GEOMORPHIC ASSESSMENT, SOUTH FORK WOLF CREEK, NEAR GRASS VALLEY, CALIFORNIA

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March 2020

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1 INTRODUCTION

Balance Hydrologics, Inc. (Balance) was asked by Rise Grass Valley, Inc. (Rise) to complete a geomorphic assessment of the South Fork (SF) Wolf Creek channel with respect to the proposed discharge of treated waters from the Idaho-Maryland Mine project in Nevada County, California. Our assessment was conducted in three phases: (1) dry season channel reconnaissance; (2) backgrounding and analysis using existing data, and data and observations collected during the channel reconnaissance; and (3) direct measurements of sediment transport and other geomorphic conditions at higher streamflow.

Treated waters from dewatering of the Idaho-Maryland Mine is proposed to be discharged to SF Wolf Creek. Discharge up to a maximum of rate of 5.6 cubic feet per second (cfs) or 2,500 gallons per minute (gpm) is expected during the approximately 6 months of initial dewatering of the mine. After initial dewatering, groundwater is anticipated to continue to infiltrate the underground workings at a rate of approximately 1.9 cfs (850 gpm) once initial dewatering is complete and will require an ongoing dewatering program. Rise proposes a maximum discharge of 5.6 cfs to provide flexibility to meet the operational requirements for continuous mine dewatering throughout the mine's operation.

This report presents our evaluation of the potential geomorphic effects and changes from the proposed mine dewatering discharge on SF Wolf Creek.

1.1 Project Location and Description

South Fork Wolf Creek is a headwater stream that drains a 2.9 square mile watershed (USGS, 2019) to Wolf Creek (**Figure 1-1**), tributary to Bear River, tributary to the Feather River, and tributary to Sacramento River. The defined bed and bank of SF Wolf Creek originates on the Brunswick Industrial Site, owned by Rise (Matuzak, 2019). SF Wolf Creek is approximately 2.6 miles in length with elevations ranging from 3,158 feet above mean sea level (msl) to 2,388 feet at its confluence with Wolf Creek. Mean annual precipitation in the watershed is approximately 53 inches (WRCC, 2020), and Matuzak (2019) has identified SF Wolf Creek as a perennial stream, with associated riparian habitat.

The watershed land cover consists of approximately 60 percent forested lands and 40 percent urban (USGS, 2019), though the entire watershed has a long history of disturbance from historical land uses. The current urban land uses are mostly concentrated in two locations: (1) the upper northeast corner of the watershed associated with the Nevada County Air and Industrial Park; and (2) the lower portion of the watershed, within the City of Grass Valley. Other developed portions of the watershed are less dense and includes industrial, rural residential, and interspersed open space. The Nevada Irrigation District (NID) operates two canals that cross the upper watershed (D-S Canal Extension and Rattlesnake Canal), and occasionally discharges canal waters to SF Wolf Creek (see **Figure 1-1**).

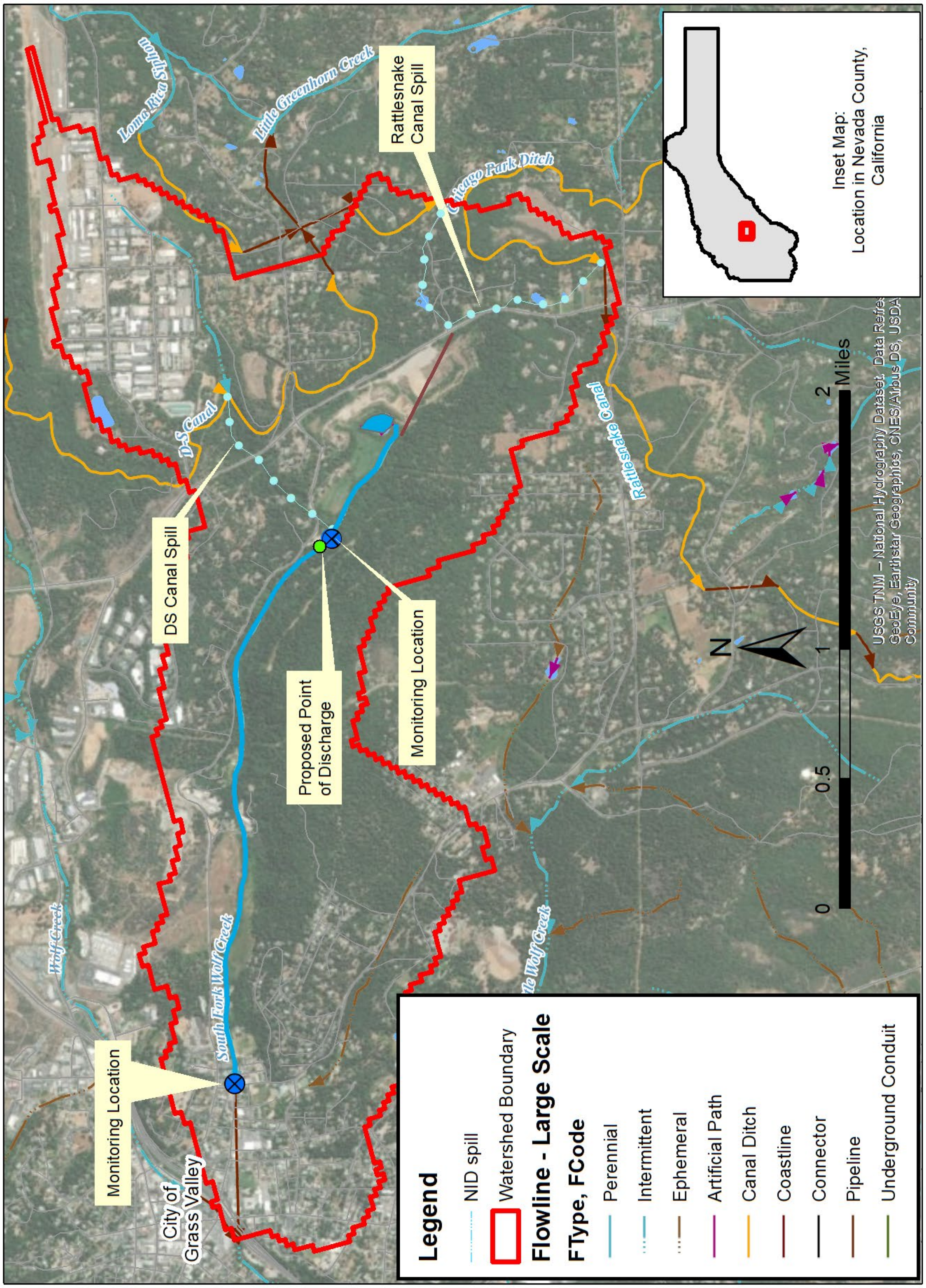

Figure 1-1 Watershed Map, South Fork Wolf Creek, Nevada County, California

1.2 Purpose of This Study

The Idaho-Maryland Mine project proposes to discharge of treated waters from mine dewatering to SF Wolf Creek. The California Environmental Quality Act (CEQA) Environmental Checklist Form (CAEP, 2019) outlines a key question related to Balance's assessment: Will the project "substantially alter the existing drainage pattern of the site or area including through the alteration of the course of a stream or river or through the addition of impervious surfaces in a manner which would result in substantial erosion or siltation on- or off-site".

Balance understands that others are investigating and mitigating for the proposed project's potential impact from storm water run-off and peak flows in South Fork Wolf Creek during storm events. In this assessment, Balance has evaluated the potential geomorphic impacts of increasing streamflow in SF Wolf Creek with the addition of treated mine water.

The specific question addressed under this study is:

Will the proposed dewatering discharge to SF Wolf Creek, substantially affect erosion or siltation in the channel on the property and/or downstream?

This study does not address the question of flooding on- or off-site, water quality, biology or aquatic resources, or capacity and competence of existing stream infrastructure (i.e., culverts).

2 REGULATORY FRAMEWORK

This section outlines federal and state regulatory information pertinent to a proposed dewatering operation with discharge of waters to a channel (i.e., industrial discharge). This information was used to guide our investigation, interpretations and recommendations regarding effects on the channel.

2.1 The Clean Water Act

The United States Environmental Protection Agency (USEPA), through the state regulatory agency (Central Valley Regional Water Quality Control Board, or RWQCB), issues general permits for industrial discharges under the National Pollutant Discharge Elimination System (NPDES). Under the NPDES, a Limited Threat Discharge permit may be authorized for discharges that are relatively pollutant-free and present no or minimal threat to water quality or the environment, including harm or impairment to existing beneficial uses of receiving waters (RWQCB, 2018).

Rise plans to meet the waste discharge requirements as set forth in General Order R5-2016-0076, limited threat discharge NPDES NO. CAG995002 for Tier 3 discharges of wastewater from hard rock mines (RWQCB, 2016).

In addition to NPDES, Section 303(d) of the Clean Water Act also establishes a program to manage water pollution in water bodies that are not meeting federal water quality standards. Section 303(d) requires that states establish a list of impaired water bodies and assess the sources of that pollution. The State Water Resources Control Board (SWRCB) lists Wolf Creek on the 303(d) list for fecal coliform impairment (SWRCB, 2012).

2.2 State of California Porter-Cologne Act

The RWQCB has adopted the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (Basin Plan) (RWQCB, 2018). The Basin Plan establishes: (a) the beneficial uses of water within the region; (b) the water quality objectives necessary to protect those uses, including an antidegradation policy; (c) the prohibitions, policies, and action plans, by which protections are implemented; and (d) the monitoring requirements, conducted to demonstrate attainment of water quality standards.

The Basin Plan does not specifically identify beneficial uses for SF Wolf Creek or its tributaries. The Basin Plan also does not name beneficial uses or regulatory criteria for Wolf Creek, to which SF Wolf Creek is tributary. The existing Basin Plan does identify present and potential beneficial uses for the Bear River (to which Wolf Creek flows), specifically naming:

- municipal and domestic supply;
- agricultural supply, including stock watering;
- hydropower generation;
- water contact recreation;
- non-contact water recreation, including aesthetic enjoyment;
- warm and cold freshwater habitat; and
- wildlife habitat.

Certain formally designated beneficial uses, such as cooling water, spawning or rearing habitat are not named for the Bear River, and do not apply to South Fork Wolf Creek[1].

The Basin Plan also specifies conditions for discharges as they relate to sediment. Discharges, including mine dewatering operations, "shall not alter the suspended sediment load and suspended sediment discharge rate of surface waters in such a manner as to cause nuisance or adversely affect beneficial uses" (Section 3.1.15, Sediment, pp. 3-13, RWQCB, 2018).

More specifically, the NPDES Limited Threat Discharge Permit (RWQCB, 2016) identifies that dischargers shall maintain baseline turbidity conditions or not exceed established standards for increases over baseline conditions. Specifically:

i. Where natural turbidity is less than 1 Nephelometric Turbidity Unit (NTU), controllable factors shall not cause downstream turbidity to exceed 2 NTUs.

ii. Where natural turbidity is between 1 and 5 NTUs, increases shall not exceed 1 NTU.

[1] Basin Plans commonly include smaller streams with larger tributaries to which they drain: *beneficial uses of any specifically identified water body generally apply to its tributary streams." (Sec. 2.1. pp 2 – 3, RWQCB, 2018) but there are exceptions such as for migration barriers downstream.*

iii. Shall not increase more than 20 percent where natural turbidity is between 5 and 50 NTUs.

iv. Shall not increase more than 10 NTU where natural turbidity is between 50 and 100 NTUs; nor

v. Shall not increase more than 10 percent where natural turbidity is greater than 100 NTUs.

To evaluate compliance, the permits will typically require regular water quality monitoring and reporting of receiving waters upstream and downstream of discharge point to establish a baseline and compare during discharge operations. Monitoring frequency will be established by the agency to evaluate impacts of the discharge and compliance with permit conditions.

