Design Basis Report: Squaw Creek Restoration, Squaw Valley Specific Plan, Placer County, California

A report Prepared for:

Squaw Valley Ski Holdings, LLC

June 2014

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1 INTRODUCTION

1.1 Purpose and Background

This report accompanies preliminary conceptual drawings for channel restoration concepts along Squaw Creek and the Olympic Channel, part of the Squaw Valley Village Specific Plan ('Specific Plan') project area in eastern Placer County, California. The design and management features presented herein have been developed with the intent of protecting and improving stream habitat functionality and water quality, as well as expanding an open-space corridor along Squaw Creek through the Specific Plan area. The purpose of this report is to describe the goals, design objectives, and design bases for the conceptual elements presented, as well as analyses that have been conducted to develop appropriate design parameters and features.

We anticipate that the proposed restoration design will retain sediment and modulate sediment transport to downstream areas, enhance groundwater recharge, and offset potential impacts to wetland and floodplain areas associated with the proposed project. Balance Hydrologics' (Balance) scope of work on this project included a site assessment, followed by development of a conceptual restoration plan in cooperation with the Squaw Valley Specific Plan Design Team.

Earlier channel restoration design work was completed by Balance for Squaw Valley Ski Holdings and is summarized in a December 2012 technical memo to Chevis Hosea (Shaw, 2012). This memo was presented and circulated to a technical review team which included members of the Squaw Valley Specific Plan Design Team, Landscape Architect Forrest Haag, Mike Liquori (Sound Watershed Consulting), Virginia Mahacek (Cardno-Entrix), and Dale Payne (Lahontan Regional Water Quality Control Board). Based on verbal feedback and comments received during this process, a number of comments were incorporated into the design and/or addressed through additional site analysis. Design responses to specific comments were summarized in a March 29, 2013 Balance Hydrologics memo, attached as Appendix A.

1.2 Goals and Objectives

Design Goals and Objectives are summarized as follows:

Goals:

- Compliance with regulatory guidance and requirements;
- Offsetting of current and historical impacts to the channel through improvement of aquatic, riparian, and wetland habitat; and
- Enhancement of the human experience through improved aesthetics and recreational, educational, and interpretive opportunities.

Objectives:

- Reduce fine sediment (sand-sized particles, less than 3 mm) transported and deposited in downstream reaches, for consistency with the Squaw Creek Sediment TMDL;
- Reduce fine sediment carried in suspension to the Truckee River (less than 2 mm), for consistency with the Truckee River Suspended Sediment Concentration TMDL;
- Maintain or increase flood conveyance;
- Increase the area and quality of wetland/riparian/aquatic habitat;
- Increase channel-floodplain connectivity through increased frequency and duration of floodplain inundation. More specifically:
    - Increase the area and quality of riparian and meadow habitat;
    - Reduce stream power and allow for deposition and sequestration of fine sediment, especially sands;
    - Facilitate re-establishment of appropriate channel form and processes;
    - Provide refuge for aquatic biota during high flows;
    - Establish opportunities for public access points with educational and interpretive features.

1.3 General Technical Approach and Work Conducted

Balance's scope of work on this project included a comprehensive site assessment and development of a channel restoration design through an iterative process to maintain consistency with Specific Plan objectives, regulatory criteria, and proposed land management strategies being considered in downstream areas.

Including initial work completed in 2011, the following site-specific data, reports, and/or information have been reviewed for this project:

- Soil survey of the Tahoe National Forest area (Hanes, 2002);
- Topographic information: 1-ft contour topographic map of the project site (Andregg, 2012);
- Preliminary Delineation of Waters of the United States, prepared by Salix Consulting (2012);
- Preliminary results of hydrologic and hydraulic modeling, prepared by MacKay and Somps Civil Engineers (2012);
- Total Maximum Daily Load for Sediment, Squaw Creek, prepared by the Lahontan Regional Water Quality Control Board (Curtis, 2007);
- Total Maximum Daily Load for Sediment, Middle Truckee River Watershed, prepared by the Lahontan Regional Water Quality Control Board (Amorfini and Holden, 2006);
- Preliminary report of findings for hydrology and bedload characterization studies for the Squaw Creek Restoration Project, prepared by Sound Watershed Consulting (2011);

- Sediment, Solute, and Nutrient Transport from Squaw Creek, prepared by Woyshner and Hecht (1988);
- Lower Squaw Creek Conceptual Restoration Plan, prepared by Phillip Williams and Associates (2007);
- Geomoprhic assessment of natural and anthropogenic sediment sources in the Squaw Creek Watershed (Malholland, B., 2002)
- Water quality monitoring data collected at various points upstream, within, and downstream of the Specific Plan Area, as provided by Squaw Valley Ski Corporation;
- Draft Master Drainage Study, prepared by MacKay and Somps Civil Engineers (2012);
- An assessment of Squaw Creek fisheries and discussion of potential impacts of the Squaw Valley Village Project, prepared by Garcia and Associates (2012);
- Squaw Creek Bioassessment data contained in Truckee River Water Quality Monitoring Annual Reports (CDM-Smith, 2013); and
- Stream-aquifer interaction studies completed by Hydrometrics and Lawrence Livermore National Laboratory (Hydrometrics, 2011; Hydrometrics, 2013a; Hydrometrics, 2013b; Moran, 2013);
- DRAFT Preliminary Design Report for the Lower Squaw Creek Restoration Project (Sound Watershed Consulting, 2013)
- Squaw Valley Far East Soil Evaluation (Raynak and Hudson, 2014)

Many site visits have also been made by Balance staff in order to observe, photograph, and document hydraulic conditions during storm events and measure channel geometry and geomorphic conditions. Additionally, a two-dimensional (“2D”) hydro-geomorphic and physical habitat model was developed to corroborate field interpretations, assess the potential for improving aquatic habitat, and to highlight unforeseen areas of scour and aggradation risk. Section 4 of this report outlines the modeling effort and, in conjunction with field data, provides the basis for sizing and designing channel and wetland restoration elements.

2 SETTING

2.1 Regulatory background

SQUAW CREEK TOTAL MAXIMUM DAILY LOAD (TMDL) FOR SEDIMENT

Squaw Creek is listed as impaired due to sediment by the Lahontan Regional Water Quality Control Board (Curtis, 2006). The TMDL for sediment recognizes ski-runs and dirt roads as primary sediment sources, with urban runoff and road sand as secondary sources. Implementation of the TMDL focuses on tracking compliance with existing regulatory actions, and monitoring channel bed conditions in lower Squaw Creek. Target instream conditions include a relative decrease in fines and sand, increased size of bed material, and higher scores on bioassessments.

MIDDLE TRUCKEE RIVER TOTAL MAXIMUM DAILY LOAD (TMDL)

The Truckee River TMDL for sediment establishes sediment load allocations for particular subwatersheds and intervening areas along the Middle Truckee River, from Tahoe City to the California-Nevada state line. The total sediment load allocation for the entire Middle Truckee River watershed (see Figure 1) is set at 40,300 tons per year. The TMDL consists of a number of indirect indicators and target values for each indicator. The only direct indicator is suspended sediment concentration (SSC) in the Truckee River, with a target of less than or equal to 25 milligrams per liter (mg/L) as an annual 90th percentile loading, as measured in the Truckee River at Farad (USGS Station 10346000). Additional indirect indicators include successful implementation and maintenance of best management practices (BMPs) for road sand application, BMPs for ski runs, and restoration activities such as decommissioning of dirt roads and repair of legacy sites.

It is important to highlight the distinction between the Truckee River and Squaw Creek TMDL requirements. While the Squaw Creek TMDL specifically targets sediment that is deposited on the bed, the Truckee River TMDL targets finer sediment that moves in suspension to downstream areas. Proposed channel restoration designs and other watershed management strategies must focus on both suspended sediment as well as the sand-size portion of bedload sediment, which rarely moves in suspension.

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) MUNICIPAL STORMWATER PERMIT FOR PLACER COUNTY

The Lahontan Water Board required the Placer County Department of Public Works to develop a Stormwater Management Program (SWMP) for compliance with the NPDES Phase 2 ("Small MS4") municipal stormwater permit. The initial SWMP covering the 5-year permit term 2007-2012 describes how six Minimum Control Measures (MCMs) will be implemented to control pollutants from construction sites, residential development, and municipal activities. Oil and grease, trace metals and nutrients in urban runoff, fine sediment and road sand and salts are particular concerns. Hydromodification of stream channels due to increased impermeable surface coverage is another major focus of the SWMP.

LAHONTAN BASIN PLAN

Under the Water Quality Control Plan for Lahontan Basin and Truckee River Hydrologic Unit, discharge of material to "lands within the 100-year floodplain" is prohibited, with the intent of protecting floodplain functions such as conveyance and storage, along with other hydrologic, geomorphic, biologic and ecologic processes such as groundwater recharge, floodwater filtration, sediment transport, spawning gravel replenishment, seed dispersal, and riparian vegetation maintenance (Lahontan Regional Water Quality Control Board, 2014). Exemptions to this prohibition may be granted on a case by case basis, as long as discharges a) do not reduce or adversely affect the existing floodplain function, or b) restore and/or improve previously impacted floodplain functions.

2.2 Hydrologic Setting and Climate

The valley floor along the project reach has an average elevation of approximately 6,200 feet. The reach is surrounded by steep hillsides to the north, south, and west that extend to the Sierra Crest where elevations exceed 9,000 feet. Most of the flow entering the upstream end of the reach comes from the North and South Forks of Squaw Creek. The North Fork drains a mostly undeveloped area (referred to as Shirley Canyon) of 3.5 square miles. The South Fork drains an area of 1.8 square miles, and has been more affected by land use changes (residential developments in the lower elevations and ski area infrastructure in the higher elevations) compared to the North Fork, but is still mostly undeveloped. Aside from intervening hillsides, the Olympic Channel is the only other major input to Squaw Creek within the Specific Plan Area. The Olympic Channel drains Searchlight Pond (used for snowmaking), and enters Squaw Creek near the downstream end of project reach. The total watershed area at the downstream end of the project reach is roughly 6 square miles.

Along the main stem of Squaw Creek several culverts convey runoff from parking lots and the Village at Squaw Valley, though their contribution to total streamflow is only significant during rainfall events or rapid snowmelt. Due to the age of the original storm drain system (1950s and 60s) water quality control features are minimal, though stormwater management features are included as part of the existing Village at Squaw drainage system, and portions of the parking lot drainage system have been retrofitted with water quality treatment devices.

Average annual precipitation in the watershed is 65.2 inches (SNOTEL, 2014), the majority of which is snowfall between November and March. Spring snowmelt events typically drive annual peak flow rates, however, some of the most extreme events regionally have been from early-winter rain-on-snow events. Eight years of data (2003 to 2010) from a streamflow gage operated by Sound Watershed Consulting (located at the Squaw Valley Road bridge 1.5 miles downstream of the project reach) were used to gain an understanding of annual peak flow magnitudes and hydrograph temporal patterns. According to that record, annual peaks varied between 160 and 630 cfs, and in all years Squaw Creek went dry from late summer to mid fall. For purposes of evaluating moderately frequent flow events which are known to convey sediment and alter the channel, we have used the hydrograph for the December 31, 2005 storm event to evaluate sediment transport dynamics.

Table 1 presents a summary of design flows established and reported by others for Squaw Creek at the lower end of the project site. MacKay and Somps (2012) developed a hydrologic model of the watershed using the U.S. Army Corps of Engineers' HEC-HMS software platform and methods outlined by Placer County Flood Control. At the downstream end of the project reach, they estimate the 2-year peak flow in Squaw Creek to be approximately 2,000 cfs, the 10-year flow to be approximately 3,300 cfs, and the 100-year flow to range as high as 5,200 cfs, consistent with recent estimates developed by FEMA (MacKay and Somps, 2012). These estimates are conservative, and appropriate for consideration and sizing of in-channel elements and bank stabilization structures. Conservative estimates in accordance with County guidelines are also necessary when evaluating potential changes in flood risk and associated infrastructure protection associated with the channel enhancement project.

Lower-magnitude, channel-forming design flows are approximated by looking at peak streamflow data recorded by others on Squaw Creek, at nearby gaging stations, and through regional-regression based approaches. As shown in Table 1, the regional-regression-based approaches and correlation to nearby stations establishes a 2-year, or 'bankfull' design discharge to be approximately 250 cfs. It is important to highlight the wide range in estimates of the 2-year flow; the variability will be considered and applied during final design to establish microtopographic features, and inundation of different areas at a range of flows.

2.3 Published Geology and Soils Information

BEDROCK GEOLOGY

The geology of Squaw Creek and its watershed is interpreted from Sylvester and others (2012) and illustrated in Figure 2. The watershed is characterized by a number of distinct types of features. Cretaceous granodiorites or crystalline rocks make up much of the basement rocks of the Sierra Nevada Range in this region and comprise a significant portion of the watershed, with Tertiary volcanic rocks along the southern ridge or boundary of the watershed (i.e., Squaw Peak, KT22). Northwest trending faults associated with the Tahoe-Sierra Frontal Fault Zone exhibit vertical displacement offset the granitic bedrock and the volcanic rocks. Glaciation has helped carve individual valleys, headwall cirques, glacially plucked bedrock cliffs, and avalanche chutes. Most recently, stream incision and hillslope erosion forms alluvial fans, talus slopes, and debris cones at the transitions between steep canyons and valley floors. Birkeland (1961) mapped glacial till and moraines within the Squaw Creek watershed connected to the Tahoe and Tioga glaciations. Glacial sediments are thought to fill Squaw Valley to depths of between 100 to 150 feet deep; the top of these sediments forms the present-day meadow (Hecht and Jett, 1988).

Lithology differs between the North Fork and the South Fork of Squaw Creek. The North Fork is primarily underlain by granitic bedrock (primarily granodiorite) and is much more resistant to erosion. Comparatively, volcanic rocks are more dominant in the South Fork and are comprised of predominantly highly weathered andesitic breccias and mixed pyroclastics and andesitic flows (Saucedo, 2005, Sylvester and others, 2012). Glacial deposits occupy a signification portion of the lower South Fork but are not well preserved in the North Fork Watershed. Erosion of volcanic rocks and glacial deposits in the South Fork typically results in higher production of very fine material, transported as suspended load, while erosion of granitic material produces sand-sized particles, which were identified by Woyshner and Hecht (1988) as the dominant component of bed load collected in downstream areas. Sylvester and others (2012) have mapped a prominent alluvial fan at the mouth of the South Fork at the head of Squaw Valley and at mouths of other steep drainages that erode volcanic rocks, including, the Olympic Channel.

PUBLISHED SOILS INFORMATION

The soils within the Squaw Creek watershed have been mapped and classified by USDA, Tahoe National Forest (Hanes, 2002, see Figure 3). Most of the soils are minimally developed and formed from the underlying parent bedrock. Soils at lower elevations in the watershed are formed on alluvial and glacial deposits and are mostly comprised of Aquolls and Borolls (AQB)—wetland type soils which support grasses, sedges and forbs. These soils are typically stable except when subject to disturbance by stream modifications or urban development (Maholland, 2002). Hillslope soils are dominated by the Jorge, Meiss, Tallac, and Waca Soil Series. These soils are generally highly susceptible to erosion and therefore more sensitive to changes in land use or disturbance. The proposed channel restoration reach is located on soils of the Tallac Series (TAE), corresponding to areas mapped as alluvial fans (Sylvester and others, 2012). Tallac soils are described as very non-cohesive gravelly, sandy loams, and very susceptible to erosion. Erosion of these soils typically forms coarse gravel bars and in-stream deposits.

Holdrege and Kull (Raynak and Hudson, 2014) recently completed a soil evaluation in the proposed restoration area and documented stratified loamy sands, silts, and some gravel, consistent with soils mapping described above, and geologic maps which show this area as the distal portion of alluvial fans.

2.4 Groundwater and surface water interaction

The project site lies within the Olympic Valley Groundwater Basin, the primary water source for Squaw Valley. Hourly water level data in monitoring wells adjacent to the project reach suggest groundwater levels are typically 3 to 5 feet above the existing streambed elevation and similar to water levels in the creek during wet conditions, and fall below the streambed during dry conditions (typically from June to November). Hydrometrics (2013a) evaluated localized surface-water and groundwater interactions along the lower portion of the project reach and found the stream to be losing water to the ground during much of the year, especially during early fall flow events when groundwater levels are at a minimum.

These findings contrast stream-aquifer conditions in the project reach with those in the meadow reaches, where the lower portions of Squaw Creek typically receive inflows from groundwater during most of the year (Moran, 2013). The presence of Aquolls and Borolls downstream of the project reach supports a notion that the lower Squaw Valley Meadow developed under conditions of frequent saturation, water retention, and shallow groundwater conditions, whereas the coarser alluvial fan deposits are more typically associated with groundwater recharge, or losing stream reaches. Moran (2013) identified groundwater recharge as occurring at elevations just above the valley floor, consistent with Hecht and Jett’s (1988) descriptions of groundwater recharge along mountain-front alluvial fans and Hydrometrics’ (2013a) measurements of seepage from the channel to the aquifer along the trapezoidal channel.

2.5 Channel Form and Process

The project site lies at the head of Squaw Valley. Prior to the establishment of human infrastructure, channel processes in this area were dominated by sediment deposition, active channel migration, and alluvial fan formation (Hecht and Jett, 1988). Early migrants and settlers used the valley for cattle and sheep grazing, and logging roads and railroads were built, most intensively in the early 1900s when a short-lived lumber camp and mill were located in the valley.

Significant changes were made in the 1950s with development of the ski resort and anticipation of the 1960 Olympics. It was at this time that the channel was modified to create the “trapezoidal channel,” which runs throughout the restoration design reach before transitioning to the less modified Lower Channel in the Squaw Valley Meadow. Figure 4 shows the historical channel pattern in comparison to the currently modified channel. Historically, the channel exhibited a meandering pattern with active in-channel bars and some apparent depositional or floodplain surfaces. As a result of channel modification, historical channel processes were altered, such that only limited sediment deposition and floodplain development takes place within the trapezoidal channel. Much of the sediment which was once deposited at the west end of the project site is now transported downstream and deposited further east in the meadow. Sand and gravel deposition in the meadow reach now appears to be causing lateral channel migration, bank instability, and sediment generation from channel banks (PWA, 2007).

Gustafson (1996) mapped channel topography prior to the geomorphically-significant flows of 1997 and 2006. Comparison of 1996 channel topography to existing conditions shows very little change in channel bed or inset floodplain elevations along the straight trapezoidal reach, indicating that sediment transport is a dominant process operating between the confluence of the North and South Forks and Squaw Meadow, with very little deposition or sediment production over the period from 1996 to 2012. The confluence of the two forks, on the other hand, appears to be functioning to store sediment generated during episodic events upstream, with an average of roughly 2 feet (approximately 3,000 cubic yards along the North Fork) of channel aggradation between 1996 and 2012. The National Resource Conservation Service reported removing approximately 3,500 cubic yards of material from the South Fork following the January 1997 flood event, further indication that this area has the capacity to store sediment during large magnitude events, slowly releasing it to downstream areas as deposits are mined by channel incision and associated fluvial processes during intervening years. Thus, the confluence reach is an area where sediment is intrinsically stored during major events, releasing material downstream during smaller flows.

Enough information is available from historical documents to establish that Squaw Creek can migrate and bifurcate as it flows through the meadow downstream from the project area – especially when the channel flowing through the meadow has accumulated sediment from a storm or series of storms. Bars form within and along the channel, deflecting flow toward erodible banks. Prior to settlement and development of the valley, sediment from these major ‘episodic’ events would be deposited near the head of the valley, then gradually re-worked by the creek. The rate of sediment transport through the meadow was modulated by this upstream storage, with limited episodic sediment deposition in the meadow and development of fine-grained wet meadow soils. Construction of the trapezoidal channel and constraining the channel to a limited planform during the past 50+ years has reduced the opportunities for sediment supply to be modulated by storage at the valley head.

2.6 Sediment Transport

Historical annual sediment loads have been evaluated using the following sources:

- Sediment sampling conducted at various locations up- and downstream of the project site by Squaw Valley Ski Corporation and its consultants during the period from 2006 to 2010;
- Suspended- and bedload-sediment sampling from the Squaw Creek Meadow Reach during 1986 and 1987 (Woyshner and Hecht, 1988);
- Suspended-sediment sampling at the mouth of Squaw Creek during 1996, 1997, and 2000, as reported by MacGraw and others (2001);
- Streamflow data collected by the Squaw Valley Public Services District and Friends of Squaw Creek from 2003 to 2010, as provided by the Friends of Squaw Creek and Sound Watershed Consulting; and
- A process-based sediment budget for the Squaw Creek watershed developed by Malholland (2003).

In most of these cases, sediment loads are estimated by establishing a relationship between sediment transport and streamflow at a given station, and applying that relationship to various streamflow scenarios, such as a design 10-year storm or annual streamflow during a year with near-average precipitation and streamflow, such as 2009. Woyshner and Hecht (1988) are the only investigators who have measured bedload-sediment transport in addition to suspended sediment, and found the bedload fraction to account for approximately 80 percent of the total sediment load during a year with above-average flows. This 4:1 (bedload:suspended-load) ratio is used to calculate bedload and total sediment load estimates based on suspended sediment data collected by others. We do caution, however, that this ratio is highly variable depending on the nature of flows in a given year, and that suspended sediment may constitute a much higher portion of the total load in years with below average precipitation and runoff.

Table 2 is a summary of sediment load estimates at a number of locations, as calculated using various data sources and design storms, and highlights wide variability in transport rates and total loads associated with various flow events and years. Total annual sediment loading in Squaw Creek during a year with average total streamflow and only minor peak flows is anticipated to be on the order of 2000 tons. This is roughly equivalent to the calculated total sediment load associated with the modeled 10-year flood event. Intervening drier years may see only a fraction of this load transported; Woyshner and Hecht (1988) reported only 257 tons/year in 1987, only 77 of which was transported as bedload. Channel bank instability throughout the meadow reach, downstream of the Specific Plan area is commonly cited as a significant contributor to the Squaw Creek sediment budget (Hecht and Jett, 1988; Malholland, 2003).

Suspended sediment data collected by Squaw Valley Ski Corporation indicates suspended sediment yield (loading per square mile of watershed area) to be roughly equal between the North and South Forks of Squaw Creek. The Olympic Channel, however, appears to account for roughly 25 to 30 percent of the total sediment load delivered to the Squaw Meadow, although its watershed size comprises only 7 percent of the total Squaw Creek watershed area at the downstream project boundary. Reconnaissance-level field observations during the December 2, 2012 storm event verify these calculations, when turbidity was visibly higher in the Olympic Channel than other water bodies. Based on the clarity of runoff directly to the channel from adjacent areas, it is inferred that the primary source of suspended sediment in the Olympic Channel is from the upper watershed draining the KT-22 and Olympic Lady portions of the mountain.

2.7 Aquatic species

A recent assessment of Squaw Creek fisheries (GANDA, 2012) summarizes relevant data in field studies and anecdotal information from over the last century. Within the project reach, brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), and Lahontan speckled dace (*Rhinichthys osculus robustus*) are the most abundant species documented in the project reach. Brook trout (*Salvelinus fontinalis*) were observed upstream of the project reach in a 2011 survey, and Paiute sculpin (*Cottus beldingii*) were documented in a 1966 survey. It is possible that other species common to eastern Sierra steams occur in Squaw Creek such as Lahotan redside (*Richardsonius egregious*), Tahoe sucker (*Catostomus tahoensis*), mountain sucker (*Catostomus platyrhynchus*), and mountain whitefish (*Prosopium williamsoni*). Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) have never been documented in Squaw Creek, and the likelihood of the their occurrence is considered low due to lack of source populations, competition with non-native trout, and lack of spawning and rearing habitat.

GANDA (2012) cites excessive sedimentation and reduced flows as the primary threats to fish populations in Squaw Creek. Additionally, a number of partial barriers to fish passage exist in the channel, including a sewer pipe crossing just downstream of the Far East Road bridge, grade control structures on the North Fork channel, and areas of discontinuous flow.

3 CONCEPTUAL RESTORATION DESIGN

3.1 Assessment of Baseline Conditions Design Implications

Based on available background information presented above, we conclude the following:

- The geology and land use in the North and South Fork Squaw Creek watersheds is significantly different, with more erodible volcanic material and greater land disturbance found in the South Fork Squaw Creek Watershed. The volcanics more easily erode to silt- and clay-size particles, whereas the granitic rocks of the North Fork watershed more naturally erode to sand-sized particles. Silts and clays are transported in suspension, and therefore are prone to affect suspended sediment concentrations and water quality impairment related to the Truckee River Suspended Sediment TMDL. Sands on the other hand are usually transported as bedload, and prone to bed deposition and impairment related to the Squaw Creek Sediment TMDL. Channel restoration approaches in Squaw Valley should focus on sequestration and settling of silts, clays, and sands.

- Construction of the trapezoidal channel and constraining the channel during the past 50+ years has reduced the opportunities for sediment supply to be modulated by storage at the valley head. As a result, episodic sediment delivery directly to the lower meadow destabilizes streambanks, causing excessive fine-sediment production and transport. Widening of the trapezoidal channel and expansion of the inset floodplain area should allow for deposition of sediment upstream of the meadow, reducing episodic sediment delivery and instability in downstream areas.

- Recharge to the Olympic Valley Groundwater Basin occurs primarily along coarse-grained soils and alluvial fans at the head and margins of the valley, including the proposed restoration reach. Accordingly, Squaw Creek often loses water to the aquifer along the trapezoidal channel, gaining flows only when the aquifer is full. Detention of water in alluvial fan soils is anticipated to enhance groundwater recharge.

