ESTIMATED FSP LOAD REDUCTIONS OF SELECT STREAM RESTORATION PROJECTS IN THE UPPER TRUCKEE RIVER WATERSHED

LAKE TAHOE, CALIFORNIA

FINAL REPORT – MARCH 2014

2NDNATURE
ecosystem science + design

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Lake Tahoe, California

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The following individuals formed the Technical Advisory Committee for this research:

Brendan Ferry, El Dorado County	Stuart Roll, CTC
Cyndi Walck, CA State Parks	Robert Larsen, LRWQCB
Joe Pepi, CTC	Jason Kuchnicki, NDEP
Theresa Cody, USFS	Jacques Landy, EPA
Stephanie Heller, USFS	Shane Romsos, TRPA
Scott Carroll, CTC	Tiff van Huysen, USFS

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The views in this report are those of the authors and do not necessary reflect those of the USDA Forest Service Pacific Southwest Research Station or the USDA Bureau of Land Management

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 EXECUTIVE SUMMARY

Estimates of the average annual FSP load reduction (MT/yr) for 7 stream restoration projects in the Upper Truckee River Watershed were completed using the Stream Load Reduction Tool; SLRT (2NDNATURE 2013). The SLRT generates an estimate of the average annual hydrology and FSP loading to the upstream boundary of an SEZ and quantifies the expected FSP load reduction from restoration actions as a result of increased inundation and pollutant retention on the floodplain and reduced bank erosion. Three of the restoration efforts had been implemented by the time of this analysis (2013) and 4 are in the planning or design phase. Data necessary to represent the previous or planned SEZ conditions were obtained from coordination with project managers, project proponents and other available sources. Existing conditions were obtained by geomorphic field surveys in 2013. The estimated FSP load reductions and cost-effectiveness ($/lb of FSP) varied across projects, with the UTR Middle Reach and UTR Sunset 5 projects expected to be the most cost-effective in terms of FSP load reductions, particularly due to the significant increase in floodplain inundation and retention expected by these projects. Cumulatively, a potential 105 MT/yr of FSP may be reduced from the Upper Truckee River (≈ 20% reduction in the total average annual FSP load) if all of these restoration projects are implemented and respond as modeled. A simple accounting method was developed to estimate the urban fraction of the average annual FSP load reduction provided by each restoration effort. We create and implement a relatively simple method to estimate the fraction of the total FSP load reductions that are derived from urban lands within each of the catchments. While the cost effectiveness of SEZ restoration actions to achieve pollutant load reductions varied across projects, this analysis does suggest that SEZ restoration is another valid and cost-effective tool in the pollutant load reduction opportunity toolbox for Tahoe Basin managers to reduce pollutant loads to Lake Tahoe.

2 RESEARCH INTRODUCTION

2NDNATURE was funded by a Round 12 SNMPLMA Research Grant to estimate the pollutant load reductions associated with 7 stream restoration projects within the Upper Truckee River (UTR) Watershed using the Stream Load Reduction Tool (SLRTv1; 2NDNATURE 2013). As the largest watershed in the Tahoe Basin, Upper Truckee River is the greatest point discharge of fine sediment particles (FSP < 16 µm) to Lake Tahoe. Numerous SEZ restoration project have been or are planned to be implemented in the UTR watershed to restore fluvial function, reduce bank erosion and improve downstream water quality. The Lake Tahoe TMDL has focused water quality improvement actions to significantly reduce FSP loading to the Lake over the next several decades. Research and monitoring that supported the development of SLRT suggests effective SEZ restoration can reduce sediment generation from bank erosion and significantly increase FSP removal in flood flows as a result of floodplain deposition (2NDNATURE 2013, Andrews et al. 2011, Simon et al. 2011). While standard methods to estimate the urban derived fraction of this FSP loading do not exist, it is likely some load reduction from catchment urban lands are being treated. There is a lot of political and social interest associated with the evaluation of restoration effectiveness within the Upper Truckee River Watershed, making the results of this research relevant and important to many stakeholders within the Lake Tahoe Basin.

SLRT was completed in 2013 and currently provides a consistent and relatively simple approach to estimate the average annual FSP load reduction as a result of SEZ restoration. SLRT estimates are completed by a customized MS Excel spreadsheet after a series of catchment characteristics and geomorphic attributes to represent the pre- and post-restoration reach conditions are input by the user. SLRT was developed to estimate the average annual hydrology and report results in a format consistent with urban load estimate tool PLRM (Pollutant Load Reduction Model [PLRM] (NHC et al. 2009)).

The density of restoration projects planned or completed in UTR Watershed provided an opportunity to apply SLRT to a series of restoration projects that vary in scale, restoration approach, and design objectives. A stakeholder process was undertaken to select the 7 restoration projects included in this research. The three main objectives of this research were:

1) Obtain and analyze the average annual FSP load reductions estimated for a series of restoration projects in the Upper Truckee Watershed both independently and collectively;
2) Evaluate the cost effectiveness ($/MT) of FSP reductions for completed restoration projects and compare to other pollutant load reduction strategies considered to meet the Lake Tahoe TMDL; and
3) Identify and implement any improvements to the SLRT methodology and user guidance and produce SLRTv2.

Stakeholder involvement was conducted through Upper Truckee River Watershed Advisory Group (UTRWAG) meetings and individual contact with stream restoration project managers to select sites, obtain available data, verify restoration site attributes, define restoration costs, and review draft products.

2.1 DOCUMENT STRUCTURE

The following report is organized to guide readers through the process conducted by 2NDNATURE. Chapter 3 provides an overview of the SLRT methodology, identifies the restoration project site selection for this effort, and details how and what the data input values are for each restoration site modeled. Chapter 4 presents and analyzes the FSP load reduction estimates for 7 selected restoration projects, their cumulative benefit, and cost effectiveness ($ per MT FSP). A simple method was developed to estimate the fraction of the FSP load reductions for each project that were derived from urban areas within the respective catchments. This was the first extensive application of SLRT, allowing the identification and incorporation of a number of improvements to both SLRT User Guidance and the customized MS Excel spreadsheet that automates the calculations and outputs. The SLRTv2 User Guidance is attached as Appendix A in the final document.

2.2 ACKNOWLEDGEMENTS

The research, data and results provided in this document are the product of extensive data collection, information sharing, discussions, meetings and other contributions from the Lake Tahoe stream restoration community. Technical advisory members listed in Table 1 provided exceptional support throughout these efforts, contributing datasets and critical guidance to the research team. Consultants from Wildscape Engineering Services (Carol Beahan), Cardno Entrix, Stream Solutions, and Graham Mathews and Associates provided much of the technical data and design work used for SLRT data input.

Table 1. Technical advisory committee members.

Contact	Lead Agency
Brendan Ferry	El Dorado County
Cyndi Walck	CA State Parks
Joe Pepi	CTC
Theresa Cody	USFS
Stephanie Heller	USFS
Tiff van Huysen	USFS
Scott Carroll	CTC
Stuart Roll	CTC
Robert Larsen	LRWQCB
Jason Kuchnicki	NDEP
Jacques Landy	EPA
Shane Romsos	TRPA

3 STREAM LOAD REDUCTION ESTIMATES

SLRT was developed to provide a consistent and relatively simple estimation approach to quantify the average annual pollutant load at the downstream boundary of an SEZ by modeling the critical processes influencing water quality over decadal time scales (2NDNATURE 2013). Downstream water quality improvements associated with a stream restoration project are a function of:

1. Increased pollutant retention on the floodplain that would have otherwise been transported downstream (floodplain retention) and
2. Reduced pollutant generation via stream bank stability that would have otherwise eroded (stream channel erosion) (Figure 1).

SLRT estimates the average annual FSP load exported from the downstream boundary of the subject reach for both pre- and post-restoration conditions, the difference being the average annual FSP load reduction as a result of restoration actions.

Users input project reach location and catchment characteristics into SLRT to generate an average annual hydrograph and FSP pollutograph at the upstream boundary of subject SEZ. SLRT requires the user to generate geomorphic attributes that represent the configuration of the channel and adjacent floodplain pre- and post-restoration. The changes in the site geomorphology are used to estimate reductions in bank erosion and increases in floodplain retention as a result of restoration. Constraining FSP loading into the project reach for both pre- and post-restoration conditions allows an isolation of the difference in downstream water quality estimates as a result of geomorphic changes from restoration, instead of variations in the input hydrology or pollutant loading.

This report assumes that the reader is familiar with SLRTv1. If additional background is needed, a review of Chapter 3 of SLRT technical document (2NDNATURE 2013) is recommended. A number of lessons learned and SLRT improvements were identified and incorporated into SLRT as a result of this research. As a result, SLRTv2 was developed and used to complete the load reduction estimates contained herein. Appendix A includes SLRTv2 User Guidance and SLRTv2 digital templates are available at www.2ndnaturellc.com/client-access/slrttrout-creek/.

Below summarizes the process and findings from the selection, input value generation and result comparisons for 7 SEZ restoration efforts either planned or completed in the Upper Truckee River Watershed.

3.1 SEZ RESTORATION SITES

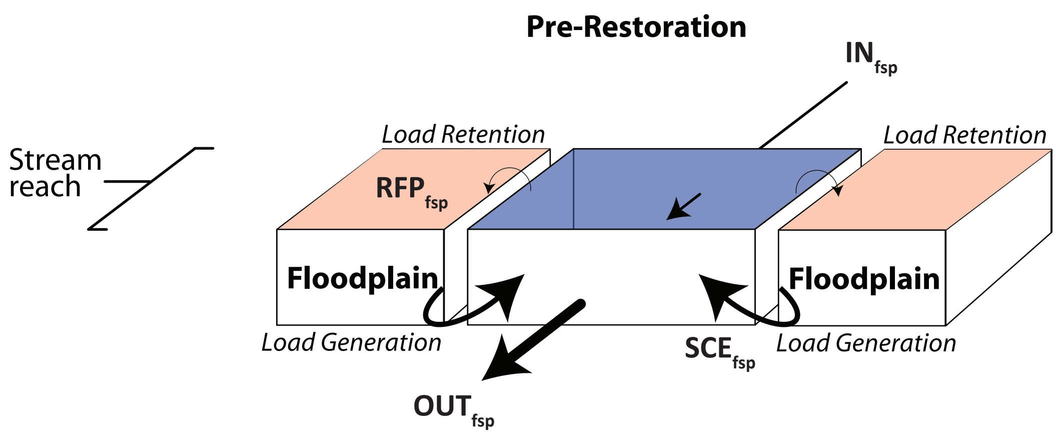
2NDNATURE used SLRTv2 to estimate the average annual FSP load reduction as a result of 7 SEZ restoration projects in the Upper Truckee River Watershed. The selection process originated with 18 projects from a comprehensive list focused on Upper Truckee River Watershed. The Upper Truckee River Watershed was chosen because it contains the largest number and highest priority restoration projects. Main channel realignment projects on Upper Truckee River and Angora Creek were targeted to generate the 7 sites presented in Table 2, which summarizes project name, current status, project manager and the respective lead agency. Each of these project managers provided invaluable collaboration to the 2N team by locating and providing available data, granting site access, reviewing draft products, and providing other information as needed. Figure 2 maps the locations of the selected restoration projects.

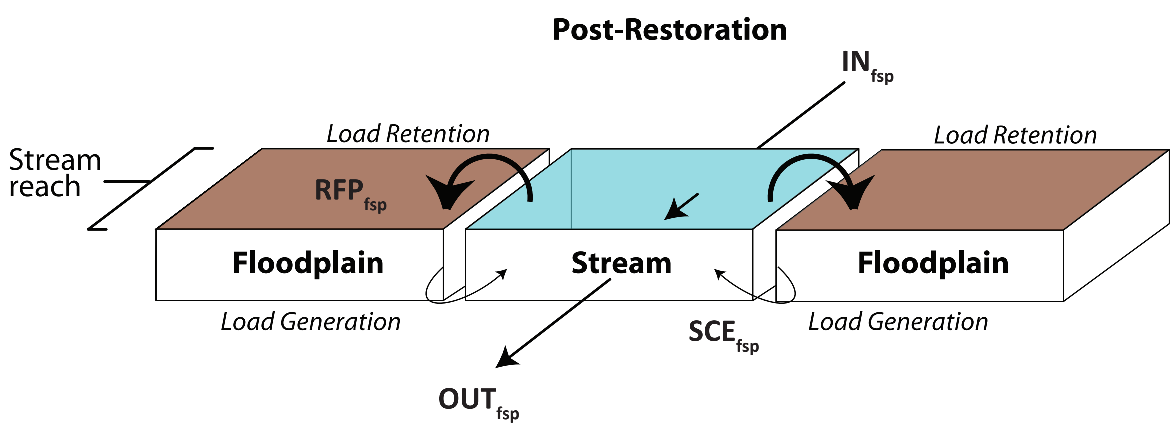
The Stream Load Reduction Tool (SLRT) computes the average annual pollutant load reduction (SEZ_{fsp}) as the difference between the pollutant load generated at the downstream boundary of a specific SEZ during pre-restoration ($OUT_{fsp\text{-}pre}$) and post-restoration ($OUT_{fsp\text{-}post}$) conditions.

$$SEZ_{fsp}\ (MT/yr) = OUT_{fsp\text{-}pre} - OUT_{fsp\text{-}post}$$

For both pre- and post-restoration scenarios, SLRT employs a pollutant mass balance approach to estimate the average annual pollutant loads at the downstream boundary of an SEZ (OUT_{fsp}). The downstream load is equal to the inflowing load at the upstream boundary (IN_{fsp}) less any sediment retained on the floodplain during overbank flow (RFP_{fsp}) plus any sediment generated by instream channel erosion during critical flows (SCE_{fsp}).

$$OUT_{fsp}\ (MT/yr) = IN_{fsp} - RFP_{fsp} + SCE_{fsp}$$





See SLRT technical document (2NDNATURE 2013) for a list of variables and their definitions.