2.3 California Environmental Quality Act (CEQA)

Chapter 3 of Title 14 of the California Code of Regulations provides guidelines for the implementation of CEQA. As amended in December 2018, Appendix G of the CEQA guidelines provides an Environmental Checklist Form with criteria that are relevant to the evaluation of a project's potential environmental effects (CAEP, 2019). Section IX provides criteria related to Hydrology and Water Quality. Specific to the focus of this study, we identified the following item on the checklist that is pertinent to this investigation:

> *"Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner which would: i) Result in substantial erosion or siltation on or off-site?"*

This study is focused on how the proposed mine dewatering program, with planned discharges to SF Wolf Creek, may increase streamflow above baseline conditions, and whether such increases may result in erosion or siltation off-site. The CEQA checklist, Basin Plan, and the NPDES Limited Threat Discharge Permit guidelines provide guidance as to what would constitute a significant impact in terms of sediment transport, turbidity, and geomorphic change along the channel. This assessment is therefore focused on characterizing baseline streamflow patterns, turbidity, and sediment transport, as related to observed geomorphic conditions in the channel.

3 EXISTING CONDITIONS IN THE SOUTH FORK WOLF CREEK WATERSHED

This section describes current watershed conditions such that it defines a baseline prior to implementation of the proposed discharge. Previous studies and documents pertinent to this project are also listed and briefly discussed.

3.1 Historical Disturbance in the Creek and Watershed

Mining disturbance in the SF Wolf Creek watershed is well documented with numerous recorded hard rock and placer mine workings (Johnston, 1940). Mining in and around the SF Wolf Creek watershed began as far back as 1848 at the start of the Gold Rush. Mining methods consisted of both hard-rock mining and placer mining methods. The latter depended on using water to wash gold deposits from the sand or gravel of stream beds occurred throughout the SF Wolf Creek Watershed. Several local hard-rock mines in the region have historically discharged water to SF Wolf Creek. The Empire mine has discharged mine water to SF Wolf Creek throughout its history, currently discharges treated mine water to SF Wolf Creek. The Brunswick, Union Hill, and numerous smaller mines also historically discharged waters to SF Wolf Creek.

SF Wolf Creek and other drainages in Nevada County were altered as early as 1840 from early mining, logging, and agricultural practices. Lowlands in the watershed were converted to agriculture and orchards. Historical aerial photographs (USGS, 1947) show agricultural uses adjacent to South Fork Wolf Creek and in the SF Wolf Creek watershed. Pear and apple trees still exist today in some areas of the watershed. At the proposed Idaho-Maryland mine dewatering discharge site, the SF Wolf Creek channel banks consist of historical mining waste rock with a diameter larger than the natural bed sediment. Many rudimentary trails and roads were constructed in the uplands for both mining and logging operations and more formal transportation networks also contributed to watershed disturbance. Historical maps depict a narrow-gauge railroad (The Nevada County Narrow Gauge Railroad) along the entire length of the creek as early as 1895 (USGS, 1895) which supported passenger and commercial transport until 1943. The Nevada County Air Park was constructed in 1935 to also facilitate transport of gold from the original Idaho-Maryland Mine to San Francisco and beyond.

The last date of Idaho-Maryland Mine operations was in 1956. Since then, portions of the watershed have been heavily urbanized including growth of the City of Grass Valley and expansion of the Nevada County Air Park to include an industrial park. These developments increased impervious surfaces in the watershed and altered the drainage patterns and flow regime of SF Wolf Creek and its tributaries. Changes in the natural watershed hydrologic processes and runoff characteristics (i.e. interception, infiltration, overland flow, interflow and groundwater flow) caused by urbanization result in modifications over time to the timing and magnitude of streamflow and changes in sediment transport. Based on a review of historical aerial imagery (Google Earth, 2019), land uses in SF Wolf Creek watershed have remained relatively unchanged since the 1990s.

SF Wolf Creek has also been modified by infrastructure and/or direct modification. Numerous culverts and crossings exist along the entire length of the channel. Some culverts exhibit scour and erosion upstream and downstream of their inlets and outlets, respectively. Fill and abundant non-native vegetation along banks and floodplains are present in discontinuous sections along the creek and appear to increase bank stability in many reaches. The downstream-most 0.4 miles of the SF Wolf Creek channel is mainly enclosed in a concrete box culvert.

3.2 Artificial Discharges and Diversions

Based on background documents and correspondence with local water providers (Nevada Irrigation District), our assessment documented other complexities to SF Wolf Creek hydrology. Other identified artificial discharges to SF Wolf Creek include: (1) NID canal discharges; and (2) Empire Mine treated water discharge.

3.2.1 Nevada Irrigation District Canals

NID operates two canals that cross the upper watershed (see **Figure 1-1**); (1) Deer Creek South (D-S) Extension Canal; and (2) Rattlesnake Canal (Chicago Park Canal spur). According to NID (Close, pers. comm., 2019), Rattlesnake Canal periodically discharges to SF Wolf Creek using two gates upstream of Brunswick Road with a maximum combined discharge rate of 11 cfs. The D-S Canal Extension periodically discharges to SF Wolf Creek using two gates upstream of Brunswick Road with a maximum combined discharge rate of 35 cfs (**Figure 3-1**). Pathways for conveyance for these discharges to SF Wolf Creek are characterized as intermittent tributaries to SF Wolf Creek and are identified by this assessment and NID. These discharges enter SF Wolf Creek upstream of the proposed point of discharge for the mine dewatering program (see **Figure 1-1** or **Figure 3-1**).

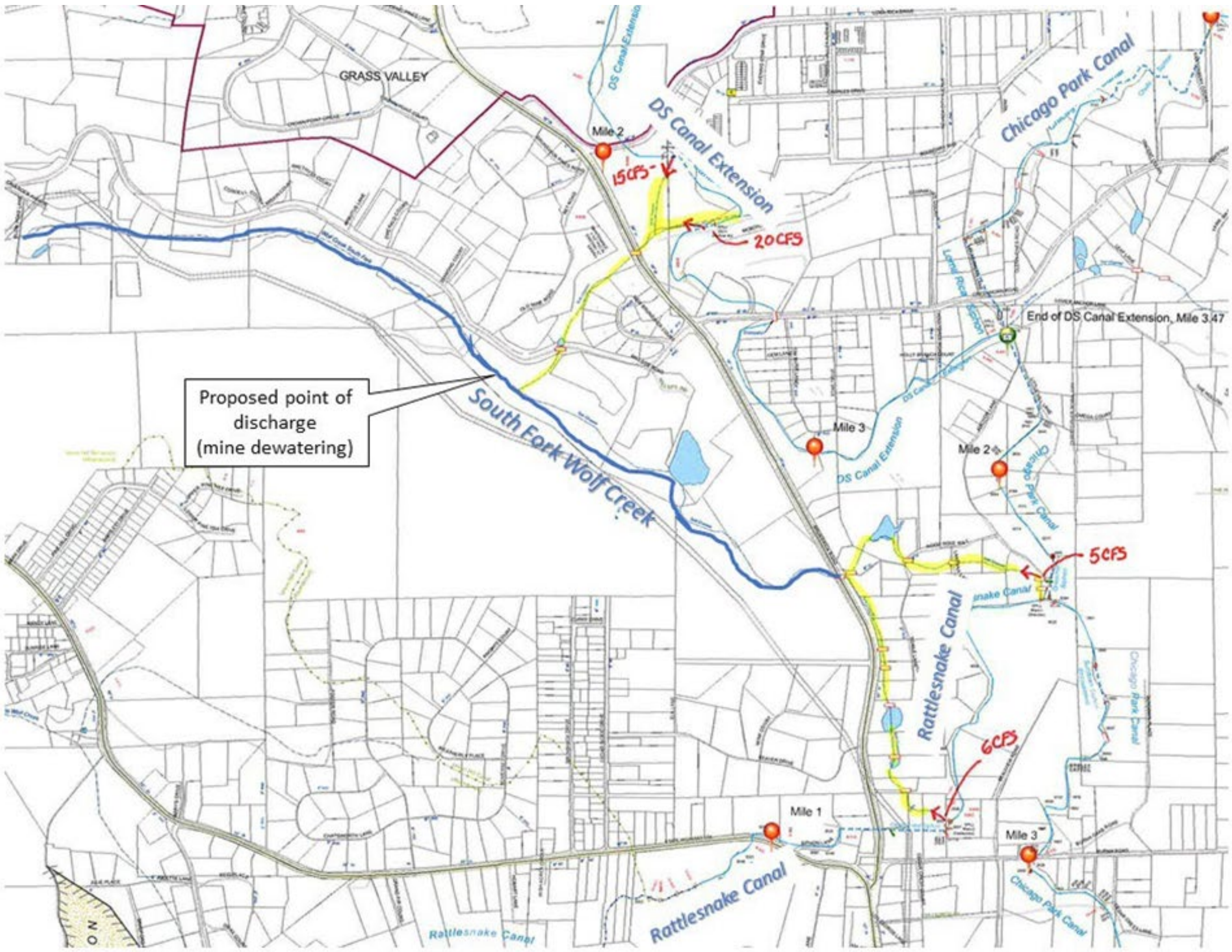

Figure 3-1 Nevada Irrigation District (NID), 2019, canal map (no scale provided). Showing D-S Canal Extension and Rattlesnake Canal points of discharge to SF Wolf Creek (yellow highlight); maximum discharge for each point of discharge are identified on the map (Close *pers. comm., 2019); Balance notes that this map shows some inaccuracies compared to other existing spatial data.*

While there is no regular conveyance use for the D-S Extension Canal or Rattlesnake Canal downstream through SF Wolf Creek, discharges to SF Wolf Creek to relieve flooding in these canals during storms (Close, C., pers. comm., 2019). NID is known to also use these spill channels to SF Wolf Creek periodically for maintenance purposes. (Halvorson, pers. comm to EMKO 2018).

Flood-relief and maintenance discharges to SF Wolf Creek are not directly measured or reported by NID but can be estimated using the difference measured at NID-operated gages located at key points of diversion or discharge. For instance, flows in D-S Extension

Canal are estimated using differences between gages at Deer Creek in flow and discharges to Wolf Creek. NID provided daily mean discharge values for releases to SF Wolf Creek from the DS Extension Canal for a period between March 5, and May 5, 2018 (**Figure 3-2**). Local daily precipitation is shown for context. These data suggest daily mean discharges between 3.6 cfs and 13.4 cfs to SF Wolf Creek occurred over 3 different periods with durations between 5 days and 15 days. Maximum or instantaneous values were not provided. The first two of the three events suggest these releases were flood relief discharges, while the last event was likely a maintenance flow. No discharge data was available for Rattlesnake Canal.

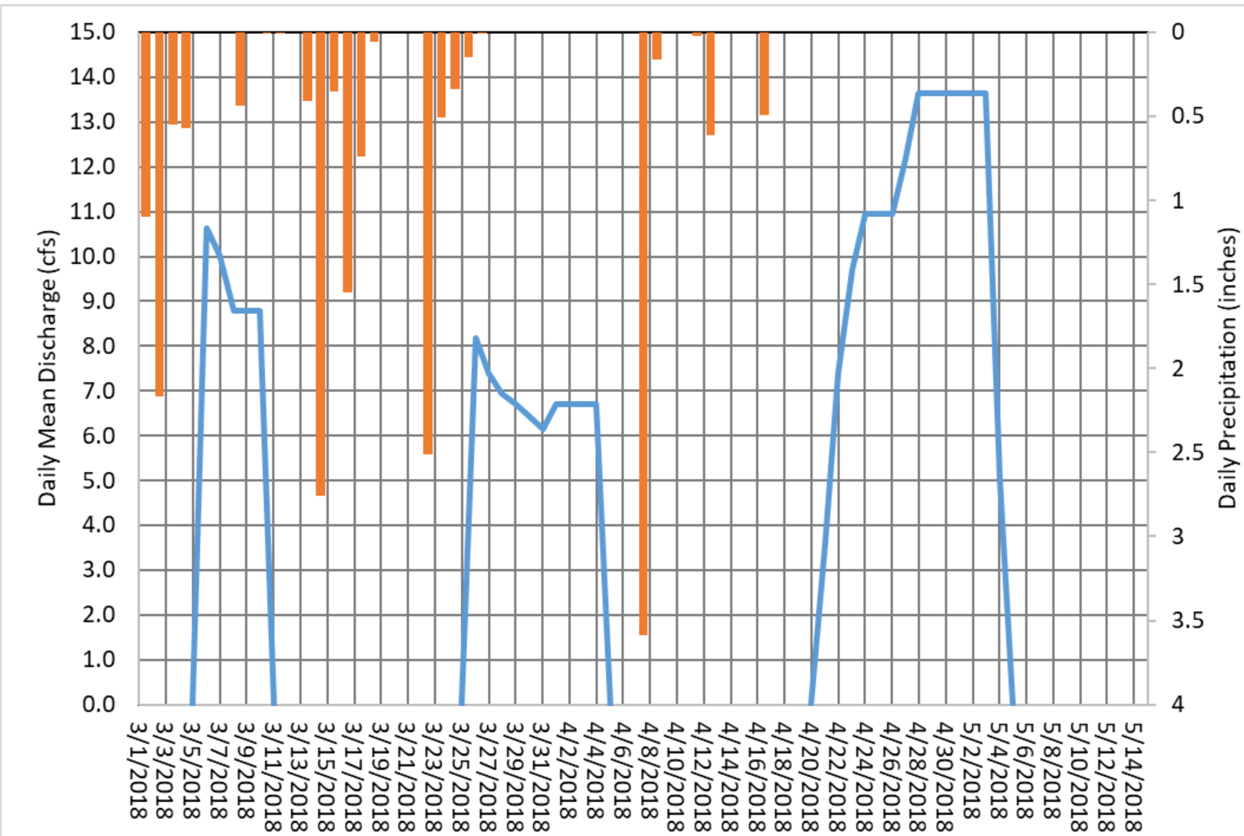

Figure 3-2 Daily mean discharge (blue line) from DS Canal to SF Wolf Creek

3.2.2 THE MAGENTA DRAIN

The Magenta Drain is a modified tributary to SF Wolf Creek with an underground confluence within the City of Grass Valley storm drain network in Reach F. The Magenta Drain is believed to drain groundwater associated with underground mine working and of the historical Empire Mine and intercepts shallow groundwater recharge from