- The Olympic Channel appears to be a significant source of fine sediment delivery to Squaw Creek. Channel restoration approaches which detain water and allow for settling of suspended sediment along the Olympic Channel will provide meaningful reductions in sediment delivery to Squaw Creek and the Truckee River.

- A range of trout and smaller species have been documented in the Squaw Creek system. The proposed design should improve or maintain habitat for these species. In particular, a 2-foot drop in the channel immediately downstream of the Far East Road Bridge should be improved to allow these species to access upstream restored areas, where holding habitat can be improved.

3.2 Design Layout and Elements

A widened channel and floodplain corridor will allow for reduction of fine and coarse sediment loads, floodplain expansion, and improved floodplain connectivity in the western one-third of Squaw Valley. The proposed design is anticipated to modulate sediment moving into the meadow reach, rather than passing through the meadow as pulses of bar-forming deposits which destabilize the channel. This concept leads directly to the primary design element of the proposed restoration concept: an inset channel and floodplain system, with increased floodplain wetlands, improved aquatic habitat, and opportunities to increase sediment deposition. Conceptual design drawings for this area are provided with this report in Appendix B. These illustrate a naturalized creek system which is anticipated to retain a significant volume of very fine and fine sediment, as called for by the Squaw Creek and Truckee River Sediment TMDLs.

In order to allow for this restoration concept to be implemented, the Squaw Creek stream environment has been set aside in the Squaw Valley Village Specific Plan as "Village-Conservation Preserve." This corridor ranges from 150 to 330 feet wide and will allow for improved riparian functions and values, including groundwater recharge, sediment deposition, terrestrial, avian, and aquatic habitat, and flood protection. Principles of 'eco-revelatory' design (Mozingo, 1997; Geist and Galatowitsch, 1999; Galatowitsch, 1998) will also be incorporated into Conservation Preserve areas, and will include a Class A bike and walking trail along the corridor, with interpretive signage and viewing areas.

The grading plans and associated cross-sections are conceptual in nature, to be modified as design details are finalized.

PROPOSED CHANNEL FORM

Using data from many western U.S. rivers, Leopold and Wolman (1957) developed a relationship between channel-forming ('bankfull') discharge, and channel slope that can be used to predict natural channel planform (Figure 5). Based on this relationship, estimated bankfull discharge (2-year recurrence, 250 cfs) and channel slope within the project reach, a meandering planform along the trapezoidal channel and a meandering or braided channel in the vicinity of the Olympic Channel is consistent with geomorphic relationships found elsewhere in the region and western U.S. Channel sinuosity, meander belt width, and meander wavelength have been established based on these parameters as measured from relict channels visible in recent aerial photography and the historical alignment of Squaw Creek as visible on a 1939 aerial photograph (see Figure 4).

Squaw Creek channel geometry (low-flow channel bank height and channel width) is designed to be variable, averaging 20 feet in width and 2 feet in height, also based on preserved historical channels and measurements taken from historical aerial photography. Variability is intended to target floodplain inundation at flows ranging from a 1- to 5-year recurrence, and in a range of floodplain microtopographic features, as is typically found in natural systems. The established average channel geometry is consistent with, but will average slightly larger than, regional relationships between watershed area and hydraulic geometry as reported by Sound Watershed Consulting (2013). Although regional relationships point to a bankfull channel that is 1.5-feet deep, we intend to maintain deeper water and higher shear stresses to maintain sediment transport continuity in the low flow channel portion of the overall wider corridor.[1]

CONFLUENCE OF THE NORTH FORK AND SOUTH FORK OF SQUAW CREEK (SHEET 3.1)

The conceptual plan provides for sediment and large wood storage during future episodic flood events, but preserves areas of willow riparian habitat at the confluence of the North and South Forks. The proposed design also includes a widened and expanded floodplain area on the north bank to allow for a more gradual transition to the trapezoidal channel and Squaw Valley Road Bridge. This is intended to promote active lateral channel migration and sediment transport continuity during intervening years, avoiding undue effects of ‘hungry water’ or sediment starvation and associated erosion in downstream reaches.

FLOODPLAIN RESTORATION WITHIN THE TRAPEZOIDAL CHANNEL (SHEET 3.2 AND 3.3)

Within the trapezoidal channel segment of the project reach, there are several existing storm drain pipes along the banks with inverts perched high above the channel. This presents a challenge in terms of maintaining their functionality with minimal redesign of the greater storm drainage system while not detracting from the aesthetic quality of the channel improvements. Bioengineered step outfalls (BESO) are proposed to provide protection against slope erosion, and will blend in with the surrounding natural landscape. BESOs are constructed of 6-inch by 6-inch redwood timber cribbing that is anchored with rebar and backfilled with crushed rock (Appendix B). Plantings are

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[1] Section 3.3 outlines the sediment transport modeling effort that supports this design decision.

strategically placed in and around the BESOs to soften their appearance and provide long-term slope stability as the timbers biodegrade.

Riffle-pool sequences have been included in the project design at a spacing similar to that observed in this reach on historical aerial photographs. Channel beds at riffles will be constructed of coarser bed material, and pools will be excavated on the outside of meander bends. Additional pools and backwater channel habitat will also be included to provide adequate depth, holding areas, and cover for fish and other aquatic species. Partially buried bank logs with rootwads intact are proposed throughout the project reach. These structures will protrude into the low flow channel to protect banks during high flows and provide cover for aquatic habitat during low to moderate flows. The logs have been located adjacent to pools and will help maintain the pools by encouraging bed scour. The logs will be securely anchored into the banks with boulders and compacted soil.

INSET DYNAMIC FLOODPLAIN ZONE (SHEET 3.4)

To offset impacts associated with sediment deposition at the downstream end of the trapezoidal channel, as well as incoming sediment from the Olympic Channel, the Conservation Preserve will be widest at the downstream (east) end of the Specific Plan Area. The proposed width increase allows for floodplain restoration, sediment deposition, and active sediment management/removal at the confluence of the Olympic Channel and Squaw Creek should a need for access arise during the post-project monitoring and adaptive management period.

The proposed Conservation Preserve and restored floodplain width is consistent with restoration alternatives identified and developed by Placer County and the Friends of Squaw Creek (Sound Watershed Consulting, 2011; 2013), and is designed to include grade control structures and depressional features for water retention, groundwater recharge, and collection and management of sediment. Channel capacity and floodplain storage will be maintained. Riparian and depressional wetlands will be expanded, enhancing functionality and acreage of wetlands in this portion of the site, and can serve as mitigation for potential impacts to wetlands and waters of the United States and State of California associated with implementation of the Specific Plan, if needed.

Channel planform in this area is designed as a braided channel, consistent with regional relationships (see Figure 5) for the design slope and discharge. Several secondary channels are included in the design at an elevation 1 foot higher than the main channel bottom and are anticipated to be inundated on a nearly annual basis.

The proposed design is intended to reduce high-flow velocities at the mouth of the restored trapezoidal channel, resulting in sediment sequestration through aggradation with modulated release over time and active channel migration downstream of the project reach, but upstream of the sensitive meadow areas to the east. Functionally, this configuration is intended to mimic the channel functions of 200 years ago, when this reach likely was the location where sediment and wood was stored following major events, before being supplied more gradually to the meadow reach downstream where overbank silts and clays have been deposited over the past 10,000+ years (Hecht and Jett, 1988).

Finally, it is important to note that maintenance and protection of existing bridges and infrastructure is a key component of the restoration plan. In particular, a set of paired monitoring wells will need to be modified or relocated as part of the proposed project, and a power pole will need to be relocated. Similarly, the restoration project will include traditional hardened banks and boulder slope protection near bridges and where high velocities and scour potential may threaten proposed lodging or improvements. In some cases, this may be combined with bioengineered slope stabilization methods.

Inset Olympic Channel Wetland (Sheet 3.5)

The proposed Olympic Channel restoration concept is designed to include grade control structures and depressional features for water retention, groundwater recharge, and collection and management of sediment. Under the proposed Specific Plan stormwater generated on site will be modulated and treated by various Low-Impact Development approaches and in-line stormwater BMPs. Stormwater discharge from these structures to bioswales along a newly-created Olympic Channel corridor will further reduce and polish stormwater as it exits the storm drain system. Additionally, sediment-laden runoff from portions of the upper mountain, outside of the Specific Plan boundary, will be routed into the Olympic Channel swale, where sediment and other contaminants can be sequestered.

Riparian and depressional wetlands will be expanded, enhancing functionality and acreage of wetlands in this portion of the site, also helping to mitigate for potential impacts to wetlands and waters of the United States and State of California associated with implementation of the Specific Plan. This increase will include daylighting a portion of the Searchlight Pond storm drain, and relocating the storm drain outfall to the south. This also allows for a settling area to be created upstream of the Emergency Vehicle Access (EVA) crossing, so that the crossing and associated culverts can be used to control grade, and serve as a point of access for maintenance of the basin, if necessary.

Retention of water in this area provides one of the greatest opportunities for enhancing recharge to the shallow aquifer and perhaps the deeper Olympic Valley Groundwater Basin as well. Raynak and Hudson (2014) identified sandy loams and gravels in this area, typical of alluvial fan deposits where recharge has been shown to occur in this valley (Hecht and Jett, 1988; Moran, 2013). Combined with targeted management of Searchlight Pond outflows, infiltration over this expanded area has the potential to increase percolation and recharge to the aquifer, for storage and later release to the stream and/or extraction by the Squaw Valley Public Service District.

Cut and Fill Volumes

Based on this preliminary conceptual design, the earthwork associated with the channel/floodplain work would result in roughly 48,000 cubic yards of cut, with 3,400 cubic yards of fill placement, resulting in a net export of approximately 44,600 cubic yards. It is anticipated that much of this material will be usable in the valley or for on-mountain operations, and off-haul outside the valley will not be required.

Critical elevations for design

Channel profiles shown in Appendix B provide an overview of channel elevations and slopes throughout the restoration reach. Channel slope and associated elevations are based on the requirement to conform grading to the existing channel at the upstream and downstream limits of the project, and with grading for improvements and construction associated with the Specific Plan. Similarly, bridge improvements are not proposed for the Squaw Valley Road and Village East Road bridges, so channel restoration improvement must conform at these locations as well.

An existing wastewater line crosses the Squaw Creek channel immediately downstream of the Far East Road Bridge, and is not proposed to be relocated. Accordingly, the channel bed elevation is set to conform to the elevation of the concrete casing around this pipe, currently exposed, and additional boulder protection will be placed to prevent damage to the pipe and encasement. As a result of this approach and conform points noted above, along with the design requirement to provide passage for small fish species at this location, channel slopes are steeper downstream of the wastewater line than upstream.

3.3 Habitat and Hydraulic Modeling of the Proposed Design

The proposed channel improvements are intended to retain sediment while also maintaining sediment transport continuity. Concurrently, we aim to reintroduce complexity to the system so high-quality habitat is more available over a range of flows. These objectives are not necessarily conflicting, but do require special attention to the design approaches and structural elements, so that we can a) evaluate the likelihood of the proposed elements achieving the objectives, and b) screen the design for unanticipated negative effects, such as bed aggradation and/or extreme high velocities, which may threaten infrastructure. We have therefore used a 2D hydraulic modeling approach to simulate existing and proposed water depths, velocities, and shear stresses at a range of flows, and have applied these variables to evaluate fish habitat suitability and calculate sediment transport capacity throughout the stream over a range of flows.

MODEL DEVELOPMENT AND PARAMETERIZATION

The model used for this study was the National Center for Computational Hydroscience and Engineering two-dimensional (CCHE2D) model, version 3.29.0. The governing equations driving the flow model of CCHE2D are based on the depth-averaged Navier-Stokes equations, and are solved over a structured, smoothed algebraic mesh. The model is capable of handling unsteady flow simulations with multiple inlets, and mixed flow regimes (combination of subcritical and supercritical flow). The model build in the present case utilizes inflow hydrographs from the December 2005 storm, as reported by Sound Watershed Consulting. The features of CCHE2D listed above—along with its reliability from strict enforcement of conservation of mass—make it an ideal tool for this application.

Regional one-foot contour data was developed by Andregg Geomatics using aerial photogrammetry methods, supplemented with detailed ground surveys of the channel, floodplain, and bridge features. Data from all sources were combined and reviewed for quality control in Autodesk Civil 3D to generate a triangular irregular network (TIN) depicting the existing conditions at the project site. The TIN was exported to the computational mesh generation module of CCHE2D to create a gridded representation of the existing bed topography suitable for hydraulic calculations. A similar procedure was followed for modeling the proposed topography, using contour data from conceptual channel improvement plans. The final mesh used for simulations was a grid of over 110,000 elements, roughly 3 feet by 3 feet in size.

CCHE2D simulates bed roughness over the modeling domain by assigning each area in the computational mesh a Manning n value. Roughness was categorized as one of four values as follows:

Manning n Value	Description
0.035	Channel bed
0.045	Sparsely vegetated banks/floodplain; newly-graded banks/floodplain (post-project)
0.075	Densely vegetated banks/floodplain
0.250	In-channel rootwad (post-project)

Roughness coefficients have different meanings in the context of one, two, or three dimensional modeling (Morvan and others, 2008) so it is important to acknowledge what features the coefficient is meant to represent in the modeling application at hand. Here, roughness values have been selected to represent grain roughness only;

that is, friction arising from features on the channel boundary (i.e. bed particles and vegetation). Roughness coefficients were not adjusted for sinuosity, contractions, expansions, or other channel irregularities since form roughness (deceleration of flow caused by pressure gradients arising from irregularities in the channel boundary) is intrinsically accounted for in 2D models.

Hydrographs from the December 30 to 31, 2005 storm event were used as input for stream discharge. This event was chosen because it is known to have had channel-altering effects regionally, making it appropriate for evaluating sediment transport dynamics. The return period of the December 2005 event was roughly 5 to 10 years. Analyzing a single, large-magnitude event allowed "snapshots" of smaller return period events to be taken on the rising and falling limbs of the hydrograph.

The hydrographs were developed from stream flow data from gages on the North Fork, South Fork, and mainstem of Squaw Creek. There is no gage on the Olympic Channel so a hydrograph needed to be synthesized. To do so, the hydrologic modeling study by MacKay and Somps Civil Engineers (2012) was used to estimate a scaling factor. Discharge in the Olympic Channel was found to be approximately 10 percent of the sum of the discharges in the North and South Forks of Squaw Creek. The major limitation of this approach is that it neglects potential differences in timing of the flood pulses from the Olympic Channel versus the North and South Forks. However, the Olympic Channel enters Squaw Creek close to the model outlet, so the vast majority of the modeling domain is unaffected by assuming the hydrograph timing is similar.

The only data available for calibrating model results were photographs from the December 2, 2012 event and anecdotal information. The flow inundation extents from the model were carefully examined against photographs from the same times, and the model was found to perform within reason.

Sediment Transport

Shear stress over the project reach was extracted from the 2D model to evaluate changes in sediment transport characteristics for a range of bed material size classes. By analyzing how the design alters spatial patterns of stream competence, or the stream's ability to transport sediment, so we can highlight potential areas of concern for scour or deposition and adjust the design accordingly. Stream competence was mapped for pre- and post-project conditions at 250 cfs, and by calculating the maximum particle size able to be mobilized at a Shields parameter of 0.03. Bankfull flow (roughly 250 cfs) is an appropriate discharge in a discussion of sediment transport since it often corresponds with a stream's ability to do work on the channel. We acknowledge that selecting a threshold (critical) Shield parameter to define the beginning of motion is subject to debate and requires making a number of simplifying assumptions; 0.03 is a widely accepted value in the scientific literature for representing a small, but measureable amount of gravel movement. Model output for shear stress was converted to maximum particle size mobilized using:

$$d_s = \frac{\tau_0}{(\gamma_s - \gamma_w)\tau_{*c}}$$

wherein d_s is the maximum particle size mobilized; $\tau_0$is the shear stress; γ_s is the specific weight of sediment (assumed as granite with a specific gravity of 2.65); $\gamma_w$is the specific weight of water; and τ_{*c} is the Shields parameter. In the interest of clarity, maximum particle sizes were reclassified in GIS to present the results in terms of standard Wentworth size classes for sands, gravels, cobbles, and boulders (<2mm, 2 to 64 mm, 64 to 256mm and >256mm, respectively; see Figure 6).

Physical Habitat Suitability Index (HSI) Modeling

Output from the 2D model was used to estimate changes to physical components of aquatic habitat (depth and velocity) from the pre- to post-project condition. The primary purposes of the HSI modeling were: (1) quantify gains or losses in high-quality habitat from the proposed channel configuration during environmentally significant flows, and (2) evaluate how the design improves longitudinal connectivity (i.e. fish passage) for species with limited jumping ability.

For the purpose of quantifying gains in high-quality habitat, brown trout were chosen as the target species. In fish surveys, brown trout consistently outnumbered rainbow trout in fish surveys, and numeric habitat criteria for Lahontan cutthroat trout are limited. The depth suitability index (DSI) curves and the velocity suitability index (VSI) curves were compared for brown trout (Raleigh and others, 1986) and rainbow trout (Raleigh and others, 1984), and were found to be very similar. However, the curves for brown trout indicated they are the more sensitive species (i.e. narrower range of optimal conditions), and thus were chosen as the target species.

Flows were carefully selected for HSI modeling so as to illuminate habitat conditions during critical times for fish survival. A low magnitude, frequent and long duration flow is significant in evaluating holding habitat just before and after the annual hydrograph peak and before the creek goes dry in the summer. A flow duration curve was generated from eight years of streamflow data (water years 2003 to 2010, Sound Watershed Consulting), from which 4 cfs was selected for being near the low flow inflection point (roughly 50 percent exceedance). A low magnitude, long duration flow is also significant in evaluating worst-case conditions for sculpin passage. The design objective of increasing the inundation area of the 2-year flow not only provides for fine sediment detention and groundwater recharge, but also increases the amount of refuge habitat for fishes. A flow of 550 cfs (roughly the peak of the December 2005 event) was selected because it fully inundates the proposed floodplain, and will adequately depict changes to overbank habitat.

The results of HSI modeling were aggregated into a single, composite suitability index (CSI) which is a function of the DSI and VSI. Typically, the CSI calculation includes a third suitability index to characterize the channel substrate; however, it was not considered in this analysis because a) variability in bed material size throughout the project reach is low, and b) the spatial distribution of optimal-sized gravels is more important for modeling of spawning habitat which was not considered since flow in the project reach is intermittent and will not typically sustain brown trout embryos through the late fall and winter. The CSI was calculated as the geometric mean of the DSI and VSI at each modeling node; this is one of several established methods for calculating the CSI (USGS, 2001), and was selected for showing the best contrast among low-, moderate-, and high-quality habitat, on a scale from 0 to 1.

Fish Passage Modeling

For the purpose of evaluating improvements to longitudinal connectivity, Paiute sculpin were chosen as the target species. Unlike trout, sculpin cannot jump, so their ability to move upstream is largely a function of their swimming performance. No studies were found that quantified swimming performance of Paiute sculpin so data for other species of sculpin with similar life histories and body morphologies were used as surrogates. Studies for swimming performance of mottled sculpin (*Cottus bairdi*) and slimy sculpin (*Cottus cognatus*) generally agree that mean sustained swimming speeds are roughly one foot per second with burst swim as fast as three to four feet per second (Webb, 1978; Facey and Grossman, 1990; Aedo and others, 2009). The threshold flow velocity for designating a portion of the project reach as impassable was set at 1.8 feet per second. This was selected for being at the upper end of the range for sustained swimming velocities found in the literature, but below the possible burst swimming speed to account for uncertainty in burst speeds specific to Paiute sculpin. In addition to high velocities, steps in the channel bed are also passage barriers to sculpin since they cannot jump. The same 3D surface of the channel bed used for hydraulic modeling was input to GIS to generate slope maps. A threshold slope value of 10 percent was selected for being impassable based on the average body size of Paiute sculpin (2 to 4.5 inches) and the grid size of the 3D surface (1 foot by 1 foot cells). In other words, anywhere with an abrupt drop of 0.1 feet or greater is designated impassable. Where an abrupt drop will be submerged and therefore passable, a deep areas grid element was included and used to designate a location as impassable only if the bed slope was greater than 10 percent and the flow depth was less than 0.2 feet.

In summary, the passage map shown in Figure 7 was generated using the following logic statement: IF bed slope is greater than 10 percent AND depth is less than 0.20 feet, OR IF velocity is greater than 1.8 feet per second, THEN a cell is impassable, OTHERWISE the cell is passable. Passage throughout the project reach can be visually evaluated by searching for longitudinal discontinuities in the passable (green) zones.

FINDINGS

Sediment transport continuity

Figure 6 shows the modeled changes in shear stress and sediment transport capacity, and highlights the anticipated low velocity, depositional environment of newly created floodplain areas. For the most part, sediment continuity is anticipated to be maintained in a similar manner to the existing condition, with a mobile gravel and cobble main channel bed at the design bankfull flow of 250 cfs. The potential for scour is anticipated to remain relatively unchanged, including scour potential where the existing sewer line crosses the channel. Boulder bed, bank, and slope protection will be necessary, however, in order to protect infrastructure at this location.

The model also highlights a potential depositional area upstream of the Far East Road bridge and existing sewer line crossing, where the channel slope approaches zero. Sound Watershed Consulting and Friends of Squaw Creek have completed a number of bed material grain size surveys, and report median grain size (D50) to be approximately 20 to 30 mm, with the 16th percentile (D16) values of 1 to 15 mm and 84th percentile (D84) values around 40 mm. This is consistent with model results for existing conditions, and also indicates that a shift toward smaller bed material may occur at this location as a result of the restoration project. In order to address this change, final design iterations will include log and boulder vanes to constrain the channel and increase velocities such that a band of gravel and cobble may be transported through this reach.

Habitat

Combined Suitability Indices (CSI) for pre- and post-project conditions at 4 and 550 cfs are shown in Figures 8 and 9. Appendix C includes figures showing modeled depths and velocities at 4 and 550 cfs, which provide the basis for the CSI calculations. Figure 8 (4 cfs) shows a shift toward a greater portion of the total area being dominated by high-quality habitat in the post-project condition. The total wetted area increases by 11,500 square feet; of that increase, 9,600 square feet have a CSI of 0.7 or greater. In general, areas of high-quality habitat are associated with deep pools located at the outsides of meander bends. Patches of high velocity are shorter in the longitudinal direction meaning less energy is needed to migrate from pool to pool.

A similar trend exists at 550 cfs (see Figure 9) where the percent of low-quality habitat decreases and the percent of high-quality habitat increases. The total wetted area of any CSI value increases by 68 percent from 141,210 to 237,030 square feet. Roughly 27,000 square feet of the increased area has a CSI of at least 0.7. Nearly all of the high-quality habitat at 550 cfs is located in overbank areas, which are anticipated to provide slower-moving water for temporary holding during the overbank flow event.

Fish Passage Modeling

As anticipated, the fish passage modeling results for pre-project conditions show a clear passage barrier just downstream of the Far East Road Bridge where Squaw Creek passes over the sewer line and associated drop structure. The same location is modeled to be passable under restored conditions, but channel hydraulics may not be entirely favorable for sculpin passage. The results suggest that the three proposed riffles at meander inflection points downstream of the Far East Road Bridge are only passable through a narrow corridor along the channel fringes. The limiting factor at the riffles is flow velocity which averages 2 to 2.5 feet per second. One study suggests that this velocity is well within the burst swimming ability for mottled sculpin (Aedo and others, 2009). It is, however, uncertain how the data translate to Paiute sculpin, so conservative assumptions used in the analysis show this to be impassable for sculpin.

The fish passage modeling results have highlighted a potential shortcoming of the conceptual design that should be addressed in subsequent design iterations. Where feasible, the slope of the proposed riffles will be further reduced to slow velocities. The coarse bed material used to armor the bed at this location includes cobbles and boulders that are anticipated to increase roughness and decrease velocity. This is a critical design element, since providing passage at this location will open 0.5 miles of additional habitat.

DISCUSSION

2D modeling indicates that the proposed design will provide areas for sediment retention, and, with additional design elements, will provide sediment transport continuity along the restoration reach. The proposed design increases the total amount of habitat in the reach and increases the percent of high quality habitat in the reach; the anticipated effect is that chances for survival will be increased during flows stressful to aquatic biota. Additional holding habitat will be available during low flow, and additional refuge habitat will be available during high flows. The current conceptual design also greatly increases the chances for Paiute sculpin and juvenile trout species to access habitat upstream of the existing drop structure, but additional design modifications will be required to resolve the riffle velocities, improve longitudinal habitat connectivity and provide protection against channel and bank scour.

By increasing channel complexity, the likelihood for aquatic biota to persist in the project reach increases since optimal conditions are available at a range of flows. At low flows, the pools at meander apexes are a critical design element for rearing habitat. Many of the pools will include rootwads protruding from the banks to provide cover. The rootwads will also help maintain the pools year to year by inducing scour during moderate to high flows. The fish passage analysis indicated that migration from pool to pool during low flows is possible by the species with the lowest swimming performance. Moreover, the design will improve or eliminate the existing barrier to passage just downstream of the Far East Road bridge, and provide longitudinal connectivity to an additional half mile of Squaw Creek. At moderate flows, velocities in pools may be intolerable for juvenile fishes; at this point backwater areas at the toes of BESO structures become important for shelter against being flushed downstream. At high flows a significant area of overbank habitat will become available for all life stages to seek refuge.

