Willow Creek Daylighting
Sausalito Marin City School District
Dr. Martin Luther King, Jr. Academy Campus
Sausalito, CA

Draft Basis of Design Report

Prepared for:
Sausalito Marin City School District

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PCI ECOLOGICAL

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Introduction

Willow Creek is a perennial stream that passes through the northern part of the City of Sausalito, CA. Since the early 1900s, development in the city has encroached on the riparian corridor, and today almost the entire length of the channel from Hwy 101 to Richardson Bay has been filled in. The creek is currently contained in a storm drain that passes underneath Hwy 101, through the center of a K-8 public school campus known as the Dr. Martin Luther King, Jr. Academy (Academy), and under City-owned residential and commercial buildings to its mouth where it empties into Richardson Bay.

The Friends of Willow Creek (FOWC), a local non-profit organization has established a vision of daylighting the entire length of the creek, from its headwaters to the bay, and has worked toward realizing this vision for over 10 years. A phased approach is being pursued by dividing the full project into smaller reaches of daylighted channel, with additional phases being implemented as funding and community support allow. The current effort focuses on restoring the creek within the school campus and is supported by the Sausalito Marin City School District (District). With funding from the US Environmental Protection Agency (EPA), the District retained PCI Ecological (PCI) to develop designs for this portion of the creek restoration to also include a creekside trail providing for student engagement, outdoor educational facilities, and connections to the existing storm drain system. This report describes the existing project site, presents the proposed design, and documents the engineering analyses to support the design. This draft Basis of Design report was developed to accompany the 65% design plans also prepared by PCI.

Site Location and Existing Conditions

The project site is located in Marin County, California on the campus of the Dr. Martin Luther King Jr. Academy at 636 Nevada Street, Sausalito, CA 94965 (Figures 1-2). The coordinates near the center of the project site are 37° 51’ 50” N, 122° 30’ 09” W with elevations ranging from approximately 50 to 110 feet above sea level.

Figure 1. Project location.

Figure 2. Project site.

The Willow Creek watershed begins in the Golden Gate National Recreation Area (GGNRA) draining 87 acres northwest of Highway 101 (Figure 3). The Willow Creek watershed above the downstream end of the proposed daylighted reach totals 125 acres. Outlet flow from the proposed creek will discharge into the storm drain infrastructure on Buchanan Drive (Figure 4**Error! Reference source not found.**).

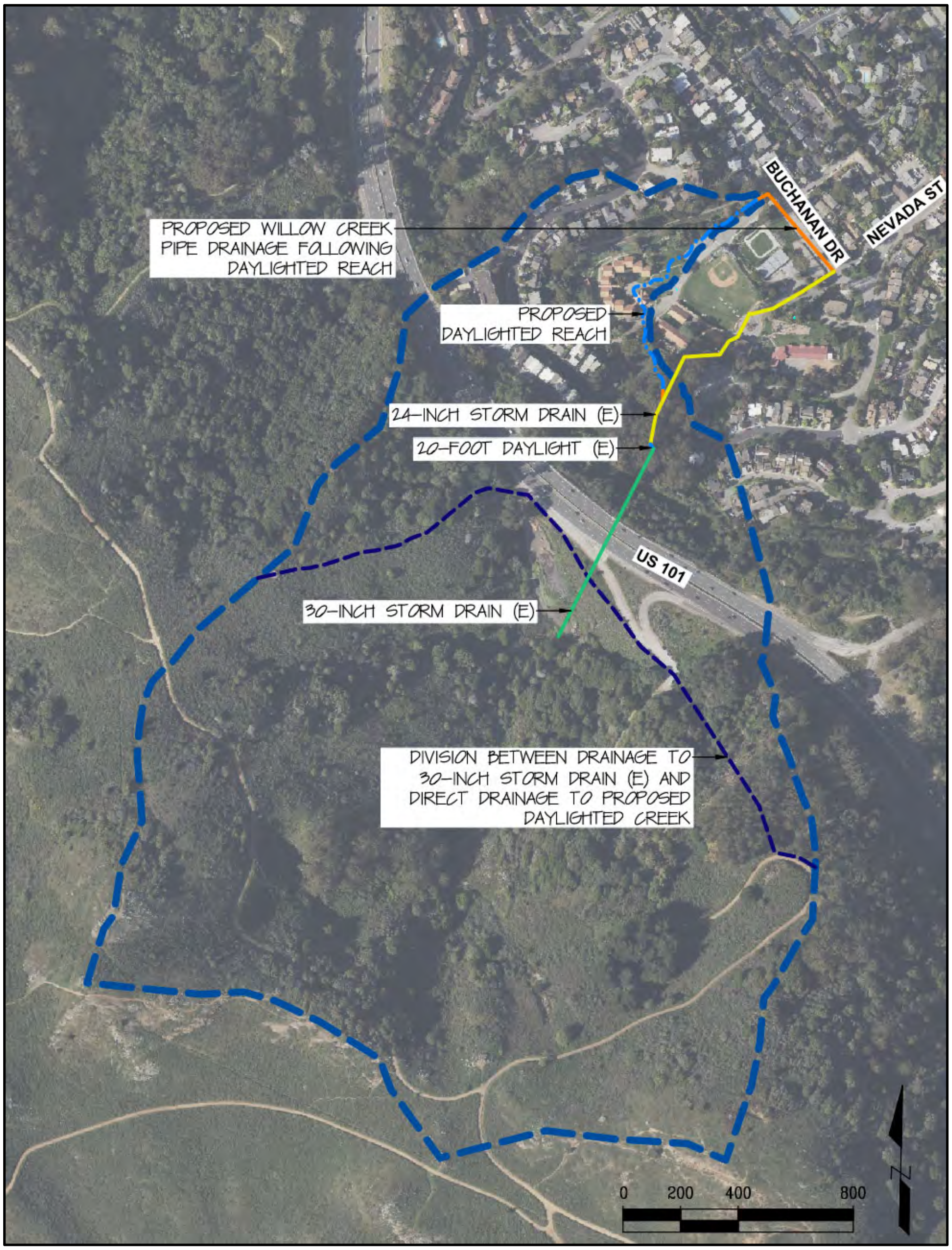

Figure 3. Willow Creek watershed and key drainage features. Note, the 30-inch storm drain increases to 48-inches under 101 and constricts back to 30-inches prior to the 20-foot daylight outfall.

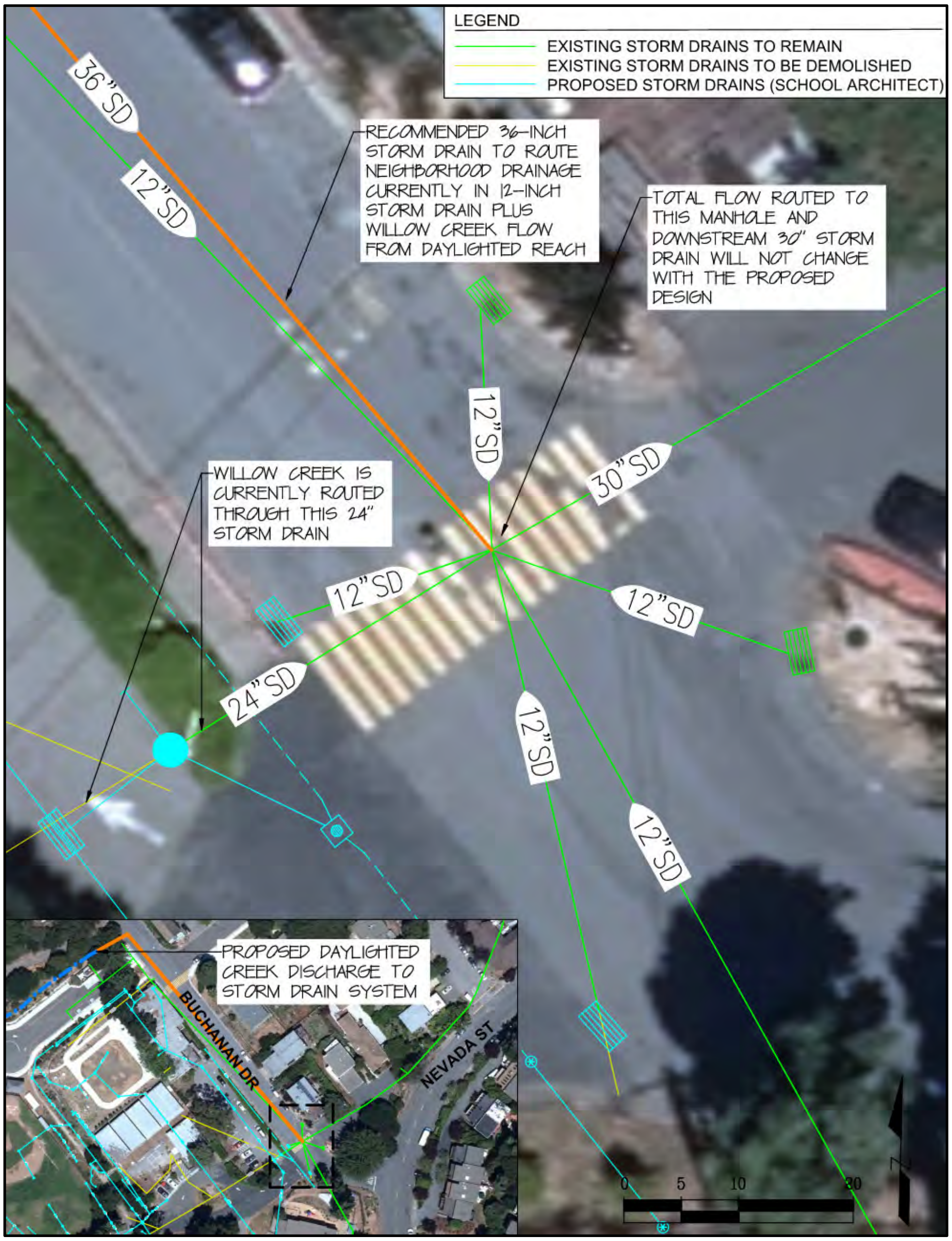

Figure 4: Existing and proposed storm drains at Buchanan Drive and Nevada Street. The manhole combines flow from one 24-inch pipe (Willow Creek) and six 12-inch pipes into one 30-inch pipe.

The Willow Creek watershed collects in an informal detention basin upslope of U.S. 101 (Figure 5). From the detention basin, flow is conveyed into a 30-inch storm drain. Additional flow from the adjacent highway corridor is collected and the storm drain size increases to 48-inches for the span routed under the highway. On the downstream side of Highway 101 and above Lincoln Drive, the storm drain diameter is reduced to 30-inches before daylighting just upstream of Lincoln Drive (Figure 6; Figure 7). At that location, additional storm water from the highway corridor is collected and combined with the Willow Creek flow into a 20-foot long surface-flow (daylighted) reach. That flow is routed to a drop inlet with a 24-inch storm drain through the school campus to the intersection of Buchanan Drive and Nevada Street (Figure 8).

Figure 5. Detention basin and US 101 embankment in the upper Willow Creek watershed upstream of the project site.

Figure 6. Storm drain carrying Willow Creek flows on the north (downstream) US 101 embankment, reducing pipe size from 48 inch to 30 inch diameter.

Figure 7. Storm drain outfall of Willow Creek flow into short surface-flow reach just above Lincoln Drive.

Figure 8. 24-inch diameter storm drain inlet at Lincoln Drive conveying Willow Creek flows through the school campus to Buchanan Drive.

The approximately 12.4-acre Academy campus is located within a residential area in western Sausalito, bounded by Buchanan Drive along the northeastern property line, Nevada Street along the southeastern property line, and Lincoln Drive on the southwestern boundary. The northwestern and southwestern sides of the site are generally bounded by ascending, east-facing slopes inclined at about 3:1 (H:V), the upper parts of which are developed with single-family homes along the downhill side of Lincoln Drive.

The upstream end of the proposed Willow Creek daylighted reach begins just below an existing fire road that provides access around the Academy campus. Downstream of the fire road the existing storm drain passes through a eucalyptus grove with tree diameters ranging from approximately 4 to 60 inches (Figure 9). The proposed design is to remove the eucalyptus trees and reestablish native plant species through the project reach. The western edge of the eucalyptus grove is bordered by a paved staff parking lot, with a path leading down to the school buildings. In the eucalyptus grove, just downstream of the fire road, is a concrete water tank and associated pumping infrastructure that will be retained.

Figure 9. Concrete water tank and eucalyptus grove at the upstream end of the proposed stream daylighting reach.

The Academy campus is being completely rebuilt in 2025-26. Knudsen Field, the existing Little League baseball field, will be shifted slightly to the southwest, requiring a retaining wall along the outfield. The former cluster of classroom and library buildings on the western side of the campus were demolished in early 2026 and provide substantial space for the restored creek corridor. On the north side of the campus, an existing vegetated hillslope is located between the cul-de-sac entering the campus from Buchanan Drive and a fire access road between the campus and adjacent residential areas. That corridor provides space for the restoration of the downstream reach of the Willow Creek daylighting project (Figure 10).

Figure 10. Existing conditions (late 2025) within the proposed Willow Creek corridor on the northwest side of the school campus, looking downslope toward Buchanan Drive.

Soils and Geology

The preliminary geotechnical evaluation from Miller Pacific Engineering Group (MPEG 2025) describes the geology of the site as lying within the Coast Ranges geomorphic province of California, a region characterized by active seismicity, steep, young topography, and abundant landsliding and erosion owing partly to its relatively high annual rainfall. The regional basement rock consists of sedimentary, igneous, and metamorphic rock of the Jurassic-Cretaceous age (65-190 million years ago) Franciscan Complex and marine sedimentary strata of the Great Valley Sequence, which is of similar age. Within central and northern California, the Franciscan and Great Valley rocks are locally overlain by a variety of late Cretaceous and Tertiary age sedimentary and volcanic rocks which have been deformed by episodes of folding and faulting. The youngest geologic units in the region are Quaternary age (last 1.8 million years) sedimentary deposits. These unconsolidated deposits partially fill many of the valleys of the region.

Regional geologic mapping (Rice and Smith 1976) indicates that the site is underlain by colluvium, which typically consists of unconsolidated and unsorted soil material and weathered rock fragments accumulated on or at the base of slopes. Franciscan “Melange” bedrock is mapped at the higher elevations north and west of the project area, consisting of a mixture of resistant rocks including sandstone, chert, greenstone, and serpentinite, embedded in a matrix of pervasively sheared shale. No faults, landslides, or other significant structural features are mapped in close proximity to the site.

The project site is located within the seismically active San Francisco Bay Area and will likely experience moderate to strong ground shaking from future earthquakes originating on any of several active faults in the region. The nearest known active fault is the San Andreas Fault, which is located about 6.1 miles (9.8 km) west of the site.

Soils on the site are derived from colluvial parent material and are typically comprised of medium to very stiff silty/sandy clay and medium to very dense sands and fine gravels. Bedrock was encountered at depths greater than 30 feet, which is expected to be well below planned channel depths relative to existing grades. As such, colluvial soils will be exposed throughout the majority of the channel alignment. It is possible that sandstone bedrock will be encountered on the north side of the channel between Stations 5+00 and 6+00.

Willow Creek Fluvial Geomorphology and Hydrology

Willow Creek can be observed as a surface stream upstream of Highway 101 and in the Willow Grove park, approximately 800 feet downstream of the restoration site. In the Willow Grove reach, the active channel is typically 3 to 4 feet wide with a typical bankfull width of 9 feet. Much of this channel reach is slightly incised within steep 2- to 3-foot-high banks and is dominated by sediment load of silt, sand and gravel typically less than 8 cm diameter (Figure 11).

Figure 11. Willow Creek at baseflow in the Willow Grove surface flow reach near Bridgeway, approximately 800 feet downstream of the project site.

Longitudinal stream slopes vary from steep above Highway 101 (0.20 to 0.30 ft/ft) to much flatter within the Willow Grove reach (0.005 to 0.010 ft/ft). Existing longitudinal slopes within the project area on the Academy campus range in between these values, typically between 0.01 and 0.20 ft/ft.

Discharge measured quarterly during 2024-2025 was within a range of 0.1 to 0.2 cubic feet per second (cfs) at Lincoln Drive and 0.1 to 0.3 cfs at Willow Grove. Measured stream water temperatures were fairly consistent throughout the sampling period, ranging from 11.2 to 12.1°C at Lincoln Drive and 11.9 to 13.3°C at Willow Grove. All measured dissolved oxygen values were supportive of good ecological function, with the lowest reading of 8.7 mg/L.

Vegetation and Wildlife

This section provides a summary of project area vegetation and wildlife communities – see the Biological Resources Evaluation (PCI 2026) for a more complete discussion. Vegetation in the preliminary project area was surveyed in April 2025, with additional survey in March 2026 to address project areas not previously surveyed. Four vegetation and land cover types were observed in the project area, all dominated by non-native species (Figure 12): ruderal herbaceous vegetation, non-native forest, eucalyptus stand, and developed land.

A wildlife survey of the project area completed in April 2025 (PCI 2025) found animals typical of local urban wildlife communities, including raccoons, black-tailed deer, house finches, American robin, and dark-eyed junco. The Himalayan blackberry scrub, eucalyptus grove, and non-native forest within the project area provide cover and foraging opportunities for bird and common mammal species. The blackberry thicket and non-native forest areas also provide potential nesting opportunities for birds.

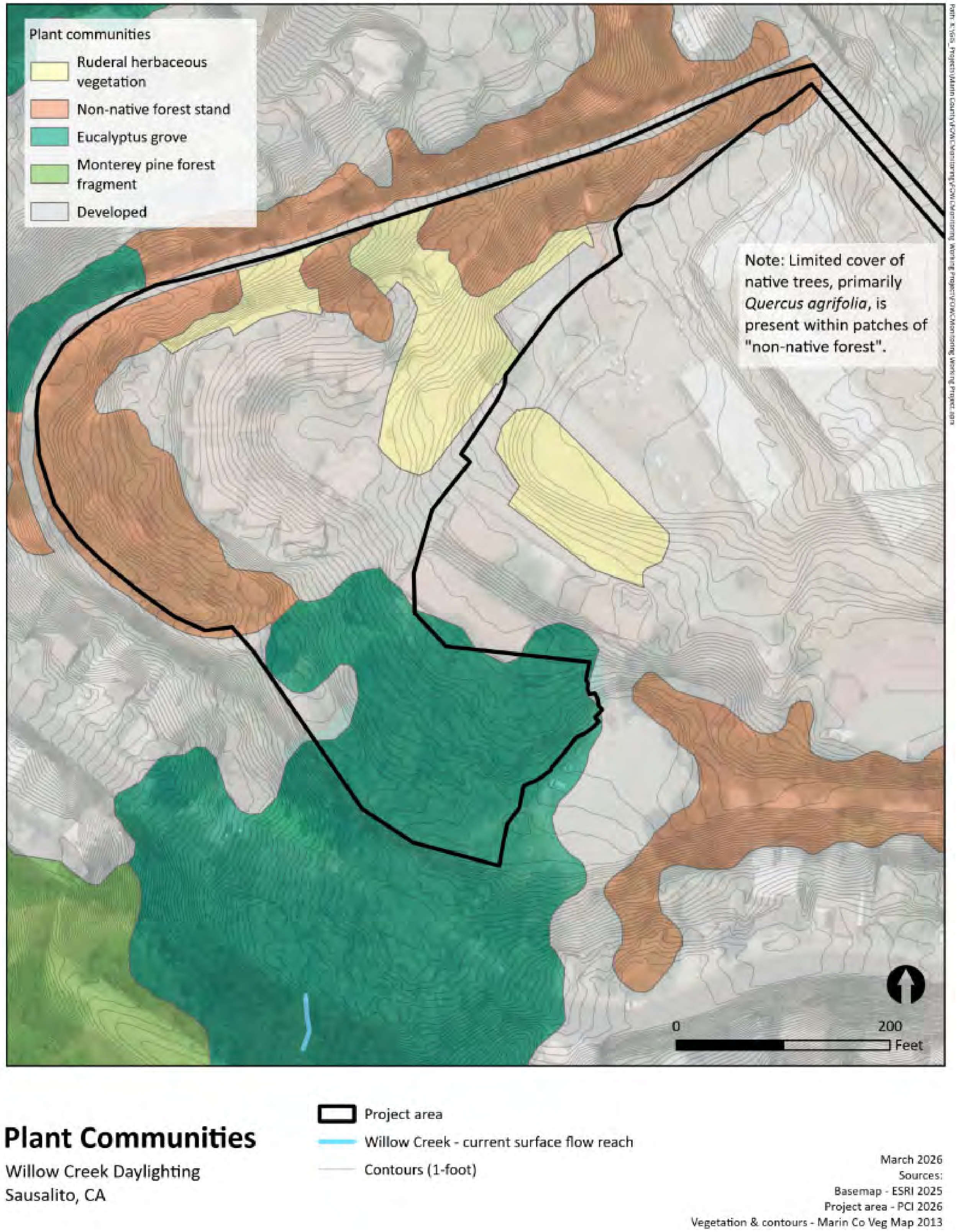

Figure 12. Vegetation types within the proposed Willow Creek corridor.