Woodpecker Ravine. Flow in the Magenta Drain occurs year-round, varies according to seasonal precipitation, and is responsive to storm events. Based on limited measurements, flows are reported to range between 1.4 cfs (623 gpm) to 2.2 cfs (982 gpm) (MFG, Inc., 2006).

Because this discharge enters the SF Wolf Creek within a culverted or concrete stormwater system (Reach F), Balance did not consider its additional flows relative to erosion and/or siltation of the natural channel in reaches susceptible to these impacts.

3.2.3 Diversions

There are no known diversions from SF Wolf Creek below the proposed point of discharge. Natural flow, discharges from NID canals, and proposed discharge from mine dewatering will be conveyed down SF Wolf Creek to its confluence with Wolf Creek.

3.3 Previous Geomorphic Work Completed

This section identifies previous studies that were accessible and reviewed by Balance.

From 2003 to 2007, the Idaho-Maryland Mining Corp estimated streamflow and measured turbidity at 3 locations along SF Wolf Creek (IMMC, 2007). Stanin and others (2008) conducted a peer review of these data, however, and concluded that the estimates contained large errors. This study also reported turbidity data collected during different flow conditions.

The Wolf Creek Community Alliance completed a water quality monitoring assessment of Wolf Creek and its tributaries between 2004 and 2012 (WCCA, 2013) and in 2017 produced a watershed disturbance inventory for the Wolf Creek watershed (WCAA, 2017) that also included measurements of turbidity; turbidity values were not, however reported as part of this study.

In 2008, re-opening of the Idaho-Maryland Mine was examined under a previous land-owner with a proposed dewatering discharge rate of 6 cfs to the South Fork of Wolf Creek. At this time, a geomorphic study was completed by Environmental Science Associates (ESA; Gragg, 2008) to evaluate the potential effects of theses discharges. Gragg (2008) examined two different locations on the Idaho-Maryland Mine property for proposed discharge and found that a downstream location was better suited based on lower sediment transport. This is the same location currently proposed and evaluated for this study. While Gragg (2008) estimated an increase in sediment transport capacity of 1.5 tons/day for a discharge of 6 cfs at this location, the report did not identify the baseline sediment transport capacity and address whether or not the additional sediment transport load generated by the discharge would result in substantial erosion or siltation.

3.4 Other Pertinent Background Review

Balance reviewed known regulations, publications, maps, and datasets provided by Rise and as available through an on-line search. Balance also completed a review of existing or former mine dewatering plans and permit conditions in the Nevada County area, permitted or approved by the RWQCB, listed here:

- Order No. R5-2012-0057: Waste Discharge Requirements for California Natural Resources Corp. and Maurice Altshuler and Bartlett Burnap, Mining, Processing, and Reclamation, French Corral Mine, Nevada County, California (RWQCB, 2012)
- Recommended Conditions of Approval, North Star Water Treatment Project, U14-009, MGT14-015, EIS14-012, Nevada County, California (Nevada County, 2015)
- Order No. R5-2008-0105, Requiring Soper Company, Spanish Mine, Nevada County, California to Cease and Desist from Violating Waste Discharge Requirements (RWQCB, 2008)

4 METHODOLOGY

This section describes methodology utilized for this study. Using standard field techniques, Balance geomorphologists with active registration in the State of California characterized the geomorphology of the watershed including the channel condition, form, and sediment characteristics. Secondly, Balance estimated the range of streamflow that is likely to initiate sediment mobility in SF Wolf Creek, as based on published empirical calculations. Finally, Balance evaluated the calculated estimates through direct observations of streamflow and sediment transport during elevated streamflow conditions. Each of these steps is described in further detail below.

4.1 Delineation and Classification of SF Wolf Creek

Based on review of available maps (NID, 2019, Rise Grass Valley, 2019, USGS, 1895, 1949), topography (Aero Geometrics, Ltd., 2019), historical aerial photographs (Google Earth, 2019, USGS, 1947), and a reconnaissance of the channel, Balance characterized channel-reach morphology using a classification system presented by Montgomery and Buffington (1997). Balance delineated SF Wolf Creek into different reaches based on: (a) slope, (b) channel morphology, (c) stream order or proximity to other tributaries, and (d) land-use, including influence of urban infrastructure or channel modification. The classification system synthesizes stream morphologies into distinct channel types, which allows for assessment of conditions and potential response to watershed perturbations (Montgomery and Buffington, 1997). Reach classifications allowed our team to identify channel environments that may be most susceptible to changes in flow from the proposed dewatering program.

4.2 Hydrology

SF Wolf Creek is an un-gaged tributary; therefore, information about the hydrology is limited to existing studies, indirect calculations, interpretations of channel condition, land-uses, and observations and measurements completed as part of this study. Estimates of common recurrence floods can be computed according Nevada County's Hydrologic Manual, and are important for flood planning and infrastructure design and protection projects; however, these estimates do not address the more frequent but lower magnitude flows that move sediment and do work on the channel (i.e. "geomorphic flows"). Peak flow calculations from runoff modeling also do not typically account for seasonal or annual variability (i.e., wet year vs. dry year ambient conditions). Therefore, Balance conducted streamflow measurements and made observations of sediment transport during a low to moderate runoff event according to USGS standard practice for measuring discharge and sediment transport at a gaging station (Turnipseed and Saur, 2010).

In addition to field observations and measurements, Balance staff estimated flows in the 1- to 10-year recurrence range by way of indirect field measurements, published regression equations, and unit-discharge from regional gaging stations.

4.2.1 Manning's Equation Supported by Field-collected Data.

Bankfull streamflow is sometimes associated with flows that transport sediment and maintain the channel form, and the peak flow of water year[2] (WY)2019 was at least a 1-year event, probably greater. Bankfull streamflow was estimated according to the bankfull capacity of the channel, as indicated in the field by breaks in slope in cross-section; absence or presence of bankside vegetation; and/or lines that delineate between active and non-active sediment deposition. The water year (WY)2019 peak flow water surface was estimated according to high-water marks observed in Fall 2019. At that time, Balance completed cross-section and slope surveys according to the field indicators, and calculated the associated flow according to Manning's Equation:

$$Q = \frac{k}{n} \cdot A \cdot R^{2/3} \cdot S^{1/2}$$

Where	*Q*	=	Discharge (m^3/sec., ft^3/sec.)
	k	=	Constant (1.00$m^{1/3}$/$m^{1/3}$ SI, 1.49$ft^{1/3}$/$ft^{1/3}$ U.S. customary)
	n	=	Manning's coefficient (unitless)
	A	=	Flow area (m^2, ft^2)
	R	=	Hydraulic radius (m, ft)
	S	=	Friction slope (m/m, ft/ft)

Manning's coefficients were selected to range from 0.038 to 0.059, as dependent on flow depth and bed and bank conditions.

[2] A water year is measured from October 1 through September 30 of the named year; for example, water year 2019 began on October 1, 2018 and ended on September 30, 2019.

4.2.2 Regional Regression

Regional equations developed by Gotvald and others (2012) are as follows:

- 2-year Flood (cfs) = 2.43*(Drainage Area)$^{0.924}$ * (Mean Basin Elevation)$^{-0.646}$ * (Mean Annual Precipitation)$^{2.06}$
- 5-year flood (cfs) = 11.6*(Drainage Area)$^{0.907}$ * (Mean Basin Elevation)$^{-0.566}$ * (Mean Annual Precipitation)$^{1.70}$
- 10-year flood (cfs) = 17.2*(Drainage Area)$^{0.896}$ * (Mean Basin Elevation)$^{-0.486}$ * (Mean Annual Precipitation)$^{1.54}$

For the purposes of calculating peak flows at the proposed discharge location as well as for the lower watershed, Drainage areas were calculated for SF Wolf Creek at the proposed discharge location (1.6 sq. mi.) and at Ophir Street, approximately 0.5 miles upstream from the confluence with Wolf Creek (2.3 sq. mi.). Mean basin elevation is 2,756 feet and mean annual precipitation is 53 inches (WRCC, 2020).

4.2.3 Unit Discharge

Unit-discharge rates were established according to Sweetland Creek near North San Juan, California (USGS Station 11413600).

4.4 Bed Sediment Mobility Calculations

Balance used the Shield's equation (Shields, 1936) and solved for the grain size (Ds) to estimate a range of potential flows when the D_{50}-sized clast is mobile. Two commonly reported values in the literature for critical shear stress (*T**) were used in order to present a range of flows when the observed D_{50}-sized clast becomes mobilized.

Shield's equation:

$$\tau_* = \theta = \frac{\tau}{(\rho_s - \rho) g D},$$

where:

- τ is a dimensional shear stress;
- ρ_s is the density of the sediment;
- ρ is the density of the fluid;
- g is acceleration due to gravity;
- D is a characteristic particle diameter of the sediment.

While the Shields' equation appears to work well in fine and well sorted sediments, its application to the poorly sorted sediment typical of small forested channels has proven more difficult. In heterogeneous sediments, there is no single flow (or mobility number) above which all clasts of the same size will move (Hassan and others, 2005); therefore, this approach should be considered an estimation. Direct measurement of the sizes of grains in transport are usually needed to quantify thresholds of sediment mobility and the inception of bedload movement in general.

4.5 Turbidity

Turbidity is a measure of relative clarity of the water or the scattering of light passing through water and is measured in nephelometric turbidity units (NTU). The higher the turbidity, the more light has been inhibited from passing through the water and sediment mixture. Material that causes water to be turbid includes clay, silt, inorganic and organic matter, algae, and plankton and other microscopic organisms (Swenson and Baldwin, 1965). Turbidity is commonly used as a surrogate for measuring suspended-sediment concentration. Balance measured turbidity during multiple site visits to gain a better understanding of baseline turbidity conditions.

4.6 Channel Reconnaissance

Balance conducted a channel reconnaissance of accessible segments of the creek between on September 25, 2019 and October 3, 2019. These visits occurred during an extended dry period that reflected summer baseflow conditions after an above-average precipitation year [WY2019: 67.3 inches; WRCC, 2020; NCDC, 2020]. During each visit, Balance evaluated channel and bed conditions, collected sediment samples, characterized bed sediment size and delineated SF Wolf Creek into distinct reaches based on geomorphic metrics. Observations during baseflow preceded observations and measurements made during elevated flows in January 2020, as described further in Section 4.8. For the purposes of this report "baseflow" is defined as the flow of water in the perennial creek during periods of no rainfall. Baseflow in perennial creeks can vary seasonally and from year to year.

4.7 Bed Sediment Characterization

Balance characterized channel bed sediment in pool-riffle reaches using several modified Wolman Pebble Counts (c.f., Wolman 1954; modified per Dunne and Leopold, 1978, p. 655). Data from pebble counts were entered in spreadsheets to compute sediment grain size distribution and are presented in terms of the 16th, 50th (median), and 84th percentile sizes, or the D_{16}, D_{50}, and D_{84}.