The preceding discussion has focused only on how the quantity and quality of "living space" is improved, but it is equally important to consider whether food base abundance (i.e. macroinvertebrates) will be sufficient to support higher trophic levels. There is a growing body of evidence that warns against assuming biological diversity is increased solely through increased physical heterogeneity (Palmer and others, 2010; Laub and others, 2012). In projects that failed to increase biodiversity, the control of watershed-scale processes (i.e. flow and sediment regimes) on lower trophic levels was usually neglected (Miller and other, 2009; Palmer and others, 2010). In the case of Squaw Creek, recovery of the fishery may be severely limited by the food base as affected by annual zero flow periods. In the most recent Truckee River Water Quality Monitoring Annual Report where bioassessment monitoring was completed, the Eastern Sierra index of biological integrity (IBI; a metric of benthic macroinvertebrate richness) for Squaw Creek was the lowest of all regional sites (CDM-Smith, 2011). In addition to sediment control and aesthetic benefits, the widened floodplain is aimed at increasing the amount of riparian habitat, which in turn, has the potential to maintain cooler water temperatures when flow is present, supporting a more abundant macroinvertebrate community. The importance of terrestrial subsidies in supporting diverse aquatic food webs is well-documented (Wallace and others, 1997; Baxter and others, 2004), and could be significant in substantiating the food base for the fishery.

It is also important to recognize that the proposed design does not address watershed-wide sources of sediment and/or water. Ongoing sediment source management is currently carried out by Squaw Valley Ski Resort with the intent of reducing sediment production from the upper watershed. Sound Watershed Consulting (2013) and others have pointed out the potential for targeted management of the Searchlight Pond to addess both sediment supply and increase late summer hydrologic support in these areas. These management elements are not included as part of the proposed restoration design, but if carried out appropriately, could improve the likelihood of achieving the design objectives described herein.

3.5 Estimated Costs

We anticipate the construction costs associated with these alternatives to potentially be as low as $1.2M and as high as $2.2M. Conceptual designs, however, lack the detail necessary to develop engineering-level estimates of project design, permitting and construction costs. Types, quantities and/or volumes of materials are not provided at this level of design. In an effort to elaborate on this estimate, however, we provide a list of items for each alternative that may greatly influence total cost.

- Earthwork and off-haul. If material can be used nearby, or in conjunction with meadow restoration efforts downstream, costs may be sharply reduced.

- Type and size of material used for slope protection. If bioengineered cribwall structures area required over traditional rock-slope protection, costs will increase.

- Timing of work. If infrastructure elements, such as the EVA Road, monitoring well and power pole relocation can be timed with improvements associated with the Specific Plan, restoration project costs can be sharply reduced. If these elements need to be constructed as part of the restoration work, costs will increase.

- Design-Bid-Build versus Design-Build. Implementing the project on a Design-Build basis typically results in a streamlined design process, avoiding the need for detailed construction document bid packages. Construction costs can be established up front to minimize change orders and extra costs during project implementation.

3.6 Monitoring and Adaptive Management

The active and dynamic nature of the channel in these areas will require an active monitoring and adaptive management program, so that channel processes can be monitored for risk to adjacent areas, and sediment can be removed if aggradation reduces channel capacity and flood conveyance to a point that infrastructure is threatened. Performance criteria and associated monitoring program elements and data should be used as the basis for adaptive management recommendations. Based on anticipated post-project sediment delivery rates and the conceptual grading, sediment removal may be necessary from the head of the Olympic Channel. The frequency of sediment removal is anticipated to be on a decadal time scale, but perhaps as frequently as every 3 to 5 years, on average.

PERFORMANCE CRITERIA

Specific performance criteria may range from very specific thresholds to identification of trends, and are related directly to the project goals and objectives presented at the beginning of this report. For this particular restoration project, project success hinges on the following criteria:

- **Increased wetland, floodplain, and riparian areas.** Wetland delineations and floodplain inundation maps have been developed and now document baseline conditions. Similar as-built maps should be prepared following restoration so that increases in wetland and floodplain area may be quantified. Vegetation transects should be established prior to and after restoration so that the evolution of plant communities and associated habitat can be tracked.
- **Maintenance of sediment transport continuity.** This can be measured in terms of vertical channel stability, in which some threshold of channel aggradation or degradation can be monitored (e.g. less than 2 feet of vertical channel instability).
- **Reductions in bedload- and suspended-sediment transport over time.** This should be measured at the downstream project boundary and Olympic Channel. Specifically, improvement in Truckee River TMDL indicators, such as Squaw Creek suspended sediment annual loads and discharge-transport relationships over time.
- **Improvement in Squaw Creek TMDL indicators.** This is currently being monitored and reported in terms of benthic macroinvertebrate populations and percent of channel bed covered by fines.
- **Increased fish populations.** Biological monitoring should take place to establish baseline fisheries distribution and abundance, for comparison to post-restoration conditions.
- **Near-annual inundation of secondary channels.** Streamflow is anticipated to inundate secondary channels approximately annually, and can be documented through the use of simple crest-gages (peak stage recorders).
- **Floodplain inundation.** The design intent is for floodplains to be inundated at a range of flows. Low-lying floodplains should be inundated nearly annually, and higher floodplain areas may be inundated as infrequently as 20 percent of all years.
- **Infrastructure protection.** Threats to infrastructure must be avoided as part of this project. Routine monitoring and identification of bank erosion and scour in the vicinity of bridges should be identified and addressed without delay.
- **Increased human use and awareness.** Recreational use and public education is a stated goal of the project and can be measured in terms of increased access and awareness.

MONITORING APPROACHES

Suspended sediment concentrations and bedload-sediment transport rates are related to streamflow and watershed-wide sediment supply. Changes in suspended sediment concentration over time may result from landscape processes or human disturbances in a watershed (Warrick and Rubin, 2007). Suspended sediment rating curves are perhaps the best tool for establishing sediment baseline loading prior to restoration or BMP implementation and for assessing the change in fine sediment supply as BMPs and restoration activities are implemented (Hecht and others, 2008). As sediment supply within a watershed diminishes, sediment concentration or bedload transport rate at a given streamflow will also diminish. Therefore, tracking changes in the relationship between suspended sediment transport and streamflow (as shown by 'shifts' in the suspended sediment rating curves) allows for an evaluation of restoration effectiveness.

Concurrent measurement of suspended sediment concentration, streamflow, and turbidity is therefore recommended as the primary means of monitoring changes in sediment delivery over time and in response to restoration in the Squaw Creek Watershed. This should begin prior to project implementation so that pre- and post-restoration conditions can be compared. Continuous streamflow and turbidity measurements in subwatersheds will also allow for computation of daily and annual suspended sediment loads and load duration—comparable to monitoring efforts on the main stem and the baseline data used to develop the TMDL.

Annual geomorphic and biologic surveys should be carried out concurrently with the sediment monitoring program so that sediment and streamflow trends can be related to changes in channel morphology and physical habitat. This should include standard geomorphic data, such as channel reconnaissance walks and qualitative observations, detailed sketch maps, channel facies maps, photopoints, cross-section topographic surveys, and monumentation for year-to-year comparisons and repeatability.

The channel restoration design includes a number of considerations to enhance physical habitat over a range of flows for juvenile and adult life stages of brown trout, rainbow trout, and Paiute sculpin. Increase in fish abundance may be limited by food availability, however, and a macroinvertebrate monitoring program in the restored reach is recommended. Initial years of post-project biological monitoring should include biological surveys to evaluate whether newly-accessible habitat poses an attractive nuisance, in that fish may become stranded in pools as the channel dries.

ADAPTIVE MANAGEMENT

Adaptive management strategies should be employed if monitoring indicates that performance criteria are not being met. Potential strategies may include sediment removal from the channel if aggradation reduces flood capacity to a point where infrastructure is threatened, introduction of roughness elements to promote scour if channel aggradation is occurring, and/or channel modification or introduction of channel roughness if floodplain inundation is not achieved.

4 LIMITATIONS

This report was prepared in general accordance with the accepted standard of practice in surface-water and groundwater hydrology existing in Northern California and the Sierra Nevada for projects of similar scale at the time the investigations were performed. No other warranties, expressed or implied, are made.

As is customary, we note that readers should recognize that interpretation and evaluation of subsurface conditions and physical factors affecting the hydrologic context of any site is a difficult and inexact art. Judgments leading to conclusions and recommendations are generally made with an incomplete knowledge of the conditions present. More extensive or extended studies, including additional hydrologic and sediment transport baseline monitoring, can reduce the inherent uncertainties associated with such studies. We note, in particular, that many factors affect local and regional hydrology and hydraulics levels. If the client wishes to further reduce the uncertainty beyond the level associated with this study, Balance should be notified for additional consultation.

We have used standard environmental information such as precipitation, hydrology, topographic mapping, and soil mapping, in our analyses and approaches without verification or modification, in conformance with local custom. New information or changes in regulatory guidance could influence the plans or recommendations, perhaps fundamentally. As updated information becomes available, the interpretations and recommendations contained in this report may warrant change. To aid in revisions, we ask that readers or reviewers advise us of new plans, conditions, or data of which they are aware.

Concepts, findings and interpretations contained in this report are intended for the exclusive use of Squaw Valley Ski Holdings LLC under the conditions presently prevailing except where noted otherwise. Their use beyond the boundaries of the site could lead to environmental or structural damage, and/or to noncompliance with water-quality policies, regulations or permits. Data developed or used in this report were collected and interpreted solely for developing an understanding of the hydrologic context at the site as an aid to conceptual planning and channel and wetland restoration design. They should not be used for other purposes without great care, updating, review of sampling and analytical methods used, and consultation with Balance staff familiar with the site. In particular, Balance Hydrologics, Inc. should be consulted prior to applying the contents of this report to geotechnical or facility design, routine wetland management, sale or exchange of land, or for other purposes not specifically cited in this report.

Finally, we ask once again that readers who have additional pertinent information, who observed changed conditions, or who may note material errors should contact us with their findings at the earliest possible date, so that timely changes may be made.

5 REFERENCES

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TABLES

Table 1. Selected flood frequencies from various sources, Squaw Creek at Golf Course Bridge Placer County, California

Percent Chance Exceedance	Recurrence Interval	Estimated Peak Discharge: PWA, 2007	Sound Watershed Consulting Gages[1]	MacKay and Somps Hydrologic Model[2]	Gage Scaling[3]	Regional Regression Equations[4]	Hagadorn, 1984
(percent)	*(years)*		*(cfs)*	*(cfs)*	*(cfs)*	*(cfs)*	*(cfs)*
50	2	705	410	2,200	200	250	
20	5		660	3,000	470	500	
10	10		860	3,500	720	740	
4	25		1,170		1,160	1,080	
2	50		1,430		1,570	1,450	
1	100	2,880	1,730	5,200	2,080	1,790	1,870

Notes:

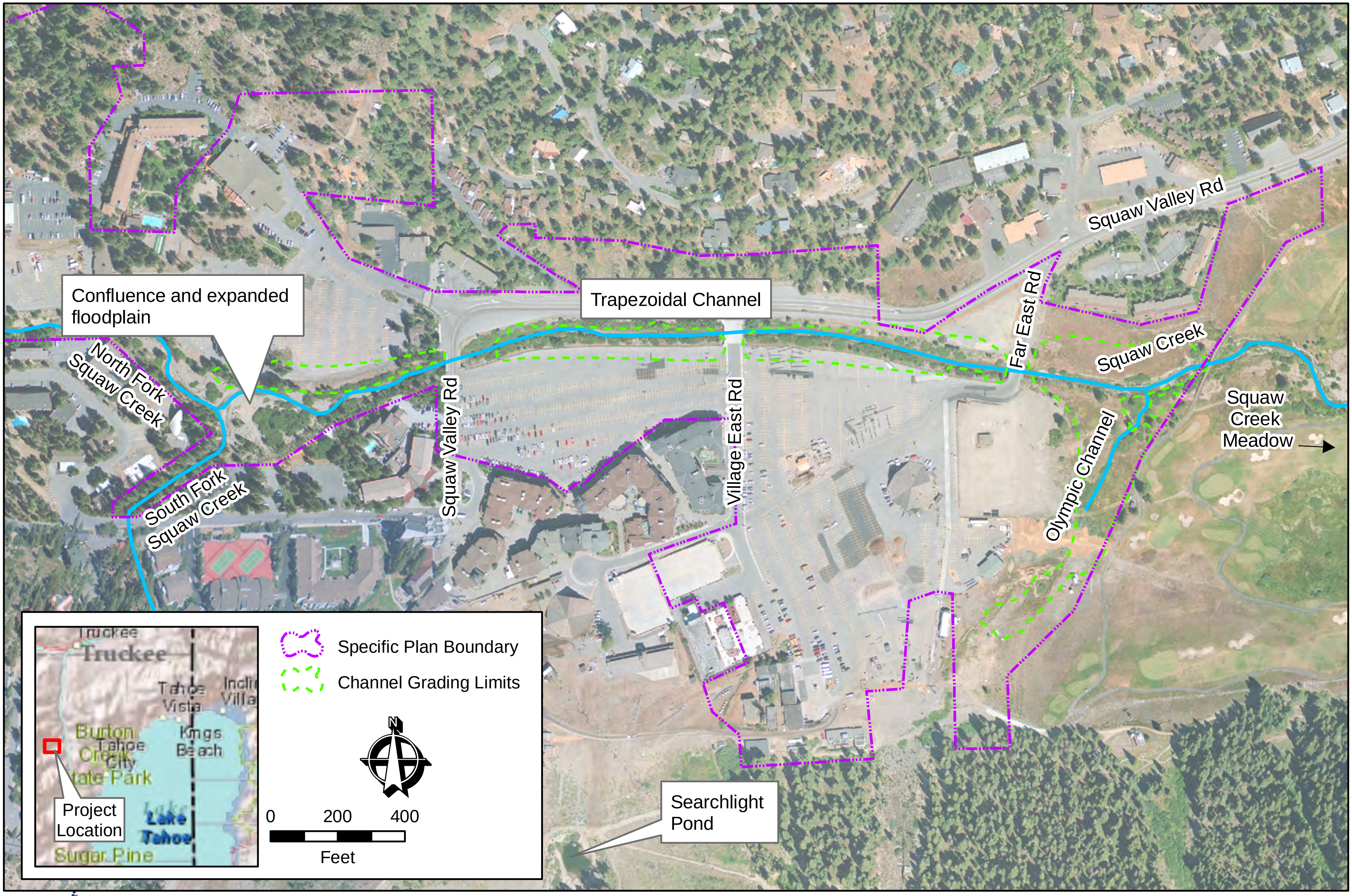
1. Analysis carried out by Balance Hydrologics using data provided by Sound Watershed Consulting. Data were only available for water years 2003 to 2010, therefore estimates from a Log Pearson Type III analysis are highly unreliable. Bulletin 17B recommends a minimum of 10 years.
2. For existing conditions and with snow melt.
3. Balance Hydrologics carried out a Log Pearson Type III regression analysis for USGS Gage 10336676 (Ward Creek at Hwy. 89 near Tahoe Pines, CA) and scaled results to the project site according to differences in drainage area.
4. Peak discharge estimates based on regional regression equations for the Lahontan region of California (Gotvald et al., 2006), and using the drainage area estimated by MacKay and Somps (2012) and mean annual precipitation from SNOTEL.

Table 2. Estimated sediment loading upstream and downstream of the Squaw Valley Village Specific Plan Area, Placer County, California

Location		North Fork Squaw Cr	South Fork Squaw Cr	Confluence	Olympic Channel	Squaw Creek at Downstream Project Boundary	Squaw Cr Downstream of Meadow
Watershed Area (sq mi)		3.5	1.7	5.2	0.42	6.2	8.2
Modeled 10-year streamflow event[1]							
Suspended Sediment Yield[2]	*(tons/event)*			168	104	349	
Estimated bedload[3]	*(tons/event)*			672	416	1396	
Total Estimated Sediment Load	*(tons/event)*			840	520	1745	
1986							
Suspended load (Woyshner and Hecht, 1988)	*(tons/yr)*						560
Bedload (Woyshner and Hecht, 1988)	*(tons/yr)*						2200
Total Estimated Sediment Load	*(tons/yr)*						2760
1987							
Suspended load (Woyshner and Hecht, 1988)	*(tons/yr)*						280
Bedload (Woyshner and Hecht, 1988)	*(tons/yr)*						77
Total Estimated Sediment Load	*(tons/yr)*						357
Application of sediment rating curves to Water Year 2009 streamflow data[4]							
Woyshner and Hecht (1988)							
Suspended Sediment Yield	*(tons/yr)*						410
Estimated bedload[3]	*(tons/yr)*						1592
Total Estimated Sediment Load	*(tons/yr)*						2002
Squaw Valley Ski Corporation data							
Suspended Sediment Yield[2]	*(tons/yr)*	24	15	39	34		
Estimated bedload[3]	*(tons/yr)*	95	59	154	136		
Total Estimated Sediment Load	*(tons/yr)*	119	74	193	170		
MacGraw and others (2001)[5]							
Suspended	*(tons/yr)*						892
Bedload	*(tons/yr)*						3568
1997 event[6]							
Deposited load	*(cu yds)*		3500				
Annual Load Estimated by Malholland (2002)						2470	6270

1 10-year streamflow hydrographs modeled according to county methodologies, as provided by MacKay and Somps.
2 Suspended sediment yields based on suspended sediment transport and streamflow data collected by Squaw Valley Ski Corporation during water years 2006 to 2010.
3 Bedload is estimated according to proportional sediment loading measured by Woyshner and Hecht during Water Year 1986 and 1987.
4 Annual streamflow provided by the Friends of Squaw Creek (http://squaw.soundwatershed.com/stream-flow-data.html)
5 The exact locations of sampling reported by MacGraw and others are not known, but are assumed to be in downstream reaches of Squaw Creek, in or below the lower meadow.
6 Based on the volume of sediment removed from the South Fork of Squaw Creek as reported by the NRCS.

FIGURES



Balance Hydrologics, Inc.

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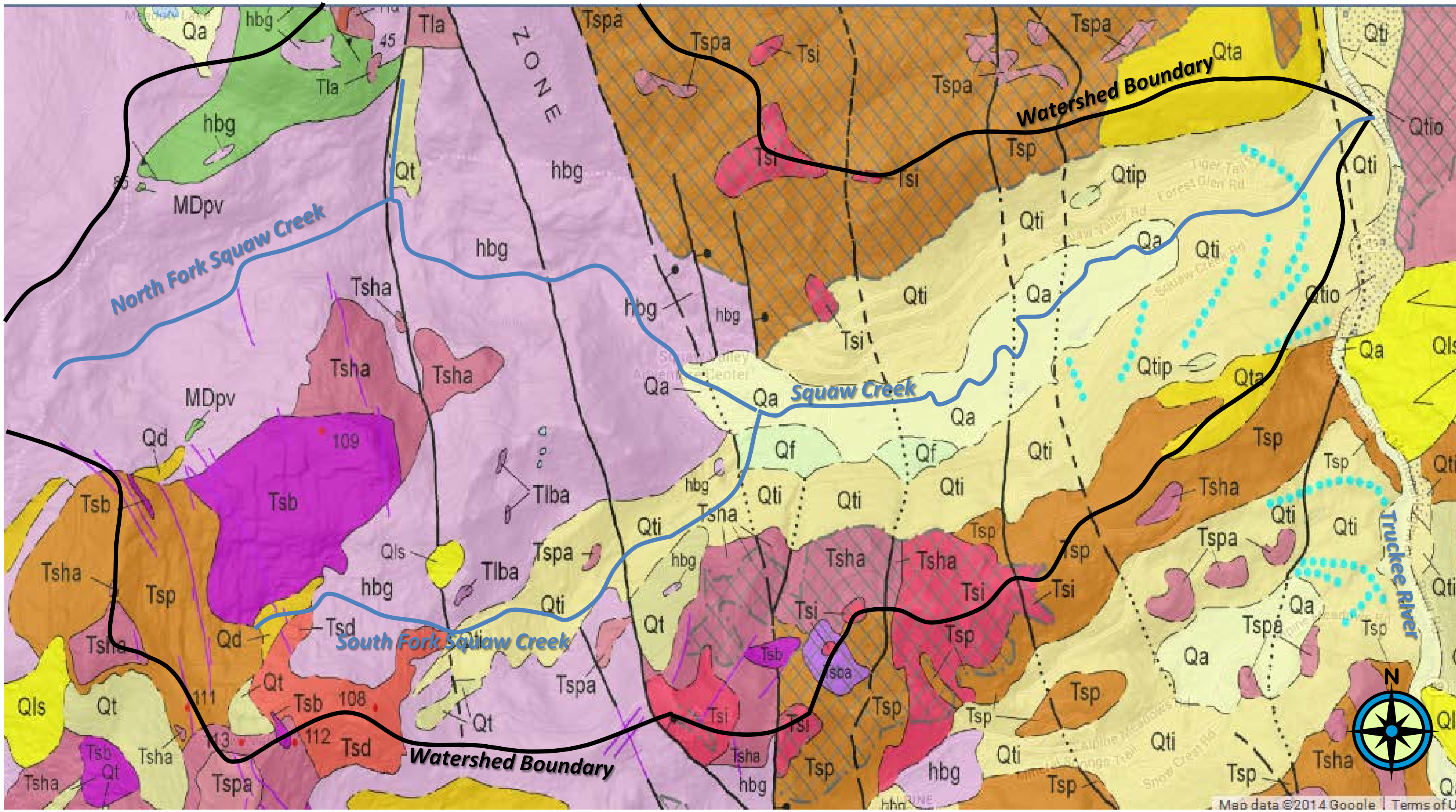
Figure 1. Squaw Creek Channel Restoration Location Map, Squaw Valley Specific Plan, Placer County, California

Aerial Photo Source: Andregg Geomatics



Geology mapped by Sylvester and others (2012)

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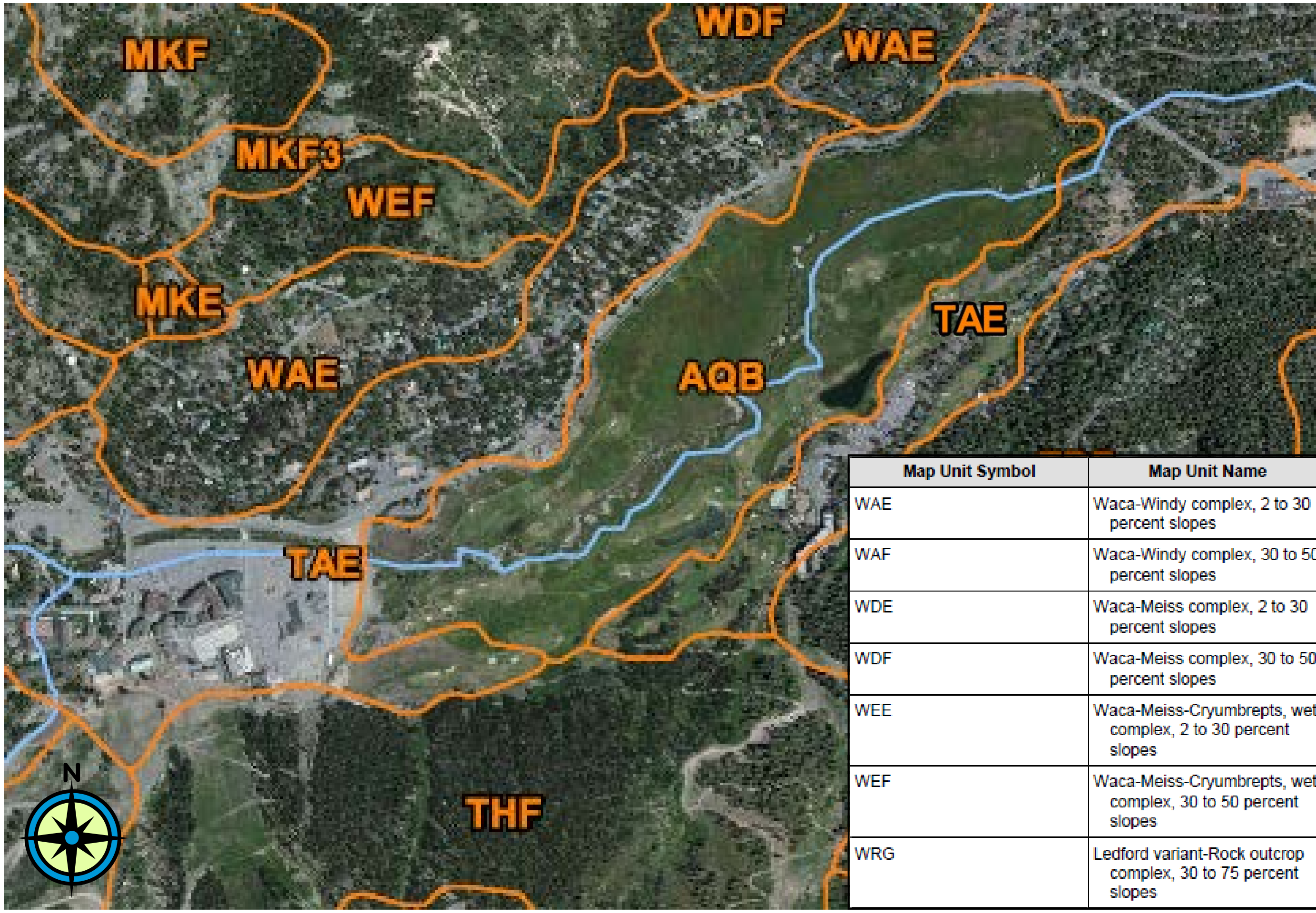
Figure 2. **Geology of the Squaw Creek watershed, Placer County, California**
The geology of the North Fork of Squaw Creek is primarily underlain by granodiorite (hbg) and differs from the South Fork and Olympic Channel watersheds, which include a mix of glacial till (Qti), volcanics (Tsd, Tsp, Tsha, Tsi, and Tsb) and granodiorite (hbg). Also note the presence of alluvial fans (Qf) at the confluence of the South Fork and Olympic Channel. Erodibility of these units varies and results in differing rates of sediment production and transport from tributaries.