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2NDNATURE | LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

BOX MODEL CONCEPTUAL MODEL

FIGURE 1

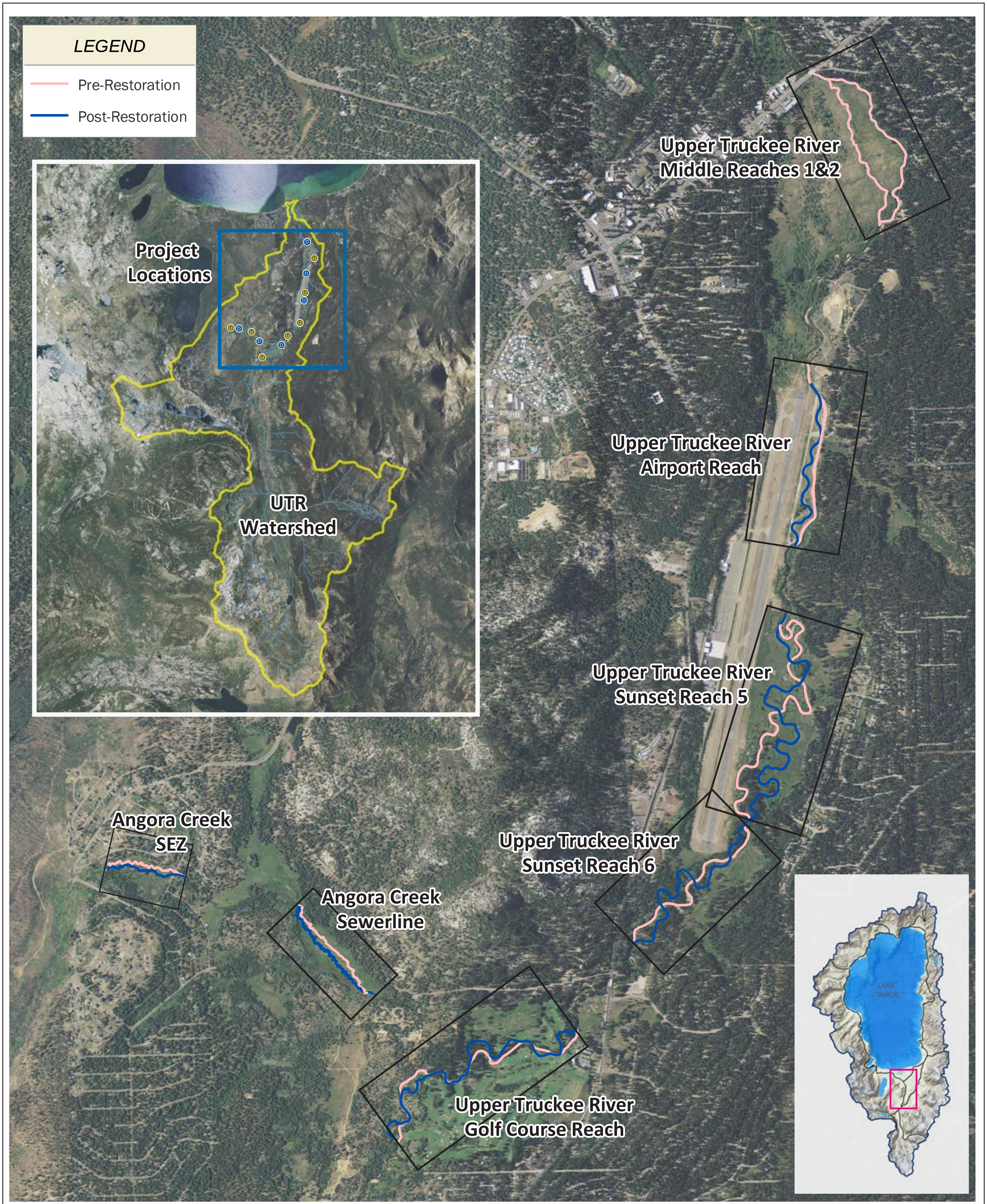

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FIGURE 2: Upper Truckee River and Angora Creek restoration projects selected for SLRT application.

Table 2. Summary table of project name, current status, project contact and lead agency.

Project Name	Aug 2013 Status	Project Manager	Lead Agency
Angora Creek SEZ	Completed	Brendan Ferry	El Dorado Co
Angora Creek Sewerline	Completed	Cyndi Walck	CA State Parks
Upper Truckee River: Golf Course Reach	Planning	Cyndi Walck	CA State Parks
Upper Truckee River: Sunset Reach 6	Planning	Joe Pepi	CTC
Upper Truckee River: Sunset Reach 5	In Progress	Theresa Cody/Stephanie Heller	USFS
Upper Truckee River: Airport Reach	Completed	Stan Hill	CSLT
Upper Truckee River: Middle Reaches 1 & 2	Planning		

3.1.1 RESTORATION COSTS OF COMPLETED PROJECTS

In order to evaluate project cost effectiveness associated with pollutant load reductions, cost estimates were collected from project managers for both completed and in progress projects. 2NDNATURE coordinated with project managers to obtain best estimates of costs associated with Design/Planning and Construction. Given that the accounting of actual total costs would be time consuming and likely inaccurate, design and construction cost estimates range +/- $100,000. Table 3 summarizes the estimated costs associated with each completed or in progress restoration project, along with the Trout Creek Upper Reach restoration project. The SLRT analysis for Trout Creek Upper Reach was completed as part of 2NDNATURE (2013), and the project is of comparable scope to the 7 UTR projects to provide a helpful comparison and provide context for the UTR project analyses.

Table 3. Summary table of costs associated with design/planning and construction for the 7 SEZ restoration projects selected for SLRT application, as well as total costs for the Trout Creek Upper Reach restoration.

Project Name	Aug 2013 Status	Estimated Cost Design/Planning ($USD)	Estimated Cost Construction ($USD)	Estimated Cost Total ($USD)
Angora Creek SEZ	Completed	$1,800,000	$2,600,000	$4,400,000
Angora Creek Sewerline	Completed	$260,000	$360,000	$620,000
Upper Truckee River: Golf Course Reach	Planning	$2,500,000	$7,500,000	$10,000,000
Upper Truckee River: Sunset Reach 6	Planning	$1,600,000	$4,000,000	$5,600,000
Upper Truckee River: Sunset Reach 5	In Progress	$1,500,000	$5,000,000	$6,500,000
Upper Truckee River: Airport Reach	Completed	$1,300,000	$6,500,000	$7,800,000
Upper Truckee River: Middle Reaches 1 & 2	Planning	$1,060,000	$3,000,000	$4,100,000
Trout Creek Upper Reach	*Completed*			*$2,000,000*

3.2 SLRT INPUT NEEDS

SLRTv2 requires two types of inputs: catchment characteristics and SEZ attributes. Catchment characteristics include the region within the Lake Tahoe Basin and catchment area to generate incoming hydrology and pollutant loads delivered to project reach on an average annual basis. The SEZ attributes include channel geometry and floodplain characteristics representative of pre- and post-project conditions. The SEZ attributes are used to estimate the frequency and duration of overbank events and associated pollutant retention, as well as the average annual FSP inputs as a result of bank erosion.

A total of 14 SEZ morphologies were generated to define both pre- and post-restoration conditions of all 7 selected sites. A number of challenges exist when generating SLRT inputs. First, in all instances, only one of the site conditions exists at the time of this analysis. When the site has yet to be restored, a vision of future restored conditions post-project was required and judgment was necessary to reasonably define representative attributes of the future desired morphology of the reach. When the project was in its restored configuration, the team had to recreate pre-project conditions using disparate and limited data obtained by others. SLRT requires users to represent a spatially complex and variable system as a single, descriptive geomorphic condition for the entire area of interest, which can be challenging. A number of techniques and considerations are provided to assist the SLRT user in overcoming these challenges in the current SLRTv2 User Guidance (Appendix A).

3.2.1 AVAILABLE DATA COMPILATION

Project evaluation using SLRTv1 methodology requires readily available geomorphic data be obtained for each project reach. Data was obtained by UTRWAG, CTC, CA State Parks, USGS, City of South Lake Tahoe, and others (Table 4). Key data included topographic cross sections throughout the project reach and any hydraulic modeling (HEC-RAS) used during project planning and design to provide a more detailed representation of the project reach. Historic maps and aerial photographs sourced from USDA Farm Service Agency National Agricultural Inventory Program (NAIP) were reviewed to assist with determining pre- or post-restored site conditions where applicable. Recent aerials from 2012 (NAIP) were used to identify current conditions channel alignment and delineation of straight and bend reaches.

Table 4. Available data compilation summary.

Project Name	Lead Agency	Aug 2013 Condition	Pre-Project		Post-Project		
			Topographic Cross Section	HEC-RAS	Topographic Cross Sections	Design Plans	HEC-RAS
Angora Creek SEZ	El Dorado County	Post-Restoration	2004	2004	2004	2004	2004
Angora Creek Sewerline	CA State Parks	Post-Restoration	1999	n/a	2013	n/a	n/a
Upper Truckee River: Golf Course Reach	CA State Parks	Pre-Restoration	2013	n/a	n/a	Prelim design plans	- -
Upper Truckee River: Sunset Reach 6	CTC	Pre-Restoration	2005/2011/ 2013	2004	n/a	50%	2004
Upper Truckee River: Sunset Reach 5	USFS	Pre-Restoration	2005/2008	2004	n/a	100%	2004
Upper Truckee River: Airport Reach	CSLT	Post-Restoration	2010	2006	2011/2012	100%	2006
Upper Truckee River: Middle Reaches 1 & 2		Pre-Restoration	2009/2011	2006	n/a	75%	2006

3.2.2 2013 FIELD SURVEYS

2NDNATURE surveyed all 7 restoration project sites in August 2013 to generate SLRT geomorphic inputs for current condition configurations (refer to Table 4 for current condition). At each project site, 2N field staff recorded upstream and downstream boundaries of the project area on a Trimble GeoXH GPS unit.

Once the project reach was delineated, the stream was evaluated at multiple straight and bend locations to record bank height, bank angle, top width, bottom width, bankfull width, toe length, toe angle and 2X bankfull width. All measurements were made with a survey tape and stadia rod. Bank height was recorded on the left and right banks using a stadia rod to measure the height from top of bank to the bottom of the toe. Bank angles were assessed by placing the stadia rod at the top of the bank toe and measuring the angle formed by the stadia rod and the top of bank using the "Tiltmeter" iPhone application (see Figure 10 for bank geometry schematic). Top width was determined by pulling the survey tape tautly across the channel from the top of left to the top of right bank and repeated at the bottom of the channel for bottom width. Field staff identified bankfull depth within the channel using bankfull indicators, and measured bankfull width between these points with the survey tape. After locating bankfull height, field personnel estimated 2X bankfull height and measured the width at this elevation with survey tape. These measurements were repeated at multiple sites in the restored reach to represent a range of data used to define the required SLRT inputs.

A series of detailed cross sections were surveyed with a stadia rod, survey tape, and level at representative straight and bend reaches of the existing stream channel. Ample photos were taken at each site location in order to inform the determination of the existing floodplain condition. Site descriptions and photos of each restoration project are located in Appendix B. 2N staff leveraged all available data for each site, including aerial photos, ground photos, topographic surveys, cross sections, and HEC-RAS models, to determine each of the SLRT input values.

3.3 SLRT INPUT GENERATION

All SLRT calculations are automated within a customized MS Excel spreadsheet that requires a series of user inputs. The process of generating these inputs for the 7 restoration projects identified a number of improvements to the SLRT User Guidance, which can be found in Appendix A. Once the inputs are generated, they are input into the SLRTv2 USER INPUT form (see Appendix A). 2NDNATURE produced each of the SLRT input values described below with input and verification by project managers listed in Table 2. All units are in metric (meters) with the exception of channel capacity, which is in cubic feet per second (cfs), and catchment area, listed in square miles.

3.3.1 CATCHMENT CHARACTERISTICS

Catchment characteristics are used to estimate the average annual hydrograph and FSP pollutograph on daily timescales for each site. All sites are located within a non-urban catchment type in either the Mainstem UTR Region or the Southwest Sub-region. To generate catchment area, Lake Tahoe subwatersheds were modified to outline all drainages leading into the upstream project boundary for each project. ArcGIS is used to calculate square miles within the delineated boundary for input into SLRT template (Table 5).

