Appendix C
Geomorphic Assessment

ESA

Final

OWENS RIVER WATER TRAIL

Geomorphic Assessment

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Geomorphic Assessment

Introduction

ESA conducted a fluvial geomorphic assessment for the Owens River Water Trail (ORWT) Project (project). The purpose of the assessment was to assess river channel morphology responses to the proposed project excavation, and evaluate sediment transport potential under the current river management regime.

River systems are complex environments which are prone to unpredictable change over annual and decadal time periods. For this assessment, ESA utilized field observations, aerial photography, an existing hydraulic model, earlier studies, and other information as provided by the County to review historic and existing river conditions and estimate future river conditions. Within the scope of our assessment, ESA was not tasked to deterministically or empirically model or predict future river behavior over two decades, but rather ESA used available data and applied geomorphology principles to provide an understanding of expected patterns and trends.

Physical Setting

The project comprises a 6.3-mile stretch of the Lower Owens River (LOR) just east of the Town of Lone Pine, in Inyo County, California (Figure 1, attached). The project area lies with the larger Owens Valley geographic area. The Owens Valley occupies the western part of the Great Basin section of the Basin and Range Province, which consists of linear, roughly parallel, north–south mountain ranges separated by valleys, most of which are closed drainage basins (Danskin, 1998). Physiographically, the Owens Valley contrasts sharply with the prominent, jagged mountains that surround it: the Sierra Nevada mountain range on the west and the Inyo and White Mountains on the east rise more than 9,000 feet above the valley floor. The valley, characterized as high desert rangeland, ranges in altitude from about 4,500 feet north of Bishop to about 3,500 feet above sea level at the Owens Lake (dry) (Danskin, 1998).

The valley floor is dissected by one major trunk stream, the Owens River, which meanders southward through the valley. As described by Danskin (1998), numerous tributaries that drain the east face of the Sierra Nevada have formed extensive coalesced alluvial fans along the west side of the valley. These fans form prominent alluvial aprons that extend eastward nearly to the center of the valley. As a result of this asymmetrical alluvial fan configuration, the Owens River flows on the east side of the valley.

The Owens Valley is a closed drainage system (i.e., it has no natural outlet). Prior to the construction of the Los Angeles Aqueduct (aqueduct), water that flowed from the mountains as a result of precipitation was transported by the tributary streams to the Owens River and then south to Owens Lake, the natural terminus of the drainage system. The aqueduct intake (the point where water is transferred from the Owens River to the aqueduct) is approximately 26 miles north (upstream) of the project reach.[1] Flow in the Lower Owens River is generally dependent on releases from the river–aqueduct system or discharge from the ground-water system.

Regional Climate

The climate in the Owens Valley is greatly influenced by the Sierra Nevada Mountains. Precipitation is derived chiefly from weather systems that originate over the Pacific Ocean and move eastward. Because of the orographic effect of the Sierra Nevada, a rain shadow is present east of the crest; precipitation on the valley floor and on the Inyo and White Mountains is appreciably less than that west of the crest. Average annual precipitation ranges from more than 30 inches at the crest of the Sierra Nevada, to about 7 to 14 inches in the Inyo and White Mountains, to approximately 5 inches on the valley floor (Hollett and others, 1991, *as cited by* Danskin, 1998). Consequently, the climate in the valley is semiarid to arid and is characterized by low precipitation, abundant sunshine, frequent winds, moderate to low humidity, and high potential evapotranspiration. Of the total average annual precipitation in the Owens Valley drainage area, about 60 to 80 percent falls as snow or rain in the Sierra Nevada, primarily during the period October to April; a lesser quantity falls during summer thunderstorms (Danskin, 1998).

Project Area Hydrology

The natural runoff, hydrology, and sediment supply of the Lower Owens River (including the project reach) has been significantly altered over many decades. For example, upstream reservoirs/dams (Pleasant Valley Reservoir, built in 1954, and Tinemaha Reservoir, built in 1962 – see Figure 1 inset) and human development (e.g., construction the aqueduct) have largely cutoff the upstream supply of coarse sediments to and altered the natural hydrology of the project reach.

Most of the flow in the Owens River is diverted into the aqueduct upstream of the project site. Any water not diverted into the aqueduct continues to flow south (downstream) of the aqueduct in the natural channel of the Lower Owens River. South of the aqueduct intake, additional tributary streams along the west side of the valley are also diverted into the aqueduct. Since 1913 (when operation of aqueduct began), little or no tributary streamflow in the Owens Lake Basin has reached the Lower Owens River in average-runoff years (Danskin, 1998). Hutchison (1986d, *as cited by* Danskin, 1998) evaluated the river-discharge record at the Keeler Bridge for runoff years 1946–86 and concluded that most streamflow at the bridge resulted either from operational releases to the river from the aqueduct system or from ground-water discharge. During wet years when surface water is abundant, however, some of the tributary streamflow either is diverted onto the alluvial fans to recharge the ground-water system or is conducted in pipes over the top of the aqueduct and then flows across the valley floor toward the Lower Owens River.

[1] The *Lower* Owens River typically refers to the section of the Owens River downstream of the aqueduct.