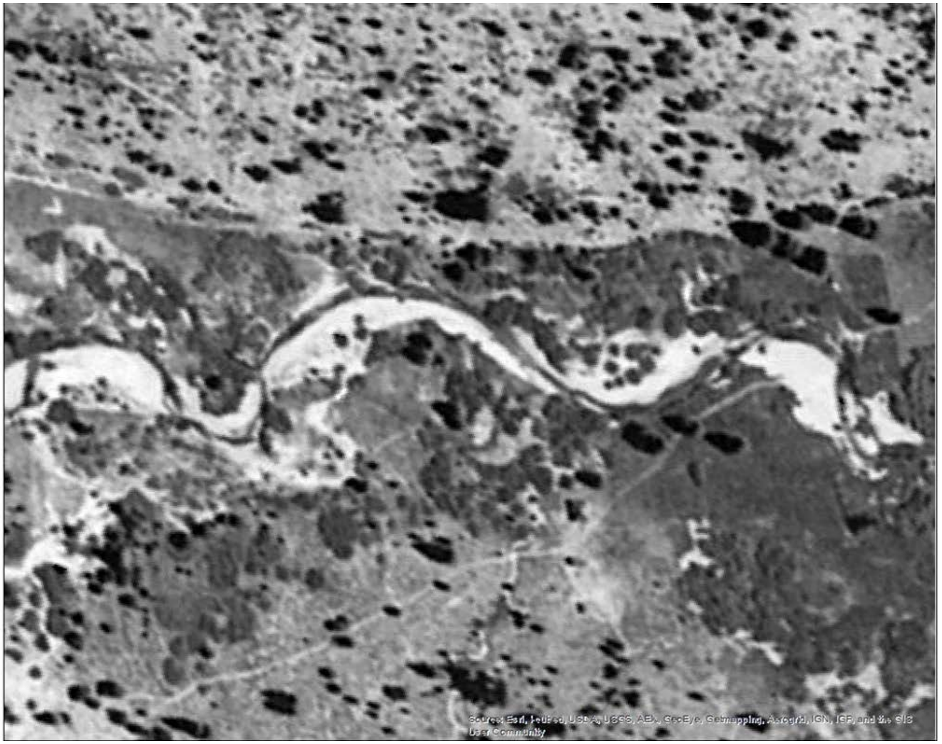
Map Unit Symbol	Map Unit Name
WAE	Waca-Windy complex, 2 to 30 percent slopes
WAF	Waca-Windy complex, 30 to 50 percent slopes
WDE	Waca-Meiss complex, 2 to 30 percent slopes
WDF	Waca-Meiss complex, 30 to 50 percent slopes
WEE	Waca-Meiss-Cryumbrepts, wet complex, 2 to 30 percent slopes
WEF	Waca-Meiss-Cryumbrepts, wet complex, 30 to 50 percent slopes
WRG	Ledford variant-Rock outcrop complex, 30 to 75 percent slopes

Map Unit Symbol	Map Unit Name
AQB	Aquolls and Borolls, 0 to 5 percent slopes
GRG	Rock outcrop, granitic
JSG	Jorge-Cryumbrepts, wet complex, 30 to 75 percent slopes
JWF	Jorge-Waca-Tahoma complex, 30 to 50 percent slopes
MHG	Meiss-Gullied land-Rock outcrop complex, 30 to 75 percent slopes
MIG	Meiss-Rock outcrop complex, 30 to 75 percent slopes
MIG3	Meiss-Rock outcrop complex, 30 to 75 percent slopes, severely er oded
MKE	Meiss-Waca complex, 2 to 30 percent slopes
MKF	Meiss-Waca complex, 30 to 50 percent slopes
MKF3	Meiss-Waca-Rock outcrop complex, 30 to 50 percent slopes, severe ly eroded
RRG	Rock outcrop, granitic-Tinker complex, 30 to 75 percent slopes
TAE	Tallac very gravelly sandy loam, 2 to 30 percent slopes
TAF	Tallac very gravelly sandy loam, 30 to 50 percent slopes
TBF	Tallac-Cryumbrepts, wet complex, 30 to 50 percent slopes
THF	Tallac-Gullied land-Cryumbrepts, wet complex, 30 to 60 percent s lopes

Soils mapped by Hanes (2002)

Balance Hydrologics, Inc.

Figure 3. Soils of the Squaw Creek watershed, Placer County, California
The location for proposed channel enhancements (white box) includes areas mapped as Tallac very gravelly loams (TAE), which differs greatly than downstream areas such as the Squaw Valley meadow, predominantly comprised of wet meadow soils (Aquolls and Borolls, AQB). Hillslopes are generally mapped as Meiss, Tallac, and Waca Series soils.



A) 1939 aerial photograph, Squaw Creek, below confluence

B) 2011 aerial photograph, Squaw Creek, below confluence

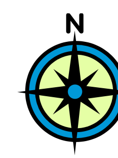


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Figure 4. Historical channel planform, Squaw Creek, Placer County, California
Historical channel patterns show sinuous channel with active bar and floodplain deposits. Current day conditions depict a straightened trapezoidal channel with restricted geomorphic processes.

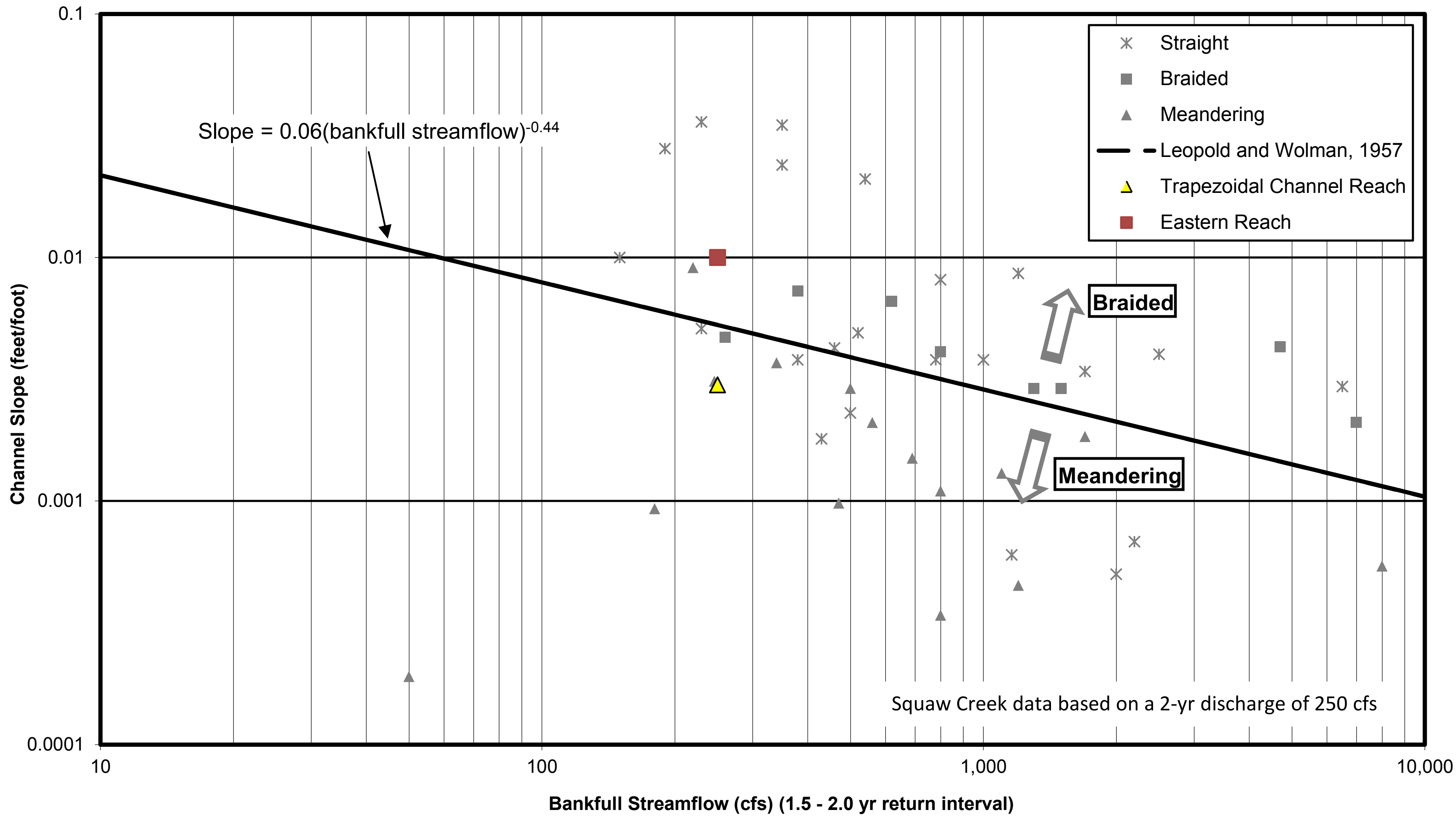

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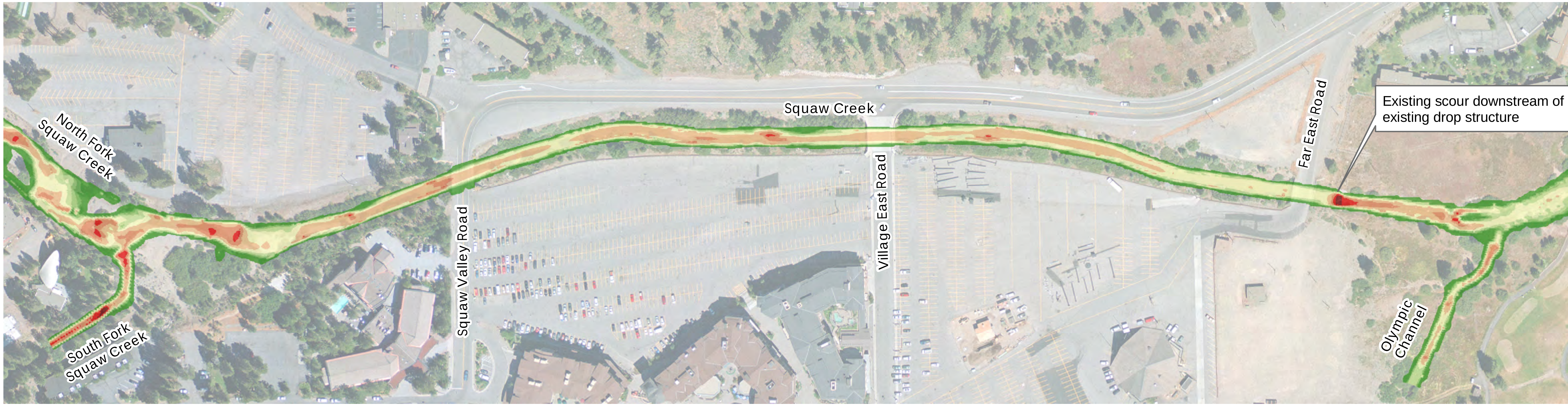
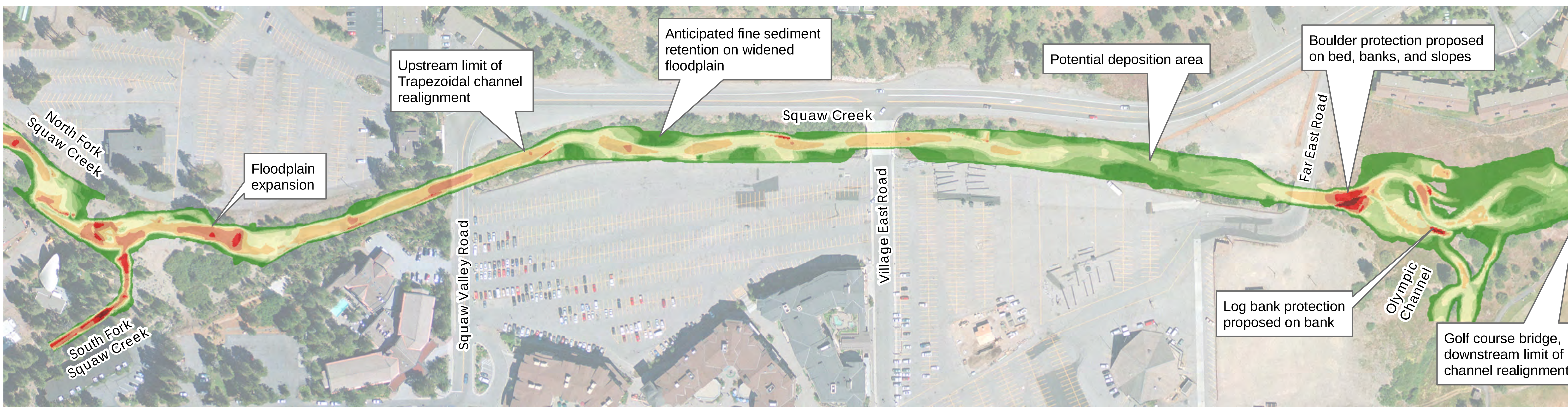
Figure 5. Squaw Creek channel planform (selected reaches) compared to predicted planform based on Leopold and Wolman (1957). The existing Squaw Creek channel exhibits two distinct reaches defined by their channel slopes: a) trapezoidal reach, and; b) reach downstream of the Far East Bridge. The latter is slightly steeper and may tend to exhibit characteristics of a braided channel.



Pre-Project Conditions



Post-Project Conditions

Aerial Photo Source: Andregg Geomatics

Balance Hydrologics, Inc.

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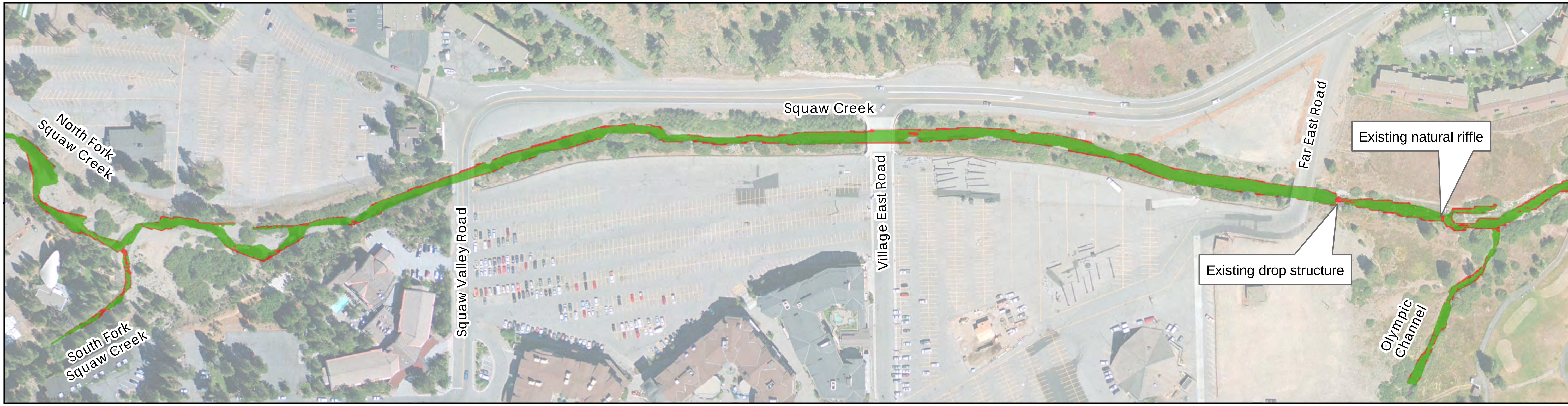
Maximum size class mobilized assuming a critical Shields Parameter of 0.03:

< 2 mm	8 - 16 mm	64 - 128 mm
2 - 4 mm	16 - 32 mm	128 - 256 mm
4 - 8 mm	32 - 64 mm	> 256 mm

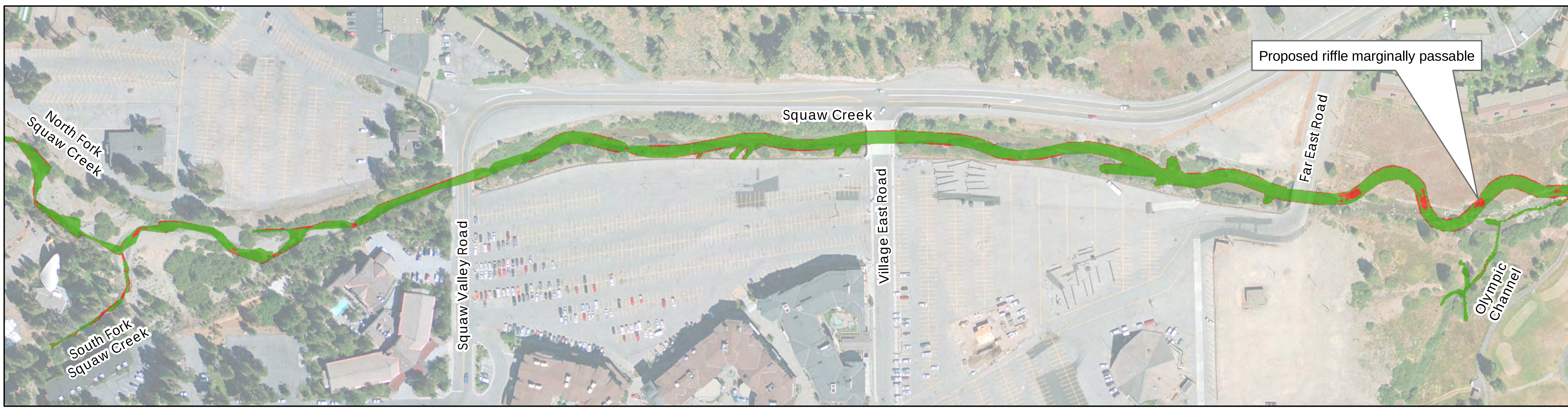
0 100 200 400

Feet

Figure 6. Pre- and Post-Project Sediment Competence at 250 cfs Squaw Creek Restoration, Placer County, California



Pre-Project Conditions



Post-Project Conditions

Aerial Photo Source: Andregg Geomatics

Balance Hydrologics, Inc.

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Passable

Impassable

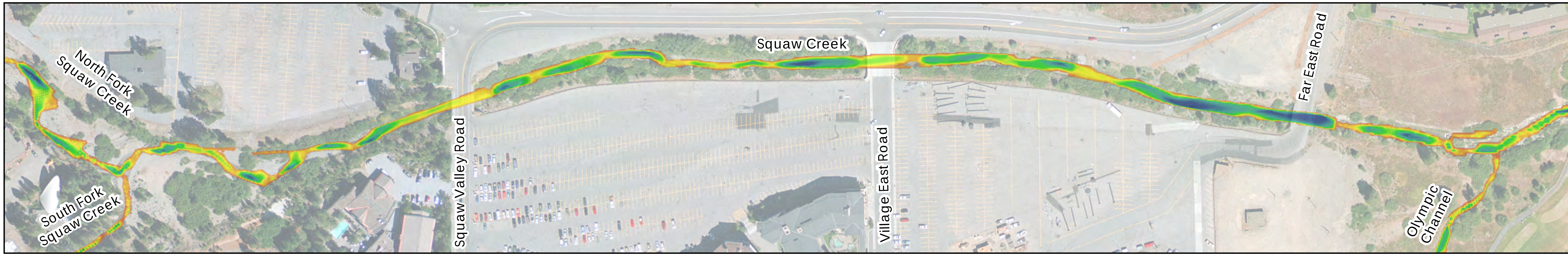
Passability is based on published criteria for mottled sculpin and slimy sculpin. Impassability occurs if bed slope > 10% and depth < 0.2 ft or if velocity > 1.8 ft/s.

N

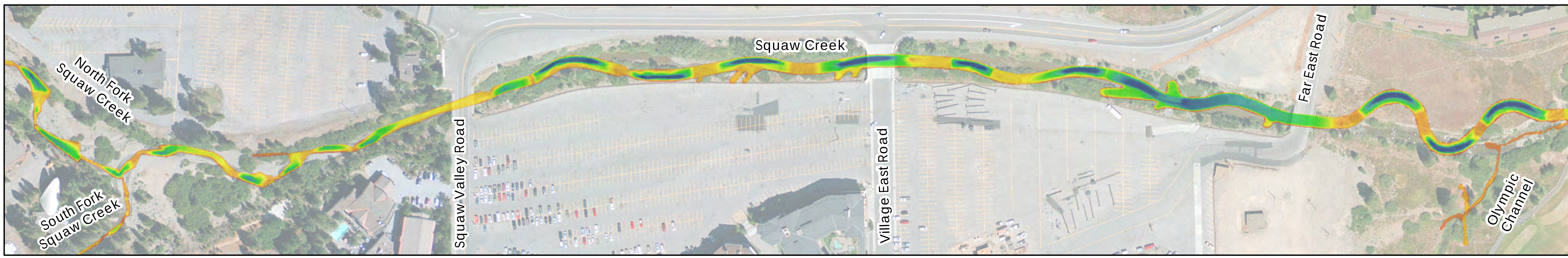
0 100 200 400

Feet

Figure 7. Pre- and Post-Project Passage at 4 cfs for Paiute Sculpin Squaw Creek Restoration, Placer County, California

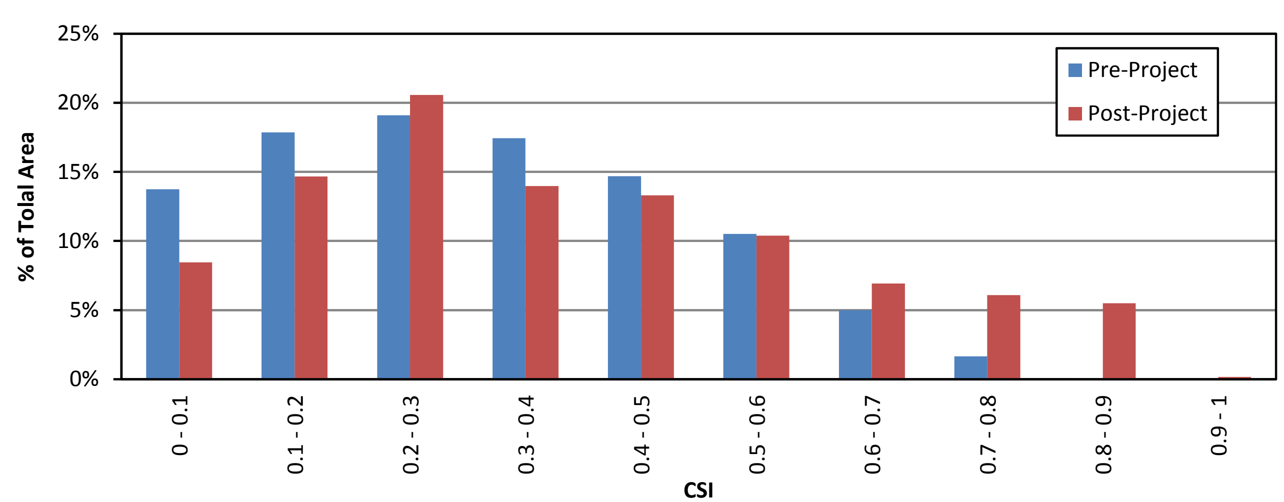


Pre-Project Conditions



Post-Project Conditions

Aerial Photo Source: Andregg Geomatics



Pre- and post-project wetted areas disaggregated by CSI for Squaw Creek from the North Fork-South Fork confluence to the golf course bridge.

CSI	Pre-Project Area *(s.f.)*	Post-Project Area *(s.f.)*
0 - 0.1	8,450	6,530
0.1 - 0.2	11,340	10,760
0.2 - 0.3	13,140	16,140
0.3 - 0.4	12,340	11,260
0.4 - 0.5	10,030	10,360
0.5 - 0.6	7,880	8,010
0.6 - 0.7	4,090	6,130
0.7 - 0.8	1,290	5,650
0.8 - 0.9	0	5,200
0.9 - 1	0	40
Total Area	68,560	80,070

According to the model high quality habitat will increase in area, with losses in low quality habitat

Balance Hydrologics, Inc.