Table 5. Catchment areas delineated to upstream boundary of project.

Project Name	Sq mi
Angora SEZ	2.6
Angora Sewerline	4.4
UTR Golf Course Reach	42.4
UTR Sunset Reach 6	50.3
UTR Sunset Reach 5	51.3
UTR Airport Reach	52.3
UTR Middle Reaches 1 & 2	53.7

3.3.2 PROJECT DELINEATION AND PLANFORM

Using ArcGIS, stream reach alignments and project extents were digitized for pre- and post-project conditions using historical aerial photos and design plans. Upstream boundaries were delineated where the post-project channel begins. Downstream boundary was defined as the confluence of pre-project and post-project channels, or the downstream end of channel rehabilitation/ stabilization if there were any in-channel modifications (i.e., Airport Reach). These reach break locations will differ from planning and permitting boundaries that include all construction related activities, since SLRT focuses on the specific channels unique to pre- and post-project alignments.

Using the project delineated alignments, simple channel length calculations were generated for pre- and post-project conditions for each stream reach. The elevation difference between the upstream and downstream project boundary was divided by the reach length to quantify the reach slope for each condition.

Pre- and post-project channel alignments were manually delineated into straight and bend reaches for each project. The resolution for this delineation was dependent upon the size of the system. Angora Creek sites were zoomed into approximately 1:500, given the relatively small channel, to split at locations that illustrated a prominent and continuous curve. Reaches that showed evidence of a steep outside bank and a low angle inside bank were delineated as outside bend reaches. Segments with limited turns or relatively straight orientation were delineated as straight reaches.

A similar methodology was employed for Upper Truckee River projects, but reviewed at a scale of approximately 1:1200. Bend locations were more apparent in these reaches with the aide of using high resolution aerial photos and a wider stream channel. In most cases, a 2012 aerial photograph (summer) was able to capture thalweg location, outside bank erosion, point bar formations and riffle/pool sequences that were used as indicators to distinguish between straight and outside bend reaches. Professional judgment was used to delineate reaches using design plans of the planned future morphology.

After reach delineation in GIS, segment lengths were summarized by project site, project condition and reach type. Figures 3-9 map pre- and post-project alignments and provide tabular summaries of reach lengths for each of the 7 subject sites.

Project	Length (m)
Angora Creek SEZ	
Pre-Restoration	580.6
Bend	207.9
Straight	372.6
Post-Restoration	526.4
Bend	192.9
Straight	333.4

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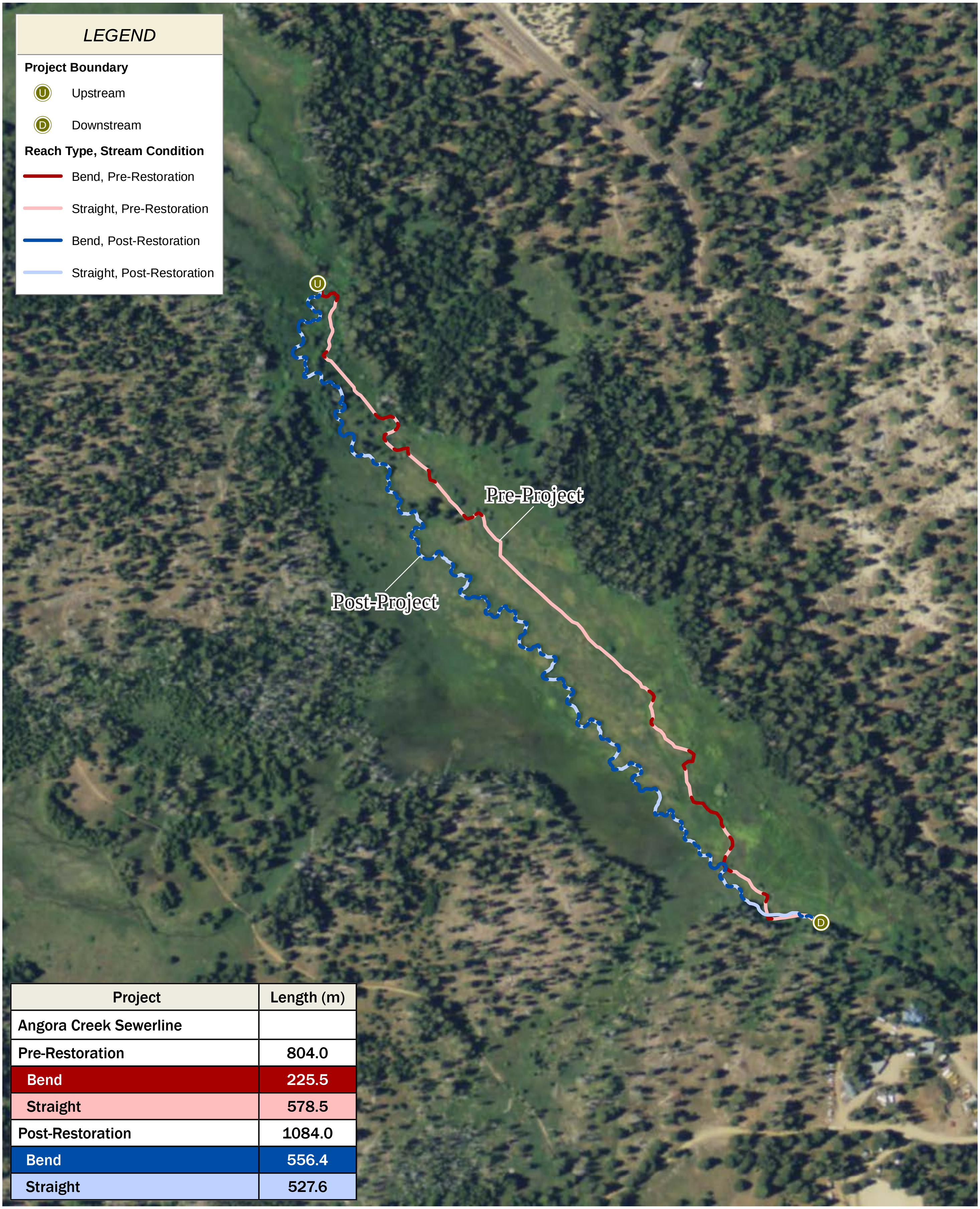
FIGURE 3: Angora Creek SEZ restoration project alignment.
Restoration status: Completed 2006
Pre-restoration alignment: IKONOS 2002
Post-restoration alignment: NAIP Aerial Photo 2012

feet
0 200 400
N



Project	Length (m)
Angora Creek Sewerline	
Pre-Restoration	804.0
Bend	225.5
Straight	578.5
Post-Restoration	1084.0
Bend	556.4
Straight	527.6

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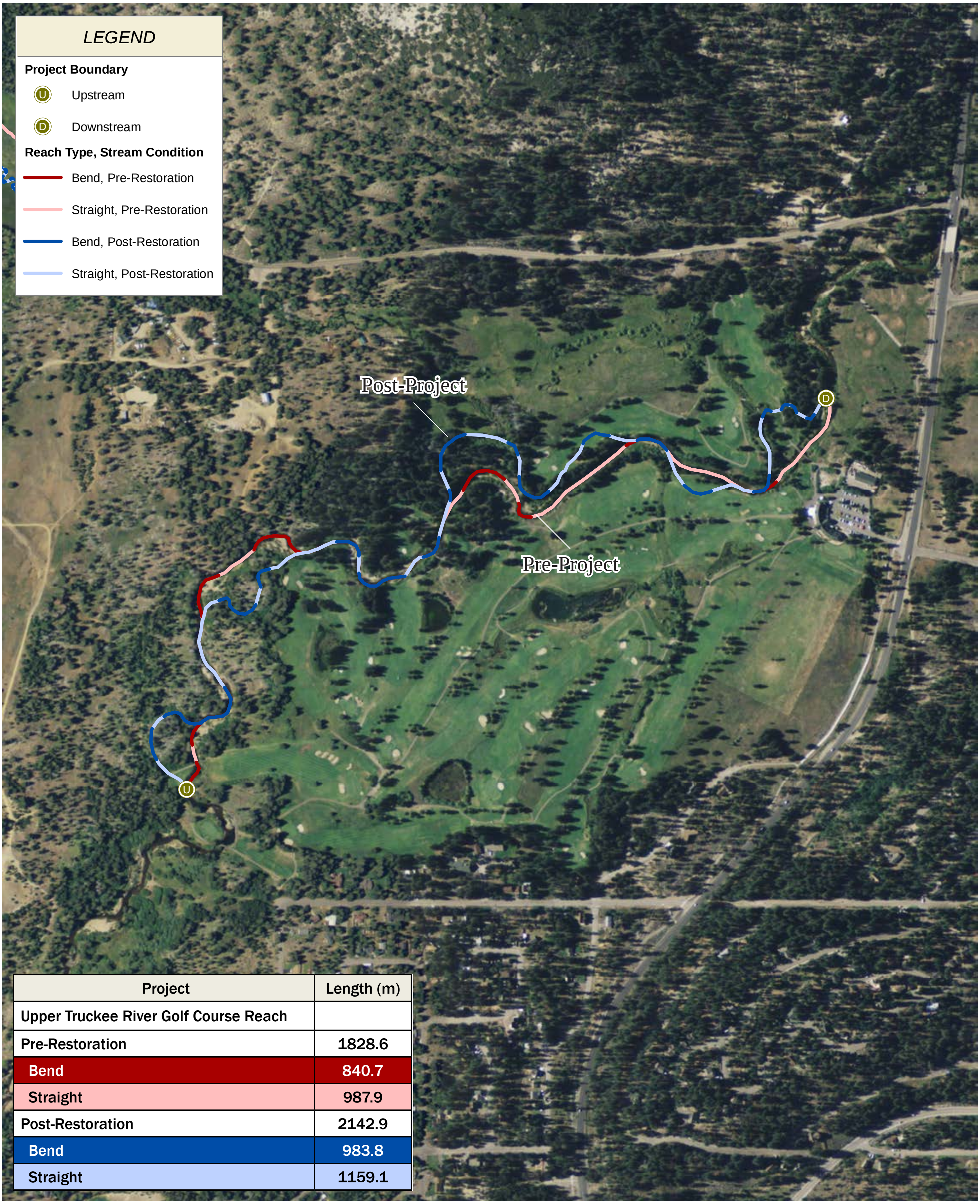
FIGURE 4: Angora Creek Sewerline restoration project alignment.
Restoration status: Completed 2002
Pre-restoration alignment: IKONOS 2002
Post-restoration alignment: NAIP Aerial Photo 2012



Project	Length (m)
Upper Truckee River Golf Course Reach	
Pre-Restoration	1828.6
Bend	840.7
Straight	987.9
Post-Restoration	2142.9
Bend	983.8
Straight	1159.1

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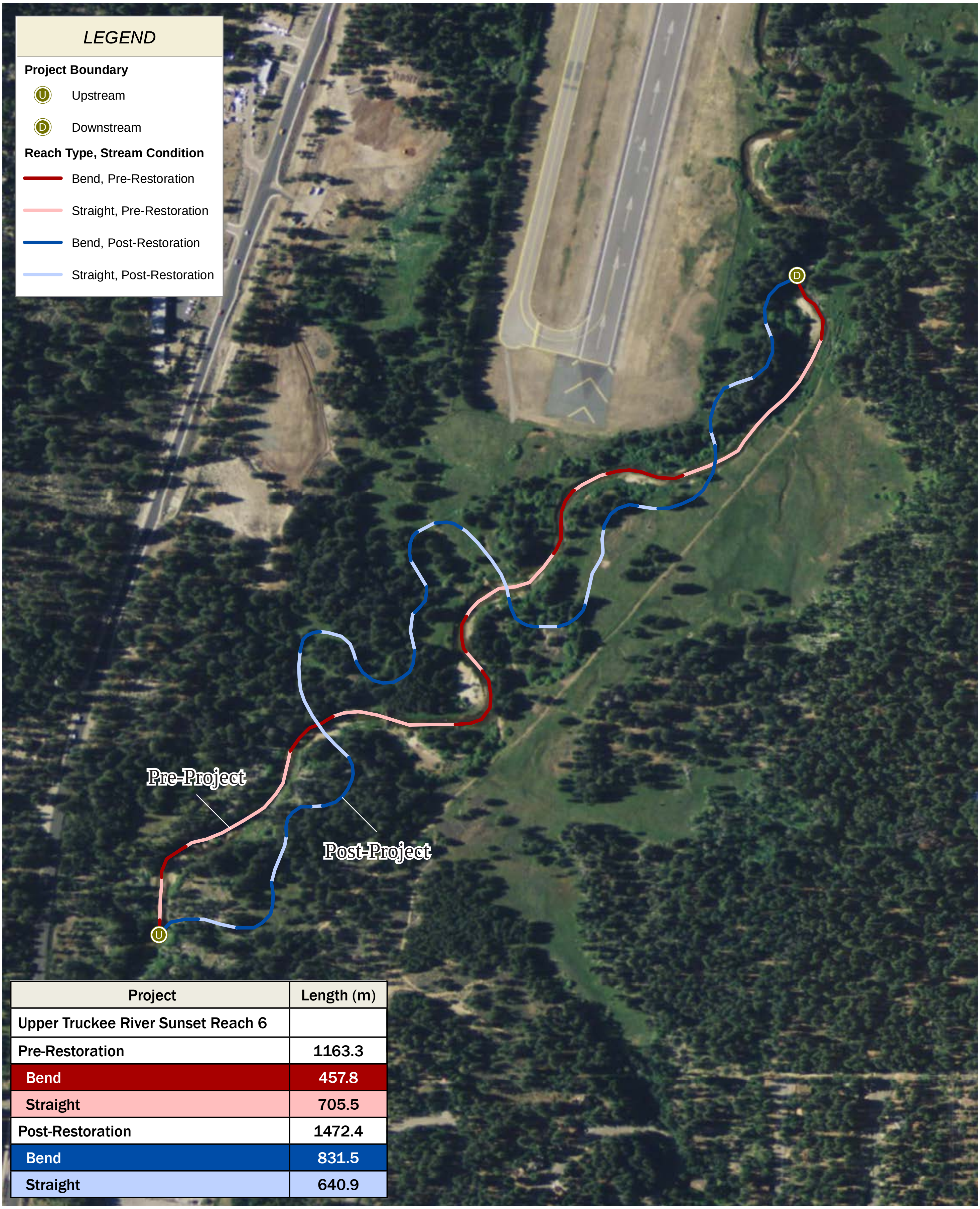
FIGURE 5: Upper Truckee River Golf Course Reach restoration project alignment.
Restoration status: Preliminary Design
Pre-restoration alignment: NAIP Aerial Photo 2012
Post-restoration alignment: Preliminary Design Plans