Today, under a recently changed operation regime for the aqueduct system, controlled releases result in a range of flows from approximately 40 cubic feet per second (cfs) (base flow) to 200 cfs (infrequently) within the project reach. Peak flows are generally less than 100 cfs, and very infrequently will be above 1,000 cfs (e.g., 1,360 cfs in 1969). Therefore, both the magnitude and variability of flow within the project reach is generally small.

Geomorphology and Stability of the Project Reach

Channel Morphology

Within the project reach, the Lower Owens River is a narrow, sinuous, low gradient channel that does not appear to be very dynamic under contemporary conditions. Based upon surveyed cross-section and channel topography data, the average bed slope within the project reach is about 0.0008 (feet/feet), with some localized areas of even flatter slopes due to channel occlusions. The sinuosity of the project reach is approximately 1.9, which is relatively high.[2] The low-flow channel is generally a single-thread channel, though at flows around 100 to 150 cubic feet per second (cfs) the flow begins to occupy some secondary channels and oxbows and take on a more anabranching plan form. The project reach is further characterized by a relatively narrow and deep low-flow channel (average width-to-depth ratio ranging from approximately 12 to 37) entrenched within a wide valley and floodplain. The modern river valley floor/floodplain generally ranges from 500 to 1500 feet wide.

Though there is evidence throughout the floodplain of a system that was historically more active (i.e., abandoned oxbows and side channels, meander scars), contemporary evidence of a laterally dynamic system (e.g., unvegetated bar deposits or laterally eroding banks) is lacking. This can be at least partially attributable to the anthropogenic impacts upon the hydrology and sediment supply mentioned above. Under existing conditions, the main supply of sediment to the project reach appears to be local (i.e., from within the reach itself by way of eroding and undercut banks and bed erosion). The bed of the river is comprised of mostly sand with some gravel and fines (i.e., silt and clay, and organics). Based upon periodic probing of the channel bed during the May 7-8, 2018 field work, there appears to be a consistent layer of fine and organic material approximately 12 to 18 inches in depth, overlying a more sandy-fine gravel layer.

In the context of Schumm's (1985) classic channel classification scheme, the project reach is a low-gradient, stable, mixed-to-suspended load system (e.g., sinuosity between 1.3 and 2.0, and a width to depth ratio between 10 and 40). The project reach has characteristics of a channel with relatively high stability – a meandering or sinuous pattern without much lateral migration or shifting, or evidence of channel widening.

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2 Sinuosity is a measure of the curvature of the channel path over distance. The value is derived by dividing the total measured channel length by the valley length.

Hydraulics

ESA also used the output from a one-dimensional hydraulic model to quantitatively assess existing and project condition hydraulics with respect to channel stability and sediment transport potential. In particular, we assessed specific stream power and shear stress.

HEC-RAS Model (Brief)

The U.S. Army Corps of Engineers' (USACE) HEC-RAS one-dimensional hydraulic model used for our analysis (ESA, 2018) was originally developed by NHC (2012). NHC (2012) identified some limitations to modeling the Lower Owens River, particularly with a one-dimensional model. The Lower Owens River is a sinuous, low gradient stream, and there are numerous complex remnant channel segments on the floodplain that are inundated by higher flows and groundwater movement. The existing model's capabilities for simulating complex multi-directional flows on the floodplain and the interaction between the sinuous channel and the floodplain are limited, and therefore the model developed for this this analysis is primarily limited to main channel hydraulic conditions (NHC, 2012). The maximum flows that can be reliably analyzed with the existing model for Plots 4 and 5 (i.e., the model sub reaches that are within the project reach) are 80 and 100 cfs, respectively (the extent of Plots 4 and 5 are shown on Figure 1).

Given the highly controlled hydrograph and the fact that high flows generally do not exceed 200 cfs in any given year, and also considering that the floodplain above the low-flow channel is relatively wide and flat, these moderate flows are likely still relevant with respect to their localized influence upon sediment transport and channel stability – i.e., large flows spread out rapidly across the floodplain and/or activate secondary channels, and thus the increase in hydraulic and shear forces within the main channel may be relatively small.

For a more detailed description of the development, parameterization, and use of the hydraulic model the reader is referred to NHC (2012) and (ESA, 2018).

For each plot ESA ran the hydraulic model for two channel configurations (existing and project condition) and two steady flow conditions: 40 and 80 cfs for Plot 4, and 40 and 100 cfs for Plot 5. The modeled project condition was Scenario 3 – *Clear vegetation by hand to minimum of 10' width along entire 6.3-mile project area; remove vegetation and large wood at occlusions with no excavation of channel ground surface. Excavate through marsh region in Plot 4 where channel is discontinuous to create a single thread channel allowing for recreational passage*.

Results and Discussion

Results for specific stream power and shear stress are summarized in Figure 3 and Figure 4 and Table 2.