Existing Engineering Features

The Academy campus is being completely rebuilt during 2025-2026, with new academic and recreational facilities expected to be completed by June 2026. Former buildings within the proposed creek corridor were demolished in early 2026, with buried utilities either removed or abandoned in place and capped.

Features that remain along the creek corridor and will be retained include:

- a drop inlet along the 24-inch storm drain carrying Willow Creek flows at the upper end of the daylighted project reach
- a water tank and associated infrastructure near the upper parking lot (Figure 9)
- two fire hydrants along the cul-de-sac near Buchanan Drive, and
- a trash vault along the cul-de-sac near Buchanan Drive.

Features planned for demolition include (see Demolition Plan):

- paving, drop inlets, and storm drain pipe along the school access road connecting to the upper perimeter fire access route
- abandoned water and sanitary sewer lines that previously serviced classroom and library buildings that were recently demolished,
- paved playground areas near the cul-de-sac turn-around, and
- a low cinder block retaining wall and V-ditch along the cul-de-sac.

Project Purpose and Need

The purpose of the proposed project is to daylight a reach of Willow Creek; that is, to return stream flows to a natural surface channel rather than the buried storm drain through which the creek currently flows through most of the City of Sausalito. That restoration of surface flow will support native riparian vegetation, expanded riparian habitat for wildlife, improved water quality, and enhanced educational opportunities. Key project objectives are presented in Table 1.

Table 1. Project objectives and benefits.

Objective	Project Beneficial Outcomes
1. Restore the surface stream of Willow Creek	• Increase habitat value and complexity • Maintain or improve water quality of flows in Willow Creek
2. Remove non-native species and restore site vegetation with native plants	• Increase native riparian plant cover and diversity • Improve habitat conditions for wildlife
3. Enhance educational opportunities	• Provide public access to the Willow Creek stream corridor • Improve student engagement via outdoor education spaces along the Willow Creek corridor

Proposed Project Design

The proposed Willow Creek restoration will daylight approximately 950 feet of creek and restore native vegetation within the adjacent riparian zone, provide a Creekside student assembly area and an outdoor classroom, and connect the features with a new accessible trail system and pedestrian bridges.

Design Parameters

The following parameters were considered in the development of the Willow Creek restoration design:

- Public safety must be considered by reducing risks along the stream and adjacent slopes.
- The stream channel design must support geomorphic stability with minimal lateral or vertical channel erosion as appropriate to the urban site.
- The stream channel hydraulics must maintain a minimum freeboard during the 100-year design discharge of the maximum water surface elevation plus velocity head throughout the channel, while the upstream and downstream proposed culverts must maintain two feet of freeboard from the 100-year inlet headwater elevation. At pedestrian bridges, minimum freeboard is two feet between the one-hundred-year water surface elevation and the bridge soffit.
- A low-flow channel must be sized appropriately for the typical baseflow.
- The aesthetics of the restored creek corridor should enhance the school campus landscape.
- Native plantings within the restoration area should support ecological functions and cultural significance.
- The stream corridor should accommodate an adjacent accessible trail wide enough to allow access for a school maintenance vehicle (“gator”).
- Numerous access points should support student engagement and exploration of the natural environment.
- The design should allow space for potential future construction of additional school buildings.
- Construction costs should be minimized where possible.

Stream Corridor Geomorphology and Geometry

The proposed Willow Creek channel alignment, profile, and cross-sectional geometry were designed to mimic natural stream conditions as much as possible within the site constraints while reducing risks to public safety, erosion, and channel migration and protecting existing critical infrastructure. A sinuous plan view alignment was selected to add stream length and reduce the overall channel profile slope. A key design element for this project is to facilitate human interaction with the riparian corridor by creating natural spaces where school children and adults can safely interact with the creek. To promote this vision, the overall depth of the channel was minimized to allow easier access to the creek bed as well as to reduce the footprint of the project and the necessity for retaining walls. This goal was balanced with the requirement for the channel to convey the 100-year design storm with adequate freeboard.

The design profile for the new channel includes different channel types with varying average slopes: riffle-pool morphology in reaches with slopes of 0.015 to 0.041 ft/ft (Figure 13) and rock cascades in reaches with slopes of 0.125 to 0.183 ft/ft (Figure 14).

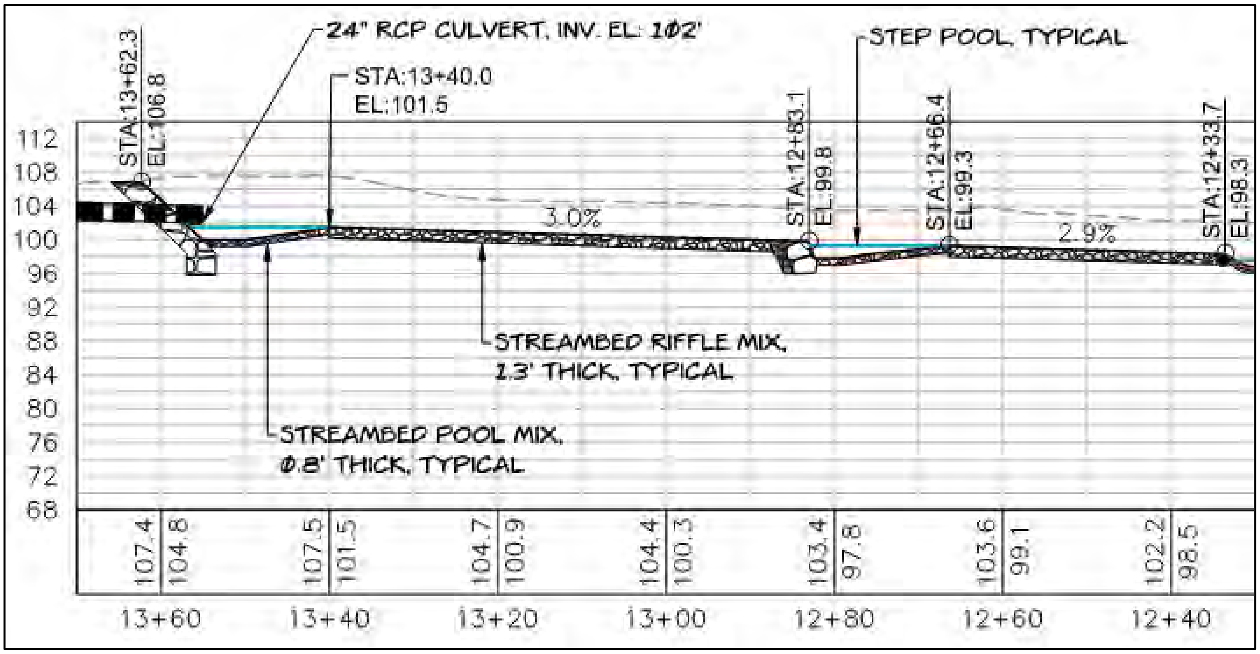

Figure 13. Typical riffle-pool section of Willow Creek design.

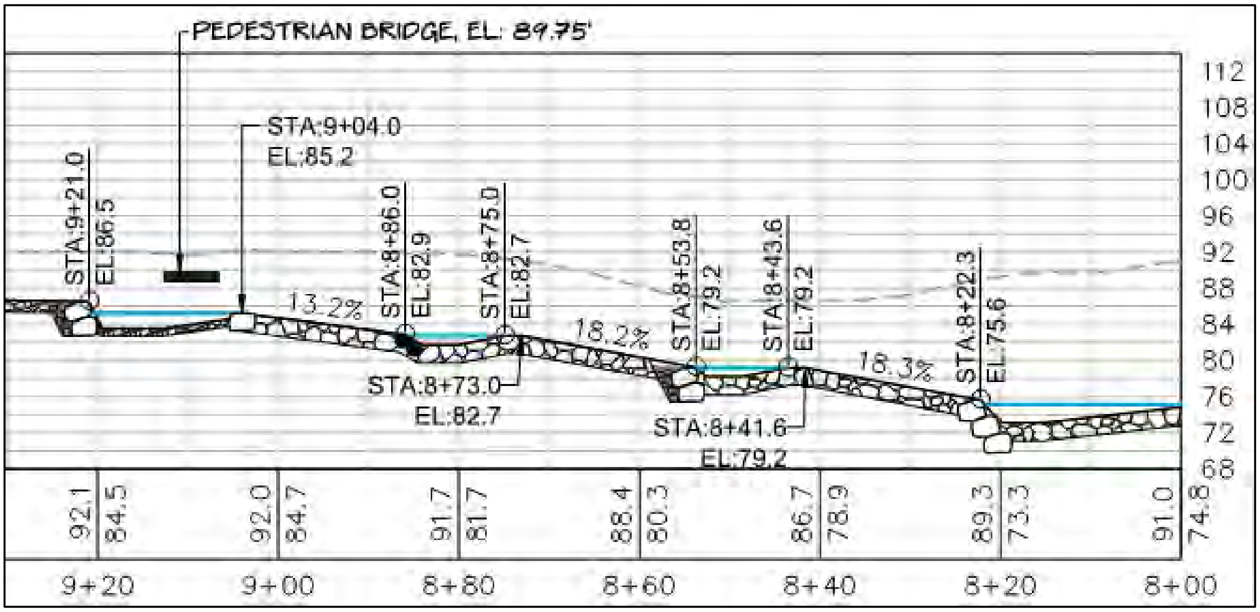

Figure 14. Typical rock cascade section of Willow Creek design.

The bankfull cross-sectional geometry of the different channel reaches was determined using regional curve data, as well as measurements from a reference reach at Willow Grove. A two-dimensional unsteady hydraulic model with a fully integrated pipe network was developed in HEC-RAS to verify that the proposed channel design has adequate capacity to convey the 100-year design storm with at least the minimum required freeboard throughout the channel, at the culverts, and at the bridges. Model results also supported analyses for rock sizing and log stability.

Regional curve data developed for the San Francisco Bay Area provide a relationship between drainage area and bankfull channel geometry (width, depth, cross-sectional area) (Leopold, 1994). Approximating the correct bankfull channel geometry is important in natural channel design, as the bankfull ("channel forming") flow does the most work overall in transporting sediment. If the bankfull width is too wide, aggradation can occur; too narrow and incision may occur. The regional curve data were used to determine a bankfull width and depth of 9 feet and 1 foot, respectively. Site measurements in the downstream reference reach closely match the regional curve data.

The riffle-pool reaches have low profile gradients with approximately 10- to 26-foot-long pools near the apex of the channel meanders. The thalweg is pushed to the outside bend through these pools to create a slightly steeper outside bank and a more gentle point bar slope along the inside of the bend. Approximately 10 large wood habitat structures will be installed in the pools to provide cover for riparian species, as well as to help maintain pool depth (Figure 15). Several of those structures are combined with a boulder weir, which dissipates energy and supports hydraulic mixing to increase dissolved oxygen (Figure 16). These large wood structures will be anchored to boulders and are designed to remain stable. Salvaged logs and rootwads from eucalyptus tree removal are proposed for these structures, providing beneficial reuse of this material and reduced project costs.

The floodplains are typically 5 to 20 feet wide and slope towards the channel at a 2% grade. Pool riffles were designed to include well-oxygenated gravels that support habitat for benthic macroinvertebrates. The bed structure through these reaches is expected to adjust somewhat over time as the pools develop a natural equilibrium, including potential aggradation of sediment within the pools, but the upstream and downstream limits of each reach have sub-surface rock or log sills to prevent critical erosion that could threaten overall site stability.

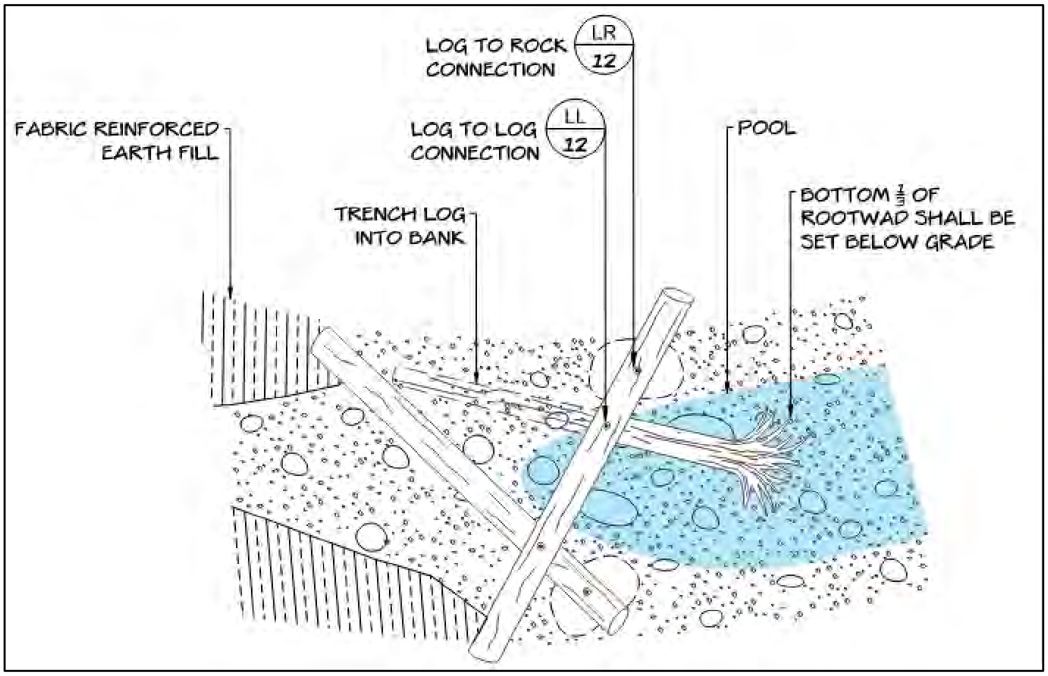

Figure 15. Log habitat structure design detail.

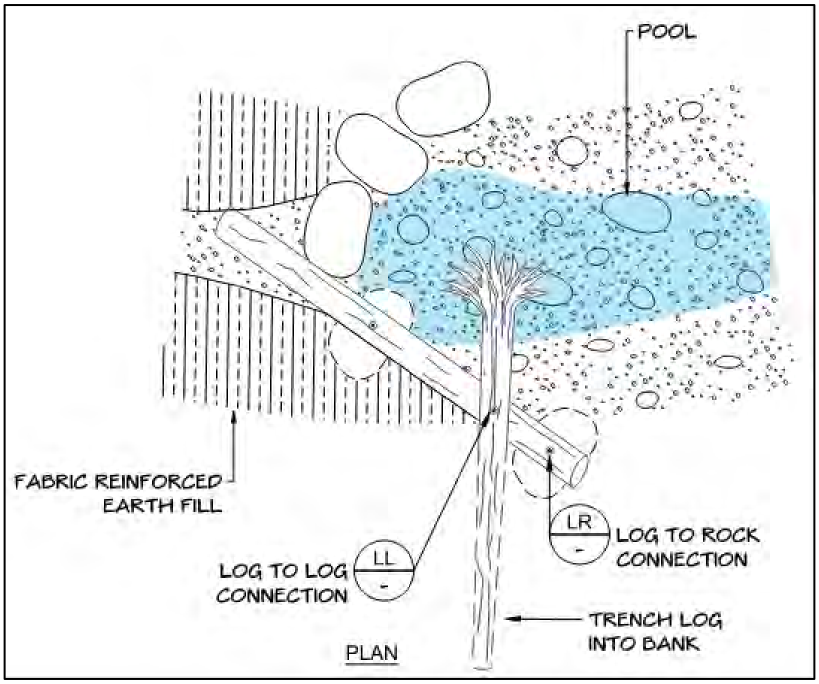

Figure 16. Boulder weir / log habitat structure design detail.

The two rock cascade reaches are designed to remain stable with little adjustment through the 100-year design discharge. Those reaches each have multiple pools: 10- to 11-foot-long pools located mid-reach and a larger approximately 16- to 22-foot-long pool for energy dissipation. The upstream end of each pool is formed with a rock weir that creates a small plunge into the pool. A fabric reinforced earth fill (FREF) will cover the edges of the rock along these two reaches to minimize the extent of exposed rock and to allow vegetation to become established along the channel margins. The rock cascade reach has a bankfull width and depth of 9 feet and 1 foot, respectively (Figure 17). The cascade reaches will support some hydraulic mixing to promote dissolved oxygen in the creek water.

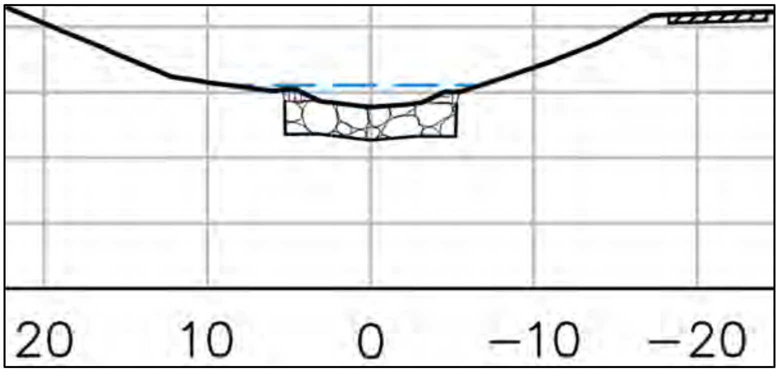

Figure 17. Section illustrating rock cascade reach at Station 8+41. Distances in feet; vertical blocks are 4 feet. Blue line indicates approximate maximum water surface elevation during a 100-year design flow.

Site Access, Outdoor Education Spaces, and Landscape Architecture

The project includes an accessible creekside trail over approximately 730 linear feet with a 6-foot width that also provides access for a school maintenance vehicle (gator). Parameters for trail design including width, grade, cross slope, and resting area intervals were developed from the U.S. Access Board accessibility standards for Federal outdoor developed areas (Table 2, Table 3). Accessible side trails provide access to Willow Creek points of interest, a creekside student assembly area, an overlook area, and an outdoor classroom. Two pedestrian bridges allow access to the west side of the creek and the student assembly area. Concrete bridge abutments and additional design details will be determined in the 95% design phase.

These outdoor education spaces will support student learning and connection to the natural environment of the stream and riparian zone. Seating in each of the spaces is provided on saw-cut logs, boulders, open lawn area, and in accessible seating stalls (Table 4). Salvaged logs from eucalyptus tree removal are proposed for log seating, providing beneficial reuse of this material and reduced project costs.

Table 2. Accessibility requirements met by trail design.

Design element	Target	Notes
Minimum width	3 Feet	
Maximum grade	12%	See Table 3
Maximum cross slope	2%	
Resting areas	5 feet	0% grade, max 2% cross slope

Table 3: Maximum segment length per longitudinal grade range. Flat resting benches of 5-feet in length are provided after any segment with grade greater than 5%.

Grade Range	Maximum Segment Length
5% to 8.33%	200 Feet
8.33% to 10%	30 Feet
10% to 12%	10 Feet

Table 4. Seating capacity of outdoor educational spaces.

	Seating Type			
Facility	Log / Boulder	Open Lawn	Accessible	TOTAL
Outdoor Classroom	38		2	40
Student Assembly Area	61	180	2	243
Overlook Area	22			22

The landscape architecture design goals are to support safe public engagement with the stream corridor, emphasize natural materials and design, and highlight the aesthetics of the landscape. Material selected for the trails, outdoor education spaces, and bridges reflect these goals. The trail surface material is stabilized aggregate (crushed stone), which provides a durable, low-maintenance, stable and accessible surface. Outdoor educational spaces include natural log and boulder seating and stabilized aggregate areas for teaching presentations and other gatherings. Recommended bridge materials are pressure treated Doug fir decking and weathering steel structure and railings.