feet
0 500 1000
N



Project	Length (m)
Upper Truckee River Sunset Reach 6	
Pre-Restoration	1163.3
Bend	457.8
Straight	705.5
Post-Restoration	1472.4
Bend	831.5
Straight	640.9

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FIGURE 6: Upper Truckee River Sunset Reach 6 restoration project alignment.
Restoration status: Preliminary Design
Pre-restoration alignment: NAIP Aerial Photo 2012
Post-restoration alignment: 50% Design Plans (12-05-08)

feet
0 325 650
N

Project	Length (m)
Upper Truckee River Sunset Reach 5	
Pre-Restoration	2261.7
Bend	1165.8
Straight	1096.0
Post-Restoration	2261.5
Bend	1137.1
Straight	1124.4

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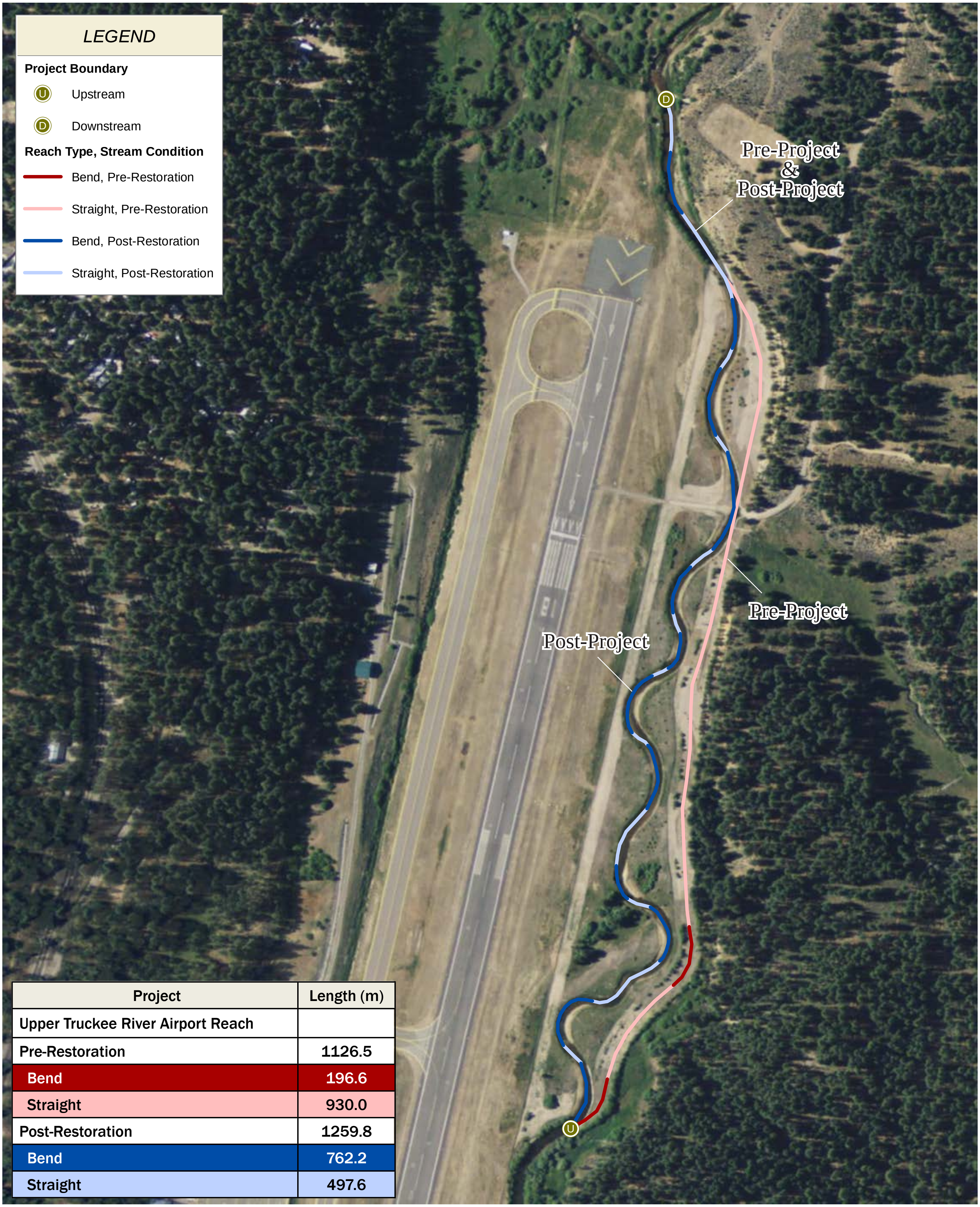
FIGURE 7: Upper Truckee River Sunset Reach 5 restoration project alignment.
Restoration status: In progress, expected completion 2016.
Pre-restoration alignment: NAIP Aerial Photo 2012
Post-restoration alignment: 90% Design Plans (04-04-11)



Project	Length (m)
Upper Truckee River Airport Reach	
Pre-Restoration	1126.5
Bend	196.6
Straight	930.0
Post-Restoration	1259.8
Bend	762.2
Straight	497.6

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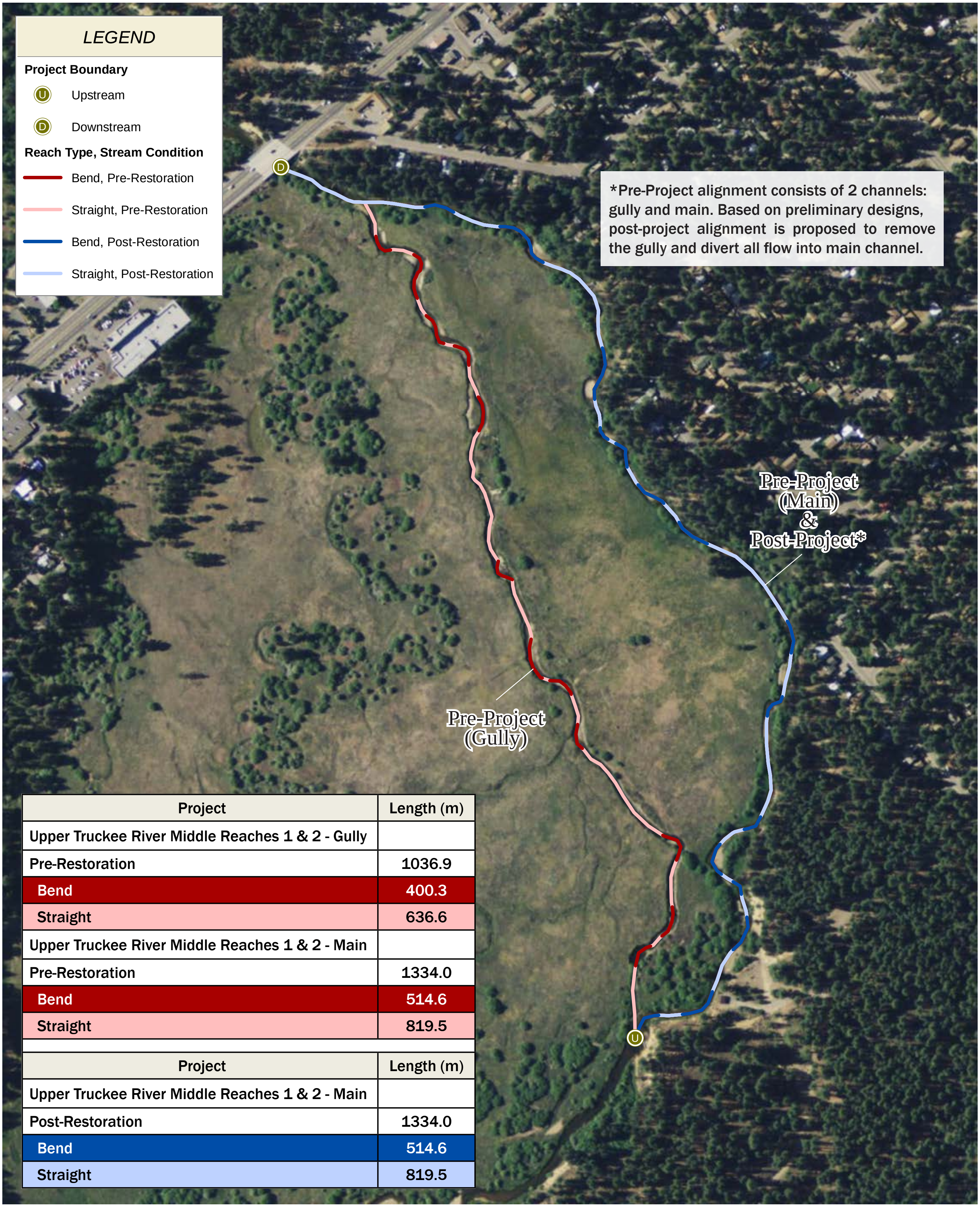
FIGURE 8: Upper Truckee River Airport Reach restoration project alignment.
Restoration status: Completed 2011
Pre-restoration alignment: IKONOS 2002
Post-restoration alignment: NAIP Aerial Photo 2012

feet
0 300 600
N



Project	Length (m)
Upper Truckee River Middle Reaches 1 & 2 - Gully	
Pre-Restoration	1036.9
Bend	400.3
Straight	636.6
Upper Truckee River Middle Reaches 1 & 2 - Main	
Pre-Restoration	1334.0
Bend	514.6
Straight	819.5

Project	Length (m)
Upper Truckee River Middle Reaches 1 & 2 - Main	
Post-Restoration	1334.0
Bend	514.6
Straight	819.5

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FIGURE 9: Upper Truckee River Middle Reaches 1 & 2 restoration project alignment.
Restoration status: Preliminary Design
Pre-restoration alignment: NAIP Aerial Photo 2012
Post-restoration alignment: NAIP Aerial Photo 2012

feet
0 300 600
N

3.3.3 CHANNEL MORPHOLOGY

A series of morphologic attributes were generated using field surveys for existing conditions and available datasets for either pre-restoration or the planned post-restoration conditions.