4.8 Concurrent Monitoring Program: Streamflow and Sediment Transport

Sediment transport is usually considered in two parts: suspended sediment and bedload sediment. Suspended sediment consists of clay, silts, fine sands, and forest-floor duff such as seeds and pine needles and is suspended and transported by turbulence in the water column. Bedload sediment includes coarser sands, fine gravels, coarse gravels, cobbles, and (sometimes) boulders. Total sediment transport (IT) is the sum of suspended sediment (IS) and bedload sediment (IB):

$$IT = IS + IB$$

Balance initiated a baseline streamflow and sediment transport monitoring program on January 25, 2020 at two different locations on SF Wolf Creek: 1) SF Wolf Creek upstream of the proposed point of discharge; and (2) SF Wolf Creek at Ophir Street. At each location, Balance installed fixed datums (staff plates) and near-continuous water-level recorders. Beginning with the storm of January 26, 2020 and for the next several months Balance will manually measure streamflow over a range of different conditions at each location to develop water depth (stage) to streamflow relationships and a near-continuous streamflow record. Streamflow is measured using standard hydrologic practices (Turnipseed and Sauer, 2010).

In addition, Balance is using standard equipment and following standard sediment measurement methods and protocols, as based on Edwards and Glysson (1999) and MacDonald and others (2011) for sample collection and computation of sediment transport (**Figure 4-1**). Suspended-sediment samples collected during the January 26, 2020 storm event were submitted to Western Environmental Testing Laboratory (WETLAB) in Sparks, Nevada for analysis of suspended-sediment concentration (SSC; ASTM D-3977 [A]). Bedload samples will be processed in Balance's Berkeley, California laboratory. Balance will collect both suspended-sediment and bedload samples over a range of streamflow to develop baseline streamflow-to-sediment-transport rating curves. Establishing this baseline will allow for future calculation of anticipated changes in sediment transport rates with changes in streamflow rates.

A

B

Figure 4-1 Equipment used for this monitoring program- (A) DH-48 suspended sediment sampler; (B) 3-inch Helley-Smith bedload sampler with a 0.25" mesh bag.

5 RESULTS

This section presents Balance's findings from the channel reconnaissance, sediment mobility calculations, and direct measurements of both streamflow and sediment transport.

5.1 Reach Delineation and Channel Morphology

A longitudinal profile for SF Wolf Creek is presented in **Figure 5-1** along with 6 identified reach designations (Reaches A through F), as based on channel slope, morphology, location of tributaries, and/or channel type (i.e., natural channel vs. engineered channel or culvert). Each reach is plotted according to channel slope in **Figure 5-2** for comparison to the morphology and characteristics predicted by Montgomery and Buffington (1997). A summary of channel characteristics and geomorphic metrics for each reach are provided in **Table 5-1**.

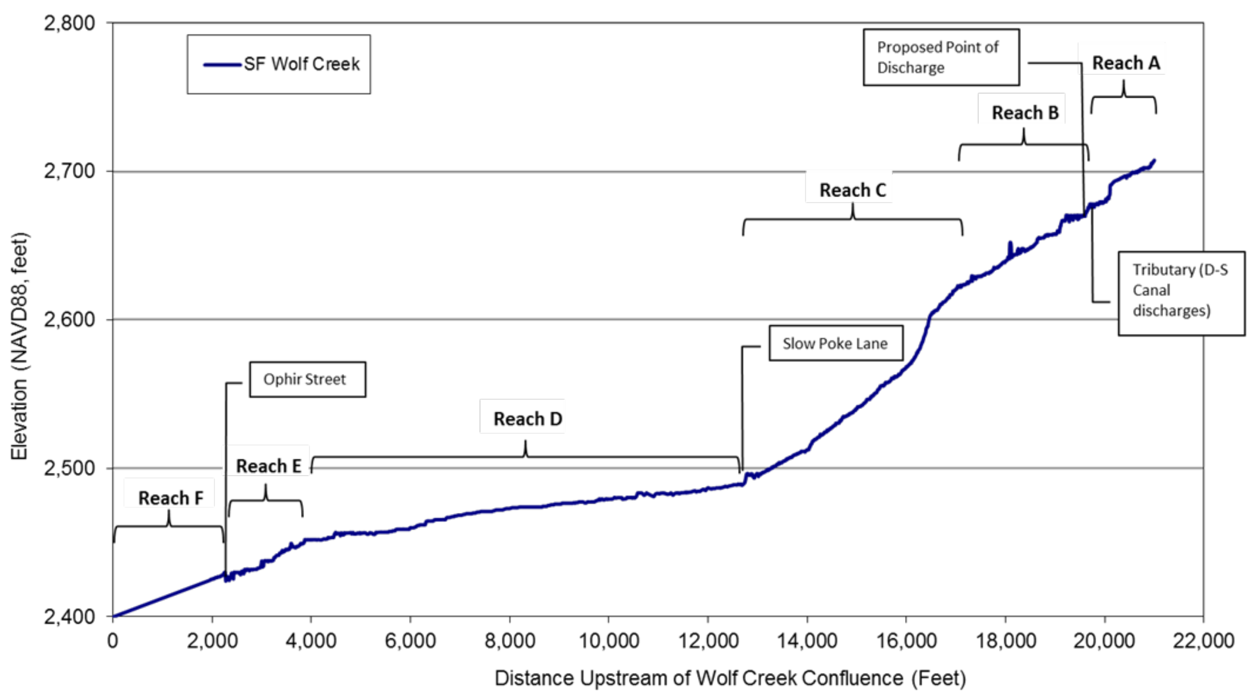

Figure 5-1 Longitudinal Profile, South Fork Wolf Creek, Nevada County, California. Profile developed from LiDAR-based topography (Aero Geomatics, Ltd, 2019) and 0.5-foot contour interval; Reach F (culvert) is estimated based on USGS topographic maps and 40-foot interval; vertical scale is exaggerated.

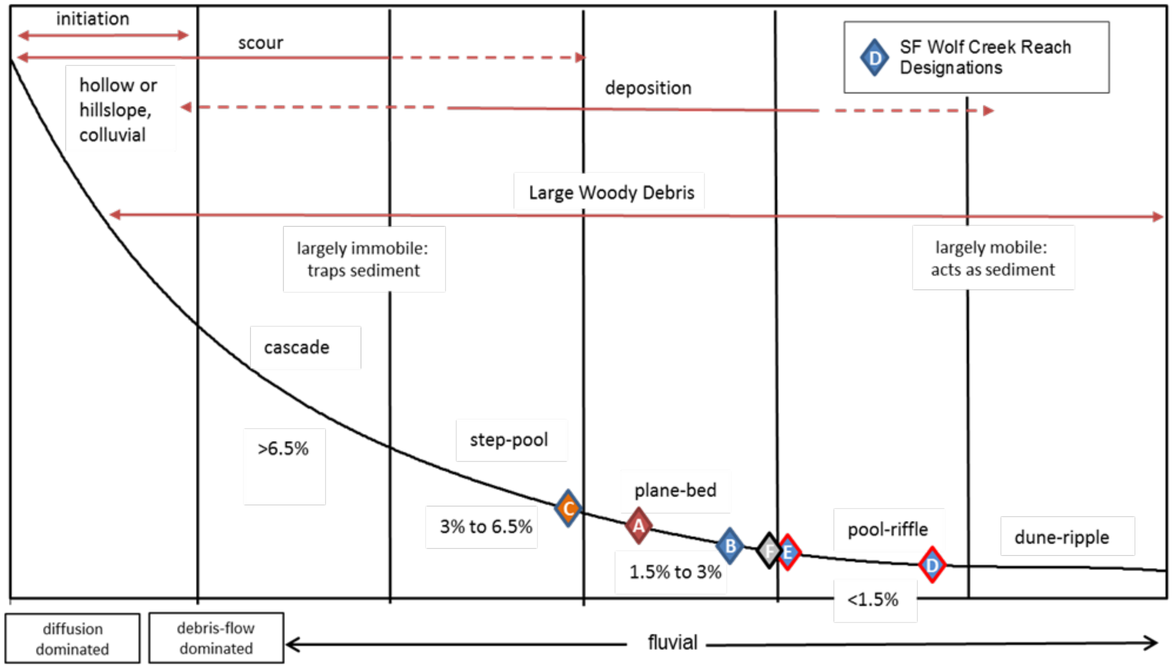

Figure 5-2 Channel morphology in relation to general distribution of alluvial channel types (adapted from Montgomery and Buffington,1997), SF Wolf Creek, Nevada County, California.

Table 5-1 Summary of channel characteristics and geomorphic metrics, SF Wolf Creek, Nevada County, California.

					Channel Geometry				Channel Morphology			Sediment Characteristics[8]		
Reach[1]	Drainage Area	Geology	Landform	Channel Slope[2]	Bankfull[3] Width	Bankfull Depth	HWM[4] Width	HWM Depth	Channel Planform[5]	Channel Bedform[6]	Majority Bed Composition[7]	D_{16}	D_{50}	D_{84}
	sq. miles			*ft/ft*	*ft*	*ft*	*ft*	*ft*				*mm*	*mm*	*mm*
A	0.8	Meta-volcanic	Valley Fill	0.025	10	3	--	--	single	plane bed	fill (waste rock)	--	*45*	--
B	1.6	Meta-volcanic	Canyon	0.02	8	1.5	20.5	5	single	plane bed	fill (waste rock)	--	*128*	--
C	1.9	Meta-volcanic	Canyon	0.03	varies due to morphology				single	step-pool	--	--	--	--
D	2.2	Sedimentary	Valley Fill	0.005	8.7	1.3	18	5.6	single	pool-riffle	gravel	5, 29	28, 63	52, 109
E	2.3	alluvium/fill	Valley Fill	0.013	Modified by urban fill encroachment				single	pool-riffle	sand/gravel	--	--	--
F	2.9	--	Urban Fill	*0.013*	enclosed in pipe				engineered	--	concrete/rock	--	--	--

Notes:

1. Reaches were delineated using channel slope, morphology, and relationship to other tributaries
2. Reach-wide slopes were calculated using LiDAR based topography (0.5-ft contours) (Rise Grass Valley, 2019b); estimated from 40-ft contour maps when italicized.
3. "bankfull" is a term used to characterize the channel dimensions of the channel under the most frequent flows (between a 1- and 2-year flood); identified by change in bank slope, vegetation, or absence and presence of sedimentation.
4. HWM = high-water mark, line of sediment or debris indicating the peak water surface elevation in the channel for flood peaks. HWM was estimated to be from either WY2017 or WY2019 annual peak flows.
5. Planform: single-threaded (s), braided channel (b), engineered (c)
6. Bedform: pool-riffle (pr), step-pool (sp), plane-bed (pb)
7. Clay, silt, sand, gravels, cobbles, fill, fill, concrete
8. Estimated by a geomorphologist where italicised; multiple values represent the range measured using modified Wolman Pebble Counts

Each reach is briefly described below; with photos associated with each reach provided in Appendix A:

Reach A

Reach A delineates the headwaters of SF Wolf Creek and receives runoff and sediment from a watershed area of approximately 0.8 square miles (USGS, 2019). The average reach slope was measured to be 2.5 percent. The channel in this reach exhibits plane-bed morphology, with a lack of discrete bedforms and typical of steeper systems. This reach is mostly composed of gravel to small boulder-sized sediment.

The watershed above this reach is mostly forested and includes Rise's Brunswick Industrial Site. An approximately 1,600-foot culvert crosses the Brunswick site and discharges to the SF Wolf Creek channel. The creek channel in this location is dominated by silty and sandy banks and bed, with eroding banks and exposed roots (see Appendix A3). Downstream, mining waste rock lines the channel and forms artificial levees along some sections of the reach. NID periodically discharges from Rattlesnake Canal to this Reach (Close, pers. comm, 2019).

Reach B

Reach B receives drainage from a watershed of approximately 1.6 square miles (USGS, 2019). Bed and banks were observed to include angular rock much larger than native sediment, likely originating from mining waste rock. The average reach slope was measured to be 2.0 percent. The channel exhibits both plane bed and step pool morphology, with cobble or boulder sized interlocking substrate forming sequential steps and pool features (see Appendix A4). Large, naturally occurring instream-wood also form these features within this reach. This reach includes a tributary that drains the Nevada County Air and Industrial Park (see Appendix A2). NID periodically discharges to this tributary from the D-S Canal (Close, pers. comm, 2019). The proposed discharge point for mine dewatering is located approximately 400 feet downstream of this tributary.