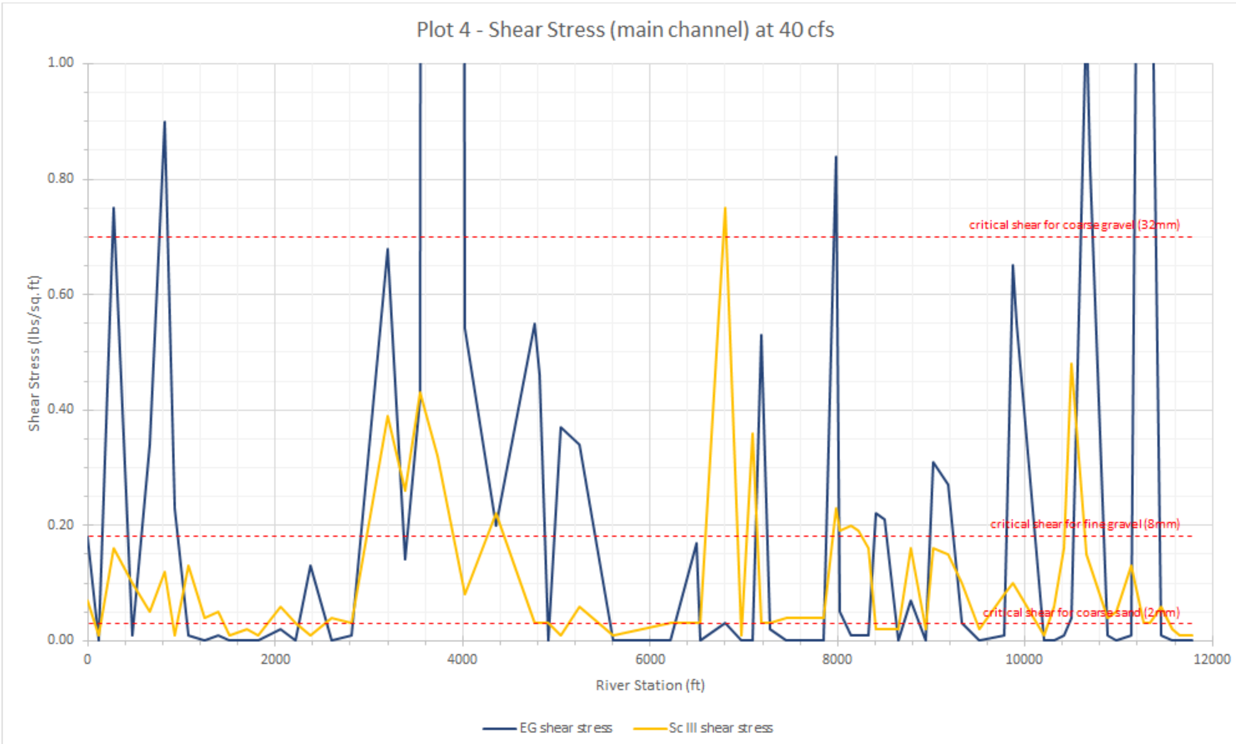
Specific Stream Power

Stream power (effectively the product of slope discharge), is an expression for the rate of potential energy expenditure per unit length of channel (or rate of doing work); specific stream power (SSP) is simply stream power per unit cross-sectional width. As shown in Table 2, the specific stream power for the project reach is very low (generally < 1 W/m2 on average), under both existing and project conditions. For context, summaries of specific stream power by Nanson and Croke (1992) and van den Berg (1995) identify three general categories: Low-energy, laterally stable (stationary), straight or meandering channels (single- or multi-thread) have specific stream power values below 10 W/m2; medium-energy, actively meandering or braiding systems typically have a specific stream power range of 10 to 350 W/m2; high-energy, straight channels (e.g., bedrock confined) or "wandering" gravel-bed rivers should have a specific stream power range of 350 to 600 W/m2.

TABLE 2
HEC-RAS RESULTS.

PLOT 4 Hydraulic Results				
	40 cfs		***80 cfs***	
	EG	***Scenario III***	***EG***	***Scenario III***
Shear Stress (lb/sq ft)				
Average	0.62	0.10	0.39	0.13
Median	0.01	0.05	0.02	0.06
Std. Dev	3.38	0.13	0.92	0.15
SSP (W/m2)				
Average	0.23	0.78	0.35	0.88
Median	0.01	0.21	0.03	0.41
PLOT 5 Hydraulic Results				
	40 cfs		***100 cfs***	
	EG	***Scenario III***	***EG***	***Scenario III***
Shear Stress (lb/sq ft)				
Average	0.50	0.17	0.59	0.19
Median	0.07	0.06	0.13	0.10
Std. Dev	0.84	0.33	0.83	0.23
SSP (W/m2)				
Average	0.59	0.62	1.10	0.94
Median	0.19	0.40	0.38	0.66

