at a minimum) present at all times when there is a risk of fire.

HAZ-11: Vehicles shall not be parked in tall grass or any other location where heat from the exhaust system could ignite a fire.

HAZ-12: The grantee shall follow any additional rules the landowner has for fire prevention.

X. Hydrology and Water Quality. Would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Violate any water quality standards or waste discharge requirements or otherwise substantially degrade surface or groundwater quality?		X		
b) Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that the project may impede sustainable groundwater management of the basin?			X	
c) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner, which would:				
(i) result in substantial erosion or siltation on- or off-site;		X		
(ii) substantially increase the rate or amount of surface runoff in a manner which would result in flooding on- or offsite;			X	
(iii) create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff; or			X	
(iv) impede or redirect flood flows?			X	
d) In flood hazard, tsunami, or seiche zones, risk release of pollutants due to project inundation?			X	
e) Conflict with or obstruct implementation of a water quality control plan or sustainable groundwater management plan?			X	

Discussion:

(a) Less Than Significant with Mitigation Incorporated: The South Fork Eel River watershed has a total maximum daily load (TMDL) established for water temperature and sediment. There is the potential for minor short-term increase in turbidity during installation of instream structures and pond construction. Additionally, there is the potential for release of water from the pond with higher than desirable temperature levels. The goal of the project is to increase water quantity and improve water quality in the dry season by adding cool water to Redwood Creek from the off-stream pond. The project design includes features designed specifically for this objective including a passive underground cooling/filtration gallery to cool water prior to discharge into Redwood Creek. This cool water discharge would reduce water temperatures in Redwood Creek and not be in conflict with the TMDL.

There is also potential for water quality in Redwood Creek downstream from the project to be adversely affected during the wet season if too much water is diverted out of Redwood Creek to fill the pond. However, this impact will be avoided through the following proposed diversion approach:

- Diversion season: December 15 to April 30.
- Diversion allowed when Redwood Creek mainstem at the Marshall Ranch is at or above 5 cubic feet per second (cfs).

- Diversion rate from the tributaries shall not exceed 10% of Redwood Creek mainstem flow at the Marshall Ranch.
- A minimum bypass flow of 5 gpm is required for each tributary.
- Cumulative diversion rates from the two tributaries will range from 75 to 200 gpm during the diversion season.
- 30 to 60 days of diversion needed to achieve 6.5 million gallons of diversion (20 ac-ft)

Close collaboration with regulatory agency staff during the final design, permitting, and implementation phases of the project will also ensure that downstream impacts are avoided. Adaptive management during project operations will be guided by monitoring results to further ensure that downstream impacts are avoided or mitigated to below a level of significance as described in **HYD-1**.

The gully stabilization components of the project would significantly reduce sediment delivery from the project area into Redwood Creek, which could benefit instream habitat. This reduction in sediment delivery would not be in conflict with the TMDL or Basin Plan.

The project area currently experiences periodic grazing by cattle, which results in increased nutrient loads into Redwood Creek during runoff periods. The project will be fenced, which will take some of the existing grazing land out of production, thereby reducing nutrient loading into Redwood Creek. No mitigation is necessary for this pollutant.

Short-term increases in turbidity associated with the instream structure installation would be controlled by isolating the project area from flowing water, installing BMPs, and revegetating disturbed surfaces.

The design features and mitigation measures **BIO 1-6, GEO 1–4** and **HAZ-1– 8** described above and in Appendix I of the BOD Report, as well as **HYD-1** described below will assure that the project actions are in compliance with water quality standards and that impacts on water quality are avoided or mitigated to below a level of significance.

HYD-1: Project operations will be adaptively managed based on flow, temperature and aquatic habitat monitoring results. These monitoring results will be presented to regulatory agency staff on an annual basis and/or as required by final permit conditions. In coordination with regulatory agency staff, the project team will adapt project operations as necessary to optimize aquatic habitat benefits resulting from the project while reducing impacts to a less than significant level. This may include changes to diversion timing/rates, changes to flow release timing/rates, and/or other changes to project operations.

(b) Less Than Significant: The project will not substantially deplete groundwater supplies, interfere substantially with groundwater recharge, or impede sustainable groundwater management in the basin This is because the project site is underlain by nearly impervious shale bedrock, with minimal groundwater recharge potential. In addition, the project is located in an area that was determined to be of low priority by the California Department of Water Resources for the development of a sustainable groundwater management plan. However, there is localized shallow groundwater that is perched on top of the shale bedrock. The project is expected to result in changes to the dynamics of this existing shallow groundwater within the project vicinity because construction of the pond will reduce the ground surface area that recharges the shallow groundwater and, by design, drain groundwater in the vicinity of the western pond to increase slope stability. Most of the water stored in the shallow groundwater aquifer drains within a few weeks following significant precipitation based on groundwater modeling results as described in the BOD Report in attachment A. Therefore, there are no groundwater wells or other existing land uses that rely on this shallow aquifer. There is a small amount of moisture that persists during the dry season along the bedrock-soil interface that provides soil moisture to support riparian vegetation within some locations in the project vicinity. The project may result in some minor changes to this dynamic. The project proposes construction of grade control structures in two drainages adjacent to the project site, which will reduce incision and improve shallow groundwater retention within those portions of the project. It is also important to consider the objective of this project is to provide a significant benefit to 5.5 miles of riparian habitat along Redwood Creek. Furthermore, By incorporating these design features and considering the overall positive effects of the project on a watershed scale, the project impacts on local groundwater will be less than significant.

(c) the project would not substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river.

> **(i) Less Than Significant with Mitigation:** The project would not result in substantial erosion or siltation on- or off-site. Such an impact will not occur because several of the project actions are designed to decrease overall erosion and sediment delivery. The instream boulder and large wood placement in Redwood Creek and rock armor grade control structures in the smaller tributary drainages will alter drainage patterns by slowing incision and erosion. The instream structure proposed in Redwood Creek will produce a local redistribution of bed load, facilitating the deposition of spawning gravel in riffles and create localized scour to maintain pools for juvenile fish habitat. This local redistribution of bed load will not produce a net increase of erosion. Further, the erosion control mitigation measures (**GEO 1–4**) described above and in Appendix I of the BOD Report will assure that all project actions, including construction activities, are in compliance with water quality standards, which would reduce impacts to a less than significant level.
>
> **(ii) Less Than Significant:** The project will not substantially alter the existing drainage pattern of the work sites, or substantially increase the rate or amount of surface runoff in a manner that would result in flooding on- or off-site. The project will capture wet-season runoff in the ponds, which would reduce flooding potential. The construction of the proposed ponds and associated infrastructure could result in an increased flood risk if the ponds suffer a catastrophic failure. However, the project is designed to minimize such a failure by being located on stable terrace features, having armored outflows, reduced berm height, and HDPE liners. These design features would reduce the potential for failure and associated downstream flood risk to a less than significant level.
>
> **(iii) Less Than Significant::** The project will not create or contribute runoff water that would exceed the capacity of existing or planned storm-water drainage systems, or provide substantial additional sources of polluted runoff. Overall, the project aims to reduce storm water runoff through capture of wet-season runoff and release it during the dry season to improve instream habitat. In addition, the project will improve the road system and associated drainage facilities to increase their capacity to drain a 100-year runoff event. Finally, the project will install grade control structure in two tributaries, which will increase the retention of groundwater, reduce erosion, and reduce delivery of sediment to Redwood Creek. Therefore, this impact would be less than significant.

(iv) Less Than Significant: The project will not place structures within a 100-year flood hazard area, which would significantly impede or redirect flood flows. The ponds are outside of the 100-year floodplain. Instream structures are built to change the direction and velocity of stream flow. However, these structures are designed to affect conditions in the low flow channel and will not impede flood flows.

(d) Less Than Significant: The project is not located in tsunami, or seiche zones. With the exception of the instream habitat structure, all of the project components (ponds, control center building, access roads, fencing, etc.) are well outside of the 100-year flood zone. As such, the risk of release of pollutants due to inundation of the project is less than significant.

(e) Less Than significant: The project is in a basin that was determined to be of low priority by the California Department of Water Resources for the development of a sustainable groundwater management plan. Therefore, there is no sustainable groundwater management plan for this basin. The project will not conflict with or obstruct the implementation of a water quality control plan. In fact, the project is in the South Fork Eel River, which is one of five priority watersheds selected for flow enhancement projects in California by the SWRCB and CDFW as part of the California Water Action Plan effort (SWRCB 2019). However, there is a potential for warm water to be discharged from the pond during extreme hot and dry periods. The project design includes the use of a passive underground filtration gallery that would cool water prior to delivery to Redwood Creek. Therefore, the impact would be less than significant.

XI. Land Use and Planning. Would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Physically divide an established community?				X
b) Cause a significant environmental impact due to a conflict with any land use plan, policy, or regulation adopted for the purpose of avoiding or mitigating an environmental effect?				X

Discussion:

(a) No Impact: The project will not physically divide an established community. This impact will not occur because the project is being entirely conducted on a single property.

(b) No Impact: The activities that compose this project do not conflict with any applicable land use plan, policy, or regulation adopted for the purpose of avoiding or mitigating an environmental effect. Such an impact will not occur because the project's activities are designed to be consistent with the County's General Plan Water Resources element goals and policies WR-G2, WR-G9, WR-P23, WR-P25, and WR-IMP19.

WR-G2 - Water Resource Habitat. River and stream habitat supporting the recovery and continued viability of wild, native salmonid and other abundant coldwater fish populations supporting a thriving commercial, sport, and tribal fishery.

Relevant project actions: Deliver cool water to Redwood Creek during the summer low flow period, which will improve dry season survivability of juvenile anadromous salmonids.

WR-G9 - Restored Water Quality and Watersheds. All water bodies de-listed and watersheds restored, providing high quality habitat and a full range of beneficial uses and ecosystem services.

Relevant project actions: Redwood Creek currently experiences low flows and warm water temperatures during the summer and early fall months. Cool water flow augmentation from the Project will improve instream habitat quality and anadromous salmonid rearing habitat.

WR-P23 - Watershed and Community Based Efforts. Support the efforts of local community watershed groups to protect, restore, and monitor water resources and work with local groups to ensure decisions and programs take into account local priorities and needs.

Relevant project actions: The Project is a collaboration of the Marshall Ranch, Salmonid Restoration Federation, and state and federal agencies with the goal of restoring cool water flow to Redwood Creek during the summer dry season.

WR-P25 - State and Federal Watershed Initiatives. Support implementation of state and federal watershed initiatives such as the Total Maximum Daily Loads (TMDLs), the North Coast Regional Water Quality Control Board's (NCRWQCB) Watershed Management Initiative, the National Marine Fisheries Services and Department of Fish and Game coho recovery plans and the California Non-Point Source Program Plan.

Relevant project actions: The Project addresses the goals of the California Water Action Plan (SWRCB, 2019), Goal B of the WCB strategic plan (WCB, 2014), Goal 2 of the State Wildlife Action

Plan (CDFW, 2015), and host of NOAA Fisheries' recovery actions for coho salmon in the South Fork Eel River. See below for additional detail regarding these goals.

WR-IMP19 - Coordinate and Support Watershed Efforts. Seek funding and work with land and water management agencies, community-based watershed restoration groups, and private property owners to implement programs for maintaining and improving watershed conditions that contribute to improved water quality and supply.

Relevant project actions: The Project is a collaboration of the Marshall Ranch, Salmonid Restoration Federation, and state and federal agencies. Funding for the Project was supplied by funded by the WCB Proposition 1 Streamflow Enhancement Program.

Additionally, as previously discussed, this project was specifically designed to directly addresses the goals of the California Water Action Plan (SWRCB, 2019) and will ensure the restoration of critically important habitat. The project also addresses Goal B of the WCB strategic plan (WCB, 2014). The Project also aligns with Goal 2 of the State Wildlife Action Plan (CDFW, 2015) – Enhance Ecosystem Conditions, and Goal 3 – Enhance Ecosystem Functions and Processes: Maintain and improve ecological conditions vital for sustaining ecosystems in California. Most specifically, the project improves the hydrologic regime and increases water quantity and availability vital for sustaining ecosystems.

XII. Mineral Resources. Would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state?				X
b) Result in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan?				X

Discussion:

(a) No Impact: The project will not result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state. Such an impact will not occur because no valuable mineral resources are known to exist at the project site.

(b) No Impact: The project will not result in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan, or other land use plan. Such an impact will not occur because no mineral resource recovery sites occur at the project work sites.

XIII. Noise. Would the project result in:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Generation of a substantial temporary or permanent increase in ambient noise levels in the vicinity of the project in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?		X		
b) Generation of excessive ground-borne vibration or ground-borne noise levels?				X
c) For a project located within the vicinity of a private airstrip or an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing or working in the project area to excessive noise levels?				X

Discussion:

(a) Less Than Significant with Mitigation Incorporated: The project will not result in significant exposure of persons to, or generation of noise levels in excess of, standards established in the local general plan or noise ordinance, or applicable standards of other agencies. There will be a temporary increase in noise levels at those work sites requiring the use of heavy equipment. It is expected that the highest noise levels would be about 88 dB at 50 ft and would come from bulldozers. However, noise attenuation is expected to be about 7.5 dB per doubling of distance from the source. The nearest residence is approximately 150 ft from the edge of the work area and over 300 ft from the pond excavation site where most of the noise would be produced. Therefore, it is estimated that the noise level received by the nearby residence from work (road and berm construction) at the edge of the work area would be about 77 dB. The noise level at the nearby residence from work conducted at the pond site would be about 70 dB.
The Project will occur on property with a General Plan zoning classification of RA. Fish and wildlife management are conditionally permitted uses on this property. The Project is consistent with General Plan's Noise Element's Goal and Policy N-S7, which states that for the RA designation, the maximum permissible noise level within the zone is 75 dB between the hours of 6 am to 10 pm. The noise expected to be produced by the Project is less than the maximum allowable. In addition, N-S7 also states that an exception (#4) applies when heavy equipment and power tools are used during construction of permitted structures when conforming to the terms of the approved permit. The project will include several mitigation measures to reduce noise impacts to a less than significant level. These mitigation measures include:

NOISE 1: To reduce the possibility of the construction noise and vibrations becoming an annoyance to sensitive receptors near the Project, exterior construction activity shall be confined to the weekday hours of 7:00 am to 7:00 pm or until sunset, whichever is later, and weekend hours of 8:00 am to 6:00 pm or until sunset, whichever is later. No heavy equipment related construction activities shall be allowed on Sundays or holidays.

NOISE 2: The Permittee shall notify sensitive receptors (all property owners within 350 feet) of potential impacts from noise and vibration prior to initiating each construction phase. The notice shall describe construction activities and anticipated noise and/or vibrations from these activities, and the duration and operational hours of construction activities. The notice will also include a contact that sensitive receptors may call to report noise or vibration concerns. The notice will include a request that property owners share the notice with any employee or tenants working within 350 feet of the project site.

NOISE 3: Construction equipment shall be properly maintained and equipped with noise control devices, such as mufflers and shrouds, in accordance with manufacturers' specifications. Following construction, the project will utilize passive structures (e.g., gravity feed diversions into ponds, passive filtration gallery, etc.) that will not generate excessive noise. As such, this operational noise will constitute a less than significant impact.

(b) No Impact: The project will not result in exposure of persons to, or generation of, excessive ground-borne vibration or ground-borne noise levels. Such an impact will not occur because only minor amounts of ground-borne vibration or noise will be generated short-term at those work sites requiring the use of heavy equipment.

(c) No Impact: None of the project work sites are located within two miles of a private airstrip, public airport, or public use airport.

XIV. Population and Housing. Would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Induce substantial population growth in an area, either directly (e.g., by proposing new homes and/or businesses) or indirectly (e.g., through extension of roads or other infrastructure)?				X
b) Displace substantial numbers of existing people or housing, necessitating the construction of replacement housing elsewhere?				X

Discussion:

(a) No Impact: The project will not induce substantial population growth in an area, either directly or indirectly. Such an impact will not occur because the project will not construct any new homes, businesses, roads, or other human infrastructure.

(b) No Impact: The project will not displace any existing people or housing and will not necessitate the construction of replacement housing elsewhere.

XV. Public Services. Would the project result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities, need for new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service ratios, response times or other performance objectives for any of the public services:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Fire protection?				X
b) Police protection?				X
c) Schools?				X
d) Parks?				X
e) Other public facilities?				X

Discussion:

(a-e) No Impact: The project will not have any significant environmental impacts associated with new or physically altered governmental facilities. Issuance of restoration grants to government agencies could, in some cases, lead to minor increases in staffing to complete projects. Such increases will not lead to any significant adverse impacts, because the increases are short term, and no significant construction will be required to accommodate additional staff.

XVI. Recreation.	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Would the project increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?				X
b) Does the project include recreational facilities or require the construction or expansion of recreational facilities which might have an adverse physical effect on the environment?				X

Discussion:

(a) No Impact: The project would not increase the use of existing neighborhood and regional parks, or other recreational facilities. Such an impact will not occur because the project actions will restore anadromous fish habitat and do not significantly alter human use or facilities at existing parks or recreational facilities. Overall, the project is expected to increase recreation opportunities by assisting in restoring populations of anadromous fish.

(b) No Impact: The project does not include recreational facilities and does not require the construction or expansion of recreational facilities.

XVII. Tribal Cultural Resources. Would the project cause a substantial adverse change in the significance of a tribal cultural resource, defined in Public Resource Code section 21074 as either a site, feature, place, cultural landscape that is geographically defined in terms of the size and scope of the landscape, sacred place, or object with cultural value to a California Native American tribe, and that is:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Listed or eligible for listing in the California Register of Historical Resources, or in a local register of historical resources as defined in Public Resource Code section 5020.1(k), or		X		
b) A resource determined by the lead agency, in its discretion and supported by substantial evidence, to be significant pursuant to criteria set forth in subdivision (c) of Public Resources Code Section 5024.1. In applying the criteria set forth in subdivision (c) of Public Resource Code Section 5024.1, the lead agency shall consider the significance of the resource to a California Native American tribe.			X	

Discussion:

(a) Less Than Significant with Mitigation Incorporated: The project will not cause a substantial adverse change in the significance of a tribal cultural resource as defined in Public Resource Code §5020.1(k).

Resources identified during site-specific surveys will be protected before ground-disturbing activities are permitted at a site. Ground disturbance will be required to implement the project at some work sites that have the potential to affect historical resources, this potential impact will be minimized to a less than significant level through implementation of the protective measures presented below and in Appendices E and I of the BOD Report. As a result, any potentially significant impacts will be avoided or mitigated to below a level of significance.

TCR-1: Inadvertent Discovery of Tribal Cultural Resources - If tribal cultural resources are encountered during construction activities, all onsite work shall cease in the immediate area and within a 50-foot buffer of the discovery location. A qualified archaeologist will be retained to evaluate and assess the significance of the discovery, and develop and implement an avoidance or mitigation plan, as appropriate. For discoveries known or likely to be associated with Native American heritage (prehistoric sites and select historic period sites), the tribes listed in Section 6.2 and those that the County has on file shall also be contacted immediately to evaluate the discovery and, in consultation with the project proponent, the County, and consulting archaeologist, develop a treatment plan in any instance where significant impacts cannot be avoided. Prehistoric materials which could be encountered include obsidian and chert debitage or formal tools, grinding implements, (e.g., pestles, handstones, bowl mortars, slabs), locally darkened midden, deposits of shell, faunal remains, and human burials. Historic archaeological discoveries may include nineteenth century building foundations, structural remains, or concentrations of artifacts made of glass, ceramics, metal or other materials found in buried pits, wells or privies.

(b) Less Than Significant Impact: A letter requesting AB-52 Tribal Consultation was sent to Bear River Band of the Rohnerville Rancheria on November 20, 2020. The county received no response. A Cultural Resources Investigation was also completed in coordination with Bear River Band, the results of which are confidential.

XVIII. Transportation. Would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Conflict with an applicable plan, ordinance or policy addressing the circulation system including transit, roadway, bicycle and pedestrian facilities?				X
b) Conflict or be inconsistent with CEQA Guidelines section 15064.3, subdivision (b)?				X
c) Substantially increase hazards due to design features (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?				X
d) Result in inadequate emergency access?				X

Discussion:

(a)No Impact: The project will not conflict with any applicable plans, ordinances or policies that address the circulation systems, transit, roadway, bicycle, and pedestrian facilities in or around the project area.

(b) No Impact: Construction of the proposed project would not permanently increase vehicle trips. There will be a small increase in vehicle trips during construction activities, ending once construction is complete. Periodic maintenance of the Project is expected to generate less trips per day than any typical land use including single-family residences and/or agricultural uses. Therefore, the Project would not result, either individually or cumulatively, in impacts related to vehicle miles traveled (VMT) and would not conflict with CEQA Guidelines section 15064.3., subsection (b). No impacts woud occur.

(c) No Impact: The project will upgrade the existing roadway inside the project area to support heavy equipment traffic and drain 100-year flood return interval events at crossings.

(d) No Impact: The project will not result in inadequate emergency access. The proposed improvements to the roadway will allow improved access by emergency fire vehicles that would need access to the pond and associated fire hydrant. In addition, the ponds would be available water sources for helicopter bucket dipping in the event of a wildfire in the Briceland area.

XIV. Utilities and Service Systems. Would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Require or result in the relocation or construction of new expanded water or wastewater treatment or stormwater drainage, electric power, natural gas, or telecommunications facilities or expansion of existing facilities, the construction or relocation of which could cause significant environmental effects?		X		
b) Have sufficient water supplies available to serve the project and reasonably foreseeable future development during normal, dry and multiple dry years?			X	
c) Result in a determination by the wastewater treatment provider, which serves or may serve the project that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?				X
d) Generate solid waste in excess of State or local standards, or in excess of the capacity of local infrastructure, or otherwise impair the attainment of solid waste reduction goals?				X
e) Comply with federal, state, and local management and reduction statutes and regulations related to solid waste?				X

Discussion:

(a) Less Than Significant with Mitigation Incorporated: : The project does not involve relocation or construction of new expanded water or wastewater treatment or stormwater drainage, natural gas, or telecommunications facilities or expansion of existing facilities. The project will construct a facility to store water during the wet season and release water during the dry season to enhance aquatic habitat, so the project is not expected to cause significant negative environmental impacts. The project also includes construction and operation of small scale solar energy system to support operations and maintenance. Impacts that could occur during installation will be primarily associated with ground disturbance, which will be localized at the trenches where utilities will be buried. Impacts will be reduced to a less than significant level by the installation of erosion control BMPs and revegetation and other mitigation measures (**GEO 1–4**) detailed in the Geology section above

(b) Less Than Significant: The project relies on wet season diversion from adjacent tributaries and rainfall to fill the ponds and water storage tanks. The diversion will require a new Appropriative Water Right, the application for which has been filed with the State Water Resource Control Board (SWRCB). A preliminary Water Availability Analyses has been prepared for the project which shows that sufficient water supplies are available during the wet season to fill the pond. The project does not include any future development that would require any future water supply.

(c) No Impact: The project will not produce wastewater or be served by a wastewater facility.

(d) No Impact: The project will not generate a significant volume of solid waste requiring disposal in a landfill. Any waste generated will be minimal and only occur during construction. No waste will be produced during operations.

(e) No Impact: The project will not violate any federal, state, or local statutes or regulations related to solid waste.

XX. Wildfire: if located in or near state responsibility areas of lands classified as very high fire hazard severity zones, would the project:	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Substantially impair an adopted emergency response plan or emergency evacuation plan?				X
b) Due to slope, prevailing winds, and other factors, exacerbate wildfire risks, and thereby expose project occupants to, pollutant concentrations from a wildfire or the uncontrolled spread of a wildfire?				X
c) Require the installation or maintenance of associated infrastructure (such as roads, fuel breaks, emergency water sources, power lines or other utilities) that may exacerbate fire risk or that may result in temporary or ongoing impacts to the environment?			X	
d) Expose people or structures to significant risks, including downslope or downstream flooding or landslides, as a result of runoff, post-fire slope instability, or drainage changes?				X

(a) No impact: The project will not substantially impair an adopted emergency response plan or emergency evacuation plan. The project includes road upgrades, which will improve emergency response and evacuation on the project property. In addition, the proposed pond and hydrants will provide water necessary for emergency fire responses.

(b) No impact: The project does not propose to construct structures that would be used for human habitation. The project reduces wildfire risk by installing a pond and hydrants that could be used to fight wildfires. The upgrading and construction of access roads will also reduce wildfire risk by providing passive fire breaks should a wildfire initiate.

(c) Less than significant: The project is located in a meadow area and will include the installation and upgrading of access roads, hydrants, pond, and powerlines. The access roads can serve as fire breaks, which would lessen the risk of fire spread over the current condition. The pond and hydrants can be called upon to supply water in the event of a wildfire, which is a significant improvement over the current condition. All new onsite power supply lines will be installed via underground burial and would not increase the risk of wildfire.

(d) Less than significant: The project is located on flat terraces adjacent to Redwood Creek that is very stable (see geotechnical report) and not prone to landslides. Any potential landslides in the project area would be diverted away from the nearby residence by the proposed berm along the northern property extent.

XXI. Mandatory Findings of Significance.	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
a) Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, substantially reduce the number or restrict the range of a rare or endangered plant or animal or eliminate important examples of the major periods of California history or prehistory?		X		
b) Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects).				X
c) Does the project have environmental effects, which will cause substantial adverse effects on human beings, either directly or indirectly?		X		

Discussion:

(a) Less Than Significant with Mitigation Incorporated: The project does have the potential to degrade the quality of the environment. However, the potential is reduced to a less than significant level by design and through implementing the mitigation measures described above and in Appendix I of the BOD Report. The project shall be implemented in a manner that will avoid short-term adverse impacts to rare plants and animals, and cultural resources during construction. The project activities are designed to improve and restore stream habitat, thereby providing long-term benefits to both anadromous salmonids and other fish and wildlife.

(b) No Impact: The project does not have adverse impacts that are individually limited, but cumulatively considerable. Cumulative adverse impacts will not occur because potential adverse impacts of the project are only minor and temporary in nature and will be mitigated to the fullest extent possible. It is the goal of the project that the beneficial effects of habitat enhancement actions will be cumulative over time and contribute to the recovery of listed anadromous salmonids.

(c) Less Than Significant with Mitigation Incorporated: The project does have the potential to cause substantial adverse effects on human beings. However, the potential is reduced to a less than significant level by design and through implementing the mitigation measures described above and in Appendix I of the BOD Report. Furthermore, measures implemented as part of this project will contribute to significant fire safety improvements for the local community through the construction of the ponds, tanks, and hydrants.

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Attachment A

Basis of Design Report

(Stillwater Sciences, Sepember 2021)

SEPTEMBER 2021

Basis of Design Report & Feasibility Analyses for Marshall Ranch Streamflow Enhancement Project

PREPARED FOR

Salmonid Restoration Federation
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Cover photo: Location of proposed off-channel pond (top photo) and Redwood Creek downstream from the proposed flow augmentation delivery location (bottom photo).

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EXECUTIVE SUMMARY

The primary goal of the Marshall Ranch Flow Enhancement Project (Project) is to augment dry season stream flow in Redwood Creek to significantly improve aquatic habitat conditions. The Salmonid Restoration Federation (SRF) has been monitoring dry season flows in the Redwood Creek watershed over the past eight years. During 2013 through 2018, flows at all gaging stations along Redwood Creek mainstem dropped below 5 gallons per minute (gpm) for multiple weeks, including long channel reaches where flows ceased completely. The 2019 water year had anomalously high flows mainly due to a relatively wet winter combined with significant precipitation in May. However, 2020 and 2021 are proving to be the driest years documented with flows dropping precipitously in late July and August to 0 to 5 gpm at all mainstem monitoring stations. These severe low flow conditions are likely to persist for several months. Dry stream conditions make it very difficult for salmonids and other native aquatic species to survive. A variety of sources likely contribute to the low-flow conditions including current human consumptive use, climate change (longer dry seasons), and legacy land use impacts (roads and timber harvest).

The Project is being designed to significantly improve these dry-season conditions. Ten million gallons of off-channel storage is proposed that will capture winter rainfall and runoff and release approximately 30 gpm of cool clean water into 5.5 miles of Redwood Creek during the 5-month dry season. The released water will have suitable temperatures via piped outflow from the bottom of the reservoir and water quality will be maintained by on-demand aeration and cooling/filtration gallery. This flow input is expected to have a significant and measurable benefit to salmonids and other aquatic habitat in Redwood Creek. The volume of flow augmentation from this single project is expected to be approximately equal to 30% of the estimated human consumptive use within the southwestern half of the Redwood Creek watershed including the Miller Creek, China Creek, Dinner Creek, and Upper Redwood Creek mainstem sub-watersheds (Stillwater Sciences 2017).

Flow augmentation pilot projects in Russian River tributaries including Dutch Bill Creek, Porter Creek, and Green Valley Creek have successfully improved instream aquatic habitat for salmonids during the dry season (RRCWRP 2017, Grantham et. al. 2018, RRCWRP 2019). Specifically, the Porter Creek and Green Valley Creek projects have utilized water stored in agricultural ponds to augment dry season streamflow which has resulted in greater pool connectivity and wetted channel area, as well as significant increases in dissolved oxygen (DO) levels.

A fire suppression component is also being designed into the project. The pond will be accessible for helicopters to dip their buckets and a fire hydrant is also being proposed for access by fire engines during emergencies.

Selection of the Marshall Ranch off-channel pond site has been guided by office- and field-based assessments of a significant portion of the Redwood Creek watershed. Based on these assessments, the proposed site is uniquely suited for the project due to the following factors: 1) the project area is comprised of a broad area with gentle topography, 2) the site is not within the Redwood Creek floodplain or within the potential Redwood Creek channel migration corridor, 3) there are no watercourses, wetlands, or other sensitive plant species within the proposed pond footprints so environmental impacts are minimized, 4) the pond sites are located at an elevation with enough pressure head to deliver the entire pond volume to Redwood Creek by gravity, and 5) the Marshall Ranch LLC (landowner) is fully supportive of the project.

The project has gone through several design iterations with a goal of gaining stakeholder and community support while also reducing long term operational costs and potential risks. An initial design iteration was completed in September 2019, a second design iteration was completed in September 2020, and a third design iteration was completed in August 2021 (the project proposed herein) as shown in Appendices A.1 to A.3. Between the 2020 and 2021 design iterations, the size of the Project has been decreased from 15.3 to 10 million gallons, based on the future objective of developing a new 5.5-million-gallon project on nearby property owned by Lost Coast Forestlands (LCF). The Marshall and LCF projects combined will generate the original target flow augmentation of 50 gpm during the 5-month dry season.

This report and associated engineering design describe the 10-million-gallon project on the Marshall Ranch designed to provide 30 gpm of flow augmentation to Redwood Creek during the 5-month dry season. The current design addresses the three primary substantive community concerns raised during the CEQA public comment period for the 2020 project design:

1) the risk of catastrophic pond failure has been drastically reduced by dividing storage into two ponds and reducing the original pond volume from 15.3 million gallons to 3.8 million gallons;
2) the current design approach allows for a separate but related flow enhancement project (i.e. future LCF project) that benefits upstream reaches of Redwood Creek with significant aquatic habitat value; and
3) the current design allows for filling of the pond and cooling of the outflow via passive gravity systems and does not rely on significant long-term energy use.

The project team has secured a commitment from the WDH Foundation to provide funding for long-term operations, maintenance, and monitoring. A 501c3 non-profit organization is being formed with the role of managing the project and will sub-contract various aspects of long-term operations, maintenance, and monitoring to SRF, Stillwater Sciences, and Eel River Watershed Improvement Group.

A key project component that will require significant attention from the project team and agency staff over the coming year is securing an Appropriative Water Right for the project that allows for wet-season diversion from two seasonal tributaries to Redwood Creek to optimize the Project's ability to augment dry season flow. It is widely agreed upon that there is "available" water in Redwood Creek during the wet season. However, the challenge that faces the project team and regulators is defining an allowable diversion schedule that balances the need to protect instream resources during the wet season while supporting the Project goal of dry season flow enhancement. Stillwater Sciences has prepared a Water Availability Analysis Report included in Appendix C.

The Project was also discussed at the Redwood Creek Salmon Habitat and Restoration Priorities (SHaRP) meeting held in Arcata in June 2019. The meeting was attended by local restoration practitioners and fisheries staff from CDFW and NOAA. Feedback was overwhelmingly positive in terms of the Project fitting into coho recovery strategies for Redwood Creek. Additionally, the project team looks forward to working closely with CDFW and SWRCB to integrate the Project into existing agency activities in Redwood Creek. Specifically, CDFW has conducted an instream flow study in Redwood Creek and the SWRCB is conducting hydrologic and temperature modeling within the South Fork Eel River watershed. It is the project team's goal to coordinate closely with agency staff as studies are finalized and align the project with these regional initiatives.

1 INTRODUCTION

This report provides the basis of design for a large-scale streamflow enhancement project. Current design work is being funded through the California Wildlife Conservation Board's Streamflow Enhancement Program and State Coastal Conservancy. The Project will capture and store winter runoff in 10 million gallons of off-channel water storage and release the stored water into Redwood Creek during the dry season at a rate of approximately 30 gallons per minute. This Project seeks to improve habitat for coho salmon (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*) in Redwood Creek, an important salmon bearing tributary to the South Fork Eel River, by addressing the limiting factor of low summer streamflows. The South Fork Eel River is one of five priority watersheds selected for flow enhancement projects in California by the State Water Resources Control Board (SWRCB) and California Department of Fish and Wildlife (CDFW) as part of the California Water Action Plan effort (SWRCB 2019). Redwood Creek is a critical tributary to the South Fork Eel River that historically supported coho and Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead.

Salmonid Restoration Federation (SRF) is the project lead and Stillwater Sciences is the technical lead with support from SHN Engineers and Geologists (Geotechnical Engineering and Water Conveyance Infrastructure), William Rich and Associates (Cultural Resources), and Hicks Law (Water Rights and Legal Consulting). The project is located on the 2,942-ac Marshall Ranch property near the unincorporated community of Briceland, in Southern Humboldt County, CA (Figure 1). This project was identified as the highest priority flow enhancement project during a feasibility study conducted by SRF and Stillwater Sciences within a portion of Redwood Creek (Stillwater Sciences 2017).

This Basis of Design (BOD) Report presents the preferred design alternative based on field and office-based analyses, as well as specific input from the landowner and Technical Advisory Committee (TAC), neighbors, and community. TAC members for this project include representatives from California Department of Fish and Wildlife (CDFW), the National Marine Fisheries Service (NMFS), North Coast Regional Water Quality Control Board, and California Wildlife Conservation Board. During the design and review process, project opportunities and constraints were identified, and project alternatives were evaluated as described in Section 10 below. Specifically, there have been three design iterations as shown in Appendices A.1 to A.3 with the 90% design shown in Appendix A.3 being advanced as the preferred alternative.

Recent flow enhancement initiatives in lower Russian River tributaries are analogous to this Project and have displayed that direct augment is one of the most successful approaches to date for enhancing dry-season streamflow. Flow releases from agricultural ponds in Green Valley Creek and Porter Creek have resulted in significant instream benefits (Grantham et.al. 2018, RRCWRP 2019). As described in Ruiz et al. (2018) of California Sea Grant, the project began in 2015 and is ongoing. Data shows that flow augmentations in all years from 2015-2018 were able to appreciably increase wetted channel habitat, increase dissolved oxygen in the stream, and decrease water temperature downstream from the flow augmentation release points. For example, releases into Dutch Bill Creek averaging 36 gpm beginning in late August of 2015 and were able to cumulatively re-wet more than 2,300 feet of stream channel with effects measurable up to 1.8 miles downstream.

While modest compared to winter flows, these augmentations have the potential to increase pool connectivity and water quality. A foundational hypothesis for this Project, that increased pool connectivity will bolster over-summer salmonid survival, is strongly supported by the work of Obedzinski et al. (2018). Their study found that days of disconnected surface flow showed a strong negative correlation with juvenile coho salmon survival rate in four tributaries to the Russian River. Provided with this evidence, it is anticipated that the Project's release of approximately 30 gallons per minute into Redwood Creek throughout the dry season can result in significant aquatic habitat benefit.

2 PROJECT DESCRIPTION

The primary objective of this project is construction of 10 million gallons of off-channel water storage and associated plumbing infrastructure designed to deliver approximately 30 gallons per minute of flow augmentation to Redwood Creek during the 5-month dry season to improve instream aquatic habitat. Storage will be in two ponds and five tanks filled with wet-season runoff including rainwater catchment and water diverted from two small Redwood Creek tributaries. Other ancillary project components include:

- Installation of a large wood habitat enhancement and bank stabilization structure in Redwood Creek.
- Stabilization of two gullied tributaries with approximately 10 rock armor grade control structures and regrading.
- Construction of a passive "cooling and filtration gallery" in the existing gully to determine the viability of this innovative approach to address water quality and temperature issues associated with the flow releases from the pond.
- Construction of a solar power system including a 1 KW solar array, battery bank, inverter, internet connection, and small control center building to support operations and monitoring capabilities.
- Upgrading access roads within the project area including three road/stream crossing upgrades and gravel surfacing to provide year-round access.
- Construct cattle exclusion fencing to protect riparian areas within the project vicinity.
- Installation of plumbing infrastructure to allow for a portion of the water stored in the tanks to be utilized for domestic, ranch, and fire suppression needs including two fire hydrants.

3 PROBLEM STATEMENT

Aquatic habitat in Redwood Creek is impaired due to a variety of factors including low dry-season flows, high water temperatures, excessive fine sediment, and lack of habitat complexity (CDFW 2014). There are two fish species with threatened status that are expected to benefit from this project: (1) southern Oregon/northern California coho salmon (*Oncorhynchus kisutch*) (SONCC) which are designated as state and federally threatened and (2) Northern California steelhead (*Oncorhynchus mykiss*) which are federally threatened and are a CDFW species of special concern. Historically, these fish flourished in Redwood Creek. However, rearing habitat for juvenile salmonids has been substantially degraded and the current lack of dry season flow is likely the leading factor. (NMFS and CDFW 2019).

Dry season flows (i.e., June - October) in north coastal California watersheds have decreased over the past half century (Sawaske and Freyberg, 2014; Asarian, 2014) likely due to a combination of changes in climate, land use and associated consumptive water demand, and vegetative cover. In watersheds most impacted by industrial and non-industrial timber harvest, homesteading, and cannabis cultivation, diminished streamflow is having lethal or sub-lethal effects on juvenile salmon and steelhead and is also negatively impacting sensitive amphibian species (Bauer et al 2015).

Today, remnant fish populations survive in Redwood Creek (NMFS 2014), but despite considerable expenditures in habitat restoration projects (i.e. sediment reduction and placement of large wood habitat structures), many stream reaches don’t have sufficient flow to maintain the diminishing populations. This project will address this key limiting factor by storing runoff during the wet season and strategically releasing the stored water to enhance flows in a critical reach of Redwood Creek during the dry season.

The Redwood Creek watershed is located within the South Fork Eel River ESU, which NOAA identifies as a core population vital to the preservation of Southern Oregon Northern California Coast (SONCC) coho salmon (NMFS 2014). The SONCC coho recovery plan indicates the need for “improving flow timing or volume” in each of the first ten action items in the SONCC Coho Recovery Plan (NMFS 2014).

In summary, the primary focus of this project is increasing dry season flows in critical reaches of Redwood Creek. Additional project elements will also address several other limiting factors including a large wood structure to increase habitat complexity and gully stabilization treatments to reduce fine sediment inputs.

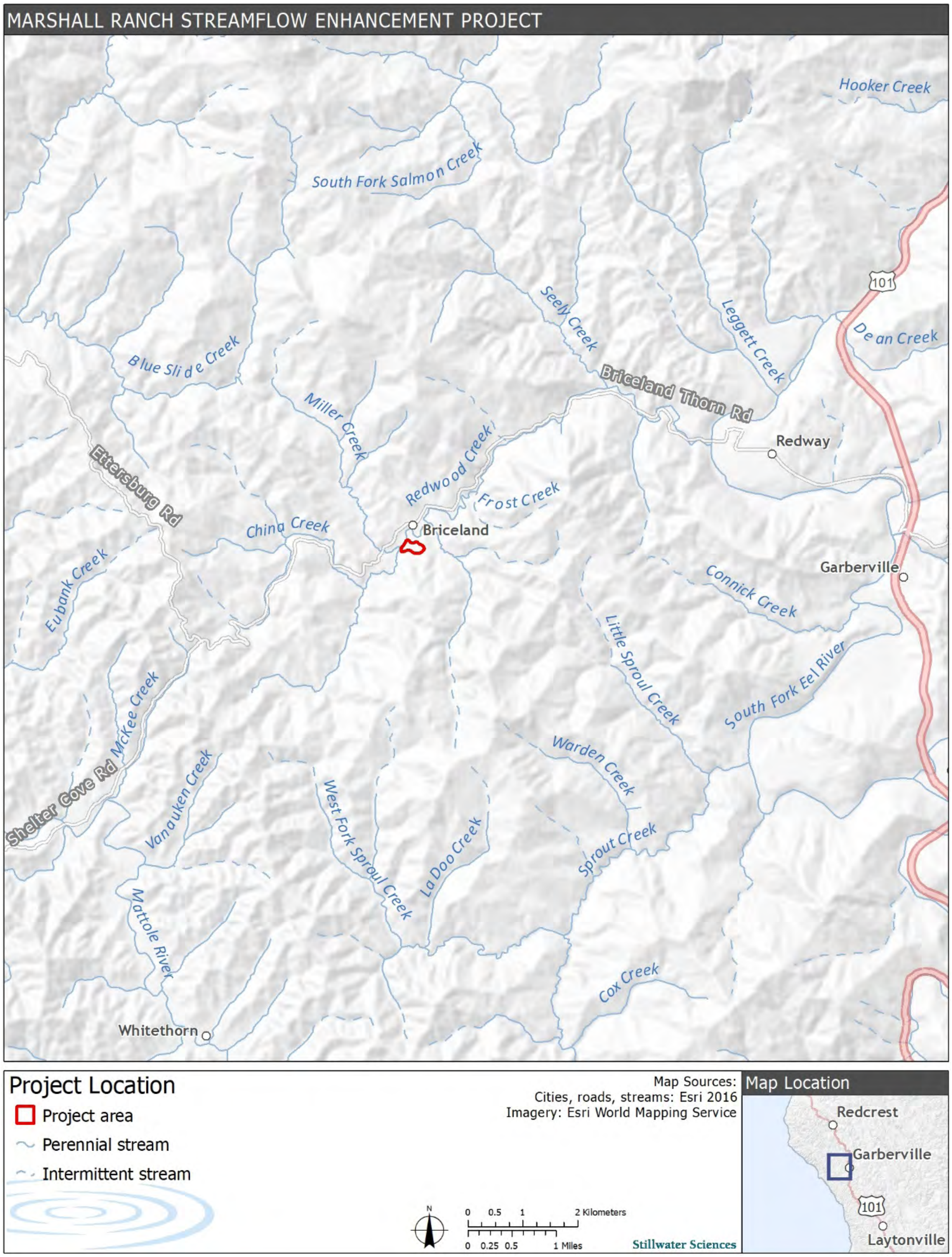

Figure 1. Vicinity map.

4 GEOLOGY AND TECTONICS

The Redwood Creek watershed is in a tectonically active plate-boundary deformation zone, defined by right-lateral movement along the San Andreas Fault Zone that separates the Pacific plate to the west from the North American plate to the east (Kelsey and Carver 1988). Northward progression of the San Andreas Fault Zone is characterized by lateral shearing and vertical compression due to the major westward turn in the fault zone upon reaching the Mendocino Triple Junction near Cape Mendocino. These primary deformation styles are what create the dominant NNW-SSE trending topographic and structural grain in the region (Kelsey and Carver 1988). The evolution of this regional topographic and structural grain has developed pervasive shearing, fracturing, and faulting throughout the north coast of California.

The Garberville-Briceland fault zone trends NNW-SSE across the watershed (Figure 2) (McLaughlin et al. 2000). The fault zone consists of multiple named and unnamed fault traces with varying orientations of displacement. Although recent displacement along the fault zone is undifferentiated, it is considered Quaternary in age (i.e., active within the last 1.6 million years). The Briceland Fault trace is approximately 4,300 feet northeast of the project site and the Garberville Fault trace is approximately 2.75 miles to the northeast (Figure 2).

The Redwood Creek watershed is primarily underlain by the diverse Coastal and Central belts of the Franciscan Complex, the younger marine and non-marine Wildcat Group, and minor amounts of serpentinized peridotite of the Coast Range Ophiolite (Figure 2). The project site is located along mainstem Redwood Creek between the Miller Creek and Somerville Creek confluences. The site is partially underlain by an isolated exposure of Pliocene-aged moderately consolidated sandstone, argillite, and conglomerate, included by some with the Wildcat Group (McLaughlin et al. 2000). The area surrounding the project site, and most of the Redwood Creek watershed, is underlain by various subunits of the Eocene to Paleocene Yager terrane (Franciscan Complex Coastal Belt), which primarily consists of sheared and highly folded mudstone (McLaughlin et al. 2000). The mudstone includes minor rhythmically interbedded arkosic sandstone and local lenses of conglomerate. This lithology produces terrain with relatively irregular topography lacking a well-incised system of sidehill drainages when compared to other subunits of the Franciscan Complex Coast Belt.

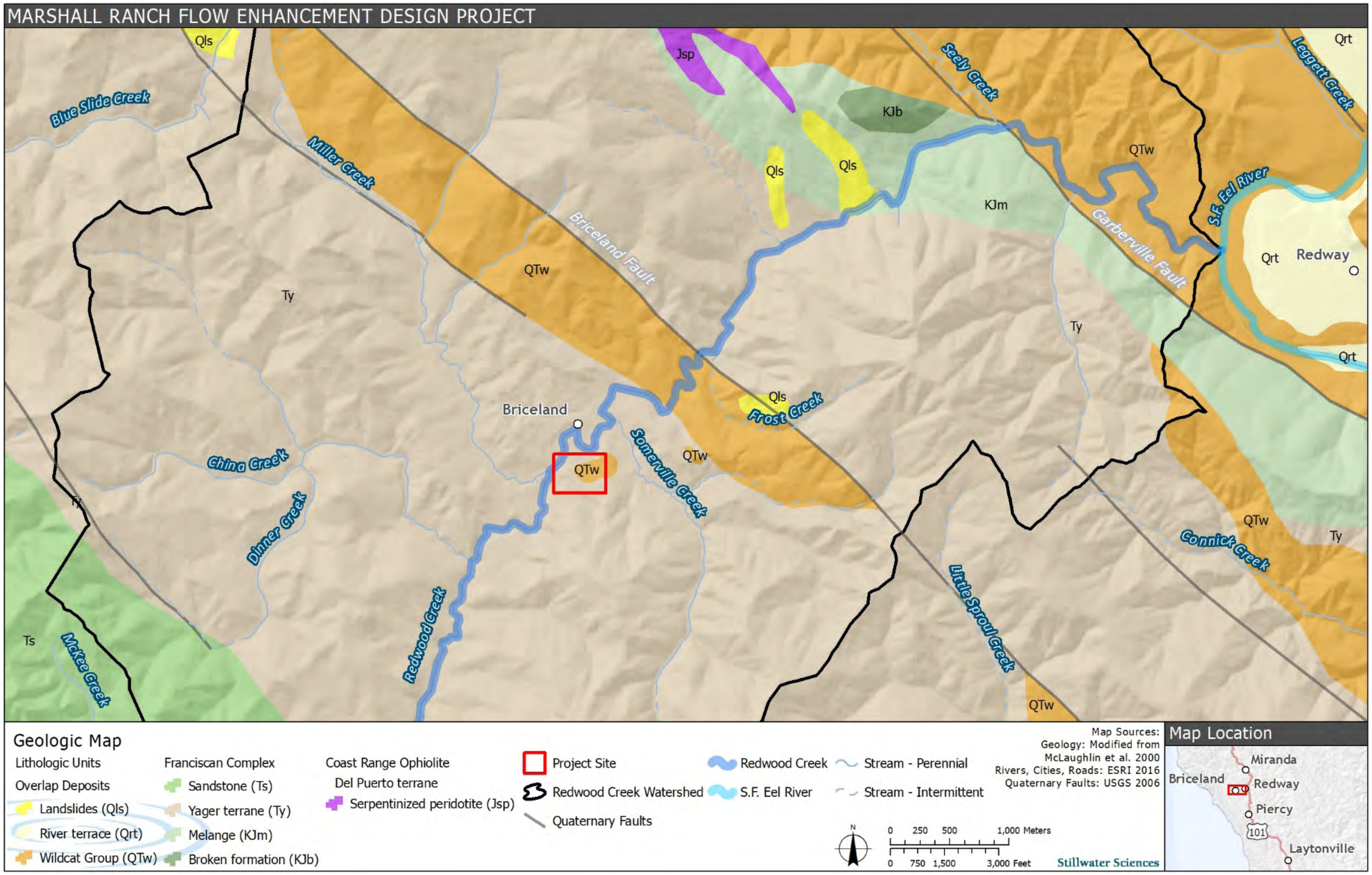

Figure 2. Generalized geologic map of the Redwood Creek watershed and project vicinity.

5 GEOMORPHIC ASSESSMENT

A geomorphic assessment was conducted to characterize the existing geomorphology of the project area, assess risks associated with potential hazards, support the opportunities and constraints assessment, and inform project designs. Specifically, the geomorphic assessment included a topographic survey that was integrated with 2007 LiDAR data, review of existing data, and a field assessment. Existing data that were reviewed included geologic mapping (McLaughlin et al. 2000), geomorphic and landslide mapping (Spittler 1984), and historical aerial photographs from 1942, 1947, 1954, 1963, 1965, 1984, 1988, 1996, 2000, 2005, 2009, 2010, 2012, and 2014. A geotechnical investigation was also conducted by SHN Engineers & Geologists and is described below in Section 6.

Hillslope and stream channel morphologies in the Redwood Creek watershed are similar to those found throughout the western side of the South Fork Eel River basin, due to the prevalence of the underlying Franciscan Coastal Belt terranes. Although there is variability among the terranes, the rock strength in Coastal Belt rocks typically leads to steeper, ridge-and-valley topography with organized drainage networks. Small to large-scale landslides are still common in the basins that drain the Coastal Belt terranes, particularly where sedimentary rocks are less competent and in mélange units.

Upper elevations in the Redwood Creek basin are characterized by narrow, steep-walled canyon slopes that are covered by relatively thin soils and dense conifer and hardwood stands and drained by perennial and intermittent streams. At mid-elevations, the steep canyons transition into gently rounded upland ridges supporting grass meadows and shrub and oak woodland vegetation. The valley width greatly expands near Briceland, where Redwood Creek meanders between large elevated terraces (Figure 3). Channel incision in the Redwood Creek basin is likely due to ongoing tectonic uplift related to the nearby Mendocino Triple Junction, extensive anthropogenic land-use practices, and climate change altering hydrologic patterns. The flight of terrace and floodplain surfaces in the project vicinity record over 120 feet of vertical incision of Redwood Creek.

The project site consists of Pleistocene-era fluvial terraces and lower floodplain surfaces adjacent to Redwood Creek, which flows from the southwest to the northeast across the project area (Figure 3). Upland hillslopes border the site to the south and east. The project site is bound by small intermittent streams to the east and west that are tributary to Redwood Creek. These streams are hereinafter referred to as the east-side and west-side tributaries. The northern central edge of the upper terrace has been eroded by a third smaller drainage. Multiple landslide features are located around the project area and are further described in the following sections.

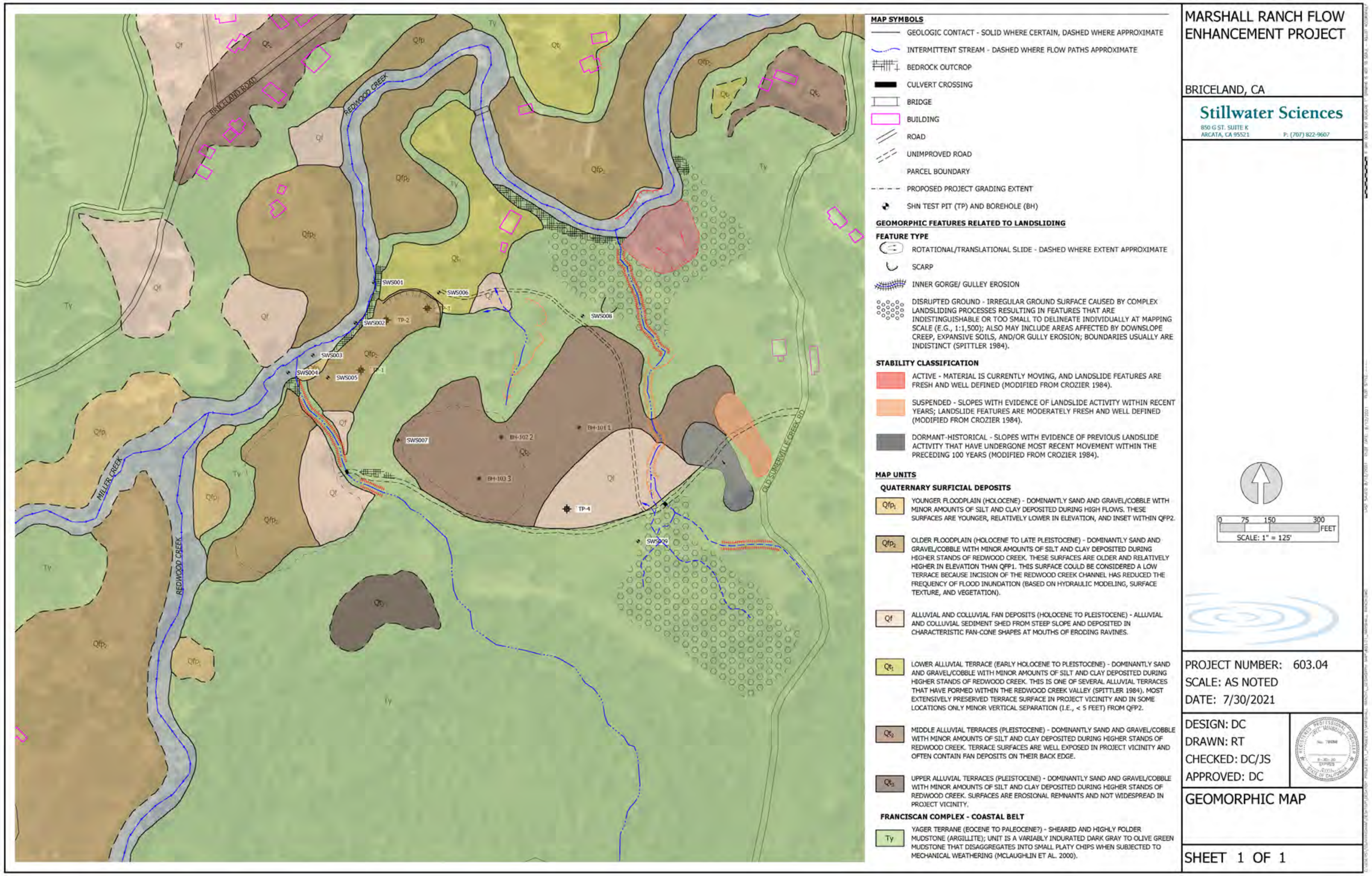

Figure 3. Geomorphic map.

5.1 Field Assessment

The geomorphic field assessment of the project area consisted of evaluating the site topography and surficial drainage features, logging shallow stratigraphy, and further characterizing features related to landsliding.

5.1.1 Proposed pond sites

The proposed eastern pond site is on a broad gently sloping Redwood Creek fluvial terrace tread (Qt_2 in Figure 3), approximately 900 feet east-west by 450 feet north-south (Figure 4). The terrace tread, or surface, slopes approximately 5% to the NNW towards Redwood Creek. The terrace has a low-gradient alluvial fan deposited by the east-side tributary on its back edge and upland hillslopes to the south and east. The east-side tributary has eroded a moderately incised channel 6-8 feet deep, which bisects the terrace and fan deposits. The central drainage has eroded the northern edge of the terrace tread and has deposited a small alluvial fan on the adjacent lower terrace (Qt_1) to the north. The pond-site terrace surface is approximately 90 feet higher in elevation than the adjacent Redwood Creek thalweg located approximately 350 feet to the northwest. An unimproved access road travels west from Old Somerville Creek Road along the back edge of the terrace and down toward the floodplain near the Redwood and Miller creek confluence. The east-side tributary passes under the access road through a culvert. Yager terrane argillite bedrock is exposed in a road cut on the terrace riser above the west-side tributary. The terrace tread is vegetated with grass and bushes, with trees around portions of its perimeter.

The proposed western pond site is located on the floodplain surface (Qfp_2 in Figure 3) to the west of the eastern pond terrace, at the bottom of a steep terrace riser (Figure 5). The floodplain is an elongated, relatively flat surface parallel to Redwood Creek. The west-side tributary crosses the floodplain and has deposited an alluvial fan on its back edge. The west-side tributary has eroded a moderate to deeply incised channel, up to 15 feet in some locations, that bisects the fan and floodplain deposits. The floodplain is 18-20 feet above the adjacent Redwood Creek thalweg. The channel bank is steep to vertical with a well-exposed Yager terrane argillite strath surface that extends approximately 450 downstream from the west-side tributary confluence with Redwood Creek (Figure 6). A groundwater spring at the bedrock strath-alluvial fill contact near the natural low-point in the floodplain is the only groundwater seep along the Redwood Creek project reach observed in summer/fall months. The spring was originally located under a large bay tree (Figure 6), which toppled into the creek channel during the 2018/2019 winter. Remnants of the floodplain surface are expansive and border much of Redwood Creek in the project vicinity. Due to recent incision over the past decades to centuries, the floodplain is infrequently inundated by only the largest flood events (e.g., 100-year recurrence interval) (Stillwater Sciences 2018). The Qfp_2 floodplain on the northwest side of Redwood Creek is 4-6 feet lower in elevation than the proposed western pond site and would therefore inundate first during a large flood event. The west-side tributary passes under the unimproved access road through a culvert crossing. The floodplain is vegetated with grass and bushes, trees around portions of its back edge, and a narrow and dense riparian corridor along the Redwood Creek channel bank.

Figure 4. Intermediate terrace surface (Qt_2), view looking west across proposed western pond site. Incised east-side tributary visible in foreground.

Figure 5. Intermediate floodplain surface (Qfp_2), view looking northeast. West-side tributary just out of view to right of photo.

Figure 6. Redwood Creek channel downstream from the proposed flow delivery point. Bedrock strath-terrace fill contact well exposed along this reach. Groundwater spring near undercut bay tree is only spring along project reach observed during summer months.

5.1.2 Surficial drainage features

As described above, the project area has three separate surface drainages that have varying impacts to the site. Each of the three drainages are further described below.

5.2.2.1 West-side tributary

The west-side tributary is the largest of the three drainages (approximately 0.05 square miles) in the project area and flows south to north along the western side of the site (Figure 3). The stream originates on the steep forested hillslopes to the south of the project site and flows primarily through a steep bedrock canyon before flowing across an alluvial fan and floodplain where it meets Redwood Creek. Only the downstream extent of the tributary and lower portions of the canyon were investigated as part of the geomorphic assessment, considering this is where potential impacts to the proposed project are most likely.

Upon exiting the canyon and flowing across the alluvial fan, the tributary has incised a moderately deep channel (i.e., 10 to 15 feet). The channel here is actively eroding and is likely exacerbated by concentrated runoff from the access road upslope. The access road off Old Somerville Creek Road crosses the channel over a double-barrel 8-inch corrugated metal pipe culvert crossing. The channel is not incised at the culvert crossing; however, the culvert outfall has incised a large scour hole approximately 8 feet wide and 10 feet deep (Figure 7). The culvert has likely promoted downstream channel incision and fill under the culvert is resisting the headward propagation of the incision, creating a 10-foot knickpoint in the channel. It is difficult to tell when the crossing was constructed based on the historical aerial photos, although the access road is clearly visible in photos from the 1940’s. From the road crossing down to the Redwood Creek confluence, the channel is actively incising with up to 12-15 feet of incision in some locations (Figure 8). Development of the incision along this portion of the tributary is difficult to determine across the aerial photo time-series record due to tree cover, although it appears to have increased following the historic 1964 storm and flood event. A Redwood Creek argillite bedrock strath is exposed in the lowest 50 feet of the tributary channel, and slopes toward Redwood Creek based on the exposure in the tributary cut-banks.

5.2.2.2 Central drainage

The central drainage is small and consists of an eroded gully along the northern edge of the pond-site terrace riser (Figure 9). The drainage collects runoff from the proposed pond site and transports it onto a small alluvial fan and lower terrace surface to the north. The fan and lower terrace surface lack an actual channel but at least two poorly defined flow paths are evident: one to the west and one to the north towards the neighboring parcel. On the main terrace riser, the drainage has eroded a moderately incised gully up to 15 feet deep that exposes argillite bedrock at its base. Groundwater was observed seeping at the bedrock-fill contact during summer/fall months. Several small scarps in the alluvium at the head of the incised gully form 0.5-2-foot knickpoints in the drainage. These knickpoints and other scarps on the eastern flank of the gully appear to have had some recent activity, albeit minor, and don’t appear to have had significant movement over the historical photo time-series record.

5.2.2.3 East-side tributary

The east-side tributary flows south to north along the east side of the site (Figure 10). The stream originates on the partially forested hillslope immediately south of the pond footprint and flows across the terrace before descending down the terrace riser to meet Redwood Creek. The entire stream length was investigated as part of the geomorphic assessment.

The stream lacks a well-defined primary channel in its headwater area due to the irregular topography it flows across (see Section 5.1.3 for further discussion). Additionally, a lead-off ditch along Old Somerville Road routes concentrated road-runoff into the drainage and has formed a large actively eroding gully. The multiple flow paths mostly converge at a culvert crossing under the access road. A secondary gully just to the west of the crossing causes some runoff to flow over the road and divert across the pond site. Downstream of the culvert crossing the stream flows across an alluvial fan and terrace tread where it has eroded a moderately incised (6 to 8 foot depth) channel. The over-steepened banks are incising via sloughing and block-toppling. Incision dramatically increases at the scarp near the outer edge of the terrace tread (see Figure 10). This increased incision is likely due to anthropogenic impacts, a natural transition from a gently sloping fan and terrace tread to a steep terrace riser, and landsliding further downstream. The change in incision depth is also controlled by a large in-channel debris pile of tires, scrap metal, and appliances placed by landowners. The lowest portion of the stream flows down a steep hillslope with irregular hummocky topography and a large active landslide (see Section 5.1.3 for further discussion). Incision along the entire stream length noticeably increased following the 1964 storm and flood event, as seen in the 1965 aerial photo.

Figure 7. Approximately 10 feet of channel incision at culvert outlet along west-side tributary. Photo taken just upstream from Figure 8.

Figure 8. Typical channel incision along west-side tributary, just upstream from Redwood Creek confluence.

Figure 9. Scarp on main terrace riser above central drainage.

Figure 10. Typical channel incision along east-side tributary. Block-topple in foreground and sloughing on far bank.

5.1.3 Features related to landsliding

Geomorphic features related to landsliding were investigated using the aerial photo time-series, LiDAR-derived topography and hillshades, and during the field assessment. Landslide features were initially mapped and classified in the office and then further characterized and validated in the field. Landslides were classified based on feature types used by Spittler (1984) for the North Coast Watershed Assessment Program (e.g., translational/rotational slide, earthflow, inner gorge, disrupted ground, etc.). Stability classifications modified from Crozier (1984) were also assigned to each mapped landslide feature and are color-coded in Figure 3.

5.1.4 Summary

Although there are unstable geomorphic features in the vicinity, the Project proposes design features that will increase geomorphic stability within the project vicinity including gully stabilization and reduction of groundwater levels. Furthermore, multiple lines of scientific evidence support the findings that the Pleistocene terrace where the eastern pond is proposed has been stable for a minimum of 10,000 years. The western pond is on a lower terrace that has likely been an active floodplain in more recent history (i.e. within the last 10,000 years), but under current conditions there are no current geomorphic drivers that are expected to negatively impact the proposed pond at this site.

Figure 11. Disrupted ground upslope from pond site. Hillslope has remained relatively stable and vegetated over photo time-series record (i.e., since 1942).

6 GEOTECHNICAL INVESTIGATION AND SEISMIC SLOPE STABILITY ANALYSES

SHN Engineers and Geologists conducted the geotechnical investigation for the site. A full Geotechnical Report is included in Appendix B and found the project to be feasible from a geohazard and geotechnical standpoint. Specifically in Section 5.7 the report states that “what low risk is associated with the site has been mitigated through development of an extremely conservative design plan”.

Based on the geotechnical investigation, groundwater well data (see Section 8.5) and the revised pond layout included in Appendix A.3, no plausible mechanisms for massive pond failure were identified.

7 TOPOGRAPHIC DATA

7.1 Field Survey

Stillwater staff conducted field surveys using a total station and differential GPS. The primary goals of the field effort were to: (1) survey cross sections along the Redwood Creek channel thalweg at the downslope extent of the proposed site to be used for hydraulic modeling; (2) obtain additional topographic data in areas where project features are proposed; and (3) survey existing features (e.g., buildings, trees, roads, and fences). A differential GPS (approximately 0.4 feet horizontal accuracy and 0.7 feet vertical accuracy) was used to establish survey control points. These control points were used to orient the surveys and relate them to a projected coordinate system so that they could be combined with existing Light Detecting and Ranging (LiDAR) topographic data. All elevations and horizontal positions shown in the plans use the local coordinate system based on these control points.

7.2 Merging Field and LiDAR Data

The field survey data was merged with 2018 USGS LiDAR. The first step in merging the topographic data sets was to overlay the new field data on the LiDAR DEMs in AutoCAD Civil3D (CAD) to check for general consistency between the two datasets. Once consistency was confirmed, new ground surfaces were created based on the field-surveyed topography and combined with the LiDAR DEMs to create a new existing ground surface DEM for each project reach. Because the extent of the topo survey was limited to the areas described above, constructing a merged terrain model from the available LiDAR and topo survey data required interpolation and interpretation of ground surface elevations in some areas lacking data and/or resolution. Due to the limited accuracy of the LiDAR data especially in the near-channel portion of the project area, it was used only to provide general topographic context and approximate elevations for areas not characterized with field-based topographic data.

8 HYDROLOGIC ANALYSIS

An assessment of site hydrology has been conducted to inform the alternatives analyses and design process. There are five key components of the hydrologic assessment:

1. Determine key regulatory considerations that influence pond size and the ability to fill pond from surface water diversion;
2. Determining the best approach to fill the ponds through a combination of direct rainfall input, sheet flow from the hillside, and diversions from surface water; and
3. Utilize existing flow monitoring data to determine a realistic/desirable flow enhancement benefit that the project can achieve.
4. Assess 100-yr storm flows to provide the basis for project design of instream and near-stream features.
5. Assess groundwater data and how groundwater dynamics are expected to affect the project.

Each of these components are discussed below.

8.1 Regulatory Considerations

There are three primary state agencies that could have jurisdiction over this project. These include:

1. CA Department of Water Resources – Division of Safety of Dams (DSOD) regulates dams above a certain size;
2. CA State Water Resources Control Board (SWRCB) requires an Appropriative Water Right for diverting water from a stream and storing it for more than 30 days; and
3. CA Department of Fish and Wildlife (CDFW) requires a Lake and Streambed Alteration Agreement (LSAA) for installing infrastructure and diverting water from a stream.

8.1.1 DSOD jurisdiction

Jurisdictional dams are dams that are under the regulatory powers of the State of California. A "dam" is any artificial barrier, together with appurtenant works as described in the California Water Code. If the dam height is more than 6 feet and it impounds 50 acre-feet or more of water, or if the dam is 25 feet or higher and impounds more than 15 acre-feet of water, it will be under DSOD jurisdictional oversight, unless it is exempted. The DSOD Jurisdictional Size Chart (Figure 12) summarizes the above criteria. Jurisdictional height of a dam, as determined by DSOD, is the vertical distance measured from the lowest point at the downstream toe of the dam to its maximum storage elevation, which is typically the spillway crest.

There are significant annual reporting requirements and fees associated with jurisdictional dams, so from a long-term operations perspective, falling outside of DSOD is desirable. Therefore, a strong consideration in sizing the pond was to stay below a 25-foot dam height and 15 acre-feet (16.3 million gallons) of water storage.

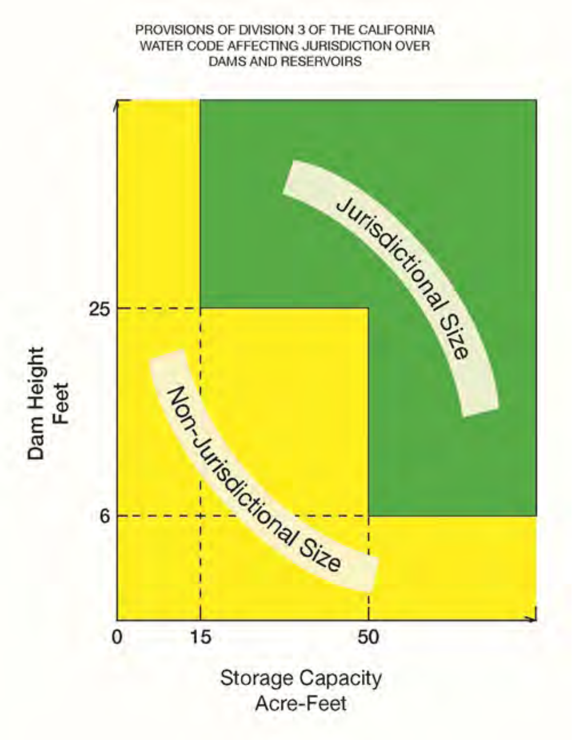

Figure 12. DSOD jurisdictional chart.

8.1.2 SWRCB appropriative water rights

Based on site geometry and the desired project outcome of maximizing flow enhancement inputs, it is not feasible to design this project to capture rainwater and sheet flow only. Therefore, it is anticipated that the Project will require an Appropriative Water Right to divert surface water from a stream and store that water for more than 30 days.

8.1.3 CDFW LSAA

Based on preliminary input from local staff, CDFW is generally supportive of the project. However, based on the project team's experience permitting water diversions on other projects, CDFW is likely to impose limitations on the diversion season and percentage of flow that can be taken from a stream.

8.1.4 Other regulatory requirements

Other permits will be required for the Project but the conditions/stipulations of those permits are not anticipated to govern the project design. These additional permits include:

1. Special Permit from Humboldt County for work within the Streamside Management Areas;
2. Grading and Building Permits from Humboldt County for construction of project infrastructure;
3. 401 Certification from SWRCB for instream work; and
4. 404 Permit from US Army Corps of Engineers.

8.2 Filling the Ponds During the Wet Season

Five different sources for filling the pond were analyzed:

1. Direct precipitation falling into the ponds;
2. Sheet flow from the hillslopes that drain into the ponds;
3. Surface water diversion from the tributary to the east of the site;
4. Surface water diversion from the tributary to the west of the site; and
5. Surface water diversion from Redwood Creek.

8.2.1 Water availability from upslope sources

To assess the water availability from Sources 1-4 listed above, the Rational Method (also known as the Rational Formula) was used to calculate expected seasonal runoff. The Rational Formula incorporates a combination of rainfall intensity, drainage area and runoff coefficient to estimate maximum flows and is defined as follows:

$$Q = CIA$$

Where:

Q = Flow Discharge
C = Runoff Coefficient
I = Rainfall Intensity
A = Area

This application of the Rational Method varies from the typical application in that here it is being used to estimate total runoff generated over the entire wet season, so the “annual design rainfall” is substituted for “rainfall intensity” in these calculations.

8.2.2 Expected annual rainfall

Two methods were applied to determine an appropriate annual rainfall to utilize for project design considerations:

1. Local rain gage data compiled by the Mattole Restoration Council (Figure 13); and
2. Annual rainfall for Briceland, CA based on PRISM Climate Group interpolations (Figure 14).

Based on these two data sources, an annual rainfall amount of 48 inches was selected as the design precipitation which represents a dry year with precipitation between the 5th and 10th percentile. This “design precipitation” was selected based on the goal that the project function at capacity during 90% to 95% of precipitation seasons. However, it was also not desirable to limit the project capacity by designing for the most extreme drought years.

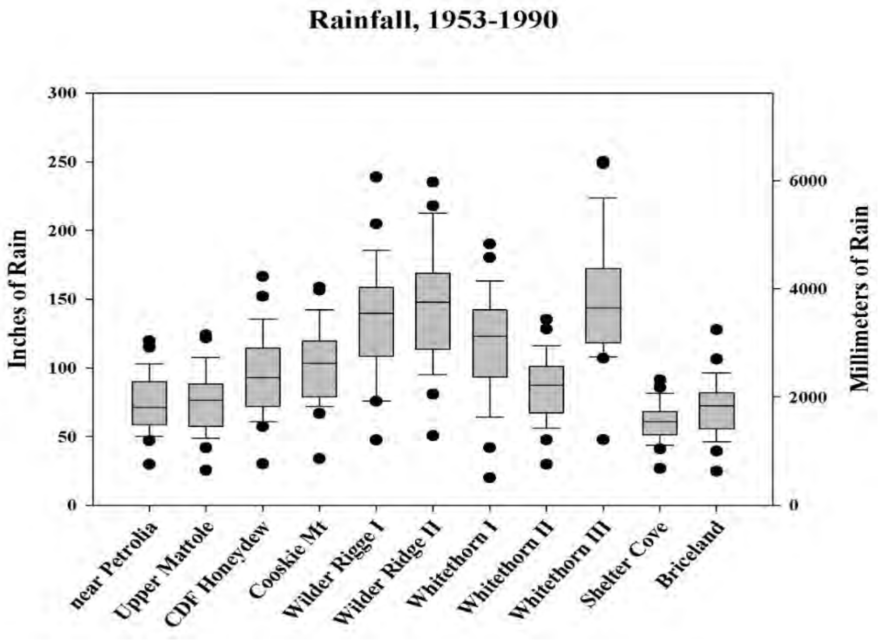

Figure 13. Local rain gage data (Mattole Restoration Council).

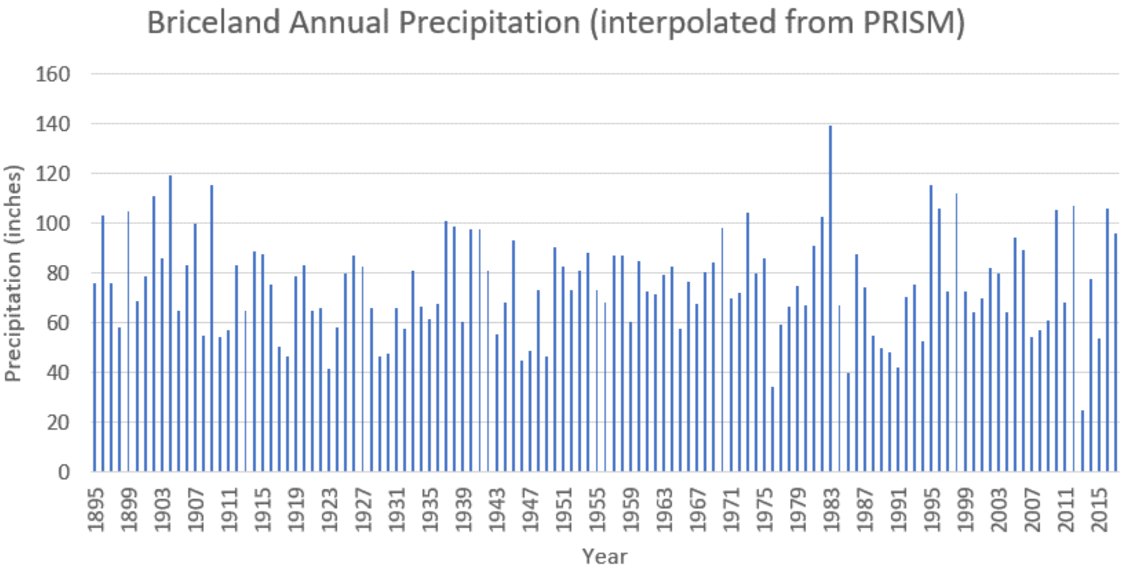

Figure 14. Briceland Annual Precipitation (PRISM).

8.2.3 Calculations

Table 1 below summarizes each of the four potential upslope water sources for the pond and calculates total expected water volume input based on 48 inches of annual precipitation. Note that for the Eastern and Western Tributaries we have reduced the runoff coefficient to 0.2 (from typical 0.4) assuming that bypass flow would be required for CDFW LSAA permit conditions.

Table 1. Summary of rational method calculations for upslope water sources.

Source	Area (acres)	Runoff coefficient	Intensity/Annual Precipitation (inches)	Volume (gallons)
Eastern Pond (direct precipitation)	1.3	1.0	48	1,656,000
Western Pond (direct precipitation)	1.8	1.0	48	2,346,000
Hillslope draining into Eastern Pond	2.5	0.4	48	1,303,000
Hillslope draining into Western Pond	5.0	0.4	48	2,607,000
Diversion from Eastern Tributary	4.0	0.2	48	1,043,000
Diversion from Western Tributary	20.0	0.2	48	5,213,000
Total				**14,168,000**

Based on the results shown in Table 1, the upslope sources have the capacity to deliver approximately 14 million gallons to the ponds based on 48 inches of annual precipitation. The total proposed volume of the ponds and tanks is 10 million gallons, so these sources provide sufficient annual water supply. However, it should be noted that the information in Table 1 is approximate and was used for planning-level analysis only. In particular, the estimates of runoff generated from hillslope sheetflow may be higher than can be actual runoff volumes. Additional detailed analyses and calculations are included in the Water Availability Analysis (Appendix C) that supersede the preliminary results presented in Table 1. Based on recent years trending toward less annual rainfall, the project is being designed to allow for flexibility to fill the total storage volume even during years where less than 48 inches of precipitation occurs.

8.2.4 Water availability for diverting from Redwood Creek

Pumping water from Redwood Creek during the wet season was also determined to be a viable option for filling the pond. This source has some advantages considering that the proposed diversion would likely be a small percentage of total flow in the creek during the wet season diversion period. A Water Availability Analysis is included in Appendix C. Based on that document, there is sufficient water available in Redwood Creek to pump during the wet season to fill the pond.

The previous project design iterations with one 15.3-million-gallon pond (Appendix A.1 and A.2) required a diversion from Redwood Creek to fill the pond. Those design scenarios proposed a 200 gallons-per-minute diversion during approximately one month of the wet season with a total diversion volume of approximately 10 million gallons. However, based on the current design iteration that includes two smaller ponds and supplemental tanks with a total volume of 10 million gallons, it has been determined that diversion from Redwood Creek is no longer necessary with the upslope sources discussed in Section 8.2.3 having sufficient runoff to fill the proposed storage.

The Appropriative Water Right is still required to divert from the two seasonal tributaries and the application that was previously filed with the SWRCB has been amended to update the location and volume of diversion.

8.3 Existing Flow Data and Expected Flow Enhancement Benefit

SRF began monitoring dry season flows in Redwood Creek in 2013. Flow monitoring results for station RC-4, located near Redwood Creek's confluence with the south Fork Eel, is shown on Figure 15. As this figure depicts, dry-season flows in Redwood Creek are extremely low with flows at RC-4 dropping below 5 gallons per minute during each of 2013 through 2018 dry seasons (2019 was anomalously high). Flows at all other monitoring stations throughout the watershed follow similar trends with zero flow recorded at the majority of monitoring stations during most years. Based on this data, the proposed project benefit of approximately 30 gallons per minute of flow augmentation provides a substantial and meaningful increase above current dry season base flow. Additionally, water temperatures of the flow releases are anticipated to be suitable for salmonids during most years as described in Appendix J.

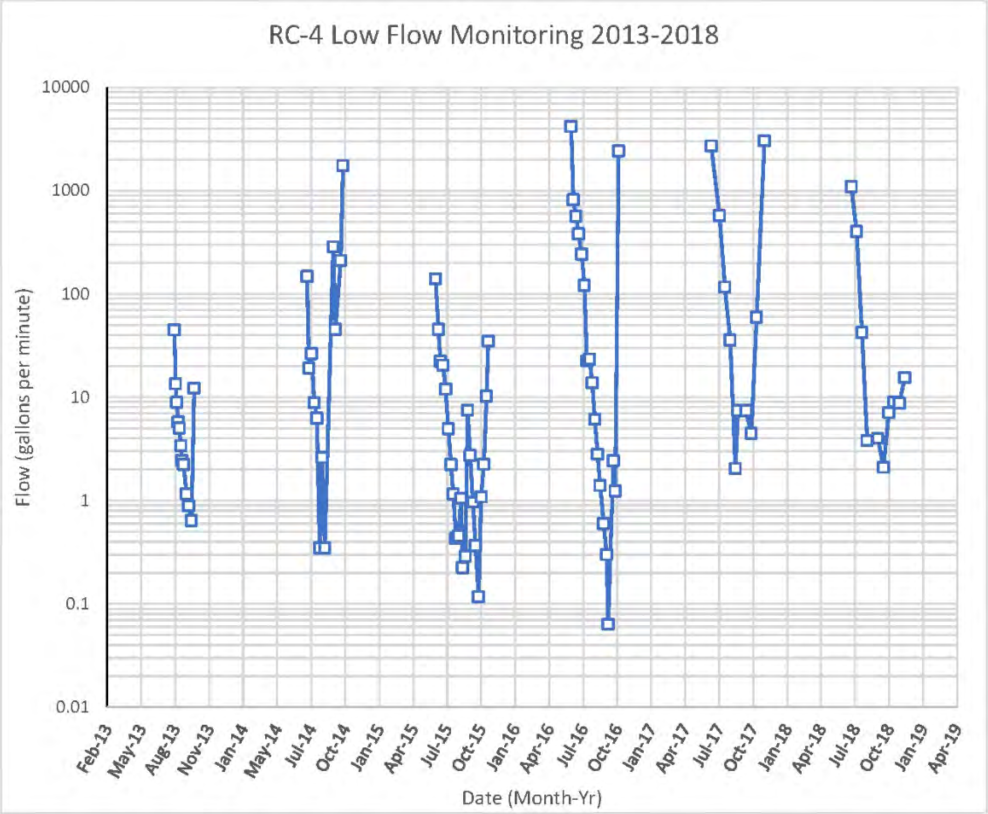

Figure 15. Dry season flow monitoring results for Redwood Creek mainstem near confluence with South Fork Eel.

8.4 100-year Storm Event Analysis

The 100-year storm event analyses utilized Rational Method runoff calculations for the upslope areas and Class III drainages running through and adjacent to the Project as well as more in-depth hydrologic and hydraulic analyses for mainstem Redwood Creek.

8.4.1 100-year storm event rational method calculations

Based on the Rational Formula defined in Section 8.2.1 above, 100-yr discharges were calculated for the outfalls of the ponds as well as the eastern and western tributaries. This method is appropriate for determining flow rates for relatively small drainage areas of less than 200 acres according to Cafferata et. al. (2004).

8.4.1.1 Determining storm duration

For the Rational Method analysis, the total area, slope, and longest flow path for each drainage was determined based on field observations and analyses of a USGS topographic map. Based on these values (summarized on Table 2), the "Time to Concentration" was estimated using the Airport Drainage Formula. The "Time to Concentration" is defined as the time it takes runoff to travel along the longest flow path within the contributing watershed and arrive at a site crossing. Per Cafferata et. al., the "Time to Concentration" can be found with the following Airport Drainage Formula[1]:

$$T_c=((1.8)(1.1–C)(D^{0.5}))/(S^{0.33})$$

Where:

Tc=Time of Concentration (minutes)
C=Runoff Coefficient (dimensionless, 0<C<1.0)
D=Distance (in feet from the point of interest to the point in the watershed from which the time of flow is the greatest)
S = Slope (percent)

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[1] Note that two methods for determining Time to Concentration were described in Cafferata et. al. including (1) the Kirpich formula and (2) the Airport Drainage equation. The Kirpich Formula was developed in 1940 based on precipitation and runoff data from seven rural watersheds in Tennessee with average slopes ranging from 3% to 10%. We believe that the Kirpich Formula does not provide good estimates for Time to Concentrations on steeper northern California watersheds. Additionally, Yee (1994) recommends use of the Airport Drainage equation.

Table 2. Summary of time-to-concentration analyses.

Site	Drainage area (ac)	Longest flow path (ft)	Maximum elevation change (ft)	Slope (%)	Time to concentration (min)	100-year intensity (in/hr)
Hillslope draining to Eastern Pond	2.5	600	80	13	13	3.1
Direct rainfall on Eastern Pond	1.3	0	0	0	13	3.1
Hillslope draining to Western Pond	5.0	720	200	28	11	3.3
Direct rainfall on Western Pond	1.8	0	0	0	11	3.3
Eastern Tributary	4.0	700	120	17	13	3.1
Western Tributary	20.0	2500	520	21	23	2.2

* Time to concentration for Eastern and Western Ponds match associated hillslope time to concentrations.

8.4.1.2 Precipitation data

The intensity-duration-frequency (IDF) curve used for the Rational Method analysis came from National Oceanic and Atmospheric Administration's National Weather Service Hydrometeorological Design Studies Center Precipitation Frequency Data Server (PFDS).[2] Rainfall intensity was determined from the IDF curves for the 100-year recurrence interval for storm durations equivalent to the "Time to Concentration" for the project sites. The 100-year rainfall intensity from the PFDS for each site is also shown on Table 2.

8.4.1.3 Runoff coefficients

Cafferata et. al. suggests a runoff coefficient ranging from 0.30 to 0.45, depending on the specific location of the crossing. Per Buxton et. al. (1996), as cited in Cafferata et. al., a runoff coefficient value of 0.4 is recommended for North Coast California specifically. Additionally, a runoff coefficient of 0.4 reflects woodland with heavy clay soil, soil with a shallow impeding horizon, or shallow soil over bedrock per Figure 16 taken from Appendix A, Table A-1 of *The Handbook for Forest, Ranch and Rural Roads* (Weaver et. al. 2015).

For this property, we have used a Runoff Coefficient of 0.4 because the drainage areas consist of mostly woodland with soil with a shallow impeding horizon. For the rain falling directly on the ponds, the runoff coefficient is 1.0.

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[2] http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html

Soils	Land use or type	C value
Sandy and gravelly soils	Cultivated	0.20
	Pasture	0.15
	Woodland	0.10
Loams and similar soils without impeded horizons	Cultivated	0.40
	Pasture	0.35
	Woodland	0.30
Heavy clay soil or those with a shallow impeding horizon; shallow over bedrock	Cultivated	0.50
	Pasture	0.45
	Woodland	0.40

Figure 16. Runoff coefficients (adopted from Appendix A, Table A-1 of the *Handbook for Forest, Ranch and Rural Roads* [2015]).

8.4.1.4 Storm discharges

Discharges from the Rational Method calculations for 100-year storm events are shown on Table 3.

Table 3. 100-year discharges.

Site	100-year discharge (cfs)
Hillslope draining to Eastern Pond	3
Direct rainfall on Eastern Pond	4
Hillslope draining to Western Pond	7
Direct rainfall on Western Pond	6
Eastern Tributary	5
Western Tributary	18

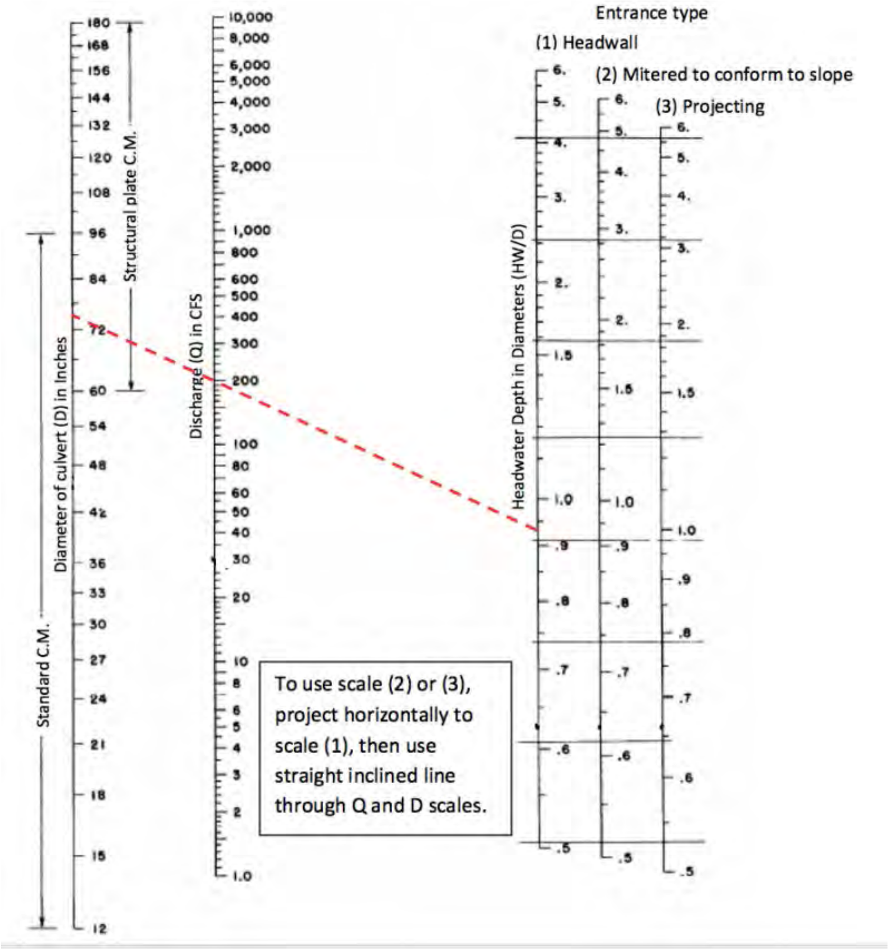
8.4.1.5 Drainage structure sizing

New drainage structures will be needed for the access road to the project which crosses the Eastern and Western Tributary and the outlets of the ponds with runoff generated from both the “hillslope draining to” each pond and the “direct rainfall on” each pond. These drainage structures are required to carry 100-year discharges and are sized using the FHWA Culvert Capacity Inlet Control Nomograph (Figure A-1 of Weaver et. al. 2015) using an HW/D ratio of 0.67, as shown in Figure 17 below. The required culverts for both tributaries and pond outflows are shown in Table 4.

Table 4. Drainage Structure Sizes

Site	100-year discharge (cfs)	Culvert diameter required (inches)
Eastern Pond Outflow	7	30
Western Pond Outflow	13	36
Eastern Tributary	5	24
Western Tributary	18	36

The rock armored grade control structures proposed for stabilization in the Western Tributary have also been designed to accommodate the 100-yr storm flows listed in Table 3.



To use scale (2) or (3), project horizontally to scale (1), then use straight inclined line through Q and D scales.

Figure 17. Culvert Capacity Inlet Control Nomograph (adopted from Appendix A, Table A-1 of *The Handbook for Forest, Ranch and Rural Roads* [Weaver et. al. 2015]).

8.4.2 Hydrologic and hydraulic overview for Redwood Creek mainstem

To understand the flow dynamics that will act on the instream features proposed in Redwood Creek and to estimate flooding potential at the project site, flow hydraulics were modeled using the U.S. Army Corps of Engineers' (USACE) *Hydrologic Engineering Center's River Analysis System (*HEC-RAS). HEC-RAS is a one-dimensional hydraulic model that is widely used for floodplain mapping and estimating general flow characteristics. This one-dimensional model assumes uniform flow direction and constant velocity distribution within the channel and floodplain portion of each cross section. Flow is modeled based on topography at a channel cross section without considering the effects of channel topography between cross sections. Therefore, it is important that these limitations are closely considered during hydraulic model setup, calibration, and application.

8.4.2.1 Hydrologic data overview

The first step in this hydraulic modeling process is to determine the hydrologic data that will be the principal input to HEC-RAS. The primary hydrologic data sets analyzed for this project were flood frequency flows (also known as recurrence interval flows) which represent higher flows that are expected to occur at a specific frequency (i.e., a 100-year flow would be expected to occur every 100 years on average). These flood frequency flows, especially those from half of "bankfull" to 2-year discharges, are biologically significant because they occur during most winters and are swift enough to flush salmonids out of the system and/or cause mortality if insufficient low-velocity habitat is available at such flows. For this analysis, 1.5-year recurrence interval flows are considered to be synonymous with "bankfull" flows. In addition, it is critical to analyze flows from larger events ranging from 2- to 100-year to determine erosion potential and flooding hazards for adjacent property and infrastructure, as well as the stability of the features being installed under high flow conditions.

Flood frequency discharges for each project reach were determined based on (1) US Geological Survey (USGS) gage data, (2) Federal Emergency Management Agency (FEMA) flood insurance studies, and (3) USGS Streamstats data. Each of these data sources are discussed below.

8.4.2.2 USGS gage data

USGS gage #11476500 has recorded annual peak flows in SF Eel River near Miranda for approximately 75 years. For this analysis, peak flow records from October 1939 to September 2016 were used. With these records, Log-Pearson Type III distributions can be used to predict the magnitude of peak flows for specific storm events. Considering the timeframe during which peak flows have been measured, this gage data is particularly accurate in predicting flows for storm events with recurrence intervals of 10 years and less.

Considering that the project reach is not located at the same location as the USGS gages, flows were estimated at each project site using the USGS formula for calculating magnitude and frequency of floods in California:

$$Q_u = Q_g(A_u/A_g)^b$$

Where: $b = 0.9$ for 2-year event and $b = 0.87$ for 100-year event

Q_u = Ungauged discharge
Q_g = Gauged discharge
A_u = Ungauged drainage area
A_g = Gauged drainage area.

Results from these calculations are shown in the first row of Table 5. Based on the updated project design proposing a pond on the western terrace, the hydraulic has been extended upstream to ensure that the pond will not be impacted by 100-yr WSEs. The hydraulic model now incorporates a major tributary confluence where Miller Creek enters Redwood Creek from the north. The flow allocation between these major tributaries has been determined via proration by drainage area as described on the bottom rows of Table 5.

Table 5. Flood frequency discharge estimates for the Redwood Creek Project Reach.

Discharge location and description:	100-year discharge (CFS)	50-year discharge (CFS)	25-year discharge (CFS)	10-year discharge (CFS)	5-year discharge (CFS)	2-year discharge (CFS)	1.5-year discharge (CFS)
Redwood Creek Downstream from Miller Creek confluence: Log-Pearson Analysis based on USGS Gage at Miranda (537 sq mi) adjusted for Drainage Area Difference based on USGS Formula				3,100	2,400	1,400	800
Redwood Creek Downstream from Miller Creek confluence: FEMA prorated	3,500	3,400		2,200			
Redwood Creek Downstream from Miller Creek confluence: USGS Streamstats for Project Site (10.7 sq mi)	3,850	3,340	2,840	2,170	1,660	930	
Redwood Creek Downstream from Miller Creek confluence: Average Combined	**3,700**	**3,400**	**2,840**	**2,500**	**2,000**	**1,200**	**800**
Miller Creek (3.7 sq mi drainage area) proration from Downstream Redwood Creek reach	**1,280**	**1,180**	**980**	**860**	**690**	**410**	**280**
Upstream Redwood Creek (7.0 sq. mi. drainage area) proration from Downstream Redwood Creek reach	**2,420**	**2,220**	**1,860**	**1,640**	**1,310**	**790**	**520**

8.4.2.3 FEMA Flood Insurance Studies

FEMA has authored a Flood Insurance Study (FIS) for Humboldt County which includes Redwood Creek (FEMA 2017). The FIS focuses on the area around Redway, downstream of the project reach. The FIS does not provide 100-year flood water surface elevations (WSEs) for the project reach, but does provide a map of estimated 100-year floodplain extents. In addition, FEMA flood discharges for SF Eel River can be prorated by drainage area to estimate flows for the project reach. FEMA predicts flood discharges for 10-, 50-, 100- and 500-year storms.

8.4.2.4 USGS Streamstats data

The USGS operates the interactive Streamstats website which can be found at: (http://water.usgs.gov/osw/streamstats/california.html)

This website uses a geographic information system (GIS) and flow regression equations to calculate storm discharges at any point along watercourses. Streamstats provides discharge data for 2-, 5-, 10-, 50- and 100-year storms. Streamstats results at the project site are shown in the third row of Table 1.

8.4.2.5 Discharges

Discharges used in the Redwood Creek hydraulic model are listed in the bottom row of Table 5. These flows have been calculated by averaging the discharges listed in the top two rows of the table. These values have been rounded to two significant digits to reflect the uncertainty of these estimates.

In addition to the flood frequency flows, additional low and moderate flows have also been modeled in HEC-RAS which correspond to winter base flow and a typical late spring/early summer flow. These flows have biological significance for restoration, especially related to spring and summer rearing as well as over-wintering habitat for salmonids. Note that for much of the summer, flows in Redwood Creek drop below 1 cfs (Stillwater 2017). However, due to the level of detail of topographic data gathered as well as hydraulic modeling constraints, there is minimal value-added in modeling flows less than 1 cfs. The low to moderate flows used in the hydraulic model are shown in Table 6. The typical winter discharge was calculated by prorating flows for the project site based on average January, February, and March flows measured at USGS gage #11476500 (SF Eel near Miranda). The typical spring/early summer discharge was calculated by prorating flows for the project site based on average May, June, and July flows measured at USGS gage #11476500 (SF Eel near Miranda).

Table 6. Additional discharge estimates used for the Redwood Creek hydraulic model.

	0.5 bankfull discharge (CFS)	**Typical winter discharge (CFS)**	**Typical late spring/early summer discharge (CFS)**
Redwood Creek Downstream reach	400	88	1
Miller Creek	140	30	1
Redwood Creek Upstream reach	260	58	1

8.4.2.6 Existing conditions hydraulic modeling

Existing conditions topography used for the HEC-RAS model was based on the DEM described in Section 7 of this report. Plan view locations of all HEC-RAS cross-sections are shown on Figure 18. Typically, cross sections are cut perpendicular to the channel thalweg. However, in cases where there is significant channel sinuosity, which is the case for this project, some skewing of the sections is required to properly model the channel and floodplain curvature. Based on sensitivity analyses conducted in HEC-RAS with different cross section placements, it was determined that the slight skewing of the cross sections away from perpendicular does not lead to significant differences in modeled outputs of velocities or flood elevations.

Cross-sections of the channel were cut from the Triangular Irregular Network (TIN) surface in AutoCAD and exported directly to HEC-RAS in order to create the hydraulic model. Manning's "n" roughness values used in HEC-RAS were 0.05 for the channel, based on the HEC-RAS Reference Manual recommendations for a "clean and winding natural stream with some pools, shoals, weeds and stones"; and 0.06 for all banks and floodplains based on a conservative value for "light brush and trees in summer." These values were calibrated based on previous work that Stillwater conducted for a restoration design project just downstream from this project (see discussion below). Flow was modeled in a subcritical regime with a normal depth downstream boundary condition at a slope of 0.0055 held constant for all flow stages.

8.4.2.7 Hydraulic model calibration

The existing conditions HEC-RAS model was calibrated using field-based evidence of 2017 high flow. Based on a review of Water Year 2017 peak flows on Bull Creek, the highest flow event which occurred on January 10, 2017 was approximately a 2-year recurrence interval flood. At Station 17+00, flood debris caught in tree branches was observed at elevations between 464 and 465.5. Based on the positioning of the tree branches where observations were made, it is likely that during high flows they were bent down several feet. The initial HEC-RAS model run predicted 2-year water surface elevations (WSEs) flows of 462.7 feet. To calibrate the model to more accurately match field observations, all Manning's n roughness values were increased by 0.005 which consequently increased the WSE at Station 17+00 to 463.3 feet which closely matches field observations assuming the branches were pushed down several feet.

8.4.2.8 Existing conditions hydraulic model results

The existing average stream channel velocity and mean total shear value results from HEC-RAS for 100-year, 10-year, 2-year, and 1.5-year flows are shown on Table 6. The corresponding WSEs and floodplain extents for these return periods are shown on Figure 18 and Figure 19. A full tabulation of hydraulic model outputs are included in Appendix D. Figure 18 shows the longitudinal profile of the channel invert and WSEs throughout the project area. Note that the Project is located within the upstream extent of the modeled profile between HEC-RAS Stations 3000 and 4200.

Within the project reach, the 100-year flows are almost entirely contained within the channel as shown on Figure 19 due to the generally incised nature of the Redwood Creek. Therefore, there are no significant constraints in placing fill or constructing infrastructure adjacent to Redwood Creek based on 100-yr flow. Furthermore, the floodplain terrace to the north of Redwood Creek is significantly lower than the terrace to the south of the creek. Therefore, even if future WSEs were higher than the model results, flooding would extend across the northern floodplain and would not reach the southern terrace where project features are proposed.

The incised and confined nature of the channel will generate high velocities and deep flows that will exert strong forces on proposed instream structures. Therefore, a stability analyses is necessary for the design of proposed instream structures (see Section 12 below).

Table 7. HEC-RAS model outputs for average channel velocity and shear for the modeled project reach.

Flow metrics	Average existing total velocity (feet per second)	Average existing total shear (pounds per square foot)
Spring/Early summer	0.64	0.13
Typical winter	2.23	0.46
0.5 Bankfull	3.49	0.79
1.5-year	4.27	0.97
2-year	4.78	1.09
5-year	5.41	1.27
10-year	5.71	1.35
25-year	5.88	1.36
50-year	6.12	1.37
100-year	6.22	1.38

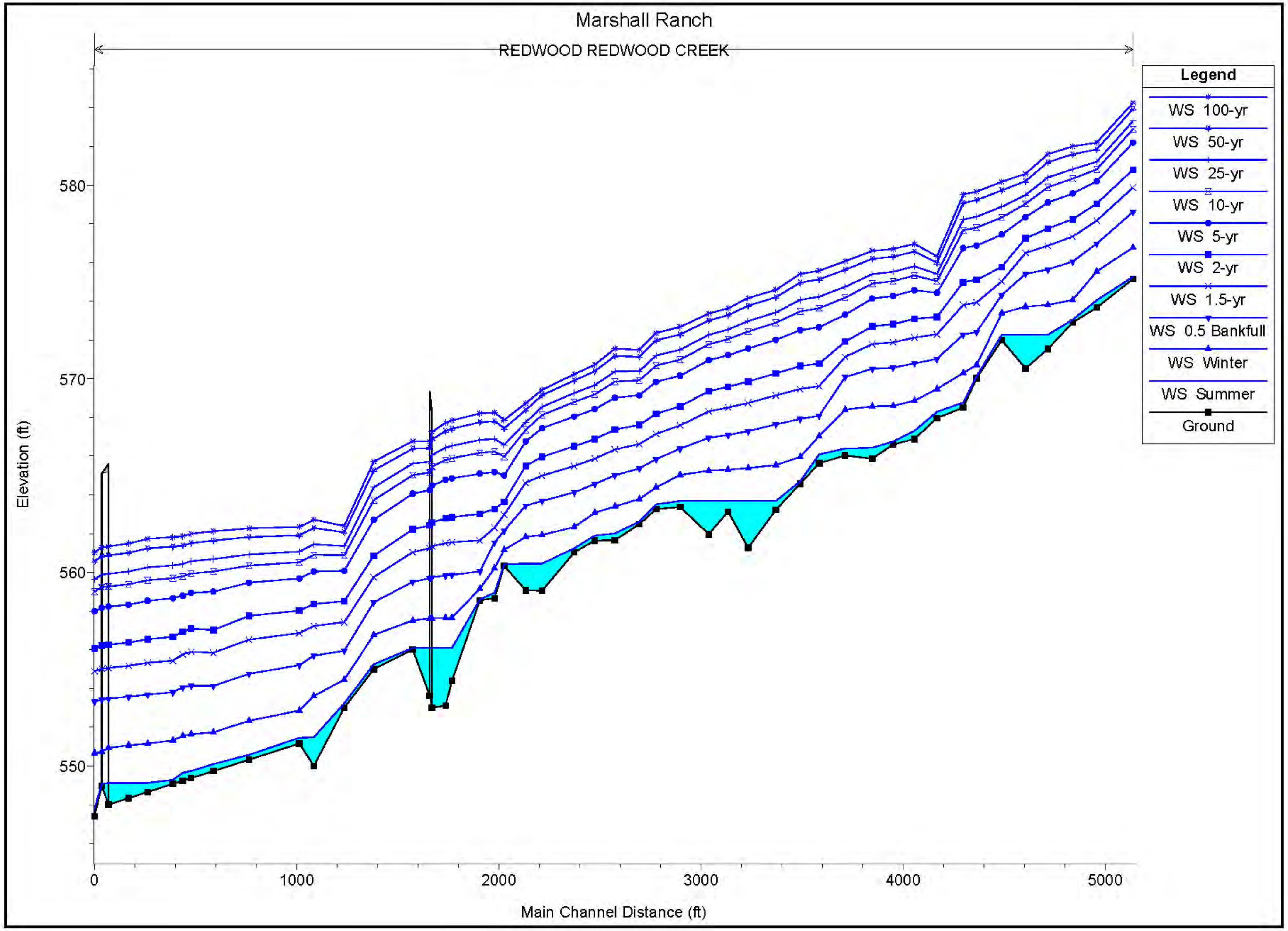


Figure 18. Modeled water surface elevations in the project reach.

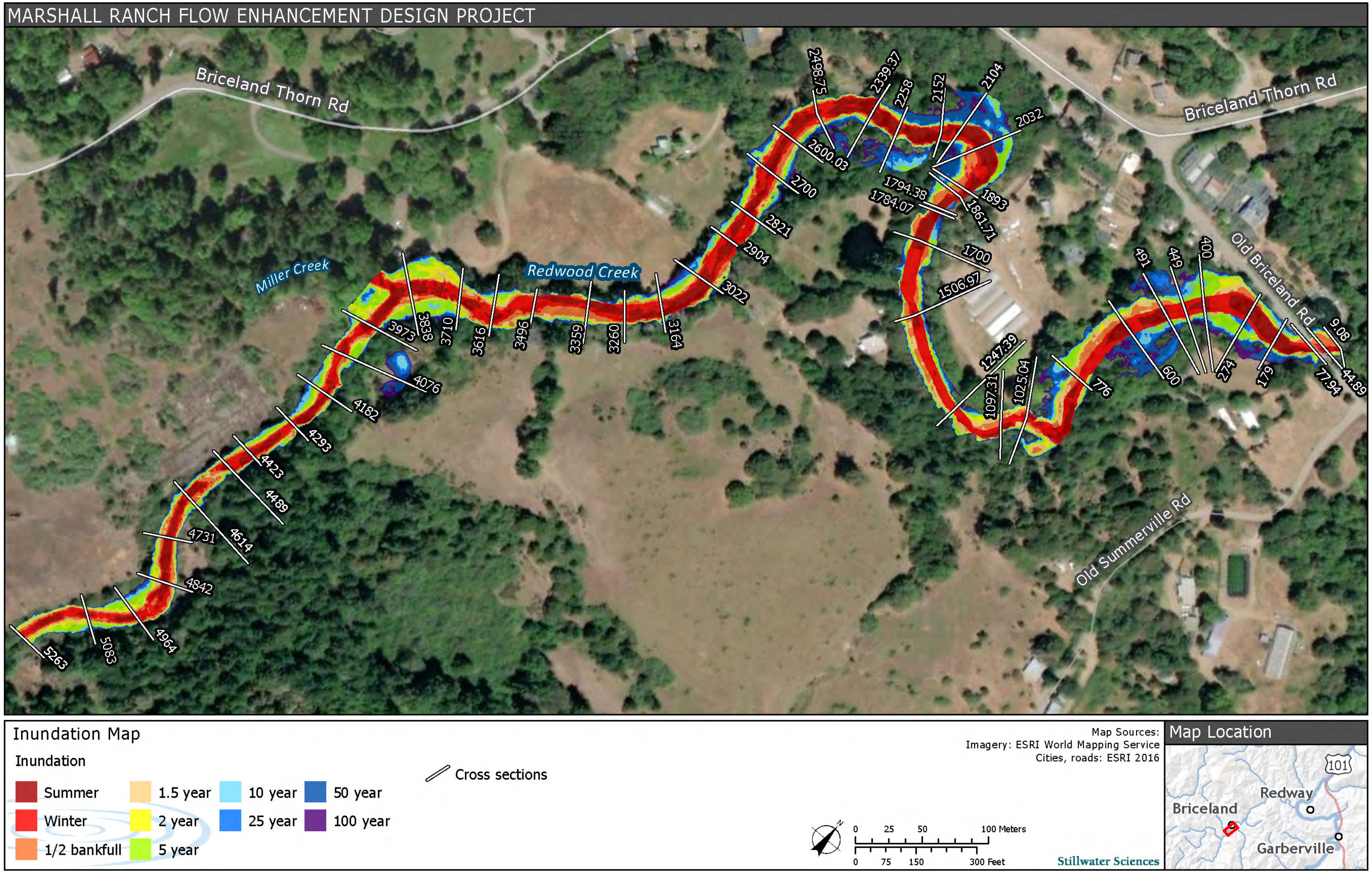


Figure 19. Inundation at various flows within the project reach.

8.4.2.9 Proposed conditions hydraulic modeling results

The proposed features within Redwood Creek are not expected to significantly change hydraulic dynamics so no proposed-conditions modeling will be conducted.

8.5 Groundwater

Groundwater wells were installed in November 2018 inside two of the boreholes (BH-101 and BH-103) and three of the test pits (TP-1, TP-2, and TP-3). Groundwater wells consisted of screened 2-inch diameter PVC pipe with data loggers measuring water elevations at 15 minute intervals. Note that the wells within BH-101 and BH-103 were constructed using standard well installation techniques with a bentonite seal around the top of the well to prevent direct precipitation and ponding around the well head from influencing measured groundwater levels. The wells within TP-1, TP-2, and TP-3 were constructed more coarsely with vertical standpipes stuck into the test pit and backfilled with loose dirt by an excavator bucket (i.e. there was no seal or soil mounding around the well head to reduce pooling and accelerated infiltration during and after significant precipitation events).

Groundwater monitoring results for the five wells are shown on Figure 20. Even with the different installation techniques, the groundwater levels measured within each well follow similar patterns. As expected, the groundwater dynamics at the site are governed by precipitation events with significant rainfall leading to increased groundwater levels within the wells. Within BH-101 and BH-103, during the dry season, the groundwater levels are perched just above the bedrock interface which is consistent with the findings from the geotechnical investigations (note that the bedrock is nearly impervious). Then, during significant rainfall events, the groundwater levels spike.

There was a visible difference between groundwater dynamics at BH-101 compared to BH-103. At BH-101 groundwater was either at the ground surface or within several feet of the ground surface during approximately two months of the 2018/2019 wet season whereas BH-103 just had several groundwater level spikes that neared the ground surface. This is likely due to surface runoff from the Eastern Tributary infiltrating into the terrace upslope from BH-101. Groundwater within the lower terrace was also near the ground surface during wet periods. Based on these groundwater dynamics, a French drain is proposed under the western pond (lower terrace) due to the expected presence of significant groundwater during much of the wet season while no French drain is proposed under the eastern pond (upper terrace near BH 103) due to generally less groundwater with only occasional spikes during significant rainfall events.

Concerns have been raised by agency staff and community members that the project could negatively impact natural groundwater inputs from the project site vicinity through installation of the french drain under the pond. The french drain is designed to drain groundwater from the lower terrace to prevent bubbling under the pond liner and significantly reduce slope stability concerns. As shown by the well data (Figure 20), under existing conditions groundwater is almost entirely drained from the shallow soil layer within two months following significant precipitation events. Furthermore, the underlying shale bedrock is impervious and does not allow for groundwater recharge. Therefore, nearly all groundwater is drained from the site and delivered to Redwood Creek before low flow conditions are reached in the mid to late summer. Therefore, the groundwater inflows provided by the site under current conditions do not measurably increase dry season flows.

Figure 20. Groundwater monitoring results.

9 ADDITIONAL SITE EVALUATIONS

9.1 Cultural Resources

Findings from a cultural resources study are included in Appendix E. The proposed project design was developed with consideration of cultural resources, so no significant impacts are expected as long as the recommendations in the cultural resources study are followed. A cultural resources construction monitor has been included in the implementation project budget.

9.2 Biological Resources

Findings from a Biological Resources study are included in Appendix F. The proposed project design was developed with the goal of enhancing local aquatic habitat, so no significant impacts are expected as long as the recommendations in the Biological Resource Technical Report are followed.

10 ALTERNATIVES ANALYSES

Based on the results of the multiple analyses described above, the project is feasible. An alternatives analysis was conducted in three phases with an initial phase defining the optimal size and filling/draining mechanisms for the reservoir, a second phase assessed in more detail specific project design considerations and features that maximize benefits and reduce risk, and a third phase took into account a broader watershed-scale perspective.

10.1 Phase I Analyses

A matrix of proposed project alternatives (Table 8) was developed to compare the flow enhancement benefits resulting from project with various pond sizes and metered versus passive pond outflow approaches.

Table 8. Summary Table of project alternatives.

Pond volume (gals)	Pond volume after evaporation loss (gals)	Flow benefit with mechanized outflow valve, assumes 5-month release time (gpm)	Flow benefit with passive outflow, assumes 5-month release time (gpm)	Comments
6,000,000	4,000,000	19	12	Fills with rainfall only
8,500,000	5,666,667	26	16	Fills with Rainfall, Trib A and hillslope
13,500,000	9,000,000	42	26	Fills with Rainfall, Trib A, Trib B and hillslope
16,300,000	10,866,667	50	31	Maximum capacity to be exempt from DSOD Jurisdiction; needs water pumped from Redwood Creek to fill
21,500,000	14,333,333	66	41	Maximum size based on site conditions and filling capacity based on realistic water sources

Based on this matrix of alternatives the design team selected a 16-million-gallon pond with mechanized outflow capable of delivering 50 gallons per minute of flow to Redwood Creek during a 5-month dry season. Preliminary vetting of this alternative was also conducted at the February 2019 TAC meeting with member of the TAC generally supporting this alternative. The preferred alternative provides a substantial flow benefit of 50 gallons per minute while being generally conservative in utilizing the available topography. This alternative is also exempt from DSOD fees and reporting which will reduce long-term operations and maintenance costs.

This alternative was advanced to the draft 65% design level with excerpts from that design included in Appendix A.1 (Draft 65% Designs Excerpts 2019). Note that based on input from adjacent landowners, further analyses were conducted, and several significant design alternatives were considered through a Phase II alternatives analyses as described below.

10.2 Phase II Analyses

Phase II of the alternatives analyses focused mainly on analyzing specific design alternatives that reduced project risks to the lowest practicable level while increasing functionality and longevity and maintaining a total volume of approximately 16 million gallons. Four new design alternatives were analyzed to increase pond stability and general long-term durability of the project:

1) **Lowering the pond elevation by eight feet.** With this grading approach, approximately 90,000 cubic yards (CY) of earth will be excavated from the terrace and approximately 3000 CY will be used to construct the berm. This will result in a net off-haul of 87,000 CY of earth or ~120,000 tons. With the pond at full capacity (65,000 tons of water), the proposed design will result in a net reduction of weight on the terrace of 55,000 tons. Note that the fill that was previously proposed under the solar arrays has been eliminated. In summary, the current design significantly reduces the soil weight on the existing terrace.
2) **Relocation of the pond spillways.** Based on the lower pond elevation, a rock-lined spillway draining out of the western extent of the pond is now feasible. This new alignment distances the spillway from the adjacent property owners. Also, the change from a culvert spillway (in the previous design phase) to a rock-lined spillway will increase longevity and reduce long-term maintenance costs.
3) **Installation of a pond liner, French drain, and subsurface restrictive barrier.** These design alternatives are being considered to ensure that the project will results in a decrease in groundwater levels downslope from the pond as compared to current groundwater levels. Results of the slope stability analyses showed that a high groundwater table increases risk of slope instability. The previous design iteration included a compacted clay liner on the inside of the pond to control seepage. However, valid concerns were raised about the longevity of that liner with wetting, drying, shrinking and swelling, as well as erosion of the native soil liner over time as the pond was filled and drained every year. Therefore, three significant design modifications for sealing the pond and reducing downslope groundwater are currently being considered: 1) a high grade plastic liner (guarantee of 25 years, life expectancy of 140 years) protected by geotechnical fabric and buried under six inches of gravel, 2) a French drain to collect and drain all groundwater flowing from upslope and under the pond liner, and 3) a subsurface restrictive barrier under the pond berm as a redundant safety feature to prevent downgradient flow of groundwater. Multiple groundwater wells will be installed in the

area downslope of the pond to ensure that groundwater levels remain lower than pre-project conditions. Data recorders measuring groundwater levels will be connected to an online network so that groundwater data can be analyzed and viewed in real time.

4) **Grade control structures in central gully.** Even though the project is likely to significantly reduce runoff rates within the central gully, continued degradation of this gully over time has the potential to slowly erode the terrace where the pond is proposed.
5) **Backup energy system.** Install backup energy system with batteries, inverter, small solar array and micro-hydro to provide capability to operate and monitor project even during power outage.

This project alternative is further described in Appendix A.2 (Draft 90% Designs Excerpts 2020). The project team believed that inclusion of these design alternatives resulted in a project that minimizes risk and maximizes long-term functionality. However, during the CEQA public comment period it became clear that strong opposition to the project still existed even with the significant design modifications. Substantive public comments were critical of the project within three primary areas: 1) concerns with long-term stability of the pond considering the scale of earthwork, 2) the desire to implement flow enhancement within the Redwood Creek watershed upstream from Briceland, and 3) the desire for a less mechanized project that would function without significant long-term electricity use. To address these considerations, a Phase III alternatives analyses was conducted.

10.3 Phase III Analyses

The third phase of the alternatives analyses looked at the option of downsizing the storage and flow enhancement volume on the Marshall Ranch while adding flow enhancement projects elsewhere in the watershed to address the three substantive public comments described above. To do this, the project team looked for opportunities outside the Marshall Ranch within the upper portions of the Redwood Creek watershed where large scale flow enhancement could be feasible. Previous on-the-ground watershed assessments throughout Redwood Creek had not identified any other feasible sites for large scale flow enhancement with willing landowners. However, in early 2020 Lost Coast Forestlands (LCF) acquired approximately 1000 acres of property in Upper Redwood Creek and in early 2021 the project team began assessing flow enhancement feasibility on that property. Based on several months of assessment, analysis, and agency discussions, it has been determined that there is strong likelihood of a feasible opportunity for significant flow enhancement via 5 to 6 million gallons of off-stream water storage on the LCF property.

This finding was incorporated into the third phase of Marshall Ranch alternative analyses with the project team looking at the potential for a smaller Marshall Ranch project whereby the Marshall and LCF projects combined would generate the target 15 million gallons of off-stream storage and 50 gpm of flow augmentation during the five-month dry season. By including a project on LCF property and reducing the water storage on the Marshall Ranch to 10 million gallons, the revised design addresses all three of the substantive public comments described in Section 10.2 above.

This preferred project alternative for the Marshall Ranch site is further described in Section 11 below and in Appendix A.3 (Draft 90% Designs 2021).

11 PROJECT DESIGN

Based on multiple rounds of alternatives analyses and solicitations/incorporation of public comments, the primary project objective for the Marshall Ranch is to construct 10 million gallons of off-stream water storage intended to deliver approximately 30 gpm of flow augmentation to Redwood Creek during the five-month dry season. This project includes the following components:

11.1 Main Components of Water Storage and Augmentation System

11.1.1 Ponds

Construction of off-channel ponds will include excavation and placement of earthen berms and spillways built into the natural topography. Construction will include removal of topsoil from the reservoir area. The topsoil will be saved and spread around the reservoir area along with mulch after construction. All critical fill placement will be subject to compaction testing to ensure 90% minimum compaction. Excavated material not used to build the berms will be placed and compacted in a designated fill areas as shown on the plans.

The project team originally proposed natural clay liners, but based on varied subsurface stratigraphy at the site, HDPE pond liners with associated woven geotextile fabric and gravel topping will be utilized. This approach is expected to maintain higher water quality in the pond by eliminating the rilling, erosion, and sedimentation that would have resulted from yearly filling of the pond with a natural clay liner. It also improves slope stability and eliminates seepage thereby resulting in better functionality of the ponds both in terms of water quality/quantity and long-term stability.

The Western Pond has a rock lined spillway sized for the 100-yr storm discharge. The Eastern Pond has an 18” diameter culvert as the primary spillway and a secondary rock lined spillway with capacity for 100-yr storm discharge.

11.1.2 Diversion Structures in Seasonal Tributaries

Two gravity fed screened inlet structures will be installed in two seasonal tributaries to allow for supplemental filling of the ponds. Water will only be diverted from the Redwood Creek tributaries during the wet season.

11.1.3 Flow enhancement delivery system and cooling/filtration gallery

The two ponds will be connected via piping and valves. Pond outflows will have screened outlets near the bottom of each pond. Valves and flow meters will control the amount of water that is released from the ponds.

During periods of the summer when water temperatures begin to warm, water will be directed into a cooling/filtration gallery prior to release to the creek. The cooling/filtration gallery will consist of an existing gully filled with ~1,350 CY of sand/gravel material sorted onsite. Initial reservoir drawdown modeling has been conducted and is discussed in Appendix H. That analysis suggests that under standard operating conditions the Western Pond will be greater than 20 feet deep during the peak of the dry season (August/September) so water should be stratified and temperature concerns should not be an issue considering that water is drawn out of the bottom of the reservoir.

In summary, the analyses indicate that the current pond design will result in flow releases with temperatures suitable for juvenile salmonids throughout the year under a standard management scenario. Under unusual circumstances, however, cooling pond water temperatures may be beneficial, and the cooling/filtration gallery will meet that need.

11.2 Additional Components

There are numerous additional project components that are required to meet the main project objective of flow enhancement as described below.

11.2.1 Off-grad energy system

A 1.0 KW solar array, battery bank, inverter, and control center building will allow for real time operations and monitoring capabilities.

11.2.2 Gully stabilization treatments

Approximately 10 rock armor grade control structures will be installed to stabilize two actively eroding intermittent drainages adjacent to the Project. The gully stabilization features are also expected to offset shallow groundwater draining that results from installation of the french drain under the pond. Specifically, treatments in the western tributary gully will significantly reduce incision rates and slow groundwater discharge.

11.2.3 Large wood structures in Redwood Creek

Instream habitat enhancement features will be constructed along Redwood Creek mainstem to improve summer rearing habitat for salmonids within the vicinity of the Project and also reduce bank erosion potential in the vicinity of the Western Pond. This includes construction of one large wood habitat enhancement structure.

11.2.4 Access road upgrades

The access roads within the Project vicinity will be improved to provide year-round access for monitoring, operations, and maintenance of all Project components. This will include reshaping and surfacing with gravel and upgrade to three small road/stream crossings.

11.2.5 Riparian fencing

Fencing will be installed to exclude cattle from watercourses and other unstable areas within the project area.

11.2.6 Additional water storage and fire suppression infrastructure

Five 100,000-gallon water storage tanks are included as part of the project to provide additional flow enhancement supply as well as water for domestic use and ranching activities on APN 220-061-011, and water supply for emergency fire suppression.

11.3 90% Design Engineer’s Cost Estimates

The 90% cost estimates are shown on Table 9 and represent costs associated with the project design shown in Appendix A.3. Due to the complexity of the Project, a budget contingency is included.

Table 9. 90% Design engineer’s cost estimate.

No.	Item	Unit Cost	Quantity	Units	Total cost
1	Mobilization	$200,000	1	Lump Sum	$200,000
2	Clearing and Grubbing	$100,000	1	Lump Sum	$100,000
3	Rough Earthwork (cut/fill balanced onsite)	$20	35630	Cubic Yard	$712,600
4	Pond Liners installation and materials	$500,000	1	Lump Sum	$500,000
5	Gully Stabilizing Grade Control Structures	$3,000	10	Each	$30,000
6	Additional Gully Armoring (rock placed)	$150	100	Tons	$15,000
7	Filtration/cooling gallery	$40	1350	Cubic Yard	$54,000
8	Dewatering	$20,000	1	Lump Sum	$20,000
9	Instream Large Wood Placed and Anchored	$2,000	8	Each	$16,000
10	Instream Boulders Placed and Anchored (as applicable)	$150	100	Tons	$15,000
11	Pond outflow pipeline materials and installation	$250,000	1	Lump Sum	$250,000
12	Spillways	$60,000	1	Lump Sum	$60,000
13	French drain materials	$50,000	1	Lump Sum	$50,000
14	100,000 gal water tanks	$80,000	5	Each	$400,000
15	Fencing	$100,000	1	Lump Sum	$100,000
16	Operations building and Electrical system	$100,000	1	Lump Sum	$100,000

17	Access road improvements and surfacing	$120,000	1	Lump Sum	$120,000
18	Erosion Control and Revegetation	$100,000	1	Lump Sum	$100,000
19	Post Project Monitoring Equipment (flow and groundwater)	$60,000	1	Lump Sum	$60,000
20	SRF Project Management	$200,000	1	Lump Sum	$200,000
21	ERWIG Project Management	$20,000	1	Lump Sum	$20,000
22	Cultural Resources Monitor	$25,000	1	Lump Sum	$25,000
23	Legal and Ranch Oversight	$140,000	1	Lump Sum	$140,000
24	SHN Engineering Oversight	$30,000	1	Lump Sum	$30,000
25	SHN Soils Testing	$15,000	1	Lump Sum	$15,000
26	Stillwater, Engineering, construction oversight, As-builts, Monitoring	$300,000	1	Lump Sum	$300,000
27	5% Contingency	$363,260	1	Lump Sum	$363,260
Total construction cost:					**$3,995,860**

12 STABILITY ANALYSES FOR LARGE WOOD

12.1 Stability Analyses Overview

A Large wood structure stability analysis was used to refine the project design based on the methodology presented in Castro and Sampson (2001). The constants, freebody diagram and equations from Castro and Sampson are included in Appendix G. In summary, this method uses a basic force balance approach in the vertical and horizontal directions to ensure that each wood structure will be stable during a specific flow regime. The calculation process begins with a sum of vertical forces to determine the boulder weight that is necessary to give each structure a factor of safety of 1.5 for buoyancy. Then based on these boulder weights, the factor of safety for momentum is calculated and more boulders are added as necessary to give each structure a momentum (sliding) factor of safety of 2.0 or greater. This stability analyses approach has been reviewed and approved by CDFW Engineer Marcin Whitman for application on several projects in Marin County.

No specific calculations were made for scour or rotational stability because the proposed large wood structures are intended to be dynamic and settle into the bed and banks as scour occurs. This is achieved by utilizing the combination of boulder ballast, live tree anchoring, and triangular anchoring of the placed large wood to allow for hinging and settlement of the structures if extensive scour occurs. Additionally, the risk of excessive scour and rotational instability will be managed by thorough oversight during construction by the engineer as well as field engineering to fine-tune the wood and boulder installation to insure proper placement.

12.1.1 Stability analyses parameters

Below is a list of assumptions that provide the basis of these calculations:

- Analysis based on maximum velocities at each station from HEC-RAS existing conditions model output. Velocity used in analyses is from adjacent station with highest output velocity.
- All boulders submerged at 100-year flows.
- Rootwad dimensions: 4 ft diameter x 4 ft length with porosity = 0.3.
- Channel bed and banks composed of medium gravel: Friction angle = 40 degrees, which results in coefficient of friction for bed of 0.84 (Castro and Sampson).
- All wood is calculated as dry Douglas Fir: density = 33.7 lb/ft^3 (Castro and Sampson).
- Anchor to live tree is assumed to be equivalent to 4 tons of ballast and 4 tons of momentum-resisting force.
- For flow force calculation on multi-log structures located along a stream bank parallel to flow, calculations may assume a shadow effect (i.e. flow does not act on all logs).
- ϴ (angle from rootwad face to vertical) = 0.

12.1.2 Stability analyses uncertainties and factors of safety

There are several areas of uncertainty associated with this stability analyses as discussed below. However, we are confident that the structures will be relatively stable for the 20-year design life of the wood structures due to the Factors of Safety built into this analysis and the on-site engineering and geomorphic expertise that will guide the final layout of the structures (based on design, installation and monitoring of 50+ similar wood structures by project team). In addition, stability will be guaranteed through proper installation as described in the plans and specifications and guided by technical oversight.

The first area of uncertainty is that average flow velocities through each project reach (determined by HEC-RAS) are used for the stability analyses. In reality, water velocities vary greatly both laterally across the channel cross section and with depth. However, we believe that using average velocities is a conservative estimate because the highest velocities generally occur well away from the channel margins and all the proposed structures are located along the streambanks. However, in some cases, especially along outside bends, velocities along the banks can be as high or higher than velocities in the middle of the channel. In these areas, structures will be designed with greater Factors of Safety for sliding stability (momentum) considering the higher shear forces that may act against them.

A second area of uncertainty is the possibility that the position of the wood structures may adjust due to scour or racking of significant new wood against the structure. Most of the structures are built along the banks with strong anchor points to existing trees or new boulders, and in many cases, the structures have been designed so that the force of the flow will hold them in place (i.e. proposed placement in channel expansion zones). In the case of these structures, minor scour and settling may help the structure stay in place because it will increase resistant forces via wedging. However, some structures may have the potential to rotate if significant scour and racking of additional wood occurs. For structures with significant potential for rotation, it is recommended that anchor boulders be keyed deeply into the channel bed and bank and that the engineer/geologist is onsite for construction to insure proper installation.

A third area of uncertainty is the possibility of contractor error or faulty materials (wood or rock with insufficient strength) leading to failure of one or more of the anchoring connections. As such, we will include a significant amount of redundancy in the anchoring of each structure. To further ensure the quality of anchoring, we strongly recommend that a contractor is selected that has previous experience with implementation of large wood projects. Also, it is recommended that an engineer and/or geologist is onsite during large wood placement and anchoring to insure proper installation.

13 LONG TERM OPERATIONS AND MAINTENANCE

A critical component of the project is to ensure that long-term operations, maintenance, and monitoring activities are conducted appropriately and funded. The project team has secured foundation funding to cover long term operations and maintenance as described in Table 10.

Table 10. Projected Long Term Project Costs (years 1-20 post construction).

	Line Item	Annual Budget	Total Cost
Year 1-3	Marshall Ranch 501c3 - General Operations	$10,000	$30,000
	Stillwater Sciences - Engineering support for operations, maintenance, and monitoring (100 hrs/yr)	$15,000	$45,000
	Hicks Law - Legal Services (20 hrs/year)	$6,000	$18,000
	SRF/ERWIG - Annual flow monitoring & project operations (500 hrs/year)	$15,000	$45,000
	Project Adaptive Management Costs	$15,000	$45,000
	Total Cost (years 1-3)	**$61,000**	**$183,000**
Year 4-20	Marshall Ranch 501c3 - General Operations)	$8,000	$136,000
	Stillwater Sciences - Engineering support for operations, maintenance, and monitoring (40 hrs/yr)	$5,400	$91,800
	Hicks Law - Legal Services (5 hrs/year)	$1,500	$25,500
	SRF/ERWIG - Annual flow monitoring and project operations (300 hrs/year)	$9,000	$153,000
	Specific Equipment Replacement/Repair Costs	$5,000	$85,000
	State Licensing & Permit fees	$1,000	$17,000
	Total Cost (years 4-20)	**$29,900**	**$508,300**

Note that additional analyses will be conducted to better refine the operations, maintenance, and monitoring plan and costs. The project team anticipates developing a detailed Operations and Maintenance (O&M) Report that will be reviewed and approved by regulatory agency staff prior to the initiation of construction. Costs to conduct in-depth monitoring and adaptive management activities during the first three years of Project operations will be covered through WCB implementation funding. We anticipate working closely with agency staff during the immediate post-project period to optimize project function.

14 PROJECT RISK AND PERFORMANCE ASSESSMENT

There are several areas of potential project risks that have been thoroughly evaluated during the project planning and design process. Project impacts and approaches to minimize those impacts are discussed in Appendix I including design features, proposed mitigation measures, and monitoring and reporting. The evolution of the project design from the first design iteration shown in Appendix A.1 to the third design iteration shown in A.3 have resulted in a significant reduction in risk.

A summary of project risks and risk management is summarized below.

14.1 Risk and Management of Pond and Hydraulic Appurtenances Failure

1) Risk: Failure of the earthen fill that constitutes the pond berm is a project risk that could result in damage to downslope property and infrastructure.

   Management: The total project storage volume has been decreased by ~5 million gallons from previous design iterations and the storage has been divided into two ponds which greatly reduces the height and amount of earthen fill. The Western Pond is located adjacent to Redwood Creek with no properties or infrastructure immediately below the pond berm. The Eastern Pond has a total volume of less than 4 million gallons and is constructed via excess cut to reduce berm height.

   Additionally, reservoir level measurements will be closely monitored post-construction to ensure that the pond is functioning as designed. Throughout, the planning, design, construction, and monitoring phases, the Project has and will utilize best professional practices with a team of licensed professionals working together to minimize project risk while maximizing benefits. Secured foundation funding will provide resources for monitoring, operations, and maintenance of the system.

2) Risk: The most common failure mechanism of ponds and reservoirs is the failure of the overflow/spillway system. This can lead to significant erosion and mass wasting and can ultimately cause complete failure of the storage pond if left untreated.

   Management: The project design includes spillways sized to pass 100-yr storm discharges. The spillways will be positioned to drain as far away as possible from the nearest neighbor downslope from the project. Secured foundation funding will provide resources for monitoring, operations, and maintenance of the spillway.

3) Risk: Although it would likely not result in catastrophic failure of the Project, there is a risk of failure or malfunction of the flow enhancement piping, flow meter, valves, and cooling gallery.

   Management: These systems will be constructed with redundancy wherever practicable. Secured foundation funding will provide resources for monitoring, operations, and maintenance of these systems.

14.2 Risks and Management Associated with Instream Structures (Redwood Creek mainstem)

1) Risk: This reach of Redwood Creek within the project area is incised approximately 10- to 15 feet below the adjacent terrace and large flow events (including the 100-year flood) are largely confined within the channel. As such, all proposed work must carefully consider the forces acting on the bed and banks during storm events. Additionally, there are several bridges downstream that could be adversely affected by mobilized large wood.

Management: To ensure that wood structures are not disarticulated and transported downstream, stability of the structures for a 20-year design life will be insured through the stability analyses described above construction oversight and post-project monitoring by the project engineer and/or geologist. Post-project monitoring should be conducted during the first two winters following significant storm events, and in following years during flow events that exceed those that the new features have previously been exposed to. This monitoring should identify changes in site conditions that may affect functionality and durability (i.e. newly mobilized large wood, new significant scour, or repositioning of an existing structure).

2) Risk: Large wood structures typically have a design life of approximately 20 years due to declining strength related to wood decay, so it is critical to design the project to account for this reality.

   Management: To account for the estimated 20-year design life of the large wood, the boulders are included in each structure will be placed tucked against the bank such that they will continue to provide bank stability and pool complexity even after the wood rots. The incorporation of riparian planting in the design will provide additional riparian wood and root matter that after 20 years will replace the rotten large wood in many cases.

3) Risk: In a future large storm event, sediment delivered to the project reach from upstream sources may change channel morphology in ways that adversely impact the functionality of the proposed structures.

   Management: The addition of large wood and boulder structures within the Project reach are expected to make channel morphology and habitat within the Project area more resilient to potential future geomorphic changes. Furthermore, the Project does not consist of any features that significantly change channel geometry or slope that could be susceptible more susceptible to failure during future large storm events.

14.3 Overall Risks and Management Approaches Associated with Long-term Project Results

1) Risk: Water produced by the project is diverted out of Redwood Creek by downstream water users. Under applicable provisions of California water law, property owners downstream of the project site whose parcels are adjacent to Redwood Creek have the riparian rights to take and use the "natural flow" of the stream for certain limited purposes. Additionally, some downstream property owners may have appropriative rights to divert water.

   Management: Downstream diverters are required by law to report their diversions to CDFW and State Water Resources Control Board (SWRCB) and those agencies have the authority to control the amount and timing of those diversions. The project team is currently conducting broad outreach among property owners and regulatory agency staff (CDFW and SWRCB) to inform all parties about the project and develop a regulatory framework, engage the community, and prepare for monitoring/enforcement activities after the project is constructed. The project team will also provide technical and coordinate grant funding opportunities to assist landowners within critical stream reaches to increase their water storage capacity.

2) Risk: Water quality and temperature produced by the pond is not suitable for aquatic species in downstream channel.

   Management: The project planning process has taken these risks into consideration with the pond and water delivery systems designed such that appropriate temperature and water quality are maintained. The water delivery system will draw water out of the bottom of the pond which will have low temperatures for most of the year. An on-demand circulation system will be installed in the pond to maintain water quality. As necessary, a cooling/filtration gallery will be utilized to decrease the temperature of flow releases. Detailed post-project monitoring and adaptive management actions will be utilized to change pond operations as necessary. Furthermore, case studies from Russian River tributaries have shown that similar project greatly improved water quality and specifically dissolved oxygen (RRCWRP 2017, Grantham et. al. 2018, RRCWRP 2019).

3) Risk: Although we know that fish need water to survive, there is some uncertainty regarding how the aquatic habitat will respond to enhanced flows, how to measure and quantify that response, and how to adjust the project flow delivery to maximize aquatic habitat benefit.

   Management: Based on similar projects conducted in Sonoma County in lower Russian River tributaries over the past several years, direct flow augmentation has been very effective in improving downstream aquatic habitat (Ruiz et al. 2018, Obedzinski et al. 2018, RRCWRP 2017, Grantham et. al. 2018, and RRCWRP 2019). However, as this habitat enhancement approach continues to develop, the risk can be addressed by post project monitoring of downstream discharge, temperature, dissolved oxygen levels, fish abundance, and fish health. Based on monitoring results from this and other projects, the Project operations can be adjusted to maximize aquatic habitat benefit.

15 CONCLUSION

Although there are risks associated with this project, the management actions described in Section 14 above reduce project risk to an acceptable level when compared to the expected project benefits. The “no-project alternative” will result in continued degradation of dry-season aquatic habitat in Redwood Creek. Also, this project will significantly improve the community’s resilience to wildfire.