Reach C

Reach C receives runoff and sediment from a watershed of approximately 1.9 square miles (USGS, 2019). The average reach slope was measured to be 3.0 percent. This is the steepest reach in the watershed and is a canyon-type reach with steep forested side slopes, step-pool morphology, and frequent naturally occurring instream-wood jams. Local channel scour and deposition at these features was observed and is common for these mountain drainages (see Appendix A5). Steep alluvial channels (cascade and step pool) tend to be more resilient to changes in discharge and sediment supply (Montgomery and Buffington, 1997).

Reach D

Reach D receives runoff and sediment from a watershed of approximately 2.2 square miles (USGS, 2019). The average reach slope was measured to be 0.5 percent. The reach is in an unconfined valley with an active floodplain and riparian zone (see Appendix A6). and exhibits pool-riffle morphology, defined by an undulating bed with a sequence of sediment bars, pools, and riffles. Bars and riffles are comprised of mostly gravel-sized sediment.

Reach E

Reach E receives runoff and sediment from a watershed of approximately 2.3 square miles (USGS, 2019). The average reach slope was measured to be 1.3 percent and exhibits pool-riffle morphology. This reach has been highly modified with evidence of fill encroaching on the floodplain and channel (see Appendix A7). Reach E also receives stormwater runoff from some residential and urban areas.

Reach F

Reach F extends downstream to the confluence with Wolf Creek and receives runoff and sediment from the entire SF Wolf Creek watershed of approximately 2.9 square miles (USGS, 2019); however, Reach F is primarily confined to a box culvert and receives stormwater runoff from a stormwater system that may not be well mapped (Lake, Z., pers. comm., 2018), including Empire Mine's Magenta Drain (see Appendix A8). Reach F average slope could not be measured but is assumed to be approximately 1.3 percent, based on an available USGS topographic map and a 20-foot contour interval (USGS, 1949).

5.1.2 Reaches Susceptible to Impacts

This sub-section provides the rationale for narrowing our assessment to specific reaches that may be more susceptible to impacts from the proposed discharge.

Reach A is located upstream of the proposed point of discharge and is therefore excluded from further assessment.

Reach B is where the discharge is proposed. Reach B was observed to have historical mining waste rock lining much of the channel and banks. The waste rock is angular and ranges in size between 3 and 12 inches in diameter, much larger than natural in-channel sediment found upstream and downstream. The waste rock serves to armor the channel making it less susceptible to erosion in response to increased discharge; therefore, Reach B was excluded from further assessment.

Downstream, Reach C was characterized as a forested, canyon-confined channel with step-pool morphology. Step-pool morphology is made up of tight interlocking boulders forming channel wide steps, separated by plunge and backwater pools containing finer sediment. Steps are stable structures and play an important flow resistance role dissipating the energy in steep stream channels (Chin, 2003); however, these forms generate complex variations in flow, sediment entrainment, transport and deposition (Blizard and Wohl, 1998). We did not attempt to estimate sediment mobility within Reach C because the use of theoretical sediment transport equations and flow hydraulic models through these features remains difficult because of these structural elements, which cause large variations in bedform geometry, roughness, flow energy and bed shear stress. Furthermore, large instream wood is a common component to Reach C and forms many step features (i.e., wood debris jams). Balance observed localized scour and sedimentation at instream wood debris jams. These features provide both temporary and long-term sediment storage. Overall, steep alluvial channels (cascade and step pool) tend to be more resilient to changes in discharge and sediment supply (Montgomery and Buffington, 1997). Therefore, Reach C is considered to be stable and was excluded from further assessment.

Reach F is confined to a culvert or engineered channel and excludes a channel with natural bed and banks; therefore, it was excluded from further assessment.

Based on channel reach morphology as a framework for disturbance response, Reaches D and E were the focus of further investigation and evaluation of potential off-site impacts related to increases in discharge. These reaches are generally low slope (< 2 percent) with channels that exhibit pool-riffle morphology with no evidence of bed armor. Unarmored pool-riffle systems typically indicate a balance between sediment transport capacity and sediment supply (Montgomery and Buffington, 1997). Discharge of the sediment-free treated mine water to SF Wolf Creek could increase sediment transport capacity, resulting in scour or erosion. Therefore, these reaches may be the most susceptible to changes in flow.

Private property severely limits access to Reach E; therefore, Balance focused additional data collection and analysis on Reach D with the assumption that the analyses on Reach D would also be applicable to Reach E given its similar morphology (i.e., pool-riffle morphology).

5.2 Hydrology

Initial dewatering of the mine is proposed to occur with a maximum constant discharge rate of 5.6 cfs for a period of approximately 6-months and will augment existing flows in the creek. Measured and estimated flows for SF Wolf Creek at two locations are included in **Table 5-2** and provide a baseline against which to consider the impacts associated with the proposed discharge.

5.2.1 Peak Flows

In Northern California, both WY2017 and WY2019 were wetter than average years with multiple high-flow events. Using the Manning's equation in combination with surveyed high-water marks, Balance calculated the recent peak flow to be roughly 300 cfs as measured in Reach D. Evaluation of nearby streamflow data collected by the USGS for Station 11413000 (NF Yuba River below Goodyear Bar) indicates that this storm system was a roughly 10- to 15-year event. Observations of the channel did not indicate any measurable change associated with these peaks, with the exception of limited localized bank erosion near culverts, the formation of in-stream woody debris jams, and localized sedimentation upstream of each debris jam.

The anticipated increase associated with the maximum 5.6 cfs discharge rate is not likely to be detectable when the creek is flowing at 300 cfs. Furthermore, the incremental flow increase is not likely to change the limited scour or erosion that would take place under such an event. However, conditions should be monitored during extreme flow events to evaluate channel stability.

5.2.2 Baseflow

Balance measured summer baseflows between 0.17 cfs in Reach B above the proposed point of discharge and 0.4 cfs in Reach F at Ophir Street culvert. These measurements were conducted in September 2019 (WY2019) and are representative of conditions following a year with above-average precipitation (NOAA, 2020b). Winter baseflows were measured between 1.5 cfs in Reach B above the proposed point of discharge and 2.5 cfs in Reach F at the Ophir Street culvert. Kopania (pers. comm., 2019) reports a manual measurement of 6.5 cfs in Reach B near the proposed point of discharge in April 2019. No measurements were conducted in Reach F during April 2019, but we can assume flows in that reach were approximately 7.5 cfs using the ratio of flows measured at both locations in January 2020.

Based on these limited field measurements of baseflow and a 50 percent factor-of-safety, the proposed dewatering discharge has the potential to elevate summer baseflow to approximately 5.8 cfs in upper SF Wolf Creek and approximately 6.2 cfs at the Ophir Street culvert. During winter, baseflow could potentially increase to approximately 15 cfs and 17 cfs at the proposed discharge location and Ophir Street location, respectively. These flows are significantly lower than the 1- to 2-year and bankfull flow estimates—those flows that typically have the capacity to modify the channel.

Balance also measured flows during a moderate runoff event to verify sediment mobility calculations and evaluate whether the bed and banks become mobilized at slightly elevated flows. Balance measured a peak flow of 11.0 cfs in Reach B during a 1.25-inch storm that occurred on January 26, 2020 (**Figure 5-3**). On the same morning, Balance measured 17.3 cfs in Reach F at the Ophir Street culvert. These flows are also significantly lower than the 1- to 2-year flow estimate and were not observed to have an effect on channel scour or erosion. These measured flows are also greater than the proposed dewatering discharge rate, and conservatively represent the increased baseflow rates that could result from the dewatering and discharge program. Observations of sediment transport at these rates are presented and discussed in **Sections 5.5** and **5.6**.

A larger event occurred on December 7-9, 2019, after 3.43 inches of precipitation was recorded (NOAA, 2020b), but before the monitoring program was initiated. Based on observation of high-water marks, peak flow from this storm event exceeded the January 26, 2020 storm event. Using indirect methods to estimate peak in Reach D[3], peak flow from the December event was estimated to be approximately 23 cfs. This is slightly higher than the 17.5 cfs measured approximately 3,300 feet downstream at Reach F which occurred on January 26, 2020; no tributaries enter the channel between these two locations. Immediately post-storm, Balance conducted a site visit on December 10, 2019 and observed fresh sediment deposited in pools along Reaches D and E and were

[3]High-water marks were better preserved and could be measured at this location relative to locations of existing monitoring stations.

characterized as sand and small gravels. These observations suggest sediment mobility was initiated and sediment transport occurred during the December 7-9 event.

Table 5-2 Range of measured and estimated streamflow for South Fork Wolf Creek, Nevada County, California

	Streamflow		Source or Comments
	Reach B (1.6 sq. miles)	Reach F (2.3 sq. miles)	
	(cfs)	*(cfs)*	
Summer Baseflow	0.17	0.4	Values measured upstream of location of proposed discharge (Reach B) and downstream at the culvert entrance to Reach F; September 2019.
Winter Baseflow	1.5	2.5	Values measured upstream of location of proposed discharge (Reach B) and downstream at the culvert entrance to Reach F; January 24, 2020. Kopania, A., (pers. comm., 2020) reported measuring winter baseflow in Reach B as high as 6.5 cfs in April 2019.
Moderate Storm Flow	11	17.3	Values measured upstream of location of proposed discharge (Reach B) and downstream at the culvert entrance to Reach F in response to 1.25 inches of rainfall on January 25-26, 2020; antecedant conditions include 17.14 inches of rainfall since the beginning of the 2020 water year (NOAA, 2020)
Annual Flood	*< 80*	*< 80*	Unknown, not measured
Bankfull Flow	*< 80*	*80 - 100*	Flow that likely fills the active channel defined by absence/presence of vegetation and active sedimentation; estimated reccurrence between 1 and 2 years; Estimated using hydraulic geometry of bankfull indicators and Manning's equation. Reach B is too modified to identify bankfull indicators
2-Year Flood	80	110	Gotvald and others (2012)
5-Year Flood	170	240	Gotvald and others (2012)
WY2017 or WY2019 Peak Flow	*unknown*	*300*	Indirect measurement using Manning's equation with survey of cross-section geometry and slope at high-water marks of a natural channel reach (Reach D); likely higher for Reach F.
10-Year Flood	250	350	Gotvald and others (2012)
WY1965 Peak Flow	350	650	Estimated peak flow using unit-discharge of peak flow measured from Sweetland Creek, California (USGS 11413600); 2.68 sq. mile watershed; 2,158 feet mean basin elevation, 54.6 inches mean annual precipitation

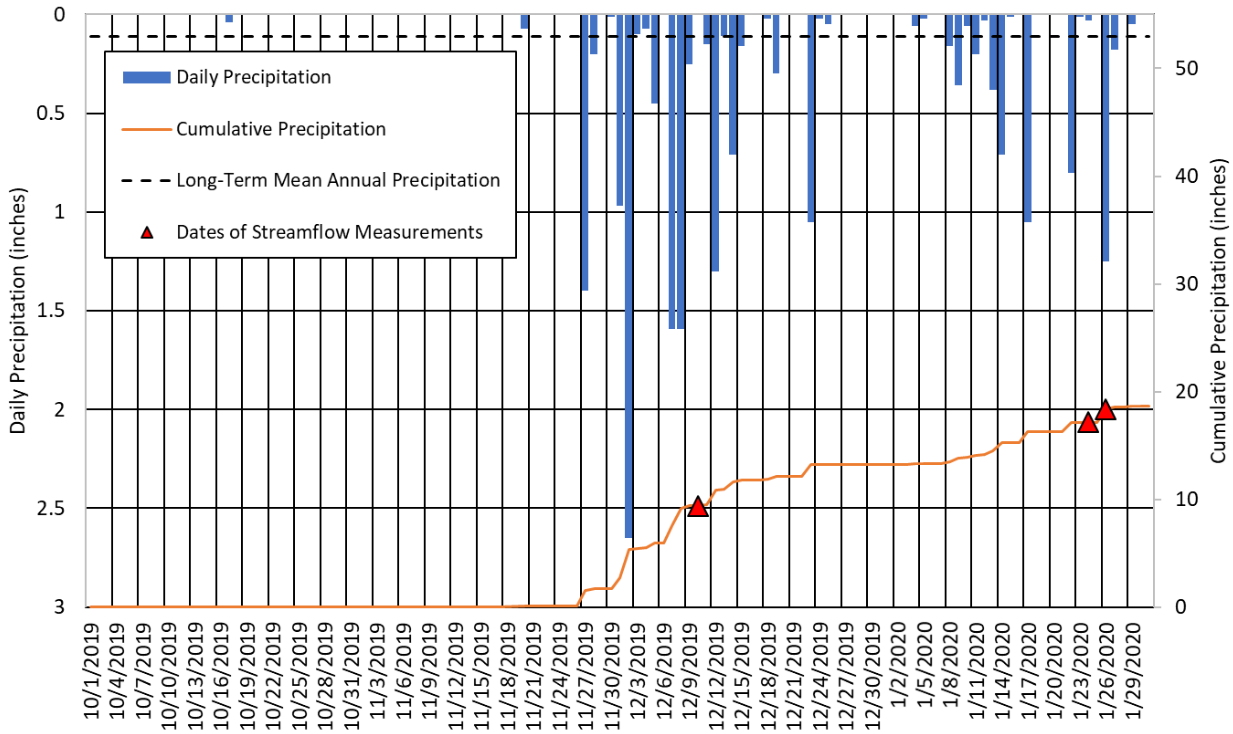

Figure 5-3 **Daily (blue bars), cumulative (orange line), and long-term mean annual precipitation (dashed line) for Grass Valley, California (ID: COOPGRAC1; NOAA, 2020b)** October 1, 2019 – January 31, 2020 (partial water year 2020); 8 days with missing values. Dates when streamflow measurements were completed are shown as red triangles.