Beneficial Reuse of Soil and Sediment

Approximately 8,900 cubic yards of soil and sediment will be excavated to construct the Willow Creek stream corridor and associated features. This material is expected to be dominantly native soil consisting of silty to sandy clay, sands, and fine gravels. To the extent feasible, that material will be reused on-site as fill to develop beneficial site features, including an area suitable for potential future classroom buildings and a hillslope that visually separates the stream corridor from the upper parking lot.

The future classroom building area was designed to accommodate approximately 10,000 square feet of buildable space for school buildings and access routes, located northwest of the stream corridor where school classrooms were previously. There is no immediate plan or timeline for constructing additional buildings on the Academy campus, thus the building pad area was designed with additional fill graded to create a natural hillslope aesthetic. This fill material could easily be removed at a future point when building construction on this site is needed. Technical specifications for the placement of fill at the building pad site will follow geotechnical guidance for compaction, maximum slopes, and any other necessary site considerations.

Additional on-site spoils placement along the upper reach of the daylighted creek corridor will allow development of a subtle, natural looking mound that will provide a visual barrier between the creek and school campus, including the upper parking lot. This topographic feature also addresses the atypical stream routing along the contour of the upper campus, creating a more natural “stream valley” feature through that reach.

Engineering Analysis

This section describes the general engineering design considerations related to Willow Creek watershed hydrology and hydraulics. Additional details are presented in the Appendices.

Stream Channel Hydrology

The Willow Creek watershed drains approximately 87 acres above US 101 and a total of 125 acres above the downstream end of the daylighted reach near Buchanan Drive. The watershed generates perennial flow during most, if not all, years. The measured baseflows described above (0.1 to 0.3 cfs) were considered in the design of the low-flow stream channel, with the goals of supporting baseflow habitat, water quality, and aesthetics. The low-flow channel is typically approximately 2 feet wide and 0.5 feet deep.

Storm event design discharges were estimated using the US Geological Survey (USGS) StreamStats tool, which uses a regression analysis of regional gauged streams and statistically significant site variables to estimate flood flows at ungauged stream sites (USGS 2018). High discharge channel design was based on hydraulic modeling of the 100-year return frequency discharge of 86 cfs as described below.

Peak design flows generated by StreamStats were scaled up slightly, as the manually delineated watershed is about two acres larger than the StreamStats watershed (Figure 3). The hydraulic model was designed to analyze potential detention upslope of US 101, which required parsing out the peak flows of the US 101 sub-watershed from the rest of the main watershed that will drain to the proposed creek. The StreamStats report is provided in Appendix A.

The hydraulic model (described below) uses a design storm hydrograph developed for the proposed (daylighted) condition in which flow from about 70% of the watershed will collect upslope of US 101 and be routed to the proposed creek through the existing 30-inch pipe, 20-foot-long daylighted reach, and adjusted 24-inch pipe. The remaining 30% of the watershed will drain directly to the creek via surface runoff. To model this condition in HEC-RAS, one boundary condition was placed in the detention area upslope of US 101, and one boundary condition was placed at the inlet of the daylighted creek. A 24-hour unit hydrograph was derived from a cumulative Type 1A storm distribution, assumed based on site location. Peak flow hydrographs for the boundary conditions (Figure 18) were then calculated from the unit hydrograph, based on the 100-year peak flows determined in Table 5. The 100-year, 24-hour storm was selected for design per Marin County Code 24.04.520 (c). The hydrograph analysis is presented in Appendix B.

Table 5: Peak design flow analysis summary. StreamStats flows were adjusted up to account for the larger manually delineated drainage area. Sub-watershed peak flows were then extrapolated from the adjusted StreamStats flows by area.

	Total Peak Flow (cfs)		Sub-watershed Peak Flow (cfs)	
Return Interval	StreamStats Estimated Flow	Adjusted Peak Flow	30-inch US 101 Storm Drain	Willow Creek Direct Drainage
Baseflow	-	-	-	0.1
2-YR	13	14	10	4
5-YR	29	30	21	9
10-YR	41	42	29	13
25-YR	58	59	41	18
50-YR	71	72	50	22
100-YR	85	86	60	26

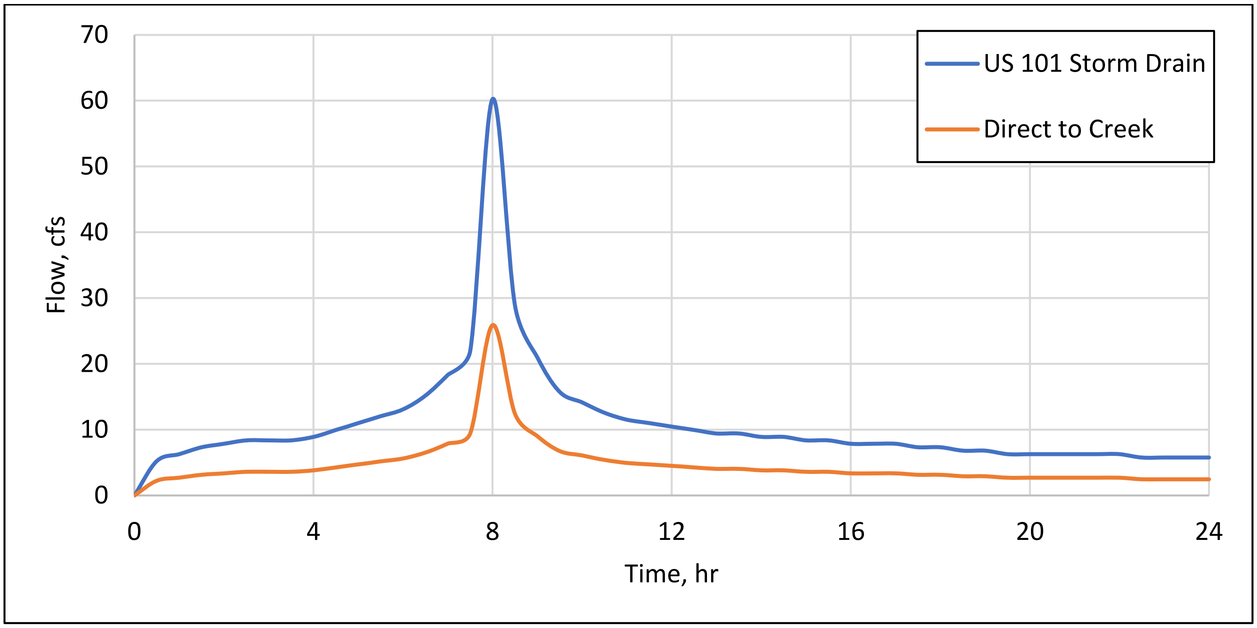

Figure 18: 100-year, 24-hour Type 1A storm hydrographs for the HEC-RAS model boundary conditions.

Stream Channel Hydraulics

The US Army Corps of Engineers HEC-RAS model was used to assess hydraulics within the design stream for base flow and the 100-year design discharge. Design considerations evaluated include addressing channel capacity (i.e., freeboard in channel, at bridges, and at culverts), bed and bank stability, and public safety.

HEC-RAS is a river modeling program created by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers capable of performing one-dimensional (1D) steady and 1D/2D unsteady flow hydraulics calculations (USACE, 2024). For this project, a 2D unsteady model was developed with a fully integrated pipe network upstream and downstream of the daylighted reach. Model inputs consist of terrain elevation data, surface roughness coefficients (Manning's n), hydrologic boundary conditions for flows entering and exiting the model, and geometric data to define the pipe network and model mesh.

Terrain and Roughness

The terrain elevation data used for the model was built from NOAA LiDAR existing elevation data, JK Architecture Engineering proposed elevations for the school, and PCI proposed elevations for the creek design (Figure 19). Surface roughness values were estimated for four distinct areas (Table 6).

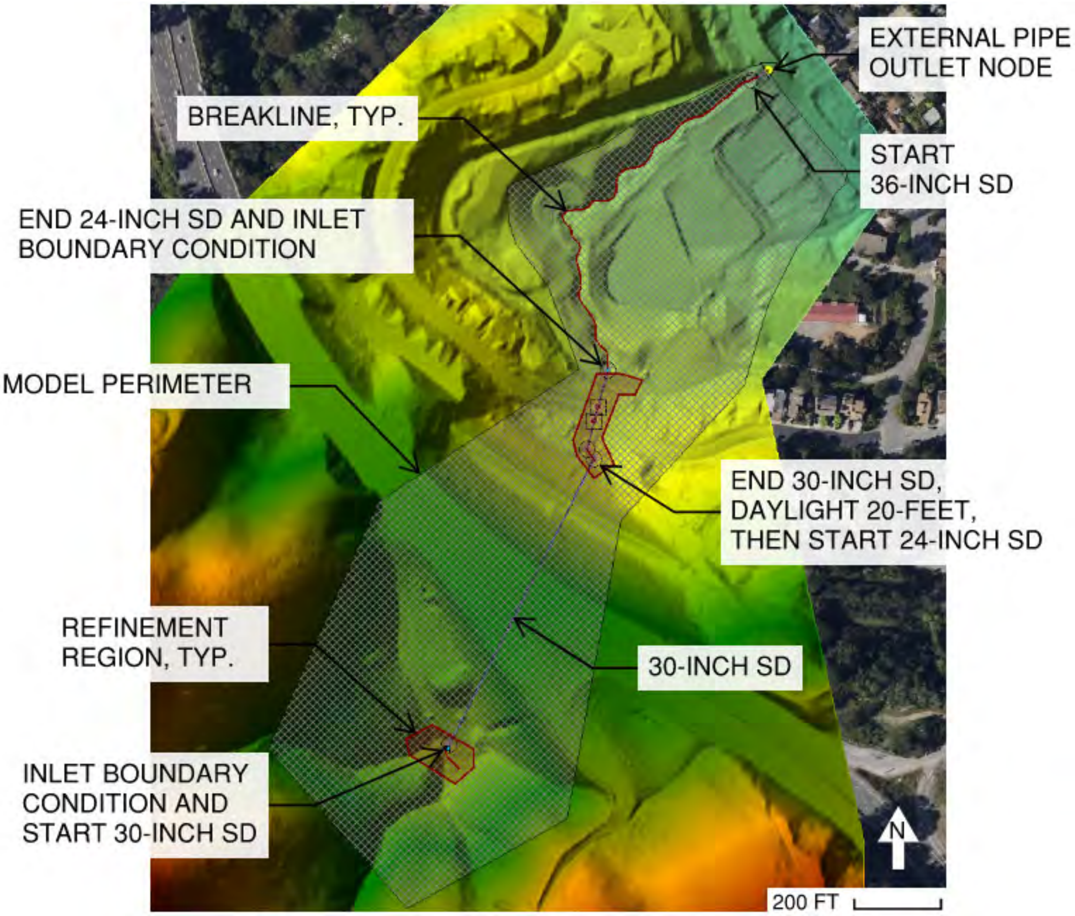

Figure 19. HEC-RAS model geometry for design conditions.

Table 6: Manning's roughness values for the HEC-RAS land cover layer.

Area	Manning’s Roughness, n
Channel Bottom	0.05
Floodplain	0.04
Riparian Zone	0.06
Pavement	0.016

Boundary Conditions

As described in the Hydrology section, the first boundary condition distributes flow to the model in the detention basin upslope of 101. The second boundary condition distributes flow directly to the creek to represent the portion of flow not captured in the detention basin that runs off directly to the creek.

Pipe Network

Two-dimensional pipe networks in HEC-RAS are defined by nodes and conduits. For this model, nodes include upstream and downstream culvert openings, junctions to represent drop inlets, and an external node for the outfall of the system. HEC-RAS inputs and model runtime parameters are presented in further detail in Appendix C.

HEC-RAS Results

Modeling of typical low flow (“baseflow”) discharge of 0.1 to 0.3 cfs indicates expected low-flow water depths of 0.1- to 0.3 feet along riffles, with 2.3 feet maximum pool depths and velocities of 0.1 to 2.6 fps (Figure 20*)*.

Hydraulic modeling of the 100-year flow event indicate that water depths range up to 1.5 to 2 feet in the majority of stream sections, with a maximum depth of 4.3 feet in certain pools and 5.5 feet at the downstream culvert pool (Figure 21). Velocity head ranges from 0.003 to 2.4 feet, which was used to determine required freeboard as described in the Freeboard Requirements section. Modeled flow velocity during the 100-year event is typically 3 to 6 fps throughout the project reach, with a maximum of 13 fps in the steep rock cascade reach (Figure 21). Rock sizing to accommodate those velocities and related shear stresses to maintain channel stability is discussed below.

HEC-RAS model results were used for various parameters for rock sizing and the log ballast, as well as to ensure minimum freeboard per Marin County Code for the channel, bridge locations, and culverts.

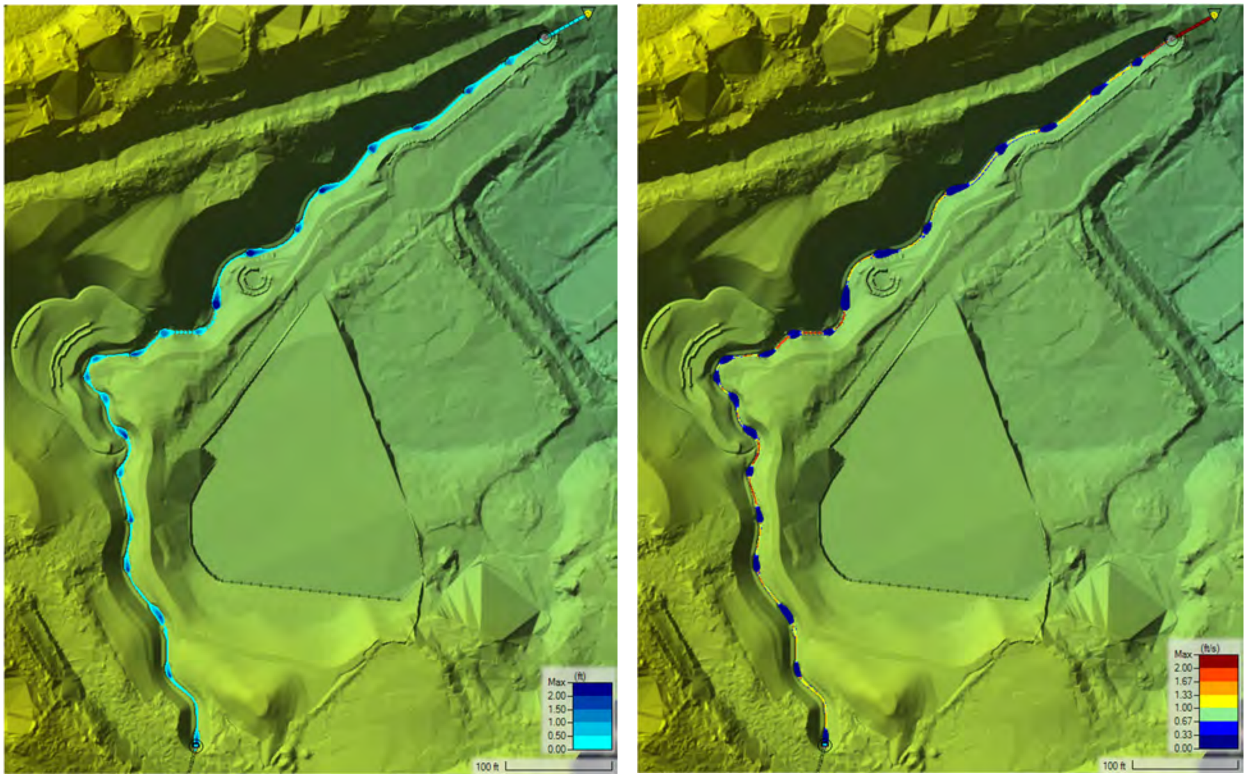

Figure 20: Depth (left) and velocity (right) at 0.3 cfs.

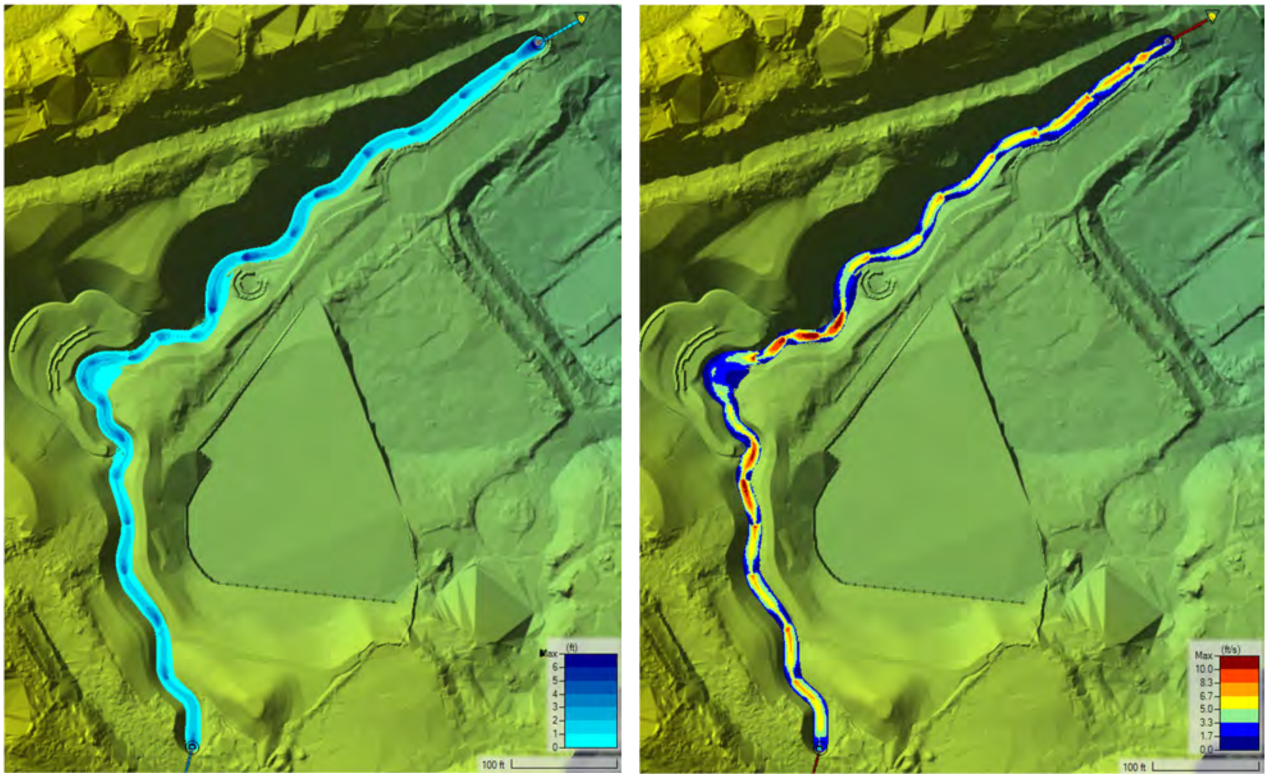

Figure 21: 100-year, 24-hour peak depth (left) and velocity (right). Upstream pipe network results are presented in Appendix C.

Culvert Hydraulic Analysis

HEC-RAS results indicate that the 36-inch storm drain that receives inflow from the daylighting project reach would convey the peak 100-yr storm discharge (73 cfs at this location) with 2.7 feet of surcharge (Figure 22). The culvert has capacity for approximately 30 cfs before first becoming surcharged. All flood water during the 100-year design discharge is predicted to be contained within the graded creek corridor with 2-feet of freeboard at the culvert outlet. Safety railing along this reach is included in the design.