EG – existing condition



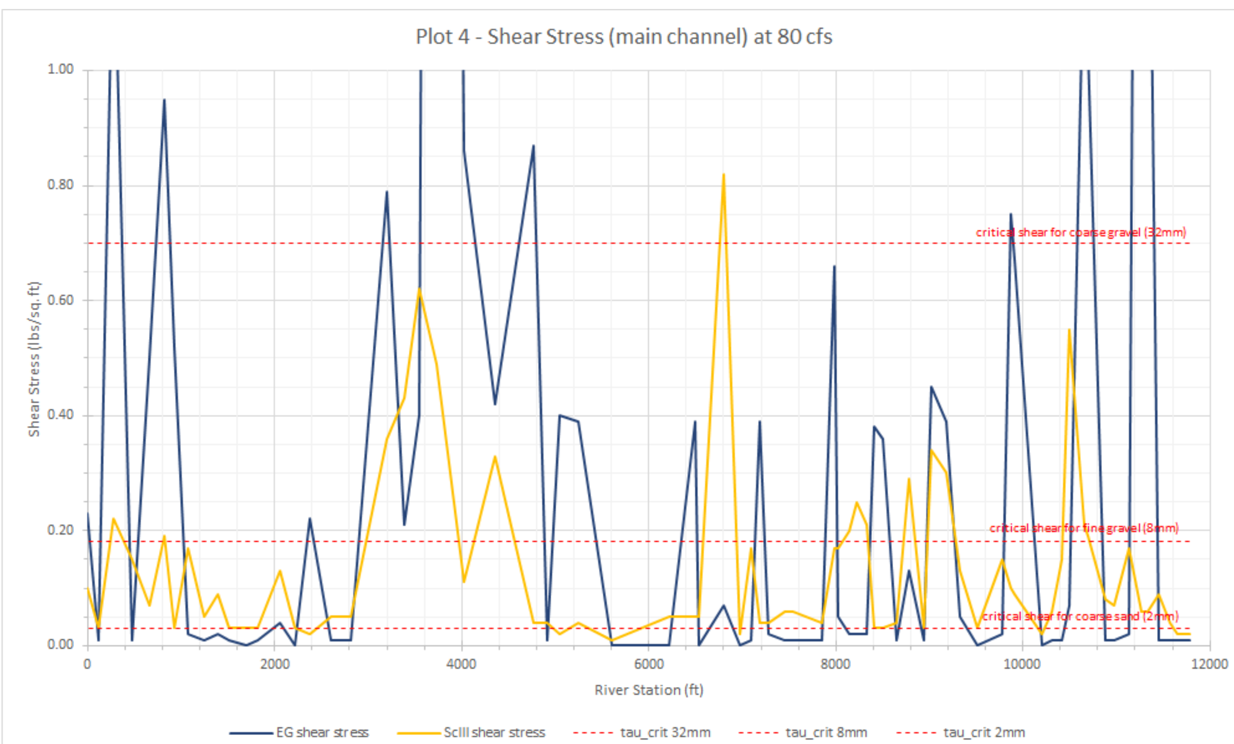
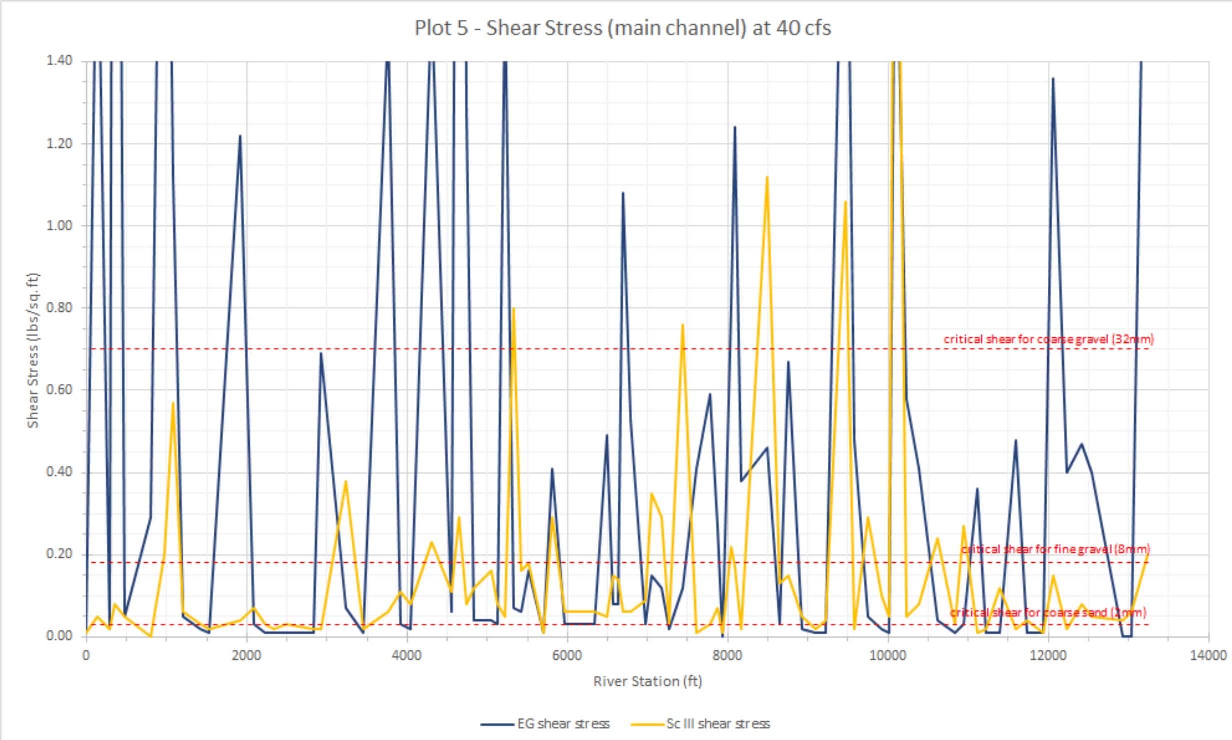