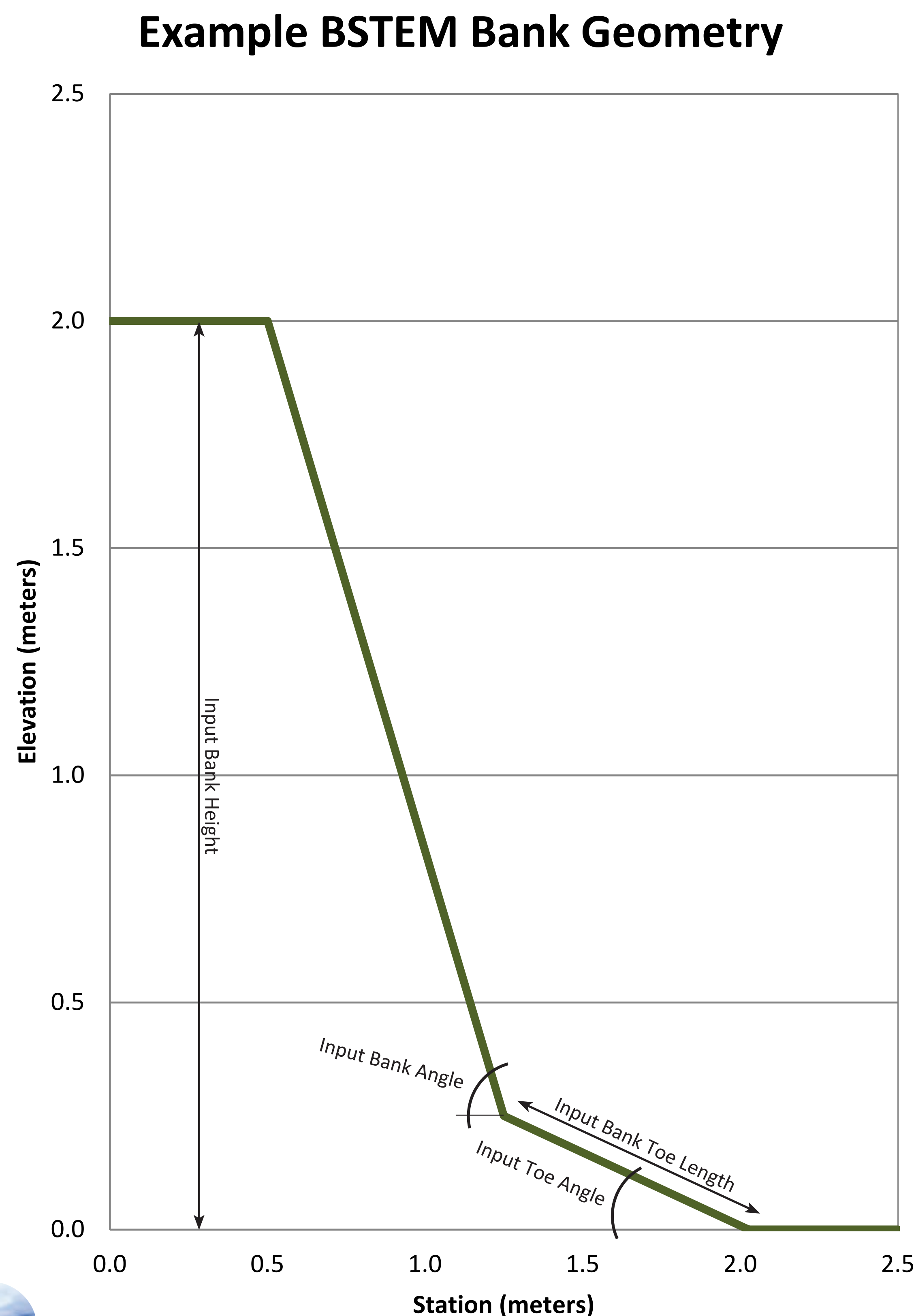
3.3.3.1 Representative Cross Section Selection

Dynamic BSTEM modeling for SLRT requires the user to select a single representative cross section for each BSTEM scenario to estimate bank erosion rates. Representative cross sections are required for both the straight and bend reaches at each site and each condition (e.g., pre- or post-project). All available cross section data was graphed and analyzed to objectively select the most appropriate cross section for each site/condition. Each cross section was summarized by a series of key parameters to quantify the average bank height, bank angle, toe length, toe angle, top width and bottom width for each site in each condition. The averages were then used to select the most representative cross section for each scenario.

3.3.3.2 Bank and Toe Geometry

Bank and toe geometry serve as the foundation for erosion modeling via BSTEM Dynamic. For straight reaches, parameters for right and left banks are averaged to generate geometry values based on the assumption that both banks experience equivalent amounts of shear stress and, on an average annual basis, contribute equally to stream channel erosion. SLRT accounts for this sediment contribution from both banks in straight reaches by doubling the length of unit erosion rates. For bend reaches, only the outer bank is used to generate geometry values based on the assumption that the outside bank is the source of the majority of erosion, while the inside bend experiences sediment deposition. In some cases, a stream reach contained a smaller active channel with portions of a small inset floodplain. When defining bank heights and channel geometry for SLRT, the morphology of larger channel was modeled to better represent site conditions during moderate and high flow conditions, rather than the more frequent, lower intensity flows.

Figure 10 illustrates the bank height, bank angle, toe length and toe angle features extracted from the representative cross sections. Bank height consists of the total bank and toe elevation change. Bank angle consists of the generalized angle between top of the toe and the top of bank. Toe length refers to the slope distance between the top and bottom of the toe. The bottom of the toe was selected from the representative cross section as the closest point to the top of the toe that is representative of the bottom of the channel elevation. The bank and toe geometry values were extracted from representative cross sections for each project and compiled in Table 6.



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BSTEM BANK GEOMETRY

FIGURE 10

Table 6. Bank and toe geometry calculated from representative cross section data for input into SLRT. Grey is used to indicate the condition of the project at time of this research (2013).

Pre-Restoration						
Project Name	**Feature**	**XS Year**	**Average Bank Height (m)**	**Average Bank Angle (deg)**	**Toe Length (m)**	**Toe Angle (deg)**
Angora SEZ	Straight	2004	1.9	23	0.7	3
Angora SEZ	Bend	2004	2.6	42	1.5	10
Angora Sewerline	Straight	1999	0.6	62	0.7	16
Angora Sewerline	Bend	1999	1.0	45	0.7	20
UTR Golf Course Reach	Straight	2006/2013	1.9	23	3.0	4
UTR Golf Course Reach	Bend	2004/2013	2.8	50	1.0	39
UTR Sunset Reach 6	Straight	2005/2013	1.1	21	0.3	37
UTR Sunset Reach 6	Bend	2005/2013	1.0	51	0.9	16
UTR Sunset Reach 5	Straight	2005/2013	1.5	6	1.6	7
UTR Sunset Reach 5	Bend	2005/2013	1.5	72	1.6	7
UTR Airport Reach	Straight	2004	2.0	22	1.0	1
UTR Airport Reach	Bend	2004	1.8	22	1.0	1
UTR Middle Reaches 1 & 2	Straight-Main	2011/2013	1.4	53	1.0	7
UTR Middle Reaches 1 & 2	Bend-Main	2011/2013	1.2	48	0.8	10
UTR Middle Reaches 1 & 2	Straight-Gully	2011/2013	1.8	75	2.1	14
UTR Middle Reaches 1 & 2	Bend-Gully	2011/2013	2.7	75	2.3	15
Post-Restoration						
Project Name	**Location**	**Year**	**Average Bank Height (m)**	**Average Bank Angle (deg)**	**Toe Length (m)**	**Toe Angle (deg)**
Angora SEZ	Straight	2013	0.7	61	0.2	3
Angora SEZ	Bend	2013	0.8	81	0.3	9
Angora Sewerline	Straight	2013	0.5	70	0.3	15
Angora Sewerline	Bend	2013	1.0	66	0.2	2
UTR Golf Course Reach	Straight	Design XS	0.6	31	2.3	6
UTR Golf Course Reach	Bend	Design XS	1.3	18	0.9	6
UTR Sunset Reach 6	Straight	Plans	1.2	28	1.0	0
UTR Sunset Reach 6	Bend	Plans	1.2	25	1.0	0
UTR Sunset Reach 5	Straight	Plans	1.2	66	1.0	2
UTR Sunset Reach 5	Bend	Plans	0.9	23	1.2	7
UTR Airport Reach	Straight	2012/2013	1.3	30	2.2	3
UTR Airport Reach	Bend	2012/2013	1.7	19	1.0	2
UTR Middle Reaches 1 & 2	Straight-Main	2011/2013	1.4	53	1.0	7
UTR Middle Reaches 1 & 2	Bend-Main	2011/2013	1.2	48	0.8	10

3.3.4 MANNING'S N

BSTEM Dynamic modeling erosion estimates are highly sensitive the Manning's n values. In general, it is assumed an n value of 0.03 is representative of sandy, highly exposed banks that lack substantial bank vegetation, such as the sites at the lower elevations within the Upper Truckee River where these projects are located. If no manual bank hardening existed, 0.03 was used for both pre-project and post-project conditions (Table 7). Sites/conditions where bank hardening using rock, logs, or rip rap was installed were assigned n values of 0.07, consistent with available HEC-RAS models where bank protection was present (e.g., Angora Sewerline Design Grade HEC-RAS model; GMA 2004 and UTR Airport Reach pre project).

Table 7. Manning's n values for pre- and post-project conditions. Grey is used to indicate the condition the project was in at time of this research (2013).

	Manning's n	
Project Name	**Pre-Project**	**Post-Project**
Angora SEZ	0.03	0.07
Angora Sewerline	0.03	0.03
UTR Golf Course Reach	0.03	0.03
UTR Sunset Reach 6	0.03	0.03
UTR Sunset Reach 5	0.03	0.03
UTR Airport Reach	0.07	0.03
UTR Middle Reaches 1 & 2	0.03	0.03

3.3.5 CHANNEL CAPACITY

Channel capacity is defined as the stage at which bank elevation is exceeded and the floodplain becomes inundated. Channel capacity can be estimated using the Manning's equation or a HEC-RAS model of the site. Fortunately for this research, 5 out of the 7 selected sites have existing HEC-RAS models developed during the restoration design. If the HEC-RAS model was available, a range of flows were modeled for both pre- and post-restoration configurations to identify the discharge that resulted in a stage that best matched the bank elevation at the collection of cross sections within the project area. These flows were averaged across cross sections to yield a channel capacity for pre- and post-project conditions.

When a HEC-RAS model was not available, the channel capacity was estimated using Manning's equation on a series of representative cross sections from straight reaches at the tops of riffles. To verify this method, 2NDNATURE values were compared to the channel capacity estimates for a collection of sites/conditions where HEC-RAS was available. Table 8 summarizes the channel capacity calculation results from this comparative analysis and their respective locations along the channel reach. The average relative difference for cross sections located on pools was 26%, while riffle/runs averaged 1% difference between HEC-RAS and Manning's equation. The SLRTv2 User Guidance (Appendix A) clarifies that channel capacity calculations using the Manning's equation be conducted only within riffle/run reaches, as the discharge that exceeds channel capacity is controlled by the shallower reaches and not the pools.

Table 8. Q_{cc} comparative analysis between HEC-RAS and cross section analysis using Manning's equation.

Project Name	Condition	XS ID	Manning's Equation n Q_{cc}	HEC-RAS WSE Q_{cc}	% Difference	Reach type
Airport Reach Modeling (2004)						
Airport Reach	Pre-Project	8+605	793	800	1%	Run
Airport Reach	Pre-Project	9+280	945	950	1%	Run
Airport Reach	Pre-Project	10+585	1100	1100	0%	Run
Airport Reach	Pre-Project	11+535	1056	1100	4%	Run
Sunset Alternative Design Modeling (2004)						
Airport Reach	Pre-Project	13+323	1338	1350	1%	Riffle
Sunset Reach 5	Pre-Project	17+687	486	500	3%	Riffle
Sunset Reach 5	Pre-Project	20+091	688	700	2%	Riffle
Sunset Reach 6	Pre-Project	22+218	492	500	2%	Riffle
Sunset Reach 6	Pre-Project	22+991	794	800	1%	Riffle
Sunset Reach 6	Pre-Project	23+442	988	1100	11%	Pool
Middle Reaches 1&2	Pre-Project	4+920	971	1200	24%	Pool
Airport Reach	Pre-Project	11+910	859	1000	16%	Pool
Airport Reach	Pre-Project	12+345	1106	1200	9%	Pool
Airport Reach	Pre-Project	12+615	2523	1500	-41%	Pool

Table 9 presents the channel capacity estimates used for each project and condition. Table 4 indicates the projects and conditions for which a HEC-RAS model was available. All other project Q_{cc} estimates were generated using the Manning equation as outlined in the SLRTv2 user guidance (Appendix A). The calculated Q_{cc} estimates were then provided to the project managers for review and feedback. The Q_{cc} for UTR Sunset Reach 5, UTR Airport Reach, and UTR Middle Reaches 1&2 were adjusted slightly by the California Tahoe Conservancy based on familiarity with specific projects.

Table 9. Channel capacity estimates for pre- and post-project conditions. Grey is used to indicate the condition the project was in at time of this research (2013).