Lewis and others (2000) work in the Sierra Foothills Experimental Forest in nearby Yuba County showed that:

> "Streamflow in these small Sierran streams has three distinct seasonal periods described by Huang (1997) as **wetting, saturation, and drying**. **Streamflow was low and constant during the early months of winter.** During this priming phase, precipitation infiltrated and recharged watershed soils and did not contribute to noticeable increases in streamflow. Streamflow responses to rainfall became elevated and rapid once soil water storage capacity was approached and the soils were saturated. Results from long-term monitoring indicate that this saturation phase was reached after **six to eight inches of annual cumulative rainfall** have occurred. Storms during the drying phase generated increased streamflow but gradually declined [as summer approached.]"

A threshold of six inches of annual cumulative rainfall is variable and may be reached in some years as early as Thanksgiving weekend, or as late as mid- to late-February. For instance, in WY2020, 6 inches of annual cumulative rainfall wasn't recorded until early

December (NOAA, 2020), so meaningful flow increases in SF Wolf Creek are also not expected until that time. This contrasts with typical seasonal construction shutdowns for control of erosion from disturbed soils, typically October 15 and sometimes as late as November 1.

5.3 Turbidity

Turbidity measurements collected in late 2019 and the first weeks of early 2020 in Reach B (proposed point of dewatering discharge) are provided in **Table 5-3**. Turbidity ranged between 9.4 NTU in winter baseflow and as high as 125 NTU during a storm event. We have not directly measured summer baseflow turbidity at this location, but observations suggest values less than 10 NTU. We discuss turbidity in greater detail in **Section 5.4**.

Table 5-3 Streamflow and turbidity measured in SF Wolf Creek, Reach B, Nevada County, California

Date	Streamflow	Turbidity	Comment
mm/dd/yyyy	*cfs*	*NTU*	
9/25/2019	0.17	NM	Summer Baseflow
12/10/2019	NM	NM	Station not visited
1/24/2020	1.56	9.4	Winter Baseflow
1/26/2020	11.0	125	Peak storm flow
1/26/2020	9.76	79	Falling limb, storm

Notes: NM = not measured

Turbidity measurements in late 2019 and early 2020 in Reach F (downstream, City of Grass Valley) are provided in **Table 5-4**. Turbidity ranged between 2.2 NTU in winter baseflow and as high as 115 NTU during a storm event. We have not directly measured summer baseflow turbidity at this location, but observations suggest values similar to those measured in December. We discuss turbidity in greater detail in **Section 5.4**.

Table 5-4 Streamflow and turbidity measured in SF Wolf Creek at Ophir Street, Reach F, Nevada County, California

Date	Streamflow	Turbidity	Comment
mm/dd/yyyy	*cfs*	*NTU*	
9/25/2019	0.4	NM	Summer Baseflow
12/10/2019	3.11	2.2	Post storm
1/24/2020	2.53	4.5	Winter Baseflow
1/26/2020	15.3	115	Rising limb, storm
1/26/2020	17.3	48	Peak storm flow

Notes: NM = not measured

The range of turbidity measured in SF Wolf Creek is typical of other Sierra foothill watersheds at similar elevations with similar land-uses, geology, soils, and other watershed influences (Lewis and others, 2002).

5.4 Bed sediment mobility calculations

Our assessment focused on Reaches D and E of SF Wolf Creek as Balance has identified these as the most sensitive reaches and thus may be susceptible to substantial changes (i.e., scour) under the proposed discharge. A grain size distribution analysis for 3 modified Wolman Pebble Counts conducted in Reach D is shown in **Figure 5-4**. Bed sediment in Reach D include sizes that range between sand and cobble. The median sediment size (D_{50}) ranges between 28 mm and 63 mm across three samples, classified as gravel.

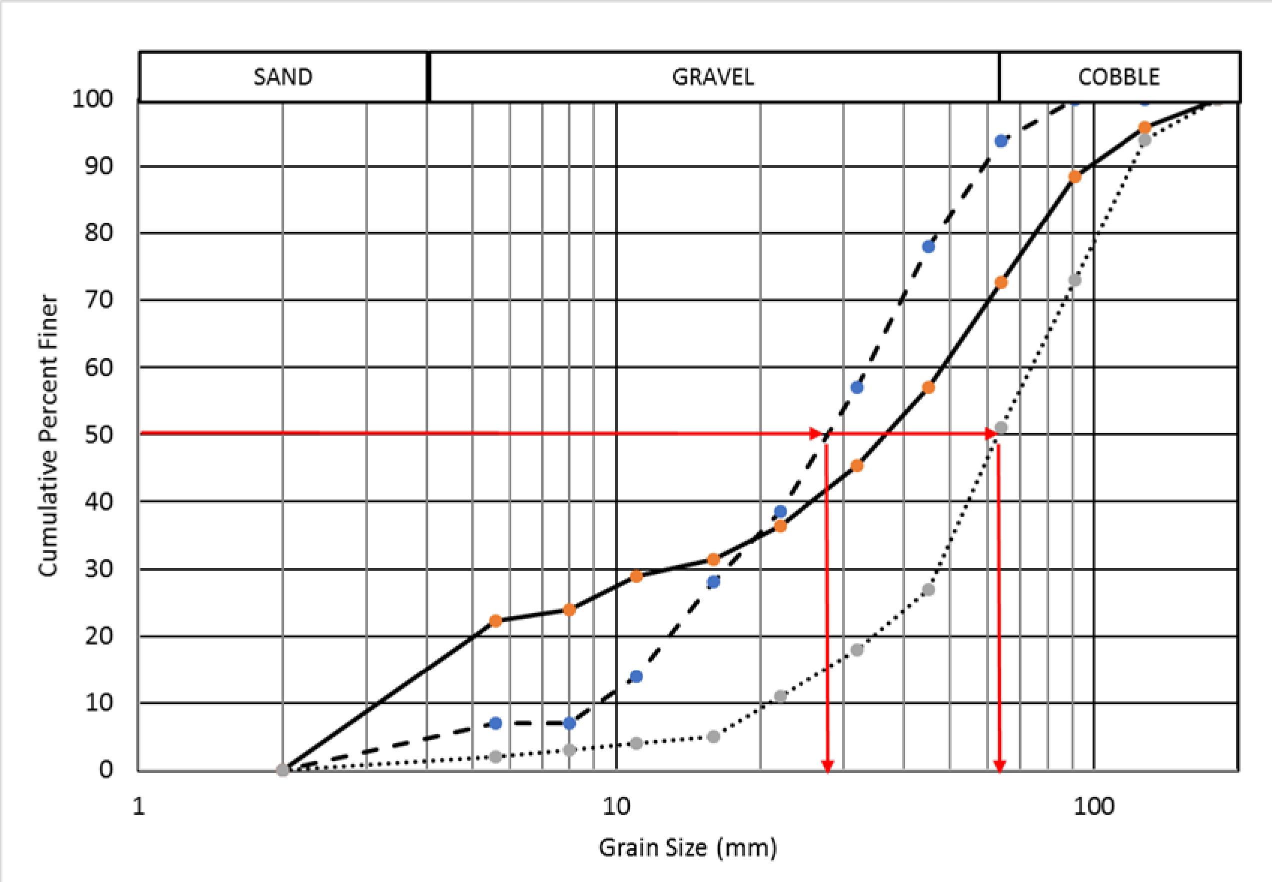

Figure 5-4 Grain size distribution analysis of three modified Wolman pebble counts completed in riffles of Reach D, SF Wolf Creek.

We then evaluated bed sediment mobility of the measured D_{50} over a range of streamflow and the range for well published Shields Parameter values (**Table 5-5**). As a conservative measure, we focused our calculations on the smallest D_{50} measured (28 mm). Results suggest sediment mobility in Reach D is initiated in streamflow between 20 cfs and 90 cfs. The wide range in initial sediment mobility at these streamflows is the result of the varying values used for the Shields Parameter. Values of the Shields Parameter used for these calculations include the range typically depicted in the literature for sand-gravel systems. The roughness of a stream bed varies within a given channel reach; therefore, spatial variations in the local critical shear stress would be expected, in addition to the temporal fluctuations in the shear stress from turbulent flow (Kirchner and others, 1990). Direct measurement of sediment transport will improve the accuracy of these estimates.

Table 5-5 Predicted range of streamflow when bed sediment mobility will occur, SF Wolf Creek, Reach D, Nevada County, California.

Parameter													
Streamflow	*cfs*	**2**	**6**	**10**	**15**	**20**	**25**	**30**	**50**	**75**	**90**	**100**	**300**
Flow Area	*ft^2*	2.7	4.2	5.7	7.6	9	10.4	11.7	17.3	24.6	25.2	25.2	50.1
Wetted Perimeter	*ft*	7.3	7.7	8.8	9.6	9.8	10.1	10.3	12.6	16.6	16.7	16.7	24.6
Hydraulic Radius	*ft*	--	0.55	0.65	0.79	0.92	1.03	1.14	1.37	1.48	1.53	1.53	2.04
Top Width	*ft*	7	7	8	9	9	9	9	11	15	15	15	22.5
Max Depth	*ft*	0.69	0.91	1.09	1.3	1.48	1.65	1.81	2.33	2.88	2.95	2.95	4.23
Average Velocity	*ft/s*	0.92	1.42	1.74	1.98	2.22	2.4	2.56	2.89	3.05	3.54	3.92	5.99
Water Surface Slope	*ft/ft*	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.006	0.007	0.009
Shear	*lb/ft^2*	--	0.17	0.2	0.25	0.29	0.32	0.35	0.43	0.46	0.57	0.67	1.14
Froude #	*dimensionless*	0.26	0.32	0.36	0.38	0.39	0.39	0.4	0.41	0.42	0.48	0.53	0.71
Roughness Coeff. (n)	*dimensionless*	0.059	0.05	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.043	0.042	0.038
Sediment D_{50} Mobilized		NO	NO	NO	NO	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Shields Parameter (0.03)	*dimensionless*		16.8	19.9	24.4	28.3	31.7	35	42.3	45.6	56.4	65.8	113.0
Shields Parameter (0.06)	*dimensionless*		8.4	10	12.2	14.1	16	17.5	21.1	22.8	28.2	32.9	56.4

Notes

Parameters were computed using measured cross-sectional area in Reach D for the water year 2017/2019 high-water mark and normal depth calculator (NOAA, 2020a).