Figure 3. HEC-RAS Shear Stress Results, Plot 4. (EG = existing condition)



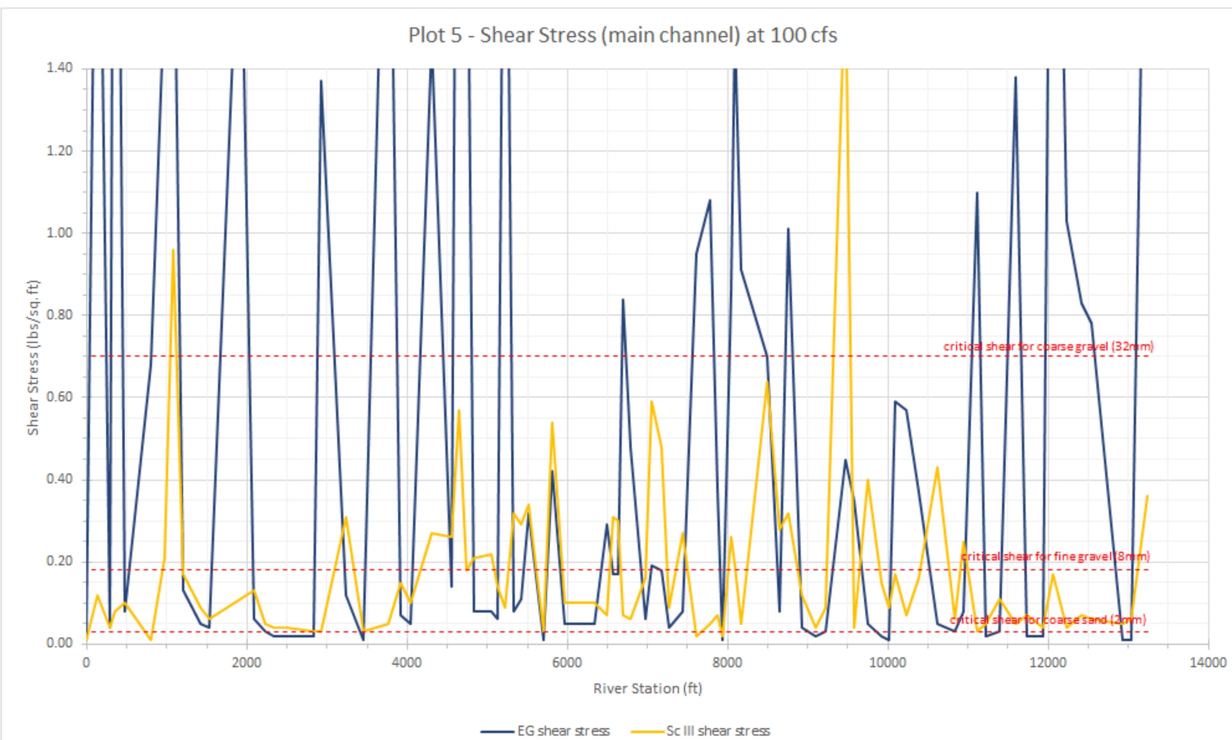


Figure 4. HEC-RAS Shear Stress Results, Plot 5.

Shear Stress

In general, under the project condition the variation in shear stress decreases noticeably, and the average shear stress also generally decreases. For the existing condition the strong "up-down" variation in shear stress is likely driven in part by the high points in the bed at occlusion locations. However, though the average shear stress decreases, the median shear stress value increases and/or the average or median stream power generally increases (or remains the same) under the project condition. These results suggest that, over the entire reach, the rate of work being done by the flow (under the analyzed conditions) may increase under the project condition, and that the channel may be slightly more capable of passing sediment and have a higher degree of sediment transport continuity throughout the project reach. However, the predicted increase would likely not result in a shift of the system to an unstable (i.e., eroding) state because the median shear stress would still be less than the critical shear stress for fine gravel. In general, the results suggest little change to the overall transport capacity of the channel when considered at the reach scale, but a more balanced distribution of shear stress throughout the project reach.

Conclusions

As a result of both natural and anthropogenic processes, the project reach is a stable, low-gradient stream system with a relative low sediment supply and transport potential. Anthropogenic impacts such as upstream reservoirs and the aqueduct have resulted in reduced inputs of flow and sediment to the project reach, and subsequently have reduced the potential for lateral migration, sediment deposition, and other processes that characterize more dynamic systems.

At the reach scale, the capability of the channel to convey sediment (including particulate organic material) is likely to remain unchanged or increase slightly as a result of project implementation. Thus, the rate at which the channel accumulates sediment is unlikely to change notably as a result of project implementation. Further, while recognizing the inherent uncertainty of sediment transport processes in vegetated channels, the predicted increase in shear stress would not be expected to shift the system to an unstable (i.e., eroding) state. The susceptibility of the channel to the proposed perturbations is likely low. However, this does not take into account the potential influence of extreme flood events, debris flows, or other such powerful yet rare processes that would impact the project area regardless of project implementation. This assessment also does not explicitly take into consideration the potential for or rate of tule re-establishment within the constructed areas, which could notably influence the fluvial and sediment transport processes examined herein.