Project Name	Pre Q_{cc} (cfs)	Post Q_{cc} (cfs)
Angora SEZ	1500	15
Angora Sewerline	25	15
UTR Golf Course Reach	1900	550
UTR Sunset Reach 6	700	450
UTR Sunset Reach 5	900	370
UTR Airport Reach	1200	590
UTR Middle Reaches 1 & 2-Main	500	500
UTR Middle Reaches 1 & 2-Gully	1200	- -

3.3.6 FLOODPLAIN CONDITION

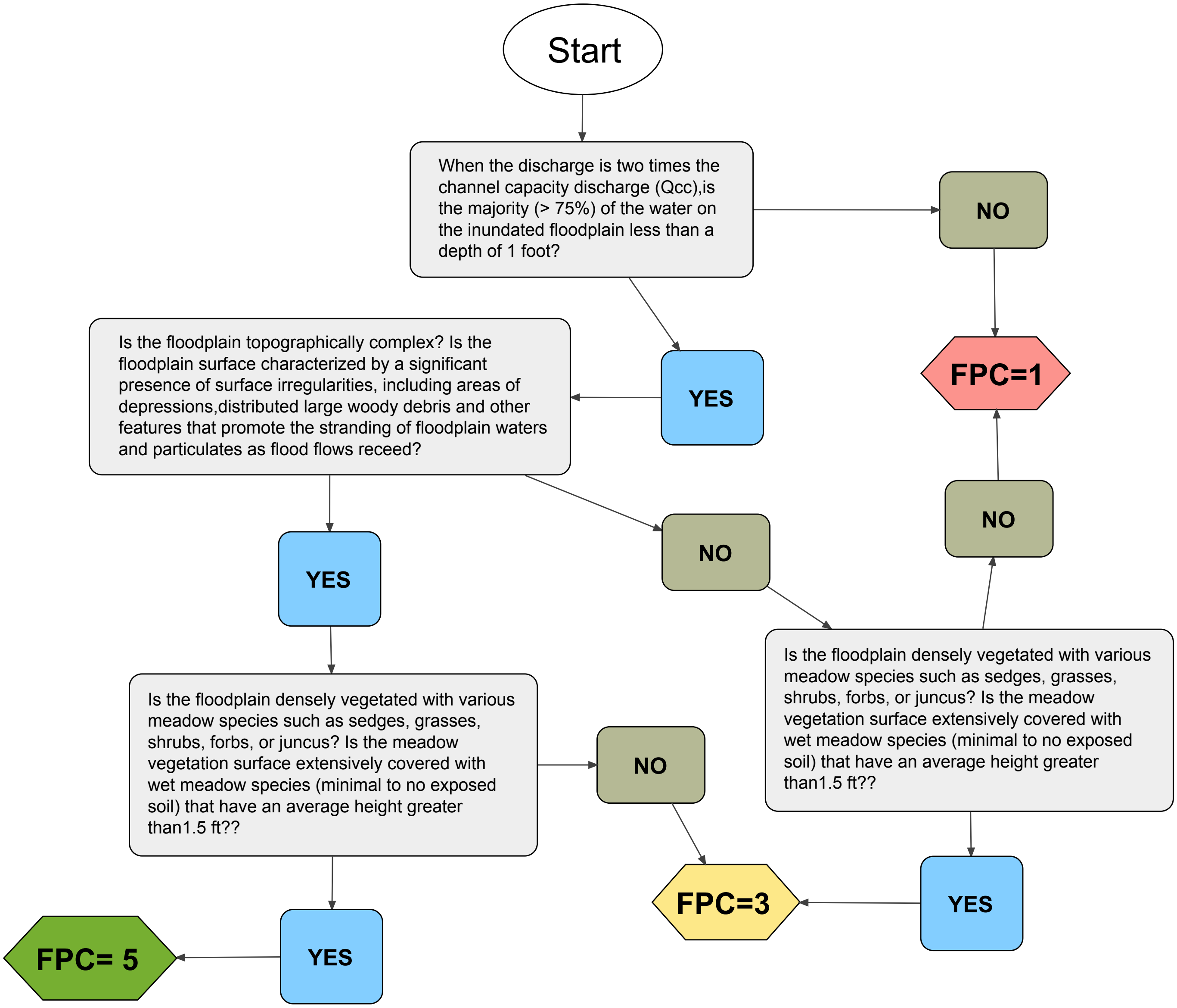
Floodplain condition (FPC) for each site/condition was determined based on assessing 3 specific characteristics of the floodplain dynamics (stage to discharge relationship, topographic complexity, and vegetation density and distribution) that contribute to fine sediment retention during overbank events.

The decision tree in Figure 11 presents the process to evaluate floodplain condition by answering series of 'Yes' or 'No' questions that yield an FPC score of 1, 3, or 5, with 5 representing optimal condition and 1 representing the worst condition. The stage to discharge relationship as flows exceed channel capacity and inundate the adjacent floodplain is critical to ensure effective shallow flow depths are sustained for a larger range of discharge conditions. An inset or laterally constrained floodplain results in much poorer retention of FSP on the floodplain. Topographic complexity of the floodplain in the form of surface undulations, woody debris, woody vegetation and other structures promotes flow deflection, ponding and deposition on the floodplain. Greater vegetation density and distribution on the floodplain, like a healthy meadow complex, provides a high density of surfaces where FSP entrained in flood flow can adhere and be removed from the water column. Figure 12 presents a series of photos that illustrate topographic complexity and vegetation density on the floodplain.

2NDNATURE conducted floodplain assessments at each of the 7 UTR restoration sites in its current condition as of August 2013. For projects where restoration has already been completed, aerials and historical ground photos were examined to evaluate pre-project floodplain condition and assign a score. At sites where the project has not yet begun, restoration design plans as well as communication with project managers were used to determine the desired long-term characteristics of the restored floodplain. Table 10 below summarizes the pre- and post-project floodplain condition scores for each project.

Table 10. Floodplain condition scores for restoration projects. Grey is used to indicate the condition the project was in at time of this research (2013).

Project Name	Pre FPC	Post FPC
Angora SEZ	1	5
Angora Sewerline	3	5
UTR Golf Course Reach	3	5
UTR Sunset Reach 6	3	5
UTR Sunset Reach 5	3	5
UTR Airport Reach	1	3
UTR Middle Reaches 1 & 2	3	5



The floodplain condition (FPC) for each site assesses 3 specific characteristics of the floodplain dynamics that contribute to fine sediment retention during overbank events. The decision tree above asks a series of 'Yes' or 'No' questions that will produce a FPC score of 1, 3, or 5, with 5 representing optimal conditions and 1 representing the worst conditions.

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2NDNATURE LLC
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TOPOGRAPHIC COMPLEXITY AND VEGETATION STRUCTURE

FIGURE 12

4 SLRT RESULTS

Each of the restoration projects were modeled using SLRTv2 to generate a series of metrics and quantify the effectiveness of the restoration efforts, including an estimate of the average annual FSP load reduced. SLRT calculations are automated in a customized MS Excel spreadsheet. The SLRT inputs and results are summarized in a series of 5 standardized tabular and graphical outputs for the 7 Upper Truckee River Watershed projects, and are included in Appendix B. The technical overview of the SLRT algorithms and calculations are detailed in Chapter 3 of 2NDNATURE 2013. Further improvements were made to the SLRTv2 MS Excel spreadsheet to allow for additional inputs and to enhance the clarity of the results (Appendix A). The only computational change to SLRTv2 is an adjustment to the percentage of eroded bank material composed of FSP (< 16 µm) from the use of < 62µm in SLRTv1. Each of these changes along with information needed to generate the necessary input data are discussed further in the SLRTv2 User Guidance (Appendix A).

4.1 COMPARATIVE SLRT RESULTS

The implementation and comparison of SLRT results from a series of stream reaches and restoration efforts within the same watershed provided an invaluable opportunity to calibrate and refine SLRT calculations and improve the User Guidance. Below are a series of tabular comparisons of the SLRT inputs and outputs by project and condition. For comparative purposes, we have also included the SLRTv2 results from the Trout Creek Upper Reach analyses that were updated from the SLRTv1 results from 2NDNATURE 2013.All SLRT results were QA/QC'd by comparing outputs across sites and conditions, or evaluating outputs relative to other sources of comparable values.

4.1.1 CATCHMENT INPUTS

SLRT is used to estimate the average annual incoming hydrology and pollutant load delivered to the SEZ. SLRT uses the same hydrology and pollutant loading for both the pre- and post-restoration conditions to ensure the estimated load reductions are attributable to geomorphologic changes at the site and not hydrologic differences. The incoming hydrology and pollutant loading values for each project used by SLRT are summarized and graphed in Appendix B.

A simple comparison across all sites is presented in Table 11, which compiles the total average annual FSP load delivered to the upstream boundary of each SEZ as estimated by SLRTv2, with the sites arranged by increasing drainage area. As expected, the annual load delivered to each reach increases with increasing drainage area (see Figure 2 for the location of each of the projects with the Upper Truckee River Watershed). The SLRT estimate of the FSP_{in} (MT/yr) at the site furthest downstream (UTR Middle Reaches 1 & 2) is reasonably comparable to the average annual fine load (< 62 µm) of 1261 MT/yr estimated at the nearby USGS site (#10336610) by Simon et al. (2003). SLRT estimates the average annual FSP (< 16µm) load (MT/yr) (which is some fraction of the clay/silt loading) using the limited available FSP concentration datasets from USGS LTIMP sites (see Chapter 3 of 2NDNATURE 2013). Given that the larger size fractions (16-62 µm) are much denser than small particles, and the differences in the data sources and techniques used to estimate the average annual loads, we expect the SLRT FSP_{in} loading estimates to be reasonable.

Table 11. Drainage area and average annual FSP load delivered to the upstream boundary of each SEZ.

Upstream Boundary of	FSP_{in} (MT/yr)	Drainage Area (sq mi)
Angora SEZ	9.1	2.6
Angora Sewerline	17.5	4.4
UTR Golf Course Reach	389.3	42.4
UTR Sunset Reach 6	481.1	50.3
UTR Sunset Reach 5	493.0	51.3
UTR Airport Reach	504.9	52.3
UTR Middle Reaches 1 & 2	521.8	53.7
Trout Creek Upper Reach	*141.5*	*23.7*

4.1.2 CHANGES IN FLOODPLAIN INTERACTIONS AND FSP RETENTION

SLRT computes the frequency and duration of overbank flow conditions for both pre- and post-restoration configurations using the site-specific incoming hydrology along with pollutant loads and graphical summaries for each project. Site-specific results are presented in Appendix B in the page titled "RFP FSP" for each project. Figure 13 compiles the pre- and post-restoration estimates of the average annual FSP load delivered to (Figure 13A) and retained on (Figure 13B) each of the floodplains, as well as the relative changes as a result of restoration. In all instances, the restoration actions result in a significant increase in the frequency and duration of overbank flow, and thus, a corresponding increase in the annual load of FSP (and other pollutants) delivered to the adjacent floodplain. Cumulatively, the restoration efforts on the UTR are estimated to increase the average annual load of FSP delivered onto floodplains by 227.6 MT/yr.

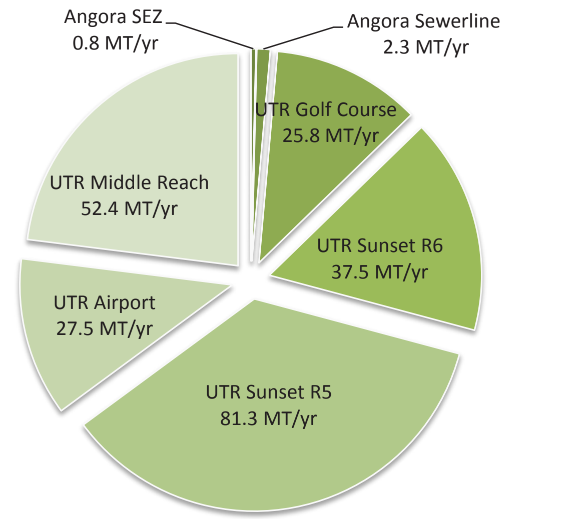
SLRT uses a series of algorithms, based on the floodplain condition (FPC) and the relative magnitude and frequency of the flood flows, to estimate the fraction of the mass of FSP delivered to the floodplain that is retained. The "RFP FSP" figures in Appendix B display the differences in the pre- and post-FSP retention for the range of flow conditions expected at the site. Figure 13B compiles the RFP_{fsp} for all of the projects and summarizes the distribution of the total estimated annual increase in FSP floodplain retention across the different restoration projects. Cumulatively, if implemented, floodplain retention is estimated to remove 72.5 MT/yr of FSP from the Upper Truckee River Watershed on an average annual basis, or a 296% increase from the pre-restored conditions.

Of the Upper Truckee restoration efforts, the UTR Sunset Reach 5 has the greatest estimated increase in FSP floodplain retention, over 80 MT/yr (or 456% increase), as a result of the significant reduction in the channel capacity of the reach and assumed high quality future floodplain. It is assumed that restoration actions will raise the bed elevation consistently throughout the reach, which will result in a corresponding increase in the surrounding groundwater elevations and adjacent floodplain soil moisture conditions. Given these functional changes, the future restored floodplain condition is anticipated to be optimal (FPC = 5) to retain FSP and other particulate pollutants, due to its un-constrained lateral width, topographic complexity and future vegetation density. The UTR Sunset Reach 5 restoration effort is estimated to remove 26.1 MT/yr of FSP as a result of floodplain retention on an average annual basis. In comparison, the Trout Creek Upper Reach restoration is estimated to have a greater relative increase in FSP floodplain

A. Delivered to Floodplain

	PRE RESTORATION		POST RESTORATION		DFP_{fsp} (MT/yr)	
Project Name	**DFP_{fsp} (MT/yr)**	**Q_{cc} (cfs)**	**DFP_{fsp} (MT/yr)**	**Q_{cc}**	***CHANGE***	***% CHANGE***
Angora SEZ	0.0	1500	0.8	15	0.8	INCREASE
Angora Sewerline	1.9	25	4.3	15	2.3	119%
UTR Golf Course Reach	0.0	1900	25.8	550	25.8	INCREASE
UTR Sunset Reach 6	27.8	700	65.2	450	37.5	135%
UTR Sunset Reach 5	17.8	900	99.2	370	81.3	456%
UTR Airport Reach	16.9	1200	44.4	590	27.5	162%
UTR Middle Reaches 1 & 2-Main	13.3	500	65.7	500	52.4	394%
UTR Middle Reaches 1 & 2-Gully	0.0	1200	-	-	-	-
UTR Total (MT/yr)	***77.8***		***305.4***		***227.6***	293%
Trout Creek Upper	*4.4*	*200*	*34.5*	*88*	*30.0*	*678%*

Pre- and post-restoration estimates of average annual FSP load **delivered** to floodplain (DFP_{fsp}) as well as the channel capacity are displayed for each site.