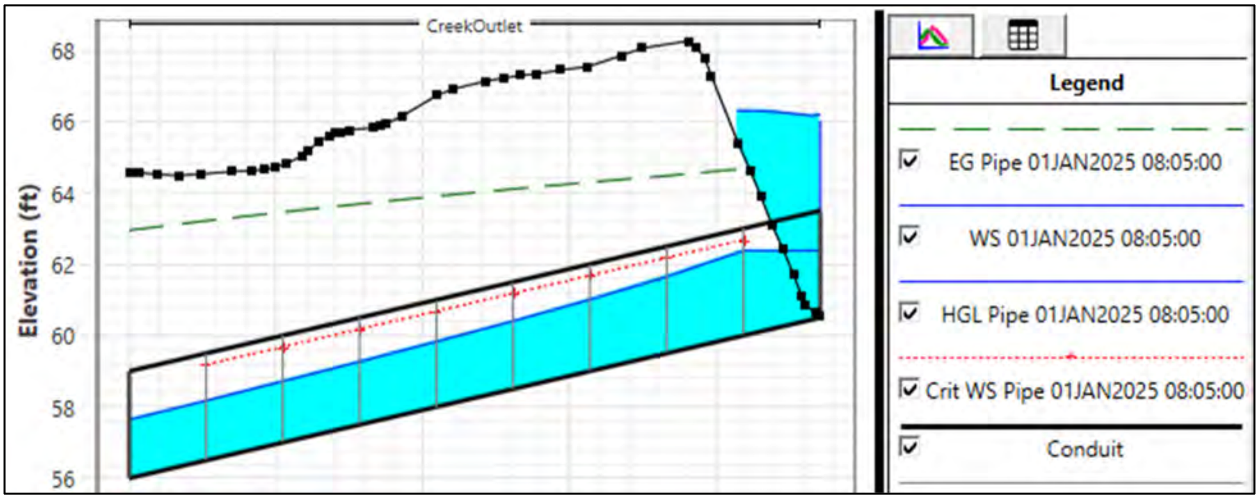

Figure 22: 100-year, 24-hour peak results at the proposed creek outlet.

Rock Sizing

Because the project is located in a well-developed urban area, the channel bed and banks were designed to remain stable under flows up to and including the 100-year event.

Engineered Streambed Material

Engineered Streambed Material (ESM) equations were used to size channel rock in the pools, steep rock chutes, and rock weirs. These equations were initially developed by the Army Corps of Engineers and later modified as described in the California Salmonid Stream Habitat Restoration Manual (Flosi, et al. 2010).The ESM equations provide a gradation for stream channel bed material from the D8 through the D100, with the D84 and above being the framework rock that is meant to remain stable through the 100-year, 24-hour design storm. See Table 7 for ESM distributions within the design channel and Appendix D for ESM calculations.

Table 7. ESM gradation results for each slope within the designed creek (minimum design guidance for rock mixes).

	Slope								
ESM size class	3.0%	12.7%	1.5%	12.5%	13.6%	18.3%	2.0%	4.0%	17.2%
D8-ESM (ft)	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066
D16-ESM (ft)	0.030	0.040	0.026	0.040	0.041	0.043	0.027	0.031	0.043
D50-ESM (ft)	0.35	0.78	0.24	0.77	0.81	0.96	0.28	0.41	0.92
D84-ESM (ft)	0.88	1.95	0.60	1.93	2.03	2.39	0.70	1.03	2.31
D100-ESM (ft)	2.19	4.88	1.49	4.84	5.07	5.98	1.75	2.57	5.77

The channel bed at riffles and pools is composed of a partially-stabilized mix of gravels and cobbles, with boulders included in riffles to provide hard points and geomorphic diversity (Table 8). An incipient motion analysis was performed to check the stability of the streambed riffle and pool mixes at the 100-year flow and is attached in Appendix E. Rock weirs will contain 1-ton boulders, which have a median diameter (D50) of 2.5 feet, which falls above the stable D84 for all slopes within the reach per Table 7. Rock cascade reaches have steeper gradients and will have an engineered streambed with material sizes ranging from sand up through 2-ton boulders as presented in Table 9.

Table 8. Stream channel bed material in riffles and pools

	Channel bed material				
Feature	Thickness	River run gravel	3- to 6-inch cobble	9- to 14-inch cobble	Boulders
Riffles	1.3 ft	30%	30%	40%	Scattered as hard points throughout
Pools	0.8 ft	70%	15%	15%	

Table 9. Rock Chute gradation based on ESM results for 18.3% sloped reach.

Rock Type	Median Diameter (ft)	Percent in Mix (%)
Class 2 Perm	0.0625	20
River Run	0.32	20
CALTRANS Class III, 150 lb	1.0	10
CALTRANS Class V, ¼ lb	1.5	15
CALTRANS Class VIII, 1 ton	2.5	20
CALTRANS Class IX, 2 ton	3.0	15

Rock Slope Protection

Rock Slope Protection (RSP) at both culvert locations was sized using equations recommended by Caltrans for stone revetments (Caltrans, 2022). The RSP equations provide a minimum D50, which was used to determine a recommended D84 size class. The resulting D50s corresponded to 60-pound and ¼-ton (Table 10). The recommended D84 for both locations is CALTRANS Class VIII, 1-ton rock. The RSP analysis is presented in Appendix F.

Table 10: RSP sizing results. Minimum RSP size class selected as size class above calculated D50 (Caltrans 2022).

Parameter	Stream Entrance	Stream Exit
D50, RSP equations (in)	5.2	16.5
Minimum RSP Size Class	II	V
Minimum Nominal Median Rock Diameter (in)	9	18
Minimum Nominal Median Rock Weight	60 lbs	1/4 ton

Log Stability and Ballast

To ensure stability of the log grade control structures, a vertical force balance analysis was conducted following the methods outlined in Chapter 7 of the Large Wood National Manual (USBR and ERDC 2016). Uplift forces used for calculation include buoyancy and lift. Resistance forces include structure weight and soil ballast weight as applicable per structure type. The calculated number of 2-ton boulder anchors per log structure provide a minimum factor of safety of 2.0. The log ballast calculations are presented in Appendix G.

Freeboard Requirements

The proposed creek and bridges were designed in accordance with Marin County Code 24.04.520 (d):

> *Open channel systems shall be designed to carry the one-hundred-year flow with a minimum freeboard equal to the velocity head. Bridges and utility crossings which span open channel waterways shall have a minimum clearance of two feet between soffit and the one-hundred-year flow elevation.*

The upstream and downstream proposed culverts were designed to maintain two feet of freeboard from the 100-year inlet headwater elevation, per Marin County Code 24.04.520 (c); however, it was impractical to pass 70-percent of the 100-year flow given the existing storm drain infrastructure.

The proposed channel maintains the required freeboard of the 100-year water surface elevation plus velocity head throughout the reach except for a 20-foot section from stations 10+91 to 11+11 (Figure 23). Grading will be adjusted in the next design phase to raise the adjacent high ground 0.1- 0.2 feet to meet freeboard requirements.

The bridges currently have 3.0- and 2.7-feet of freeboard from the 100-year WSE to the foot deck. Once the bridge design is finalized, the creek design will be adjusted as needed to meet the minimum two-foot freeboard from 100-year water surface elevation to bridge soffit.

The above freeboard checks are summarized in Figure 23. In addition to superimposed profiles of adjacent high ground to the creek (primarily the Willow Creek Trail), ground surface elevations from the Lower Assembly Seating Access Path and Outdoor Classroom Outer Trail are also provided in Figure 23. The trails for both gathering areas are above the 100-year water surface elevation plus velocity head.

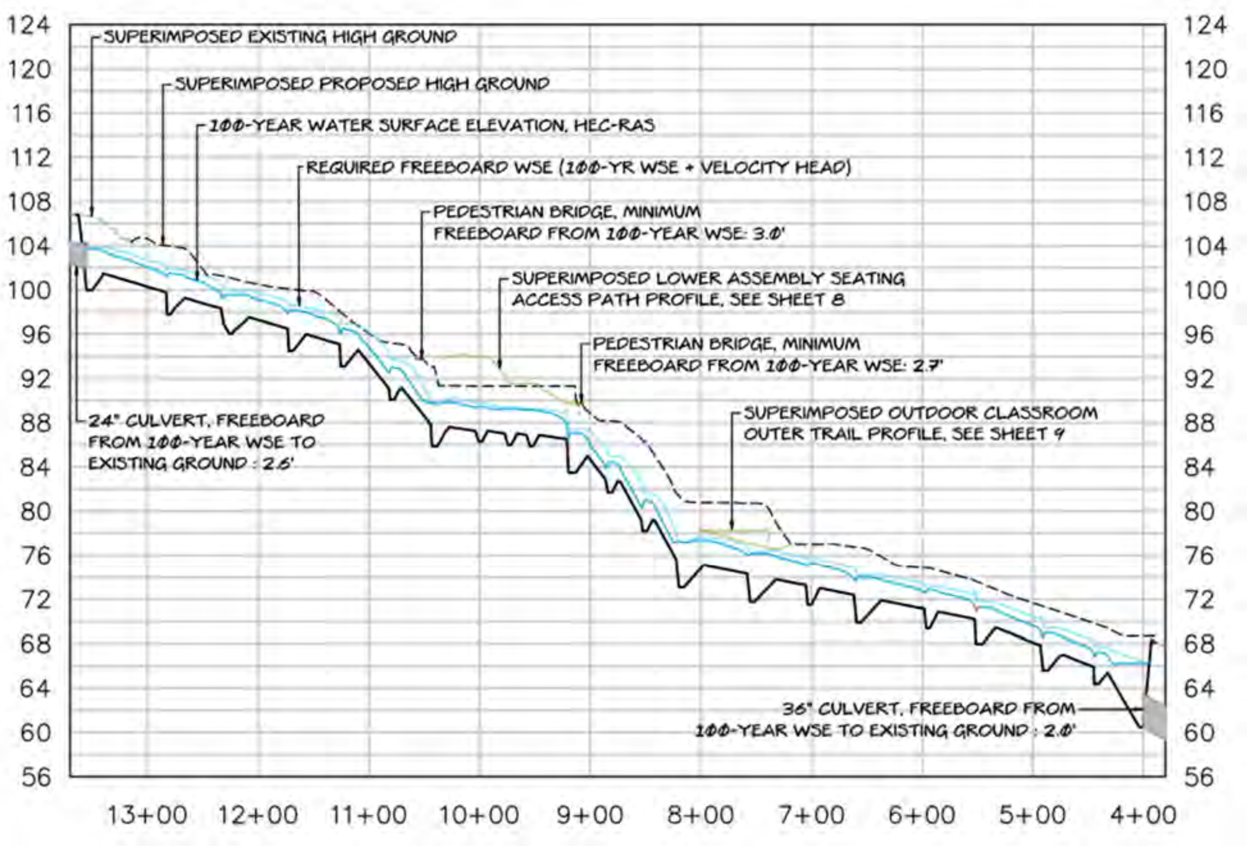

Figure 23: Freeboard check summary including culvert, channel, bridge, assembly area, and outdoor classroom.

Overlook Trail Swale

A swale was designed along the outer edge of the Overlook Trail to convey upslope runoff to the proposed creek and protect the Overlook Trail and Assembly Area from erosion. The swale was designed to convey the 10-year peak flow from the upslope sub-watershed with 2 to 1 side slopes, 1-foot bottom width, and 0.5-foot depth. Swale sizing calculations are documented in Appendix H.

Structures

Structural engineering design for the proposed project is limited to two elements: abutments for the two pedestrian bridges and a new concrete curb along the existing cul-de-sac off of Buchanan Drive

Pedestrian Bridges

Two pedestrian bridges are designed as pre-fabricated steel bridges that will be placed on poured-in-place concrete abutments, which are scheduled to be designed in the 95% plans. All abutments will be designed by a licensed structural engineer working with the bridge manufacturer.

Concrete Curb

A new, low concrete curb ranging in height above the existing ground surface from 0.5 to 1.9 feet is needed along the edge of the sidewalk on the north side of the cul-de-sac off Buchanan drive to meet freeboard requirements for the 100-year design water surface elevation plus velocity head. That curbing will be designed by a licensed civil engineer using a cantilevered retaining wall analysis to resist overturning, sliding and settling. A pedestrian handrail is designed to be bolted on to the curb.

Operations and Maintenance Considerations

Standard post-construction monitoring includes two years of annual inspections to assess channel stability and the establishment of native vegetation plantings. Inspections by a qualified hydrologist or engineer would identify any need for maintenance or adaptive management. It is recommended that the Sausalito Marin City School District conduct additional stability inspections after any major flow events, at a minimum to check for debris blockage (e.g. downed trees or large branches). A complete monitoring plan will be developed to support resource agency permit applications.

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Leopold, 1994. A view of the river. Harvard Press, Cambridge, Massachusetts.

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PCI Ecological. 2026. Biological Resources Evaluation, Willow Creek Daylighting Project, Sausalito, CA. Unpublished Report.

Rice, SJ and TC Smith. 1976. Geology of the Tiburon Peninsula, Sausalito, and Adjacent Areas, Marin County, California, Department of Conservation, California Division of Mines and Geology (California Geological Survey), Scale 1:12,000.

U.S. Army Corps of Engineers (USACE). 2024.

U.S. Bureau of Reclamation (USBR) and U.S. Army Engineer Research and Development Center (ERDC). 2016. *National Large Wood Manual: Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Ecosystems: Restoring Process, Function, and Structure*. National Large Wood Manual - Engineering With Nature.

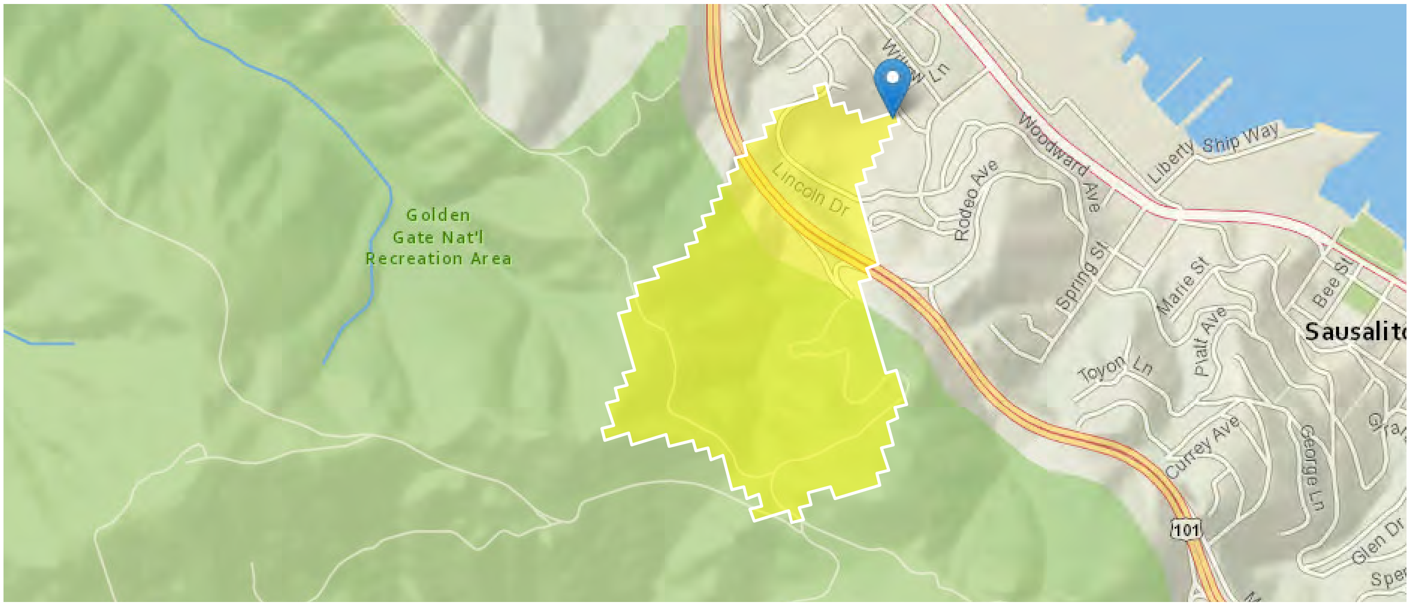
U.S. Geological Survey. 2019. The StreamStats program, online at https://streamstats.usgs.gov/ss/, accessed on February 18, 2025.

Appendix A. USGS StreamStats Report.

APPENDIX A

StreamStats Report

Region ID: CA
Workspace ID: CA20250218172130043000
Clicked Point (Latitude, Longitude): 37.86405, -122.50198
NHD Stream GNIS Name of Click Point: Stream name not found
Time: 2025-02-18 09:22:05 -0800



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
BASINPERIM	Basin perimeter measured along entire drainage-basin divide	2.57	miles
BSLDEM30M	Mean basin slope computed from 30 m DEM	32	percent
CENTROXA83	X coordinate of the centroid, in NAD_1983_Albers, meters	-2280041	meters
CENTROYA83	Basin centroid horizontal (y) location in NAD 1983 Albers	1967109.2	meters
DRNAREA	Area that drains to a point on a stream	0.2	square miles
EL6000	Percent of area above 6000 ft	0	percent
ELEV	Mean Basin Elevation	439	feet
ELEVMAX	Maximum basin elevation	894	feet
FOREST	Percentage of area covered by forest	31.5	percent
JANMAXTMP	Mean Maximum January Temperature	56	degrees F
JANMINTMP	Mean Minimum January Temperature	42.52	degrees F
LAKEAREA	Percentage of Lakes and Ponds	0	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	39.3	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	8.8	percent
LFPLENGTH	Length of longest flow path	1	miles

Parameter Code	Parameter Description	Value	Unit
MINBELEV	Minimum basin elevation	35	feet
OUTLETELEV	Elevation of the stream outlet in feet above NAVD88	35	feet
PRECIP	Mean Annual Precipitation	33.6	inches
RELIEF	Maximum - minimum elevation	859	feet
RELRELF	Basin relief divided by basin perimeter	334	feet per mi

Peak-Flow Statistics

Peak-Flow Statistics Parameters [2012 5113 Region 1 North Coast]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.2	square miles	0.04	3200
PRECIP	Mean Annual Precipitation	33.6	inches	20	125

Peak-Flow Statistics Flow Report [2012 5113 Region 1 North Coast]

PIL: Lower 90% Prediction Interval, PIU: Upper 90% Prediction Interval, ASEp: Average Standard Error of Prediction, SE: Standard Error, PC: Percent Correct, RMSE: Root Mean Squared Error, PseudoR^2: Pseudo R Squared (other -- see report)

Statistic	Value	Unit	PIL	PIU	ASEp
50-percent AEP flood	13.4	ft^3/s	5.36	33.5	58.6
20-percent AEP flood	29.3	ft^3/s	13.7	62.7	47.4
10-percent AEP flood	41.4	ft^3/s	20.1	85.5	44.2
4-percent AEP flood	57.9	ft^3/s	28.8	116	42.7
2-percent AEP flood	70.9	ft^3/s	35.2	143	42.7
1-percent AEP flood	84.9	ft^3/s	41.1	176	44.3
0.5-percent AEP flood	98.3	ft^3/s	47.3	204	44.4
0.2-percent AEP flood	116	ft^3/s	54.4	247	46

Peak-Flow Statistics Citations

Gotvald, A.J., Barth, N.A., Veilleux, A.G., and Parrett, Charles,2012, Methods for determining magnitude and frequency of floods in California, based on data through water year 2006: U.S. Geological Survey Scientific Investigations Report 2012–5113, 38 p., 1 pl. (http://pubs.usgs.gov/sir/2012/5113/)

Bankfull Statistics

Bankfull Statistics Parameters [Pacific Mountain System D Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.2	square miles	6.1776	8079.9147

Bankfull Statistics Parameters [Pacific Border P Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.2	square miles	6.169878	3938.976756

Bankfull Statistics Parameters [USA Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.2	square miles	0.07722	59927.7393

Bankfull Statistics Disclaimers [Pacific Mountain System D Bieger 2015]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors.

Bankfull Statistics Flow Report [Pacific Mountain System D Bieger 2015]

Statistic	Value	Unit
Bieger_D_channel_width	6.97	ft
Bieger_D_channel_depth	0.622	ft
Bieger_D_channel_cross_sectional_area	6.1	ft^2

Bankfull Statistics Disclaimers [Pacific Border P Bieger 2015]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors.