References

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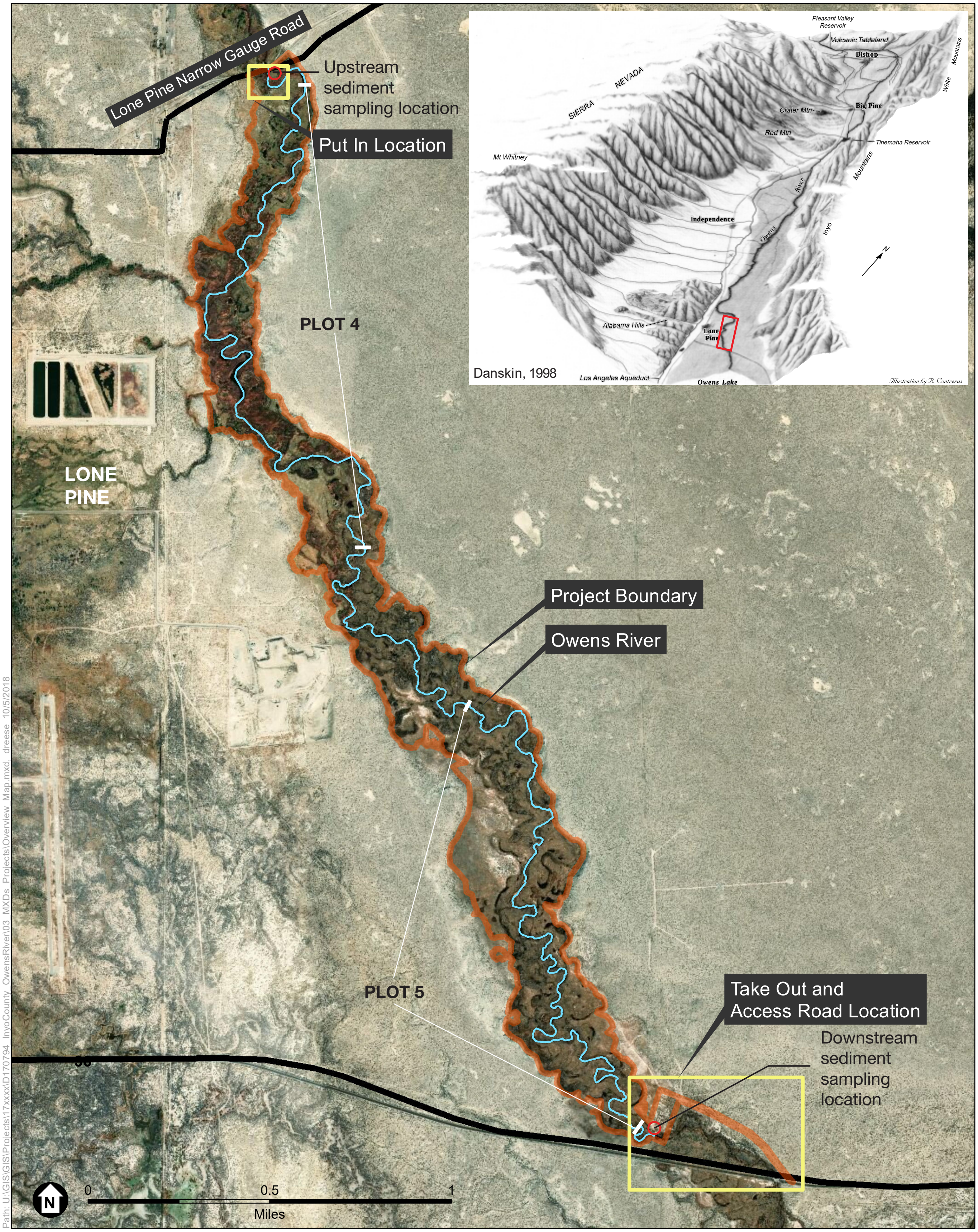

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Owens River Water Trail

Project Location Map

Figure 1

ESA

Attachment A

Particle Size Distribution & Solids Analysis of Water Samples (ASTM D 3977C m)