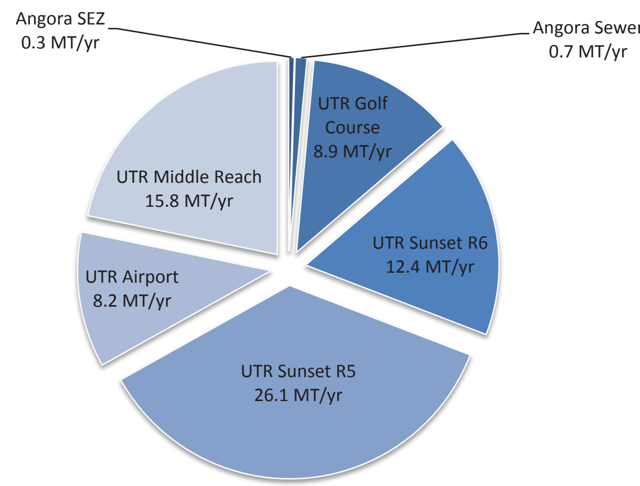


Increases FSP load **delivered** to the floodplain from restoration (DFP_{fsp})

B. Retained on Floodplain

	PRE RESTORATION		POST RESTORATION		RFP_{fsp} (MT/yr)	
Project Name	**RFP_{fsp} (MT/yr)**	**FPC**	**RFP_{fsp} (MT/yr)**	**FPC**	***CHANGE***	***% CHANGE***
Angora SEZ	0.0	1	0.3	5	0.3	INCREASE
Angora Sewerline	0.7	3	1.4	5	0.7	105%
UTR Golf Course Reach	0.0	3	8.9	5	8.9	INCREASE
UTR Sunset Reach 6	8.5	3	20.9	5	12.4	147%
UTR Sunset Reach 5	5.3	3	31.4	5	26.1	492%
UTR Airport Reach	4.7	1	12.9	3	8.2	176%
UTR Middle Reach	5.3	3	21.1	5	15.8	296%
UTR Total (MT/yr)	***24.4***		***96.9***		***72.5***	296%
Trout Creek Upper	1.6	3	12.1	5	10.5	652%

Pre- and post-restoration estimates of annual FSP load retained on floodplain (RFP_{fsp}). The process of determining each floodplain condition is explained in Figure FPC.



Increased FSP load **retained** on the floodplain from restoration (RFP_{fsp})

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COMPARISON OF SLRT FLOODPLAIN RESULTS

FIGURE 13

retention (652%), though a smaller overall load reduction of 10.5 MT/yr of FSP. This smaller absolute load reduction for Trout Creek Upper is due to the fact that FSP_{in} load delivered to UTR Sunset Reach 5 is 3 times more than the FSP_{in} load delivered to the Trout Creek reach (See Table 11).

The Trout Creek Upper Reach (from Pioneer Trail to Cold Creek confluence) restoration was completed in 2001 and has been a model of desired restored channel and floodplain conditions in the Tahoe Basin. Event specific reach scale FSP mass balance research and detailed FSP floodplain sampling have been conducted along this reach. Definitive load reductions were measured were measured along the Trout Creek Upper Reach during the sustained overbank WY11 snow melt event (2NDNATURE 2013). The Trout Creek Upper Reach SLRT DFP_{fsp} and RFP_{fsp} estimates were validated with measured data to the extent possible given the temporal limitations of measured data compared to the need to model average annual load reductions (2NDNATURE 2013).

4.1.3 BANK EROSION AND ASSOCIATED FSP LOADING

SLRT uses BSTEM Dynamic to estimate the volume of sediment generated from the reach on an average annual basis. The average annual volume is estimated by generating unit bank erosion rates in straight and outer bend reaches for a range of annual hydrographs. The unit erosion rates are integrated spatially based on the length of each reach type within the project site. Temporally, a series of annual hydrographs are used to estimate the volume of bank erosion during wet, average and dry years. The results are integrated based on the frequency of occurrence of each of the flow conditions over long time frames. The content of the bank material that is <16µm is used to estimate the FSP load derived from bank erosion from each site on an average annual basis. The "SCE FSP" Figures in Appendix B display the differences in the pre- and post-restoration bank erosion rates for the range of flow conditions expected at the site.

The BSTEM outputs can be used to estimate the average annual bank erosion rate expressed as a volume of sediment lost per km of stream length (m^3/km/yr). These SLRT estimates were then compared to estimates by Simon et al. (2003) generated using repeat cross-section datasets compiled on a series of stream reaches in the Tahoe Basin. Table 12 presents the bank erosion rates generated using the SLRT methods with the estimates from Simon et al. (2003). These comparisons were used to inform refinements of the SLRT User Guidance for BSTEM modeling procedures to ensure bank erosion rate outputs align with comparable estimates generated by different methods. The CA State Parks extensive cross section monitoring program along the UTR Golf Course reach used by Simon et al. (2003) yielded an estimated bank erosion rate of 645 m^3/km/yr, compared to the SLRT pre-restoration estimate of 460 m^3/km/yr. Given the differences in the methods (direct measurements over decade v. modeled values over an 18yr time frame) we believe the SLRT estimates of the bank erosion rates for the UTR Golf Course reach to be reasonable. The relative comparison of the pre-restoration bank erosion rates across each of the restoration sites from highest to lowest per unit length of stream channel follow expectations based on channel morphology and the relative bank erosion hazards. The SLRTv2 MS Excel template now includes the estimate of bank erosion rate (m^3/km/yr) to provide users with a value that can be directly compared to quantified bank erosion rates from available cross section time series datasets. The m^3/km/yr generated by dividing the volume of sediment lost within the reach by the time interval the cross-sections represent normalized per km of channel length. The SLRT user is encouraged to consider their results in the context of the site values provided in Table 12 and can use these results to make informed adjustments to BSTEM Dynamic modeling inputs when necessary. The user guidance (Appendix A) provides further detail on how to evaluate and adjust BSTEM estimates.

Table 12. Bank erosion rate (total sediment volume per kilometer of stream channel per year) estimates are compared between SLRT and Simon et al. (2003).

	Bank Erosion Rate (m^3/km/yr)		
	SLRT ESTIMATES		Simon et al. (2003)
Project Name	Pre-Rest	Post-Rest	
UTR Golf Course Reach	459.8	52.1	645
UTR Middle Reaches 1 & 2-Gully	215.0	-	*n/a*
UTR Middle Reaches 1 & 2-Main	22.1	28.5	*n/a*
UTR Sunset Reach 5	61.0	9.4	*n/a*
Angora SEZ	18.6	1.0	*n/a*
Trout Creek Upper Reach	14.9	3.8	*n/a*
Angora Sewerline	3.6	1.2	*n/a*
UTR Sunset Reach 6	1.4	0.0	*n/a*
UTR Airport Reach	0.0	12.2	*n/a*
Blackwood	*n/a*	*n/a*	217
General	*n/a*	*n/a*	14.3
Logan House	*n/a*	*n/a*	-
Edgewood	*n/a*	*n/a*	-

The bank erosion rates are used to estimate the average annual load of FSP generated from bank erosion within the project reach for both pre- and post-restored conditions (Table 13) and the change as a result of restoration. These FSP volumes are a very small fraction of the total sediment volume eroded, because in pre-historic Tahoe Basin floodplain deposits the percent of the bank material < 16μm is very low (<3%). As expected, the highly incised and eroding channel through the UTR Golf Course Reach is predicted to have the highest FSP load reduction if the reach morphology is restored per the design configuration provided by CA State Parks. The UTR Middle Reach restoration intends to decommission the entrenched and actively eroding Gully channel to the west, providing the next greatest potential reduction in contribution of FSP loads as a result of restoration. Sunset Reach 5 restoration is expected to have some (3.5 MT/yr) bank erosion FSP load reductions as well. All other restoration efforts are estimated to have a < 1 MT/yr FSP load reduction benefit as a result of reduced bank erosion. While the reduction of 1 MT/yr of FSP is not a trivial contribution toward reducing FSP loads to Lake Tahoe, the cost of these large stream restoration efforts may not be justified if they were conducted with the single goal of reducing FSP from bank erosion. Supporting the Lake Tahoe TMDL evaluations of the pollutant load reduction opportunities associated with controlling FSP contributions from stream bank erosion (LRWQCB and NDEP 2008; 2010), the erosion of native floodplain deposits is not a primary source of FSP, and thus reducing FSP loads from Lake Tahoe stream bank erosion, by itself, is not a priority FSP pollutant control strategy in the Tahoe Basin.

Table 13. Annual bank erosion rate predicted change based on Dynamic BSTEM models. Grey cells indicate project has been implemented prior to 2013.

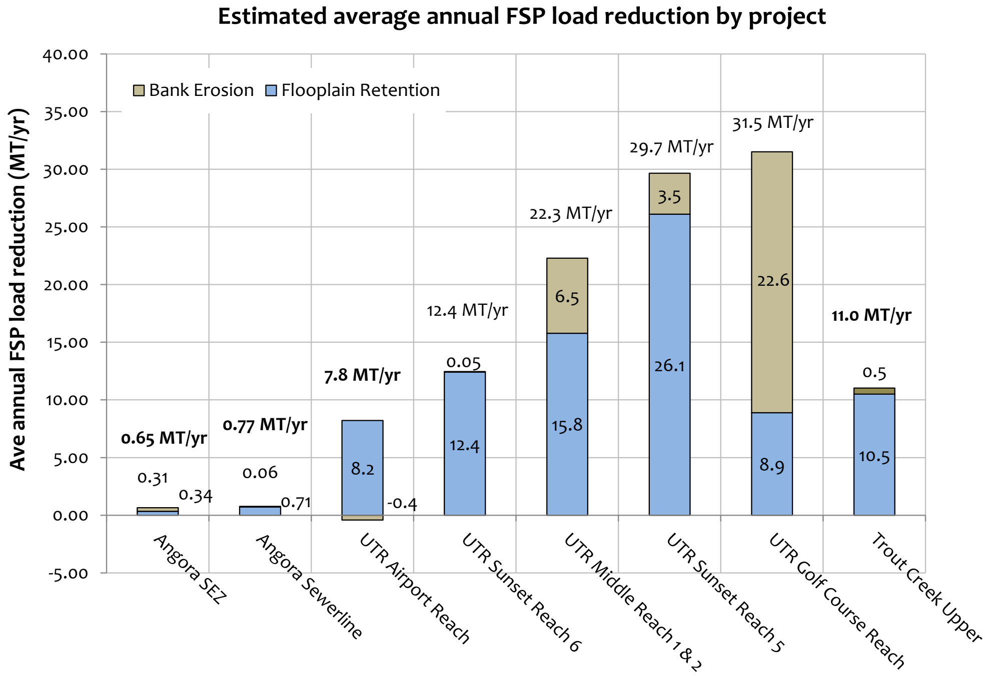
	SCE_{fsp} (MT/yr) (< 16µm)			
Project Name	**Pre-Rest**	**Post-Rest**	***Change***	***% Change***
Angora SEZ	0.33	0.02	-0.31	-95%
Angora Sewerline	0.09	0.03	-0.06	-68%
UTR Golf Course Reach	25.5	2.9	-22.6	-89%
UTR Sunset Reach 6	0.05	0.00	-0.05	-100%
UTR Sunset Reach 5	4.19	0.64	-3.5	-85%
UTR Airport Reach	0.00	0.42	0.4	INCREASE
UTR Middle Reaches (Combined)	7.66	1.16	-6.5	-85%
UTR Middle Reaches 1 & 2-Main	0.90	1.16	-	-
UTR Middle Reaches 1 & 2-Gully	6.76	-	-	-
UTR Total (MT/yr)	**37.8**	**5.2**	**32.7**	-86%
Trout Creek Upper Reach	*0.7*	*0.2*	*-0.5*	*-74%*

4.2 FSP LOAD REDUCTIONS AND COST EFFECTIVENESS

The estimated average annual FSP load reduction is calculated as the difference between the FSP load at the downstream boundary of the subject reach estimated for pre-restoration minus post-restoration. The load reduction achieved by each project is the sum of the FSP load reduction associated with increased floodplain retention and the load reduced with a decrease in the amount of FSP inputs to the system from bank erosion. Figure 14 presents the total estimated average annual FSP load reduction by project displaying the relative contribution of floodplain retention and bank erosion. Cumulatively, the estimated potential FSP load reduction is 105 MT/yr should all 7 of these restoration efforts be implemented within the Upper Truckee River watershed as planned, or nearly a 20% reduction in the annual FSP load of the Upper Truckee River Watershed (assumed to be 521.8 MT/yr, see Table 11). Over 69% of this cumulative FSP load reduction estimate on the UTR is achieved by floodplain retention, which likely includes a significant contribution of urban-derived FSP (see below). Note that Trout Creek Upper Reach estimates are provided for context, but not included in UTR summary estimates. In order to provide a more direct comparison, Table 14 presents the FSP load reduction per km of restored channel length.