Bankfull Statistics Flow Report [Pacific Border P Bieger 2015]

Statistic	Value	Unit
Bieger_P_channel_width	5.4	ft
Bieger_P_channel_cross_sectional_area	4.79	ft^2
Bieger_P_channel_depth	0.555	ft

Bankfull Statistics Flow Report [USA Bieger 2015]

Statistic	Value	Unit
Bieger_USA_channel_width	7.03	ft
Bieger_USA_channel_depth	0.856	ft
Bieger_USA_channel_cross_sectional_area	7.17	ft^2

Bankfull Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
Bieger_D_channel_width	6.97	ft
Bieger_D_channel_depth	0.622	ft
Bieger_D_channel_cross_sectional_area	6.1	ft^2
Bieger_P_channel_width	5.4	ft
Bieger_P_channel_cross_sectional_area	4.79	ft^2
Bieger_P_channel_depth	0.555	ft
Bieger_USA_channel_width	7.03	ft
Bieger_USA_channel_depth	0.856	ft
Bieger_USA_channel_cross_sectional_area	7.17	ft^2

Bankfull Statistics Citations

Bieger, Katrin; Rathjens, Hendrik; Allen, Peter M.; and Arnold, Jeffrey G.,2015, Development and Evaluation of Bankfull Hydraulic Geometry Relationships for the Physiographic Regions of the United States, Publications from USDA-ARS / UNL Faculty, 17p. (https://digitalcommons.unl.edu/usdaarsfacpub/1515?utm_source=digitalcommons.unl.edu%2Fusdaarsfacpub%2F1515&utm_medium=PDF&utm_campaign=PDFCoverPages)

NHD Features of Delineated Basin

NHD Streams Intersecting Basin Delineation Boundary

This functionality attempts to find the stream name at the delineation point. The name of the nearest intersecting National Hydrography Dataset (NHD) stream is selected by default to appear in the report above. NHD streams do not correspond to the StreamStats stream grid and may not be accurate. If you would like a different stream to appear in the above section, please make a selection below.

No NHD streams intersect the delineated basin.

Watershed Boundary Dataset (WBD) HUC 8 Intersecting Basin Delineation Boundary

This functionality attempts to find the intersecting HUC 8 of the delineated watershed. HUC boundaries do not correspond to the StreamStats data and may not be accurate.

HUC 8	Name
18050005	Tomales-Drake Bays
18050002	San Pablo Bay

NHD Hydrologic Features Citations

U.S. Geological Survey, 2022, USGS TNM - National Hydrography Dataset, accessed July 21, 2022 at URL https://hydro.nationalmap.gov/arcgis/rest/services/nhd/MapServer/6. (https://hydro.nationalmap.gov/arcgis/rest/services/nhd/MapServer/6) U.S. Geological Survey, 2022, USGS TNM - National Hydrography Dataset, accessed July 21, 2022 at URL https://hydro.nationalmap.gov/arcgis/rest/services/wbd/MapServer/4. (https://hydro.nationalmap.gov/arcgis/rest/services/wbd/MapServer/4)

Application Version: 4.27.0
StreamStats Services Version: 1.2.22
NSS Services Version: 2.2.1

Appendix B. Hydrographs Developed for Hydraulic Modeling.

FC
11/21/2025

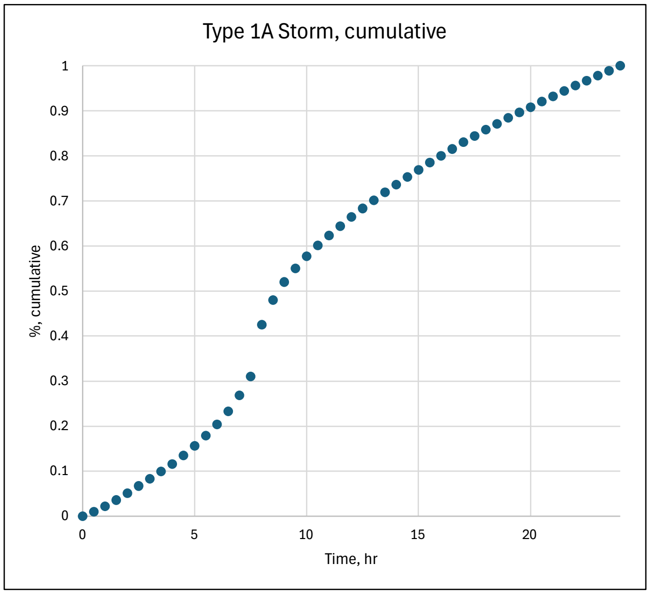
Input	Intermediate	Results

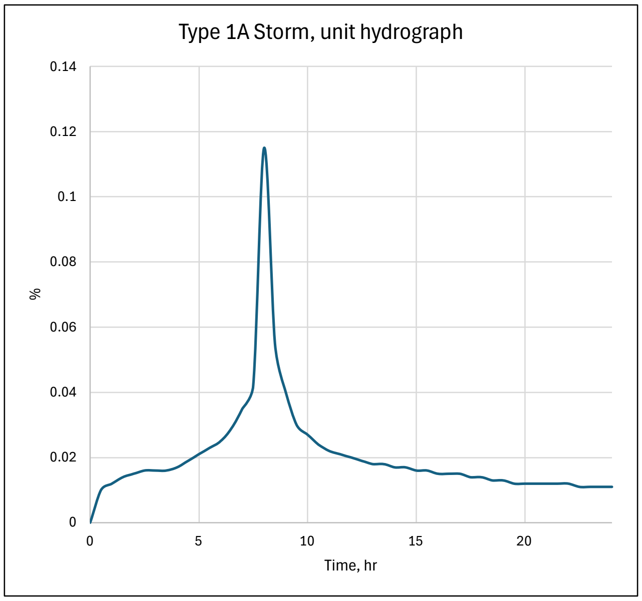
Approach

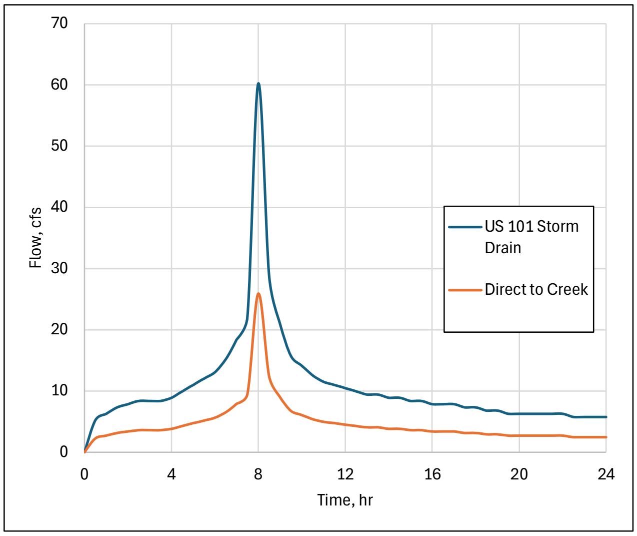
Peak flow rates for the HECRAS model have been derived from StreamStats and split up by watershed area for the inlet boundary condition to the 101 culvert (watershed 1) and the inlet boundary condition to the proposed creek (watersheds 2). The Type 1A storm distribution (HydroCAD Software Solutions LLC, 2025) was converted to a unit hydrograph for a 24-hour storm assuming no lag. Approximate 100-year storm hydrographs for the 101 pipe inlet and creek inlet were then derived from the Type 1A unit hydrograph.

100-year peak flow		
Watershed 1	60	cfs
Watershed 2	26	cfs
100-year flow volume to distribute		
Watershed 1	524	cfs
Watershed 2	225	cfs

time	%, cumulative	%	Watershed 1	Watersheds 2
			cfs	cfs
0	0	0	0	0
0.5	0.01	0.01	5.24	2.25
1	0.022	0.012	6.29	2.70
1.5	0.036	0.014	7.34	3.15
2	0.051	0.015	7.86	3.38
2.5	0.067	0.016	8.38	3.60
3	0.083	0.016	8.38	3.60
3.5	0.099	0.016	8.38	3.60
4	0.116	0.017	8.91	3.83
4.5	0.135	0.019	9.95	4.28
5	0.156	0.021	11.00	4.73
5.5	0.179	0.023	12.05	5.18
6	0.204	0.025	13.10	5.63
6.5	0.233	0.029	15.19	6.53
7	0.268	0.035	18.34	7.88
7.5	0.31	0.042	22.01	9.46
8	**0.425**	**0.115**	**60.25**	**25.89**
8.5	0.48	0.055	28.82	12.38
9	0.52	0.04	20.96	9.01
9.5	0.55	0.03	15.72	6.75
10	0.577	0.027	14.15	6.08
10.5	0.601	0.024	12.57	5.40
11	0.623	0.022	11.53	4.95
11.5	0.644	0.021	11.00	4.73
12	0.664	0.02	10.48	4.50
12.5	0.683	0.019	9.95	4.28
13	0.701	0.018	9.43	4.05
13.5	0.719	0.018	9.43	4.05
14	0.736	0.017	8.91	3.83
14.5	0.753	0.017	8.91	3.83
15	0.769	0.016	8.38	3.60
15.5	0.785	0.016	8.38	3.60
16	0.8	0.015	7.86	3.38
16.5	0.815	0.015	7.86	3.38
17	0.83	0.015	7.86	3.38
17.5	0.844	0.014	7.34	3.15
18	0.858	0.014	7.34	3.15
18.5	0.871	0.013	6.81	2.93
19	0.884	0.013	6.81	2.93
19.5	0.896	0.012	6.29	2.70
20	0.908	0.012	6.29	2.70
20.5	0.92	0.012	6.29	2.70
21	0.932	0.012	6.29	2.70
21.5	0.944	0.012	6.29	2.70
22	0.956	0.012	6.29	2.70
22.5	0.967	0.011	5.76	2.48
23	0.978	0.011	5.76	2.48
23.5	0.989	0.011	5.76	2.48
24	1	0.011	5.76	2.48







Appendix C. HEC-RAS Model.

Appendix C: HEC-RAS Documentation

Modeler: Fiona Connor, P.E.
Model Version: HEC-RAS 6.7 Beta 5

Terrain

The terrain was built in Civil 3D using existing elevations from 2018-2019 bare-earth LiDAR data from USGS Northern California Wildfires mapping, proposed school campus elevations from JK Architecture Engineering, and proposed elevations from the Willow Creek Daylight Project plans, 65% Submittal, PCI Ecological. The terrain was exported as a DEM and projected in ArcGIS Pro for HEC-RAS import.

Horizontal datum: NAD83 California State Plane (Zone 3)

Vertical datum: NAVD 1988

Geometry

The model geometry is presented in Figure 1. Mesh sizing per the model perimeter, refinement regions, and breaklines are given in Table 1 and Table 2. Pipe network parameters for nodes and conduits are shown in Table 3 and Table 4.

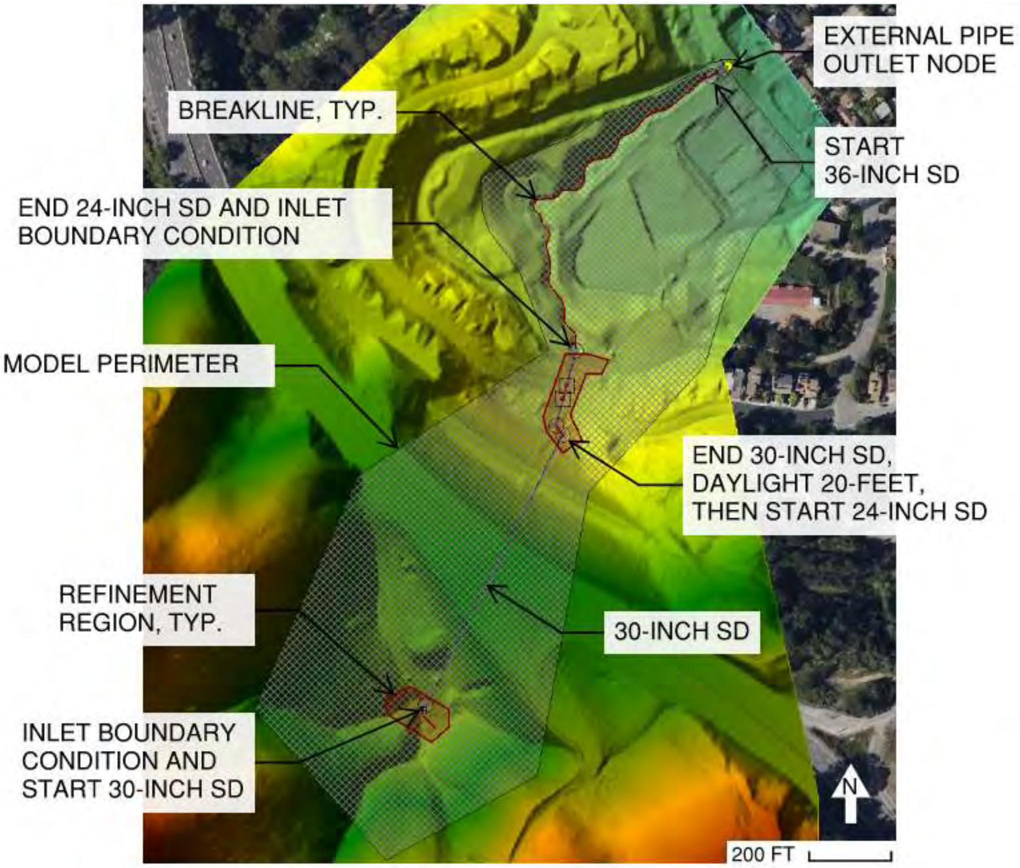


Figure 1: HEC-RAS model geometry.

Table 1: Mesh sizing information for perimeter and refinement regions. Cells are 1 foot.

Mesh Area	Mesh Size
Perimeter	10x10
Refinement Regions	3x3

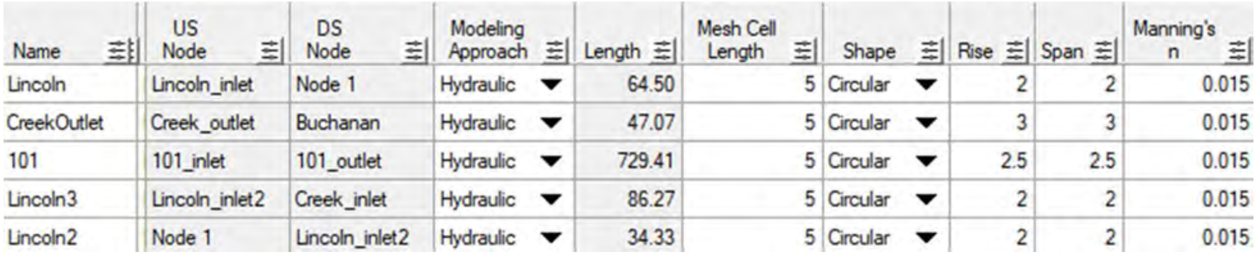
Table 2: Breakline parameters.

Breakline	Near Spacing	Near Repeats	Far Spacing
Centerline	1	12	8
Daylight	1	6	3
Detention	3	6	3

Table 3: Pipe network node input parameters. Terrain modifications were used in conjunction with terrain overrides for proper culvert opening and junction functioning.

Name	Node Type	Node Status	Conduit Connections (US:DS)	Invert Elevation	Base Area	Top Inlet Type	Drop Inlet Elevation	Drop Inlet Weir	Drop Inlet Orifice Area	Drop Inlet Orifice
Creek_inlet	Culvert Opening	DS Culvert opening	1:0	101.5	0			3		0.67
Lincoln_inlet	Culvert Opening	US Culvert opening	0:1	114.3	0			3		0.67
101_outlet	Culvert Opening	DS Culvert opening	1:0	122.42	0			3		0.67
101_inlet	Culvert Opening	US Culvert opening	0:1	202.5	0			3		0.67
Creek_outlet	Culvert Opening	US Culvert opening	0:1	60.5	0			3		0.67
Buchanan	External	Outfall of system	1:0	56	0			3		0.67
Lincoln_inlet3	Junction	Junction -with top...	1:1	107.3	5	Grate-Curb-Inlet-	114		5	
Lincoln_inlet2	Junction	Junction -with top...	1:1	111.2	5	Grate-Curb-Inlet-	114		5	

Table 4: Pipe network conduit input parameters. Default loss coefficients used.



Name	US Node	DS Node	Modeling Approach	Length	Mesh Cell Length	Shape	Rise	Span	Manning's n
Lincoln	Lincoln_inlet	Node 1	Hydraulic	64.50	5	Circular	2	2	0.015
CreekOutlet	Creek_outlet	Buchanan	Hydraulic	47.07	5	Circular	3	3	0.015
101	101_inlet	101_outlet	Hydraulic	729.41	5	Circular	2.5	2.5	0.015
Lincoln3	Lincoln_inlet2	Creek_inlet	Hydraulic	86.27	5	Circular	2	2	0.015
Lincoln2	Node 1	Lincoln_inlet2	Hydraulic	34.33	5	Circular	2	2	0.015

Land Cover

Surface roughness values were estimated for four distinct areas, listed in Table 5.

Table 5: Manning's roughness values for the HEC-RAS land cover layer.

Area	Manning's Roughness, n
Channel Bottom	0.05
Floodplain	0.04
Riparian Zone	0.06
Pavement	0.016

Unsteady Flow Data

Internal Boundary Conditions

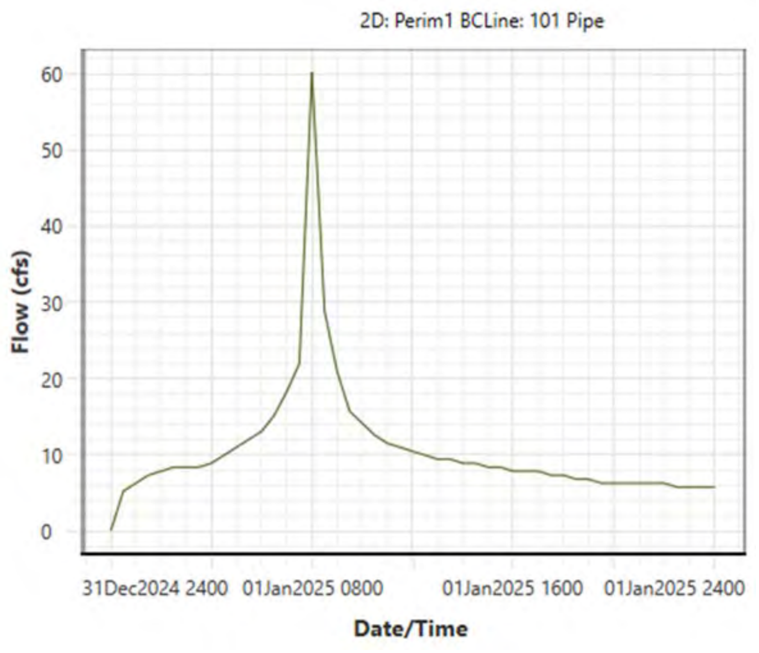


Figure 2: 100-yr, 24-hour hydrograph at the top of watershed detention that flows into the 30-inch pipe below US 101. EG Slope for distributing flow along BC Line = 0.33.

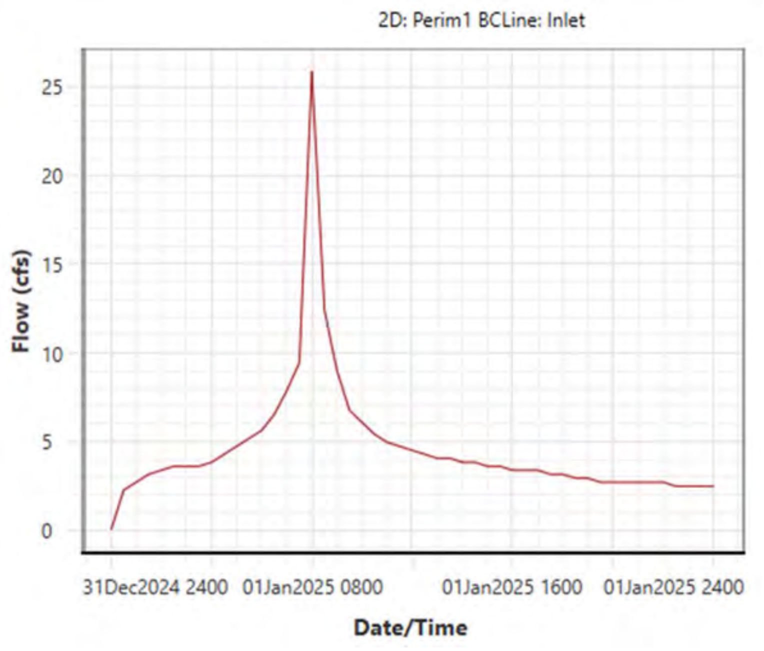


Figure 3: 100-year, 24-hour hydrograph at the creek inlet. Represents all additional flow that will drain to creek beyond the US 101 Pipe watershed. EG Slope for distributing flow along BC Line = 0.0325.