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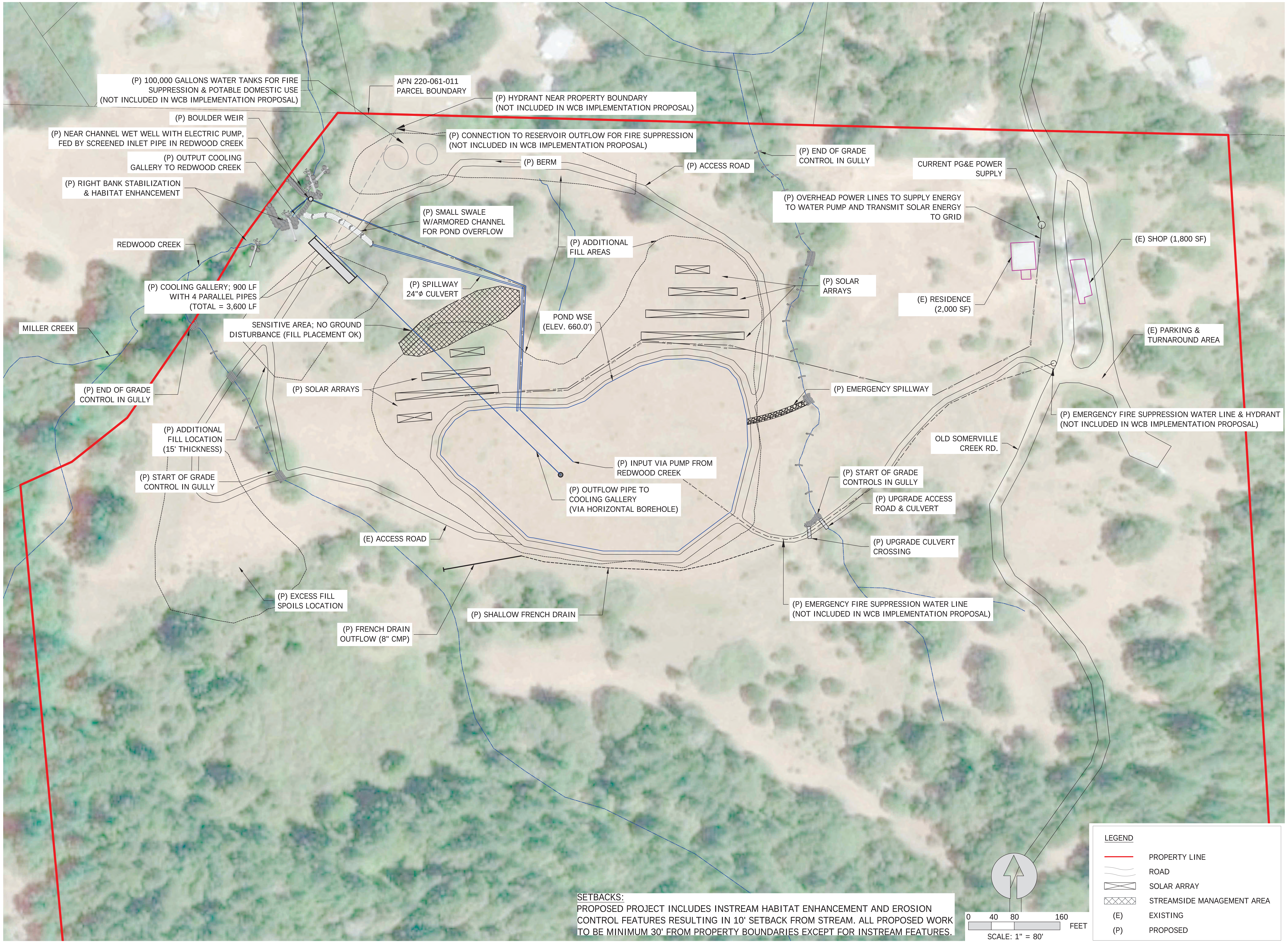
Appendices

Appendix A.1

Excerpts from Draft 65% Design Plans (September 2019)



SETBACKS:
PROPOSED PROJECT INCLUDES INSTREAM HABITAT ENHANCEMENT AND EROSION CONTROL FEATURES RESULTING IN 10' SETBACK FROM STREAM. ALL PROPOSED WORK TO BE MINIMUM 30' FROM PROPERTY BOUNDARIES EXCEPT FOR INSTREAM FEATURES.

LEGEND

🟥	PROPERTY LINE
═	ROAD
⊠	SOLAR ARRAY
▨	STREAMSIDE MANAGEMENT AREA
(E)	EXISTING
(P)	PROPOSED

MARSHALL RANCH FLOW ENHANCEMENT PROJECT

APN 220-061-011

HUMBOLDT COUNTY, CA

Stillwater Sciences
2855 TELEGRAPH AVENUE, SUITE 400
BERKELEY, CA 94705
P: (510) 848-8098

PROJECT NUMBER: 603.01
SCALE: AS NOTED
DATE: 9/9/2019

DESIGN: JM
DRAWN: CL
CHECKED: JM
APPROVED: JM

JOEL MONSCHKE
No. 79688
9-30-20
EXPIRES

SITE PLAN

SHEET 3 OF 30

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE – ADJUST ACCORDINGLY

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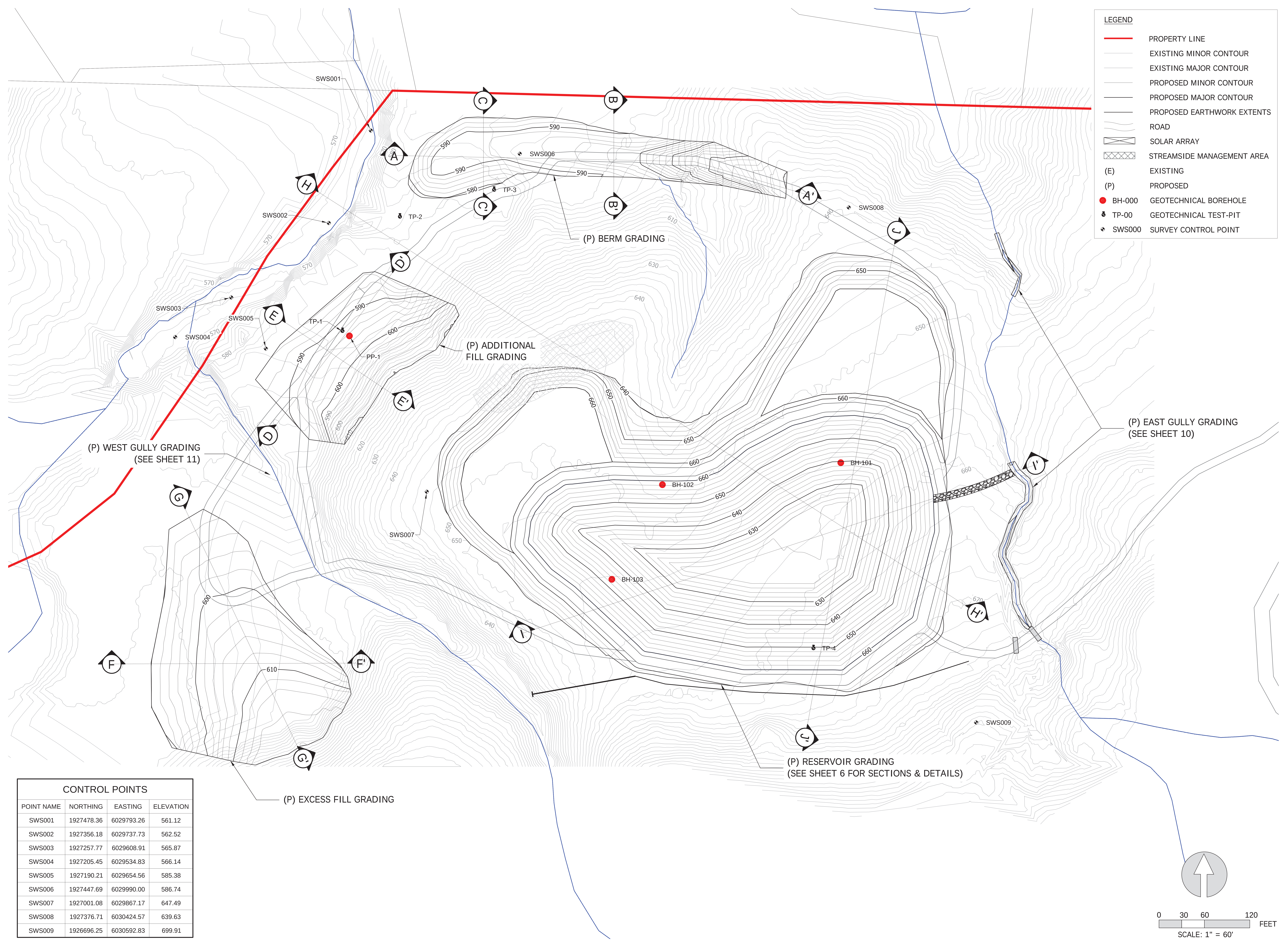

LEGEND

🟥	PROPERTY LINE
—	EXISTING MINOR CONTOUR
—	EXISTING MAJOR CONTOUR
—	PROPOSED MINOR CONTOUR
—	PROPOSED MAJOR CONTOUR
—	PROPOSED EARTHWORK EXTENTS
≈	ROAD
☒	SOLAR ARRAY
▨	STREAMSIDE MANAGEMENT AREA
(E)	EXISTING
(P)	PROPOSED
● BH-000	GEOTECHNICAL BOREHOLE
TP-00	GEOTECHNICAL TEST-PIT
⌖ SWS000	SURVEY CONTROL POINT

CONTROL POINTS

POINT NAME	NORTHING	EASTING	ELEVATION
SWS001	1927478.36	6029793.26	561.12
SWS002	1927356.18	6029737.73	562.52
SWS003	1927257.77	6029608.91	565.87
SWS004	1927205.45	6029534.83	566.14
SWS005	1927190.21	6029654.56	585.38
SWS006	1927447.69	6029990.00	586.74
SWS007	1927001.08	6029867.17	647.49
SWS008	1927376.71	6030424.57	639.63
SWS009	1926696.25	6030592.83	699.91

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GRADING PLAN

SHEET 5 OF 30

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PLOT DATE: 9/9/2019
LAST SAVED: 9/8/2019

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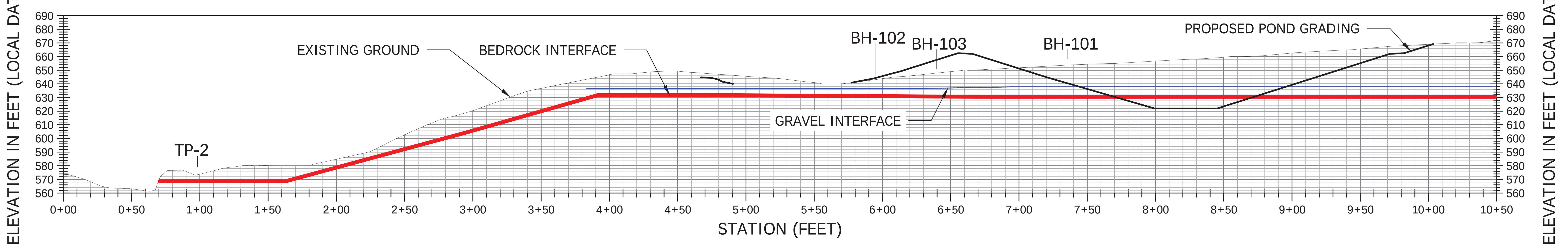
RESERVOIR SECTION H-H'



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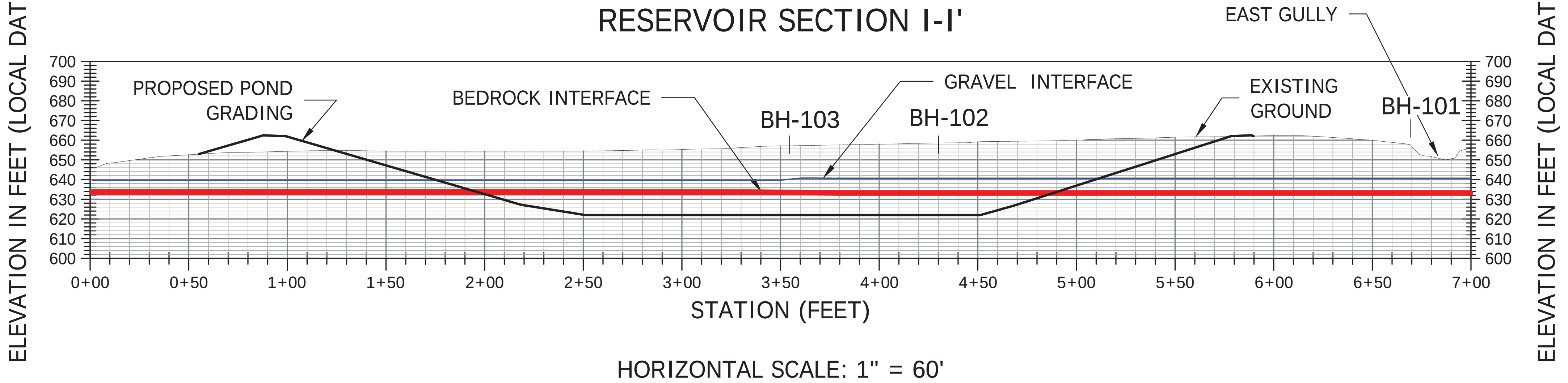
VERTICAL SCALE: 1" = 60'

RESERVOIR SECTION I-I'



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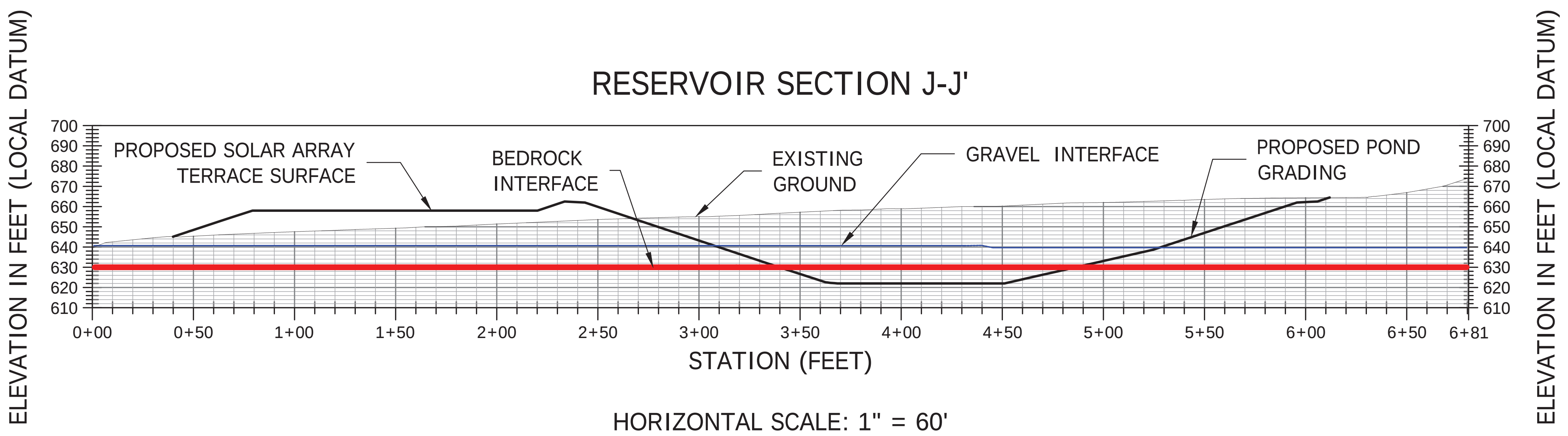
RESERVOIR SECTION J-J'



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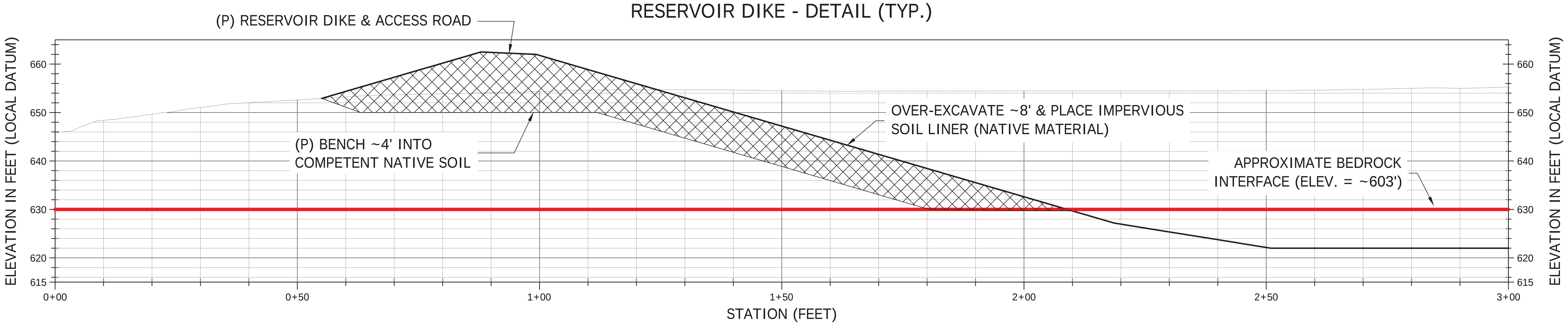
VERTICAL SCALE: 1" = 60'

RESERVOIR DIKE - DETAIL (TYP.)



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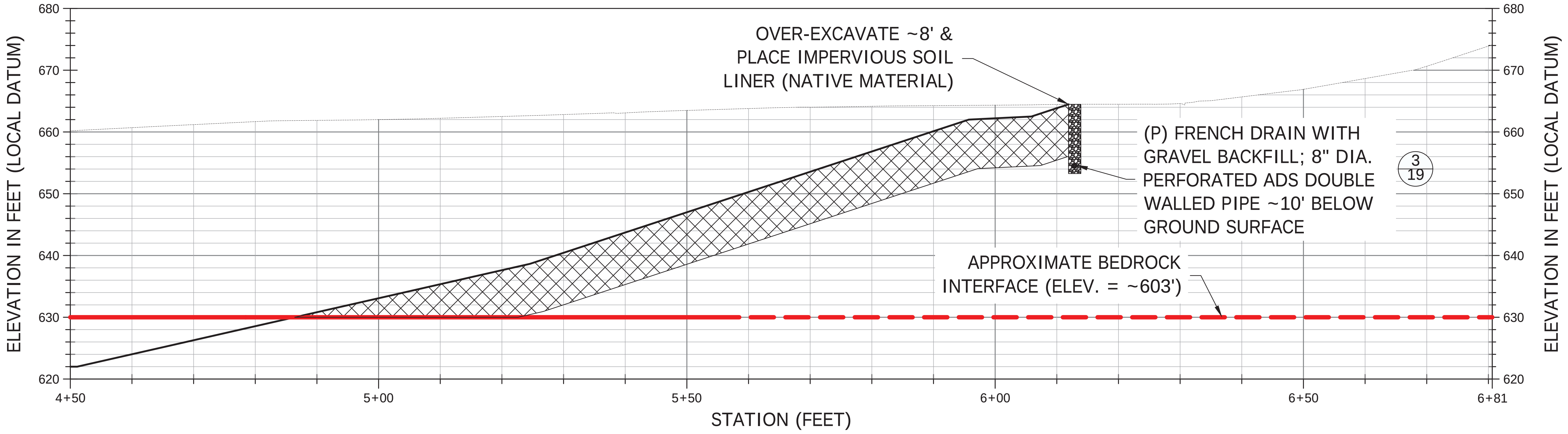
CUT SLOPE & FRENCH DRAIN - DETAIL (TYP.)



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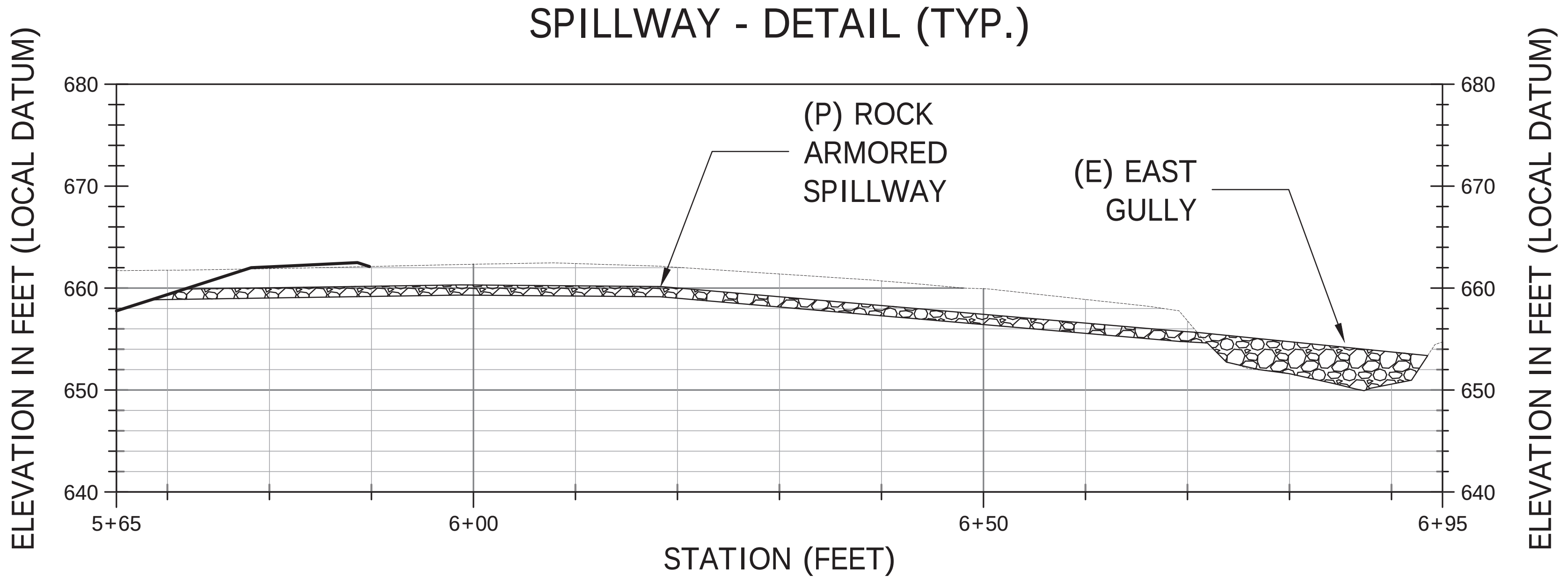
VERTICAL SCALE: 1" = 15'

SPILLWAY - DETAIL (TYP.)



HORIZONTAL SCALE: 1" = 15'
VERTICAL SCALE: 1" = 15'

LEGEND

EXISTING GROUND SURFACE
PROPOSED GROUND SURFACE

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RESERVOIR SECTIONS & DETAILS

SHEET 6 OF 30

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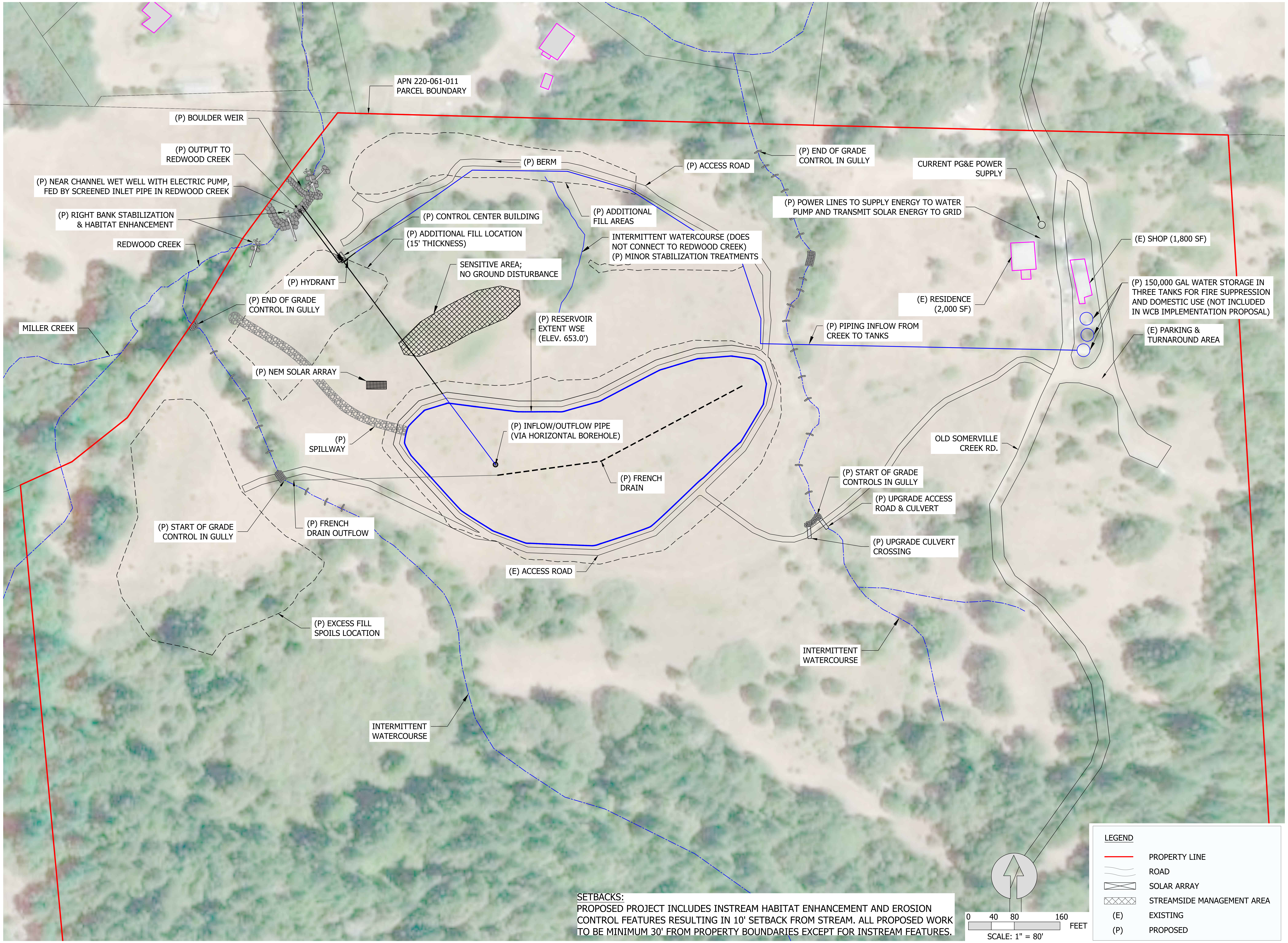
Appendix A.2

Excerpts from 90% Design Plans (September 2020)



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SITE PLAN

SHEET 3 OF 22

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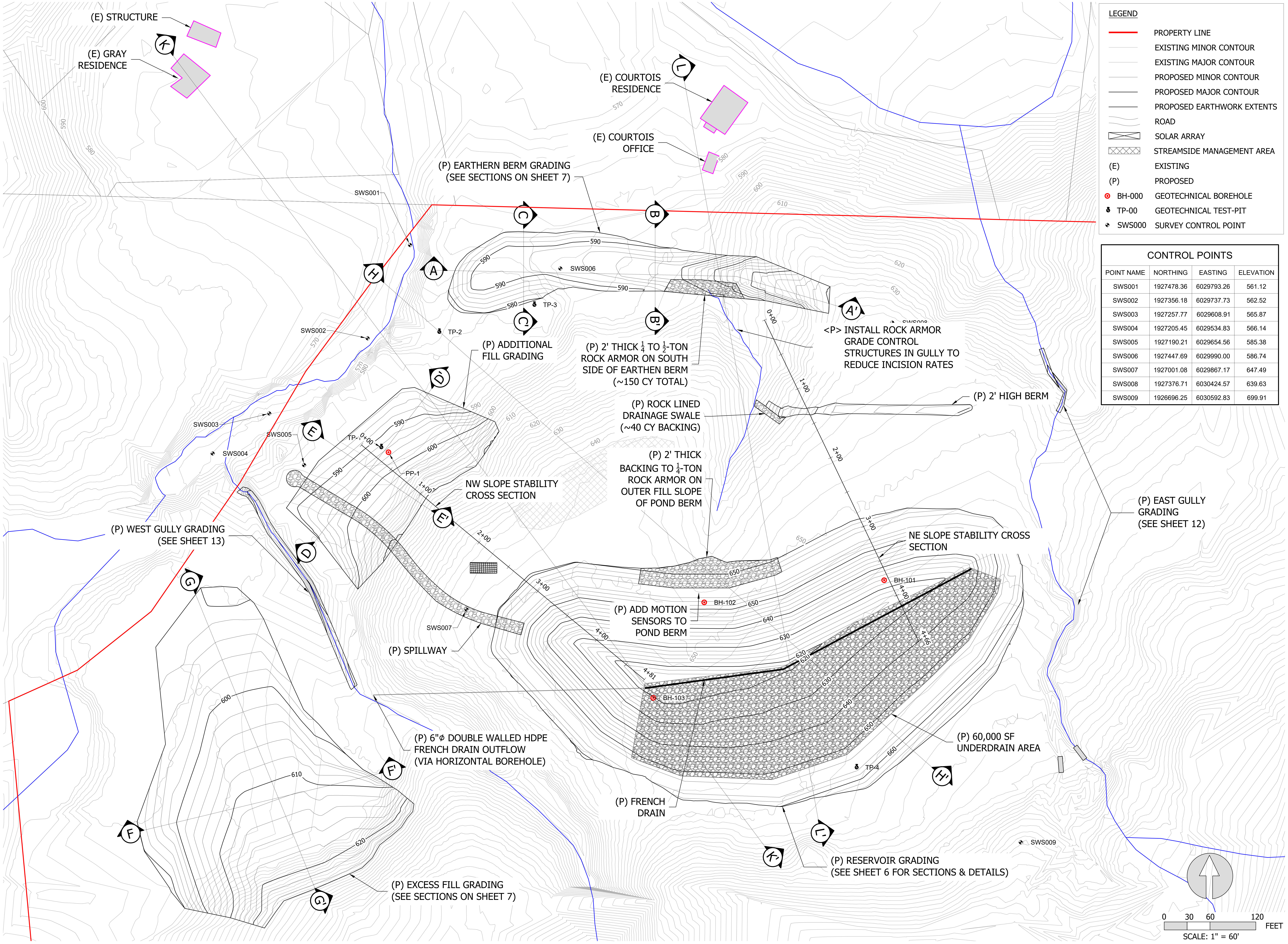

LEGEND

—	PROPERTY LINE
—	EXISTING MINOR CONTOUR
—	EXISTING MAJOR CONTOUR
—	PROPOSED MINOR CONTOUR
—	PROPOSED MAJOR CONTOUR
—	PROPOSED EARTHWORK EXTENTS
≈	ROAD
⊠	SOLAR ARRAY
▨	STREAMSIDE MANAGEMENT AREA
(E)	EXISTING
(P)	PROPOSED
◎ BH-000	GEOTECHNICAL BOREHOLE
● TP-00	GEOTECHNICAL TEST-PIT
⊕ SWS000	SURVEY CONTROL POINT

CONTROL POINTS

POINT NAME	NORTHING	EASTING	ELEVATION
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SWS002	1927356.18	6029737.73	562.52
SWS003	1927257.77	6029608.91	565.87
SWS004	1927205.45	6029534.83	566.14
SWS005	1927190.21	6029654.56	585.38
SWS006	1927447.69	6029990.00	586.74
SWS007	1927001.08	6029867.17	647.49
SWS008	1927376.71	6030424.57	639.63
SWS009	1926696.25	6030592.83	699.91

MARSHALL RANCH FLOW ENHANCEMENT PROJECT

APN 220-061-011

HUMBOLDT COUNTY, CA

Stillwater Sciences
2855 TELEGRAPH AVENUE, SUITE 400
BERKELEY, CA 94705
P: (510) 848-8098

PROJECT NUMBER: 603.01
SCALE: AS NOTED
DATE: 8/2/2020

DESIGN: JM
DRAWN: CL
CHECKED: JM
APPROVED: JM

JOEL MONSCHKE
No. 79688
9-30-20
EXPIRES

GRADING PLAN

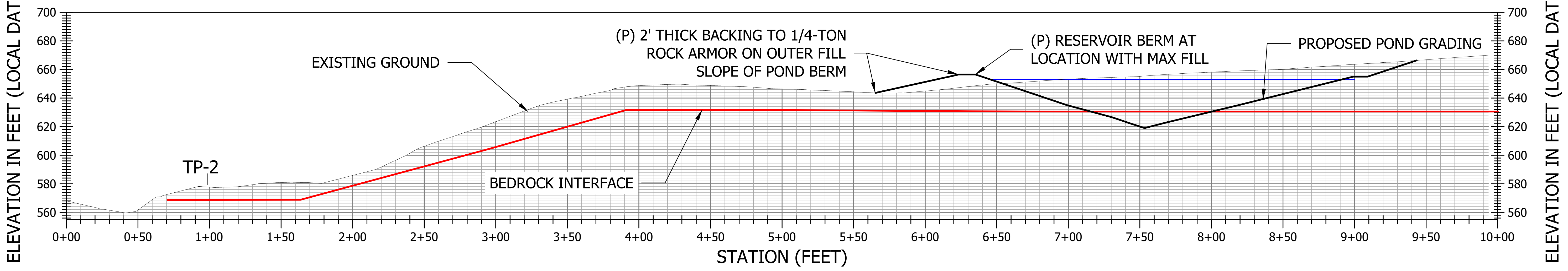
SHEET 5 OF 22

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE – ADJUST ACCORDINGLY

LAST SAVED: 9/30/2020 PLOT DATE: 9/30/2020 PLOT STYLE: ----

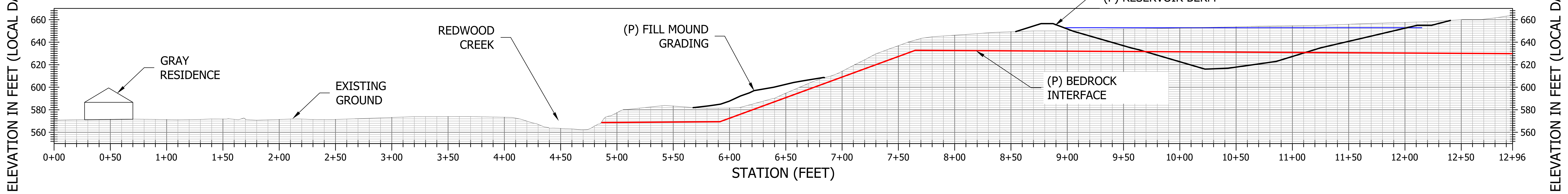
Z:\DATA\603.01_MARSHALLRANCH\ACAD\2_MODEL\603.00_REDWOOD_RECHARGE_RESERVOIR.DWG

RESERVOIR SECTION H-H'



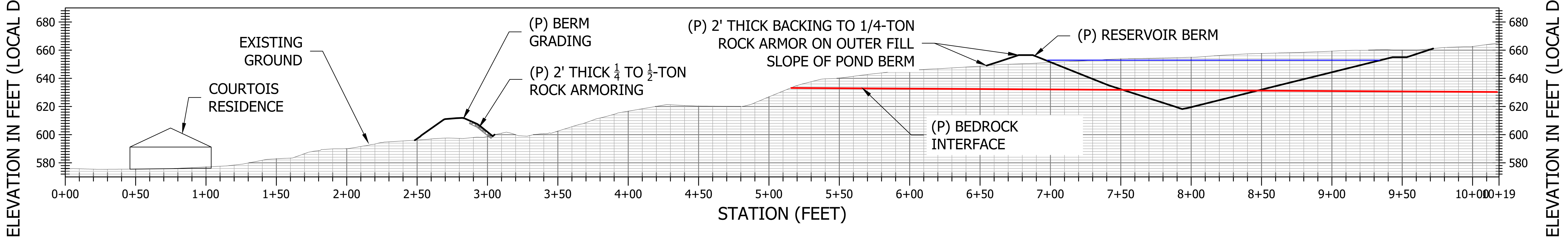
HORIZONTAL SCALE: 1" = 60'
VERTICAL SCALE: 1" = 60'

SECTION K-K'



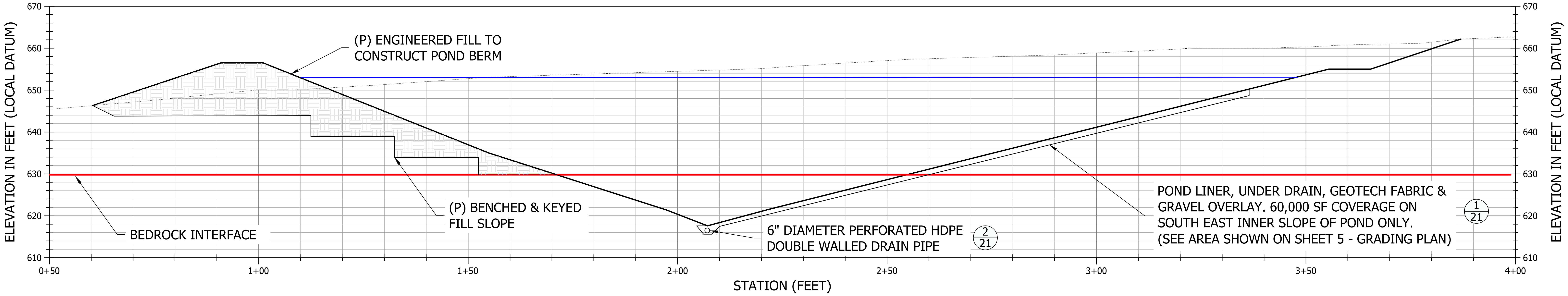
HORIZONTAL SCALE: 1" = 60'
VERTICAL SCALE: 1" = 60'

SECTION L-L'



HORIZONTAL SCALE: 1" = 60'
VERTICAL SCALE: 1" = 60'

FRENCH DRAIN AND SUBSURFACE RESTRICTIVE BARRIER DETAIL (TYP.)



HORIZONTAL SCALE: 1" = 15'
VERTICAL SCALE: 1" = 15'

LEGEND

─ (light)	EXISTING GROUND SURFACE
─ (bold)	PROPOSED GROUND SURFACE

MARSHALL RANCH FLOW
ENHANCEMENT PROJECT
APN 220-061-011

HUMBOLDT COUNTY, CA

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APPROVED: JM

JOEL MONSCHKE
No. 79688
9-30-20
EXPIRES

RESERVOIR SECTIONS & DETAILS

SHEET 6 OF 22

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE - ADJUST ACCORDINGLY

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Z:\DATA\603.01_MARSHALLRANCH\ACAD\2_MODEL\603.00_REDWOOD_RECHARGE_RESERVOIR.DWG

Appendix A.3

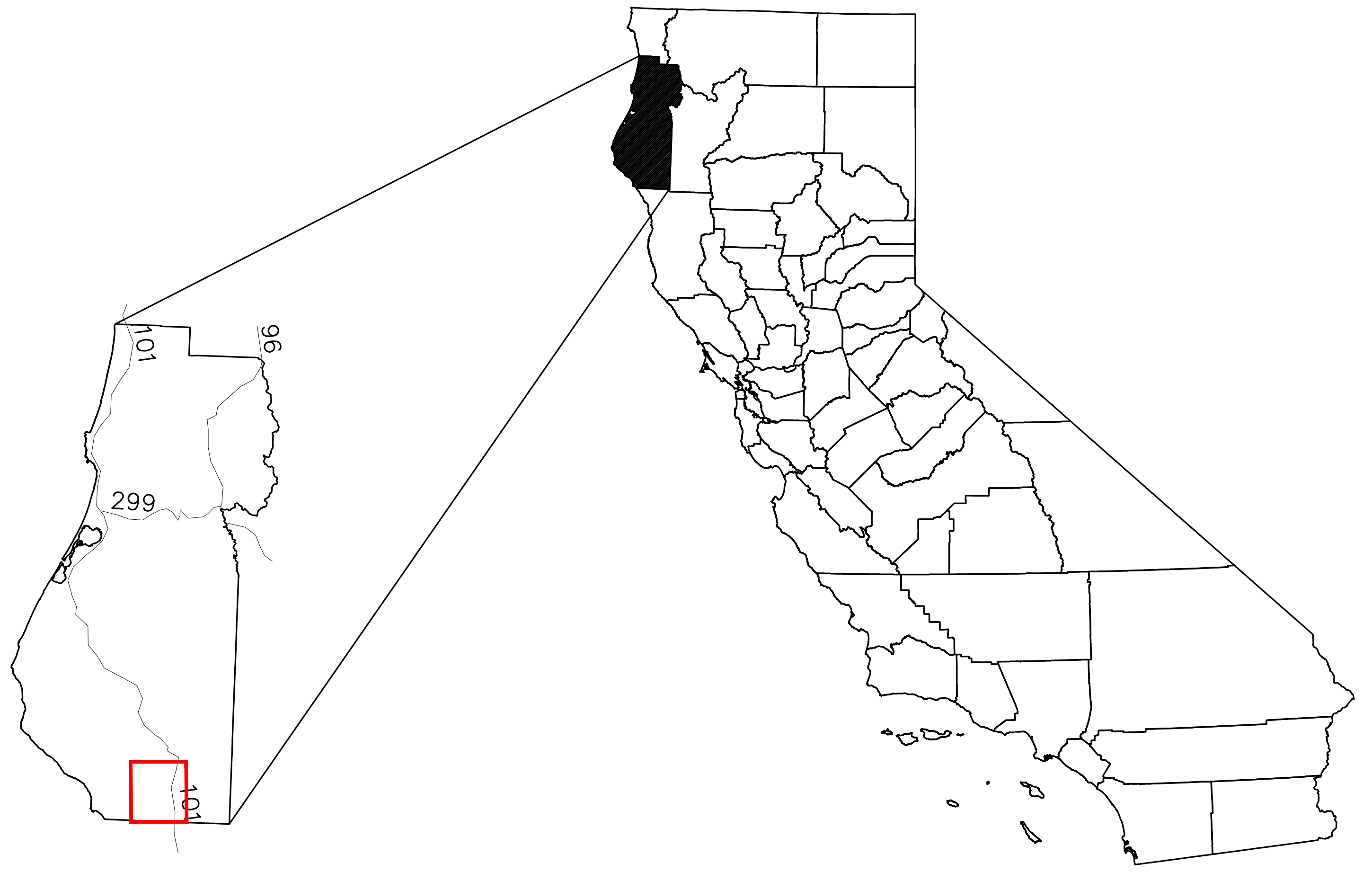
90% Design Plans (August 2021)

MARSHALL RANCH FLOW ENHANCEMENT PROJECT (APN 220-061-011)

90% DESIGN PLANS

BRICELAND, CA

CALIFORNIA LOCATION MAP



HUMBOLDT COUNTY MAP
NTS

CALIFORNIA MAP
NTS

OWNER:

THE MARSHALL RANCH, LLC
VELMA V. MARSHALL ESTATE
5720 OLD BRICELAND ROAD
GARBERVILLE, CA 95542

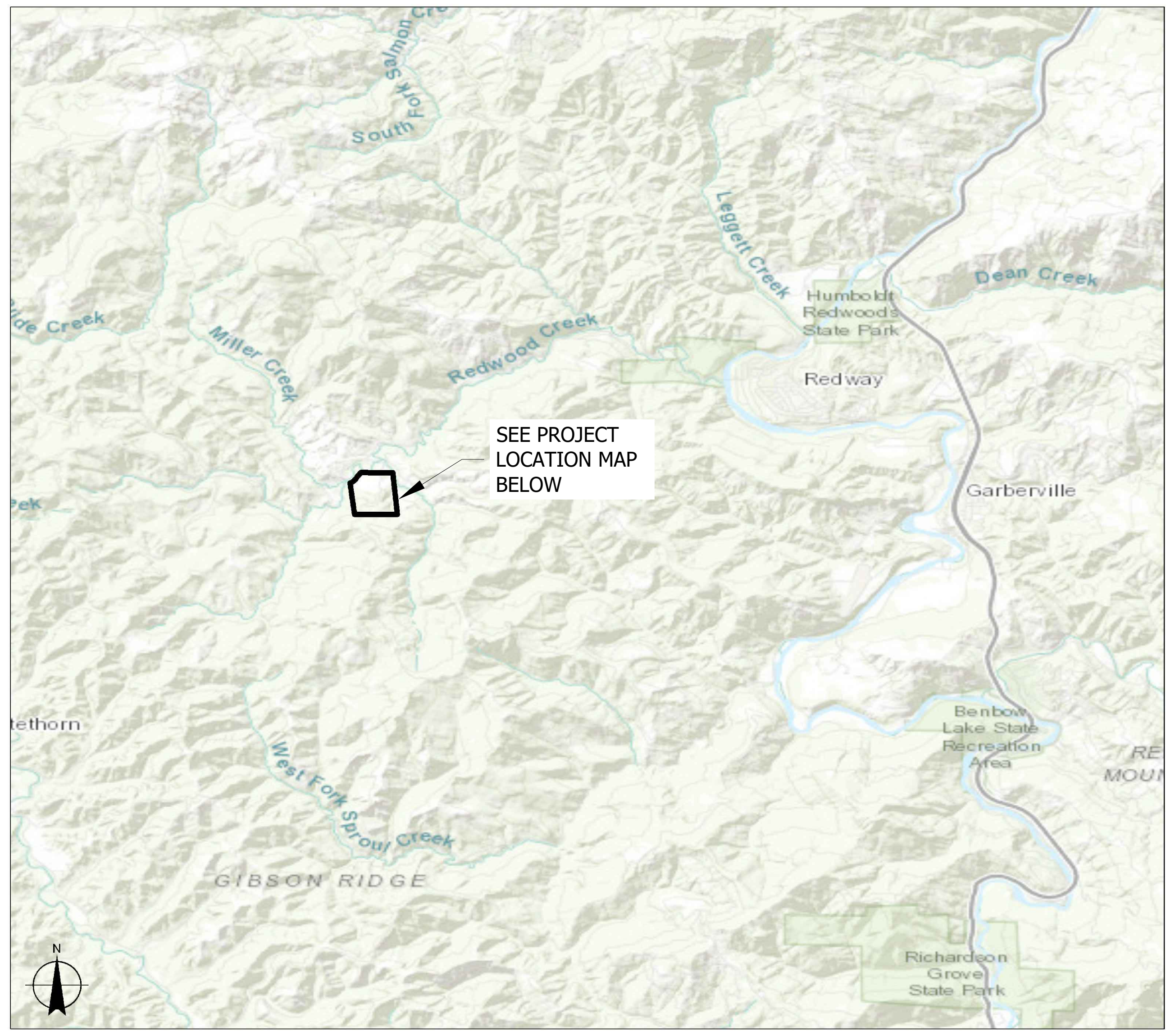
APPLICANT:

SALMONID RESTORATION FEDERATION
425 SNUG ALLEY, UNIT D
EUREKA, CA 95501
SRF@CALSALMON.ORG

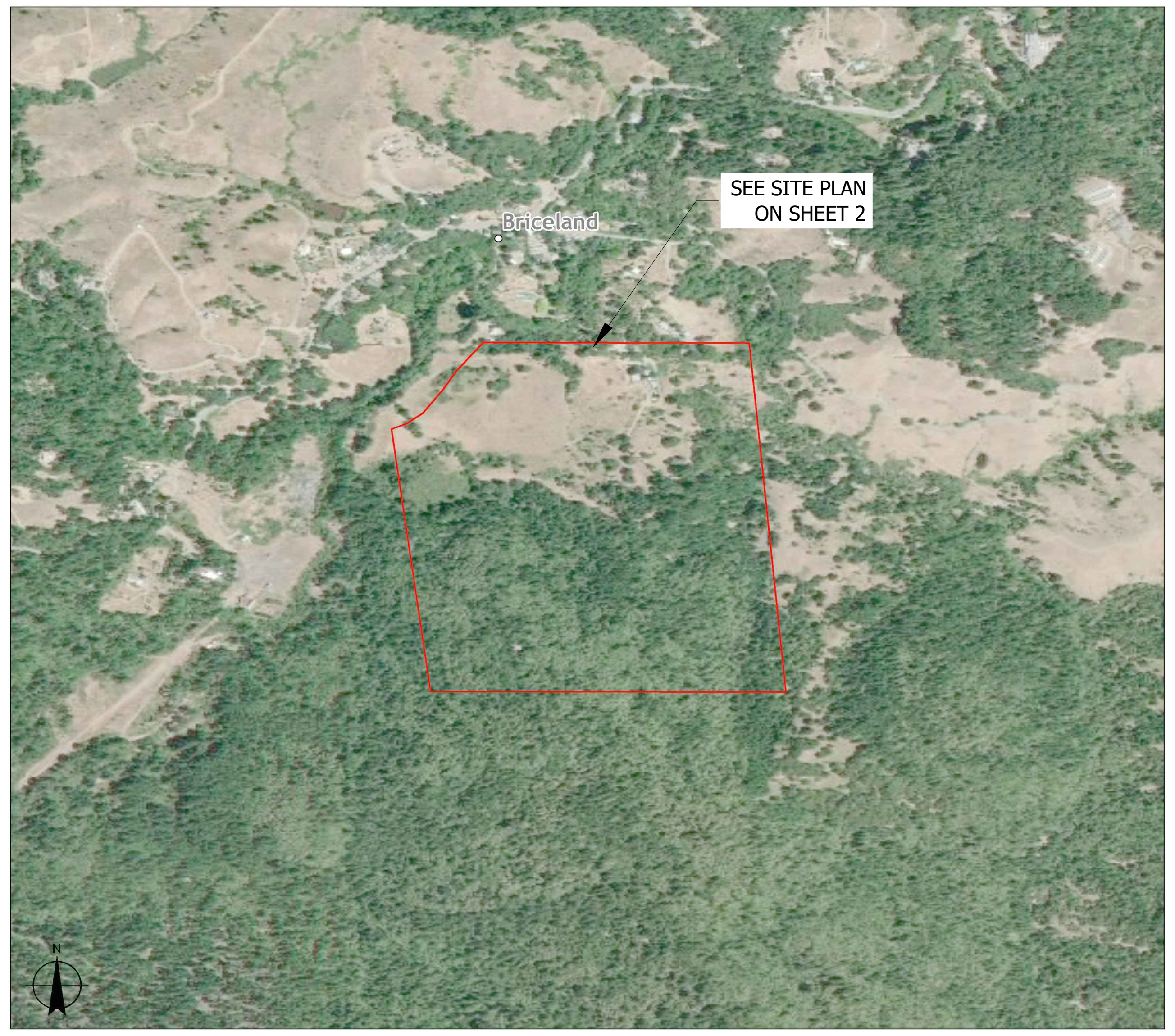
AGENT:

JOEL MONSCHKE PE
STILLWATER SCIENCES
850 G STREET, SUITE K
ARCATA, CA 95521
707-496-7075
JMONSCHKE@STILLWATERSCI.COM

VICINITY MAP



PROJECT LOCATION MAP



SHEET LIST TABLE

SHEET NUMBER	SHEET TITLE
1	TITLE SHEET
2	OVERVIEW
3	SITE PLAN
4	SITE PROTECTION STAGING AND TEMPORARY ACCESS
5	GRADING PLAN
6	RESERVOIR SECTIONS AND DETAILS
7	SPILLWAY PLAN AND PROFILE
8	REDWOOD CREEK-DEWATERING
9	REDWOOD CREEK-INSTREAM COMPONENTS
10	WEST GULLY PLAN & PROFILE
11	PERMANENT ACCESS ROAD PLAN
12	ELECTRICAL PLAN
13	WATER INFRASTRUCTURE PLAN
14	FENCING PLAN
15	MONITORING AND INSTRUMENTATION PLAN
16	EROSION CONTROL & REVEGETATION
17	DETAILS - 1
18	DETAILS - 2
19	DETAILS - 3

PROJECT DESCRIPTION:

THE PRIMARY OBJECTIVE OF THIS PROJECT IS CONSTRUCTION OF 10 MILLION GALLONS OF OFF-CHANNEL WATER STORAGE AND ASSOCIATED PLUMBING INFRASTRUCTURE DESIGNED TO DELIVER APPROXIMATELY 30 GALLONS PER MINUTE OF FLOW AUGMENTATION TO REDWOOD CREEK DURING THE 5-MONTH DRY SEASON TO IMPROVE INSTREAM AQUATIC HABITAT. STORAGE WILL BE IN TWO PONDS AND FIVE TANKS FILLED WITH WET-SEASON RUNOFF INCLUDING RAINWATER CATCHMENT AND WATER DIVERTED FROM TWO SMALL REDWOOD CREEK TRIBUTARIES. OTHER ANCILLARY PROJECT COMPONENTS INCLUDE:

- INSTALLATION OF A LARGE WOOD HABITAT ENHANCEMENT AND BANK STABILIZATION STRUCTURE IN REDWOOD CREEK.
- STABILIZATION OF ONE DEEPLY INCISED TRIBUTARY WITH APPROXIMATELY 10 ROCK ARMOR GRADE CONTROL STRUCTURES AND REGRADING.
- CONSTRUCTION OF A PASSIVE “COOLING AND FILTRATION GALLERY” IN THE EXISTING GULLY TO DETERMINE THE VIABILITY OF THIS INNOVATIVE APPROACH TO ADDRESS WATER QUALITY AND TEMPERATURE ISSUES ASSOCIATED WITH THE FLOW RELEASES FROM THE POND.
- CONSTRUCTION OF A SOLAR POWER SYSTEM INCLUDING A 1 KW SOLAR ARRAY, BATTERY BANK, INVERTER, INTERNET CONNECTION, AND SMALL CONTROL CENTER BUILDING TO SUPPORT OPERATIONS AND MONITORING CAPABILITIES.
- UPGRADING ACCESS ROADS WITHIN THE PROJECT AREA INCLUDING THREE ROAD/STREAM CROSSING UPGRADES AND GRAVEL SURFACING TO PROVIDE YEAR-ROUND ACCESS.
- INSTALLATION OF PLUMBING INFRASTRUCTURE TO ALLOW FOR A PORTION OF THE WATER STORED IN THE TANKS TO BE UTILIZED FOR DOMESTIC, RANCH, AND FIRE SUPPRESSION NEEDS INCLUDING TWO FIRE HYDRANTS.

ADDITIONAL NOTES:

1. NORTH AND WEST PARCEL BOUNDARIES FROM 2021 SURVEY. NORTHWEST BOUNDARY IS THE CENTERLINE OF REDWOOD CREEK AND IS DRAWN BASED ON 2018 USGS LIDAR. SOUTH AND EAST PARCEL BOUNDARIES TAKEN FROM HUMBOLDT COUNTY GIS AND MODIFIED BASED ON NORTH AND WEST BOUNDARIES, APPROXIMATE ONLY.

EARTHWORK ESTIMATES:

35,630 CY CUT/CY FILL BALANCED ON SITE

IMPORT:
  INSTREAM FEATURES & GULLY REPAIR - 100 CY RIPRAP ROCK (BACKING TO 4 TON)
  POND SPILLWAYS - 100 CY (BACKING TO $\frac{1}{4}$ TON)
  FRENCH DRAIN - 50 CY DRAIN ROCK
  ROAD SURFACING - 530 CY GRAVEL
  LARGE WOOD - 8 PIECES

ABBREVIATIONS AND SYMBOLS:

(E)	EXISTING
(P)	PROPOSED

$\frac{3}{8}$ — DETAIL # ON SHEET / SHEET #

MARSHALL RANCH FLOW
ENHANCEMENT PROJECT

BRICELAND, CA

Stillwater Sciences
850 G STREET SUITE K
ARCATA, CA 95521
P: (707) 822-9607

REGISTERED PROFESSIONAL ENGINEER
JOEL MONSCHKE
C 79688
EXP. 9/22
CIVIL
STATE OF CALIFORNIA

PROJECT NUMBER: 603.04
SCALE: AS NOTED
DATE: 7/30/2021

DESIGN: JM
DRAWN: CL,TC
CHECKED: JM
APPROVED: JM

JOEL MONSCHKE
No. 79688
9-30-22
EXPIRES
CIVIL

TITLE SHEET

SHEET 1 OF 19

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE - ADJUST ACCORDINGLY

LAST SAVED: 8/4/2021 PLOT DATE: 8/13/2021 PLOT STYLE: ----

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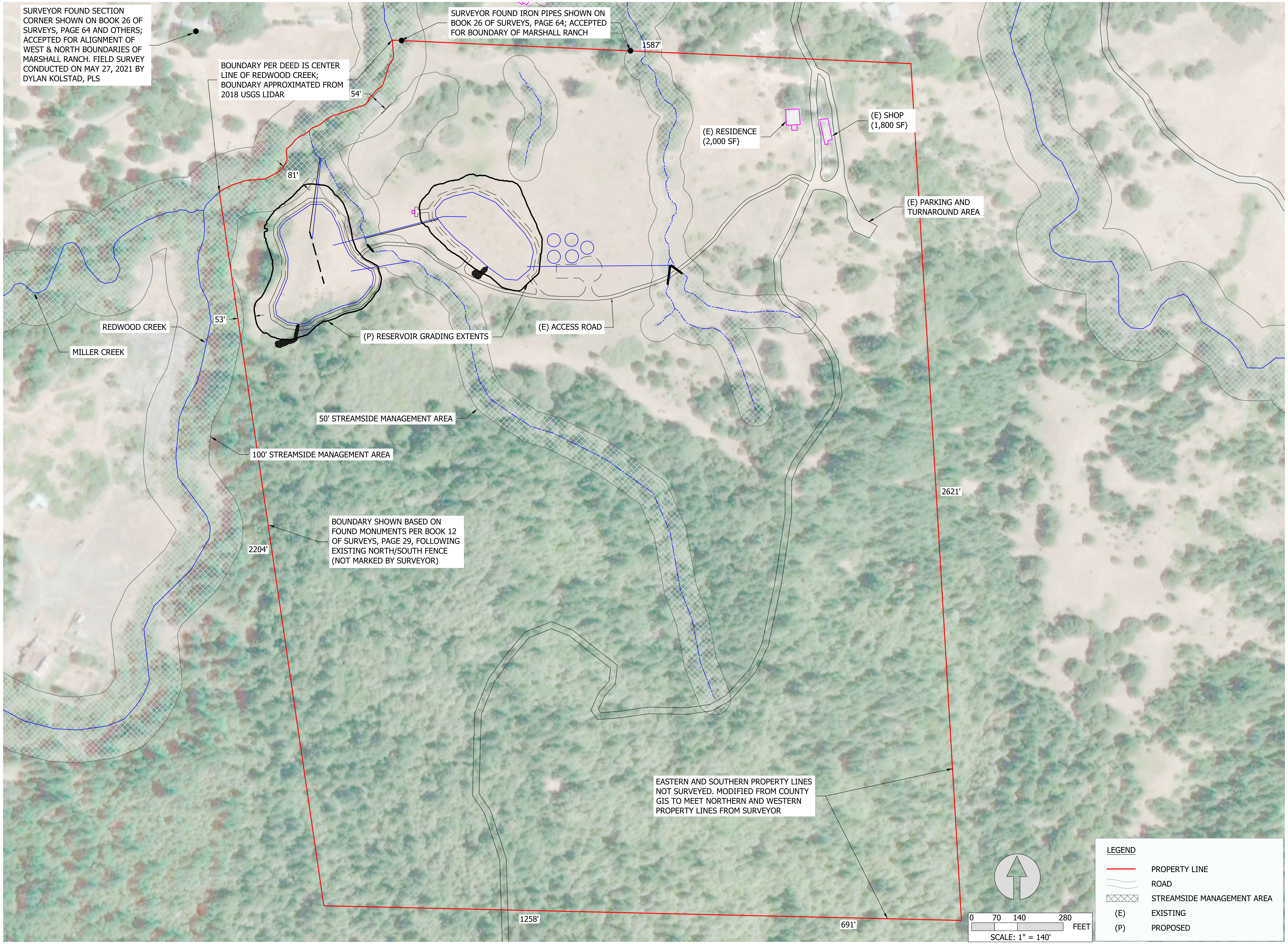

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APPROVED: JM

No. 79688
9-30-22

OVERVIEW

SHEET 2 OF 19

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE – ADJUST ACCORDINGLY

LAST SAVED: 8/13/2021 PLOT DATE: 8/13/2021 PLOT STYLE: ----

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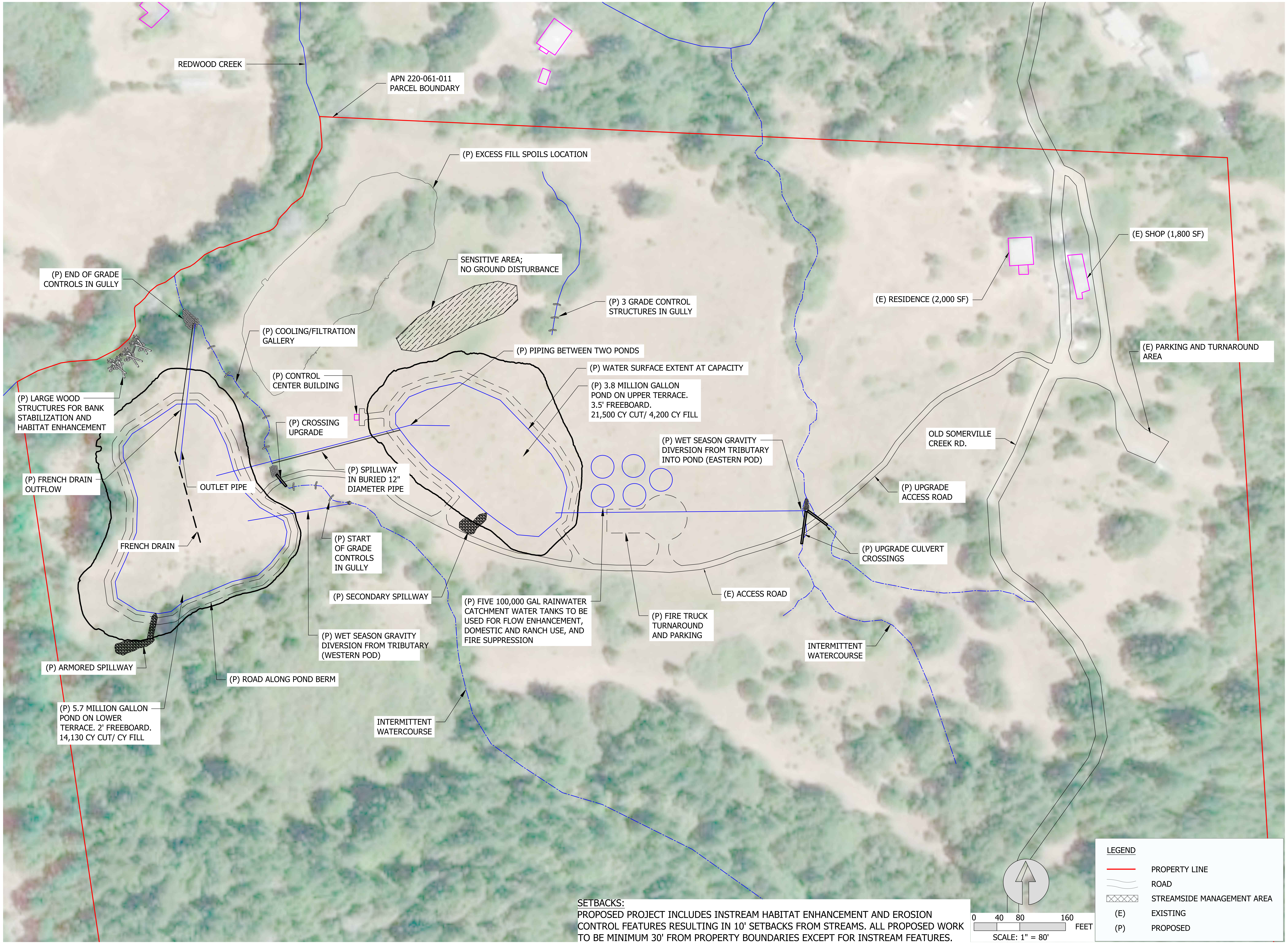

SETBACKS:
PROPOSED PROJECT INCLUDES INSTREAM HABITAT ENHANCEMENT AND EROSION CONTROL FEATURES RESULTING IN 10' SETBACKS FROM STREAMS. ALL PROPOSED WORK TO BE MINIMUM 30' FROM PROPERTY BOUNDARIES EXCEPT FOR INSTREAM FEATURES.

LEGEND

🟥	PROPERTY LINE
〰	ROAD
▨	STREAMSIDE MANAGEMENT AREA
(E)	EXISTING
(P)	PROPOSED

MARSHALL RANCH FLOW ENHANCEMENT PROJECT

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9-30-22
EXPIRES

SITE PLAN

SHEET 3 OF 19

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE - ADJUST ACCORDINGLY

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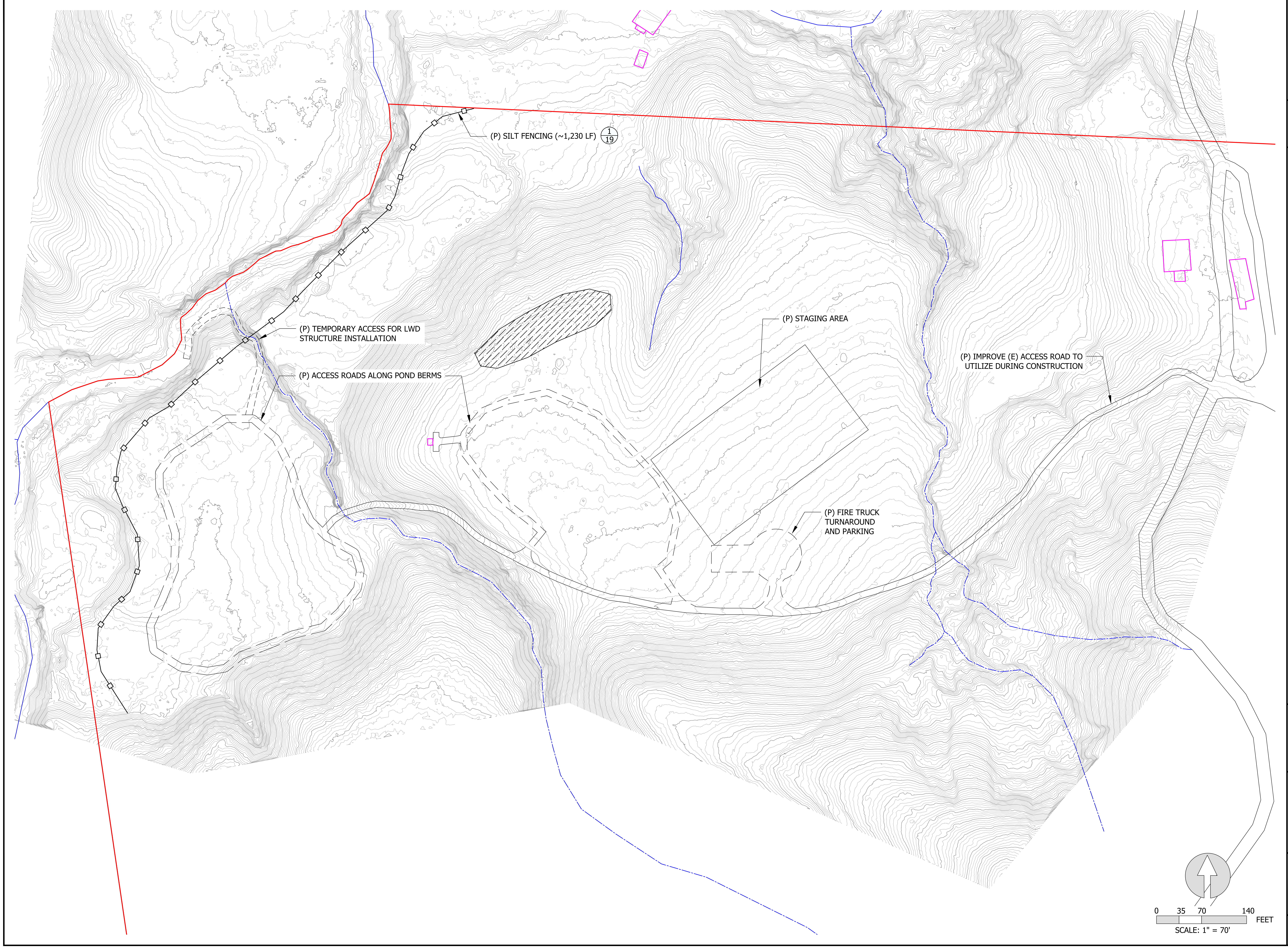

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No. 79688
9-30-22
EXPIRES

SITE PROTECTION STAGING AND TEMPORARY ACCESS

SHEET 4 OF 19

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE – ADJUST ACCORDINGLY

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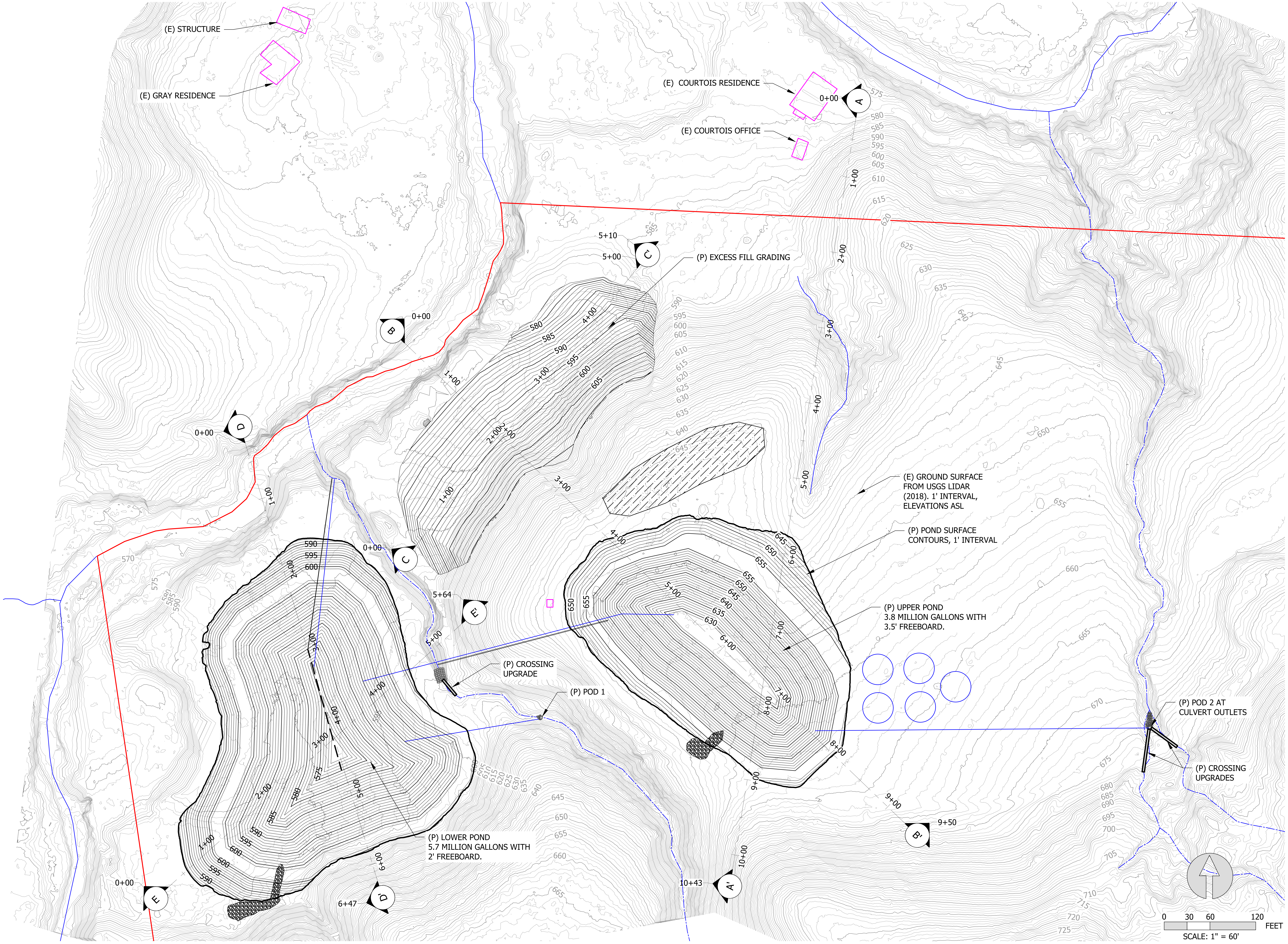

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No. 79688
9-30-22
EXPIRES

GRADING PLAN

SHEET 5 OF 19

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE – ADJUST ACCORDINGLY

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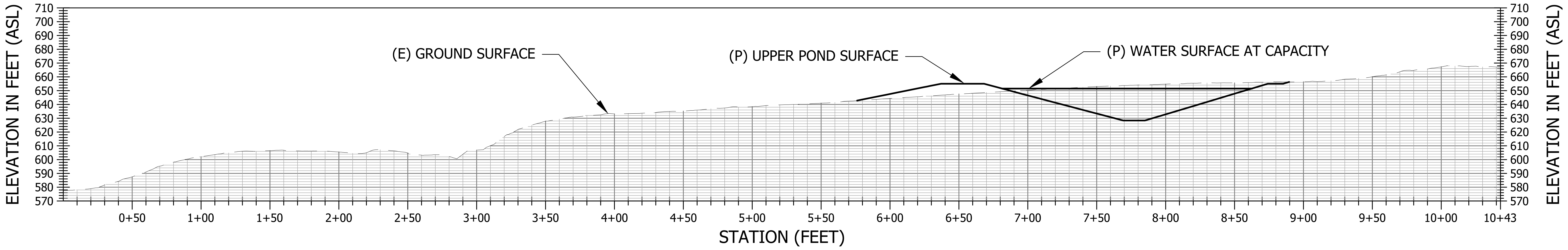
SECTION A-A'



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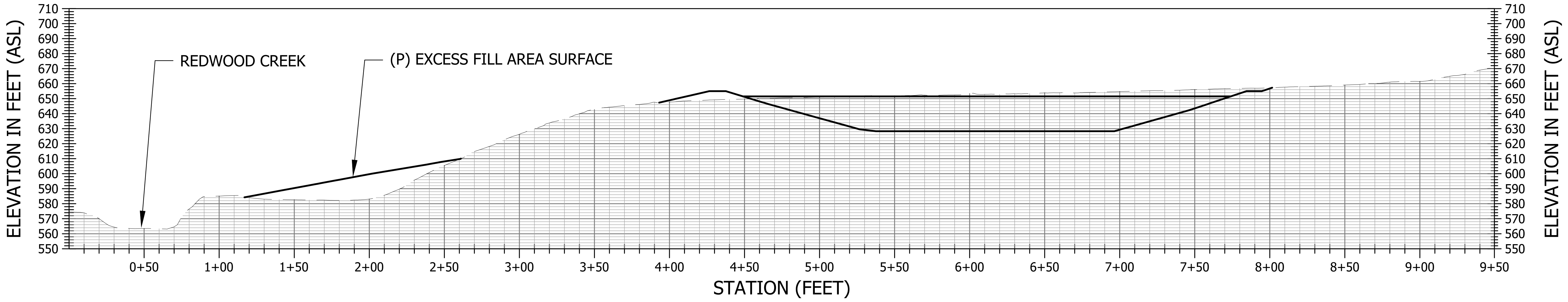
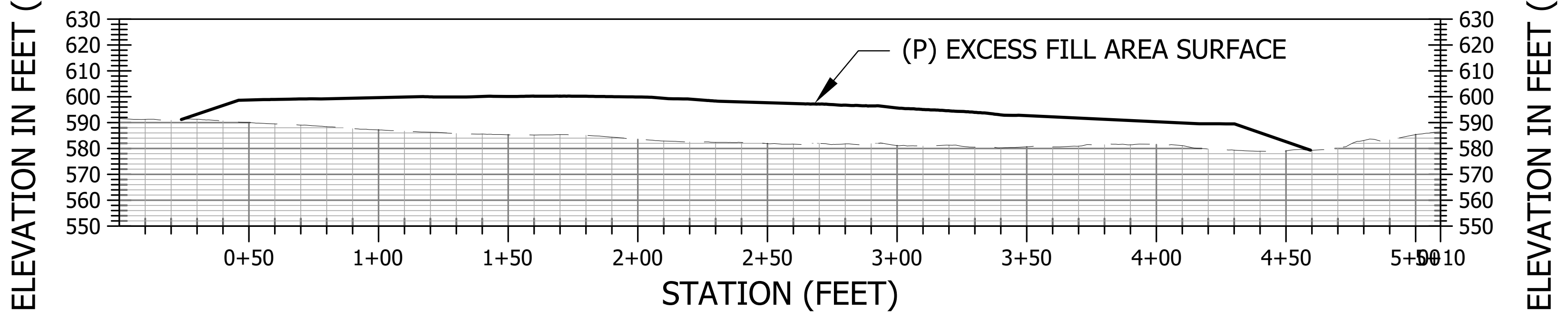
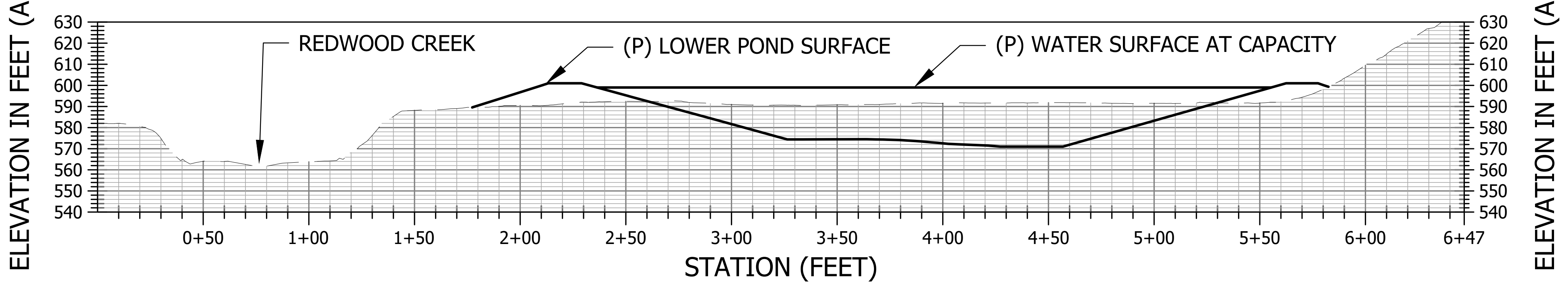


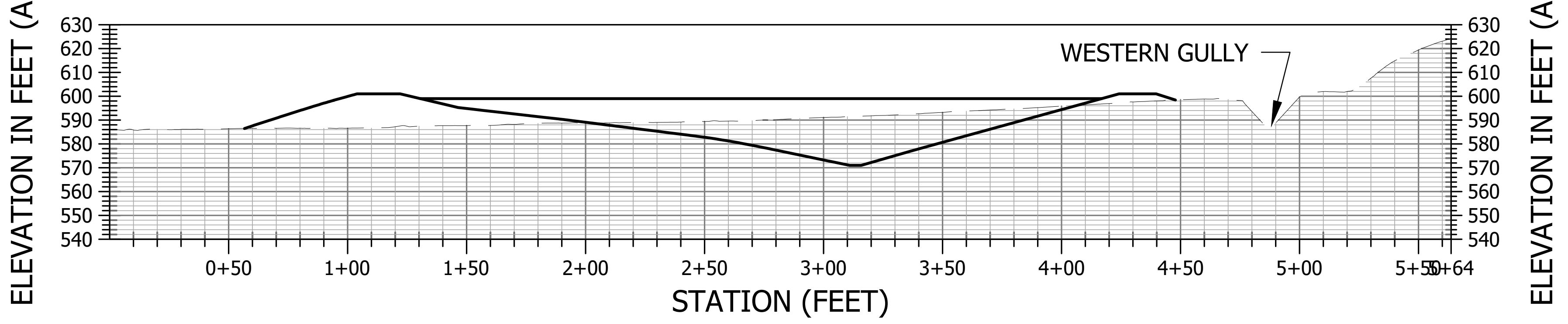
SECTION C-C'



SECTION D-D'



SECTION E-E'



0 30 60 120
FEET
SCALE: 1" = 60'

MARSHALL RANCH FLOW ENHANCEMENT PROJECT

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Stillwater Sciences
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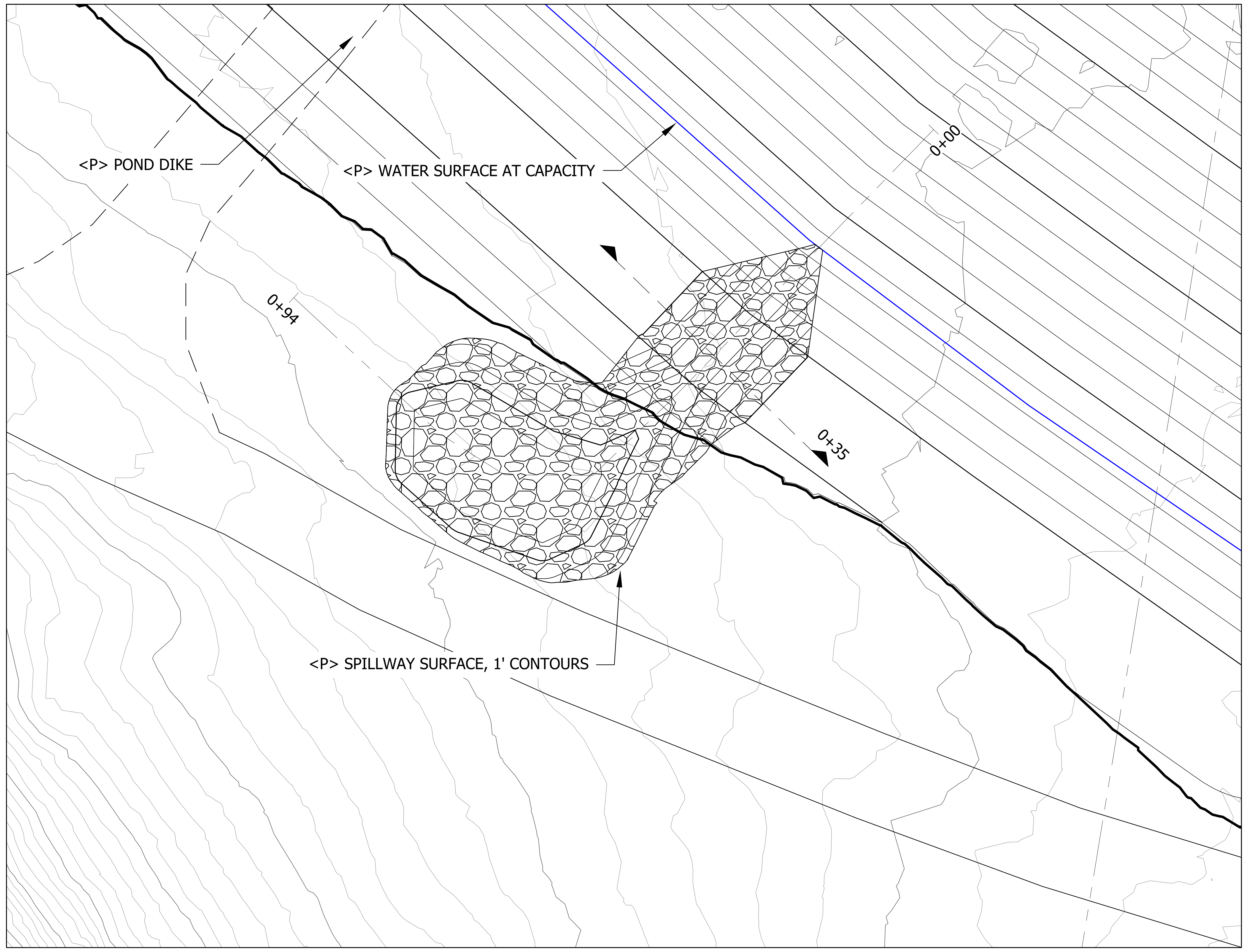
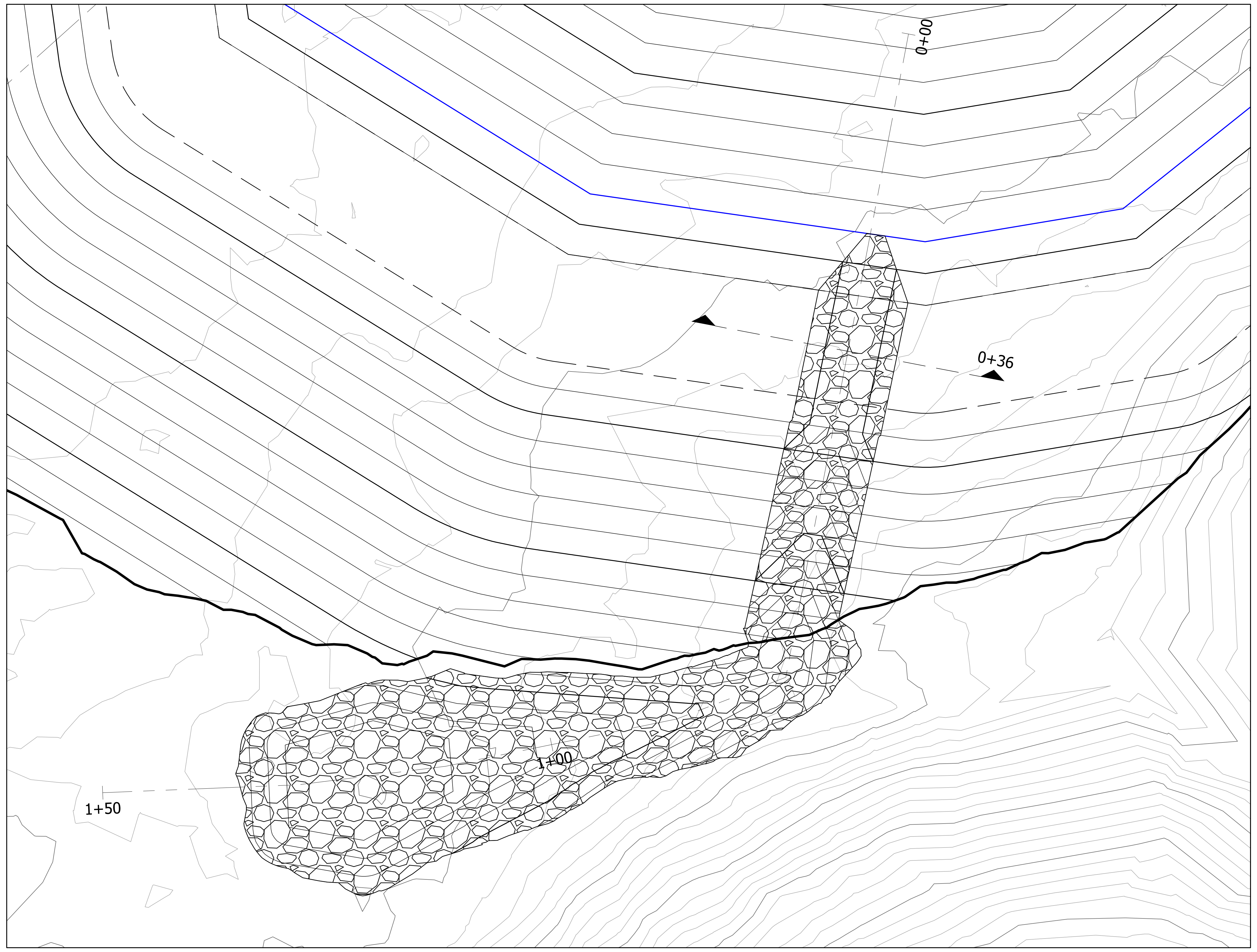
No. 79688
9-30-22

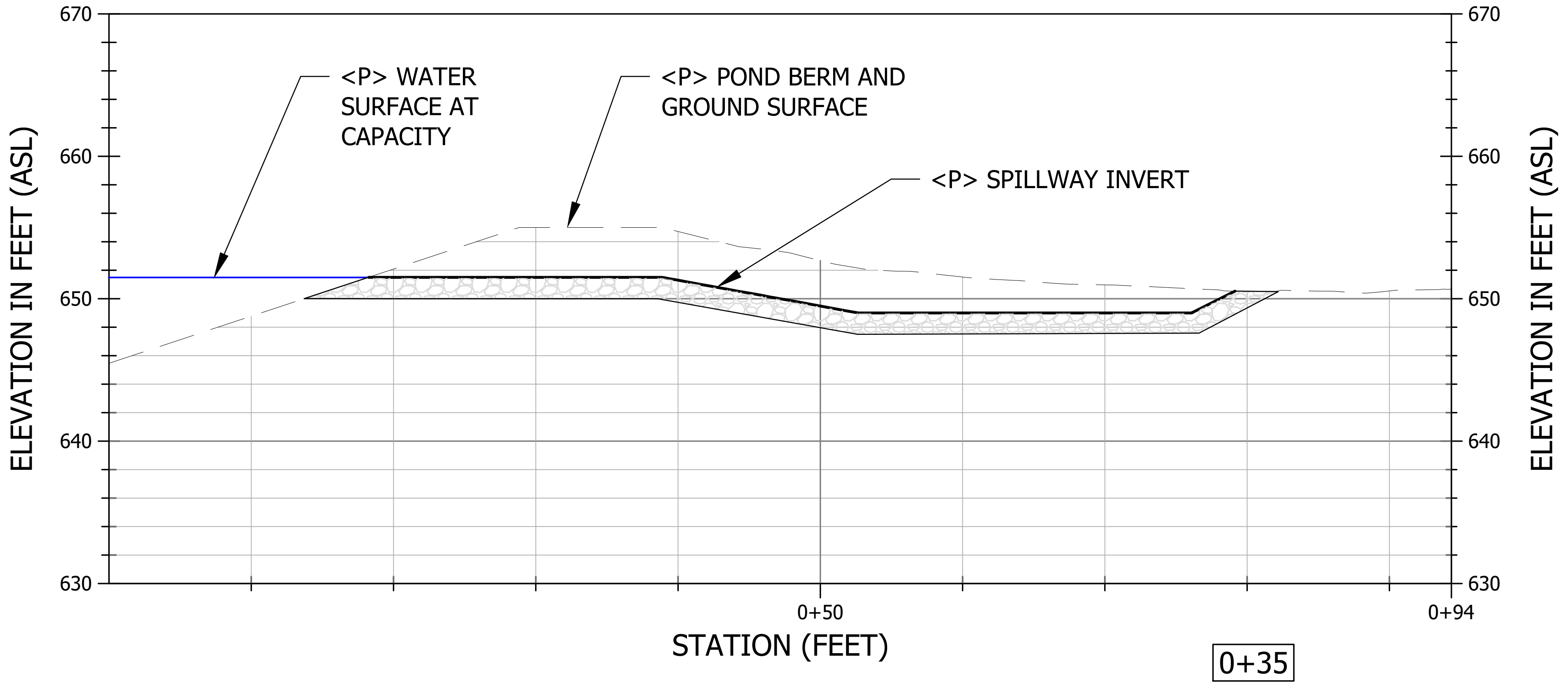
RESERVOIR SECTIONS AND DETAILS

SHEET 6 OF 19

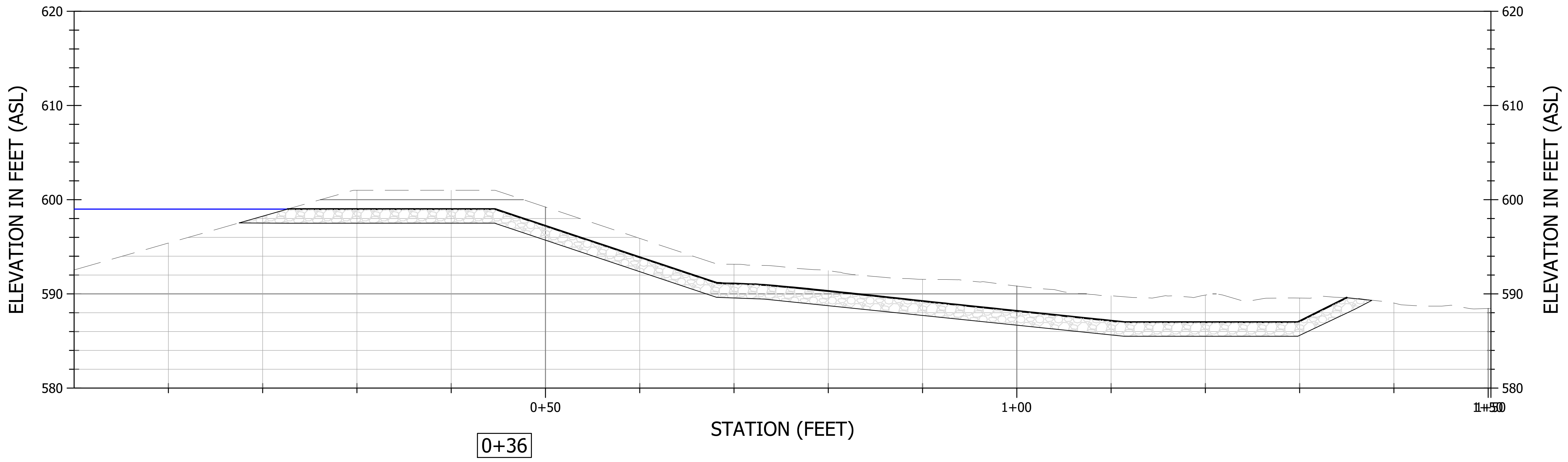


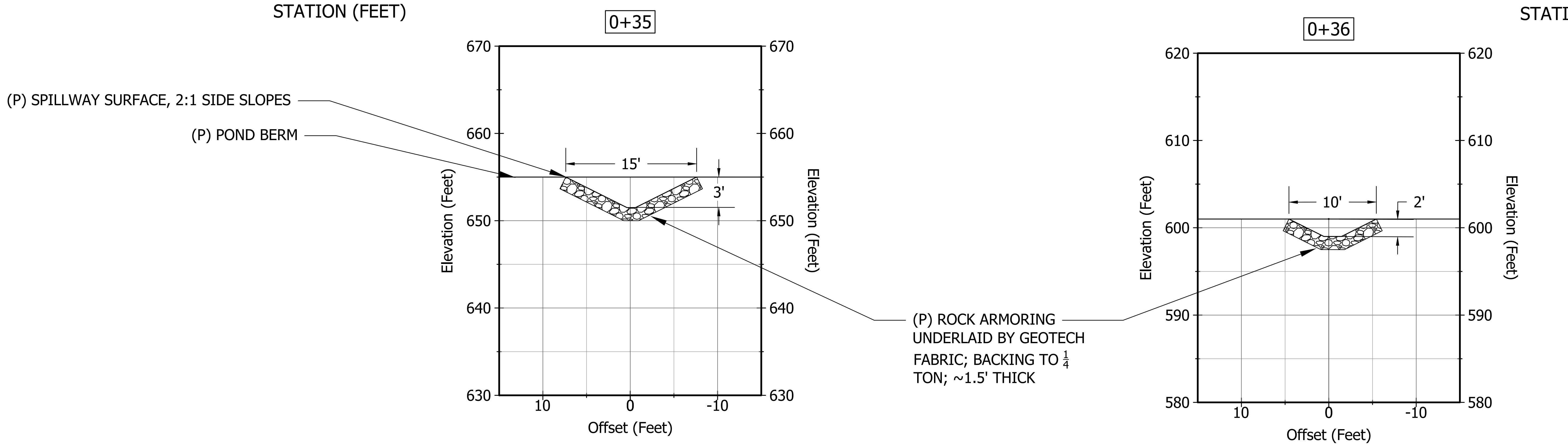


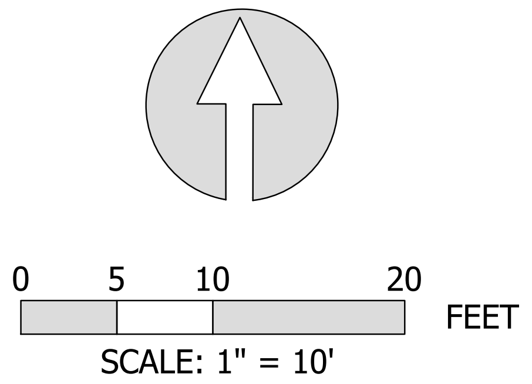
UPPER POND SPILLWAY



LOWER POND SPILLWAY







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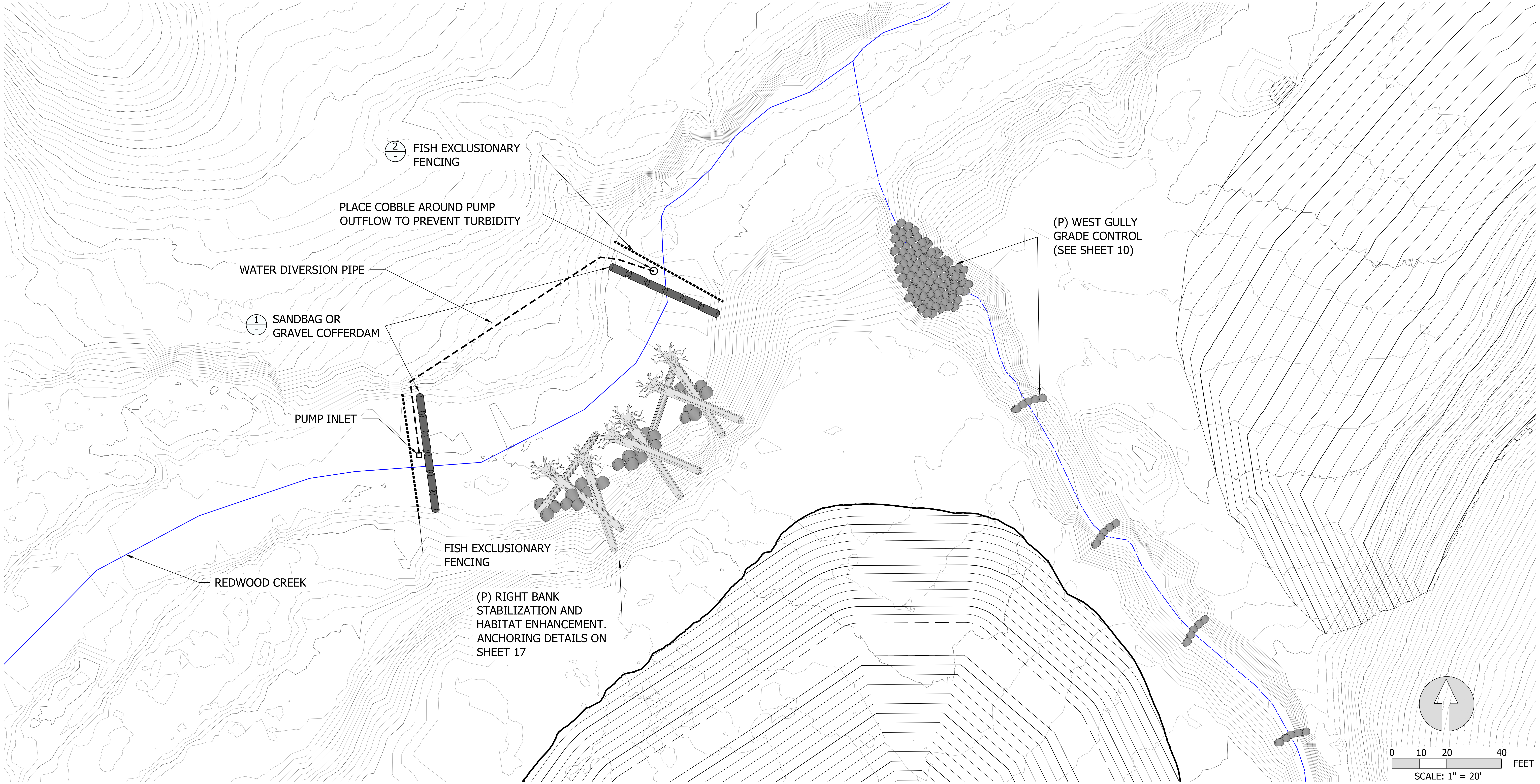
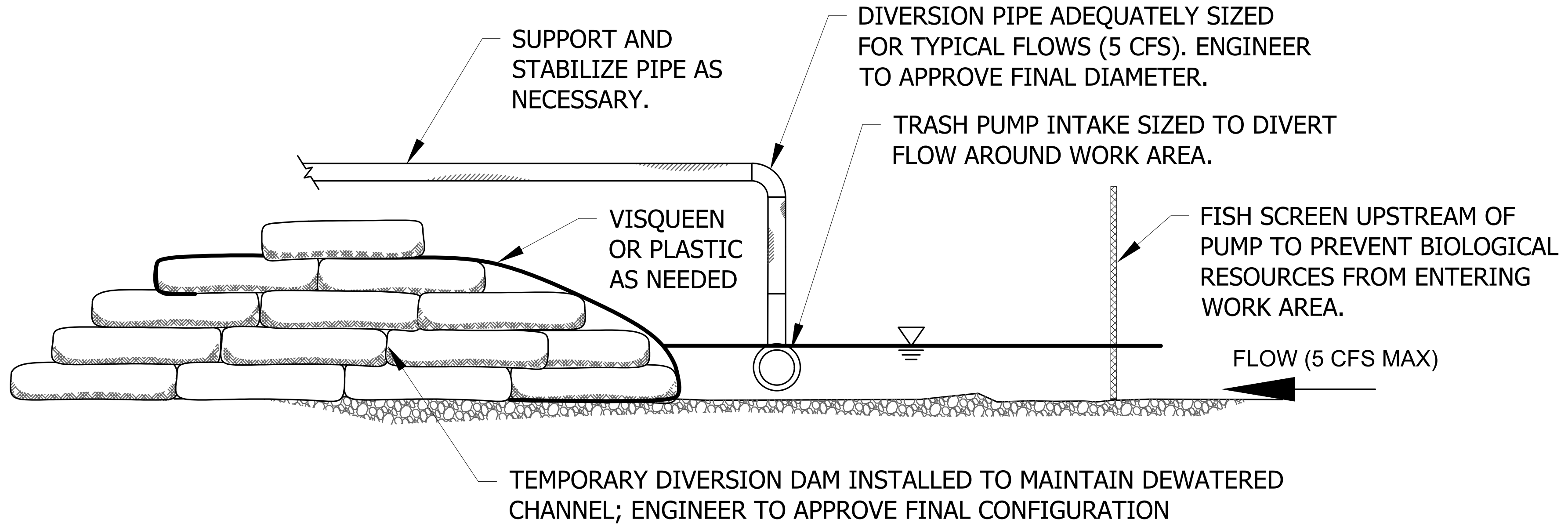
SPILLWAY PLAN AND PROFILE

SHEET 7 OF 19

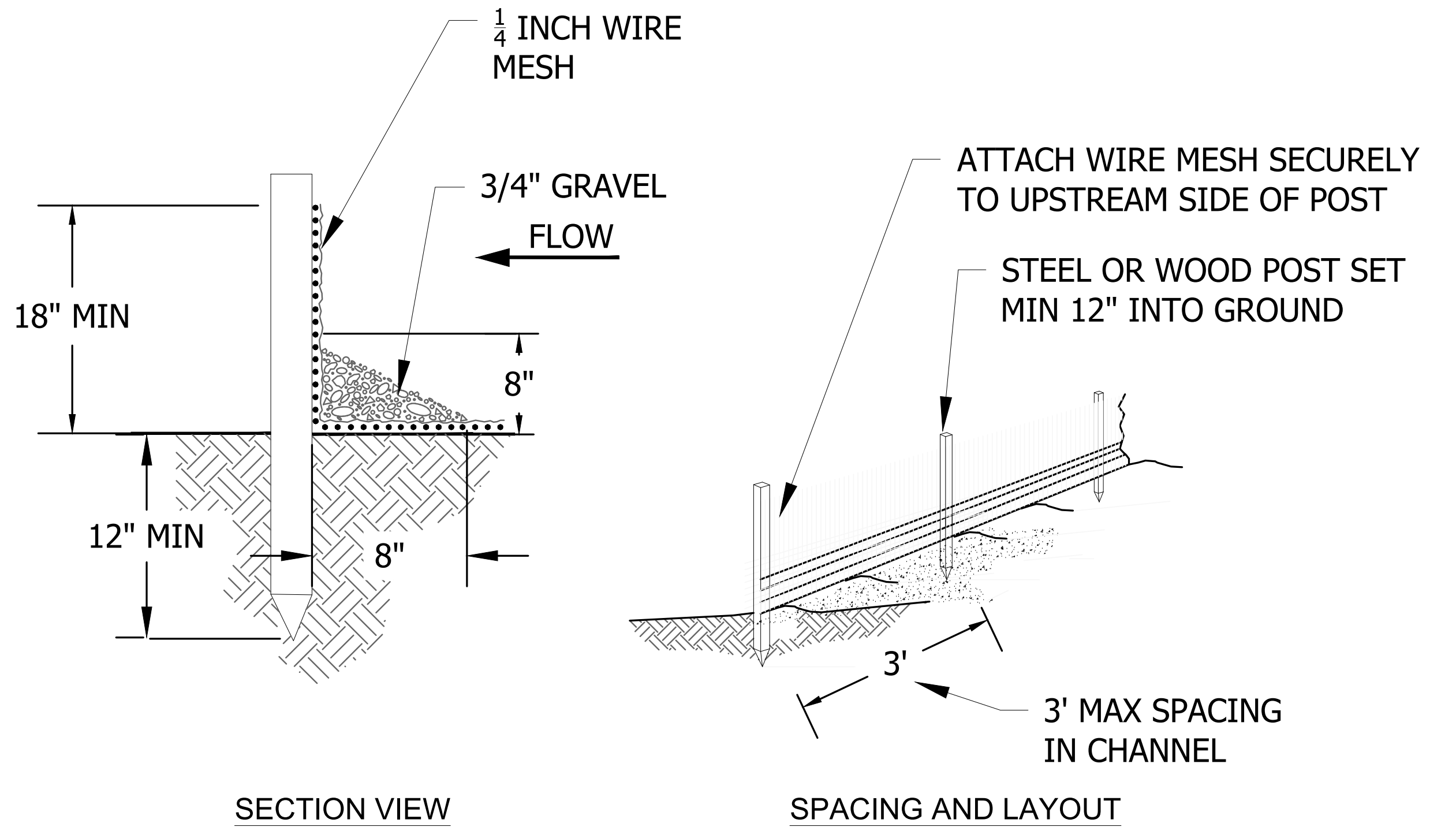


DEWATERING AND CONSTRUCTION SEQUENCING NOTES:

1. THE ENTIRE LENGTH OF CHANNEL WITHIN THE LIMIT OF WORK SHALL BE ELECTRO-FISHED BY DFW STAFF PRIOR TO ANY CONSTRUCTION ACTIVITY THAT COULD DISTURB THE CHANNEL
2. CONSTRUCT NEW CHANNEL AND ALL FEATURES EXCEPT UPSTREAM AND DOWNSTREAM CONNECTIONS TO EXISTING CHANNEL; DEWATER EXCAVATIONS AS NEEDED DURING CONSTRUCTION TO INSURE THAT NO TURBID WATER RUNS OFF THE SITE
3. CONSTRUCT DOWNSTREAM CONNECTION BETWEEN NEW AND CURRENT CHANNEL; INSTALL TEMPORARY DEWATERING AND BYPASS FLOW SYSTEM AS SHOWN IN THE FIGURE ABOVE
4. CONSTRUCT UPSTREAM CONNECTION BETWEEN NEW AND CURRENT CHANNEL; INSTALL TEMPORARY DEWATERING AND BYPASS FLOW SYSTEM AS SHOWN IN THE FIGURE ABOVE



1 COFFER DAM AND PUMP INTAKE
NTS



2 FISH EXLUSIONARY FENCING
NTS

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REDWOOD CREEK-DEWATERING

SHEET 8 OF 19

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE

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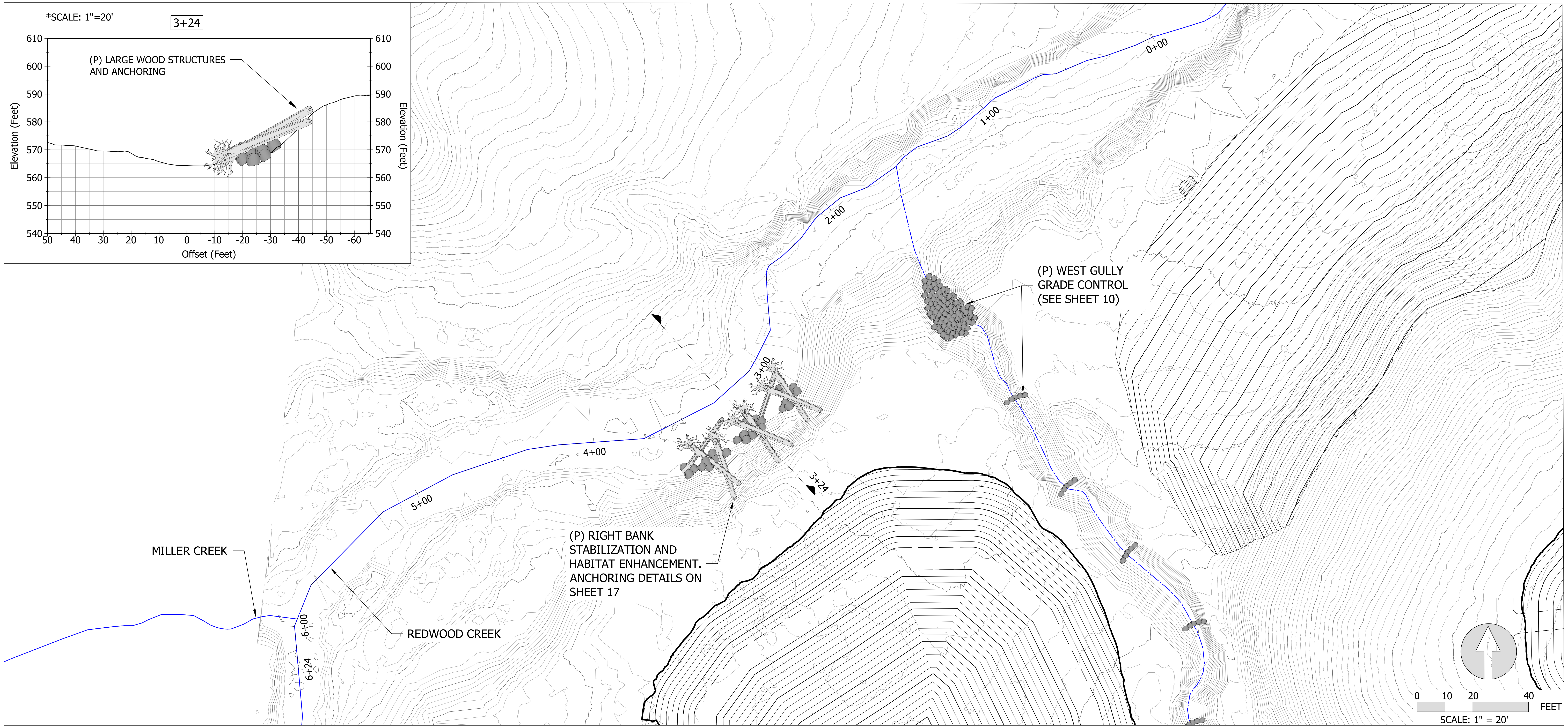
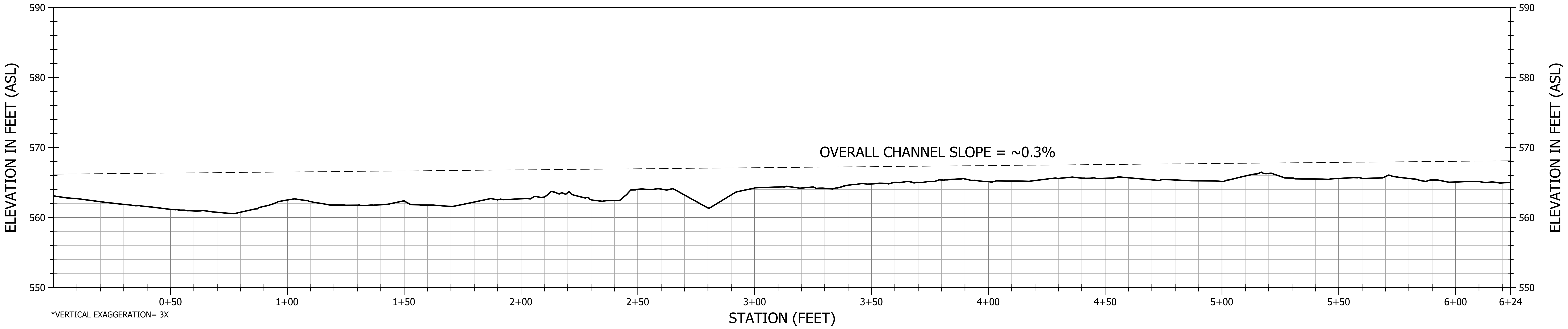


REDWOOD CREEK- ALIGNMENT PROFILE



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9-30-22

REDWOOD CREEK-INSTREAM COMPONENTS

SHEET 9 OF 19

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE - ADJUST ACCORDINGLY

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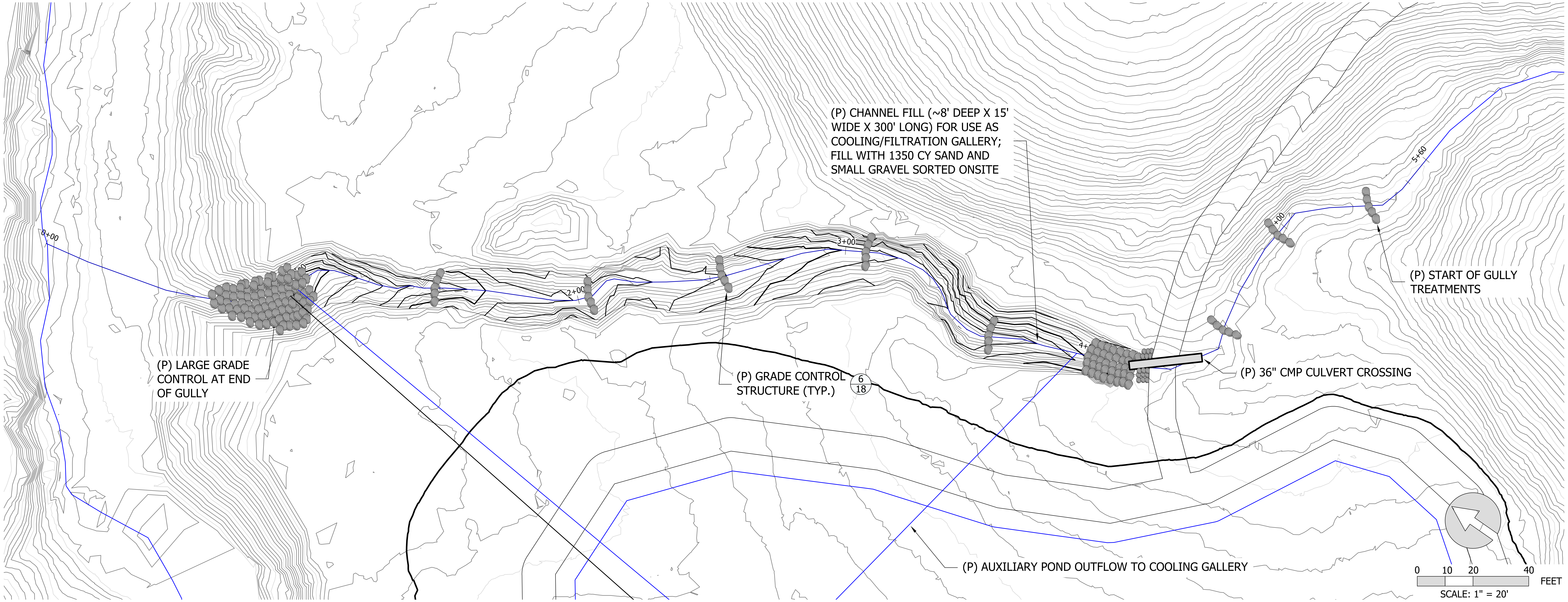
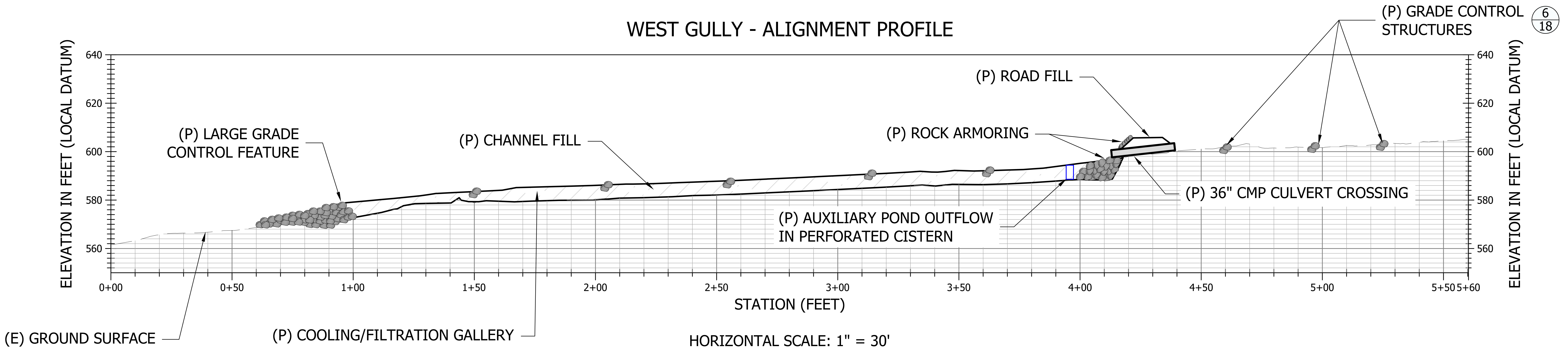


WEST GULLY - ALIGNMENT PROFILE



HORIZONTAL SCALE: 1" = 30'
VERTICAL SCALE: 1" = 30'

MARSHALL RANCH FLOW ENHANCEMENT PROJECT

BRICELAND, CA

Stillwater Sciences
850 G STREET SUITE K
ARCATA, CA 95521
P: (707) 822-9607

C 79688
EXP. 9/22
CIVIL

PROJECT NUMBER: 603.04
SCALE: AS NOTED
DATE: 7/30/2021

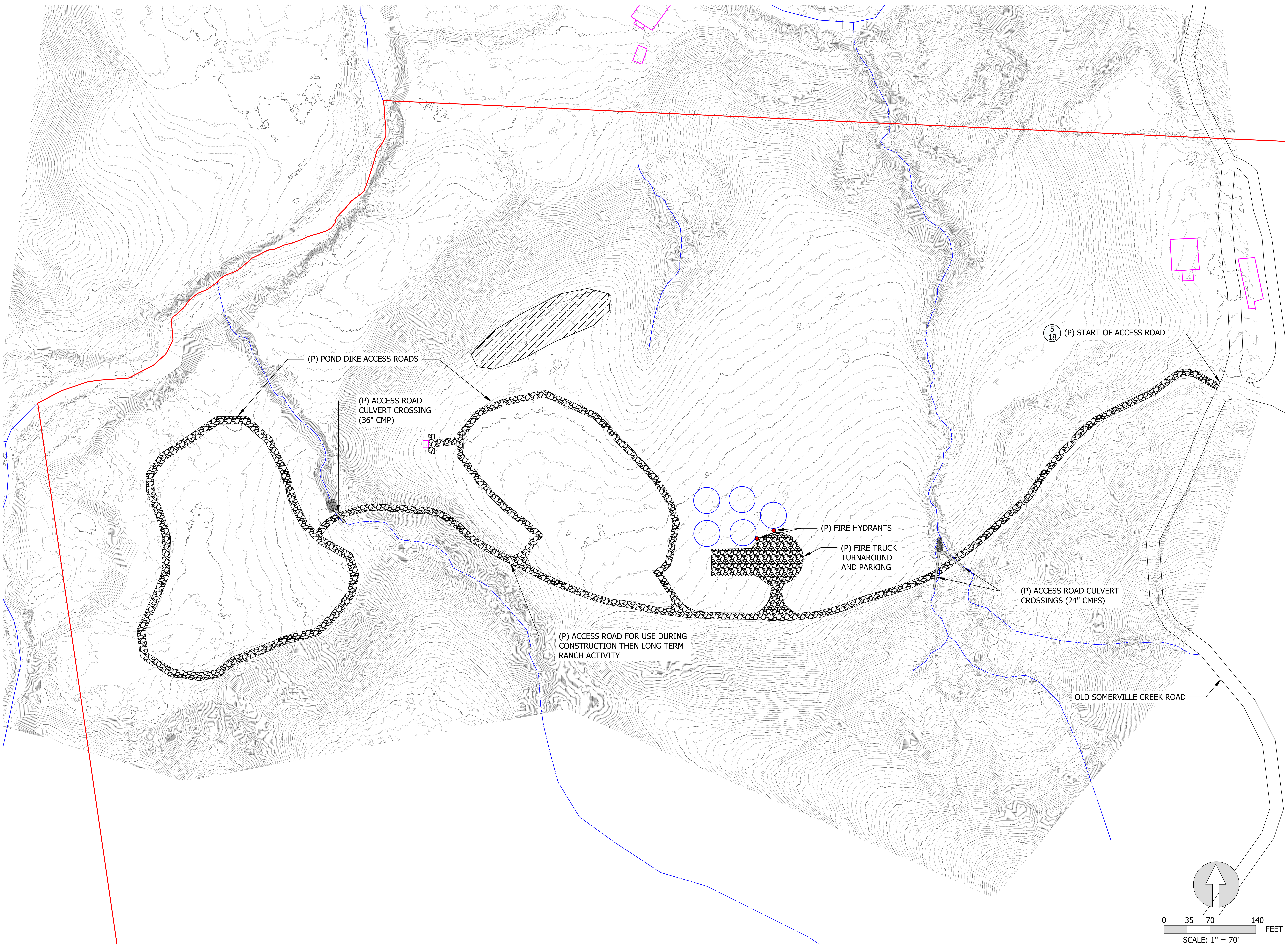
DESIGN: JM
DRAWN: CL,TC
CHECKED: JM
APPROVED: JM

No. 79688
9-30-20
EXPIRES

WEST GULLY PLAN & PROFILE

SHEET 10 OF 19

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE



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JOEL MONSCHKE
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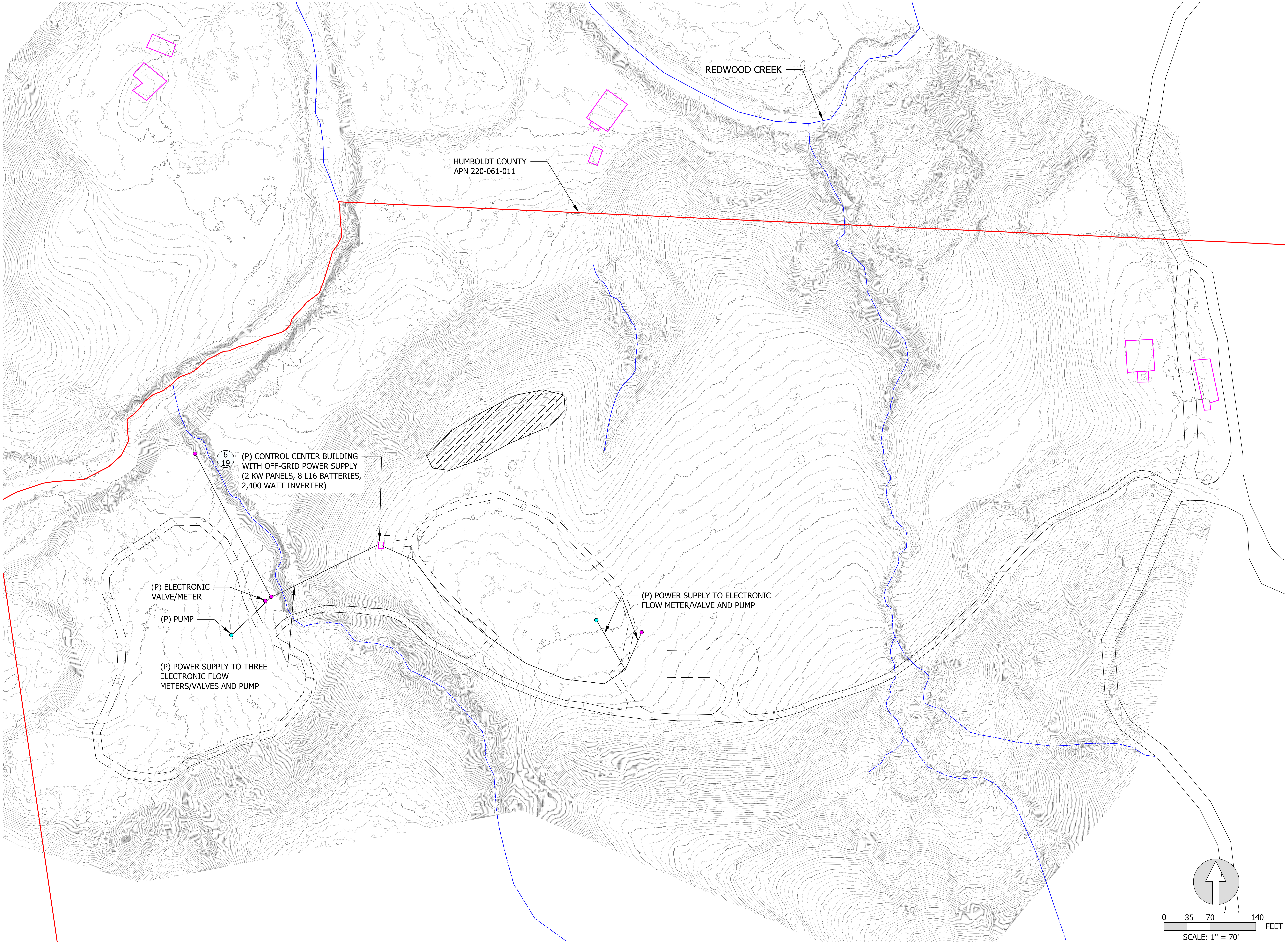
No. 79688
9-30-22

PERMANENT ACCESS ROAD PLAN

SHEET 11 OF 19

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE



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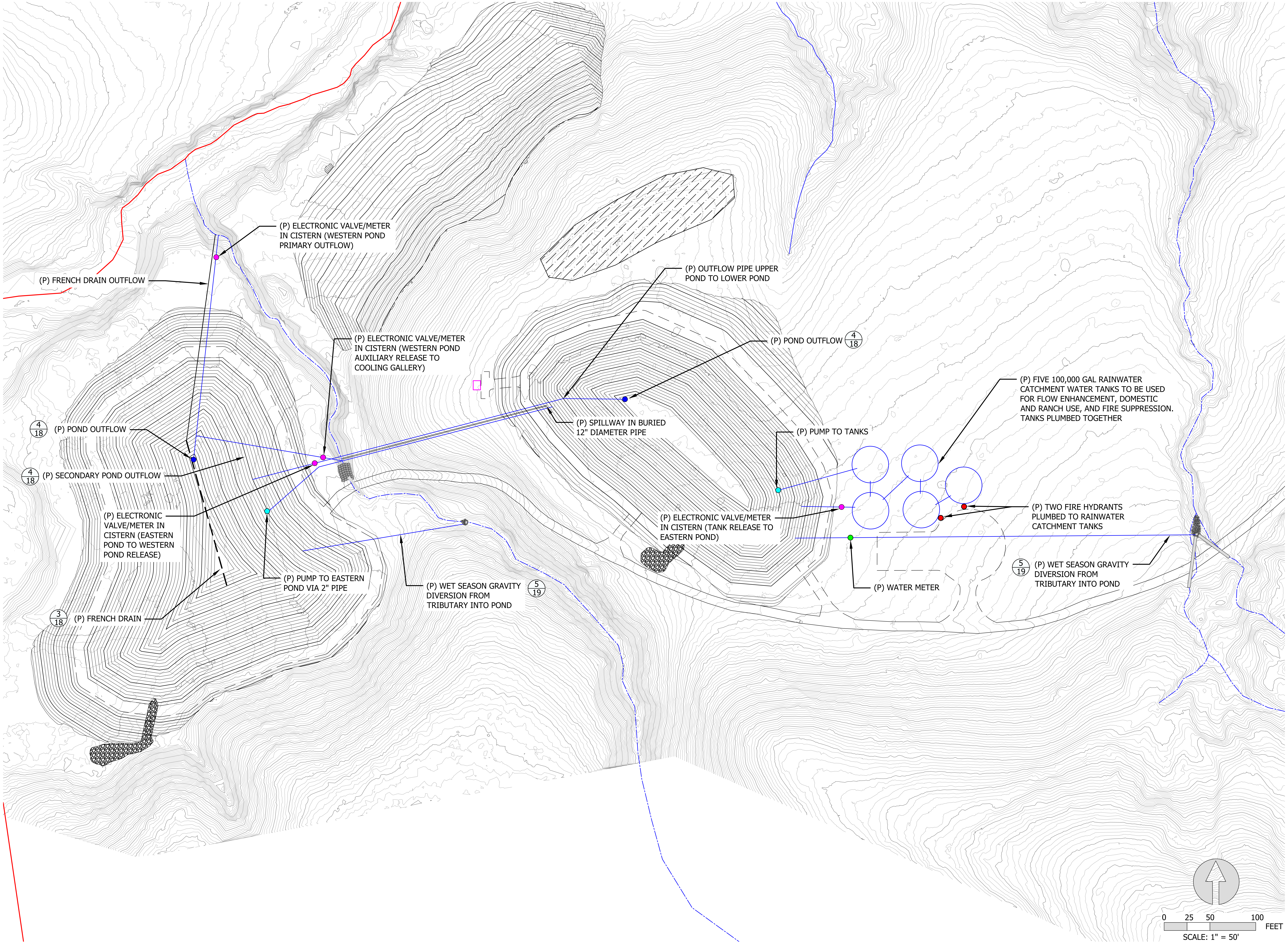
APPROVED: JM

JOEL MONSCHKE
No. 79688
9-30-22
EXPIRES

ELECTRICAL PLAN

SHEET 12 OF 19

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE



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REGISTERED PROFESSIONAL ENGINEER
JOEL MONSCHKE
C 79688
EXP. 9/22
CIVIL
STATE OF CALIFORNIA

PROJECT NUMBER: 603.04
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APPROVED: JM

WATER INFRASTRUCTURE PLAN

SHEET 13 OF 19

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE – ADJUST ACCORDINGLY

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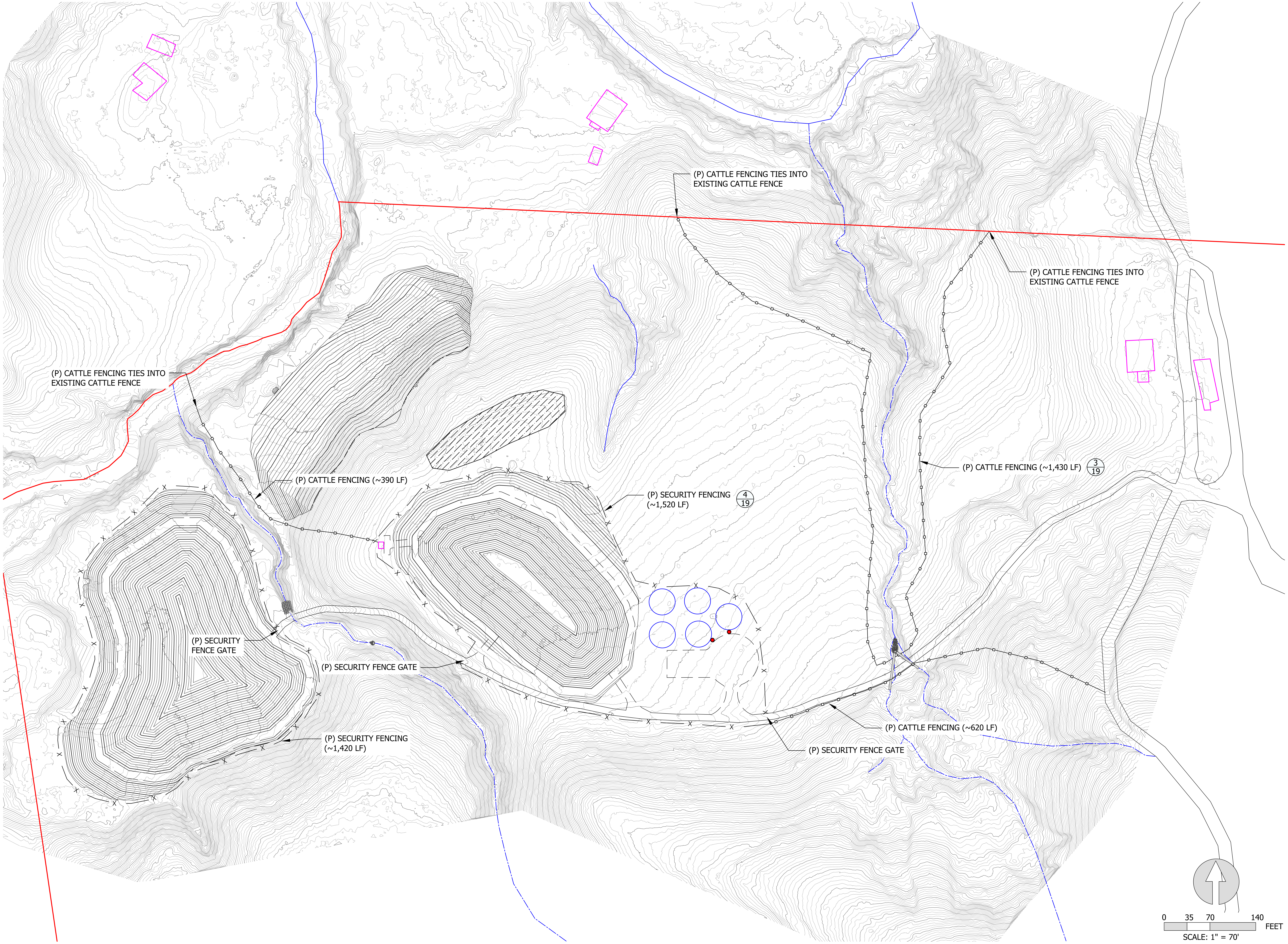

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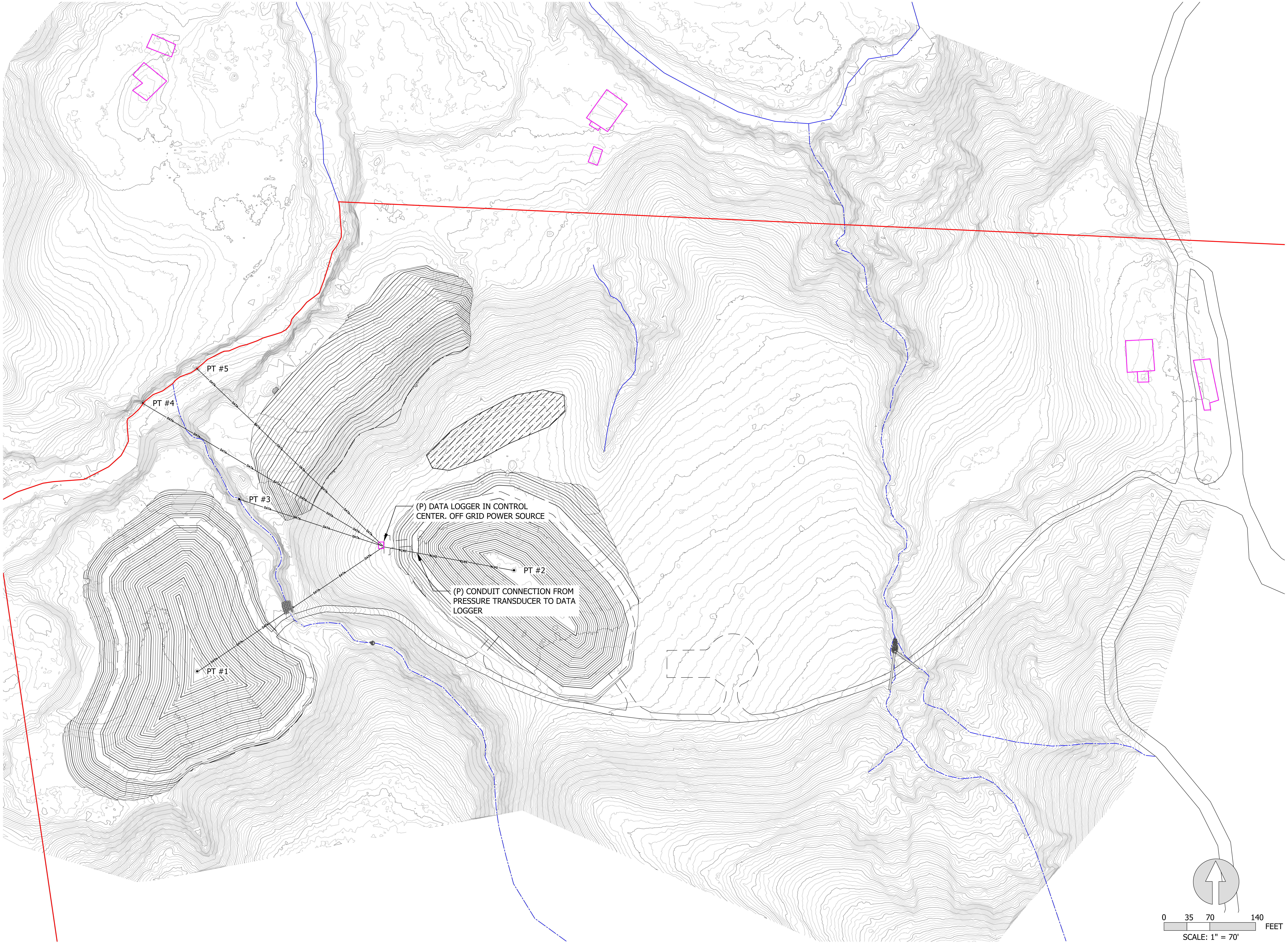
9-30-22
EXPIRES

FENCING PLAN

SHEET 14 OF 19



(P) DATA LOGGER IN CONTROL CENTER. OFF GRID POWER SOURCE

(P) CONDUIT CONNECTION FROM PRESSURE TRANSDUCER TO DATA LOGGER

MARSHALL RANCH FLOW ENHANCEMENT PROJECT

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9-30-22

MONITORING AND INSTRUMENTATION PLAN

SHEET 15 OF 19

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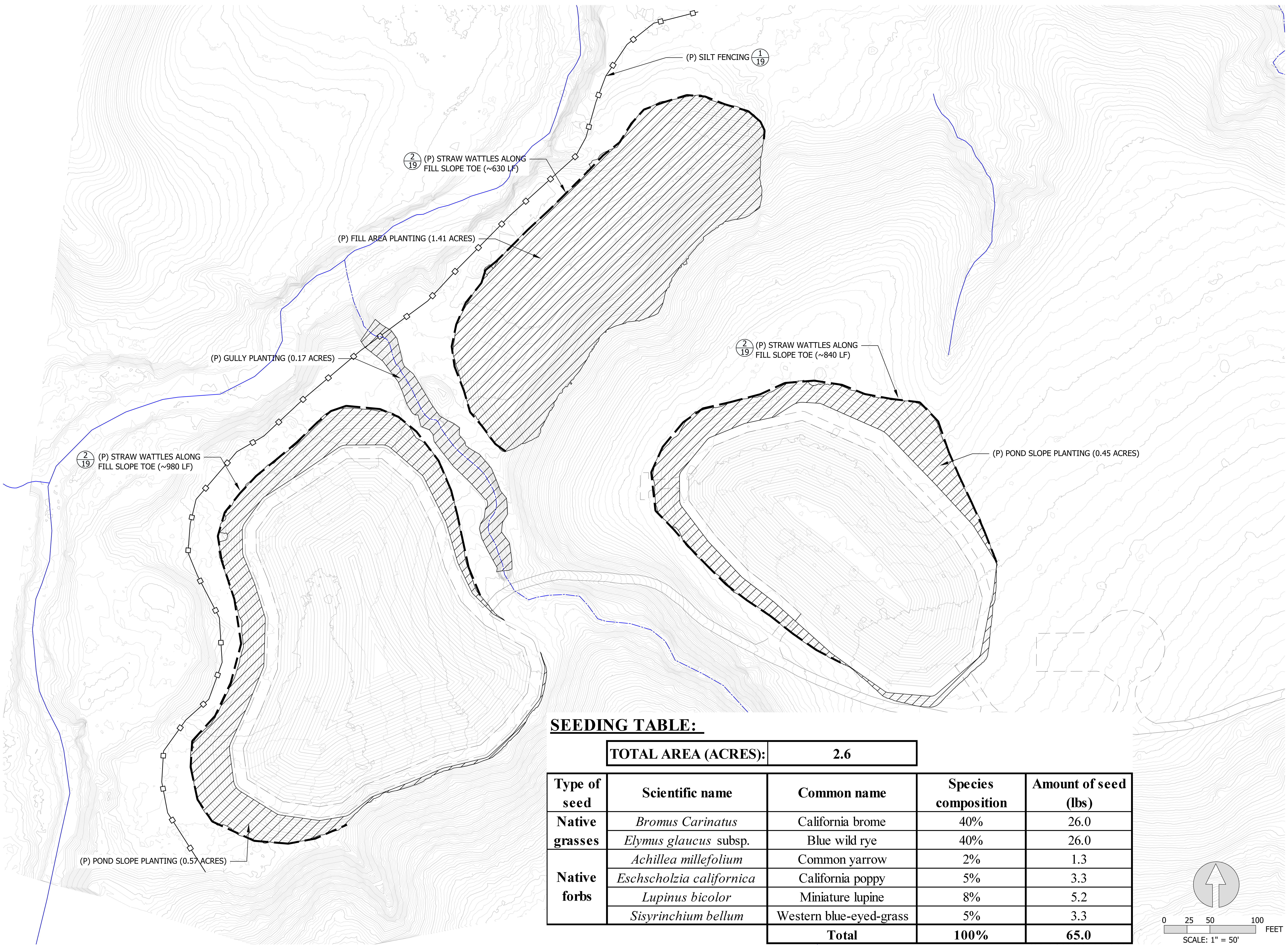

SEEDING TABLE:

TOTAL AREA (ACRES):	2.6

Type of seed	Scientific name	Common name	Species composition	Amount of seed (lbs)
Native grasses	*Bromus Carinatus*	California brome	40%	26.0
	Elymus glaucus subsp.	Blue wild rye	40%	26.0
Native forbs	*Achillea millefolium*	Common yarrow	2%	1.3
	Eschscholzia californica	California poppy	5%	3.3
	Lupinus bicolor	Miniature lupine	8%	5.2
	Sisyrinchium bellum	Western blue-eyed-grass	5%	3.3
		Total	**100%**	**65.0**

MARSHALL RANCH FLOW
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EXPIRES

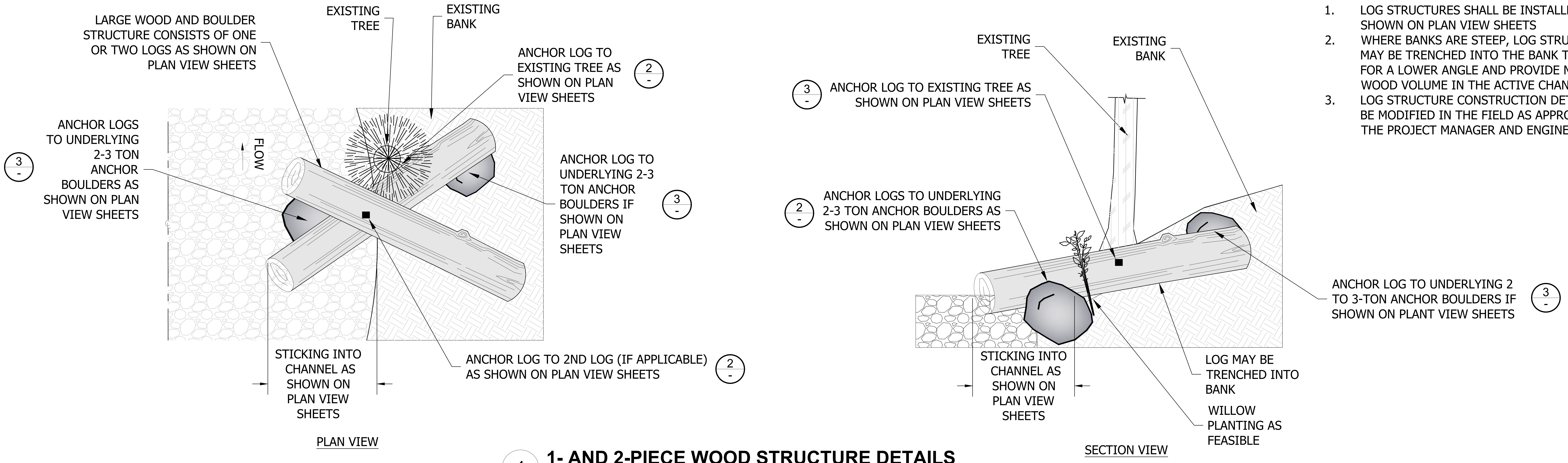
EROSION CONTROL &
REVEGETATION

SHEET 16 OF 19

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE

NOTES:

1. LOG STRUCTURES SHALL BE INSTALLED AS SHOWN ON PLAN VIEW SHEETS
2. WHERE BANKS ARE STEEP, LOG STRUCTURES MAY BE TRENCHED INTO THE BANK TO ALLOW FOR A LOWER ANGLE AND PROVIDE MORE WOOD VOLUME IN THE ACTIVE CHANNEL
3. LOG STRUCTURE CONSTRUCTION DETAILS MAY BE MODIFIED IN THE FIELD AS APPROVED BY THE PROJECT MANAGER AND ENGINEER

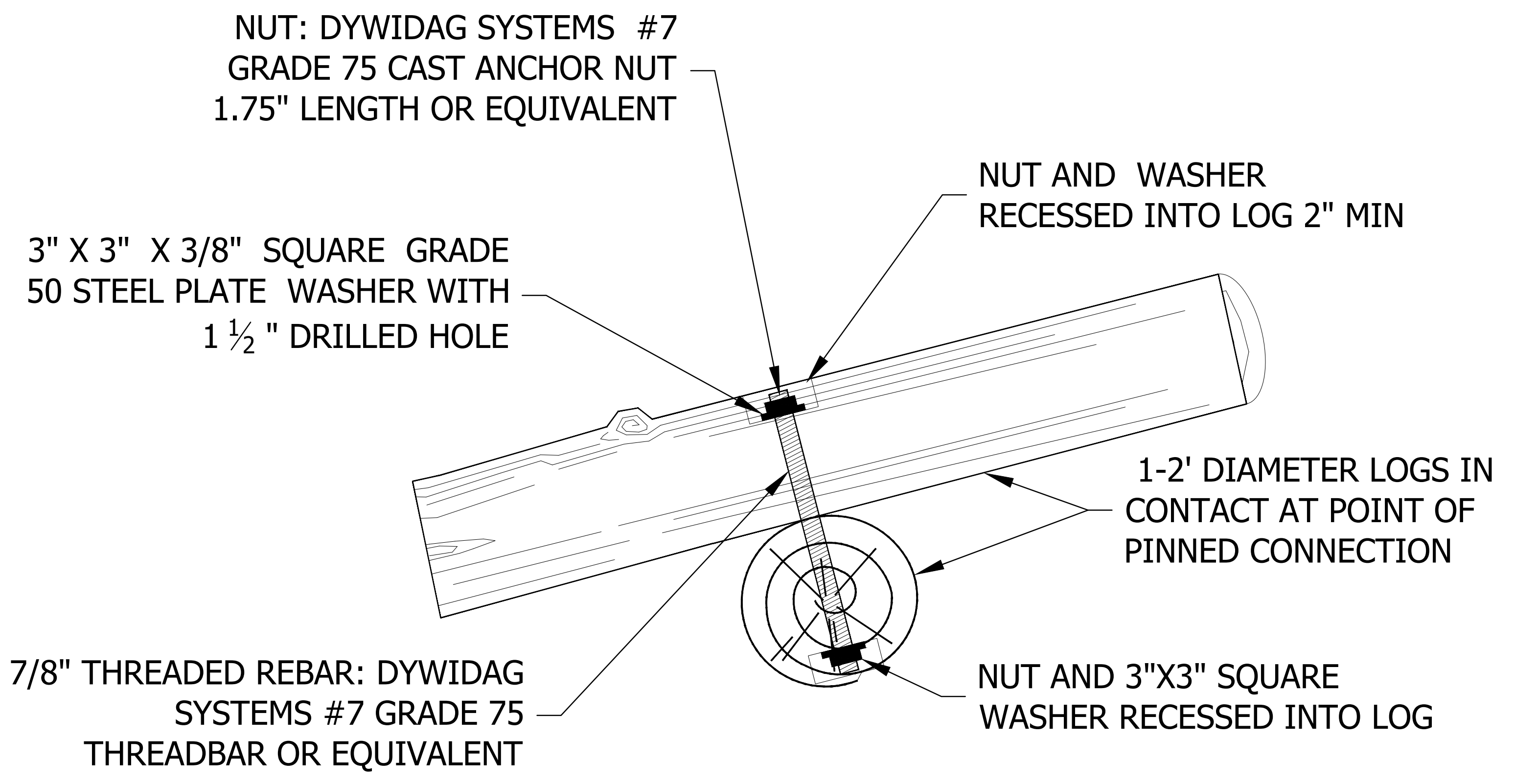


PLAN VIEW

SECTION VIEW

1 1- AND 2-PIECE WOOD STRUCTURE DETAILS

NTS

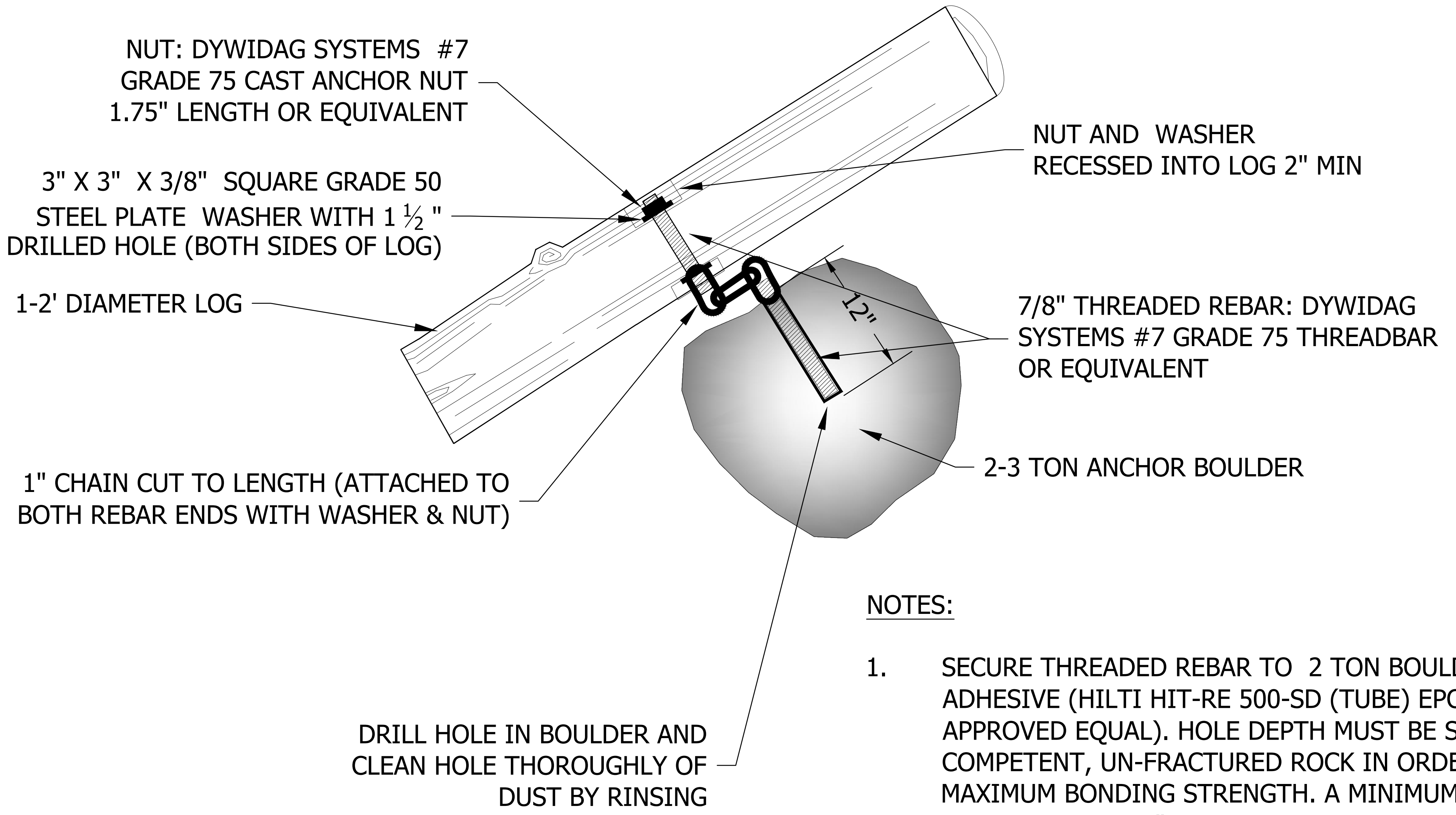


NOTES:

1. NOTCHING NOT REQUIRED ON LIVE TREES TO REDUCE IMPACTS TO TREE HEALTH

2 LOG-LOG OR LOG-TREE ANCHORING

NTS



NOTES:

1. SECURE THREADED REBAR TO 2 TON BOULDER USING EPOXY ADHESIVE (HILTI HIT-RE 500-SD (TUBE) EPOXY CARTRIDGES, OR APPROVED EQUAL). HOLE DEPTH MUST BE SUFFICIENT TO REACH COMPETENT, UN-FRACTURED ROCK IN ORDER TO OBTAIN MAXIMUM BONDING STRENGTH. A MINIMUM OF 12 INCHES IS RECOMMENDED; 1" DIAMOND-TIPPED DRILL (TIGHT FIT).