Sediment D_{50} mobilized calculated using Shield's Equation, rearranged to solve for sediment diameter

Normal depth calculator was calibrated using manual flow measurements in the field and estimates of hydraulic roughness (Manning's n)

Manning's n values were estimated from Reach D during winter conditions (stems without leaves)

Water surface slope uses channel topographic slope from LiDAR data (Rise Grass Valley, 2019); water surface slope at higher flows typically increases and is estimated

Shields Parameter reflects the range most reported in the literature

5.5 Preliminary monitoring results for bedload sediment transport

Balance observed and measured bedload sediment transport over a range of small to moderate flows (11 cfs to 17.3 cfs) in a storm event on January 26, 2020 which measured 1.25 inches of precipitation over a 12-hour period (NOAA, 2020b). Bedload sampling found no evidence of bedload transport within this range of streamflow and supports the predicted range the flows (less than 20 cfs) when no sediment transport occurs for the minimum D_{50} (28 mm) measured from modified Wolman pebble counts. Observations of fresh sand and small gravel deposits following the December 7-9, 2019 events further supports the predicted low-end range of sediment mobility estimated to be near 20 cfs.

Under existing conditions, the range of streamflow that initiates bedload sediment mobility in SF Wolf Creek is found to be well above both: (a) summer baseflow of around 0.5 cfs to 1.0 cfs; and (b) winter baseflow; between 1.5 cfs and 6.5 cfs. Bedload sediment transport appears to initiate at approximately 20 cfs. The proposed dewatering and discharge program, at 5.6 cfs is therefore unlikely to have a significant impact on erosion or siltation during summer and winter baseflow conditions.

5.6 Turbidity baseline and as a surrogate for suspended-sediment transport

The Basin Plan specifies that discharges, including mine dewatering operations, "shall not alter the suspended sediment load and suspended sediment discharge rate of surface waters in such a manner as to cause nuisance or adversely affect beneficial uses" (**Section 3.1**, Sediment, pp. 3-13, RWQCB, 2018) and "dischargers shall maintain baseline turbidity conditions or not exceed established standards for increases over baseline conditions" (RWQCB, 2016).

Rise has authorized Balance to instrument SF Wolf Creek and collect near-continuous turbidity measurements to establish a baseline. Suspended-sediment load is typically associated with turbidity. The magnitude of turbidity in streams, lakes, and estuaries is often proportional to suspended-sediment concentration (SSC). When proportional, the turbidity-SSC relationship can be quantified through linear regression analysis (Walling, 1977) to establish a baseline condition. Once established, a turbidity-SCC relationship a and continuously monitored turbidity data enable computation of the SSC time series that can be used with its paired streamflow time series to compute near-continuous suspended-sediment load without the routine need for interpolation or estimation.

Balance did observe and measure suspended-sediment transport across the same range of streamflow during the same event and at both monitoring locations (**Figure 5-7**). Based on laboratory analytical results and instantaneous measures of streamflow, the suspended-sediment loads measured in Reach B ranged between 0.04 tons/day during winter baseflow of 1.5 cfs to 2.5 tons/day in elevated streamflow (11 cfs) measured during a moderate storm event. Downstream, in Reach F, instantaneous suspended-sediment loads increased from 0.03 tons/day during winter baseflow of 2.5 cfs to 4.6 tons/day during a moderate flow (15.3 cfs) during the same storm event (**Table 5-6**).

Preliminary baseline suspended-sediment load rating curves for both monitoring stations are provided in **Figure 5-6** and **Figure 5-7**. These preliminary relationships begin to define a baseline condition. Additional data collection over different streamflow will provide additional information and provide a baseline for comparison of suspended sediment loads under future dewatering discharge.

Figure 5-5 Balance hydrologist measuring streamflow (11 cfs) and suspended-sediment transport at a monitoring station in Reach B, SF Wolf Creek, Nevada County, California.

Table 5-6 Preliminary instantaneous suspended-sediment transport, SF Wolf Creek at two locations, Nevada County, California.

Site Conditions: SF Wolf Creek above proposed point of discharge (Reach B)							Suspended Sediment		
Sample Date:Time	Observer(s)	Stage	Streamflow	Streamflow Value Source	Stream Condition	Event Type	Suspended-Sediment Concentration	Turbidity	Suspended-Sediment Transport Rate
WY2020		*(ft)*	*(cfs)*	*M,R,E*	*R,F,B,U,S*	*R, R/S, SM*	*(mg/l)*	*(NTU)*	*(tons/day)*
1/24/2020 15:00	bkh, bt	7.33	1.56	M	S	S	9.0	9.4	0.04
1/24/2020 15:15	bkh, bt	7.33	1.56	R	S	S	5.0	5.3	0.02
1/26/2020 7:30	bkh, jj	7.78	10.8	M	F	R	85.0	130	2.47
1/26/2020 10:30	bkh, jj	7.73	9.5	M	F	R	54.0	67	1.38

Site Conditions: SF Wolf Creek at Ophir Street (Reach F)							Suspended Sediment		
Sample Date:Time	Observer(s)	Stage	Streamflow	Streamflow Value Source	Stream Condition	Event Type	Suspended-Sediment Concentration	Turbidity	Suspended-Sediment Transport Rate
WY2020		*(ft)*	*(cfs)*	*M,R,E*	*R,F,B,U,S*	*R, R/S, SM*	*(mg/l)*	*(NTU)*	*(tons/day)*
1/24/2020 11:30	bkh, bt	0.16	2.5	M	B	--	4.0	4.8	0.03
1/26/2020 6:35	bkh, jj	0.50	15.3	M	S	R	112	100	4.62
1/26/2020 11:15	bkh, jj	0.48	17.3	M	F	R	90.0	100	4.20

Notes

Observer Key: BKH is Brian Hastings, JJ is Jack Jacquet, BT is Ben Trustman

Stage: arbitrary datum

Streamflow is the measured streamflow when sediment was sampled

Streamflow Value Source: M = measured; R = rating curve; E = estimated

Stream Condition: R = rising, F = falling, B = baseflow, U = uncertain, S = steady

Event Type: R = rain, R/S = rain on snow, SM = snowmelt runoff

Suspended-sediment load (tons/day) is calculated by multiplying SSC (mg/L) by streamflow (cfs) and a conversion factor of 0.0027

Values are preliminary and subject to revision

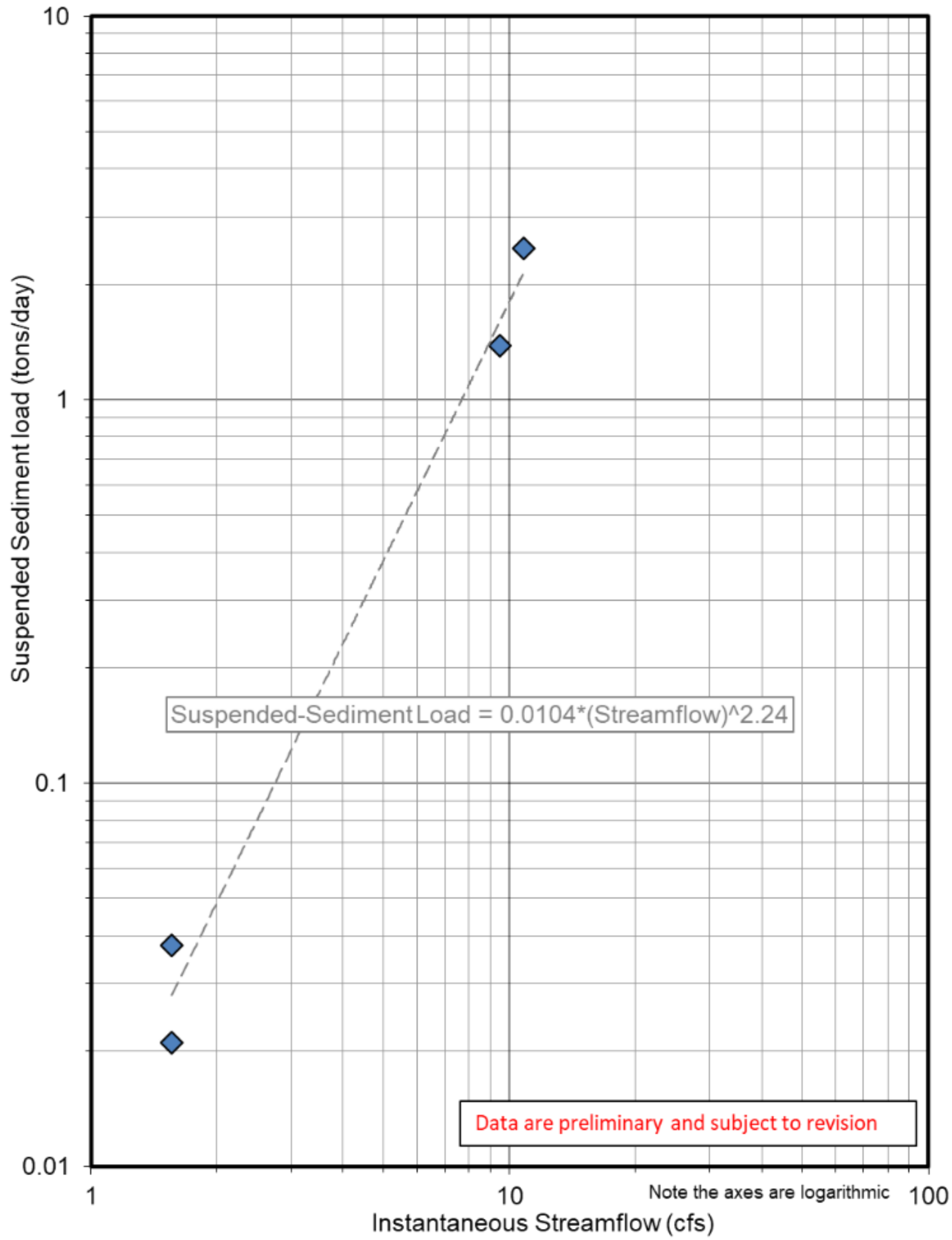

Figure 5-6 Preliminary suspended-sediment load rating curve, South Fork Wolf Creek above proposed discharge location, Nevada County, California. Data collection is on-going; line establishes a baseline condition that can be used to evaluate suspended-sediment transport under active discharge conditions.

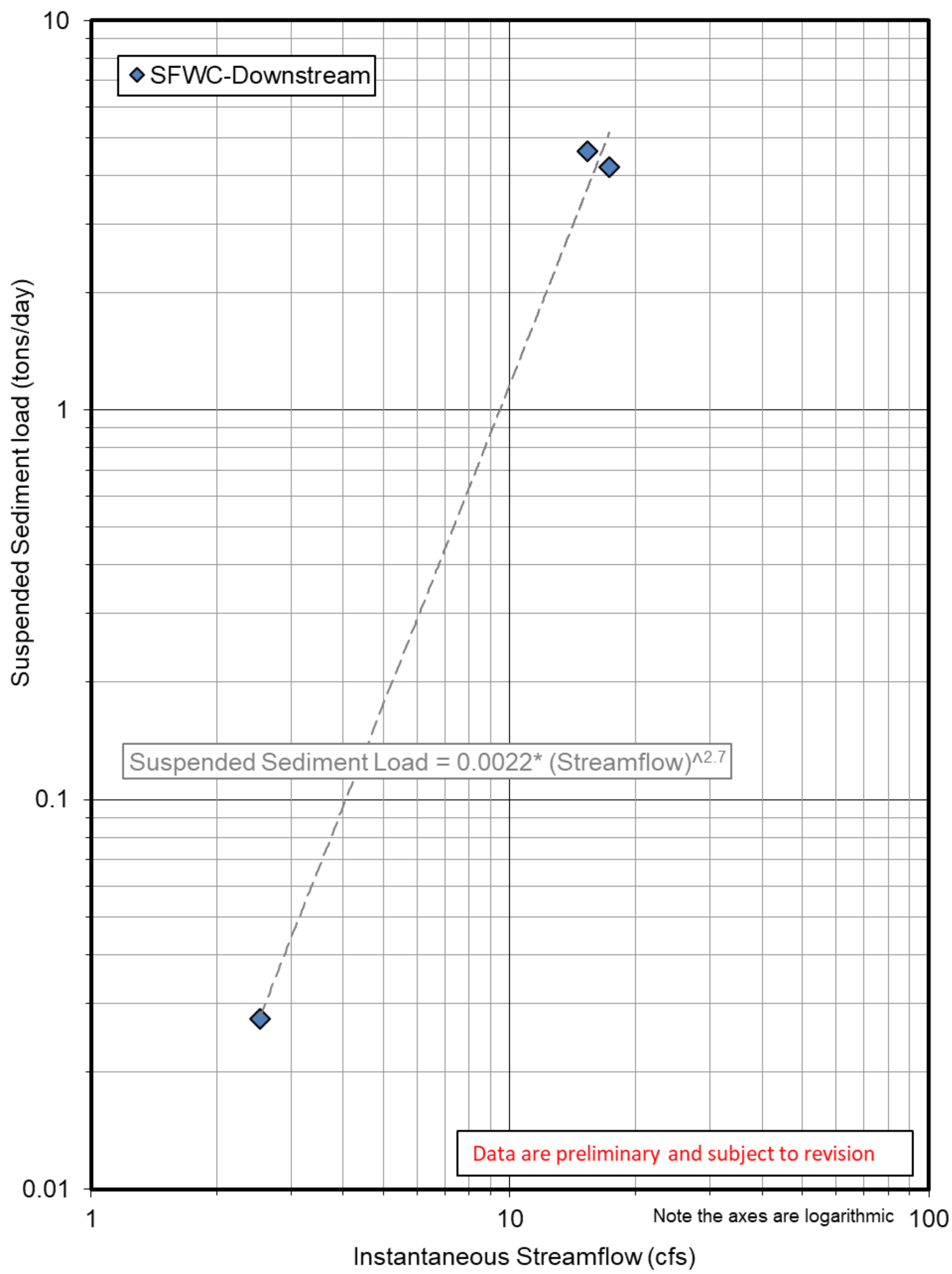

Figure 5-7 Preliminary suspended-sediment load rating curve, South Fork Wolf Creek downstream at Ophir Street, City of Grass Valley, California. Data collection is on-going; line establishes a baseline condition that can be used to evaluate suspended-sediment transport under active discharge conditions.