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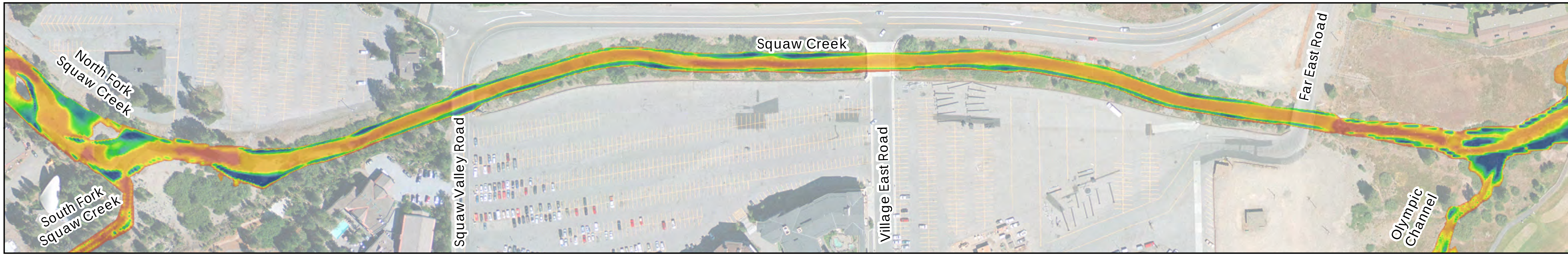
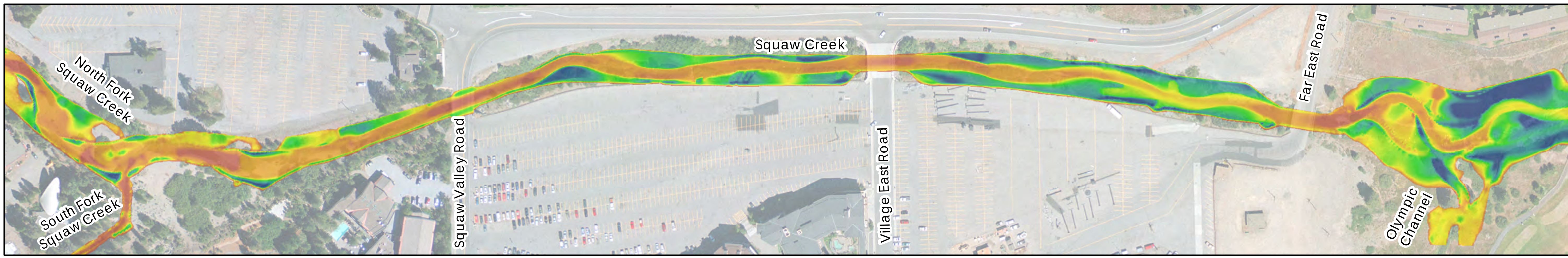
Combined Suitability Index
High : 1
Low : 0

0 100 200 400
Feet

Figure 8. Pre- and Post-Project Combined Suitability Indices (CSI) at 4 cfs, Squaw Creek Restoration, Placer County, California

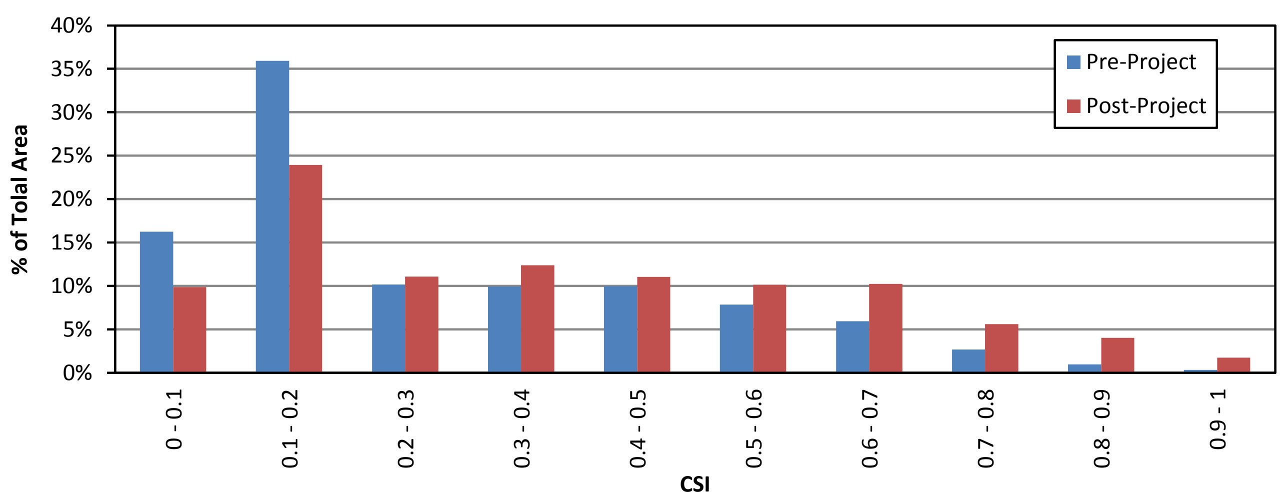


Pre-Project Conditions



Post-Project Conditions

Aerial Photo Source: Andregg Geomatics



Pre- and post-project wetted areas disaggregated by CSI for Squaw Creek from the North Fork-South Fork confluence to the golf course bridge.

CSI	Pre-Project Area (s.f.)	Post-Project Area (s.f.)
0 - 0.1	22,640	18,290
0.1 - 0.2	59,420	52,580
0.2 - 0.3	13,340	24,910
0.3 - 0.4	11,720	31,240
0.4 - 0.5	11,710	28,200
0.5 - 0.6	10,830	24,490
0.6 - 0.7	6,810	25,520
0.7 - 0.8	3,200	15,500
0.8 - 0.9	1,240	11,310
0.9 - 1	310	4,980
Total Area	141,210	237,030

At high-magnitude, low-frequency flows, habitat complexity and quality is anticipated to increase, with less low-quality habitat and more high-quality habitat than under the current impaired condition.

Balance Hydrologics, Inc.

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Combined Suitability Index

High : 1

Low : 0

0 100 200 400

Feet

Figure 9. Pre- and Post-Project Combined Suitability Indices (CSI) at 550 cfs, Squaw Creek Restoration, Placer County, California

APPENDICES

APPENDIX A

Balance Hydrologics Memo to Chevis Hosea, dated March 29, 2013: Summary of Squaw Creek Channel Enhancement Design Revisions and Response to Comments Received by the Technical Design Review Team

Memo

To: Chevis Hosea

From: David Shaw

Date: March 29, 2013

Cc: Forrest Haag, Landscape Architect
Dale Payne, Lahontan Water Quality Control Board
Virginia Mahacek, Cardno-Entrix
Mike Liquori, Sound Watershed Consulting

Subject: Summary of Squaw Creek Channel Enhancement Design Revisions and Response to Comments received by the Technical Design Review Team

This memo follows a design review committee meeting during which technical reviewers offered feedback and comments regarding conceptual channel enhancement plans for Squaw Creek within the Squaw Valley Village Specific Plan. Verbal feedback has been summarized in meeting notes circulated via email on January 23, 2013. Written comments were received from Sound Watershed Consulting (SWC) on February 11, 2013. The purpose of this memo is to summarize and respond to these comments, either through design modifications, additional analyses, or clarifications of the ideas presented.

Revised to project goals and objectives are presented first, followed by a summary of design modifications and proposed additional analysis. This memo concludes with a point by point discussion of all the comments received.

Revisions to Goals and Objectives

Design Goals and Objectives have been revised as follows:

Goals:

1. Compliance with regulatory guidance and requirements;
2. Offsetting current and historical impacts to the channel through improvement of aquatic, riparian, and wetland habitat; and
3. Enhancement of the human experience through improved aesthetics and recreational, educational, and interpretive opportunities.

Objectives:

- Reduce fine sediment (silt and sand-sized particles, 2 to 4 mm) transported and deposited in downstream reaches, for consistency with the Squaw Creek Sediment TMDL;
- Reduce fine sediment carried in suspension to the Truckee River (less than 2 mm), for consistency with the Truckee River Suspended Sediment Concentration TMDL;
- Maintain flood conveyance;
- Increase the areas and quality of wetland/riparian habitat;
- Increase frequency and duration of floodplain inundation in order to:
- Increase the areas and quality of riparian and meadow habitat;
- Reduce stream power and allow for deposition and sequestration of fine sediment, especially sands;
- Facilitate re-establishment of geomorphically appropriate channel form and process;
- Establish public access points with educational and interpretive features.

Design modifications

East End and Olympic channel confluence

Channel shape and sinuosity have been reconsidered and redesigned to account for a slightly steeper (1.2 percent) channel downstream of the Far East Road Bridge.

- The channel planform has been modified to provide high-flow secondary channels and dynamic channel movement within the floodplain corridor.
- The proposed design also aims to re-occupy abandoned historical channels, drawing on channel geometries that were stable prior to development of the site.
- Channel bed elevations will be higher than the utility crossing at the Far East Road bridge, and will include scour protection via a constructed riffle;
- The Access Road has been reconfigured to provide floodplain access to excavators and maintenance access to the mountain;
- Olympic channel swale is redesigned to promote diffuse flow and ponded water across a vegetated swale, while preserving existing riparian vegetation in functioning floodplain areas;
- A more gradual transition in floodplain width is provided in the transition from the Far East Road Bridge constriction to the floodplain enhancement area.

Confluence of the North and South Forks

- Modification of access road location;
- Minimal to no engineering in this area sediment removal and management only, if/as needed (see discussion and response to Sound Watershed design concepts below);
- Inclusion of 3:1 slopes on the north bank, pull top of bank to within 20 feet of proposed condominiums as shown in illustrative plan.

Trapezoidal channel

- Modification of sinuosity and plan form;
- Increased floodplain width;
- Establishment of appropriate channel slopes where feasible;
- Identification of existing outfalls, and inclusion of Bio Engineered Stormwater Outfall structures;
- Protection of existing mature riparian/vegetation, especially along the north bank.

Proposed additional analyses

We propose establishing a 2-dimensional geomorphic model of the existing and proposed channel condition in order to evaluate the following comments and design considerations:

1. Timing of flows associated with sediment deposition and mobilization at the confluence of the North and South Forks are important considerations;
2. Promotion of coarse bedload transport through the system, while providing vegetated floodplains for fine sediment deposition;
3. The channel is widened and constrained in a number of locations, and may induce sediment deposition or scour;
4. It is necessary to evaluate how widening the trapezoidal channel may alter sediment transport. The transition from the confluence area to a widened Trapezoidal channel at the Squaw Creek Road Bridge should be evaluated for hydraulic issues, as well as constrictions at existing crossings.
5. At what flow depth does sediment transition from depositing to scouring?
6. Channel geometry: design should allow a low-flow, active channel to access the floodplain at least 5-6 times in a decade;
7. Shear stress analysis to identify areas of anticipated erosion or scour and modification of design concepts to reduce shear stress in those areas;
8. Assess flood conveyance, critical high-water elevations, and free-board under bridges and below the top of bank.

Development of a robust hydrologic and geomorphic analysis of the channel under existing and proposed conditions will provide a useful visualization and communication tool for the technical review team, regulatory staff, and other interested parties. The model will be supplemented with field measurements of bedload sediment transport, offering multiple lines of evidence to inform the final channel design.

We will utilize the Center for Computational Hydroscience and Engineering 2D (CCHE2D) model to develop velocity and depth estimates at a range of flows, combined with field observations of channel characteristics and visual verification of bed material grain size distributions previously collected by Friends of Squaw Creek and Truckee River Watershed Council Volunteers, as presented in Sound Watershed Consulting's 2011 report.

We will evaluate existing and proposed hydraulic conditions at the 2- and 10-year flows. 2- and 10-year flows will be developed based on historical streamflow data collected in the watershed and at nearby long-term gaging station. In addition, we will utilize peak flow data from the December 30-31, 2005 rain-on-snow event to evaluate sediment transport dynamics during an event that was known regionally to have channel-altering effects.

We propose carrying out a suspended-sediment and bedload sediment gaging program in order to evaluate the following:

1. Whether sediment transport data collected during 1986-7 apply to larger flows, or current watershed conditions;
2. The relationships between sediment transport and flow have likely changed with the implementation of upper watershed sediment management strategies. This program will evaluate whether sediment production from the watershed has been reduced by the efforts of Squaw Valley Ski Corporation over the past decade;
3. Populate the 2D hydraulic model to assess areas of excess sedimentation or scour

Additional analyses not currently proposed, but will likely be required prior to finalization of the channel enhancement design.

1. Areas of project impacts and created wetlands will need to be accurately quantified during development of Phase 1 plans, and compared to increases in floodplain and riparian areas for determination of mitigation ratios resulting from the channel enhancement;
2. The existing 1D channel hydraulic model (completed by MacKay and Somps) should be modified to evaluate changes in water surface elevations associated with the 100-year event, per FEMA and County guidelines.

Response to comments

General Comments

Comment 1:

The Water Quality study should address conditions and impacts associated with Phase 1 of the SVSP project.

Response 1:

The Water Quality study addresses conditions and impacts associated with Phase 1 of the SVSP and is outlined in a document separate from the channel improvements basis for design. It should be noted, however, that results of the water quality study are the driving force behind establishment of the in-stream water quality improvements and channel enhancement plan.

Comment 2:

Design Goals and elements should be related to the driving forces behind them (i.e. County General Plan Guidelines, TMDL, community and FOSC desires, Basin Plan requirements, other permitting requirements, etc.)

Response 2:

Goals and objectives have been revised for clarity upon revision of the project design and design basis memo. In particular, objectives will be tied directly to the following primary project goals:

- Compliance with regulatory guidance and requirements;
- Offsetting current and historical impacts to the channel through improvement of aquatic, riparian, and wetland habitat; and
- Enhancement of the human experience through improved aesthetics and recreational, educational, and interpretive opportunities.

Objectives are largely consistent with those presented by PWA (2007) and subsequently by Sound Watershed Consulting (2008, 2011, 2012), as follows:

- Reduce fine sediment (silt and sand-sized particles, 2 to 4 mm) transported and deposited in downstream reaches, for consistency with the Squaw Creek Sediment TMDL;
- Reduce fine sediment carried in suspension to the Truckee River (less than 2 mm), for consistency with the Truckee River Suspended Sediment Concentration TMDL;
- Maintain or increase the area of the 100-year floodplain, for maintenance of conveyance associated with peak flows and flooding;
- Increase the areas and quality of wetland/riparian habitat;
- Increase frequency and duration of floodplain inundation in order to:
- Increase the areas and quality of riparian and meadow habitat;
- Reduce stream power and allow for deposition and sequestration of coarse sediment and sand;
- Establish public access points with educational and interpretive features.

Comment 3:

Channel improvement designs need to be integrated with the Specific Plan and overall site plan.

Response 3:

Channel improvement designs are integrated with various specific plan elements and observed watershed conditions. Low-flow water quality treatment swales are located to receive treated runoff from urbanized areas of the Specific Plan, and recreational elements such as bikeways and interpretive features are co-located to enhance the recreational experience.[1]

Comment 4:

Restoration designs include a phasing plan, if implementation should occur over multiple years.

Response 4:

The proposed channel enhancement plan is anticipated to be completed during a single construction season. Adaptive management and channel maintenance activities will be conducted as needed after project implementation.

Design Comments by Reach

Upper Reach: Conflunce of North and South Forks to Squaw Valley Road Bridge

Comment 5:

The probable backwatering effects of channel narrowing at the upstream-most bridge and implications for design of the confluence area. The timing and flows associated with sediment deposition and mobilization are important considerations in the design of the confluence.

Response 5:

Development of a robust hydrologic and geomorphic analysis of the channel under existing and proposed conditions will provide a useful visualization and communication tool for the technical review team, regulatory staff, and other interested parties. The model will be supplemented with field measurements of bedload sediment transport, offering multiple lines of evidence to inform the final channel design.

We will utilize the Center for Computational Hydroscience and Engineering 2D (CCHE2D) model to develop velocity and depth estimates at a range of flows, combined with field observations of channel characteristics and visual verification of bed material grain size distributions previously collected by

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[1]Adrienne Graham or members of the project CEQA team may wish to elaborate further on integration

Friends of Squaw Creek and Truckee River Watershed Council Volunteers, as presented in Sound Watershed Consulting's 2011 report.

We will evaluate existing and proposed hydraulic conditions at the 2- and 10-year flows. 2- and 10-year flows will be developed based on historical streamflow data collected in the watershed and at nearby long-term gaging station. In addition, we will utilize peak flow data from the December 30-31, 2005 rain-on-snow event to evaluate sediment transport dynamics during an event that was known regionally to have channel-altering effects.

East Reach: Far East Road Bridge to downstream property line (Golf Course bridge)

Comment 6:

It was suggested that the channel alignment be modified to account for a steeper channel downstream of the Far East Road bridge, with a lower sinuosity, and longer meander wavelength. Another alternative was put forth in which the channel is not designed in this area, but allowed to 'find its own way' and equilibrate to the new slope, as dictated by a number of grade control structures. Localized step pools were also suggested as another design alternative.

Response 6

The existing channel gradient in this reach is approximately .01 (1 percent), well within the appropriate range for a riffle-pool channel morphology and well below the range appropriate for natural development of step-pool features. Increasing sinuosity through this reach will further reduce channel slope. Literature (Leopold and Wolman, 1967) suggests that a bankfull discharge approaching 200 cfs may tend to form a multi-threaded channel system. We have modified the design accordingly to provide high-flow secondary channels an dynamic channel movement within the floodplain corridor (Exhibit 2).

The proposed design also aims to re-occupy abandoned historical channels, drawing on channel geometries that were stable prior to development of the site.

Comment 7:

The utility crossing downstream of the Far East Bridge was noted as being in disrepair, with some uncertainty as to who's responsibility it is to fix it. This line may or may not need to be relocated, but will likely need to be reinforced at a minimum. (Note: According to Dennis Meyer, Andregg: Original easement was granted to TTSA. It is currently part of the SVPSD collection system)

Response 7:

The proposed design calls for burial of the wastewater pipe, and final designs will include elements to better encase and protect the pipe. This can be achieved while maintaining a channel slope of approximately 0.01 ft/ft, well within the appropriate range for a meandering riffle-pool channel type.

Comment 8:

It was suggested that the access road be moved to east (rather than north) of the maintenance yard.

Response 8:

The access road has been relocated.

Comment 9:

It was suggested that instead of a meandering low-flow swale, the Olympic channel be re-designed as a broad wetland, with minimal or no designed channels. A sediment basin was also suggested for treatment of excess sediment in this area as well.

Response 9:

We agree that a broad wetland and shallow swale will provide valuable habitat and water quality treatment functions and have incorporated this concept into the overall design. The slopes and anticipated peak flows emanating from this reach will likely require some management of channel and wetland grade, so a number of grade control structures have been proposed.

Sound Watershed Consulting Comments

Comment 10:

More precise goals will lead to more clarity in design. Goals should focus on primary eco-geomorphic performance criteria instead of implied goals, should be founded on a sound technical basis, and should include:

- Improving bedload continuity to supply substrate materials to downstream reaches in appropriate volumes and at appropriate frequencies and magnitudes;
- Reducing peak flow energy in the reaches immediately below the Trapezoidal Channel
- Providing sufficient sequestration of fine sediments

Reponse 10:

See revised goals and objectives above.

It is important to notes that bedload continuity and supply to downstream reaches is not a stated objective of this project, since analyses indicate that bedload transport to and sediment deposition in downstream reaches has increased as a result of disturbance. Rather, we intend to reduce bedload transport to downstream reaches through sequestration and metering of sediment, as called for by the Squaw Creek TMDL.

Comment 11:

Channel migration and widening are not currently problems in the meadow. The meadow design is intended to encourage channel migration. The current condition of the meadow is more complex than implied by the Balance memo (some reaches are aggrading and others are incising). The planform of the channel is controlled by rip-rap installation, and the barforms historically appear in similar locations, despite annual changes in shape and depth. A more complete understanding of these processes should help to better inform the project design.

Reponse 11:

Our field observations are consistent with surveyed cross-sections and findings presented by PWA (2007) and Sound Watershed Consulting (2011), which conclude that channel widening and aggradation is occurring in the meadow immediately downstream of the SVSP project. This is presumably due to effective sediment transport through the trapezoidal channel and deposition just downstream of the trapezoidal channel mouth. Stated objectives of the meadow restoration project, as presented by SWC in 2011 include a) Stabilizing Channel Banks and b) Managing Channel Migration Risks along this reach to maintain a channel migration corridor. Our proposed design is wholly consistent with this approach.

It should be noted that our analysis of the meadow is largely focused on Reaches 5 and 6, immediately downstream from the proposed project. We have not evaluated channel condition along the entire meadow, as that is outside the scope of this project, but agree that a thorough understanding of the channel within the meadow will be required for design of the meadow restoration.

Comment 12:

It is not clear why we would want to increase the area of the bankfull floodplain. What functional objective does this provide?

Reponse 12:

Increasing the area of the bankfull floodplain a) provides for more frequent inundation over a larger area, providing hydrology suitable for development of wetland ecology and riparian habitat, b) reduces flow velocities and allows for sediment deposition and sequestration, and c) retains water in floodplain depressions, potentially allow for infiltration and groundwater recharge. We wish to note that this is consistent with the objective presented by Sound Watershed Consulting in May 2011: Improve Floodplain Connectivity

Comment 13:

It's not clear that bankfull should equate to the 2-yr recurrence interval. A smaller channel may be more desireable where appropriate.

Reponse 13:

The final design target inundation frequency will be variable and influenced by design grading and micotopgraphic features, as is found in natural systems.   For the purposes of initial conceptual design and analysis, however, it is necessary to establish a particular flow at which to calculated target depths, floodplain elevations, and anticipated hydraulics. Final designed 'bankfull' channel geometries and floodplain elevations will likely become inundated at flows ranging in recurrence from 1- to 5-years, in order to provide a range of floodplain hydrology and associated vegetation and habitat types.

Comment 14:

Increasing the area associated with the bankfull channel has implications for bedload transport that warrants more thoughtful consideration.

Reponse 14:

Increasing the area of the bankfull channel is not a design objective nor a design element. The proposed design concept includes an active, low-flow channel with similar geometry as what exists today.

Comment 15:

Removing existing floodplain may affect bank storage and thus may affect baseflow.

Reponse 16:

Hourly groundwater levels were examined in six monitoring wells in relation to Squaw Creek streambed elevations in a wet year (WY2011) and a dry year (WY2012). Data suggests that groundwater levels are typically 3 to 5 feet above the existing streambed elevation, similar to water levels in the creek during extremely wet conditions, falling below the streambed during dry conditions (June through November).

Current conceptual plans call for removal of roughly 20,000 cubic yards of material, roughly 25 percent of which may be saturated and providing streamflow to the channel during the snowmelt period and afterward. Assuming that the channel is nearly dry , along with conservative assumptions of porosity in this area (0.25), imply that roughly 0.75 acre-feet of water that is available to support flows during May and June may be removed as a result of the project.

During the two-month period when this area may drain to the creek, the potential 0.75 acre-feet equates to approximately 0.003 cubic feet per second (cfs), or 1.5 gallons per minute (gpm). Inclusion of overbank storage areas, especially along the reconfigured Olympic Channel, are anticipated to retain similar or larger quantities of water, offsetting the potential impacts of removing a portion of the aquifer.

Comment 17:

The design team should break out more specific objectives by project area/reach to make the objectives functionally relevant to each design solution.

Reponse 17:

We choose to treat this project holistically, with consistent objectives for the design based on upstream conditions and identified goals for the meadow area downstream. The listed objectives are applicable to each project reach.

Comment 18:

Design objectives should be quantified.

Reponse 18:

Design objectives are largely based on regulatory criteria. For example, the TMDL uses pebble count data to evaluate the percent of the streambed covered by fines as an indicator. Clean Water Act and NPDES guidelines call for no degradation of water quality emanating from the project site and are also useful indicators. Specific quantitative and qualitative performance metrics and adaptive management criteria as part of final design and monitoring plan development and are likely to be conditions of a range or permits issued for the project.

Comment 19:

The design objectives and design components should distinguish between how to manage for fine sediment and how to manage for coarse sediment (bedload). Overall, we want the coarse bedload fraction to continue to transport through the system and we need to provide opportunities for the fines to settle out.

Response 19:

We caution against using the terms, 'bedload,' 'coarse sediment,' and 'bed material, ' interchangeably. Bed load is the sediment that moves by sliding, rolling, or saltating on or very near the streambed. Bed material includes the material found on and in the bed. Woyshner and Hecht (1988) measured bed load and found sand to comprise the vast majority of bed load in the system. In addition, sand (defined as particles 3mm and smaller) is considered to be excessive on the channel bed and part of the 'fine' sediment fraction that is detrimental to fish and invertebrates (Curtis, 2006).

Our approach to this design challenge is to mimic the sediment modulation effects found in meadows with frequently inundated floodplains and at channel confluences: through the expansion and thick planting of inset floodplain areas, low-velocity sediment settling zones will be established, while higher velocities and deeper water in the channel should allow for transport of coarser material. 2-dimensional hydraulic modeling will be used to evaluate whether the proposed conceptual design adequately achieves this goal.

Comment 20:

The Balance memo suggests that "very little infrastructure developed until the 1950s." However, considerable channelization of the creek in the meadow area occurred during the 19th Century in association with various grazing and mining activities.

Response 20:

Indeed, the Squaw Creek Meadow was not pristine prior to 1950. The focus of this statement, however, is on the project reach within the SVSP area, where the most significant changes and impacts, are, by far, associated with the infrastructure constructed for the ski area and the 1960 Olympics. Addressing impacts to the meadow associated with channelization by ranchers and sheep herders is outside the scope of this project.

Comment 21:

The MacKay and Somps HEC-HMS model produced results that are considerably higher than we are seeing from direct flow measurements or other modeling efforts. Using such numbers could result in design failure due to over-estaimating critical flow and associated channel dimensions.

Response 21:

MacKay and Somps have used methods outlined by Placer County Public Works to develop estimates for the 100-year flow. These are, by nature, conservative for consideration and sizing of in-channel elements and bank stabilization structures. Conservative estimates in accordance with county guidelines are also necessary in evaluating potential changes in flood risk and associated infrastructure protection associated with the channel enhancement project.

2-year flow estimates provided by MacKay and Somps have not been used for design.

Comment 22:

Developing proper design flows is critical to the success of the project.

Response 22:

As stated above, the conservatively-modeled 100-year design flows are appropriate for evaluating flooding and potential scour in the vicinity of infrastructure. 2- and 10-year design flows will be established based on peak flow data reported by Sound Watershed Consulting. Specifically, we anticipate using the streamflow hydrograph associated with the December 30-31, 2006 rain-on-snow event, an approximately 10-yr event, along with streamflow data reported for the June, 2010 snowmelt peak, a roughly 2- to 5-year flow.