3 LOG-BOULDER ANCHORING

NTS

MARSHALL RANCH FLOW ENHANCEMENT PROJECT

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EXPIRES
CIVIL

DETAILS - 1

SHEET 17 OF 19

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE - ADJUST ACCORDINGLY

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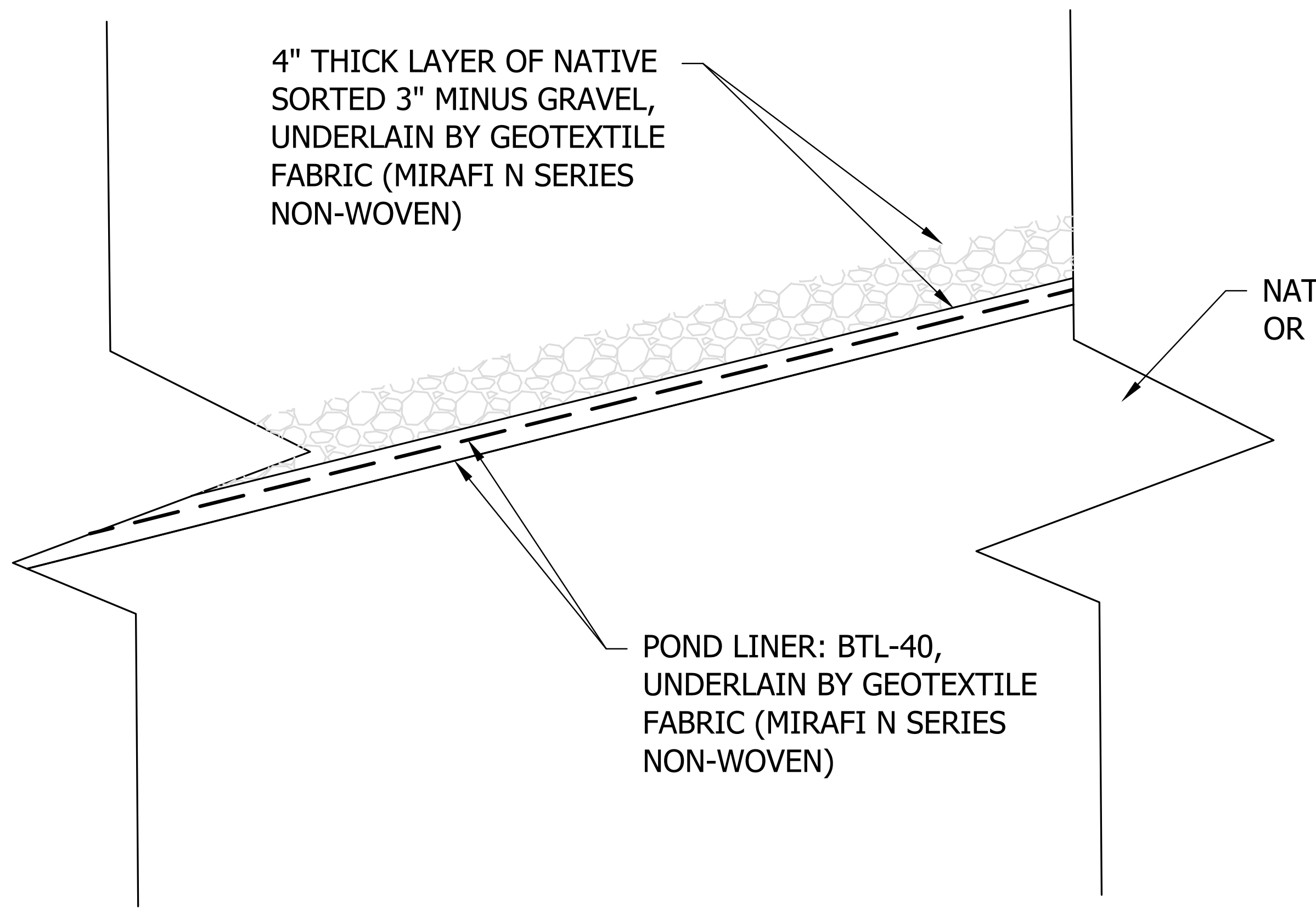
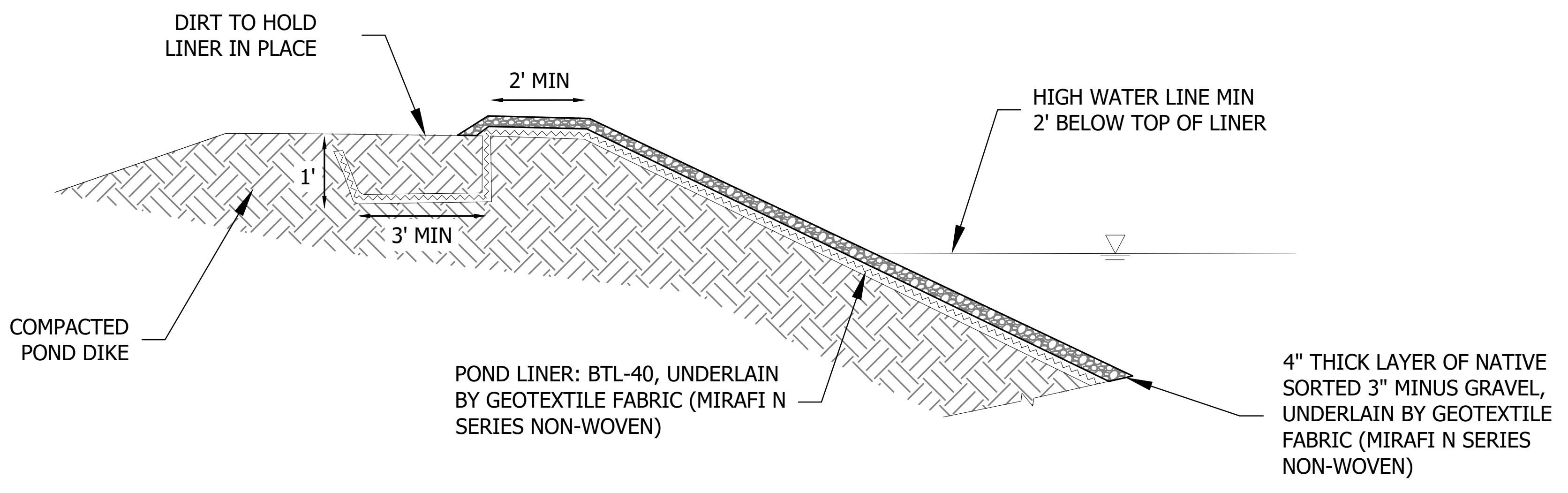


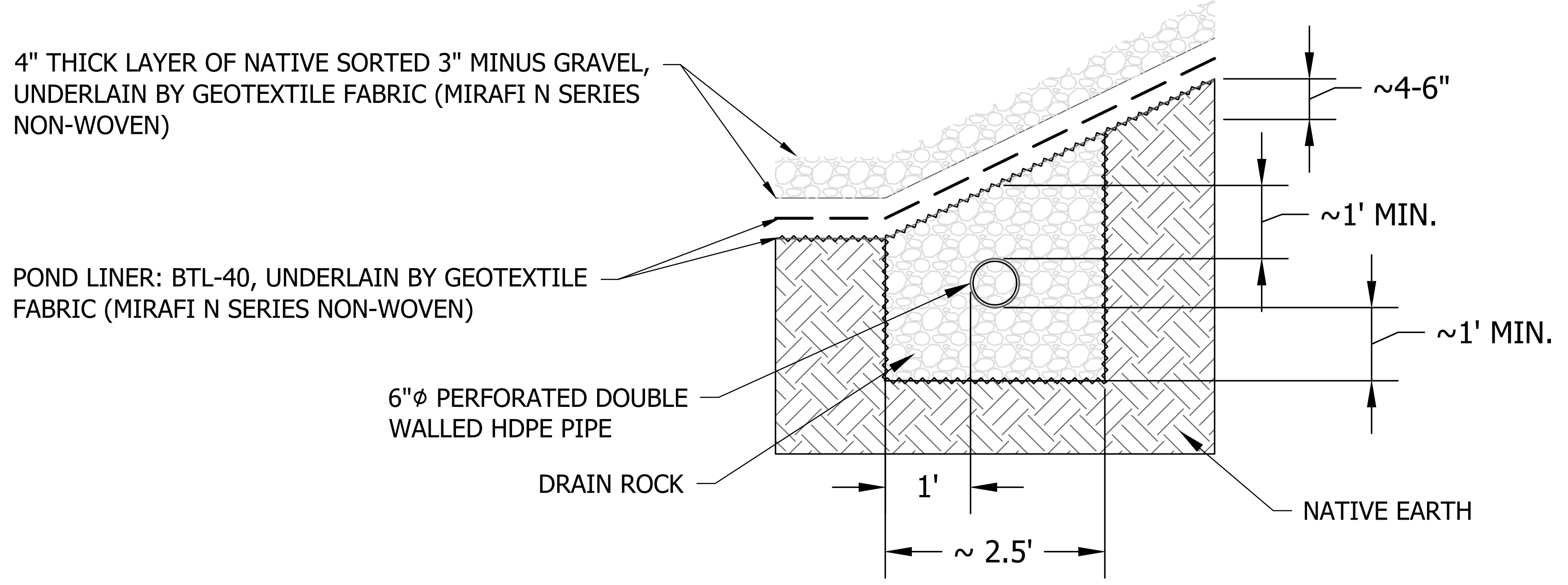
1 POND LINER DETAIL

NTS



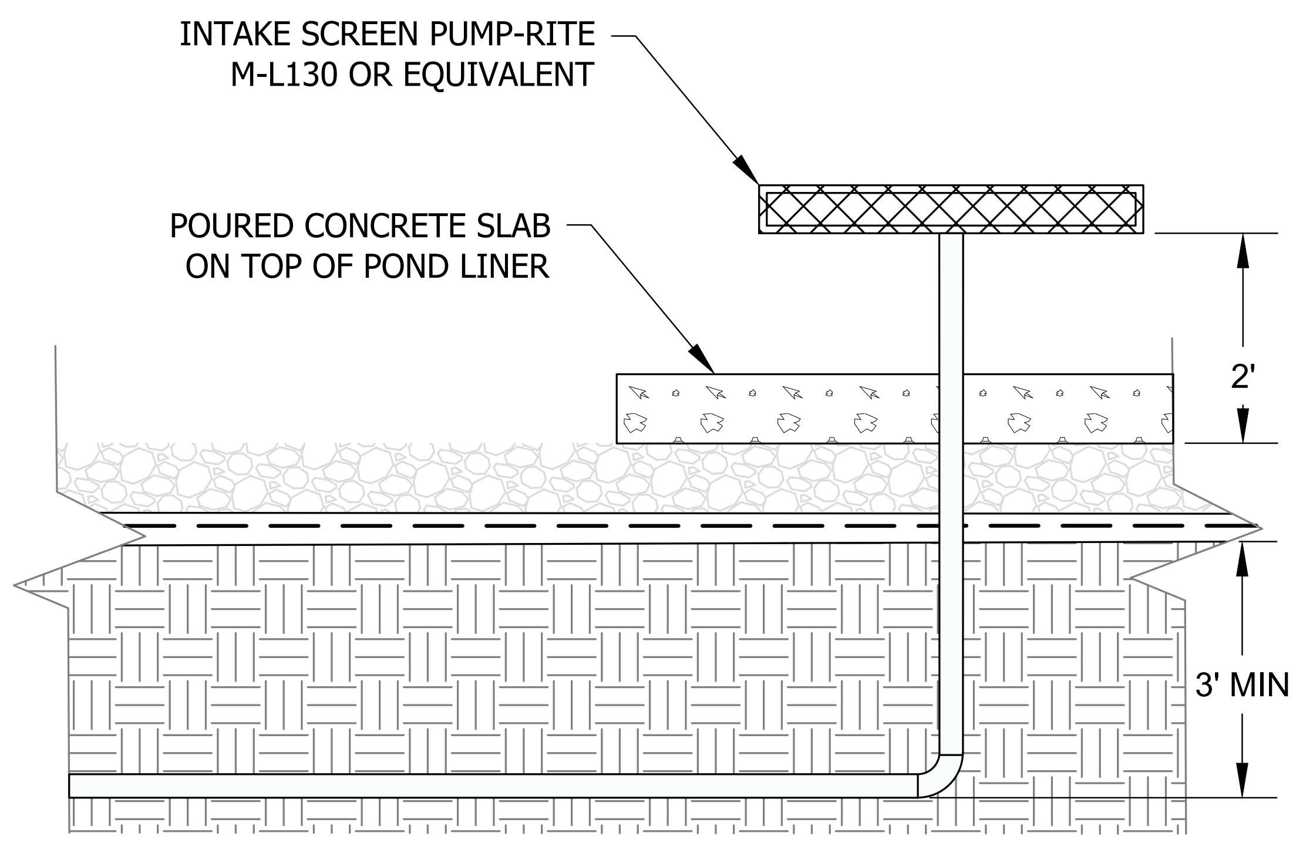
2 POND EDGE DETAIL

NTS



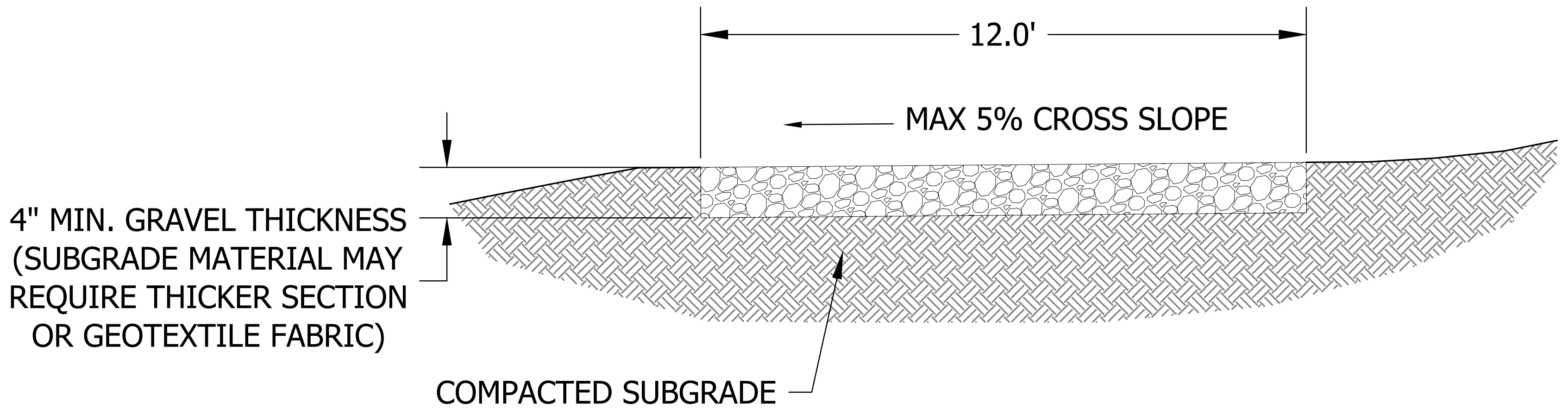
3 FRENCH DRAIN DETAIL

NTS



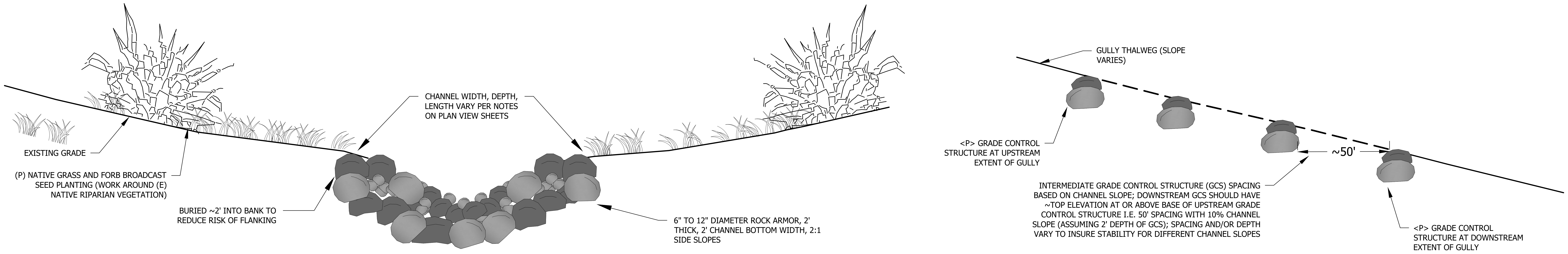
4 POND OUTFLOW DETAIL

NTS



5 GRAVEL ACCESS ROAD

NTS



GRADE CONTROL - CROSS SECTION

GRADE CONTROL - PROFILE

6 GRADE CONTROL STRUCTURE

NTS

MARSHALL RANCH FLOW ENHANCEMENT PROJECT

BRICELAND, CA

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APPROVED: JM

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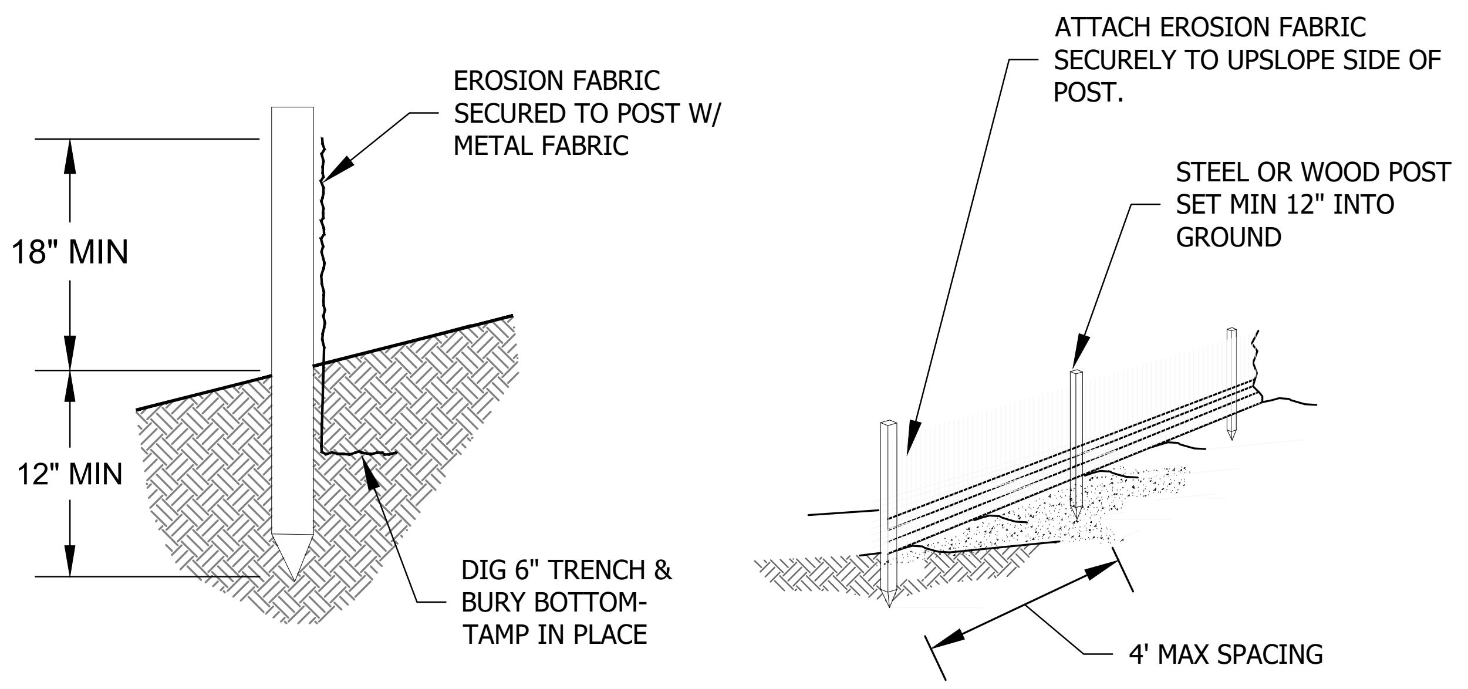
9-30-22

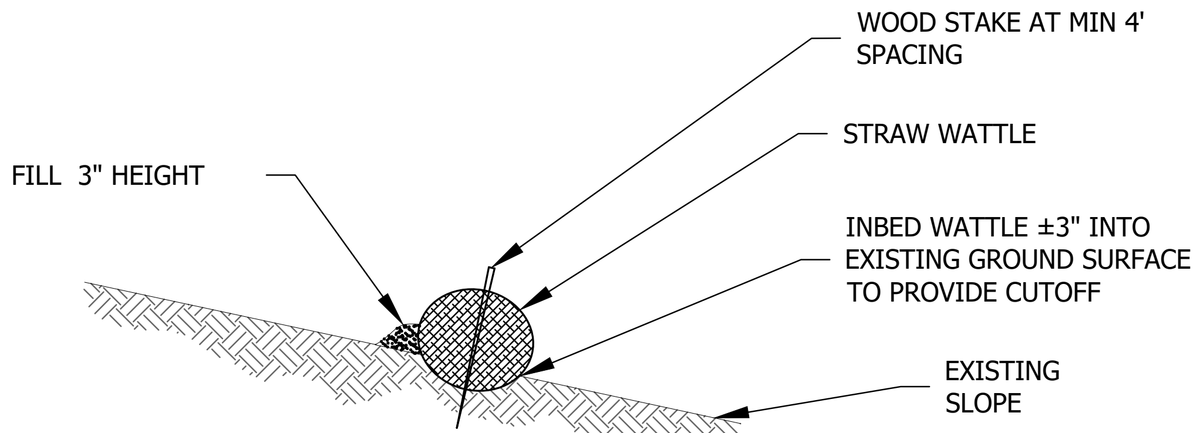
DETAILS - 2

SHEET 18 OF 19



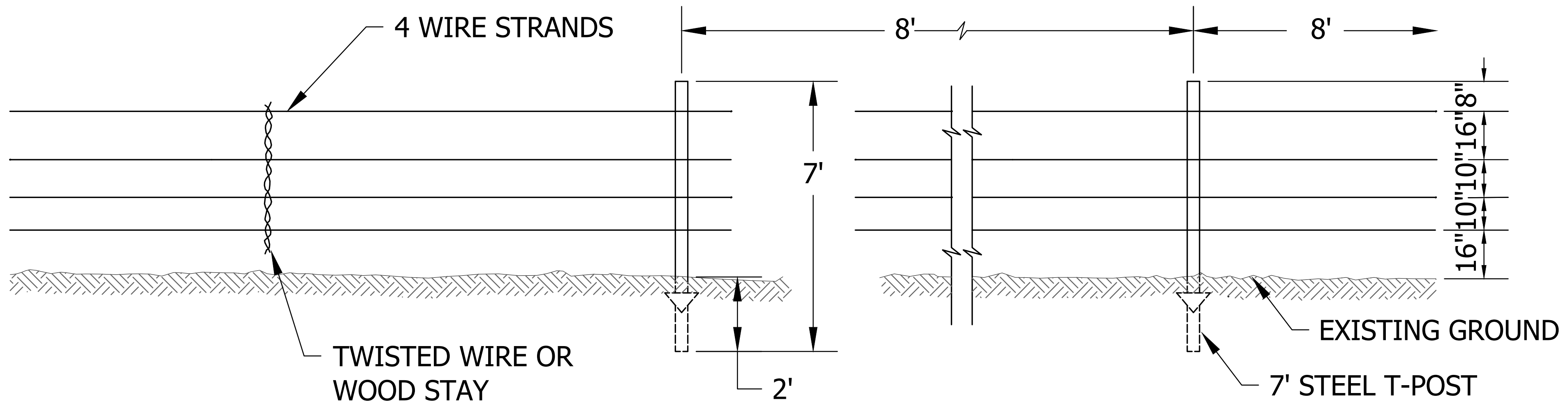
1 SILT FENCING

NTS



2 STRAW WATTLE

NTS



3 CATTLE FENCING

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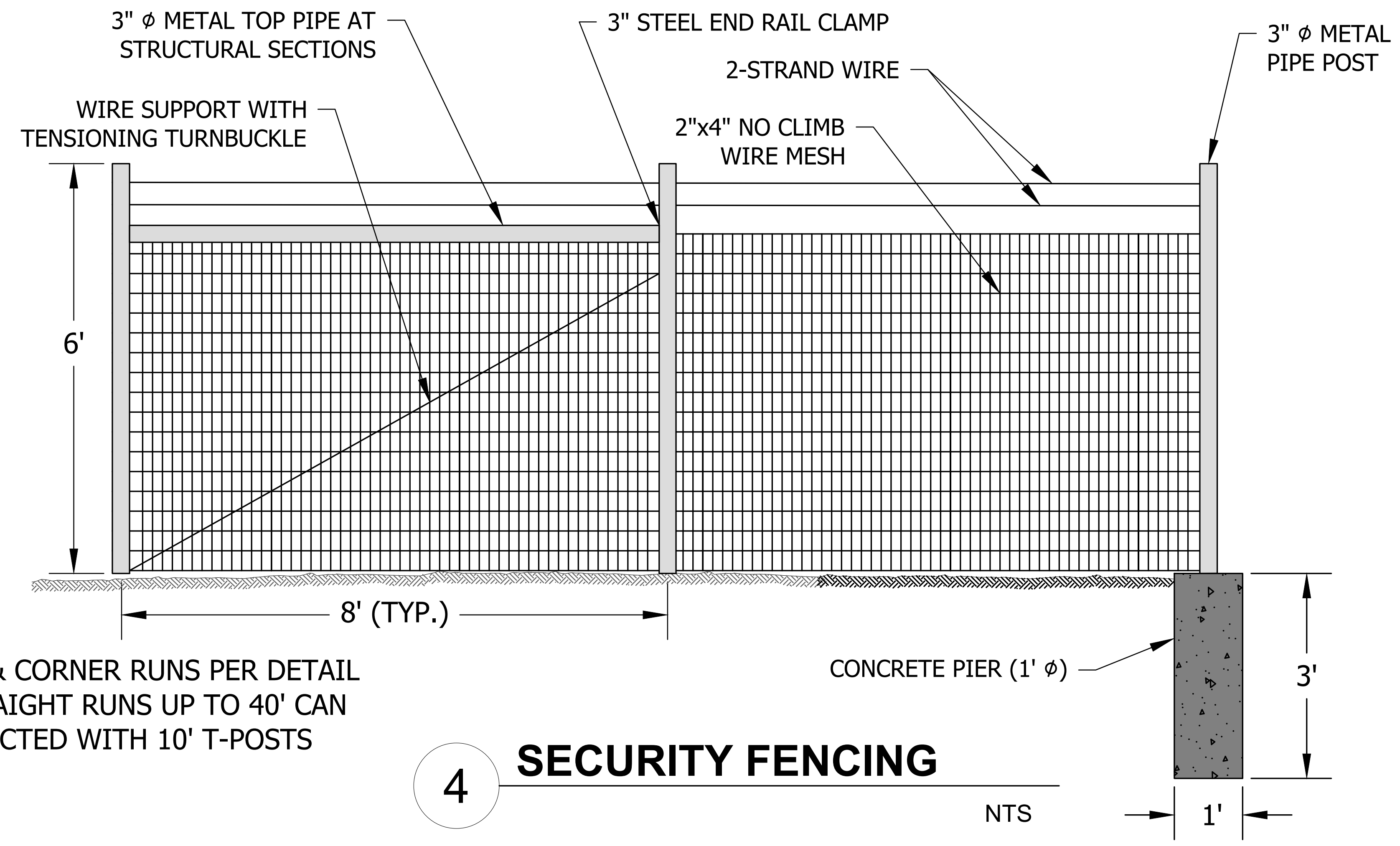
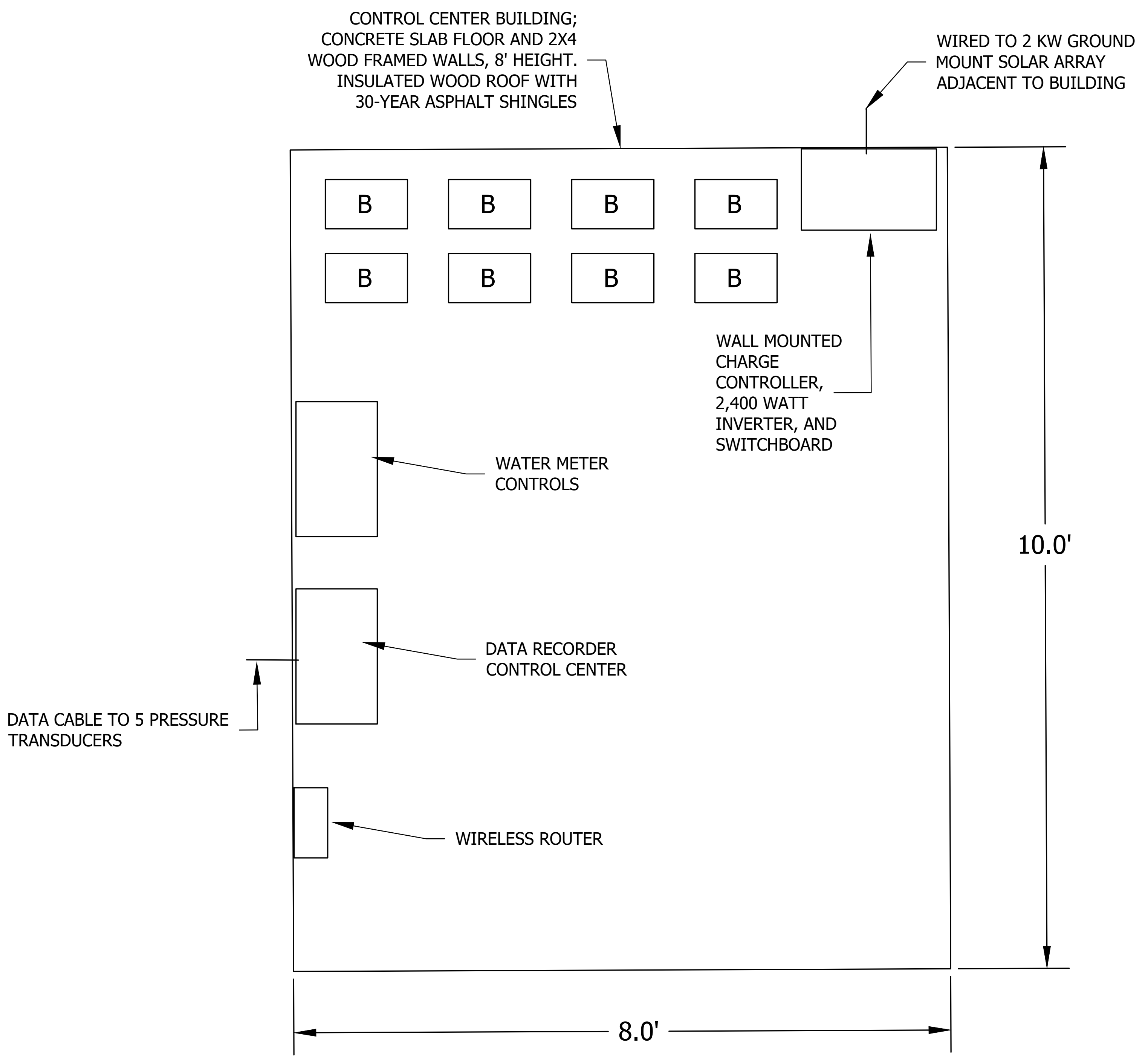


NOTE: END & CORNER RUNS PER DETAIL ABOVE; STRAIGHT RUNS UP TO 40' CAN BE CONSTRUCTED WITH 10' T-POSTS

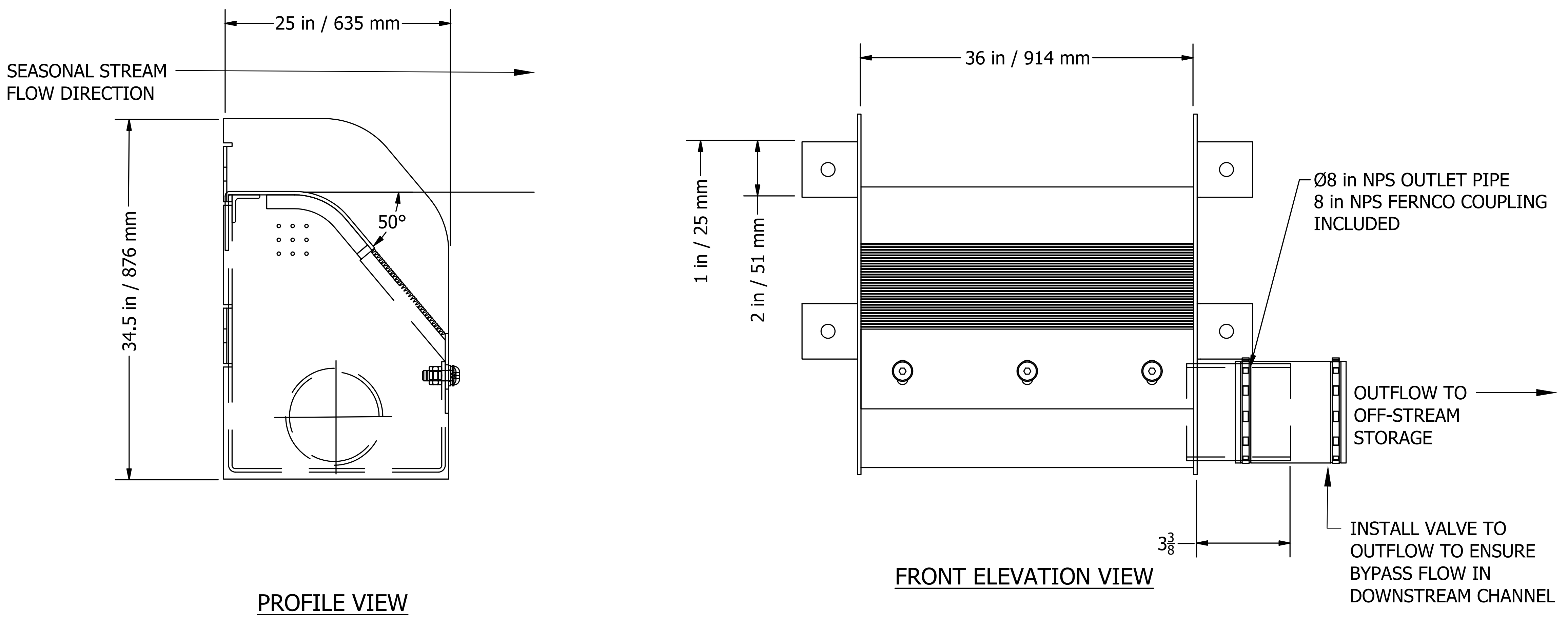
4 SECURITY FENCING

NTS



6 CONTROL CENTER

NTS



5 DIVERSION INTAKE

NTS

COANDA BOX OR SIMILAR. SCREEN SLOT WIDTH OF 1MM, FABRICATED FROM 304 STAINLESS STEEL.

MARSHALL RANCH FLOW ENHANCEMENT PROJECT

BRICELAND, CA

Stillwater Sciences
850 G STREET SUITE K
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REGISTERED PROFESSIONAL ENGINEER
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C 79688
EXP. 9/22
CIVIL
STATE OF CALIFORNIA

PROJECT NUMBER: 603.04
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9-30-22

DETAILS - 3

SHEET 19 OF 19

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Appendix B

Geotechnical Investigation Report

Phone: (707) 441-8855 Email: info@shn-engr.com Web: shn-engr.com
812 W. Wabash Avenue, Eureka, CA 95501-2138

Reference: 018135

August 20, 2021

Dana Stolzman, Executive Director
Salmonid Restoration Federation
425 Snug Alley, Unit D
Eureka, CA 95501

Subject: Geotechnical Investigation Report for Proposed Water Storage Basins and Associated Infrastructure for Redwood Creek Flow Enhancement, Marshall Ranch, 195 Somerville Road, Briceland, Humboldt County, California; APN 220-061-011–Revision 2

Dana:

This report presents the results of SHN's investigation of geotechnical conditions for a proposed dry season flow enhancement project along Redwood Creek in Briceland, California. The project consists of the development of a 3.8-million-gallon water storage basin and a 5.7-million-gallon water storage basin that are intended for a habitat improvement project along a critical fish-bearing stream. Five 100,000-gallon rainwater catchment water tanks are also proposed. Our geotechnical investigation was completed primarily to inform the project design team (Stillwater Sciences), and to provide the necessary background information to submit to regulatory agencies or Humboldt County to support permitting for the project. In terms of the application to the County for grading and other permits, this report is intended to address all the items on the "Soils Engineering/Engineering Geology Report Checklist" provided on the Humboldt County Planning and Building Department's website (Humboldt County, 2008).

The purpose of our investigation was to evaluate the geotechnical conditions relative to the proposed water storage basins. Our assessment focuses on the geologic suitability of the site (exposure to geohazards and potential to influence site geologic conditions) and general geotechnical conditions (identification of problematic soil conditions, for example). In this report, we provide generic recommendations for site preparation and grading for construction of the storage basin; we understand that detailed engineering plans for the project, including the storage basin, are being prepared by Stillwater Sciences. The recommendations in this report are intended to satisfy the needs of the project and the requirements for obtaining a Humboldt County Building Permit, while maintaining the professional standard of care for this type of work.

1.0 Project Location and Description

We understand the project consists of the construction of two water storage basins totaling about 9.5 million gallons five 100,000-gallon rainwater catchment water tanks (for flow enhancement, ranch use, and fire suppression), and related infrastructure on the property known as the Marshall Ranch, at 195

Somerville Road, in Briceland, Humboldt County, California (Figure 1). Latitude and longitude of the site are 40.104018 °N and -123.899881°W, respectively. The project design was conceptual during our field investigation and has evolved since that time. Our understanding of the current project design is based on the Marshall Ranch Flow Enhancement Project design plans provided by Stillwater Sciences, dated July 30, 2021 (Appendix 1). The water storage basins are designed to deliver approximately 30 gallons per minute of flow augmentation to Redwood Creek during the 5-month dry season to improve instream aquatic habitat. The storage basins will be filled during the rainy season with direct rainfall (rainwater catchment) and two gravity diversions from small tributaries. Piping between Redwood Creek and the storage basins is part of the project design. Other proposed project components include:

- installation of a large wood habitat enhancement and bank stabilization structure in redwood creek;
- stabilization of one deeply incised tributary with approximately 10 rock armor grade control structures and regrading;
- construction of a passive “cooling and filtration gallery” in the existing gully to determine the viability of this innovative approach to address water quality and temperature issues associated with the flow releases from the pond;
- construction of a solar power system including 1 KW solar array, battery bank, inverter, internet connection, and small control center building to support operations and monitoring capabilities;
- upgrading access roads within the project area including three road/stream crossing upgrades and gravel surfacing to provide year-round access; and
- installation of plumbing infrastructure to allow for a portion of the water stored in the tanks to be utilized for domestic, ranch, and fire suppression needs including one fire hydrant.

The proposed water storage basins with subsurface exploration locations are shown on Figure 2.

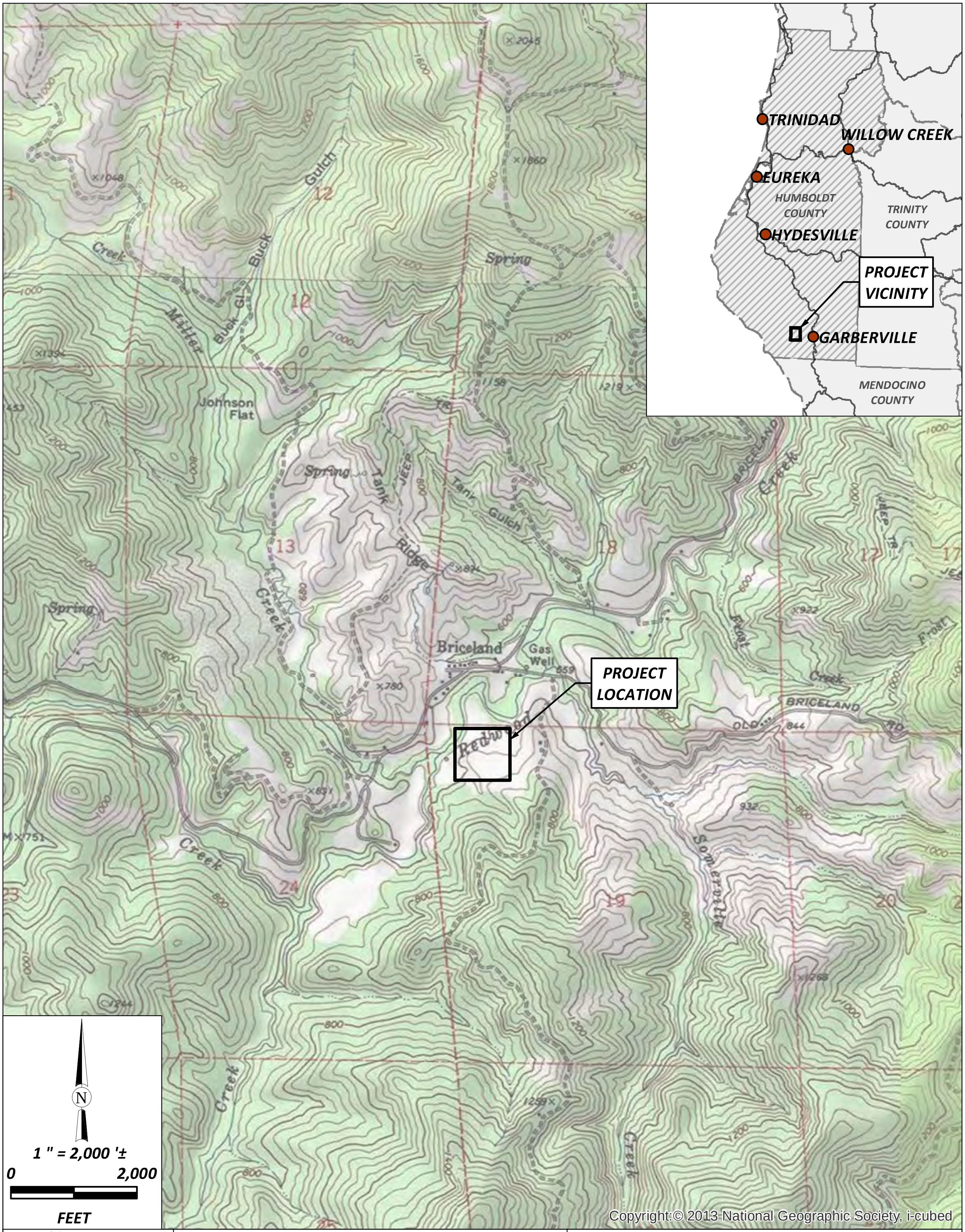
2.0 Scope of Work

The scope of SHN’s services included reviewing available geologic and subsurface information; overseeing the advancement of geotechnical borings and excavation of soil test pits; percolation testing; performing laboratory testing on selected soil samples; and providing engineering geologic and geotechnical recommendations to aid in project planning, design, and construction.

Specifically, the following information, recommendations, and design criteria are presented in this report:

- description of site terrain and local geology;
- description of soil and groundwater conditions, based on our field exploration, laboratory testing, and review of existing geotechnical information;
- logs of the exploratory geotechnical borings and test pits (Appendix 2) and results of laboratory tests conducted for this investigation (Appendix 3);
- assessment of potential earthquake-related geologic/geotechnical hazards (for example, strong earthquake ground shaking, surface fault rupture, liquefaction, settlement);

Path: \\eureka\projects\2018\018135-RedwCkFlowGEO\GIS\PROJ_MXD\2021\Figure1_ProjectLocationMap.mxd User Name: psundberg DATE: 8/17/21, 4:39PM



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Stillwater Sciences
Redwood Creek Flow Enhancement Project
Briceland, Humboldt County, California

Project Location Map

SHN 018135

August 2021	Figure1_ProjectLocationMap	Figure 1

Path: \\eureka\projects\2018\018135-RedwCkFlowGEO\GIS\PROJ_MXD\2021\Figure2_SiteMap_Rev2.mxd User Name: psundberg DATE: 8/17/21, 4:33PM

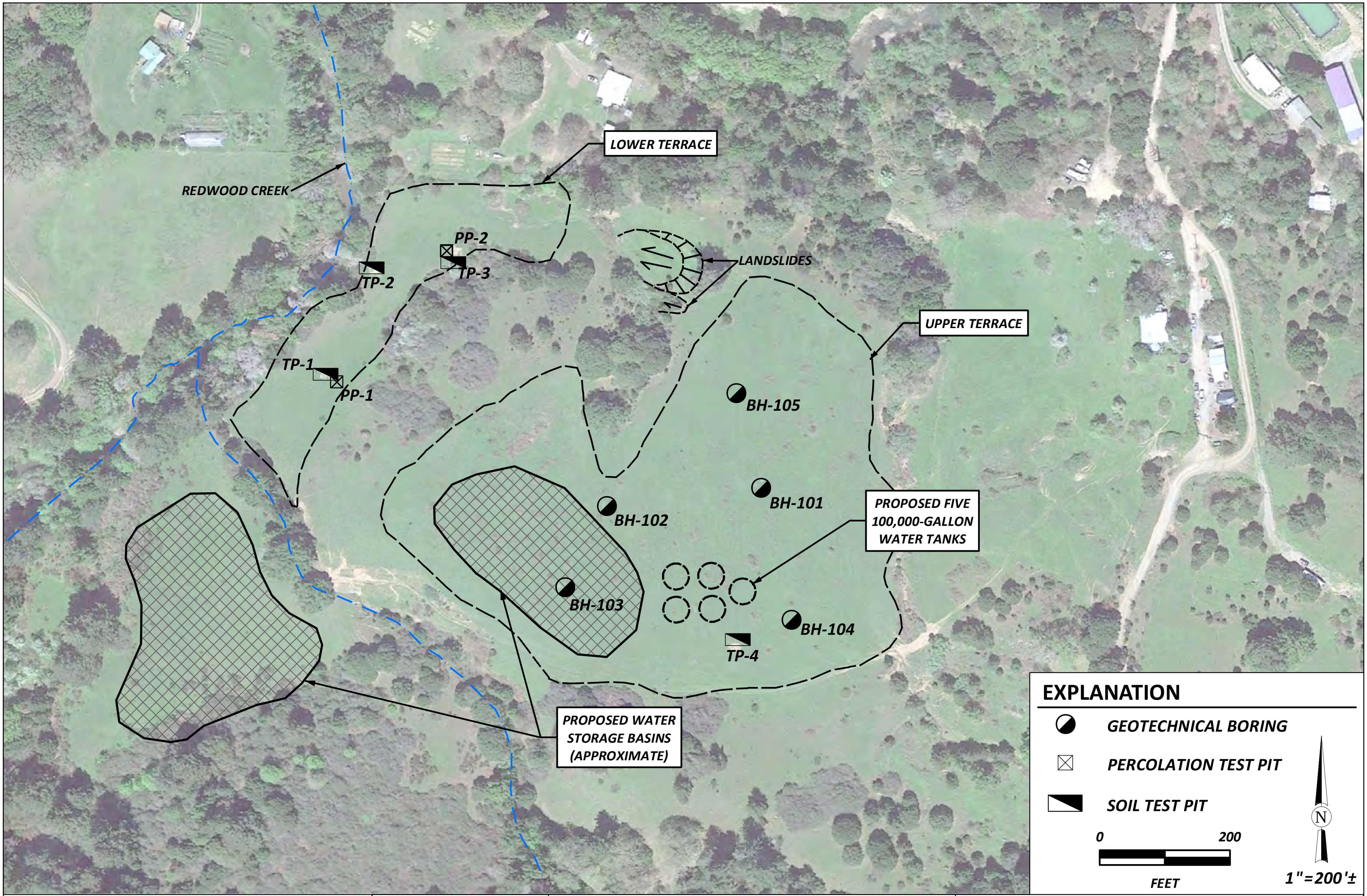

IMAGE SOURCE: GOOGLE EARTH, DATED 4/21/2019

Stillwater Sciences
Redwood Creek Flow Enhancement Project
Briceland, Humboldt County, California

Site Map Showing
Test Locations
SHN 018135

August 2021

Figure2_SiteMap_Rev2

Figure 2

- seismic design parameters in accordance with the applicable portions of the 2019 California Building Code (CBC) and American Society of Civil Engineers (ASCE) 7-16 Standard, including site soil classification, seismic design category, and spectral response accelerations;
- recommendations for site improvements, including site and subgrade preparation, fill material, placement, and compaction requirements;
- discussion and recommendations for storage basin construction, including strategies to enhance the retention capacity of site soils; and
- recommendations for observation of storage basin construction, materials testing and inspection, and other construction considerations.

3.0 Field Investigation and Lab Testing

Geologists from SHN conducted site visits on August 27 and 28, 2018, to oversee the advancement of three exploratory geotechnical borings (BH-101 through BH-103) and oversee the excavation of four soil test pits (TP-1 through TP-4) and two percolation pits (PP-1 and PP-2). We conducted a supplemental geotechnical investigation in October 2020 that consisted of drilling two additional borings to further characterize the subsurface conditions in support of a slope stability analysis that was conducted by Stillwater Sciences. The exploration locations (borings and test pits) were chosen based on the initial locations of the proposed water storage basin and plumbing infrastructure to assess sub-surface soil and groundwater conditions, and infiltration rates (Figure 2). The project has since evolved with the proposed storage basins shown on Figure 2. Our exploration target depths were dictated based on our understanding of the desired depth of the proposed storage basin and related infrastructure at the time of our investigation.

Classifications of the earth materials encountered in the borings and test pits were made during the field investigation in general accordance with the Manual-Visual Classification Method (ASTM-International [ASTM] D 2488). The final boring and test pit logs, presented in Appendix 2, were prepared based on the field logs, examination of samples in the laboratory, and laboratory test results.

Selected soil samples were tested in SHN's certified soils-testing laboratory in Eureka, California and Cooper Testing Labs in Palo Alto, California to determine index properties of the subsurface materials. Samples were tested for in-place moisture content and dry density at SHN; hydraulic conductivity tests (falling head permeability test) were conducted by Cooper Testing Labs. Laboratory test results are presented in Appendix 3.

4.0 Site Conditions

The following sections describe the geologic setting of the site, the site surface and subsurface conditions, and subsurface soil and groundwater conditions encountered at the time of our field exploration.

4.1 Geologic Setting

The proposed project is situated on a pair of adjacent stream terraces east of the confluence of Miller Creek and Redwood Creek in Briceland, California. The site of the proposed 3.8-million-gallon water storage basin is situated on an elevated river terrace approximately 80 feet above the active channel of Redwood Creek ("upper terrace" on Figure 2). The low terrace ("lower terrace" on Figure 2) is approximately 10 feet above the active channel of Redwood Creek. The two terraces are separated by a 60- to 70-foot-high terrace riser with slope gradients of about 40 percent. The 5.7-million-gallon water storage basin is proposed just upstream of the mapped lower terrace.

Published geologic mapping indicates the upper terrace is a "Holocene- to Pleistocene-age river terrace," and the lower terrace is situated on "Quaternary-age alluvium" (Spittler, 1984). In our opinion, the elevation of the upper terrace above Redwood Creek precludes it being of Holocene age; as such, we interpret this higher geomorphic surface to reflect significant tectonic uplift and to be of late Pleistocene age (or older). The river terrace deposits are described as:

> "dominantly sand and gravel with minor amounts of silt and clay, deposited during higher stands of major streams and rivers." The alluvium is described as: "unconsolidated sand, gravel and silt, deposited above active channel; in places grades into river terrace deposits" (Spittler, 1984).

These materials are likely of Holocene age.

Bedrock underlying the site is mapped as Tertiary-age Yager formation (Spittler, 1984). Spittler describes the Yager formation as: "siltstone, sandstone, silty shale, mudstone, and conglomerate; moderately well consolidated; highly sheared in places; silty shale and mudstone often disintegrates by slaking when wetted; sandstone units are generally massive; finer-grained strata are often well bedded." Spittler (1984) has mapped areas of "disrupted ground" on upland slopes to the east and south of the project site. Disrupted ground is described as:

> "Irregular ground surface caused by complex landsliding processes resulting in features that are indistinguishable or too small to delineate individually at the map scale; also may include areas affected by downslope creep, expansive soils, and/or gully erosion; boundaries are usually indistinguishable. (Spittler, 1984).

This vague geomorphic description is commonly applied to prairie ground in Humboldt County, in areas with irregular ground that often reflects erosion or soil creep (as opposed to landsliding).

The site is approximately 4,000 feet southwest of the Briceland fault, which is part of the Garberville-Briceland fault zone. According to Kelsey and Carver (1988), the Garberville-Briceland fault zone is a discontinuous series of north-northwest trending lineaments that extend south-southeast from Bull Creek, through Garberville, to just north of Laytonville. The fault zone can be traced as a 4-kilometer-long, north-northwest trending zone (approximately 200 meters wide) of sag ponds, notched ridges, and aligned springs. The Garberville-Briceland fault zone is not zoned as active by the State of California (CGS, 2018).

4.2 Site Surface and Subsurface Description

Our subsurface explorations were focused on the site of the proposed 3.8-million-gallon storage basin on the upper terrace and the lower terrace, downstream of the current proposed 5.7-million-gallon storage basin. Subsurface investigation at the site of the 5.7-million-gallon storage basin is planned for the future. Descriptions of these sites are included below.

4.2.1 Upper Terrace Site

The site of the proposed 3.8-million-gallon water storage basin is on the western portion of an elevated river terrace with an average elevation of 660 feet. The surface is gently sloping (approximately 4 percent) to the northwest. A small Class III stream flows across the upper terrace just east of the proposed storage basin site, toward Redwood Creek. This creek flows in a narrow gully across the upper terrace. A stream along the southwest side of the upper terrace flows in a deeply incised channel that forms a steep valley wall slope defining the southwestern edge of the terrace. A small, ephemeral creek originates at a spring in the swale on the terrace riser north of the storage basin. This stream flows across the lower terrace to Redwood Creek. The terrace is generally vegetated with grasses and is bordered by trees.

Test locations for the proposed storage basin include exploratory borings BH-101 through BH-103 and test pit TP-4 (Figure 2). At boring BH-101, we noted 27 feet of alluvium overlying bedrock (see the boring log in Appendix 2). Terrace deposits in this boring consisted of a fining upward sequence grading upward from a gravel lag to upper gravelly silts. Note that the gravel lag deposit at the base of the terrace section is noted on the project plans as the “gravel interface” directly above the bedrock surface. Siltstone/shale bedrock is present below the alluvium to the total depth of 51 feet below ground surface (BGS). This material is hard, breaks into angular chips when drilled, and is highly fractured.

Boring BH-102 encountered 15.5 feet of terrace deposits overlying bedrock. The terrace cover sediments in this boring can also be described as a fining upward sequence, with sandy silt overlying a gravelly lag deposit. Similar bedrock conditions were encountered in this boring relative to other borings, suggesting relatively uniform bedrock conditions beneath the storage basin. We note the comment on the boring log of “hammer bouncing,” referring to the difficulty in advancing the sampler into the bedrock at depth.

Boring BH-103 encountered 20.5 feet of terrace deposits overlying bedrock. A similar fining upward sequence was encountered in this boring. Siltstone/shale bedrock is present beginning at a depth of 20.5 feet to the total depth of 50.5 feet BGS.

Soils encountered in TP-4, located on the uphill portion (back edge) of the terrace, consist of dark brown, medium stiff, silt with sand (ML) and brown, stiff, lean clay with sand (CL) to a depth of 8 feet BGS. We note the fine-grained material in this pit, and infer that the material is, in part, slope wash (colluvium) veneering the alluvium along the back edge of the upper terrace.

We note that the alluvial soils underlying the upper terrace are noted to have clay skins, as well as iron oxide or manganese staining. These are weathering byproducts that reflect the age of this older, uplifted terrace.

Laboratory test results for samples collected from the borings indicate moisture contents that range from 11.8 to 27.4 percent and dry densities that range from 89 to 115 pounds per cubic foot (pcf).

Falling head permeability testing on samples collected from BH-101 and BH-102 revealed hydraulic conductivity of $3x10^{-07}$ centimeters per second (cm/sec), $5x10^{-06}$ cm/sec in BH-101, and $8x10^{-06}$ cm/sec in BH-102. These values suggest low permeability for the alluvial materials in area of the proposed storage basin.

Laboratory test results are presented in Appendix 3.

4.2.2 Lower Terrace Site

The lower terrace is approximately 100 feet east of Redwood Creek with an average elevation of approximately 580 feet. The 5.7-million-gallon water storage basin is planned on an analogous terrace, immediately upstream of our mapped lower terrace along Redwood Creek. We did not conduct a subsurface investigation in the location of this storage basin, but consider the conditions to be similar. Further subsurface investigations at this site are planned at a future date.

The lower terrace is west of the proposed storage basin site, on a generally planar surface that is gently sloping (less than 5 percent) to the northeast. The site is vegetated with grasses and is bordered by trees.

Test pits TP-1 through TP-3 were excavated on the lower terrace (Figure 2). Percolation pits PP-1 and PP-2 were excavated adjacent to TP-1 and TP-3, respectively. All the pits exposed alluvial soils, with test pit TP-2 reaching the bedrock abrasion surface beneath the alluvium. Alluvial soils in these pits consisted of interbedded gravels and fine-grained over-bank deposits (silts and clays). These materials are generally loose and non-cemented or mildly cemented.

Falling head permeability testing conducted on a sample collected from TP-3 revealed hydraulic conductivity of $7x10^{-05}$ cm/sec.

Soils encountered in the exploration locations are consistent with the mapped geology for the area; mainly sediments associated with streams and bedrock associated with the Yager formation.

4.2.3 Groundwater

Groundwater was encountered on the upper terrace in BH-101 at a depth of 26 feet BGS, in BH-102 at a depth of 11 feet BGS, and in BH-103 at a depth of 15 feet BGS. In each case, groundwater was perched within about 5 feet of the bedrock surface. Wet zones noted in the underlying bedrock are likely associated with water-bearing bedrock shears. Soil mottling, an indicator of the presence of historical high groundwater conditions, was observed in some of the test locations, at varying depths. On the upper terrace, mottled soils were observed in BH-102 and BH-103 at a depth of 3 feet, and in TP-4 at a depth of 2.5 feet. Groundwater was not encountered in TP-4.

On the lower terrace, mottled soils were observed in TP-1 at a depth of 3 feet. Groundwater was encountered on the lower terrace in TP-2 at a depth of 9 feet BGS and in TP-3 at a depth of 9.5 feet BGS. Groundwater levels can be expected to fluctuate seasonally on the order of several feet in elevation. We anticipate shallow groundwater conditions to occur on the lower terrace during the rainy season.

Stillwater Sciences collected additional groundwater data, subsequent to our field investigation, within wells installed in several boreholes and test pits and results are included in the basis of design report for the project. Based on the proposed excavation depths for the project, groundwater may be encountered during grading and construction for the proposed storage basins and related infrastructure.

4.3 Percolation Tests

Percolation testing was conducted on the lower terrace, adjacent to TP-1 and TP-3, to determine approximate infiltration rates. Initially, an infiltration gallery was proposed on the lower terrace, but the project has evolved, and the infiltration gallery is no longer being proposed.

Percolation testing consisted of digging 12-inch deep by 12-inch-wide test holes, at desired test depths. The soils exposed in the test holes were then presoaked for up to an hour prior to testing. Testing consisted of filling the holes with water and recording the rate of drop of the water in inches per minute. Percolation testing in pit PP-1 revealed a percolation rate of 6 minutes per inch at a depth range of 24 to 36 inches BGS. Testing in PP-2 revealed a percolation rate of 10 minutes per inch at a depth range of 18 to 30 inches BGS. These percolation rates are relatively fast and are typical for the soils encountered. Results of the test are included on the test pit logs in Appendix 2.

5.0 Geologic Hazards

Potential geologic/geotechnical hazards common to the local area include seismic ground shaking, surface fault rupture, seismically induced ground deformation (liquefaction, coseismic compaction, and lateral spreading), slope stability and flooding. The assessment of these potential hazards is presented below.

5.1 Seismic Ground Shaking

The project site is in a seismically active area with the potential for strong earthquakes and strong ground shaking. As stated above, the site is west of the Garberville-Briceland fault zone. This fault zone is not considered active by the State of California (CGS, 2018). The site is located approximately 9.5 miles northeast of the northern most extent of the San Andreas fault. Strong seismic ground shaking should be expected during the economic lifespan of the proposed water storage basins and water storage tanks. Seismic design parameters are presented below in Section 6.1.

5.2 Surface Fault Rupture

The project site is not located in an Earthquake Fault Zone (CGS, 2018). The nearest active fault is the San Andreas fault, which is approximately 9.5 miles southwest of the project site. The San Andreas fault is a northwest-trending, strike-slip fault. Surface ruptures associated with 1906 San Francisco earthquake were identified at Shelter Cove (Lawson, 1908). The proposed project is situated on surfaces that are gently-sloping and generally planar, which are useful geomorphic surfaces for the interpretation of past fault deformation, if it is present. During our field visit, we did not observe any geomorphic evidence suggesting recent surface rupture.

5.3 Liquefaction

Liquefaction is the sudden loss of soil shear strength due to a rapid increase of soil pore water pressure caused by cyclic loading from a seismic event.

Generally, in order for liquefaction to occur, the following soil conditions are needed:

- Non-plastic granular soils—Sand, silty sand, sandy silt, and some gravels
- A shallow depth to groundwater—Less than 50 feet BGS
- Low relative density soil—Standard penetration test (SPT) blow count ($[N_1]_{60}$) less than 30, usually associated with materials of young geologic age

The adverse effects of liquefaction include localized ground settlement, ground cracking and expulsion of water and sand (sand boils), the partial or complete loss of bearing and confining forces used to support loads, amplification of seismic shaking, and lateral spreading.

Susceptibility to liquefaction decreases with increasing geologic age due to the effects of weathering and the degree of densification, compaction, and/or cementation. Based on the published results of geotechnical testing and post-earthquake studies, the susceptibility of sediments to liquefaction can be directly correlated to the type, origin, and age of the deposits. Geologic materials most susceptible to liquefaction are geologically recent (that is, late Holocene age) sand- and silt-rich deposits, located adjacent to streams, rivers, bays, or ocean shorelines. According to Youd and Hoose (1978), “areas especially vulnerable to ground failure have been over steepened slopes, such as streambanks and coastal bluffs, and lowland deposits, principally Holocene flood plain deposits, deltaic deposits, and poorly compacted fills.”

Our subsurface investigation revealed the upper terrace to be underlain by stiff to hard non-plastic fine-grained deposits with $(N_1)_{60}$ values that were locally less than 30, and medium dense non-plastic coarse-grained deposits with $(N_1)_{60}$ values that were locally less than 30. Groundwater was encountered on the upper terrace at depths ranging from 11 to 26 feet BGS. If geologically youthful, these materials would be marginally liquefiable under extreme circumstances. Given that the materials beneath the upper terrace are described as having clay skins and iron and manganese accumulations, it is likely the alluvium on the upper terrace is too old and well cemented to liquefy. We consider that to be a low potential for liquefaction on the upper terrace.

The lower terrace is underlain by medium stiff to stiff plastic fine-grained deposits and medium dense to dense coarse-grained deposits. Groundwater was encountered on the lower terrace in TP-2 at a depth of 9 feet BGS and in TP-3 at a depth of 9.5 feet BGS. These materials are described as loose to mildly cemented, and we interpret their age as being Holocene. As such, we conclude there is a low to moderate potential for liquefaction at the lower terrace under strong, sustained ground shaking.

5.4 Lateral Spreading

Lateral spreading is defined as lateral earth movement of liquefied soils, or competent strata riding on a liquefied soil layer, downslope toward an unsupported slope face (such as a coastal bluff), or an inclined slope face. In general, lateral spreading has been observed on low- to moderate-gradient slopes and has been noted on slopes inclined as flat as one degree.

Due to the age of the alluvial sediments on the upper terrace and the low potential for liquefaction, there is a low potential for lateral spreading to impact the storage basin. There is a modest potential for lateral spreading on the lower terrace, but it is unlikely to extend to the back edge of the terrace to the area where the majority of plumbing infrastructure is proposed.

5.5 Slope Stability

Disrupted ground is shown on the geologic map (Spittler, 1984) on upland slopes southeast and east of the project site. Aerial imagery shows features (such as small landslide scars, rills, and gullies) that are consistent with the mapped disrupted ground. These localized areas of subtle mass wasting are unlikely to impact the areas under consideration for development here. Both project sites are on planar, generally level ground.

The upper terrace is flanked by descending slopes with gradients up to 40 percent to the northwest and north. A review of aerial imagery shows the northern slope, adjacent to the small spring-fed drainage, has two small landslides. Other shallow slides were observed along gully sidewalls, indicating that slope instability is most common on steep streamside slopes. We did not observe evidence for landsliding on the planar terrace riser, across which the piping for the upper storage basin will extend.

Due to the proximity to nearby active faults and the potential for strong seismic ground shaking to occur at the site, there is moderate potential for localized slumping or small landslides to occur along steep streamside slope. These areas should be avoided to the extent feasible in the project design. It may be prudent for piping to and from the water storage basin to have shut-off valves in case of uncontrolled releases that may occur if the plumbing system is compromised by slope movement or other means.

Using data obtained in the SHN borings and in our October 2021 supplemental investigation, Stillwater Sciences conducted a slope stability analysis titled “Supplemental Geotechnical Investigations and Slope Stability Analyses for the Marshall Ranch Flow Enhancement Project-Technical Memorandum” in February 2021. Their analysis suggests that the majority of the project area is stable under current and proposed conditions. Their analysis, which contains our supplemental geotechnical investigation, is included in Appendix 4.

5.6 Flooding

The proposed project is located to the east of Redwood Creek. Both terraces (upper and lower) are located outside the mapped 100-year flood zone. Clearly, the upper terrace is outside the flood zone, and the flooding potential at that elevation is negligible. The lower terrace is 10 feet above the Redwood Creek channel and would be associated with a low potential for flooding under extreme conditions (floods exceeding the 100-year-flood level).

5.7 Conclusions Relative to Geologic Hazards

The project appears associated with a low exposure to geologic hazards. What low risk is associated with the site has been mitigated through development of an extremely conservative design plan. The proposed storage basins are designed as a largely below-grade, lined structures with modest embankments, and large setbacks from adjacent slopes. The proposed embankments are designed with a low permeability cut-off trench extending into the underlying bedrock in order to reduce lateral groundwater flow through the terrace deposits.

The primary geologic hazards at the site are seismic shaking and landsliding. Seismic shaking is a regional hazard and is regularly mitigated through standard engineering design.

The existing landslide hazard at the site is primarily associated with shallow slumping on the terrace riser below the reservoir site and above the upper terrace to the east. The risk of impacts associated with this hazard is negligible, due to the large setback of infrastructure from vulnerable slopes and the low permeability of the subsurface materials at the site.

The potential for sliding along the “bedrock interface” (that is, the slightly dipping contact between the bedrock abrasion surface and the overlying terrace deposits) is negligible. The basal part of the section of terrace deposits contacting the bedrock surface is described as a “lag deposit” that will be associated with large clasts with high surface friction. Bedrock beneath the terrace is structurally deformed and is associated with a variety of orientations; it is not forming a smooth planar surface.

6.0 Conclusions and Recommendations

Based on the results of our field and laboratory investigation, it is our opinion the project is feasible from a geohazard and geotechnical standpoint, if our recommendations are implemented during design and construction. The major geotechnical considerations for development of the proposed water storage basins, water tanks, and associated infrastructure include the potential for strong seismic ground shaking and the potential for instability on the moderately steep slopes on the northwest and north sides of the upper terrace.

6.1 Seismic Design Parameters

Based on the subsurface conditions encountered at our exploration locations, laboratory test results, and our interpretation of soil conditions within 100 feet of the ground surface, we classify the site as a Site Class C consisting of a “Very Dense Soil and Soft Rock” in accordance with Chapter 20 of ASCE 7-16. On this basis, the mapped and design spectral response accelerations were determined using the Structural Engineers Association of California (SEAOC) and California Office of Statewide Health Planning and Development (OSHPD) Seismic Design Maps (Accessed August 17, 2021) in conjunction with the site class and the site coordinates for the proposed project. Calculated values for ASCE 7-16 are presented in the following table.

Table 1. ASCE 7-16 Spectral Acceleration Parameters—Redwood Creek Flow Enhancement Project Site (40.104385° N, -123.900039° W)

Parameter	0.2 Second	1 Second
Maximum Considered Earthquake Spectral Acceleration (MCE_R)	S_S = 1.823	S_1 = 0.865
Site Class	C	
Site amplification factor	F_a = 1.2	Fv = 1.4
Site-modified spectral acceleration	S_{MS} = 2.188	S_{M1} = 1.211
Numeric seismic design value	S_{DS} = 1.458	S_{D1} = 0.807
Seismic Design Category (SDC)	F	
MCE_G peak ground acceleration (PGA)	0.761	
Site amplification factor at PGA (F_{PGA})	1.2	
Site modified peak ground acceleration (PGA_M)	0.913	

6.2 Site Preparation and Grading

Site preparation includes removal of debris, organics, organic topsoil, loose soil and/or soft bedrock, and any other unsuitable material. Site preparation operations should extend at least 5 feet beyond the limits of improvements. We anticipate that stripping to a depth of about 2 to 4 inches will be required to remove the organics and topsoil. Deeper stripping may be locally required to remove concentrations of vegetation, such as brush and tree roots. Where the removal of large tress is required, it will be necessary to remove all major root systems, then fill the excavations with properly placed engineered fill compacted to at least 90 percent relative compaction[1]. The cleared vegetation and debris should be removed from the site, but the strippings can be stockpiled for reuse in landscape areas.

Any vegetation and organic topsoil with more than 2 percent organic material by dry weight should be removed. The Geotechnical Engineer should observe and approve the prepared site prior to any excavation, subgrade preparation, and placement of fill or improvements.

All areas to receive engineered fill should be stripped of loose and/or soft surface soils and vegetation and benched into firm soil/rock. If zones of weak or saturated soils are encountered during site preparation, they should be removed by further excavation to expose firm natural soil/rock and replaced with engineered fill.

Non-engineered fill that may be present within the limits of grading should be identified and excavated to expose firm natural ground. This includes backfill in SHN test pits located within areas to be graded, and/or where structures are planned. In areas intended to support new water storage tanks and engineered fill, and for a distance of at least 5 feet beyond the limits of these improvements, topsoil and loose native soils should be excavated to expose firm, undisturbed native soil. The resulting surface created by removal of non-engineered fill and loose soils should be checked by the Geotechnical

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[1] Relative compaction refers to the in-place dry density of a soil expressed as a percentage of the maximum dry density of the same soil, as determined by the ASTM D1557 compaction test procedure. Optimum moisture is the water content (percentage by dry weight) corresponding to the maximum dry density.

Engineer or qualified representative to determine whether further excavation is required to remove any loose or unsuitable materials. The approved surface may then be brought to pad grade with placement of engineered fill.

Fill placed in swales and drainage channels should be benched into firm soils along the bottom and sides to provide a firm level surface on which to place new engineered fill. Cut and fill slopes up to 5 feet in height should be placed no steeper than 1.5H:1V and 2H:1V (horizontal to vertical), respectively. Higher or steeper slopes should be reviewed by this office for stability.

Site grading during and shortly after the rainy season is typically difficult and/or uneconomical. On-site soils will have moisture contents well above optimum and will require greater than normal spreading, mixing and/or aeration to achieve a near-optimum moisture content suitable for required compaction.

The Contractor shall be responsible for the stability of all temporary excavations and should comply with applicable Occupational Safety and Health Administration (OSHA) regulations (California Construction Safety Orders, Title 8). The Contractor should periodically monitor all open cuts for evidence of incipient stability failures.

6.3 Select Engineered Fill

Fill placed in areas to support proposed water-tank foundations should meet the requirements for select engineered fill. Select engineered fill should have less than 2 percent by dry weight of vegetation and deleterious material and should meet the gradation requirements presented in Table 2.

Table 2. Fill Gradation Criteria

Sieve Designation	Percent Passing by Dry Weight
3-inch (50 mm)[a]	100
2½-inch (37.5 mm)	85 minimum
¾-inch (19 mm)	70 minimum
No. 4 (4.75 mm)	60 minimum
No. 200 (75 µm) [b]	5 minimum, 30 maximum

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[a] mm: millimeters
[b] µm: micrometers

We anticipate that on-site soils will be suitable for reuse as select engineered fill following removal of debris, organics, and any other unsuitable material. Fine-grained soil with a liquid limit greater than 40 and a plasticity index greater than 15 should not be used as select engineered fill. If clayey soils do not meet the plasticity requirements, mixing of the clayey soils with sandier soils may be required. Crushing and/or removal of rock particles greater than 3 inches in size will be required. Select engineered fill should have a low corrosion potential, which is defined as a minimum resistivity of 2,000 ohms-cm and maximum sulfate and chloride concentrations of 250 parts per million (ppm). In addition, we do not recommend using river-run material as select engineered fill; crushed, angular material should have at least 50 percent of the material (as determined by the material's dry weight) containing a minimum of two fractured faces.

Engineered fill should be placed in loose lifts not exceeding 8 inches in thickness and compacted to a minimum of 90 percent relative compaction. The Geotechnical Engineer should approve all fill prior to placement.

A qualified field technician should be present to observe fill placement and perform field density tests in accordance with ASTM D 6938 at random locations throughout each lift to verify that the specified compaction is being achieved.

Samples of proposed import fill materials should be submitted to SHN for approval at least three business days prior to use at the site.

6.4 Water Tank Foundations

Based on our geotechnical investigation, we conclude that the proposed new water storage tanks may be supported by a concrete ring-wall footing provided that a level pad is excavated at each tank and the foundations are underlain by at least 12 inches of engineered fill in order to provide uniform support under the entire tank. We recommend that over-excavation be performed across the entire footprint of the new water tanks to a minimum depth of 30 inches below the proposed subgrade surface, or more if necessary, such that a minimum of 12 inches of new engineered fill is present beneath the “base of footing” depth. The limits of over-excavation should extend at least 5 feet horizontally from the edges of planned foundations. Additional over-excavation may be required to remove soft, wet, yielding, or otherwise unsuitable material. The depth and extent of additional over-excavation should be approved in the field by the Geotechnical Engineer, or their qualified representative, prior to placement of engineered fill.

The exposed subgrade should be nearly level and should be scarified to a minimum depth of 6 inches, moisture conditioned or aerated, and compacted to at least 90 percent relative compaction. The approved surface may then be brought to pad grade with placement of properly compacted engineered fill compacted to a minimum of 90 percent relative compaction.

Footings should be embedded at least 18 inches below the lowest adjacent grade. SHN defines lowest adjacent grade as the tank bottom, or exterior soil subgrades, whichever results in a deeper footing. Footing thicknesses and widths should meet the minimum requirements in the 2019 CBC and America Water Works Association (AWWA) Standard D100-05. Footings bearing on a minimum of 12 inches of properly compacted engineered fill should be designed using a maximum allowable bearing capacity of 3,000 pounds per square foot (psf) for dead plus normal duration live loads. This allowable bearing capacity may be increased by one-third for total load conditions, including wind and seismic.

Base friction resistance may be calculated using an ultimate friction coefficient of 0.35 for concrete on fill. If AB is used as engineered fill beneath the new water tank, an ultimate base friction coefficient of 0.4 may be used. For the steel tank bottom on any soil, a friction coefficient of 0.25 should be used. Passive resistance may be calculated using an equivalent fluid unit weight of 300 pcf. The recommended passive resistance is reduced by a factor of about 1.5 from the ultimate value to reduce deflections to tolerable amounts. The recommended passive pressure and friction coefficients may be combined, without reduction, for calculating total lateral resistance. The passive resistance contributed by soils within 1 foot of the ground surface should be neglected unless these soils are protected and confined by a slab-on-grade or pavement. Gaps between the footing and adjacent ground should be completely backfilled using engineered fill, concrete, or lean cement slurry with a 28-day unconfined compressive strength of at least 100 pounds per square inch (psi).

We recommend that a representative of the Geotechnical Engineer observe all foundation excavations prior to the placing of reinforcing steel. This inspection should be conducted to ensure that the bottoms and sides of all foundation excavations are level or suitably benched and are free of loose or soft soil, ponded water, and debris. If any loose pockets are encountered in the bottom of the foundation excavations, they should be over-excavated, and the base of the excavation should be backfilled with lean concrete. It is important that foundation excavations be clean and free of loose or soft soils, water, or other debris at the time concrete is placed.

The ring-wall footing should be reinforced to resist hoop stresses within the wall. Hoop stresses may be calculated by assuming outward lateral pressure acting on the foundation equal to 0.45 times the vertical pressure imposed on the subgrade within the ring-wall. Lateral soil pressures acting on buried vaults that may be constructed adjacent to the tank should likewise be calculated using a lateral soil pressure equal to 0.45 times the vertical pressure acting on the adjacent subgrade.

Tank bottoms are typically domed upward from the perimeter to the center to allow differential settlement to occur without overstressing the tank bottom in tension. The settlement is anticipated to be greater at the center than at the perimeter. The imposed loads under full hydrostatic pressure may result in some settlement of the underlying engineered fill. Post-construction vertical settlement due to full hydrostatic loading is estimated at ½ inch near the center of the tank. Differential settlement is estimated at less than ½ inch between the center and the perimeter ring footing.

6.5 Water Storage Basin Design and Construction

We understand the intent of the storage basins is to retain water, using a plastic liner. However, considering the potential for liner failure over time, features are included into the design to reduce the risk of downslope saturation even with liner failure. Hydraulic conductivity tests from materials collected at the site suggest low permeability. The "gravel interface" shown on the project plans would be the stratigraphic interval most likely to facilitate leakage from the storage basins (although we note that the hydraulic conductivity testing on a sample of this material indicated low permeability). Careful design and construction of the storage basins will be critical in ensuring they retain water. Attention is directed to the discussion below regarding a core trench and the need to develop a low permeability core within the embankments.

- The interior and exterior slopes of the engineered fill embankments for the storage basins should be inclined no steeper than 2.5H:1V and 2H:1V, respectively.
- The crest of the storage basin embankments should be at least 2 feet above the maximum water level (freeboard) to minimize the potential for breaching during a seismic event.
- The crest of the storage basin embankments should be at least 6 feet wide for embankments less than 10 feet high; taller embankments should have crest widths of at least 10 feet.

- A core trench (equivalent in width to the crest width) should be excavated beneath the axis of dam embankments. The trench should extend at least 2 feet vertically into firm, native soils or rock. This trench should be included regardless of the slope upon which the embankment is built.
- If embankment fills are placed on existing slopes steeper than 5H:1V, then the fill should be benched into firm, native soil a minimum of 2 feet, and the toe should be supported by a keyway. The keyway should be at least 10 feet wide and sloped 2 percent into the slope.
- Finished grading should be designed such that ponding or concentrated runoff is avoided. Where concentrated runoff does occur (such as at storage-basin outlets), flow energy should be dissipated by installing rock slope protection (RSP). A permeable, nonwoven geotextile fabric should be placed over the prepared ground surface before installation of any RSP.

For storage basin construction, we recommend the following:

- All earthworks should be performed by an experienced, licensed contractor.
- Strip and remove all existing vegetation and root systems from the footprint of the storage basin, plus an additional 5 feet outward. Note that the footprint area is delineated by the total extent of earthwork to be performed (that is, the perimeter of all cut and fill surfaces).
- During excavation of the design cuts, stockpile the excavated spoils for future use as embankment fill. All embankment fills should be free from woody debris, roots, organics, and rocks retained on the 3-inch sieve. If coarser soils (gravel and/or cobbles) are encountered during excavation and construction, measures should be taken to remove the coarse material. A rock sorter and/or crusher may be required to remove/modify the oversized particles (rocks retained on a 3-inch sieve). Embankment fill should be comprised of greater than 50 percent fine-grained material (silts and clays) to minimize water seepage through the embankment. To the extent feasible, segregate fine-grained materials and blend the remainder of the stockpiled material into a uniform mixture.

  The Geotechnical Engineer or qualified representative should be present during excavating and stockpiling to ensure the adequacy of the excavated material. If the excavated material is deemed inadequate for use as fill, then an alternate source must be determined (from either a borrow area elsewhere onsite or soil imported from offsite).

  Excess fill spoils to be used as structural fill, intended to support the proposed solar arrays, should be engineered according to our recommendations for engineered fill as described above.
- After completion of the design cuts, scarify the upper 6 inches of exposed subgrade soils, moisture-condition to a uniform moisture content of at least 2 percent above optimum, and compact to at least 90 percent relative compaction.
- Place embankment fill materials in horizontal layers no greater than 8 inches in loose thickness, moisture-condition to a uniform moisture content at least 2 percent above optimum, and compact to at least 90 percent relative compaction.
- To enhance the ability of the storage basin to retain water, place the fine-grained, low permeability spoils that were segregated during stockpiling in the center of the embankment to create a low permeability core.

- Immediately following completion of earthwork, exterior slopes should be seeded/planted with suitable erosion-control vegetation (native grass, for example). Trees and large shrubs should not be planted on the embankment.
- Sufficient construction inspection and materials testing should be performed, as determined by the Geotechnical Engineer or qualified representative, to confirm that the storage basin is constructed in accordance with the design recommendations. At a minimum, the following should be tested for adequate compaction:
    - Scarified and compacted subgrade soils
    - Initial lifts of embankment–fill material to verify the contractor's means and methods
    - Middle lifts of embankment–fill material (that is, the lift that is halfway up the total design height of the embankment)
    - Final lifts of embankment–fill material

6.6 Storage Basin Spillway

The proposed water storage basins will require the use of an engineered spillway. We understand current environmental regulatory standards require discharge from a storage basin is away from any slopes or watercourses. Discharge shall be directed away from steep slopes. Design and construction of the spillway should follow recommendations for storage basin design and construction presented in Section 6.5 above, namely, "where concentrated runoff occurs, flow energy should be dissipated by installing rock slope protection (RSP). A permeable, nonwoven geotextile fabric should be placed over the prepared ground surface prior to the installation of any RSP."

7.0 Limitations

This report is based on an investigation of inherently limited scope. The work scope and investigative approach have been tailored to meet the minimum requirements for geotechnical and geologic reporting, while reflecting the low-impact approach of the primary intended uses. If the intended use for the property changes, additional investigation and reporting may be required.

Our conclusions and interpretations are also based on conditions at the time of our work. We cannot preclude changes that may occur in the future that could alter site conditions. This is especially true in Humboldt County, which is located in a dynamic geologic environment subject to large scale, catastrophic events (such as great earthquakes and large storms).

Lastly, this report applies only to the site described above. Because of the high degree of variability in geology in this region, it is not possible to extrapolate the results described herein to any other site. This report is to be considered in its entirety. No part, section, paragraph, sentence, or phrase is to be quoted, evaluated, or otherwise used without considering its context and relationship to the entire report.

We trust that this report provides the information you need at this time. If you have any questions or require additional information, please contact our office at (707) 441-8855.

Sincerely,

SHN

PAUL SUNDBERG
No. 9723
Signed 8-20-21

GARY D. SIMPSON
No. 2107
Signed 8-20-21

Paul Sundberg, PG 9723
Project Geologist

Gary Simpson, CEG 2107
Sr. Engineering Geologist

JOHN H. DAILEY
GE 256
EXP. 03/31/22
Signed 8-20-21

John H. Dailey, GE 256
Sr. Geotechnical Engineer

PRS:GDS:JHD:lam

Appendices:
1. Marshal Ranch Flow Enhancement Project Site Plan
2. Exploratory Boring and Test Pit Logs
3. Laboratory Results
4. Supplemental Geotechnical Investigations and Slope Stability Analysis for the Marshal Ranch Flow Enhancement Project–Technical Memorandum

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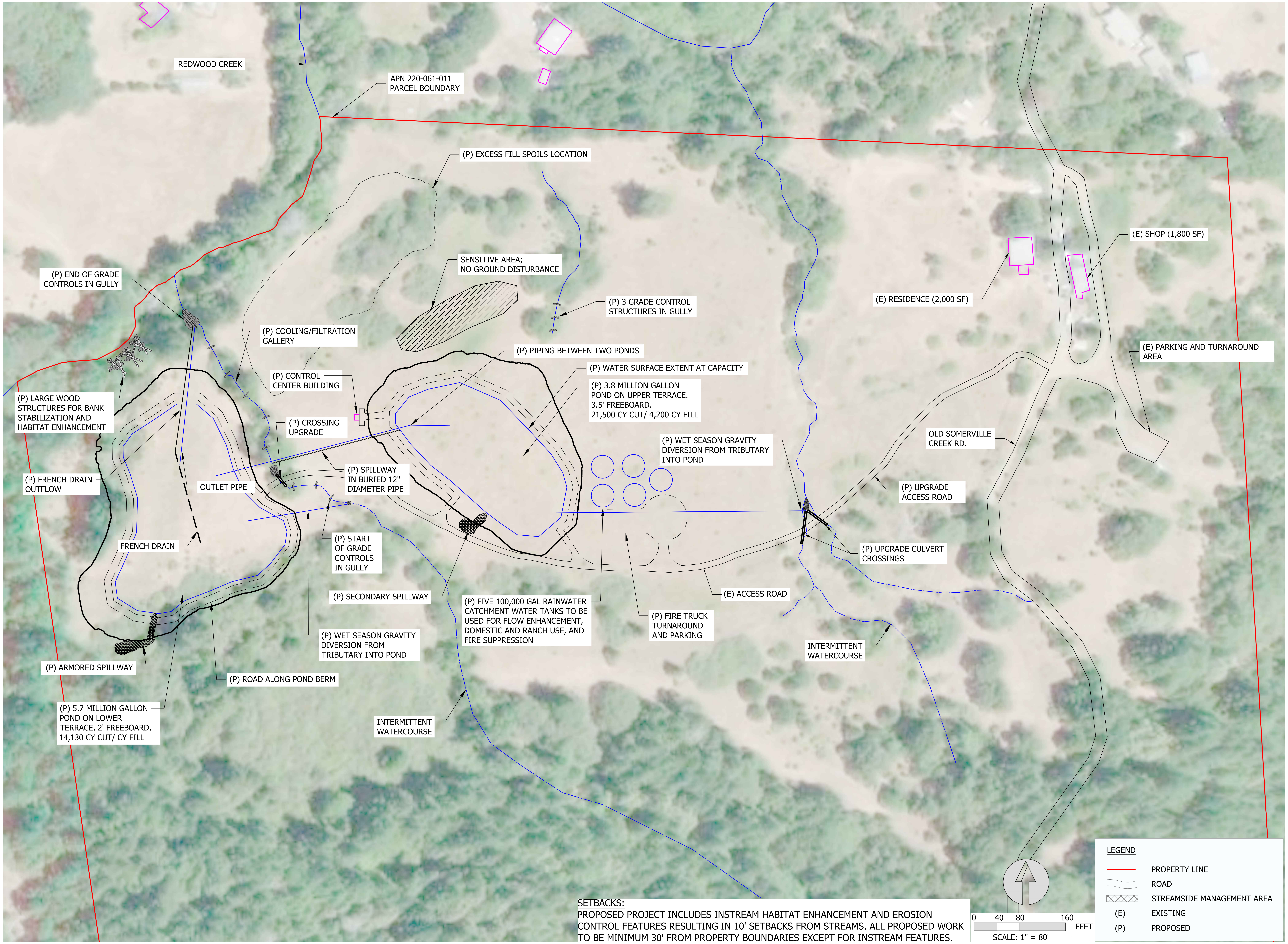
Marshal Ranch Flow Enhancement Project Site Plan

1



SETBACKS:
PROPOSED PROJECT INCLUDES INSTREAM HABITAT ENHANCEMENT AND EROSION CONTROL FEATURES RESULTING IN 10' SETBACKS FROM STREAMS. ALL PROPOSED WORK TO BE MINIMUM 30' FROM PROPERTY BOUNDARIES EXCEPT FOR INSTREAM FEATURES.

LEGEND

—	PROPERTY LINE
—	ROAD
▨	STREAMSIDE MANAGEMENT AREA
(E)	EXISTING
(P)	PROPOSED

MARSHALL RANCH FLOW ENHANCEMENT PROJECT

BRICELAND, CA

Stillwater Sciences
850 G STREET SUITE K
ARCATA, CA 95521
P: (707) 822-9607

JOEL MONSCHKE
C 79688
EXP. 9/22
CIVIL

PROJECT NUMBER: 603.04
SCALE: AS NOTED
DATE: 7/30/2021

DESIGN: JM
DRAWN: CL,TC
CHECKED: JM
APPROVED: JM

No. 79688
9-30-22

SITE PLAN

SHEET 3 OF 19

Exploratory Boring and Test Pit Logs

2

PROJECT: Redwood Creek Flow Enhancement Project
LOCATION: Briceland
GROUND SURFACE ELEVATION: 655 Feet
EXCAVATION METHOD: 7" O.D Hollow Stem Auger
LOGGED BY: A. Call

JOB NUMBER: 018135
DATE DRILLED: 8/27/18
TOTAL DEPTH OF BORING: 51.0 Feet BGS
SAMPLER TYPE: Modified Cal Barrel, SPT
Track Mounted Drill Rig

BORING NUMBER
BH-101

DEPTH (FT)	SAMPLE NO.	SS SAMPLES	BLOWS PER 0.5'	USCS	PROFILE	DESCRIPTION	% Moisture	Dry Density (pcf)	Unc. Com. (psf)	U.C. (psf) by P.P.	% Passing 200	REMARKS
0.0				ML		GRAVELLY SILT with SAND; Light brown, very stiff, damp, deeply weathered angular to subangular rock fragments, tight, clay skins and bridges.						ALLUVIAL DEPOSITS
-2.5												
-5.0		☒	11 18 23				23.2	94				
-7.5						Becomes brown, moist.						
-10.0		☒	9 13 13				27.4	93				
-12.5												
-15.0	☒	☒	6 19 35			Becomes hard; Alternating siltier and sandier intervals. Becomes increasingly larger, more common gravels.	14.8	114				Average Hydraulic Conductivity @ 16-16.5' = 3E-07 cm/sec Driller's note: At 20 feet BGS, becomes granular, "crunchy" when advancing.
-17.5												
-20.0	☒	☒	10 14 14	SM		SILTY SAND with GRAVEL; Brown and reddish brown, medium dense, wet, deeply weathered subangular gravels with strong manganese stain on fracture surfaces.	19.2	111				Average Hydraulic Conductivity @ 21-21.5' = 5E-06 cm/sec
-22.5												
				GW-GM		WELL-GRADED GRAVEL with SILT AND SAND; Brown, medium dense, saturated, poorly graded subrounded sand.						
-25.0 ▽	☒	☒	5 7 12									
-27.5		☒	34 50/5"			SILTSTONE/SHALE; Dark bluish-gray, damp to dry, competent, hard angular chips, intensely fractured.						BEDROCK Driller's note: At 27 feet BGS, becomes slow, difficult to drill. Water perched above 27
-30.0												

LOG OF BORING

PROJECT: Redwood Creek Flow Enhancement Project
LOCATION: Briceland
GROUND SURFACE ELEVATION: 655 Feet
EXCAVATION METHOD: 7" O.D Hollow Stem Auger
LOGGED BY: A. Call

JOB NUMBER: 018135
DATE DRILLED: 8/27/18
TOTAL DEPTH OF BORING: 51.0 Feet BGS
SAMPLER TYPE: Modified Cal Barrel, SPT
Track Mounted Drill Rig

BORING NUMBER
BH-101

DEPTH (FT)	SAMPLE NO.	SS SAMPLES	BLOWS PER 0.5'	USCS	PROFILE	DESCRIPTION	% Moisture	Dry Density (pcf)	Unc. Com. (psf)	U.C. (psf) by P.P.	% Passing 200	REMARKS
-30.0	☒		21 40 50/6"			SILTSTONE/SHALE; Dark bluish-gray, damp to dry, competent, hard angular chips, intensely fractured.						feet BGS.
-32.5												
-35.0												At 34 feet BGS, cuttings saturated, highly fluid.
-37.5												At 37 feet BGS, cuttings become less fluid. Decreasing moisture in cuttings with depth.
-40.0	☒		37 41 47									
-42.5												
-45.0												
-47.5												
-50.0	☒		36 50/5"									
-52.5						Boring terminated at 51 feet BGS. Installed Peizometer. Screen interval 47.8 feet BGS to 7.8 feet BGS. Blank fro 7.8 feet BGS to surface. #3 sand from bottom of boring to 5 feet BGS. Bentonite from 5 feet BGS to 1.0 feet BGS. Flush mount Christie Box installed at surface. Groundwater encountered at a depth of 26 feet BGS.						
-55.0												
-57.5												

PROJECT: Redwood Creek Flow Enhancement Project
LOCATION: Briceland
GROUND SURFACE ELEVATION: 649 Feet
EXCAVATION METHOD: 7" O.D Hollow Stem Auger
LOGGED BY: A. Call

JOB NUMBER: 018135
DATE DRILLED: 8/28/18
TOTAL DEPTH OF BORING: 51.0 Feet BGS
SAMPLER TYPE: Modified Cal Barrel, SPT
Track Mounted Drill Rig

BORING NUMBER
BH-102

DEPTH (FT)	SAMPLE NO.	SS SAMPLES	BLOWS PER 0.5'	USCS	PROFILE	DESCRIPTION	% Moisture	Dry Density (pcf)	Unc. Com. (psf)	U.C. (psf) by P.P.	% Passing 200	REMARKS
0.0				ML		SILT with SAND; Light brown, stiif, damp to dry, occassional deeply weathered subangular gravel, tight, clay skins and bridges.						ALLUVIAL DEPOSITS
-2.5			7 9 13			Becomes weakly mottled; gray, yellowish brown and brown.	11.3	89				
-5.0			15 21 23			Becomes very stiff Increased clay content; skins and bridges on clast surfaces. Becomes damp.	19.2	101				
-7.5												
-10.0 ▽			12 15 17	GW-GM		WELL-GRADED GRAVEL with SILT AND SAND; Brown, medium dense, wet, subrounded gravel and poorly graded sand, manganese stain on gravel fracture faces, free water observed on ped faces, clay skins and bridges observed on gravels.	15.1 16.7	110 111				Average Hydraulic Conductivity @ 10.5-11' = 8E-06 cm/sec
-12.5												
-15.0			12 24 35			SILTSTONE/SHALE; Dark bluish gray, damp to dry, competent, hard angular chips, intensely fractured.						BEDROCK
-17.5												
-20.0			20 36 50/4"									Hammer bouncing.
-22.5												
-25.0			25 36 50/3"									Hammer bouncing.
-27.5												
-30.0												

LOG OF BORING

PROJECT: Redwood Creek Flow Enhancement Project
LOCATION: Briceland
GROUND SURFACE ELEVATION: 649 Feet
EXCAVATION METHOD: 7" O.D Hollow Stem Auger
LOGGED BY: A. Call

JOB NUMBER: 018135
DATE DRILLED: 8/28/18
TOTAL DEPTH OF BORING: 51.0 Feet BGS
SAMPLER TYPE: Modified Cal Barrel, SPT
Track Mounted Drill Rig

BORING NUMBER
BH-102

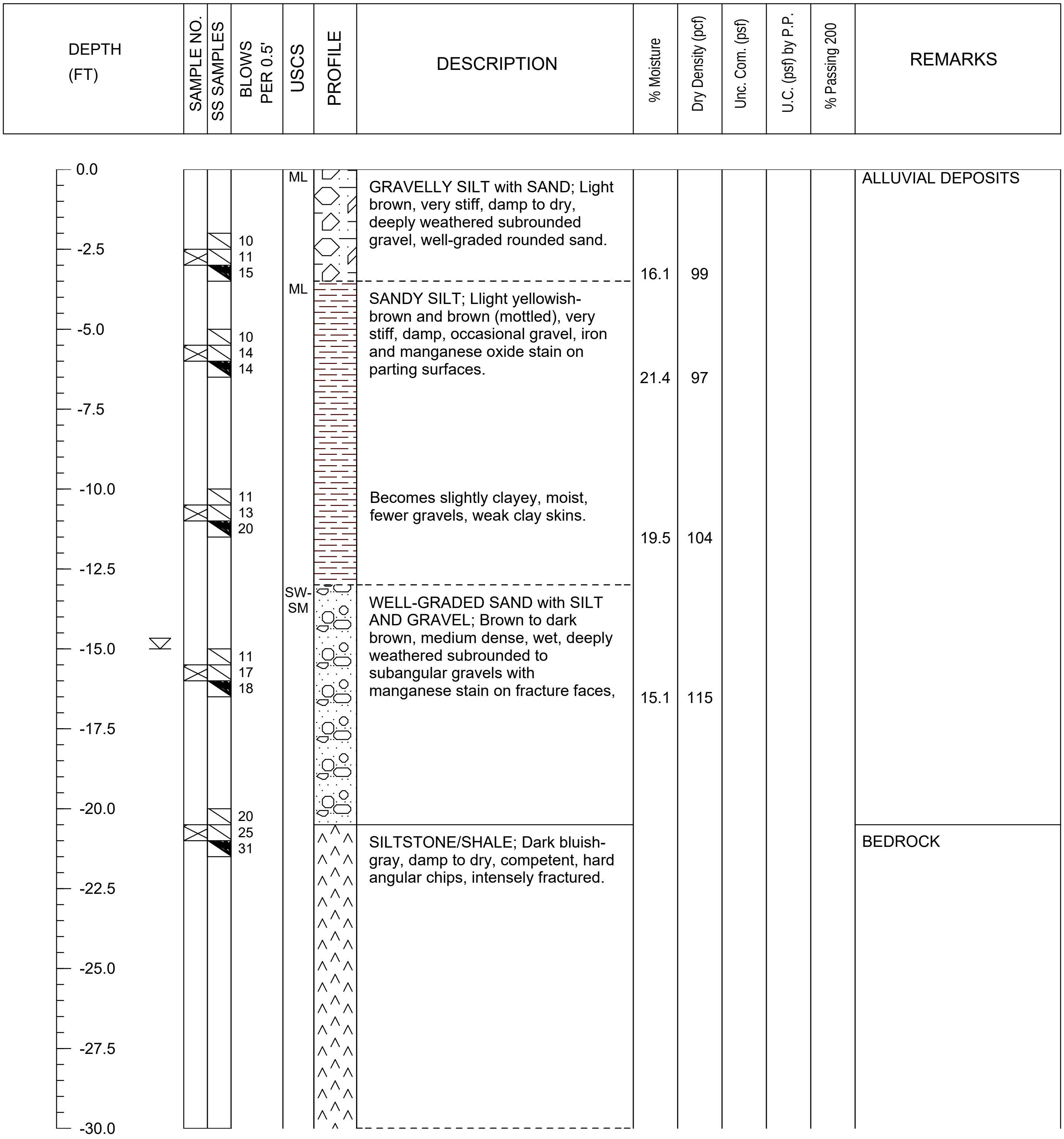
DEPTH (FT)	SAMPLE NO.	SS SAMPLES	BLOWS PER 0.5'	USCS	PROFILE	DESCRIPTION	% Moisture	Dry Density (pcf)	Unc. Com. (psf)	U.C. (psf) by P.P.	% Passing 200	REMARKS
-30.0	☒ ☒	☐ ☐	27 50/5"		^ ^	SILTSTONE/SHALE; Dark bluish gray, damp to dry, competent, hard angular chips, intensely fractured.						Hammer bouncing.
-32.5					^ ^							
-35.0					^ ^							
-37.5					^ ^							
-40.0	☒ ☒ ☒	☐ ☐ ☐	30 42 50/5.5"		^ ^							Hammer bouncing.
-42.5					^ ^							
-45.0					^ ^							
-47.5					^ ^							
-50.0	☒ ☒	☐ ☐	29 50/5.5"		^ ^							Hammer bouncing.
-52.5						Boring terminated at a depth of 51 feet. Groundwater encountered at a depth of 11 feet. Borehole backfilled with cuttings.						
-55.0												
-57.5												

LOG OF BORING

PROJECT: Redwood Creek Flow Enhancement Project
LOCATION: Briceland
GROUND SURFACE ELEVATION: 654 Feet
EXCAVATION METHOD: 7" O.D Hollow Stem Auger
LOGGED BY: A. Call

JOB NUMBER: 018135
DATE DRILLED: 8/28/18
TOTAL DEPTH OF BORING: 50.5 Feet BGS
SAMPLER TYPE: Modified Cal Barrel, SPT
Track Mounted Drill Rig

BORING NUMBER
BH-103



DEPTH (FT)	SAMPLE NO.	SS SAMPLES	BLOWS PER 0.5'	USCS	PROFILE	DESCRIPTION	% Moisture	Dry Density (pcf)	Unc. Com. (psf)	U.C. (psf) by P.P.	% Passing 200	REMARKS
0.0				ML		GRAVELLY SILT with SAND; Light brown, very stiff, damp to dry, deeply weathered subrounded gravel, well-graded rounded sand.						ALLUVIAL DEPOSITS
-2.5			10 11 15	ML		SANDY SILT; Light yellowish-brown and brown (mottled), very stiff, damp, occasional gravel, iron and manganese oxide stain on parting surfaces.	16.1	99				
-5.0			10 14 14				21.4	97				
-7.5												
-10.0			11 13 20			Becomes slightly clayey, moist, fewer gravels, weak clay skins.	19.5	104				
-12.5				SW-SM		WELL-GRADED SAND with SILT AND GRAVEL; Brown to dark brown, medium dense, wet, deeply weathered subrounded to subangular gravels with manganese stain on fracture faces,						
-15.0 ▽			11 17 18				15.1	115				
-17.5												
-20.0			20 25 31			SILTSTONE/SHALE; Dark bluish-gray, damp to dry, competent, hard angular chips, intensely fractured.						BEDROCK
-22.5												
-25.0												
-27.5												
-30.0												

PROJECT: Redwood Creek Flow Enhancement Project
LOCATION: Briceland
GROUND SURFACE ELEVATION: 654 Feet
EXCAVATION METHOD: 7" O.D Hollow Stem Auger
LOGGED BY: A. Call

JOB NUMBER: 018135
DATE DRILLED: 8/28/18
TOTAL DEPTH OF BORING: 50.5 Feet BGS
SAMPLER TYPE: Modified Cal Barrel, SPT
Track Mounted Drill Rig

BORING NUMBER
BH-103

DEPTH (FT)	SAMPLE NO.	SS SAMPLES	BLOWS PER 0.5'	USCS	PROFILE	DESCRIPTION	% Moisture	Dry Density (pcf)	Unc. Com. (psf)	U.C. (psf) by P.P.	% Passing 200	REMARKS
-30.0	☒	☐	50/6"			SILTSTONE/SHALE; Dark bluish-gray, damp to dry, competent, hard angular chips, intensely fractured.						Hammer bouncing. Slow drilling.
-32.5												
-35.0												
-37.5												
-40.0	☒ ☒ ☒	☐ ☐ ☐	14 29 29									
-42.5												
-45.0												
-47.5												
-50.0	☒	☐	50/6"									Hammer bouncing.
						Boring terminated at a depth of 50.5 feet BGS. Installed Peizometer. Screen interval 47.5 feet BGS to 7.5 feet BGS. Blank fro 7.5 feet BGS to surface. #3 sand from bottom of boring to 5 feet BGS. Bentonite from 5 feet BGS to 1.0 feet BGS. Flush mount Christie Box installed at surface. Groundwater encountered at a depth of 15 feet BGS.						
-52.5												
-55.0												
-57.5												

PROJECT: Redwood Creek Flow Enhancement Project

LOCATION: Lower Terrace, South

GROUND SURFACE ELEVATION: 585 Feet (Google Earth)

EXCAVATION METHOD: Backhoe

LOGGED BY: PRS

JOB NUMBER: 018135

DATE EXCAVATED: 8/27/2018

TOTAL DEPTH OF TEST PIT: 8 Feet

SAMPLER TYPE: Hand-driven tube

TEST PIT NUMBER
TP-1

DEPTH (FT)	BULK SAMPLES	TUBE SAMPLES	USCS	PROFILE	DESCRIPTION	% Moisture	Dry Density (pcf)	Unc. Com. (psf)	U.C. (psf) by P.P.	% Passing 200	REMARKS
0.0	☒		ML		SANDY SILT; Dark brown, medium stiff, dry to moist, low plasticity, moderate cementation, fine to coarse sub-angular sand, roots.						Observation well OW-1 installed from 0-8' bgs; 5' of screen PVC pipe from 3-8', 5' of blank PVC pipe from 0-3'; 2' of pipe above grade.
-1.0	☒	■	SW-SC		WELL-GRADED SAND with CLAY AND GRAVEL; Brown, medium dense, dry to moist, weak cementation, non-plastic to low plasticity, fine to coarse sub-rounded to rounded gravel.						
-2.0			SC								
-3.0	☒	■	CL		SANDY LEAN CLAY; Brown, medium stiff to stiff, dry to moist, fine to coarse sub-rounded sand.						Bulk bucket sample from 3-4'
-4.0	☒				LEAN CLAY with SAND; Brown, medium stiff to stiff, fine sand, low to medium plasticity, moderate cementation, mottled.						
-5.0											
-6.0			SW-SC		WELL-GRADED SAND with CLAY AND GRAVEL; Brown, medium dense, moist, fine to coarse sub-rounded to rounded sand, non-cemented, low plasticity fines.						
-7.0	☒										Bulk bucket and bag sample from 7-8'
-8.0					Excavation terminated at a depth of 8 feet. Groundwater not encountered. Installed observation well OW-1 and backfilled with excavated spoils.						
-9.0											
-10.0											
-11.0											
-12.0											
-13.0											
-14.0											
-15.0											

LOG OF TEST PIT

PROJECT: Redwood Creek Flow Enhancement Project

LOCATION: Lower Terrace, Central

GROUND SURFACE ELEVATION: 580 Feet (Google Earth)

EXCAVATION METHOD: Backhoe

LOGGED BY: PRS

JOB NUMBER: 018135

DATE EXCAVATED: 8/27/2018

TOTAL DEPTH OF TEST PIT: 11.5 Feet

SAMPLER TYPE: Hand-driven tube

TEST PIT NUMBER
TP-2

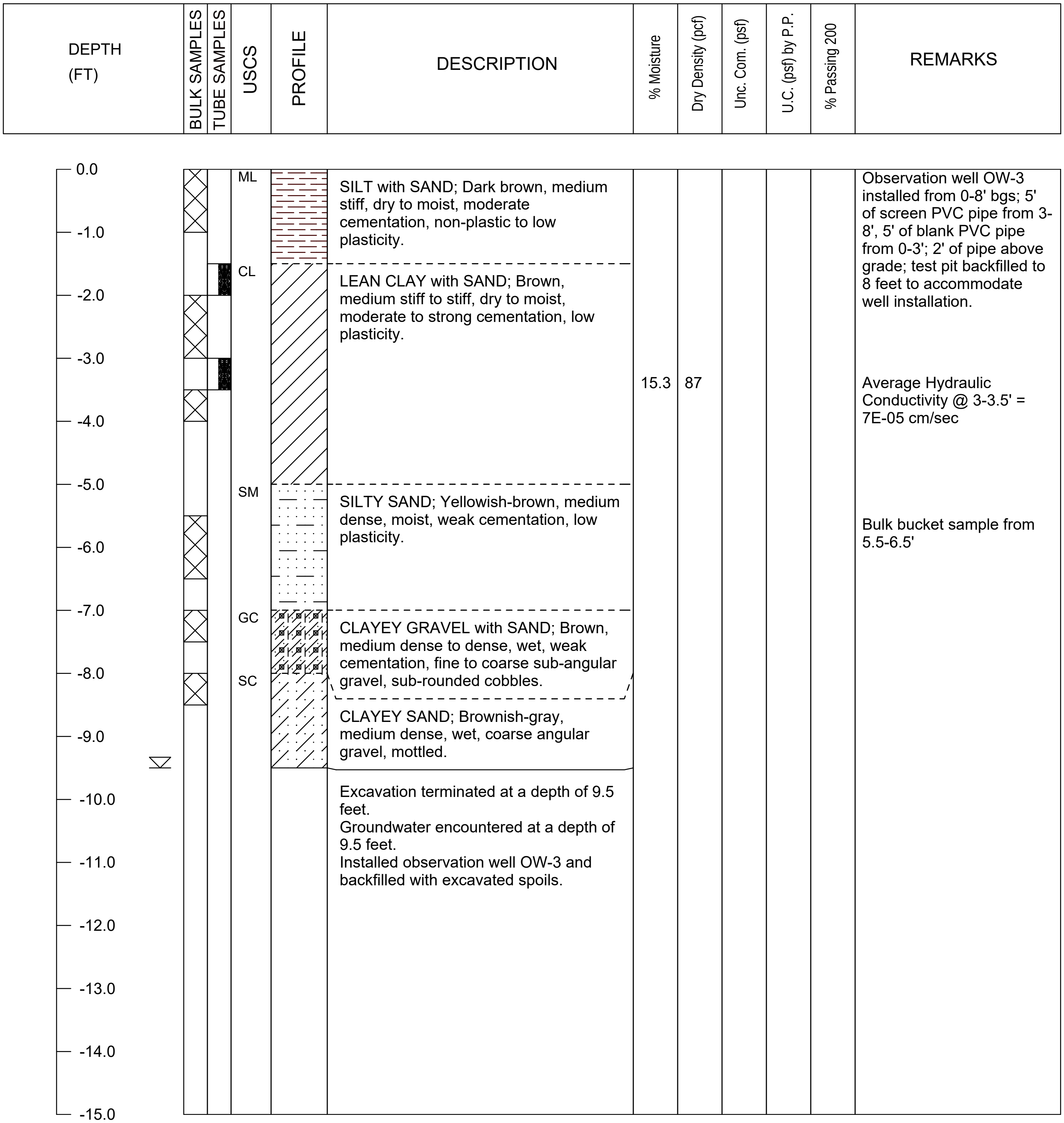
DEPTH (FT)	BULK SAMPLES	TUBE SAMPLES	USCS	PROFILE	DESCRIPTION	% Moisture	Dry Density (pcf)	Unc. Com. (psf)	U.C. (psf) by P.P.	% Passing 200	REMARKS
0.0			ML		SANDY SILT; Brown, medium stiff, moist, moderate cementation.						Observation well OW-2 installed from 0-8' bgs; 5' of screen PVC pipe from 3-8', 5' of blank PVC pipe from 0-3'; 2' of pipe above grade; test pit backfilled to 8 feet to accommodate well installation.
-1.0			SC		SANDY LEAN CLAY; Brown, medium stiff, moist.						
-2.0											
-3.0											
-4.0			SM		SILTY SAND; Dark brown, medium dense, moist, non-cemented.						
-5.0											
-6.0	☒		SW-SM		WELL-GRADED SAND with SILT AND GRAVEL; Brown, medium dense, non-cemented.						Bulk bucket sample from 6-7'
-7.0											
-8.0											
-9.0 ▽					increase in coarse rounded gravel						
-10.0											
-11.0					SILTSTONE; Dark gray (encountered at bottom of test pit in bucket teeth).						
-12.0					Excavation terminated at a depth of 11.5 feet. Groundwater encountered at a depth of 9 feet. Installed observation well OW-2 and backfilled with excavated spoils.						
-13.0											
-14.0											
-15.0											

LOG OF TEST PIT

PROJECT: Redwood Creek Flow Enhancement Project
LOCATION: Lower Terrace, Northeast
GROUND SURFACE ELEVATION: 583 Feet (Google Earth)
EXCAVATION METHOD: Backhoe
LOGGED BY: PRS

JOB NUMBER: 018135
DATE EXCAVATED: 8/27/2018
TOTAL DEPTH OF TEST PIT: 9.5 Feet
SAMPLER TYPE: Hand-driven tube

TEST PIT NUMBER
TP-3



DEPTH (FT)	BULK SAMPLES	TUBE SAMPLES	USCS	PROFILE	DESCRIPTION	% Moisture	Dry Density (pcf)	Unc. Com. (psf)	U.C. (psf) by P.P.	% Passing 200	REMARKS
			ML		SILT with SAND; Dark brown, medium stiff, dry to moist, moderate cementation, non-plastic to low plasticity.						Observation well OW-3 installed from 0-8' bgs; 5' of screen PVC pipe from 3-8', 5' of blank PVC pipe from 0-3'; 2' of pipe above grade; test pit backfilled to 8 feet to accommodate well installation.
			CL		LEAN CLAY with SAND; Brown, medium stiff to stiff, dry to moist, moderate to strong cementation, low plasticity.	15.3	87				Average Hydraulic Conductivity @ 3-3.5' = 7E-05 cm/sec
			SM		SILTY SAND; Yellowish-brown, medium dense, moist, weak cementation, low plasticity.						Bulk bucket sample from 5.5-6.5'
			GC		CLAYEY GRAVEL with SAND; Brown, medium dense to dense, wet, weak cementation, fine to coarse sub-angular gravel, sub-rounded cobbles.						
			SC		CLAYEY SAND; Brownish-gray, medium dense, wet, coarse angular gravel, mottled.						
					Excavation terminated at a depth of 9.5 feet. Groundwater encountered at a depth of 9.5 feet. Installed observation well OW-3 and backfilled with excavated spoils.						

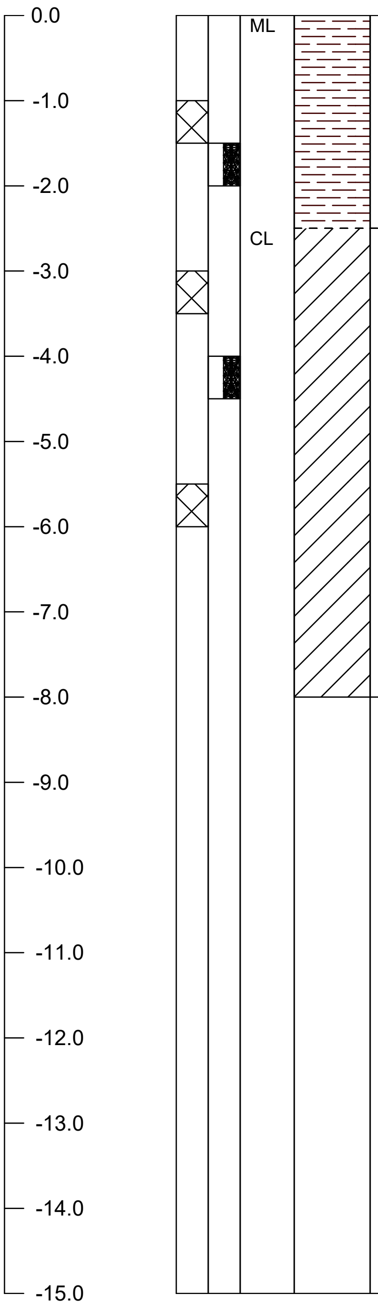
The log and data presented are a simplification of actual conditions encountered at the time of drilling at the drilled location. Subsurface conditions may differ at other locations and with the passage of time.

LOG OF TEST PIT

PROJECT: Redwood Creek Flow Enhancement Project
LOCATION: Upper Terrace, South
GROUND SURFACE ELEVATION: 665 Feet (Google Earth)
EXCAVATION METHOD: Backhoe
LOGGED BY: PRS

JOB NUMBER: 018135
DATE EXCAVATED: 8/27/2018
TOTAL DEPTH OF TEST PIT: 8 Feet
SAMPLER TYPE: Hand-driven tube

TEST PIT NUMBER
TP-4



DEPTH (FT)	BULK SAMPLES	TUBE SAMPLES	USCS	PROFILE	DESCRIPTION	% Moisture	Dry Density (pcf)	Unc. Com. (psf)	U.C. (psf) by P.P.	% Passing 200	REMARKS
0.0			ML		SILT with SAND; Dark brown, medium stiff, dry to moist, moderate to strong cementation, non-plastic.						Observation well OW-4 installed from 0-8' bgs; 5' of screen PVC pipe from 3-8', 5' of blank PVC pipe from 0-3'; 2' of pipe above grade.
			CL		LEAN CLAY with SAND; Brown, stiff, dry to moist, moderate cementation, low to medium plasticity, mottled.						
-8.0					Excavation terminated at a depth of 8 feet. Groundwater not encountered. Installed observation well OW-4 and backfilled with excavated spoils.						