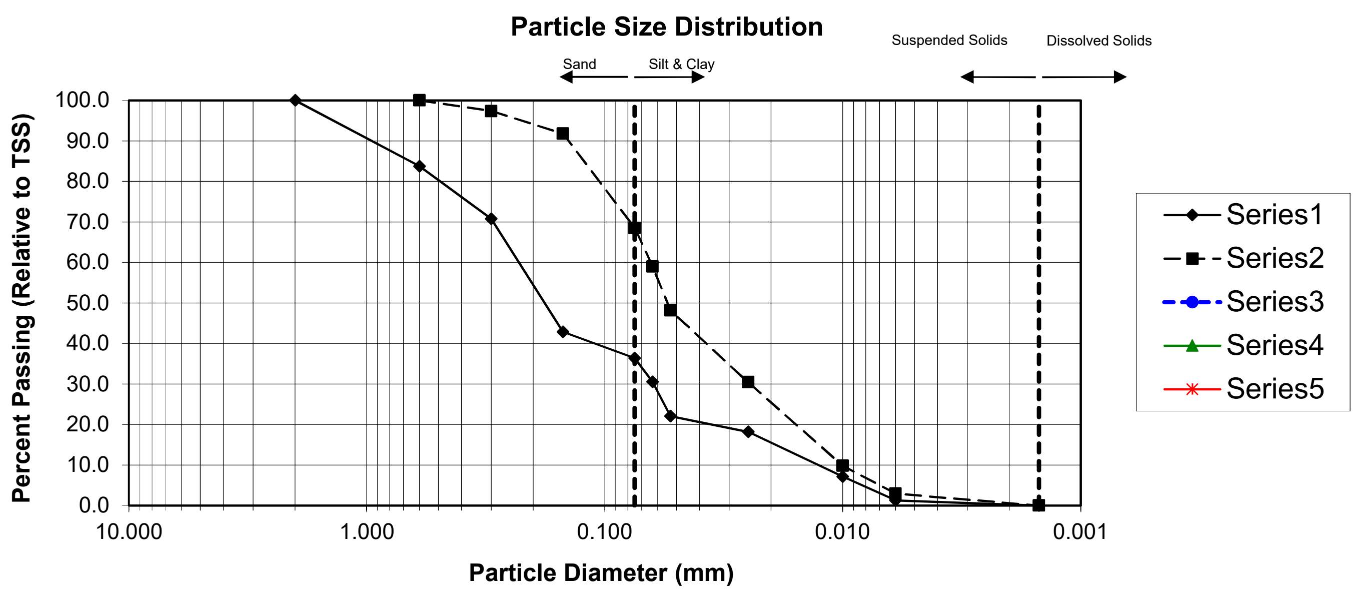
COOPER TESTING LABORATORY

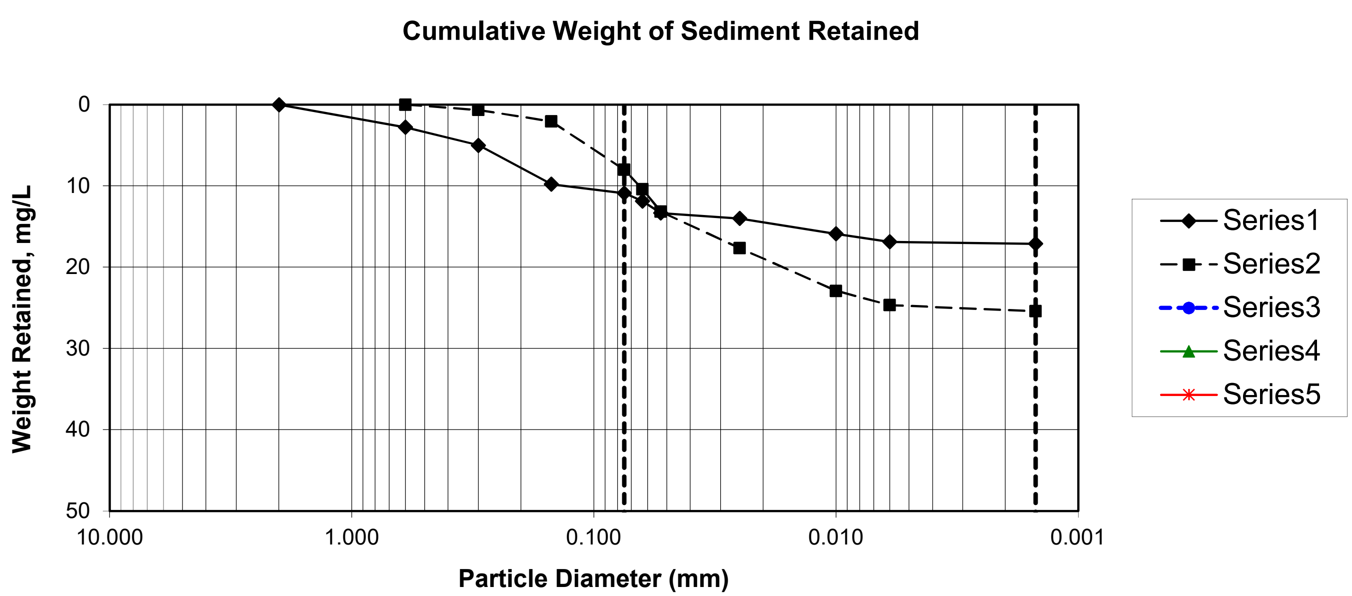
CTL Job No.:	381-029	**Project Name:**	ORWT	**Date:**	7/27/2018
Client:	ESA	**Project No.:**	D170794.00	**By:**	PJ
				Checked:	PJ

Series No.:	**Series 1**	**Series 2**	**Series 3**	**Series 4**	**Series 5**
Source/ Boring No.:	SS-01 & SS-02	SS-03 & SS-04 & S--05	-	-	-
Sample No.:	Composite	Composite	-	-	-
Sample Date:	-	-	-	-	-
Total Suspended Solids, mg/L:	17	25	-	-	-
Total Dissolved Solids, mg/L:	-	-	-	-	-
Total Solids, mg/L:	-	-	-	-	-