Channel dimensions will not be based on target flows. Rather, channel dimensions will be based on geomorphically-appropriate relationships found regionally and demonstrated in this particular system. Modeling results will be used to confirm or redesign floodplain elevations such that the enhanced floodplain areas are engaged or inundated 5 to 7 times a decade.

Comment 23:

Blending 3 sediment size fractions into a single values and raises challenges in interpreting how the data may affect various design components.

Response 23:

Table 1 in the design memo distinguishes between suspended load and bed load. To consider the total volume of sediment moving through the system, or potentially trapped behind sediment retention structures, it is necessary to add these together.

Comment 24:

The Woyshner and Hecht (1988) data reported only 7 bedload values during flows ranging from about 4.5 to 45 lbs/min (as calculated by SWC) at 50 to 140 cfs at a location 1600 feet below the Trapezoidal

Channel. We suspect that monthly values are derived from regression, although regression equations are not provided in their report.

Reponse 24:

Regression equations are provided in Table 8 of the Woyshner and Hecht (1988) report. The report describes a total of 16 samples that were used to establish the regression for bedload sediment transport through the meadow reach.

Comment 25:

Most bedload samplers have an entrance orifice of only 7.6 cm, but the median coarse bedload fraction (D50) near their reported sampling location was 17.5 to 20.0 cm in 2011 and 2012 respectively (SWC data). By our estimates, a bedload sampler will only capture 13% of the gravel size fraction.

Response 25:

We caution against using the terms 'bedload,' 'bed material,' and 'gravel' interchangeably. SWC and volunteers measured the distribution of bed material , which is different from and not comparable to the grain size distribution of bed load material (i.e. sediment in transport during flows). Woyshner and Hecht (1988) reported bedload sediment to consist primarily of coarse sand (< 4 mm) in the meadow reach of Squaw Creek and coarse sand is targeted for reduction as part of the Squaw Creek Sediment TMDL (Curtis, 2006). Bed material is typically coarser than bedload sediment due to winnowing of fines and bed armoring and likely represents the portion of material that is not readily transported during most peak flows.

Comment 26:

Relationships between suspended sediment loading and streamflow should consider the hysteresis associated with suspended sediment loadings.

Response 26:

Suspended sediment loadings are based on data for which hydrograph position (i.e. rising vs falling) or type of event (i.e. rain on snow vs snowmelt vs rain on ground) was not reported, making this analysis impossible. Balance has, however, quantified hysteresis effects in other Middle Truckee River tributaries (Cold Creek, Donner Creek, and Trout Creek) and found that total annual loads could change by more than 20 percent. Sediment transport estimates from the Squaw Creek watershed are therefore considered to have an accuracy of +/- 20 percent. This level of accuracy is reflected in the range of sediment transport estimates developed thus far for this project.

Comment 27:

The project will benefit by a more detailed technical description for how the suspended sediment and bedload numbers were derived, and whether this analysis is relevant to the critical design questions.

Response 27:

As described in the Draft Design Basis Memo, a more complete summary of this work is available in Balance's forthcoming Water Quality Investigation Report. This report can be available by request and permission of the client.

Comment 28:

Is the 4:1 bedload to suspended sediment ratio appropriate? It is likely higher for higher flows. Some fundamental sediment transport calculations should help to inform this question.

Response 28

As cautioned in the Draft Design Basis Memo, this ratio is highly variable depending on the nature of flows in a given year. Woyshner and Hecht (1988) found, for example, that more suspended sediment than bedload sediment was transported during water year 1987, a substantially drier-than-normal year.

Fundamental sediment transport calculations and 2-dimensional shear stress calculations will be conducted prior to finalization of the channel enhancement design.

Comment 29:

Flow duration is critical in estimated total sediment load, so estimating by peak flows alone will not provide adequate estimates of total sediment transport rates.

Response 29:

As stated on p. 5 and in Table 1 of the Draft Design Basis Memo, we have used peak flow hydrographs with a 3-day duration to evaluate changes in sediment supply for design storms, as well as a complete record of annual flow for water year 2009 to estimate sediment delivery during a year with average runoff.

Comment 30:

Typo: Table 1 1987 sediment numbers are switched.

Response 30:

Noted and corrected.

Comment 31:

We suspect that large sediment loads from the Olympic Channel are associated with snow storage above the channel head, and that other BMPs may be more appropriate design factors to address this issue.

Response 31:

Snow Storage BMPs and implementation of Phase 1 of the project will undoubtedly improve water quality. However, field observations during the storm of December 2, 2012 suggest that the Olympic Drain outfall, which is fed primarily by Searchlight Pond and portions of the parking lot is the primary source of turbidity in the Olympic Channel. Unlike the rest Squaw Creek Watershed, the subwatershed which drains to the Searchlight Pond consists almost entirely of highly erodible Tertiary Volcanic bedrock over very steep terrain with ski runs and roads, and likely produces fine sediment at markedly higher rates than other major tributary streams.

(a) looking upstream of culvert outfall

(b) looking downstream from culvert outfall

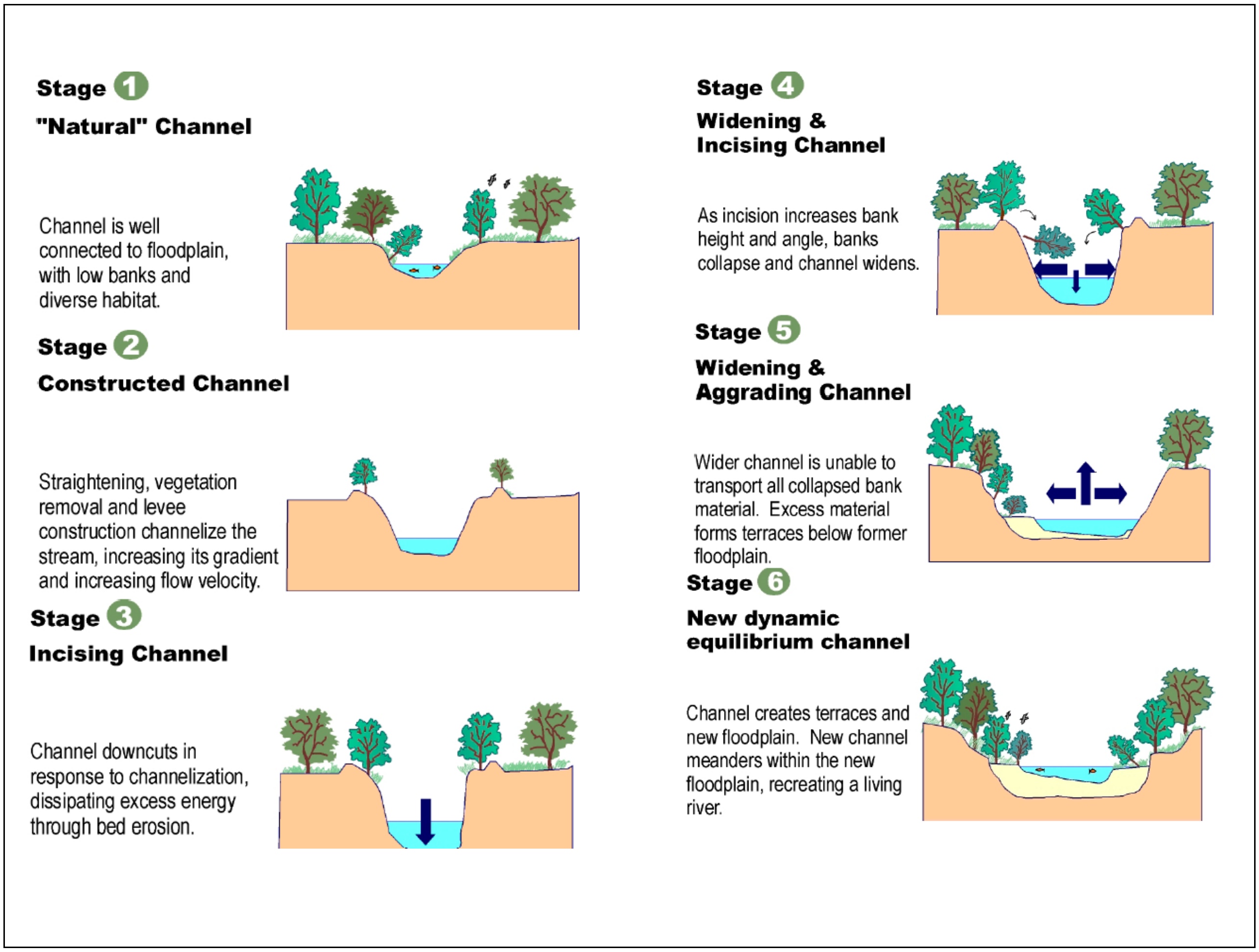
Local surface runoff (a) and Olympic Drain outfall (b) during the rain-on-snow event of December 2, 2012 indicate upstream areas to be primary sources of sediment to the Olympic Channel and more significant than localized melting of stored snow.

Comment 32:

We are not sure that "sand and gravel deposition on the meadow reach now appears to be causing lateral channel migration, bank instability and sediment generation from channel banks (PWA, 2007) is an accurate statement. Current understanding is more complicated, but the primary issue in the 2007 report was incision, not lateral migration, and incision continues to be an issue in the meadow reach.

Response 32:

Our analysis of the downstream meadow reach focuses primarily on the area immediately downstream of the SVSP project, Reaches 5 and 6 as presented by PWA (2007). Field evaluations and aerial photography interpretation indicate that this reach has indeed experienced incision, followed by aggradation and widening, which has led to bank instability. This conceptual model is observable and has been documented in other Sierran meadows.



Schumm and others' (1984) conceptual model of the channel incision, widening, and equilibration model.

Interpretation of geomorphic conditions is, indeed, an inexact science, so rather than recognizing exactly which stage the channel as it in this cycle, we recognize the cycle itself, noting that achievement of Stage 6 corresponds to a quasi-stable channel in dynamic equilibrium, and target our design conditions to this condition.

Comment 33:

The Balance memo suggests that the South Fork can store up to 3500 cubic yards of sediment, as estimated by removals from NRCS following the 1997 event. However, these removals were associated with channel avulsion (the South Fork left its banks and was diverted thru the Squaw Valley Lodge). Under the current configuration of the South Fork channel, there is no real sediment storage capacity between the Ski Run bridge and the confluence zone.

Response 33:

This estimate was used to approximate the volume of sediment that could be delivered by the South Fork, not as a measure of existing storage capacity in the South Fork Channel.

Comment 34:

The Balance memo suggests that "the confluence reach is an area where sediment is intrinsically stored during major events, releasing material downstream during smaller flows. We believe the process is actually opposite – smaller flows accumulate coarse sediments in the confluence area, and moderate to high flows flush these stored sediments downstream. However, we suspect the actual sediment dynamics in the confluence zone is highly dynamic, and deserves additional analysis (e.g., modeling).

Response 34

2-dimensional hydraulic modeling and sediment transport calculations will be conducted to evaluate these hypotheses. It should be noted that we observed minimal coarse sediment transport during the peak flow of December 2, 2012, estimated to be a roughly 2- to 5-year event.

Comment 35:

We suspect that sediment transport dynamics in the North Fork are relatively undisturbed by existing land use, and should be allowed to continue downstream to support meadow functions. Thus the primary problem area (for sediment) is the South Fork, where a mixed load of sandy matrix and coarse gravel is probably significantly higher overall (and higher in sandy fraction) than can be supported by downstream reaches.

Response 35:

The basis for this hypothesis seems reasonable—that the relative disturbance between the North Fork and South Fork watersheds may cause sediment production from the South Fork to be higher. However, this hypothesis is untested.

Comment 36:

We disagree that “bar-forming deposits…destabilize the channel.” We suspect that there is a complex relationship between sediment storage and downstream transport that allow the barforms to help support bedload supply to various areas within the meadow reach. Again, the story is more complex.

Response 36:

The suspected relationship described in this comment, which involves re-mobilization of sediment stored in bars is not inconsistent with our interpretation that the bars affect channel hydraulics by spreading flow toward the banks. Indeed, sediment stored in bars may become remobilized and transported to other areas.

Comment 37:

We’d generally like to see a broader set of alternatives developed for consideration rather than a single proposed design solution.

Response 37:

This conceptual design is the third in a series of design iterations. The first alternative was presented during a meeting with the Friends of Squaw Creek on September 20, 2012, during which comments were made by Placer County Staff, Sound Watershed Consulting, and Friends of Squaw Creek members. That design was revised and presented to Lahontan Regional Board Staff and members of the project EIR (consultants and Placer County Staff) for feedback and subsequently revised accordingly. Based on these comments and comments provided during our January 17, 2013 design review meeting, this channel enhancement plan will be revised a third time in order to present a 4th alternative, developed largely through involvement of stakeholders and collaborators.

Comment 38:

We’d also like to see designs more carefully constructed to meet specific design objectives, functional requirements and performance criteria.

Response 38:

The designs presented have been carefully constructed to meet the design objectives presented in the Design Basis memo. Performance metrics and adaptive management criteria will be established as part of the final design and post-project monitoring plan.

Comment 39:

The proposed configuration would more likely capture sediment from the North Fork while allowing most fine sediment from the South Fork continue downstream. This is opposite of the desired effect we believe is necessary to support sediment continuity functions.

Response 39:

The basis for this conclusion is unclear. As noted in an earlier comment above (see comment 34), sediment transport dynamics in the confluence reach is dynamic and warrants additional analysis. In addition, the 'desired effect' for sediment continuity in this reach is based on an untested hypothesis that allowing sediment from the North Fork to pass while trapping South Fork sediment will benefit the project.

Comment 40:

We believe that preserving the willows in the confluence adds an unnecessary constraint that will limit the range of alternatives and functionality of the confluence area. We would therefore design the ideal solution first, and then seek to identify areas where we could add or preserve willows.

Response 40:

The cottonwoods, some willows and channel configuration in this area have remained intact through the extreme high flows of 1997 and provide high-quality riparian habitat for potential use by special-status species. Removal of the more mature vegetation would represent a significant impact to a functional element of the existing system.

Comment 41:

The proposed equipment access road is poorly located, and will likely present undesired effects.

Response 41:

Alternative locations and ramp configurations are under consideration.

Comment 42:

We suspect that the transition from the confluence area to a widened Trapezoidal channel using the existing channel alignment and bridge may cause problems. We'd like to see this configuration tested against a hydraulic model.

Response 42:

The proposed configuration will be tested using a 2-dimensional hydraulic model.

Comment 43:

[A conceptual wetland detention structure illustration was presented along with channel widening on the north bank]

Response 43:

The wetland detention structure represents an engineered solution and potential method of trapping sediment delivered from the South Fork and has been evaluated for feasibility and potential impacts on flood elevations and sensitive habitat. The scale of the channels and location within the watershed would present a number of challenges to constructing a sediment basin across the South Fork at the confluence. Rough calculations based on the existing topography show that a containment berm with a top elevation of approximately 6210 feet (to contain 100-year flows) would have a footprint on the order 0.5 acres, nearly all of which would be require removal of existing riparian cover. The need to safely convey 100-year flood flows over the structure would require a spillway with a width of roughly 200 feet (roughly half the length of the berm), all of which would have to be heavily armored. At this width, the appropriate spillway crest elevation would be at 6205 feet, limiting storage capacity to approximately 3,000 cubic yards of sediment or less. This is less material than was observed as having been deposited in the South Fork during the 1997 event.

Our understanding is that the need for this structure is based on an untested notion that the South Fork delivers significantly more habitat-impairing sediment than the North Fork. We conclude that the cost, ecological impacts, risk, and anticipated efficacy of the described sediment basin at this location should not be included as part of the channel enhancement strategy.

Comment 46:

At what flow depth does sediment transition from depositing to scouring in the confluence zone? How does this change with grain size? With proposed design elements?

Response 46:

The 2-D geomorphic model that will be developed will allow us to evaluate these questions. It should be noted, however, that analysis of these questions will provide answers with a significant degree of uncertainty, and that post-project monitoring and adaptive management will be key to the long-term success of the restoration project.

Comment 47:

How can the transition at the entrance to the Trapezoidal Channel [be designed] without causing sedimentation immediately below the bridge structure?

Response 47:

Sedimentation in channel margins and on the newly-constructed inset floodplain is a desired goal of the project, and final channel designs will be developed to encourage this. Widening the bridge crossing may help offset hydraulic discontinuities but such a widening is not proposed as part of the SVSP.

Comment 48:

The sediment extrapolations from the 1986-7 data are probably not appropriate to very large events. Some effort to quantify bedload from larger events will be necessary to properly size any detention structures. Can we derive any insights from the cleanup effort following 1997?

Response 48:

We have used the cleanup effort from 1997 to develop estimates of bedload transport and deposition under extremely high flows (3,500 cu yds removed from the South Fork after the 1997 event).

Comment 49:

Maintaining channel width along the lower 160 feet of the existing trapezoidal channel may present a backwater effect upstream and cause increased velocities downstream.

Response 49:

The 2-D geomorphic hydraulic model that will be developed will allow us to evaluate these questions. It should be noted, however, that analysis of these questions will provide answers with a significant degree of uncertainty, and that post-project monitoring and adaptive management will be key to the long-term success of the restoration project.

Comment 50:

SWC has presented a number of design elements for the trapezoidal channel

Response 50:

We agree that the design elements presented, including non-uniform widening, varying the width of the set-back, vertical variation, habitat structures, and modifying channel alignments to better maintain hydraulic continuity are worthy of inclusion in the final design.

Comment 51:

We think a basic geomorphic analysis of the meander profile likely to be supported by the existing or design gradient would be appropriate.

Response 51:

A basic geomorphic analysis of the meander profile will be included in the revised design basis memo.

Comment 52:

The proposed alignment at the Golf Course should be reconsidered to better align flows with the downstream reach. The floodplain should align with the floodplain feature downstream of the bridge. The proposed configuration is much too wide on the upstream side of this bridge.

Response 52:

Significant care was taken to align the channel and floodplain with the existing features at the downstream end of the project. The proposed floodplain embankments and channel banks on both the north and south banks conform to these features as indicated by 1-foot topographic mapping provided by Andregg. If SWC has information suggesting that this mapping is incorrect we should resolve the discrepancy immediately.

Comment 53:

Not sure that a grade control at the golf course is necessary or advisable, as it may affect the stability of the bridge footings:

Response 53:

The necessity of the grade control structure at the bridge will be further evaluated. If engineering analyses indicate it to be required, it will be designed to avoid impacts to and/or protect bridge footings.

Comment 54:

The extent of floodplain widening is wider than envisioned. The wider area may result in more active channel migration, resulting in large sediment barforms. We might want to control the zone of deposition more to improve overall aesthetics.

Response 54:

The floodplain width will be modified to be more narrow. The proposed vision for this reach is, however, a dynamic one of active sediment accumulation and channel migration, within a controlled and well-vegetated riparian corridor for maximization of riprarian habitat, overbank flooding, water quality and sediment management, and flow retention for infiltration and groundwater recharge.

Comment 55:

It is not clear that the proposed design will provide the sediment continuity that it purports to provide.

Response 55:

Additional analysis is being conducted to further elucidate the proposed hydraulics and sediment transport conditions

Comment 56:

The hillslope gradient does not need to be very steep. A shallower gradient (e.g. 3:1 to 5:1 or shallower) can reduce (eliminate?) the need for rock/slope protection. Alternatively, biotechnical stabilization should be considered.

Response 56:

The side slopes presented in the conceptual plan vary between 3:1 and 8:1, with the exception of a few areas. The steeper slopes are included in order to expand floodplain areas and conform to existing conditions at bridges, and will be stabilized using bioengineering approaches. Slope toe protection includes rock, log, and rootwads, and will be designed to be planted, to enhance fish habitat in the channels. Slope toe protection will be further minimized by narrowing the corridor in the eastern reach (downstream of Far East Road Bridge) and increasing the distance to condominiums on the north side of the channel.

Comment 57:

Not clear that the oxbows are well-located.

Response 57:

Oxbow locations and design will be reconsidered.

Comment 59:

Consider moving the access road behind the [Maintenance Yard].

Response:59

The access road will be relocated.

Comment 60:

The hydraulic model should be revised and re-run using the empirical flood frequency data described in SWC, 2011 to better estimate the range of flood risk and channel dimension associated with more likely design flows.

Response 60:

Flood risk must be evaluated according to Placer County- and FEMA-approved standards. Channel-forming flows will be evaluated using streamflow data measured during the peak flows of water year 2006. Uncertainty associated with a Log-Pearson III flood frequency analysis based on 10 years of data does not allow for establishment of defensible 100-year design flows, but is appropriate for establishment of a design bankfull flow of a 1- to 2-yr recurrence.

Comment 61:

The modified Trapezoidal Channel will most likely attenuate flow depths (and velocity). An analysis to determine the extent and its associated geomorphic effects will be critical to success. How much additional reduction will the inset floodplain reach thus need to provide? Does this change the objectives for the inset floodplain numbers?

Response 61:

A 2-D hydraulic geomorphic model and associated calculations will be carried out to address these and other questions posed in the SWC memo.

Comment 62:

The Olympic Channel gradient will likely be higher than the mainstem channel, and may require some grade controls to limit any incision or headcutting that may occur.

Response 62:

The Olympic channel gradient will be reduced to approximately .013 (1.3-percent), and has been redesigned as a broad swale with detention and ponded features. Buried rock and exposed log grade control structures also be used to maintain channel bed elevations, promote localized scour and enhancement of backwater rearing habitat for fish.

Comment 63:

We'd like to see the Olympic Channel become more of a broader swale with wetland and/or ponding features, and less of a linear channel. This will help support groundwater infiltration and more perennial flow qualities in Squaw Creek. It will also provide more water quality treatment functions. The design objectives for this reach should include these functions.

Response 63:

We agree that a broad wetland and shallow swale will provide valuable habitat and water quality treatment functions and will incorporate this concept into the overall design.

Comment 64:

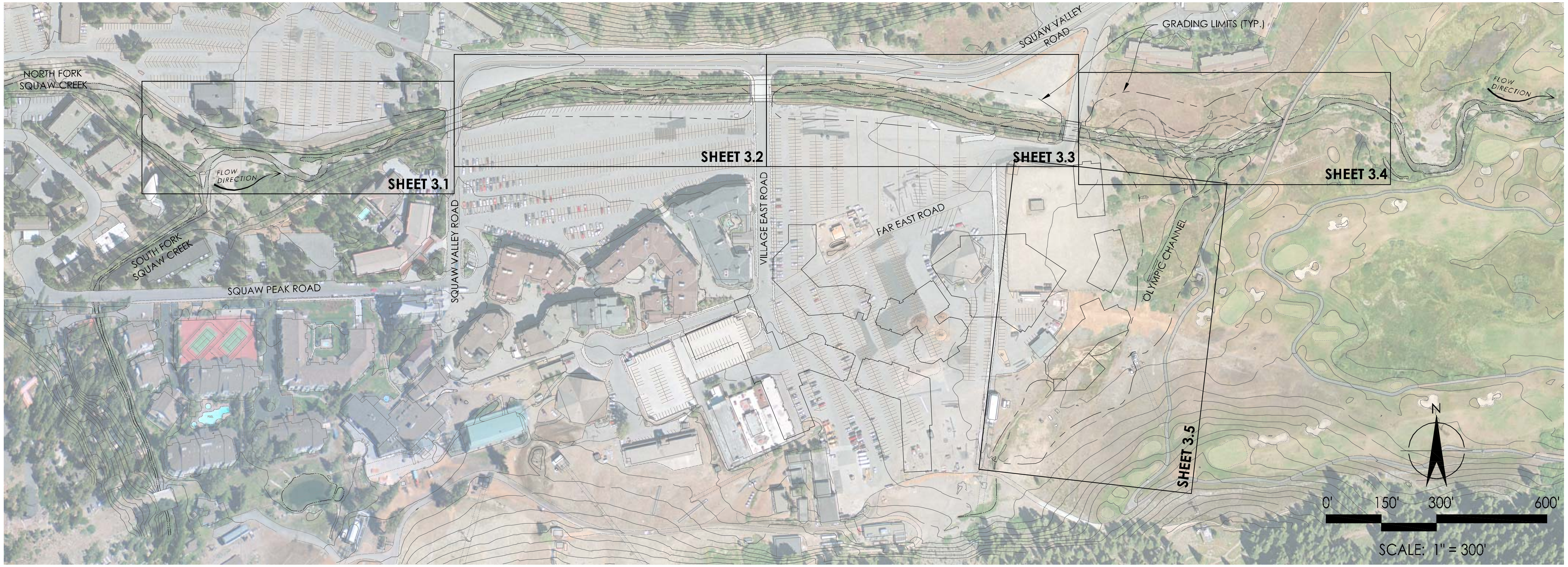
There may need to be some source control features upstream to prevent sediment delivery to the channel, such as a sediment Forebay at the Searchlight Pond outlet.

Response 64:

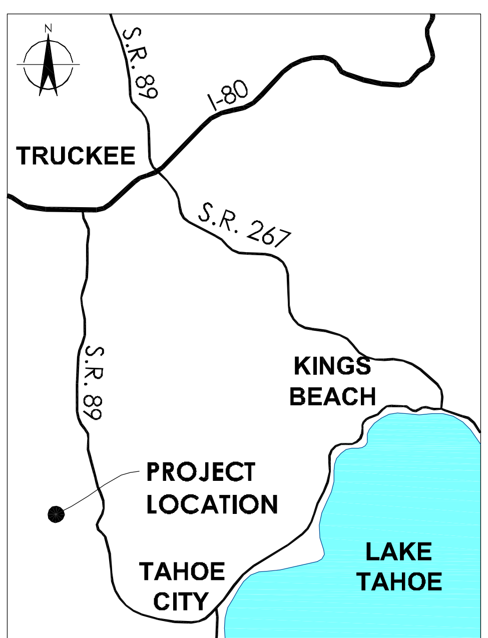
We agree that sediment source control on the mountain is an important component of sediment management in this watershed. Source control is outside of the scope of this particular design project, however.