LOG OF TEST PIT

Laboratory Results

3

COOPER TESTING LABORATORY

Hydraulic Conductivity
ASTM D 5084
Method C: Falling Head Rising Tailwater

Job No: 054-177 **Boring:** BH-101 **Date:** 10/23/18
Client: SHN Engineers & Geologists **Sample:** **By:** MD/PJ
Project: 018135 **Depth, ft.:** 16-16.5 **Remolded:**
Visual Classification: Yellowish Brown Clayey SAND w/ Gravel (Weathered Rock)

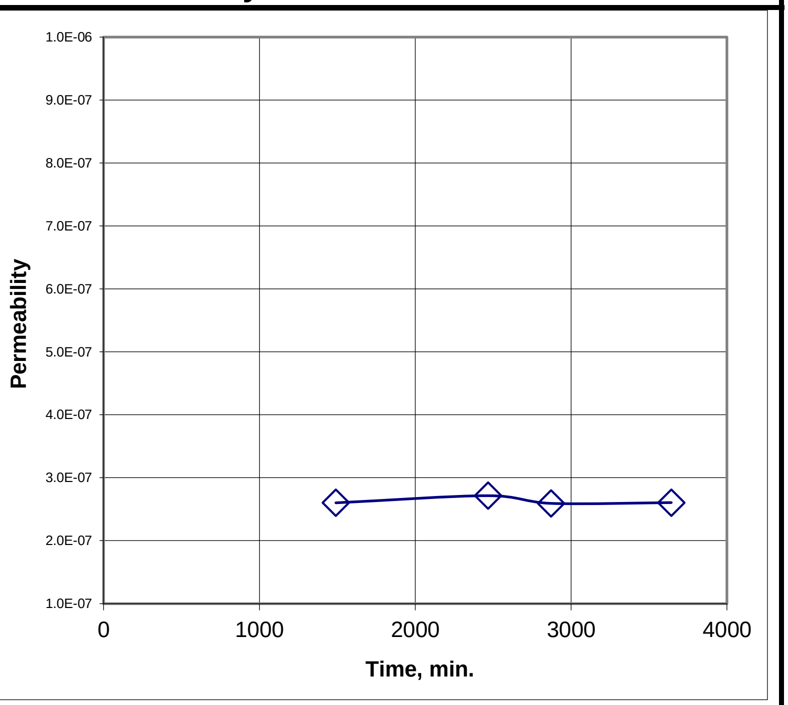
Max Sample Pressures, psi:

Cell:	Bottom	Top	Avg. Sigma3
54	49.5	48.5	5

B: = >0.95 **("B" is an indication of saturation)**

Max Hydraulic Gradient: = 17

Date	Minutes	Head, (in)	K,cm/sec
10/9/2018	0.00	42.69	**Start of Test**
10/10/2018	1491.00	30.69	2.6E-07
10/11/2018	2468.00	24.69	2.7E-07
10/11/2018	2872.00	22.79	2.6E-07
10/12/2018	3643.00	19.29	2.6E-07



Average Hydraulic Conductivity: **3.E-07** **cm/sec**

Sample Data:	Initial (As-Received)		Final (At-Test)
Height, in	2.52		2.52
Diameter, in	2.42		2.42
Area, in2	4.59		4.60
Volume in3	11.55		11.57
Total Volume, cc	189.3		189.6
Volume Solids, cc	127.8		127.8
Volume Voids, cc	61.4		61.7
Void Ratio	0.5		0.5
Total Porosity, %	32.4		32.6
Air-Filled Porosity (θa),%	5.4		0.3
Water-Filled Porosity (θw),%	27.0		32.3
Saturation, %	83.2		99.2
Specific Gravity	2.70	Assumed	2.70
Wet Weight, gm	396.3		406.4
Dry Weight, gm	345.2		345.2
Tare, gm	0.00		0.00
Moisture, %	14.8		17.7
Wet Bulk Density, pcf	130.7		133.8
Dry Bulk Density, pcf	113.8		113.6
Wet Bulk Dens.ρb, (g/cm^3)	2.09		2.14
Dry Bulk Dens.ρb, (g/cm^3)	1.82		1.82

Remarks:

COOPER
TESTING LABORATORY

Hydraulic Conductivity
ASTM D 5084
Method C: Falling Head Rising Tailwater

Job No:	054-177	**Boring:**	BH-101	**Date:**	10/23/18
Client:	SHN Engineers & Geologists	**Sample:**		**By:**	MD/PJ
Project:	018135	**Depth, ft.:**	21-21.5	**Remolded:**	

Visual Classification: Olive Brown Clayey GRAVEL w/ Sand (Weathered Rock)

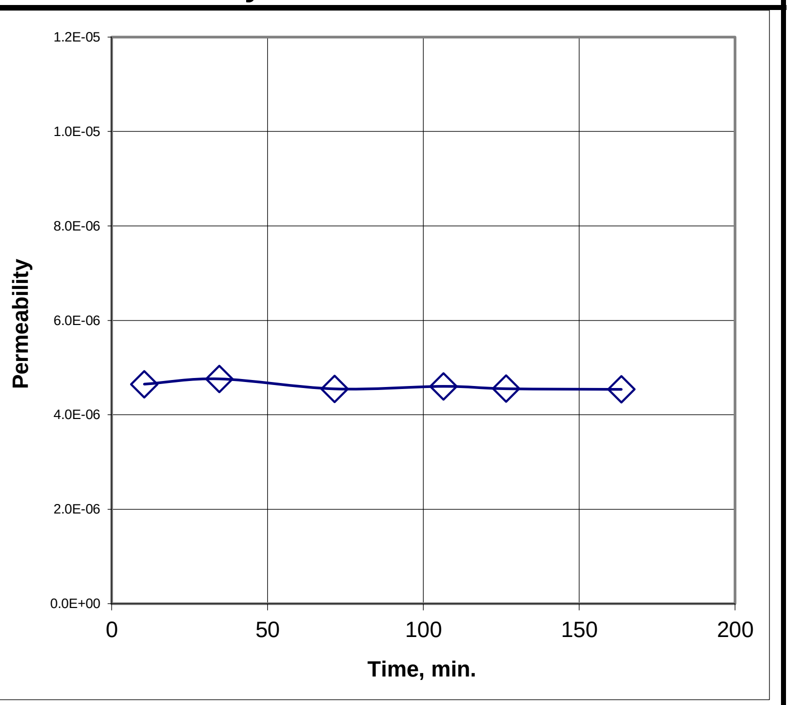
Max Sample Pressures, psi:

Cell:	Bottom	Top	Avg. Sigma3
53.5	49	48	5

B: = >0.95 **("B" is an indication of saturation)**

Max Hydraulic Gradient: = 20

Date	Minutes	Head, (in)	K,cm/sec
10/17/2018	0.00	49.69	**Start of Test**
10/17/2018	10.50	47.69	4.6E-06
10/17/2018	34.50	43.29	4.8E-06
10/17/2018	71.50	37.89	4.5E-06
10/17/2018	106.50	33.09	4.6E-06
10/17/2018	126.50	30.89	4.6E-06
10/17/2018	163.50	27.09	4.5E-06



Average Hydraulic Conductivity: **5.E-06** **cm/sec**

Sample Data:	**Initial (As-Received)**		**Final (At-Test)**
Height, in	2.50		2.47
Diameter, in	2.41		2.43
Area, in2	4.54		4.63
Volume in3	11.35		11.43
Total Volume, cc	186.0		187.3
Volume Solids, cc	122.2		122.2
Volume Voids, cc	63.8		65.1
Void Ratio	0.5		0.5
Total Porosity, %	34.3		34.7
Air-Filled Porosity (θa),%	0.3		1.1
Water-Filled Porosity (θw),%	34.0		33.7
Saturation, %	99.2		96.9
Specific Gravity	2.70	Assumed	2.70
Wet Weight, gm	393.2		393.0
Dry Weight, gm	330.0		330.0
Tare, gm	0.00		0.00
Moisture, %	19.2		19.1
Wet Bulk Density, pcf	131.9		131.0
Dry Bulk Density, pcf	110.7		110.0
Wet Bulk Dens.ρb, (g/cm^3)	2.11		2.10
Dry Bulk Dens.ρb, (g/cm^3)	1.77		1.76

Remarks:

COOPER TESTING LABORATORY

Hydraulic Conductivity
ASTM D 5084
Method C: Falling Head Rising Tailwater

Job No:	054-177	**Boring:**	BH-102	**Date:**	10/23/18
Client:	SHN Engineers & Geologists	**Sample:**		**By:**	MD/PJ
Project:	018135	**Depth, ft.:**	10.5-11	**Remolded:**	

Visual Classification: Yellowish Brown Clayey SAND w/ Gravel

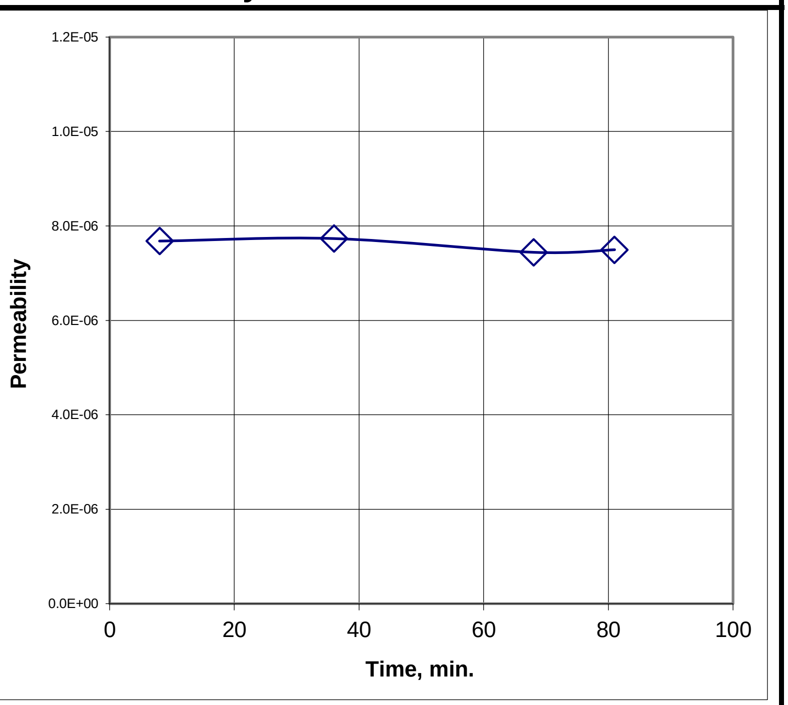
Max Sample Pressures, psi:

Cell:	Bottom	Top	Avg. Sigma3
53.5	49	48	5

B: = >0.95 ("B" is an indication of saturation)

Max Hydraulic Gradient: = 16

Date	Minutes	Head, (cm)	K,cm/sec
10/17/2018	0.00	97.33	**Start of Test**
10/17/2018	8.00	93.53	7.7E-06
10/17/2018	36.00	81.33	7.7E-06
10/17/2018	68.00	70.33	7.4E-06
10/17/2018	81.00	66.03	7.5E-06



Average Hydraulic Conductivity: **8.E-06** **cm/sec**

Sample Data:	Initial (As-Received)		Final (At-Test)
Height, in	2.51		2.47
Diameter, in	2.40		2.41
Area, in2	4.54		4.56
Volume in3	11.37		11.27
Total Volume, cc	186.4		184.6
Volume Solids, cc	121.9		121.9
Volume Voids, cc	64.5		62.8
Void Ratio	0.5		0.5
Total Porosity, %	34.6		34.0
Air-Filled Porosity (θa),%	7.9		1.4
Water-Filled Porosity (θw),%	26.7		32.6
Saturation, %	77.1		96.0
Specific Gravity	2.70	Assumed	2.70
Wet Weight, gm	378.8		389.3
Dry Weight, gm	329.1		329.1
Tare, gm	0.00		0.00
Moisture, %	15.1		18.3
Wet Bulk Density, pcf	126.8		131.6
Dry Bulk Density, pcf	110.2		111.2
Wet Bulk Dens.ρb, (g/cm^3)	2.03		2.11
Dry Bulk Dens.ρb, (g/cm^3)	1.76		1.78

Remarks:

COOPER TESTING LABORATORY

Hydraulic Conductivity
ASTM D 5084
Method C: Falling Head Rising Tailwater

Job No:	054-177	**Boring:**	TP-3	**Date:**	10/23/18
Client:	SHN Engineers & Geologists	**Sample:**		**By:**	MD/PJ
Project:	018135	**Depth, ft.:**	3-3.5	**Remolded:**	

Visual Classification: Yellowish Brown Sandy SILT (slightly plastic) w/ surface organics/ Sandy CLAY (Silty)

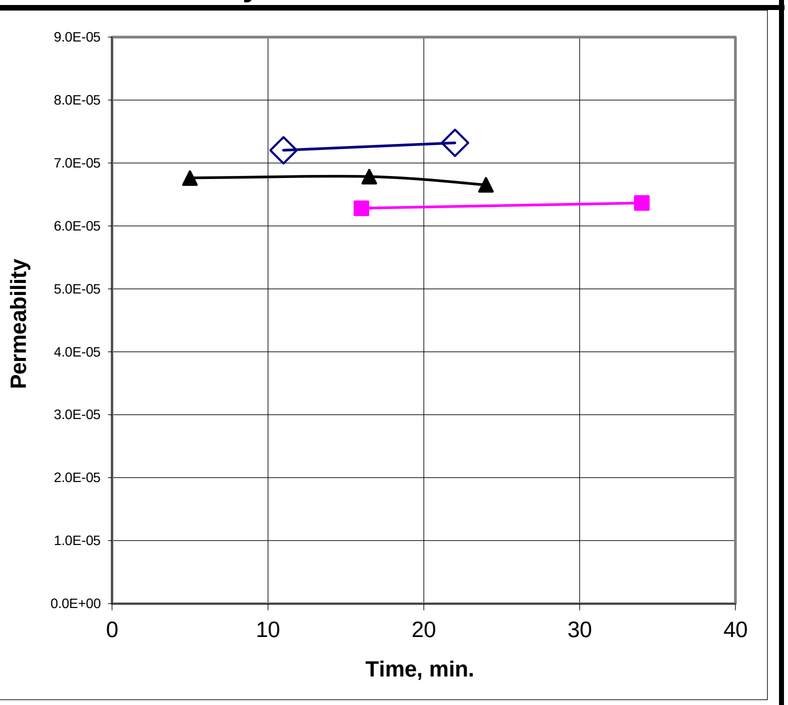
Max Sample Pressures, psi:

Cell:	Bottom	Top	Avg. Sigma3
74	69	69	5

B: = >0.95 **("B" is an indication of saturation)**

Max Hydraulic Gradient: = 3

Date	Minutes	Head, (cm)	K,cm/sec
10/12/2018	0.00	8.20	**Start of Test**
10/12/2018	11.00	5.00	7.2E-05
10/12/2018	22.00	3.00	7.3E-05
10/15/2018	16.00	6.60	6.3E-05
10/15/2018	34.00	3.20	6.4E-05
10/17/2018	5.00	14.00	6.8E-05
10/17/2018	16.50	8.60	6.8E-05
10/17/2018	24.00	6.40	6.7E-05



Average Hydraulic Conductivity: 7.E-05 cm/sec

Sample Data:	Initial (As-Received)		Final (At-Test)
Height, in	2.51		2.48
Diameter, in	2.41		2.39
Area, in2	4.55		4.49
Volume in3	11.40		11.13
Total Volume, cc	186.9		182.3
Volume Solids, cc	96.5		96.5
Volume Voids, cc	90.3		85.8
Void Ratio	0.9		0.9
Total Porosity, %	48.3		47.1
Air-Filled Porosity (θa),%	26.9		2.1
Water-Filled Porosity (θw),%	21.4		45.0
Saturation, %	44.3		95.6
Specific Gravity	2.70	Assumed	2.70
Wet Weight, gm	300.6		342.6
Dry Weight, gm	260.6		260.6
Tare, gm	0.00		0.00
Moisture, %	15.3		31.5
Wet Bulk Density, pcf	100.4		117.3
Dry Bulk Density, pcf	87.0		89.2
Wet Bulk Dens.ρb, (g/cm^3)	1.61		1.88
Dry Bulk Dens.ρb, (g/cm^3)	1.39		1.43

Remarks:

CONSULTING ENGINEERS & GEOLOGISTS, INC.
812 W. Wabash Eureka, CA 95501-2138 Tel: 707/441-8855 FAX: 707/441-8877 E-mail: shninfo@shn-engr.com

DENSITY BY DRIVE- CYLINDER METHOD (ASTM D2937)

Project Name:	**RCEP Redwood Creek**	**Project Number:**	**018135**
Performed By:	**ESP**	**Date:**	**9/25/2018**
Checked By:	**NAN**	**Date:**	**9/25/2018**
Project Manager:	**GDS**		

Lab Sample Number	18-820	18-821			
Boring Label	**BH-101**	**BH-101**			
Sample Depth (ft)	**6.0-6.5**	**11.0-11.5**			
Diameter of Cylinder, in	2.38	2.41			
Total Length of Cylinder, in.	6.00	6.00			
Length of Empty Cylinder A, in.	0.00	0.00			
Length of Empty Cylinder B, in.	0.85	0.15			
Length of Cylinder Filled, in	5.15	5.85			
Volume of Sample, in^3	22.91	26.69			
Volume of Sample, cc.	375.45	437.30			

Pan #	A2	A3			
Weight of Wet Soil and Pan	787.6	915.4			
Weight of Dry Soil and Pan	655.6	737.1			
Weight of Water	132.0	178.3			
Weight of Pan	87.7	85.4			
Weight of Dry Soil	567.9	651.7			
Percent Moisture	**23.2**	**27.4**			
Dry Density, g/cc	1.51	1.49			
Dry Density, lb/ft^3	**94.4**	**93.0**			

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DENSITY BY DRIVE- CYLINDER METHOD (ASTM D2937)

Project Name:	**RCEP Redwood Creek**	**Project Number:**	**018135**
Performed By:	**ESP**	**Date:**	**9/25/2018**
Checked By:	**NAN**	**Date:**	**9/25/2018**
Project Manager:	**GDS**		

Lab Sample Number	18-835	18-837	18-839		
Boring Label	**BH-102**	**BH-102**	**BH-102**		
Sample Depth (ft)	**3.0-3.5**	**6.0-6.5**	**11.0-11.5**		
Diameter of Cylinder, in	2.41	2.40	2.40		
Total Length of Cylinder, in.	6.00	6.00	6.00		
Length of Empty Cylinder A, in.	0.00	0.22	0.00		
Length of Empty Cylinder B, in.	0.55	0.28	0.30		
Length of Cylinder Filled, in	5.45	5.50	5.70		
Volume of Sample, in^3	24.86	24.88	25.79		
Volume of Sample, cc.	407.40	407.73	422.56		

Pan #	A4	A5	A6		
Weight of Wet Soil and Pan	732.5	870.3	967.5		
Weight of Dry Soil and Pan	667.1	744.3	841.5		
Weight of Water	65.4	126.0	126.0		
Weight of Pan	87.9	86.8	87.4		
Weight of Dry Soil	579.2	657.5	754.1		
Percent Moisture	**11.3**	**19.2**	**16.7**		
Dry Density, g/cc	1.42	1.61	1.78		
Dry Density, lb/ft^3	**88.8**	**100.7**	**111.4**		

CONSULTING ENGINEERS & GEOLOGISTS, INC.

812 W. Wabash Eureka, CA 95501-2138 Tel: 707/441-8855 FAX: 707/441-8877 E-mail: shninfo@shn-engr.com

DENSITY BY DRIVE- CYLINDER METHOD (ASTM D2937)

Project Name:	**RCEP Redwood Creek**	**Project Number:**	**018135**
Performed By:	**ESP**	**Date:**	**9/25/2018**
Checked By:	**NAN**	**Date:**	**9/25/2018**
Project Manager:	**GDS**		

Lab Sample Number	18-849	18-851	18-853	18-855	
Boring Label	**BH-103**	**BH-103**	**BH-103**	**BH-103**	
Sample Depth (ft)	**3.0-3.5**	**6.0-6.5**	**11.0-11.5**	**16.0-16.5**	
Diameter of Cylinder, in	2.40	2.41	2.41	2.38	
Total Length of Cylinder, in.	6.00	6.00	6.00	6.00	
Length of Empty Cylinder A, in.	0.40	0.00	0.40	0.00	
Length of Empty Cylinder B, in.	0.28	0.00	0.15	0.33	
Length of Cylinder Filled, in	5.32	6.00	5.45	5.67	
Volume of Sample, in^3	24.07	27.37	24.86	25.22	
Volume of Sample, cc.	394.39	448.51	407.40	413.36	

Pan #	A7	A8	A9	A10	
Weight of Wet Soil and Pan	810.8	934.9	895.2	966.6	
Weight of Dry Soil and Pan	710.5	785.7	763.5	851.5	
Weight of Water	100.3	149.2	131.7	115.1	
Weight of Pan	86.7	87.4	88.2	87.1	
Weight of Dry Soil	623.8	698.3	675.3	764.4	
Percent Moisture	**16.1**	**21.4**	**19.5**	**15.1**	
Dry Density, g/cc	1.58	1.56	1.66	1.85	
Dry Density, lb/ft^3	**98.7**	**97.2**	**103.5**	**115.4**	

Supplemental Geotechnical Investigations and Slope Stability Analysis for the Marshal Ranch Flow Enhancement Project–Technical Memorandum

4

Stillwater Sciences

850 G Street, Suite K, Arcata, CA 95521
phone 707.822.9607

TECHNICAL MEMORANDUM

DATE: February 16, 2021

TO: Salmonid Restoration Federation

FROM: Joel Monschke PE and Jay Stallman PG, Stillwater Sciences

SUBJECT: Supplemental Geotechnical Investigations and Slope Stability Analyses for the Marshall Ranch Flow Enhancement Project

---

During October and November 2020, three significant activities were conducted to further characterize subsurface conditions and assess stability of the proposed Marshall Ranch Flow Enhancement Project. These included the following:

1) Supplemental Geotechnical Investigation consisting of two additional boreholes led by SHN
2) Shear Wave Velocity Analyses conducted by Dr. Dimitrios Zekkos
3) Slope Stability Analyses conducted by Dr. Adda Athanasopoulos-Zekkos

Supplemental Geotechnical Investigation

Drilling of two additional boreholes was conducted in October 2020 and overseen by SHN geologist Paul Sundberg. The key finding from this investigation is that there is an incline in the bedrock-soil interface downslope from the pond which will increase stability of the proposed pond (see Appendix A, Figure 2).

Shear Wave Velocity Analyses

Shear wave velocity analyses was conducted to further characterize subsurface conditions. This analysis utilizes an array of sensers to measure shear wave velocities within the subsurface soil profile – varying soil and rock types have different shear wave velocity signatures. One of the specific data collection sites was located immediately adjacent to one of the new boreholes to relate shear wave velocities to specific subsurface soil/rock conditions. Data collection was focused adjacent to and just downslope from the proposed pond berm as well as one data collection point in the vicinity of the proposed deflector berm on the lower terrace. This analysis is further described in Appendix B.

Slope Stability Analyses

Slope stability analyses was conducted as described in Appendix C. These analyses incorporated data from the geotechnical investigations and shear wave velocity analyses. Results are summarized on page 7 of the report in Appendix C and are generally consistent with Stillwater Sciences' and SHN's previous findings.

The analysis considered two earthquake scenarios including a ~9.0 magnitude subduction zone earthquake and a ~7.0 magnitude earthquake along the San Andreas Fault. These two scenarios are described on Figure 17 in Appendix C. However, the nearest subduction zone fault is located ~25 km from the site, so a maximum ground motion equivalent to a 7.8 magnitude earthquake is expected at the site based on standard Seismic Design Code Specifications for a seismic event with a return period of 2,475 years.

The Slope Stability Analyses determined that the proposed pond site would experience displacements of less than one inch during this earthquake scenario, but more significant displacements of up to several feet are possible along the steeper slope downgradient from the proposed pond.

Additionally, resumes from the lead preparers of the shear wave and slope stability analyses are included in Appendix D for reference.

Appendix A

Supplemental Geotechnical Investigation

Phone: (707) 441-8855 **Email:** info@shn-engr.com **Web:** shn-engr.com
812 W. Wabash Avenue, Eureka, CA 95501-2138

Reference: 018135

November 25, 2020

Dana Stolzman, Executive Director
Salmonid Restoration Federation
425 Sung Alley, Unit D
Eureka, CA 95501

Subject: Supplemental Geotechnical Investigation for Redwood Creek Flow Enhancement, Marshall Ranch, 195 Somerville Road, Briceland, Humboldt County, California; APN 220-061-011

Dana Stolzman:

This letter summarizes the results of a recent supplemental geotechnical investigation for the proposed Redwood Creek Flow Enhancement project on the Marshall Ranch property in Briceland, California. SHN previously prepared a report titled "Geotechnical Investigation Report for a Proposed Water Storage Basin and Associated Infrastructure for Redwood Creek Flow Enhancement, Marshall Ranch, 195 Somerville Road, Briceland, Humboldt County, California; APN 220-061-01—Revision 1," September 30, 2020. The initial investigation was conducted in 2018 related to the development of the storage basin and associated infrastructure.

The project has evolved since our initial investigation, and two additional borings were drilled in October 2020. The purpose of the two additional borings was to gain further understanding of the subsurface conditions below the proposed storage basin, and to inform the design team's ongoing stability analyses. The additional borings, BH-104 and BH-105 (Figure 1), were advanced south and north of the previously drilled boring, BH-101. The borings were advanced using a track-mounted drill rig using hollow-stem augers, operated by Taber Drilling out of West Sacramento, California. Piezometers were installed in the borings for ongoing groundwater monitoring at the site. Groundwater monitoring is to be conducted by Stillwater Sciences. In general, the results of our supplemental investigation were consistent with our previous investigations and reinforce our previous conclusions about the site conditions.

Boring BH-104 was drilled south and upslope of BH-101 (Figure 1), and revealed as much as 35 feet of alluvium (silt, lean clay, sandy lean clay, and clayey sand) over siltstone bedrock to the total depth drilled of 46.5 feet BGS. Lean clay with sand and sandy lean clay is present at this location starting at 6 feet below ground surface (BGS) and continuing to a depth of 31 feet BGS. The clay was tested for unconfined compression in the field using a pocket penetrometer. The tests resulted in unconfined compression values ranging from 1.75 tons per square foot (tsf) to greater than 4.5 tsf.

Boring BH-105 was drilled north and downslope of BH-101 (Figure 1) and revealed up to 16 feet of alluvium (silt, lean clay, and sandy lean clay) over siltstone bedrock to the total depth drilled of 26.5 feet BGS. Lean clay with sand and sandy clay is present at this location starting at approximately 5 feet BGS and continuing to a depth of 16 feet BGS. The clay was tested for unconfined compression in the field using a pocket penetrometer resulting in an unconfined compression value of greater than 4.5 tsf.

A thicker sequence of alluvium is present in the upslope portion of the proposed storage basin. Groundwater was not encountered in either boring at the time of drilling. A generalized geologic cross section of the subsurface conditions encountered in BH-101, BH-104, and BH-105 is presented on Figure 2. Boring logs are included as Appendix 1.

We hope that this summary provides the information you need at this time. If you have additional questions or require clarification of the information presented herein, please call me at (707) 441-8855.

Sincerely,

SHN

PROFESSIONAL GEOLOGIST
PAUL SUNDBERG
No. 9723
STATE OF CALIFORNIA

11/25/2020

Paul R. Sundberg, PG 9723
Project Geologist

PRS:GDS:ame

Appendix: Boring Logs

Reference Cited

SHN. (September 30, 2020). “Geotechnical Investigation Report for a Proposed Water Storage Basin and Associated Infrastructure for Redwood Creek Flow Enhancement, Marshall Ranch, 195 Somerville Road, Briceland, Humboldt County, California; APN 220-061-011—Revision 1.” Eureka, CA:SHN.

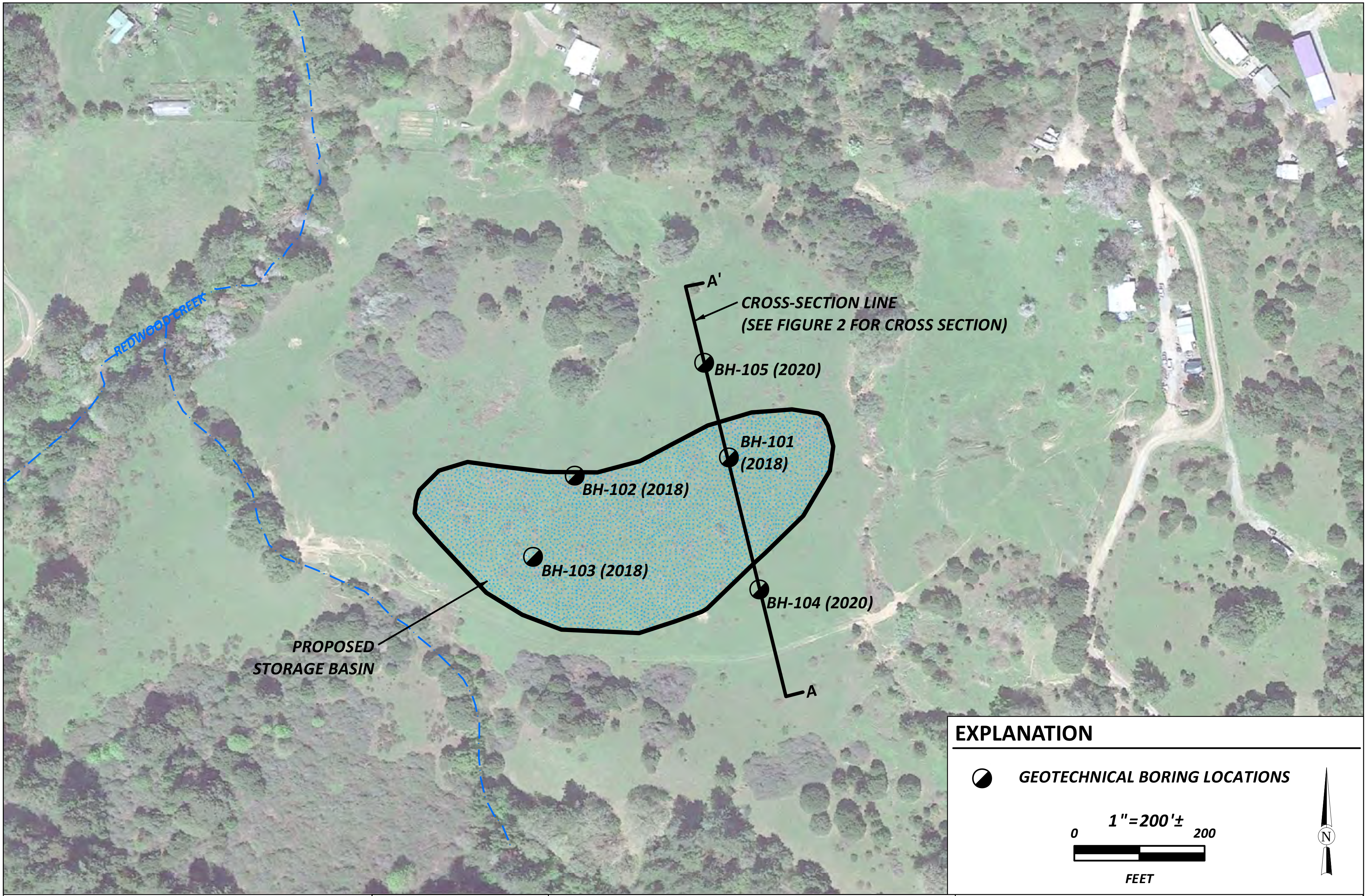


IMAGE SOURCE: GOOGLE EARTH, DATED 4/30/2019

Salmonid Restoration Federation
Redwood Creek Flow Enhancement Project
Briceland, California

Site Map Showing
Geotechnical Boring Locations

SHN 018135

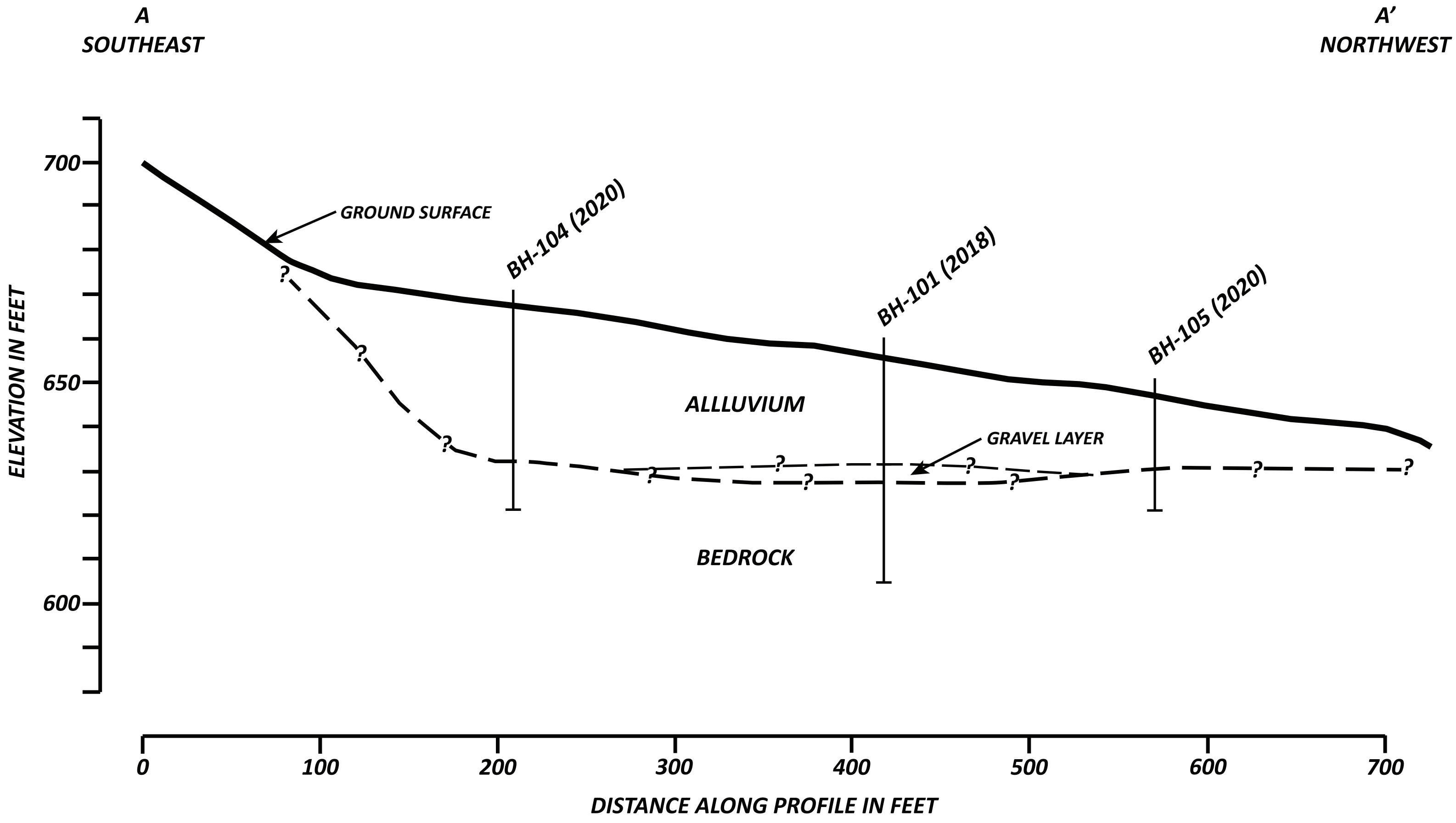
November 2020

Figure1_SiteMap

Figure 1

Path: \\eureka\projects\2018\018135-RedwCkFlowGEO\GIS\FIGURES\2020_SupplementalWork\Figure2_GeologicCrossSection User Name: psundberg DATE: 11/25/20, 11:30AM

REDWOOD CREEK FLOW ENHANCEMENT PROJECT
GEOLOGIC CROSS SECTION A - A’



NOTES:

1). SEE FIGURE 1 FOR LOCATION OF CROSS SECTION.

2). CROSS SECTION REPRESENTS IDEALIZED CONDITIONS BASED ON LIMITED SUBSURFACE DATA.

3). SEE APPENDIX 1 FOR GEOTECHNICAL BORING LOGS.

ELEVATION DATA FROM USGS LIDAR, 2018-2019

SCALE:
HORIZONTAL: 1” = 100’
VERTICAL: 1” = 40’
V.E. = 2.5

0 1
INCH

Salmonid Restoration Federation
Redwood Creek Flow Enhancement Project
Briceland, California

Geologic Cross Section
A - A’
SHN 018135

November 2020
Figure2_GeologicCrossSection
Figure 2

Boring Logs

1

BORING NUMBER BH-104

CLIENT Salmonid Restoration Federation

PROJECT NAME Redwood Creek Flow Enhancement Project

PROJECT NUMBER 018135

PROJECT LOCATION Briceland, Humboldt County, California

DATE STARTED 10/13/20 **COMPLETED** 10/13/20

GROUND ELEVATION 667 ft NAVD 88 **HOLE SIZE** 8"

DRILLING CONTRACTOR Taber Drilling

GROUNDWATER DEPTH

DRILLING METHOD Rotary Hollow Stem Auger

▽ **AT TIME OF DRILLING** ---

LOGGED BY P. Sundberg **CHECKED BY** G. Vadurro

▼ **AT END OF DRILLING** ---

NOTES Piezometer installed in boring upon completion

▼ **AFTER DRILLING** ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS			FINES CONTENT (%)
									LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	
0		(ML) SILT with SAND; Brown, medium stiff to stiff, non- to weakly cemented, fine sand. (ALLUVIUM)										
5		(CL) LEAN CLAY with SAND; Brown, hard, dry to moist, low to medium plasticity, fine sand, moderately cemented, slightly mottled. (ALLUVIUM)	MC		25-30-39 (69)	>4.5						
10		becomes very stiff; few coarse sand	SPT		6-9-13 (22)							
15		few fine subangular gravel	MC		6-10-20 (30)	3.25						
20		2" layer of coarse sand and charcoal; becomes medium stiff	SPT		2-4-6 (10)	1.75						
25		(CL) SANDY LEAN CLAY; Olive brown, stiff, moist, coarse angular sand, low plasticity, moderately cemented. (ALLUVIUM)	MC		5-8-15 (23)	4.0						
30												

(Continued Next Page)

BORING NUMBER BH-104

PAGE 2 OF 2

CLIENT Salmonid Restoration Federation

PROJECT NAME Redwood Creek Flow Enhancement Project

PROJECT NUMBER 018135

PROJECT LOCATION Briceland, Humboldt County, California

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS			FINES CONTENT (%)
									LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	
30			SPT		7-8-8 (16)							
		(SC) CLAYEY SAND; Brown, medium dense, wet, fine to coarse angular to subangular sand, slightly cohesive, non-cemented. (ALLUVIUM)										
35		SILTSTONE; Very dark gray, very weak field strength, very dense, fine grained, highly decomposed, very intensely fractured. (BEDROCK)	SPT		9-16-25 (41)							
40			SPT		21-30-39 (69)							
45			SPT		13-20-32 (52)							

Bottom of borehole at 46.5 feet.

BORING NUMBER BH-105

CLIENT Salmonid Restoration Federation

PROJECT NAME Redwood Creek Flow Enhancement Project

PROJECT NUMBER 018135

PROJECT LOCATION Briceland, Humboldt County, California

DATE STARTED 10/14/20 **COMPLETED** 10/14/20

GROUND ELEVATION 647 ft NAVD 88 **HOLE SIZE** 8"

DRILLING CONTRACTOR Taber Drilling

GROUNDWATER DEPTH

DRILLING METHOD Rotary Hollow Stem Auger

▽ **AT TIME OF DRILLING** ---

LOGGED BY P. Sundberg **CHECKED BY** G. Vadurro

▼ **AT END OF DRILLING** ---

NOTES Piezometer installed in boring upon completion

▼ **AFTER DRILLING** ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS			FINES CONTENT (%)
									LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	
0		(ML) SILT with SAND; Brown, medium stiff to stiff, fine sand. (ALLUVIUM)										
5		(CL) LEAN CLAY with SAND; Brown, very stiff, dry to moist, medium plasticity, moderately cemented, fine sand, slightly mottled. (ALLUVIUM)	MC		9-17-28 (45)	>4.5						
10		(CL) SANDY LEAN CLAY with GRAVEL; Brown, very stiff, moist, low plasticity, fine to coarse subangular sand and gravel (15%), weakly cemented, cohesive. (ALLUVIUM)	SPT		6-11-14 (25)							
15			MC		14-43-50 (93)							
		SILTSTONE; Very dark gray, weak field strength, very dense, highly to moderately decomposed, very intensely fractured, very thinly bedded, fine grained. (BEDROCK)										
20												
25			SPT		10-39-50/3"							

Bottom of borehole at 26.5 feet.

Appendix B

Shear Wave Velocity Analyses

In Situ Shear Wave Velocity Measurements

Redwood Creek Flow Enhancement
Marshall Ranch
Briceland, Humboldt County, California

Prepared by
ARGO-E LLC

Prepared for

Stillwater Sciences
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www.stillwatersci.com

November 24 2020

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LIST OF APPENDICES

1. INTRODUCTION

At the request of Mr. Joel Monschke, Stillwater Sciences, in situ seismic geophysical surveys have been performed at the Marshall Ranch in Briceland, Humboldt County, California with the intent to characterize the subsurface conditions in areas where boreholes do not exist. Field measurements were performed under the direction of Dr. Dimitrios Zekkos on October 25 2020 with the assistance of Parker Blunts and Brittany Russo. Analyses were conducted with the assistance of Dr. George Zalachoris. This report documents the field testing and was prepared by Dr. Dimitrios Zekkos, and Dr. George Zalachoris with reviews and feedback by Dr. Adda Athanasopoulos-Zekkos.

2. FIELD TESTING DESCRIPTION

Field testing consisted of the measurement of surface wave velocities at four locations at the study site as shown in Figures 1 and 2. One of the location was selected to be adjacent to a borehole, while the remaining were conducted in areas where subsurface data does not exist. The coordinates of the testing locations are shown in Appendix A and are considered accurate within ±10 ft. Photographs from the various testing locations are shown in Figures 3 through 7.

3. METHODOLOGY

Surface wave seismic methods are used to estimate the shear wave velocity (V_s) profile. Surface methods are appealing because of their advantages compared to other seismic geophysical methods, which require boreholes such as downhole, crosshole, and suspension logging. Among their main advantages are that they are non-intrusive, efficient, and reliable. Specifically, a technique that combines active and passive measurements was performed. The 1D and 2D Multichannel Analysis of Surface Waves (MASW) method (Park et al. 1999a) was used for active measurements, and the Microtremor Analysis Method (MAM) (Okada 2003) was used for passive. Generally, these techniques involve three steps: collection of field measurement data, dispersion curve analysis, and the forward modeling process. The procedure used in the field is described in more detail by Sahadewa et al. (2012).

3.1 MASW Method Field Measurements

In the MASW method, data acquisition was performed by recording the ground roll from a 10-lb sledge hammer blow. The source offset (x_s) was varied and was typically 10-30% of the total array length. Twenty four 2-Hz geophones were positioned with spacing (d_x) of 3 ft or 5 ft in a linear array, at each testing location. Thus, the spread length

(*D*) varied from 72 ft to 120 ft. A schematic of the data acquisition setup is shown in Fig. 8. Stacking was performed to improve the signal to noise ratio (S/N). Generally, 5-8 stacks were used to generate one active MASW record.

3.2 MAM Method Field Measurements

The MAM captures surface waves from ambient activities or background noise. The 3ft and 5ft-spacing linear array setup was also used for the passive measurements. At least twenty 32-second recordings were collected from each location and the recordings were combined and analyzed.

3.3 2D MASW Method Field Measurements

Similar to 1D MASW surveys, 2D MASW testing use an active source with a linear spread of geophones. Instead of one shot however, numerous shots are taken at locations in between the geophones. Therefore, a V_S cross-section can be generated. In this study, 2D MASW surveys were performed at two of the testing locations (Locations 2 and 4).

For the 2D MASW surveys, we employed a fixed receiver spread configuration. The geophones were set up in a line at fixed locations and the shot was moved through the spread. The first and last shots were located off-end at a near offset of one-half the geophone interval (5ft). The survey depth was approximately 1/4 to 1/2 of the spread length. Note that, 2D MASW testing with fixed receiver spread configuration and shots in between geophones results in reduced depth of investigation at the sides of the survey, while the maximum depth of investigation is reached at the center of the array. Also, note that the technique has a reduced resolution with depth, i.e., it is easier to discern soil stratigraphy features near the surface than at depth. In addition, its accuracy with depth is reduced. Overall, the depth of each layer of different shear wave velocity should not be considered as deterministic, but as a "best-estimate".

3.4 Dispersion Curve Analysis and Forward Modeling Process

Records from MASW or MAM measurements are independently transformed to a dispersion curve using the Park et al. (1999b) method. Before the transformation, MAM records are processed using Spatial Autocorrelation (SPAC) (Aki 1957). This allows for an independent comparison of the MASW and MAM dispersion curves. If the measured dispersion curves from MASW and MAM overlap over a frequency range, they are combined to generate a single dispersion curve. The combined dispersion curve typically has a greater frequency range and allows for a better identification of the modal identity of the dispersion curve (Park et al. 2005).

To obtain the V_s profile, the measured dispersion curve is compared against a theoretical dispersion curve through a forward modeling process. An assumed V_s profile is used to obtain a theoretical dispersion curve and modifications to the V_s profile are made iteratively until the two dispersion curves closely match. Matching of the measured dispersion curve and its theoretical counterpart was assessed by implementing a non-linear least squares method (Xia et al. 1999). Sensitivity analysis is performed to evaluate the depth to which the V_s profile is reliably estimated, typically yielding results to depth of about one-third of the maximum wavelength (λ_{max}).

Note that there is no single solution to the forward modeling problem. Different combinations of shear wave velocity values and layer thicknesses may yield similar measured results. The available borehole data in one location were used to assess the stratigraphy and restrain the model in an effort to generate representative shear wave velocity values.

4. RESULTS

The results of the measurements are shown individually in Figures 9 through 17 along with their corresponding dispersion curves. The numeric values of the 1D V_S profiles are included in Appendix B. The results of the 1D surveys are also combined in Figure 18. On average, Locations 2, 3, and 4, all located at the upper terrace, show similar profiles that are also consistent with the data from Borehole BH-105 (Figure 14). The V_S profile at Location 1, which is situated at the lower terrace, indicates slightly softer layers and a bedrock at a depth of approximately 20.5ft.

5. REFERENCES

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FIGURES

Locations accurate to ±7-10ft

Figure 1: Google Earth Site Map and Sounding Locations		ARGO-E LLC
October 2020	Marshall Ranch, Briceland, CA	

Figure 2: UAV photo and Sounding Locations (ongoing testing in Location 2)

October 2020	Marshall Ranch, Briceland, CA	ARGO-E LLC

Figure 3
Surface wave testing at Location 1

October 2020

Marshall Ranch,
Briceland, CA

ARGO-E LLC

Figure 4
Surface wave testing at Location 2

October 2020	Marshall Ranch, Briceland, CA	ARGO-E LLC

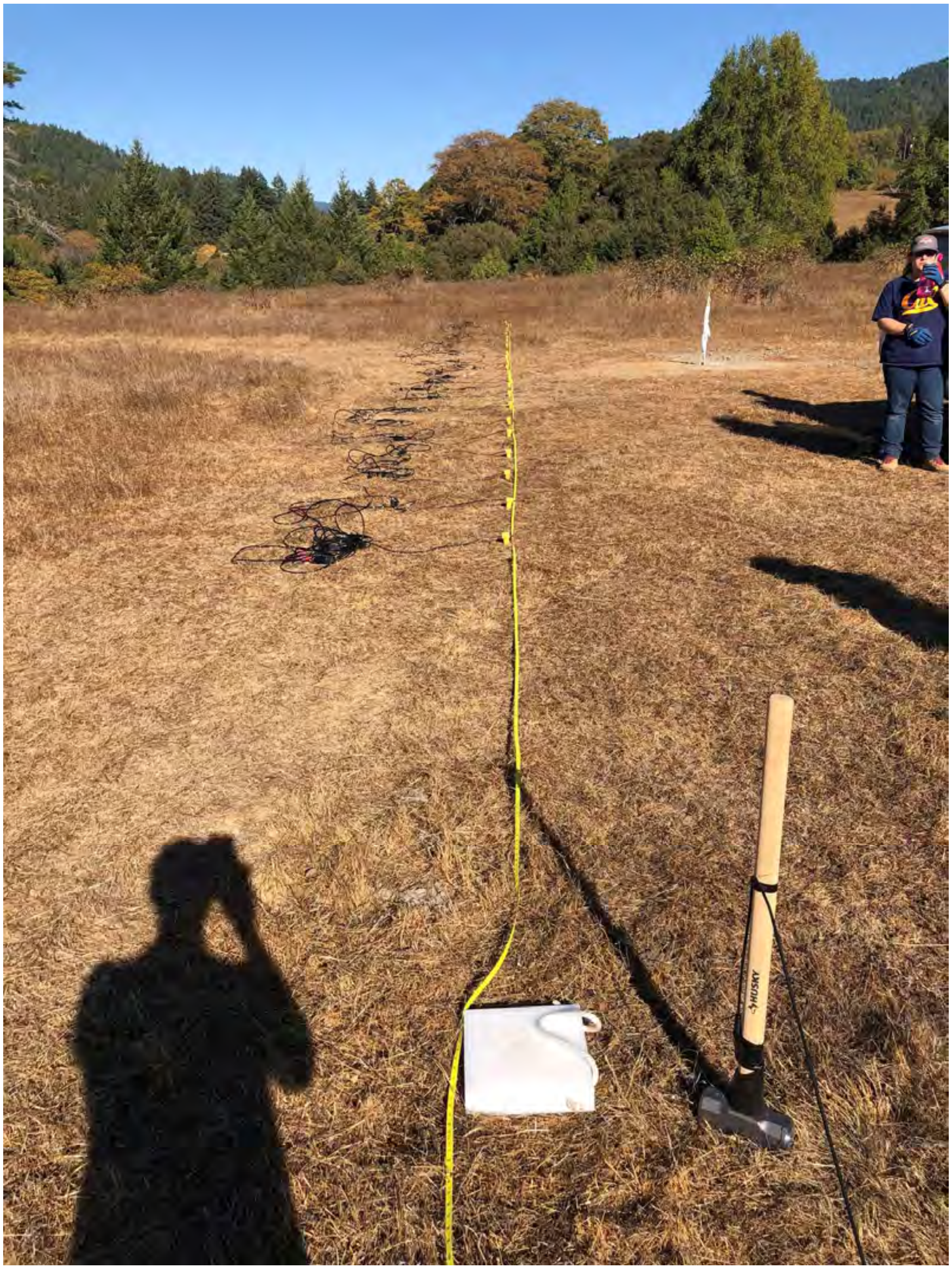


Figure 5
Surface wave testing at Location 3

October 2020

Marshall Ranch,
Briceland, CA

ARGO-E LLC

Figure 6
Borehole BH-105 near Location 3

October 2020

Marshall Ranch,
Briceland, CA

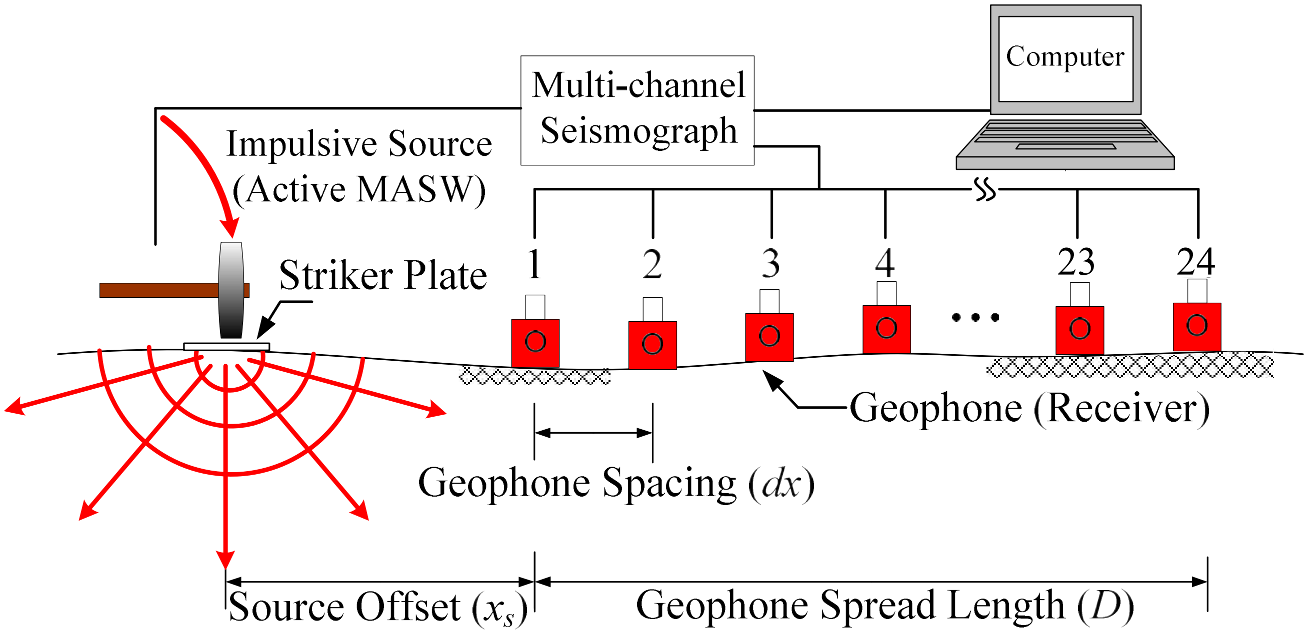
ARGO-E LLC

Figure 7
Surface wave testing at Location 4

October 2020

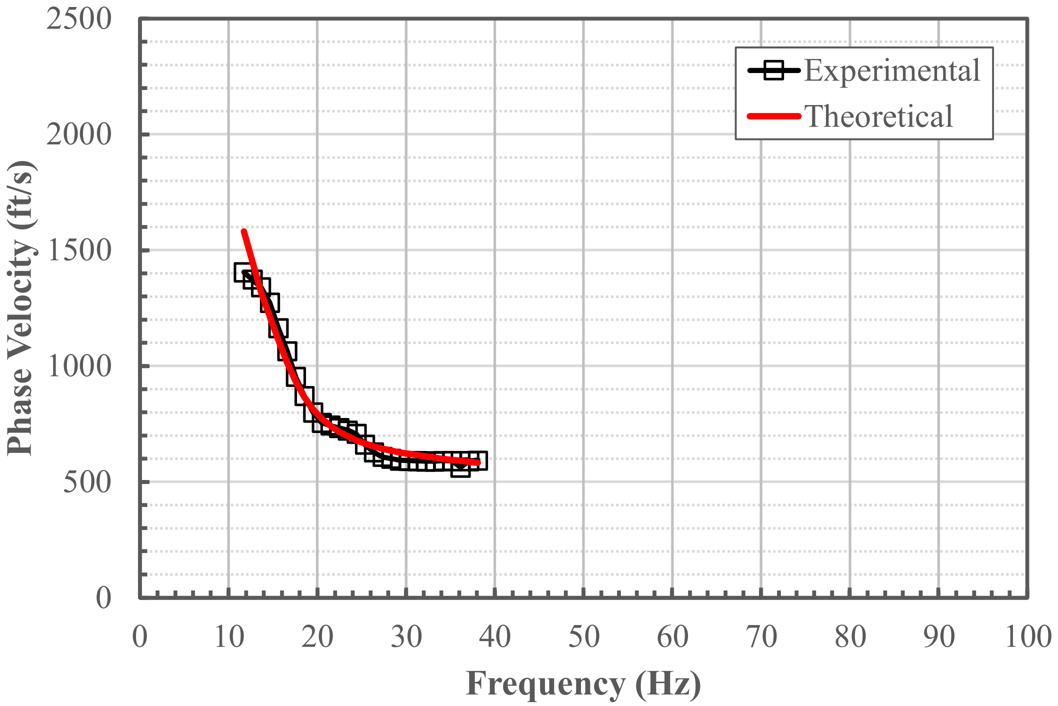
Marshall Ranch,
Briceland, CA

ARGO-E LLC



Sahadewa et al. (2012)

Figure 8: Schematic of linear array for surface wave measurements		ARGO-E LLC
October 2020	Marshall Ranch, Briceland, CA	



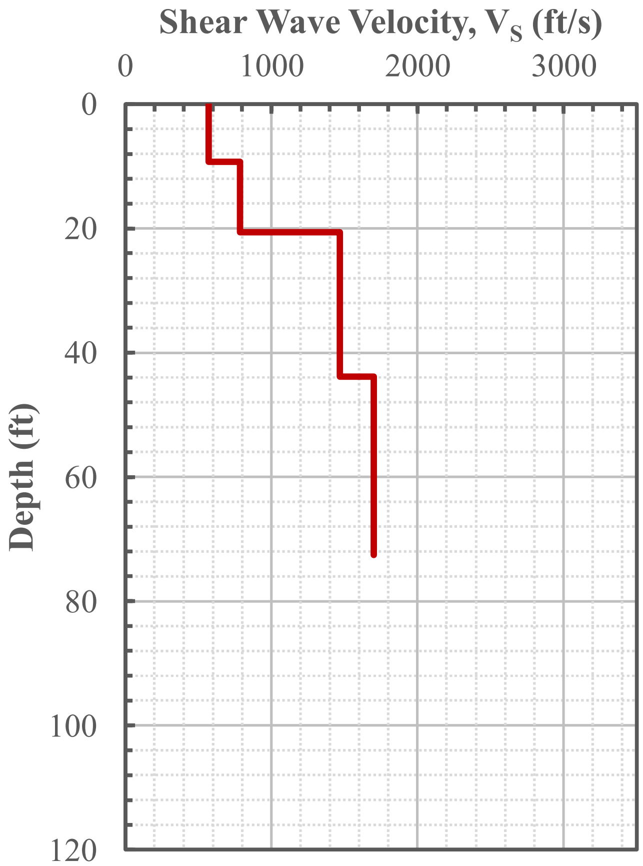
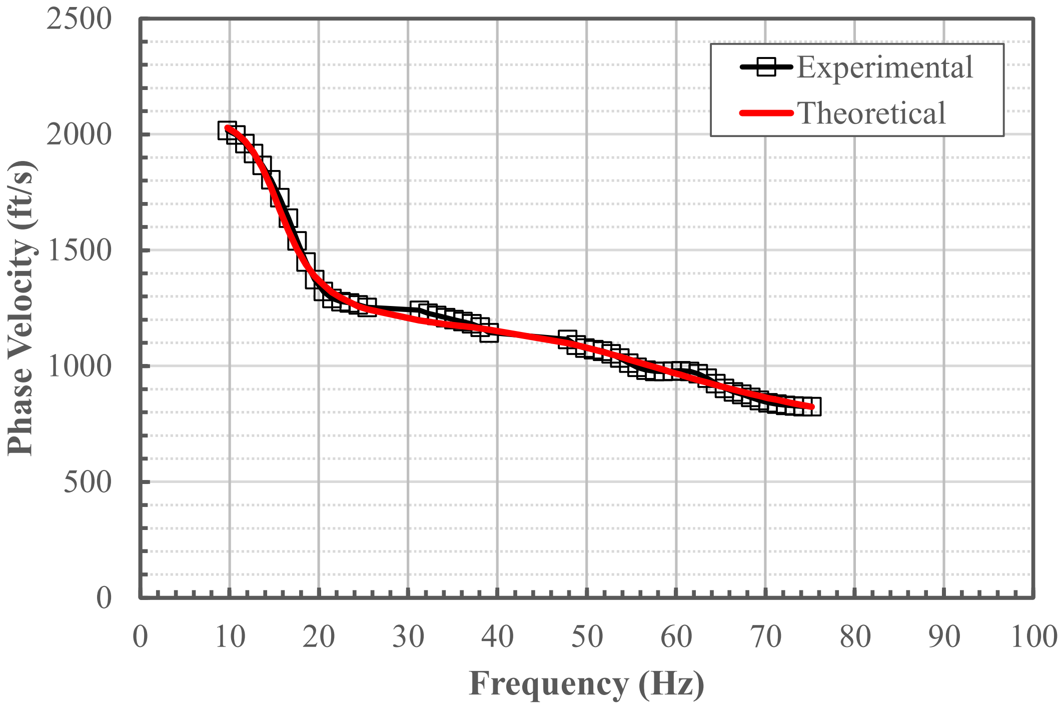


Figure 9: Dispersion Curve and Shear Wave Velocity Profile at Location 1		ARGO-E LLC
October 2020	Marshall Ranch, Briceland, CA	



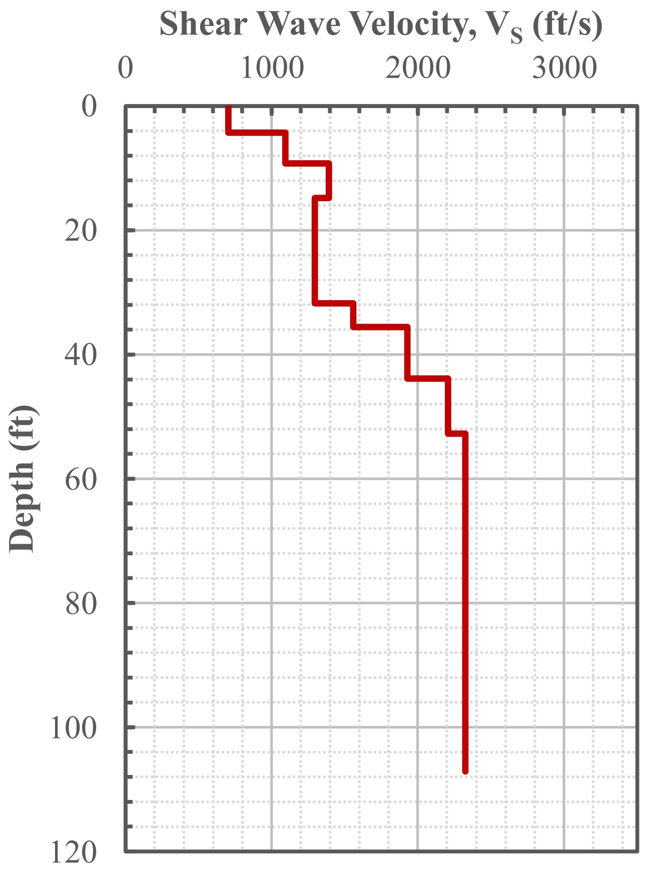
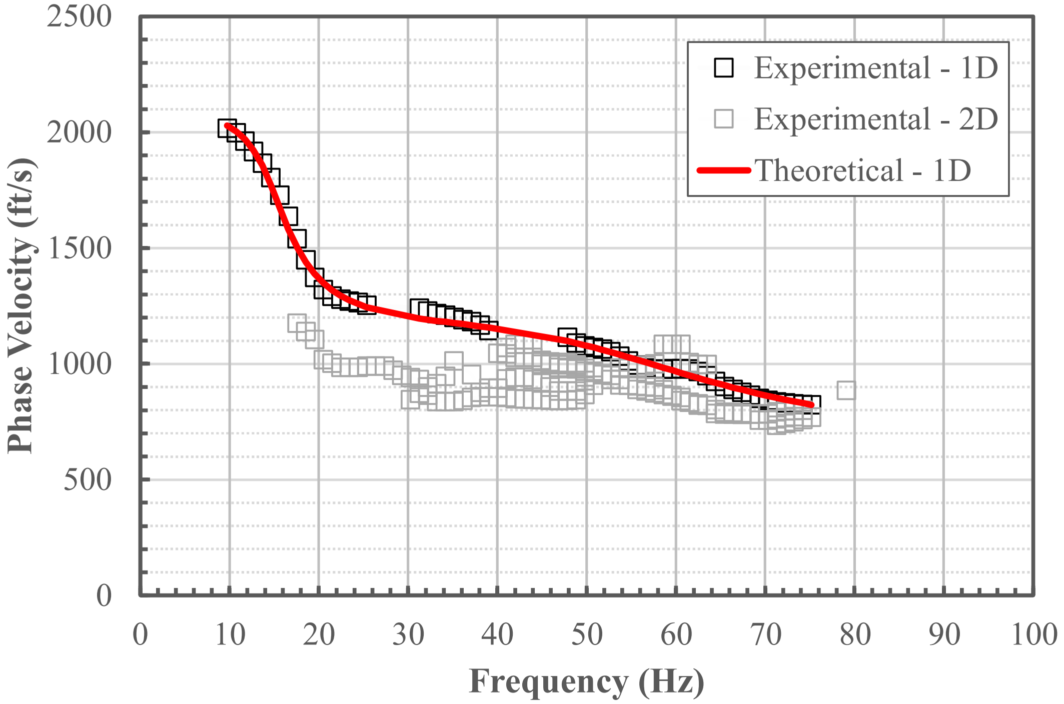


Figure 10: Dispersion Curve and Shear Wave Velocity Profile at Location 2		ARGO-E LLC
October 2020	Marshall Ranch, Briceland, CA	



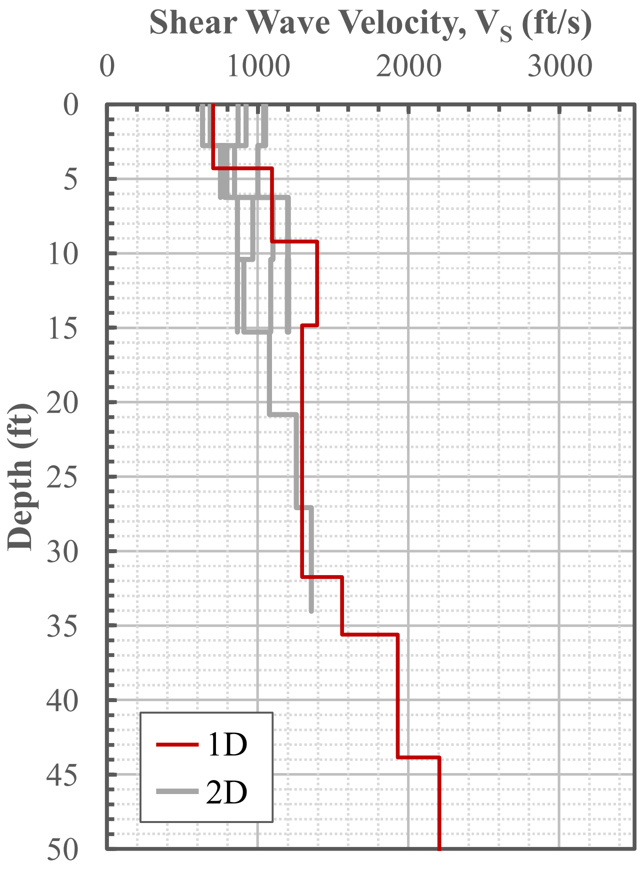
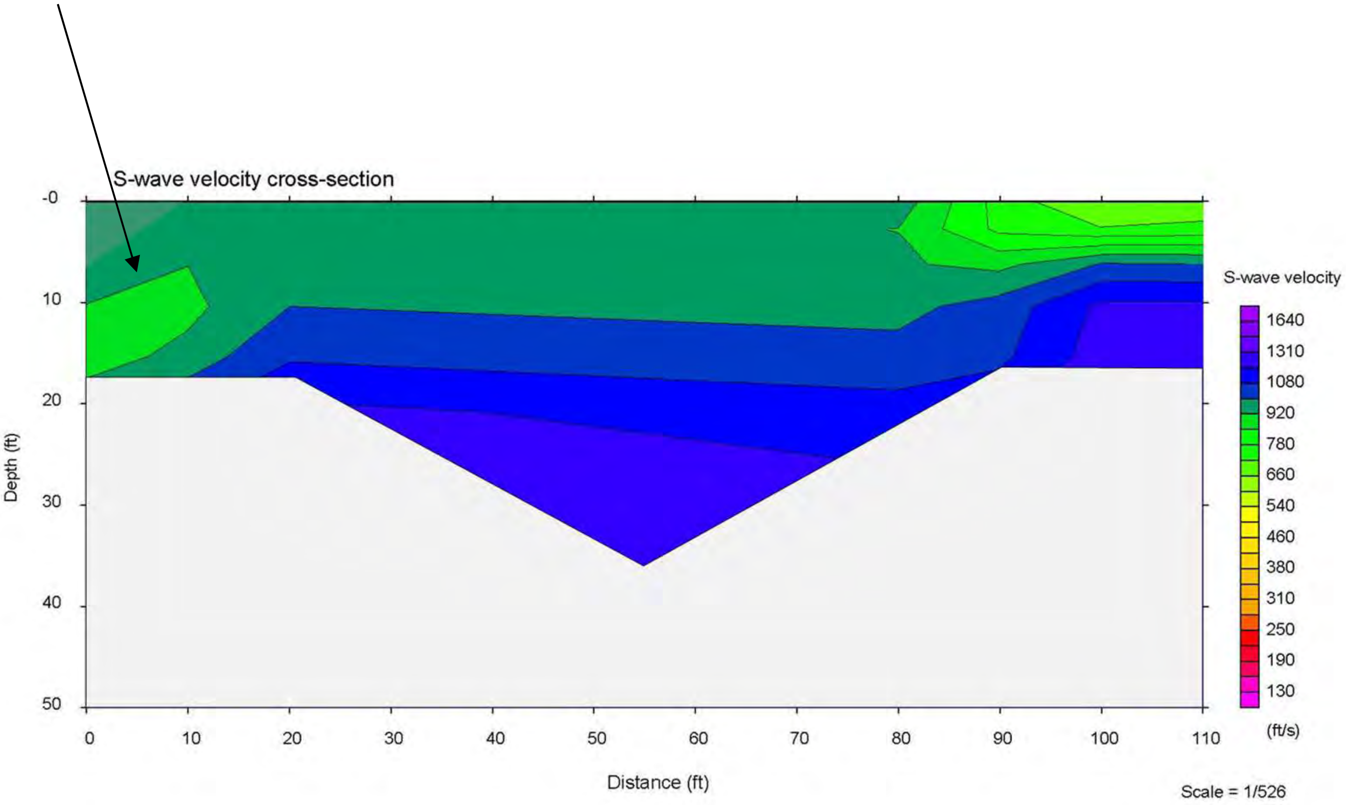


Figure 11: Dispersion Curves and V_S Profiles from 2D MASW at Location 2

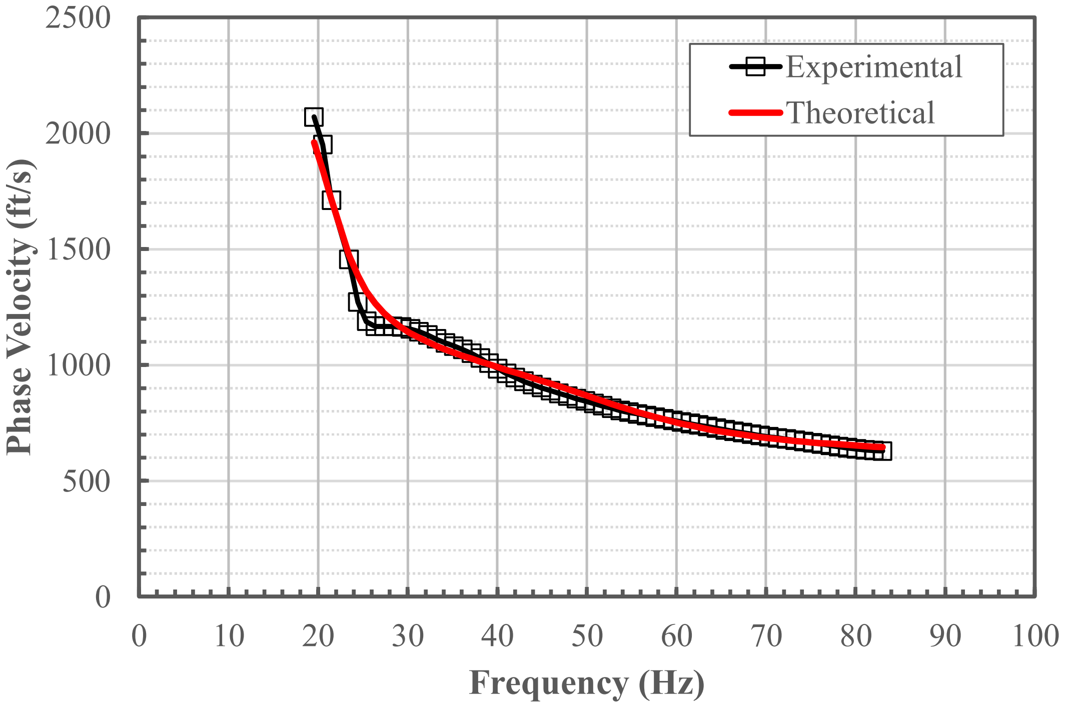
October 2020	Marshall Ranch, Briceland, CA	ARGO-E LLC

Thicker soil on southwest end of array



Note: The ground surface along the array was not entirely flat, but that is not shown in the Figure below.

Figure 12: 2D Shear Wave Velocity Profile at Location 2		ARGO-E LLC
October 2020	Marshall Ranch, Briceland, CA	



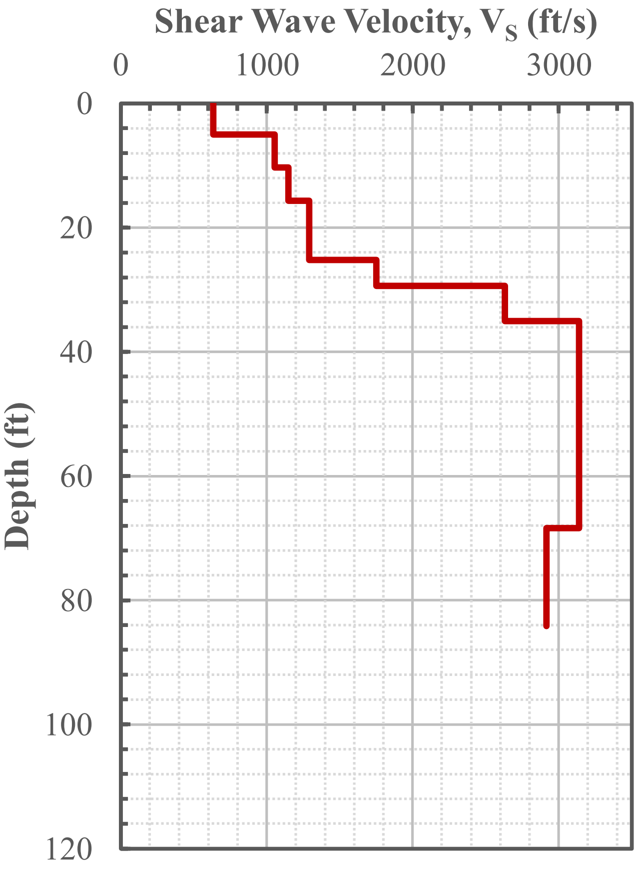
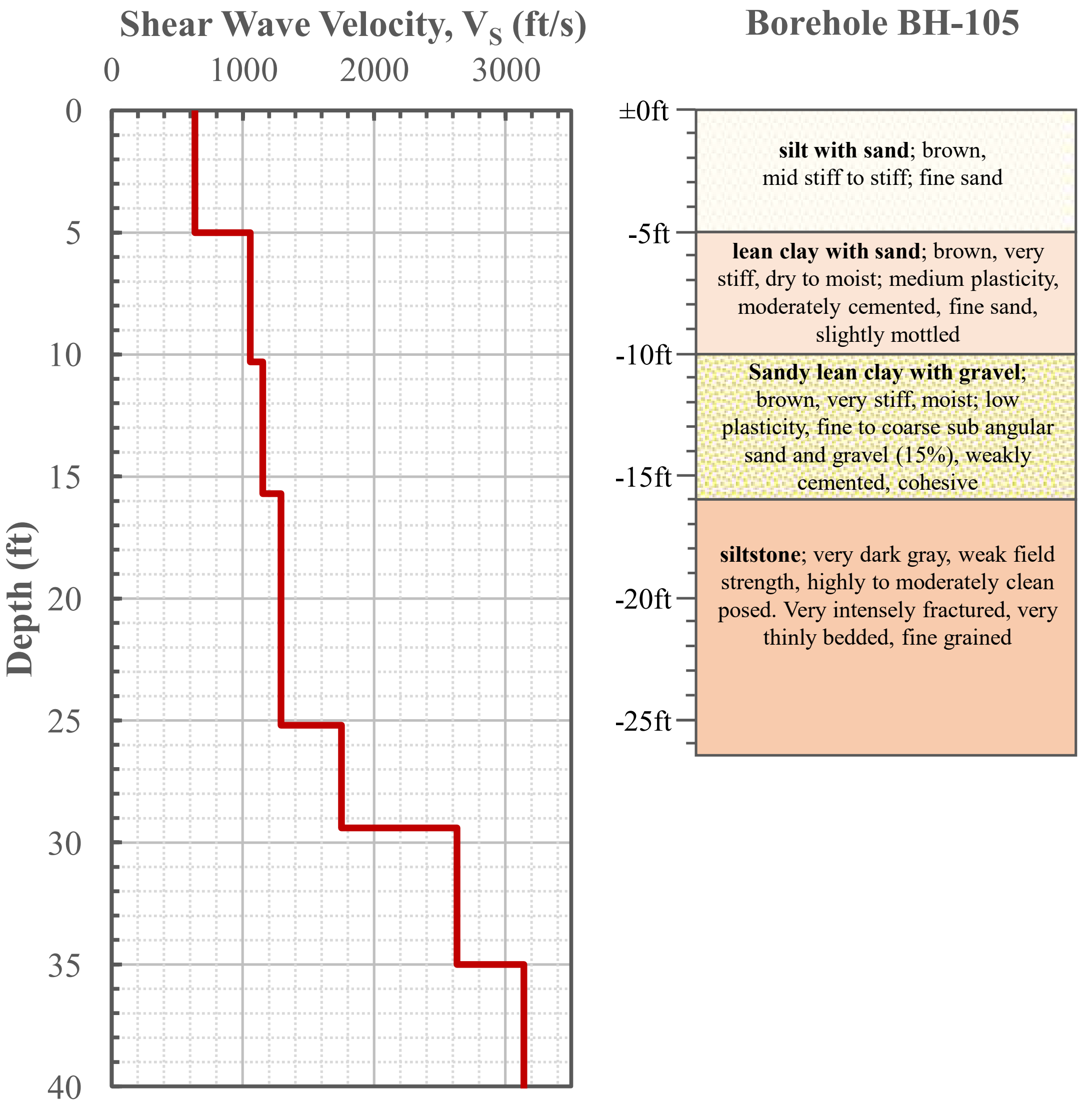


Figure 13: Dispersion Curve and Shear Wave Velocity Profile at Location 3

October 2020	Marshall Ranch, Briceland, CA	ARGO-E LLC



silt with sand; brown, mid stiff to stiff; fine sand

lean clay with sand; brown, very stiff, dry to moist; medium plasticity, moderately cemented, fine sand, slightly mottled

Sandy lean clay with gravel; brown, very stiff, moist; low plasticity, fine to coarse sub angular sand and gravel (15%), weakly cemented, cohesive

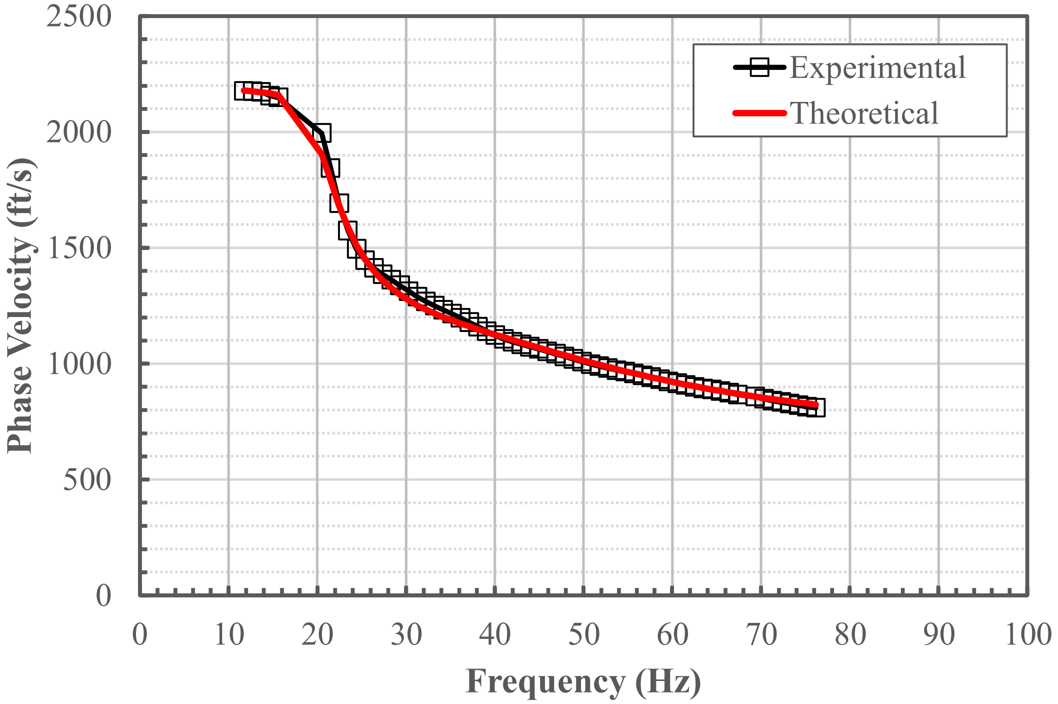
siltstone; very dark gray, weak field strength, highly to moderately clean posed. Very intensely fractured, very thinly bedded, fine grained

Figure 14: Upper 40ft Shear Wave Velocity Profile at Location 3 and Borehole BH-105

October 2020

Marshall Ranch,
Briceland, CA

ARGO-E LLC



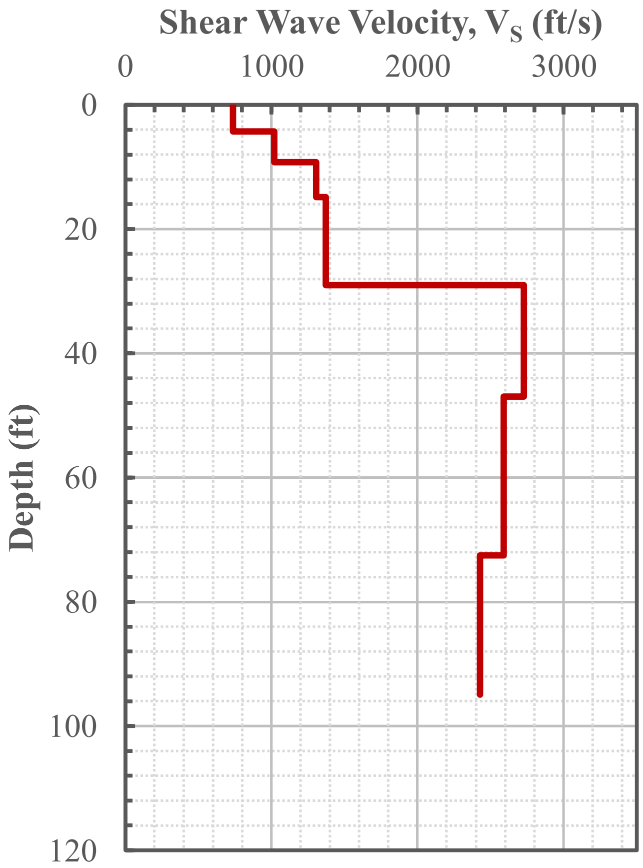


Figure 15: Dispersion Curve and Shear Wave Velocity Profile at Location 4		ARGO-E LLC
October 2020	Marshall Ranch, Briceland, CA	

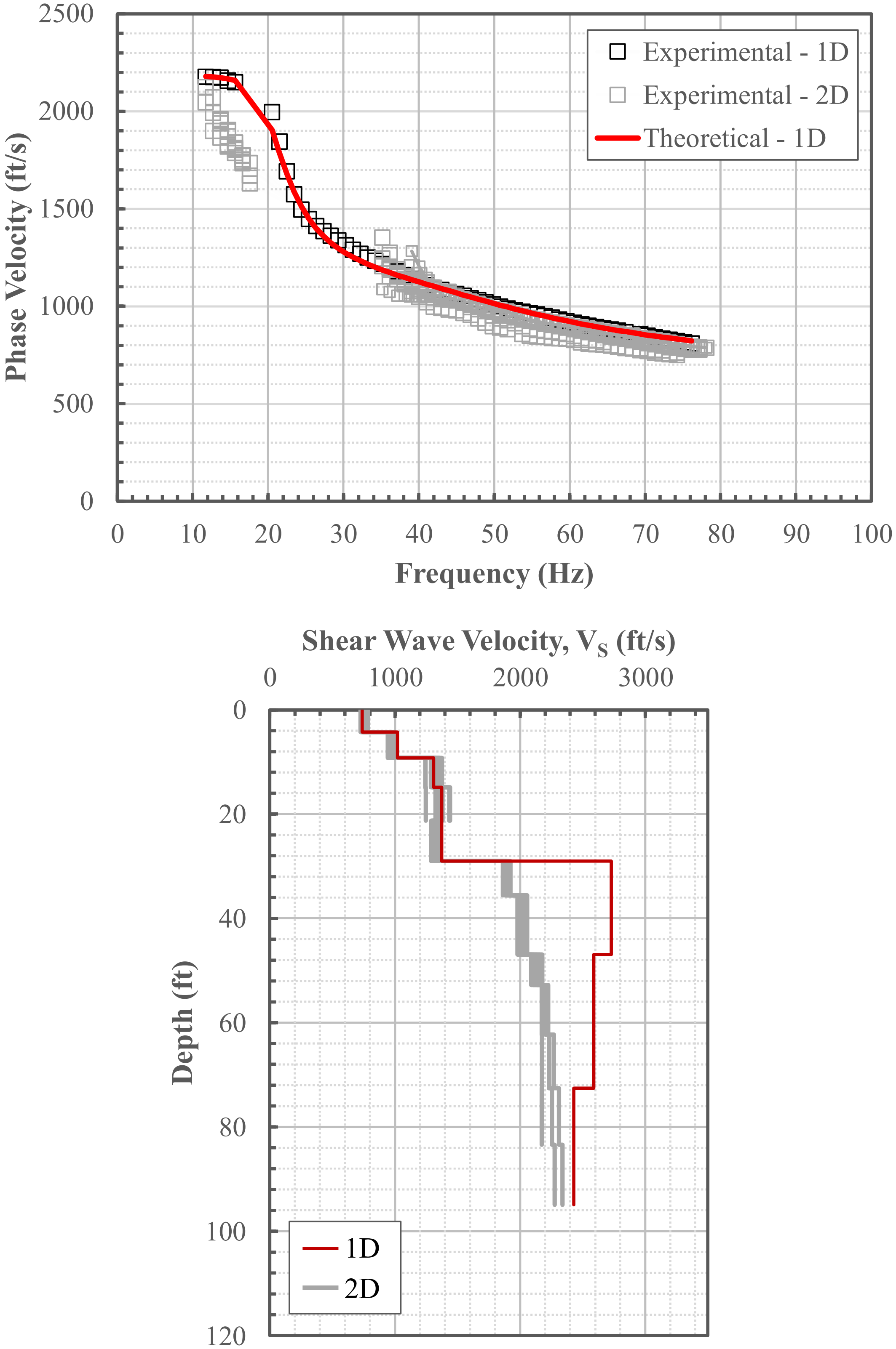
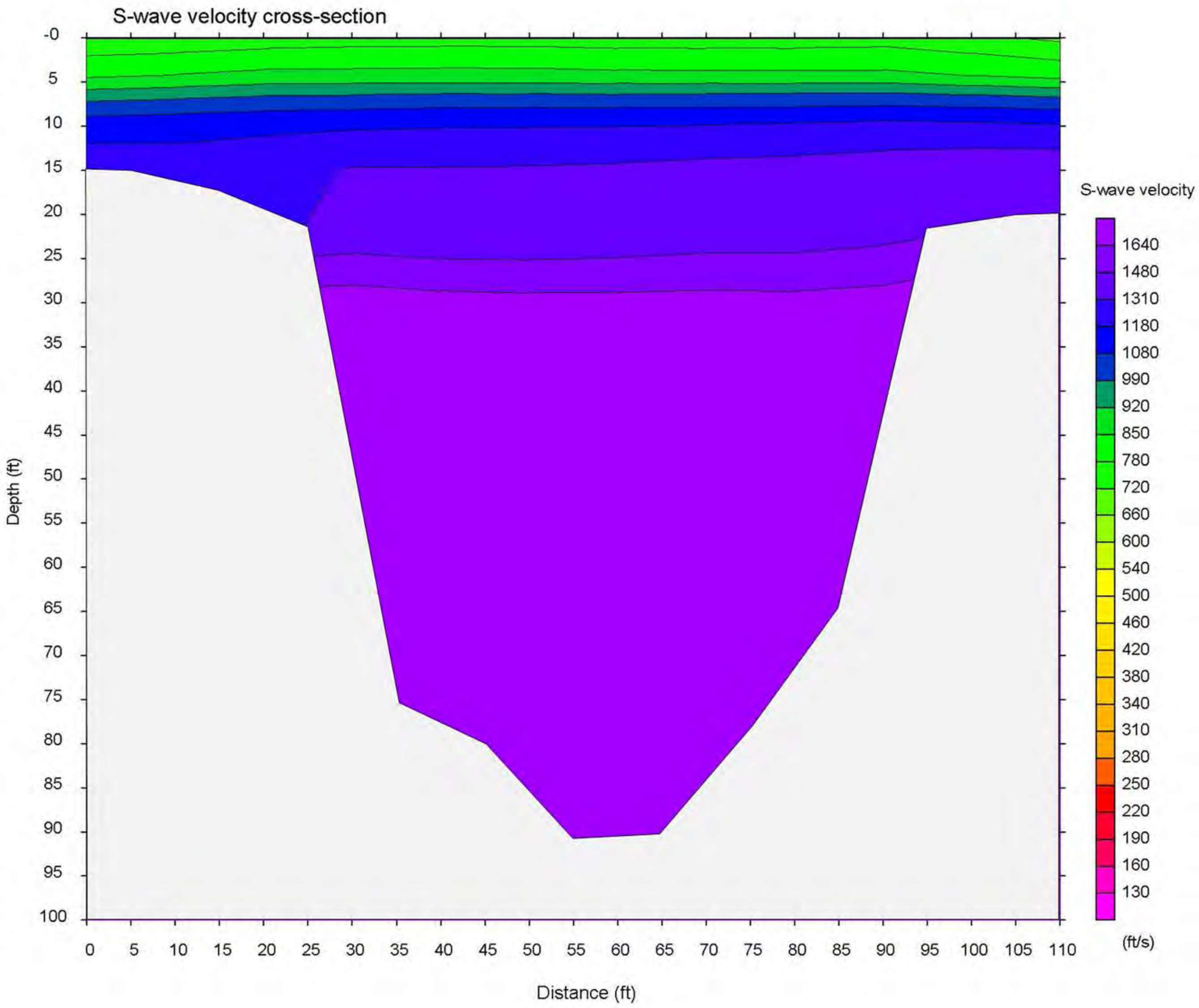


Figure 16: Dispersion Curves and V_S Profiles from 2D MASW at Location 4

October 2020

Marshall Ranch,
Briceland, CA

ARGO-E LLC



Note: The ground surface along the array was not entirely flat, but that is not shown in the Figure below.

Figure 17: 2D Shear Wave Velocity Profile at Location 4		ARGO-E LLC
October 2020	Marshall Ranch, Briceland, CA	

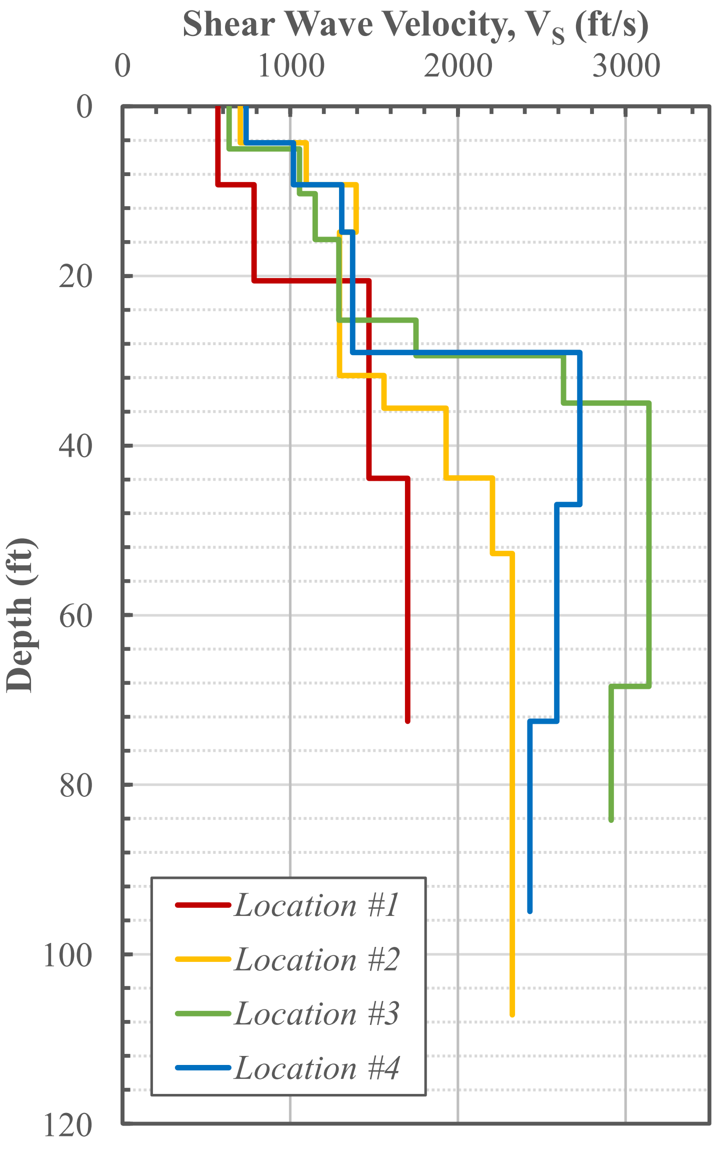


Figure 18: All 1D Shear Wave Velocity Profiles		ARGO-E LLC
October 2020	Marshall Ranch, Briceland, CA	

APPENDIX A

Surface Wave Testing Locations

Appendix A: Surface Wave Testing Locations.

MASW/MAM Site Name	Remarks	Testing Date	Testing Type	Near Offset, ft	Spacing, ft	MASW/MAM Line Location	WGS84	
							Latitude	Longitude
1	Lowest terrace, near neighbor	Oct. 25	Active 1D	10	3	Source	40.1053400	-123.900299
			Passive 1D		3	First Geophone	40.1053510	-123.900354
						Farthest Geophone	40.1052950	-123.900603
2	Upper terrace, central location parallel to expected embankment	Oct. 25	Active 1D	15	5	Source	40.1043440	-123.9003260
			Active 2D	varying	5	First Geophone	40.1043710	-123.9002510
			Passive 1D		5	Farthest Geophone	40.1044650	-123.8997980
3	By borehole BH-105 location	Oct. 25	Active 1D	14	3	Source	40.1046028	-123.899567
						First Geophone	40.1046194	-123.899536
						Farthest Geophone	40.1047167	-123.899369
4	Perpendicular to Location 2 array and along geotech cross-section	Oct. 25	Active 1D	20	5	Source	40.1047230	-123.899905
			Active 2D	varying	5	First Geophone	40.1046700	-123.899870
						Farthest Geophone	40.1044180	-123.899682

Note: Measurements made using geotagged photos. Uncertainty in each location is +/- 7-10 ft

APPENDIX B

Shear Wave Velocity Profiles in Tabular Format

Location 1		**Location 2**		**Locaion 3**		**Location 4**	
Depth (ft)	Vs (ft/sec)	Depth (ft)	Vs (ft/sec)	Depth (ft)	Vs (ft/sec)	Depth (ft)	Vs (ft/sec)
0.0	570	0.0	703	0.0	635	0.0	737
4.3	570	4.3	703	2.0	635	4.3	737
4.3	570	4.3	1096	2.0	635	4.3	1020
9.2	570	9.2	1096	5.0	635	9.2	1020
9.2	785	9.2	1393	5.0	1055	9.2	1307
18.5	785	14.8	1393	10.3	1055	14.8	1307
18.5	785	14.8	1295	10.3	1150	14.8	1373
20.6	785	21.0	1295	13.0	1150	21.3	1373
20.6	1470	21.0	1295	13.0	1150	21.3	1373
29.7	1470	31.7	1295	15.7	1150	29.0	1373
29.7	1470	31.7	1559	15.7	1290	29.0	2728
35.6	1470	35.6	1559	25.2	1290	35.6	2728
35.6	1470	35.6	1930	25.2	1750	35.6	2728
43.9	1470	43.8	1930	29.4	1750	47.0	2728
43.9	1700	43.8	2206	29.4	2630	47.0	2590
52.8	1700	52.7	2206	35.0	2630	52.7	2590
52.8	1700	52.7	2325	35.0	3140	52.7	2590
62.3	1700	62.3	2325	41.0	3140	62.3	2590
62.3	1700	62.3	2325	41.0	3140	62.3	2590
72.5	1700	72.5	2325	47.3	3140	72.5	2590
		72.5	2325	47.3	3140	72.5	2430
		83.4	2325	54.0	3140	83.4	2430
		83.4	2325	54.0	3140	83.4	2430
		94.9	2325	61.0	3140	94.9	2430
		94.9	2325	61.0	3140		
		107.1	2325	68.4	3140		
				68.4	2915		
				76.1	2915		
				76.1	2915		
				84.2	2915		

Appendix C

Slope Stability Analyses

Slope Stability Analyses

Redwood Creek Flow Enhancement
Marshall Ranch
Briceland, Humboldt County, California

Prepared by

Adda Athanasopoulos-Zekkos, PhD
George Zalachoris, PhD

Prepared for

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tel 707-822-9607   fax 888-766-5110
www.stillwatersci.com

December 7 2020

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1. INTRODUCTION

At the request of Mr. Joel Monschke, Stillwater Sciences, slope stability analyses were performed for the proposed development at the Marshall Ranch in Briceland, Humboldt County, California with the intent to assess the landslide hazard at the project site. Analyses were conducted under the direction of Dr. Adda Athanasopoulos-Zekkos with the assistance of Dr. George Zalachoris. This report documents the analytical results and was prepared by Dr. Adda Athanasopoulos-Zekkos and Dr. George Zalachoris.

2. SLOPE STABILITY ANALYSIS

To assess the slope stability at the project site, initially, a geometrical model was developed, based on LiDAR and topographic data of the area and the proposed development, as provided by Mr. Joel Monschke. Subsequently, a complete three-dimensional (3D), conceptual model of the project site was generated by leveraging data from in-situ and laboratory geotechnical investigation efforts, as reported by SHN (2019) (i.e., boreholes, test pits, and index property tests), as well as shear wave velocity (V_S) profiles obtained from four field seismic geophysical surveys performed by Dr. Dimitrios Zekkos in October 2020, using the 1D and 2D Multichannel Analysis of Surface Waves (MASW) method. The project site, and the locations of the field investigations are illustrated in Figure 1. Simplified stratigraphies at each borehole/test pit location, based on the in-situ data, are tabulated in Appendix A, while in Figure 2 the generated V_S profiles from the four MASW arrays are illustrated. Accordingly, the final 3D model of the project site is shown in Figure 3. The 3D model was generated using the commercial software SoilVision SVDESIGNER v.10. Two, two-dimensional (2D) cross-sections within and around the indicated area of interest (Figure 1) were selected as shown in Figure 4, for both static and seismic slope stability analyses. The analyses were performed using the commercial software SoilVision SVSLOPE v10. The selected 2D cross-sections are illustrated in Figures 5 through 8.

Material properties for the soil/rock layers of the model (i.e., unit weight, γ, cohesion, c, and friction angle, φ) were developed based on the in-situ data (Appendix A), and published values in the literature (Lambe and Whitman, 1979; Meyerhof, 1956; Peck et al., 1974; Kulhawy and Mayne, 1990; Budhu, 1999; NAVFAC, 1986). The assigned material properties for the modeled layers are shown in Table 1. Nonetheless, acknowledging the uncertainty around these values, sensitivity analyses were performed, by varying the shear strength parameters (i.e., c and φ) of the layers mostly affecting the slope stability of the system. Finally, the analyses were performed for drained conditions, and the water table was assumed to be located at the ground surface to account for wet season conditions.

Table 1. Material properties of the model layers (Baseline Case)

Layer	**Description**	**Dry Unit Weight, γ_d (pcf)**	**Total Unit Weight, γ_t (pcf)**	**Cohesion, c (psf)**	**Friction Angle, φ (deg.)**
ML	silt and sand	99	118	200	32
SM	sand with silt	113	132	450	34
CL	lean clay with sand	87	100	650	28
GW	well-graded gravel with sand	111	128	0	38
SC	clayey sand	110	127	200	31
Bedrock	siltstone/shale	145	150	50000	30

3. METHODOLOGY

Once the model geometry, soil layering, material properties and ground water conditions have been established, slope stability is assessed by calculating the resisting and destabilizing forces acting on a slope. Thus, a Factor of Safety (FOS) is estimated using one of several Limit Equilibrium Methods (LEM). The seismic slope stability is assessed via pseudo-static analysis, where the value of a limiting yield acceleration (α_y), i.e., the level of seismic acceleration that initiates a slope failure, is obtained. Then, simplified approaches to quantify the seismically induced permanent displacements are employed, by using the obtained α_y and considering the seismicity at the project site and the Seismic Design Code Specifications (ASCE 7-16).

3.1 Limit Equilibrium Method

In the Limit Equilibrium Method (LEM), the Factor of Safety (FOS) is defined by employing the equations of static equilibrium. In essence, the FOS represents the factor by which the shear strength must be reduced so that it is in equilibrium with the shear stress, i.e., the shear stress required to maintain a just-stable slope for a particular slip surface, hence the term *limit equilibrium*. There are several different procedures available to satisfy static equilibrium within a limit equilibrium analysis framework. Herein, we used the General Limit Equilibrium Method (GLE) (Fredlund et al., 1981). The method is based on the calculation of two FOS equations; one equation provides the FOS with respect to the moment equilibrium, while the other gives the FOS with respect to horizontal force equilibrium. The critical slip surface is the one that results in the lowest FOS values. For static conditions, the engineering state-of-practice, typically, requires a FOS greater than 1.5. For the two selected cross sections (Cross Section 1 and Cross Section 2), the computed FOS and critical slip surfaces for the Baseline Case (Table 1) are shown in Figures 9 and 11, respectively. Moreover, in Figures 10 and 12, contour plots of the estimated FOS values obtained through sensitivity analyses for the shear strength parameters of the most critical soil layers, are presented for Cross Sections 1 and 2, respectively.

3.2 Pseudo-Static Seismic Slope Stability

Screening analysis of slope stability under dynamic conditions (i.e., earthquake) are performed using a pseudo-static procedure. The earthquake loading is represented by a static force, equal to the soil weight multiplied by a seismic coefficient, k. The pseudo-static force is then input as an additional force in a conventional limit equilibrium slope stability analysis. The limitation of the method is that the seismic pseudo-static force is applied as an additional static force acting on the direction of sliding, while in reality seismic loading is acting in changing directions, thus tending to stabilize rather than destabilize the slope at certain instances in time. In a pseudo-static analysis, the value of a limiting yield seismic coefficient ($k_y=\alpha_y/g$) is obtained when the Factor of Safety is unity. For the two selected cross sections (Cross Section 1 and Cross Section 2), the computed k_y and critical slip surfaces for the Baseline Case (Table 1) are shown in Figures 13 and 15, respectively. Moreover, in Figures 14 and 16, contour plots of the estimated k_y values obtained through sensitivity analyses for the shear strength parameters of the most critical soil layers, are presented for Cross Sections 1 and 2, respectively.

3.3 Seismic Slope Displacements

To evaluate the seismic performance of the slopes at the project site location, simplified seismic slope displacement approaches are employed. Herein, the Bray and Rathje (1998), and Bray and Travasarou (2007) procedures were applied. In general, in a seismic displacement analysis, the critical components are: (1) the earthquake ground motion, (2) the dynamic resistance of the structure, and (3) the dynamic response of the potential sliding mass. Bray and Rathje (1998) use simplified parameters such as the peak ground acceleration (PGA), mean period (T_m), and significant duration (D_{5-95}) to characterize the intensity, frequency content, and duration, respectively, of an earthquake ground motion. Bray and Travasarou (2007) utilize the spectral acceleration at a degraded period equal to 1.5 times the initial fundamental period (T_S) of the slope (i.e., $Sa(1.5T_S)$), as the most efficient ground motion parameter. The initial fundamental period of the sliding mass (T_S) can be estimated using the expression: $T_S=4H/V_{S,slope}$, where H is the average height of the potential sliding mass, and $V_{S,slope}$ is the average shear wave velocity of the sliding mass (ex., MASW #2, #3, and #4 profiles, Figure 2). The dynamic resistance of a slope is represented by the yield coefficient (k_y), obtained through pseudo-static limit equilibrium analyses (see Section 3.2). Finally, the dynamic response of the potential sliding mass is quantified by estimating the maximum seismic coefficient k_{max}, which represents the maximum horizontal equivalent acceleration (*MHEA*) acting on the slope.

For the project site (Latitude/Longitude: 40.104393°,-123.900098°), the peak ground acceleration at the base of the slope (PGA_{rock}), the spectral acceleration at a degraded period ($Sa(1.5T_S)=S_{DS}$), the mean period (T_m), and significant duration ($D_{5–95}$) parameters are obtained based on Seismic Design Code Specifications (ASCE 7-16), the seismicity scenario with a 2% probability of exceedance in 50 years (i.e., return period of 2475 years) at the project area ($M_w=7.8$, $R_{rup}=18km$) (USGS Seismic Hazard Tool), and available ground motion parameter empirical relationships (Figure 17). The estimated parameters are tabulated in Table 2.

Table 2. Seismic Design Code Specifications and Seismic Hazard Parameters for Marshall Ranch site in Briceland, Humboldt County, California (Latitude/Longitude: 40.104393°,-123.900098°). Seismic hazard values correspond to 2% probability of exceedance in 50 years (return period of 2475 years).

ASCE 7-16		**Seismic Hazard**	
$V_{s,rock}$ (ft/sec)	2500	M	7.8
Site Class	B	R (km)	18
S_{DS} (g)	1.094	T_m (sec)	0.58
PGA_{rock} (g)	0.438	D_{5-95} (sec)	30

Using estimates of k_y (Figures 13 and 15), the seismic displacement, *U*, can be estimated (in cm), based on the Bray and Rathje (1998) method (Figure 16), as a function of k_y/k_{max} using:

$$\log_{10}(U/k_{max}D_{5-95}) = 1.87 - 3.477(k_y/k_{max}\ ) \ \pm\ \varepsilon$$

where $\sigma=0.35$. The seismic displacement values are estimated at the median (i.e., corresponding to the scenario with 2% probability of exceedance in 50 years), 16% ($+1\sigma$), and 84% exceedance (-1σ) levels to develop a range of estimated performance. The maximum seismic coefficient, $k_{max}=MHEA/g$, can be estimated as function of *PGA*, the mean period (T_m), and the initial fundamental period of the sliding mass (T_S) (Figure 18).

The Bray and Travasarou (2007) approach of estimating seismically induced displacements has two computations. First, the probability of negligible (“zero”) displacement is estimated as:

$$P(D = “0”) = 1 - \Phi\big(-1.76 - 3.22\ln(k_y) - 0.484(T_S)\ln(k_y) + 3.52\ln(Sa(1.5T_S))\big)$$

where *P(D="0")* is the probability of occurrence of "zero" displacements, and Φ is the standard normal cumulative distribution function. If there is low probability for "zero" displacements, the amount of "nonzero" displacement (D, in cm) is computed using:

$$\begin{aligned}\ln(D) = {} & -1.10 - 2.83\ln(k_y) - 0.333(\ln(k_y))^2 + 0.566\ln(k_y)\ln(Sa(1.5T_S)) \\ & + 3.04\ln(Sa(1.5T_S)) - 0.244(\ln(Sa(1.5Ts)))^2 + 1.5T_S + 0.278(M-7) \\ & \pm \varepsilon\end{aligned}$$

where $\sigma=0.66$. The seismic displacement values are, again, estimated at the median (i.e., corresponding to the scenario with 2% probability of exceedance in 50 years), 16 ($+1\sigma$), and 84% exceedance (-1σ) levels to develop a range of estimated performance.

The results of the Bray and Rathje (1998), and Bray and Travasarou (2007) simplified seismic displacement approaches, for the Cross Sections 1 and 2, are tabulated in Tables 3 and 4, respectively.

Table 3. Estimated Seismic Slope Displacements for Cross Section 1

Slope Specific Info		**Bray and Rathje (1998)**			
H (ft)	35	$\sigma = 0.35$	Median	16% exceedance	84% exceedance
$V_{s,slope}$ (ft/sec)	1100	$\log(U/(k_{max}*D_{5\text{-}95}))$	0.16	0.51	-0.19
T_S (sec)	0.13	$U/(k_{max}*D_{5\text{-}95})$	1.44	3.23	0.64
k_y	0.211	U (in.)	**7.3**	**16.4**	**3.3**
T_S/T_m	0.22	**Bray and Travasarou (2007)**			
NRF	0.98	P(D="0") (%)	1.3E-02		
MHEA (g)	0.429	$\sigma = 0.66$	Median	16% exceedance	84% exceedance
$Sa(1.5T_S)$ (g)	1.094	ln(D)	3.1	3.8	2.4
k_{max}	0.429	D (in.)	**8.8**	**16.9**	**4.5**

Table 4. Estimated Seismic Slope Displacements for Cross Section 2

Slope Specific Info		**Bray and Rathje (1998)**			
H (ft)	35	$\sigma = 0.35$	Median	16% exceedance	84% exceedance
$V_{s,slope}$ (ft/sec)	1100	$\log(U/(k_{max}*D_{5\text{-}95}))$	1.00	1.35	0.65
T_S (sec)	0.13	$U/(k_{max}*D_{5\text{-}95})$	10.06	22.51	4.49
k_y	0.107	U (in.)	**50.9**	**114.0**	**22.8**
T_S/T_m	0.22	**Bray and Travasarou (2007)**			
NRF	0.98	P(D="0") (%)	1.9E-07		
MHEA (g)	0.429	$\sigma = 0.66$	Median	16% exceedance	84% exceedance
$Sa(1.5T_S)$ (g)	1.094	ln(D)	4.1	4.8	3.5
k_{max}	0.429	D (in.)	**24.5**	**47.5**	**12.7**

4. VALIDATION STUDY USING FINITE ELEMENT ANALYSIS

To validate the results of the pseudo-static, limit-equilibrium seismic slope stability analyses and assess the spatial distribution of the potential seismically-induced permanent displacements at the project site, a Finite Element Analysis (FEA) was performed upon request of Mr. Joel Monschke, Stillwater Sciences. The numerical model was developed using the commercial program PLAXIS 2D CONNECT Edition. Focus was given specifically to Cross Section 2 which, as shown in Figure 15 and Table 4, is characterized by lower yield acceleration ($k_y=0.107$) and larger seismically-induced permanent displacements (median displacement values of *25-51 in.*). The geometric model, layering and material parameters used for the Finite Element Analysis were identical to the ones used for the Limit Equilibrium Method (LEM) calculations (Figure 8 and Table 1). The Mohr-Coulomb constitutive model and drained conditions were considered for the analysis. To be able to directly compare numerical results with the ones obtained through LEM and the simplified seismic slope displacement methods (Table 4), the shear wave velocities of the soil materials and the bedrock were set to $V_{s,slope} = 1100$ *ft/sec*, and $V_{s,rock} = 2500$ *ft/sec*, respectively. The developed finite element model is shown in Figure 19.

The finite element analysis was performed using the pseudo-static procedure, as analyzed in Section 3.2. To simulate the seismic load, a maximum horizontal equivalent acceleration (*MHEA*) of *0.429g* (i.e., $k_{max}=0.429$), as defined earlier (Table 4), was applied. The numerical results in terms of deformed shape and displacement contours are presented in Figures 20 and 21, respectively. The slope failure mechanism is fully developed when the phase multiplier ΣM_{stage} reaches a value of *0.228*. Therefore, the critical horizontal yield acceleration coefficient, k_y, is estimated as:

$$k_y = \Sigma M_{stage} \cdot k_{max} = 0.098$$

The resulting numerically obtained yield acceleration validates the computed value from LEM ($k_y=0.107$). Moreover, the critical yield surface from FEA (Figure 21) is similar to the one obtained via LEM (Figure 15). The FEA-computed maximum slope displacements are on the order of *~2.5 ft* (*~30 in.*) at the toe of the slope (Figures 20 through 22), a value that is within the range of the computed seismically induced slope displacements from the simplified Bray and Rathje (1998) and Bray and Travasarou (2007) procedures (Table 4). Nonetheless, as indicated in Figure 21, the distribution of the displacements is heavily concentrated around the slip surface; i.e., the pond berm and most of the upper terrace are not significantly affected. Indeed, as presented in Figure 22, at a horizontal equivalent acceleration of *0.098g*, the crest of the pond berm exhibits only minimal displacements (*0.15 in.*).

5. RESULTS

The results of the static slope stability analyses indicate that the Factors of Safety are borderline acceptable, with static FOS=1.68 for Cross Section 1, and FOS=1.35 for

Cross Section 2, for the Baseline Case material parameters (Figures 9 and 11). Sensitivity analyses do not significantly alter this remark (Figures 10 and 12). Moreover, based on the LEM results, the pond and berm developments on the upper terrace are not expected to have a significant effect on the stability of the slopes, since all the critical slip surfaces are at a substantial distance from the pond.

In terms of screening seismic slope stability, both Cross Sections are characterized by relatively low seismic capacity (i.e., $k_y=0.211$ and $k_y=0.107$ for Cross Sections 1 and 2, respectively) (Figures 13 and 15). Considering a seismic scenario with a 2% probability of exceedance in 50 years (return period of 2475 years), the computed, based on simplified methods (Bray and Rathje, 1998; and Bray and Travasarou, 2007), seismically induced displacements could potentially reach *7-9 in.* for Cross Section 1, and *25-51 in.* for Cross Section 2 (median values in Tables 3 and 4). A validation study involving a pseudo-static Finite Element Analysis of Cross Section 2 yielded similar results with the ones obtained through LEM and the simplified seismic slope displacement methods (Figures 19 through 22). The numerically obtained yield acceleration was estimated as *0.098g*, while the maximum displacement at the toe of the slope was on the order of *~2.5 ft* (*30 in.*). Nonetheless, the spatial distribution of the seismically-induced permanent displacements are heavily concentrated in the vicinity of the slope, with the pond berm and most of the upper terrace exhibiting only minimal displacements (0.15 in., Figure 22). Therefore, based on the FEA results, the pond and berm developments on the upper terrace are not expected to have a significant effect on the seismic stability of the slopes. Finally, it should be noted that, due to topographic and geomorphological particularities of the project site, it is anticipated that 3D effects could be significant; in general, 3D slope stability analyses tend to produce higher factors of safety both for static and dynamic conditions (Duncan and Wright, 2005).

6. REFERENCES

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FIGURES

Locations accurate to ±7-10ft

Figure 1: Google Earth Site Map and Field Investigation Locations

December 2020	Marshall Ranch, Briceland, CA

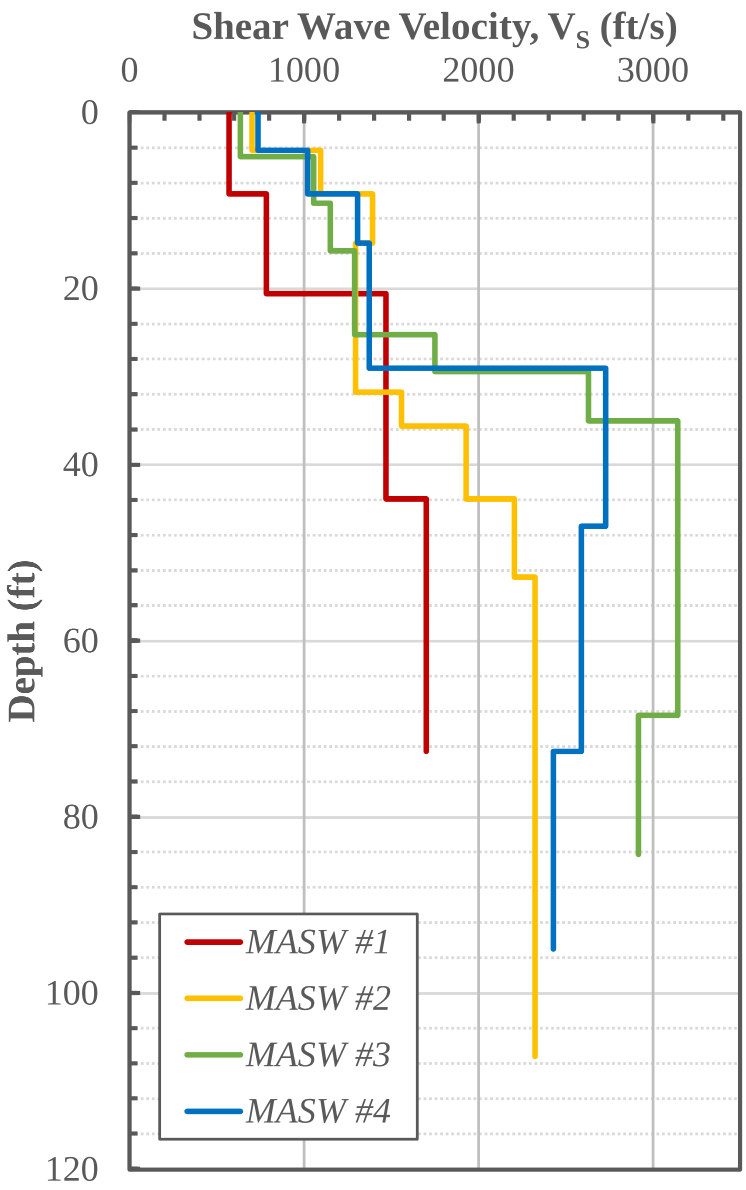

Figure 2: 1D Shear Wave Velocity Profiles from MASW Geophysical Surveys

December 2020	Marshall Ranch, Briceland, CA

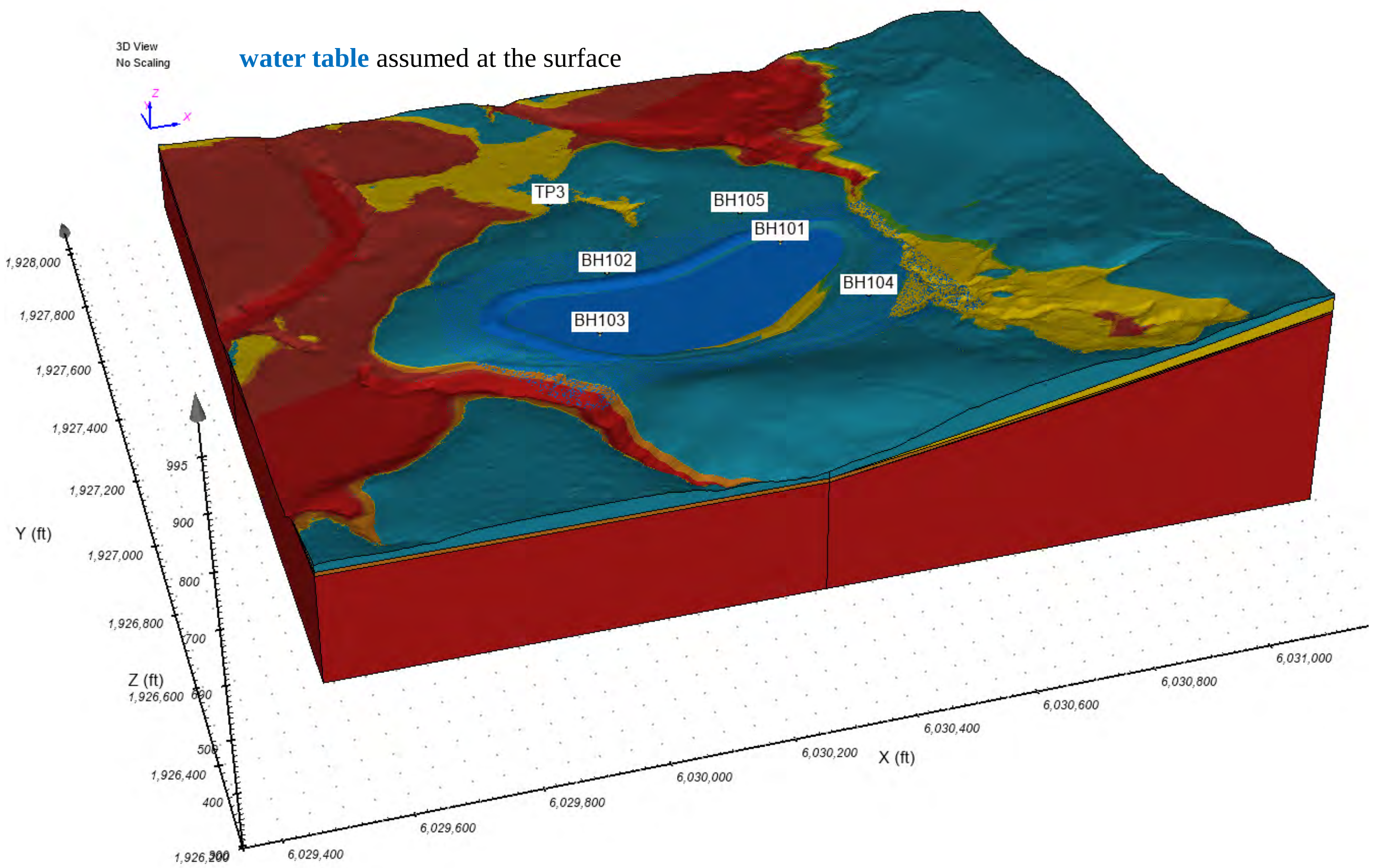

Figure 3: Three-dimensional, conceptual model of the project site.

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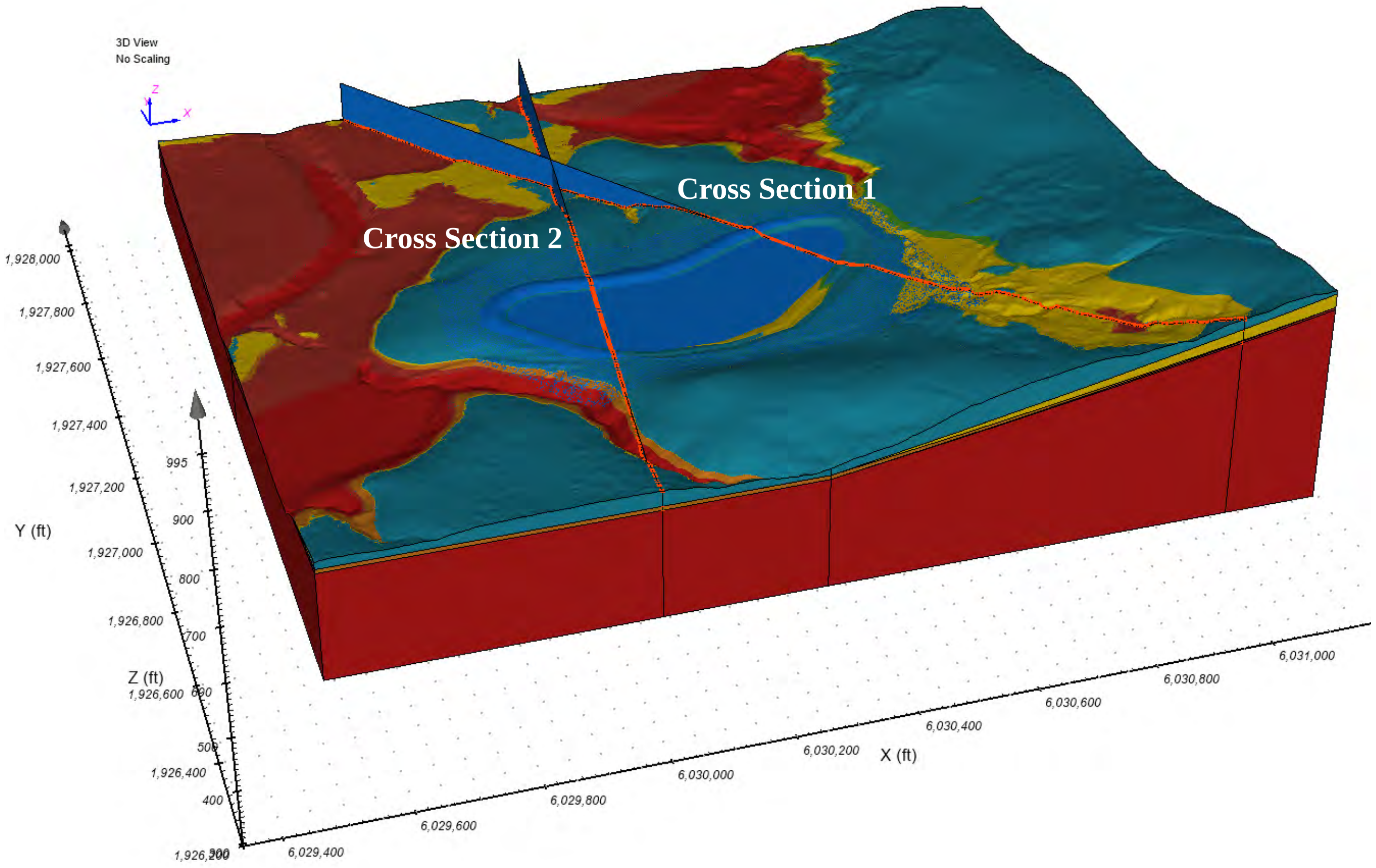

Figure 4:
Selected Cross Sections

December 2020	Marshall Ranch, Briceland, CA

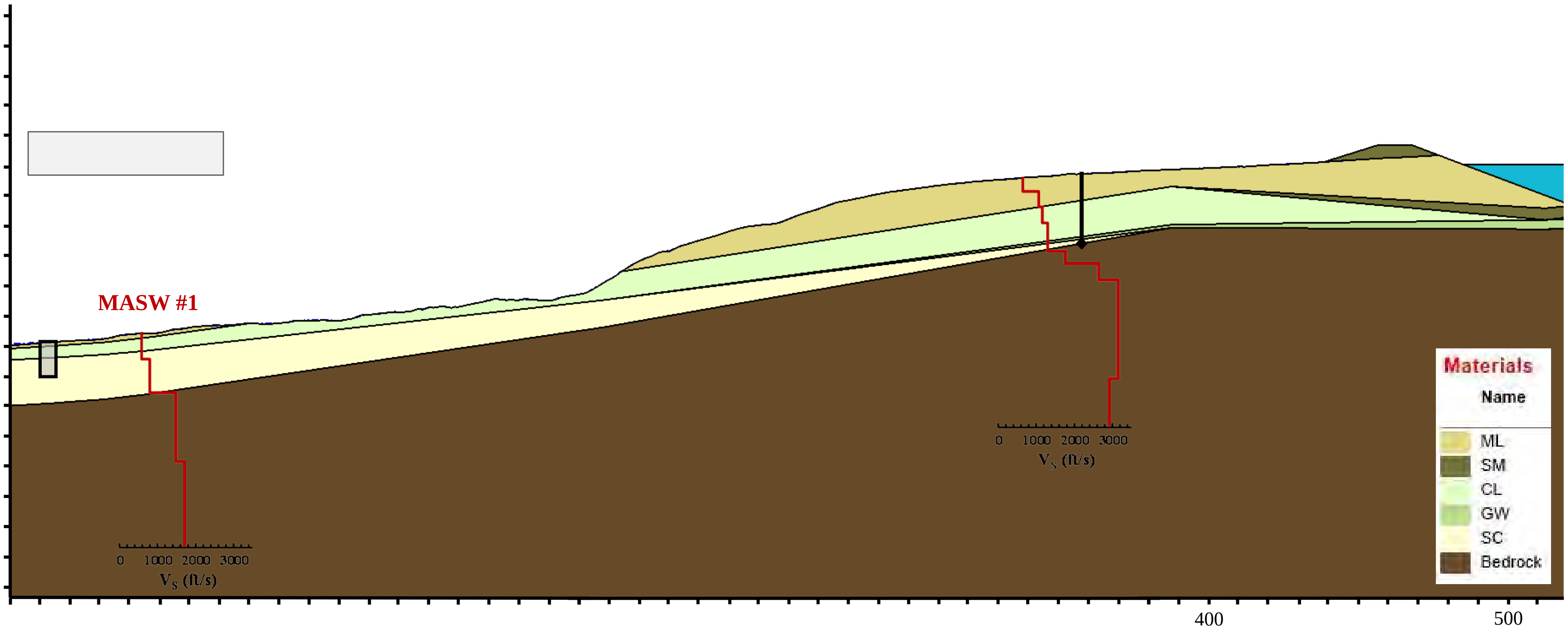

Figure 5: Approximate Locations of MASW V_S Profiles along Selected Cross Section 1

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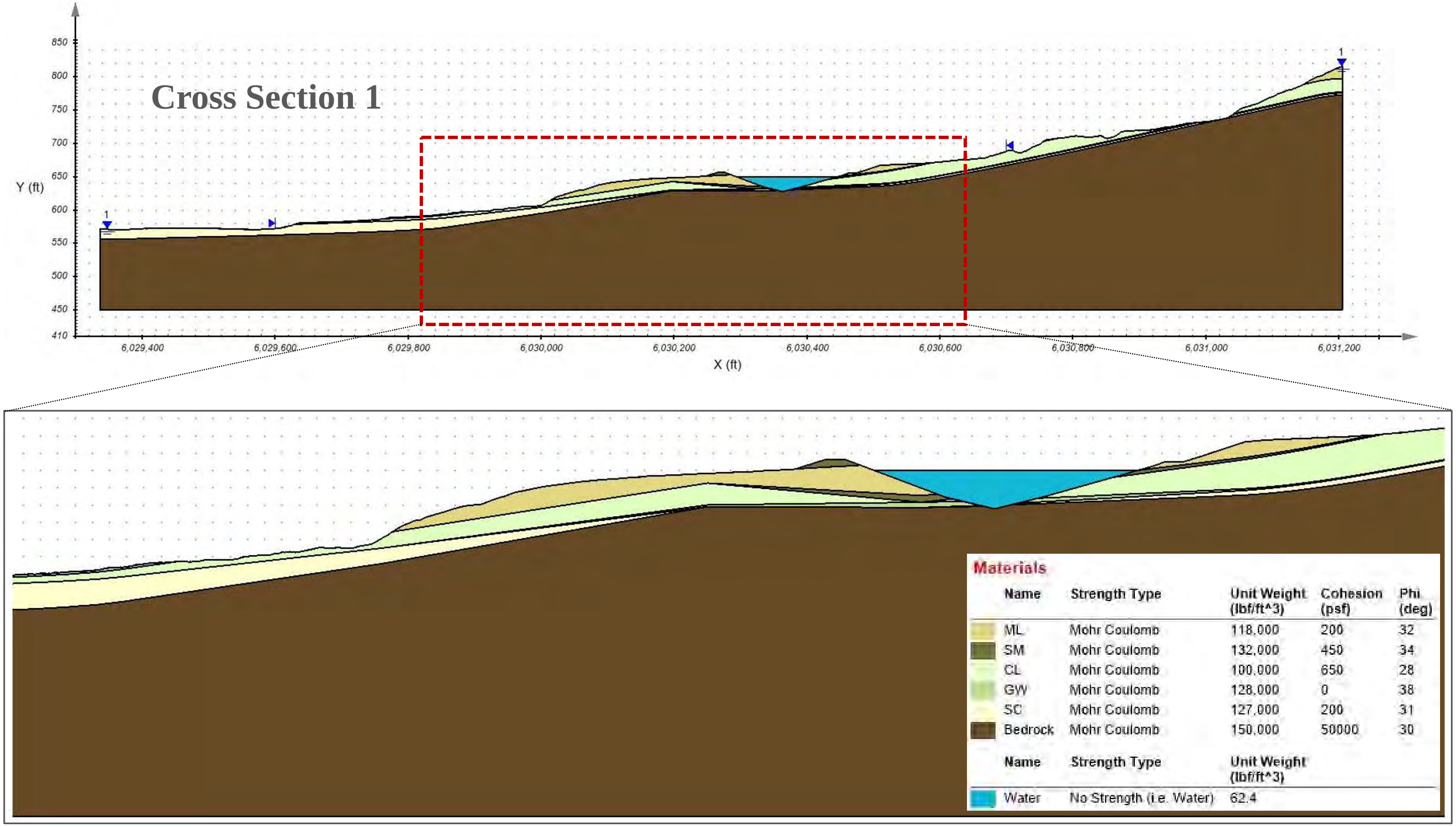
Briceland, CA



Materials

Name	Strength Type	Unit Weight (lbf/ft^3)	Cohesion (psf)	Phi (deg)
ML	Mohr Coulomb	118.000	200	32
SM	Mohr Coulomb	132.000	450	34
CL	Mohr Coulomb	100.000	650	28
GW	Mohr Coulomb	128.000	0	38
SC	Mohr Coulomb	127.000	200	31
Bedrock	Mohr Coulomb	150.000	50000	30

Name	Strength Type	Unit Weight (lbf/ft^3)
Water	No Strength (i.e. Water)	62.4

Figure 6:
Selected Cross Section 1

December 2020

Marshall Ranch,
Briceland, CA

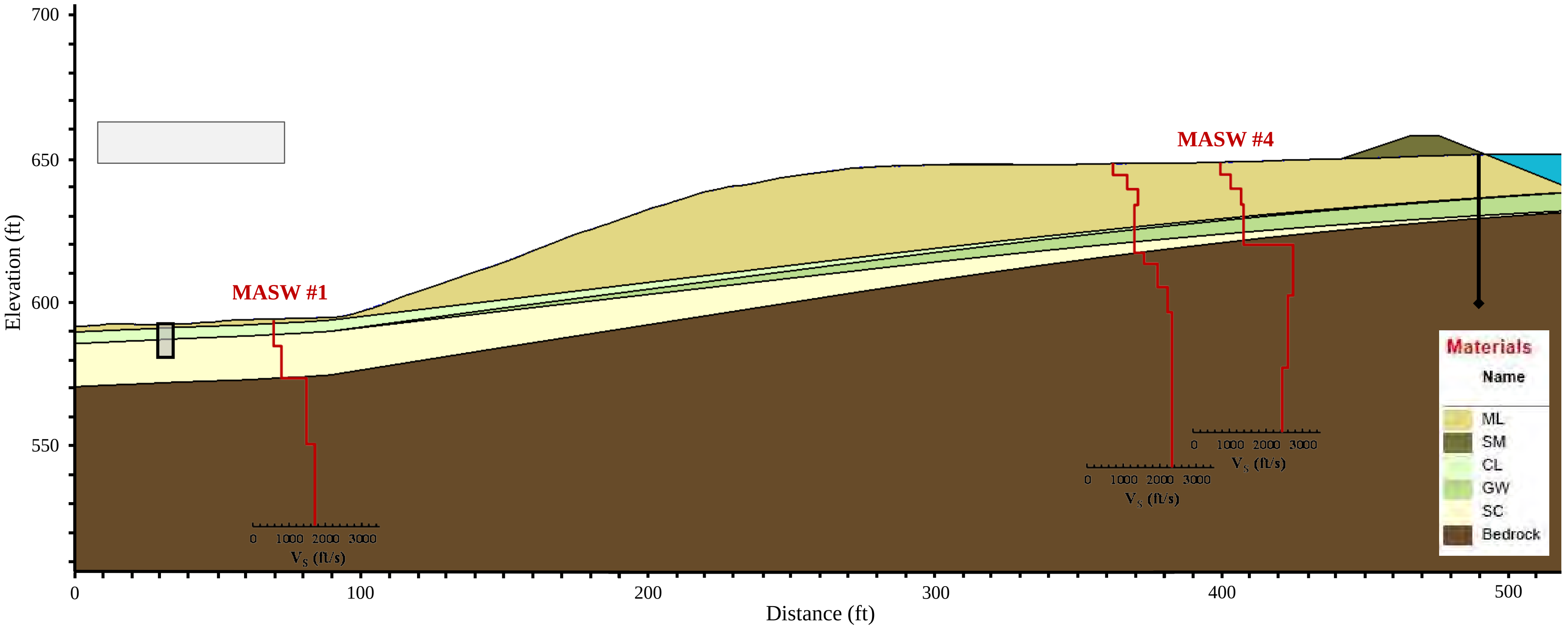
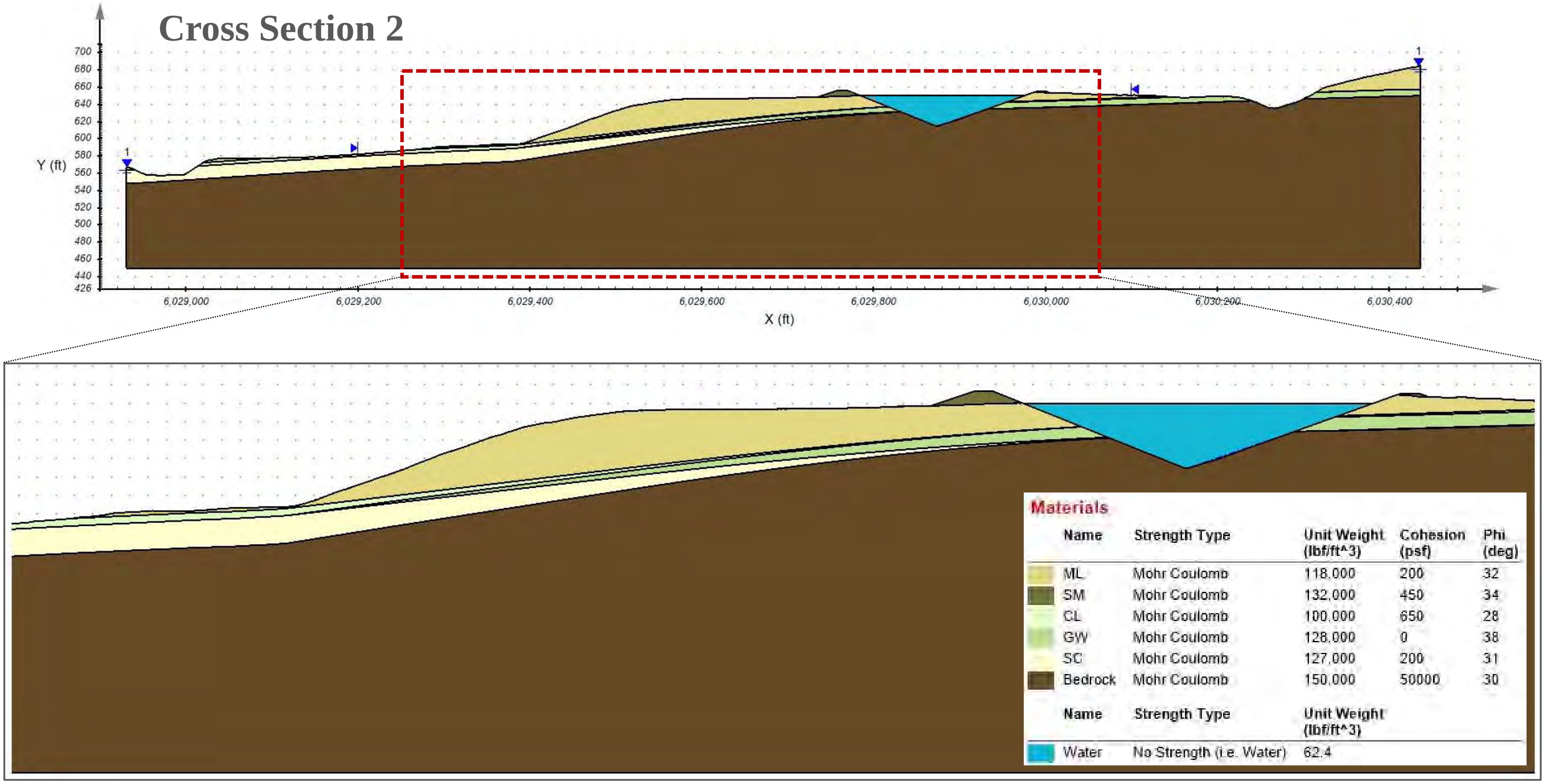


Figure 7: Approximate Locations of MASW V_S Profiles along Selected Cross Section 2

December 2020	Marshall Ranch, Briceland, CA



Materials

	Name	Strength Type	Unit Weight (lbf/ft^3)	Cohesion (psf)	Phi (deg)
🟨	ML	Mohr Coulomb	118.000	200	32
🟫	SM	Mohr Coulomb	132.000	450	34
⬜	CL	Mohr Coulomb	100.000	650	28
🟩	GW	Mohr Coulomb	128.000	0	38
⬜	SC	Mohr Coulomb	127.000	200	31
🟫	Bedrock	Mohr Coulomb	150.000	50000	30

	Name	Strength Type	Unit Weight (lbf/ft^3)
🟦	Water	No Strength (i.e. Water)	62.4

Figure 8:
Selected Cross Section 2

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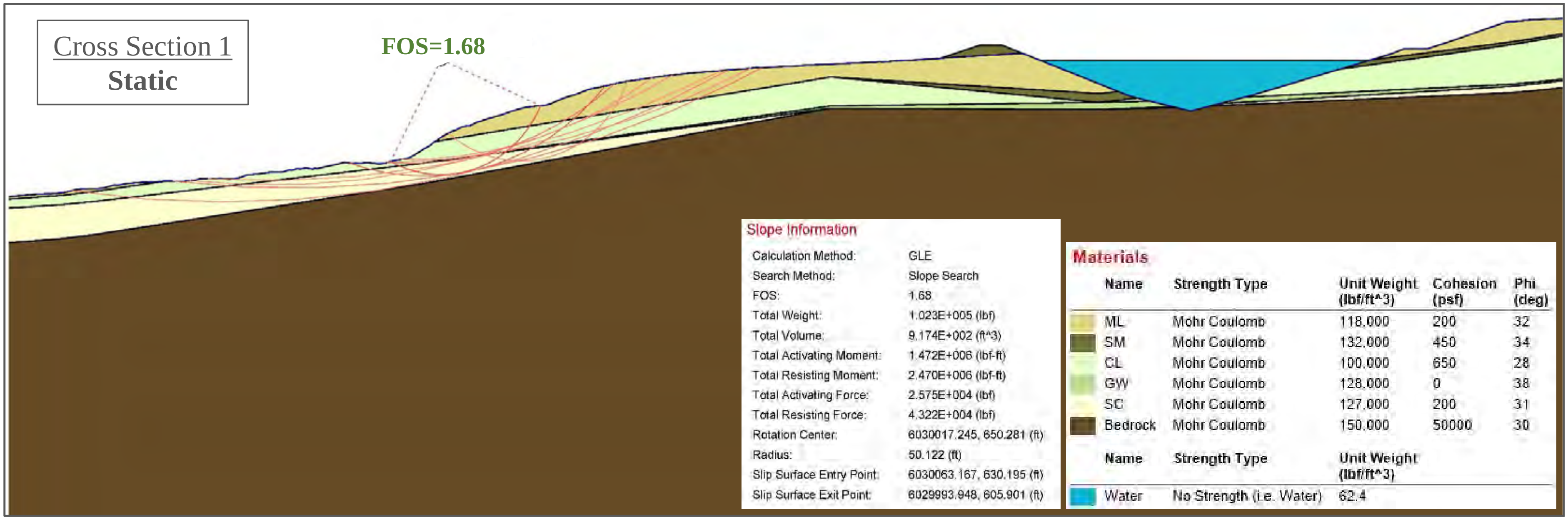
Marshall Ranch,
Briceland, CA



Slope Information

Calculation Method:	GLE
Search Method:	Slope Search
FOS:	1.68
Total Weight:	1.023E+005 (lbf)
Total Volume:	9.174E+002 (ft^3)
Total Activating Moment:	1.472E+006 (lbf-ft)
Total Resisting Moment:	2.470E+006 (lbf-ft)
Total Activating Force:	2.575E+004 (lbf)
Total Resisting Force:	4.322E+004 (lbf)
Rotation Center:	6030017.245, 650.281 (ft)
Radius:	50.122 (ft)
Slip Surface Entry Point:	6030063.167, 630.195 (ft)
Slip Surface Exit Point:	6029993.948, 605.901 (ft)

Materials

	Name	Strength Type	Unit Weight (lbf/ft^3)	Cohesion (psf)	Phi (deg)
▨	ML	Mohr Coulomb	118.000	200	32
▨	SM	Mohr Coulomb	132.000	450	34
▨	CL	Mohr Coulomb	100.000	650	28
▨	GW	Mohr Coulomb	128.000	0	38
▨	SC	Mohr Coulomb	127.000	200	31
▨	Bedrock	Mohr Coulomb	150.000	50000	30

	Name	Strength Type	Unit Weight (lbf/ft^3)
▨	Water	No Strength (i.e. Water)	62.4

Figure 9: Static Slope Stability Analysis - Cross Section 1

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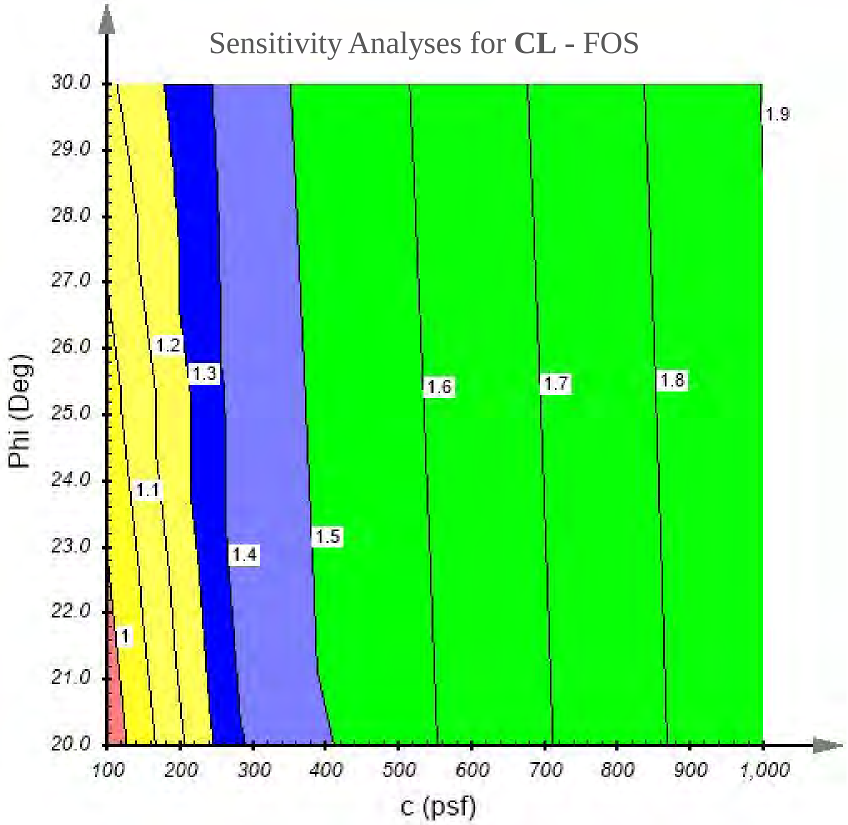