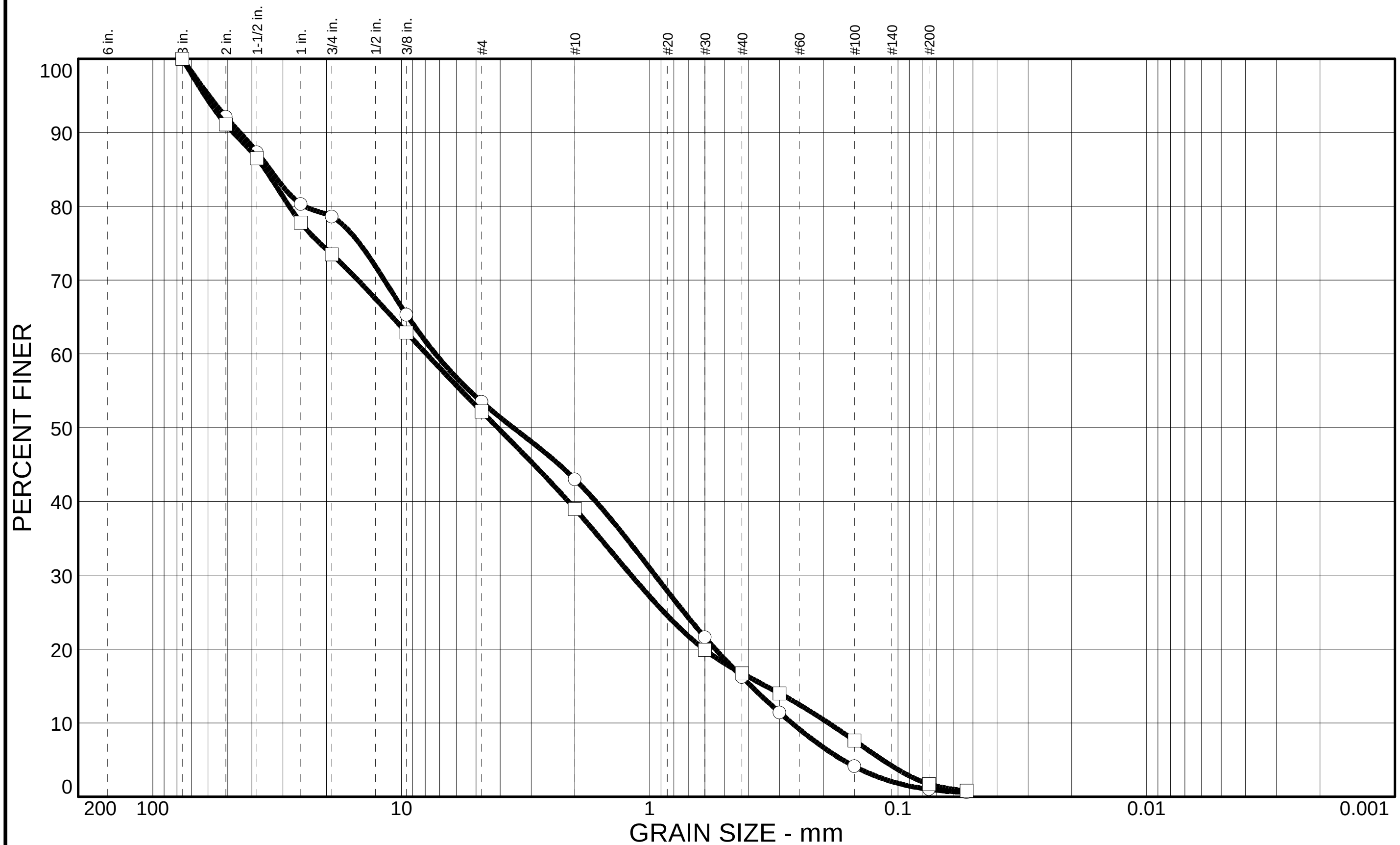
Comments:

Note:The standard test method has been modified slightly by splitting on the #500 (25µm) sieve instead of the #230 (63µm) sieve. Also, enough data points were collected to generate a gradation curve instead of collecting only two.





Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		46.5	52.5	1.0					
□		47.8	50.5	1.7					

SIEVE inches size	PERCENT FINER ○	□	
3"	100.0	100.0	
2	92.1	91.1	
1.5"	87.3	86.5	
1"	80.3	77.8	
3/4"	78.6	73.5	
3/8"	65.3	62.9	
	GRAIN SIZE		
D_{60}	7.28	7.92	
D_{30}	0.951	1.19	
D_{10}	0.268	0.191	
	COEFFICIENTS		
C_c	0.46	0.93	
C_u	27.14	41.44	

SIEVE number size	PERCENT FINER ○	□	
#4	53.5	52.2	
#10	43.0	39.0	
#30	21.6	19.9	
#40	16.2	16.7	
#50	11.4	14.0	
#100	4.1	7.6	
#200	1.0	1.7	
#270	0.6	0.8	

SOIL DESCRIPTION

○ Brown Poorly Graded SAND w/ Gravel

□ Brown Poorly Graded SAND w/ Gravel

REMARKS:

○

□

○ Source: SED-01

□ Source: SED-02

COOPER TESTING LABORATORY

Client: ESA

Project: ORWT - D170794.00

Project No.: 381-029

Figure