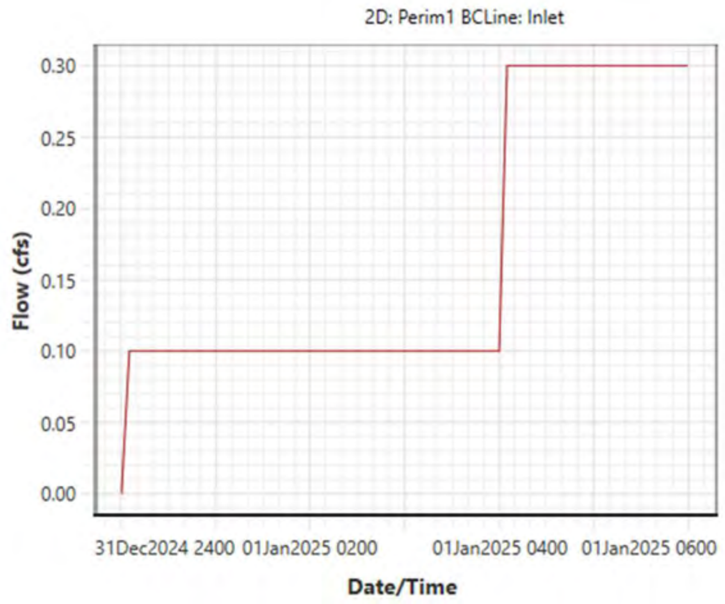


Figure 4: Baseflow hydrograph at the creek inlet benched at 0.1 cfs and 0.3 cfs. EG Slope for distributing flow along BC Line = 0.0325.

External Boundary Condition

Pipe node at Buchanan, Normal Depth: Friction Slope = 0.1

Run-time Parameters

Model type: 2-Dimensional Unsteady Flow

Parameters switched from Default

2D Flow Option Equation Set: SWE-ELM (original/faster)

Pipe Systems Equation Set: SWE-ELM (original/faster) + Compute Every 2D Iteration

Advanced Time Step Control: Adjust Time Step Based on Courant

Results

Baseflow

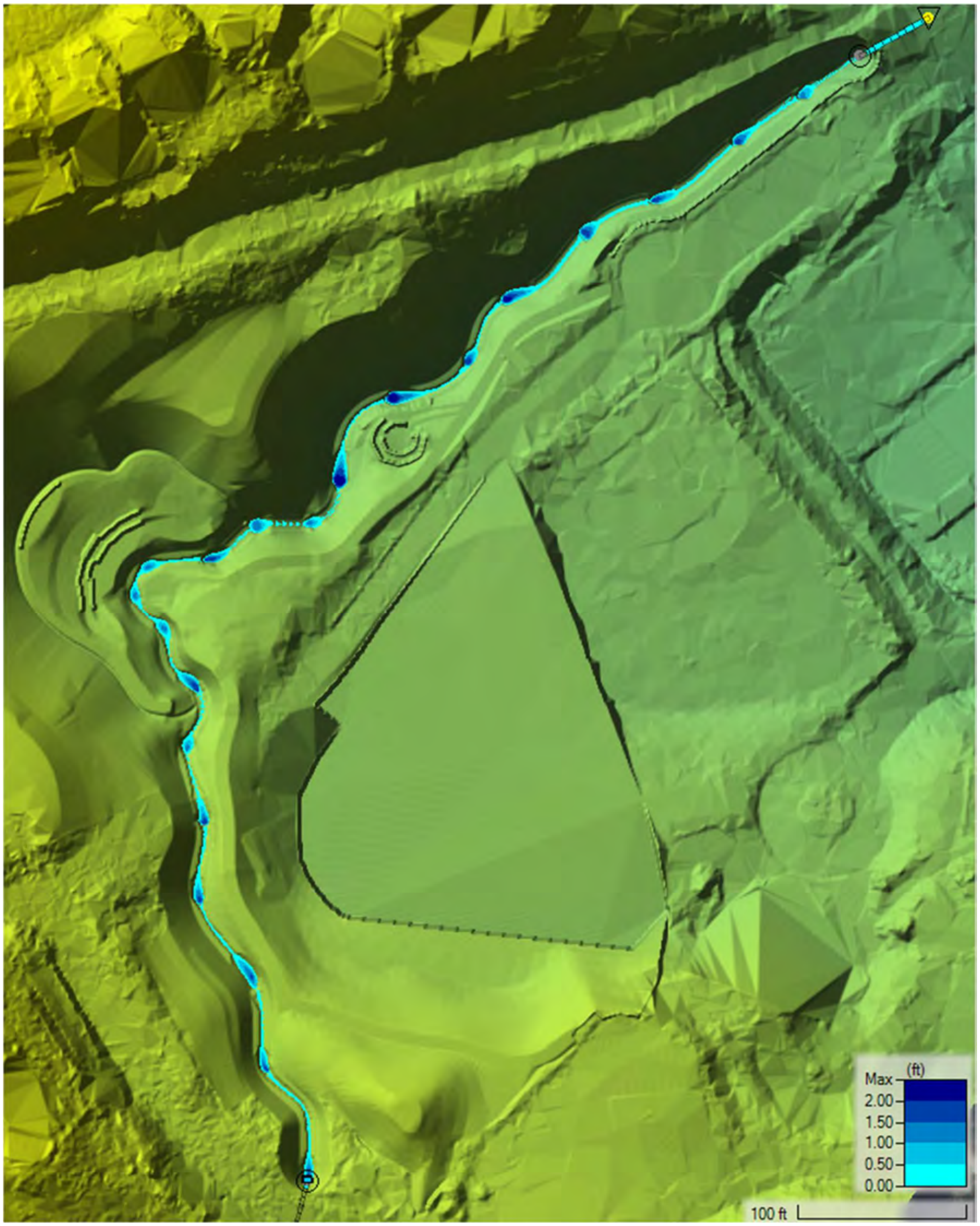


Figure 5: Depth at 0.1 cfs.

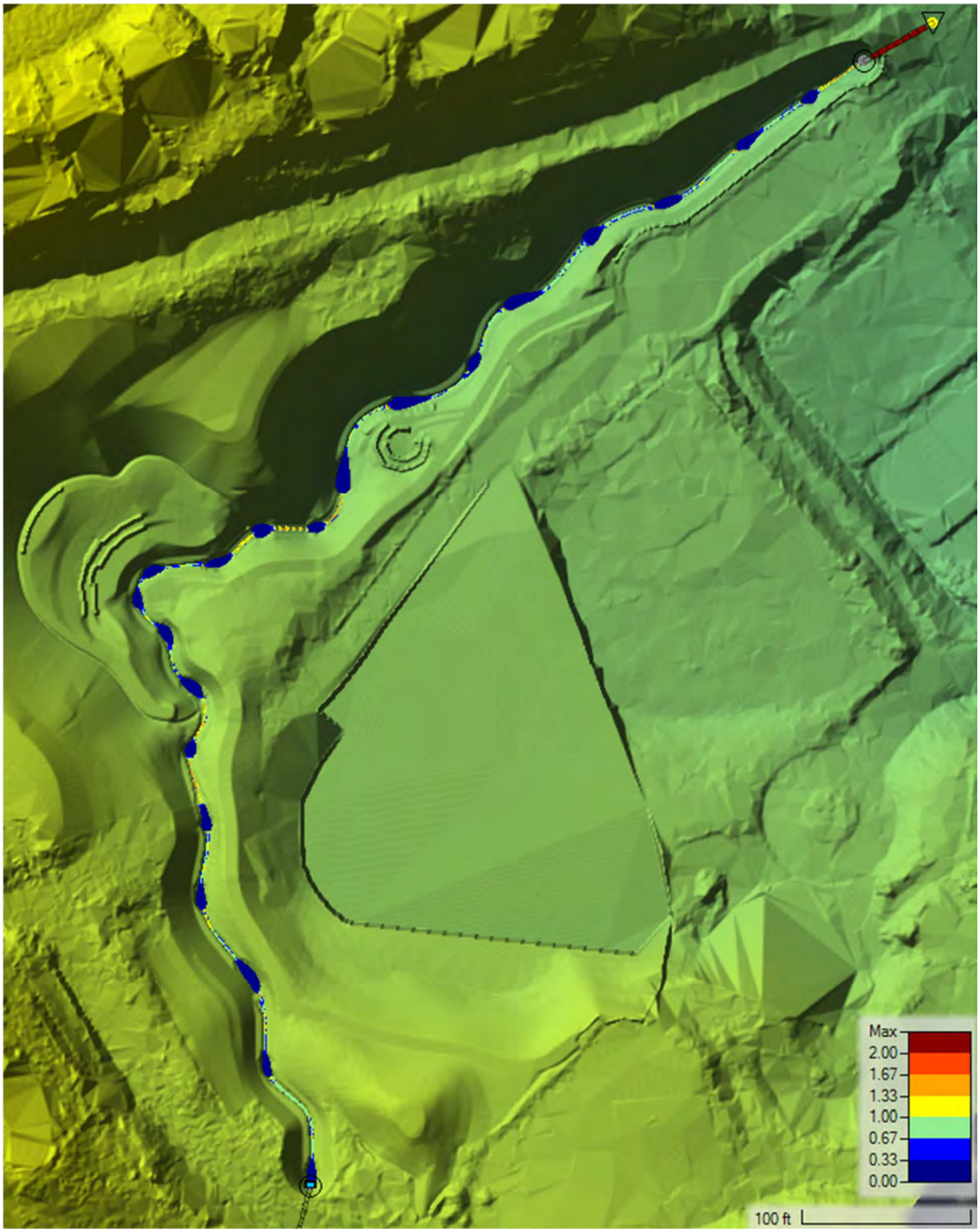


Figure 6: Velocity at 0.1 cfs.

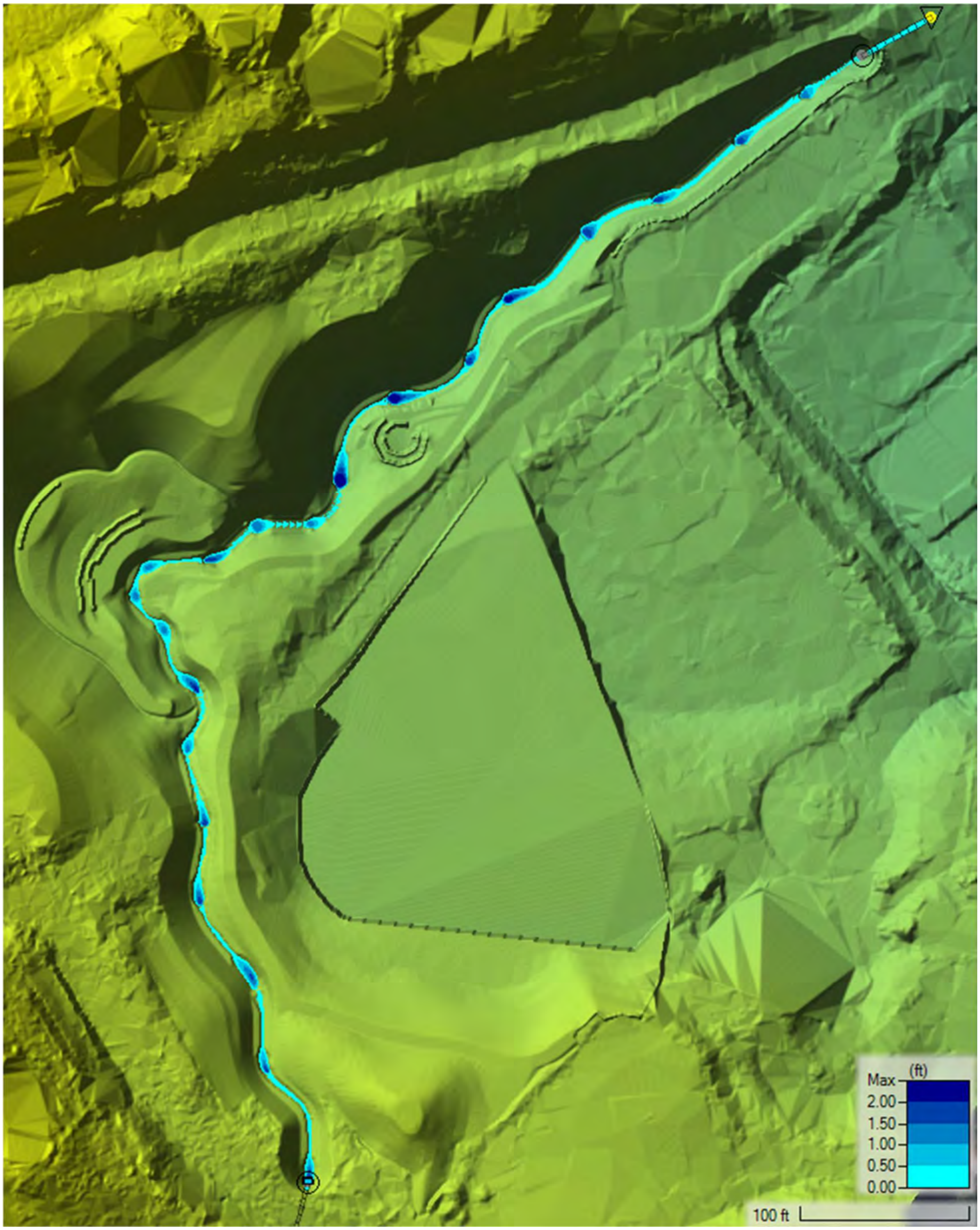


Figure 7: Depth at 0.3 cfs.

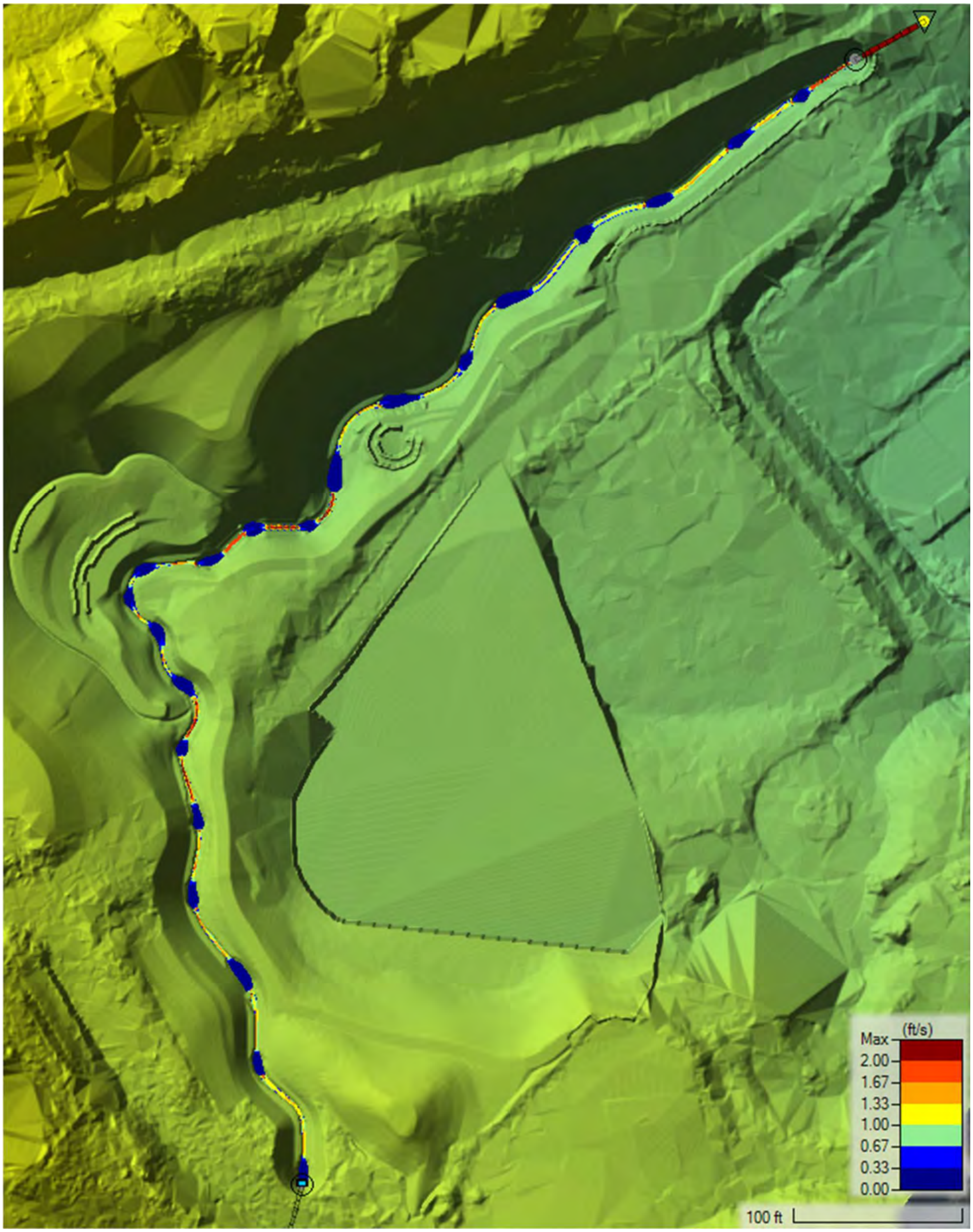


Figure 8: Velocity at 0.3 cfs.

100-year, 24-hour Storm

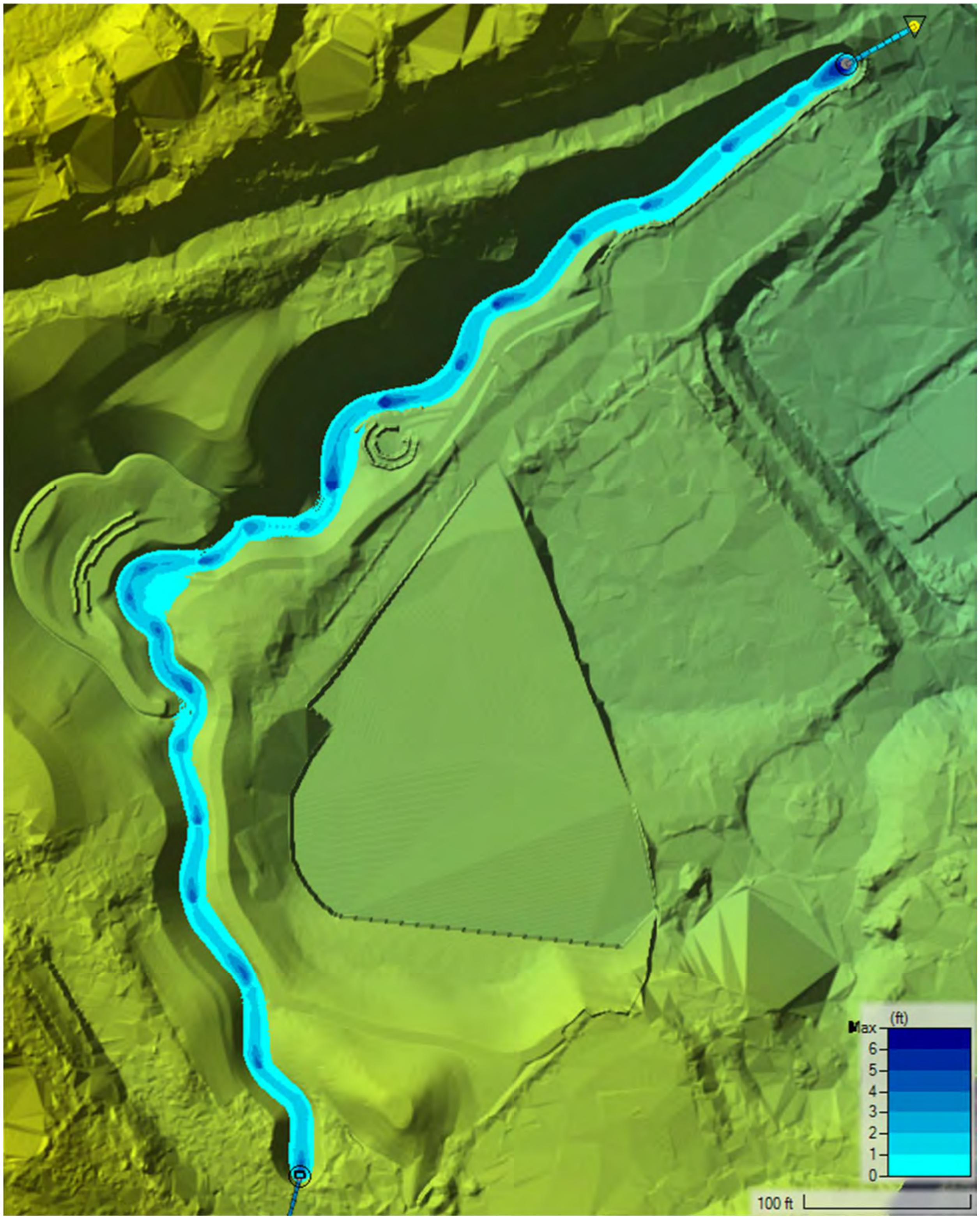


Figure 9: Depth at 100-year peak flow. Zoomed-in view of creek.