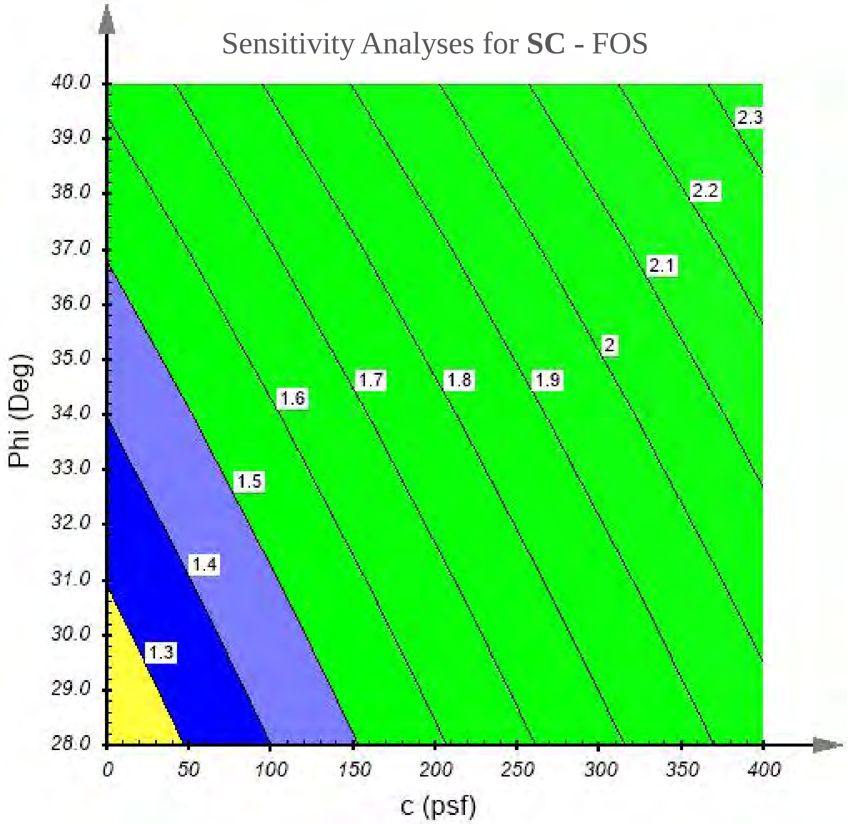
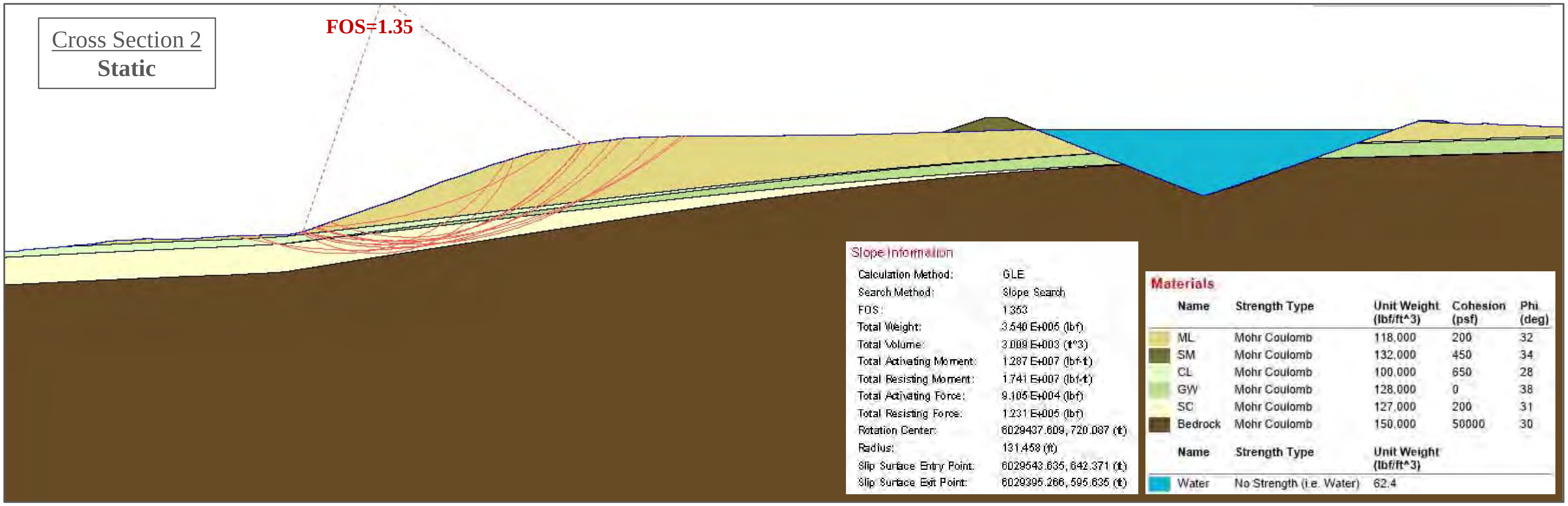


Figure 10: Static Slope Stability Analysis – Sensitivity Analyses - Cross Section 1

December 2020	Marshall Ranch, Briceland, CA



Slope Information

Calculation Method:	GLE
Search Method:	Slope Search
FOS:	1.353
Total Weight:	3.540 E+005 (lbf)
Total Volume:	3.009 E+003 (ft^3)
Total Activating Moment:	1.287 E+007 (lbf-ft)
Total Resisting Moment:	1.741 E+007 (lbf-ft)
Total Activating Force:	9.105 E+004 (lbf)
Total Resisting Force:	1.231 E+005 (lbf)
Rotation Center:	6029437.609, 720.087 (ft)
Radius:	131.458 (ft)
Slip Surface Entry Point:	6029543.635, 642.371 (ft)
Slip Surface Exit Point:	6029395.266, 595.635 (ft)

Materials

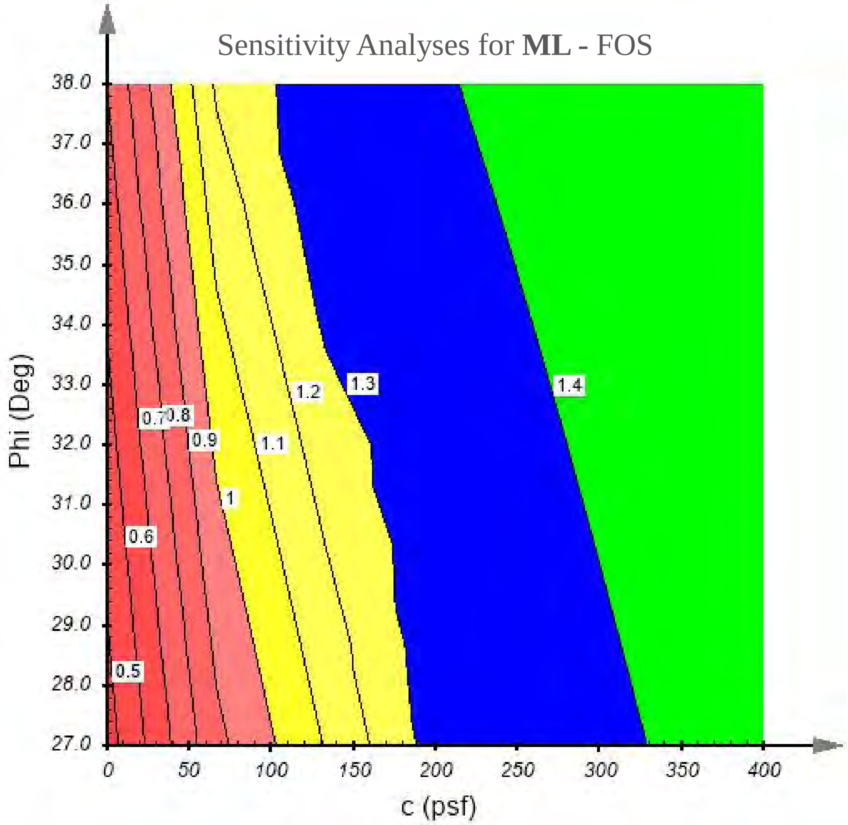
	Name	Strength Type	Unit Weight (lbf/ft^3)	Cohesion (psf)	Phi (deg)
🟨	ML	Mohr Coulomb	118.000	200	32
🟫	SM	Mohr Coulomb	132.000	450	34
🟩	CL	Mohr Coulomb	100.000	650	28
🟩	GW	Mohr Coulomb	128.000	0	38
🟨	SC	Mohr Coulomb	127.000	200	31
🟫	Bedrock	Mohr Coulomb	150.000	50000	30

	Name	Strength Type	Unit Weight (lbf/ft^3)
🟦	Water	No Strength (i.e. Water)	62.4

Figure 11: Static Slope Stability Analysis - Cross Section 2

December 2020

Marshall Ranch,
Briceland, CA



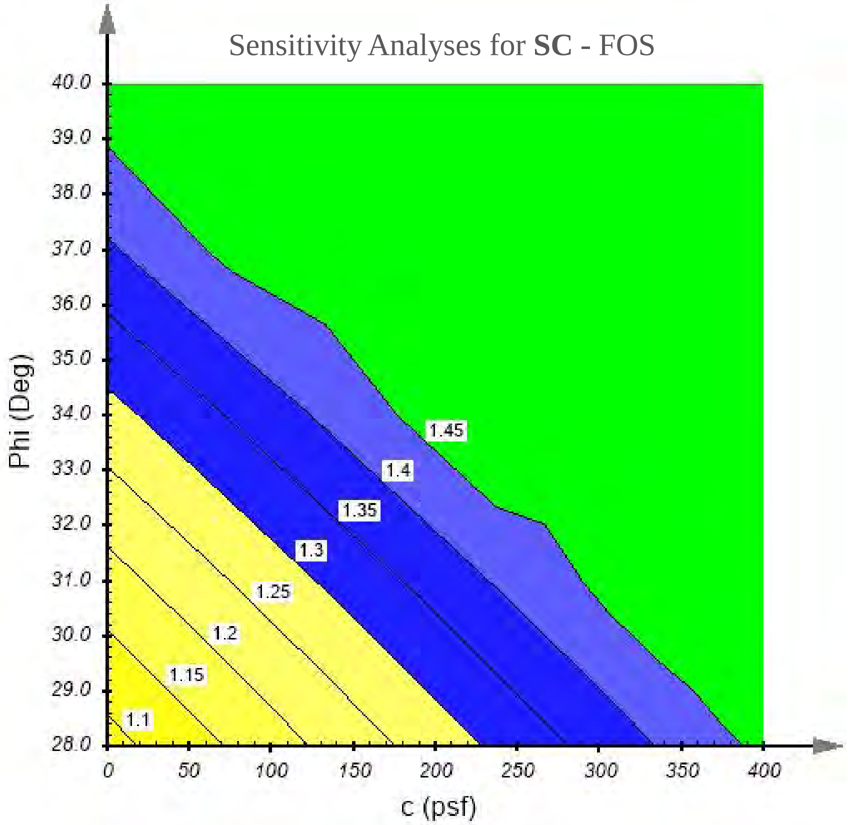
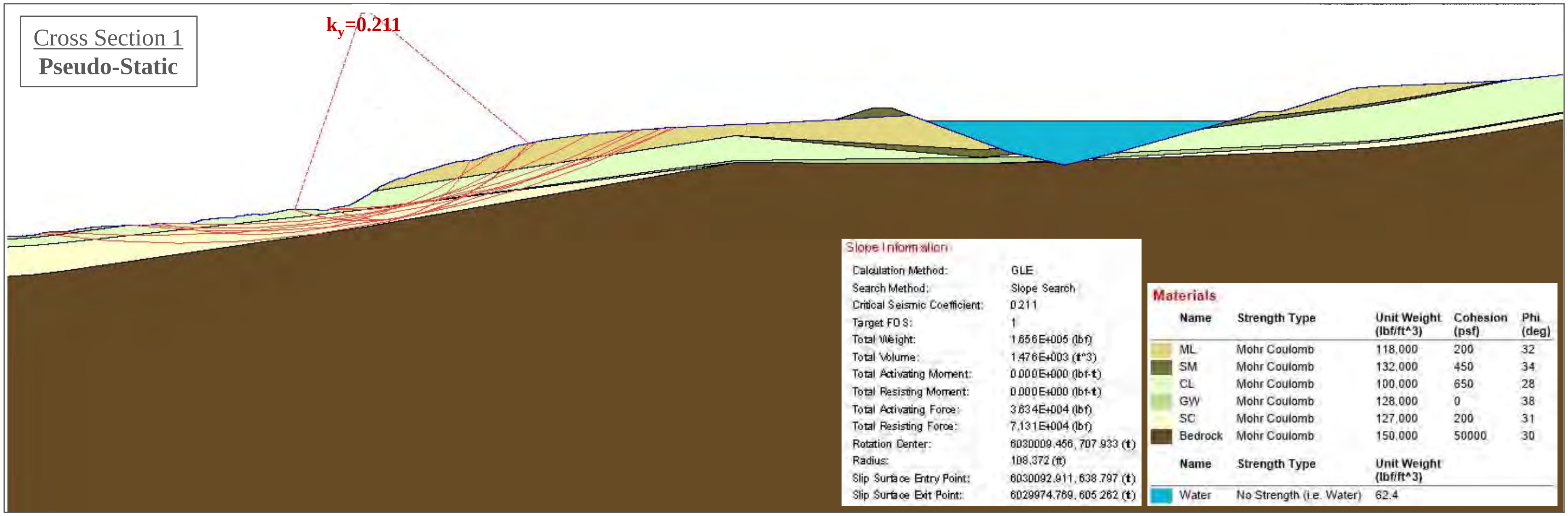


Figure 12: Static Slope Stability Analysis – Sensitivity Analyses - Cross Section 2	
December 2020	Marshall Ranch, Briceland, CA



Cross Section 1
Pseudo-Static

Slope Information

Calculation Method:	GLE
Search Method:	Slope Search
Critical Seismic Coefficient:	0.211
Target FOS:	1
Total Weight:	1.656E+005 (lbf)
Total Volume:	1.476E+003 (ft^3)
Total Activating Moment:	0.000E+000 (lbf-ft)
Total Resisting Moment:	0.000E+000 (lbf-ft)
Total Activating Force:	3.634E+004 (lbf)
Total Resisting Force:	7.131E+004 (lbf)
Rotation Center:	6030009.456, 707.933 (ft)
Radius:	108.372 (ft)
Slip Surface Entry Point:	6030092.911, 638.797 (ft)
Slip Surface Exit Point:	6029974.769, 605.262 (ft)

Materials

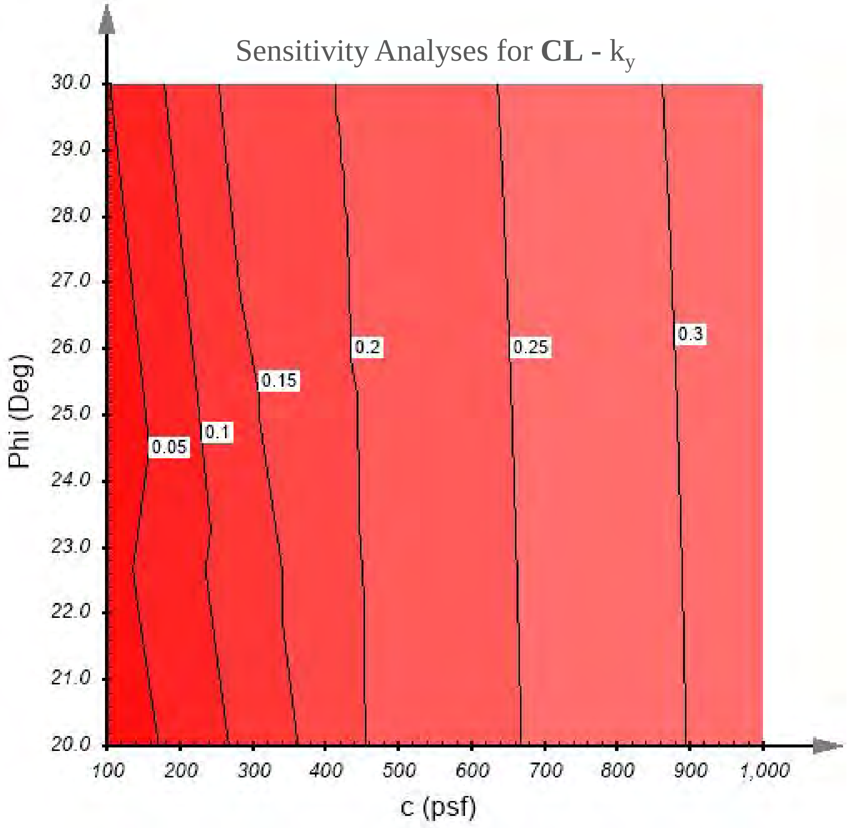
	Name	Strength Type	Unit Weight (lbf/ft^3)	Cohesion (psf)	Phi (deg)
🟨	ML	Mohr Coulomb	118.000	200	32
🟫	SM	Mohr Coulomb	132.000	450	34
🟩	CL	Mohr Coulomb	100.000	650	28
🟩	GW	Mohr Coulomb	128.000	0	38
🟨	SC	Mohr Coulomb	127.000	200	31
🟫	Bedrock	Mohr Coulomb	150.000	50000	30

	Name	Strength Type	Unit Weight (lbf/ft^3)
🟦	Water	No Strength (i.e. Water)	62.4

Figure 13: Pseudo-Static Slope Stability Analysis - Cross Section 1

December 2020

Marshall Ranch,
Briceland, CA


Sensitivity Analyses for **CL** - k_y

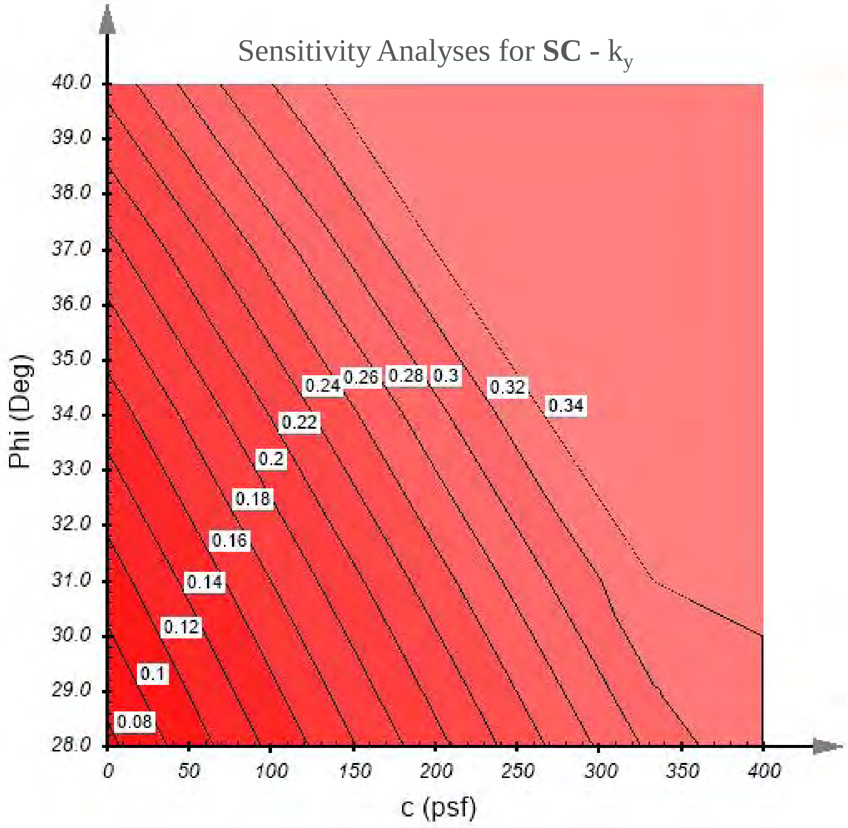
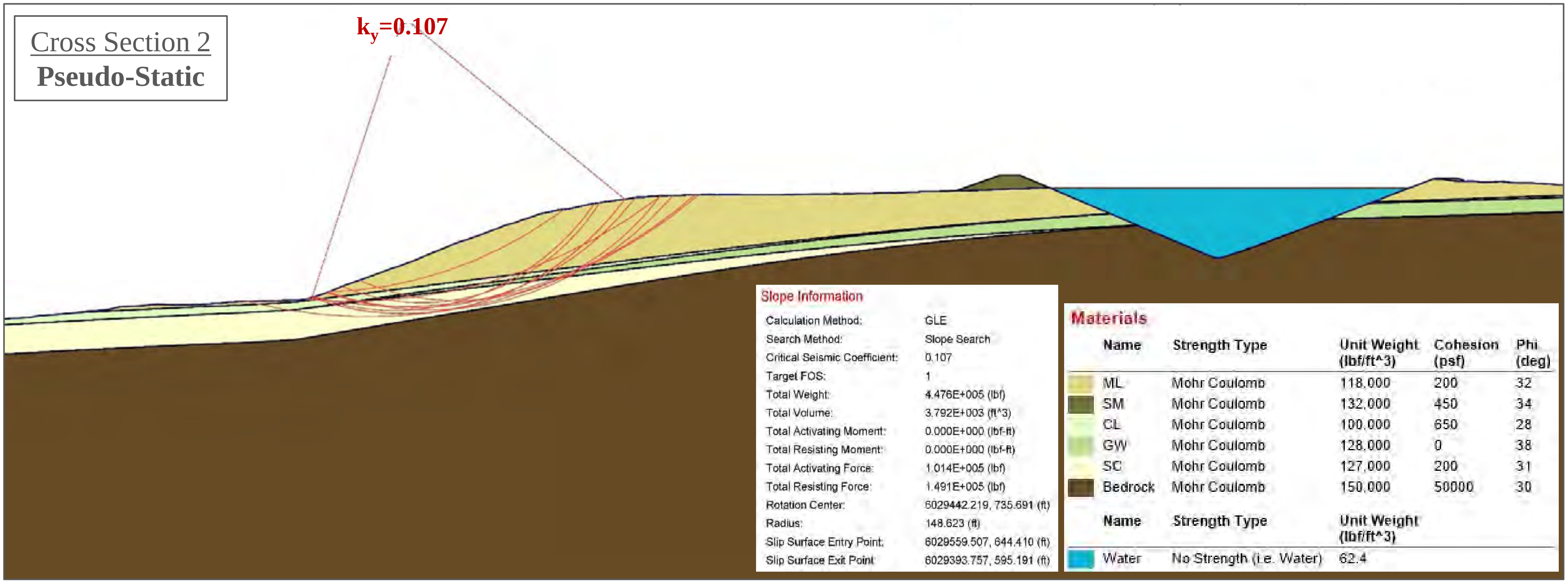

Sensitivity Analyses for **SC** - k_y

Figure 14: Pseudo-Static Slope Stability – Sensitivity Analyses - Cross Section 1

December 2020

Marshall Ranch,
Briceland, CA



Slope Information

Calculation Method:	GLE
Search Method:	Slope Search
Critical Seismic Coefficient:	0.107
Target FOS:	1
Total Weight:	4.476E+005 (lbf)
Total Volume:	3.792E+003 (ft^3)
Total Activating Moment:	0.000E+000 (lbf-ft)
Total Resisting Moment:	0.000E+000 (lbf-ft)
Total Activating Force:	1.014E+005 (lbf)
Total Resisting Force:	1.491E+005 (lbf)
Rotation Center:	6029442.219, 735.691 (ft)
Radius:	148.623 (ft)
Slip Surface Entry Point:	6029559.507, 644.410 (ft)
Slip Surface Exit Point:	6029393.757, 595.191 (ft)

Materials

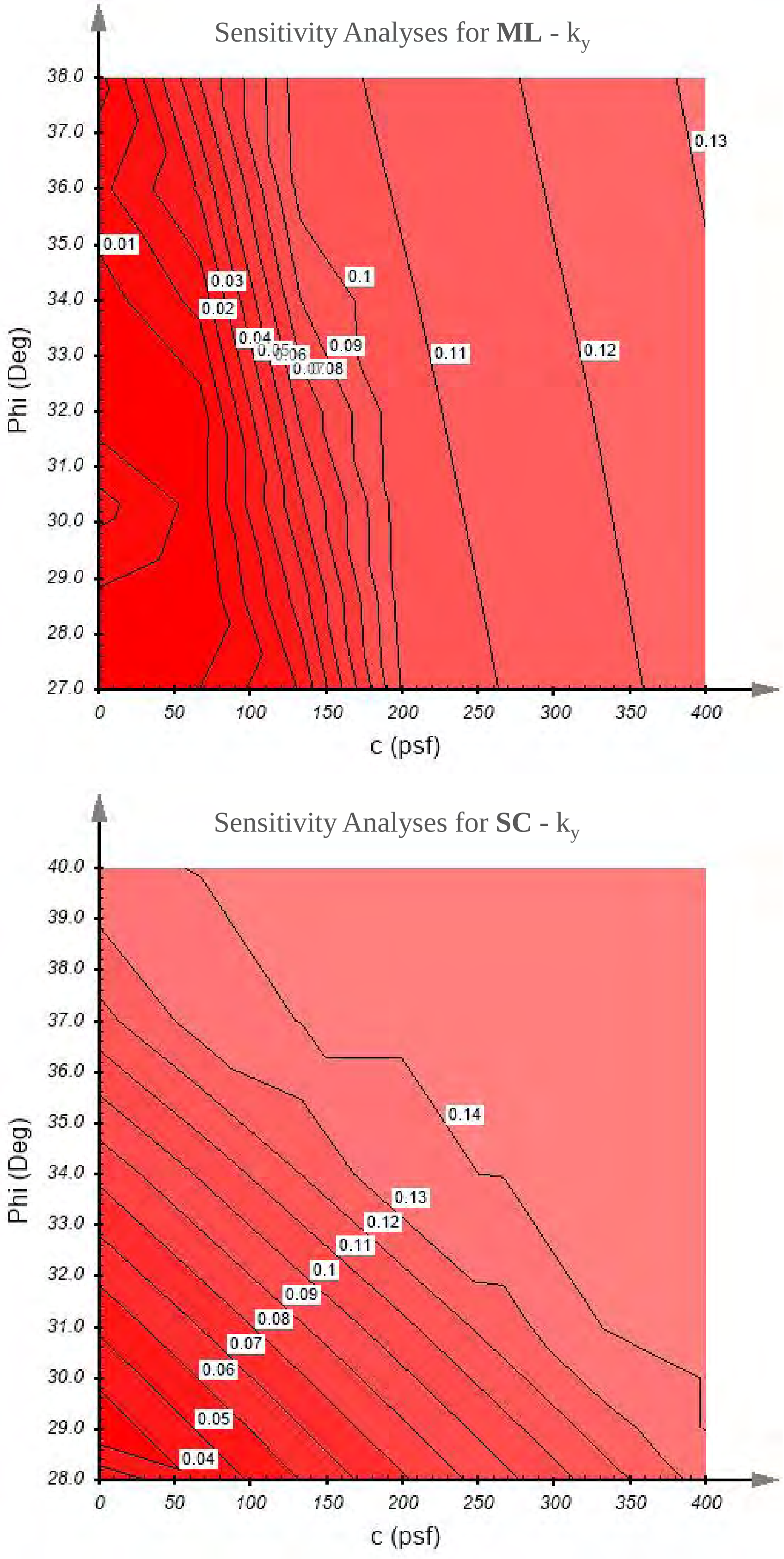
	Name	Strength Type	Unit Weight (lbf/ft^3)	Cohesion (psf)	Phi (deg)
🟨	ML	Mohr Coulomb	118.000	200	32
🟫	SM	Mohr Coulomb	132.000	450	34
⬜	CL	Mohr Coulomb	100.000	650	28
🟩	GW	Mohr Coulomb	128.000	0	38
⬜	SC	Mohr Coulomb	127.000	200	31
🟫	Bedrock	Mohr Coulomb	150.000	50000	30

	Name	Strength Type	Unit Weight (lbf/ft^3)
🟦	Water	No Strength (i.e. Water)	62.4

Figure 15: Pseudo-Static Slope Stability Analysis - Cross Section 2

December 2020

Marshall Ranch,
Briceland, CA



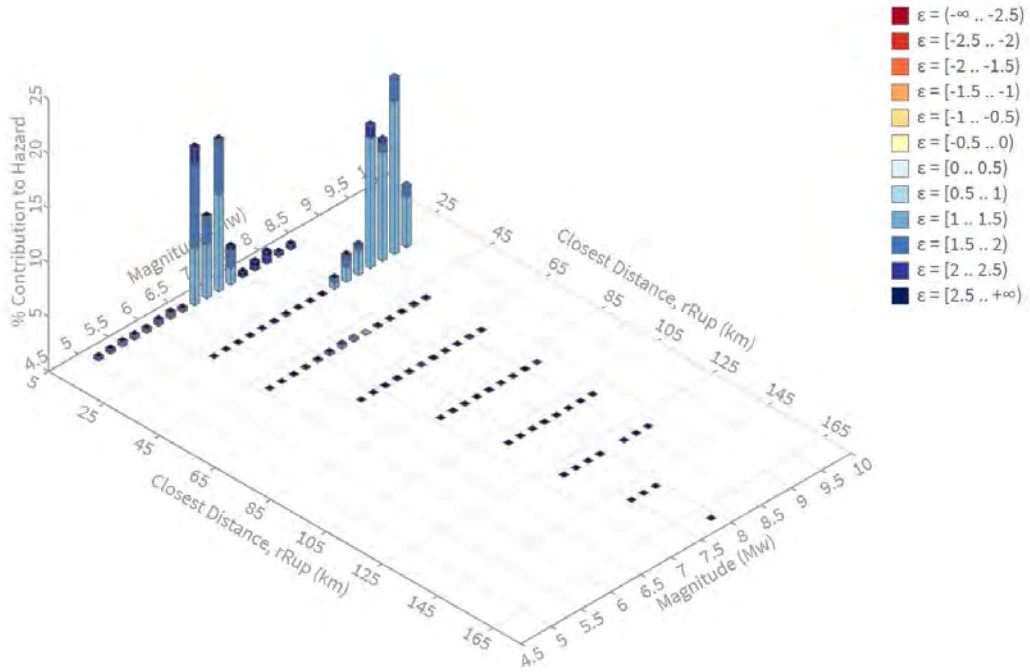
Sensitivity Analyses for **ML** - k_y

Sensitivity Analyses for **SC** - k_y

Figure 16: Pseudo-Static Slope Stability –
Sensitivity Analyses - Cross Section 2

December 2020

Marshall Ranch,
Briceland, CA



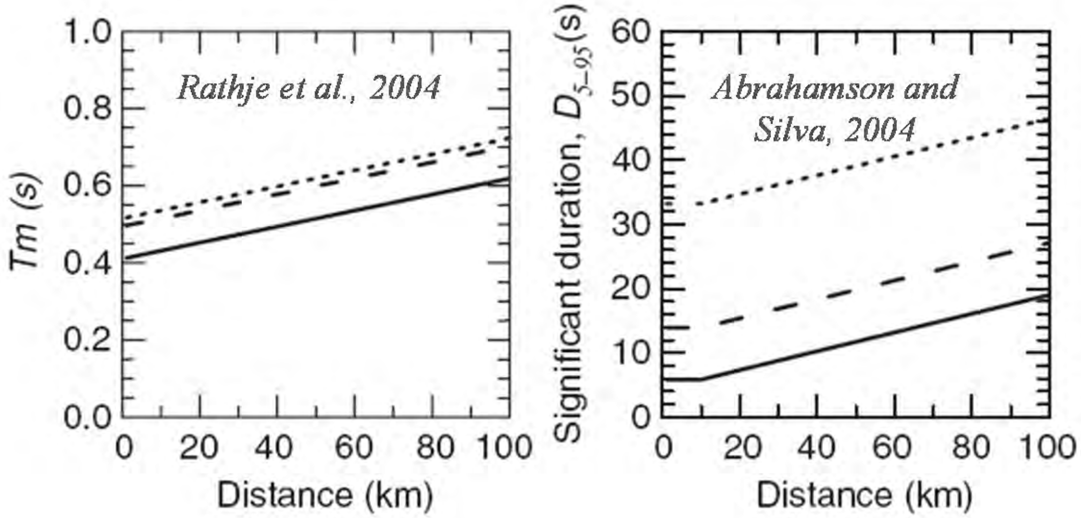


Figure 17: Seismic Hazard Deaggregation and ground motion parameter relationships

December 2020	Marshall Ranch, Briceland, CA

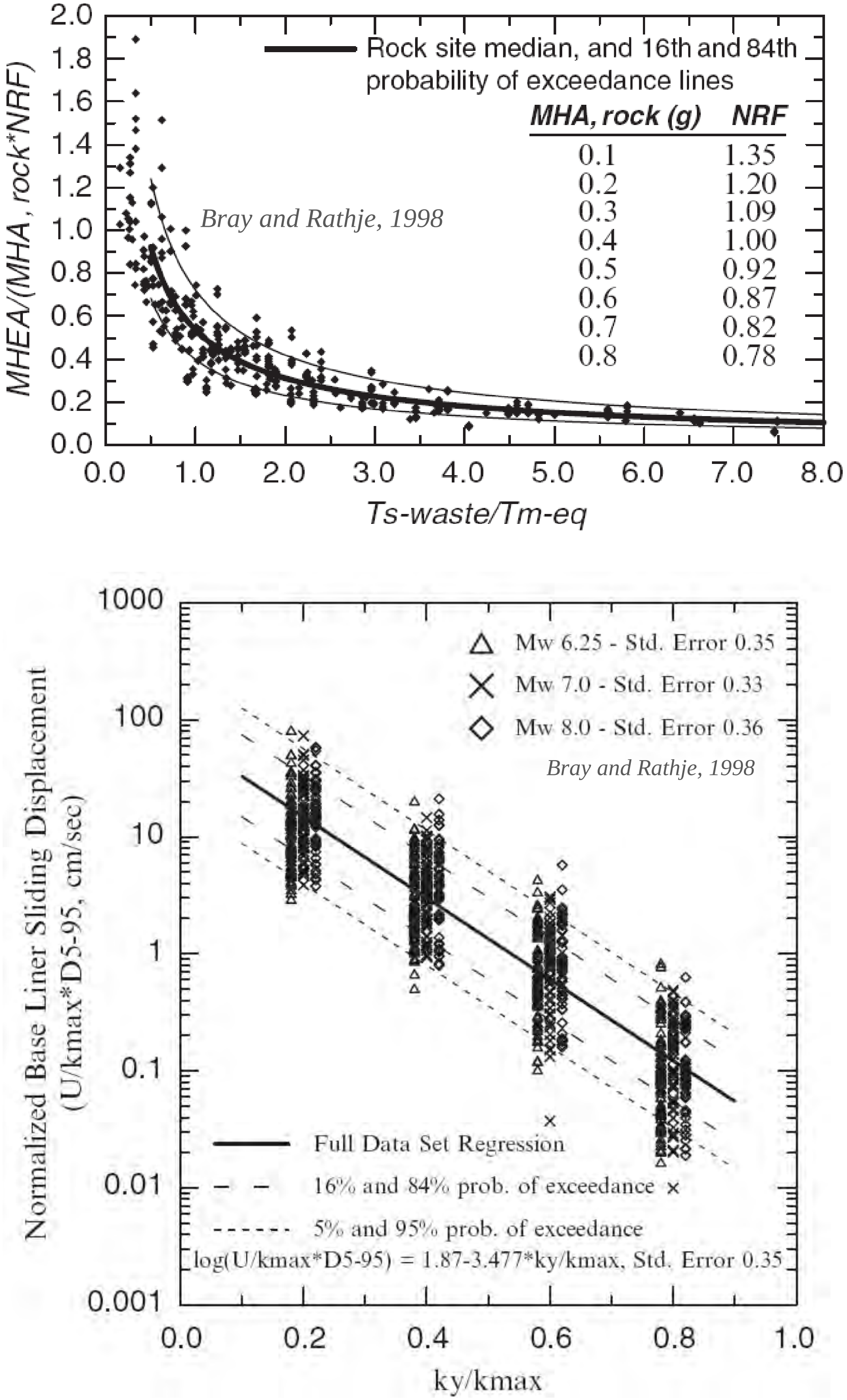


Figure 18: Bray and Rathje (1998) Seismic Displacement Approach

December 2020

Marshall Ranch,
Briceland, CA

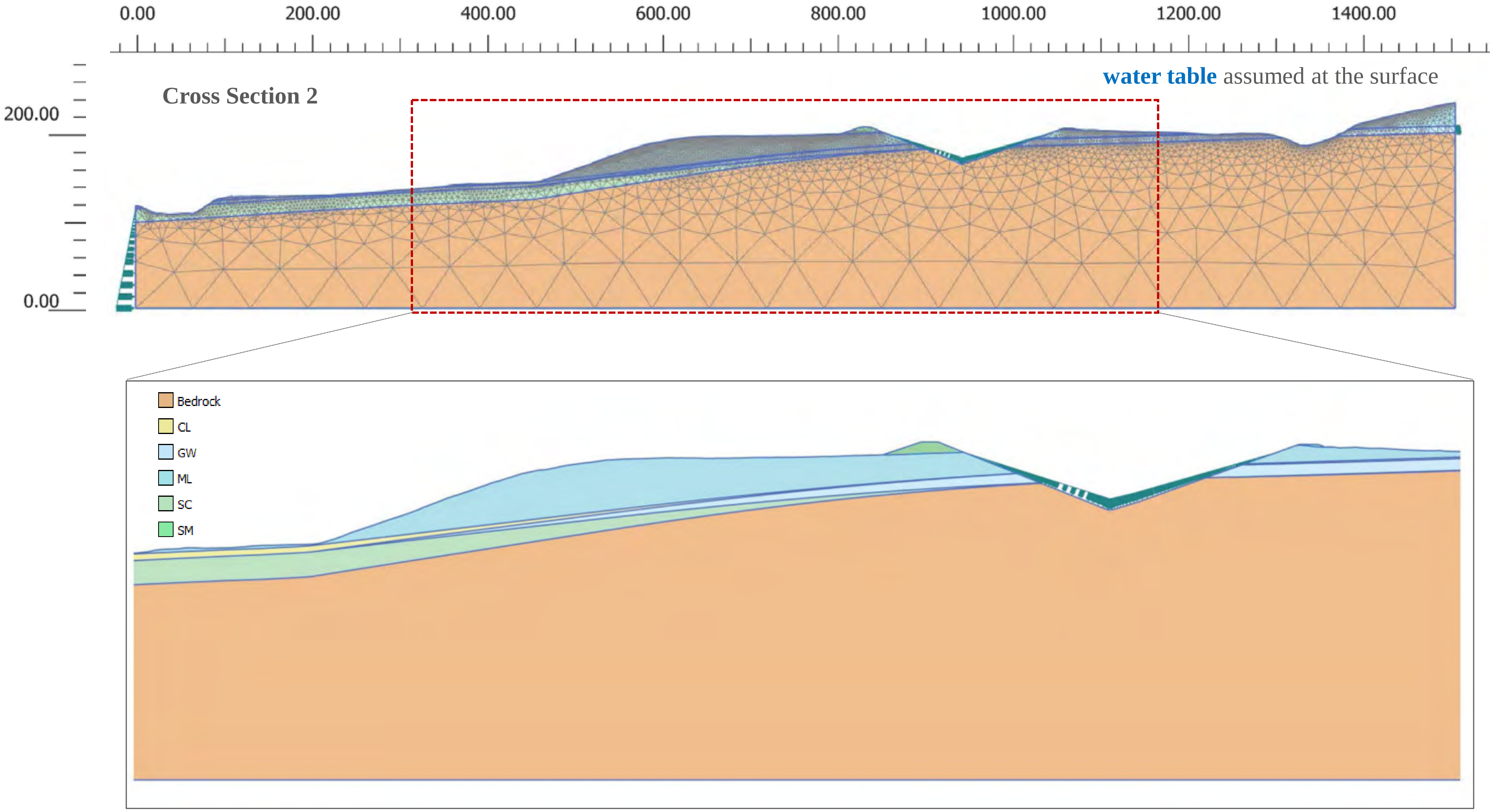
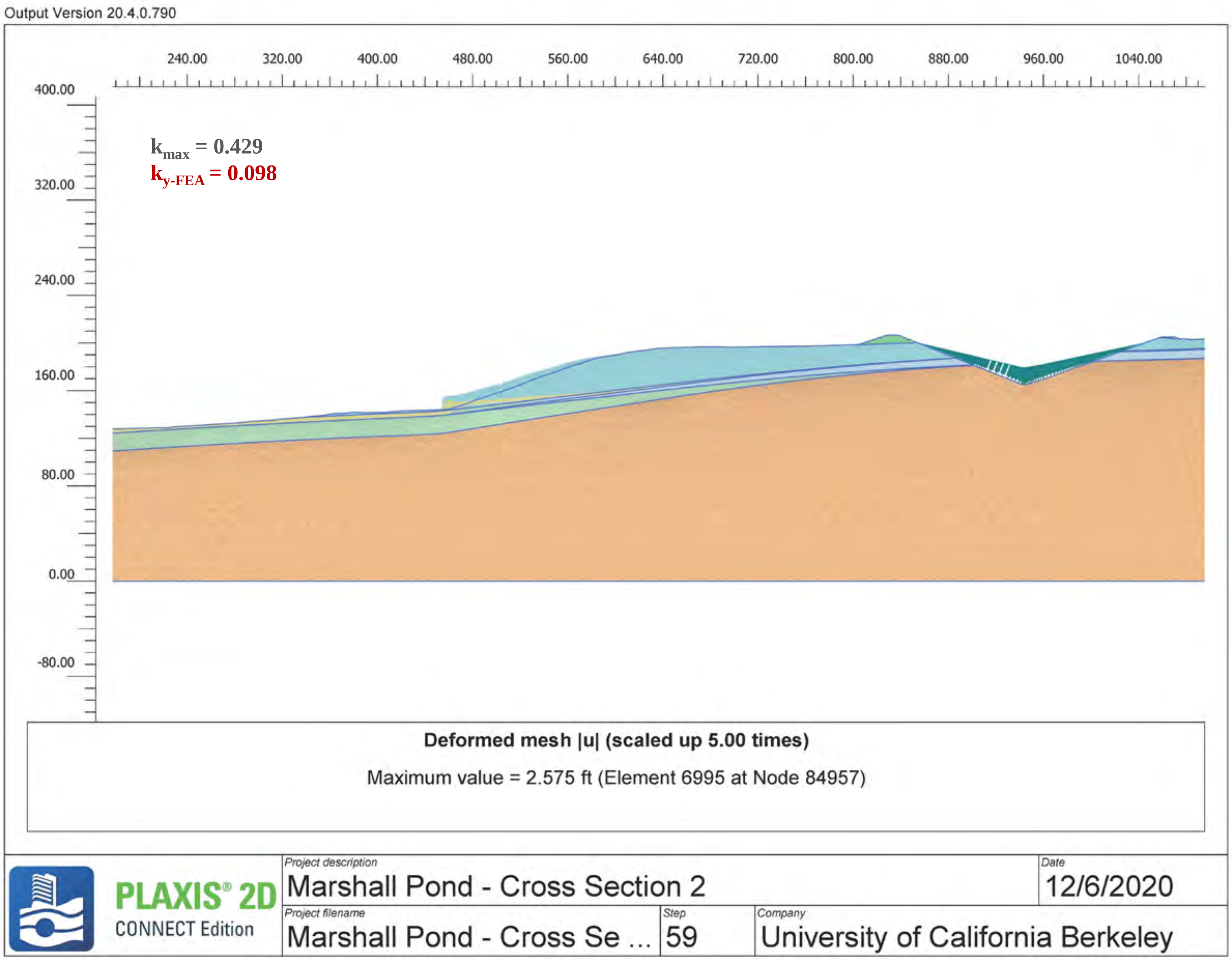


Figure 19: Finite Element Model (PLAXIS 2D)
Cross Section 2

December 2020	Marshall Ranch, Briceland, CA



k_{max} = 0.429

$k_{y\text{-}FEA}$ = 0.098

Deformed mesh |u| (scaled up 5.00 times)

Maximum value = 2.575 ft (Element 6995 at Node 84957)

Project description: Marshall Pond - Cross Section 2

Date: 12/6/2020

Project filename: Marshall Pond - Cross Se ...

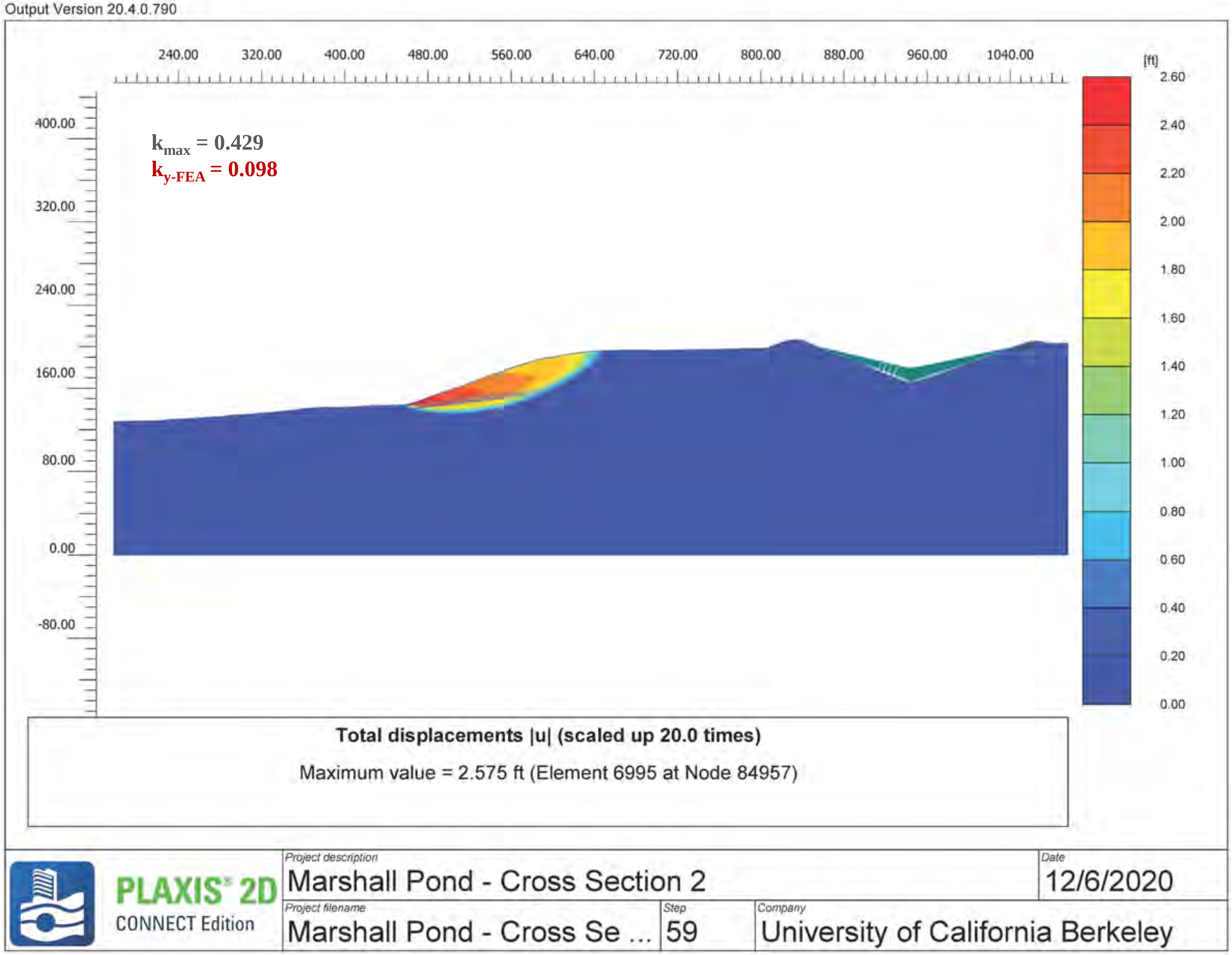
Step: 59

Company: University of California Berkeley

Figure 20: Finite Element Analysis - Deformed Shape - Cross Section 2

December 2020

Marshall Ranch,
Briceland, CA



Total displacements |u| (scaled up 20.0 times)

Maximum value = 2.575 ft (Element 6995 at Node 84957)

Project description Marshall Pond - Cross Section 2

Date 12/6/2020

Project filename Marshall Pond - Cross Se ...

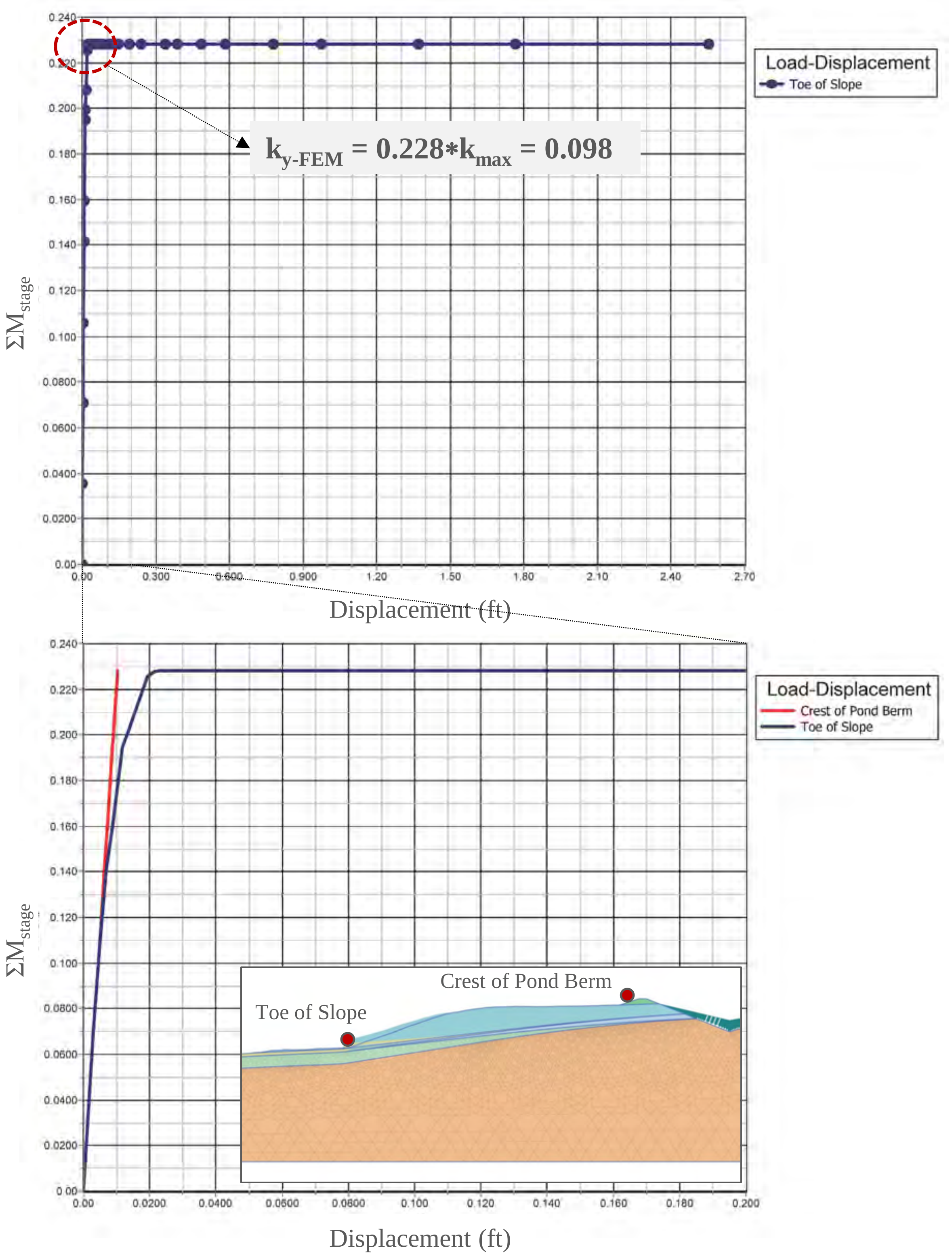
Step 59

Company University of California Berkeley

Figure 21: Finite Element Analysis - Displacement Contours - Cross Section 2

December 2020

Marshall Ranch,
Briceland, CA



$k_{y\text{-}FEM} = 0.228 * k_{max} = 0.098$

Figure 22: Finite Element Analysis – Load-Displacement Curves - Cross Section 2

December 2020	Marshall Ranch, Briceland, CA

APPENDIX

Simplified Stratigraphies and Index Properties at the Borehole/Test Pit Locations

Test Pit TP-3

From Depth (ft)	To Depth (ft)	Corrected Blows per ft	USCS	Description	Water Content (%)	Dry Density (pcf)
0	1.5	-	ML	silt and sand	-	-
1.5	5	-	CL	lean clay with sand	-	-
5	8	-	SM	silty sand with gravel	-	-
8	9.5	-	SC	clayey sand	-	-

Borehole BH-102

From Depth (ft)	To Depth (ft)	Corrected Blows per ft	USCS	Description	Water Content (%)	Dry Density (pcf)
0	10	21	ML	silt and sand	15.3	95.0
10	15.5	25	GW-GM	well graded gravel with silt and sand	15.9	110.5
15.5	51	-	-	siltstone/shale	-	-

Borehole BH-103

From Depth (ft)	To Depth (ft)	Corrected Blows per ft	USCS	Description	Water Content (%)	Dry Density (pcf)
0	3	20	ML	gravelly silt with sand	16.1	99
3	13	21	ML	sandy silt	20.5	100.5
13	20.5	25	SW-SM	well graded sand with silt and gravel	15.1	115
20.5	50.5	-	-	siltstone/shale	-	-

Borehole BH-105

From Depth (ft)	To Depth (ft)	Corrected Blows per ft	USCS	Description	Water Content (%)	Dry Density (pcf)
0	5	-	ML	silt with sand	-	-
5	10	36	CL	lean clay with sand	-	-
10	15.5	24	CL	sandy lean clay with gravel	-	-
15.5	26.5	-	-	siltstone/shale	-	-

Borehole BH-101

From Depth (ft)	To Depth (ft)	Corrected Blows per ft	USCS	Description	Water Content (%)	Dry Density (pcf)
0	20	33	ML	gravelly silt with sand	21.8	100.3
20	24	25	SM	silty sand with gravel	19.2	111
24	27	16	GW-GM	well graded gravel	-	-
27	51	-	-	siltstone/shale	-	-

Borehole BH-104

Start Depth (ft)	End Depth (ft)	Corrected Blows per ft	USCS	Description	Water Content (%)	Dry Density (pcf)
0	6	-	ML	silt with sand	-	-
6	25	30	CL	lean clay with sand	-	-
25	31	17	CL	snady lean clay	-	-
31	35	16	SC	clayey sand	-	-
35	46.5	-	-	siltstone/shale	-	-

Appendix D

Resumes

ADDA ATHANASOPOULOS-ZEKKOS, Ph.D.

Dept. of Civil and Environmental Engineering
University of California, Berkeley
421 Davis Hall, Berkeley, CA 94720

E-mail: adda.zekkos@berkeley.edu
Cell: 510-333-7187

EDUCATION

Ph.D., Civil & Environmental Engineering Dept, University of California at Berkeley, 2008
MSc., Civil & Environmental Engineering Dept, University of California at Berkeley, 2004
Ptychion, Civil Engineering Dept (5-year mandatory program), University of Patras, Greece, 2003

ACADEMIC APPOINTMENTS

Assistant Professor (effective 1/1/2020), Department of Civil and Environmental Engineering, University of California, Berkeley, CA

Graduate Chair (9/2017 – 12/2019), Department of Civil and Environmental Engineering, University of Michigan at Ann Arbor, Ann Arbor, MI

Associate Professor (2015 – 2019), Department of Civil and Environmental Engineering, University of Michigan at Ann Arbor, Ann Arbor, MI

Assistant Professor (2008 – 2015), Department of Civil and Environmental Engineering, University of Michigan at Ann Arbor, Ann Arbor, MI

Graduate Student Instructor (GSI) and **Graduate Student Research Assistant (GSRA)** (2003-2008), Department of Civil and Environmental Engineering, University of California at Berkeley, Berkeley, CA

AWARDS AND HONORS

- Invited Speaker at the 35th Annual Geoengineering Distinguished Lecture Series, UC Berkeley, 2017
- Excellence in Teaching Award, Chi Epsilon Great Lakes District, 2016
- Thomas Middlebrooks Award, American Society of Civil Engineers (ASCE), 2015
- Arthur Casagrande Professional Development Award: For "contributions in the seismic risk assessment of levee protection systems against flooding", American Society of Civil Engineers (ASCE), 2015
- Excellence in CEE, Departmental Faculty Award, 2014
- National Science Foundation (NSF) CAREER Award, 2013
- National Science Foundation (NSF) Fellow for NEES ENHANCE, 2012
- Elizabeth C. Crosby Research Award, ADVANCE, University of Michigan, 2010, 2011
- Outstanding Graduate Student Instructor Award, University of California, Berkeley, 2006
- National Science Foundation (NSF), Graduate Research Fellowship (GRF) Award, 2004-2007
- Harry Bolton Seed Outstanding Graduate Student Award, University of California, Berkeley, Geoengineering Group, 2004

PROFESSIONAL CONTRIBUTIONS

Professional Affiliations

Member, Association of State Dam Safety Officials (ASDSO), 2011-pres.

Member, International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE), 2008-pres.
Member, Geotechnical Earthquake Engineering Reconnaisance (GEER), 2007-pres.
Member, United States Society of Dams (USSD), 2007-pres.
Member, Earthquake Engineering Research Institute (EERI), 2006-pres.
Member, American Society of Civil Engineers (ASCE), Geo-Institute, 2004-pres.

Professional Service

Committees (National/International)

Member, USUCGER Board, Elected position, 01/2019-pres.
Member, ASCE Geo-Institute Awards Committee, 2018-pres.
Member, NHERI User Forum Committee, Elected position, 2017-pres.
Member, Dykes and Levees Technical Committee (ISSMGE), 2012-pres.
Member, Earthq Eng. and Soil Dyn. Geo-Institute Technical Committee (ASCE), 2011-pres.
Member, Committee on Levees (USSD), 2010-pres.
Member, Embankments, Slopes and Dams Geo-Institute Technical Committee (ASCE), 2008-pres.
Member, Earthquake Geotechnical Engineering and Associated Problems (ISSMGE), 2019-pres.

Editorships

Associate Editor, ASCE Journal of Geotechnical and Geoenvironmental Engineering, 2015-pres.

Guest Editor, "Special Issue: PBD-III Invited Papers", Soil Dynamics and Earthquake Engineering Journal, July 2018

Technical Co-Editor, 3rd International Conference on Performance-Based Design in Earthquake Geotechnical Engineering, Vancouver, BC, July 2017.

Technical Co-Editor and Member of Organizing Committee, 2012 GeoCongress Conference: State of the Art and Practice in Geotechnical Engineering, ASCE, 2009-2012.

Conference/Event Organization

Session Chair, 2019 USSD 39th Annual Conference and Exhibition, Chicago, April 8-12, 2019.

Session Chair, 2015 International Foundations Congress and Equipment Expo, Session: "Hurricanes and Floods", ASCE Geo-Institute (G-I), International Association of Foundation Drilling, San Antonio, TX, March 18-21 2015.

Session Chair, 2013 GeoCongress Conference: Stability and Performance of Slopes and Embankments III, Session "Seepage and Slope Stability for Earth Dams and Levees", ASCE Geo-Institute (G-I), 2013.

Professional Activities

Member, 2016 Geotechnical Earthquake Engineering Reconnaissance (GEER) in New Zealand

Invited presenter and participant, 2016 US-NZ-Japan International Workshop on Liquefaction Effects

Member, 2016 Geotechnical Earthquake Engineering Reconnaissance (GEER) in Ecuador

Invited panelist, 2015 IFCEE Student Professional Development Workshop, San Antonio TX

Invited Participant, 2012 Second US-PRC Young Researcher's Forum MCEER, IEM in China

Participant, 2010 USSD Levee Workshop, Memphis TN

Invited participant and speaker, 2010 Innovative teaching methods in Geotechnical Engineering Workshop, Volos, Greece, workshop sponsored by the 6th National Hellenic Conference on Geot. and Geoenvironmental Engineering, in Volos, Greece, Sept. 29-Oct. 1, 2010

Participant, 2010 Research Summit, East Lansign, MI, Michigan Department of Transportation Office of Research and Best Practices

Invited Participant, 2010 Vision 2020 Workshop, St. Louis, MO, Sponsored by NSF/NEES

Invited Participant, 2009 7th NEES/E-Defense planning meeting for Collaborative Research, Kobe, Japan

Participant, 2009 Pile Driving Workshop for Professors, Utah State Univ. Logan, UT, Sponsored by Pile Driving Contr. Of America

Participant, 2009 Workshop for the Multiscale Science Based-Modeling and Simulation and Experimental Validation on Enabling Materials, Northwestern University, IL

Student Team Leader, Independent Levee Investigation (August 2005-May 2006)

STUDENT ADVISEES

Doctoral Thesis Advisees (2 in progress)

- Michelle Basham (expected 2023) *Liquefaction assessment of gravelly soils in the field and the laboratory*
- Nina Zabihi (expected 2020) *Liquefaction analyses of coarse grained soils using the Discrete Element Method (DEM)*

Doctoral Thesis Advisees (4 completed)

- Jonathan Hubler "*Monotonic and dynamic response of gravelly soils", May 2017* ***(currently: Assistant Professor at Villanova University)***
- Athina Gkrizi "Characterization of *Pile-driving induced ground motions", December 2016 (currently:* ***Assistant Professor at Notingham University, UK****)*
- Adam Lobbestael "*Feasibility Study of High-Performance Cutoff Walls for Levees in Seismic Regions", September 2014 (****currently: Assistant Professor at Lawrence Tech University, MI****)*
- Mustafa Saadi "*GIS-based methodology for assessing spatial variability of soil properties in seismic evaluation of levee systems", December 2011 (****currently: Project Engineer at Geosyntec Consultants, Atlanta, GA****)*

Graduate Research Advisees

- Goldie Gunawan (MSE 2018) *Seismically induced landslides after the 2016 New Zealand earthquake*
- Josh Colley (MSE 2014) *Effect of thin soil layers on progressive failure of earthen levees*
- Heidi Pence (MSE 2013) *Ground motion selection for seismic clope stability analysis of earthen levees*
- Mohammad Kabalan (MSE 2012) *Pile-driving induced vibration field measurements.*
- Kimberly Lamote (MSE 2011) *Seismic isolation of earth retaining structures with use of EPS-Geofoam compressible inclusion*

COURSES

- CEE 345 – Geotechnical Engineering (4-credits, undergraduate)
- CEE 546 – Slopes, Dams and Retaining Structures (3-credits, graduate)
- CEE 548 – Geotechnical Earthquake Engineering (3-credits, graduate)
- CEE 543 – Numerical Modelling in Geotechnical Engineering (3-credits, graduate)

SPONSORED RESEARCH (Total: $2.6M, as PI: $1.9M)

- *Collaborative Research: Integrated Field and Laboratory Based Assessment of Liquefaction Triggering and Residual Strength of Gravelly Soil (PI, with co-PI D. Zekkos from U. of Michigan and K. Rollins from BYU)*
  National Science Foundation, 2017-2020 (total: $521,889, PI share: $333,533)
- *RAPID: Collaborative research: Topographic Change and Cascading Hazards Following the Mw7.8 Kaikoura (New Zealand) Earthquake (co-PI, with PI M. Clark and co-PI D. Zekkos from U. of Michigan)*
  National Science Foundation, 2016-2018 ($46,517)
- *Asset Management for Retaining Walls (PI, with co-PI J. Lynch and D. Zekkos from U. of Michigan)*
  Michigan Department of Transportation, 2016-2019 ($310,675)
- *Collaborative Research: Connecting Women Faculty in Geotechnical Engineering: Thriving in a Networked World (UMich PI, Syracuse Univ. lead)*
  National Science Foundation, 2016-2019 (total: $513,019, PI share: $49,749)
- *CAREER: Promoting a Fundamental Understanding of Post-Liquefaction Response and Deformations: A Next-Generation Analytical and Experimental Methodology (PI)*
  National Science Foundation, 2013-2018 ($400,000)
- *Continuation of UM Network for Women in Civil and Environmental Engineering (NEWinCEE) (co-PI)*
  Rackham School of Graduate Studies (UM), 2013-2015 ($77,600)
- *Dynamic Response of Levees and Ebmankments (PI)*
  Rackham Graduate School and ADVANCE at Univ. of Michigan, 2012-2013 ($10,363)
- *On-Line International Network for Women in Geotechnical Engineering (PI)*
  ADVANCE at the Univ.of Michigan, 2012-2013 ($4,990)
- *Effects of pile-driving induced vibrations on nearby structures and other assets (PI)*
  Michigan Department of Transportation, 2011-2013 ($229,370)
- *UM Network for Excellence in Women in Civil Engineering (co-PI, with G. Parra-Montesinos, A. Demond, D. Zekkos and S. Lee from U. of Michigan)*
  Rackham School of Graduate Studies (UM), 2011-2013 ($96,736)
- *Feasibility Study of High-Performance Cut-off Walls for Levees in Seismic Regions: Dynamic Wall Analyses and Ductile Slurry Development (PI, with V. Li from U. of Michigan*)
  National Science Foundation, 2010-2014 ($384,406)
- *Seismic isolation of earth retaining structures with use of EPS-Geofoam compressible inclusion – Centrifuge Testing (PI)*
  European Manufacturers of EPS, 2010-2012 ($37,500)
- *Seismic isolation of earth retaining structures with use of EPS-Geofoam compressible inclusion – Centrifuge Testing (PI)*
  ADVANCE at the Univ.of Michigan, 2010-2011 ($14,647)

PUBLICATIONS AND PRESENTATIONS

Books

1. Taiebat, M., Athanasopoulos-Zekkos, A., and Wijewickreme, D. eds (2017) “3rd International Conference on Performance-based Design in Earthquake Geotechnical Engineering”, Vancouver BC

2. Hryciw, R.D., Athanasopoulos-Zekkos, A. and Yesiller, N. eds. (2012) "GeoCongress 2012 - State of the Art and Practice in Geotechnical Engineering", Geotechnical Special Publication No. 225, Proceedings of the Annual GeoCongress of the Geo-Institute of ASCE, 4504 pages.

Special Issues

1. Boulanger, R., Taiebat, M., Wijewickreme, D. and Athanasopoulos-Zekkos, A. eds (2018) *"Special Issue: PBD-III Invited Papers"*, Soil Dynamics and Earthquake Engineering Journal, July 2018

Chapters in Books

1. Zekkos, D., Matasovic, N., El-Sherbiny, R., Athanasopoulos-Zekkos, A., Towhata, I., Maugeri, M. (2011) "Chapter 4: Dynamic Properties of Municipal Solid Waste", "Geotechnical Characterization, Field Measurement, and Laboratory Testing of Municipal Solid Waste", ASCE Geotechnical Special Publication, No 209.

Refereed Journal Publications (published only)

1. Zekkos, D., Greenwood, W., Lynch, J., Manousakis, J., Athanasopoulos-Zekkos, A., Clark, M., Cook, K.L. and Saroglou, C. (2018). Lessons Learned from The Application of UAV-Enabled Structure-From-Motion Photogrammetry in Geotechnical Engineering. *International Journal of Geoengineering Case Histories*, Vol.4, Issue 4, p.254-274. *doi: 10.4417/IJGCH-04-04-03*
2. Hubler, J., Athanasopoulos-Zekkos, A., and Zekkos, D. (2018) "Monotonic and Cyclic Simple Shear Response of Gravel-Sand Mixtures", *Soil Dynamics and Earthquake Engineering, Vol 115, pp. 291-304, Dec 2018,* https://doi.org/10.1016/j.soildyn.2018.07.016
3. Zekkos, D., Athanasopoulos-Zekkos, A., Hubler, J., Fei, X., Zehtab, K.H., and Marr, A. (2017) "Development Of A Large-Size Cyclic Direct Simple Shear Device For Characterization Of Ground Materials With Oversized Particles", *Geotechnical Testing Journal https://doi.org/10.1520/GTJ20160271. ISSN 0149-6115*
4. Hubler, J., Athanasopoulos-Zekkos, A., and Zekkos, D. (2017). "Monotonic, Cyclic and Post-Cyclic Simple Shear Response of Three Uniform Gravels in Constant Volume Conditions", ASCE *Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 143, Issue 9, doi 10.1061/(ASCE)GT.1943-5606.0001723
5. Dellow,S., Massey, C., Cox, S., Archibald, G., Begg, J., Bruce, Z., Carey, J., Davidson, J., Della Pasqua, F., Glassey, P., Hill, M., Jones, K., Lyndsell, B., Lukovic, B., McColl, S., Rattenbury, M., Read, S., Rosser, B., Singeisen, C., Townsend, D., Villamor,P., Villeneuve, M., Godt, J., Jibson, R., Allstadt, K., Rengers, F., Wartman, J., Rathje, E., Sitar, N., Athanasopoulos-Zekkos, A., Manousakis, J., and Little, M. (2017). "Landslides caused by the M_w7.8 Kaikōura earthquake and the immediate response", *Bulletin of the New Zealand Society for Earthquake Engineering, Vol. 50, No. 2, June 2017*
6. Stringer, M., Bastin, S., McGann, C.R., Cappellaro, C., El Kortbawi, M., McMahon, R., Wotherspoon, L.M., Green, R.A., Aricheta, J., Davis, R., McGlynn, L., Hargraves, S., van Ballegooy, S., Cubrinovski, M., Bradley, B.A., Bellagamba, X., Foster, K., Lai, C., Ashfield, D., Baki, A., Athanasopoulos-Zekkos, A., Lee, R. and Ntritsos, N. (2017). "Geotechnical aspects of the 2016 Kaikōura earthquake on the south island of New Zealand", *Bulletin of the New Zealand Society for Earthquake Engineering, Vol. 50, No. 2, June 2017*
7. Stahl, T., Clark, M., Zekkos, D., Athanasopoulos-Zekkos, A., Willis, M., Medwedeff, W., Knoper, L., Townsend, K., and Jin, J. (2017). "Earthquake Science in Resilient Societies: Earthquakes in Resilient Societies", *Tectonics, April 2017*
8. Zekkos, D., Athanasopoulos-Zekkos, A., Grizi, A., and Greenwood, W. (2016). The May 25th 2011 Railroad Embankment Failure in Ann Arbor, Michigan, As a Means for Teaching Geotechnical

Engineering. International Journal of Geoengineering Case histories, Vol.3, Issue 4, p.234-245. doi: 10.4417/IJGCH-03-04-03

9. Grizi, A., Athanasopoulos-Zekkos, A., and Woods, R. (2016). "Ground Vibration Measurements near Impact Pile Driving." *J. Geotech. Geoenviron. Eng.* , 10.1061/(ASCE)GT.1943-5606.0001499, 04016035.
10. Athanasopoulos-Zekkos, A., Pence, H., and Lobbestael, A. (2016.) "Ground Motion Selection for Seismic Slope Displacement Evaluation of Earthen Levees", *Earthquake Spectra, Earthquake Engineering Research Institute,* doi: 10.1193/062513EQS169M, February 2016, Vol. 32, No. 1, pp. 217-237.
11. Carlson, C., Zekkos, D., Athanasopoulos-Zekkos, A. (2016). "Predictive Equations to Quantify the Impact of Spectral Matching on Ground Motion Characteristics", *Earthquake Spectra, Earthquake Engineering Research Institute (EERI) Journal*, doi: 10.1193/090914EQS140M February 2016, Vol. 32, No. 1, pp. 125-142.
12. Carlson, C., Zekkos, D., Athanasopoulos-Zekkos, A. and J. Hubler (2014). "Statistical assessment of impact of ground motion modification on ground motion characteristics and time histories" *Earthquake Engineering Journal*, DOI: 10.1080/13632469.2014.898602.
13. Saadi, M. and Athanasopoulos-Zekkos, A. (2013). "A GIS-enabled approach for assessing damage potential of levee systems based on underlying geology and river morphology", Journal of *Mathematical Problems in Engineering, Special Issue: Structural Damage Modelling and Assessment Volume 2013 (2013), Article ID 936468, Article can be accessed at: http://dx.doi.org/10.1155/2013/936468.*
14. Lobbestael, A., Athanasopoulos-Zekkos, A., and Colley, J. (2013). "Factor of Safety Reduction Factors for Accounting for Progressive Failure for Earthen Levees with Underlying Thin Layers of Sensitive Soils", Journal of *Mathematical Problems in Engineering, Special Issue: Structural Damage Modelling and Assessment Volume 2013 (2013), Article ID 893602. Article can be accessed at: http://dx.doi.org/10.1155/2013/893602.*
15. Athanasopoulos-Zekkos, A., Vlachakis, V.S. and Athanasopoulos, G.A. (2013). "Phasing issues in the seismic response of yielding, gravity-type earth retaining walls – overview and results from a FEM study", *Soil Dynamics and Earthquake Engineering, Vol.55, pp. 59-70.*
16. Saadi, M. and Athanasopoulos-Zekkos, A. (2013). "A framework for assessing spatial distribution of soil properties in levee systems based on underlying geology and river morphology", Journal of *Geography and Geology, Vol. 5, No.3, pp.22-42.*
17. Athanasopoulos-Zekkos, A. and Seed, R.B., (2013). "Simplified Methodology for Consideration of 2D Dynamic Response of Levees in Liquefaction Triggering Evaluation", ASCE *Journal of Geotechnical and Geoenvironmental Engineering, Vol. 139, No. 11, pp.1911-1922.*
18. A. Athanasopoulos-Zekkos, K. Lamote, and G. A. Athanasopoulos, (2012). "Use of EPS geofoam compressible inclusions for reducing the earthquake effects on yielding earth retaining structures", *Soil Dynamics and Earthquake Engineering Journal, Vol.41, pp.59-71.*
19. A. Athanasopoulos-Zekkos and M. Saadi, (2012). "Ground Motion Selection for Liquefaction Evaluation Analysis of Earthen Levees", *Earthquake Spectra, Earthquake Engineering Research Institute, Vol. 28 (4), pp. 1331-1351.*
20. J.D. Rogers, G.P. Boutwell, D.W. Schmitz, D. Karadeniz, C.M. Watkins, A. Athanasopoulos-Zekkos, and D. Cobos-Roa, (2008). "Geologic Conditions Underlying the 2005 17th Street Canal Levee Failure in New Orleans", *ASCE Journal of Geotechnical and Geoenvironmental Engineering* Vol.134(5), 583-601.
21. R. B. Seed, R. G. Bea, R. I. Abdelmalak, A. Athanasopoulos-Zekkos, G. P. Boutwell, J.-L. Briaud, C. Cheung, D. Cobos-Roa, L. Ehrensing, A. V. Govindasamy, L. F. Harder, K. S. Inkabi, J. Nicks, J. M. Pestana, J. Porter, K. Rhee, M. F. Riemer, J. D. Rogers, R. Storesund, X. Vera-Grunauer, J.

Wartman, (2008). "New Orleans & Hurricane Katrina: I - Introduction, Overview, and the East Flank", *ASCE Journal of Geotechnical and Geoenvironmental Engineering*, Vol.134(5), 701-717.

22. R. B. Seed, R. G. Bea, A. Athanasopoulos-Zekkos, G. P. Boutwell, J. D. Bray, C. Cheung, D. Cobos-Roa, L. Ehrensing, L. F. Harder, J. M. Pestana, M. F. Riemer, J. D. Rogers, R. Storesund, X. Vera-Grunauer, and J. Wartman, (2008). "New Orleans & Hurricane Katrina: II - The Central Region and the Lower Ninth Ward", *ASCE Journal of Geotechnical and Geoenvironmental Engineering* Vol.134(5), 718-739.
23. R. B. Seed, R. G. Bea, A. Athanasopoulos-Zekkos, G. P. Boutwell, J. D. Bray, C. Cheung, D. Cobos-Roa, L. F. Harder, R. E. S. Moss, J. M. Pestana, J. Porter, M. F. Riemer, J. D. Rogers, R. Storesund, X. Vera-Grunauer, and J. Wartman, (2008). "New Orleans & Hurricane Katrina: III - The 17th Street Drainage Canal", *ASCE Journal of Geotechnical and Geoenvironmental Engineering* Vol.134(5), 740-761.
24. R. B. Seed, R. G. Bea, A. Athanasopoulos-Zekkos, G. P. Boutwell, J. D. Bray, C. Cheung, D. Cobos-Roa, J. Cohen-Waeber, B. D. Collins, L. F. Harder, R.E. Kayen, R. E. S. Moss, J. M. Pestana, J. Porter, M. F. Riemer, J. D. Rogers, R. Storesund, X. Vera-Grunauer, and J. Wartman, (2008). "New Orleans & Hurricane Katrina: IV - The Orleans East Bank (Metro) Protected Basin", *ASCE Journal of Geotechnical and Geoenvironmental Engineering* Vol.134(5), 762-779.

Invited Conference Publications

1. Seed, R.B., Athanasopoulos-Zekkos, A., Cobos-Roa, D., Pestana, J.M., and Inamine, M. (2012). "State of the Art: U.S. Levee and Flood Protection Engineering in the Wake of Hurricane Katrina", *2012 GeoCongress Conference: State of the Art and Practice in Geotechnical Engineering*, ASCE, 25-29 March, Oakland CA

Refereed Conference Publications

1. Zabihi, N. and Athanasopoulos-Zekkos, A. (2020). “Discrete Element Modelling of Large Scale Stacked-Ring Simple Shear Test of Steel Spheres”, ASCE *GeoCongress 2020*, February 25-28, 2020, Minneapolis, MN (paper accepted)
2. Basham, M., and Athanasopoulos-Zekkos, A. (2020). “The Effect of Static Shear Stress on Cyclic Resistance of Uniform Gravels”, ASCE *GeoCongress 2020*, February 25-28, 2020, Minneapolis, MN (paper accepted)
3. Athanasopoulos-Zekkos, A., Zekkos, D., Rollins, K., Hubler, J., Higbee, J. and Platis, A. (2019). “Earthquake Performance and Characterization of Gravel-Size Earthfills in the Ports of Cephalonia, Greece, following the 2014 Earthquakes”, *7th International Conference on Earthquake Geotechnical Engineering,* Rome 17-20 June, 2019
4. Basham, M., Athanasopoulos-Zekkos, A. and Zekkos, D. (2019). “The Importance of Vertical Displacement Control During Constant Volume Cyclic Simple Shear Testing”, *7th International Conference on Earthquake Geotechnical Engineering,* Rome 17-20 June, 2019
5. Gkrizi, A., Athanasopoulos-Zekkos, A., and Woods, R.D. (2019). “Surface Wave Development during Impact Pile Driving” *XVII European Conference on Soil Mechanics and Geotechnical Engineering,* Reykjavik, Iceland, 1-6 September, 2019
6. Kidus A. Admassu, Jerome P. Lynch, Adda Athanasopoulos-Zekkos, Dimitrios Zekkos, "Long-term wireless monitoring solution for the risk management of highway retaining walls," *Proc. SPIE 10971, Nondestructive Characterization and Monitoring of Advanced Materials, Aerospace, Civil Infrastructure, and Transportation XIII*, 1097103 (1 April 2019);
7. Gallagher, P, Bhatia, S., Alestalo, S., Soundarajan, S., and Athanasopoulos-Zekkos, A. (2019). “Do Seed Grants Increase Collaboration? A Case Study from the “Geotechnical Engineering Women

Faculty: Networked and Thriving" Project", *Geo-Congress 2019: The Eighth International Conference on Case Histories in Geotechnical Engineering*, March 24-27, 2019

8. Zekkos, D., Clark, M., Willis, M., Athanasopoulos-Zekkos, A., Manousakis, J., Knoper, L., Stahl, T., Massey, C., Archibald, G., Greenwood, W., and Medwedeff, W. (2018a). "3D models of the Leader Valley using satellite & UAV imagery following the 2016 Kaikoura earthquake", *Eleventh U.S. National Conference on Earthquake Engineering, Integrating Science, Engineering & Policy, June 25-29, 2018, Los Angeles, California.*
9. Zekkos, D., Manousakis, J., Athanasopoulos-Zekkos, A., Clark, M., Knoper, L., Massey, C., Archibald, G., Greenwood, W., Hemphill-Haley, M., Rathje, E., Litchfield, N., Medwedeff, W., Van Dissen, R.J., Ries, W., Villamor, P., Langridge, R.M., and Kearse, J. (2018b). "Structure-from-Motion based 3D mapping of landslides & fault rupture sites during 2016 Kaikoura earthquake reconnaissance", *Eleventh U.S. National Conference on Earthquake Engineering, Integrating Science, Engineering & Policy, June 25-29, 2018, Los Angeles, California.*
10. Hubler, J.F., Athanasopoulos-Zekkos, A. and Zekkos, D. (2018). "Post-Liquefaction Volumetric Strain of Gravel-Sand Mixtures in Constant Volume Simple Shear." *Geotechnical Earthquake Engineering and Soil Dynamics V 2018, June 10-13*
11. Grizi, A., Athanasopoulos-Zekkos, A., and Woods, R.D. (2018). "Pile Driving Vibration Attenuation Relationships: Overview and Calibration Using Field Measurements", *Geotechnical Earthquake Engineering and Soil Dynamics V 2018, June 10-13* .
12. Grizi, A., Athanasopoulos-Zekkos, A., and Woods, R.D. (2018). "Understanding the energy transfer mechanism in the near field of impact driven piles", *10th International Conference on Stress Wave Theory and Testing Methods for Deep Foundations*
13. Hubler, J.F., Athanasopoulos-Zekkos, A. and Zekkos, D. (2018) "Evaluation of Post-Liquefaction Shear Strength and Shear Wave Velocity of Uniform Gravels." *International Foundations Congress and Equipment Expo, March 5-10, 2018.*
14. Grizi, A., Athanasopoulos-Zekkos, A. and Woods, R. D. (2018). "H-Pile Driving Induced Vibrations: Reduced-Scale Laboratory Testing and Numerical Analysis", *IFCEE 2018, March 5-10, ASCE.*
15. Gallagher, P.M., Alestalo, S., Bhatia, S.K., Athanasopoulos-Zekkos, A., and Soundarajan, S. (2018). "Geotechnical Women Faculty From 1989-2017: A U.S. Case Study Outline", *Submitted to International Foundations Congress and Equipment Expo, March 5-10, 2018.*
16. Hubler, J., Athanasopoulos-Zekkos, A., and Zekkos, D. (2017). "Pore Pressure Generation of Pea Gravel, Sand, and Gravel-Sand Mixtures in Constant Volume Simple Shear", 3rd International Conference on Performance-Based Design for Earthquake Geotechnical Engineering, Vancouver, BC, Canada, July 17-19, 2017
17. Hubler, J., Athanasopoulos-Zekkos, A., and Zekkos, D. (2017.) "Monotonic, Cyclic and Post-Cyclic Shear Response of a Gravelly Sand ", 2017 Geofrontiers ASCE conference, Olrando, FL, March 12-15
18. Nikolaou, S., Vera-Grunauer X., Gilsanz, R. Luque, R. Kishida, T. Diaz-Fanas, G. Antonaki, N. Toulkeridis T., Miranda, E. Diaz, V. Alzamora, D. Athanasopoulos-Zekkos, A. Lyvers, G. Morales, E. Lopez, P. Rollins, K. Wood, C. O'Rourke, T. Lopez, S. (2017). "GEER-ATC Mw7.8 ECUADOR 4/16/16 EARTHQUAKE RECONNAISSANCE PART I : SEISMOLOGICAL & GROUND MOTION ASPECTS", *16th World Conference on Earthquake Engineering, 16WCEE 2017 Santiago Chile, January 9th to 13th 2017*
19. Vera-Grunauer, X., Nikolaou, S., Gilsanz, R., Diaz-Fanas, G., Antonaki, N., Lopez, S., Luque, R., Casares, B., Caicedo, A., Alzamora, D., Rollins, K., Wood, C., Athanasopoulos-Zekkos, A., Lyvers, G., Diaz, V., Toulkeridis, T., Morales, E. (2017). "GEER-ATC Mw7.8 ECUADOR 4/16/16 EARTHQUAKE RECONNAISSANCE PART II: SELECTED GEOTECHNICAL OBSERVATIONS", *16th World Conference on Earthquake Engineering, 16WCEE 2017 Santiago Chile, January 9th to 13th 2017*

20. Kitsis, V., Vlachakis, V., Athanasopoulos-Zekkos, A., and Athanasopoulos, G. (2015). “Seismic Thrust vs Wall Inertia in Non-Yielding Retaining Walls Under Earthquake Loading: Synchronous or Asynchronous Action?” 2015 International Foundations Congress and Equipment Expo, American Society of Civil Engineers (ASCE), San Antonio, TX, March 17-21.
21. Zekkos, D., Athanasopoulos-Zekkos, A., Grizi, A., Greenwood, W. (2014). “The Railroad Embankment Failure of the City of Ann Arbor, Michigan, Case history As a Means for Teaching Geotechnical Engineering”, 7th Hellenic Conference in Geotechnical Engineering, Athens, 5-7 November 2014 (in greek).
22. Hubler, J., Athanasopoulos-Zekkos, A., Ohm, H-S, and Hryciw, R. (2014). “Effect of Particle Morphology on the Monotonic Response of Gravel-sized Soils through Large Scale Simple Shear Testing”, GeoCongress 2014, GSP 234-235, ASCE, Atlanta, GA, February 23-26.
23. Vlachakis, V., Athanasopoulos, G.A., and Athanasopoulos-Zekkos, A. (2014). “Seismic displacements of yielding gravity-type earth retaining walls – Results from a FEM study”, GeoCongress 2014, GSP 234-235, ASCE, Atlanta, GA, February 23-26.
24. Woods, R.D., Athanasopoulos-Zekkos, A., Gkrizi, A., Pietrangelo, A., and Zimmerman, A. (2014). “Measurement of Ground Motion near Piles during Driving”, ASCE Geotechnical Special Publication (GSP 233): Principles and Practices in Geotechnical Engineering, A GSP Honoring Roy Olson, PhD, PE, NAE, DistMASCE.
25. Athanasopoulos-Zekkos, A. and Seed, R.B. (2013). “Seismic Slope Stability of Earthen Levees”, Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris, September 2-6 2013.
26. Lobbestael, A and Athanasopoulos-Zekkos, A. (2013). “The Effect of Input Frequency on the Soil-Structure Interaction during dynamic excitation of Levees with Cutoff Walls”, GeoCongress 2013, GSP 231, ASCE, San Diego, March 3-6.
27. Athanasopoulos-Zekkos, A., and Seed, R. (2012). "Dynamic Response and Performance of Earthen Levees", International Conference on Earthquake Engineering Research Challenges in the 21st Century, Institute of Engineering Mechanics (IEM) of the China Earthquake Administration, 18-21 May, 2012, Harbin, China.
28. Lobbestael, A., and Athanasopoulos-Zekkos, A. (2011). "The Behavior of Failure Surfaces Resulting from Progressive Failure Through Thin Layers of Soft Sensitive Soil Beneath Earthen Levees", *Dam Safety 2011, ASDSO,* Washington, DC., September 25-29 2011.
29. Athanasopoulos-Zekkos, A., Lamote, K., and Athanasopoulos, G., (2011). “Seismic isolation of earth retaining walls using EPS compressible inclusions – Results from centrifuge testing”, *4th International Conference on Geofoam Blocks in Construction Applications*, Oslo, Norway, 4-6 June, 2011.
30. Lobbestael, A. and Athanasopoulos-Zekkos, A. (2011). "High Performance Cutoff Walls for Levees in Seismic Regions", *U.S. Society of Dams 2011 Annual Meeting and Conf.*, San Diego, CA, April 11-15 2011 (poster).
31. Lobbestael, A. and Athanasopoulos-Zekkos, A. (2011). “A Parametric Analysis of the Effects of Progressive Failure on Embankments Founded on Soft Sensitive Soils”, *Geo-frontiers 2011, GSP 211, ASCE*, Dallas, Texas, March 13-16, 2011.
32. Athanasopoulos-Zekkos, A. and Seed, R. (2010). “A Simplified Methodology for the Seismic Vulnerability Assessment of Earthen Levees”, *6th National Hellenic Conference on Geotechnical and Geoenvironmental Engineering,* Volos, Greece, Sept. 29-Oct. 1, 2010 (in greek).
33. Saadi, M. and Athanasopoulos-Zekkos, A. (2010). “A GIS-enabled approach for the risk assessment of levee systems”, *9th US National and 10th Canadian Conference on Earthquake Engineering: Reaching beyond Borders*, Toronto, Canada, July 25-29, 2010.
34. Zekkos, D., Boominathan, A., and Athanasopoulos-Zekkos, A. (2010). “Engineering Seismology, Ground Motions and Local Site Effects”, General Report on Seesion 3, *5th International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics*, San Diego, CA, May 24-29, 2010.

35. Athanasopoulos-Zekkos, A. (2010). "Variability in earthen levee seismic response due to time-history selection", *5th International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics*, San Diego, CA, May 24-29, 2010.
36. Athanasopoulos-Zekkos A**.**, Zekkos D. and Matasovic N., (2008). "Validation of generic municipal solid waste material properties for seismic design of landfills", *4th Geotechnical Earthquake Engineering and Soil Dynamics Conference,* GSP 181, Sacramento, CA, May 18-22, 2008.
37. R. B. Seed, R. G. Bea, R. I. Abdelmalak, A. G. Athanasopoulos, G. P. Boutwell, J. D. Bray, J.-L. Briaud, C. Cheung, J. Cohen-Waeber, B. D. Collins, D. Cobos-Roa, D. Farber, M. Hanenmann, L. F. Harder, K. S. Inkabi, A. M. Kammerer, D. Karadeniz, R.E. Kayen, R. E. S. Moss, J. Nicks, S. Nimala, J. M. Pestana, J. Porter, K. Rhee, M. F. Riemer, K. Roberts, J. D. Rogers, R. Storesund, A. V Govindasamy, X. Vera-Grunauer, J. Wartman, C. M. Watkins, E.Wenk, and S. Yim, (2007). "Investigation of the performance of the New Orleans Regional Flood Protection Systems during Hurricane Katrina: Lessons learned", *Geo-Denver Congress, Geo-Institute, GSP 157-174, ASCE*, Denver, CO, February 2007.
38. R. B. Seed, R. G. Bea, A. G. Athanasopoulos, G. P. Boutwell, J. D. Bray, C. Cheung, B. D. Collins, D. Cobos-Roa, J. Cohen-Waeber, L. F. Harder, R.E. Kayen, R. E. S. Moss, J. M. Pestana, J. Porter, M. F. Riemer, J. D. Rogers, R. Storesund, X. Vera-Grunauer, J. Wartman, (2007). "Investigation of levee performance in Hurricane Katrina: The New Orleans drainage canals", *Geo-Denver Congress, Geo-Institute, GSP 157-174, ASCE,* Denver, CO, February 2007.
39. R. B. Seed, R. G. Bea, A. G. Athanasopoulos, G. P. Boutwell, J. D. Bray, C. Cheung, B. D. Collins, D. Cobos-Roa, L. F. Harder, R.E. Kayen, J. M. Pestana, J. Porter, M. F. Riemer, J. D. Rogers, R. Storesund, X. Vera-Grunauer, J. Wartman, (2007). "Investigation of levee performance in Hurricane Katrina: The Inner Harbor navigation channel", *Geo-Denver Congress, Geo-Institute, GSP 157-174, ASCE*, Denver, CO, February 2007.
40. Zekkos, D., Athanasopoulos, G., Athanasopoulos, A. Manousakis, J. (2006). "Elements of engineering geology and geotechnical engineering in the Homeric Poems", *International Symposium on Science and Technology in Homeric Epics*, Ancient Olympia, Greece, 27-30 August 2006.
41. Zekkos D.P., Athanasopoulos G.A. and Athanasopoulos A.G**.**, (2004). "Deep Supported Excavation in Difficult Ground Conditions in the City of Patras, Greece - Measured vs. Predicted Behavior", *5th International Conference on Case Histories in Geotechnical Engineering*, 13-17 April 2004, NY

Other Publications

1. Gallagher, P.M., Alestalo, S., Athanasopoulos-Zekkos, A., Bhatia, S.K., and Soundarajan, S. (2017). "Connecting Faculty in Geotechnical Engineering: Thriving in a Networked World", *GeoStrata, March/April Issue, Geo-Institute of ASCE.*
2. Lobbestael, A., and Athanasopoulos-Zekkos, A. (2011). "High Performance Cutoff Walls for Levees in Seismic Regions", *U.S. Society of Dams Newsletter*, Issue No. 154, July 2011
3. Zekkos D.P., Athanasopoulos A.G., (2004). "Milos Island: Working with earth for 9000 years", *AEG News, Association of Engineering Geologists Magazine*, March 2004, Vol.47, Issue 1
4. Zekkos, D., Athanasopoulos, A., Manousakis, J., (2003). "Geotechnical Engineering Experiences in the Homeric Poems", *Newsletter of the Technical Chamber of Greece*, Issue 2231, January 20th, 2003.

Technical Reports – Theses

1. Bastin, S., Bradley, B., Bray, J., Capellaro, C., Cubrinovski, M., del la Torre, C., Green, R., McGann, C., Olsen, M., Palermo, A., M., Stringer, Wotherspoon, L., Aricheta, J., Athanasopoulos-

Zekkos, A., et al. (2017). "Geotechnical reconnaissance of the 2016 Mw 7.8 Kaikoura, New Zealand earthquake", GEER report GEER-053, Cubrinovski and Bray eds, Version 1.0, June 2017

2. Alvarado, A., Alzamora, D., Antonaki, N., Arteta, C., Athanasopoulos-Zekkos, A., Bassal, P., Caicedo, A., Casares, B., Davila, D., Diaz, V., Diaz-Fanas, G., Gilsanz, R., González, O., Hernandez, L., Kishida, T., Kokkali, P., López, P., Luque, R., Lyvers, G.M., Maalouf, S., Mezher, J., Miranda, E., Morales Moncayo, E., Nikolaou, S., O'Rourke, T., Ochoa, I., O'Connor, J.S., Ripalda, F., Rodríguez, L.F., Rollins, K., Stavridis, A., Toulkeridis, T., Vaxevanis, E., Vera-Grunauer, X., Villagrán León, N., Wood, C., Yepes, H., Yepez, Y. (2016). "GEER-ATC Earthquake reconnaissance, April 16, 2016 Muisne, Ecuador", GEER report GEER-049, Nikolaou, Grunauer and Gilsanz eds, Version 1.0b, October 2016
3. Athanasopoulos-Zekkos, A., Woods, R.D. and Gkrizi, A. (2014). "Effect of pile-driving induced vibrations on nearby structures and other assets", final report submitted to MDOT, ORBP Number OR10-046, RC-1600
4. Cortese, G., Zekkos, D., Athanasopoulos-Zekkos, A. (2012a). "Network for Women in Civil and Environmental Engineering – First Annual Report", May 31 2012, University of Michigan
5. Cortese, G., Zekkos, D., Athanasopoulos-Zekkos, A. (2012b). "Results of 2011 Undergraduate and Graduate Survey", September 15, 2012, University of Michigan.
6. Athanasopoulos, A.G. (2008)., "Select Topics on the Static and Dynamic Response and Performance of Earthen Levees", *Dissertation, Doctor of Philosophy*, Department of Civil and Environmental Engineering, University of California, Berkeley, California, USA.
7. Athanasopoulos, A.G. (2006). "Investigation of the performance of the flood-protection systems of New Orleans in Hurricane Katrina, on August 29, 2005", *report for the Technical Chamber of Greece.*
8. R. B. Seed, R. G. Bea, R. I. Abdelmalak, A. G. Athanasopoulos, G. P. Boutwell, J. D. Bray, J.-L. Briaud, C. Cheung, D. Cobos-Roa, J. Cohen-Waeber, B. D. Collins, L. Ehrensing, D. Farber, M. Hanemann, L. F. Harder, K. S. Inkabi, A. M. Kammerer, D. Karadeniz, R.E. Kayen, R. E. S. Moss, J. Nicks, S. Nimmala, J. M. Pestana, J. Porter, K. Rhee, M. F. Riemer, K. Roberts, J. D. Rogers, R. Storesund, A. V. Govindasamy, X. Vera-Grunauer, J. E. Wartman, C. M. Watkins, E. Wenk Jr., and S. C. Yim, (2006). "Investigation of the performance of the New Orleans flood protection systems in hurricane Katrina on August 29, 2005", *Report No.UCB/CCRM - 06/01*, July 2006, University of California at Berkeley, (http://www.ce.berkeley.edu/~new_orleans/)
9. Athanasopoulos, A., Zekkos D. (2006). "Geoengineering, refereed journals and case histories: A survey", *Geoengineer.org report* GEO/01/06, September 2006.
10. Athanasopoulos, A.G. (2003). "Rion – Antirion Bridge: The foundation system of the Antirion approach viaduct and results of axial and lateral loading tests on 2m – diameter steel pipe piles", *Undergraduate Thesis, Ptychion*, Department of Civil Engineering, University of Patras, Greece.

Invited Lecture Presentations

1. "Liquefaction Assessment of Gravelly Soils using the DPT", *Impact Testing for Site Characterization Workshop at SuperPile '19*, DFI, Seattle, May 1, 2019
2. "Liquefaction of Gravelly Soils and Their Impact on Infrastructure", Purdue Geotechnical Society *Workshop on Geotechnics of Natural Hazards*, Lafayette, April 26, 2019
3. "Liquefaction of Gravelly Soils and Their Impact on Infrastructure", *Civil and Environmental Engineering Department Seminar*, UC Berkeley, March 1, 2019

4. "Laboratory and In-Situ Assessment of Liquefaction of Gravelly Soils", Themed Lecture, Geosystems Session, *3rd International Conference on Performance-based Design in Earthquake Geotechnical Engineering", Vancouver BC, July 18, 2017*
5. "Liquefaction Triggering and Post-Liquefaction response of Gravelly Soils", *4th Annual ACEC NY Geotechnical Symposium, Syracuse, NY, May 8, 2017*
6. "Evaluation of Gravelly Soil Liquefaction through Laboratory and Field Testing", *35th Geoengineering Distinguished Lecture Series, UC Berkeley, May 4, 2017*
7. "Post-Liquefaction Response of Gravelly Soils", *US-NZ-Japan International Workshop on Liquefaction-Induced Ground Movement Effects, UC Berkeley,* November 3, 2016
8. "Characterization of pile-driving induced vibrations", invited by the *Civil Engineering Dept. of the National Technical University of Athens (NTUA) Greece, and the National Scientific Committee of Geotechnical Engineering,* June 1, 2016
9. "Pile driving induced vibrations and their effects on nearby structures", *UM, CEE Geotechnical Seminar*, November 4, 2015
10. "Pile driving induced vibrations and their effects on nearby structures", *UC Davis, CEE Geotechnical Seminar*, April 2, 2015
11. Keynote presentation: "Assessment of Seismic Vulnerability of Earthen Levees", *22nd Vancouver Geotechnical Society Symposium*, Vancouver B.C., June 13, 2014
12. "Effect of pile-driving induced vibrations on nearby structures and other assets", *2013 Midwest Geotechnical Conference, Madison, WI,* September 24, 2013
13. "Levees: Learning from the past – Looking to the future", *CEE Department, Syracuse University, NY,* April 12, 2013
14. "Techniques for reviewing journal articles and the process for getting your work published", *UROP/WISE seminar, University of Michigan*, October 17, 2012
15. "Performance of the flood-protection systems of New Orleans in Hurricane Katrina – Lessons Learned", invited by the *Civil Engineering Dept. of the National Technical University of Athens (NTUA) Greece, the National Scientific Committee of Geotechnical Engineering and the National Committee of Earthquake Engineering,* December 17, 2010
16. "Investigation of the levee failures in New Orleans after Hurricane Katrina", *UROP Research seminar, University of Michigan,* October 20, 2010
17. "Teaching techniques for increasing female participation and retention in Civil Engineering" at the *6th National Hellenic Conference on Geotechnical and Geoenvironmental Engineering,* in Volos, Greece, Sept. 29-Oct. 1, 2010 for the special session titled: "Innovative teaching methods in Geotechnical Engineering", September 30, 2010
18. "Lessons learned from the performance of the flood-protection systems after Hurricane Katrina" *2010 CEEFA Spring Technical Session, University of Michigan,* April , 2010
19. "Levees: Learning from the past – Looking to the future", *ASCE chapter, University of Michigan*, Ann Arbor, MI, February 13, 2009
20. "Assessment of Seismic Vulnerability of Levees in Select California Regions", *EERI Student Chapter of the University of Notre Dame,* Notre Dame, IN, January 27, 2009
21. "Variability of Levee Response Due to Time History Selection", *COSMOS annual meeting and technical session*, Oakland, CA, November 21, 2008
22. "Assessment of Seismic Vulnerability of Levees in Select California Regions", *University of California, Berkeley, Geoengineering Wednesday Seminar Series,* April 16, 2008

23. “Seismic Levee Fragility and Flooding Hazard for Select California Regions”, *ASCE San Francisco chapter* - *Geotechnical Group Workshop*, February 19, 2008
24. “Investigation of the performance of the flood-protection systems of New Orleans in Hurricane Katrina, on August 29, 2005”, *Technical Chamber of Greece, Special Scientific Committee of Soil Mechanics and Foundations and the Technical Chamber of Greece,* December 19, 2006
25. “Overview of the Investigation of the Performance of the New Orleans’ Flood Protection Systems in Hurricane Katrina on August 29, 2005”, *ASCE-Geo-Institute chapter of Texas A&M University, College Station*, November 16, 2006
26. “Performance of the flood-protection systems of New Orleans in hurricane Katrina on August 29, 2005 – Lessons Learned”, *University of California at Berkeley, Civil & Environmental Engineering Graduate Student Societ*,. October 24, 2006

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EDUCATION

2002 – 2005 : Doctor of Philosophy (PhD), University of California at Berkeley. Department of Civil & Environmental Engineering, Geoengineering Program.
2001 –2002 : Master of Science (MSc), University of California at Berkeley. Department of Civil & Environmental Engineering, Geoengineering Program
1996 – 2001 : Joint B.S/M.Eng. (5-year required program), University of Patras, Department of Civil Engineering, Greece.

AWARDS-HONORS

Awards

- 2019 Rackham Faculty Recognition Award, University of Michigan. This award recognizes mid-career faculty who have demonstrated remarkable contributions to the University of Michigan through outstanding achievements in scholarly research and/or creative endeavors; excellence as a teacher, advisor and mentor; and distinguished participation in the service activities of the university and elsewhere.
- 2017 Shamsher Prakash Research Award, Shamsher Prakash Foundation. International award for excellence in research.
- 2014 Collingwood Prize, American Society of Civil Engineers (ASCE). Awarded for the paper: Zekkos, D., Kabalan, M., and Flanagan, M. (2013). "Lessons Learned From Case Histories of Dynamic Compaction at Municipal Solid Waste Sites." Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 139(5), 738-752.
- 2013 Outstanding Innovator Award, International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE). This award is "in recognition of innovations in Geo-engineering that have a pronounced impact on geo-engineering practice, research and education. The term "innovation" is used broadly to describe any major, unprecedented achievements that led to a major advancement in our profession."
- 2013 Faculty Excellence Award, Civil and Environmental Engineering Department, University of Michigan.
- 2012 ASCE Arthur Casagrande Professional Development Award "for his contributions to the advancement of solid waste engineering and dedicated service and leadership in promoting geo-engineering research, education and practice through the creation of a pioneering website and online journal."
- 2012 Great Lakes District of Chi Epsilon James M. Robbins Excellence in Teaching Award. Students in each of the 17 Universities in the Great Lakes District nominate one faculty member per institution to compete for this award for excellence in teaching at the district level.
- 2011 Outstanding Research Mentorship Award, Undergraduate Research Opportunities Program (UROP), University of Michigan (awarded to top 5 faculty sponsors out of approximately 750 university-wide).
- 2010 Thomas A. Middlebrooks Award, American Society of Civil Engineers (ASCE). Awarded for the paper: Bray, J. D., Zekkos, D., Kavazanjian, E., Jr., Athanasopoulos, G. A., Riemer, M. F. (2009), "Shear Strength of Municipal Solid Waste," Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 135 (6):709-722, which was judged worthy of special commendation for its merit as a contribution to geotechnical engineering.
- 2003 Outstanding Graduate Student Instructor Award, University of California at Berkeley. In recognition of exceptional achievements as a Graduate Student Instructor of CE172 "Introduction to Rock Mechanics."
- 2002 Harry Bolton Seed Award, University of California at Berkeley. Awarded to the M.S. student who completes "in an exemplary manner" the program in Geoengineering in the Department of Civil & Environmental Engineering.

Other Recognitions

- Prize, Great Challenge Competition, US Bureau of Reclamation (USBR) and US Army Corps of Engineers, "Detecting the Movement of Soils (Internal Erosion) Within Earthen Dams, Canals, Levees, and their Foundations" (with Prof. Jean-Louis Briaud, Texas A&M)
- 2013 Technical Committee of the Year, ASCE Geo-institute, Geoenvironmental Technical Committee, Vice Chair.
- Honorable Award, Eurasian National University, Kazakhstan, for great contributions in ISSMGE Board Activity during 2009-2013 term.

- Eminent Engineer, Tau Beta Pi, December 2012.
- 2010 Outstanding Research Mentorship Award, Honorable Mention, Undergraduate Research Opportunities Program (UROP), University of Michigan (awarded to top 8 sponsors out of approximately 700)
- Chi-Epsilon, member, University of Michigan Chapter, Member, December 2009.

Academic Scholarships/Fellowships

- Graduate Research Assistantship, University of California at Berkeley (8/2002 – 11/2005)
- Graduate Fellowship, Civil & Environmental Engineering Department, University of California at Berkeley (January 2002).
- Graduate Teaching Assistantship, University of California at Berkeley (Fall 2001-CEE171; Spring 2002-CE172).

PROFESSIONAL HISTORY

- 1/2020-present: Associate Professor, Department of Civil and Environmental Engineering, University of California at Berkeley
- 2015-present: Founder & CEO, ARGO-E LLC, Ann Arbor, Michigan, USA
- 2002- present: Board Member and Vice President, Elxis Group S.A., Athens, Greece
- 6/2014- 12/2019: Associate Professor, Department of Civil and Environmental Engineering, University of Michigan.
- 9/2017-12/2019: Associate Professor, Department of Earth and Environmental Science, University of Michigan (dry appointment).
- 1/2016-7/2016: Visiting Professor, Geotechnical Engineering Department, School of Civil Engineering, National Technical University of Athens (NTUA).
- 9/2008-6/2014: Assistant Professor, Department of Civil and Environmental Engineering, University of Michigan.
- 11/2005-6/2008: Engineer, Geosyntec Consultants, Oakland California.

PUBLICATIONS

The ASCE reference format (http://www.asce.org/Content.aspx?id=29605) is used for the references. Current graduate student names are single underlined. Former graduate student names are double underlined. Undergraduate student names are single underlined and noted by an asterisk * after their name.

Books / Chapters in books – Special Publications

Books Edited

1. Zekkos, D., Farid, A., De, A., Reddy, K., Yessiler, N., (eds.) (2016) *Sustainability and Resiliency in Geotechnical Engineering*, Proceedings of Geo-Chicago 2016, ASCE Geotechnical Special Publication 269, Chicago, Illinois, August 14–18, 2016.
2. Farid, A. De, A., Reddy, K., Yessiler, N., Zekkos, D. (eds.) (2016). *Geotechnics for Sustainable Energy*, Proceedings of Geo-Chicago 2016, ASCE Geotechnical Special Publication 270, Chicago, Illinois, August 14–18, 2016.
3. De, A., Reddy, K., Yessiler, N., Zekkos, D., Farid, A.(eds.) (2016). *Sustainable Geoenvironmental Systems*, Proceedings of Geo-Chicago 2016, ASCE Geotechnical Special Publication 271, Chicago, Illinois, August 14–18, 2016.
4. Reddy, K., Yessiler, N., Zekkos, D., Farid, A., De, A., (eds.) (2016*). Sustainable Materials and Resource Conservation*, Proceedings of Geo-Chicago 2016, ASCE Geotechnical Special Publication 272, Chicago, Illinois, August 14–18, 2016.
5. Yessiler, N., Zekkos, D., Farid, A., De, A., Reddy, K., (eds.) (2016) *Sustainable Waste Management and Remediation*, Proceedings of Geo-Chicago 2016, ASCE Geotechnical Special Publication 273, Chicago, Illinois, August 14–18, 2016.
6. Zekkos, D. (2015). Geotechnical Section co-Editor, "*Encyclopedia of Earthquake Engineering*" Springer. Editors-in-Chief: Michael Beer, Ioannis A. Kougioumtzoglou, Edoardo Patelli, Ivan Siu-Kui Au.
7. Rollins, K., Zekkos, D. (2012), eds. "*Geotechnical Engineering State of the Art and Practice, Keynote Lectures from Geocongress 2012,*" March 25-29, 2012, Geotechnical Special Publication No. 226, ASCE, Va., 832 pp.
8. Zekkos, D. (2011) ed., "*Geotechnical Characterization, Field Measurements, and Laboratory Testing of Municipal Solid Waste,*" ASCE Geotechnical Special Publication No. 209, ASCE, Va., 249 pp.

Chapters in Books

1. Gourc, J-P., and Zekkos, D. (2019). “Chapter 5.1. – Waste Mechanical Properties.” In *Solid Waste Landfilling*, Cossu R. & Stegmann R. (eds.), Elsevier, 193-210.
2. Gourc, J-P., and Zekkos, D. (2019). “Chapter 5.2. – Mechanical Stability at Landfill Scale.” In *Solid Waste Landfilling*, Cossu R. & Stegmann R. (eds.), Elsevier, 211-228.
3. Zekkos, D., Matasovic, N., El-Sherbiny, R., Athanasopoulos-Zekkos, A., Towhata, I., Maugeri, M. (2011). “Chapter 4: Dynamic Properties of Municipal Solid Waste,” in *Geotechnical Characterization, Field Measurements, and Laboratory Testing of Municipal Solid Waste*, ASCE Geotechnical Special Publication No. 209, Zekkos, D. ed., ASCE, Va., 112-134.
4. Bray, J. D., Zekkos, D., Merry, S. M. (2011). “Chapter 3: Shear Strength of Municipal Solid Waste,” in *Geotechnical Characterization, Field Measurements, and Laboratory Testing of Municipal Solid Waste*, ASCE Geotechnical Special Publication No. 209, Zekkos, D. ed., ASCE, Va., 44-75.

Refereed Journal Papers

1. Athanasopoulos, G. A., Kechagias, G. C., Zekkos, D., Batilas, A., Karatzia, X., Lyrantzaki, F., & Platis, A. (2020). Lateral spreading of ports in the 2014 Cephalonia, Greece, earthquakes. Soil Dynamics and Earthquake Engineering, 128, 105874.
2. Greenwood, W., Lynch, J., Zekkos, D. (2019). Applications of UAVs in Civil Infrastructure, *Infrastructure Systems*, *J. Infrastruct. Syst*., 2019, 25(2): 04019002.
3. Datta, S., Zekkos, D., Fei, X., McDougall, J. (2018). Waste-composition-dependent ‘HBM’model parameters based on degradation experiments, Environmental Geotechnics, *Environmental Geotechnics*, 1-10.
4. Zekkos, D., Greenwood, W., Manousakis, J., Athanasopoulos-Zekkos, A., Clark, M., Cook, K.L. and Saroglou, C. (2018). Lessons Learned from the Application of UAV-Enabled Structure-From-Motion Photogrammetry in Geotechnical Engineering. *International Journal of Geoengineering Case Histories*, Vol.4, Issue 4, p.254-274. doi:10.4417/IJGCH-04-04-03
5. Hubler, J. F., Athanasopoulos-Zekkos, A., & Zekkos, D. (2018). Monotonic and cyclic simple shear response of gravel-sand mixtures. *Soil Dynamics and Earthquake Engineering*, 115, 291-304.
6. Saroglou, H., Asteriou, P., Zekkos, D., Tsiambaos, G., Clark, M., Manousakis, J. (2018) “UAV-enabled reconnaissance and trajectory modeling of a co-seismic rockfall in Lefkada”, *Natural Hazards and Earth System Sciences*, 18(1):321-333. DOI: 10.5194/nhess-18-321-2018
7. Fei, X., Zekkos, D. (2018), “Coupled experimental assessment of physico-biochemical characteristics of municipal solid waste undergoing enhanced biodegradation” *Geotechnique*, DOI: 10.1680/jgeot.16.p.253
8. Zekkos, D., Athanasopoulos-Zekkos, A., Hubler, J., Fei, X., Zehtab, K. H., Marr, W. A. (2017) “Development of a large-size cyclic direct simple shear device for characterization of ground materials with oversized particles”, ASTM *Geotechnical Testing Journal*, March 2018 Volume 41 (2), 263-279, DOI: 10.1520/GTJ20160271 .
9. Nevett, L., Tsigarida, E., Archibald, Z., Stone, D., Horsley, T., Ault, B., Panti, A., Lynch, K. M., Pethen, H., Stallibras, S. M., Salminen, E., Gaffney, C., Sparrow, T. J., Taylor, S., Manousakis, J., and Zekkos, D. (2017). Towards a multi-scalar, multidisciplinary approach to the classical greek city: The Olynthos project. *The Annals of the British School at Athens*, 112, 155-206. doi:10.1017/S0068245417000090
10. Von Voigtlander, J., Clark, M., K., Zekkos, D., Greenwood, W., W., Anderson, S. P., Anderson, R. S., Godt, J. W. (2017) Influence of Weathering on Seismic Velocities of a Basalt Climosequence, *Earth Surface Processes and* Landforms. DOI: 10.1002/esp.4290.
11. Fei, X., Zekkos, D. (2017), “Comparison of Direct Shear and Simple Shear Response of MSW”, Environmental Geotechnics Journal, September 2017, DOI: 10.1680/jenge.16.00036
12. Zekkos, D., Clark, M., Whitworth, M., Greenwood, W., West, J., Roback, K., Li, G., Chamlagain, D., Manousakis, J., Quackenbush, P., Medwedeff, W., Lynch, J., (2017). Observations of landslides caused by the April 2015 Gorkha earthquake in Nepal based on land, UAV and satellite reconnaissance. *Earthquake Spectra*, 33(S1), S95–S114, December 2017; DOI: 10.1193/121616EQS237M.
13. Carlson, C., Zekkos, D. (2017) “A Metric to Screen Acceptable Velocity and Displacement Time Histories of Modified Ground Motions”, Earthquake Spectra, 33 (4), 1495-1512 https://doi.org/10.1193/011117EQS012M.
14. Stahl, T., Clark, M. K., Zekkos, D., Athanasopoulos-Zekkos, D., Willis, M., Medwedeff, W., Knoper, L., Townsend, T., and Jin, J. (2017). Earthquake science in resilient societies, *Tectonics*, doi: 10.1002/2017TC004604
15. Hubler, J., Athanasopoulos-Zekkos, A., Zekkos, D. (2017). “Monotonic, Cyclic and Post-Cyclic Simple Shear Behavior of Three Uniform Gravels.” *Journal of Geotechnical and Geoenvironmental Engineering*, 143(9), September 2017. DOI: http://dx.doi.org/10.1061/(ASCE)GT.1943-5606.0001723. Editor’s Choice paper in October 2017.
16. Roback, K., Clark, M. K., West, J., Zekkos, D., Li, G., Gallen, S. F., Chamlagain, D., Godt, J. W. (2018). "The size, distribution, and mobility of landslides caused by the 2015 Mw7.8 Gorkha earthquake, Nepal." *Geomorphology*, 301, 121-138, https://doi.org/10.1016/j.geomorph.2017.01.030.

17. Zekkos, D., Fei, X. (2016). “Comparison of Constant Load and Constant Volume Shearing Response in Simple Shear Testing of Municipal Solid Waste.” *Waste Management*, http://dx.doi.org/10.1016/j.wasman.2016.09.029.
18. Zekkos, D., Athanasopoulos-Zekkos, A., Grizi, A., Greenwood, W. (2016). “The May 25th 2011 Railroad Embankment Failure in Ann Arbor, Michigan, As a Means for Teaching Geotechnical Engineering.” *International Journal of Geoengineering Case Histories*, 3 (4), 234-245. doi: 10.4417/IJGCH-03-04-03
19. Zekkos, D., Fei, X., Grizi, A., Athanasopoulos, G. A. (2016). “Response of Municipal Solid Waste to Mechanical Compression.” *Journal of Geotechnical and Geoenvironmental Engineering*, 10.1061/(ASCE)GT.1943-5606.0001608 , 04016101.
20. Fei, X., Zekkos D., Lei, L., Woods, R. D., Sanford, L. (2015). “Geoenvironmental Characterization of Water Treatment Lime Sludge” *Environmental Geotechnics Journal*. 2 (6), 319-325.
21. Greenwood, W., Zekkos, D., and Sahadewa, A. (2015). ”Spatial Variation of Shear Wave Velocity of Waste Materials from Surface Wave Measurements.” *Journal of Environmental and Engineering Geophysics*, 20(4), 287-301.
22. Fei, X., Zekkos, D., Raskin, L. (2016). “Quantification of parameters influencing methane generation due to biodegradation of municipal solid waste in landfills and laboratory experiments.” Waste Management 55, 276-287. http://dx.doi.org/10.1016/j.wasman.2015.10.015
23. Carlson, C., Zekkos, D., Athanasopoulos-Zekkos, A. (2015) Predictive Equations to Quantify the Impact of Spectral Matching on Ground Motion Characteristics. Earthquake Spectra, 32 (1), 125-142.
24. Sahadewa, A., Zekkos, D., Woods, R. D., Stokoe, K. H. (2015). “Field Testing Method for Evaluating the Small-strain Shear Modulus and Shear Modulus Reduction of Solid Waste.” ASTM Geotechnical Testing Journal, June 2015, 38 (4), 427-441.
25. Hoyos, L R., DeJong, J. T., McCartney, J. S., Puppala, A. J., Reddy, K. R., and Zekkos, D. (2014). “Environmental Geotechnics in the U.S. Region: A Brief Overview.” *Environmental Geotechnics Journal,* DOI: 10.1680/envgeo.14.00024, Available online: March 31 2015.
26. Carlson, C. P., Zekkos, D. and McCormick, J. P. (2014). "Impact of time and frequency domain ground motion modification on the response of a SDOF system." *Earthquakes and Structures*, 7(6), 1283-1301. DOI: 10.12989/eas.2014.7.6.1283
27. Fei, X., Zekkos, D., Raskin, L. (2014). “Archaeal Community Structure in Leachate and Solid Waste is Correlated to the Methane Generation and Volume Reduction during Biodegradation of Municipal Solid Waste.” *Waste Management Journal* (http://dx.doi.org/10.1016/j.wasman.2014.10.027)
28. Sahadewa, A., Zekkos, D., Woods, R. D., Stokoe, K. H., II, Matasovic, N. (2014). “In-situ assessment of the dynamic properties of municipal solid waste at a landfill in Texas.” *Soil Dynamics and Earthquake Engineering*, 65 (2014), 303–313.
29. Carlson, C., Zekkos, D., Athanasopoulos-Zekkos, A. & Hubler, J. (2014). “Impact of modification on ground motion characteristics and geotechnical seismic analyses for a California site”, *Journal or Earthquake Engineering* DOI: 10.1080/13632469.2014.898602.
30. Zekkos, D., Sahadewa, A., Woods, R. D., Stokoe, K. II (2014). “Development of a model for shear wave velocity of Municipal Solid Waste”, *ASCE Journal of Geotechnical and Geoenvironmental Engineering,* March 2014, 140 (3), 04013030(14).
31. Fei, X., Zekkos, D., Raskin, L. (2014). "An Experimental Setup for Simultaneous Physical, Geotechnical, and Biochemical Characterization of Municipal Solid Waste Undergoing Biodegradation in the Laboratory", *ASTM Geotechnical Testing Journal*, 37 (1), 1–12.
32. Zekkos, D., Vlachakis, V. S., Athanasopoulos, G. A. (2014). “The 2010 Xerolakka Landfill Slope Instability”, *Environmental Geotechnics Journal*, 1 (EG1), 55-65.
33. Zekkos, D., Gkrizi, A., Athanasopoulos, G. A. (2013) “Investigation of fibrous reinforcement effect on shear resistance of soil-waste mixtures”, *ASTM Geotechnical Testing Journal*, 36 (6), 867-880.
34. Ohm, H.-S., Sahadewa, A., Hryciw, R. D., Zekkos, D., and Brant, N. (2013). “Sustainable Soil Particle Size Characterization through Image Analysis.” *Journal of Geotechnical and Geological Engineering*, December 2013, 31(6), 1647-1652
35. Zekkos, D. Kabalan, M., Syal*, S. M., Hambright, M., and Sahadewa, A. (2013). “Geotechnical Characterization of a Municipal Solid Waste Incineration Ash from a Michigan Monofill.” *Waste Management Journal*, 33, 1442–1450.
36. Zekkos, D., Kabalan, M., and Flanagan, M. (2013). “Lessons Learned From Case Histories of Dynamic Compaction of Municipal Solid Waste Sites.” *ASCE Journal of Geotechnical and Geoenvironmental Engineering*, Va., 139(5), 738-752.
37. Fei, X. and Zekkos, D. (2013). “Factors Influencing Long-Term Settlement of Municipal Solid Waste in Laboratory Bioreactor Landfill Simulators.” *ASCE Journal of Hazardous, Toxic and Radioactive Waste*, 17 (4), 259-271.
38. Cox, B. R., Boulanger, R. W., Tokimatsu, K., Wood, C. M., Abe, A. Ashford, S. Donahue, J. , Ishihara, K., Kayen, K., Katsumata, K., Kishida, T., Kokusho, T., Mason, H. B., Moss, R., Stewart, J. P., Tohyama, K., and Zekkos, D. (2013). “Liquefaction at Strong Motion Stations and in Urayasu City During the 2011 Great East Japan,

Earthquake." *Earthquake Spectra Journal*, 29 (S1), 55-80.

39. Zekkos, D., Carlson, C., Nisar, A. and Guisbert, S. (2012). "Effect of Ground Motion Modification Technique on Seismic Geotechnical Engineering Analyses." *Earthquake Spectra*, 28 (4), 1643-1662.
40. Zekkos, D., Bray, J. D., and Riemer, M. F. (2012). "Drained Response of Municipal Solid Waste in Large-Scale Triaxial Shear Testing." *Waste Management*, 32 (10), 1873–1885.
41. Medley, E. W., and Zekkos, D. (2011). "Geopractitioner Approaches to Working with Antisocial Mélanges," in: Wakabayashi, J., and Dilek, Y., eds., *Mélanges: Processes of Formation and Societal Significance*, Geological Society of America Special Paper 480, 261-277. Note: invited, peer reviewed special paper.
42. Zekkos, D., Kavazanjian, E. Jr., Bray, J. D., Matasovic, N., and Riemer, M. F. (2010). "Physical Characterization of Municipal Solid Waste for Geotechnical Purposes." *Journal of Geotechnical and Geoenvironmental Engineering,* ASCE, Va., 136 (9), 1231-1241.
43. Zekkos, D., Athanasopoulos, G. A., Bray, J. D., Theodoratos, A., and Grizi, A. (2010). "Large-Scale Direct Shear Testing of Municipal Solid Waste." *Waste Management Journal*, 30, 1544–1555.
44. Bray, J. D., Zekkos, D., Kavazanjian, E., Jr., Athanasopoulos, G. A., and Riemer, M. F. (2009). "Shear Strength of Municipal Solid Waste." *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, Va., 135 (6), 709-722.
45. Zekkos, D., Bray, J.D., and Riemer, M.F. (2008). "Shear Modulus and Material Damping of Municipal Solid Waste Based on Large-Scale Cyclic Triaxial Testing." *Canadian Geotechnical Journal*, 45 (1), 45-58.
46. Zekkos, D., Bray, J. D., Kavazanjian, E. Jr., Matasovic, N., Rathje, E. M., Riemer, M. F., and Stokoe, K .H. (2006). "Unit Weight of Municipal Solid Waste." *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, 132 (10), 1250-1261.

Shorter communications, letters, notes or briefs in refereed Journals

1. Bray, J. D., Zekkos, D., Kavazanjian, E., Jr., Athanasopoulos, G. A., Riemer, M. F. (2009). Closure of "Shear Strength of Municipal Solid Waste", *Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 136, No. 12, December 2010, pp. 1731-1732.
2. Bray, J. D., Athanasopoulos, G. A., Bathurst, R., Myers Bohlke, B., Brandl, H., Christian, J., Doe, T., Duncan, M., Gue, S. S., de Mello, L. G. Hynes, M., Katzenbach, R., Kavazanjian, E., Jr., Koutsoftas, D., Lacasse, S., Marinos, P.G., Mayne, P. W., Morgenstern, N., Phoon, K. K., Poulos, H., Powderham, A., Prakash, S., Romo, M. P., Seed, R. B., Tokimatsu, K., Van Impe, W., Zekkos, D. P. (2004). "Foreword." *International Journal of Geoengineering Case Histories*, 1 (1), 1-3.

Refereed Conference Papers & Geotechnical Special Publications

1. Champagne, C. L., Zekkos, D., Lynch, J. P., and O'Loughlin, S. (2020) "Waste Settlement Measurements using Unmanned Aerial Vehicles at a Municipal Solid Waste Landfill in Michigan, Geocongress 2020 (accepted).
2. Draughon, G. T., Lynch, J. P., Zekkos, D., & O'Laughlin, S. (2019). Development of an autonomous flux chamber for continuous methane measurements at MSW landfills. Sardinia 2019.
3. Kallimogiannis, V., Saroglou, H., Zekkos, D., and Manousakis, J. (2019) "2D and 3D Back-analysis of a landslide in Egremnoi caused by the November 17 2015 Lefkada earthquake." *2nd International Conference on Natural Hazards and Infrastructure*, 23-26 June 2019, Chania, Greece.
4. Zekkos, D., Tsavalas-Hardy, A., Mandilaras, G., and Tsantilas, K. (2019) "Using social media to assess earthquake impact on people and infrastructure: Examples from earthquakes in 2018." *2nd International Conference on Natural Hazards and Infrastructure*, 23-26 June 2019, Chania, Greece.
5. Saroglou, H., Kalimogiannis, V., Bar, N., Manousakis, J., and Zekkos, D. (2019) "Analysis of slope instabilities in the Corinth Canal using UAV-enabled mapping" *2nd International Conference on Natural Hazards and Infrastructure*, 23-26 June 2019, Chania, Greece.
6. Basham, M., Athanasopoulos-Zekkos, A., Zekkos, D. (2019) "The importance of vertical displacement control during constant volume cyclic simple shear testing, *7th International Conference on Earthquake Geotechnical Engineering*, Rome, Italy, June 17-20 2019.
7. Athanasopoulos-Zekkos, A., Zekkos, D., Rollins, K., Hubler, J., Higbee, J. and Platis, A. (2019) "Earthquake Performance and Characterization of Gravel-Size Earthfills in the Ports of Cephalonia, Greece, following the 2014 Earthquakes", *7th International Conference on Earthquake Geotechnical Engineering*, June 17-20 2019.
8. Admassu, K. A., Lynch, J. P., Athanasopoulos-Zekkos, A., Zekkos, D. (2019). Long-term Wireless Monitoring Solution for the Risk Management of Highway Retaining Walls , *Sensors and Smart Structures Technologies for Civil, Mechanical, and Aerospace Systems*, March 2019.
9. Zhou, H., Lynch, J., Zekkos, D. (2019). Vision-based Precision Localization of UAVs for Sensor Payload Placement and Pickup for Field Monitoring Applications, *Sensors and Smart Structures Technologies for Civil, Mechanical, and Aerospace Systems*, March 2019.DOI: 10.1117/12.2516049
10. Fei, X., & Zekkos, D. (2018). Cyclic Simple Shear Testing of Degraded Municipal Solid Waste from California

Under Constant Volume and Constant Load Conditions. In 8^{th} *International Congress on Environmental Geotechnics* (pp. 35-42). 28 October – 1 November 2018, Springer, Singapore.

11. Datta, S., and Zekkos, D. (2018). "Waste Composition Dependent Landfill Gas Generation Parameters for Large-Size Laboratory Degradation Experiments" *8th International Congress on Environmental Geotechnics*, Hangzhou, China, 28 October – 1 November 2018, Springer, Singapore
12. Zekkos, D., Clark, M., Willis, M., Athanasopoulos-Zekkos, A., Manousakis, J., Knoper, L., Stahl, T., Massey, C., Archibald, G., Greenwood, W., and Medwedeff, W. (2018a). 3D models of the Leader Valley using satellite & UAV imagery following the 2016 Kaikoura earthquake, *Eleventh U.S. National Conference on Earthquake Engineering*, Integrating Science, Engineering & Policy, June 25-29, 2018, Los Angeles, California.
13. Zekkos, D., Manousakis, J., Athanasopoulos-Zekkos, A., Clark, M., Knoper, L., Massey, C., Archibald, G., Greenwood, W., Hemphill-Haley, M., Rathje, E., Litchfield, N., Medwedeff, W., Van Dissen, R.J., Ries, W., Villamor, P., Langridge, R.M., and Kearse, J. (2018b). Structure-from-Motion based 3D mapping of landslides & fault rupture sites during 2016 Kaikoura earthquake reconnaissance, *Eleventh U.S. National Conference on Earthquake Engineering*, Integrating Science, Engineering & Policy, June 25-29, 2018, Los Angeles, California.
14. Greenwood, W., Zhou, H., Zekkos, D., Lynch, J. (2018). "Experiments using a UAV-Deployed Impulsive Source for Multichannel Analysis of Surface Waves Testing." *Geotechnical Earthquake Engineering and Soil Dynamics V*, June 10-13 2018, Austin, TX.
15. Matasovic, N., Zekkos, D., Sahadewa, A., Carlson, C. P., (2018). "In-Situ Testing for Evaluation of Modulus and Damping of Solid Waste at a Hazardous Waste Landfill." *Geotechnical Earthquake Engineering and Soil Dynamics V*, June 10-13 2018, Austin, TX.
16. Carlson, C., Zekkos, D. (2018). "Impact of Ground Motion Modification on Results of Newmark-type Displacement Analyses." *Geotechnical Earthquake Engineering and Soil Dynamics V*, June 10-13 2018, Austin, TX (accepted).
17. Hubler, J.F., Athanasopoulos-Zekkos, A. and Zekkos, D. (2018). "Post-Liquefaction Volumetric Strain of Gravel-Sand Mixtures in Constant Volume Simple Shear." *Geotechnical Earthquake Engineering and Soil Dynamics V*, June 10-13 2018, Austin, TX.
18. Hubler, J.F., Athanasopoulos-Zekkos, A. and Zekkos, D. (2018) "Evaluation of Post-Liquefaction Shear Strength and Shear Wave Velocity of Uniform Gravels." *International Foundations Congress and Equipment Expo*, Orlando, March 5-10, 2018.
19. Greenwood, W., Zekkos, D., Lynch, J., Clark, M. (2017). Data Fusion of Digital Imagery and Seismic Surface Waves for a Rock Road Cut in *Hawaii. 3rd International Conference on Performance-based Design in Earthquake Geotechnical Engineering*, July 16-19 2017, Vancouver.
20. Hubler, J., Athanasopoulos-Zekkos, A., and Zekkos, D. (2017) "Pore Pressure Generation of Pea Gravel, Sand, and Gravel-Sand Mixtures in Constant Volume Simple Shear", *3rd International Conference on Performance-Based Design for Earthquake Geotechnical Engineering*, Vancouver, BC, Canada, July 17-19, 2017.
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2. USGS, "Characterization of landslides and rock mass strength leveraging the 2015 Mw 6.5 Lefkada earthquake in Greece," $90,740, August 1 2017 – July 31 2018. PI: Dimitrios Zekkos. Co-PI: Marin Clark (UM EES).
3. Geosyntec Consultants, "Simple Shear Testing of Hazardous Waste at BKK Landfill," $111,000, June 2015 – September 2016. PI: Dimitrios Zekkos.
4. National Science Foundation, "CyberSEES: TYPE 2: Sustainably Unlocking Energy from Municipal Solid Waste Using a Sensor-Driven Cyber-Infrastructure Framework," $1,199,600, Sept. 2014-August 2018. PI: Dimitrios Zekkos. Co-PIs: Edwin Olson, (UM ECS), Jerome Lynch (UM CEE).
5. National Science Foundation, "Scalable and Autonomous Post-Event Geo-Characterization from UAAV-based Quantitative Surface Measurements," $389,845, Sept. 2014-August 2017. PI: Dimitrios Zekkos. Co-PIs: Vineet Kamat (UM CEE), Jerome Lynch (UM CEE).
6. National Science Foundation, "NEESR-CR: Seismic Response of Landfills: *In situ* Evaluation of Dynamic Properties of Municipal Solid Waste: Comparison to Laboratory Testing and Impact on Numerical Analyses," $693,770, Sept. 2010-August 2014. PI: Dimitrios Zekkos. Co-PIs: Neven Matasovic (Geosyntec Consultants) and Mark Tufenkjian (California State University, Los Angeles).
7. Conetec, Inc., "Collaboration Agreement between the University of Michigan and Conetec Education Foundation," $106,500, January 2013 – December 2017.
8. Geosyntec Consultants, "In Situ Characterization of Dynamic Properties of Hazardous Waste at BKK Landfill," $24,996, June 2012 – June 2015. PI: Dimitrios Zekkos.
9. Geosynthetics Research Institute, "Impact of municipal solid waste biodegradation on separator geotextile," $15,000, May 2012 – May 2014. PI: Dimitrios Zekkos (with PhD advisee Xunchang Fei).

As Principal Investigator (internal grants) (total of $349,336) :

10. University of Michigan, “U-M as an Agent of Change in Transforming a Greenhouse Gas Emission Problem into a Sustainable Energy Production Solution”, $60,000, Planet Blue Renewable Energy Demonstration Project, Sept 2018-May 2020. PI: Zekkos
11. University of Michigan, “Pipeline Enhancement to support a community of excellence for under-represented minority students in civil and environmental engineering programs”, $11,000, Rackham Graduate School. PI: Dimitrios Zekkos. Co-PIs: Athanasopoulos-Zekkos, Love, Demond, Clack.
12. University of Michigan, “MCUBED: Drone-enabled Photogrametry for the Characterization of Earthquake-Induced Landslides” $60,000, Sept. 2015-August 2017. PI: Dimitrios Zekkos. Co-PIs: Marin Clark (EES), Jerome Lynch (CEE).
13. University of Michigan Plane Blue Initiatives, “PBSIF: Transforming Campus Waste”, $30,000, May 2016 – May 2017 (with PhD advisee Julie Bateman).
14. University of Michigan Center for Research on Learning and Teaching (CRLT), “Gilbert Whitaker Grant Fund: Enhancing Undergraduate Student Engagement in Geotechnical Engineering Beyond the Classroom Using Online Applications” $6,000, January 2015-December 2016. PI: Dimitrios Zekkos
15. University of Michigan Center for Research on Learning and Teaching (CRLT), “Opening the Classroom to the Profession: Assessment of Web-based Class Projects on Student Learning,” $8,000, May 2014-April 2015. PI: Dimitrios Zekkos
16. Horace Rackham School of Graduate Studies (UM), “Continuation of UM Network for Women in Civil and Environmental Engineering (NEWinCEE),” $77,600, September 2013 – August 2015. PI: Dimitrios Zekkos. Co-PIs: Adda Athanasopoulos-Zekkos (UM CEE), Avery Demond (UM CEE) and Nancy Love (UM CEE).
17. Horace Rackham School of Graduate Studies (UM), “UM Network for Female Excellence in Civil Engineering (NEWinCEE),” $96,736, September 2011 – August 2013. PI: Dimitrios Zekkos. Co-PIs: Adda Athanasopoulos-Zekkos (UM CEE), Gustavo Parra-Montesinos (UM CEE), Avery Demond (UM CEE), Sang-Huyn Lee (UM CEE).

As Co-Principal Investigator (external grants) (total of $3,089,240)

18. National Aeronautical Space Agency (NASA), “Enabling landslide disaster risk reduction and response throughout the disaster life cycle with a multi-scale toolbox” $1,856,663.36, May 2019-April 2023, Co-PI(s): Zekkos, D., Clark, M. U of M share: $695,103
19. National Science Foundation, “Collaborative Research: Integrated Field and Laboratory Based Assessment of Liquefaction Triggering and Residual Strength of Gravelly Soils,” $322,124, September 2017 – August 2018, PI: Athanasopoulos-Zekkos, Co-PI: D. Zekkos
20. National Science Foundation, “RAPID: Collaborative Research: Topographic Change and Cascading Hazards Following the Mw7.8 Kaikoura (New Zealand) Earthquake,” $46,517, December 2016-November 2017, PI: Marin Clark (UM EES), co-PI: D. Zekkos, A. Athanasopoulos-Zekkos.
21. National Science Foundation, “Collaborative Research: Landslides related to the 2015 Mw7.8 Gorkha earthquake, from ground motion and hazard to geomorphic response,” $285,660.00, September 2016 – August 2019. PI: Marin Clark (UM EES), Co-PI: D. Zekkos.
22. Michigan Department of Transportation (MDOT), “Asset Management of Retaining Walls,” $314,943.19. Sept. 2016 – August 2018. PI: Adda Athanasopoulos-Zekkos (UM CEE). Co-PI: Dimitrios Zekkos (UM CEE), Jerome Lynch (UM CEE)
23. Michigan Department of Transportation (MDOT), “Sedimaging: Image-Based Soil Characterization,” $130,000. September 2010 – August 2011. PI: Roman Hryciw (UM CEE). Co-PI: Dimitrios Zekkos (UM CEE).
24. Chinese National Science Foundation, “Strength Evolution and Disaster Mechanism of Sewage Sludge and MSW Mixture Landfill,” $133,333, Sept. 2014-August 2017, PI: Dr. Li Lei, Hohai University. Co-PI: D. Zekkos.

As Co-Principal Investigator (internal grants) (total of $5,000)

25. University of Michigan ADVANCE, “Faculty Leading Change in CEE” $5,000. PI: Clack, Co-PI: Love, Zekkos

RESEARCH STUDENTS SUPERVISED

PhD students

1. Andhika Sahadewa, Thesis title: “In-Situ Assessment of Linear and Nonlinear Dynamic Properties of Municipal Solid Waste”. Graduation Date: 5/2014.
   Currently Assistant Professor, Civil Engineering, Bandung Institute of Technology, Indonesia.