6 CONCLUSIONS

1. SF Wolf Creek is a heavily disturbed watershed. Historical land-uses include logging, hard rock and placer mining, agriculture, and construction and maintenance of road and railroad transportation networks. Field evidence suggests that the channel location, morphology, and functions have likely been modified over the years by these historical land-uses. For instance, some reaches of the creek are confined by constructed rock walls or buried by urban fill, while other reaches include a streambed and banks lined with mining waste rock. Over more recent times, the natural flow regime of SF Wolf Creek has been modified with urban stormwater contributions, discharges from canals, and treated drainage from other mines.

2. Channel conditions in most reaches of SF Wolf Creek indicate a quasi-stable system under the current flow regime, which includes baseflow, increased flows during storms and canal discharges, and peak flows during flood events. Floodplains in unconfined reaches are intact and exhibit flood and sediment storage functions, and the channel appears to be largely stable at intermediate peak flows, with the exception of localized bank erosion within close proximity of culverts and in-stream wood debris jams or localized sedimentation upstream of those same features.

3. Calculations presented in this report indicate that bed sediment becomes mobilized at approximately 20 cfs in reaches that are susceptible to bed mobility. This includes unconfined channels with gravel-dominated beds and pool-riffle morphology. Field measurements at streamflows between 11 cfs and 17.3 cfs showed no active bedload transport and are consistent with these calculations. Limited sediment deposits were observed in some pools after a flow event on December 7-9, 2019 with an estimated peak of 23 cfs. Since most of these sediment deposits were characterized as fine sand and gravel with minimal or no bank erosion, bed scour, or channel avulsion we conclude that the threshold for causation of substantial erosion or sedimentation is greater than 23 cfs. Additional work would be required to establish what flow and associated sediment transport rates are required to do significant work on the channel, but it is higher than 23 cfs.

4. Summer and winter baseflow in SF Wolf Creek at the proposed discharge location ranges from 0.17 cfs to 6.5 cfs, respectively. With the addition of the maximum proposed discharge of 5.6 cfs and increasing measured baseflows by

a 50 percent safety factor, post-project baseflows during non-storm periods would be expected to range between approximately 5.8 cfs and 15 cfs. These estimates are less than 23 cfs, the threshold for bedload sediment mobility and well below flows that commonly exhibit significant work on the channel (i.e., 1- to 2-year flood). We therefore conclude that discharges during baseflow periods will not result in substantial erosion or siltation on site in South Fork Wolf Creek.

5. Summer and winter baseflow in SF Wolf Creek downstream at Ophir Street ranges from 0.4 cfs to 7.5 cfs, respectively. With the addition of the maximum proposed discharge of 5.6 cfs and increasing measured baseflows by a 50 percent safety factor post-project baseflows during non-storm periods would be expected to range between approximately 6.2 cfs and 17 cfs. These estimates are less than 23 cfs, the threshold for bedload sediment mobility and well below flows that commonly exhibit significant work on the channel (i.e., 1- to 2-year flood). We therefore conclude that discharges during baseflow periods will not result in substantial erosion or siltation offsite in lower South Fork Wolf Creek.

6. NID canal maintenance discharges periodically increase flows in SF Wolf Creek. Discharges vary in rate, date, and season. Available data suggest that these discharges are often greater than the proposed discharge (5.6 cfs) for multiple, continuous days and can occur in the winter and spring. The maintenance discharges are part of the baseline variability in this system and have been ongoing for decades with little or no substantial effect on channel morphology or sedimentation downstream. The discharged treated mine water, as proposed, is unlikely to result in substantial changes in siltation or erosion on-site or offsite—further downstream in SF Wolf Creek. In the event that mine discharge coincides with NID maintenance discharges, the effects of the cumulative discharge on the channel should be monitored.

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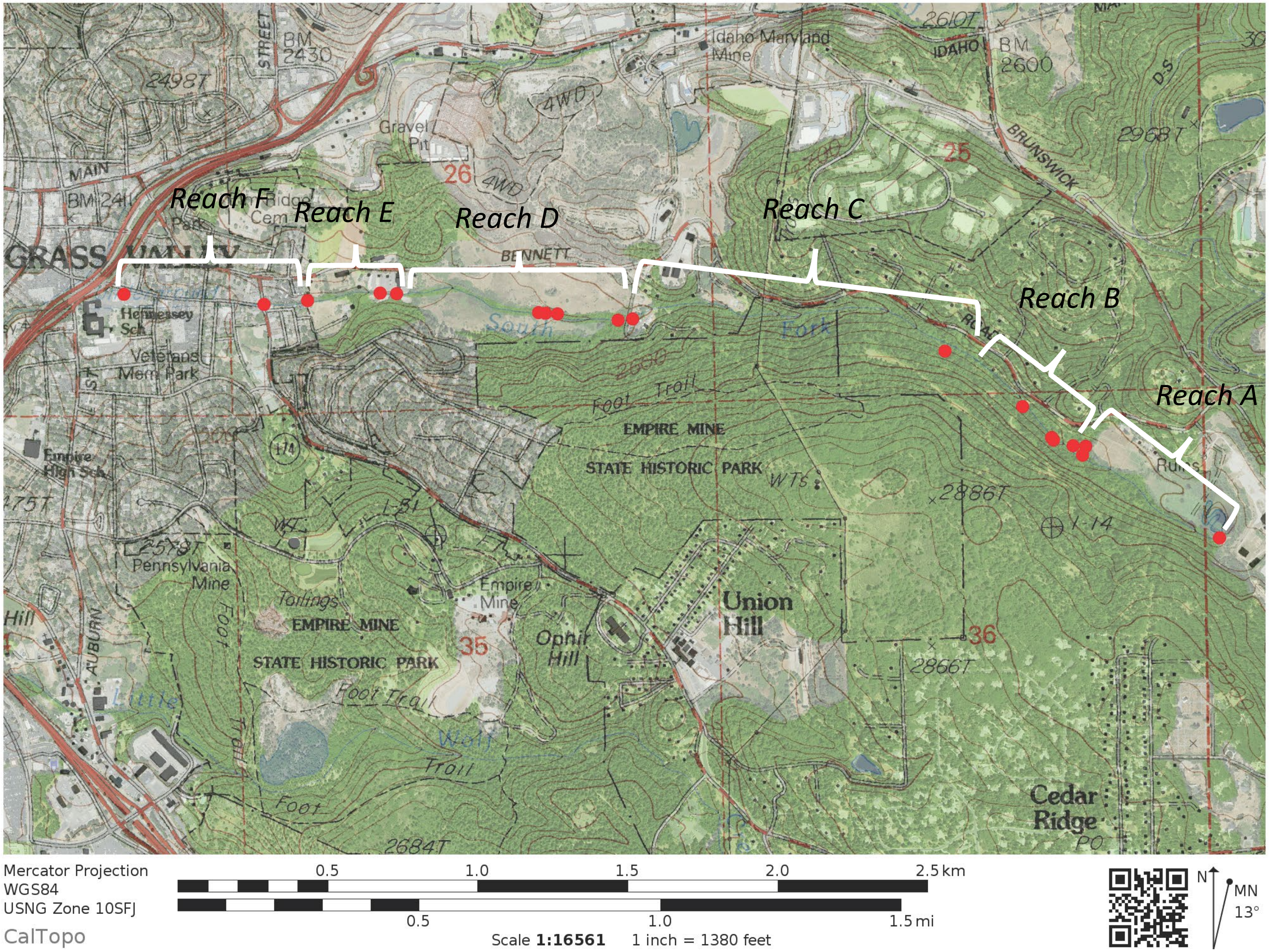
APPENDIX A

Representative Photos of SF Wolf Creek Reaches A-F



Source: CalTopo.com

Balance Hydrologics, Inc.

Figure A1 . Project Location Map, South Fork Wolf Creek, Nevada County, California. Red dots indicate locations where the channel was accessed, assessed, and photographed.

(A)

(B)

Balance Hydrologics, Inc.

Figure A2. **Tributary to South Fork Wolf Creek, Reach A. This channel receives discharges from D-S Canal that have been measured to be up to 13.6 cfs (NID, 2019). Photo (A) shows summer baseflow conditions, September 2019; Photo (B) shows winter baseflow conditions, January 25, 2020.**

(A)

(B)

Balance Hydrologics, Inc.

Figure A3. **South Fork Wolf Creek, Reach A; Photo (A) showing the existing culvert that discharges waters from the headwaters; staining in the culvert suggests a seasonal or high-water mark for higher discharges; Photo (B) SF Wolf Creek below culvert showing some recent or historical erosion of the channel.**

(A)

(B)

(C)

Balance Hydrologics, Inc.

Figure A4. **South Fork Wolf Creek, Reach B. Photo (A) shows an historical rock wall along the bank and angular mining waste rock in the channel; Photo (B) shows proposed location of discharge during elevated streamflow (11 cfs); Photo (C) shows proposed location of discharge during summer baseflow (0.17 cfs); also shows large, angular waste rock in channel.**

219119 Photos.ppt

(A)

(B)

(C)

Balance Hydrologics, Inc.

Figure A5. **South Fork Wolf Creek, Reach C: Photo (A) shows typical coarse step-pool morphology; Photo (B) shows typical instream wood jam and upstream sedimentation; Photo (C) shows localized bank scour near an existing instream wood jam.**

(A)

(C)

(B)

(D)

Balance Hydrologics, Inc.

Figure A6. **South Fork Wolf Creek, Reach D: Photo (A) shows typical active channel, floodplain and riparian; Balance hydrologist measures streamflow; Photo (B) shows small in-stream wood jam; Photo (C) shows some active bank erosion and gravel bar; Photo (D) shows a Balance hydrologist identifying recent high water mark assumed to be from the December 7-8, 2019 storm event.**

(A)

(C)

(B)

Balance Hydrologics, Inc.

Figure A7. South Fork Wolf Creek, Reach E: Photo (A) shows urban fill on the floodplain (above dashed line); Photo (B) shows abundant non-native bankside vegetation; Photo (C) shows pool-riffle morphology in a slightly urban-confined channel with stormwater outfall.

(A)

(B)

(C)

Balance Hydrologics, Inc.

Figure A8. **South Fork Wolf Creek, Reach F: Photo (A) shows the culvert entrance to Reach F at Ophir Street during elevated streamflow, January 26, 2020; Photo (B) shows an engineered rectangular channel and bridge/pipe infrastructure crossing channel, near confluence with Wolf Creek; Photo (C) shows Wolf Creek immediately downstream of SF Wolf Creek confluence.**