APPENDIX B

Squaw Creek Restoration Revised Conceptual Plans: Squaw Valley Village Specific Plan



LOCATION MAP



LEGEND:

EXISTING MAJOR CONTOUR - 5 FT	5835
EXISTING MINOR CONTOUR -1 FT	
PROPOSED MAJOR CONTOUR - 5 FT	
PROPOSED MINOR CONTOUR - 1FT	
EXISTING OVERHEAD ELECTRIC LINE AND POWERPOLE	OHW OHW
EXISTING WATER LINE	WTR WTR
EXISTING SEWER LINE	SWR SWR
EXISTING STORM DRAIN LINE	SD SD
EXISTING TELEPHONE LINE	TEL TEL
EXISTING CABLE LINE	CTV CTV
EXISTING UNDERGROUND ELECTRIC LINE	UGE UGE
ABANDONED UNDERGROUND UTILITY	

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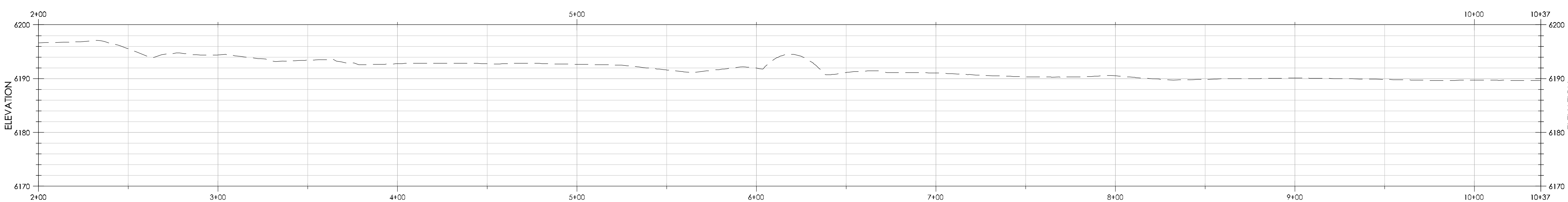
20140211	DS	REVISED CONCEPTUAL PLANS

DESIGNED BY D SHAW
DRAWN BY P KULCHAWIK
CHECKED BY E RIEDNER
IN CHARGE E BALLMAN
DATE

KEY MAP AND CONSTRUCTION ACCESS AND STAGING PLAN

SQUAW CREEK RESTORATION
SQUAW VALLEY VILLAGE SPECIFIC PLAN
PLACER COUNTY, CALIFORNIA

PROJECT NUMBER 211022
SCALE 1" = 150'
SHEET 3.0



SQUAW CREEK

PROFILE VIEW 1" = 30' (H) ; 1" = 10' (V)

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NORTH AND SOUTH FORKS OF SQUAW CREEK CONFLUENCE TO SQUAW VALLEY ROAD

SQUAW CREEK RESTORATION
SQUAW VALLEY VILLAGE SPECIFIC PLAN
PLACER COUNTY, CALIFORNIA

PROJECT NUMBER 211022
SCALE 1" = 30'
SHEET 3.1

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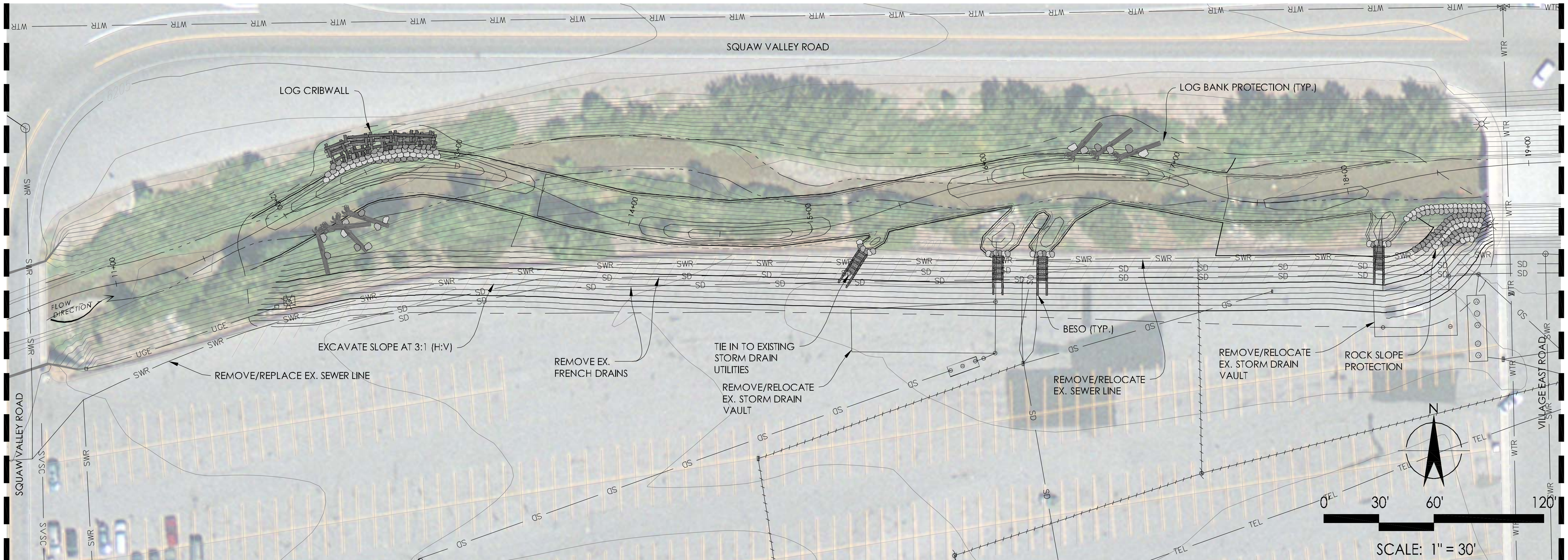

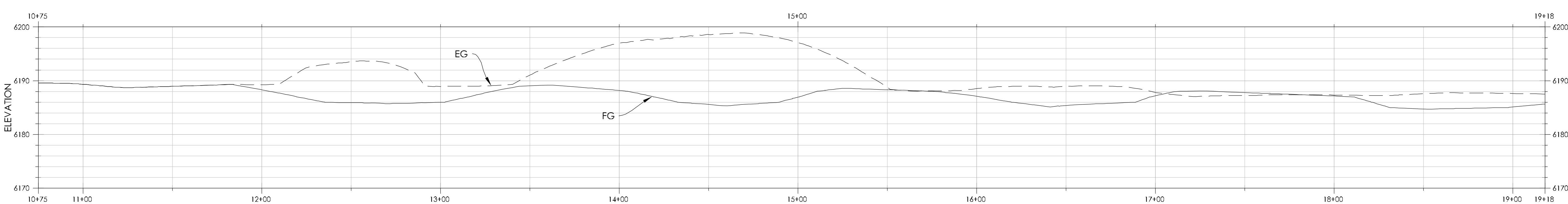

SQUAW CREEK

PROFILE VIEW 1" = 30' (H) ; 1" = 10' (V)

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SQUAW VALLEY ROAD TO VILLAGE EAST ROAD

SQUAW CREEK RESTORATION
SQUAW VALLEY VILLAGE SPECIFIC PLAN
PLACER COUNTY, CALIFORNIA

PROJECT NUMBER 211022
SCALE 1" = 30'
SHEET 3.2

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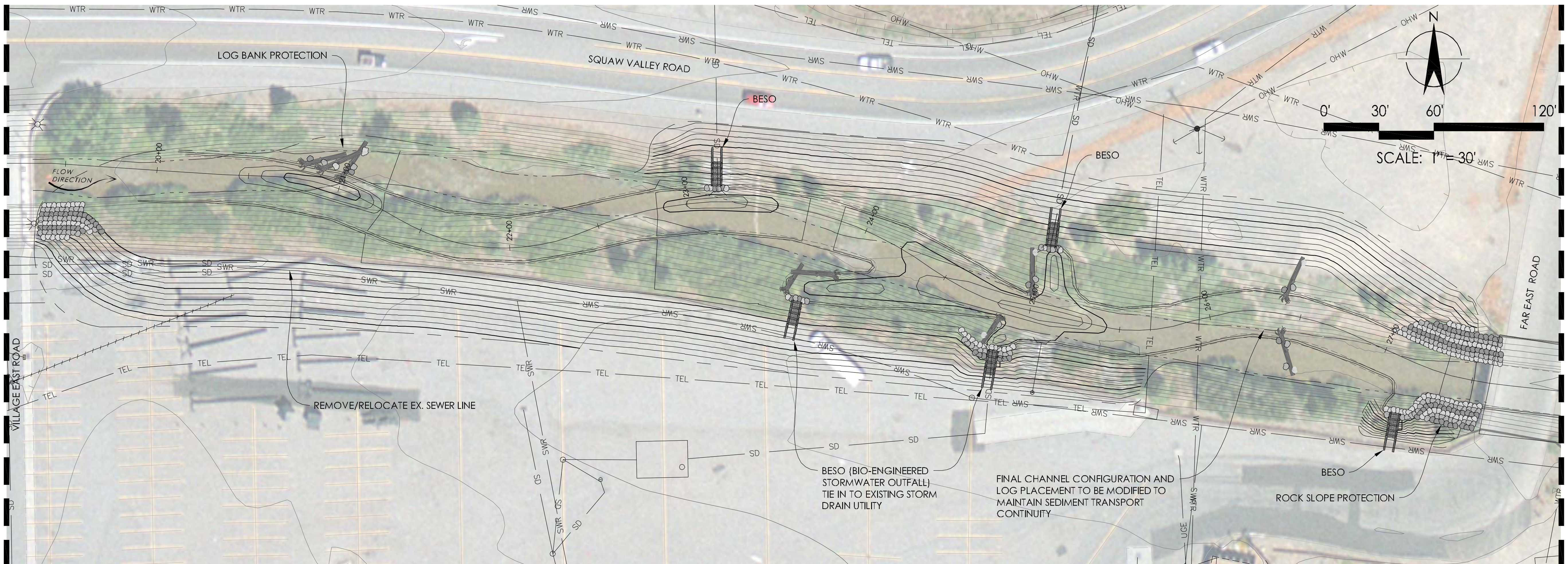

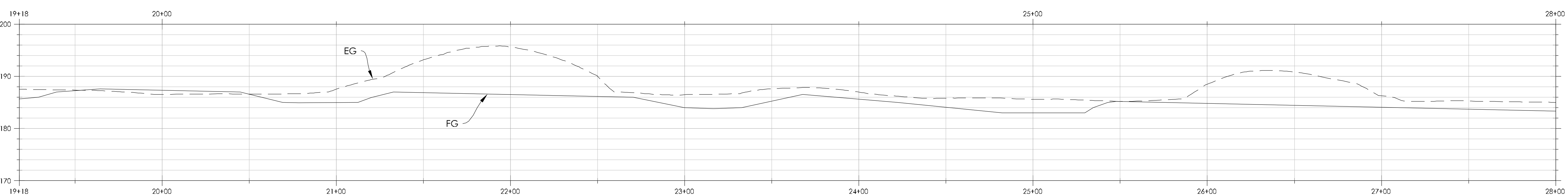

SQUAW CREEK

PROFILE VIEW 1" = 30' (H) ; 1" = 10' (V)

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IN CHARGE E BALLMAN
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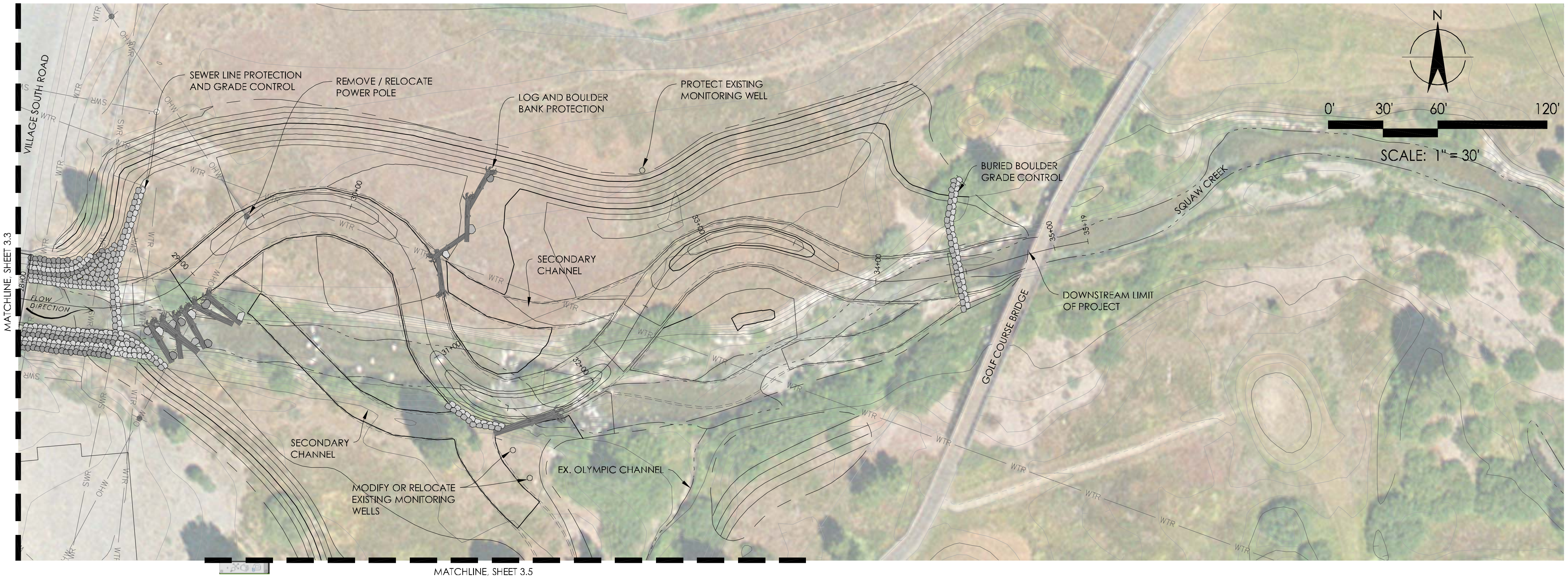
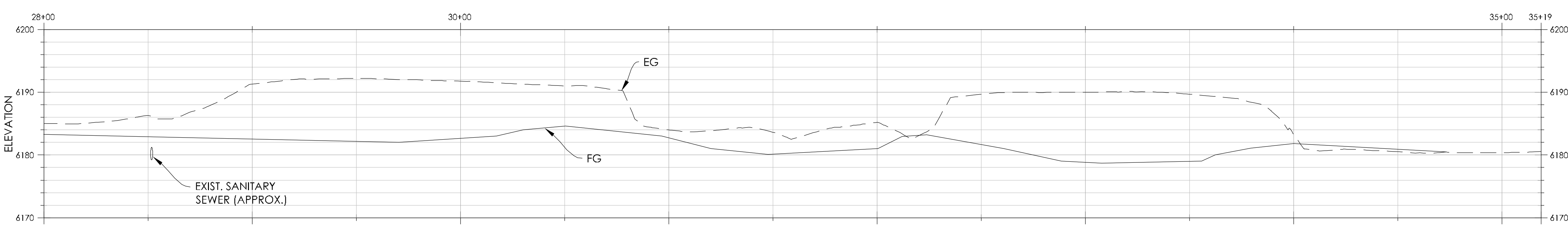
VILLAGE EAST ROAD TO FAR EAST ROAD

SQUAW CREEK RESTORATION
SQUAW VALLEY VILLAGE SPECIFIC PLAN
PLACER COUNTY, CALIFORNIA

PROJECT NUMBER 211022
SCALE 1" = 30'
SHEET 3.3





SQUAW CREEK

PROFILE VIEW 1" = 30' (H) ; 1" = 10' (V)

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FAR EAST ROAD TO GOLF COURSE BRIDGE

SQUAW CREEK RESTORATION
SQUAW VALLEY VILLAGE SPECIFIC PLAN
PLACER COUNTY, CALIFORNIA

PROJECT NUMBER 211022
SCALE 1" = 30'
SHEET 3.4

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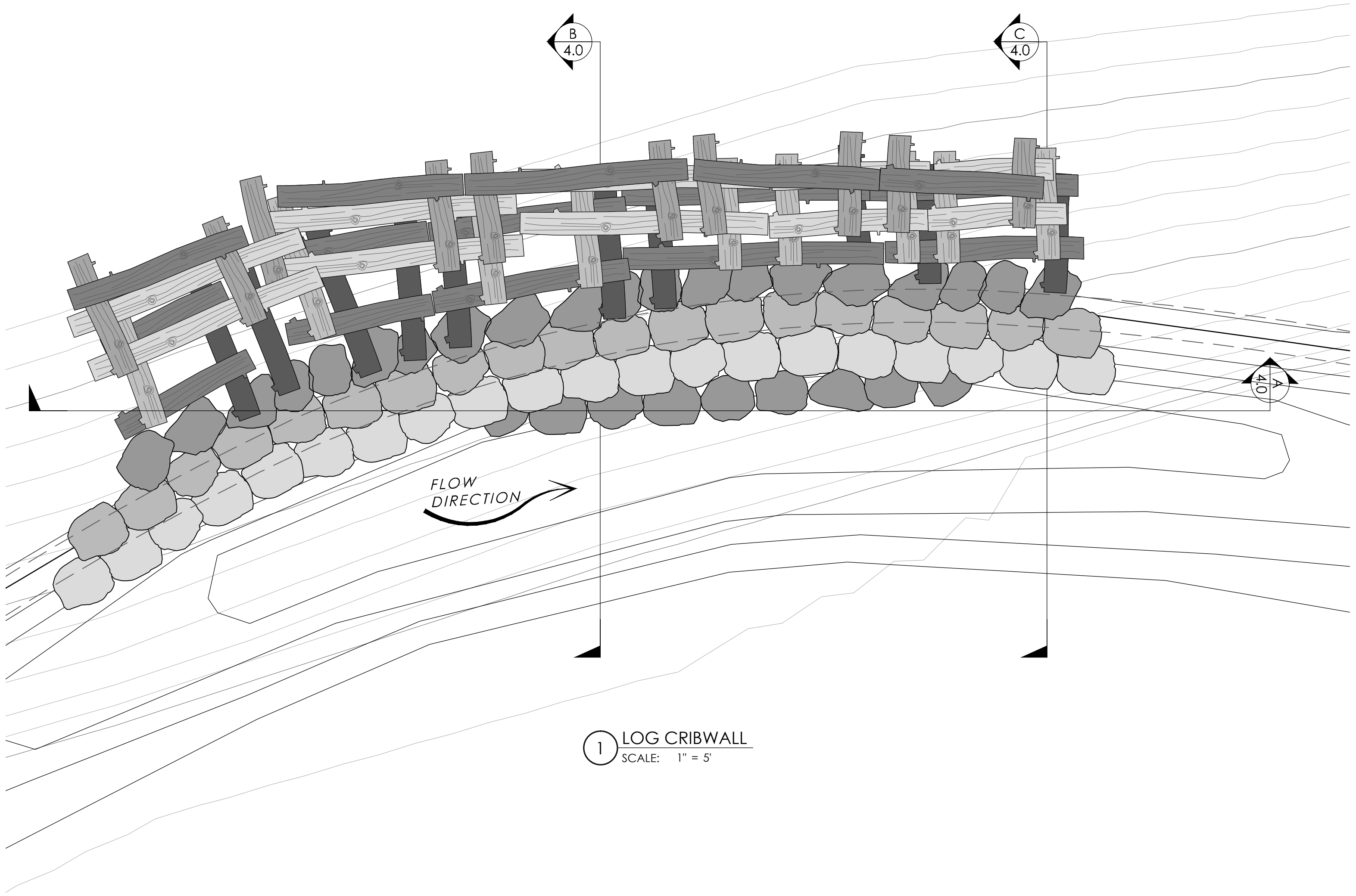
OLYMPIC CHANNEL

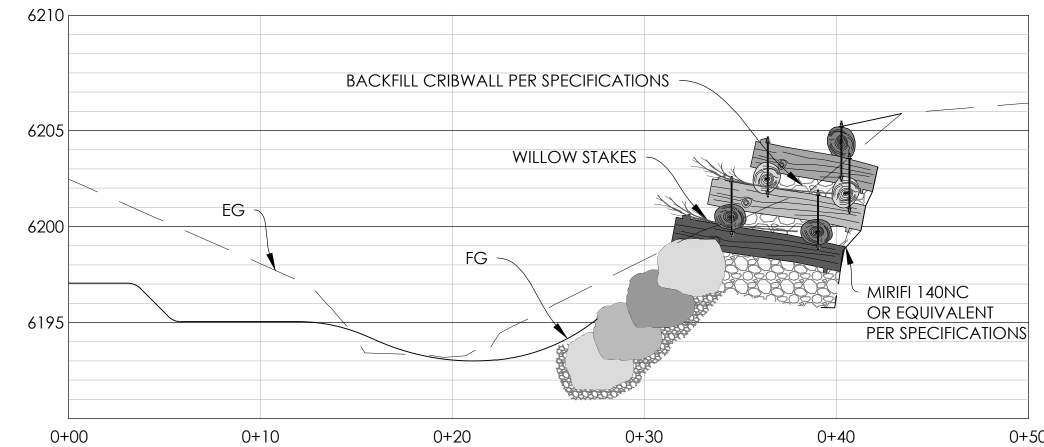
SQUAW CREEK RESTORATION
SQUAW VALLEY VILLAGE SPECIFIC PLAN
PLACER COUNTY, CALIFORNIA

PROJECT NUMBER 211022
SCALE 1" = 30'
SHEET 3.5

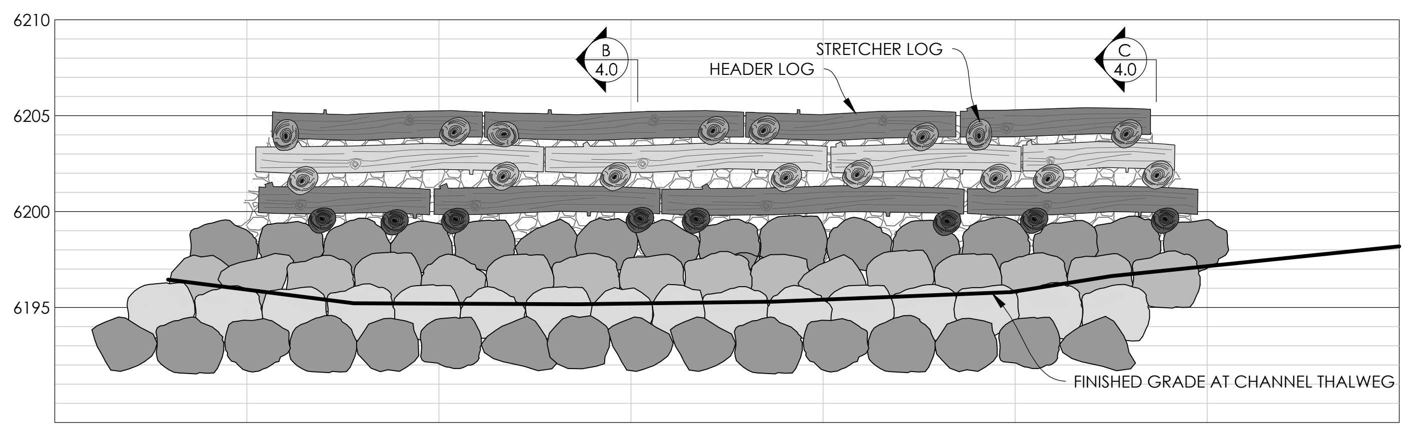
REVISED CONCEPTUAL PLANS - NOT FOR CONSTRUCTION



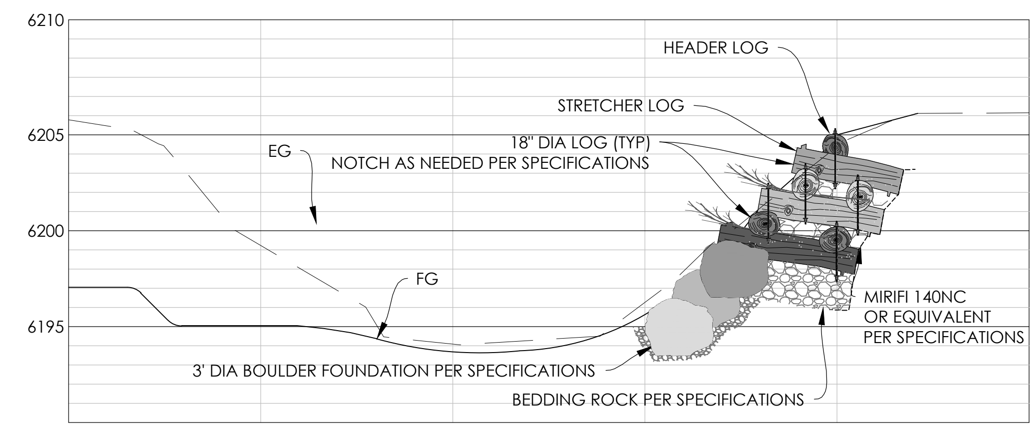
1 LOG CRIBWALL
SCALE: 1" = 5'