2. Clinton Carlson, Thesis title: “Assessment of the Effects of Ground Motion Modification on Ground Motions and Seismic Response of Geotechnical Systems”. Graduation Date: 9/2014.
   Currently with Geosyntec Consultants, Atlanta, Georgia.
3. Xunchang Fei, PhD Candidate, Thesis title: “Experimental Assessment of coupled physical-biochemical-mechanical-hydraulic processes of Municipal Solid Waste Undergoing Biodegradation” Graduation Date: 12/2015.
   Currently: Assistant Professor, Civil and Environmental Engineering Department, Nanyang Technological University (NTU), Singapore
4. William Greenwood, PhD student, “UAV-enabled Surface and Subsurface Characterization for Post-Earthquake Geotechnical Reconnaissance”, Graduation Date: 5/2018.
   Currently Assistant Professor, Department of Civil and Environmental Engineering, San Jose State University
5. Sampurna Datta, PhD student, “A multi-physics model for the degradation of Municipal Solid Waste.” Graduation date: 12/2019 (expected)
6. Hao Zhou, PhD student, “UAV-enabled Multichannel Analysis of Surface Waves.” Graduation date; 12/2020 (expected)
7. William Medwedeff, PhD student, “Geomechanical characterization of landslides from the 2015 Gorkha earthquake, Nepal.” Graduation date: 6/2021 (expected)
8. Cassandra Champagne, PhD student, “Robotics-based assessment of emissions from Municipal Solid Waste landfills.” Graduation date: 6/2021 (expected)
9. Gabriel Draughon, PhD student, “Sensing-based Energy Harvesting from Solid Waste.” Graduation date: 6/2021 (expected)
10. Weibing Gong, PhD student, “Regional landslide modelling.” Graduation date: 6/2023 (expected)

MSc students

1. Michael Flanagan, 2010, “Deep Dynamic Compaction of Municipal Solid Waste Landfills.”
2. Matt Hambright, 2010, “Characterization of Municipal Solid Waste Incineration Ash.”
3. Mohammad Kabalan, 2010, “Development of Triaxial Testing Device for Testing of Incinerated Ash.”
4. Stephanie Guisbert, 2010, “Impact of Ground Motion Modification on Geotechnical Seismic Response Analyses.”
5. Lu Chen, 2014, “Reuse of Municipal Water Treatment Sludge.”
6. Lauren Riedle, 2015, “Life Cycle Analysis of Sustainable Energy Reactor Facilities.”
7. Michael Partenio, 2016, “Mechanical Properties Characterization of Hazardous Waste.”
8. Julie Bateman, 2017, “Field Measurements of Emissions on MSW landfills.”
9. Chenghang Liu, 2018, “Soil characterization using Infrared Thermography.”

Undergraduate Students

Total number of undergraduate students directed on research projects: 47
Number of women undergraduate students: 22 (47%)
Number of underrepresented minority undergraduate students: 6 (13%)

1. Iain Ferguson, Fall 2017-Winter 2018, “Understanding the impact of natural disasters on infrastructure using social media”
2. Shurong Liang, Winter 2017-Winter 2018, “Effect of initial shear stress on the cyclic response of gravels”
3. Nataly Figueroa, Spring 2016-Winter 2017, “Assessment of composting as a sustainable waste management technology”
4. Brinda Yarlagadda, Spring – Summer 2016, “Energy from Waste”, Marian-Sarah Parker Program
5. Mehul Kulkarni, Fall 2015-Winter 2016, “Degradation of MSW with septage in laboratory landfill simulators”, UROP
6. Andrea Ventola, Fall 2015-Winter 2016, “Cyclic Simple Shear Testing of Gravelly Soils”, independent study
7. Tianhao Zhou, Summer 2015, “Image-based characterization of basaltic rock specimens”, SURE
8. Jad Zalzal, Summer 2015, “Degradation of MSW in laboratory landfill simulators”, international visiting UG
9. Paul Maamari, Summer 2015, “Laboratory testing of Elastizel foam cement” international visiting UG
10. Alesha Jackson, Summer 2015, “Cyclic Simple Shear Testing of Gravelly Soils”, SROP
11. Theau Heral, Fall 2014-Winter 2015, “Use of drone technology in civil engineering infrastructure”, UROP
12. Shihcheng Chu, Fall 2014-Winter 2015, “Simple shear testing of MSW”, UROP
13. Rebecca Martin, Fall 2014-Winter 2015, “A review of ancient hydraulic projects”, UROP.
14. Michael Schiavone, Fall 2014-Winter 2015, “A review of ancient fortifications projects”, UROP.
15. Danielle Park, Fall 2014-Winter 2015, “A review of ancient engineering projects in the Bible”, UROP.
16. Andrew Tamer, Spring-Summer 2014, “Large-scale Simple Shear Testing of Municipal Solid Waste,”

17. Rachel Thompson, Spring-Summer-Fall 2014, “Liquefaction Resistance of Gravelly Soils,” Network for Women in Civil and Environmental Engineering (NeWinCEE) Summer Program.
18. Hannah Wasserman, Spring-Summer 2014, “Undrained Shear Strength of Gravelly Soils,” Network for Women in Civil and Environmental Engineering (NeWinCEE) Summer Program.
19. Charles Davis, Spring-Summer 2014, ‘Characterization of Municipal Water Treatment Sludge,” Summer Research Opportunities Program (SROP).
20. Paro Sen, Fall-Winter 2014, “Degradation of Municipal Solid Waste,” UROP.
21. Alex Gildee, Fall-Winter 2014, “Simple Shear Testing of Municipal Solid Waste,” UROP
22. Xavier Rivera-Hernandez, Spring-Summer 2013, “Large-Scale Simple Shear Testing of Gravelly Soils,” Summer Research Opportunities Program (SROP).
23. Jose Rivera-Perez, Spring-Summer 2013, “Large-Scale Simple Shear Testing of Gravelly Soils,” SROP.
24. Calvin Nyakundi, Spring-Summer 2013, “Large-Scale Simple Shear Testing of Municipal Solid Waste,” College Outreach and Diversity Program.
25. Jane Gregg, Spring-Summer 2012 & Spring-Summer 2013, “Monitoring of Degradation of Municipal Solid Waste in Landfill Simulators,” Network for Women in Civil and Environmental Engineering (NeWinCEE) Summer Program.
26. Jiacheng Li, Winter 2013 and Spring-Summer 2013. “In-situ Crosshole and Downhole of Municipal Solid Waste,” 2 credits of independent study and Summer Undergraduate Research in Engineering Program (SURE).
27. Saya Kajiwara, Fall 2012-Winter 2013, “Shear Wave Velocity Measurements on Various Waste Materials,” Undergraduate Research Opportunities Program (UROP).
28. Kelley Langlois, Fall 2012-Winter 2013, “Monitoring of Degradation of Municipal Solid Waste in Landfill Simulators,” UROP.
29. Renee Wiwel, Fall 2012-Winter 2013, “In-situ Crosshole and Downhole of Municipal Solid Waste,” UROP.
30. Sachin Jain, Fall 2012-Winter 2013, “Development of Landfill Simulators in the Laboratory,” UROP.
31. Gina Cortese, Spring-Summer 2012, “Development of Outreach Material for NeWinCEE,” NeWinCEE.
32. Savannah Tibbets, Spring-Fall 2012, “Monitoring of Degradation of Municipal Solid Waste in Landfill Simulators,” Marian Sarah Parker Scholars Program (MSP) & NeWinCEE.
33. Kristina Vaclarek, Spring-Summer 2012, “Assessment of the Impact of Ground Motion Modification on the Response of a Single Degree of Freedom System,” SURE.
34. Michael Klein, Spring-Summer 2012, “Large-Scale Cyclic Simple Shear Testing in Ottawa Sand,” SURE.
35. Stacia Simonsen, Spring-Summer 2011, “Monitoring of Degradation of Municipal Solid Waste in Landfill Simulators,” MSP.
36. Mohammad Kabalan, Fall 2010-Winter 2011, Spring Summer 2011, “Laboratory Testing of Incinerated Waste,” UROP and SURE.
37. Alex Demetriou, Fall 2011-Winter 2012, “Monitoring of Degradation of Municipal Solid Waste in Landfill Simulators,” UROP.
38. Zach Jones, Fall 2011-Winter 2012, “Monitoring of Degradation of Municipal Solid Waste in Landfill Simulators,” UROP.
39. Rob Glew, Fall 2011-Winter 2012, “Development of a Software for the Evaluation of damping from surface wave measurements,” UROP.
40. Dimitris Tolios, Fall 2010-Winter 2011, “Evaluation of Damping from Surface Wave Measurements,” UROP.
41. Sita Syal, Fall 2009-Winter 2011, “Characterization of Incinerated Waste,” UROP.
42. Sarah Chronister, Spring-Summer 2010, “Geotechnical Characterization of Incinerated Waste,” Michigan STEM Academy.
43. Anna Kathleen James, Spring-Summer 2010 “Geotechnical Characterization of Waste Materials,” SURE.
44. Zaher Hamzeh, Fall 2009-Winter 2010, “Inversion of Shear Wave Velocity Measurements,” UROP.
45. Osai Robinson, Fall 2009-Winter 2010, “Dam Construction in the Ancient World,” UROP.
46. Stephanie Guisbert, Spring - Summer 2009, “Impact of Ground Motion Modification on Analyses,” Summer independent study.
47. Adam Lobbestael, Spring -Summer 2009, “Application of Seismic Geophysics in Landfills,” Summer independent study.

Post-Doctoral Advisees

1. Xunchang Fei, January 2016-September 2016

Research Scholars Hosted

1. Renee Gerring, University of Liberia, University of Michigan African Presidential Scholars Program (UMAPS), September 2014-February 2015.
2. Lilei Li, Associate Professor, Hohai University, China

TEACHING EXPERIENCE

Faculty Instructor:

- CEE 345 undergraduate level course "Geotechnical Engineering", University of Michigan, Ann Arbor (Fall 2018, Fall 2017, Fall 2016, Fall 2015, Fall 2013, Winter 2012, Fall 2010, Winter 2010).
- CEE 544 graduate level course "Rock Mechanics", University of Michigan, Ann Arbor (Winter 2017, Winter 2015, Fall 2012, Fall 2009).
- CEE 549 graduate level course "Geoenvironmental Engineering", University of Michigan, Ann Arbor (Fall 2019, Fall 2017, Fall 2015, Winter 2014, Winter 2013, Fall 2010, Winter 2009).
- CEE 542 graduate level course "Soil and Site Improvement", University of Michigan, Ann Arbor (Fall 2016, Winter 2014, Fall 2011, Fall 2008).
- CEE 546 graduate level course "Slopes, Dams and Retaining Structures", University of Michigan, Ann Arbor (Winter 2008).
- CEE 541 graduate level course 'Soil Sampling and Testing", University of Michigan, Ann Arbor (Fall 2013) (instructor for 25% of the course).
- CEE 840 "Geotechnical Seminar Series", University of Michigan, Ann Arbor (Fall 2014, Winter 2013, Fall 2012, Winter 2012, Fall 2011, Winter 2010, Fall 2009).

Course Evaluations

Q1: Overall, this was an excellent course. (5: Strongly Agree, 1: Strongly Disagree)

Course #	Course title	Term	**Zekkos' score**	College-Wide Score	
				Median (50%)	*Top 25%*
CEE 549	Geoenvironmental Engineering	Fall 2019	**4.80**	4.50	NR
CEE 345	Geotechnical Engineering	Fall 2018	**4.70**	4.30	NR
CEE 546	Slopes, Dams & Retaining Str.	Winter 2018	**4.00**	4.50	4.75
CEE 549	Geoenvironmental Engineering	Fall 2017	**4.83**	4.53	4.79
CEE 345	Geotechnical Engineering	Fall 2017	**4.00**	4.19	4.55
CEE 544	Rock Mechanics	Winter 2017	**5.00**	4.50	4.75
CEE 542	Soil and Site Improvement	Fall 2016	**4.90**	4.53	4.75
CEE 345	Geotechnical Engineering	Fall 2016	**4.62**	4.17	4.50
CEE 549	Geoenvironmental Engin.	Fall 2015	**4.79**	4.61	4.79
CEE 345	Geotechnical Engineering	Fall 2015	**4.68**	4.17	4.58
CEE 544	Rock Mechanics	Winter 2015	**4.50**	4.30	4.70
CEE 542	Soil and Site Improvement	Winter 2014	**4.58**	4.50	4.75
CEE 549	Geoenvironmental Engin.	Winter 2014	**4.60**	4.50	4.75
CEE 345	Geotechnical Engineering	Fall 2013	**4.44**	4.22	4.61
CEE 549	Geoenvironmental Engin.	Winter 2013	**4.73**	4.50	4.75
CEE 544	Rock Mechanics	Fall 2012	**4.79**	4.42	4.75
CEE 345	Geotechnical Engineering	Winter 2012	**4.59**	4.10	4.50
CEE 542	Soil and Site Improvement	Fall 2011	**4.80**	4.43	4.68
CEE549	Geoenvironmental Engin.	Fall 2010	**4.86**	4.33	4.68
CEE 345	Geotechnical Engineering	Fall 2010	**4.59**	4.17	4.50
CEE 345	Geotechnical Engineering	Winter 2010	**4.59**	4.00	4.50
CEE 544	Rock Mechanics	Fall 2009	**4.94**	4.33	4.70
CEE549	Geoenvironmental Engin.	Winter 2009	**4.88**	4.33	4.69
CEE542	Soil and Site Improvement	Fall 2008	**4.88**	4.38	4.63

NR: No longer reported by the University

Q2: Overall, the instructor was an excellent teacher. (5: Strongly Agree, 1: Strongly Disagree)

Course #	Course title	Term	**Zekkos'**	College-Wide Score

			score		
				Median (50%)	*Top 25%*
CEE 549	Geoenvironmental Engineering	Fall 2019	**4.90**	4.60	NR
CEE 345	Geotechnical Engineering	Fall 2018	**4.90**	4.40	NR
CEE 546	Slopes, Dams & Retaining Str.	Winter 2018	**4.40**	4.71	4.88
CEE 549	Geoenvironmental Engineering	Fall 2017	**4.93**	4.71	4.83
CEE 345	Geotechnical Engineering	Fall 2017	**4.60**	4.64	4.85
CEE 544	Rock Mechanics	Winter 2017	**5.00**	4.72	4.86
CEE 542	Soil and Site Improvement	Fall 2016	**5.00**	4.72	4.90
CEE 345	Geotechnical Engineering	Fall 2016	**4.90**	4.60	4.79
CEE 549	Geoenvironmental Engin.	Fall 2015	**4.94**	4.68	4.88
CEE 345	Geotechnical Engineering	Fall 2015	**4.82**	4.50	4.75
CEE 544	Rock Mechanics	Winter 2015	**4.90**	4.59	4.85
CEE 542	Soil and Site Improvement	Winter 2014	**4.81**	4.69	4.83
CEE 549	Geoenvironmental Engin	Winter 2014	**4.85**	4.69	4.83
CEE 345	Geotechnical Engineering	Fall 2013	**4.82**	4.44	4.75
CEE 549	Geoenvironmental Engin.	Winter 2013	**4.93**	4.63	4.83
CEE 544	Rock Mechanics	Fall 2012	**4.94**	4.67	4.83
CEE 345	Geotechnical Engineering	Winter 2012	**4.90**	4.45	4.71
CEE 542	Soil and Site Improvement	Fall 2011	**4.92**	4.59	4.82
CEE549	Geoenvironmental Engin.	Fall 2010	**4.94**	4.53	4.79
CEE 345	Geotechnical Engineering	Fall 2010	**4.88**	4.38	4.71
CEE 345	Geotechnical Engineering	Winter 2010	**4.67**	4.17	4.65
CEE 544	Rock Mechanics	Fall 2009	**4.94**	4.50	4.83
CEE549	Geoenvironmental Engin,	Winter 2009	**5.00**	4.63	4.83
CEE542	Soil and Site Improvement	Fall 2008	**4.88**	4.50	4.79

NR: No longer reported by the University

Guest Lecturer in Courses

- CEE 200: “What is geotechnical Engineering”, January 25 2017, November 6 2018.
- EARTH287: “Documenting natural disasters using Unmanned Aerial Vehicles”, February 22nd 2017

Short Courses / Webinars Taught

- Franke, K., and Zekkos, D. “The use of small unmanned aerial vehicles for post-disaster geotechnical reconnaissance.” Webinar delivered on April 20 2016, Geotechnical Engineering Extreme Event Reconnaisance Association (GEER). Available at: http://geerassociation.org/geer-activities/short-courses

PROFESSIONAL CONTRIBUTIONS

Conference – Workshop Organization

- Conference Chair, *9th International Congress on Environmental Geotechnics*, June 2022, Chania, Greece.
- Member, International Scientific Board, *TRANSCOLD2019 Transportation Soil Engineering in Cold Regions.* 20 – 23 May, 2019, Saint-Petersburg, Russia.
- Member, Steering Committee, *2nd Int. Conference on Natural Hazards and Infrastructure*, 23-26 June 2019, Chania, Greece.
- Member, Scientific Committee, *8th International Congress on Environmental Geotechnics*, 28 October – 1 November 2018, Hangzhou, China.
- Member of Conference Organizing Committee, *Geotechnical Earthquake Engineering and Soil Dynamics Conference, June 10-13 2018, Austin, TX, ASCE Geo-Institute.*
- Member, Scientific Committee, *4th GeoShanghai International Conference*, May 27-30 2018.
- Session Chair, “Bio-Stabilization Session 1 & 2”, co-chaired with Jason Dejong and Kenichi Soga, *International Foundation Congress and Expo*, March 5-10 2018, Orlando, FL,
- Member, Scientific Committee, *16th World Conference on Earthquake Engineering*, January 9-12, 2017, Santiago, Chile.
- Member, Scientific Committee, TGG-2017 «Transportation Geotechnics and Geoecology», St. Petersburg, Russia, 17-19 May, 2017

- Member, Steering Committee, *1st Int. Conference on Natural Hazards and Infrastructure*, 28-30 June 2016, Chania, Greece.
- Technical Program Chair and Proceedings Lead Editor, *Geo-Chicago 2016: Sustainability, Energy and the Geoenvironment Conference*, ASCE Geo-Institute, Chicago, IL, August 14-18 2016.
- Conference Chair, *Geocongress 2012: State of the Art and Practice in Geoengineering Conference*, ASCE Geo-Institute, San Francisco, CA, March 25-28, 2012.
- Co-Chair, *Plenary Forum Session on Promoting Innovation in Geotechnical Engineering, International Conference on Soil Mechanics and Geotechnical Engineering, 18th International Conference on Soil Mechanics and Geotechnical Engineering*, September 2-6, 2013, Paris, France.
- Member, Organizing Committee, *7th Conference on Geotechnical Engineering Case Histories*, organized by Missouri S&T, Chicago, IL, September16-21, 2013.
- Member, Organizing Committee, *Annual Michigan Solid Waste Conference*, Engineering Society of Detroit, Detroit, MI, 2011-2018.
- Member, International Scientific Committee, *Advances in Civil Engineering*, Ankara, Turkey, October17-19, 2012.
- Chair, Organizing Committee, *International Symposium on Waste Mechanics*, ASCE Geo-Institute, New Orleans, LA, March 11-13, 2008.
- Member, Organizing Committee, *5th International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics and Symposium in honor of Professor I. M. Idriss*, San Diego, CA, May 24-29, 2010.
- Member, International Advising Committee, *12th International Conference of the International Association for Computer Methods and Advances in Geomechanics*, October 1-6, 2008.
- Member, Organizing Committee, *6th Conference on Geotechnical Engineering Case Histories*, Arlington, VA, August 11-16, 2008.
- Member, Organizing Committee, Workshop "Geotechnical Earthquake Engineering Related to Monuments and Historical Sites," *4th International Conference on Earthquake Geotechnical Engineering*, Thessaloniki, Greece, June 25-28, 2006.
- Chair, Workshop "International Journal of Geoengineering Case Histories: Case Histories in the Information Technology Age," *ASCE Geo-Institute Geocongress 2006*, Atlanta, GA, February 26-March 1, 2006.
- Conference Chair, *1st Hellenic Civil Engineering Students Conference*, Patras, Greece, May 7-8, 2001.

Journal and Conference Paper Reviews

Journals & Special Publications

- Editor-in-Chief, *International Journal of Geoengineering Case Histories*, International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE), 2017-present.
- Associate Editor, *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, 2014-present.
- Editorial Board Member, *Environmental Geotechnics Journal*, Institution of Civil Engineers, 2012-present.
- Reviewer, *Journal of Aerospace Information Systems, 2018*
- Reviewer, *Applied Geophysics, 2018*
- Reviewer, *Canadian Geotechnical Journal*, 2009, 2017, 2018.
- Reviewer, Journal of Aerospace Information Systems, 2018
- Reviewer, *Computers and Geotechnics*, 2017
- Reviewer, *Soil Dynamics and Geotechnical Earthquake Engineering*, 2017
- Reviewer, *Natural Hazards*, 2017
- Reviewer, *Engineering Mechanics*, ASCE, 2016.
- Reviewer, *Bridge Engineering*, ASCE, 2015
- Reviewer, *Geotextiles and Geomembranes*, Elsevier, 2014, 2015, 2016.
- Reviewer, *Earthquakes and Structures*, Techno-Press, 2014, 2015
- Reviewer, *Geomechanics and Engineering*, 2014
- Reviewer, *Earthquake Spectra*, EERI, 2014
- Reviewer, *Waste Management Journal*, Elsevier, 2008-2018.
- Reviewer, *Waste Management and Research*, SAGE, 2014
- Reviewer, *Journal of Solid Waste Technology and Management*, 2014
- Reviewer, *ASCE Journal of Geotechnical and Geoenvironmental Engineering*, 2006-2014.
- Reviewer, *Journal of Geotechnical and Geological Engineering*, 2011-2013.
- Reviewer, *ASCE Journal of Hazardous, Toxic, and Radioactive Waste Management*, 2012.
- Reviewer, *Earthquake Engineering Journal*, 2011.
- Reviewer, *Geosynthetics International Journal*, 2006.

- Reviewer, *ASCE Geotechnical Special Publication in Honor of Prof. Robert Holtz*, 2011.

Conferences

- Reviewer, *8th International Conference on Geotechnical Engineering Case Histories – Geocongress 2019*, Philadelphia, PA, Mar 24-27, 2019.
- Reviewer, *8th International Congress on Environmental Geotechnics*, Hangzhou, China, Oct. 28 – Nov. 1, 2018
- Reviewer, *7th International Conference on Unsaturated Soils*, Hong Kong, 3-5 August 2018.
- Reviewer, *International Foundations Congress and Expo*, Orlando, FL, March 5-10 2018.
- Reviewer, *19th International Conference on Soil Mechanics and Geotechnical Engineering*, Seoul, Korea, 17-22 September 2017.
- Reviewer, *3rd International Conference on Performance-based Design in Earthquake Geotechnical Engineering, July 16-19 2017, Vancouver*
- Reviewer, *International Foundations Congress and Equipment Expo 2015*, San Antonio, Texas, March 17-21 2015
- Reviewer, *ASCE Geo-Institute GeoCongress 2014*, Atlanta, GA, February 23-26, 2014.
- Reviewer, *GeoShanghai International Conference*, Shanghai, China, May 26-28, 2014.
- Reviewer, *Transportation Research Board* (TRB) 92nd Annual Meeting, Washington, DC, January 13-17, 2013.
- Reviewer, *10th International Conference on Advances in Civil Engineering*, Ankara, Turkey, October 17-19, 2012.
- Reviewer, *ASCE Geo-Institute GeoFrontiers*, 2011, Dallas TX, March 13-16, *2011*.
- Reviewer, *ASCE Geo-Institute GeoFlorida*, 2010, West Palm Beach, FL, February 20-24 2010.
- Reviewer, *5th International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics and Symposium in Honor of Professor I. M. Idriss*, San Diego, CA, May 24-29, 2010.
- Reviewer, *17th International Conference of Soil Mechanics and Geotechnical Engineering (ICSMGE)*, Alexandria, Egypt, October 5-9, 2009.
- Reviewer, *International Foundation Congress & Equipment Expo*, Orlando, FL, March 15-19, 2009.
- Reviewer, *4th Decennial Geotechnical Earthquake Engineering and Soil Dynamics Conference (GEESD)*, EESD Committee of ASCE Geo-Institute, Sacramento, CA, May 18-22, 2008.
- Reviewer, *42nd U.S. Rock Mechanics Symposium & 2nd U.S.-Canada Rock Mechanics Symposium*, San Francisco, CA, June 29-July 2, 2008.
- Reviewer, *6th Conference on Geotechnical Engineering Case Histories*, Arlington, VA, August 11-16, 2008.
- Reviewer, "The Challenge of Sustainability in the Geoenvironment," ASCE Geo-Institute GeoCongress 2008, New Orleans, LA, March 9-12, 2008.

Other Major Professional Activities

- Chair (2014-present), Vice-Chair (2011-2014) & Member (2006-2010), Geoenvironmental Engineering Technical Committee, *ASCE Geo-Institute*, 2006-present.
- Chair, Board-Level Committee on Innovation and Development, *International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE)*, 2009-present.
- Member, International Advisory Council, *ASCE Geo-Institute*, 2013-present.
- Member, Environmental Geotechnics Technical Committee (TC 215), *International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE)*, 2011-present.
- Board Member, Hellenic Geosynthetics Society, 6/2016-present
- Member, Selection committee, Research Projects on Field Experimentation *for the "10 year NEES retrospective volume"*, 2013.
- Member, Website Development Task Force, *ASCE Geo-Institute*, 2010-2012.
- Member, Student Participation Committee, *ASCE Geo-Institute*, 2008-2009.
- Chair, Steering Committee, *Berkeley Geoengineering Alumni Association*, 2006-2008.
- Member, Steering Committee, *ASCE San Francisco Section Geotechnical Group*, 2004-2008.

University Service

UM: University or College-Wide service; CEE: CEE Department service; GeoT: Geotechnical Program

Present

- Member, Faculty Ally for Diversity (UM), Rackham Graduate School, 9/2010-present.
- Group Leader, Civil Infrastructure Systems Engineering (CISE) Group, (CEE), 9/2017-present.
- Chair (CEE), Strategic Planning Committee, (CEE), 9/2017-present
- Co-director, Geotechnical Engineering Laboratories (GeoT), 2008-present.
- Director, Geoenvironmental Engineering Laboratory (GeoT), 2010-present.

- Member, Tenure Committee for Krista Wigginton, (CEE), 8/2018-present.
- Faculty Advisor, Geo-Institute Graduate Student Organization (CEE), 8/2018-present.

Previous

- Faculty Reviewer (UM), 2017-2018, Rackham Merit Fellowships (RMF) Selection Committee for Rackham School
- Faculty Reviewer (UM), Transformative grants for Rackham Sustainability Institute, 2018
- Member (CEE), Facilities Committee, 9/2017-6/2018
- Member, Safety Committee (CEE), 9/2012-6/2017
- Faculty Reviewer (UM), Dow Sustainability Fellows Doctoral program, 2017
- Chair (CEE), Laboratory Staff Search Committee, 2/2017-8/2017.
- Chair (CEE), Laboratory Staff Strategic Hiring Task Force, 11/2016-2/2017
- Chair, Information Technology Committee (CEE), 9/2014-6/2017.
- Elected Member, Executive Committee (CEE), 9/2014-8/2016.
- Member, President Schlissel's Committee on Landfill Waste Reduction, (UM), 09/2014-06/2015
- Member, Strategic Implementation Committee (CEE), 9/2013-8/2015
- Member, Casebook Committee for Glen Daigger’s candidacy as Professor of Practice (CEE), 11/2014-1/2015
- Judge, Richard and Eleanor Towner Prize for Outstanding Ph.D. Research Award (College), Fall 2015.
- Faculty Reviewer (UM), 2015 NextProf Workshop, Summer 2015.
- Faculty Reviewer (UM), 2014 NextProf Workshop, Summer 2014.
- Faculty Search Committee (CEE) on Water-Geo-Energy Systems, 9/2013-4/2014, member.
- Curriculum Committee (CEE) 9/2011-8/2012, member.
- Faculty Search Committee (CEE) on Resilient Infrastructure Systems, 9/2011-6/2012, member.
- Faculty Search Committee (CEE) on Environmental Systems Engineering, 9/2011-6/2012, member.
- ABET Accreditation Committee (CEE), 1/2011-9/2011, member.
- MS Student Admissions (GeoT), 2010-2011.
- Operating Budget Committee (CEE), 9/2009-5/2011, member.
- Information Technology Committee (CEE), 9/2008-8/2014, member.
- Strategic Research Faculty Committee (CEE), 2/2008-3/2008, member.
- Departmental Visitation Committee (CEE), 01/2008-3/2008, member.
- Member, Ph.D. Committees (completed):
    - Vasilis Kitsis, University of Patras, 2018 (Chair: George Athanasopoulos)
    - Jonathan Huber, U of M, 2017 (Chair: Adda Athanasopoulos-Zekkos)
    - Pavlos Asteriou, National Technical University of Athens, 2016 (Chair: George Tsiambaos)
    - Derya Ayral, U of M, 2014 (Chair: Avery Demond)
    - Adam Lobestael, , U of M, 2014 (Chair: Adda Athanasopoulos-Zekkos).
    - Zhang Yao, U of M, 2014 (Chair: Radoslaw Michalowski)
    - Srinivasa Nudukuru, U of M, 2013 (Chair: Radoslaw Michalowski).
    - Hyon-Sohk Ohm, U of M, 2013 (Chair: Roman Hryciw).
    - Mustafa Saadi, U of M, 2012 (Chair: Adda Athanasopoulos-Zekkos).

CONSULTING EXPERIENCE

Dr. Zekkos has been involved in the design, analysis or construction of a number of projects in the US, Greece, Peru, Finland, Romania and Angola including ground improvement projects, in-situ characterization, landfill design and construction, foundation design of power plant facilities, settlement prediction of dams, monitoring and analyses of deep supported excavations, rockmass excavations, field and laboratory testing for highway construction, tunnelling construction with the New Austrian Tunnelling Method (NATM), seismic site response analyses, liquefaction engineering evaluation, ground motion selection and spectral matching for offshore platforms and LNG facilities, and onshore and offshore construction on soft soils. In addition, he has been engaged in forensics investigations involving geosynthetic performance, deep fill settlement, and landslides. Indicative project titles can be found here: http://dimitrioszekkos.org/consulting/indicative-consulting-projects

INVITED LECTURES

Invited Presentations at Conferences or Symposia

1. Zekkos, D. (2019). “Use of Unmanned Aerial Vehicles for the Characterization of Ground Instability, Workshop on Urban Geotechnics, Geotechnical Society of Singapore. March 11 2019, Singapore.
2. Zekkos, D. (2018). “Recent Advances on Municipal Solid Waste Properties, Degradation and Implications in Design”, 19th Annual Michigan Solid Waste Conference, April 11-12 2018, Lansing, MI.
3. Zekkos, D. (2018). “Applications of Aerial and Land-Based Robotic Platforms in Landfills”, 19th Annual Michigan Solid Waste Conference, April 11-12 2018, Lansing, MI.
4. Zekkos, D. (2017). Opportunities for professional networking through GeoWorld, Geotechnical Women Faculty Network Workshop, April 11 2017, Washington DC (invited).
5. Zekkos, D. (2016). ISSMGE Innovations for a cyber-interconnected Geo-profession" Monday February 15 2016, “Geo-Structures 2016: Phoenix, AR.
6. Zekkos, D. (2014). “Ground Improvement Technologies in Landfill Engineering”, *24th Annual Solid Waste Technical Conference*, Lansing, MI, March 17-18 2014.
7. Zekkos, D. (2013). “Experimental Evidence of Anisotropy in Municipal Solid Waste,” *Proc., Coupled Phenomena in Environmental Geotechnics, Politecnico di Torino*, Torino, Italy, July 1-3, 2013 (invited keynote presentation).
8. Zekkos, D. (2013). “Case Histories of Geological, Rock and Mining Engineering, Underground Structures and Excavations – General Report for Session 5.” *Seventh International Conference on Case Histories in Geotechnical Engineering*, April 29-May 4, 2013, Chicago, IL.
9. Zekkos D. (2013). “From Waste Containment to Energy Harvesting: Ongoing Research.” *Texas A&M University International Geo-Engineering Symposium in Honor of ISSMGE Board Members*, April 26, 2013, College Station TX.
10. Zekkos, D. (2011). “Life after Graduation in Industry and Academia.” *Student Symposium, Network for Earthquake Engineering Simulation (NEES) & Multidisciplinary Center for Earthquake Engineering Research MCEER Annual Meeting: Quake Summit 2011*, Buffalo, NY, June 9, 2011.
11. Zekkos, D. (2010). “Use of Case Histories and Technology in Geotechnical Engineering Education,” *6th Hellenic Geotechnical and Geoenvironmental Engineering Conference*, September 27-30, 2010, Volos, Greece.
12. Zekkos, D. (2011). “Engineering Considerations for Post-Closure Development of Landfills.” *21st Annual Solid Waste Conference*, Michigan Solid Waste Industries Association and Engineering Society of Detroit April 10-11, 2011, Lansing, MI.
13. Zekkos (2010). “Stability of Municipal Solid Waste Landfills: Fundamentals and Recent Advances.” *20th Annual Solid Waste Conference*, Michigan Solid Waste Industries Association and Engineering Society of Detroit, March 23-24, 2010, Lansing, MI.
14. Zekkos, D., Boominathan, A., Athanasopoulos-Zekkos, A. (2010). “Engineering Seismology, Ground Motions, & Local Site Effects: General Report on Session 3.” *5th International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics*, May 24-29, 2010, San Diego, CA.
15. Zekkos, D. (2007). “Geological, Rock and Mining Engineering, Including Underground Structures and Excavations, and Subsidence of Deltas – General Report for Sessions 6a and 6b.” *6th International Conference on Case Histories in Geotechnical Engineering*, August 11-16, 2007, Arlington, VA.

Seminars or Invited Lectures at Institutions & Organizations

1. “Recent Advances in Infrastructure and Geosystems Resiliency empowered by Autonomy”, University of California at Berkeley, April 29 2019.
2. “Applications of Unmanned Aerial Vehicles for Infrastructure and Geosystem Resiliency”, Nanyang Technological University, NTU-JTC Industrial Infrastructure Innovation Centre, March 12 2019.
3. "Applications of Aerial and Land-Based Robotic Platforms in Landfills." CTI Associates, Novi, August 29 2018.
4. “Robot-enabled Research Efforts to Promote Resiliency and Sustainability of Geo-Systems.” Department of Earth and Environmental Science, University of Michigan, January 27 2017.
5. “Evaluation of the mechanical properties of Municipal Solid Waste.” Hellenic Society for Soil Mechanics and Geotechnical Engineering, June 15 2016, Athens.
6. "From Waste Containment to Energy Harvesting: Experimental Assessment of Coupled Physico-Biochemical & Mechanical Processes of Municipal Solid Waste Undergoing Biodegradation." February 19 2016, Department of Civil and Environmental Engineering, University of California at Berkeley.
7. “Seismic Characterization of Municipal Solid Waste Landfills,” University of Illinois, Chicago, Civil and Materials Departmental Lecture, April 10, 2014.
8. “Recent Advances on the Dynamic Properties of Municipal Solid Waste,” Queen’s University and RMC Geoengineering Centre, Kingston, Canada, February 15, 2012.
9. “Stability of Municipal Solid Waste Landfills: Fundamentals and Recent Advances,” Waste and Hazardous Materials Division, Michigan Department of Environmental Quality (MDEQ), Lansing, MI, June 17, 2010.

10. "Evaluation of Static and Dynamic Properties of Municipal Solid Waste," Department of Civil and Environmental Engineering, Texas A&M, College Station, TX, April 28, 2008.
11. "Evaluation of Static and Dynamic Properties of Municipal Solid Waste," Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, MI, April 7, 2008.
12. "Evaluation of Static and Dynamic Properties of Municipal Solid Waste," Department of Civil and Environmental Engineering, University of Washington, Seattle, WA, April 2, 2008.
13. "Evaluation of Static and Dynamic Properties of Municipal Solid Waste," Department of Structural Engineering, University of California, San Diego, CA, February 22, 2008.
14. "Evaluation of Static and Dynamic Properties of Municipal Solid Waste," ASCE-Geo-Institute Chapter of Texas A&M University, College Station, TX, November 14, 2006.
15. "Evaluation of Static and Dynamic Properties of Municipal Solid Waste," webinar presented to all offices of Geosyntec Consultants, June 30, 2006.
16. "Evaluation of Static and Dynamic Properties of Municipal Solid Waste," Berkeley Geoengineering Society, University of California at Berkeley, Berkeley, CA, September 7, 2005.
17. "Evaluation of Static and Dynamic Properties of Municipal Solid Waste," ASCE San Francisco Geotechnical Group, Oakland, CA, August 23, 2005.
18. "Recent Advances in the Properties of Municipal Solid Waste," Fugro West, Oakland, CA, July 11, 2005.

PROFESSIONAL REGISTRATIONS

- Licensed Civil Professional Engineer, California, USA (#71745) (since 2007)
- Licensed Civil Professional Engineer, Greece (#93932)
- Licensed Remote Pilot of Unmanned Aerial Vehicle, Federal Aviation Authority (# 3930747) (since 2016)

PROFESSIONAL MEMBERSHIP & AFFILIATIONS

- Geo-Institute of American Society of Civil Engineers, member
- Hellenic Society for Soil Mechanics and Geotechnical Engineering, member
- International Society for Soil Mechanics and Geotechnical Engineering, member
- Earthquake Engineering Research Institute, member
- American Rock Mechanics Association (ARMA), lifetime member
- International Society for Rock Mechanics (ISRM), lifetime member
- American Society for Engineering Education, member
- Berkeley Geoengineering Society, member
- Technical Chamber of Greece, member

Appendix C

Water Availability Analysis

FINAL REPORT ◦ SEPTEMBER 2021

Redwood Creek
Water Availability Analysis Report

PREPARED FOR

Salmonid Restoration Federation
425 Snug Alley, Unit D
Eureka, CA 95501

PREPARED BY

Stillwater Sciences
850 G Street, Suite K
Arcata, CA 95521

Stillwater Sciences

Suggested citation:
Stillwater Sciences. 2021. Redwood Creek Water Availability Analyses Report. Prepared by Stillwater Sciences, Arcata, California for Salmonid Restoration Federation, Eureka, California.

Cover photo: 2018 Redwood Creek dry-season flow conditions near the town of Briceland, July (top photo) and September (bottom photo).

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Figures

1 INTRODUCTION

This report analyzes water availability in Redwood Creek, tributary to the South Fork Eel. This analysis is being funded through the California Wildlife Conservation Board's Streamflow Enhancement Program. Salmonid Restoration Federation (SRF) is the project proponent and Stillwater Sciences is the technical lead for the project. The South Fork Eel River is one of five priority watersheds selected for flow enhancement projects in California by the State Water Resources Control Board (SWRCB) and California Department of Fish and Wildlife (CDFW) as part of the California Water Action Plan effort (SWRCB 2019). Redwood Creek is a critical tributary to the South Fork Eel River that historically supported coho and Chinook salmon and steelhead.

This water availability analysis is a component within an array of actions aimed at improving aquatic habitat in Redwood Creek by addressing the limiting factor of low summer streamflows. The primary purposes of this analysis are two-fold:

1. Provide site-specific water availability information for an Appropriative Water Right that will be filed with the SWRCB for a large-scale flow enhancement project on the Marshall Ranch near the town of Briceland (Stillwater Sciences 2021). The water availability analysis will specifically inform the amount and timing of water that is available for diversion to storage for this project.
2. Provide watershed-wide water availability information to inform watershed-scale planning outreach, data collection and analyses to develop an implementable plan for improving dry season streamflows in Redwood Creek with the goal of recovery of steelhead and salmon. The water availability analysis will specifically provide information for siting and prioritizing future projects.

This water balance analyzes inflows and outflows from the watershed:

1. Water in: Precipitation
2. Water Out: Streamflow draining into the South Fork Eel River; evapotranspiration; and human use.

Data used for analyses includes flow data collected by the project team in Redwood Creek, USGS gage data, PRISM rainfall data, and Appropriative Water Rights data. It is also important to note that flow enhancement planning work in Redwood Creek is being conducted in close collaboration with work in the Mattole watershed which has a history of flow-related initiatives dating back more than a decade (Trout Unlimited 2013).

2 WATERSHED CHARACTERISTICS

The Redwood Creek watershed comprises 26 square miles of area and approximately 22.4 miles of anadromous stream channel (Figure 1), draining into the South Fork Eel River from the west near the town of Redway. For the purpose of easing future water availability analyses, Redwood Creek watershed was divided into the following six sub-watersheds shown in Figure 1:

- China Creek
- Upper Redwood Creek
- Miller Creek

- Somerville Creek
- Seely Creek
- Redwood Creek Mainstem

Within Redwood Creek, 80% of the watershed is privately owned residential and ranching parcels with the remaining 20% in timber production. The land was extensively logged in the 1950s through the 1970s and now suffers from excessive sediment loading as a result. After the logging boom, the land was sub-divided into 40+ acre parcels that were purchased by homesteaders and families participating in the back-to-the-land movement. Currently, the majority of residents live in rural sub-divisions and the primary land use practices include marijuana cultivation, ranching, homesteading, and forestry.

Watershed conditions and water diversions greatly impact salmonid-bearing creeks. Water diversions, pumping and continual reliance on spring water during the dry months of summer are currently affecting water resources. Many parcels that once supported one family now have multiple curtilages and poorly maintained logging roads are now used daily by hundreds of residents contributing to chronic sediment problems.

The population of this rural enclave has nearly tripled since the 1960s and many people have moved here in hopes of capitalizing on the Green Rush. Many residents have increased their water storage for irrigation, light domestic use, and fire safety but they are not necessarily filing their water rights or forbearing from diverting water during the dry season. Climate change, drought, and the cumulative impacts of a multitude of unregulated water diversions will require regulatory compliance and forbearance incentives.

The Redwood Creek watershed is primarily underlain by the diverse Coastal and Central belts of the Franciscan Complex, the younger marine and non-marine overlap deposits of the Wildcat Group, and minor amounts of serpentinized peridotite of the Coast Range Ophiolite (Figure 2). Most of the Redwood Creek watershed is underlain by various subunits of the Eocene to Paleocene Yager terrane (Franciscan Complex Coastal Belt), which primarily consists of sheared and highly folded mudstone (McLaughlin et al. 2000). The mudstone includes minor rhythmically interbedded arkosic sandstone and local lenses of conglomerate. This lithology produces terrain with relatively irregular topography lacking a well-incised system of sidehill drainages when compared to other subunits of the Franciscan Complex Coastal Belt. The mudstone units also typically result in more wet-season runoff and less dry-season base flow than other Coastal Belt units comprised of fractured sandstone.

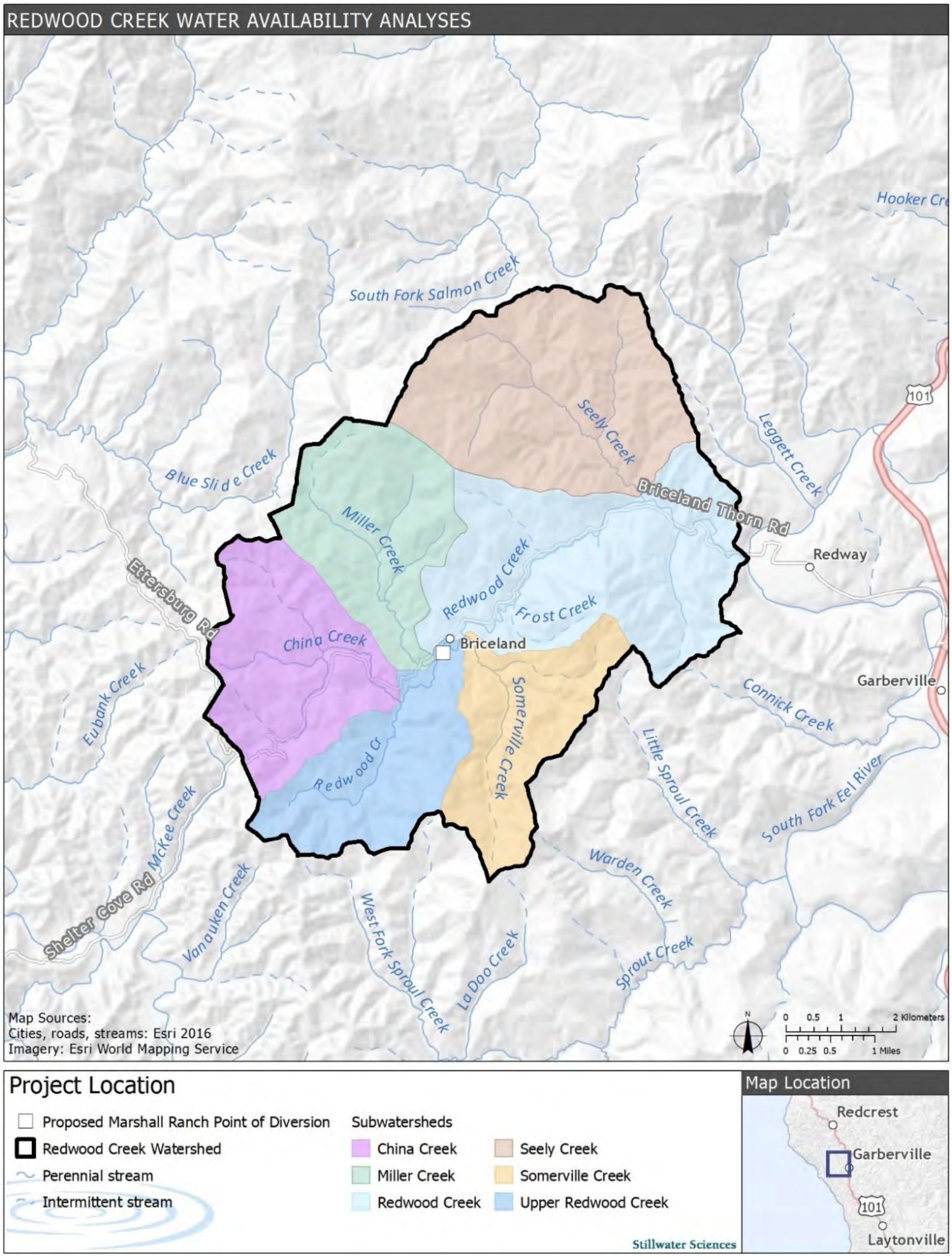

Figure 1. Redwood Creek watershed and sub-watersheds.

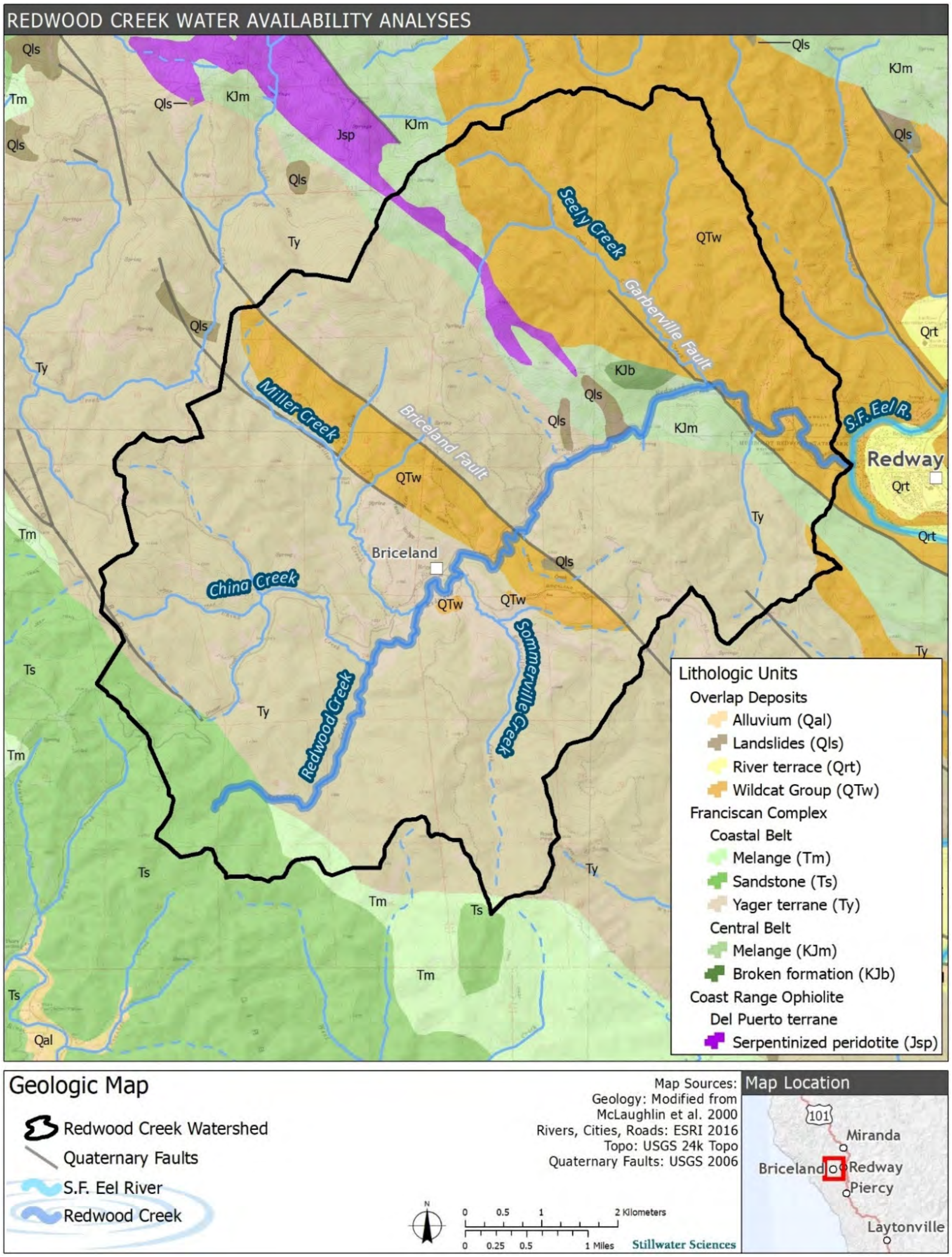

Figure 2. Generalized geologic map of the Redwood Creek watershed.

3 WATER BALANCE

Each of the primary drivers of the Redwood Creek water balance are described in detail below.

3.1 Precipitation

Rainfall data for the watershed was acquired from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) developed by the PRISM Climate Group out of Oregon State University. The model generates spatial climate datasets using monitoring data and state-of-the-art climate modeling techniques. Average annual precipitation based on the past 30 years of rainfall monitoring data is shown on Figure 3 and summarized on Table 1. On average, Redwood Creek receives approximately 69.2 inches of precipitation annually. Typical of the Mediterranean climate, nearly all of this precipitation occurs in the form of rainfall during the winter and spring. The summer and early fall are characterized as warm and dry, with very minimal precipitation.

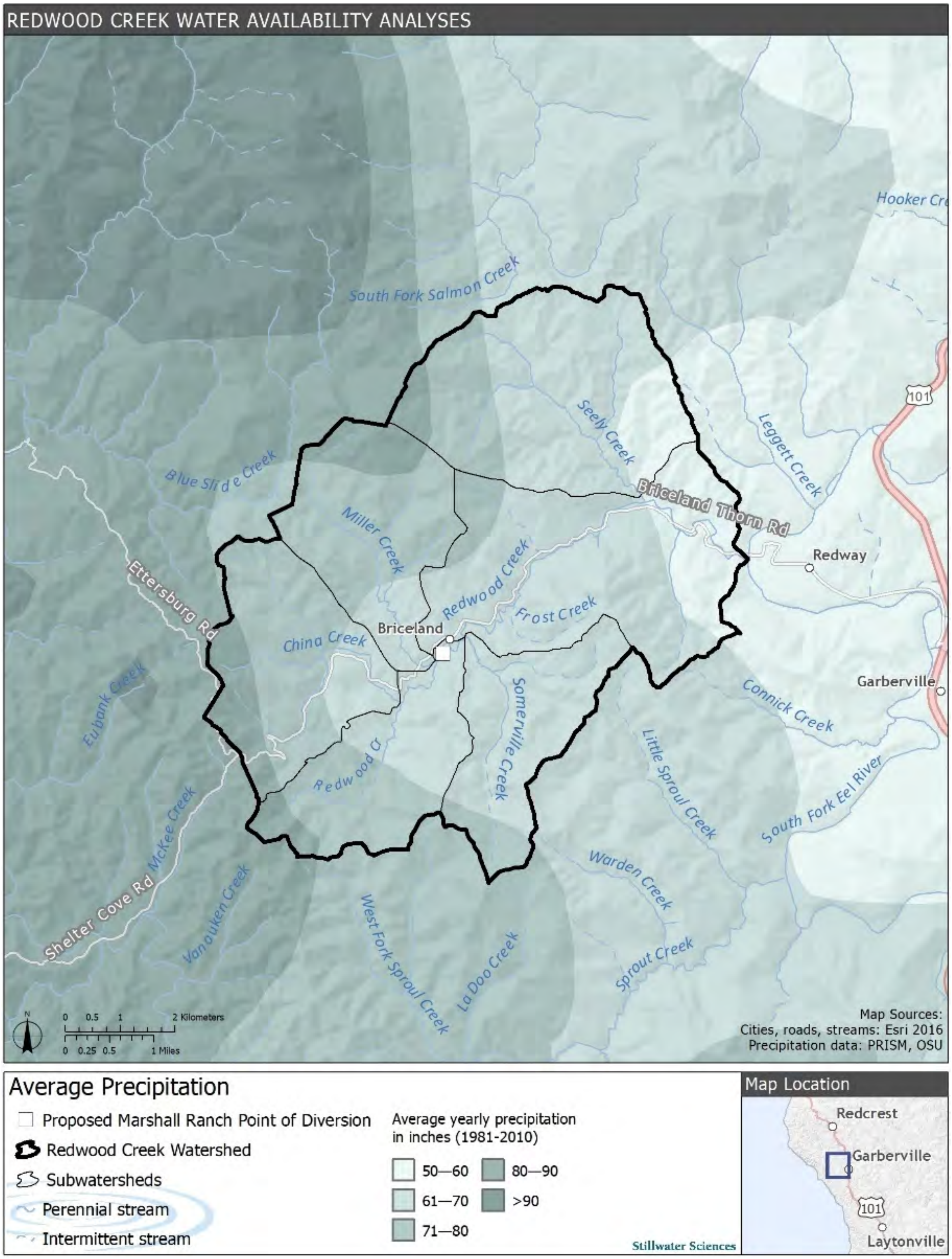

Figure 3. Redwood Creek watershed average annual precipitation.

Table 1. Summary of PRISM precipitation data.

Sub-watershed	Sub-watershed area (mi^2)	Average annual precipitation (inches)	Average annual input volume (ac-ft)
China Creek	3.9	74.9	15,669
Upper Redwood Creek	3.1	72.8	12,174
Miller Creek	3.7	84.1	16,429
Somerville Creek	3.0	67.3	10,846
Seely Creek	5.8	66.3	20,649
Mainstem Redwood Creek	6.4	63.8	21,654
Entire Redwood Creek watershed	25.9	69.2	95,728

3.2 Discharge

There are no flow gages that operate year-round on Redwood Creek, so the best way to determine discharge exiting the watershed during the winter is the proration method as described in the Policy for Maintaining Instream Flows in Northern California Coastal Streams (SWRCB 2014) referred to as “the Policy” hereon. As described in CDFW’s Flow Monitoring and Unimpaired Flow Estimation Report for Redwood Creek, Humboldt County (Cowan 2018), the USGS Bull Creek gage near Weott provides a long record of streamflow that can be used to estimate the unimpaired flow in Redwood Creek. Bull Creek is a similar sized watershed located approximately 15 miles north of Redwood Creek. Bull Creek is believed to have remained relatively unimpaired since installation of the USGS gage (Cowan 2018). Results from the average Bull Creek flows (1960 to 2018) prorated to Redwood Creek are shown on Figure 4 as well as Tables 2 and 3.

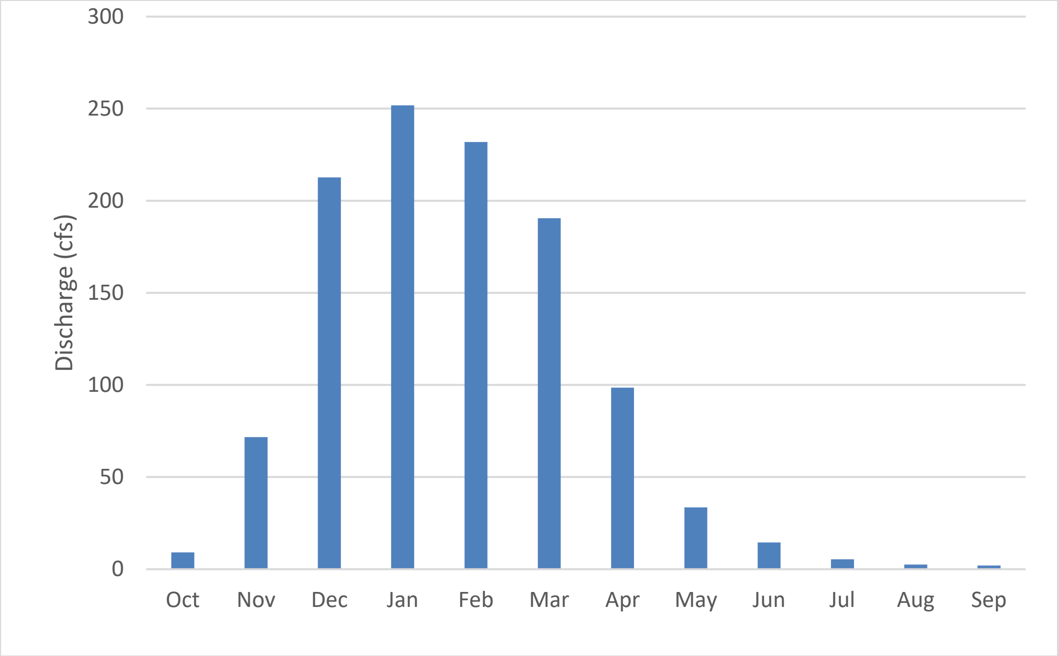

Figure 4. Graph of Redwood Creek average monthly streamflow prorated from Bull Creek gage.

Table 2. Summary of Annual Discharge in Redwood Creek based on proration from Bull Creek gage.

Sub-watershed	Sub-watershed area (mi^2)	Average annual discharge (cfs)	Average annual output volume (ac-ft)
China Creek	3.9	17.0	12,000
Upper Redwood Creek	3.1	13.2	10,000
Miller Creek	3.7	17.8	13,000
Somerville Creek	3.0	11.7	9,000
Seely Creek	5.8	22.4	16,000
Mainstem Redwood Creek	6.4	23.5	17,000
Entire Redwood Creek watershed	25.9	103.7	75,000

Table 3. Summary of wet season flows in Redwood Creek based on proration from Bull Creek gage.

Sub-watershed	Sub-watershed area (mi^2)	Average December output volume (ac-ft)	Average January output volume (ac-ft)	Average February output volume (ac-ft)	Average March output volume (ac-ft)	Average April output volume (ac-ft)
China Creek	3.9	2,387	2,826	2,351	2,138	1,070
Upper Redwood Creek	3.1	1,854	2,195	1,826	1,661	831
Miller Creek	3.7	2,502	2,963	2,465	2,242	1,122
Somerville Creek	3.0	1,652	1,956	1,627	1,480	741
Seely Creek	5.8	3,145	3,724	3,098	2,818	1,410
Mainstem Redwood Creek	6.4	3,298	3,905	3,249	2,955	1,478
Entire Redwood Creek watershed	25.9	14,580	17,264	14,362	13,063	6,536

As highlighted in Figure 4 as well as Tables 2 and 3 above, there is significant water availability in Redwood Creek during the wet season generated by precipitation and extensive runoff. In addition to the wet-season discharge which has been prorated from the Bull Creek USGS gage data, SRF has been monitoring dry season flows in Redwood Creek beginning in 2013. The Redwood Creek gage locations are shown on Figure 5. Flow monitoring results for station RC-4, located near Redwood Creek's confluence with the south Fork Eel River, is shown on Figure 6. As this figure depicts, dry-season flows in Redwood Creek are extremely low with flows at RC-4 dropping below 10 gallons per minute during each of the last six dry seasons. Flows at all other monitoring stations throughout the watershed follow similar trends with zero flow recorded at the majority of monitoring stations during most years. Table 4 shows a comparison of dry-season flow measurements in Redwood Creek versus proration from Bull Creek.

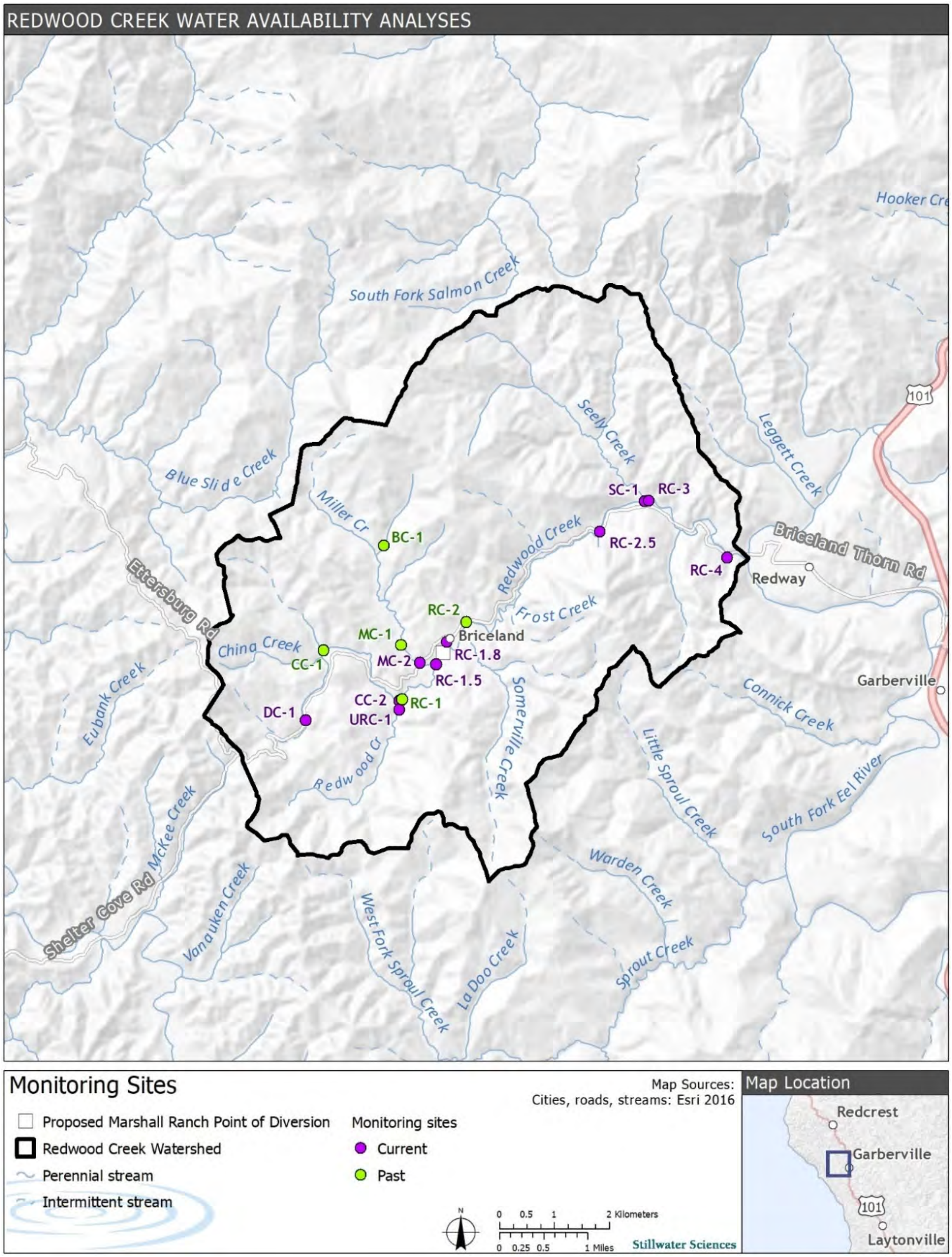

Figure 5. Dry season monitoring stations in Redwood Creek.

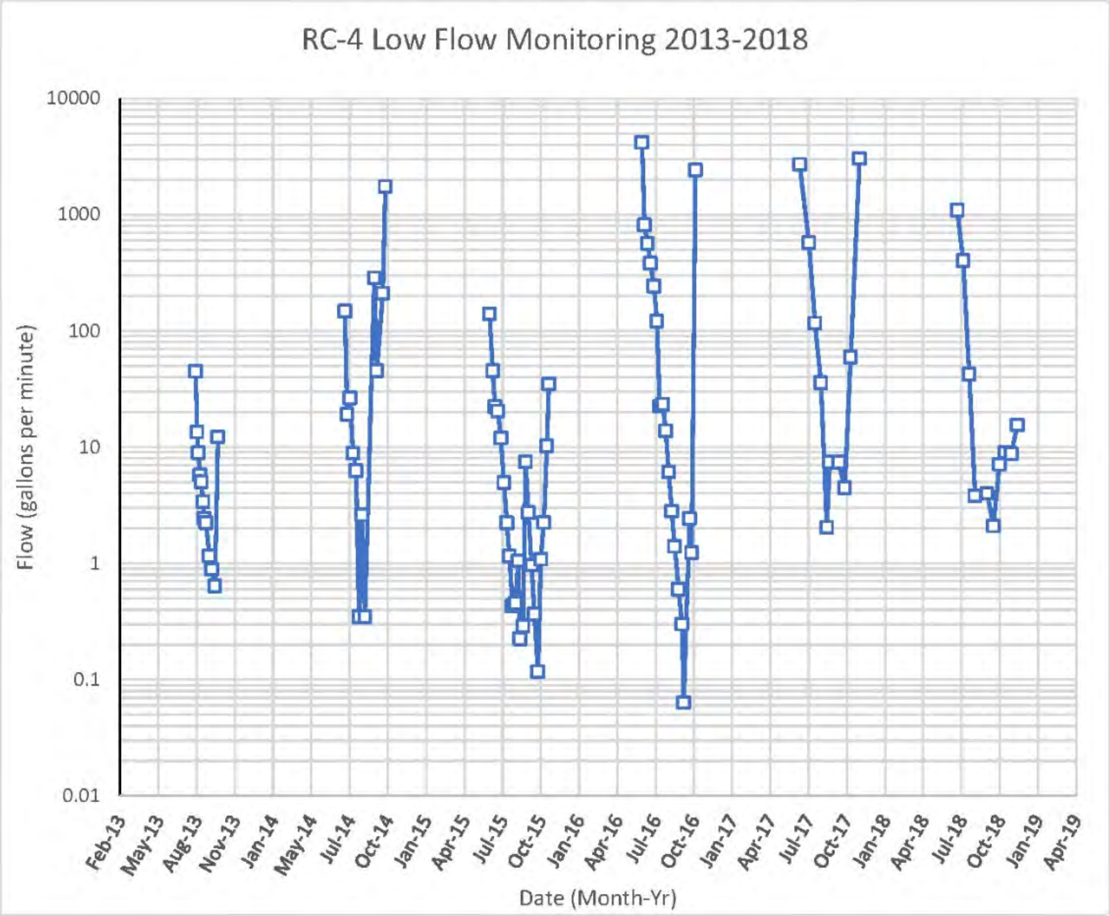

Figure 6. Dry season flow monitoring results for Redwood Creek mainstem near confluence with South Fork Eel.

Table 4. Comparison of dry-season flows measured in Redwood Creek and prorated from Bull Creek.

Sub-watershed	Sub-watershed area (mi^2)	Average July discharge measured (cfs)	Average July discharge prorated (cfs)	Average August discharge measured (cfs)	Average August discharge prorated (cfs)	Average September discharge measured (cfs)	Average September discharge prorated (cfs)
China Creek	3.92	0.20	0.97	0.01	0.44	NA	0.34
Upper Redwood Creek	3.14	0.29	0.76	0.01	0.34	0.00	0.27
Miller Creek	3.66	0.14	1.02	0.00	0.46	NA	0.36
Seely Creek	5.84	0.05	1.28	0.01	0.58	0.00	0.45
Entire Redwood Creek watershed	25.94	0.47	5.95	0.03	2.71	0.01	2.10

The Bull Creek discharge data was used to estimate the Redwood Creek unimpaired hydrograph because of similar watershed characteristics (size, precipitation, location, gradient) and because Bull Creek is believed to be relatively unimpaired since 1988 (Cowan 2018). Water diversions and other impairment likely play a role in the difference between the measured and prorated discharge averages in the summer months. However, other key differences between the watersheds, including geology, may be factors in the difference. Redwood Creek has more siltstone and shale bedrock compared to more sandstone bedrock in Bull Creek that likely supports more robust dry season base flows. Additionally, the measured monthly averages for Redwood Creek were based off only a few measurements and may not accurately represent the monthly average flow, although monitoring results strongly support the overall trend that dry season flows in Redwood Creek are significantly lower than proration calculations would suggest.

3.3 Evapotranspiration

A significant portion of the precipitation in the basin returns to the atmosphere through evaporation or transpiration from vegetation in the watershed. It is difficult to quantify the actual evapotranspiration rates at the watershed scale, but the evapotranspiration potential has been estimated by the California Irrigation Management Information System (CIMIS) developed by Department of Water Resources and UC Davis[1]. The group uses weather station data and complex models to delineate reference evapotranspiration zones across California. The reference evapotranspiration rate is the rate at which water evaporates and transpires from a well-watered reference grass crop. According to the map, the Redwood Creek watershed has an average annual reference evapotranspiration of 46.3 inches per year. The actual evapotranspiration rate in Redwood Creek watershed is likely significantly less because it does not have unlimited soil moisture and the vegetation is comprised of conifer forest, oak woodlands, shrublands, grassland and some agriculture.

3.4 Human Water Use

Stillwater Sciences conducted a Flow Enhancement Feasibility Study (Feasibility Study) for a portion of Redwood Creek between 2015 and 2017 (Stillwater Sciences 2017). During that study, human consumptive water use was estimated from a variety of sources as described below. In this report, the approach and data from Stillwater 2017 has been extrapolated out to all of Redwood Creek. It is important to note that 2016/2017 was the peak of cannabis cultivation in the watershed and a downswing in consumptive water use related to cannabis has likely occurred over the past several years. However, considering that the objective of this report is not to determine precise consumptive use for cannabis, the data from Stillwater 2017 provides sufficient baseline information for the water balance.

As is the case with many rural areas with dispersed water sources and users, quantification of consumptive use is difficult. Considering this difficulty, in the Feasibility Study, Stillwater Sciences used several different approaches to quantify water use, including: (1) landowner responses to a water use survey conducted within the study area by SRF, (2) landowner responses from a survey conducted by Sanctuary Forest in the adjacent Mattole River watershed, (3) information reported in Bauer et al. 2015, and (4) new GIS analyses conducted within the study area that estimated water use based on area of agricultural cultivation determined from aerial imagery. Each approach for estimating water use is described below and summarized on Table 5.

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[1] https://cimis.water.ca.gov/Default.aspx

3.4.1 Landowner responses within the study area

A water use survey was sent to 100 residents within the study area. Response rate was 12%. Based on the 12 responses, average domestic (i.e. household) water use was 102 gallons per day and average irrigation use was 376 gallons per day for a total average water use of 478 gallons per day (Table 5). The low response rate and relatively low resulting estimate of average daily use suggests that many of the larger water users within the study area did not respond, and therefore it may not be appropriate to apply these results more broadly across the entire watershed area. Despite the limited sample size, the survey provided some interesting findings:

- Approximately half of respondents use a spring as their water source for domestic and irrigation water supply.
- Only 1/3 of the respondents have separate domestic and irrigation water systems.
- Half of respondents are currently forbearing for 3 or 4 months.
- Water storage capacity varied widely among respondents.

Table 5. Consumptive water use estimates.

Water use estimate approach	Estimated water use per parcel (gal/day)	Total water use per parcel during 5-month growing season (gal)
1) Redwood Creek water use survey	478	71,700
2) Upper Mattole water use survey	708	106,200
3) CDFW data for Study Area (from Bauer et. al. 2015)	725	108,750
4) Updated GIS analyses of study area	925	138,750

3.4.2 Landowner responses from adjacent watersheds

A water survey of 40 residents in the upper Mattole River resulted in an average estimated water use of 708 gallons per day during the 6-month dry season (Table 5) (Trout Unlimited 2013[2]). Results from this survey are applicable to the Redwood Creek study area considering that the upper Mattole River is located directly adjacent to, and west of the Redwood Creek study area and the Mattole watershed has many of the same physiographic, ecological, and land use characteristics.

3.4.3 Compilation of CDFW data for the Redwood Creek study area

Using the mapping and assumptions of Bauer et al. (2015), Stillwater Sciences estimated cannabis-related water use within the Redwood Creek feasibility study area. The approach involved GIS overlay of the study area boundary and the Bauer et al. (2015) mapping. Estimates of cannabis irrigation on 77 parcels in the study area averaged 425 gallons per day (excludes parcels serviced with water from the Briceland Community Service District). This included approximately 36,000 ft^2 of greenhouse and 2,200 outdoor cannabis plants. When average domestic use of approximately 300 gallons per day per parcel was added, the average water use

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[2] Trout Unlimited. 2013. Mattole River Headwaters Streamflow Improvement Plan.

determined through this method is 725 gallons per day (Table 1). The results of this analysis were generally consistent with results from the upper Mattole River survey.

3.4.4 Updated GIS analysis

Since estimates of water use for cannabis cultivation by Bauer et al. (2015) were based on 2012 aerial imagery, the desktop GIS analysis of water use within the study area was updated based on 2014 aerial imagery. This analysis considered consumptive water use for cannabis cultivation, as well as other land uses (e.g., vegetable gardens and landscaping). Primary results of the analysis include:

- Greenhouse square footage 53,000 (increase of 17,000 square feet from 2012 to 2014)
- Outdoor cannabis plants 2,800 (increase of 600 from 2012 to 2014).
- ~5.6 acres of vegetable gardens, orchards, and vineyards that weren't included in the CDFW analysis.

Estimated water use (gallons per day) was then updated using these data and the following assumptions:

- Input from cultivators suggests cannabis plants in greenhouses typically require 3 gallons per day (lower than that estimated by Bauer et al. [2015]).
- Cultivation of outdoor cannabis plants typically requires 6 gallons per day per, a relatively high estimate that accounts for inefficiencies evident in many irrigation systems.
- For other irrigated areas the following formula was used:

(Eto x PF x SF x 0.62) / IE =Gallons of Water per day[3]

Where:

> **Eto** = evapotranspiration factor. Taken from http://www.rainmaster.com/historicET.aspx and using zip code 95553 a value of 0.16 is obtained.
>
> **PF** = plant factor. Typically, a value of 1.0 is used for lawn 0.80 for water loving shrubs, 0.5 for average water use shrubs, and 0.3 for low water use shrubs (0.5 was used).
>
> **SF** = irrigated area (square feet).
>
> **0.62** = constant.
>
> **IE** = irrigation efficiency factor. This value compensates for irrigation water that isn't used by the plant. Efficient sprinkler systems with little run-off can have efficiencies of 80%. Drip irrigation systems typically have efficiencies of 90%. (A value of 0.75 was used to account for general leakage and inefficiencies seen in most rural water systems).

Based on these assumptions and calculations, the average water use per parcel was 625 gallons per day for irrigation. Irrigation for cannabis cultivation accounts for 66% and non-cannabis irrigation accounts for 34% of total estimated irrigation use. When domestic use of 300 gallons per day is included, the total estimated water use per parcel increases to 925 gallons per day (Table 5). Over the five-month dry season, this equals 93,750 gallons of irrigation water and 45,000 gallons of domestic water.

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[3] http://www.irrigationtutorials.com/how-to-estimate-water-useage-required-for-an-irrigation-system/

Based on these analyses, 1,000 gallons per day per parcel is a reasonable and conservative estimate for total water use within the feasibility study area (as used in the target flow memorandum).

The analysis from the Feasibility Study was extrapolated out to the rest of the Redwood Creek watershed and utilized to populate the data shown on Table 6.

Table 6. Consumptive water use estimates by sub-watershed.

Sub-watershed	Sub-watershed area (mi^2)	Number of parcels	Total water use per sub-shed during 5-month dry season (ac-ft)*	Total water use during 3.5-month wet season (ac-ft)**	Demand volume (face value) of upstream appropriative water right diversions (af/yr)	% Winter flow impairment***
China Creek	3.9	58	26.7	5.6	13.1	0.06%
Upper Redwood Creek	3.1	24	11.0	2.3	0.2	0.01%
Miller Creek	3.7	46	21.2	4.4	7.3	0.04%
Somerville Creek	3.0	18	8.3	1.7	0.5	0.01%
Seely Creek	5.8	61	28.1	5.9	8.8	0.04%
Redwood Creek (mainstem)	6.4	134	61.7	13.0	21.7	0.08%
Entire Redwood Creek Watershed	25.9	341	157.0	33.0	51.6	0.05%

* Based on estimate of 1000 gal/day/parcel over 5-month dry season

** Based on estimate of 300 gal/day/parcel over 3.5-month diversion season

*** Sum of estimated water use during 3.5-month diversion season and appropriative diversion volume as percentage of 3.5-month unimpaired discharge volume (prorated from Bull Cr. Gage).

3.4.5 State Water Board water use reporting data

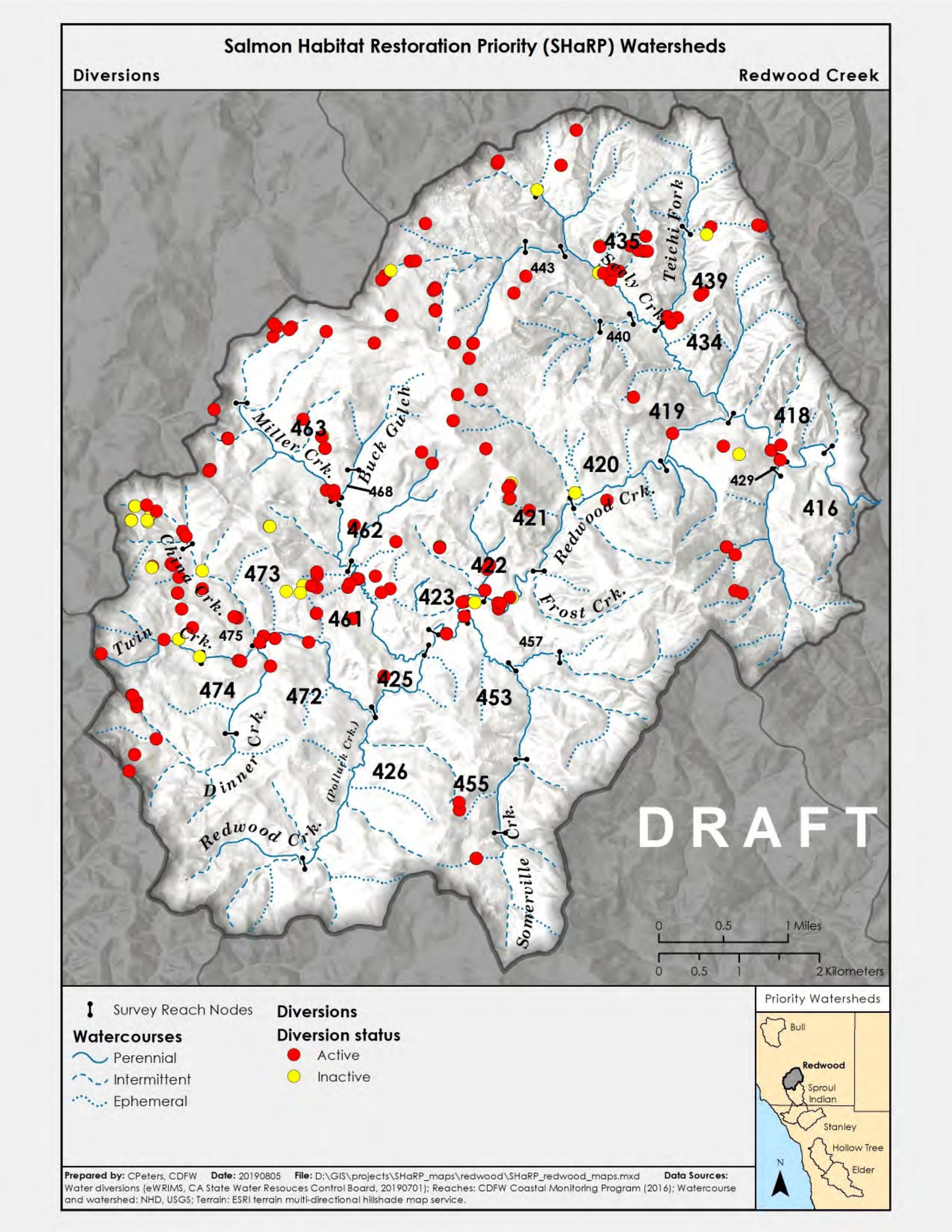
The State Water Board’s EWRIMS website contains records of all water rights and reported water use. Human consumptive use water demand is mainly during the dry season (Riparian Water Rights) with the exception of Appropriative Water Rights users that fill up storage during the wet season. Water users with Riparian Water Rights typically use very small amounts of water in winter for domestic use only because they are not legally allowed to divert and store water for more than 30 days. A list of all Appropriative Water Rights holders in Redwood Creek as shown on Table 7.

Table 7. List of appropriative water rights.

Application ID	Water right type	Owner	Latitude	Longitude	Source	Face value (ac-Ft)
China Creek Sub-Watershed						
D032082	Registration Domestic	Charles Liphart	40.1058	-123.9267	China Creek	8.07
D032176	Registration Domestic	Leonard Anderson	40.1088	-123.9387	Unnamed Spring	1.1
D032233	Registration Domestic	Robin Downing	40.1084	-123.9190	Unnamed Stream	0.2
D032319	Registration Domestic	Genaro Rust	40.0905	-123.9461	Unnamed Spring	0.13
D032339	Registration Domestic	Mercedes Butterworth	40.1198	-123.9426	China Creek	0.32
D032428	Registration Domestic	Nocona Mendes	40.0978	-123.9451	Unnamed Drainage	0.47
D032721	Registration Domestic	Frank Canning	40.1170	-123.9382	China Creek	0.82
D032873	Registration Domestic	Geraldine Fitzgerald	40.1137	-123.9400	Unnamed Spring	0.12
D033226	Registration Domestic	John L Casali	40.0929	-123.9391	Dinner Creek	0.308
H500703	Registration Cannabis	Dimitar Zaykov	40.1030	-123.9300	China Creek	0.23
H502403	Registration Cannabis	Nocona Mendes	40.0983	-123.9452	Unnamed Spring	0.55
H503715	Registration Cannabis	Shannon Martin	40.1106	-123.9393	Unnamed Spring	0.61
H508759	Registration Cannabis	Briceland Farm LLC	40.0924	-123.9453	Unnamed Spring	0.2
Miller Creek Sub-Watershed						
D032281	Registration Domestic	Laura Glauberman	40.1283	-123.9184	Unnamed Spring	1.4
D032402	Registration Domestic	Johanna M. Hamel	40.1270	-123.9179	Unnamed Spring	0.47
D032443	Registration Domestic	George Truett	40.1119	-123.9141		1.69
H500861	Registration Cannabis	Elizabeth Worley	40.1223	-123.9177	Unnamed Spring	0.46
H503687	Registration Cannabis	Jomra Kan	40.1312	-123.9343	Unnamed Spring	0.48
H504579	Registration Cannabis	Aaron Lieberman	40.1403	-123.9234	Unnamed Spring	2.14
H504852	Registration Cannabis	Daniel Kulchin	40.1109	-123.9095	Unnamed Stream	0.64

Application ID	Water right type	Owner	Latitude	Longitude	Source	Face value (ac-Ft)
Sommerville Creek Sub-Watershed						
H503686	Registration Cannabis	Garrett Gradin	40.0811	-123.8952	Unnamed Spring	0.31
H505220	Registration Cannabis	Dejan Petrushevski	40.0865	-123.8977	Unnamed Spring	0.18
Seely Creek Sub-Watershed						
D032295	Registration Domestic	Hal Hale	40.1463	-123.8764	Seely Creek	1.33
D032323	Registration Domestic	Cameron Cleaves	40.1501	-123.8735	Leaf Spring	0.33
D032341	Registration Domestic	Shanon Taliaferro	40.1523	-123.8618	Seely Creek	1.04
D032342	Registration Domestic	Shanon Taliaferro	40.1422	-123.8680	Seely Creek	1.23
D032687	Registration Domestic	Juan Arellano	40.1390	-123.8964	Unnamed Spring	0.3
D033045	Registration Domestic	Nancy Johnson	40.1526	-123.8549	Unnamed Spring	0.8
H500477	Registration Cannabis	Kelsey Beehrle	40.1390	-123.8992	Unnamed Spring	0.15
H500701	Registration Cannabis	Shanon Taliaferro	40.1422	-123.8680	Seely Creek	0.54
H500765	Registration Cannabis	Enoch Tatton	40.1450	-123.9020	Unnamed Spring	0.63
H500917	Registration Cannabis	Utah Blue	40.1426	-123.9020	Unnamed Stream	0.06
H502512	Registration Cannabis	Cameron Cleaves	40.1495	-123.8710	Unnamed Spring	0.69
H503674	Registration Cannabis	Hal Hale	40.1474	-123.8760	Unnamed Stream	0.64
H504958	Registration Cannabis	Enoch Tatton	40.1420	-123.9084	Unnamed Spring	0.6
H509688	Registration Cannabis	Humboldt Ranch Inc	40.1390	-123.8964	Unnamed Stream	0.45
Lower Redwood Creek Sub-Watershed						
A010198	Appropriative	John R Foster	40.1273	-123.8526	Unnamed Stream	13.4
H500723	Registration Cannabis	Katherine Wolman	40.1098	-123.8920	Redwood Creek	0.18
H500876	Registration Cannabis	Tao Ryce	40.1164	-123.8590	Unnamed Stream	0.32
H501958	Registration Cannabis	Sarah Clarke	40.1279	-123.8512	Unnamed Spring	0.13
H503616	Registration Cannabis	Lisa Deloury	40.1338	-123.8952	Unnamed Spring	0.2
H503694	Registration Cannabis	John Neill	40.1160	-123.9010	Unnamed Stream	0.29
H503718	Registration Cannabis	Thomas Hayes	40.1338	-123.8952	Unnamed Spring	0.38
H509241	Registration Cannabis	David Arellano Sanchez	40.1213	-123.8607	Unnamed Stream	0.43

Application ID	Water right type	Owner	Latitude	Longitude	Source	Face value (ac-Ft)
D032179	Registration Domestic	Michael Labonte	40.1099	-123.8973	Unnamed Stream	1.95
D032298	Registration Domestic	Cecelia A. Lanman	40.1105	-123.8907	Redwood Creek	1.49
D032404	Registration Domestic	Peter Holbrook Living Trust	40.1112	-123.8943	Tank Gulch Creek	0.35
D032407	Registration Domestic	Katherine Wolman	40.1098	-123.8924	Redwood Creek	0.41
D032729	Registration Domestic	John Neill	40.1160	-123.9010	Unnamed Spring	0.25
D032950	Registration Domestic	Cathy Studebaker	40.1216	-123.8908	Unnamed Spring	0.61
D033101	Registration Domestic	John Deim	40.1119	-123.8896	Redwood Creek	1.34
Upper Redwood Creek Sub-Watershed						
H500603	Registration Cannabis	Shawn Richter	40.1063	-123.8999	Redwood Creek	0.18



Prepared by: CPeters, CDFW **Date:** 20190805 **File:** D:\GIS\projects\SHaRP_maps\redwood\SHaRP_redwood_maps.mxd **Data Sources:** Water diversions (eWRIMS, CA State Water Resouces Control Board, 20190701); Reaches: CDFW Coastal Monitoring Program (2016); Watercourse and watershed: NHD, USGS; Terrain: ESRI terrain multi-directional hillshade map service.

Figure 7. Registered Points of Diversion within the Redwood Creek Watershed (figure courtesy of CDFW).

Table 8. Summary of Water Rights by sub-watershed.

Sub-watershed	Sub-watershed area (mi^2)	# Riparian water rights	# Appropriative water rights	Total volume Appropriative water rights (ac-ft)
China Creek	3.9	31	13	13.13
Upper Redwood Creek	3.1	2	1	0.18
Miller Creek	3.7	24	7	7.28
Somerville Creek	3.0	4	2	0.49
Seely Creek	5.8	25	14	8.79
Lower Redwood Creek	6.4	27	15	21.73
Entire Redwood Creek watershed	25.9	113	53	51.60

4 WATER AVAILABILITY ANALYSIS FOR REDWOOD CREEK

As described above in this report, due to the Mediterranean climate within Redwood Creek there is extensive runoff from the watershed during the wet season and generally insufficient instream flows to support aquatic habitat and human consumptive use during portions of the dry season. Below, wet season water availability in each of the six tributary areas are further analyzed to spatially define the amount of unappropriated water available during the wet season.

4.1 Water Supply and Diversions in Redwood Creek

The quantity of water available instream based on estimates of riparian diversions as well as appropriated senior water rights is summarized in Table 9 below. Overall, appropriated senior water rights represent a very small percentage of wet-season instream flows (<0.1% of total discharge in all sub-watersheds during the Dec 15–Mar 31 period).

The season of diversion was assumed to be December 15-March 31 because this is the allowed period for new diversions under the Policy for Maintaining Instream Flows in Northern California Coastal Streams (SWRCB 2014) which has been applied to the neighboring Mattole watershed. Note that the 2014 Policy does not apply to Redwood Creek, although it is being used as a general guide for this analysis.

The Policy recommends that the maximum cumulative diversion should be 5% of the 1.5-year peak flow. The Policy also outlines a minimum bypass flow equation of 8.8*(mean annual unimpaired flow)*(drainage area)^-0.47 which is 138 cfs for Redwood Creek adjacent to the proposed Marshall Ranch project. On average, the unimpaired Redwood Creek hydrograph only reaches 138 cfs on 34 days during the year.

As discussed below, a minimum bypass flows of 5 cfs is proposed herein which is significantly below the recommendations of the Policy. Although the goal of the project is to divert when flows are high to reduce downstream impacts, it is important to maintain the project's operational flexibility during dry years where high flow events are less frequent, because these conditions often coincide with years where dry-season flow enhancement is most needed. The 2014 Policy does also allow for site specific studies to adjust bypass flows and/or extend the allowable season of diversion.

Table 9. Wet Season Water Impairment by sub-watershed.

Watershed	**Area (mi2)**	**Average precipitation (inches)**	**Average discharge Dec 15–Mar 31 (cfs), prorated from Bull Cr.**	**Average outflow from Dec 15–Mar 31 (af/yr), prorated from Bull Cr.**	**Wet season (Dec 15–Mar 31) demand volume of all upstream diversions (af/yr)**	**% wet season (Dec 15–Mar 31) flow impairment**
China Creek	3.9	74.9	41.7	30163.5	18.7	0.06%
Upper Redwood Creek	3.1	72.8	32.4	23434.4	2.5	0.01%
Miller Creek	3.7	84.1	43.7	31626.2	11.7	0.04%
Somerville Creek	3.0	67.3	28.8	20879.2	2.2	0.01%
Seely Creek	5.8	66.3	54.9	39749.3	14.7	0.04%
Redwood Creek (mainstem)	6.4	63.8	57.6	41684.2	34.7	0.08%
Entire Redwood Creek Watershed	25.9	69.2	254.5	184276.8	84.6	0.05%

Total estimated wet season discharges from 1960 to 2017 are shown on Figure 8. As shown on Tables 9 above, the percentage of unappropriated water supply available during the wet season is high throughout the watershed. Therefore, the potential to cause injury to downstream water users is low, and this analysis will focus on setting diversion criteria that reduce risk to aquatic habitat throughout the watershed. At a minimum, the following criteria should be met:

- No significant diversion when flows are below "non-stressful rearing habitat" target of 0.2 CFS per square mile (Stillwater Sciences 2017).
- Typical wet-season diversion rates from Class I tributaries should be less than 10% of total flow.

Note that these are general guidelines and should be assessed on a case-by-case basis depending on the location of a proposed point of diversion and the purpose for which the diverted water will be used.

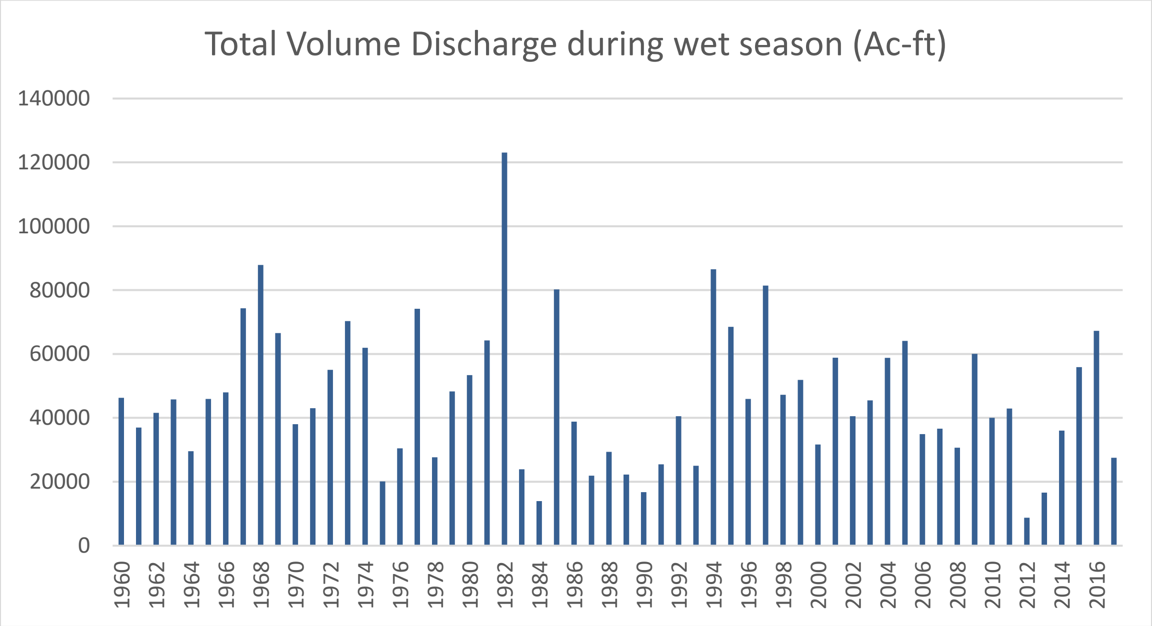


Figure 8. Total wet season unimpaired flow volume for Redwood Creek—1960 to present (prorated from Bull Creek).

5 WATER AVAILABILITY ANALYSIS FOR MARSHALL RANCH

In addition to conducting a water availability analyses for all of Redwood Creek, this technical report presents specific information to support a large-scale flow enhancement project on the Marshall Ranch.

5.1 Project Purpose and Description

The Marshall Ranch Flow Enhancement Project proposes construction of 10 million gallons of off-channel water storage along with a filtration/cooling gallery with the primary objective of delivering approximately 30 gallons per minute of flow augmentation to Redwood Creek during the 5-month dry season to improve instream aquatic habitat.

The off-stream storage is designed to fill from three sources:

1) Precipitation that falls on the 3.2-acre footprint of the ponds and tanks,
2) 7.5 acres of hillslope that will provide sheetflow runoff to the ponds, and
3) Water diverted during the wet season from two seasonal tributaries to Redwood Creek.

Planning level analysis presented in the Marshall Ranch Basis of Design Report shows that the storage would easily fill based on 48 inches of annual rainfall. However, it is desirable to have the pond fill with less rainfall, including the situation of dry years where there may be minimal sheetflow runoff. Therefore, the requested onstream diversion volume has been calculated based on 42 inches of annual rainfall and assuming no hillslope sheetflow inputs to storage as shown on Table 10.

Table 10. Water Availability in seasonal tributaries based on Bull Creek proration.

Source	Area (acres)	Runoff Cooefficient	Intensity (inches)	Volume (gallons)
Eastern Pond (direct precipitation)	1.3	1.0	42	1,500,000
Western Pond (direct precipitation)	1.8	1.0	42	2,000,000
Hillslope draining into Eastern Pond	2.5	0.0	0	-
Hillslope draining into Western Pond	5.0	0.0	0	-
Additional Volume needed to fill 10,000,000 gal of storage	4.0	0.2	35	6,500,000

Based on the information presented on Table 10, a total onstream diversion volume of 6.5 million gallons is being requested from two tributaries. The locations of the two PODs are shown on Sheet 3 of the Design Plans in Appendix A.3 of the Basis of Design Report, and their setting is depicted in the photos below (Figures 9 and 10). The proposed diversion rate will vary based on the flow in each seasonal tributary at the point of diversion. For the smaller eastern tributary, diversion rate is anticipated to range between 10 and 50 gpm during 30 to 60 days of the wet season. For the larger western tributary, diversion rate is anticipated to range between 60 and 150 gpm during 30 to 60 days of the wet season. The total water volume diverted from both tributaries would not exceed 6.5 million gallons (20 ac-ft) with approximately 1.08 million gallons diverted from the eastern tributary and 5.42 million gallons diverted from the western tributary.

Figure 9. Proposed Western POD showing upstream and downstream channel (photo taken 28 September 2021)

Figure 10. Proposed Eastern POD showing upstream and downstream channel (photo taken 28 September 2021)

The average stream discharge for the diversion period of December 15 to March 31 for each tributary was calculated by prorating Bull Creek gage records by drainage area (Table 11). Based on proration for this time period, the eastern tributary is expected to have an average discharge of 31 gpm generating approximately 4.7 million gallons of total flow and the western tributary is expected to have an average discharge of 154 gpm generating 23.3 million gallons of total flow. Based on these calculations, the proposed diversion amounts to less than a quarter of the wet season runoff from these tributaries during average rainfall years. During drier years, the total diversion volume may approach one half of the total flow.

Table 11. Water Availability in seasonal tributaries based on Bull Creek proration.

Source	**Area (acres)**	**Area (mi2)**	**Average discharge Dec 15–Mar 31 (cfs), prorated from Bull Cr.**	**Average discharge Dec 15–Mar 31 (gpm), prorated from Bull Cr.**	**Proposed average diversion Rate (GPM)**	**Total discharge during period (gal)**	**Proposed diversion during period**
Eastern POD	4.0	0.00625	0.06875	31	15	4,667,355	1,083,333
Western POD	20.0	0.03125	0.34375	154	75	23,336,775	5,416,667

The project team has had initial discussions with CDFW and NOAA staff regarding the proposed diversion approach, with general agreement that diversion from seasonal tributaries is more desirable than the previous proposal of diversion from Redwood Creek mainstem. It is anticipated that discussions and negotiations will be ongoing over the next year to refine the specifics of the diversion timing and bypass flow, but we anticipate that the final agreement will include the following guidelines:

- Diversion season: December 15 to March 31.
- Diversion allowed when Redwood Creek mainstem at the Marshall Ranch is at or above 5 cubic feet per second (cfs).
- Diversion rate from the tributaries shall not exceed 10% of Redwood Creek mainstem flow at the Marshall Ranch.
- A minimum bypass flow of 5 gpm is required for each tributary.
- Cumulative diversion rates from the two tributaries will range from 75 to 200 gpm during the diversion season.
- 30 to 60 days of diversion needed to achieve 6.5 million gallons of diversion (20 ac-ft)

It is important to consider that the diversions are proposed on seasonal tributaries that flow through eroding gullies between the proposed PODs and Redwood Creek, so there is limited aquatic habitat value within these reaches.

5.2 Water Supply Report for Marshall Ranch

The general location of the proposed Marshall Ranch diversions is shown on Figure 1. The proposed point of diversions (PODs) will draw water from the Upper Redwood Creek sub-watersheds also shown in Figure 1. However, the portion of Redwood Creek mainstem immediately impacted by the proposed diversion is also fed by the Miller Creek and China Creek sub-watersheds. Water availability in Redwood Creek adjacent to the two proposed PODs is shown on Table 12. The first row of Table 12 shows that existing upstream diversions account for 0.04% of the total wet season discharge. The second row of Table 12 shows how the proposed Marshall Ranch diversions would increase the total wet season diversion to 0.06% of total discharge.

Table 12. Water supply/availability for Marshall Ranch Flow Enhancement Project.

Watershed	**Area (mi2)**	**Average precipitation (inches)**	**Average discharge Dec 15–Mar 31 (cfs), prorated from Bull Cr.**	**Average outflow from Dec 15–Mar 31 (af/yr), prorated from Bull Cr.**	**Wet season (Dec 15–Mar 31) demand volume of all upstream diversions (af/yr)**	**% wet season flow impairment**
Redwood Creek at Marshall Ranch (includes Miller Cr, China Cr, and Upper Redwood Creek subsheds)	10.7	77.3	117.7	85224.2	33.0	0.04%
Redwood Creek at Marshall Ranch with proposed Diversion	10.7	77.3	117.7	85224.2	53.0	0.06%

5.3 Cumulative Diversion Analysis

There are five active appropriative water rights and nine claimed riparian diversions on Redwood Creek downstream from the proposed Marshall Ranch diversions. The active appropriative rights are listed below in Table 13. In total, the downstream diversions amount to 15.66 acre-feet of diversion volume per year. A summary of all registered downstream water users is included on Table 14. Based on the diversion guidelines listed above in Section 5.1, the Marshall Ranch Project will not significantly impact downstream diversions.

Table 13. Redwood Creek appropriative diversions downstream of proposed diversion application ID.

	Water right type	Owner	Latitude	Longitude	Source	Face value (ac-ft)
H500723	Registration Cannabis	Katherine Wolman	40.1098	-123.892	Redwood Creek	0.18
D032298	Registration Domestic	Cecelia A. Lanman	40.1105	-123.8907	Redwood Creek	1.49
A010198	Appropriative	John R Foster	40.127284	-123.852584	UNST	13.4
H500603	Registration Cannabis	Shawn Richter	40.1063	-123.8999	Redwood Creek	0.18
D032407	Registration Domestic	Katherine Wolman	40.1098	-123.8924	Redwood Creek	0.41

Table 14. All registered water users downstream of proposed diversion application ID.

ID	LATITUDE	LONGITUDE	SOURCE	PARCEL NUMBER	DIVERSION STORAGE AMOUNT	FACE VALUE AMOUNT	WR TYPE	WR STAT	NAME	Address	City, State, Zip
S024781	40.1291	-123.867	Redwood Creek	220-261-003	0.0307	0	Statement of Div and Use	Claimed	John Angu	PO BOX 1957	REDWAY CA 95560-1957
S025316	40.1091	-123.892	Redwood Creek	220-241-17	0.1074	0	Statement of Div and Use	Claimed	Ram a	PO BX 2456	REDWAY CA 95560-2456
S028232	40.1109	-123.891	Redwood Creek	220-241-016	0.0104	0	Statement of Div and Use	Claimed	Bill Davidso	PO BOX 1003	REDWAY CA 95560-1003
A010198	40.12728	-123.853	Redwood Creek	222-171-004	0	13.4	Appropriative	Licensed	John Foster	PO BOX 193	GARBERVILLE CA 95542-0193
D032298	40.1105	-123.891	Redwood Creek	220-241-007	1.49	1.49	Registration Domestic	Registered	Cecilia Lanma	PO BX 1985	REDWAY CA 95560-1985
S024849	40.1093	-123.892	Redwood Creek	220-241-012	0.1013	0	Statement of Div and Use	Claimed	Katherine Wolman	PO BOX 1060	REDWAY CA 95560-1060
D032407	40.1098	-123.892	Redwood Creek	220-241-012	0.41	0.41	Registration Domestic	Registered	Katherine Wolman	PO BOX 1060	REDWAY CA 95560-1060
H500723	40.1098	-123.892	Redwood Creek	220-241-012	0.18	0.18	Registration Cannabis	Registered	Katherine Wolman	PO BOX 1060	REDWAY CA 95560-1060
S024232	40.1083	-123.897	Redwood Creek	220-251-029	0.31	0	Statement of Div and Use	Claimed	Mikal Jakuba	6070 BRICELAN D- THORNE	WHITETHORN CA 95560
H500603	40.1063	-123.9	Redwood Creek	220-252-034	0.18	0.18	Registration Cannabis	Registered	Monica Mohr	6152 BRICELAN D- THORNE	GARBERVILLE CA 95542
S026237	40.1063	-123.9	Redwood Creek	220-252-034	0.1534	0	Statement of Div and Use	Claimed	Monica Mohr	6152 BRICELAN D- THORNE	GARBERVILLE CA 95542

5.4 Expected Project Benefits

As previously described, this project will deliver ~30 gallons per minute of flow augmentation to Redwood Creek during the dry season with the purpose of enhancing aquatic habitat. See Figure 11 showing upstream extent of Redwood Creek flow enhancement reach. Recent flow enhancement initiatives in lower Russian River tributaries are analogous to this Project and have displayed that direct augmentation is one of the most successful approaches for enhancing dry-season streamflow. Flow releases from three different agricultural ponds in Sonoma County exhibit encouraging results. As described in Ruiz et al. (2019) of California Sea Grant, the project began in 2015 and is ongoing. Data show that flow augmentations in all years from 2015–2018 were able to appreciably increase wetted channel habitat, increase dissolved oxygen in the stream water, and decrease water temperature downstream from the flow augmentation release points. For example, releases into Dutch Bill Creek averaging 36 GPM beginning in late August of 2015 and were able to cumulatively re-wet more than 2,300 feet of stream channel with effects measurable up to 1.8 miles downstream.

While modest compared to winter flows, these augmentations have the potential to increase pool connectivity and water quality. A foundational hypothesis for this Project, that increased pool connectivity will bolster over-summer salmonid survival, is also supported by the work of Obedzinski et al. (2018). Their study found that days of disconnected surface flow showed a strong negative correlation with juvenile coho salmon survival rate in four tributaries to the Russian River. Provided this evidence, it is anticipated that the Project’s release of approximately 30 gallons per minute into Redwood Creek throughout the dry season can result in significant aquatic habitat benefit.

This project also has the added benefit of storage and forbearance whereby the landowner will capture water in the wet season and using it in the dry season allowing them to forebear on water diversions during the dry season for domestic and livestock uses. See Figure 12 showing the domestic and livestock grazing place of use.

Figure 11. Proposed upstream extent of flow augmentation reach where project will enhance fish and wildlife habitat (photo taken 28 September 2021).

Figure 12. Proposed place of use including livestock grazing area in foreground and residence/domestic place of use in background (photo taken 28 September 2021).

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Appendix D

HEC-RAS Hydraulic Model Outputs

HEC-RAS Plan: RedwoodCreek   River: REDWOOD   Reach: REDWOOD CREEK

Reach	River Sta	Profile	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Vel Total	Shear LOB	Shear ROB	Shear Total	Flow Area	Top Width	Froude # Chl
			(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(sq ft)	(ft)	
REDWOOD CREEK	5263	Summer	575.27		575.29	0.040225	1.19	1.19			0.22	0.84	9.44	0.70
REDWOOD CREEK	5263	Winter	576.77		576.88	0.005982	2.59	2.59			0.45	22.44	18.20	0.41
REDWOOD CREEK	5263	0.5 Bankfull	578.61		578.87	0.006499	4.07	4.07			0.90	63.96	27.60	0.47
REDWOOD CREEK	5263	1.5-yr	579.87		580.25	0.007485	4.95	4.95			1.25	104.96	37.48	0.52
REDWOOD CREEK	5263	2-yr	580.80		581.27	0.007572	5.51	5.51			1.47	143.25	43.86	0.54
REDWOOD CREEK	5263	5-yr	582.19		582.79	0.007281	6.20	6.20			1.74	211.44	52.64	0.54
REDWOOD CREEK	5263	10-yr	582.89		583.56	0.006888	6.59	6.59		0.09	1.85	248.89	54.55	0.54
REDWOOD CREEK	5263	25-yr	583.31		584.04	0.006672	6.85	6.84	0.05	0.15	1.90	271.97	56.28	0.54
REDWOOD CREEK	5263	50-yr	583.93		584.75	0.006426	7.27	7.20	0.12	0.23	1.87	308.16	62.45	0.54
REDWOOD CREEK	5263	100-yr	584.24		585.11	0.006335	7.49	7.37	0.19	0.27	1.88	328.37	64.92	0.54
REDWOOD CREEK	5083	Summer	574.05	573.86	574.05	0.002722	0.60	0.60			0.04	1.68	6.96	0.21
REDWOOD CREEK	5083	Winter	575.54	574.95	575.66	0.007768	2.83	2.83			0.54	20.49	17.72	0.46
REDWOOD CREEK	5083	0.5 Bankfull	576.97		577.33	0.011677	4.82	4.82			1.34	53.99	28.27	0.61
REDWOOD CREEK	5083	1.5-yr	578.16		578.67	0.010280	5.76	5.76		0.02	1.69	90.29	32.61	0.61
REDWOOD CREEK	5083	2-yr	579.04		579.71	0.009769	6.59	6.47		0.33	1.82	122.08	38.65	0.61
REDWOOD CREEK	5083	5-yr	580.19		581.18	0.010688	8.07	7.73		0.80	2.43	169.40	43.61	0.67
REDWOOD CREEK	5083	10-yr	580.80		581.97	0.011031	8.80	8.31		0.96	2.69	197.45	47.37	0.69
REDWOOD CREEK	5083	25-yr	581.20		582.46	0.011074	9.18	8.58		1.06	2.80	216.80	50.12	0.69
REDWOOD CREEK	5083	50-yr	581.84		583.22	0.010848	9.65	8.87		1.22	2.92	250.36	54.30	0.69
REDWOOD CREEK	5083	100-yr	582.19		583.61	0.010574	9.83	8.97	0.03	1.32	2.96	269.74	56.27	0.69
REDWOOD CREEK	4964	Summer	573.04	573.04	573.09	0.103940	1.68	1.68			0.48	0.59	8.07	1.09
REDWOOD CREEK	4964	Winter	574.07		574.27	0.019233	3.61	3.61			0.98	16.08	19.41	0.70
REDWOOD CREEK	4964	0.5 Bankfull	576.05		576.29	0.006379	3.91	3.91			0.84	66.48	30.42	0.47
REDWOOD CREEK	4964	1.5-yr	577.34		577.70	0.006141	4.79	4.79			1.13	108.59	35.07	0.48
REDWOOD CREEK	4964	2-yr	578.23		578.71	0.006594	5.54	5.36	0.11		0.99	147.26	58.87	0.51
REDWOOD CREEK	4964	5-yr	579.56		580.14	0.005812	6.30	5.64	0.48	0.10	1.18	232.25	68.62	0.50
REDWOOD CREEK	4964	10-yr	580.33		580.94	0.005186	6.56	5.72	0.62	0.19	1.22	286.48	72.86	0.49
REDWOOD CREEK	4964	25-yr	580.82		581.44	0.004823	6.68	5.76	0.68	0.24	1.23	322.84	75.48	0.47
REDWOOD CREEK	4964	50-yr	581.59		582.22	0.004316	6.84	5.81	0.77	0.30	1.25	382.23	78.61	0.46
REDWOOD CREEK	4964	100-yr	581.99		582.64	0.004087	6.91	5.84	0.80	0.33	1.26	414.52	79.91	0.45
REDWOOD CREEK	4842	Summer	572.27		572.27	0.000029	0.11	0.11			0.00	9.11	15.82	0.03
REDWOOD CREEK	4842	Winter	573.80		573.84	0.001227	1.46	1.46			0.13	39.70	22.97	0.20
REDWOOD CREEK	4842	0.5 Bankfull	575.64		575.77	0.002643	2.92	2.92			0.44	89.04	31.99	0.31
REDWOOD CREEK	4842	1.5-yr	576.87		577.10	0.003533	3.87	3.83	0.04	0.03	0.61	135.77	47.40	0.37
REDWOOD CREEK	4842	2-yr	577.75		578.07	0.003627	4.57	4.34	0.17	0.12	0.70	182.00	56.28	0.39
REDWOOD CREEK	4842	5-yr	579.09		579.54	0.003673	5.52	5.00	0.39	0.26	0.91	262.19	63.29	0.41
REDWOOD CREEK	4842	10-yr	579.89		580.39	0.003502	5.89	5.23	0.50	0.34	0.99	313.57	66.06	0.41
REDWOOD CREEK	4842	25-yr	580.39		580.92	0.003388	6.09	5.35	0.55	0.37	1.02	347.35	68.06	0.41
REDWOOD CREEK	4842	50-yr	581.18		581.75	0.003235	6.39	5.52	0.60	0.42	1.06	402.49	72.83	0.41
REDWOOD CREEK	4842	100-yr	581.59		582.18	0.003159	6.54	5.58	0.61	0.45	1.07	433.39	75.75	0.40
REDWOOD CREEK	4731	Summer	572.27		572.27	0.000002	0.05	0.05			0.00	19.63	15.96	0.01
REDWOOD CREEK	4731	Winter	573.72		573.74	0.000622	1.20	1.19	0.01		0.07	48.92	25.09	0.14
REDWOOD CREEK	4731	0.5 Bankfull	575.41		575.53	0.001806	2.83	2.67	0.13		0.32	97.55	32.52	0.26
REDWOOD CREEK	4731	1.5-yr	576.49		576.75	0.002829	4.20	3.82	0.31	0.08	0.59	136.03	38.31	0.34
REDWOOD CREEK	4731	2-yr	577.25		577.66	0.003718	5.32	4.75	0.51	0.20	0.88	166.28	40.97	0.40
REDWOOD CREEK	4731	5-yr	578.34		579.04	0.005169	7.09	6.16	0.89	0.46	1.43	212.65	44.61	0.49
REDWOOD CREEK	4731	10-yr	579.03		579.87	0.005509	7.84	6.72	1.09	0.60	1.67	244.17	46.32	0.52
REDWOOD CREEK	4731	25-yr	579.48		580.41	0.005607	8.24	7.01	1.21	0.68	1.80	265.44	47.34	0.53
REDWOOD CREEK	4731	50-yr	580.20		581.24	0.005669	8.79	7.40	1.38	0.79	1.97	299.91	48.85	0.54
REDWOOD CREEK	4731	100-yr	580.58		581.68	0.005678	9.07	7.59	1.46	0.85	2.06	318.71	49.62	0.54
REDWOOD CREEK	4614	Summer	572.26	572.14	572.27	0.006298	0.72	0.72			0.07	1.39	8.17	0.31
REDWOOD CREEK	4614	Winter	573.38	573.01	573.53	0.011552	3.10	3.10			0.69	18.71	18.98	0.55
REDWOOD CREEK	4614	0.5 Bankfull	574.32	574.32	574.92	0.035669	6.20	6.20			2.59	41.93	35.23	1.00
REDWOOD CREEK	4614	1.5-yr	575.03	575.03	575.89	0.032660	7.47	7.47			3.34	69.65	41.34	1.01
REDWOOD CREEK	4614	2-yr	575.77	575.62	576.70	0.024614	7.72	7.72			3.28	102.27	46.56	0.92
REDWOOD CREEK	4614	5-yr	577.44		578.17	0.011207	6.88	6.88			2.26	190.36	56.74	0.66
REDWOOD CREEK	4614	10-yr	578.33		579.04	0.008458	6.78	6.78			2.06	241.86	59.21	0.59
REDWOOD CREEK	4614	25-yr	578.88		579.59	0.007416	6.76	6.76			1.99	274.98	60.99	0.56
REDWOOD CREEK	4614	50-yr	579.72		580.43	0.006355	6.77	6.77			1.92	327.76	64.37	0.53
REDWOOD CREEK	4614	100-yr	580.16		580.88	0.005976	6.78	6.78			1.89	356.74	66.70	0.52
REDWOOD CREEK	4489	Summer	570.12	570.12	570.15	0.128059	1.44	1.44			0.40	0.70	14.00	1.14
REDWOOD CREEK	4489	Winter	570.70	570.70	570.98	0.044812	4.21	4.21			1.53	13.77	24.92	1.00
REDWOOD CREEK	4489	0.5 Bankfull	572.41		572.66	0.008043	4.01	4.01			0.93	64.79	34.04	0.51
REDWOOD CREEK	4489	1.5-yr	573.93		574.22	0.005014	4.32	4.32			0.92	120.49	38.88	0.43
REDWOOD CREEK	4489	2-yr	575.11		575.45	0.004328	4.70	4.70			1.01	168.17	42.10	0.41
REDWOOD CREEK	4489	5-yr	576.87		577.31	0.003958	5.31	5.31			1.18	246.68	47.27	0.41
REDWOOD CREEK	4489	10-yr	577.80		578.29	0.003865	5.62	5.62			1.28	291.96	50.26	0.41
REDWOOD CREEK	4489	25-yr	578.36		578.88	0.003824	5.79	5.79			1.34	320.97	52.19	0.41
REDWOOD CREEK	4489	50-yr	579.22		579.79	0.003778	6.05	6.05			1.42	367.16	55.38	0.41
REDWOOD CREEK	4489	100-yr	579.66		580.26	0.003772	6.17	6.17			1.46	392.07	57.25	0.42
REDWOOD CREEK	4423	Summer	568.77		568.77	0.000933	0.31	0.31			0.01	3.28	16.78	0.12
REDWOOD CREEK	4423	Winter	570.29		570.33	0.001576	1.48	1.48			0.14	39.12	26.85	0.22
REDWOOD CREEK	4423	0.5 Bankfull	572.27		572.37	0.002059	2.59	2.59			0.34	100.27	35.10	0.27
REDWOOD CREEK	4423	1.5-yr	573.80		573.97	0.002183	3.28	3.28			0.49	158.51	39.79	0.29
REDWOOD CREEK	4423	2-yr	574.98		575.21	0.002296	3.82	3.82			0.63	206.74	42.04	0.30
REDWOOD CREEK	4423	5-yr	576.74		577.07	0.002557	4.60	4.60			0.86	284.66	46.66	0.33
REDWOOD CREEK	4423	10-yr	577.66		578.04	0.002675	4.99	4.99			0.98	328.79	49.00	0.34
REDWOOD CREEK	4423	25-yr	578.22		578.64	0.002728	5.21	5.21			1.05	356.68	50.16	0.34
REDWOOD CREEK	4423	50-yr	579.07		579.55	0.002799	5.55	5.55			1.16	400.02	51.74	0.35
REDWOOD CREEK	4423	100-yr	579.51		580.02	0.002840	5.72	5.72			1.22	422.75	52.51	0.36
REDWOOD CREEK	4293	Summer	568.29	568.29	568.37	0.069131	2.25	2.25			0.67	0.44	2.80	1.00
REDWOOD CREEK	4293	Winter	569.47		569.77	0.026560	4.42	4.42			1.44	13.13	14.46	0.82
REDWOOD CREEK	4293	0.5 Bankfull	571.02		571.70	0.020737	6.59	6.59			2.47	39.48	19.08	0.81
REDWOOD CREEK	4293	1.5-yr	572.29		573.25	0.019516	7.86	7.86			3.18	66.12	22.99	0.82
REDWOOD CREEK	4293	2-yr	573.18	572.80	574.44	0.020701	8.98	8.98			3.93	87.98	26.06	0.86
REDWOOD CREEK	4293	5-yr	574.43	574.17	576.19	0.020859	10.66	10.52	0.53	0.40	4.45	124.50	32.98	0.90
REDWOOD CREEK	4293	10-yr	575.04	574.88	577.12	0.020937	11.64	11.32	1.08	0.75	4.89	144.93	34.94	0.92
REDWOOD CREEK	4293	25-yr	575.40	575.32	577.69	0.020965	12.22	11.77	1.39	0.96	5.16	158.02	36.07	0.93
REDWOOD CREEK	4293	50-yr	575.99	575.97	578.56	0.020725	13.02	12.36	1.79	1.29	5.50	179.54	37.88	0.94
REDWOOD CREEK	4293	100-yr	576.32	576.32	579.02	0.020240	13.35	12.58	1.96	1.44	5.59	192.44	38.99	0.94
REDWOOD CREEK	4182	Summer	567.31	567.07	567.31	0.001471	0.46	0.46			0.02	2.19	8.63	0.16
REDWOOD CREEK	4182	Winter	568.86		568.91	0.003206	1.83	1.83			0.23	31.77	27.72	0.30

HEC-RAS Plan: RedwoodCreek   River: REDWOOD   Reach: REDWOOD CREEK (Continued)

Reach	River Sta	Profile	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Vel Total	Shear LOB	Shear ROB	Shear Total	Flow Area	Top Width	Froude # Chl
			(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(sq ft)	(ft)	
REDWOOD CREEK	4182	0.5 Bankfull	570.78		570.91	0.002553	2.85	2.85			0.42	91.12	32.90	0.30
REDWOOD CREEK	4182	1.5-yr	572.12		572.34	0.003022	3.80	3.80	0.01		0.64	136.77	37.21	0.34
REDWOOD CREEK	4182	2-yr	573.09		573.41	0.003292	4.58	4.46	0.13	0.04	0.74	177.10	45.33	0.37
REDWOOD CREEK	4182	5-yr	574.56		575.03	0.003453	5.61	5.15	0.31	0.14	0.89	254.19	56.92	0.39
REDWOOD CREEK	4182	10-yr	575.32		575.87	0.003530	6.12	5.48	0.40	0.20	0.98	299.32	62.24	0.41
REDWOOD CREEK	4182	25-yr	575.80		576.39	0.003542	6.40	5.64	0.45	0.24	1.03	329.96	66.04	0.41
REDWOOD CREEK	4182	50-yr	576.56		577.21	0.003462	6.75	5.81	0.54	0.28	1.09	381.83	70.44	0.41
REDWOOD CREEK	4182	100-yr	576.95		577.63	0.003433	6.93	5.90	0.58	0.27	1.10	410.21	74.17	0.42
REDWOOD CREEK	4076	Summer	566.75	566.75	566.81	0.103643	1.82	1.82			0.54	0.55	6.65	1.11
REDWOOD CREEK	4076	Winter	568.59		568.63	0.002165	1.57	1.57			0.16	36.94	30.06	0.25
REDWOOD CREEK	4076	0.5 Bankfull	570.57		570.67	0.001945	2.52	2.52			0.32	103.25	37.26	0.27
REDWOOD CREEK	4076	1.5-yr	571.87		572.05	0.002364	3.36	3.36			0.52	154.66	41.24	0.31
REDWOOD CREEK	4076	2-yr	572.81		573.07	0.002830	4.05	4.05			0.73	194.95	44.52	0.34
REDWOOD CREEK	4076	5-yr	574.27		574.65	0.003290	4.95	4.90	0.01	0.09	0.90	267.45	57.25	0.38
REDWOOD CREEK	4076	10-yr	575.04		575.48	0.003235	5.37	5.24	0.06	0.21	0.98	313.16	60.35	0.38
REDWOOD CREEK	4076	25-yr	575.52		576.01	0.003191	5.62	5.43	0.10	0.28	1.03	342.51	61.32	0.39
REDWOOD CREEK	4076	50-yr	576.30		576.83	0.003072	5.93	5.62	0.14	0.19	0.89	395.25	80.08	0.39
REDWOOD CREEK	4076	100-yr	576.70		577.25	0.003005	6.08	5.62	0.16	0.18	0.80	430.45	94.57	0.39
REDWOOD CREEK	3973	Summer	566.43		566.43	0.000097	0.13	0.13			0.00	7.91	27.85	0.04
REDWOOD CREEK	3973	Winter	568.57		568.57	0.000205	0.70	0.70			0.03	83.33	38.10	0.08
REDWOOD CREEK	3973	0.5 Bankfull	570.51		570.55	0.000544	1.61	1.61			0.12	161.36	42.18	0.15
REDWOOD CREEK	3973	1.5-yr	571.79		571.88	0.000903	2.40	2.40			0.25	216.78	44.66	0.19
REDWOOD CREEK	3973	2-yr	572.70		572.85	0.001246	3.06	3.06			0.39	258.53	46.58	0.23
REDWOOD CREEK	3973	5-yr	574.13		574.38	0.001600	3.99	3.85	0.06	0.03	0.45	340.21	69.79	0.27
REDWOOD CREEK	3973	10-yr	574.91		575.20	0.001701	4.41	4.12	0.12	0.05	0.49	398.38	79.63	0.28
REDWOOD CREEK	3973	25-yr	575.40		575.72	0.001730	4.64	4.25	0.16	0.06	0.53	438.14	82.67	0.29
REDWOOD CREEK	3973	50-yr	576.19		576.54	0.001717	4.92	4.40	0.23	0.08	0.58	504.80	85.70	0.29
REDWOOD CREEK	3973	100-yr	576.60		576.97	0.001711	5.06	4.48	0.27	0.09	0.60	540.13	87.37	0.29
REDWOOD CREEK	3838	Summer	566.40		566.40	0.001361	0.42	0.42			0.02	2.36	9.73	0.15
REDWOOD CREEK	3838	Winter	568.41		568.47	0.003459	2.10	2.10			0.28	41.88	30.81	0.32
REDWOOD CREEK	3838	0.5 Bankfull	570.08	568.78	570.32	0.005465	3.93	3.77		0.23	0.70	106.11	49.40	0.44
REDWOOD CREEK	3838	1.5-yr	571.12		571.52	0.006829	5.21	4.79	0.12	0.51	0.97	167.09	70.82	0.51
REDWOOD CREEK	3838	2-yr	571.91		572.42	0.006748	5.99	5.28	0.32	0.76	1.13	227.29	81.56	0.53
REDWOOD CREEK	3838	5-yr	573.30		573.92	0.005805	6.78	5.49	0.59	0.63	1.11	364.44	115.60	0.51
REDWOOD CREEK	3838	10-yr	574.18		574.77	0.004818	6.83	5.33	0.72	0.72	1.13	469.44	121.60	0.48
REDWOOD CREEK	3838	25-yr	574.74		575.31	0.004256	6.80	5.28	0.76	0.77	1.12	538.25	123.30	0.46
REDWOOD CREEK	3838	50-yr	575.62		576.17	0.003604	6.78	5.25	0.80	0.81	1.12	647.95	126.05	0.43
REDWOOD CREEK	3838	100-yr	576.06		576.61	0.003377	6.81	5.26	0.83	0.82	1.11	703.95	128.33	0.42
REDWOOD CREEK	3710	Summer	566.09	565.95	566.09	0.005616	0.60	0.60			0.05	1.67	11.72	0.28
REDWOOD CREEK	3710	Winter	567.04	567.04	567.35	0.046549	4.48	4.48			1.70	19.66	33.08	1.02
REDWOOD CREEK	3710	0.5 Bankfull	568.08	568.08	568.84	0.033803	6.99	6.99			3.06	57.20	38.41	1.01
REDWOOD CREEK	3710	1.5-yr	569.62		570.27	0.014264	6.51	6.48	0.12	0.06	2.04	123.41	52.03	0.72
REDWOOD CREEK	3710	2-yr	570.77		571.42	0.008787	6.54	6.04	0.40	0.24	1.25	198.79	85.23	0.60
REDWOOD CREEK	3710	5-yr	572.65		573.22	0.004892	6.41	5.47	0.67	0.64	1.17	365.91	92.25	0.48
REDWOOD CREEK	3710	10-yr	573.64		574.20	0.004036	6.48	5.45	0.73	0.72	1.16	458.41	95.59	0.45
REDWOOD CREEK	3710	25-yr	574.23		574.80	0.003702	6.58	5.50	0.77	0.77	1.18	516.00	97.28	0.43
REDWOOD CREEK	3710	50-yr	575.13		575.72	0.003357	6.78	5.63	0.81	0.83	1.21	604.40	100.16	0.42
REDWOOD CREEK	3710	100-yr	575.57		576.18	0.003228	6.89	5.70	0.84	0.86	1.23	649.28	101.47	0.42
REDWOOD CREEK	3616	Summer	564.70	564.70	564.73	0.097055	1.43	1.43			0.37	0.70	11.46	1.02
REDWOOD CREEK	3616	Winter	565.95		566.01	0.003615	1.89	1.89			0.25	46.63	42.67	0.32
REDWOOD CREEK	3616	0.5 Bankfull	567.92		568.05	0.002538	2.89	2.89			0.43	138.28	50.11	0.31
REDWOOD CREEK	3616	1.5-yr	569.46		569.67	0.002506	3.65	3.65			0.60	219.48	54.87	0.32
REDWOOD CREEK	3616	2-yr	570.65		570.92	0.002436	4.15	4.04	0.12		0.61	297.10	70.78	0.33
REDWOOD CREEK	3616	5-yr	572.50		572.86	0.002229	4.89	4.57	0.27	0.08	0.71	437.88	81.39	0.33
REDWOOD CREEK	3616	10-yr	573.48		573.88	0.002148	5.25	4.80	0.34	0.11	0.75	520.55	88.14	0.33
REDWOOD CREEK	3616	25-yr	574.07		574.51	0.002120	5.47	4.95	0.37	0.14	0.78	574.15	92.34	0.33
REDWOOD CREEK	3616	50-yr	574.96		575.45	0.002086	5.81	5.16	0.43	0.19	0.83	659.33	98.10	0.34
REDWOOD CREEK	3616	100-yr	575.41		575.91	0.002069	5.97	5.26	0.47	0.21	0.86	703.52	100.47	0.34
REDWOOD CREEK	3496	Summer	563.68		563.68	0.000768	0.36	0.36			0.01	2.75	9.29	0.12
REDWOOD CREEK	3496	Winter	565.54		565.60	0.003264	1.96	1.87	0.03	0.10	0.22	47.12	42.72	0.31
REDWOOD CREEK	3496	0.5 Bankfull	567.63		567.77	0.002162	3.07	2.82	0.13	0.28	0.38	141.62	47.44	0.30
REDWOOD CREEK	3496	1.5-yr	569.13		569.37	0.002381	4.12	3.71	0.24	0.44	0.59	215.39	50.76	0.33
REDWOOD CREEK	3496	2-yr	570.27		570.61	0.002569	4.92	4.38	0.34	0.57	0.77	274.21	52.78	0.35
REDWOOD CREEK	3496	5-yr	572.00		572.54	0.002940	6.24	5.43	0.51	0.80	1.09	368.29	56.08	0.40
REDWOOD CREEK	3496	10-yr	572.89		573.55	0.003166	6.96	5.96	0.62	0.88	1.26	419.25	59.23	0.42
REDWOOD CREEK	3496	25-yr	573.42		574.16	0.003319	7.42	6.29	0.70	0.94	1.37	451.19	61.25	0.43
REDWOOD CREEK	3496	50-yr	574.20		575.08	0.003573	8.13	6.80	0.82	1.02	1.55	500.34	64.72	0.46
REDWOOD CREEK	3496	100-yr	574.59		575.54	0.003696	8.48	7.04	0.88	1.07	1.64	525.65	66.47	0.47
REDWOOD CREEK	3359	Summer	563.68		563.68	0.000001	0.04	0.04			0.00	27.17	19.05	0.01
REDWOOD CREEK	3359	Winter	565.38		565.41	0.000692	1.36	1.36			0.10	64.93	25.89	0.15
REDWOOD CREEK	3359	0.5 Bankfull	567.29		567.43	0.002753	3.05	3.05			0.47	131.20	44.33	0.31
REDWOOD CREEK	3359	1.5-yr	568.74		569.00	0.003215	4.04	4.04			0.74	198.25	48.69	0.35
REDWOOD CREEK	3359	2-yr	569.85		570.20	0.003563	4.71	4.71			0.96	254.70	53.19	0.38
REDWOOD CREEK	3359	5-yr	571.55		572.06	0.004023	5.70	5.70			1.32	350.73	59.73	0.41
REDWOOD CREEK	3359	10-yr	572.43		573.03	0.004251	6.17	6.17			1.51	405.30	63.87	0.43
REDWOOD CREEK	3359	25-yr	572.97		573.62	0.004248	6.45	6.45	0.04	0.02	1.59	440.15	65.62	0.44
REDWOOD CREEK	3359	50-yr	573.77		574.51	0.004205	6.91	6.88	0.11	0.10	1.66	493.91	69.93	0.44
REDWOOD CREEK	3359	100-yr	574.16		574.95	0.004201	7.15	7.09	0.16	0.13	1.70	521.87	72.17	0.45
REDWOOD CREEK	3260	Summer	563.68	563.28	563.68	0.000061	0.11	0.11			0.00	9.10	27.82	0.03
REDWOOD CREEK	3260	Winter	565.30	564.04	565.33	0.000996	1.28	1.28			0.10	68.94	42.42	0.18
REDWOOD CREEK	3260	0.5 Bankfull	567.09	565.07	567.20	0.001872	2.68	2.68			0.35	149.41	47.48	0.27
REDWOOD CREEK	3260	1.5-yr	568.50	565.92	568.71	0.002324	3.66	3.66			0.59	218.31	49.72	0.31
REDWOOD CREEK	3260	2-yr	569.58	566.62	569.88	0.002663	4.41	4.41			0.81	272.38	51.05	0.34
REDWOOD CREEK	3260	5-yr	571.21	567.77	571.70	0.003215	5.60	5.60	0.02		1.20	357.28	52.95	0.38
REDWOOD CREEK	3260	10-yr	572.04	568.39	572.64	0.003495	6.23	6.22	0.05		1.42	401.61	53.93	0.40
REDWOOD CREEK	3260	25-yr	572.54	568.79	573.22	0.003675	6.63	6.62	0.07	0.01	1.56	428.79	54.52	0.41
REDWOOD CREEK	3260	50-yr	573.28	569.39	574.10	0.003916	7.26	7.24	0.10	0.07	1.77	469.41	55.36	0.43
REDWOOD CREEK	3260	100-yr	573.64	569.71	574.53	0.004050	7.59	7.56	0.11	0.10	1.89	489.37	55.76	0.44
REDWOOD CREEK	3164	Summer	563.68	562.11	563.68	0.000002	0.04	0.04			0.00	26.50	31.43	0.01
REDWOOD CREEK	3164	Winter	565.24	563.38	565.26	0.000474	1.02	1.02			0.06	86.30	41.99	0.13
REDWOOD CREEK	3164	0.5 Bankfull	566.94	564.54	567.04	0.001438	2.47	2.47			0.29	162.05	47.03	0.23
REDWOOD CREEK	3164	1.5-yr	568.31	565.44	568.50	0.002073	3.50	3.50			0.54	228.88	51.14	0.29

HEC-RAS Plan: RedwoodCreek   River: REDWOOD   Reach: REDWOOD CREEK (Continued)