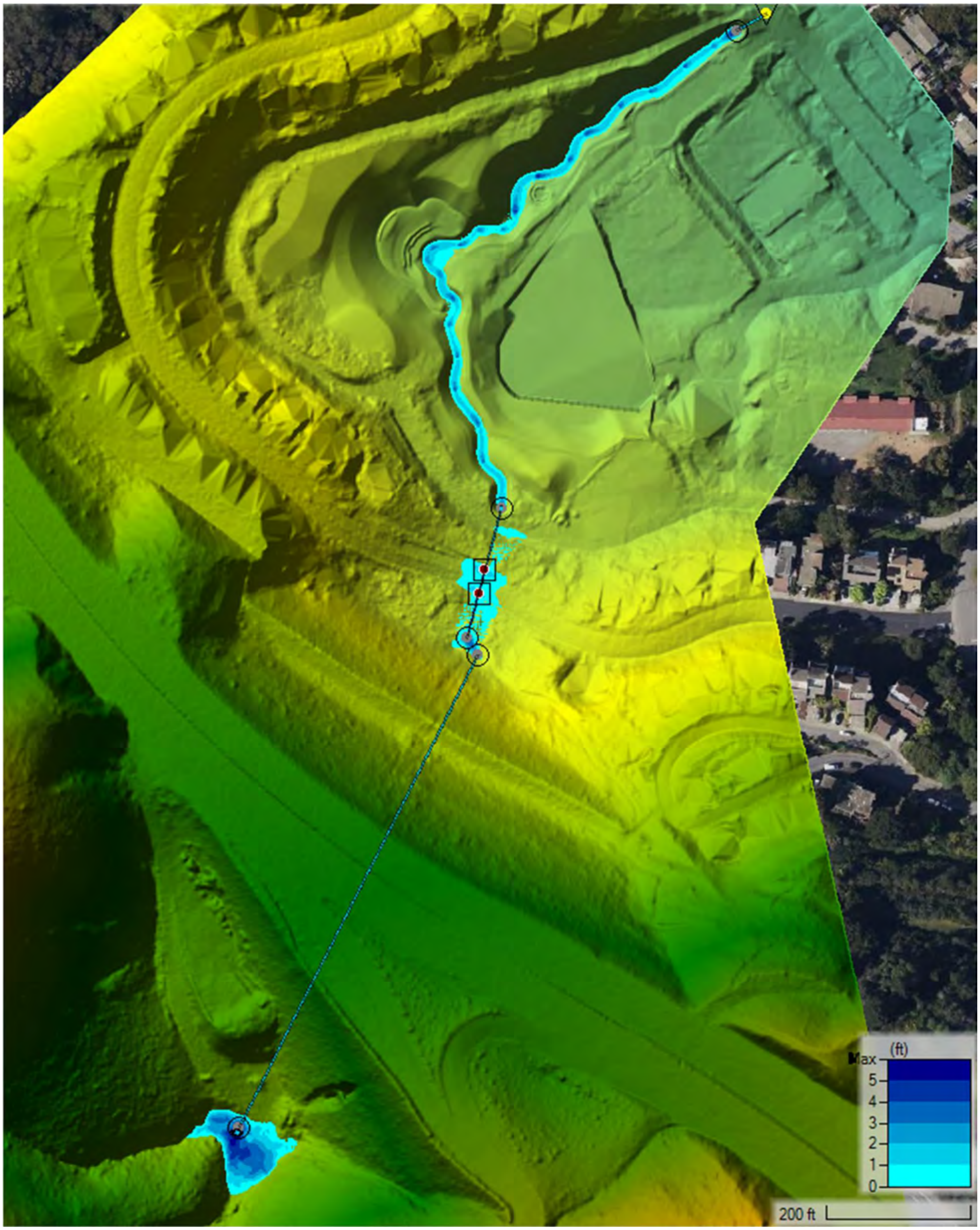


Figure 10: Depth at 100-year peak flow. Note, the model predicts surface flooding will occur for about 30 min after the 100-year peak on Lincoln Drive. This potential flooding is an existing condition and is not related to the creek daylighting project.

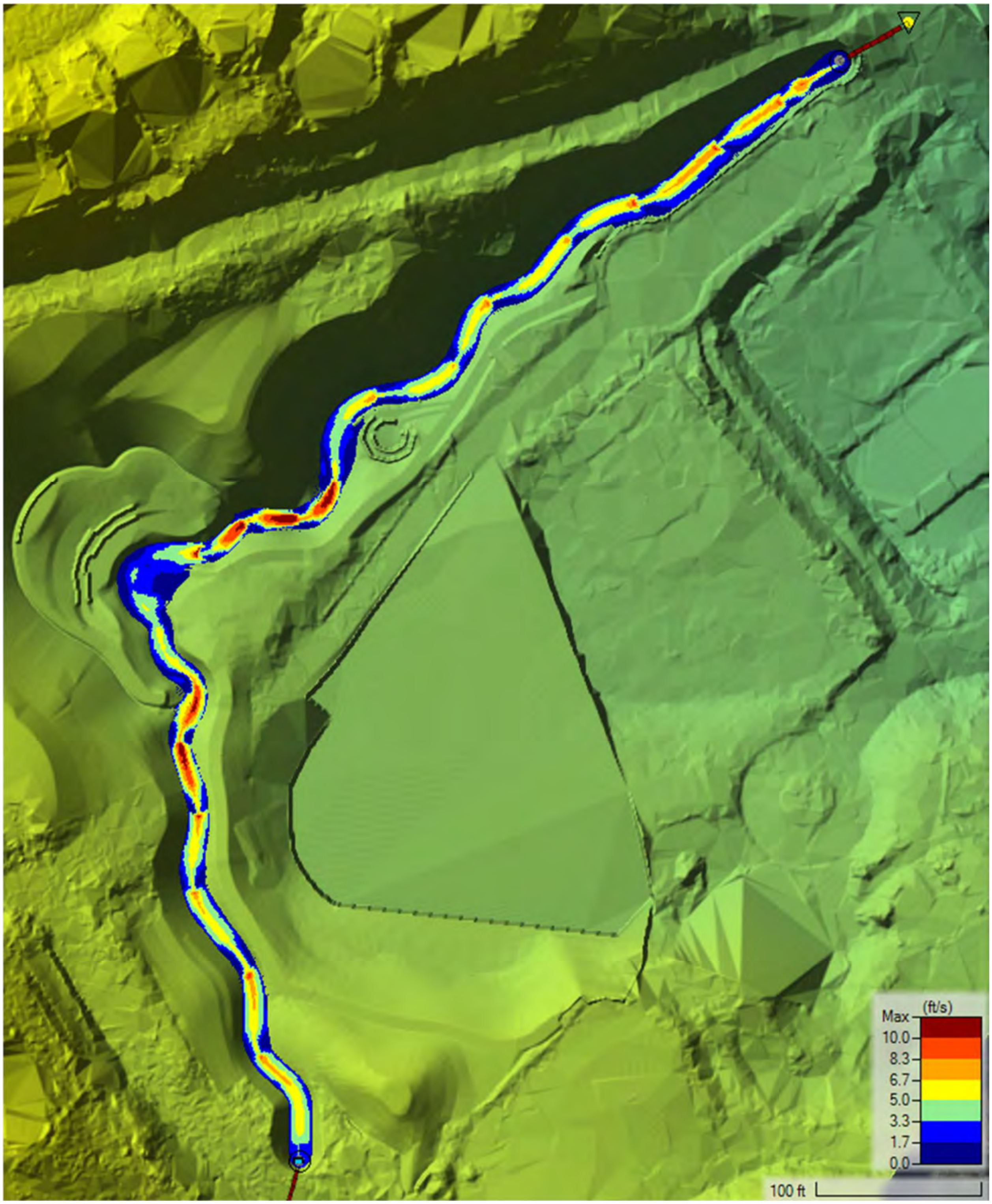


Figure 11: Velocity at 100-year, 24-hour peak flow. Zoomed-in view of creek.

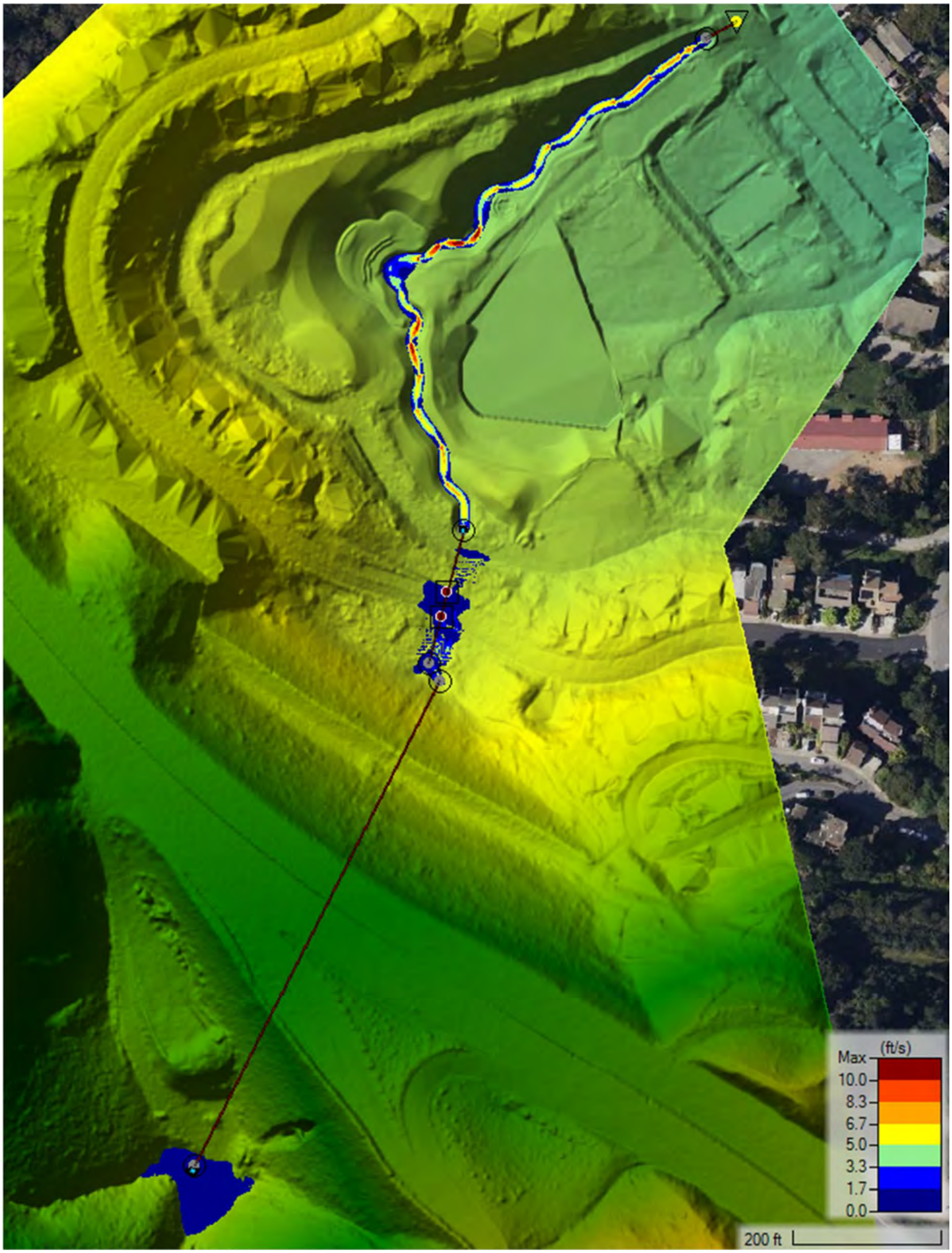


Figure 12: Velocity at 100-year, 24-hour peak flow. Note, the model predicts surface flooding will occur for about 30 min after the 100-year peak on Lincoln Drive. This potential flooding is an existing condition and is not related to the creek daylighting project.

Appendix D. Engineered Streambed Material (ESM).

ESM, all riffle slopes

Calculations by: Fiona Connor
Date: 1/28/2026
Engineered Streambed Material equations from Army Corps of Engineers, modified in CDFW CA Salmonid Stream Habitat Restoration Manual

Input	Intermediate	Results

Parameters

Design Flow (100-yr):	74	74	74	74	74	74	74	74	74
Active Channel Width:	6	6	6	6	6	6	6	6	6
hydraulic slope (S):	0.03	0.127	0.015	0.125	0.136	0.183	0.02	0.04	0.172

Note: This is only the portion of flow in the active channel. Overbank flow should be subtracted from the total flow. See p. XII-68 of Restoration Manual.

Unit Discharge in Chute

q = Qdesign/Wactive	12.3333	12.3333	12.3333	12.3333	12.3333	12.3333	12.3333	12.3333	12.3333

ESM Gradation

$$D_{30-riprap} = \frac{1.95S^{0.555}1.25q^{2/3}}{g^{1/3}}$$

$D_{30\text{-riprap}}$=	0.58414	1.30114	0.39760	1.28973	1.35153	1.59358	0.46643	0.68526	1.53968

$D_{84-ESM} = 1.5D_{30-Riprap}$ $D_{50-ESM} = 0.4D_{84-ESM}$ $D_{100-ESM} = 2.5D_{84-ESM}$

$D_{84\text{-ESM}}$ =	0.87621	1.95171	0.59640	1.93459	2.02730	2.39037	0.69964	1.02789	2.30952
$D_{50\text{-ESM}}$ =	0.35048	0.78068	0.23856	0.77384	0.81092	0.95615	0.27986	0.41116	0.92381
$D_{100\text{-ESM}}$ =	2.19052	4.87928	1.49099	4.83648	5.06825	5.97592	1.74911	2.56973	5.77381

Interstitial Voids

$D_{8-ESM} = 0.16^{1/n}D_{50-ESM}$ $D_{16-} = 0.32^{1/n}D_{50-}$

modified form of the Fuller-Thompson equation.

n =	0.461346956	0.383939393	0.510818	0.384649	0.380907	0.368296	0.489052	0.44352	0.37086004
$D_{8\text{-ESM}}$ =	0.006600001	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066	0.006599997
$D16_{\text{-ESM}}$ =	0.029651483	0.040142086	0.025636	0.040009	0.040723	0.043341	0.027232	0.031497	0.042781065

Adjust n until D8 is roughly 2mm (0.0066 ft) (coarse sand). This is to ensure that between 5-10% of the ESM consists of sands and silts.

Summary	**3.0%**	**12.7%**	**1.5%**	**12.5%**	**13.6%**	**18.3%**	**2.0%**	**4.0%**	**17.2%**
	ft	**ft**	**ft**	**ft**	**ft**	**ft**	**ft**	**ft**	**ft**
D8-ESM =	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066
D16-ESM =	0.030	0.040	0.026	0.040	0.041	0.043	0.027	0.031	0.043
D50-ESM =	0.35	0.78	0.24	0.77	0.81	0.96	0.28	0.41	0.92
D84-ESM =	0.88	1.95	0.60	1.93	2.03	2.39	0.70	1.03	2.31
D100-ESM =	2.19	4.88	1.49	4.84	5.07	5.98	1.75	2.57	5.77

	bed thickness = D84								
D-84 (inches)	**10.5**	23.4	**7.2**	23.2	24.3	28.7	**8.4**	**12.3**	27.7

ESM for steeper riffles, 18.3% results used to be conservative

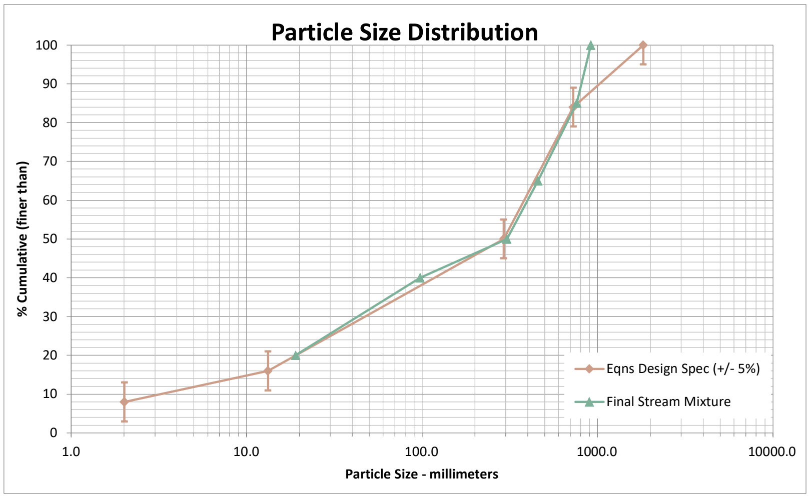
Distribution per ESM calculations for 18.3% riffle:

ft	mm	cumulative % in mix	%
0.0066	2.0	8	8
0.0433	13.2	16	8
0.9561	291.4	50	42
2.3904	728.6	84	42
5.9759	1821.5	100	58

Distribution to spec for contractor:

Rock	ft	mm	cumulative % in mix	%
class 2 perm	0.0625	19	20	20
river run	0.32	98	40	20
CALTRANS Class III, 150 lb	1	305	50	10
CALTRANS class V, 1/4 ton	1.5	457	65	15
CALTRANS class VIII, 1 ton	2.5	762	85	20
CALTRANS class IX, 2 ton	3	914	100	15

"Note, median particle diameters (D50) used for CALTRANS rock classes; for example, a 2-ton rock has a D50 of 3 feet and D100 of 4.4 feet.



Appendix E. Incipient Motion.