LOG CRIBWALL
SECTION VIEW 1" = 5' B 4.0



LOG CRIBWALL
ELEVATION VIEW 1" = 5' A 4.0



LOG CRIBWALL
SECTION VIEW 1" = 5' C 4.0

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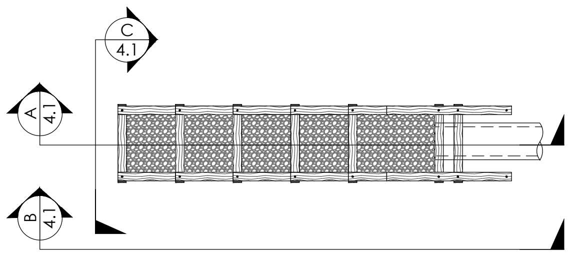
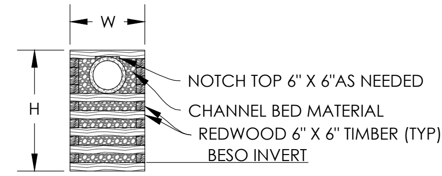
LOG CRIBWALL DETAIL
SQUAW VALLEY DRAINAGE MASTER PLAN
PLACER COUNTY, CALIFORNIA

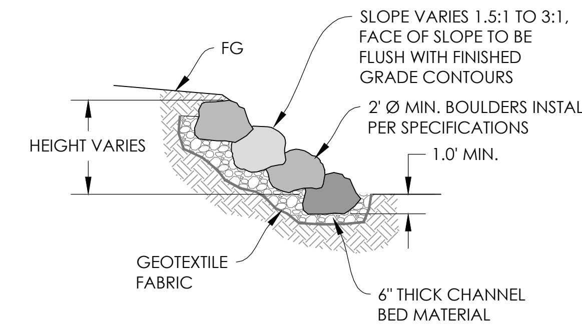
PROJECT NUMBER 211022
SCALE 1" = 5'
SHEET
4.0



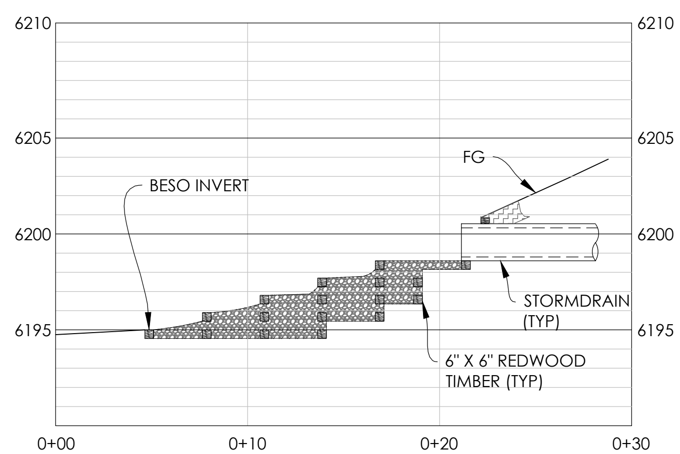
1 BESO
SCALE: 1" = 5'



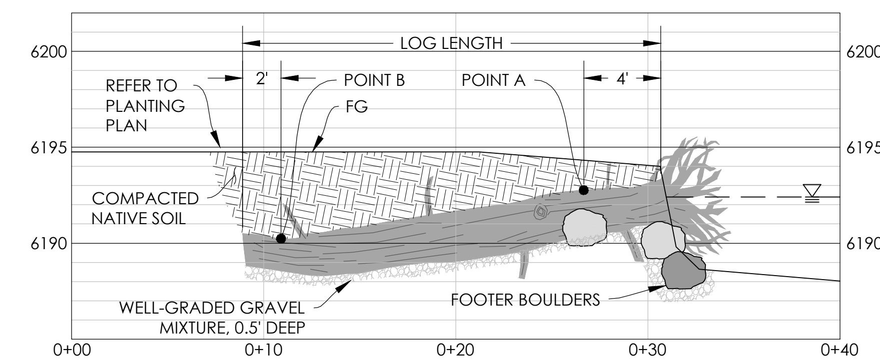
BESO
ELEVATION VIEW 1" = 5' C 4.1



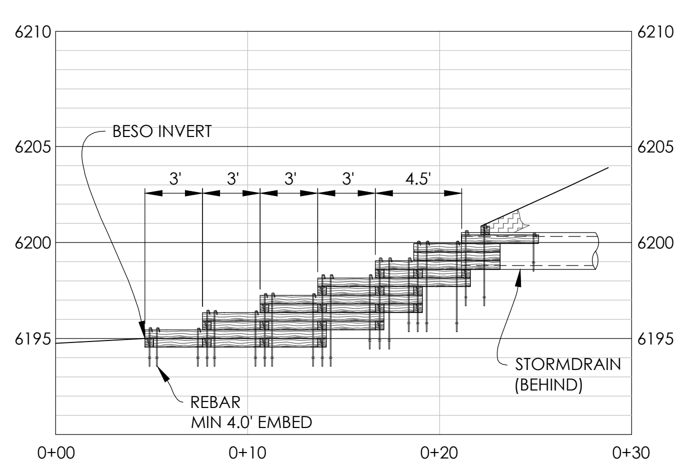
2 ROCK SLOPE PROTECTION
SCALE: 1" = 5'



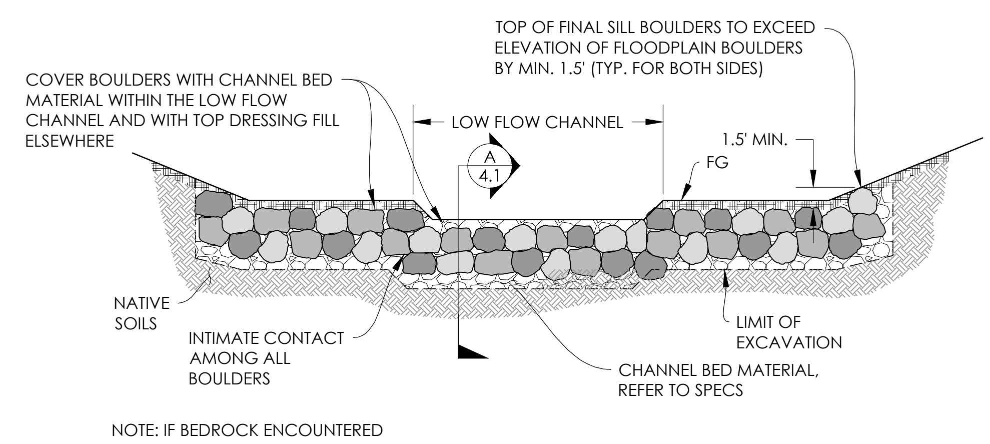
BESO
SECTION VIEW 1" = 5' A 4.1



3 LOG BANK PROTECTION
SCALE: 1" = 5'

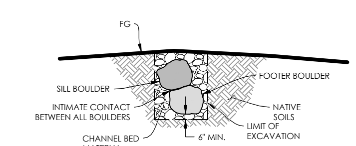


BESO
ELEVATION VIEW 1" = 5' B 4.1



NOTE: IF BEDROCK ENCOUNTERED DURING EXCAVATION, REFER TO SPECS

4 BOULDER GRADE CONTROL
SCALE: 1" = 10'



BOULDER GRADE CONTROL
SECTION VIEW SCALE: 1" = 5' A 4.1

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BESO AND CHANNEL STRUCTURE DETAILS

SQUAW VALLEY DRAINAGE MASTER PLAN
PLACER COUNTY, CALIFORNIA

PROJECT NUMBER 211022
SCALE AS NOTED
SHEET
4.1

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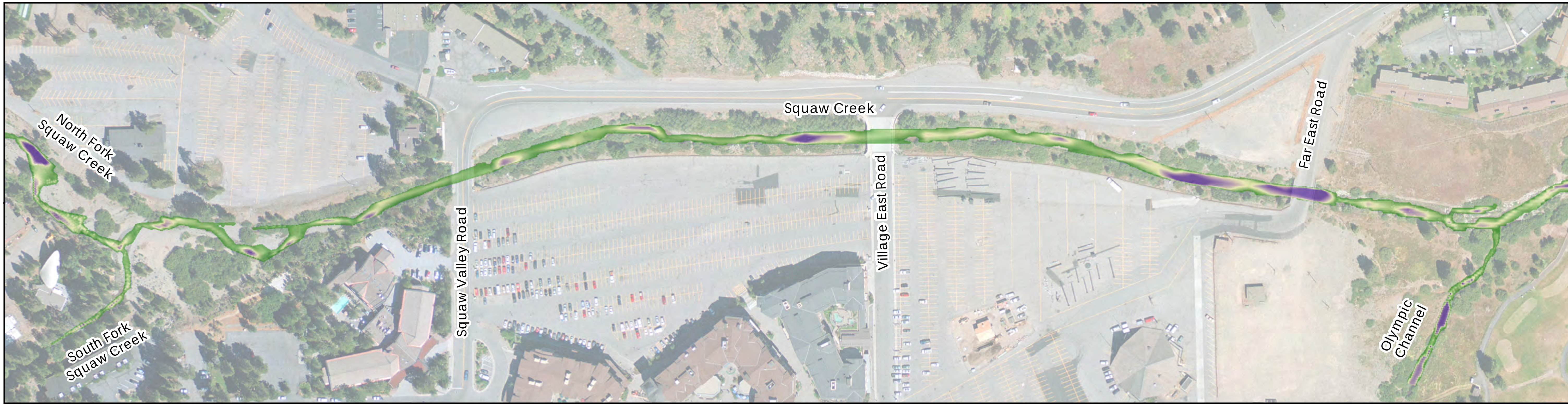
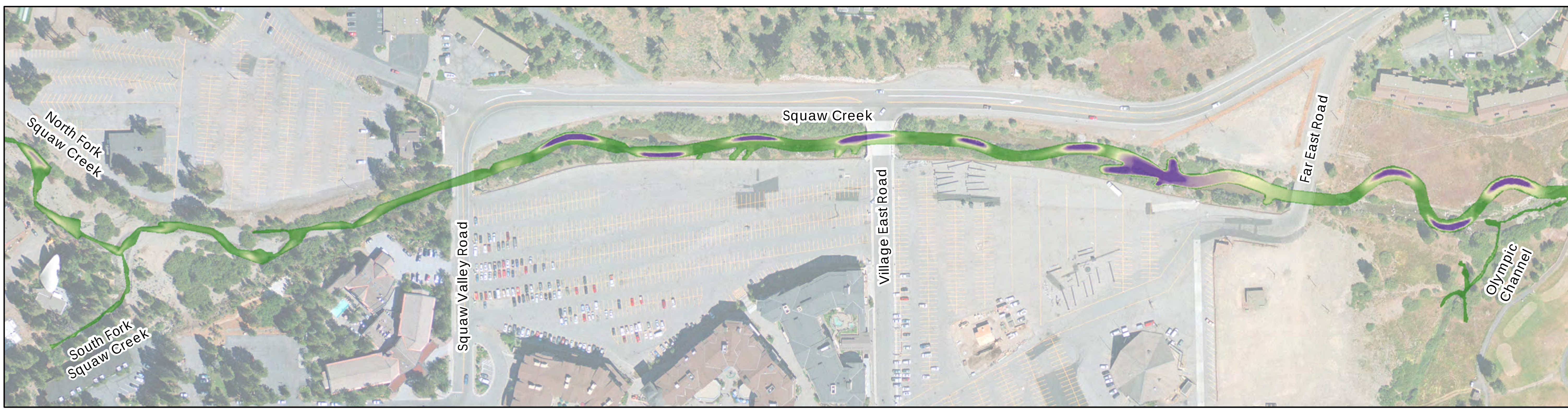
APPENDIX C

2-Dimensional Hydraulic Model Output



Pre-Project Conditions



Post-Project Conditions

Aerial Photo Source: Andregg Geomatics

Balance Hydrologics, Inc.

W:\Projects\211022\SquawCrk_04cfs_h.mxd

Flow Depth (ft)

3.8

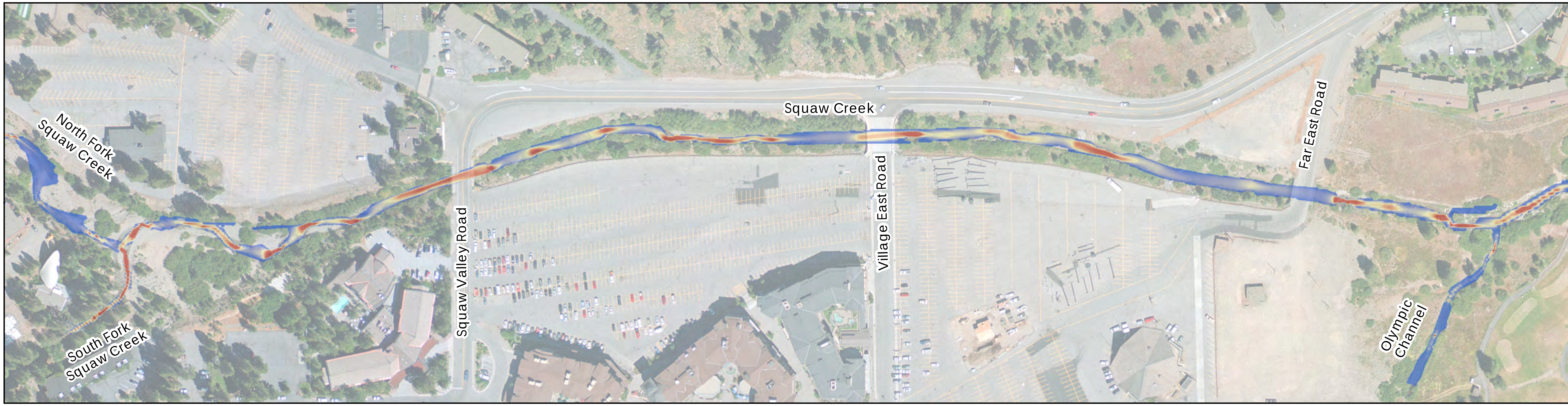
0.0

N

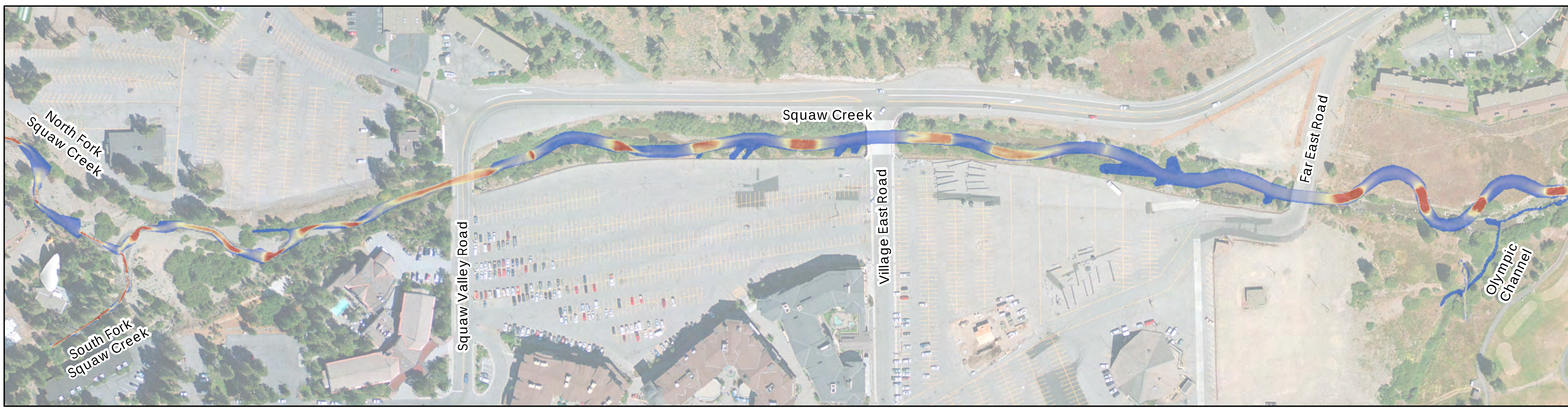
0 100 200 400

Feet

Figure C1. Pre- and Post-Project Depths at 4 cfs
Squaw Creek Restoration,
Placer County, California



Pre-Project Conditions



Post-Project Conditions

Aerial Photo Source: Andregg Geomatics

Balance Hydrologics, Inc.

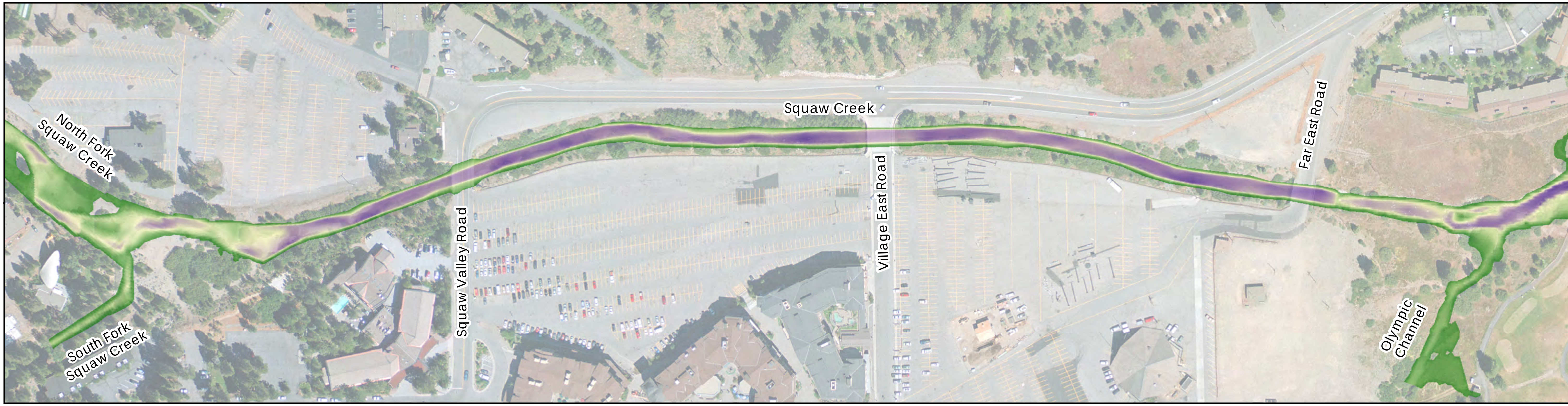
W:\Projects\211022\SquawCrk_04cfs_v.mxd

Flow Velocity (ft/sec)
5.3
0.0

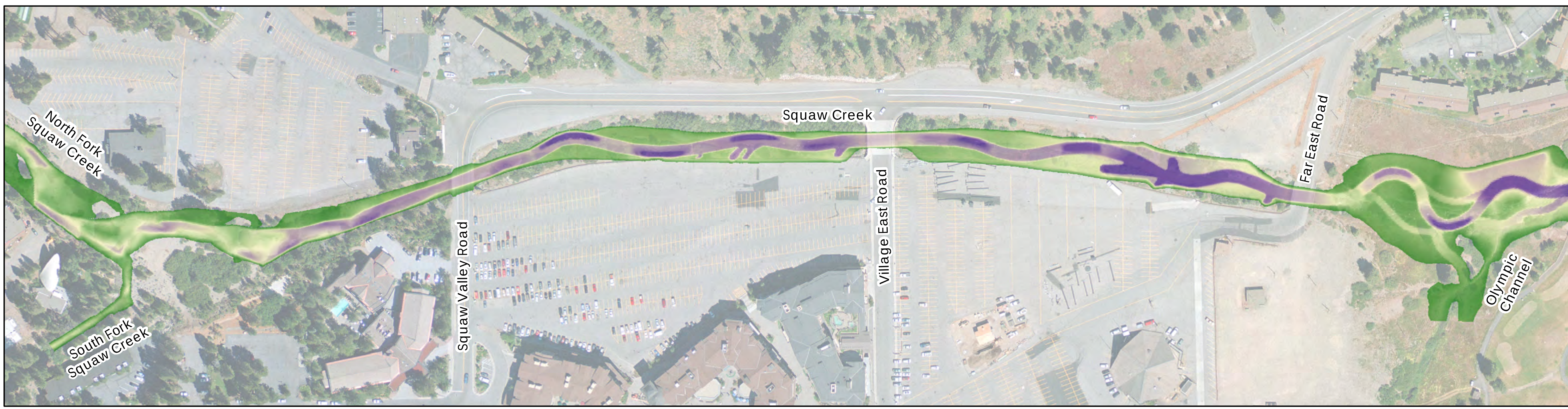
N

0 100 200 400
Feet

Figure C2. Pre- and Post-Project Velocities at 4 cfs
Squaw Creek Restoration,
Placer County, California



Pre-Project Conditions



Post-Project Conditions

Aerial Photo Source: Andregg Geomatics

Balance Hydrologics, Inc.

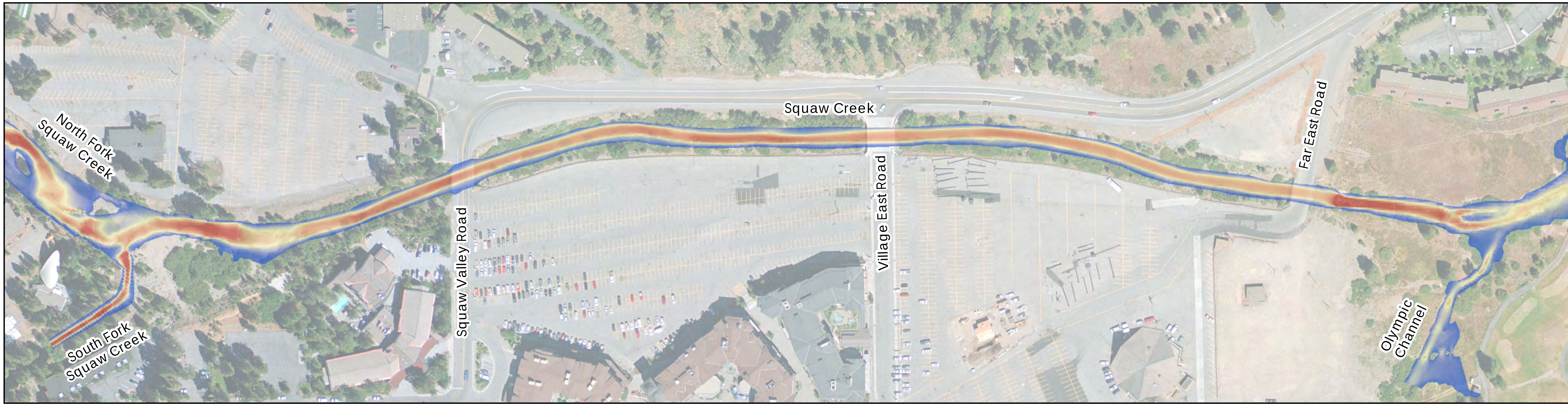
W:\Projects\211022\SquawCrk_550cfs_h.mxd

Flow Depth (ft)
7.2
0.0

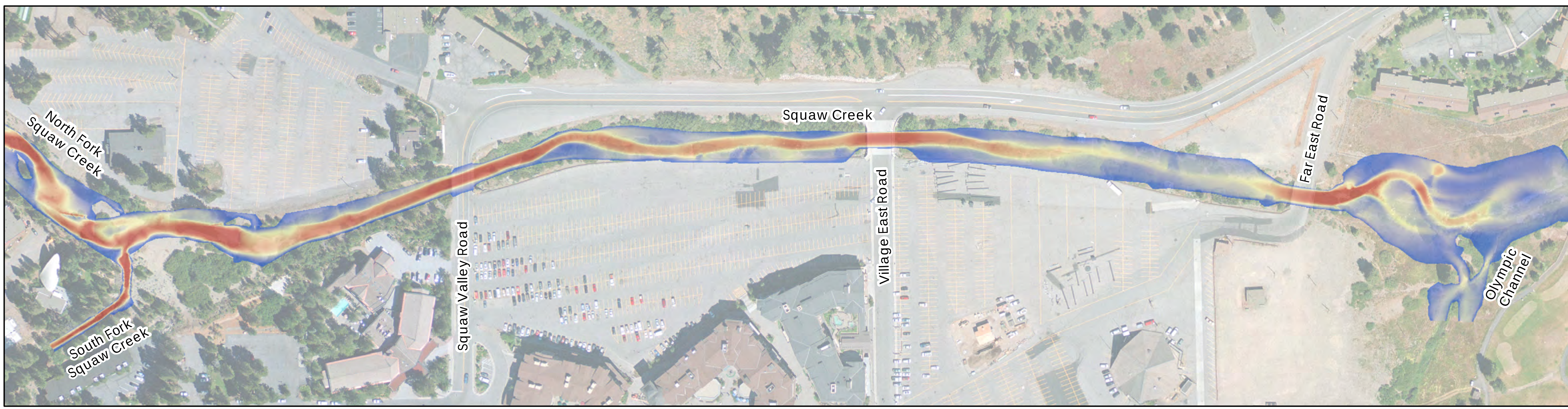
N

0 100 200 400
Feet

Figure C3. Pre- and Post-Project Depths at 550 cfs
Squaw Creek Restoration,
Placer County, California



Pre-Project Conditions



Post-Project Conditions

Aerial Photo Source: Andregg Geomatics

Balance Hydrologics, Inc.

W:\Projects\211022\SquawCrk_550cfs_v.mxd

Flow Velocity (ft/sec)

12.7

0.0

N

0 100 200 400

Feet

Figure C4. Pre- and Post-Project Velocities at 550 cfs
Squaw Creek Restoration,
Placer County, California