Reach	River Sta	Profile	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Vel Total	Shear LOB	Shear ROB	Shear Total	Flow Area	Top Width	Froude # Chl
			(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(sq ft)	(ft)	
REDWOOD CREEK	3164	2-yr	569.35	566.16	569.63	0.002410	4.23	4.22	0.05	0.01	0.70	284.25	56.20	0.32
REDWOOD CREEK	3164	5-yr	570.95	567.36	571.40	0.002759	5.39	5.26	0.20	0.16	0.95	380.36	63.39	0.36
REDWOOD CREEK	3164	10-yr	571.77	568.01	572.32	0.002935	5.99	5.77	0.29	0.22	1.09	433.53	66.49	0.38
REDWOOD CREEK	3164	25-yr	572.27	568.42	572.88	0.003053	6.36	6.08	0.35	0.26	1.19	466.92	68.32	0.39
REDWOOD CREEK	3164	50-yr	573.00	569.03	573.73	0.003244	6.94	6.56	0.44	0.33	1.34	518.29	71.40	0.41
REDWOOD CREEK	3164	100-yr	573.36	569.36	574.15	0.003352	7.24	6.80	0.47	0.36	1.41	544.10	73.53	0.42
REDWOOD CREEK	3022	Summer	563.68		563.68	0.000741	0.30	0.30			0.01	3.32	14.55	0.11
REDWOOD CREEK	3022	Winter	565.02		565.10	0.005081	2.16	2.16			0.33	40.65	38.89	0.37
REDWOOD CREEK	3022	0.5 Bankfull	566.38		566.64	0.006979	4.05	4.05			0.91	98.76	46.33	0.49
REDWOOD CREEK	3022	1.5-yr	567.59		567.99	0.006824	5.08	5.08			1.27	157.54	51.23	0.51
REDWOOD CREEK	3022	2-yr	568.57		569.08	0.006583	5.73	5.72		0.03	1.45	209.72	57.33	0.52
REDWOOD CREEK	3022	5-yr	570.15		570.82	0.005950	6.61	6.46		0.36	1.61	309.48	68.48	0.52
REDWOOD CREEK	3022	10-yr	570.98		571.73	0.005739	7.03	6.80		0.55	1.75	367.74	72.16	0.52
REDWOOD CREEK	3022	25-yr	571.49		572.30	0.005524	7.28	6.93	0.10	0.66	1.54	409.59	88.50	0.51
REDWOOD CREEK	3022	50-yr	572.28		573.15	0.005150	7.60	7.04	0.28	0.77	1.54	482.81	96.82	0.51
REDWOOD CREEK	3022	100-yr	572.67		573.57	0.004992	7.76	7.10	0.36	0.83	1.57	521.14	99.42	0.50
REDWOOD CREEK	2904	Summer	563.51	563.42	563.51	0.004016	0.41	0.41			0.03	2.42	23.59	0.23
REDWOOD CREEK	2904	Winter	564.38		564.45	0.005882	1.99	1.99			0.30	44.28	54.15	0.39
REDWOOD CREEK	2904	0.5 Bankfull	565.84		566.00	0.003941	3.22	3.16	0.16	0.14	0.52	126.59	58.79	0.38
REDWOOD CREEK	2904	1.5-yr	567.14		567.39	0.003373	4.02	3.85	0.21	0.23	0.64	208.02	66.55	0.37
REDWOOD CREEK	2904	2-yr	568.19		568.50	0.003105	4.58	4.29	0.32	0.29	0.74	279.77	70.62	0.38
REDWOOD CREEK	2904	5-yr	569.84		570.27	0.002927	5.45	5.01	0.51	0.39	0.94	399.30	74.01	0.38
REDWOOD CREEK	2904	10-yr	570.68		571.19	0.002939	5.94	5.41	0.60	0.44	1.05	462.08	75.94	0.39
REDWOOD CREEK	2904	25-yr	571.19		571.76	0.002960	6.24	5.66	0.66	0.47	1.13	501.65	77.22	0.40
REDWOOD CREEK	2904	50-yr	571.98		572.62	0.003001	6.71	6.04	0.75	0.52	1.25	563.07	79.21	0.41
REDWOOD CREEK	2904	100-yr	572.36		573.05	0.003036	6.95	6.23	0.80	0.55	1.31	593.56	80.16	0.41
REDWOOD CREEK	2821	Summer	562.62	562.62	562.64	0.067118	1.28	1.28			0.28	0.78	11.54	0.87
REDWOOD CREEK	2821	Winter	563.78		563.88	0.008135	2.47	2.47			0.45	35.62	39.84	0.46
REDWOOD CREEK	2821	0.5 Bankfull	565.36		565.60	0.005879	3.90	3.90			0.82	102.46	44.17	0.45
REDWOOD CREEK	2821	1.5-yr	566.63		567.01	0.005917	5.00	5.00			1.20	159.90	46.87	0.48
REDWOOD CREEK	2821	2-yr	567.61		568.13	0.006147	5.80	5.80			1.51	207.02	49.55	0.50
REDWOOD CREEK	2821	5-yr	569.14		569.90	0.006485	6.98	6.94	0.13		1.87	288.00	58.31	0.53
REDWOOD CREEK	2821	10-yr	569.91		570.80	0.006501	7.58	7.46	0.33	0.06	1.99	335.03	63.93	0.54
REDWOOD CREEK	2821	25-yr	570.40		571.37	0.006444	7.95	7.74	0.45	0.18	2.06	366.82	67.27	0.55
REDWOOD CREEK	2821	50-yr	571.13		572.23	0.006370	8.48	8.14	0.63	0.35	2.20	417.52	70.80	0.55
REDWOOD CREEK	2821	100-yr	571.48		572.65	0.006379	8.76	8.35	0.72	0.42	2.28	442.89	72.48	0.56
REDWOOD CREEK	2700	Summer	562.01		562.01	0.000732	0.23	0.23			0.01	4.42	29.59	0.10
REDWOOD CREEK	2700	Winter	563.40		563.44	0.001901	1.53	1.53			0.15	57.48	44.38	0.24
REDWOOD CREEK	2700	0.5 Bankfull	565.00		565.12	0.002480	2.79	2.71	0.09	0.07	0.35	147.35	64.23	0.30
REDWOOD CREEK	2700	1.5-yr	566.34		566.53	0.002340	3.57	3.33	0.18	0.17	0.46	240.58	75.52	0.32
REDWOOD CREEK	2700	2-yr	567.37		567.62	0.002278	4.11	3.71	0.25	0.21	0.53	323.48	85.59	0.33
REDWOOD CREEK	2700	5-yr	569.01		569.34	0.002190	4.88	4.21	0.35	0.33	0.65	475.05	98.85	0.33
REDWOOD CREEK	2700	10-yr	569.85		570.23	0.002174	5.26	4.46	0.41	0.41	0.71	560.12	104.60	0.34
REDWOOD CREEK	2700	25-yr	570.37		570.78	0.002160	5.48	4.61	0.44	0.44	0.75	615.81	107.97	0.34
REDWOOD CREEK	2700	50-yr	571.17		571.62	0.002141	5.82	4.83	0.51	0.49	0.81	704.06	113.08	0.35
REDWOOD CREEK	2700	100-yr	571.55		572.03	0.002154	6.00	4.95	0.55	0.44	0.83	747.88	118.34	0.35
REDWOOD CREEK	2600.03	Summer	561.90		561.90	0.002082	0.39	0.39			0.02	2.59	16.96	0.17
REDWOOD CREEK	2600.03	Winter	563.07		563.14	0.005043	2.13	2.11	0.08		0.31	41.63	42.16	0.37
REDWOOD CREEK	2600.03	0.5 Bankfull	564.56		564.77	0.005141	3.72	3.63	0.36		0.70	110.08	49.19	0.43
REDWOOD CREEK	2600.03	1.5-yr	565.87		566.19	0.004969	4.60	4.47	0.54		0.96	179.11	56.49	0.45
REDWOOD CREEK	2600.03	2-yr	566.87		567.29	0.004716	5.23	5.05	0.63		1.13	237.75	59.71	0.45
REDWOOD CREEK	2600.03	5-yr	568.42		569.01	0.004654	6.25	5.99	0.81	0.06	1.43	334.09	64.84	0.47
REDWOOD CREEK	2600.03	10-yr	569.18		569.89	0.004708	6.85	6.49	0.85	0.12	1.54	384.93	69.96	0.48
REDWOOD CREEK	2600.03	25-yr	569.66		570.43	0.004733	7.21	6.78	0.89	0.21	1.62	418.92	72.86	0.49
REDWOOD CREEK	2600.03	50-yr	570.38		571.27	0.004773	7.75	7.19	0.95	0.34	1.75	472.87	76.67	0.50
REDWOOD CREEK	2600.03	100-yr	570.72		571.67	0.004850	8.04	7.42	0.99	0.40	1.83	498.87	78.65	0.51
REDWOOD CREEK	2498.75	Summer	561.25	561.25	561.27	0.071949	1.36	1.36			0.32	0.74	10.49	0.90
REDWOOD CREEK	2498.75	Winter	562.34		562.45	0.009741	2.72	2.72			0.54	32.35	35.98	0.51
REDWOOD CREEK	2498.75	0.5 Bankfull	564.14		564.31	0.003896	3.34	3.25	0.22	0.18	0.54	123.15	54.56	0.38
REDWOOD CREEK	2498.75	1.5-yr	565.49		565.75	0.003433	4.21	4.01	0.32	0.30	0.71	199.39	58.29	0.38
REDWOOD CREEK	2498.75	2-yr	566.51		566.87	0.003394	4.91	4.61	0.41	0.36	0.86	260.47	61.65	0.40
REDWOOD CREEK	2498.75	5-yr	568.04		568.58	0.003584	6.07	5.56	0.57	0.51	1.13	359.63	67.51	0.43
REDWOOD CREEK	2498.75	10-yr	568.79		569.45	0.003777	6.72	6.08	0.69	0.59	1.31	410.90	70.04	0.44
REDWOOD CREEK	2498.75	25-yr	569.26		569.99	0.003898	7.12	6.40	0.77	0.61	1.41	443.95	72.50	0.46
REDWOOD CREEK	2498.75	50-yr	569.91		570.81	0.004299	7.90	6.87	0.94	0.28	1.22	494.70	104.76	0.49
REDWOOD CREEK	2498.75	100-yr	570.23		571.20	0.004418	8.21	6.92	1.00	0.26	1.09	534.48	131.18	0.50
REDWOOD CREEK	2339.37	Summer	560.45		560.45	0.000003	0.05	0.05			0.00	18.92	20.02	0.01
REDWOOD CREEK	2339.37	Winter	561.93		561.96	0.001388	1.45	1.45			0.13	60.75	39.57	0.21
REDWOOD CREEK	2339.37	0.5 Bankfull	563.68		563.81	0.002424	2.90	2.90			0.42	137.79	47.23	0.30
REDWOOD CREEK	2339.37	1.5-yr	564.99		565.23	0.003093	3.95	3.95			0.71	202.32	51.76	0.35
REDWOOD CREEK	2339.37	2-yr	565.96		566.31	0.003566	4.71	4.71			0.96	254.70	55.35	0.39
REDWOOD CREEK	2339.37	5-yr	567.44		567.98	0.003973	5.91	5.88	0.10	0.12	1.30	340.41	60.68	0.43
REDWOOD CREEK	2339.37	10-yr	568.12		568.80	0.004310	6.61	6.53	0.17	0.21	1.51	382.62	63.34	0.45
REDWOOD CREEK	2339.37	25-yr	568.54		569.31	0.004518	7.05	6.92	0.22	0.20	1.57	410.35	68.42	0.47
REDWOOD CREEK	2339.37	50-yr	569.15		570.08	0.004884	7.75	7.48	0.30	0.22	1.61	454.63	80.54	0.49
REDWOOD CREEK	2339.37	100-yr	569.42		570.44	0.005118	8.12	7.74	0.34	0.23	1.59	477.98	90.29	0.51
REDWOOD CREEK	2258	Summer	560.45		560.45	0.000007	0.06	0.06			0.00	15.88	21.98	0.01
REDWOOD CREEK	2258	Winter	561.82		561.86	0.001219	1.43	1.43			0.12	61.62	37.19	0.20
REDWOOD CREEK	2258	0.5 Bankfull	563.44		563.60	0.002780	3.15	3.15			0.50	126.81	42.44	0.32
REDWOOD CREEK	2258	1.5-yr	564.63		564.94	0.003930	4.48	4.48			0.91	178.58	45.01	0.40
REDWOOD CREEK	2258	2-yr	565.49		565.96	0.004925	5.50	5.50			1.32	218.16	47.45	0.45
REDWOOD CREEK	2258	5-yr	566.75		567.53	0.007453	7.06	7.06	0.02		2.09	283.25	59.14	0.56
REDWOOD CREEK	2258	10-yr	567.35		568.31	0.008043	7.84	7.77	0.21	0.12	2.14	321.94	71.15	0.60
REDWOOD CREEK	2258	25-yr	567.74		568.80	0.008172	8.28	8.05	0.33	0.14	1.87	352.80	91.77	0.61
REDWOOD CREEK	2258	50-yr	568.37		569.55	0.008045	8.80	8.05	0.34	0.31	1.60	422.10	127.41	0.61
REDWOOD CREEK	2258	100-yr	568.72		569.92	0.007701	8.92	7.89	0.44	0.42	1.59	468.83	136.26	0.60
REDWOOD CREEK	2152	Summer	560.41	560.41	560.44	0.105863	1.40	1.40			0.36	0.71	12.95	1.05
REDWOOD CREEK	2152	Winter	561.16	561.16	561.45	0.044816	4.31	4.31			1.59	20.41	35.92	1.01
REDWOOD CREEK	2152	0.5 Bankfull	562.15	562.15	562.84	0.033614	6.64	6.64			2.82	60.22	44.45	1.01
REDWOOD CREEK	2152	1.5-yr	562.99	562.99	563.97	0.030087	7.96	7.96			3.60	100.49	51.88	1.01
REDWOOD CREEK	2152	2-yr	563.64	563.64	564.84	0.028150	8.79	8.79			4.11	136.52	57.70	1.01
REDWOOD CREEK	2152	5-yr	565.00	564.63	566.30	0.018352	9.13	9.13			3.92	218.96	62.62	0.86

HEC-RAS Plan: RedwoodCreek River: REDWOOD Reach: REDWOOD CREEK (Continued)

Reach	River Sta	Profile	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Vel Total	Shear LOB	Shear ROB	Shear Total	Flow Area	Top Width	Froude # Chl
			(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(sq ft)	(ft)	
REDWOOD CREEK	2152	10-yr	565.97		567.20	0.013292	8.90	8.90	0.03	0.08	3.34	281.03	67.88	0.76
REDWOOD CREEK	2152	25-yr	566.58		567.79	0.010983	8.84	8.71	0.19	0.27	2.73	325.91	79.83	0.70
REDWOOD CREEK	2152	50-yr	567.44		568.65	0.008950	8.89	8.44	0.36	0.46	2.23	402.97	99.05	0.65
REDWOOD CREEK	2152	100-yr	567.87		569.07	0.008186	8.91	8.27	0.42	0.53	2.05	447.45	109.48	0.63
REDWOOD CREEK	2104	Summer	558.95	558.78	558.95	0.001404	0.33	0.33			0.01	3.02	18.62	0.14
REDWOOD CREEK	2104	Winter	560.21	559.60	560.29	0.005290	2.24	2.24			0.35	39.35	37.17	0.38
REDWOOD CREEK	2104	0.5 Bankfull	561.54	560.72	561.79	0.008058	4.00	4.00			0.92	100.10	54.16	0.52
REDWOOD CREEK	2104	1.5-yr	562.30		562.77	0.011706	5.52	5.52			1.64	144.93	63.86	0.65
REDWOOD CREEK	2104	2-yr	563.27		563.76	0.009357	5.62	5.62			1.60	213.48	77.35	0.60
REDWOOD CREEK	2104	5-yr	565.18		565.60	0.005351	5.16	5.16			1.22	387.94	105.24	0.47
REDWOOD CREEK	2104	10-yr	566.23		566.61	0.004120	4.94	4.94			1.07	506.53	120.57	0.42
REDWOOD CREEK	2104	25-yr	566.89		567.25	0.003564	4.82	4.82			1.00	588.85	130.15	0.40
REDWOOD CREEK	2104	50-yr	567.80		568.16	0.003063	4.76	4.76			0.94	713.77	143.47	0.38
REDWOOD CREEK	2104	100-yr	568.25		568.60	0.002756	4.75	4.75	0.02	0.03	0.89	779.12	149.07	0.36
REDWOOD CREEK	2032	Summer	558.59	558.59	558.61	0.141215	1.13	1.13			0.28	0.88	27.46	1.11
REDWOOD CREEK	2032	Winter	559.15	559.15	559.41	0.046289	4.11	4.11			1.49	21.42	41.45	1.01
REDWOOD CREEK	2032	0.5 Bankfull	560.04	560.04	560.68	0.034759	6.42	6.42			2.71	62.30	49.35	1.01
REDWOOD CREEK	2032	1.5-yr	561.65		562.04	0.008329	5.14	4.65	0.32		0.93	172.19	95.25	0.55
REDWOOD CREEK	2032	2-yr	563.02		563.29	0.003709	4.51	3.82	0.39	0.12	0.64	314.11	112.90	0.40
REDWOOD CREEK	2032	5-yr	565.09		565.32	0.001957	4.32	3.47	0.39	0.19	0.50	576.02	139.09	0.31
REDWOOD CREEK	2032	10-yr	566.16		566.39	0.001580	4.33	3.42	0.39	0.21	0.47	731.81	150.93	0.28
REDWOOD CREEK	2032	25-yr	566.83		567.06	0.001408	4.33	3.40	0.40	0.21	0.46	834.38	156.35	0.27
REDWOOD CREEK	2032	50-yr	567.75		567.98	0.001281	4.45	3.46	0.42	0.21	0.46	982.87	166.91	0.26
REDWOOD CREEK	2032	100-yr	568.20		568.44	0.001226	4.50	3.49	0.43	0.23	0.47	1058.90	168.67	0.26
REDWOOD CREEK	1893	Summer	556.09		556.09	0.000000	0.02	0.02			0.00	49.76	34.81	0.00
REDWOOD CREEK	1893	Winter	557.65		557.66	0.000210	0.81	0.81			0.03	108.14	40.16	0.09
REDWOOD CREEK	1893	0.5 Bankfull	559.86		559.92	0.000653	1.95	1.95		0.00	0.16	205.32	48.16	0.16
REDWOOD CREEK	1893	1.5-yr	561.55		561.67	0.000911	2.76	2.71		0.05	0.27	295.54	58.63	0.20
REDWOOD CREEK	1893	2-yr	562.84		563.01	0.001064	3.33	3.19		0.10	0.35	376.33	66.63	0.23
REDWOOD CREEK	1893	5-yr	564.85		565.11	0.001250	4.12	3.83		0.20	0.49	522.79	79.09	0.25
REDWOOD CREEK	1893	10-yr	565.89		566.19	0.001325	4.50	4.11		0.25	0.55	608.04	85.51	0.26
REDWOOD CREEK	1893	25-yr	566.53		566.86	0.001363	4.71	4.27		0.29	0.60	664.33	89.50	0.27
REDWOOD CREEK	1893	50-yr	567.41		567.78	0.001465	5.09	4.56		0.33	0.67	745.34	96.33	0.28
REDWOOD CREEK	1893	100-yr	567.84		568.24	0.001509	5.27	4.70		0.37	0.71	787.69	98.92	0.29
REDWOOD CREEK	1861.71	Summer	556.09		556.09	0.000000	0.02	0.02			0.00	58.49	27.28	0.00
REDWOOD CREEK	1861.71	Winter	557.64		557.65	0.000182	0.84	0.84			0.03	104.99	32.76	0.08
REDWOOD CREEK	1861.71	0.5 Bankfull	559.83		559.90	0.000822	2.12	2.12			0.20	188.33	44.86	0.18
REDWOOD CREEK	1861.71	1.5-yr	561.50		561.64	0.001201	2.96	2.95	0.03		0.35	271.02	54.04	0.23
REDWOOD CREEK	1861.71	2-yr	562.78		562.97	0.001394	3.52	3.48	0.09		0.46	344.68	61.18	0.25
REDWOOD CREEK	1861.71	5-yr	564.78		565.06	0.001484	4.31	4.16	0.18	0.07	0.56	480.49	74.53	0.27
REDWOOD CREEK	1861.71	10-yr	565.80		566.14	0.001501	4.71	4.46	0.22	0.12	0.61	559.92	80.52	0.28
REDWOOD CREEK	1861.71	25-yr	566.44		566.81	0.001511	4.95	4.64	0.25	0.15	0.64	612.35	84.62	0.28
REDWOOD CREEK	1861.71	50-yr	567.30		567.73	0.001582	5.37	4.94	0.30	0.19	0.70	687.73	90.90	0.30
REDWOOD CREEK	1861.71	100-yr	567.72		568.18	0.001618	5.58	5.09	0.33	0.22	0.74	726.77	93.96	0.30
REDWOOD CREEK	1794.38	Summer	556.09	553.17	556.09	0.000000	0.02	0.02			0.00	53.49	23.12	0.00
REDWOOD CREEK	1794.38	Winter	557.63	554.34	557.64	0.000241	0.95	0.95			0.04	92.41	28.21	0.09
REDWOOD CREEK	1794.38	0.5 Bankfull	559.74	555.86	559.83	0.001119	2.47	2.47			0.27	162.04	37.42	0.21
REDWOOD CREEK	1794.38	1.5-yr	561.34	557.20	561.53	0.001727	3.54	3.53		0.04	0.51	226.69	43.21	0.27
REDWOOD CREEK	1794.38	2-yr	562.56	558.26	562.85	0.002101	4.28	4.25		0.10	0.69	282.31	47.65	0.30
REDWOOD CREEK	1794.38	5-yr	564.47	559.89	564.92	0.002586	5.35	5.28		0.22	1.00	379.03	53.69	0.35
REDWOOD CREEK	1794.38	10-yr	565.45	560.68	565.98	0.002803	5.87	5.77		0.28	1.17	433.08	56.77	0.37
REDWOOD CREEK	1794.38	25-yr	566.06	561.17	566.65	0.002925	6.18	6.07		0.32	1.27	468.08	58.75	0.38
REDWOOD CREEK	1794.38	50-yr	566.86	561.89	567.55	0.003214	6.72	6.59		0.38	1.46	516.07	61.41	0.40
REDWOOD CREEK	1794.38	100-yr	567.25	562.29	568.00	0.003361	6.99	6.85		0.42	1.57	540.24	62.70	0.41
REDWOOD CREEK	1784.08		Bridge											
REDWOOD CREEK	1784.07	Summer	556.09		556.09	0.000001	0.03	0.03			0.00	34.85	23.28	0.00
REDWOOD CREEK	1784.07	Winter	557.61		557.64	0.000469	1.18	1.18			0.07	74.60	28.30	0.13
REDWOOD CREEK	1784.07	0.5 Bankfull	559.69		559.81	0.001651	2.88	2.88			0.38	138.90	34.12	0.25
REDWOOD CREEK	1784.07	1.5-yr	561.24		561.51	0.002508	4.11	4.11			0.72	194.87	37.44	0.32
REDWOOD CREEK	1784.07	2-yr	562.42		562.81	0.003106	4.99	4.99			1.01	240.36	39.64	0.36
REDWOOD CREEK	1784.07	5-yr	564.24		564.86	0.004015	6.35	6.35			1.55	314.97	42.70	0.41
REDWOOD CREEK	1784.07	10-yr	565.15		565.92	0.004509	7.05	7.05			1.87	354.68	44.34	0.44
REDWOOD CREEK	1784.07	25-yr	565.71		566.58	0.004835	7.48	7.48			2.08	379.84	45.57	0.46
REDWOOD CREEK	1784.07	50-yr	566.42		567.47	0.005444	8.24	8.23	0.07		2.40	412.88	48.32	0.49
REDWOOD CREEK	1784.07	100-yr	566.75		567.91	0.005746	8.64	8.62	0.13		2.54	429.37	50.07	0.50
REDWOOD CREEK	1700	Summer	556.09	556.03	556.09	0.003493	0.35	0.35			0.02	2.83	31.46	0.21
REDWOOD CREEK	1700	Winter	557.52		557.56	0.002103	1.68	1.68			0.18	52.24	37.28	0.25
REDWOOD CREEK	1700	0.5 Bankfull	559.51		559.65	0.002472	3.00	3.00			0.45	133.48	44.40	0.30
REDWOOD CREEK	1700	1.5-yr	561.04		561.28	0.002764	3.89	3.89			0.68	205.91	49.87	0.34
REDWOOD CREEK	1700	2-yr	562.22		562.54	0.002934	4.49	4.49			0.85	267.26	54.11	0.36
REDWOOD CREEK	1700	5-yr	564.06		564.51	0.003175	5.36	5.36	0.01		1.12	372.99	62.10	0.38
REDWOOD CREEK	1700	10-yr	565.02		565.53	0.003114	5.77	5.65	0.10	0.03	0.97	442.38	83.95	0.39
REDWOOD CREEK	1700	25-yr	565.62		566.17	0.003002	5.98	5.72	0.15	0.08	0.92	496.52	96.51	0.38
REDWOOD CREEK	1700	50-yr	566.39		567.01	0.003006	6.39	5.89	0.23	0.14	0.94	576.97	110.24	0.39
REDWOOD CREEK	1700	100-yr	566.77		567.42	0.002995	6.57	5.98	0.30	0.16	0.99	619.24	111.50	0.39
REDWOOD CREEK	1506.97	Summer	555.25		555.26	0.005415	0.68	0.68			0.06	1.48	8.57	0.29
REDWOOD CREEK	1506.97	Winter	556.77		556.88	0.006603	2.75	2.75			0.50	32.01	25.93	0.44
REDWOOD CREEK	1506.97	0.5 Bankfull	558.45		558.82	0.008416	4.86	4.86			1.25	82.29	33.40	0.55
REDWOOD CREEK	1506.97	1.5-yr	559.75		560.34	0.009464	6.16	6.16			1.84	129.80	39.99	0.60
REDWOOD CREEK	1506.97	2-yr	560.86		561.57	0.009138	6.77	6.77			2.10	177.26	46.05	0.61
REDWOOD CREEK	1506.97	5-yr	562.71		563.55	0.007971	7.35	7.35			2.30	271.96	56.10	0.59
REDWOOD CREEK	1506.97	10-yr	563.73		564.61	0.007512	7.52	7.52			2.34	332.41	63.43	0.58
REDWOOD CREEK	1506.97	25-yr	564.39		565.27	0.007339	7.53	7.52	0.04	0.06	2.14	377.80	77.36	0.58
REDWOOD CREEK	1506.97	50-yr	565.27		566.17	0.006220	7.67	7.34	0.21	0.20	1.51	463.43	115.67	0.54
REDWOOD CREEK	1506.97	100-yr	565.72		566.62	0.005668	7.68	7.15	0.33	0.25	1.48	517.19	120.17	0.52
REDWOOD CREEK	1247.39	Summer	553.23	553.23	553.29	0.074773	1.95	1.95			0.55	0.51	4.33	1.00
REDWOOD CREEK	1247.39	Winter	554.46	554.46	554.87	0.041626	5.16	5.16			2.04	17.05	21.18	1.01
REDWOOD CREEK	1247.39	0.5 Bankfull	555.94	555.81	556.77	0.026091	7.30	7.30			3.06	54.79	27.85	0.92
REDWOOD CREEK	1247.39	1.5-yr	557.43		558.45	0.017745	8.11	8.11			3.25	98.67	31.13	0.80
REDWOOD CREEK	1247.39	2-yr	558.51		559.76	0.016475	8.99	8.99			3.72	133.52	33.51	0.79
REDWOOD CREEK	1247.39	5-yr	560.08		561.82	0.016881	10.59	10.59			4.79	188.88	36.90	0.83

HEC-RAS Plan: RedwoodCreek River: REDWOOD Reach: REDWOOD CREEK (Continued)

Reach	River Sta	Profile	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Vel Total	Shear LOB	Shear ROB	Shear Total	Flow Area	Top Width	Froude # Chl
			(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(sq ft)	(ft)	
REDWOOD CREEK	1247.39	10-yr	560.87		562.90	0.017078	11.42	11.42	0.03	0.11	5.29	218.97	38.75	0.84
REDWOOD CREEK	1247.39	25-yr	561.35	560.69	563.58	0.016831	11.96	11.91	0.24	0.26	5.19	238.41	42.59	0.85
REDWOOD CREEK	1247.39	50-yr	562.06	561.47	564.60	0.016713	12.81	12.55	0.55	0.46	5.04	270.84	50.03	0.86
REDWOOD CREEK	1247.39	100-yr	562.39	561.87	565.11	0.016826	13.26	12.80	0.60	0.57	4.71	289.02	58.24	0.87
REDWOOD CREEK	1097.31	Summer	551.48		551.48	0.000009	0.08	0.08			0.00	12.37	13.93	0.02
REDWOOD CREEK	1097.31	Winter	553.61		553.64	0.001215	1.49	1.49			0.13	59.20	32.89	0.20
REDWOOD CREEK	1097.31	0.5 Bankfull	555.70		555.82	0.002006	2.77	2.77			0.38	144.23	45.21	0.27
REDWOOD CREEK	1097.31	1.5-yr	557.23		557.44	0.002381	3.69	3.69			0.60	216.64	49.33	0.31
REDWOOD CREEK	1097.31	2-yr	558.36		558.66	0.002664	4.38	4.38			0.80	274.07	51.88	0.34
REDWOOD CREEK	1097.31	5-yr	560.04		560.51	0.003189	5.50	5.50			1.18	363.35	54.59	0.38
REDWOOD CREEK	1097.31	10-yr	560.89		561.47	0.003502	6.09	6.09			1.41	410.79	56.52	0.40
REDWOOD CREEK	1097.31	25-yr	561.45		562.09	0.003635	6.42	6.41	0.04		1.49	442.82	59.92	0.41
REDWOOD CREEK	1097.31	50-yr	562.29		563.03	0.003744	6.90	6.75	0.15	0.07	1.20	503.50	90.43	0.42
REDWOOD CREEK	1097.31	100-yr	562.72		563.49	0.003710	7.10	6.81	0.20	0.15	1.21	543.48	96.36	0.42
REDWOOD CREEK	1025.04	Summer	551.45		551.47	0.016884	1.26	1.26			0.20	0.79	4.20	0.51
REDWOOD CREEK	1025.04	Winter	552.86	552.86	553.34	0.040164	5.54	5.54			2.25	15.88	17.14	1.02
REDWOOD CREEK	1025.04	0.5 Bankfull	555.20		555.52	0.010357	4.50	4.50			1.18	88.81	47.49	0.58
REDWOOD CREEK	1025.04	1.5-yr	556.86		557.18	0.005244	4.54	4.54			1.00	176.30	55.11	0.45
REDWOOD CREEK	1025.04	2-yr	558.02		558.41	0.004430	4.98	4.98			1.11	240.79	56.33	0.42
REDWOOD CREEK	1025.04	5-yr	559.68		560.23	0.004408	5.96	5.96			1.44	335.58	57.99	0.44
REDWOOD CREEK	1025.04	10-yr	560.52		561.17	0.004595	6.50	6.50			1.66	384.86	59.73	0.45
REDWOOD CREEK	1025.04	25-yr	561.06		561.78	0.004647	6.80	6.80		0.02	1.76	417.91	61.89	0.46
REDWOOD CREEK	1025.04	50-yr	561.91		562.72	0.004581	7.22	7.11		0.13	1.54	478.22	80.88	0.46
REDWOOD CREEK	1025.04	100-yr	562.34		563.19	0.004526	7.41	7.18	0.03	0.18	1.44	515.59	93.43	0.46
REDWOOD CREEK	776	Summer	550.58		550.58	0.001495	0.32	0.32			0.01	3.17	22.02	0.15
REDWOOD CREEK	776	Winter	552.33		552.36	0.001142	1.37	1.37			0.11	64.40	39.82	0.19
REDWOOD CREEK	776	0.5 Bankfull	554.75		554.83	0.001088	2.23	2.19		0.06	0.21	182.88	56.28	0.21
REDWOOD CREEK	776	1.5-yr	556.52		556.63	0.001034	2.73	2.40	0.08	0.12	0.21	332.80	100.31	0.22
REDWOOD CREEK	776	2-yr	557.75		557.88	0.000972	3.07	2.61	0.14	0.15	0.26	459.56	105.51	0.22
REDWOOD CREEK	776	5-yr	559.47		559.65	0.001043	3.74	3.07	0.24	0.16	0.34	651.90	121.07	0.23
REDWOOD CREEK	776	10-yr	560.35		560.56	0.001062	4.05	3.29	0.29	0.21	0.39	759.35	123.36	0.24
REDWOOD CREEK	776	25-yr	560.92		561.15	0.001066	4.23	3.42	0.31	0.24	0.42	830.98	125.79	0.24
REDWOOD CREEK	776	50-yr	561.82		562.07	0.001072	4.51	3.59	0.33	0.29	0.46	947.57	131.20	0.25
REDWOOD CREEK	776	100-yr	562.27		562.54	0.001061	4.62	3.67	0.35	0.30	0.48	1007.54	131.20	0.25
REDWOOD CREEK	600	Summer	550.10		550.10	0.006050	0.74	0.74			0.07	1.36	7.46	0.30
REDWOOD CREEK	600	Winter	551.74		551.90	0.009002	3.30	3.30			0.71	26.68	20.35	0.51
REDWOOD CREEK	600	0.5 Bankfull	554.13		554.43	0.006101	4.36	4.36			0.98	91.84	34.12	0.47
REDWOOD CREEK	600	1.5-yr	555.84		556.24	0.005490	5.09	5.09			1.21	157.03	42.13	0.47
REDWOOD CREEK	600	2-yr	557.02		557.51	0.005496	5.65	5.37		0.14	0.92	223.36	80.37	0.48
REDWOOD CREEK	600	5-yr	559.00		559.33	0.003577	5.03	3.87	0.03	0.36	0.57	517.33	196.85	0.40
REDWOOD CREEK	600	10-yr	560.04		560.29	0.002307	4.54	3.43	0.15	0.37	0.50	729.24	206.65	0.33
REDWOOD CREEK	600	25-yr	560.68		560.90	0.001854	4.36	3.29	0.17	0.37	0.47	863.02	209.69	0.30
REDWOOD CREEK	600	50-yr	561.63		561.83	0.001447	4.21	3.19	0.19	0.37	0.44	1064.49	214.10	0.27
REDWOOD CREEK	600	100-yr	562.11		562.31	0.001305	4.16	3.17	0.20	0.37	0.43	1167.79	216.33	0.26
REDWOOD CREEK	491	Summer	549.74		549.75	0.002043	0.48	0.48			0.03	2.07	9.58	0.18
REDWOOD CREEK	491	Winter	551.63		551.65	0.000796	1.08	1.08			0.07	81.81	55.49	0.16
REDWOOD CREEK	491	0.5 Bankfull	554.15		554.19	0.000632	1.74	1.74			0.14	230.38	62.55	0.16
REDWOOD CREEK	491	1.5-yr	555.89		555.98	0.000724	2.31	2.27		0.04	0.20	352.89	77.70	0.18
REDWOOD CREEK	491	2-yr	557.09		557.21	0.000813	2.77	2.66		0.05	0.24	450.36	92.19	0.20
REDWOOD CREEK	491	5-yr	558.94		559.11	0.000885	3.40	3.02	0.04	0.10	0.27	663.34	130.39	0.21
REDWOOD CREEK	491	10-yr	559.94		560.12	0.000867	3.64	3.13	0.03	0.15	0.27	798.69	154.30	0.21
REDWOOD CREEK	491	25-yr	560.57		560.77	0.000843	3.76	3.14	0.04	0.17	0.27	903.07	172.99	0.21
REDWOOD CREEK	491	50-yr	561.51		561.72	0.000807	3.91	3.18	0.08	0.20	0.29	1070.12	178.83	0.21
REDWOOD CREEK	491	100-yr	561.99		562.20	0.000789	3.99	3.20	0.10	0.22	0.30	1155.67	181.74	0.21
REDWOOD CREEK	449	Summer	549.65	549.44	549.65	0.002197	0.53	0.53			0.03	1.87	7.83	0.19
REDWOOD CREEK	449	Winter	551.55		551.60	0.002282	1.68	1.68			0.18	52.25	39.91	0.26
REDWOOD CREEK	449	0.5 Bankfull	554.06		554.15	0.001438	2.48	2.48			0.29	161.31	47.21	0.24
REDWOOD CREEK	449	1.5-yr	555.77		555.92	0.001774	3.19	3.19			0.45	250.49	58.48	0.27
REDWOOD CREEK	449	2-yr	556.93		557.15	0.002226	3.69	3.69			0.59	325.39	72.95	0.31
REDWOOD CREEK	449	5-yr	558.78		559.04	0.002347	4.06	4.06			0.69	492.37	100.06	0.32
REDWOOD CREEK	449	10-yr	559.79		560.06	0.002124	4.17	4.14	0.05		0.63	603.48	122.27	0.31
REDWOOD CREEK	449	25-yr	560.43		560.71	0.001972	4.22	4.14	0.08		0.59	686.75	138.98	0.31
REDWOOD CREEK	449	50-yr	561.38		561.66	0.001756	4.29	4.11	0.15	0.00	0.58	826.86	153.12	0.29
REDWOOD CREEK	449	100-yr	561.86		562.14	0.001623	4.32	4.10	0.17	0.02	0.56	901.85	160.20	0.29
REDWOOD CREEK	400	Summer	549.28	549.28	549.33	0.073030	1.83	1.83			0.50	0.55	4.99	0.98
REDWOOD CREEK	400	Winter	551.32	550.52	551.43	0.005335	2.66	2.66			0.45	33.11	23.83	0.40
REDWOOD CREEK	400	0.5 Bankfull	553.81	552.04	554.03	0.003835	3.78	3.78			0.71	105.78	34.13	0.38
REDWOOD CREEK	400	1.5-yr	555.44	553.20	555.77	0.004531	4.66	4.45	0.11		0.68	179.92	72.55	0.42
REDWOOD CREEK	400	2-yr	556.67	554.11	557.00	0.003516	4.77	4.01	0.25	0.11	0.55	299.56	116.58	0.39
REDWOOD CREEK	400	5-yr	558.66	555.94	558.93	0.002088	4.65	3.68	0.38	0.18	0.51	543.73	133.98	0.32
REDWOOD CREEK	400	10-yr	559.70	556.68	559.97	0.001745	4.69	3.57	0.42	0.16	0.46	700.02	162.25	0.30
REDWOOD CREEK	400	25-yr	560.36	556.97	560.62	0.001560	4.68	3.51	0.43	0.18	0.45	809.32	174.00	0.29
REDWOOD CREEK	400	50-yr	561.33	557.42	561.58	0.001348	4.68	3.46	0.45	0.19	0.43	984.00	193.41	0.27
REDWOOD CREEK	400	100-yr	561.82	557.61	562.06	0.001260	4.68	3.44	0.46	0.20	0.43	1076.99	200.67	0.26
REDWOOD CREEK	274	Summer	549.12		549.12	0.000426	0.24	0.24			0.01	4.13	16.54	0.09
REDWOOD CREEK	274	Winter	551.15		551.18	0.000874	1.29	1.29			0.10	68.47	37.66	0.17
REDWOOD CREEK	274	0.5 Bankfull	553.68		553.76	0.001042	2.24	2.22	0.00	0.01	0.19	180.13	58.65	0.20
REDWOOD CREEK	274	1.5-yr	555.33		555.46	0.001160	2.93	2.67	0.04	0.10	0.26	299.33	77.39	0.23
REDWOOD CREEK	274	2-yr	556.54		556.71	0.001218	3.44	2.90	0.07	0.11	0.26	414.25	112.94	0.24
REDWOOD CREEK	274	5-yr	558.52		558.72	0.001102	3.91	2.98	0.11	0.16	0.28	671.82	160.06	0.24
REDWOOD CREEK	274	10-yr	559.59		559.79	0.000989	4.01	2.94	0.12	0.19	0.29	849.07	170.61	0.23
REDWOOD CREEK	274	25-yr	560.25		560.45	0.000917	4.04	2.95	0.12	0.21	0.30	963.91	173.86	0.22
REDWOOD CREEK	274	50-yr	561.23		561.43	0.000845	4.12	2.99	0.12	0.24	0.32	1136.73	179.14	0.22
REDWOOD CREEK	274	100-yr	561.73		561.92	0.000817	4.18	3.02	0.12	0.25	0.33	1225.55	182.82	0.22
REDWOOD CREEK	179	Summer	549.12		549.12	0.000018	0.09	0.09			0.00	11.60	20.61	0.02
REDWOOD CREEK	179	Winter	551.07		551.09	0.000941	1.32	1.32		0.02	0.10	66.90	38.40	0.17
REDWOOD CREEK	179	0.5 Bankfull	553.58		553.66	0.001062	2.36	2.30		0.08	0.23	173.92	47.39	0.21
REDWOOD CREEK	179	1.5-yr	555.17		555.32	0.001632	3.18	3.08		0.19	0.41	260.10	62.48	0.27
REDWOOD CREEK	179	2-yr	556.37		556.57	0.001641	3.73	3.54	0.05	0.16	0.44	339.15	75.51	0.28
REDWOOD CREEK	179	5-yr	558.32		558.60	0.001502	4.36	3.73	0.16	0.20	0.43	536.28	111.97	0.28
REDWOOD CREEK	179	10-yr	559.38		559.67	0.001378	4.55	3.80	0.20	0.25	0.47	657.31	116.71	0.27
REDWOOD CREEK	179	25-yr	560.04		560.34	0.001317	4.67	3.86	0.23	0.29	0.49	735.09	119.47	0.27

HEC-RAS Plan: RedwoodCreek River: REDWOOD Reach: REDWOOD CREEK (Continued)

Reach	River Sta	Profile	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Vel Total	Shear LOB	Shear ROB	Shear Total	Flow Area	Top Width	Froude # Chl
			(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(ft/s)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(sq ft)	(ft)	
REDWOOD CREEK	179	50-yr	561.01		561.32	0.001263	4.89	3.99	0.25	0.33	0.52	852.45	124.46	0.27
REDWOOD CREEK	179	100-yr	561.49		561.82	0.001244	5.00	4.05	0.25	0.35	0.53	913.49	128.10	0.27
REDWOOD CREEK	77.94	Summer	549.11	548.11	549.11	0.000014	0.09	0.09			0.00	11.01	14.30	0.02
REDWOOD CREEK	77.94	Winter	550.93	549.42	550.97	0.001636	1.57	1.57			0.15	55.95	36.74	0.22
REDWOOD CREEK	77.94	0.5 Bankfull	553.48	550.95	553.55	0.001154	2.14	2.12	0.02	0.04	0.21	188.59	63.40	0.21
REDWOOD CREEK	77.94	1.5-yr	555.06	551.98	555.18	0.001144	2.79	2.70	0.07	0.09	0.28	296.21	72.65	0.23
REDWOOD CREEK	77.94	2-yr	556.26	552.63	556.42	0.001165	3.28	3.09	0.10	0.13	0.34	388.32	80.82	0.24
REDWOOD CREEK	77.94	5-yr	558.22	553.63	558.45	0.001152	3.95	3.60	0.20	0.18	0.44	555.28	88.19	0.25
REDWOOD CREEK	77.94	10-yr	559.27	554.14	559.54	0.001142	4.28	3.85	0.25	0.21	0.49	649.37	91.12	0.25
REDWOOD CREEK	77.94	25-yr	559.92	554.50	560.21	0.001139	4.48	4.00	0.28	0.23	0.52	709.36	92.82	0.26
REDWOOD CREEK	77.94	50-yr	560.87	555.05	561.20	0.001158	4.81	4.26	0.33	0.27	0.57	798.51	95.59	0.26
REDWOOD CREEK	77.94	100-yr	561.34	555.32	561.69	0.001190	5.01	4.38	0.30	0.29	0.58	844.73	102.28	0.27
REDWOOD CREEK	44.90		Bridge											
REDWOOD CREEK	44.89	Summer	549.07	549.07	549.11	0.085362	1.60	1.60			0.42	0.63	7.93	1.00
REDWOOD CREEK	44.89	Winter	550.73		550.86	0.006884	2.95	2.95			0.56	29.78	22.12	0.45
REDWOOD CREEK	44.89	0.5 Bankfull	553.43		553.50	0.001479	2.23	2.23			0.25	179.71	64.03	0.23
REDWOOD CREEK	44.89	1.5-yr	555.02		555.14	0.001417	2.80	2.80			0.35	285.51	68.79	0.24
REDWOOD CREEK	44.89	2-yr	556.22		556.38	0.001411	3.24	3.24	0.01	0.02	0.42	370.76	74.42	0.25
REDWOOD CREEK	44.89	5-yr	558.18		558.41	0.001328	3.89	3.80	0.11	0.11	0.50	526.11	83.20	0.26
REDWOOD CREEK	44.89	10-yr	559.22		559.50	0.001298	4.21	4.06	0.13	0.14	0.53	615.88	88.52	0.26
REDWOOD CREEK	44.89	25-yr	559.88		560.17	0.001284	4.41	4.21	0.15	0.16	0.55	674.77	92.04	0.26
REDWOOD CREEK	44.89	50-yr	560.82		561.16	0.001286	4.72	4.45	0.20	0.20	0.60	763.55	95.47	0.27
REDWOOD CREEK	44.89	100-yr	561.29		561.65	0.001291	4.88	4.57	0.21	0.22	0.63	808.86	97.49	0.27
REDWOOD CREEK	9.08	Summer	547.81	547.59	547.81	0.002000	0.51	0.51			0.03	1.95	8.07	0.18
REDWOOD CREEK	9.08	Winter	550.66	548.93	550.72	0.002003	1.94	1.94			0.22	45.47	23.85	0.25
REDWOOD CREEK	9.08	0.5 Bankfull	553.33	550.85	553.44	0.002003	2.63	2.63			0.35	152.15	51.55	0.27
REDWOOD CREEK	9.08	1.5-yr	554.90	552.18	555.07	0.002001	3.37	3.36	0.05	0.03	0.49	238.08	57.05	0.29
REDWOOD CREEK	9.08	2-yr	556.07	552.88	556.31	0.002000	3.96	3.91	0.10	0.07	0.59	306.86	60.26	0.30
REDWOOD CREEK	9.08	5-yr	557.98	554.03	558.34	0.002002	4.83	4.67	0.19	0.16	0.73	428.51	67.21	0.31
REDWOOD CREEK	9.08	10-yr	559.00	554.58	559.42	0.002002	5.27	4.99	0.20	0.19	0.77	500.65	75.19	0.32
REDWOOD CREEK	9.08	25-yr	559.64	554.95	560.10	0.002001	5.53	5.16	0.21	0.22	0.77	550.90	82.77	0.32
REDWOOD CREEK	9.08	50-yr	560.56	555.50	561.08	0.002001	5.90	5.39	0.29	0.27	0.83	630.49	86.83	0.33
REDWOOD CREEK	9.08	100-yr	561.03	555.80	561.58	0.002000	6.08	5.52	0.34	0.29	0.88	670.85	87.62	0.33

Appendix E

Cultural Resources Report

Cultural Resources Report is confidential and not available for public review.

Appendix F

Biological Resources Technical Report

JULY 2021

Biological Resources Technical Report for the Marshall Ranch Streamflow Enhancement Project, Humboldt County, California




PREPARED FOR

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Cover photos: Images of the Marshall Ranch and associated habitat during the biological surveys conducted in May 2019.

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1 PROJECT BACKGROUND

The Salmonid Restoration Federation (SRF) is planning to construct a 15.3-million-gallon off-stream pond on the Marshall Ranch, adjacent to Redwood Creek, a tributary to the South Fork Eel River. This Project seeks to improve habitat for coho salmon (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*), in Redwood Creek, an important salmon bearing tributary, by addressing the limiting factor of low summer streamflows. The South Fork Eel River is one of five priority watersheds selected for flow enhancement projects in California by the State Water Resources Control Board (SWRCB) and California Department of Fish and Wildlife (CDFW) as part of the California Water Action Plan effort (SWRCB 2019). Redwood Creek is a critical tributary to the South Fork Eel River that historically supported coho and Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead.

Coho salmon have experienced precipitous declines in abundance and are currently listed as threatened under the federal Endangered Species Act (ESA) and the California Endangered Species Act (CESA). Numerous factors are responsible for the declines in coho salmon abundance, and many of these limiting factors are also impacting Chinook salmon and steelhead, which are also severely depressed in abundance relative to historical population estimates. Land use practices including logging and road systems have greatly increased winter run off resulting in decreased groundwater storage capacity and lower summer streamflows. Widespread removal of large wood from streams has also decreased groundwater storage through channel incision and loss of floodplain connectivity and resulted in fewer and shallower instream pools that are of insufficient size to withstand drought. Cannabis cultivation has also expanded in the last 15 years, which has resulted in increased water diversions that have affected area watercourses and summer stream flows. Industrial logging practices combined with fire suppression have resulted in overly dense even aged forests with higher evapotranspiration rates which significantly contribute to lower dry season flows. The problems of reduced groundwater storage and increased evapotranspiration are intensified in a longer dry season. In low flow years, Redwood Creek has experienced dry conditions at two of the four mainstem Redwood Creek flow gages downstream from the proposed flow enhancement site.

The Project would provide significant, measurable benefits in terms of dry season flow enhancement for coho salmon, steelhead, and other aquatic habitat along the 5.5 miles (mi) of Redwood Creek mainstem downstream from the Project. The Project is designed to deliver approximately 50 gallons per minute of high-quality water during the five-month dry season, which will be wholly dedicated to instream values including reasonable and beneficial fish and wildlife uses of the water. Quantifiable long-term objectives include increased summer streamflow, enhanced fish and wildlife habitat, and improved water quality.

The Project design is based on the best available science and is informed by the *California Salmonid Stream Habitat Restoration Manual* edition (Flosi et al. 2010), and *Ponds – Planning, Design, Construction* (USDA NRCS 1997). Additionally, the Project is informed by scientific studies and streamflow enhancement techniques that have been used in the Mattole River watershed, California.

1.1 Project Location

The Project is located on a 39-acre (ac) area within the 2,942-ac Marshall Ranch property, approximately 3.16 mi east of Redway and just south (0.1 mi) of the unincorporated community of Briceland, Humboldt County, California (Latitude: 40.104256, Longitude: -123.900020) (Figure 1-1). To the west of the Project is Redwood Creek, approximately 5 mi upstream from the confluence of the South Fork Eel River, a tributary to the Eel River and eventually the Pacific Ocean (Figure 1-1). The Project area is in Section 19 of Township 4 South, Range 3 East of the Briceland, U.S. Geological Survey (USGS) 7.5-minute topographic quadrangle. The elevation within the Project area ranges from approximately 570 to 780 feet (ft) above mean sea level. The Project can be accessed from the Briceland Thorn Road after exiting Highway 101 at Redway, California (Figure 1-1).

1.2 Report Purpose and Organization

This biological resource technical report has been developed to describe the special-status and/or sensitive biological resources in or with potential to occur in the Project area (plants, vegetation communities, fish, wildlife, and wetlands and waters) that may be affected by Project construction activities. Potential impacts on biological resources are discussed along with suggested minimization measures to reduce impacts.

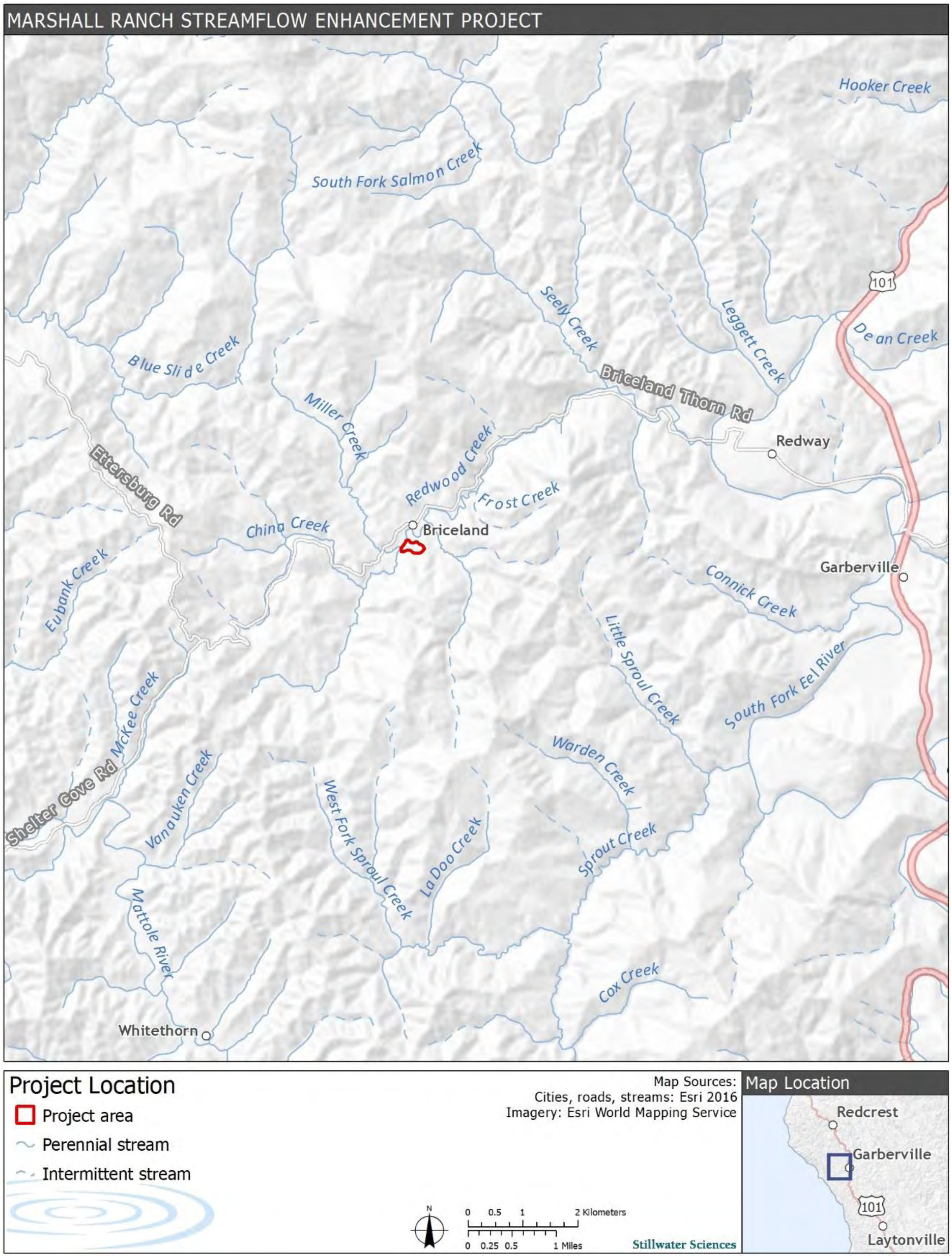

Figure 1-1. Project location.

2 PROJECT DESCRIPTION

The proposed Project includes construction of ten million gallons of off-channel water storage in ponds and tanks and associated plumbing, erosion control structures within intermittent streams, instream habitat enhancement structures along Redwood Creek mainstem, and a small control center building that will run on an off-grid power system run on solar energy. Additional Project details are provided below in Section 2.2, Figure 2-1.

2.1 Site Description

The Project will occur on the Marshall Ranch in the Redwood Creek watershed, which is located immediately west of the town of Redway in southern Humboldt County (Figure 1-1).

Redwood Creek is a fish-bearing watercourse that is known to contain coho and Chinook salmon and steelhead. Redwood Creek experiences very low or intermittent flows during the summer and fall, inhibiting habitat for these species.

Hillslope and stream channel morphologies in the Redwood Creek watershed are similar to those found throughout the western side of the South Fork Eel River basin, due to the prevalence of the underlying Franciscan Coastal Belt terranes. Although there is variability among the terranes, the strength in Coastal Belt rocks typically leads to steeper, ridge-and-valley topography with organized drainage networks. Small to large-scale landslides are still common in the basins that drain the Coastal Belt terranes, particularly where sedimentary rocks are less competent and in mélange units.

Upper elevations in the Redwood Creek basin are characterized by narrow, steep-walled canyon slopes that are covered by relatively thin soils and dense conifer and hardwood stands and drained by perennial and intermittent streams. At mid-elevations, the steep canyons transition into gently rounded upland ridges supporting grass meadows and shrub and oak woodland vegetation. The valley width greatly expands near Briceland, where Redwood Creek meanders between large, elevated terraces. Channel incision in the Redwood Creek basin is likely due to ongoing tectonic uplift related to the nearby Mendocino Triple Junction, extensive anthropogenic land-use practices, and altered hydrologic patterns due to climate change.

The Project site consists of uplifted fluvial terraces and lower floodplain surfaces adjacent to Redwood Creek, which flows from the southwest to the northeast across the Project area. Upland hillslopes border the site to the south and east. The Project site is bound by small intermittent streams to the east and west that are tributaries to Redwood Creek (Figure 1-1).

2.2 Proposed Project

The primary objective of this project is construction of 10 million gallons of off-channel water storage designed to deliver approximately 30 gallons per minute of flow augmentation to Redwood Creek during the 5-month dry season to improve instream aquatic habitat. Storage will be in two ponds and five tanks filled with wet-season runoff including rainwater catchment and water diverted from two small Redwood Creek tributaries. Other ancillary project components include:

- Installation of a large wood habitat enhancement and bank stabilization structure in Redwood Creek.

- Stabilization of one deeply incised tributary with approximately 10 rock armor grade control structures and regrading.
- Construction of a passive "cooling and filtration gallery" in the existing gully to determine the viability of this innovative approach to address water quality and temperature issues associated with the flow releases from the pond.
- Construction of a solar power system including a 1 KW solar array, battery bank, inverter, internet connection, and small control center building to support operations and monitoring capabilities.
- Upgrading access roads within the project area including three road/stream crossing upgrades and gravel surfacing to provide year-round access.
- Installation of plumbing infrastructure to allow for a portion of the water stored in the tanks to be utilized for domestic, ranch, and fire suppression needs including one fire hydrant.

2.2.1 Off-channel ponds

Construction of the off-channel ponds will include excavation and construction of earthen berms and spillways built into the natural topography. Construction will include removal of topsoil from the reservoir area. The topsoil will be saved and spread around the reservoir area along with mulch after construction. All excavated material not used to build the berms will be placed and compacted in the designated fill areas as shown on the plans. The spillways for the ponds will be engineered for 100-year storm events and armored with rock cobble or other non-erodible materials.

Materials for the reservoir will include rock for the spillways and weed free straw. Equipment will include heavy equipment for clearing and excavation and a sheepsfoot roller for compacting the berm and sealing the reservoir.

2.2.2 Hydraulic appurtenances (piping, valves, pumps, etc.)

The primary outflow pipes that deliver water from the reservoirs to Redwood Creek will be plumbed into the bottom of the ponds. Valves will control how much water is released from the ponds. The ponds will be filled with rainwater, hillslope sheet flow, and gravity diversion from two small tributaries. Water will only be diverted from the tributaries during the wet season. Additional hydraulic-related infrastructure includes piping and tanks for fire suppression and domestic use on the property.

2.2.3 Instream habitat enhancement

One instream habitat enhancement features will be constructed to improve summer rearing habitat for salmonids and reduce streambank erosion within the vicinity of the Project.

2.2.4 Gully stabilization

Approximately 10 rock armor grade control structures will be installed to stabilize three actively eroding intermittent drainages adjacent to the Project. The grade control structures will be installed with an excavator and designed to promote long-term stability of the gully channels.

2.2.5 Off-grid energy system

A one KW solar array, battery bank, inverter, and control center building will be constructed to allow for operations and monitoring capabilities.

2.2.6 Access road improvements

The access roads within the Project vicinity will be improved to provide year-round access for monitoring and maintenance of all Project components. This will include reshaping and surfacing with gravel.

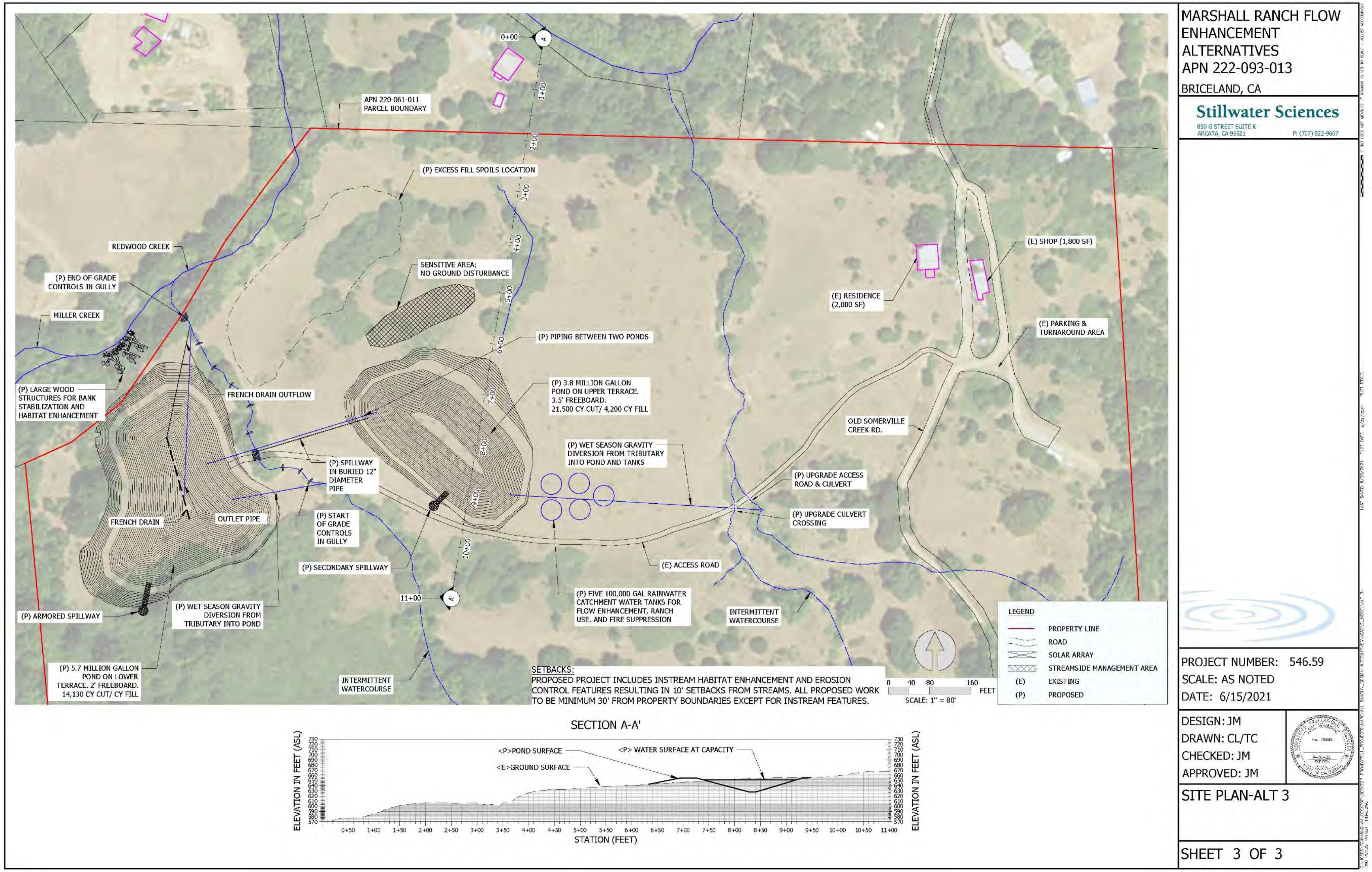

Figure 2-1. Project site plan.

3 VEGETATION ASSESSMENT

A vegetation assessment was conducted on 3 May 2019 concurrent with the early-blooming botanical survey to map vegetation within the approximately 30-ac Project area to the alliance level following classification using the online edition of *A Manual of California Vegetation* (California Native Plant Society [CNPS] 2019a). The resulting vegetation map was used to: (1) determine if any stands are considered special-status natural communities; (2) assess the likelihood of occurrence for special-status species in the Project area; and (3) inform the Project's potential to impact special-status natural communities and species.

Special-status natural communities are defined as those with a state ranking of S1, S2, or S3 (critically imperiled, imperiled, or vulnerable, respectively) on CDFW's *California Sensitive Natural Communities List* (CDFW 2018a).

3.1 Methods

3.1.1 Desktop review

Prior to the vegetation assessment, existing information from the CALVEG geodatabase (USDA Forest Service 2019) and the USGS regional geologic map (McLaughlin et al. 2000) on vegetation and soils in the Project area were reviewed. These data were transposed onto aerial imagery using geographical information systems (GIS) software to create maps for reference in the field.

The CDFW's California Natural Diversity Database (CNDDB) (CDFW 2019a) was queried for the U.S. Geological Survey (USGS) 7.5-minute quadrangle where the Project is located (Briceland), and the surrounding seven quadrangles (Garberville, Honeydew, Shelter Cove, Miranda, Bear Harbor, Piercy, and Ettersburg) (hereinafter Project vicinity) to determine if a special-status natural community was recorded in the Project area. The CNDDB query identified only one special-status natural community, Upland Douglas Fir Forest, in the Project Vicinity.

3.1.2 Field survey

The field survey was conducted by a qualified botanist and ecologist with: (1) experience conducting floristic surveys; (2) knowledge of plant taxonomy and plant community ecology and classification; (3) familiarity with the plant species of the area; and (4) familiarity with appropriate state and federal statutes related to plants and plant collecting. The survey followed the methods of the *CDFW-CNPS Protocol for the Combined Vegetation Rapid Assessment and Relevé Method* (CNPS and CDFW 2018a) and *Protocols for Surveying and Evaluating Impacts to Special-Status Native Plant Populations and Natural Communities* (CDFW 2018b).

Field maps with existing vegetation information from CALVEG (USDA Forest Service 2019) were reviewed and representative locations for each stand type were sampled using the rapid assessment method. Plot size varied based on stand size and access. Dominant vegetation and their plant associates, habitat characteristics (e.g., disturbance, substrates/soils, aspects/slopes), known site history, and overall health of the stand were noted on a *CNPS and CDFW Combined Vegetation Rapid Assessment and Relevé Field Form* (CNPS and CDFW 2018b). If plant identification was not possible in the field, the plants were collected for identification in the laboratory using the "1 in 20" rule (Wagner 1991) or, if a potential special-status plant, according to the botanists' current CDFW plant voucher collection permit guidelines (e.g., not more than five individuals or 2% of the population, whichever is less, for one voucher sheet). Plants were identified following the taxonomy of *Jepson eFlora* (Jepson Flora Project 2019). Visual estimates of cover were noted for each species as well as its size, strata, and height class. Regeneration within sampling locations was also noted. Photographs were taken at each sampling location to document stand characteristics. A field-assessed vegetation alliance was assigned based on dominant and diagnostic species of the stand. Vegetation sampling points were mapped using a handheld sub-meter geographic positioning system (GPS) and stand boundaries within the Project area were delineated onto field maps. The digital data were post-processed and corrected, then incorporated into a geographical information systems (GIS) database. Data on field maps were digitized onto aerial imagery using GIS software.

Each field-assessed vegetation alliance was keyed using the vegetation composition data and the online edition of *A Manual of California Vegetation* (CNPS 2019a) to determine final vegetation alliances. Where applicable, vegetation was characterized and mapped to the finer association level. The finalized vegetation alliance/association names were checked against CDFW's *California Sensitive Natural Communities List* (CDFW 2018a) to determine if any of these types are considered special-status natural communities. These alliances were also used to further assess the likelihood of occurrence for special-status plants in the Project (see Section 4).

3.2 Results

Vegetation alliances observed in the approximately 39-ac Project area are listed in Table 3-1 and presented in Figure 3-1. Developed areas (i.e., residential) totaled 0.7 ac in the Project area. One sensitive vegetation alliance with a state rank of S3 (*Acer macrophyllum* Forest Alliance) was observed in the Project area (Table 3-2). Descriptions of the vegetation cover types are provided in the sub-sections below, along with representative photographs.

Table 3-1. Vegetation alliances and associations observed in the Project area.

Cover types	State status[1]	Total area (ac)
Acer macrophyllum Forest Alliance	S3	6.3
Annual/perennial grassland	None	21.4
Ceanothus incanus Shrubland Alliance	S4	2.2
Pseudotsuga menziesii Forest Alliance	S4	2.8
Quercus spp. Forest Alliance	S4	5.6
Total		**39.1**

[1] State ranks for special-status natural communities:
S3 Vulnerable—Vulnerable in the state due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation from the state.
S4 Apparently Secure—Uncommon but not rare; some cause for long-term concern due to declines or other factors.

Figure 3-1. Vegetation cover types within the Project area.

3.2.1 *Ceanothus incanus* Shrubland Alliance

The southwestern corner of the Project area contains a dense stand of shrubs predominantly composed by *Ceanothus incanus* (coast whitethorn). Stands of coast whitethorn are described within the *Ceanothus thyrsiflorus* Shrubland Alliance (blue blossom chaparral) (CNPS 2019a) since they are more limited in distribution and are ecologically similar to *Ceanothus thyrsiflorus* (blue blossom) (Klein et al. 2015). Coast whitethorn is dominant in the shrub canopy with low to moderate cover of *Baccharis pilularis* (coyote brush), *Fraxinus latifolia* (Oregon ash) saplings, *Toxicodendron diversilobum* (western poison oak), and *Cytisus scoparius* (Scotch broom). Herbaceous understory was not observed under the dense shrub canopy although *Rubus ursinus* (California blackberry) was observed throughout.

This alliance is associated with chaparral and coastal bluff scrub habitats. The coast whitethorn shrubland association has a total geographic extent of 2.2 ac in the Project area (Table 3-1, Figure 3-1).

3.2.2 *Pseudotsuga menziesii* Forest Alliance

The Douglas-fir Forest Alliance is composed of continuous canopy cover by Douglas-fir (60%) with low cover of *Acer macrophyllum* (big leaf maple) (15%) and black oak (15%). This alliance can occur along all topographical positions and aspects and on varying substrates (CNPS 2019a). In the Project area, this alliance is present on moderate slopes down to the creek bed. Associate tree species in the Project area included *Umbellularia californica* (California bay laurel) and *Arbutus menziesii* (Pacific madrone). The shrub layer varied from open to low cover of *Polystichum munitum* (western swordfern), *Quercus wislizeni* (interior live oak) saplings, and western poison oak. Regenerating tree cover was low (2–5%) comprised of California bay laurel and *Notholithocarpus densiflorus* (tanoak) seedlings and Douglas-fir saplings. Herbaceous species observed throughout this alliance included *Oxalis oregana* (redwood sorrel), *Whipplea modesta* (modest whipplea), *Scoliopus bigelovii* (California fetid adder's-tongue), Viola ocellata (western heart’s ease), *Sanicula crassicaulis* (Pacific sanicula), and *Pteridium aquilinum* var. *pubescens* (western bracken fern).

Douglas-fir forest is associated with broadleaved upland forest, north coast coniferous forest, and lower montane coniferous forest habitats. This forest alliance has a total geographic extent of 2.8 ac in the Project area (Table 3-1, Figure 3-1).

3.2.3 *Acer macrophyllum* Forest Alliance

The bigleaf maple forest alliance is composed primarily of bigleaf maple along with Douglas-fir and various hardwoods including black oak, *Salix sitchensis* (Sitka willow), and California bay laurel to form a continuous, sometimes two-tiered canopy bordering Redwood Creek and other waters in the Project area. This alliance is typically located along raised stream terraces, benches, and lower slopes with seeps (CNPS 2019a) and associated with north coast riparian areas in Douglas-fir forest. The shrub layer varied from open to dense cover by western poison oak, western sword fern, *Corylus cornuta* (California hazelnut), and *Rubus parviflorus* (thimbleberry). Herbaceous species varied from sparse to moderate cover and included *Oxalis oregana* (redwood sorrel), modest whipplea, California fetid adder's-tongue, and western bracken fern.

This forest alliance is associated with riparian forest and north coast coniferous forest habitats. It has a total geographic extent of 6.3 ac in the Project area (Table 3-1, Figure 3-1). *Acer macrophyllum* Forest Alliance is a sensitive natural community (S3) on CDFW's *California Sensitive Natural Communities List* (CDFW 2018a).

3.2.1 *Quercus* spp. Forest Alliance

The mixed oak forest alliance is present on the upper slopes on the southern side of the Project area and on the sloped transition between the upper and lower terrace. This forest alliance is composed of a mixture of *Quercus wislizeni* (interior live oak) and *Quercus kelloggii* (black oak) with Douglas-fir, *Arbutus menziesii* (Pacific madrone), and *Notholithocarpus densiflorus* (tanoak) in the upper canopy. The shrub layer varied from moderate to dense cover by western poison oak, coast whitethorn, coyote brush, Scotch broom, and Himalayan blackberry. Herbaceous species cover including western bracken fern and *Lonicera hispidula* (hispid honeysuckle) was low under the oak canopy though this alliance was present within and around annual/perennial grasslands which were dominated by herbaceous species.

The mixed oak forest alliance is associated with cismontane woodland and broadleaved upland forest habitats and has a total geographic extent of 5.6 ac in the Project area (Table 3-1, Figure 3-1).

3.2.2 Annual/perennial grassland

Annual/perennial grasslands in the Project area are managed pastures currently used for livestock grazing. This grassland cover type is best characterized within the Mediterranean California Naturalized Annual and Perennial Grassland Group (Sawyer et al. 2008). This group includes alliances that are primarily composed by nonnative grasses. Grasses observed within areas mapped as grassland included *Bromus hordeaceus* (soft chess), *Anthoxanthum odoratum* (sweet vernal grass), *Aira caryophyllea* (silver hair grass), *Dactylis glomerata* (orchard grass), *Cynosurus echinatus* (bristly dogtail grass), *Elymus glaucus* subsp. *glaucus* (blue wild-rye), *Avena barbata* (slender wild oat), and *Danthonia californica* (California oat grass). Herbaceous vegetation included *Luzula comosa* var. *comosa* (Pacific wood-rush), western bracken fern, *Eschscholzia californica* (California poppy), *Plantago lanceolata* (English plantain), *Juncus patens* (spreading rush), *Lythrum hyssopifolia* (hyssop loosestrife), *Juncus bufonis* var. *bufonis* (toad rush), *Hypochaeris radicata* (rough cat's ear), *Rumex acetosella* (sheep sorrel), *Erodium botrys* (long beaked filaree), *Bellis perennis* (English daisy), *Lysimachia arvensis* (scarlet pimpernel), and *Trifolium* spp. (various clovers). Small patches of *Rubus armeniacus* (Himalayan blackberry), *Rosa rubiginosa* (sweet-brier), coyote brush, and Scotch broom were observed throughout this alliance. Species dominance varied through the grassland with California oat grass dominating the upper hill slopes and nonnative grasses soft chess and bristly dogtail grass dominating the lower open grazed pasture. Patches of Himalayan blackberry and western bracken fern were observed throughout the flat lower terrace. Two wetland habitats were observed within this cover type, in which *Carex praegracilis* (freeway sedge), *Ranunculus parviflorus* (few-flowered buttercup), *Mentha pulegium* (pennyroyal), *Juncus bufonius* (toad rush), and *Juncus patens* (spreading rush) were prevalent (Figure 3-1).

This grassland cover type is associated with valley and foothill grassland habitat and has a total geographic extent of 21.4 ac in the Project area (Table 3-1, Figure 3-1).

4 SPECIAL-STATUS PLANTS

Special-status plant species are defined as those listed, proposed, or under review as threatened or endangered under the federal ESA and/or CESA; designated as rare under the California Native Plant Protection Act; and/or taxa that meet the criteria for listing as described in Section 15380 of the California Environmental Quality Act (CEQA) Guidelines including species listed on the CDFW's *Special Vascular Plants, Bryophytes, and Lichens List* (CDFW 2018c); that have a California Rare Plant Rank (CRPR) of 1, 2, 3 or 4; and/or that are considered a locally significant species (i.e., rare or uncommon in the county or region).

4.1 Methods

A list of special-status plants that may occur in the Project area was developed by querying the following resources:

- The U.S. Fish and Wildlife Service (USFWS) online *Information for Planning and Consultation* (IPaC) (USFWS 2019a),
- The California Native Plant Society's (CNPS) online *Inventory of Rare and Endangered Vascular Plants of California* (CNPS 2019b), and
- CDFW's CNDDB (CDFW 2019).

The database queries were based on a search of the Project vicinity (as defined in Section 3.1.1). Appendix A (Table A–1) lists special-status plants identified from the sources described above and provides mapped locations of CNDDB occurrences in the Project vicinity (Appendix A).

The potential for species meeting the above criteria to occur in the Project area was determined by: (1) reviewing the current distribution of each species (i.e., whether it overlaps with the Project area); (2) reviewing the documented occurrence information from the CNDDB; (3) reviewing existing information on vegetation in the CALVEG geodatabase (USDA Forest Service 2019) and soils in the USGS regional geologic map (McLaughlin et al. 2000); (4) comparing the habitat associations of each species with the vegetation alliances and habitat conditions documented in and adjacent to the Project area; and (5) using professional judgement to evaluate habitat quality and the relevance of occurrence data, or lack thereof.

This review and analysis resulted in the following categories of the likelihood for a special-status species to occur in the Project area:

- None: the Project area is outside the species' current distributional or elevation range and/or the species' required habitat is lacking from the Project area (e.g., coastal dunes).
- Low: the species' known distribution or elevation range overlaps with the Project vicinity but not the Project area, and/or the species' required habitat is of very low quality or quantity in the Project area.
- Moderate: the species' known distribution or elevation range overlaps with the Project area and/or the species' required habitat occurs in the Project area.
- High: the species has been documented in the Project area and/or its required habitat occurs in the Project area and is of high quality.

4.2 Results

4.2.1 Desktop review

A total of 29 special-status plant species were documented as occurring within the Project vicinity (Appendix A). Alliances documented during the vegetation assessment (Section 3.2) are associated with the following habitats: valley and foothill grassland, north coast coniferous forest, cismontane woodland, broadleaved upland forest, lower montane coniferous forest, riparian forest and chaparral (Table 4-1). Based on these habitat associations along with landform, soils, and known elevation range within the Project area, 11 special-status plants have low potential to occur (Appendix A) and eight have moderate potential to occur in the Project area (Appendix A and Table 4-1). Of these eight species with moderate potential to occur, none are federally listed, one is listed with the state as endangered, two have a CRPR of 1B (rare, threatened, or endangered in California and elsewhere), three have a CRPR of 2B (rare, threatened, or endangered in California and more common elsewhere), and two have a CRPR of 4 (plants of limited distribution in California, a watch list species) (Table 4-1). Furthermore, only one species, *Piperia candida* (white-flowered rein orchid), has documented occurrences within one mile of the Project area, all others are located 5 to 10 mi from the Project. A spring survey in May was selected to capture the appropriate phenological stage for all species with low and moderate potential to occur in the Project area, as well as to capture the peak blooming period for the habitats observed in this region.

Table 4-1. Special-status plant species with moderate potential to occur in the Project area.

Scientific name (common name)	Status (Federal, State, CRPR[1])	Habitat association[2]	Source	Likelihood of occurrence
Astragalus agnicidus (Humboldt County milk-vetch)	None/CE/1B.1	Openings, disturbed areas, and sometimes roadsides in broadleafed upland forest and north coast coniferous forest; 390–2,625 ft. Blooming period: April–September	CNPS, CDFW	**Moderate:** Broadleafed upland and north coast coniferous forest habitats present within Project area. Two occurrences within 5–10 mi of the Project area.
Coptis laciniata (Oregon goldthread)	None/None/4.2	Mesic meadows and seeps and streambanks in north coast coniferous forest; 0–3,280 ft. Blooming period: (February) March–May (September–November)	CNPS, CDFW	**Moderate:** North coast coniferous forest habitat present within Project area. Two occurrences within 5–10 mi of the Project area.
Erythronium oregonum (giant fawn lily)	None/None/2B.2	Sometimes serpentinite, rocky, openings in cismontane woodland and meadows and seeps; 325–3,775 ft. Blooming period: March–June (July)	CNPS, CDFW	**Moderate:** Cismontane woodland habitat present within Project area. No ultramafic soils mapped or observed in Project area. One occurrence is within 5–10 mi of the Project area.
Erythronium revolutum (coast fawn lily)	None/None/2B.2	Mesic, streambanks, bogs and fens, broadleafed upland forest, and north coast coniferous forest; 0–5,250 ft. Blooming period: March–July (August)	CNPS, CDFW	**Moderate:** Broadleafed upland and north coast coniferous forest habitats present within Project area. Two occurrences within 5–10 mi of the Project area.
Gilia capitata subsp. *pacifica* (Pacific gilia)	None/None/1B.2	Coastal bluff scrub, openings in chaparral, coastal prairie, and valley and foothill grassland; 15–5,465 ft. Blooming period: April–August	CNPS, CDFW	**Moderate:** Chaparral and valley and foothill grassland habitats present within Project area. Multiple occurrences within 5–10 mi of the Project area.
Montia howellii (Howell's montia)	None/None/2B.2	Vernally mesic, sometimes roadsides in meadows and seeps, north coast coniferous forest, and vernal pools; 0–2,740 ft. Blooming period: (February) March–May	CNPS, CDFW	**Moderate:** North coast coniferous forest habitat present within Project area. Two occurrences within 5–10 mi of the Project area.

Scientific name (common name)	Status (Federal, State, CRPR[1])	Habitat association[2]	Source	Likelihood of occurrence
Piperia candida (white-flowered rein orchid)	None/None/1B.2	Sometimes serpentinite in broadleafed upland forest, lower montane coniferous forest, and north coast coniferous forest; 95–4,300 ft. Blooming period: (March) May–September	CNPS, CDFW	**Moderate:** Broadleafed upland, lower montane coniferous, and north coast coniferous forest habitats present within Project area. No ultramafic soils mapped or observed in Project area. Multiple occurrences within 1 mi of the Project area.
Usnea longissima (Methuselah's beard lichen)	None/None/4.2	On tree branches, usually on old growth hardwoods and conifers in broadleafed upland forest and north coast coniferous forest; 160–4,790 ft. Blooming period: N/A (lichen)	CNPS, CDFW	**Moderate:** Broadleafed upland and north coast coniferous forest habitats present within Project area. Multiple occurrences within 5–10 mi of the Project area.

[1] Status:

State:

CE	California endangered

California Rare Plant Rank (CRPR):

1B	Plants rare, threatened, or endangered in California and elsewhere
2B	Plants rare, threatened, or endangered in California, but more common elsewhere
4	Plants of limited distribution, on watchlist

CRPR Threat Ranks:

0.1	Seriously threatened in California (over 80% of occurrences threatened / high degree and immediacy of threat)
0.2	Moderately threatened in California (20–80% occurrences threatened / moderate degree and immediacy of threat)

[2] Months in parentheses are uncommon; N/A = Not applicable

4.2.2 Field survey

No special-status plant species were observed during the 3 May 2019 protocol-level botanical survey conducted in the Project area. A comprehensive list of all plant species observed in the Project area is provided in Appendix B.

5 WETLANDS AND WATERS

Waters and wetlands are under United States Army Corps of Engineers (USACE) jurisdiction pursuant to Section 404 of the Clean Water Act (CWA) regulatory authority and under SWRCB jurisdiction by Section 401 of the CWA. Section 404 of the CWA applies to all waters, including wetlands, that have sufficient nexus to interstate commerce (USACE 1986).

A formal delineation of potential USACE jurisdictional waters or wetlands was not conducted as part of the field assessment; however, a wetland characterization within the Project area was conducted in conjunction with the special-status plant survey performed on 3 May 2019 (Section 4) to provide preliminary information on wetland conditions and assist with Project planning.

5.1 Methods

Results of topographic surveys conducted by Stillwater Sciences were used to characterize watercourses within the Project area. Waters were categorized as perennial (i.e., support water year-round) or seasonal based on the results of the fisheries assessment (Section 6). Connectivity of these waters to traditional navigable waters as defined by the USACE was evaluated in GIS.

Prior to the wetlands assessment, existing information on vegetation, soils, and hydrology for the site was evaluated. Available data from the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey website was reviewed for the Project area and nearby vicinity. Information on potential jurisdictional waters and wetlands in the Project area and nearby vicinity was obtained from the USFWS National Wetlands Inventory (NWI) online application, *Wetlands Mapper* (USFWS 2019b).

Any potential USACE- and/or state-jurisdictional three-parameter wetland observed in the Project area was drawn onto field maps and later digitized using GIS. Evidence of a three-parameter wetland included the observation of at least two of the following wetland parameters: (1) dominant cover by hydrophytic vegetation (i.e., plants with a wetland indicator status of OBL [obligate], FACW [facultative-wet], or FAC [facultative] in the *Western Mountains, Valleys, and Coast Region* [Lichvar et al. 2016]), (2) wetland hydrology (e.g., saturated soils, standing water), and/or (3) mapped hydric soils. Per the 2001 United States Supreme Court issued decision on *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers* (SWANCC), any three-parameter wetland not adjacent or abutting a USACE-jurisdictional water of the U.S. does not fall under federal jurisdiction. Instead, these isolated three-parameter wetlands are potentially state jurisdictional under the *Porter-Cologne Water Quality Control Act at Water Code section 13000 et seq.* (Porter-Cologne Act) by the Regional Water Quality Control Board (RWQCB).

5.2 Results

Based on thalwegs calculated from topographic survey data, the Project area contains 1.17 ac of potential waters of the U.S. These waters are comprised of Redwood Creek (which flows perennially), two intermittently flowing tributaries to Redwood Creek, and an additional intermittent water that has no clear surface water connection to Redwood Creek (Figure 5-1). Redwood Creek accounts for 0.5 ac of potential waters of the U.S. in the Project area and has an approximate width ranging from 8 ft to 46 ft. Unnamed intermittent waters account for 0.6 ac of potential waters of the U.S. in the Project area; these waters have an average approximate width of 10 ft (Figure 5-1).

Per the USFWS NWI query, Redwood Creek was the only surface water noted in the Project area. Potential waters of the U.S. in the Project area are also considered potential waters of the state by CDFW and SWRCB. Furthermore, riparian vegetation adjacent to waters of the state is interpreted by CDFW as being within the streambed and thereby falls under CDFW jurisdiction (Figure 5-1). Riparian vegetation totals 5.8 ac in the Project area and is associated with the *Acer macrophyllum* Forest Association (Figures 3-1 and 5-1).

Two three-parameter wetlands were also observed in the Project area and totaled 0.20 ac. Standing water observed at both locations indicated a high-water table, a primary indicator for wetland hydrology. Recent bioturbation from livestock was noted at both locations. Tadpoles were observed in areas within the larger wetland (0.19 ac) to the north where standing water was present in hoof punch and one adult tree frog was observed in the smaller wetland (0.01 ac) just downslope of the existing access road (Figure 5-1). Both wetlands are located within the

Briceland-Tankridge complex, 15–50% slopes soil map unit. All components within this map unit were not listed as a hydric soil (NRCS 2019). Hydrophytic vegetation was evident in these areas and included freeway sedge (FACW), pennyroyal (OBL), toad rush (FACW), and spreading rush (FACW). No surface water connection to a watercourse was observed and these two isolated wetlands were not considered to be potentially USACE-jurisdictional wetlands; however, they may be considered state-jurisdictional wetlands by the RWQCB (Figure 5-1).

Figure 5-1. Preliminary waters and wetlands within the Project area.

6 SPECIAL-STATUS FISH AND WILDLIFE

6.1 Methods

An assessment of suitable habitat for special-status fish and wildlife was conducted to inform future analysis of the Project's potential to impact such species. Special-status species are defined as those that are:

- listed as endangered or threatened, or are proposed/candidates for listing, under ESA and/or CESA);
- designated by CDFW as a Species of Special Concern

6.1.1 Desktop review

The following biological databases were queried for records of special-status fish and wildlife or critical habitat that have potential to occur in the Project area:

- USFWS species list using the USFWS IPaC portal (USFWS 2019a),
- CDFW's CNDDB (CDFW 2019),
- CDFW's CNDDB northern spotted owl viewer (CDFW 2021), and
- National Marine Fisheries Service's (NMFS) *California Species List Tools* database (NMFS 2019).

The CNDDB and USFWS database queries were each based on a search of records within the Project vicinity (see Section 3.1.1). The NMFS database query was based on a query of the Briceland quadrangle. Literature on recent occurrences of special-status species in the region was also consulted to determine which special-status species could occur in the Project area.

6.1.2 Fish and wildlife site assessment

A habitat assessment was conducted on 4 May 2019 to evaluate habitat conditions for special-status fish and wildlife species in the in the Project area. The site visit included a field review of the Project area, general characterization of aquatic and wildlife habitat, and photo documentation. The field survey was conducted in the entire construction zone, along intermittent watercourses and a 450-ft long reach of Redwood Creek, and in an area extending between 450 to 1,200 ft into the forest south of the proposed reservoir area.

A second field survey was conducted on 6 May 2021 to evaluate habitat conditions within and adjacent to the lower terrace, which will be the site of the proposed 5.7 million gallon pond.

6.2 Results

A total of 21 special-status wildlife species were identified from the database queries as having potential to occur in the Project area (Appendix A). Suitable habitat for some of the queried species does not occur in the Project area. Appendix A provides information about queried species without suitable habitat or with a low potential to occur in the Project area and these species are not discussed further in the main body of this document.

There are 12 special-status fish and wildlife species that have a moderate or high potential to occur and/or be affected by Project activities (Table 6-1). These species include Pacific lamprey, which did not appear in the database search results, but are known to occur within the South Fork Eel River in large numbers and likely in Redwood Creek. Each of these species are discussed in further detail in the sections below.

Table 6-1. Special-status fish and wildlife species with moderate to high potential to occur in the Project area.

Species name	Status[1] Federal/ State	Distribution and habitat associations	Location of suitable habitat in Project area	Likelihood of occurrence
Fish				
Oncorhynchus kisutch (Coho salmon – southern Oregon/ northern California coast Evolutionarily Significant Unit)	FT, CH/ST	Spawn in coastal streams and large mainstem rivers (i.e., Klamath/Trinity rivers) in riffles and pool tails-outs and rear in pools $\geq$ 3 ft deep with overhead cover with high levels oxygen and temperatures between 50–59ºF.	Suitable habitat occurs in the South Fork Eel River and Redwood Creek.	**High**: Present in Redwood Creek.
Oncorhynchus tshawytscha (Chinook salmon – California Coastal ESU*)*	FT, CH/None	Wild coastal, spring, and fall-run Chinook found in streams and rivers between Redwood Creek, Humboldt County to the north and the Russian River, Sonoma County to the south.	Suitable habitat occurs in the South Fork Eel River and Redwood Creek.	**High**: Present in Redwood Creek.
Oncorhynchus mykiss (Steelhead – northern California coast Distinct Population Segment)	FT, CH/None	Inhabits small coastal streams to large mainstem rivers with gravel-bottomed, fast-flowing habitat for spawning. However, habitat criteria for different life stages (spawning, fry rearing, juvenile rearing) are can vary significantly.	Suitable habitat occurs in the South Fork Eel River and Redwood Creek.	**High**: Present in Redwood Creek.
Entosphenus tridentatus (Pacific lamprey)	None/SSC	Similar to anadromous salmonids, inhabits coastal streams and rivers with gravel-bottomed, fast-flowing habitat for spawning. Ammocoetes rear in backwater areas with sand, silt, and organic material for 4 to 10 years before migrating to the ocean.	Suitable habitat is present and spawning/rearing occurs in the South Fork Eel River. Spawning and rearing habitat is likely to occur in Redwood Creek.	**High:** Suitable habitat present.

Species name	Status[1] Federal/ State	Distribution and habitat associations	Location of suitable habitat in Project area	Likelihood of occurrence
Amphibians				
Rana boylii (foothill yellow-legged frog)	None/SSC, CT	Associated with partially shaded, shallow streams, and riffles with rocky substrate. Some cobble-sized substrate required for egg laying. Adults move into smaller tributaries after breeding.	Suitable habitat is present and breeding occurs in the South Fork Eel River. Observed in Redwood Creek downstream of Project area.	**High**: Suitable habitat present.
Taricha rivularis (red-bellied newt)	None/SSC	Ranges from southern Humboldt to Sonoma counties. Found in streams during breeding season. Moist habitats under woody debris, rocks, and animal burrows.	Suitable habitat is present and sightings have occurred in the Mattole River, approximately 5 mi west of the Project area.	**High**: Habitat present in the Project area.
Birds				
Strix occidentalis caurina (northern spotted owl)	FT/ST	Typically found in large, contiguous stands of mature and old-growth coniferous forest with dense multi-layered structure.	Suitable foraging habitat is present within the Project area. Habitat within the Project area is unsuitable for nesting. The closest activity center is over 1.7 mi to the south-southeast of the Project area.	**Moderate**: Suitable foraging habitat exists in the Project area.
Asio otus (long-eared owl)	None/SSC	Distributed throughout North America. Recorded in north coast from Bald Hills, Humboldt County to Willits, Mendocino County. In Humboldt County, nest in mixed stands of conifers and oaks with edges and openings such as meadows or prairies.	Suitable nesting and foraging habitat present in the Project area.	**High**: Habitat present in the Project area.
Reptiles				
Emys marmorata (western pond turtle)	None/SSC	Ponds, marshes, rivers, streams, and irrigation ditches with abundant vegetation, and either rocky or muddy bottoms, in woodland forest and grasslands. Below 6,000 ft elevation. Basking sites are required. Egg-laying sites are located on suitable upland habitats (grassy open fields) up to 1,640 ft from water.	Suitable habitat occurs in the South Fork Eel River. Ponds that may contain western pond turtles are located on neighboring properties.	**Moderate.** May occur in neighboring ponds.

Species name	Status[1] Federal/ State	Distribution and habitat associations	Location of suitable habitat in Project area	Likelihood of occurrence
Mammals				
Arborimus pomo (Sonoma tree vole)	None/SSC	Associated nearly exclusively with Douglas-fir trees and occasionally grand fir trees within the north coast fog belt between the northern Oregon border and Sonoma County. Eats Douglas-fir needles exclusively.	Early to mid-seral Douglas-fir stands are present adjacent to the Project area, which could provide nesting and foraging habitat.	**High**: Recorded occupying timber stands adjacent to the Project area
Corynorhinus townsendii (Townsend's big-eared bat)	None/SSC, CT	Found throughout California in all but subalpine and alpine habitats. Roosts in cavernous habitats, usually in tunnels, caves, buildings, mines, and basal hollows of trees, but also rock shelters, preferentially close to water. Caves near water's edge are favored. Forages in riparian zone and follows creeks and river drainages on foraging bouts. Feeds primarily on moths. Drinks at stream pools.	Suitable foraging habitat throughout most of the Project area; however, barns, old buildings, and bridges for roosting are not present within the Project area.	**Moderate**: May be present in some of the barns and older structures adjacent to the Project area.
Antrozous pallidus (pallid bat)	None/SSC	Found throughout California. Roosts in rock crevices, outcrops, cliffs, mines, and caves; trees (underneath exfoliating bark of pine and oak) and in basal hollows; and a variety of vacant and occupied structures (e.g., bridges) or buildings. Roost individually or in small to large colonies (hundreds of individuals). Feeds low to or on the ground in a variety of open habitats, primarily on ground-dwelling arthropods. Forages most frequently in riparian zone, in open oak savannah, and open mixed deciduous forest. Drinks at stream pools.	Suitable foraging habitat throughout most of the Project area, however barns, old building, and bridges are not present within the Project area.	**Moderate**: May be present in some of the older structures adjacent to the Survey Area

[1] Status:

Federal		**State**	
FT	Federal Threatened	ST	Threatened
FC	Federal Candidate	CT	Candidate Threatened
CH	Designated critical habitat within the Project vicinity	SSC	CDFW species of special concern

6.2.1 Fish

Fish-bearing watercourses in the Project area are inhabited by coho and Chinook salmon, steelhead, and Pacific lamprey. Suitable habitat for salmon, steelhead, and lamprey spawning and rearing was observed in Redwood Creek adjacent to the Project area during the field reconnaissance. Gravel in the creek was relatively unembedded and a suitable size for spawning. The pool:riffle:flatwater ratio was approximately 50:15:35 with the pools being between 2–5 ft deep. Brief life history discussions for each species are below.

6.2.1.1 Coho salmon, Southern Oregon/Northern California Coast ESU

The Southern Oregon/Northern California Coast evolutionary significant unit (ESU) for coho salmon is listed as threatened under the federal ESA (NMFS 2005a) and was listed as threatened under the California ESA in 2005. Critical habitat was designated in 1999 between the Mattole River in California and the Elk River in Oregon, inclusive (NMFS 1999a). Critical habitat includes all accessible streams and waters of estuarine areas. Coho salmon are known to spawn and rear in the South Fork Eel River and its tributaries. Upon emergence from the gravels, coho fry seek low-velocity areas along shallow stream margins (Shapovalov and Taft 1954). As they grow, juvenile coho move to deeper habitats, although they continue to prefer low-velocity habitat throughout the rearing period.

Coho salmon adults typically migrate upstream from October through December, and spawn from November through January. Spawning generally occurs in low-gradient stream reaches with gravel and cobble substrates. Females dig nests (redds) in the gravel, and deposit 2,500–5,000 eggs in a sequence of egg pockets, which are fertilized by one or more males (Beacham 1982, Sandercock 1991). Egg development is temperature-dependent, with fry emerging from the gravel in the spring, approximately three to four months after spawning. Upon emergence from the gravels, coho fry seek low-velocity areas along shallow stream margins (Shapovalov and Taft 1954). As they grow, juvenile coho move to deeper habitats, although they continue to prefer low-velocity habitat throughout the rearing period. Juveniles typically spend one to two years rearing in fresh water before outmigrating. Emigration from streams to the estuary and ocean generally takes place from February through June. Coho typically spend two years foraging at sea before returning to their natal streams to spawn.

Suitable habitat for coho salmon spawning and rearing was observed in Redwood Creek adjacent to the Project area during the field reconnaissance. Young-of-the-year coho salmon were observed in Redwood Creek during an instream habitat inventory in 2009 (CDFG 2009).

6.2.1.2 Chinook salmon, California coastal ESU

California coastal Chinook salmon were listed in 1999 as threatened under the federal ESA (NMFS 1999b). The California coastal Chinook salmon ESU extends from the Klamath River (exclusive) south to the Russian River (inclusive). Critical habitat for the species was designated in 2005 (NMFS 2005b) and includes the South Fork Eel River and Redwood Creek.

Chinook salmon in the California coastal ESU exhibit life history characteristics of the fall-run ecotype. In California, most adult fall-run Chinook enter streams from August through November, with peak arrival usually occurring in October and November. Spawning occurs from early October through December. Upon arrival at the spawning grounds, adult females dig shallow depressions or pits in gravel and cobble substrate, deposit eggs in the bottom during the act of spawning, and cover them with additional gravel. Female fall-run Chinook deposit an average of about 5,500 eggs. Egg incubation generally lasts between 40 to 90 days at water temperatures of 42.8 to 53.6°F, and the alevins remain in the gravel for two to three weeks before emerging from the gravel. Fall-run Chinook salmon fry usually begin migrating downstream soon after emergence in February or March, with outmigration continuing into late-July. Chinook spend two or more years at sea before migrating back to their natal streams to spawn.

Suitable habitat for Chinook salmon spawning and rearing was observed in Redwood Creek adjacent to the Project area during the field reconnaissance. Chinook salmon have been identified as being present in Redwood Creek (CWPAP 2014).

6.2.1.3 Steelhead, Northern California Coast DPS

The Northern California Coast steelhead DPS was listed as threatened in 2006 under the federal ESA (NMFS 2006). The Northern California Coast steelhead DPS extends from Redwood Creek in Humboldt County to the Gualala River in Mendocino County (inclusive). Critical habitat for the species was designated in 2005 (NMFS 2005b). Critical habitat includes the South Fork Eel River and its tributaries, including Redwood Creek.

Adult winter steelhead generally begin migrating to spawning areas in October, with the peak migration in December through February. Steelhead spawning occurs in mainstems, tributaries, and intermittent streams in December through May. Spawning occurs in gravel and cobble substrates where the female digs an egg pocket and deposits her eggs, which are fertilized externally by one or more males. Redds typically consist of a series of egg pockets that excavated and subsequently covered during redd construction process. Unlike Chinook and coho salmon, steelhead typically do not remain on the spawning grounds for extended periods to defend the completed redd to reduce the potential for superimposition. Egg development time is inversely proportional to water temperature and varies from about 19 days at 60°F to about 80 days at 42°F. Fry typically emerge from the gravel two to three weeks after hatching. Upon emerging from the gravel, fry move to shallow edgewater habitats to rear, and gradually move into deeper habitats as they grow. During winter, when water temperatures are cold, juveniles are less active and hide in the interstitial spaces between cobbles and bounders. Juvenile steelhead typically rear in fresh water for two to three years prior to migrating downstream to the estuary and ocean. Steelhead spend between six months and three years at sea before returning to their natal streams to spawn. Unlike salmon, steelhead are capable of repeat spawning.

Suitable habitat for steelhead spawning and rearing was observed in Redwood Creek adjacent to the Project area during the field reconnaissance. Young-of-the-year and Age 1+ steelhead were observed in Redwood Creek during an instream habitat inventory in 2009 (CDFG 2009).

6.2.1.4 Pacific lamprey

The Pacific lamprey is a large, widely distributed anadromous species that rears in fresh water before outmigrating to the ocean, where it grows to full size (approximately 16–28 in) prior to returning to freshwater streams to spawn and ultimately die. The species is distributed across the northern margin of the Pacific Ocean, from central Baja California north along the west coast of North America to the Bering Sea in Alaska and off the coast of Japan. Adults migrate into and spawn in a wide range of river systems, from short coastal streams to tributaries of large rivers.

Pacific lampreys typically spawn from March through July depending on water temperatures and local conditions such as seasonal flow regimes (Kan 1975, Brumo et al. 2009, Gunckel et al. 2009). Spawning generally occurs at daily mean water temperatures from 50–64°F, with peak spawning around 57–59°F (Stone 2006, Brumo 2006). Redds are typically constructed by both males and females in gravel and cobble substrates within pool and run tailouts and low gradient riffles into which eggs are deposited (Stone 2006, Brumo et al. 2009, Gunckel et al. 2009).

Hatching occurs following about 15 days of incubation, the egg-sac larval stage spend another 15 days in the redd gravels during which time they absorb the remaining egg sac, until they emerge at night and drift downstream (Brumo 2006). After drifting downstream, the eyeless larvae, known as ammocoetes, settle out of the water column and burrow into fine silt and sand substrates that often contain organic matter. Within the stream network they are generally found in low-velocity, depositional areas such as pools, alcoves, and side channels (Torgensen and Close 2004). Depending on factors influencing growth rates, they rear in these habitats from 4 to 10 years, filter-feeding on algae and detrital matter prior to metamorphosing into the adult form (Pletcher 1963, Moore and Mallatt 1980, van de Wetering 1998). During metamorphosis, Pacific lampreys develop eyes, a suctoral disc, sharp teeth, and more-defined fins (McGree et al. 2008).

After metamorphosis, smolt-like individuals known as macrophthalmia migrate to the ocean—typically in conjunction with high-flow events between fall and spring (van de Wetering 1998, Goodman et al. 2015). In the ocean, Pacific lampreys feed parasitically on a variety of marine fishes (Richards and Beamish 1981, Beamish and Levings 1991, Murauskas et al. 2013). They are thought to remain in the ocean, feeding for approximately 18–40 months before returning to fresh water as sexually immature adults, typically from winter to early summer (Kan 1975, Beamish 1980, Starcevich et al. 2014, Stillwater Sciences and Wiyot Tribe Natural Resources Department 2016).

Pacific lamprey are known to occur in the South Fork Eel River and its tributaries. Redwood Creek has suitable spawning and rearing habitat for this species.

6.2.2 Wildlife

6.2.2.1 Foothill yellow-legged frog

Foothill yellow-legged frog is a California species of special concern and has recently been designated as a candidate for threatened listing under the CESA. Within California, foothill yellow-legged frogs were historically found in the Sierra Nevada foothills, up to elevations of approximately 6,000 ft, and in the Coast Range from the Oregon state border south to the San Gabriel River in southern California (Stebbins 2003). Currently, populations are thought to have disappeared from the southern Sierra Nevada foothills, in areas south of the Transverse ranges, and along the coast south of Monterey County (Jennings and Hayes 1994).

Foothill yellow-legged frogs are typically found in perennial streams or rivers, and intermittent creeks with pools. The species often breeds in open and sunny, low-gradient stream reaches near junctions with tributary streams, due to the proximity of adult overwintering habitat in tributaries and to the presence of boulders and cobbles in these locations. Egg deposition usually occurs in cobble bars or under large boulders in areas of low-velocity flow. Tadpoles show affinity to the oviposition site, remaining in edgewater habitat with substrate interstices, vegetation, and/or detritus for cover. Adults prefer areas with exposed basking sites and cool, shady areas adjacent to the water’s edge.

No foothill yellow-legged frogs were observed within or adjacent to the Project area during the field survey in May 2019 or 2021. Suitable habitat for foothill yellow-legged frog breeding occurs in the South Fork Eel River where the channel widens and the tree canopy opens to allow sun to reach the channel for several hours a day. Although the portion of Redwood Creek in the Project area is more heavily shaded than some section of the South Fork Eel River, suitable breeding and larval rearing habitat for foothill yellow-legged frog is present. In addition, Redwood Creek and its tributaries could be used by adults and juveniles of this species for dispersal in the fall.

6.2.2.2 Red-bellied newt

The red-bellied newt is a California species of special concern. In California, this species is found along the coast from near Bodega, Sonoma County, to near Honeydew, Humboldt County, and inland to Lower Lake and Kelsey Creek, Lake County. It lives in coastal woodlands, especially redwood forests.

Adults are terrestrial and become aquatic when breeding. Terrestrial animals spend the dry summer in moist habitats under woody debris, rocks, in animal burrows. Adults forage on the forest floor for a variety of invertebrates. Adults move toward streams in late February at the start of the breeding season, which extends into May. This species avoids ponds or lakes. Females lay eggs under rocks or attached to submerged roots in rocky streams and rivers with moderate to fast flow. Incubation lasts between two weeks to one month. Larval development to metamorphosis occurs over four to six months, after which they emerge from the streams and occupy terrestrial habitat. Juveniles spend most of their time underground and are not active on the surface until near sexual maturity, which occurs at about four to six years of age.

This species was not observed during the field survey in May 2019, however suitable aquatic and terrestrial habitat is present within or adjacent to Redwood Creek.

6.2.2.3 Northern spotted owl

The northern spotted owl is federally and state-listed as threatened. Critical habitat has been designated for this species, but it is not present within or adjacent to the Project area. Northern spotted owls are uncommon year-round residents in the northern California coastal ranges from Marin County north, as well as within the Cascade Range in northern California, southeast to the Pit River in Shasta County below 7,600 ft (Harris 1993, Gutiérrez et al. 1995, USFWS 2010). South of Burney in the southern Cascade Range and Sierra Nevada, the northern spotted owl is replaced by the California spotted owl (*Strix occidentalis occidentalis*) (Gutiérrez et al. 1995).

Northern spotted owls are typically associated with complex mature or old-growth stands dominated by conifers, particularly redwoods with hardwood understories (Pious 1994, USFWS 2011). Roosting sites are characterized by dense canopy cover dominated by large-diameter trees (i.e., greater than 30-in diameter at breast height [dbh]), multiple canopy layers, and north-facing slopes, often in cool shady areas (Gutiérrez et al. 1995, Courtney et al. 2004). Nests tend to be found in tree or snag cavities, on platforms (e.g., abandoned raptor or raven nests, squirrel nests, mistletoe brooms, or debris accumulations), or on broken-top snags (Zeiner et al. 1990a). Northern spotted owls are generally monogamous, forming long-term pair bonds that often last for life (Courtney et al. 2004). In late February or early March, pairs begin roosting in cavities, the tops of broken trees, or abandoned nests; nesting is followed by peak breeding in April and May (Zeiner et al. 1990a, Gutiérrez et al. 1995, Courtney et al. 2004). Northern spotted owls generally lay a single clutch of one to four eggs (Gutiérrez et al. 1995). A pair may use the same nesting location for several years, although breeding may not occur every year (Zeiner et al. 1990a).

Primary prey items for northern spotted owls are small mammals, but birds and insects are also taken (Forsman et al. 1984, Zeiner et al. 1990a). Foraging habitats vary more than roosting and nesting habitats, but are similarly characterized by high canopy closure and complex structure (Thomas et al. 1990). Open areas are also important foraging areas in northern California, as the abundance and diversity of prey is higher in early successional habitats (Folliard et al. 2000). Spotted owls are likely to forage in stands that are young enough to contain an abundance of prey, such as woodrats, but are old enough to allow the owls to fly under the canopy (Thome et al. 1999).

Suitable nesting habitat for northern spotted owl is not present in or adjacent to the Project area; however, species may forage in the area. The forest to the south of the Project area is dominated by a dense stand of 12- to 24-inch dbh Douglas-fir with a lesser amount of hardwoods. No evidence (pellets, nests, whitewash on trees or forest floor, etc.) of owl nesting or occupancy was observed in this area and the trees within it are not suitable for nesting. The nearest activity center (HUM0580) for this species is located approximately 1.7 mi to the southwest and the last recorded observation at this activity center was of a female and male pair in 2019 (CDFW 2021).

6.2.2.4 Long-eared owl

The long-eared owl is considered a species of special concern in California. It occurs and breeds the length and breadth of the state east of the northern humid coastal region and from sea level to 7000 ft (Shuford and Gardali 2008). The species is considered to be “common” to “abundant locally” (Shuford and Gardali 2008). Surveys for the Humboldt County breeding bird atlas found long-eared owls in 11 scattered blocks in the southern half of the county, mainly in the interior (Hunter et al. 2005, as cited in Shuford and Gardali 2008). Prior records for the region representing possible breeding birds extend from Bald Hills, Humboldt County, south to Willits, Mendocino County (Harris 2005, as cited in Shuford and Gardali 2008).

Long-eared owls nests in conifer, oak, riparian, pinyon-juniper, and desert woodlands that are either open or are adjacent to grasslands, meadows, or shrublands. Key habitat components are some dense cover for nesting and roosting, suitable nest platforms, and open foraging areas. In Humboldt County, the owls apparently nest in mixed stands of conifers and oaks with edges and openings such as meadows or prairies (Hunter et al. 2005, as cited in Shuford and Gardali 2008).

Although no evidence (pellets, nests, whitewash on trees or forest floor, etc.) of owl nesting or occupancy was observed during the field survey, the Project area contains suitable nesting and foraging habitat for long-eared owls. The closest sighting occurred in Humboldt Redwoods State Park at Bull Creek, approximately 17.5 mi north of the Project area. However, observation records may be relatively scarce due to the nocturnal habitat of the species.

6.2.2.5 Sonoma tree vole

The Sonoma tree vole is a candidate for state listing as threatened. In California, the Sonoma tree vole is restricted to coastal forests in the humid fog belt from Sonoma County north to the Klamath mountains (Williams 1986, Jameson and Peeters 2004, Adam and Hayes 1998). Distribution of Sonoma tree voles in many parts of their range is patchy (Hall 1981), but this species can be locally common (Williams 1986).

The Sonoma tree vole is a nocturnal rodent that is active year-round (Zeiner et al. 1990b). This species lives, nests, and feeds within the forest canopy, though males are rarely terrestrial (Williams 1986). The home range usually consists of one or more trees (Brown 1985, as cited in

Carey 1991). Both sexes construct nests of Douglas-fir needles, typically located 6–18 m (20–60 ft) above the ground in branches or against trunks of Douglas-fir trees (Williams 1986). In cases where nests were found in species other than Douglas-fir, grand fir, and redwood, nests were on branches interlocking with branches of Douglas-fir. Breeding occurs throughout the year, peaking from February through September. The young are weaned at 30–40 days (Zeiner et al. 1990b). The diet of the red tree vole consists of needles, buds, and the tender bark of twigs of Douglas-fir, western hemlock, grand fir, and Bishop pine (Williams 1986, Wooster 1996). Needle resin ducts are removed before the remaining part is eaten. Young needles may be consumed entirely (Harris 1990). Tree voles obtain water from food or by licking dew or rainwater from coniferous trees (Maser 1965). Where present, tree voles are a common component of spotted owl diets (Forsman et al. 2004).

In Mendocino County, nests have occasionally been located on open ridge tops and in previously heavily logged and/or grazed areas (Wooster 1996). The predominant tree species used by Sonoma tree voles is Douglas-fir, with larger trees able to support colonies of tree voles (Meiselman 1987, Carey 1991, Wooster 1996, Thompson and Diller 2002, Jones 2003). Based on a study by Thompson and Diller (2002), tree voles are hypothesized to start colonizing in tree stands as young as around 20 years old. Density of active vole nests increases significantly as stands mature beyond 20 years old (Thompson and Diller 2002). Tree voles have also been documented nesting in tanoak, presumably due to its common occurrence in many Douglas-fir stands (Thompson and Diller 2002).

Although a stand search for nests and resin ducts (discarded after feeding on fir needles and used for nesting material) did not yield evidence of occupancy by this species, suitable habitat for Sonoma Tree vole is present in the Douglas-fir-dominated forest south of the Project area.

6.2.2.6 Townsend's big-eared bat

Townsend's big-eared bat is a candidate for state listing as threatened and a California species of special concern. This species occurs throughout California and is associated with caves and structures in a variety of habitats from deserts to coastal scrub to montane forests. Townsend's big-eared bats have been documented from sea level to 10,800 ft, although in California maternity roosts appear to be confined to elevations below 5,900 ft (Pierson and Fellers 1998, Sherwin and Piaggio 2005).

This cavity-dwelling species roosts and hibernates in caves (commonly limestone or basaltic lava), mines, buildings, bridges (with a cave-like understructure), rock crevices, tunnels, basal hollows in large trees, and cave-like attics (Pierson and Fellers 1998, Pierson and Rainey 2007, Pierson et al. 2001, Pierson and Rainey 1996, Sherwin et al. 2000, Sherwin and Piaggio 2005). Townsend's big-eared bats breed in both transitory migratory sites and hibernacula between September or October and February (CDFW 2013). The maternity season extends from 1 March through 31 October, with colonies forming between March and June and breaking up by September or October (CDFW 2013). Maternity colonies and winter hibernacula (found in caves, tunnels, mines, and buildings [Zeiner et al. 1990b]) are particularly sensitive to disturbance. This species could be directly impacted by removal or disturbance of maternal roosts (e.g., trees, abandoned buildings) during the breeding season (March–October).

Townsend's big-eared bat is a moth specialist with over 90% of its diet composed of lepidopterans. Foraging habitat associations include edge habitats along streams, adjacent to and within a variety of wooded habitats. These bats often travel large distances while foraging, including movements of over 93 mi during a single evening (Sherwin et al. 2000). Evidence of large foraging distances and large home ranges has also been documented in California (Pierson and Rainey 1996).

Snags and large trees may be important roosts for this species. In northwestern California, Fellers and Pierson (2002, as cited in Woodruff and Ferguson 2005) documented individual Townsend's bats using tree hollows created by fire or rot in very large redwood (*Sequoia sempervirens*) and California bay trees (*Umbellularia californica*). A nursery colony was found using the basal hollows of large redwood trees in northwestern California (Mazurek 2004, as cited in Woodruff and Ferguson 2005) and in Muir Woods National Monument near San Francisco (Heady and Frick 2001, as cited in Woodruff and Ferguson 2005).

There is limited roosting habitat for Townsend's big-eared bat in the Project area (i.e., no caves, buildings, or bridges); however the species has the potential to roost in cavities present in older madrone and oak trees south of the Project area. Foraging habitat for Townsend's big-eared bat is present in the Project area.

6.2.2.7 Pallid bat

Pallid bat is a California species of special concern. This species occurs year-round in California. Pallid bats are associated with a variety of habitats from desert to coastal regions. At low- to mid-elevations, they are particularly associated with oak habitat (oak savannah, black oak, and oak grasslands) (Pierson and Rainey 2002). In natural settings, day and night roosts are in rock crevices and cliffs, but can also be found in trees (underneath exfoliating bark of pine and oak and in hollows) and caves (Sherwin and Rambaldini 2005, Hermanson and O'Shea 1983, Pierson et al. 2001, Pierson and Rainey 1996). However, in more urban settings (e.g., Central Valley and western Sierran foothills), day and night roosts are frequently associated with human structures such as abandoned buildings, old mine workings, and bridges (Sherwin and Rambaldini 2005, Pierson and Rainey 1996, Pierson et al. 2001). Overwintering roosts require relatively cool and stable temperatures out of direct sunlight. Pallid bats primarily forage in open spaces away from water. They can feed on the ground, on vegetation, and in the air by using a 'wing-cupping' method that forces the prey to the ground (Sherwin and Rambaldini 2005). Their generalist diet consists primarily of large ground-dwelling or slow flying insects and arachnids (Zeiner et al. 1990b), but can also include scorpions (pallid bats are immune to the sting), small rodents, and lizards.

The Project area does not contain tunnels, caves, or mines for roosting; however, suitable roosting habitat for the species occurs within the forest south of the Project area. Suitable foraging habitat for pallid bat occurs throughout the Project area.

6.2.2.8 Western pond turtle

Western pond turtle is a California species of special concern. In California, this species is found from the Oregon border along the Pacific Coast Ranges to the Mexican border, and west of the crest of the Cascades and Sierras.

Western pond turtles inhabit fresh or brackish water characterized by areas of deep water, low flow velocities, moderate amounts of riparian vegetation, warm water and/or ample basking sites, and underwater cover elements, such as large woody debris and rocks (Jennings and Hayes 1994). Along major rivers, western pond turtles are often concentrated in side channel and backwater areas. Turtles may move to off-channel habitats, such as oxbows, during periods of high flows (Holland 1994). Although adults are habitat generalists, hatchlings and juveniles require specialized habitat for survival through their first few years. Hatchlings spend much of their time feeding in shallow water with dense submerged or short emergent vegetation (Jennings and Hayes 1994). Although an aquatic reptile, western pond turtles require upland habitats for basking, overwintering, and nesting, typically within 0.6 mi of aquatic habitats (Holland 1994).

Western pond turtle eggs are typically laid in June and July, though they may be laid throughout the year (Holland 1994, Reese 1996). Egg-laying sites vary from sandy shoreline to forest soil types, though are generally located in grassy meadows, away from trees and shrubs (Holland 1994), with canopy cover commonly less than about 10% (Reese 1996). Young hatch in late fall or overwinter in the nest and emerge in early spring.

Western pond turtles are known to occupy the South Fork Eel River. However, Redwood Creek, adjacent to the Project area has a relatively closed canopy, which would limit the basking opportunities for turtles. In addition, water flow during the summer months is very low or intermittent, which is not the preferred habitat for turtles. However, suitable habitat occurs in ponds on adjacent properties and there is moderate potential for the species to occupy the Project area on at least a seasonal basis.

7 POTENTIAL EFFECTS AND MINIMIZATION MEASURES

7.1 Special-status Plants and Sensitive Natural Communities

No special-status plant species were observed during the protocol-level botanical survey conducted in the Project area on 4 May 2019. In addition, there are no records of special-status plant occurrences within the Project area based on the 2019 CDFW CNDDB queries (Section 4.1) (CDFW 2019) and collection records in the Consortium of California Herbaria (ucjeps.berkeley.edu/consortium). As such, Project activities will have no impact on known special-status plant populations.

One sensitive natural community, *Acer macrophyllum* Forest Alliance (S3), was observed within the Project area. This alliance comprised the riparian forest (also under CDFW preliminary jurisdictional throughout the Project area) adjacent to Redwood Creek and its tributaries in the Project. Some disturbance is anticipated within this natural community during the instream habitat enhancement and gully stabilization Project activities. Installation of the off-channel reservoir will not affect this sensitive natural community, as it will replace a portion of the annual/perennial grassland in the Project area.

A portion of the annual/perennial grassland and *Ceanothus incanus* Shrubland Alliance vegetation cover types along the lower terrace will be impacted by the construction of the 5.7-million-gallon pond. A review of this area indicated the only trees that will be removed are approximately ten *Fraxinus latifolia* (Oregon ash) saplings. Five saplings were observed with less than 2-inch diameter breast height (DBH) and five additional small trees had less than 6-inch DBH during the May 2021 site visit.

The following minimization measures will be implemented to reduce potential impacts on sensitive natural communities during Project activities:

- The Project footprint will be minimized to the extent possible.
- Ground disturbance and vegetation clearing and/or trimming will be confined to the minimum amount necessary to facilitate Project implementation.

- Heavy equipment and vehicles will use existing access roads to the extent possible.
- Construction materials will be stored in designated staging areas.
- Measures to prevent the spread of invasive weeds and sudden oak death pathogens will be taken, including, where appropriate, inspecting equipment for soil, seeds, and vegetative matter, cleaning equipment, utilizing weed-free materials and native seed mixes for revegetation, and proper disposal of soil and vegetation. Prior to entering and leaving the work site, workers will remove all seeds, plant parts, leaves, and woody debris (e.g., branches, chips, bark) from clothing, vehicles, and equipment.

7.2 Wetlands and Waters

Construction activities associated with the proposed streamflow enhancement Project have the potential to affect preliminary waters of the U.S. and CDFW riparian zones as some of the work will take place within the active stream channel. The access road and other Project components will avoid all isolated wetlands within the Project area thus, the Project will not affect potential state-jurisdictional isolated wetlands. The following minimization measures are will be implemented to minimize any potential negative impacts on these waters and avoid impacting waters outside of the Project footprint:

- The Project footprint will be minimized to the extent possible.
- Isolated wetlands in the Project area will be flagged and avoided during all construction activities.
- Heavy equipment and vehicles will use existing access roads to the extent possible.
- Work will be conducted during the dry season to the extent possible.
- Construction materials will be stored in designated staging areas.
- The following erosion, sediment, material stockpile, and dust control best management practices will be employed on-site:
    - Locate temporary storage areas away from vehicular traffic
    - Locate stockpiles a minimum of 50 feet away from concentrated flows of storm water, drainage courses, and inlets
    - Protect all stockpiles from storm water run-on using a temporary perimeter sediment barrier such silt fences, compost socks, or sandbag barriers.
    - Keep stockpiles covered or protected with soil stabilization measures to avoid direct contact with precipitation and to minimize sediment discharge.
    - Implement wind erosion control practices as appropriate on all stockpiled material.
- All construction equipment will be well maintained to prevent leaks of fuels, lubricants, or other fluids and extreme caution will be used when handling chemicals (fuel, hydraulic fluid, etc.). Service and refueling procedures will not be conducted where there is potential for fuel spills to seep or wash into wetlands or waters. Appropriate materials will be on-site to prevent and manage any spills.

7.3 Special-status Fish and Wildlife

7.3.1 Fish

Coho and Chinook salmon, steelhead, and Pacific lamprey are special-status fish species known to occur in Redwood Creek within to the Project area. Indirect Project-related impacts on these species could result from discharge of sediment from pond excavations, gully stabilization, and instream habitat enhancement. In addition, installation of the habitat enhancements could have direct impacts on special-status fish species that could be in the construction footprint. However, long-term beneficial impacts would accrue coho salmon, steelhead, and lamprey from water entering Redwood Creek from pond inputs. Benefits for juvenile Chinook salmon would be limited since they typically migrate to the ocean prior to the planned water deliveries to the Redwood Creek associated with the Project.

The following measures will be employed by the Project to avoid, minimize, or mitigate indirect sediment-related impacts on special-status fish species and their habitat.

- The use of cofferdams will contain any turbid water produced during the Project within the work area, thereby avoiding impacts on downstream salmonids. Any turbid water within the confined work areas would be pumped to a receiving site outside the channel or to frak tanks. Any turbid water within the work area would be allowed to settle prior to removal of the cofferdams, thereby minimizing downstream effects on salmonids.
- Discharge of sediment will be controlled and minimized with the implementation of best management practices (BMPs) on all disturbed soils that have the potential to discharge into area watercourses. Applicable BMPs include, but are not limited to, installation of silt fences, straw wattles, and placement of seed-free rice straw. BMPs will be installed at all access points to the work sites, which will minimize the potential for sediment delivery and deleterious effects on salmonids.
- All gully stabilization work will be conducted when the individual sites are dry (i.e. no surface water).

There is the potential for instream Project activities to directly impact salmonid species through contact with heavy equipment and entrainment into dewatering pumps. To minimize the potential for injury or mortality of fish, the following measures will be applied:

- A 15 July–15 October instream work window will be established to allow time for young-of-the-year salmonids to be very mobile and capable of avoiding injury. The work window will also allow downstream migration of smolts to be completed prior to any Project-related channel disturbance taking place. In addition, the work window coincides with the summer low-flow season during which flow in the creek will be at its summer base flow. Finally, the 15 October date will insure all work is done prior to the rainy season and arrival of any upstream migrating adult salmonids.
- Prior to the initiation of any instream work in areas with surface water, a qualified biologist will survey the site to determine fish presence. The biologist will herd or relocate any fish that may be in work sites to suitable habitat downstream. Block nets will be installed to prevent fish from reentering the work area. Any fish remaining in the work area will be captured by hand, dip net, or as a last resort, using a backpack electrofisher. Cofferdams will be constructed in the channel at sites where streamflow is present. Pumps will then be installed outside of the stream channel to divert water around the work area.
- The Project will follow the Fish Screening Criteria for Salmonids (NMFS 1997), NOAA Restoration Center/Army Corps of Engineers programmatic biological opinion requirements.

There is also the potential for accidental release of hydrocarbons into Redwood Creek during construction operations. The following measures will be implemented to minimize the accidental release of hydrocarbons.

- All fueling and servicing of heavy equipment will occur at least 100 ft from any watercourse.
- Spill kits will be on-site in case of an accidental release of fuels, lube oil, or hydraulic fluids from equipment.

There would be long-term beneficial effects resulting from the addition of wood to the stream channel. The increase in wood and construction of channel-spanning post-assisted check dams would result in localized reductions in high flow velocities, allowing for sorting and deposition of bed load materials.

Critical habitat for listed salmonids species would also benefit in the short and long-term. The wood would help create debris jams, increase habitat complexity, stabilize floodplains, create off-channel habitat, improve winter and summer habitat conditions, create scour pools, and increase cover for juvenile and adult salmonids. The input of water during the summer and late fall would increase summer and fall flow in Redwood Creek during the dry season. Stabilization of the gullies on the property would reduce sediment input into Redwood Creek and adverse effects on spawning and rearing habitat for fish.

7.3.2 Wildlife

7.3.2.1 Foothill yellow-legged frog

The reservoir construction activities will take place in open meadow areas not utilized by foothill yellow-legged frogs. However, foothill yellow-legged could be affected by proposed activities that would take place within Redwood Creek and at gully stabilization sites. Impacts on adult, juvenile, or larval frogs could occur through direct contact with heavy equipment or disturbed soil. Adverse impacts could occur from instream structure construction, dewatering of work areas, trampling of larvae during instream operations, contact with heavy equipment, and sediment discharge. The gully stabilization sites are not utilized by foothill yellow-legged frogs for breeding or larval rearing and impact on these life history stages would not occur at these locations.

The Project would result in the development of additional instream habitat, which should benefit foothill yellow-legged frogs by maintaining and potentially expanding the amount of instream habitat available for breeding and larval development in Redwood Creek.

The following species-specific conservation measures will be employed to avoid or minimize the potential for impacts on foothill yellow-legged frogs:

- An egg mass survey will be conducted in May prior to the operations season to determine if breeding occurs within the Project reaches.
- A visual observation survey of the Project areas will be conducted within two weeks prior to the start of operations to determine if adult and juvenile foothill yellow-legged frogs are present in the Project area.
- If foothill yellow-legged frogs are present, then a qualified CDFW-approved biologist will be present immediately prior to the start of operations to remove any frogs and relocate them to suitable habitat.

- The Project manager or qualified designee will conduct daily morning inspections of the area slated for work to determine if foothill yellow-legged frogs entered the areas overnight. Any individuals will be captured and relocated by a CDFW-approved biologist prior to the start of the construction work for the day.

The following additional general conservation measures will be employed to further avoid or minimize the potential impacts on foothill yellow-legged frogs:

- All gully stabilization work will be conducted when the individual sites are dry (i.e. no surface water).
- All fueling and servicing of heavy equipment will occur at least 100 ft from any watercourse.
- Spill kits will be on-site in case of an accidental release of fuels, lube oil, or hydraulic fluids from equipment.

7.3.2.2 Red-bellied newt

Adult and juvenile red-bellied newts have the potential to be present in terrestrial portions of the Project area during the planned construction period and could be affected by heavy equipment that collapses burrows or moves woody debris. Larval newts have the potential to be present in aquatic portions of the Project area and could be affected by instream operations.

The following conservation measures will be employed to avoid or minimize the potential for impacts on red-bellied newt:

- Terrestrial woody debris will be left in place to the greatest extent practicable during operations within the riparian areas.
- The Project manager or qualified designee will conduct daily morning inspections of the area slated for work to determine if adult newts are present on the ground surface. Any adult newts will be captured and relocated to suitable habitat outside of the Project area by a CDFW-approved biologist prior to the start of construction for the day.
- Prior to the initiation of any instream work in areas with surface water, a qualified biologist will survey the site to determine larval newt presence. If larval red-bellied newts are present, then a CDFW-approved biologist will relocate them to suitable habitat outside the Project area prior to the start of construction for the day.

The Project will result in additional dry season flows in Redwood Creek, which would benefit red-bellied newts by maintaining or improving instream habitat available for this species.

7.3.2.3 Northern spotted owls

The closest northern spotted owl activity center to the Project is approximately 1.7 mi away from the Project area and recent surveys (i.e., within the last four years) have documented presence, but not nesting within this activity center. Nesting habitat does not occur within the Project area or in the adjacent forest. The Project activities do not include removal of any trees that could provide habitat for owls. Therefore, there will not be any direct impacts on northern spotted owls or their habitat. However, there is the potential for construction-related noise to affect northern spotted owls that may be on adjacent properties or away from the Project area.

The potential for Project construction to indirectly impact nesting northern spotted owls was preliminary evaluated using USFWS (2006) guidelines. Owls can be affected by noise-related, visual, or physical disturbances, such as created by heavy equipment. USFWS (2006) identifies the distance that sound associated with different types of construction equipment is estimated to disturb northern spotted owls during the breeding season, relative to ambient noise levels. Most types of standard construction equipment (e.g., backhoes, bulldozers, construction vehicles, etc.) would require disturbance buffers of 330–1,320 ft from nesting spotted owl activity centers. No Project activities utilizing these types of equipment are expected to occur within 1,320 ft of a northern spotted owl nest. In addition, as stated above, recent surveys have not found nesting northern spotted owls with the closest known activity center (1.7 mi from the Project area). Therefore, northern spotted owls are unlikely to be indirectly affected by the Project.

7.3.2.4 Long-eared owl

Long-eared owls have not been observed within 17 mi of the Project area. However, this species nests in conifer and oak woodlands that are either open or are adjacent to grasslands, meadows, or shrublands. These habitats exist within the Project area, although no evidence of occupancy was observed during the field survey. Construction activities associated with the Project would not affect nesting or roosting habitat since no trees would be removed. However, potential foraging habitat could be affected due to the construction of the reservoirs. In addition, construction noise may affect nesting owls.

The construction of the ponds will result in approximately 4 ac of grazed grassland area being permanently converted to open water and associated containment berm features. This conversion could affect the amount of foraging habitat available for long-eared owls. A preliminary estimate of available grasslands in the Briceland area conducted using satellite imagery showed approximately 470 ac of grassland (not including numerous small openings) within a one-mile radius of the Project area. The Project would convert approximately 1.0 % of this area to reservoir, a relatively minor impact in consideration of the amount of suitable foraging habitat in the vicinity and the lack of evidence indicating species presence in and around the Project area.

The following conservation measure will be employed to avoid or minimize the potential for impacts on long-eared owls:

- A pre-construction nesting bird survey will be conducted during the breeding season and within two weeks of the start of construction. Appropriate buffers will be established around all active nests within the Project area.

7.3.2.5 Sonoma tree vole

Suitable habitat for Sonoma tree voles is present in the timber stand adjacent to the Project area. The Project will not occur within the forest nor remove any trees; therefore, there will be no impact on this species.

7.3.2.6 Pallid bat

Suitable habitat for pallid bats is present in the timber stand adjacent to the Project area. The Project will not occur within the forest nor remove any trees or structures that could be occupied by this species; therefore, there will be no impact on pallid bat.

7.3.2.7 Townsend's big-eared bat

Suitable habitat for Townsend's big-eared bats is present in the timber stand adjacent to the Project area. The Project will not occur within the forest nor remove any trees or structures that could be occupied by this species; therefore, there will be no impact on Townsend's big-eared bat.

7.3.2.8 Western pond turtles

Redwood Creek, within the Project area has a relatively closed canopy, which would limit the basking opportunities for turtles. In addition, water flow during the summer months is very low or intermittent, which is not the preferred habitat for turtles. In addition, no ponds are located in the Project area that could contain this species. However, there is the potential that turtles could be within the Project area at the start of construction.

The following conservation measure will be employed to avoid or minimize impacts on western pond turtles:

- Prior to the initiation of any instream work in areas with surface water, a qualified biologist will survey the site to determine turtle presence. The biologist will capture and relocate any turtle that may be in work sites to suitable habitat downstream. Block nets will be installed to prevent turtles from reentering the work area.

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Appendices

Appendix A

Scoping List of CNDDB Special-Status Plant and Wildlife Species in the Project Vicinity

Table A-1. Comprehensive scoping list of special-status plants in the Project vicinity.

Scientific name (common name)	Lifeform	Status (Federal, State, CRPR[1])	Habitat associations and blooming period[2]	Source	Likelihood of occurrence
Antennaria suffrutescens (evergreen everlasting)	perennial stoloniferous herb	None/None/4.3	Serpentine in lower montane coniferous forest; 1,640–5,250 ft. Blooming period: January–July	CNPS	**None**: Project area is outside of the known elevation range.
Astragalus agnicidus (Humboldt County milk-vetch)	perennial herb	None/CE/1B.1	Openings, disturbed areas, and sometimes roadsides in broadleafed upland forest and north coast coniferous forest; 390–2,625 ft. Blooming period: April–September	CNPS, CDFW	**Moderate:** Broadleafed upland and north coast coniferous forest habitats present within Project area. Two occurrences within 5–10 mi of the Project area.
Calamagrostis bolanderi (Bolander's reed grass)	perennial rhizomatous herb	None/None/4.2	Mesic bogs and fens, broadleafed upland forest, closed-cone coniferous forest, coastal scrub, mesic meadows and seeps, freshwater marshes and swamps, and north coast coniferous forest; 0–1,495 ft. Blooming period: May–August	CNPS	**Low:** Broadleafed upland forest habitat present within Project area. No occurrences within 10 mi of the Project.
Calamagrostis foliosa (leafy reed grass)	perennial herb	None/CR/4.2	Rocky coastal bluff scrub and north coast coniferous forest; 0–4,005 ft. Blooming period: May–September	CNPS, CDFW	**None:** No suitable habitat present within the Project area.
Castilleja litoralis (Oregon coast paintbrush)	perennial herb (hemiparasitic)	None/None/2B.2	Sandy coastal bluff scrub, coastal dunes, and coastal scrub; 45–330 ft. Blooming period: June	CNPS, CDFW	**None**: Project area is outside of the known elevation range.
Castilleja mendocinensis (Mendocino Coast paintbrush)	perennial herb (hemiparasitic)	None/None/1B.2	Coastal bluff scrub, closed-cone coniferous forest, coastal dunes, coastal prairie, and coastal scrub; 0–525 ft. Blooming period: April–August	CNPS, CDFW	**None**: Project area is outside of the known elevation range.
Ceanothus gloriosus var. *exaltatus* (glory brush)	perennial evergreen shrub	None/None/4.3	Chaparral; 95–2,000 ft. Blooming period: March–June (August)	CNPS	**Low:** Chaparral habitat present within Project area. No occurrences within 10 mi of the Project.
Clarkia amoena subsp. *whitneyi* (Whitney's farewell-to-spring)	annual herb	None/None/1B.1	Coastal bluff scrub and coastal scrub; 30–330 ft. Blooming period: June–August	CNPS, CDFW	**None**: Project area is outside of the known elevation range.

Scientific name (common name)	**Lifeform**	**Status (Federal, State, CRPR[1])**	**Habitat associations and blooming period[2]**	**Source**	**Likelihood of occurrence**
Coptis laciniata (Oregon goldthread)	perennial rhizomatous herb	None/None/4.2	Mesic meadows and seeps and streambanks in north coast coniferous forest; 0–3,280 ft. Blooming period: (February) March–May (September–November)	CNPS, CDFW	**Moderate:** North coast coniferous forest habitat present within Project area. Two occurrences within 5–10 mi of the Project area.
Epilobium septentrionale (Humboldt County fuchsia)	perennial herb	None/None/4.3	Sandy or rocky areas in broadleafed upland forest and north coast coniferous forest; 145–5,905 ft. Blooming period: July–September	CNPS	**None:** No suitable habitat present within the Project area.
Erigeron biolettii (streamside daisy)	perennial herb	None/None/3	Rocky, mesic areas in broadleafed upland forest, cismontane woodland, and north coast coniferous forest; 95–3,610 ft. Blooming period: June–October	CNPS	**None:** No suitable habitat present within the Project area.
Erythronium oregonum (giant fawn lily)	perennial herb	None/None/2B.2	Sometimes serpentinite, rocky, openings in cismontane woodland and meadows and seeps; 325–3,775 ft. Blooming period: March–June (July)	CNPS, CDFW	**Moderate:** Cismontane woodland habitat present within Project area. No ultramafic soils mapped or observed in Project area. One occurrence is within 5–10 mi of the Project area.
Erythronium revolutum (coast fawn lily)	perennial bulbiferous herb	None/None/2B.2	Mesic, streambanks, bogs and fens, broadleafed upland forest, and north coast coniferous forest; 0–5,250 ft. Blooming period: March–July (August)	CNPS, CDFW	**Moderate:** Broadleafed upland and north coast coniferous forest habitats present within Project area. Two occurrences within 5–10 mi of the Project area.
Gilia capitata subsp. *pacifica* (Pacific gilia)	annual herb	None/None/1B.2	Coastal bluff scrub, openings in chaparral, coastal prairie, and valley and foothill grassland; 15–5,465 ft. Blooming period: April–August	CNPS, CDFW	**Moderate:** Chaparral and valley and foothill grassland habitats present within Project area. Multiple occurrences within 5–10 mi of the Project area.
Kopsiopsis hookeri (small groundcone)	perennial rhizomatous herb (parasitic)	None/None/2B.3	North coast coniferous forest; 295–2,905 ft. Blooming period: April–August	CNPS, CDFW	**Low:** North coast coniferous forest habitat present within Project area. No occurrences within 10 mi of the Project.

Scientific name (common name)	Lifeform	Status (Federal, State, CRPR[1])	Habitat associations and blooming period[2]	Source	Likelihood of occurrence
Lasthenia burkei (Burke's goldfields)	annual herb	FE/CE/1B.1	Mesic meadows and seeps and vernal pools; 45–1,970 ft. Blooming period: April–June	USFWS	**None:** No suitable habitat present within the Project area.
Lasthenia californica subsp. *macrantha* (perennial goldfields)	perennial herb	None/None/1B.2	Coastal bluff scrub, coastal dunes, and coastal scrub; 15–1,705 ft. Blooming period: January–November	CNPS, CDFW	**None:** No suitable habitat present within the Project area.
Lasthenia conjugens (Contra Costa goldfields)	annual herb	FE/None/1B.1	Mesic cismontane woodland, alkaline playas, valley and foothill grassland, and vernal pools; 0–1,540 ft. Blooming period: March–June	USFWS	**Low:** Cismontane woodland habitat present within Project area. No occurrences within 10 mi of the Project.
Lathyrus palustris (marsh pea)	perennial herb	None/None/2B.2	Mesic bogs and fens, coastal prairie, coastal scrub, lower montane coniferous forest, marshes and swamps, and north coast coniferous forest; 0–330 ft. Blooming period: March–August	CNPS, CDFW	**None**: Project area is outside of the known elevation range.
Lilium rubescens (redwood lily)	perennial bulbiferous herb	None/None/4.2	Sometimes serpentinite, sometimes roadsides, broadleafed upland forest, chaparral, lower montane coniferous forest, north coast coniferous forest, and upper montane coniferous forest; 95–6,265 ft. Blooming period: April–August (September)	CNPS	**Low:** Broadleafed upland forest, lower montane coniferous forest, chaparral, and north coast coniferous forest habitats present within Project area. No ultramafic soils mapped or observed in Project area. No occurrences within 10 mi of the Project.
Listera cordata (heart-leaved twayblade)	perennial herb	None/None/4.2	Bogs and fens, lower montane coniferous forest, and north coast coniferous forest; 15–4,495 ft. Blooming period: February–July	CNPS	**Low:** North coast coniferous and lower montane coniferous forest habitats present within Project area. No occurrences within 10 mi of the Project.
Micranthes marshallii (Marshall's saxifrage)	perennial rhizomatous herb	None/None/4.3	Rocky streambanks and riparian forest; 295–6,990 ft. Blooming period: March–August	CNPS	**Low:** Riparian forest habitat present within Project area. No occurrences within 10 mi of the Project.

Scientific name (common name)	Lifeform	Status (Federal, State, CRPR[1])	Habitat associations and blooming period[2]	Source	Likelihood of occurrence
Mitellastra caulescens (leafy-stemmed mitrewort)	perennial rhizomatous herb	None/None/4.2	Mesic, sometimes roadsides broadleafed upland forest, lower montane coniferous forest, meadows and seeps, and north coast coniferous forest; 15–5,575 ft. Blooming period: (March) April–October	CNPS, CDFW	**Low:** Broadleafed upland, lower montane coniferous, and north coast coniferous forest habitats present within Project area. No occurrences within 10 mi of the Project.
Montia howellii (Howell's montia)	annual herb	None/None/2B.2	Vernally mesic, sometimes roadsides in meadows and seeps, north coast coniferous forest, and vernal pools; 0–2,740 ft. Blooming period: (February) March–May	CNPS, CDFW	**Moderate:** North coast coniferous forest habitat present within Project area. Two occurrences within 5–10 mi of the Project area.
Piperia candida (white-flowered rein orchid)	perennial herb	None/None/1B.2	Sometimes serpentinite in broadleafed upland forest, lower montane coniferous forest, and north coast coniferous forest; 95–4,300 ft. Blooming period: (March) May–September	CNPS, CDFW	**Moderate:** Broadleafed upland, lower montane coniferous, and north coast coniferous forest habitats present within Project area. No ultramafic soils mapped or observed in Project area. Multiple occurrences within 1 mi of the Project area.
Pityopus californicus (California pinefoot)	perennial herb (achlorophyllous)	None/None/4.2	Mesic broadleafed upland forest, lower montane coniferous forest, north coast coniferous forest, and upper montane coniferous forest; 45–7,300 ft. Blooming period: (March–April) May–August	CNPS	**Low:** Broadleafed upland, lower montane coniferous, and north coast coniferous forest habitats present within Project area. No occurrences within 10 mi of the Project.
Sidalcea malachroides (maple-leaved checkerbloom)	perennial herb	None/None/4.2	Often in disturbed areas in broadleafed upland forest, coastal prairie, coastal scrub, north coast coniferous forest, and riparian woodland; 0–2,395 ft. Blooming period: (March) April–August	CNPS, CDFW	**Low:** Broadleafed upland forest, riparian woodland, and north coast coniferous forest habitats present within Project area. No occurrences within 10 mi of the Project.