Date: 3/9/2026
By: LW
Purpose: Verify rock gradation in low gradient riffles will be stable during Q100

Critical Shear Stress - Shields

$$\tau_c = \tau_c^* \cdot (\gamma_s - \gamma_w) \cdot D_{50}$$

River Run

		0.32	in
D50	Particle Size:	0.0266667	ft
T*_c	Dimensionless Shields Parameter:	0.045	Gravel - loose, flat bed (assumed)
y_s	Unit weight of sediment:	165	lbs/ft^3
y_w	Unit weight of water:	62.4	lbs/ft^3
	Critical Shear Stress:	0.12	lbs/ft^2

3-6"

		4.5	in
D50	Particle Size:	0.375	ft
T*_c	Dimensionless Shields Parameter:	0.045	Gravel - loose, flat bed (assumed)
y_s	Unit weight of sediment:	165	lbs/ft^3
y_w	Unit weight of water:	62.4	lbs/ft^3
	Critical Shear Stress:	1.7	lbs/ft^2

6-9"

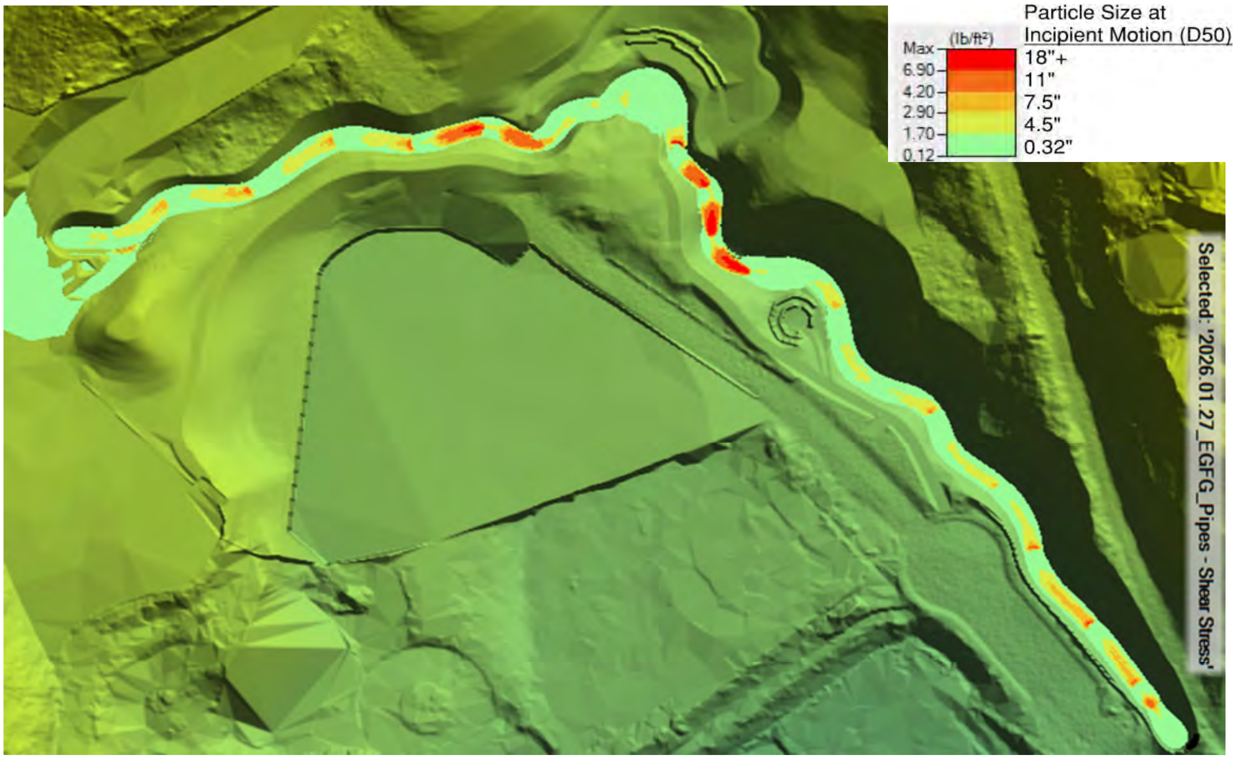
		7.5	in
D50	Particle Size:	0.625	ft
T*_c	Dimensionless Shields Parameter:	0.045	Gravel - loose, flat bed (assumed)
y_s	Unit weight of sediment:	165	lbs/ft^3
y_w	Unit weight of water:	62.4	lbs/ft^3
	Critical Shear Stress:	2.9	lbs/ft^2

9-14"

		11	in
D50	Particle Size:	0.9166667	ft
T*_c	Dimensionless Shields Parameter:	0.045	Gravel - loose, flat bed (assumed)
y_s	Unit weight of sediment:	165	lbs/ft^3
y_w	Unit weight of water:	62.4	lbs/ft^3
	Critical Shear Stress:	4.2	lbs/ft^2

9-14"

		18	in
D50	Particle Size:	1.5	ft
T*_c	Dimensionless Shields Parameter:	0.045	Gravel - loose, flat bed (assumed)
y_s	Unit weight of sediment:	165	lbs/ft^3
y_w	Unit weight of water:	62.4	lbs/ft^3
	Critical Shear Stress:	6.9	lbs/ft^2



Appendix F. Rock Slope Protection (RSP).

RSP

Calculations by: Fiona Connor

Date: 1/29/2026

Input	Intermediate	Results

RSP Stone Sizing (CALTRANS 2022) - Definitions and Recommendations copied and or summarized

$$d_{30} = y(S_f C_S C_V C_T)\left[\frac{V_{des}}{\sqrt{K_1(S_g-1)gy}}\right]^{2.5}$$

	Upstream Bridge	Downstream Bridg	Stream Entrance	Stream Exit	
General parameters					
y	1.4	2.5	4	3.5	local flow depth, ft (flow depth at toe of slope or average channel depth) {HECRAS}
Sf	1.1	1.1	1.1	1.1	Safety factor (1.1 is recommended for bank revetment))
Cs	0.3	0.3	0.3	0.3	Stability coefficient (0.30 for angular rock)
Cv	1	1	1	1	velocity distribution coefficient (1.0 for straight channels or inside of bends)
Ct	1	1	1	1	blanket thickness coefficient (1.0 for standard riprap)
Sg	2.65	2.65	2.65	2.65	Specific gravity of stone
g	32.2	32.2	32.2	32.2	acceleration due to gravity (32.2 ft/s2)

Velocity

For natural channels,

$V_{des}=V_{avg}\ (1.74 - 0.52 \log (R_c/W))$

$V_{des}=V_{avg}$ for $R_c/W > 26$

For trapezoidal channels,

$V_{des}=V_{avg}\ (1.71 - 0.78 \log (R_c/W))$

$V_{des}=V_{avg}$ for $R_c/W > 8$

For a straight channel, Rc is infinite therefore Rc/W > 26 and Vdes=Vavg; In this case, design velocity taken directly from 100-year HECRAS run, which already accounts for channel morphology and bends

	Upstream Bridge	Downstream Bridg	Stream Entrance	Stream Exit	
Rc	NA	NA	NA	NA	Centerline radius of curvature of channel bend, ft
W	NA	NA	NA	NA	Width of water surface at upstream end of channel bend, ft
Vavg	NA	NA	NA	NA	Channel cross-sectional average velocity, ft/s
Vdes	10	5.4	4	6.25	Characteristic velocity for design (ft/s) {HECRAS}

Side Slope Correction Factor

$$K_1 = \sqrt{1-\left[\frac{\sin(\theta-14°)}{\sin 32°}\right]^{1.6}}$$

	Upstream Bridge	Downstream Bridg	Stream Entrance	Stream Exit	
theta	26.6	26.6	45	45	bank angle (degrees) (2:1 @bridges, 1:1 @ US/DS culverts))
	0.46	0.46	0.79	0.79	radians
14 deg	0.24	0.24	0.24	0.24	radians
32 deg	0.56	0.56	0.56	0.56	radians
K1	0.87	0.87	0.21	0.21	side slope correction factor

Results

	Upstream Bridge	Downstream Bridg	Stream Entrance	Stream Exit	
d30	0.794	0.147	0.364	1.148	particle size for which 30% is finer by weight, ft
d50	1.0	0.2	0.4	1.4	1.20d30 ft
	11.4	2.1	5.2	16.5	inch

Appendix G. Large Wood Ballast.

Project: Willow Creek Daylighting Project
Date: 3/27/2026
Calc by: FC

PCI ECOLOGICAL

Parameters

g:	32.2	ft/sec^2	gravity
$\varnothing$:	0	degrees	Soil Internal Friction Angle
C_w:	200	lbf/sf	Cohesion of soil with wood (timber with soft clay)
C_A:	20	lb/sf	Soil Cohesion
$k_{s:}$	1	-	Lateral Earth Pressure Coefficient
C_D:	1.5	-	Drag Coefficient
C_L:	0.2	-	Lift Coefficient (typically ranges from 0.1-0.2, max of .45)
γ_{water}:	62.4	lb/cf	Sp. weight of water (density *g)
γ_{soil}:	120	lb/cf	Sp. weight of soil (density*g)
γ_{log}:	38	lb/cf	Sp. weight of log (density*g)
$\gamma_{Boulder}$:	162	lb/cf	Sp weight of boulder (density*g)
$W_{bu\ water}$:	1245	lbs/ton	Weight of submerged 1 ton boulder

Piles	**r**			Piling radius
	D_s:			Calculated pier scour
	L			Total pile length
	D_e:			Pile embeddment depth
	D			Functional depth of Pile
	V_{piling}:			Volume Piling
Rootwad	**V_{TRW}**	8.2	cf	Rootball total wood and soil volume (estimate)
	V_{RW}	6.2	cf	Rootball wood volume (estimate)
	$V_{R\text{-}S}$	2.1	cf	Rootball soil volume (estimate)
	$D_{b:}$			Average ballast depth for additional friction ballast calc
	F_{tree}		lbs-f	Equivalent resistance from tree connection (assumed)

$$V = \frac{1}{3}\pi h(R^2 + Rr + r^2)$$ Rootwad vol

Assumptions

Wood density used for damp Douglas Fir with 20% MC (38 lb/cf)
No skin friction between horizontal log members and soil
Ballast resistive capacity neglects soil cohesion
Soil internal friction angle selected for loose silty sand
Soil Ballast Force assumes all soil above logs is fully saturated (weight of soil reduced by weight of water)
Approach velocity for lift determined by design storm dictated under risk scenario (See Factors of Safety tab)
Entire structure is connected together and acts as a rigid composite structure
Equivalent resistance from tree connection 8,000lbf

FS Limit: 2
Structures less than "FS Limit": 0

Vertical Force Balance

Inputs														
Structure #	**# of Logs**	**# of Rootwads**	**# of piles**	**Log to Tree Connections**	**Soil Vertical Ballast**	**Total buried log perimeter length**	**Avg Soil Ballast Depth**	**Total Boulder Ballast**	**Boulder Ballast above Design WSEL**	**Total Wood Volume**	**Wood Volume Above Design WSEL**	**Rootwad Soil Volume**	**Area Exposed to Flow**	**U_o, Approach velocity (HEC-RAS)**
	#	#	#	#	CY	ft	ft	ton	ton	cf	cf	cf	sq ft	ft/sec
Bouldert Weir/Log Habitat Structure 1	2	0	0		0			4		53		0	15	6.0
Single Rootwad Habitat Structure 1	0	1	0		0.6			2		27		2	6	7.0
Log Weir 1	3	1	0		0.4			8		116		2	12	6.0
Single Rootwad Habitat Structure 2	0	1	0		0.6			2		33		2	5	5.0
Bouldert Weir/Log Habitat Structure 2	1	1	0		0			6		68		2	18	6.0
Bouldert Weir/Log Habitat Structure 3	1	1	0		0			6		68		2	18	11.0
Log Weir 2	3	1	0		1.1			8		116		2	12	11.0
Single Rootwad Habitat Structure 3	0	1	0		0.8			2		33		2	9	9.0
Bouldert Weir/Log Habitat Structure 4	1	1	0		0.7			4		54		2	15	7.0
Log Habitat Structure	2	1	0		0			8		80		2	30	9.0
Total	**13**	**9**	**0**					**50**		**648**		**19**		

	Resistance Forces						Uplift Forces			
Structure #	**Soil Ballast Force**	**Soil/log Max Shear Force**	**Boulder Ballast Force**	**Structure Wood Weight**	**Total Pile Resistance**	**Total Resistance Forces**	**Lift Force**	**Structure Buoyant Force**	**Total Uplift Force**	**FS**
	lb-f	lb-f	lb-f	lb-f	lb-f	lb-f	lb-f	lb-f	lb-f	2
Bouldert Weir/Log Habitat Structure 1	0	0	4981	2015	0	**6996**	105	3308	**3413**	2.05
Single Rootwad Habitat Structure 1	983	0	2491	1041	0	**4514**	57	1709	**1766**	2.56
Log Weir 1	724	0	9962	4398	0	**15084**	84	7223	**7306**	2.06
Single Rootwad Habitat Structure 2	983	0	2491	1242	0	**4716**	22	2040	**2062**	2.29
Bouldert Weir/Log Habitat Structure 2	119	0	7472	2585	0	**10176**	126	4245	**4371**	2.33
Bouldert Weir/Log Habitat Structure 3	119	0	7472	2585	0	**10176**	422	4245	**4667**	2.18
Log Weir 2	1847	0	9962	4398	0	**16207**	281	7223	**7504**	2.16
Single Rootwad Habitat Structure 3	1328	0	2491	1242	0	**5061**	141	2040	**2181**	2.32
Bouldert Weir/Log Habitat Structure 4	1156	0	4981	2048	0	**8185**	142	3363	**3506**	2.33
Log Habitat Structure	119	0	9962	3055	0	**13136**	471	5017	**5488**	2.39

	Logs			RWs (length = stem)								
DS to US	**# 1.5'x15' Logs**	**# 1.5'x17' Logs**	**# 1.5'x20' Logs**	**# 1.5'x12' RWs**	**# 1.5'x15' RWs**	**# VLAs**	**# Pins**	**Log volume (cf)**	**RW wood volume (cf)**	**RW soil volume (cf)**	**Piles Volume (cf)**	**Total volume (cf)**
Bouldert Weir/Log Habitat Structure 1	2							53	0	0	0	53
Single Rootwad Habitat Structure 1				1				0	27	2	0	29
Log Weir 1	2	1			1			83	33	2	0	118
Single Rootwad Habitat Structure 2					1			0	33	2	0	35
Bouldert Weir/Log Habitat Structure 2			1		1			35	33	2	0	70
Bouldert Weir/Log Habitat Structure 3			1		1			35	33	2	0	70
Log Weir 2	2	1			1			83	33	2	0	118
Single Rootwad Habitat Structure 3					1			0	33	2	0	35
Bouldert Weir/Log Habitat Structure 4	1			1				27	27	2	0	56
Log Habitat Structure	2			1				53	27	2	0	82
Total	**9**	**2**	**2**	**3**	**6**							**666**

Log Volume Table	
Length (ft)	**18" Dia Log Vol (cf)**
12	21
15	27
17	30
20	35

Appendix H. Overlook Trail Swale.

Assembly Area Swale

FC 3/26/2036

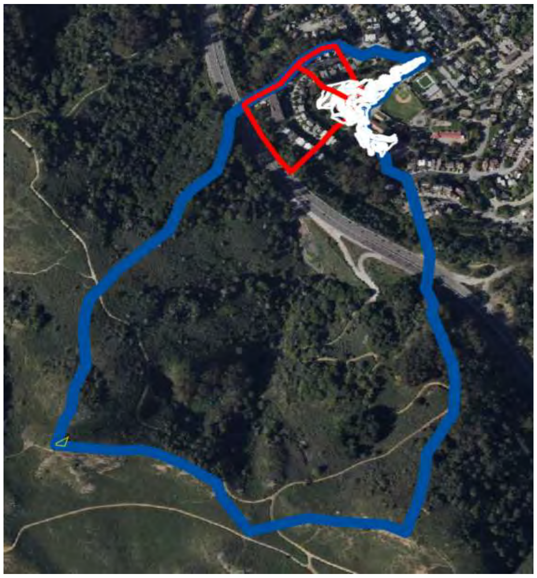
Approach

Determine required swale depth for Assembly Area. First, sub-watershed areas for the swale determined. The swale slopes in two different directions from the top of the Assembly Overlook platform; therefore, there are two sub-watersheds to consider. The 10-year flow for each swale sub-watershed was determined via watershed scaling. Swale geometry, slope, roughness, and 10-year peak flow were then analyzed in hydraulic toolbox. The flattest slope was analyzed to be conservative.

Input	Intermediate	Results

Hydrology

Main Watershed Area	125	ac
Sub-watershed Area 1	6.2	ac
Sub-watershed Area 2	1.8	ac
10-year peak flow, main watershed	42	cfs
10-year peak flow, sub-watershed	2.09	cfs
10-year peak flow, sub-watershed	0.61	cfs



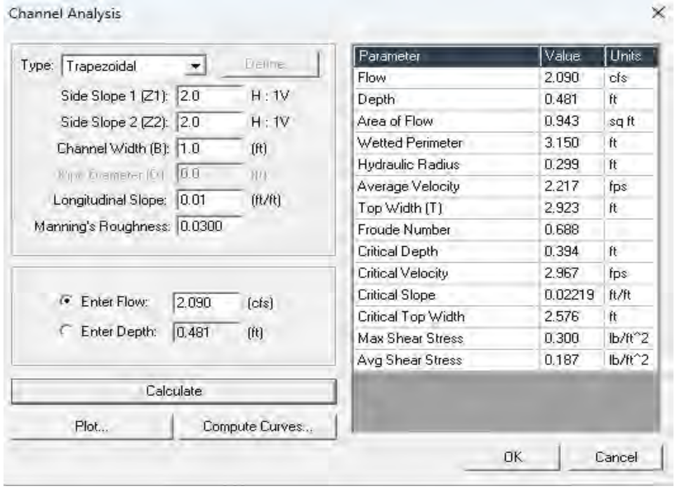
Blue = Main Watershed. Red = Assembly Area Swale Sub-watersheds.

Swale Parameters

Side slopes	2 to 1	H to V
Bottom Width	1	ft
Slope	0.01	
Roughness	0.030	grass-lined

Hydraflow Express Results

10-year depth Area 1 Swale	0.48	ft
10-year depth Area 2 Swale	0.26	ft

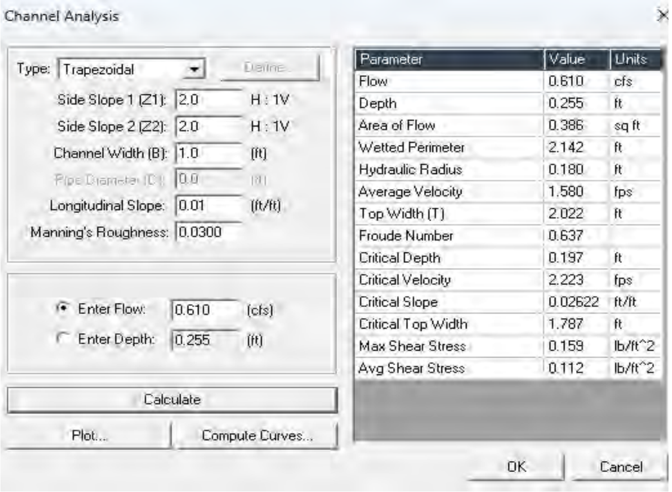


Channel Analysis

Type: Trapezoidal
Side Slope 1 (Z1): 2.0 H : 1V
Side Slope 2 (Z2): 2.0 H : 1V
Channel Width (B): 1.0 (ft)
Pipe Diameter (D): 0.0 (ft)
Longitudinal Slope: 0.01 (ft/ft)
Manning's Roughness: 0.0300

● Enter Flow: 2.090 (cfs)
○ Enter Depth: 0.481 (ft)

Parameter	Value	Units
Flow	2.090	cfs
Depth	0.481	ft
Area of Flow	0.943	sq ft
Wetted Perimeter	3.150	ft
Hydraulic Radius	0.299	ft
Average Velocity	2.217	fps
Top Width (T)	2.923	ft
Froude Number	0.688	
Critical Depth	0.394	ft
Critical Velocity	2.967	fps
Critical Slope	0.02219	ft/ft
Critical Top Width	2.576	ft
Max Shear Stress	0.300	lb/ft^2
Avg Shear Stress	0.187	lb/ft^2



Channel Analysis

Type: Trapezoidal
Side Slope 1 (Z1): 2.0 H : 1V
Side Slope 2 (Z2): 2.0 H : 1V
Channel Width (B): 1.0 (ft)
Pipe Diameter (D): 0.0 (ft)
Longitudinal Slope: 0.01 (ft/ft)
Manning's Roughness: 0.0300

● Enter Flow: 0.610 (cfs)
○ Enter Depth: 0.255 (ft)

Parameter	Value	Units
Flow	0.610	cfs
Depth	0.255	ft
Area of Flow	0.386	sq ft
Wetted Perimeter	2.142	ft
Hydraulic Radius	0.180	ft
Average Velocity	1.580	fps
Top Width (T)	2.022	ft
Froude Number	0.637	
Critical Depth	0.197	ft
Critical Velocity	2.223	fps
Critical Slope	0.02622	ft/ft
Critical Top Width	1.787	ft
Max Shear Stress	0.159	lb/ft^2
Avg Shear Stress	0.112	lb/ft^2

Hydraulic Toolbox Results