Scientific name (common name)	Lifeform	Status (Federal, State, CRPR[1])	Habitat associations and blooming period[2]	Source	Likelihood of occurrence
Trifolium amoenum (two-fork clover)	annual herb	FE/None/1B.1	Coastal bluff scrub and sometimes serpentinite in valley and foothill grassland; 15–1,360 ft. Blooming period: April–June	USFWS	**Low:** Valley and foothill grassland habitat present within Project area. No ultramafic soils mapped or observed in Project area. No occurrences within 10 mi of the Project.
Usnea longissima (Methuselah's beard lichen)	fruticose lichen (epiphytic)	None/None/4.2	On tree branches, usually on old growth hardwoods and conifers in broadleafed upland forest and north coast coniferous forest; 160–4,790 ft. Blooming period: N/A (lichen)	CNPS, CDFW	**Moderate:** Broadleafed upland and north coast coniferous forest habitats present within Project area. Multiple occurrences within 5–10 mi of the Project area.

[1] Status:

Federal:		**State:**	
FE	Federally endangered	CE	California endangered
		CR	California rare

California Rare Plant Rank (CRPR):

1B	Plants rare, threatened, or endangered in California and elsewhere
2B	Plants rare, threatened, or endangered in California, but more common elsewhere
4	Plants of limited distribution, on watchlist

CRPR Threat Ranks:

0.1	Seriously threatened in California (over 80% of occurrences threatened / high degree and immediacy of threat)
0.2	Moderately threatened in California (20–80% occurrences threatened / moderate degree and immediacy of threat)
0.3	Not very threatened in California (less than 20% of occurrences threatened / low degree and immediacy of threat or no current threats known)

[2] Months in parentheses are uncommon; N/A = Not applicable

Table A-2. Comprehensive scoping list of special-status fish and wildlife in the Project vicinity.

Scientific name (common name)	Status[1] (Federal/ State)	Distribution and habitat associations	Location of suitable habitat	Likelihood of occurrence in the Project area
Fish				
Oncorhynchus kisutch (coho salmon - southern Oregon / northern California ESU)	FT, CH/ST	Oregon border to Punta Gorda, California. Spawn in coastal streams and large mainstem rivers in riffles and pool tails-outs and rear in pools >3 ft deep with overhead cover with high levels oxygen and temperatures of 50–59°F.	Suitable habitat occurs in the South Fork Eel River and associated tributaries.	**High**: Present in the Project area.
Oncorhynchus kisutch (coho salmon -Central California Coast ESU)	FE, CH/SE	Punta Gorda, California south to Aptos Creek in Santa Cruz County. Spawn in coastal streams and large mainstem rivers in riffles and pool tails-outs and rear in pools >3 ft deep with overhead cover with high levels oxygen and temperatures of 50–59°F.	Suitable habitat is present in the South Fork Eel River but is unlikely to be occupied since the species range ends at Punta Gorda.	**None:** Outside of species range.
Oncorhynchus mykiss (steelhead trout – Northern California DPS)	FT, CH/None	Inhabits small coastal streams to large mainstem rivers with gravel-bottomed, fast-flowing habitat for spawning. However, habitat criteria for different life stages (spawning, fry rearing, juvenile rearing) are can vary significantly.	Suitable habitat occurs in the South Fork Eel River and associated tributaries.	**High**: Present in the Project area.
Oncorhynchus tshawytscha (Chinook salmon – California Coastal ESU*)*	FT, CH/None	Wild coastal, spring, and fall-run Chinook found in streams and rivers between Redwood Creek, Humboldt County to the north and the Russian River, Sonoma County to the south.	Suitable habitat occurs in the South Fork Eel River and associated tributaries.	**High**: Present in the Project area.

Scientific name (common name)	Status[1] (Federal/ State)	Distribution and habitat associations	Location of suitable habitat	Likelihood of occurrence in the Project area
Entosphenus tridentatus (Pacific lamprey)	None/SSC	Similar to anadromous salmonids, inhabits coastal streams and rivers with gravel-bottomed, fast-flowing habitat for spawning. Ammocoetes rear in backwater areas with sand, silt, and organic material for 4 to 10 years before migrating to the ocean.	Suitable habitat is present and spawning/rearing occurs in the South Fork Eel River. Spawning and rearing habitat is likely to occur in Redwood Creek.	**High:** Suitable habitat present.
Eucyclogobius newberryi (Tidewater goby)	FE/SSC	Tillas Slough (mouth of the Smith River, Del Norte County) to Agua Hedionda Lagoon (northern San Diego County)	Coastal lagoons and the uppermost zone of brackish large estuaries; prefer sandy substrate for spawning, but can be found on silt and rocky mud substrates; can occur in water up to 4 m (15 ft) in lagoons and within a wide range of salinity (0–42 parts per thousand)	**None:** Habitat not suitable
Amphibians				
Ascaphus truei (Pacific tailed frog)	None/SSC	Associated with high-gradient, perennial and montane streams in hardwood conifer, redwood, Douglas-fir, and ponderosa pine habitats. Tadpoles require water temperatures below 59°F.	Suitable habitat may occur in high gradient watercourses adjacent to the Project area, but not within the Project area.	**Low:** No habitat present.
Rana boylii (foothill yellow-legged frog)	None/ SSC, SCT	Associated with partially shaded, shallow streams, and riffles with rocky substrate. Some cobble-sized substrate required for egg laying.	Suitable habitat occurs in the South Fork Eel River and associated tributaries.	**High**: Likely to be present in Redwood Creek and tributaries adjacent to the Project area.
Rhyacotriton variegatus (southern torrent salamander)	None/SSC	Coastal redwood, Douglas-fir, mixed conifer, montane riparian and montane hardwood-conifer habitats. Seeps and small streams in coastal redwood, Douglas-fir, mixed conifer, montane riparian, and montane hardwood-conifer habitats. Seeps and springs need to be relatively unembedded with fine sediment.	Suitable habitat occurs in high-gradient gravelly seeps and springs within redwood and montane riparian habitat types adjacent to, but not within the Project area.	**Low**: High-gradient seeps are not present in the Project area.

Scientific name (common name)	Status[1] (Federal/ State)	Distribution and habitat associations	Location of suitable habitat	Likelihood of occurrence in the Project area
Taricha rivularis (red-bellied newt)	None/SSC	Ranges from southern Humboldt to Sonoma counties. Found in streams during breeding season. Moist habitats under woody debris, rocks, and animal burrows.	Suitable habitat is present and sightings have occurred in the Mattole River, approximately 5 mi west of the Project area.	**High**: Habitat present in the Project area.
Birds				
Brachyramphus marmoratus (marbled murrelet)	FT,CH/SE	Associated with mature conifers (i.e., redwood and Douglas-fir) for nesting. During the breeding season, may be present 6–8 mi inland.	No suitable habitat within or adjacent to the Project area.	**None**: No suitable habitat
Strix occidentalis caurina (Northern spotted owl)	FE/ST	Typically found in large, contiguous stands of mature and old-growth coniferous forest with dense multi-layered structure.	Suitable foraging habitat is present within the Project area. Habitat within the Project area is unsuitable for nesting. The closest activity center is over 1.7 mi to the south-southeast of the Project area.	**Moderate**: Suitable foraging habitat exists in the Project area.
Asio otus (Long-eared owl)	None/SSC	Distributed throughout North America. Recorded in north coast from Bald Hills, Humboldt County to Willits, Mendocino County. In Humboldt County, the owls apparently nest in mixed stands of conifers and oaks with edges and openings such as meadows or prairies.	Suitable nesting and foraging habitat present in the Project area.	**High**: Habitat present in the Project area.

Scientific name (common name)	**Status[1] (Federal/ State)**	**Distribution and habitat associations**	**Location of suitable habitat**	**Likelihood of occurrence in the Project area**
Haliaeetus leucocephalus (Bald eagle)	None/SE	Distributed throughout North America. Found at lakes, reservoirs, rivers, and some rangelands and coastal wetlands. Build large stick nests in the upper canopy of the largest trees in the area.	Suitable foraging habitat is present in the South Fork Eel River. Redwood Creek is unsuitable for foraging.	**Low.** No habitat present.
Empidonax traillii brewsteri (Little willow flycatcher)	None/SE	Typically breeds in wet meadows and montane riparian habitats (with a significant shrub component within or near a taller overstory) from 2,000-8,000 ft in elevation from Tulare County north, along the western side of the Sierra Nevada and Cascades. Common spring (mid-May to early June) and particularly fall (mid-August to early September) migrant in riparian habitats at lower elevations, including the north coast of California.	The nearest recorded sighting of this species was along the South Fork Eel River near Miranda in June 2000. Multi-storied riparian forest or woodland (e.g., alder, cottonwood, willow) habitat is not present in the Project area.	**Low**: Suitable habitat not present.
Charadrius alexandrinus nivosus (Western snowy plover)	FT/None	Nests on barren to sparsely vegetated dune-backed beaches, barrier beaches, and salt-evaporation ponds, infrequently on bluff-backed beaches.	No ocean beaches or open large gravel bars are located within or adjacent to the Project area	**None**: No suitable habitat
Phoebastria (Diomedea) albatrus (Short-tailed Albatross)	FE/None	Pacific Ocean (nests in Japan)	Feeds in north Pacific Ocean.	**None**: Habitat not suitable

Scientific name (common name)	Status[1] (Federal/ State)	Distribution and habitat associations	Location of suitable habitat	Likelihood of occurrence in the Project area
Coccyzus americanus (Yellow-billed Cuckoo)	FT/SE	Breeds in limited portions of the Sacramento River and the South Fork Kern River; small populations may nest in Butte, Yuba, Sutter, San Bernardino, Riverside, Inyo, Los Angeles, and Imperial counties	Summer resident of valley foothill and desert riparian habitats; nests in open woodland with clearings and low, dense, scrubby vegetation. The nearest recorded sighting of this species was in the Eel River delta area.	**None**: Habitat not suitable
Reptiles				
Emys marmorata (Western pond turtle)	None/SSC	Ponds, marshes, rivers, streams, and irrigation ditches with abundant vegetation, and either rocky or muddy bottoms, in woodland forest and grasslands. Below 6,000 ft elevation. Basking sites are required. Egg-laying sites are located on suitable upland habitats (grassy open fields) up to 1,640 ft from water.	Suitable habitat occurs in the South Fork Eel River. Ponds that may contain western pond turtles are located on neighboring properties.	**Moderate**. May occur in neighboring ponds.
Mammals				
Arborimus pomo (Sonoma tree vole)	None/SSC	Associated nearly exclusively with Douglas-fir trees and occasionally grand fir trees within the north coast fog belt between the northern Oregon border and Sonoma County. Eats Douglas-fir needles exclusively.	Small patches of Douglas-fir are present within the Project area.	**High**: Recorded occupying timber stands adjacent to the Project area
Pekania pennanti (Pacific fisher – West Coast DPS/Northern California ESU)	FC/SSC	Associated with dense advanced-successional conifer forests, with complex forest structure and high percent canopy closure; den in hollow trees and snags.	Habitat in most of the Project area does not correspond to the dense advanced-successional forest this species prefers. Nearest recorded sighting is approximately 10 mi to the southeast near Cooks Valley.	**Low**. Suitable habitat not present.
Corynorhinus townsendii (Townsend's big-eared bat)	None/SSC, CT	Found throughout California in all but subalpine and alpine habitats. Roosts in cavernous habitats, usually in tunnels,	Suitable foraging habitat throughout most of the Project area; however, barns, old buildings, and bridges for	**Moderate**: May be present in some of the barns and older structures

Scientific name (common name)	Status[1] (Federal/ State)	Distribution and habitat associations	Location of suitable habitat	Likelihood of occurrence in the Project area
		caves, buildings, mines, and basal hollows of trees, but also rock shelters, preferentially close to water. Caves near water's edge are favored. Forages in riparian zone and follows creeks and river drainages on foraging bouts. Feeds primarily on moths. Drinks at stream pools.	roosting are not present within the Project area.	adjacent to the Project area.
Antrozous pallidus (Pallid bat)	None/SSC	Found throughout California. Roosts in rock crevices, outcrops, cliffs, mines, and caves; trees (underneath exfoliating bark of pine and oak) and in basal hollows; and a variety of vacant and occupied structures (e.g., bridges) or buildings. Roost individually or in small to large colonies (hundreds of individuals). Feeds low to or on the ground in a variety of open habitats, primarily on ground-dwelling arthropods. Forages most frequently in riparian zone, in open oak savannah, and open mixed deciduous forest. Drinks at stream pools.	Suitable foraging habitat throughout most of the Survey Area, however barns, old building, and bridges are not present within the Survey Area.	**Moderate**: May be present in some of the older structures adjacent to the Survey Area

[1] Status:

Federal

FE	Federal endangered
FT	Federal threatened
FCT	Federal candidate threatened
CH	Critical habitat designated within the Project vicinity

State

SE	Endangered
ST	Threatened
SCT	State candidate threatened
SSC	CDFW species of special concern

Appendix B

List of Plant Species Observed in the Project Area

Table B-1. Plant species observed during the May 3, 2019 botanical survey.

Scientific name (common name)	Family	Native status	Cal-IPC rating	WMVC wetland indicator status[1]
Acer macrophyllum (big-leaf maple)	Sapindaceae	native	None	FACU
Acmispon americanus var. *americanus* (American bird's-foot-trefoil)	Fabaceae	native	None	FACU
Aira caryophyllea (silver hair grass)	Poaceae	naturalized	None	FACU
Anthoxanthum odoratum (sweet vernal grass)	Poaceae	naturalized	Limited	FACU
Arbutus menziesii (Pacific madrone)	Ericaceae	native	None	Not Listed—UPL
Arctostaphylos glandulosa subsp. *glandulosa* (glandular manzanita)	Ericaceae	native	None	Not Listed—UPL
Avena barbata (slender wild oat)	Poaceae	naturalized	Moderate	Not Listed—UPL
Baccharis pilularis (coyote brush)	Asteraceae	native	None	Not Listed—UPL
Bellis perennis (English daisy)	Asteraceae	naturalized	None	Not Listed—UPL
Briza maxima (rattlesnake grass)	Poaceae	naturalized	Limited	Not Listed—UPL
Bromus carinatus (California brome)	Poaceae	native	None	Not Listed—UPL
Bromus diandrus (ripgut grass)	Poaceae	naturalized	Moderate	Not Listed—UPL
Bromus hordeaceus (soft chess)	Poaceae	naturalized	Limited	FACU
Callitriche heterophylla (variable-leaved water starwort)	Plantaginaceae	native	None	OBL
Calocedrus decurrens (California incense-cedar)	Cupressaceae	native	None	Not Listed—UPL
Carduus pycnocephalus subsp. *pycnocephalus* (Italian thistle)	Asteraceae	naturalized	Moderate	Not Listed—UPL
Carex praegracilis (freeway sedge)	Cyperaceae	native	None	FACW
Ceanothus incanus (coast whitethorn)	Rhamnaceae	native	None	Not Listed—UPL

Scientific name (common name)	**Family**	**Native status**	**Cal-IPC rating**	**WMVC wetland indicator status[1]**
Cerastium glomeratum (sticky mouse-ear chickweed)	Caryophyllaceae	naturalized	None	FACU
Cirsium vulgare (bull thistle)	Asteraceae	naturalized	Moderate	FACU
Clinopodium douglasii (yerba buena)	Lamiaceae	native	None	FACU
Clintonia andrewsiana (Andrews's clintonia)	Liliaceae	native	None	Not Listed—UPL
Corylus cornuta subsp. *californica* (California hazel)	Betulaceae	native	None	FACU
Cynosurus echinatus (bristly dogtail grass)	Poaceae	naturalized	Moderate	Not Listed—UPL
Cytisus scoparius (Scotch broom)	Fabaceae	naturalized	High	Not Listed—UPL
Dactylis glomerata (orchard grass)	Poaceae	naturalized	Limited	FACU
Danthonia californica (California oat grass)	Poaceae	native	None	FAC
Daucus carota (Queen Anne's lace)	Apiaceae	naturalized	None	FACU
Elymus glaucus subsp. *glaucus* (glaucous wild rye)	Poaceae	native	None	FACU
Epilobium ciliatum (ciliate willowherb)	Onagraceae	native	None	FACW
Erodium botrys (long-beaked filaree)	Geraniaceae	naturalized	None	FACU
Eschscholzia californica (California poppy)	Papaveraceae	native	None	Not Listed—UPL
Festuca bromoides (brome fescue)	Poaceae	naturalized	None	FAC
Fragaria vesca (wood strawberry)	Rosaceae	native	None	FACU
Fraxinus latifolia (Oregon ash)	Oleaceae	native	None	FACW
Galium aparine (goose grass)	Rubiaceae	native	None	FACU
Geranium dissectum (dissected geranium)	Geraniaceae	naturalized	Limited	Not Listed—UPL
Glyceria ×occidentalis (western manna grass)	Poaceae	naturalized	None	Not Listed—UPL

Scientific name (common name)	**Family**	**Native status**	**Cal-IPC rating**	**WMVC wetland indicator status[1]**
Hypericum perforatum subsp. *perforatum* (klamathweed)	Hypericaceae	naturalized	Limited	Not Listed—UPL
Hypochaeris radicata (rough cat's-ear)	Asteraceae	naturalized	Moderate	FACU
Iris purdyi (Purdy's iris)	Iridaceae	native	None	Not Listed—UPL
Juncus bufonius var. *bufonius* (common toad rush)	Juncaceae	native	None	Not Listed—UPL
Juncus patens (spreading rush)	Juncaceae	native	None	FACW
Leontodon saxatilis (hairy hawkbit)	Asteraceae	naturalized	None	FACU
Leptosiphon bicolor (bicolored leptosiphon)	Polemoniaceae	native	None	FACU
Linum bienne (pale flax)	Linaceae	naturalized	None	Not Listed—UPL
Lonicera hispidula (hispid honeysuckle)	Caprifoliaceae	native	None	FACU
Lupinus bicolor (miniature lupine)	Fabaceae	native	None	Not Listed—UPL
Luzula comosa var. *comosa* (Pacific wood-rush)	Juncaceae	native	None	Not Listed—UPL
Lysimachia arvensis (scarlet pimpernel)	Myrsinaceae	naturalized	None	Not Listed—UPL
Lythrum hyssopifolia (hyssop-leaved lythrum)	Lythraceae	naturalized	Moderate	Not Listed—UPL
Mentha pulegium (pennyroyal)	Lamiaceae	naturalized	Moderate	OBL
Myosotis discolor (changing forget-me-not)	Boraginaceae	naturalized	None	FAC
Oxalis oregana (redwood sorrel)	Oxalidaceae	native	None	FACU
Plantago lanceolata (English plantain)	Plantaginaceae	naturalized	Limited	FACU
Plectritis congesta subsp. *congesta* (sea blush)	Valerianaceae	native	None	FACU
Poa pratensis subsp. *pratensis* (Kentucky blue grass)	Poaceae	naturalized	Limited	FAC

Scientific name (common name)	**Family**	**Native status**	**Cal-IPC rating**	**WMVC wetland indicator status**[1]
Polystichum munitum (western sword fern)	Dryopteridaceae	native	None	FACU
Prunella vulgaris (common selfheal)	Lamiaceae	native	None	FACU
Prunus sp. (domestic prunus)	Rosaceae		None	Not Listed—UPL
Pseudotsuga menziesii var. *menziesii* (Douglas-fir)	Pinaceae	native	None	FACU
Pteridium aquilinum var. *pubescens* (western bracken fern)	Dennstaedtiaceae	native	None	FACU
Quercus garryana (Oregon oak)	Fagaceae	native	None	FACU
Quercus kelloggii (California black oak)	Fagaceae	native	None	Not Listed—UPL
Quercus wislizeni (interior live oak)	Fagaceae	native	None	Not Listed—UPL
Ranunculus parviflorus (few-flowered buttercup)	Ranunculaceae	naturalized	None	FACU
Rosa nutkana subsp. *nutkana* (Nootka rose)	Rosaceae	native	None	FAC
Rosa rubiginosa (sweet-brier)	Rosaceae	naturalized	None	UPL
Rubus armeniacus (Himalayan blackberry)	Rosaceae	naturalized	High	FAC
Rubus laciniatus (cutleaf blackberry)	Rosaceae	naturalized	None	FACU
Rubus parviflorus (thimbleberry)	Rosaceae	native	None	FACU
Rumex acetosella (sheep sorrel)	Polygonaceae	naturalized	Moderate	FACU
Rumex crispus (curly dock)	Polygonaceae	naturalized	Limited	FAC
Salix sitchensis (Sitka willow)	Salicaceae	native	None	FACW
Sanicula crassicaulis (Pacific sanicula)	Apiaceae	native	None	Not Listed—UPL
Scirpus microcarpus (small-fruited bulrush)	Cyperaceae	native	None	OBL

Scientific name (common name)	**Family**	**Native status**	**Cal-IPC rating**	**WMVC wetland indicator status[1]**
Scoliopus bigelovii (California fetid adder's-tongue)	Liliaceae	native	None	Not Listed—UPL
Stachys sp. (hedge-nettle)	Lamiaceae		None	Not Listed—UPL
Toxicodendron diversilobum (western poison oak)	Anacardiaceae	native	None	FAC
Trifolium dubium (little hop clover)	Fabaceae	naturalized	None	FACU
Trifolium subterraneum (subterranean clover)	Fabaceae	naturalized	None	Not Listed—UPL
Umbellularia californica (California bay-laurel)	Lauraceae	native	None	FAC
Vaccinium ovatum (California huckleberry)	Ericaceae	native	None	FACU
Veronica sp. (speedwell)	Plantaginaceae		None	Not Listed—UPL
Vicia americana subsp. *americana* (American vetch)	Fabaceae	native	None	FAC
Vicia hassei (slender vetch)	Fabaceae	native	None	Not Listed—UPL
Viola ocellata (western heart's ease)	Violaceae	native	None	Not Listed—UPL
Whipplea modesta (modest whipplea)	Hydrangeaceae	native	None	Not Listed—UPL

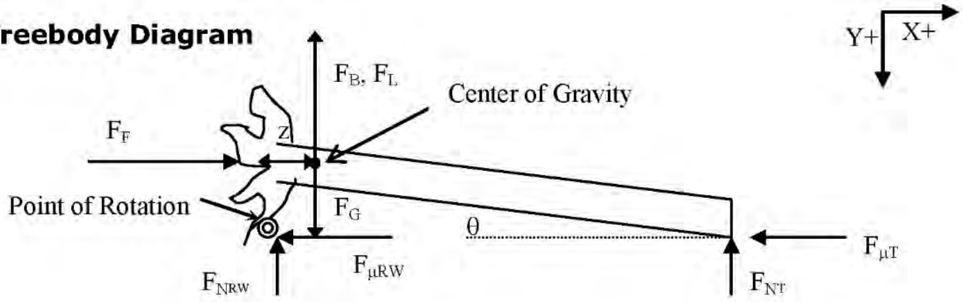
[1] Wetland indicator status (Lichvar et al. 2012 and 2016):
OBL (Obligate Wetland Plants)—Almost always occur in wetlands.
FACW (Facultative Wetland Plants)—Usually occur in wetlands, but may occur in non-wetlands.
FAC (Facultative Wetland Plants)—Occur in wetlands and non-wetlands.
FACU (Facultative Upland Plants)—Usually occur in non-wetlands, but may occur in wetlands.
UPL (Upland Plants)—Almost never occur in wetlands
Not Listed – UPL (Upland Plants)—Plant species not listed in the *2016 National Wetland Plant List* were considered upland (UPL) species.

Appendix G

Wood Stability Analyses

Large Wood Stability Analysis																					1.5			2				NUMBER OF BOULDERS WITH AVERAGE TONS OF BELOW
Feature number	Station	Feature component number	Total pieces of wood (#)	Log length (ft)	Log width (ft)	Tree with rootwad	Rootwad length (ft)	Rootwad width (ft)	Tree volume (ft^3)	Rootwad volume (ft^3)	Total volume (ft^3)	% submerged	Force gravity (lbs)	Force boyancy (lbs)	Ballast from live tree anchor (lbs)	Log flow acting area (ft^2)	Rootwad flow acting area (ft^2)	Channel velocity for force of lift calculation	Force of lift from flow (lbs)	Force of flow (lbs)	Weight of boulder required to counteract buoyancy & lift (tons) FS_B=1.5	Normal force (without live tree ballast) (lbs)	Resistance force from live tree ballast (lbs)	Factor of safety for momentum (FS_M=2 min)	Governing factor of safety	Final weight of boulder required for FS_B=1.5 min & $FS_{M=2}$ min (tons)	Final rock weight (tons)	3.5
LWD.1	1+20	A	8	35	2.5	No	0	0	172	0	172	100%	5787	10715	0	88	0	5	749	636	86.9	7795	0	6.5	Bouyancy/ Lift	86.9	86.9	25
LWD.1	1+20	B		35	2.5	No	0	0	172	0	172	100%	5787	10715	0	88	0	5	749	636		7795	0					
LWD.1	1+20	C		35	2.5	Yes	5	4	172	42	214	100%	7209	13348	0	75	14	5	933	952		6400	0					
LWD.1	1+20	D		35	2.5	Yes	5	4	172	42	214	100%	7209	13348	0	75	14	5	933	952		6400	0					
LWD.1	1+20	E		35	2.5	Yes	5	4	172	42	214	100%	7209	13348	0	75	14	5	933	952		6400	0					
LWD.1	1+20	F		35	2.5	Yes	5	4	172	42	214	100%	7209	13348	0	75	14	5	933	952		6400	0					
LWD.1	1+20	G		35	2.5	Yes	5	4	172	42	214	100%	7209	13348	0	75	14	5	933	952		6400	0					
LWD.1	1+20	H		35	2.5	Yes	5	4	172	42	214	100%	7209	13348	0	75	14	5	933	952		6400	0					

Figure 1: Freebody Diagram



Required Calculations

Force Balance / Momentum

$\Sigma Fy = 0$, $F_F (\sin\theta) + F_G = F_B + F_L + F_{NT} + F_{NRW}$

$\Sigma Fx = 0$, $F_F (\cos\theta) = F_{\mu RW} + F_{\mu T}$

$\Sigma Mo = 0$, $F_{NT} (L_T\cos\theta+z) + F_B z + F_L z = (F_G + B_R)z + F_F (2/3\ d_w)$

Geometric Calculations and Forces

$\mu_{BED} = \tan\phi$

$\theta = \tan^{-1} ((½D_{RW})/(L_T))$

$z = (½\ D_{RW}) \sin\theta$

$\forall_{RW} = (\pi (D_{RW})^2)/4)\ L_{RW}\ (1-\eta_P)$

$\forall_T = (\pi (D_T/2)^2)\ L_T$

$\forall_{Tsub} = (d_w/\sin\theta)(\pi r^2)$

$A_{Rwsub} = (A_{RW})(P_{sub})$

$\forall_{Rwsub} = A_{RWsub}L_{RW}$

$F_G = (\forall_T + \forall_{RW})\ \rho_T$

$F_B = (\forall_{Tsub} + \forall_{RWsub})\ \rho_w$

STOP, CHECK FS_B

$F_F = (v^2/2g)\ A_{RWsub}\ \rho_w\ C_D$

$F_L = (v^2/2g)\ (\forall_T + \forall_{RW})\ \rho_w\ C_L$

$FS_B = F_G/F_B$

If $FS_B < 1.5$, add required ballast (B_R) to obtain $FS_B = 1.5$ before continuing calculations

$FS_B = (F_G + B_R)/F_B$

$B_R = ((FS_B)(F_B)) - F_G$

Sum of Moments and Factors of Safety

1. ΣFy, $F_F (\sin\theta) + (F_G + B_R) = F_B + F_L + F_{NT} + F_{NRW}$
2. ΣMo, $F_{NT} (L_T\cos\theta+z) + F_B z + F_L z = (F_G + B_R) z + F_F (2/3\ d_w)$

Solve Equation 2. for F_{NT}, substitute into Equation 1. Solve for F_{NRW}

3. $F_{\mu T} = F_{NT}\ \mu_{BED}$ 4. $F_{\mu RW} = F_{NRW}\ \mu_{BED}$

$FS_M = (F_{\mu T} + F_{\mu RW}) / (F_F (\cos\theta))$

$FS_B = ((F_G + B_R) + F_F (\sin\theta)) / (F_B + F_L)$

Notation and Constants

F_B = force due to buoyancy
F_G = force due to gravity
F_F = force due to flow
F_μ = force due to friction between LW and bed
F_L = force due to lift
F_N = force normal to LW at the tip and the rootwad

Subscripts T and RW refer to the tree and rootwad respectively

ρ_T = density of the tree — See Table 2
ρ_W = density of water = 62.4 #/ft^3
S_g = Specific Gravity
Water = 1.0
Rock (average for quartz) = 2.65
g = acceleration due to gravity = 32.2 ft/s^2
B_R = ballast required (submerged weight) = #
v = velocity of flowing water = ft/s
d_w = depth of water = ft
η_P = porosity
θ = angle from rootwad face to vertical = degrees

ϕ = internal angle of friction for bed material (*See Table 1*) = degrees
μ_{BED} = coefficient of friction for bed material
z = distance in the x direction from the center of gravity to the point of interest = ft
L_T = length of the tree = ft
D_T = diameter of the tree = ft
L_{RW} = thickness of the rootwad = ft
D_{RW} = diameter of the rootwad = ft
$\forall$ = volume = ft^3
A = area = ft^2
P_{sub} = proportion submerged (from Figure 2)

Subscripts T, RW, and BD refer to tree, rootwad, and boulder respectively. *Subscript SUB refers to the submerged values.*

C_D = coefficient of fluid drag
C_{DT} = 0.3
C_{DRW} = 1.2
C_{DBD} = 0.2
C_L = coefficient of lift for large roughness element = 0.18
FS_B = factor of safety – buoyancy
FS_M = factor of safety -- momentum

C_D and C_L values derived from: D'Aoust and Millar, 1999

Appendix H

Pond Operation and Temperature Analysis

Stillwater Sciences

850 G Street, Suite K, Arcata, CA 95521
phone 707.822.9607

TECHNICAL MEMORANDUM

DATE: Aug 31, 2021

TO: Salmonid Restoration Federation

FROM: Joel Monschke PE, Jay Stallman PG

SUBJECT: Preliminary Marshall Ranch Pond Operations and Water Temperature Analysis

Stillwater Sciences conducted an analysis of annual pond operations to determine the likelihood and extent to which flow releases from the proposed Marshall Ranch project could have elevated water temperatures and result in negative effects on salmonids.

1 POND VOLUME CALCULATIONS

The first step of the analysis was to determine the physical characteristics of the proposed ponds in AutoCAD Civil3D. For each pond depth ranging from 0 to 28 feet, the volume and surface area were calculated. Results are summarized in Table 1. Based on this data, rating curve formulas were developed in Excel for depth-volume and depth-surface area relationships.

Next, evapotranspiration (ET) for the pond site was determined using calculations from the Western Regional Climate Center's Eel River Camp[1]. The Eel River Camp is located approximately 4.6 miles northeast of the Marshall Ranch project site. ET is calculated using the Penman equation based on physical site conditions including solar radiation, wind speed, temperature and humidity. For this analysis, we used the total 2019 monthly ET rates to calculate an average daily ET for each month as summarized in Table 2. Note that 2019 monthly ET rates were compared to previous years and although there are variations between years of +/-approximately one inch per month, the 2019 monthly totals provide a good representation of expected dry season ET rates.

Based on the data listed in Tables 1 and 2, a spreadsheet was developed in Excel that calculates pond volume, water surface area, evaporation and depth based on a beginning pond volume and the amount of water released from the ponds each week. Table 3 describes an annual simulation of pond conditions under a standard management scenario. This scenario assumes the following:

- The ponds are topped off on April 15 to their capacities of 3.77 million gallons (Eastern Pond) and 5.68 million gallons (Western Pond) with no additional inputs from precipitation or diversion after that date. Note that the diversion period ends on March 31, although some rainfall and sheet flow inputs are anticipated in April.
- Flow releases to the Redwood Creek from the lower pond will begin on July 1st at a constant rate of 32 GPM or 322,560 gallons per week. At this time, water from the Eastern Pond will be piped to the Western Pond, continually replenishing the losses to flow augmentation and evaporation.

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[1] Available online at https://raws.dri.edu/cgi-bin/rawMAIN.pl?caCEEC

> Water level in the Western Pond will thereby be maintained at a depth of 27 feet until the Eastern Pond is drained, which is estimated to occur between the 19th and 26th of August. Water release from the Western Pond will continue at 32 GPM until it is drained between the 25th of November and 2nd of December. As shown in Table 3, flow release in this last week is estimated to total 241,920 gallons.

Note that flow releases through the end of November will likely not be needed in most years. However, recent climatic trends in 2018-2020 resulted in very dry conditions in October and November during which time aquatic habitat in some reaches of Redwood Creek mainstem would have likely benefited greatly from additional flow releases during these months. Therefore, it is prudent to allow for an operational approach that provides pond capacity to support flow releases through the end of November. However, during the late season, flow releases could likely be scaled back significantly or turned off completely based on specific conditions during each individual year.

2 IMPLICATIONS FOR WATER TEMPERATURE

During the winter, spring and fall, the cool water layer at the bottom of the Western Pond is expected to have a temperature within the range of 52 to 57 degrees Fahrenheit (11 to 14 degrees Celsius) which is the shallow groundwater temperature for the northern CA coastal region per the EPA's Ecosystem Research online map[2]. Note that this temperature range is consistent with instream water temperature data collected by Salmonid Restoration Federation in Redwood Creek from continuous data loggers. Specifically, in 2018 at monitoring site RC1.8 (Redwood Creek mainstem just downstream from the Marshall Ranch project) the water temperatures measured by the data logger in the disconnected pool ranged from 52 to 58 degrees Fahrenheit when flows were entirely hyporheic.

However, during the peak of the dry season when water is being drained and circulated between the ponds, it is anticipated that flow release temperatures may increase. To understand this dynamic, water temperature monitoring at a nearby in-stream pond on a tributary to Miller Creek is being conducted. Monitoring results from September to November of 2020 are displayed in Figure 1. The Miller Creek pond is approximately 15 ft deep with 2.8 million gallon storage capacity. Water temperatures were recorded by temperature loggers hung from a buoy at depths of 5ft, 9ft, and 13ft below the water surface. An additional logger was supposed to measures temperatures at a depth of 17 ft, but actually just sat on the bottom of the pond throughout the monitoring period due to the maximum pond depth of 15 ft. In the beginning of September, water temperatures at 5 ft hovered around 68°F, while the water temperature at the bottom of the pond was around 64°F. By mid-September, temperature at the bottom of the pond decreased to about 63°F where it remained before sharply declining in the first week of October to between 60°F and 61°F. Water temperature in the pond dropped further in the last week of October to near 50 degrees.

The outflow pipe from the proposed Western Pond on the Marshall Ranch will be drawing water from the bottom 2 ft of the pond. Based on the standard reservoir operating scenario shown in Table 3, water depths in September range from 25 to 22 feet. Given the additional depth as well as volume of the Western Pond relative to the Miller Creek pond, it is anticipated that outflow temperatures will typically be in the range of 61°F to 64°F (16°C to 18°C) throughout the flow release period. Therefore, it is expected that the temperature of the flow released during the critical late summer weeks under the standard operating scenario will be suitable for juvenile salmonids[3] (i.e. 18°C or less). Furthermore, as necessary, water from the lower pond can be released into an approximately 300 ft long, 8 ft deep channel

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[2] Available online at https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/ex/jne_henrys_map.html.

[3] U.S. Environmental Protection Agency. 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. Region 10 Office of Water, Seattle, WA

filled with sand and gravel to ensure that water inputs to Redwood Creek are comparable in temperature to natural shallow groundwater baseflows. The project will also have the ability to release water directly from the tanks for short critical periods as necessary.

Water depth in the Western Pond continue to drop throughout the fall. As day length shortens and air temperatures cool, however, the temperature and thickness of the warm water layer at the top of the pond will diminish. Figure 1 shows that water temperatures in the Miller Creek pond declined sharply in the first two weeks of October. Even at the end of October, the Western Pond on the Marshall Ranch remains 15 feet deep. Under the standard operating scenario shown on Table 3, water temperatures of the flow release are therefore expected to remain suitable for salmonids throughout the year.

3 CONCLUSIONS AND NEXT STEPS

In summary, the analyses included herein indicate that the current pond design will result in flow releases with temperatures suitable for juvenile salmonids throughout the year under a standard management scenario. Under unusual circumstances, however, cooling pond water temperatures may be beneficial, and a filtration/cooling gallery is proposed to meet that need.

Temperature monitoring of nearby ponds has continued during the summer of 2021 to help validate the assumptions of water temperature of stratification depths described above and those results will be incorporated into this memo at the end of the monitoring season. The project team also plans to integrate project outcomes with the hydrologic and temperature modeling work funded by the State Water Board to assess the likely water temperature implications of the flow releases on Redwood Creek.

Additionally, based on feedback from agency personnel the Operations and Management Plan being developed through the next phase of this project will look at how the flow releases will be managed under specific hydrologic scenarios. It is anticipated that an adaptive and collaborative management approach will be needed to maximize yearly project function.

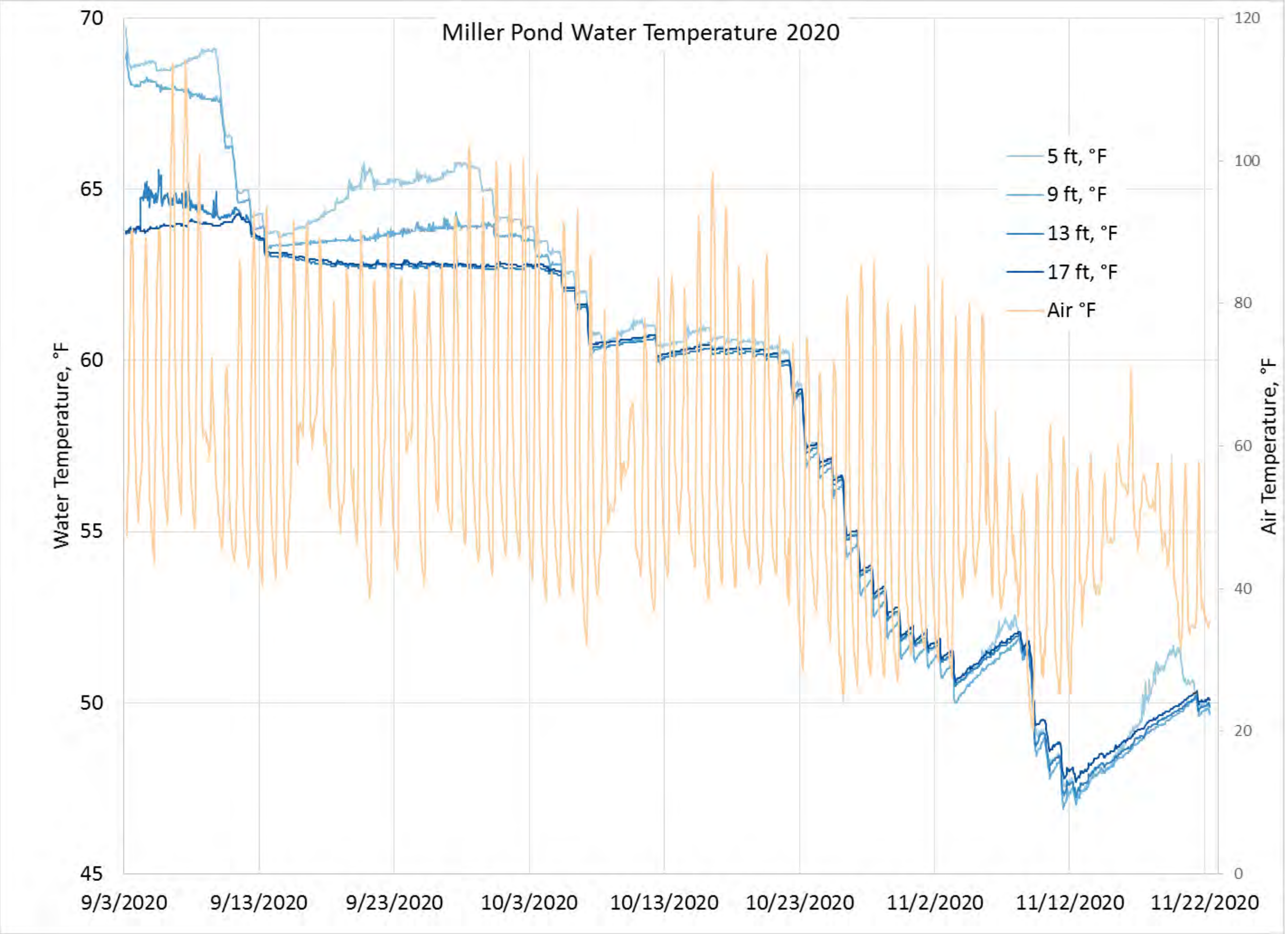


Figure 1. Miller Creek pond water temperatures at 5ft, 9ft, 13ft, and 17ft below water surface. Air temperature was also measured onsite.

Table 1. Pond volume and surface area for all depths.

Water Depth (ft)	Eastern Pond Volume (gal)	Eastern Pond Surface Area (sq ft)	Western Pond Volume (gal)	Western Pond Surface Area (sq ft)
0	0	3,016	0	409
1	26,790	4,161	4,558	835
2	62,446	5,386	12,956	1,437
3	107,559	6,688	26,561	2,229
4	162,671	8,059	35,485	3,509
5	228,288	9,496	66,876	4,924
6	304,903	10,999	109,365	6,471
7	393,003	12,566	163,939	8,152
8	493,069	14,198	231,604	9,970
9	605,569	15,890	313,423	11,935
10	730,951	17,642	410,522	14,054
11	869,664	19,454	524,010	16,316
12	1,022,155	21,326	654,812	18,682
13	1,188,873	23,258	803,689	21,148
14	1,370,265	25,250	971,394	23,714
15	1,566,779	27,300	1,158,647	26,373
16	1,778,851	29,409	1,366,134	29,123
17	2,006,918	31,577	1,594,534	31,964
18	2,251,414	33,802	1,844,506	34,890
19	2,512,775	36,086	2,116,678	37,899
20	2,791,437	38,427	2,411,659	40,988
21	3,087,835	40,828	2,730,050	44,157
22	3,402,404	43,286	3,072,451	47,407
23	3,769,938	46,057	3,439,461	50,736
24			3,831,680	54,146
25			4,249,709	57,636
26			4,694,145	61,207
27			5,165,590	64,857
28			5,664,643	68,588

Table 2. Monthly ET rates at the Eel River Camp Weather Station.

Year	**Month**	**Days in the Month**	**Total ET for Month (inches)**	**Daily Average ET (inches)**
2019	April	30	4.67	0.156
2019	May	31	6.1	0.197
2019	June	30	8.01	0.267
2019	July	31	8.47	0.273
2019	August	31	7.96	0.257
2019	September	30	5.31	0.177
2019	October	31	3.64	0.117
2019	November	30	1.93	0.064

Table 3. Annual simulation of pond conditions under a standard management scenario in 1-week time steps.

Date	Upper pond volume (gal)	Upper pond depth (ft)	Upper pond release to lower (gal)	Lower pond volume (gal)	Lower pond depth (ft)	Flow release during following week (GPM)	Discharge volume during following week (gal)	Combined evaporation loss over following week (gal)
15-Apr	3,769,938	23	0	5,677,661	28	0	0	77,875
22-Apr	3,738,653	23	0	5,631,072	28	0	0	77,533
29-Apr	3,707,454	23	0	5,584,737	28	0	0	77,274
6-May	3,676,514	23	0	5,538,403	28	0	0	97,035
13-May	3,637,404	23	0	5,480,478	28	0	0	96,600
20-May	3,598,729	22	0	5,422,553	27	0	0	95,525
27-May	3,560,487	22	0	5,365,270	27	0	0	94,885
3-Jun	3,522,245	22	0	5,308,627	27	0	0	128,164
10-Jun	3,470,941	22	0	5,231,768	27	0	0	127,300
17-Jun	3,419,636	22	0	5,155,773	27	0	0	125,858
24-Jun	3,368,913	22	0	5,080,637	27	0	0	124,422
1-Jul	3,318,771	22	398,571	5,006,358	27	32	322,560	126,733
8-Jul	2,869,478	20	398,571	5,006,358	27	32	322,560	122,678
15-Jul	2,424,240	19	398,571	5,006,358	27	32	322,560	118,211
22-Jul	1,983,469	17	398,571	5,006,358	27	32	322,560	113,397
29-Jul	1,547,512	15	398,571	5,006,358	27	32	322,560	108,313
5-Aug	1,116,639	12	393,994	5,006,358	27	32	322,560	96,404
12-Aug	697,675	10	393,994	5,006,358	27	32	322,560	90,606
19-Aug	284,509	6	210,000	5,006,358	27	32	322,560	83,246
26-Aug	62,697	2	0	4,822,364	26	32	322,560	75,976
2-Sep	56,520	2	0	4,430,006	25	32	322,560	49,400
9-Sep	52,457	2	0	4,062,109	24	32	322,560	47,031
16-Sep	48,587	2	0	3,696,388	24	32	322,560	44,894
23-Sep	44,717	1	0	3,332,803	23	32	322,560	42,089
30-Sep	41,038	1	0	2,971,834	22	32	322,560	39,536
7-Oct	37,358	1	0	2,613,418	21	32	322,560	24,450
14-Oct	35,042	1	0	2,268,724	19	32	322,560	22,521
21-Oct	32,726	1	0	1,925,959	18	32	322,560	20,528
28-Oct	30,533	1	0	1,585,064	17	32	322,560	18,423
4-Nov	28,339	1	0	1,246,274	15	32	322,560	8,834
11-Nov	27,138	1	0	916,081	14	32	322,560	7,640
18-Nov	25,936	1	0	587,083	11	32	322,560	6,044
25-Nov	24,801	1	0	259,614	8	24	241,920	4,095
2-Dec	23,666	1	0	14,734	2	0	0	1,558
Total							**7,015,680**	**2,395,078**

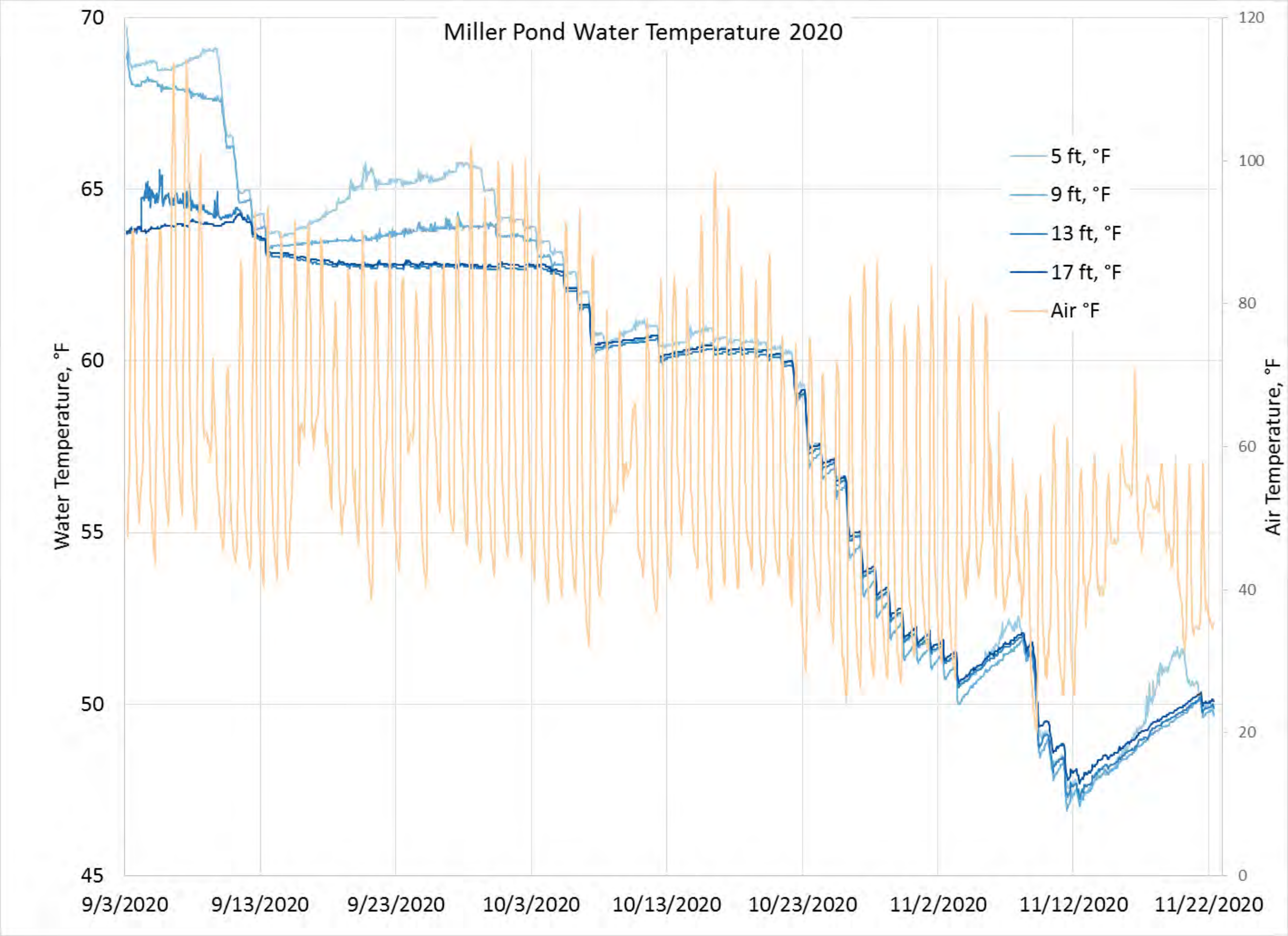


Figure 1. Miller Creek pond water temperatures at 5ft, 9ft, 13ft, and 17ft below water surface. Air temperature was also measured onsite.

Appendix I

Design Features, Mitigation Measures & Monitoring Program

DESIGN FEATURES, MITIGATION MEASURES & MONITORING PROGRAM FOR THE MARSHALL RANCH STREAMFLOW ENHANCEMENT PROJECT

1 ADMINISTRATIVE MEASURES

Permittee shall meet each administrative requirement described below.

1.1 Documentation at Project Site.

Salmonid Restoration Federation (SRF) shall make the Agreement, any extensions and amendments to the Agreement, and all related notification materials and California Environmental Quality Act (CEQA) documents, readily available at the project site at all times and shall be presented to CDFW personnel, or personnel from another state, federal, or local agency upon request.

1.2 Providing Agreement to Persons at Project Site.

SRF shall provide copies of the Agreement and any extensions and amendments to the Agreement to all persons who will be working on the project at the project site on behalf of Permittee, including but not limited to contractors, subcontractors, inspectors, and monitors.

1.3 Notification of Conflicting Provisions.

SRF shall notify regulatory agencies if SRF determines or learns that a provision in the Agreement might conflict with a provision imposed on the project by another local, state, or federal agency.

1.4 Project Site Entry.

SRF and landowner will allow access to the project site for regulatory authorities provided they provide 24 hours advance notice and allow project permittee, or representative, to be present.

2 PROJECT DESIGN AND MITIGATION MEASURES

Project design and mitigation measures are identified below for each environmental checklist item contained in the Initial Study/Mitigated Negative Declaration (ISMND). In many cases, measures have been incorporated into the project design and are therefore, not considered mitigation measures. These are described below within each relevant subsection.

Mitigation measures that have been included in the Project's ISMND are identified below using an abbreviated checklist item title and number (e.g. BIO-1). Mitigation measures were incorporated into the ISMND for those checklist items where an answer of "Less Than Significant with Mitigation Incorporated" was given. The Permittee is responsible for ensuring the general and specific mitigation measures are implemented.

2.1 Aesthetics

2.1.1 Design features

- All final grading to be inspected by engineer and revegetation specialist to ensure that it meets specifications including that graded features are blended into natural landscape and also avoid over compaction of surficial soils to allow for vigorous growth of native vegetation.
- Natural vegetation barriers will be incorporated into the final project design to improve project aesthetics and minimize impacts.

2.1.2 Mitigation measures

- None

2.2 Agriculture and Forestry Resources

No specific design features or mitigation measures are required to minimize impacts.

2.3 Air Quality

2.3.1 Design features

- All bare mineral soils and excavation areas will be watered during construction activities to minimize the potential for fugitive dust production.
- The construction portion of the project will last for less than one year (June 1 to November 1). During this period, the project will comply with Rule 104, Section D and cover open body trucks hauling materials off site and use water during the grading of roads, excavation, and land clearing.

2.3.2 Mitigation measures

- None

2.4 Biological Resources

A biological resources technical report has been prepared by Stillwater Sciences to describe the special-status and/or sensitive biological resources (plants, vegetation communities, fish, wildlife, and wetlands and waters) in or with potential to occur in the Project area that may be affected by Project construction activities. This report titled “Biological Resources Technical Report for the Marshall Ranch Flow Enhancement Project, Humboldt County, CA”, has been used to inform the sections below with regard to specific species of concern within the Project area.

2.4.1 Design features

- The project team will work closely with California Department of Fish and Wildlife (CDFW) and the California State Water Resources Control Board Division of Water Rights (SWRCB) to develop final approved diversion protocols for the project that limit impacts to aquatic resources during the wet season flow diversion period. This will be conducted through the CDFW’s Lake and Streambed Alteration Agreement (LSAA) and the SWRCB’s Appropriative Water Rights application processes. Through ongoing discussions and final permit and water rights negotiations with CDFW and SWRCB, a Final Water Availability Analyses (WAA) will be developed that describes a mutually agreed upon scientific basis for flow diversion protocols. Information in the final WAA will provide the basis for development of the project's Operations Plan that defines pumping schedule and rates based on site specific discharge rates in Redwood Creek with the intent of protecting aquatic resources related to flow diversion to the maximum extent practical.

- The project team will work closely with CDFW and NOAA to develop final approved flow release protocols for the project that maximize the benefits to aquatic resources during the dry season and reduce negative impacts of the flow releases. A preliminary assessment of flow release schedule and temperature has been conducted as described in the Basis of Design (BOD) Report Appendix H. A cooling/filtration gallery will be installed to address concerns with higher than optimal flow release temperatures that may occur during rare occasions. Yearly flow release rates and schedules will be based on specific hydrologic conditions during each year and finalized through a collaborative adaptive management process with CDFW and NOAA staff. The project's Operations Plan will define general procedures for the flow releases with the intent of enhancing aquatic resources in Redwood Creek to the maximum extent possible.
- The project's Operations Plan will be revised as needed after project construction through adaptive management and in close collaboration with CDFW, SWRCB and NOAA staff. This will be based on ongoing monitoring of downstream flow and habitat characteristics. Monitoring will occur at a minimum over the first 20 years of project operations with the most robust monitoring occurring over the first 3 years after construction. The Operations Plan will be developed with the intention to fill the reservoir with the minimum impact possible to aquatic resources and release flows to enhance aquatic habitat to the maximum extent possible.
- Aquatic species relocation plan. Prior to dewatering a construction site, fish and amphibian species shall be captured and relocated by CDFW personnel (or designated agents). The following measures shall be taken to minimize harm and mortality to listed salmonids resulting from fish relocation and dewatering activities:
    - Fish relocation and dewatering activities shall only occur between June 15 and November 1 of each year.
    - Fish relocation shall be performed by a qualified fisheries biologist, with all necessary State and Federal permits. Captured fish shall be moved to the nearest appropriate site outside of the work area. A record shall be maintained of all fish rescued and moved. The record shall include the date of capture and relocation, the method of capture, the location of the relocation site in relation to the project site, and the number and species of fish captured and relocated. The record shall be provided to CDFW within two weeks of the completion of the work season or project, whichever comes first.
    - Prior to capturing fish, the most appropriate release location(s) shall be determined. These would have water temperatures similar to the capture location and ample habitat area for dispersal.
    - A block net will be installed at the upstream end of the work area to keep fish from entering from above.
    - If a single thread channel with surface flow is present, fish would initially be hazed downstream using beach seines and dip nets. A block net would then be installed at the downstream end of the work area to keep fish from reentering. At

least three sweeps will be conducted to deplete the area of fish as best as possible without handling.

- Once sweeping in completed, the cofferdam and flow bypass would be installed. Pumping of the work area could then commence.
- Any remaining fish would become concentrated in deep locations and would be removed using dipnets, seining, or hand capture as water depth continues to decrease.
- Electrofishing would only occur as a last resort. If deemed necessary, electrofishing shall be conducted by properly trained personnel following NOAA Guidelines for Electrofishing Waters Containing Salmonids Listed under the Endangered Species Act, June 2000.
- Handling of salmonids shall be minimized. However, when handling is necessary, always wet hands or nets prior to touching fish.
- Temporarily hold fish in cool, shaded, aerated water in a container with a lid. Provide aeration with a battery-powered external bubbler. Protect fish from jostling and noise and do not remove fish from this container until time of release.
- Air and water temperatures shall be measured periodically. A thermometer shall be placed in holding containers and, if necessary, periodically conduct partial water changes to maintain a stable water temperature. If water temperature reaches or exceeds 18°C, fish shall be released and rescue operations ceased.
- Overcrowding in containers shall be avoided by having at least two containers and segregating young-of-year (YOY) fish from larger age-classes to avoid predation. Larger amphibians, such as Pacific giant salamanders, shall be placed in the container with larger fish. If fish are abundant, the capturing of fish and amphibians shall cease periodically and shall be released at the predetermined locations.
- Anesthetization or measuring fish shall be avoided.
- If feasible, initial fish relocation efforts shall be performed several days prior to the start of construction. This provides the fisheries biologist an opportunity to return to the work area and perform additional electrofishing passes immediately prior to construction. In many instances, additional fish will be captured that eluded the previous day's efforts.
- If mortality during relocation exceeds three percent, capturing efforts shall be stopped and the appropriate agencies shall be contacted immediately.
- In regions of California with high summer temperatures, relocation activities shall be performed in the morning when the temperatures are cooler.
- The Permittee shall minimize the amount of wetted stream channel that is dewatered at each individual project site to the fullest extent possible.
- Additional measures to minimize injury and mortality of salmonids during fish relocation and dewatering activities shall be implemented as described in Part IX, pages 52 and 53 of the California Salmonid Stream Habitat Restoration Manual.
- If these measures cannot be implemented, or the project actions proposed at a specific work site cannot be modified to prevent or avoid potential impacts to anadromous salmonids or their habitat, then activity at that work site shall be discontinued.

- The construction and operations of the pond has the potential to create habitat for bullfrogs and subsequently impact native species. The following avoidance and minimization measures will be incorporated in the project design, monitoring and maintenance plan. In order to avoid bullfrogs from infesting the project sites the following strategies will be implemented:
    - Landowner and resident education is one of the most important strategies, as people have been known to intentionally introduce bullfrogs to local bodies of water as a source of food.
    - Monitoring of project sites will also be very important as early detection, before populations can get established, is a key component of control. Monitoring will be conducted as per Appendix K of the BOD Report: Bullfrog Monitoring and Management Plan prepared by CDFW.
    - If needed, the off-channel pond may be drained. David Manthorne, CDFW Senior Environmental Scientist recommends draining of ponds if invasive bullfrogs are present to interrupt their life cycle (CDFW Compliance Guidance). According to research by Doubledee et al, 2007, "*Bullfrogs, Disturbance Regimes, and the Persistence of California Red-Legged Frogs ",* draining of ponds can be effective for bullfrog management if draining occurs at least every 2 years.
    - If annual monitoring shows that bullfrogs are present, active measures will be taken in consultation with CDFW and will follow the methods described in Exhibit A: Bullfrog Monitoring and Management Plan

2.4.1.1 Plants

- The Project footprint will be minimized to the extent possible.
- The pond will be positioned to minimize impacts on existing vegetation to the extent possible.
- Ground disturbance and vegetation clearing and/or trimming will be confined to the minimum amount necessary to facilitate Project implementation.
- Heavy equipment and vehicles will use existing access roads to the extent possible.
- Construction materials will be stored in designated staging areas.
- Measures to prevent the spread of invasive weeds and sudden oak death pathogens will be taken, including, where appropriate, inspecting equipment for soil, seeds, and vegetative matter, cleaning equipment, utilizing weed-free materials and native seed mixes for revegetation, and proper disposal of soil and vegetation.

2.4.2 Mitigation measures

BIO-1: The use of cofferdams will contain any turbid water produced during the Project within the work area, thereby avoiding impacts on downstream salmonids. Any turbid water within the confined work areas would be pumped to a receiving site outside the channel or to frak tanks. Any turbid water within the work area would be allowed to settle prior to removal of the cofferdams, thereby minimizing downstream effects on salmonids.

BIO-2: Discharge of sediment will be controlled and minimized with the implementation of best management practices (BMPs) on all disturbed soils that have the potential to discharge into area watercourses. Applicable BMPs include, but are not limited to, installation of silt fences, straw wattles, and placement of seed-free rice straw. BMPs will be installed at all access points to the work sites, which will minimize the potential for sediment delivery and deleterious effects on salmonids.

BIO-3: All gully stabilization work will be conducted when the individual sites are dry (i.e. no surface water).

BIO-4: A June 15 – November 1 instream work window will be established to allow time for young-of-the-year salmonids to be very mobile and capable of avoiding injury. The work window will also allow downstream migration of smolts to be completed prior to any Project-related channel disturbance taking place. In addition, the work window coincides with the summer low-flow season during which flow in the creek will be at its summer base flow. Finally, the November 1 date will ensure all work is done prior to the rainy season and arrival of any upstream migrating adult salmonids.

BIO-5: Prior to the initiation of any instream work in areas with surface water, a qualified biologist will survey the site to determine fish presence. The biologist will herd or relocate any fish that may be in work sites to suitable habitat downstream. Block nets will be installed to prevent fish from reentering the work area. Any fish remaining in the work area will be captured by hand, dip net, or as a last resort, using a backpack electrofisher. Cofferdams will be constructed in the channel at sites where streamflow is present. Water will then be diverted around the work area.

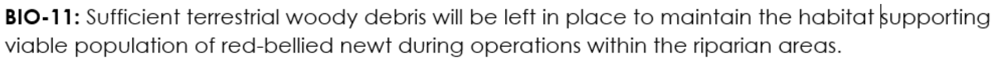
BIO-6: The Project will follow the Fish Screening Criteria for Salmonids (NMFS 1997), NOAA Restoration Center/Army Corps of Engineers programmatic biological opinion requirements.

BIO-7: A foothill yellow-legged frog egg mass survey will be conducted in May prior to the operations season to determine if breeding occurs within the Project reaches.

BIO-8: A visual observation survey of the project areas will be conducted within three days to two weeks prior to the start of operations to determine if adult and juvenile foothill yellow-legged frogs are present in the Project area.

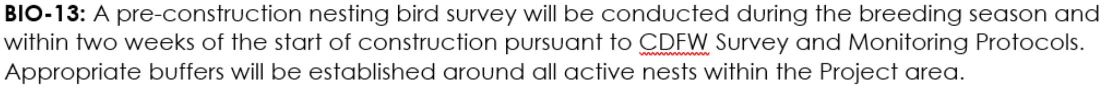
BIO-9: If foothill yellow-legged frogs are present, then a qualified CDFW-approved biologist will be present immediately prior to the start of operations to remove any frogs and relocate them in suitable habitat.

BIO-10: The Project manager or qualified designee will conduct daily morning inspections of the area slated for work to determine if amphibians entered the areas overnight. Any individuals will be captured and relocated prior to the start of the day's work.



BIO-11: Sufficient terrestrial woody debris will be left in place to maintain the habitat supporting viable population of red-bellied newt during operations within the riparian areas.

BIO-12: Prior to the initiation of any instream work in areas with surface water, a qualified biologist will survey the site to determine larval newt presence. If red-bellied newts are present, then a qualified CDFW-approved biologist will be present immediately prior to the start of operations to remove any individuals and relocate them in suitable habitat.



BIO-13: A pre-construction nesting bird survey will be conducted during the breeding season and within two weeks of the start of construction pursuant to CDFW Survey and Monitoring Protocols. Appropriate buffers will be established around all active nests within the Project area.

BIO-14: Prior to the initiation of any instream work in areas with surface water, a qualified biologist will survey the site to determine turtle presence. The biologist will capture and relocate any turtle that may be in work sites to suitable habitat downstream. Block nets will be installed to prevent turtles from reentering the work area.

BIO-15: Planting of seedlings shall begin after December 1, or when sufficient rainfall has occurred to ensure the best chance of survival of the seedlings, but in no case after April 1.

BIO-16: Any disturbed banks shall be fully restored upon completion of construction. Revegetation shall be done using native species. Planting techniques can include seed casting, hydroseeding, or live planting methods using the techniques in Part XI of the California Salmonid Stream Habitat Restoration Manual.

BIO-17: Disturbed and compacted areas shall be re-vegetated with native plant species. The species shall be comprised of a diverse community structure that mimics the native riparian corridor. Planting ratio shall be 2:1 (two plants to every one removed). Unless otherwise specified, the standard for success is 80 percent survival of plantings or 80 percent ground cover for broadcast planting of seed after a period of 3 years.

BIO-18: To ensure that the spread or introduction of invasive exotic plants shall be avoided to the maximum extent possible, equipment shall be cleaned of all dirt, mud, and plant material prior to entering a work site. When possible, invasive exotic plants at the work site shall be removed. Areas disturbed by project activities will be restored and planted with native plants.

BIO-19: Mulching and seeding shall be done on all exposed soil which may deliver sediment to a stream. Soils exposed by project operations shall be mulched to prevent sediment runoff and transport. Mulches shall be applied so that not less than 90% of the disturbed areas are covered. All mulches, except hydro-mulch, shall be applied in a layer not less than two (2) inches deep. Where feasible, all mulches shall be kneaded or tracked-in with track marks parallel to the contour, and tackified as necessary to prevent excessive movement. All exposed soils and fills, including the downstream face of the road prism adjacent to the outlet of culverts, shall be reseeded with a mix of native grasses common to the area, free from seeds of noxious or invasive weed species, and applied at a rate which will ensure establishment.

BIO-20: If erosion control mats are used in re-vegetation, they shall be made of material that decomposes. Erosion control mats made of nylon plastic, or other non-decomposing material shall not be used.

BIO-21: If riparian vegetation is to be removed with chainsaws, the Permittee shall use saws that operate with vegetable-based bar oil

2.5 Cultural Resources

2.5.1 Design features

The project design has been developed to avoid culturally sensitive areas.

2.5.2 Mitigation measures

An archaeological assessment (Appendix C) and tribal group consultation have indicated that cultural resources are present within a portion of the project site. Potential for inadvertent impacts at all sites will be avoided through implementation of the following mitigation measures:

CR-1: Cultural and/or paleontological resources on the site will be protected by the Permittee through implementation of the following protective measures before work can proceed:

- The archaeological site boundary as identified in the Cultural Resources Investigation shall be clearly marked during project implementation. Boundary markers such as flagging, stakes, fencing, or other highly visible barrier should be used.
- The area containing the archaeological site shall be completely excluded from ground disturbing activities. The proposed path of the pond intake pipeline and primary spillway have been rerouted to avoid ground disturbance to the identified sensitive area.
- Spoils from pond excavation may be placed directly on the existing archaeological site surface however, no grading or scarifying shall be conducted. Heavy equipment shall not enter

archaeological site unless atop a sufficient layer of fill, such that the underlying soil is not displaced.

- All ground-disturbing activities and placement of fill material within the known archaeological site shall be monitored by a professional archaeologist familiar with specific project conditions. A monitoring plan should be developed and used to guide monitoring and discovery protocol.

- In the event additional archaeological material is encountered during project implementation or during future site monitoring efforts, all work shall stop in the area of the find and the discovery protocol initiated as described below in CR-3.

CR-2: The Permittee shall ensure that the implementation contractor or responsible party is aware of these site-specific conditions, and shall inspect the work site before, during, and after completion of the action item.

CR-3: Inadvertent Discovery of Cultural Resources - If cultural resources are encountered during construction activities, all onsite work shall cease in the immediate area and within a 50-foot buffer of the discovery location. A qualified archaeologist will be retained to evaluate and assess the significance of the discovery, and develop and implement an avoidance or mitigation plan, as appropriate. For discoveries known or likely to be associated with Native American heritage (prehistoric sites and select historic period sites), the tribes listed in Section 6.2 and those that the County has on file shall also be contacted immediately to evaluate the discovery and, in consultation with the project proponent, the County, and consulting archaeologist, develop a treatment plan in any instance where significant impacts cannot be avoided. Prehistoric materials which could be encountered include obsidian and chert debitage or formal tools, grinding implements, (e.g., pestles, handstones, bowl mortars, slabs), locally darkened midden, deposits of shell, faunal remains, and human burials. Historic archaeological discoveries may include nineteenth century building foundations, structural remains, or concentrations of artifacts made of glass, ceramics, metal or other materials found in buried pits, wells or privies.

CR-4: Inadvertent Discovery of Human Remains - If human remains are discovered during project construction, work shall stop at the discovery location, within 20 meters (66 feet), and any nearby area reasonably suspected to overlie adjacent human remains (Public Resources Code, Section 7050.5). The county coroner shall be contacted to determine if the cause of death must be investigated. If the coroner determines that the remains are of Native American origin, it is necessary to comply with state laws relating to the disposition of Native American burials, which fall within the jurisdiction of the Native American heritage Commission (NAHC) (Public Resources Code, Section 5097). The coroner will contact the NAHC. The descendants or most likely descendants of the deceased will be contacted, and work shall not resume until they have made a recommendation to the landowner or the person responsible for the excavation work for means of treatment and disposition, with appropriate dignity, of the human remains and any associated grave goods, as provided in Public Resources Code, Section 5097.98.

CR-5: Procedures for treatment of an inadvertent discovery of human remains:

a) Immediately following discovery of known or potential human remains all ground-disturbing activities at the point of discovery shall be halted.

b) No material remains shall be removed from the discovery site, a reasonable exclusion zone shall be cordoned off.

c) The property owner shall be notified and the Permittee Project Manager shall contact the county coroner.
d) The Permittee shall retain the services of a professional archaeologist to immediately examine the find and assist the process.
e) All ground-disturbing construction activities in the discovery site exclusion area shall be suspended.
f) The discovery site shall be secured to protect the remains from desecration or disturbance, with 24-hour surveillance, if prudent.
g) Discovery of Native American remains is a very sensitive issue, and all project personnel shall hold any information about such a discovery in confidence and divulge it only on a need-to-know basis, as determined by the CDFW.
h) The coroner has two working days to examine the remains after being notified. If the remains are Native American, the coroner has 24 hours to notify the NAHC in Sacramento (telephone 916/653-4082).
i) The NAHC is responsible for identifying and immediately notifying the Most Likely Descendant (MLD) of the deceased Native American.
j) The MLD may, with the permission of the landowner, or their representative, inspect the site of the discovered Native American remains and may recommend to the landowner and Permittee means for treating or disposing, with appropriate dignity, the human remains and any associated grave goods. The descendants shall complete their inspection and make recommendations or preferences for treatment with 48 hours of being granted access to the site (Public Resource Code, Section 5097.98(a)). The recommendation may include the scientific removal and non-destructive or destructive analysis of human remains and items associated with Native American burials.
k) Whenever the NAHC is unable to identify a MLD, or the MLD identified fails to make a recommendation, or the landowner or his/her authorized representative rejects the recommendation of the MLD and mediation between the parties by the NAHC fails to provide measures acceptable to the landowner, the landowner or his/her authorized representatives shall re-inter the human remains and associated grave offerings with appropriate dignity on the property in a location not subject to further subsurface disturbance in accordance with Public Resource Code, Section 5097.98(e).
l) Following final treatment measures, the Permittee shall ensure that a report is prepared that describes the circumstances, nature and location of the discovery, its treatment, including results of analysis (if permitted), and final disposition, including a confidential map showing the reburial location. Appended to the report shall be a formal record about the discovery site prepared to current California standards on DPR 523 form(s). Permittee shall ensure that report copies are distributed to the appropriate California Historic Information Center, NAHC, and MLD.
m) The Permittee shall report any previously unknown historic, archeological, and paleontological remains discovered at a project location to the USACE as required in the RGP.
n) If it becomes impossible to implement the project at a work site without disturbing cultural or paleontological resources, then activity at that work site shall be discontinued.

2.6 Energy

No specific design features or mitigation measures are required to minimize impacts.

2.7 Geology and Soils

Implementation of the streamflow enhancement project is expected to contribute to an overall reduction in stormwater runoff and associated erosion at the project site. The following design features and mitigation measures will ensure that impacts on geology and soils are less than significant.

2.7.1 Design features, Construction Oversight and Monitoring

- The project design has incorporated numerous features to reduce the potential for landsliding and other risks associated with geology and soils:
    - Pond liner made of long-lasting High-density Polyethylene (HDPE) and covered with gravel will reduce the risk of a clay liner breaking down over time due to erosion and expansive soils. This will prevent undesirable increases in groundwater levels thereby reducing the risk of landslides.
    - French drain under the western pond will drain water from the pond site and downslope terrace improving stability.
    - Gully treatments will significantly reduce gully incision rates that over long time periods could destabilize portions of the site. Grade control structures will be utilized to control channel scour, sediment routing, and headwall cutting.
    - Crossing upgrades will return runoff to more natural pathways and reduce the risk of overtopping during large storm events.
    - Foundation funding has been secured to cover long-term operations, monitoring, and maintenance.
    - Data recorders/sensors will monitor pond water levels, groundwater levels.
    - Off-grid power supply will provide energy to data recorders, valves and internet in the case of a power outage.
- Additionally, a long-term Operations, Monitoring and Maintenance Plan will be developed that describes yearly project operations and monitoring and the individuals/organizations responsible for each item. Specifically, Stillwater Sciences licensed geologist and engineer will be responsible for annual inspections of the project features. Additionally, Stillwater will be responsible for continuous monitoring of groundwater well data loggers and dam motion sensors to ensure that the project is functioning as designed and no issues arise that would lead to increased risk of landslides.
- Licensed professionals from Stillwater Sciences and SHN Engineers and Geologists will be onsite and closely involved during construction activities to ensure that the project is constructed as designed and any necessary field engineering arising from changing site conditions are addressed professionally based on best available science and engineering/geotechnical techniques.
- Stillwater Sciences' licensed geologist and engineer will be responsible for post-construction inspections of the project features and will be responsible for monitoring of data loggers to ensure that the project is functioning as designed and no issues arise that would lead to increased risk of geologic instability.

2.7.2 Mitigation measures

GEO-1: Work sites shall be winterized at the end of each day to minimize the eroding of unfinished excavations when significant rains are forecasted. Winterization procedures shall be supervised by a professional trained in erosion control techniques and involve taking necessary measures to minimize erosion on unfinished work surfaces. Winterization includes the following: smoothing unfinished surfaces to allow water to freely drain across them without concentration or ponding; compacting unfinished surfaces where concentrated runoff may flow with an excavator bucket or similar tool, to minimize surface erosion and the formation of rills; and installation of culverts, silt fences, and other erosion control devices where necessary to convey concentrated water across unfinished surfaces, and trap exposed sediment before it leaves the work site.

GEO-2: Effective erosion control measures shall be in-place at all times during construction. Construction within the 5-year flood plain shall not begin until all temporary erosion controls (i.e., straw bales or silt fences that are effectively keyed-in) are in place down slope or down stream of project activities within the riparian area. Erosion control measures shall be maintained throughout the construction period. If continued erosion is likely to occur after construction is completed, then appropriate erosion prevention measures shall be implemented and maintained until erosion has subsided.

GEO-3: An adequate supply of erosion control materials (gravel, straw bales, shovels, etc.) shall be maintained onsite to facilitate a quick response to unanticipated storm events or emergencies.

GEO-4: Upon project completion, all exposed soil present in and around the project site shall be stabilized within 7 days. Soils exposed by project operations shall be mulched to prevent sediment runoff and transport. Mulches shall be applied so that not less than 90% of the disturbed areas are covered. All mulches, except hydro-mulch, shall be applied in a layer not less than two (2) inches deep. Where feasible, all mulches shall be kneaded or tracked-in with track marks parallel to the contour, and tackified as necessary to prevent excessive movement. All exposed soils and fills, including the downstream face of the road prism adjacent to the outlet of culverts, shall be reseeded with a mix of native grasses common to the area, free from seeds of noxious or invasive weed species, and applied at a rate which will ensure establishment.

2.8 Greenhouse Gas Emissions

No specific mitigation measures are required. Long term fire suppression benefits of the project are expected to offset greenhouse gas emissions associated with construction.

2.9 Hazards and Hazardous Materials

No hazardous materials will be transported to the project site other than fuel, hydraulic fluid, lube oil, and coolant for the heavy equipment that will be used during construction. The following design features and mitigation measures will ensure that impacts relating to hazards and hazardous materials are less than significant.

2.9.1 Design features

Outside of the construction period, the project would not generate or involve use of any hazardous materials.

2.9.2 Mitigation measures

HAZ-1: Heavy equipment that will be used in these activities will be maintained according to a maintenance and repair schedule and will be inspected for leakage of coolant and petroleum products and repaired, if necessary, before work is started.

HAZ-2: When operating vehicles in wetted portions of the stream channel, or where wetland vegetation, riparian vegetation, or aquatic organisms may be destroyed, the responsible party shall, at a minimum, do the following:

- All equipment shall be cleaned to remove external oil, grease, dirt, or mud. Wash sites shall be located in upland locations so that dirty wash water does not flow into the stream channel or adjacent wetlands;
- Check and maintain on a daily basis any vehicles to prevent leaks of materials that, if introduced to water, could be deleterious to aquatic life, wildlife, or riparian habitat;
- Take precautions to minimize the number of passes through the stream and to avoid increasing the turbidity of the water to a level that is deleterious to aquatic life; and
- Allow the work area to rest to allow the water to clear after each individual pass of the vehicle that causes a plume of turbidity above background levels, resuming work only after the stream has reached the original background turbidity levels.

HAZ-3: All equipment operators shall be trained in the procedures to be taken should an accident occur. Prior to the onset of work, the Permittee shall prepare a Spill Prevention/Response plan to help avoid spills and allow a prompt and effective response should an accidental spill occur. All workers shall be informed of the importance of preventing spills. Operators shall have spill clean-up supplies on site and be knowledgeable in their proper deployment.

HAZ-4: All activities performed in or near a stream will have absorbent materials designed for spill containment and cleanup at the activity site for use in case of an accidental spill. In an event of a spill, work shall cease immediately. Clean-up of all spills shall begin immediately. The responsible party shall notify the State Office of Emergency Services at 1-800-852-7550 and the CDFW immediately after any spill occurs and shall consult with the CDFW regarding clean-up procedures.

HAZ-5: All fueling and maintenance of vehicles and other equipment and staging areas shall occur outside of Streamside Management Areas and place fuel absorbent mats under pump while fueling. The USACE and the CDFW will ensure contamination of habitat does not occur during such operations. Prior to the onset of work, the Permittee shall prepare a plan to allow a prompt and effective response to any accidental spills. All workers will be informed of the importance of preventing spills and of the appropriate measures to take should a spill occur.

HAZ-6: Location of staging/storage areas for equipment, materials, fuels, lubricants, and solvents, will be located outside of the streams high water channel and associated riparian area. The number of access routes, number and size of staging areas, and the total area of the work site activity shall be limited to the minimum necessary to complete the restoration action. To avoid contamination of habitat during restoration activities, trash will be contained, removed, and disposed of throughout the project.

HAZ-7: Petroleum products, fresh cement, and other deleterious materials shall not enter the stream channel.

HAZ-8: Stationary equipment such as motors, pumps, generators, compressors, and welders, located within the dry portion of the stream channel or adjacent to the stream, will be positioned over drip-pans.

HAZ-9: All internal combustion engines shall be fitted with spark arrestors.

HAZ-10: The Permittee shall have an appropriate fire extinguisher(s) and firefighting tools (shovel and axe at a minimum) present at all times when there is a risk of fire.

HAZ-11: Vehicles shall not be parked in tall grass or any other location where heat from the exhaust system could ignite a fire.

HAZ-12: The grantee shall follow any additional rules the landowner has for fire prevention.

2.10 Hydrology and Water Quality

Short-term increases in turbidity associated with the instream structure installation would be controlled by isolating the project area from flowing water, installing BMPs, and revegetating disturbed surfaces. The design features and mitigation measures **BIO 1-6, GEO 1–4** and **HAZ-1–8** described above, as well as **HYD-1** described below will assure that the project actions are in compliance with water quality standards and that impacts on water quality are avoided or mitigated to below a level of significance.

2.10.1 Design features

- Before instream work proceeds, turbidity control measures will be in place.
- Any wastewater from construction area shall be discharged to an upland location where it will not drain sediment-laden water back to stream channel.
- To control erosion during and after project implementation, the Permittee shall implement best management practices, as identified by the appropriate Regional Water Quality Control Board.
- Sediment-laden water caused by construction activity shall be filtered before it leaves the right-of-way or enters the stream network or an aquatic resource area. Silt fences or other detention methods shall be installed as close as possible to culvert outlets to reduce the amount of sediment entering aquatic systems.
- Diversions to fill storage facilities during the winter and spring months shall be made pursuant to the appropriate type of water right and filed with the SWRCB. CDFW will review the appropriation of water to ensure fish and wildlife resources are protected. The

following preliminary conditions are proposed for surface water diversions and shall be revised as appropriate through consultation and permit condition negotiation with CDFW and SWB:

  - Diversion season: December 15 to April 30.
  - Diversion allowed when Redwood Creek mainstem at the Marshall Ranch is at or above 5 cubic feet per second (cfs).
  - Diversion rate from the tributaries shall not exceed 10% of Redwood Creek mainstem flow at the Marshall Ranch.
  - A minimum bypass flow of 5 gpm is required for each tributary.
  - Cumulative diversion rates from the two tributaries will range from 75 to 200 gpm during the diversion season.
  - 30 to 60 days of diversion needed to achieve 6.5 million gallons of diversion (20 ac-ft)

- CDFW and SWB shall be granted access to inspect the diversion system. Access is limited to the portion of the landowner's real property where the pump is located and those additional portions of the real property which must be traversed to gain access to the pump site. Landowners shall be given reasonable notice and any necessary arrangements will be made prior to requested access including a mutually-agreed-upon time and date. Notice may be given by mail or by telephone with the landowner or an authorized representative of the landowner. The landowner shall agree to cooperate in good faith to accommodate CDFW and SWB access.
- Off-channel ponds will be constructed to minimize erosion through engineering of berms and spillways to carry 100-year flows and withstand seismic force.
- Dry season flow releases shall have sufficiently low temperature and nutrient levels to provide high quality rearing habitat for juvenile salmonids. This shall be achieved through the project features described in Design Plans in Appendix A.3 of the Basis of Design Report including the outflow at the bottom of the pond, cooling/filtration gallery, and fence excluding livestock from the pond. Water quality will be maintained during the life of the project through implementation of the Operations, Monitoring and Maintenance Plan that will be developed for the project and will define yearly project operations, monitoring and maintenance the individuals/organizations responsible for each action.

2.10.2 Mitigation measures

HYD-1: Project operations will be adaptively managed based on flow, temperature and aquatic habitat monitoring results. These monitoring results will be presented to regulatory agency staff on an annual basis and/or as required by final permit conditions. In coordination with regulatory agency staff, the project team will adapt project operations as necessary to optimize aquatic habitat benefits resulting from the project while reducing impacts to a less than significant level. This may include changes to diversion timing/rates, changes to flow release timing/rates, and/or other changes to project operations.

2.11 Land Use and Planning

No specific design features or mitigation measures are required to minimize impacts.

2.12 Mineral Resources

No specific design features or mitigation measures are required to minimize impacts.

2.13 Noise

2.13.1 Design features

The project will utilize passive structures that will not generate excessive noise.

2.13.2 Mitigation Measures

NOISE 1: To reduce the possibility of the construction noise and vibrations becoming an annoyance to sensitive receptors near the Project, exterior construction activity shall be confined to the weekday hours of 7:00 am to 7:00 pm or until sunset, whichever is later, and weekend hours of 8:00 am to 6:00 pm or until sunset, whichever is later. No heavy equipment related construction activities shall be allowed on Sundays or holidays.

NOISE 2: The Permittee shall notify sensitive receptors (all property owners within 350 feet) of potential impacts from noise and vibration prior to initiating each construction phase. The notice shall describe construction activities and anticipated noise and/or vibrations from these activities, and the duration and operational hours of construction activities. The notice will also include a contact that sensitive receptors may call to report noise or vibration concerns. The notice will include a request that property owners share the notice with any employee or tenants working within 350 feet of the project site.

NOISE 3: Construction equipment shall be properly maintained and equipped with noise control devices, such as mufflers and shrouds, in accordance with manufacturers' specifications.

2.14 Population and Housing

No specific design features or mitigation measures are required to minimize impacts.

2.15 Public Services

No specific design features or mitigation measures are required to minimize impacts.

2.16 Recreation

No specific design features or mitigation measures are required to minimize impacts.

2.17 Tribal Cultural Resources

2.17.1 Design Features

A Cultural Resources Investigation was completed for the project.

2.17.2 Mitigation Measures

TCR: Inadvertent Discovery of Tribal Cultural Resources - If tribal cultural resources are encountered during construction activities, all onsite work shall cease in the immediate area and within a 50-foot buffer of the discovery location. A qualified archaeologist will be retained to evaluate and assess the significance of the discovery, and develop and implement an avoidance or mitigation plan, as appropriate. For discoveries known or likely to be associated with Native American heritage (prehistoric sites and select historic period sites), the tribes listed in Section 6.2 and those that the County has on file shall also be contacted immediately to evaluate the discovery and, in consultation with the project proponent, the County, and consulting archaeologist, develop a treatment plan in any instance where significant impacts cannot be avoided. Prehistoric materials which could be encountered include obsidian and chert debitage or formal tools, grinding implements, (e.g., pestles, handstones, bowl mortars, slabs), locally darkened midden, deposits of shell, faunal remains, and human burials. Historic archaeological discoveries may include nineteenth century building foundations, structural remains, or concentrations of artifacts made of glass, ceramics, metal or other materials found in buried pits, wells or privies.

2.18 Transportation

No specific design features or mitigation measures are required to minimize impacts.

2.19 Utilities and Service Systems

The project will construct a facility to store water during the wet season and release water during the dry season to enhance aquatic habitat, so the project is not expected to cause significant negative environmental impacts. The project also includes construction and operation of small off-grid energy system to support operations and monitoring.

2.19.1 Design features

Underground lines will also run between the solar panels, control center building, valves, and sensors. Impacts that could occur during installation will be primarily associated with ground disturbance, which will be localized along the trenches where utilities will be buried.

2.19.2 Mitigation Measures

Impacts will be reduced to a less than significant level by the installation of erosion control BMPs and revegetation and other mitigation measures (**GEO 1–4**) detailed in the Geology section above.

2.20 Wildfire

The project is located in a meadow area and will include the installation and upgrading of access roads, hydrants, pond, and buried underground electrical lines.

2.20.1 Design features

The access roads can serve as fire breaks, which would lessen the risk of fire spread over the current condition. The pond and hydrants can be called upon to supply water in the unlikely event of a wildfire, which is a significant improvement over the current condition. All onsite utility lines will be underground and would not increase the risk of wildfire.

2.20.2 Mitigation Measures

No specific mitigation measures are required to minimize impacts.

3 MONITORING AND REPORTING

The Project will be funded through agency and foundation grants that include effectiveness monitoring and reporting. Additionally, agency–specific permits will be obtained prior to implementation and the Project will comply with all state, federal and county regulations. The permittee shall implement the following measures to ensure that the treatments at all Project sites will minimize take of listed salmonids, monitor and report take of listed salmonids, and to obtain specific information to account for the effects and benefits of the Project.

1) The Permittee shall notify all agencies (CDFW, Humboldt County, NCRWQCB, USACE, NOAA, and USFWS) prior to the commencement of work based on the conditions listed in the agency-specific permit.
2) The Permittee Project Manager shall inspect the work site before, during, and after completion of each action item, to ensure that all necessary mitigation measures to avoid impacts are properly implemented.

3) The Permittee shall perform implementation monitoring immediately after each project feature is completed to ensure that projects are completed as designed.
4) The Permittee shall perform effectiveness/validation monitoring for the project.
5) Current monitoring forms and instructions used by CDFW for the implementation monitoring and effectiveness monitoring are found in the California Salmonid Stream Habitat Restoration Manual. Additional monitoring protocols for groundwater and streamflow currently not included in the manual but developed by the Permittee, CDFW, and consultants will also be used.
6) The Permittee shall provide reports to all agencies, (CDFW, Humboldt County, NCRWQCB, SWRCB, USACE, NOAA, and USFWS) based on requirements of the agency-specific permits obtained for the project.
7) The Permittee shall monitor and maintain the structures or work conducted at a given site as per the requirements of agency- specific permits and funding obtained for the project.

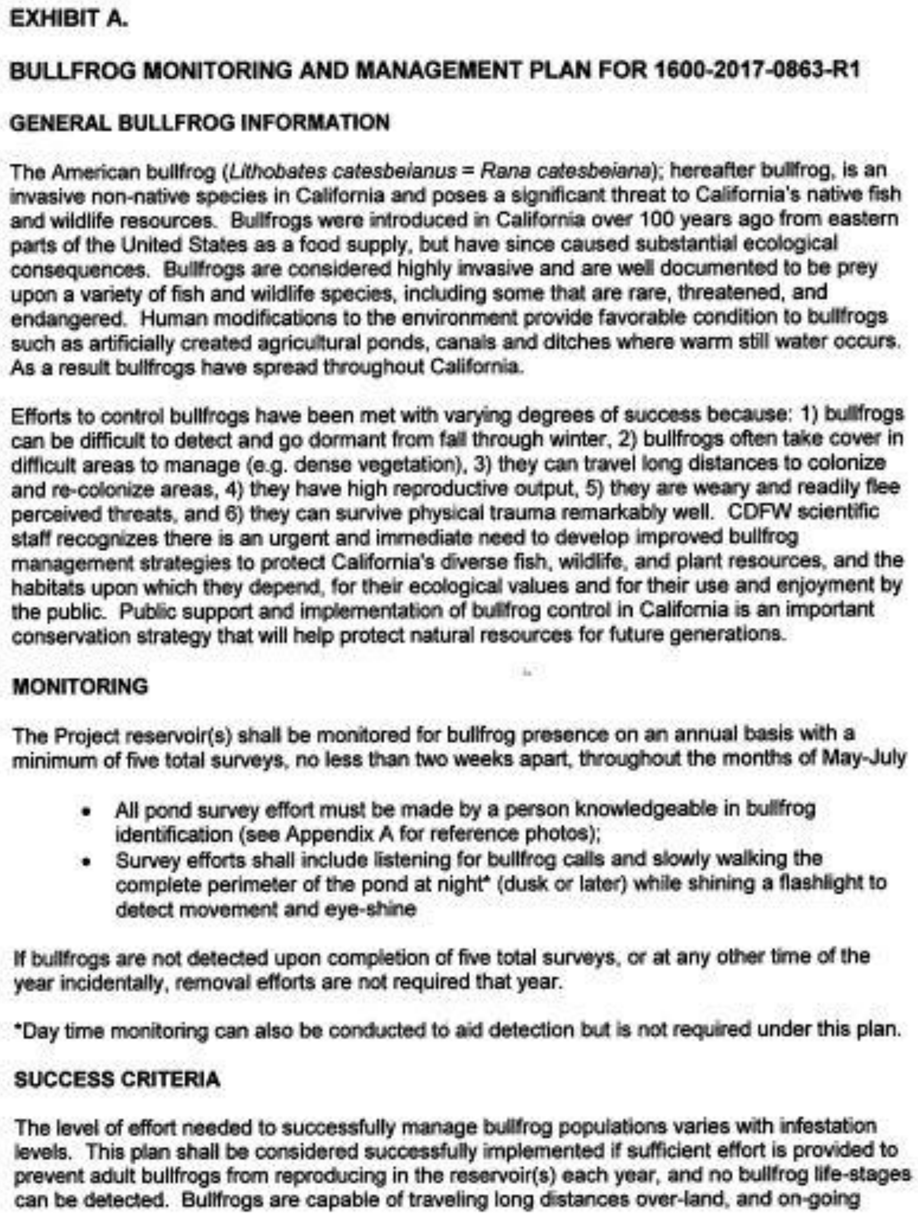


EXHIBIT A.

BULLFROG MONITORING AND MANAGEMENT PLAN FOR 1600-2017-0863-R1

GENERAL BULLFROG INFORMATION

The American bullfrog (*Lithobates catesbeianus* = *Rana catesbeiana*); hereafter bullfrog, is an invasive non-native species in California and poses a significant threat to California's native fish and wildlife resources. Bullfrogs were introduced in California over 100 years ago from eastern parts of the United States as a food supply, but have since caused substantial ecological consequences. Bullfrogs are considered highly invasive and are well documented to be prey upon a variety of fish and wildlife species, including some that are rare, threatened, and endangered. Human modifications to the environment provide favorable condition to bullfrogs such as artificially created agricultural ponds, canals and ditches where warm still water occurs. As a result bullfrogs have spread throughout California.

Efforts to control bullfrogs have been met with varying degrees of success because: 1) bullfrogs can be difficult to detect and go dormant from fall through winter, 2) bullfrogs often take cover in difficult areas to manage (e.g. dense vegetation), 3) they can travel long distances to colonize and re-colonize areas, 4) they have high reproductive output, 5) they are weary and readily flee perceived threats, and 6) they can survive physical trauma remarkably well. CDFW scientific staff recognizes there is an urgent and immediate need to develop improved bullfrog management strategies to protect California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. Public support and implementation of bullfrog control in California is an important conservation strategy that will help protect natural resources for future generations.

MONITORING

The Project reservoir(s) shall be monitored for bullfrog presence on an annual basis with a minimum of five total surveys, no less than two weeks apart, throughout the months of May-July

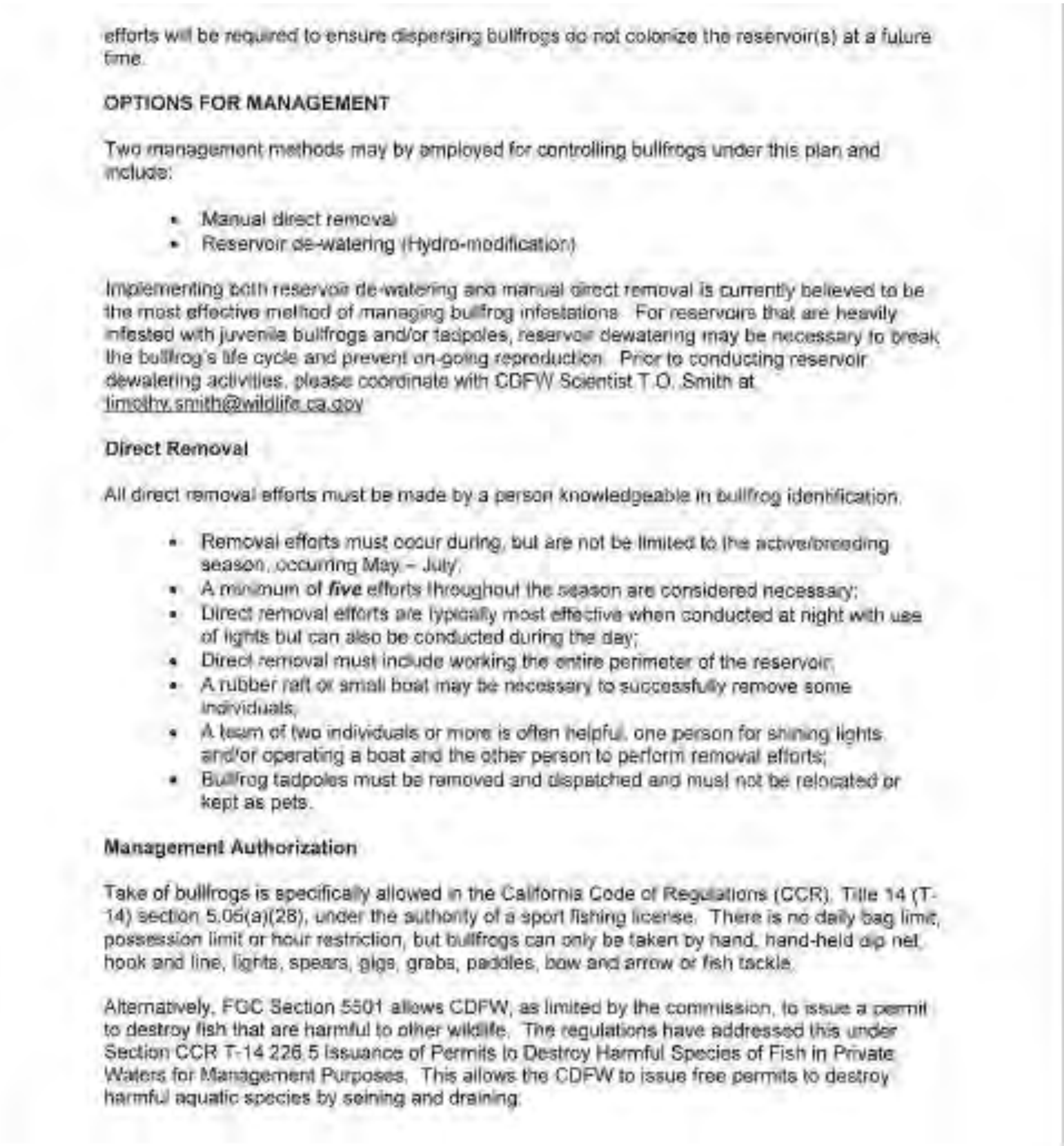
- All pond survey effort must be made by a person knowledgeable in bullfrog identification (see Appendix A for reference photos);
- Survey efforts shall include listening for bullfrog calls and slowly walking the complete perimeter of the pond at night* (dusk or later) while shining a flashlight to detect movement and eye-shine

If bullfrogs are not detected upon completion of five total surveys, or at any other time of the year incidentally, removal efforts are not required that year.

*Day time monitoring can also be conducted to aid detection but is not required under this plan.

SUCCESS CRITERIA

The level of effort needed to successfully manage bullfrog populations varies with infestation levels. This plan shall be considered successfully implemented if sufficient effort is provided to prevent adult bullfrogs from reproducing in the reservoir(s) each year, and no bullfrog life-stages can be detected. Bullfrogs are capable of traveling long distances over-land, and on-going



efforts will be required to ensure dispersing bullfrogs do not colonize the reservoir(s) at a future time.

OPTIONS FOR MANAGEMENT

Two management methods may by employed for controlling bullfrogs under this plan and include:

- Manual direct removal
- Reservoir de-watering (Hydro-modification)

Implementing both reservoir de-watering and manual direct removal is currently believed to be the most effective method of managing bullfrog infestations. For reservoirs that are heavily infested with juvenile bullfrogs and/or tadpoles, reservoir dewatering may be necessary to break the bullfrog's life cycle and prevent on-going reproduction. Prior to conducting reservoir dewatering activities, please coordinate with CDFW Scientist T.O. Smith at timothy.smith@wildlife.ca.gov

Direct Removal

All direct removal efforts must be made by a person knowledgeable in bullfrog identification.

- Removal efforts must occur during, but are not be limited to the active/breeding season, occurring May – July;
- A minimum of ***five*** efforts throughout the season are considered necessary;
- Direct removal efforts are typically most effective when conducted at night with use of lights but can also be conducted during the day;
- Direct removal must include working the entire perimeter of the reservoir;
- A rubber raft or small boat may be necessary to successfully remove some individuals;
- A team of two individuals or more is often helpful, one person for shining lights and/or operating a boat and the other person to perform removal efforts;
- Bullfrog tadpoles must be removed and dispatched and must not be relocated or kept as pets.

Management Authorization

Take of bullfrogs is specifically allowed in the California Code of Regulations (CCR), Title 14 (T-14) section 5.05(a)(28), under the authority of a sport fishing license. There is no daily bag limit, possession limit or hour restriction, but bullfrogs can only be taken by hand, hand-held dip net, hook and line, lights, spears, gigs, grabs, paddles, bow and arrow or fish tackle.

Alternatively, FGC Section 5501 allows CDFW, as limited by the commission, to issue a permit to destroy fish that are harmful to other wildlife. The regulations have addressed this under Section CCR T-14 226.5 Issuance of Permits to Destroy Harmful Species of Fish in Private Waters for Management Purposes. This allows the CDFW to issue free permits to destroy harmful aquatic species by seining and draining.

Pond Dewatering

Pond dewatering may be appropriate if the reservoir can be successfully dewatered without adversely affecting stream resources. Careful planning and coordination with CDFW, is necessary to ensure potential impacts to stream resources can be addressed, prior to commencing with pond draining. Discharge of polluted water to waters of the state may require permitting from other agencies with permitting authority, such as the Regional Water Quality Control Board.

In general, bullfrog tadpoles require two years to develop into frogs, whereas native amphibians only require one year. Therefore, draining a reservoir every year is intended to interrupt bullfrog tadpole development, dramatically decrease bullfrog populations and allow for reduced efforts as a measure of adaptive management. Typically in Northern California, reservoir draining should occur in September through October to avoid impacts to sensitive native amphibian and fishery resources. While draining occurs, direct removal efforts should be employed as described above if possible.

REPORTING

A written log shall be kept of monitoring and management efforts and shall be provided to CDFW **each year** by December 31. The written log shall include: 1) date and time of each monitoring and management effort, 2) approximate number of each bullfrog life stage detected and/or removed per effort, and 3) amount of time spent for each monitoring and management effort.

APPENDIX A. BULLFROG REFERENCE PHOTOS

This is a photo of a Bullfrog tadpole. (Photo taken by Mike van Hattem).

The photos shown in this Appendix demonstrate a medium sized adult bullfrog that was removed from Ten Mile Creek, Mendocino County. Note the bullfrog has a large tympanum, (circular ear drum shown with an arrow) and **does not** have distinct ridges along its back (dorsolateral folds). Photo taken by Wes Stokes.

The bullfrog has somewhat distinct mottling and **the underside of the bullfrogs hind legs are not shaded pink or red.**

Attachment B

Project Emissions Background Documentation

(CalEEMod)

Marshall Ranch Flow Enhancement

Humboldt County, Annual

1.0 Project Characteristics

1.1 Land Usage

Land Uses	Size	Metric	Lot Acreage	Floor Surface Area	Population
Recreational Swimming Pool	140.00	1000sqft	3.21	140,000.00	0

1.2 Other Project Characteristics

Urbanization	Rural	**Wind Speed (m/s)**	2.2	**Precipitation Freq (Days)**	103
Climate Zone	1			**Operational Year**	2022
Utility Company	Pacific Gas & Electric Company				
CO2 Intensity (lb/MWhr)	641.35	**CH4 Intensity (lb/MWhr)**	0.029	**N2O Intensity (lb/MWhr)**	0.006

1.3 User Entered Comments & Non-Default Data

Project Characteristics -

Land Use - This project does not fit the pre-defined land use types or subtypes so the nearest possible landuse was selected - recreational swimming pool.

Grading -

Construction Phase - Modified construction start time so all work will occur in one year. Modified proportion of grading vs proportion of building to better align with this project type. Overlapped grading and building phases to match reality of likely construction sequencing. Minimized days of paving and architectural coating because this project only involves a minor amount of those tasks.

Off-road Equipment - Modifed equipment to match equipment that will be used for this project.

Off-road Equipment - Modified equipment based on what will be used for this project.

Off-road Equipment - Modifed equipment to match equipment that will be used for this project.

Off-road Equipment - Modifed equipment to match equipment that will be used for this project.

Off-road Equipment -

Off-road Equipment -

Stationary Sources - Emergency Generators and Fire Pumps - For this analyses, diesel fire pump substituted for electric pump with similar horsepower; Assumes pump runs 30 days/year.

Road Dust -

Water And Wastewater - Energy used for pumping and cooling water entered seperately.

Solid Waste - Project will generate minimal solid waste.

Stationary Sources - User Defined -

Stationary Sources - Process Boilers - For this analyses, diesel boiler substituted for electric water chiller with similar energy usage; Assumes that it runs 7 days/year.

Land Use Change -

Energy Mitigation -

Vehicle Trips - There is no actual recreation at this pool.

Table Name	Column Name	Default Value	New Value
tblConstructionPhase	NumDays	8.00	181.00
tblConstructionPhase	NumDays	230.00	67.00
tblConstructionPhase	NumDays	18.00	1.00
tblConstructionPhase	NumDays	18.00	1.00

tblConstructionPhase	PhaseEndDate	2/16/2021	10/15/2021
tblConstructionPhase	PhaseEndDate	1/4/2022	10/15/2021
tblConstructionPhase	PhaseEndDate	1/28/2022	10/16/2021
tblConstructionPhase	PhaseEndDate	2/23/2022	10/18/2021
tblConstructionPhase	PhaseStartDate	2/17/2021	7/15/2021
tblConstructionPhase	PhaseStartDate	1/5/2022	10/15/2021
tblConstructionPhase	PhaseStartDate	1/29/2022	10/17/2021
tblGrading	AcresOfGrading	90.50	4.00
tblGrading	AcresOfGrading	7.50	0.00
tblOffRoadEquipment	HorsePower	84.00	81.00
tblOffRoadEquipment	HorsePower	212.00	247.00
tblOffRoadEquipment	HorsePower	212.00	247.00
tblOffRoadEquipment	HorsePower	158.00	97.00
tblOffRoadEquipment	LoadFactor	0.74	0.73
tblOffRoadEquipment	LoadFactor	0.43	0.40
tblOffRoadEquipment	LoadFactor	0.43	0.40
tblOffRoadEquipment	LoadFactor	0.38	0.37
tblOffRoadEquipment	LoadFactor	0.50	0.50
tblOffRoadEquipment	OffRoadEquipmentType	Concrete/Industrial Saws	Generator Sets
tblOffRoadEquipment	OffRoadEquipmentType	Rubber Tired Dozers	Crawler Tractors
tblOffRoadEquipment	OffRoadEquipmentType	Rubber Tired Dozers	Crawler Tractors
tblOffRoadEquipment	OffRoadEquipmentType	Tractors/Loaders/Backhoes	Excavators
tblOffRoadEquipment	OffRoadEquipmentType		Off-Highway Trucks
tblOffRoadEquipment	OffRoadEquipmentType		Bore/Drill Rigs
tblProjectCharacteristics	UrbanizationLevel	Urban	Rural
tblSolidWaste	LandfillCaptureGasFlare	94.00	0.00
tblSolidWaste	LandfillNoGasCapture	6.00	0.00

tblSolidWaste	SolidWasteGenerationRate	798.00	1.00
tblStationaryBoilersUse	AnnualHeatInput	0.00	24.02
tblStationaryBoilersUse	BoilerRatingValue	0.00	1.43
tblStationaryBoilersUse	DailyHeatInput	0.00	0.07
tblStationaryBoilersUse	NumberOfEquipment	0.00	1.00
tblStationaryGeneratorsPumpsEF	CH4_EF	0.07	0.07
tblStationaryGeneratorsPumpsEF	ROG_EF	2.2480e-003	2.2477e-003
tblStationaryGeneratorsPumpsUse	HorsePowerValue	0.00	7.50
tblStationaryGeneratorsPumpsUse	HoursPerDay	0.00	2.00
tblStationaryGeneratorsPumpsUse	HoursPerYear	0.00	720.00
tblStationaryGeneratorsPumpsUse	NumberOfEquipment	0.00	1.00
tblTripsAndVMT	HaulingTripNumber	0.00	625.00
tblTripsAndVMT	WorkerTripNumber	23.00	15.00
tblTripsAndVMT	WorkerTripNumber	35.00	18.00
tblVehicleTrips	ST_TR	9.10	0.00
tblVehicleTrips	SU_TR	13.60	0.00
tblVehicleTrips	WD_TR	33.82	0.00
tblWater	IndoorWaterUseRate	8,280,040.17	0.00
tblWater	OutdoorWaterUseRate	5,074,863.33	0.00

2.0 Emissions Summary

2.1 Overall Construction

Unmitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2021	0.5062	4.7807	3.4721	8.0300e-003	0.6498	0.2078	0.8576	0.3401	0.1921	0.5322	0.0000	708.1022	708.1022	0.1967	0.0000	713.0190
Maximum	**0.5062**	**4.7807**	**3.4721**	**8.0300e-003**	**0.6498**	**0.2078**	**0.8576**	**0.3401**	**0.1921**	**0.5322**	**0.0000**	**708.1022**	**708.1022**	**0.1967**	**0.0000**	**713.0190**

Mitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2021	0.5062	4.7807	3.4720	8.0300e-003	0.6498	0.2078	0.8576	0.3401	0.1921	0.5322	0.0000	708.1014	708.1014	0.1967	0.0000	713.0183
Maximum	**0.5062**	**4.7807**	**3.4720**	**8.0300e-003**	**0.6498**	**0.2078**	**0.8576**	**0.3401**	**0.1921**	**0.5322**	**0.0000**	**708.1014**	**708.1014**	**0.1967**	**0.0000**	**713.0183**

	ROG	**NOx**	**CO**	**SO2**	**Fugitive PM10**	**Exhaust PM10**	**PM10 Total**	**Fugitive PM2.5**	**Exhaust PM2.5**	**PM2.5 Total**	**Bio- CO2**	**NBio-CO2**	**Total CO2**	**CH4**	**N20**	**CO2e**
Percent Reduction	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Quarter	Start Date	End Date	Maximum Unmitigated ROG + NOX (tons/quarter)	Maximum Mitigated ROG + NOX (tons/quarter)
1	**1-1-2021**	**3-31-2021**	1.5314	1.5314
2	**4-1-2021**	**6-30-2021**	1.3076	1.3076
3	**7-1-2021**	**9-30-2021**	2.0627	2.0627
		Highest	2.0627	2.0627

2.2 Overall Operational

Unmitigated Operational

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Area	1.1300e-003	1.0000e-005	1.2900e-003	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000	2.5000e-003	2.5000e-003	1.0000e-005	0.0000	2.6700e-003
Energy	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mobile	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Stationary	4.1600e-003	0.0222	0.0248	4.0000e-005		1.3000e-003	1.3000e-003		1.2400e-003	1.2400e-003	0.0000	3.8648	3.8648	2.9000e-004	0.0000	3.8720
Waste						0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water						0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**5.2900e-003**	**0.0222**	**0.0261**	**4.0000e-005**	**0.0000**	**1.3000e-003**	**1.3000e-003**	**0.0000**	**1.2400e-003**	**1.2400e-003**	**0.0000**	**3.8673**	**3.8673**	**3.0000e-004**	**0.0000**	**3.8747**

2.2 Overall Operational

Mitigated Operational

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Area	1.1300e-003	1.0000e-005	1.2900e-003	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000	2.5000e-003	2.5000e-003	1.0000e-005	0.0000	2.6700e-003
Energy	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000	-3.7819	-3.7819	-0.0002	0.0000	-3.7967
Mobile	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Stationary	4.1600e-003	0.0222	0.0248	4.0000e-005		1.3000e-003	1.3000e-003		1.2400e-003	1.2400e-003	0.0000	3.8648	3.8648	2.9000e-004	0.0000	3.8720
Waste						0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water						0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**5.2900e-003**	**0.0222**	**0.0261**	**4.0000e-005**	**0.0000**	**1.3000e-003**	**1.3000e-003**	**0.0000**	**1.2400e-003**	**1.2400e-003**	**0.0000**	**0.0855**	**0.0855**	**1.3000e-004**	**0.0000**	**0.0780**

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio-CO2	Total CO2	CH4	N20	CO2e
Percent Reduction	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**97.79**	**97.79**	**56.67**	**0.00**	**97.99**

2.3 Vegetation

Vegetation

	CO2e
Category	MT
Vegetation Land Change	-17.2400
Total	**-17.2400**

3.0 Construction Detail

Construction Phase

Phase Number	Phase Name	Phase Type	Start Date	End Date	Num Days Week	Num Days	Phase Description
1	Demolition	Demolition	1/1/2021	1/28/2021	5	20	
2	Site Preparation	Site Preparation	1/29/2021	2/4/2021	5	5	
3	Grading	Grading	2/5/2021	10/15/2021	5	181	
4	Building Construction	Building Construction	7/15/2021	10/15/2021	5	67	
5	Paving	Paving	10/15/2021	10/16/2021	5	1	
6	Architectural Coating	Architectural Coating	10/17/2021	10/18/2021	5	1	

Acres of Grading (Site Preparation Phase): 0

Acres of Grading (Grading Phase): 4

Acres of Paving: 0

Residential Indoor: 0; Residential Outdoor: 0; Non-Residential Indoor: 300; Non-Residential Outdoor: 100; Striped Parking Area: 0 (Architectural Coating – sqft)

OffRoad Equipment

Phase Name	Offroad Equipment Type	Amount	Usage Hours	Horse Power	Load Factor
Demolition	Generator Sets	1	8.00	81	0.73
Demolition	Crawler Tractors	2	8.00	247	0.40
Demolition	Excavators	3	8.00	158	0.38
Grading	Excavators	1	8.00	158	0.38
Site Preparation	Crawler Tractors	3	8.00	247	0.40
Site Preparation	Excavators	4	8.00	97	0.37
Grading	Graders	1	8.00	187	0.41
Grading	Rubber Tired Dozers	1	8.00	247	0.40
Grading	Tractors/Loaders/Backhoes	3	8.00	97	0.37
Building Construction	Cranes	1	7.00	231	0.29
Building Construction	Forklifts	3	8.00	89	0.20
Building Construction	Generator Sets	1	8.00	84	0.74
Building Construction	Tractors/Loaders/Backhoes	3	7.00	97	0.37
Building Construction	Welders	1	8.00	46	0.45
Paving	Cement and Mortar Mixers	2	6.00	9	0.56
Paving	Pavers	1	8.00	130	0.42
Paving	Paving Equipment	2	6.00	132	0.36
Paving	Rollers	2	6.00	80	0.38
Paving	Tractors/Loaders/Backhoes	1	8.00	97	0.37
Architectural Coating	Air Compressors	1	6.00	78	0.48
Grading	Off-Highway Trucks	2	8.00	402	0.38
Building Construction	Bore/Drill Rigs	1	8.00	221	0.50
Demolition	Concrete/Industrial Saws	1	8.00	81	0.73
Demolition	Rubber Tired Dozers	2	8.00	247	0.40
Site Preparation	Rubber Tired Dozers	3	8.00	247	0.40
Site Preparation	Tractors/Loaders/Backhoes	4	8.00	97	0.37

Trips and VMT

Phase Name	Offroad Equipment Count	Worker Trip Number	Vendor Trip Number	Hauling Trip Number	Worker Trip Length	Vendor Trip Length	Hauling Trip Length	Worker Vehicle Class	Vendor Vehicle Class	Hauling Vehicle Class
Demolition	9	15.00	0.00	0.00	16.80	6.60	20.00	LD_Mix	HDT_Mix	HHDT
Site Preparation	14	18.00	0.00	0.00	16.80	6.60	20.00	LD_Mix	HDT_Mix	HHDT
Grading	8	20.00	0.00	625.00	16.80	6.60	20.00	LD_Mix	HDT_Mix	HHDT
Building Construction	10	59.00	23.00	0.00	16.80	6.60	20.00	LD_Mix	HDT_Mix	HHDT
Paving	8	20.00	0.00	0.00	16.80	6.60	20.00	LD_Mix	HDT_Mix	HHDT
Architectural Coating	1	12.00	0.00	0.00	16.80	6.60	20.00	LD_Mix	HDT_Mix	HHDT

3.1 Mitigation Measures Construction

3.2 Demolition - 2021

Unmitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Off-Road	0.0470	0.4956	0.3035	6.2000e-004		0.0228	0.0228		0.0212	0.0212	0.0000	54.3293	54.3293	0.0147	0.0000	54.6963
Total	**0.0470**	**0.4956**	**0.3035**	**6.2000e-004**		**0.0228**	**0.0228**		**0.0212**	**0.0212**	**0.0000**	**54.3293**	**54.3293**	**0.0147**	**0.0000**	**54.6963**

3.2 Demolition - 2021

Unmitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	1.6700e-003	1.5000e-003	0.0118	2.0000e-005	1.8000e-003	2.0000e-005	1.8200e-003	4.8000e-004	2.0000e-005	4.9000e-004	0.0000	1.6014	1.6014	1.0000e-004	0.0000	1.6040
Total	**1.6700e-003**	**1.5000e-003**	**0.0118**	**2.0000e-005**	**1.8000e-003**	**2.0000e-005**	**1.8200e-003**	**4.8000e-004**	**2.0000e-005**	**4.9000e-004**	**0.0000**	**1.6014**	**1.6014**	**1.0000e-004**	**0.0000**	**1.6040**

Mitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Off-Road	0.0470	0.4956	0.3035	6.2000e-004		0.0228	0.0228		0.0212	0.0212	0.0000	54.3293	54.3293	0.0147	0.0000	54.6963
Total	**0.0470**	**0.4956**	**0.3035**	**6.2000e-004**		**0.0228**	**0.0228**		**0.0212**	**0.0212**	**0.0000**	**54.3293**	**54.3293**	**0.0147**	**0.0000**	**54.6963**

3.2 Demolition - 2021

Mitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	1.6700e-003	1.5000e-003	0.0118	2.0000e-005	1.8000e-003	2.0000e-005	1.8200e-003	4.8000e-004	2.0000e-005	4.9000e-004	0.0000	1.6014	1.6014	1.0000e-004	0.0000	1.6040
Total	**1.6700e-003**	**1.5000e-003**	**0.0118**	**2.0000e-005**	**1.8000e-003**	**2.0000e-005**	**1.8200e-003**	**4.8000e-004**	**2.0000e-005**	**4.9000e-004**	**0.0000**	**1.6014**	**1.6014**	**1.0000e-004**	**0.0000**	**1.6040**

3.3 Site Preparation - 2021

Unmitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Fugitive Dust					0.0452	0.0000	0.0452	0.0248	0.0000	0.0248	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Off-Road	0.0159	0.1759	0.0948	1.9000e-004		8.2600e-003	8.2600e-003		7.6000e-003	7.6000e-003	0.0000	16.6522	16.6522	5.3900e-003	0.0000	16.7868
Total	**0.0159**	**0.1759**	**0.0948**	**1.9000e-004**	**0.0452**	**8.2600e-003**	**0.0534**	**0.0248**	**7.6000e-003**	**0.0324**	**0.0000**	**16.6522**	**16.6522**	**5.3900e-003**	**0.0000**	**16.7868**

3.3 Site Preparation - 2021

Unmitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	5.0000e-004	4.5000e-004	3.5300e-003	1.0000e-005	5.4000e-004	1.0000e-005	5.4000e-004	1.4000e-004	0.0000	1.5000e-004	0.0000	0.4804	0.4804	3.0000e-005	0.0000	0.4812
Total	**5.0000e-004**	**4.5000e-004**	**3.5300e-003**	**1.0000e-005**	**5.4000e-004**	**1.0000e-005**	**5.4000e-004**	**1.4000e-004**	**0.0000**	**1.5000e-004**	**0.0000**	**0.4804**	**0.4804**	**3.0000e-005**	**0.0000**	**0.4812**

Mitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Fugitive Dust					0.0452	0.0000	0.0452	0.0248	0.0000	0.0248	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Off-Road	0.0159	0.1759	0.0948	1.9000e-004		8.2600e-003	8.2600e-003		7.6000e-003	7.6000e-003	0.0000	16.6521	16.6521	5.3900e-003	0.0000	16.7868
Total	**0.0159**	**0.1759**	**0.0948**	**1.9000e-004**	**0.0452**	**8.2600e-003**	**0.0534**	**0.0248**	**7.6000e-003**	**0.0324**	**0.0000**	**16.6521**	**16.6521**	**5.3900e-003**	**0.0000**	**16.7868**

3.3 Site Preparation - 2021

Mitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	5.0000e-004	4.5000e-004	3.5300e-003	1.0000e-005	5.4000e-004	1.0000e-005	5.4000e-004	1.4000e-004	0.0000	1.5000e-004	0.0000	0.4804	0.4804	3.0000e-005	0.0000	0.4812
Total	**5.0000e-004**	**4.5000e-004**	**3.5300e-003**	**1.0000e-005**	**5.4000e-004**	**1.0000e-005**	**5.4000e-004**	**1.4000e-004**	**0.0000**	**1.5000e-004**	**0.0000**	**0.4804**	**0.4804**	**3.0000e-005**	**0.0000**	**0.4812**

3.4 Grading - 2021

Unmitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Fugitive Dust					0.5471	0.0000	0.5471	0.2998	0.0000	0.2998	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Off-Road	0.3169	3.1913	2.0875	5.0700e-003		0.1399	0.1399		0.1287	0.1287	0.0000	445.7200	445.7200	0.1442	0.0000	449.3239
Total	**0.3169**	**3.1913**	**2.0875**	**5.0700e-003**	**0.5471**	**0.1399**	**0.6870**	**0.2998**	**0.1287**	**0.4285**	**0.0000**	**445.7200**	**445.7200**	**0.1442**	**0.0000**	**449.3239**

3.4 Grading - 2021

Unmitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	2.7900e-003	0.0953	0.0155	2.5000e-004	5.1400e-003	4.3000e-004	5.5700e-003	1.4100e-003	4.2000e-004	1.8300e-003	0.0000	23.5520	23.5520	7.2000e-004	0.0000	23.5700
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	0.0202	0.0181	0.1422	2.1000e-004	0.0217	2.0000e-004	0.0219	5.7800e-003	1.9000e-004	5.9700e-003	0.0000	19.3236	19.3236	1.2600e-003	0.0000	19.3550
Total	**0.0230**	**0.1134**	**0.1577**	**4.6000e-004**	**0.0268**	**6.3000e-004**	**0.0275**	**7.1900e-003**	**6.1000e-004**	**7.8000e-003**	**0.0000**	**42.8756**	**42.8756**	**1.9800e-003**	**0.0000**	**42.9249**

Mitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Fugitive Dust					0.5471	0.0000	0.5471	0.2998	0.0000	0.2998	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Off-Road	0.3169	3.1913	2.0875	5.0700e-003		0.1399	0.1399		0.1287	0.1287	0.0000	445.7195	445.7195	0.1442	0.0000	449.3233
Total	**0.3169**	**3.1913**	**2.0875**	**5.0700e-003**	**0.5471**	**0.1399**	**0.6870**	**0.2998**	**0.1287**	**0.4285**	**0.0000**	**445.7195**	**445.7195**	**0.1442**	**0.0000**	**449.3233**

3.4 Grading - 2021

Mitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	2.7900e-003	0.0953	0.0155	2.5000e-004	5.1400e-003	4.3000e-004	5.5700e-003	1.4100e-003	4.2000e-004	1.8300e-003	0.0000	23.5520	23.5520	7.2000e-004	0.0000	23.5700
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	0.0202	0.0181	0.1422	2.1000e-004	0.0217	2.0000e-004	0.0219	5.7800e-003	1.9000e-004	5.9700e-003	0.0000	19.3236	19.3236	1.2600e-003	0.0000	19.3550
Total	**0.0230**	**0.1134**	**0.1577**	**4.6000e-004**	**0.0268**	**6.3000e-004**	**0.0275**	**7.1900e-003**	**6.1000e-004**	**7.8000e-003**	**0.0000**	**42.8756**	**42.8756**	**1.9800e-003**	**0.0000**	**42.9249**

3.5 Building Construction - 2021

Unmitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Off-Road	0.0724	0.6857	0.6251	1.2200e-003		0.0352	0.0352		0.0330	0.0330	0.0000	105.4553	105.4553	0.0277	0.0000	106.1486
Total	**0.0724**	**0.6857**	**0.6251**	**1.2200e-003**		**0.0352**	**0.0352**		**0.0330**	**0.0330**	**0.0000**	**105.4553**	**105.4553**	**0.0277**	**0.0000**	**106.1486**

3.5 Building Construction - 2021

Unmitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	3.5600e-003	0.0907	0.0247	2.0000e-004	4.4700e-003	3.7000e-004	4.8400e-003	1.3000e-003	3.5000e-004	1.6500e-003	0.0000	18.7699	18.7699	9.7000e-004	0.0000	18.7940
Worker	0.0221	0.0198	0.1552	2.3000e-004	0.0237	2.2000e-004	0.0239	6.3100e-003	2.0000e-004	6.5200e-003	0.0000	21.1011	21.1011	1.3700e-003	0.0000	21.1354
Total	**0.0256**	**0.1105**	**0.1799**	**4.3000e-004**	**0.0282**	**5.9000e-004**	**0.0288**	**7.6100e-003**	**5.5000e-004**	**8.1700e-003**	**0.0000**	**39.8710**	**39.8710**	**2.3400e-003**	**0.0000**	**39.9294**

Mitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Off-Road	0.0724	0.6857	0.6251	1.2200e-003		0.0352	0.0352		0.0330	0.0330	0.0000	105.4552	105.4552	0.0277	0.0000	106.1484
Total	**0.0724**	**0.6857**	**0.6251**	**1.2200e-003**		**0.0352**	**0.0352**		**0.0330**	**0.0330**	**0.0000**	**105.4552**	**105.4552**	**0.0277**	**0.0000**	**106.1484**

3.5 Building Construction - 2021

Mitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	3.5600e-003	0.0907	0.0247	2.0000e-004	4.4700e-003	3.7000e-004	4.8400e-003	1.3000e-003	3.5000e-004	1.6500e-003	0.0000	18.7699	18.7699	9.7000e-004	0.0000	18.7940
Worker	0.0221	0.0198	0.1552	2.3000e-004	0.0237	2.2000e-004	0.0239	6.3100e-003	2.0000e-004	6.5200e-003	0.0000	21.1011	21.1011	1.3700e-003	0.0000	21.1354
Total	**0.0256**	**0.1105**	**0.1799**	**4.3000e-004**	**0.0282**	**5.9000e-004**	**0.0288**	**7.6100e-003**	**5.5000e-004**	**8.1700e-003**	**0.0000**	**39.8710**	**39.8710**	**2.3400e-003**	**0.0000**	**39.9294**

3.6 Paving - 2021

Unmitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Off-Road	5.5000e-004	5.4200e-003	6.1300e-003	1.0000e-005		2.9000e-004	2.9000e-004		2.7000e-004	2.7000e-004	0.0000	0.8185	0.8185	2.6000e-004	0.0000	0.8250
Paving	0.0000					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**5.5000e-004**	**5.4200e-003**	**6.1300e-003**	**1.0000e-005**		**2.9000e-004**	**2.9000e-004**		**2.7000e-004**	**2.7000e-004**	**0.0000**	**0.8185**	**0.8185**	**2.6000e-004**	**0.0000**	**0.8250**

3.6 Paving - 2021

Unmitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	1.1000e-004	1.0000e-004	7.9000e-004	0.0000	1.2000e-004	0.0000	1.2000e-004	3.0000e-005	0.0000	3.0000e-005	0.0000	0.1068	0.1068	1.0000e-005	0.0000	0.1069
Total	**1.1000e-004**	**1.0000e-004**	**7.9000e-004**	**0.0000**	**1.2000e-004**	**0.0000**	**1.2000e-004**	**3.0000e-005**	**0.0000**	**3.0000e-005**	**0.0000**	**0.1068**	**0.1068**	**1.0000e-005**	**0.0000**	**0.1069**

Mitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Off-Road	5.5000e-004	5.4200e-003	6.1300e-003	1.0000e-005		2.9000e-004	2.9000e-004		2.7000e-004	2.7000e-004	0.0000	0.8185	0.8185	2.6000e-004	0.0000	0.8250
Paving	0.0000					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**5.5000e-004**	**5.4200e-003**	**6.1300e-003**	**1.0000e-005**		**2.9000e-004**	**2.9000e-004**		**2.7000e-004**	**2.7000e-004**	**0.0000**	**0.8185**	**0.8185**	**2.6000e-004**	**0.0000**	**0.8250**

3.6 Paving - 2021

Mitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	1.1000e-004	1.0000e-004	7.9000e-004	0.0000	1.2000e-004	0.0000	1.2000e-004	3.0000e-005	0.0000	3.0000e-005	0.0000	0.1068	0.1068	1.0000e-005	0.0000	0.1069
Total	**1.1000e-004**	**1.0000e-004**	**7.9000e-004**	**0.0000**	**1.2000e-004**	**0.0000**	**1.2000e-004**	**3.0000e-005**	**0.0000**	**3.0000e-005**	**0.0000**	**0.1068**	**0.1068**	**1.0000e-005**	**0.0000**	**0.1069**

3.7 Architectural Coating - 2021

Unmitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Archit. Coating	2.3200e-003					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Off-Road	1.1000e-004	7.6000e-004	9.1000e-004	0.0000		5.0000e-005	5.0000e-005		5.0000e-005	5.0000e-005	0.0000	0.1277	0.1277	1.0000e-005	0.0000	0.1279
Total	**2.4300e-003**	**7.6000e-004**	**9.1000e-004**	**0.0000**		**5.0000e-005**	**5.0000e-005**		**5.0000e-005**	**5.0000e-005**	**0.0000**	**0.1277**	**0.1277**	**1.0000e-005**	**0.0000**	**0.1279**

3.7 Architectural Coating - 2021

Unmitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	7.0000e-005	6.0000e-005	4.7000e-004	0.0000	7.0000e-005	0.0000	7.0000e-005	2.0000e-005	0.0000	2.0000e-005	0.0000	0.0641	0.0641	0.0000	0.0000	0.0642
Total	**7.0000e-005**	**6.0000e-005**	**4.7000e-004**	**0.0000**	**7.0000e-005**	**0.0000**	**7.0000e-005**	**2.0000e-005**	**0.0000**	**2.0000e-005**	**0.0000**	**0.0641**	**0.0641**	**0.0000**	**0.0000**	**0.0642**

Mitigated Construction On-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Archit. Coating	2.3200e-003					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Off-Road	1.1000e-004	7.6000e-004	9.1000e-004	0.0000		5.0000e-005	5.0000e-005		5.0000e-005	5.0000e-005	0.0000	0.1277	0.1277	1.0000e-005	0.0000	0.1279
Total	**2.4300e-003**	**7.6000e-004**	**9.1000e-004**	**0.0000**		**5.0000e-005**	**5.0000e-005**		**5.0000e-005**	**5.0000e-005**	**0.0000**	**0.1277**	**0.1277**	**1.0000e-005**	**0.0000**	**0.1279**

3.7 Architectural Coating - 2021

Mitigated Construction Off-Site

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Hauling	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vendor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Worker	7.0000e-005	6.0000e-005	4.7000e-004	0.0000	7.0000e-005	0.0000	7.0000e-005	2.0000e-005	0.0000	2.0000e-005	0.0000	0.0641	0.0641	0.0000	0.0000	0.0642
Total	**7.0000e-005**	**6.0000e-005**	**4.7000e-004**	**0.0000**	**7.0000e-005**	**0.0000**	**7.0000e-005**	**2.0000e-005**	**0.0000**	**2.0000e-005**	**0.0000**	**0.0641**	**0.0641**	**0.0000**	**0.0000**	**0.0642**

4.0 Operational Detail - Mobile

4.1 Mitigation Measures Mobile

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Mitigated	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Unmitigated	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

4.2 Trip Summary Information

	Average Daily Trip Rate			Unmitigated	Mitigated
Land Use	Weekday	Saturday	Sunday	Annual VMT	Annual VMT
Recreational Swimming Pool	0.00	0.00	0.00		
Total	0.00	0.00	0.00		

4.3 Trip Type Information

	Miles			Trip %			Trip Purpose %		
Land Use	H-W or C-W	H-S or C-C	H-O or C-NW	H-W or C-W	H-S or C-C	H-O or C-NW	Primary	Diverted	Pass-by
Recreational Swimming Pool	14.70	6.60	6.60	33.00	48.00	19.00	52	39	9

4.4 Fleet Mix

Land Use	LDA	LDT1	LDT2	MDV	LHD1	LHD2	MHD	HHD	OBUS	UBUS	MCY	SBUS	MH
Recreational Swimming Pool	0.489041	0.045286	0.209606	0.134980	0.040724	0.006674	0.014654	0.046205	0.003398	0.001529	0.005553	0.001505	0.000846

5.0 Energy Detail

Historical Energy Use: N

5.1 Mitigation Measures Energy

Kilowatt Hours of Renewable Electricity Generated

Percent of Electricity Use Generated with Renewable Energy

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Electricity Mitigated						0.0000	0.0000		0.0000	0.0000	0.0000	-3.7819	-3.7819	-0.0002	0.0000	-3.7967
Electricity Unmitigated						0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NaturalGas Mitigated	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NaturalGas Unmitigated	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

5.2 Energy by Land Use - NaturalGas

Unmitigated

	NaturalGas Use	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Land Use	kBTU/yr	tons/yr										MT/yr					
Recreational Swimming Pool	0	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total		**0.0000**	**0.0000**	**0.0000**	**0.0000**		**0.0000**	**0.0000**		**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**

Mitigated

	NaturalGas Use	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Land Use	kBTU/yr	tons/yr										MT/yr					
Recreational Swimming Pool	0	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total		**0.0000**	**0.0000**	**0.0000**	**0.0000**		**0.0000**	**0.0000**		**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**

5.3 Energy by Land Use - Electricity

Unmitigated

	Electricity Use	Total CO2	CH4	N2O	CO2e
Land Use	kWh/yr	MT/yr			
Recreational Swimming Pool	0	0.0000	0.0000	0.0000	0.0000
Total		**0.0000**	**0.0000**	**0.0000**	**0.0000**

Mitigated

	Electricity Use	Total CO2	CH4	N2O	CO2e
Land Use	kWh/yr	MT/yr			
Recreational Swimming Pool	-13000	-3.7819	-0.0002	0.0000	-3.7967
Total		**-3.7819**	**-0.0002**	**0.0000**	**-3.7967**

6.0 Area Detail

6.1 Mitigation Measures Area

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Category	tons/yr										MT/yr					
Mitigated	1.1300e-003	1.0000e-005	1.2900e-003	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000	2.5000e-003	2.5000e-003	1.0000e-005	0.0000	2.6700e-003
Unmitigated	1.1300e-003	1.0000e-005	1.2900e-003	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000	2.5000e-003	2.5000e-003	1.0000e-005	0.0000	2.6700e-003

6.2 Area by SubCategory

Unmitigated

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
SubCategory	tons/yr										MT/yr					
Architectural Coating	2.3000e-004					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Consumer Products	7.8000e-004					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Landscaping	1.2000e-004	1.0000e-005	1.2900e-003	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000	2.5000e-003	2.5000e-003	1.0000e-005	0.0000	2.6700e-003
Total	**1.1300e-003**	**1.0000e-005**	**1.2900e-003**	**0.0000**		**0.0000**	**0.0000**		**0.0000**	**0.0000**	**0.0000**	**2.5000e-003**	**2.5000e-003**	**1.0000e-005**	**0.0000**	**2.6700e-003**

6.2 Area by SubCategory

Mitigated

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
SubCategory	tons/yr										MT/yr					
Architectural Coating	2.3000e-004					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Consumer Products	7.8000e-004					0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Landscaping	1.2000e-004	1.0000e-005	1.2900e-003	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000	2.5000e-003	2.5000e-003	1.0000e-005	0.0000	2.6700e-003
Total	**1.1300e-003**	**1.0000e-005**	**1.2900e-003**	**0.0000**		**0.0000**	**0.0000**		**0.0000**	**0.0000**	**0.0000**	**2.5000e-003**	**2.5000e-003**	**1.0000e-005**	**0.0000**	**2.6700e-003**

7.0 Water Detail

7.1 Mitigation Measures Water

	Total CO2	CH4	N2O	CO2e
Category	MT/yr			
Mitigated	0.0000	0.0000	0.0000	0.0000
Unmitigated	0.0000	0.0000	0.0000	0.0000

7.2 Water by Land Use

Unmitigated

	Indoor/Outdoor Use	Total CO2	CH4	N2O	CO2e
Land Use	Mgal	MT/yr			
Recreational Swimming Pool	0 / 0	0.0000	0.0000	0.0000	0.0000
Total		**0.0000**	**0.0000**	**0.0000**	**0.0000**

7.2 Water by Land Use

Mitigated

	Indoor/Outdoor Use	Total CO2	CH4	N2O	CO2e
Land Use	Mgal	MT/yr			
Recreational Swimming Pool	0 / 0	0.0000	0.0000	0.0000	0.0000
Total		**0.0000**	**0.0000**	**0.0000**	**0.0000**

8.0 Waste Detail

8.1 Mitigation Measures Waste

Category/Year

	Total CO2	CH4	N2O	CO2e
	MT/yr			
Mitigated	0.0000	0.0000	0.0000	0.0000
Unmitigated	0.0000	0.0000	0.0000	0.0000

8.2 Waste by Land Use

Unmitigated

	Waste Disposed	Total CO2	CH4	N2O	CO2e
Land Use	tons	MT/yr			
Recreational Swimming Pool	1	0.0000	0.0000	0.0000	0.0000
Total		**0.0000**	**0.0000**	**0.0000**	**0.0000**

Mitigated

	Waste Disposed	Total CO2	CH4	N2O	CO2e
Land Use	tons	MT/yr			
Recreational Swimming Pool	1	0.0000	0.0000	0.0000	0.0000
Total		**0.0000**	**0.0000**	**0.0000**	**0.0000**

9.0 Operational Offroad

Equipment Type	Number	Hours/Day	Days/Year	Horse Power	Load Factor	Fuel Type

10.0 Stationary Equipment

Fire Pumps and Emergency Generators

Equipment Type	Number	Hours/Day	Hours/Year	Horse Power	Load Factor	Fuel Type
Fire Pump	1	2	720	7.5	0.73	Diesel

Boilers

Equipment Type	Number	Heat Input/Day	Heat Input/Year	Boiler Rating	Fuel Type
Boiler	1	0.07	24.02	1.43	Diesel

User Defined Equipment

Equipment Type	Number

10.1 Stationary Sources

Unmitigated/Mitigated

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Equipment Type	tons/yr										MT/yr					
Boiler - Diesel (0 - 9999 MMBTU)	3.0000e-005	6.2000e-004	4.3000e-004	2.0000e-005		9.0000e-005	9.0000e-005		2.0000e-005	2.0000e-005	0.0000	1.9456	1.9456	2.0000e-005	0.0000	1.9460
Fire Pump - Diesel (0 - 11 HP)	4.1300e-003	0.0216	0.0243	2.0000e-005		1.2200e-003	1.2200e-003		1.2200e-003	1.2200e-003	0.0000	1.9192	1.9192	2.7000e-004	0.0000	1.9259
Total	**4.1600e-003**	**0.0222**	**0.0248**	**4.0000e-005**		**1.3100e-003**	**1.3100e-003**		**1.2400e-003**	**1.2400e-003**	**0.0000**	**3.8648**	**3.8648**	**2.9000e-004**	**0.0000**	**3.8720**

11.0 Vegetation

	Total CO2	CH4	N2O	CO2e
Category	MT			
Unmitigated	-17.2400	0.0000	0.0000	-17.2400

11.1 Vegetation Land Change

Vegetation Type

	Initial/Final	Total CO2	CH4	N2O	CO2e
	Acres	MT			
Grassland	20 / 16	-17.2400	0.0000	0.0000	-17.2400
Total		**-17.2400**	**0.0000**	**0.0000**	**-17.2400**