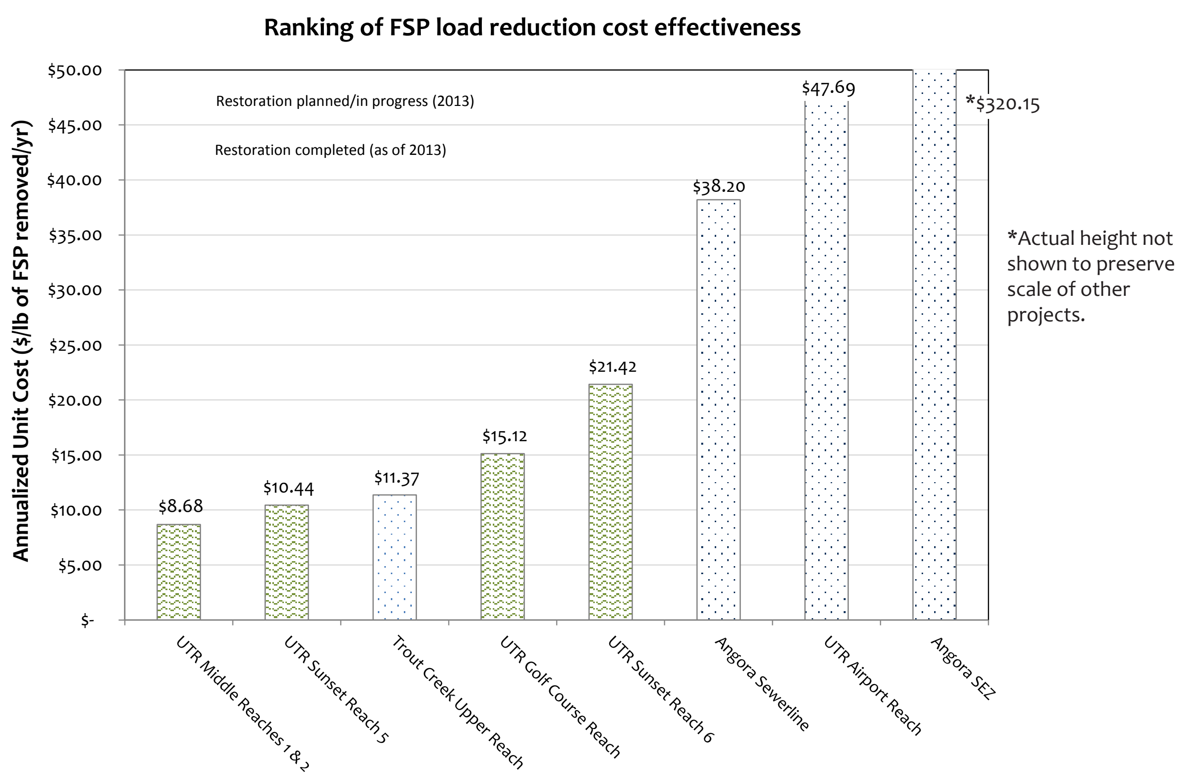
At the time of this analysis, Angora SEZ, Angora Sewerline and the UTR Airport Reach have been fully implemented, providing an estimated 9.2 MT/yr average annual FSP load reduction to date. It must be noted that while the Angora projects have been in ground for years and the post-restoration conditions modeled were observed in the field, the UTR Airport Reach restoration was completed in 2010 and is still in the transitional period. It is recommended that a project site is re-evaluated 8-10 years post-restoration to validate the SLRT inputs. This will allow time for the site to equilibrate to its post-restoration condition and for the appropriate adaptive management actions to be taken, as necessary.

A.



A. SLRTv2 estimates of the average annual FSP load reduction provided, and **B.** Comparison of the annualized unit cost to remove a pound of FSP by project. To date, the 4 completed projects provide an estimated FSP load reduction of 20.2 MT/yr, but should all 8 of these projects be fully implemented, it is the potential FSP load reduction of 116 MT/yr to Lake Tahoe. The planned restoration on the UTR Middle Reach is estimated to be the most cost-effective with respect to water quality improvements. UTR Golf Course Reach and UTR Sunset Reach 5 are the next most cost-effective projects.

B.



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SLRT LOAD REDUCTION AND COST EFFECTIVENESS COMPARISONS

FIGURE 14

Table 14. Annual FSP load reduction per kilometer of restored channel length. Grey cells indicate project has been implemented prior to 2013.

Project Name	FSP Load Reduction (MT/yr/km)
UTR Middle Reach	16.7
UTR Golf Course Reach	14.7
UTR Sunset Reach 5	13.1
UTR Sunset Reach 6	8.5
UTR Airport Reach	6.2
Angora SEZ	1.2
Angora Sewerline	0.7
UTR Average	***8.7***
Trout Creek Upper Reach	6.0

The cost estimates provided by the project managers (see Table 3) and the average annual FSP load reduction estimates (see Figure 14A) were used to calculate the cost-effectiveness of each project relative to the water quality benefit expressed as the $ per lb of FSP reduced per year. In order to make the estimates directly comparable to best available annualized unit cost estimates of urban load reduction opportunities, annualized adaptive management costs of 0.5% per year of implementation costs over a 10yr period were incorporated. While we estimated relatively high adaptive management costs per project, it is critical to have adaptive management resources available when necessary to address a past restoration effort in need of modification to ensure the expected benefit of the restoration effort and the estimated annual load FSP reductions estimated herein are maintained year after year. The tabular calculations are provided in Table 15 and the relative cost effectiveness by project is presented graphically in Figure 14 B. However, these comparisons provide another piece of information for agencies and proponents to consider regarding the planned restoration configurations that have not yet been fully designed or implemented.

Table 15. Estimated annual cost to remove 1lb of FSP ($/lb of FSP removed/yr).

Project Name	Estimated Restoration Cost (USD$)	0.5% Annual Adaptive Management	Annual Cost ($/yr) (10 yr period)	FSP Load Reduced (MT/yr)	Annualized Unit Cost ($/lb of FSP removed/yr)
UTR Middle Reaches 1&2	$4,060,000	$20,300	$ 426,300	22.3	$ 8.68
UTR Sunset Reach 5	$6,500,000	$32,500	$ 682,500	29.7	$ 10.44
Trout Creek Upper Reach*	$2,630,000	$13,150	$276,150	11.0	$ 11.37
UTR Golf Course Reach	$10,000,000	$50,000	$ 1,050,000	31.5	$ 15.12
UTR Sunset Reach 6	$5,600,000	$28,000	$ 588,000	12.4	$ 21.42
Angora Sewerline	$620,000	$3,100	$ 65,100	0.77	$ 38.20
UTR Airport Reach	$7,800,000	$39,000	$819,000	7.8	$ 47.69
Angora SEZ	$4,400,000	$22,000	$462,000	0.65	$ 320.15

**Trout Creek Restoration was completed in 2001 for an estimated cost of $2,000,000 (see Table 3). These costs were adjusted for inflation to represent 2014 $US dollars (a cumulative inflation rate of 32% using CPI estimates.)*

4.3 URBAN DERIVED FSP LOAD REDUCTIONS

One critical information gap necessary to better align SLRT estimates with the urban load reduction accounting methods supporting the Lake Tahoe TMDL is to provide a reasonable estimate of the urban derived FSP load reductions achieved as a result of SEZ restoration actions. Below we provide a relatively simple estimation approach to isolate the fraction of the FSP average annual load reductions that may have been derived from urban lands within the contributing catchments. The approach was implemented using the following assumptions:

- Any urban derived load reductions are only achieved as a result of increased floodplain inundation and FSP retention.
- FSP load reductions achieved from reduced bank erosion are not urban derived pollutants.
- The Lake Tahoe TMDL estimates 72% of the average annual FSP load in Tahoe Basin runoff is generated from urban lands that comprise 10% of the land area. This relative contribution suggest than a unit area urban surface contributes 24 times more FSP mass than the same area of non-urban land. The assumption allows an estimate of the FSP load reduction derived from urban sources, but assumes 100% hydrologic connectivity of these pollutants to UTR.
- The current Road Shoulder Condition GIS Layer available at (http://www.tiims.org/TIIMS-Sub-Sites/PLRM/docs-downloads.aspx) can be used to estimate the directly connected impervious area (DCIA) for each catchment. This % DCIA is a reasonable estimate of the average annual hydrologic connectivity of the urban areas within each projects contributing catchment.

The assumptions above were used to estimate the fraction of the total average annual FSP load reductions that are assumed to be of urban derivation, including a simple estimate of hydrologic connectivity. It must be noted that the simple land use loading scaling is overly simplified and lacks site specific FSP loading and transport information that could be generated in the future. More rigorous GIS and PLRM loading analyses could be done to better estimate the FSP average annual loads derived from urban lands and contributed to each subject SEZ modeled in SLRT, but both the determination and implementation of a more rigorous approach was outside the scope of this effort. The estimates of the urban derived FSP loads contributed to and reduced as a result of effective and sustained SEZ restoration can certainly be improved if desired.

Given the above caveats, Table 16 summarizes the urban area contribution within each catchment, the total FSP load reduction from increased floodplain retention (ΔRFP_{fsp}), the estimated fraction of total FSP load reduction that is estimated from urban origin load reduction estimate (MT/yr), and the annualized unit costs to achieve these urban load reductions, rounded the nearest dollar. Table 17 presents the comparable annualized unit cost estimates for a series of urban water quality improvement strategies developed for Placer County to inform their TMDL stormwater load reduction strategy in 2011 (2NDNATURE and NHC 2011).

Table 16. Estimated annual cost to remove 1lb of urban derived FSP ($/lb of urban FSP removed/yr).

Project Name	Catchment Area (sq mi)	%Urban	%DCIA	ΔRFP_{fsp} (MT/yr)	Urban derived Δ RFP_{fsp} (MT/yr)	Annualized Unit Cost ($/lb of Urban FSP removed/yr)
UTR Middle Reach	53.7	7.6%	48%	15.8	4.97	$39.00
UTR Sunset Reach 5	51.3	6.3%	44%	26.1	7.07	$44.00
Trout Creek Upper Reach	23.7	2.3%	65%	10.5	2.47	$51.00
UTR Sunset Reach 6	50.3	6.1%	43%	12.4	3.22	$83.00
Angora Sewerline	4.4	6.4%	70%	0.7	0.31	$95.00
UTR Airport	52.3	6.9%	48%	8.2	2.50	$148.00
UTR Golf Course	42.4	3.7%	34%	8.9	1.44	$330.00
Angora SEZ	2.6	3.0%	70%	0.3	0.10	$2,047.00

Table 17. Annualized unit cost estimates for a series of urban water quality improvement strategies developed for Placer County ($/lb of FSP removed/yr). From Table ES.3 in 2NDNATURE and NHC (2011).

	Annualized Unit Cost ($/lb of FSP removed/yr)	
Urban Strategy	Low Estimate	High Estimate
Water quality minded road operation improvements	$ 3.50	$ 4.25
Increased implementation of private parcel BMPs (stormwater volume reductions)	$ 20.00	$ 41.00
Water quality improvement projects (WQIP)	$ 70.00	$ 88.00

Using these methods, three to four of the projects in Table 16 are estimated to be more cost effective than typical urban water quality improvement projects. Urban capital improvement projects are costly and require significant regular maintenance to ensure water quality benefits are sustained over time. Comparisons of the timing of "stormwater treatment" opportunities and the typical volumes of water that can "treated" by urban dry basins verses SEZ meadows vary dramatically and should be considered in more detail to better understand FSP load reduction opportunities of treatment processes. While stream restoration efforts also require significant resources to implement, these annualized cost estimates suggest they can provide relatively cost-effective water quality benefits, with potentially minimal long term maintenance costs. A few stream restoration projects have annualized costs estimated comparable to high density implementation and continued maintenance of private parcel BMPs that are implemented and maintained to retain the 20yr 1hr storm on the parcel. But, as expected, improved road maintenance practices is the most cost effective strategy to reduce FSP loads at the source and continued and sustained focus on FSP source control is assumed critical to achieve long term TMDL goals. We believe this analysis provides substantial evidence that effective stream restoration provides both a desired water quality benefit, in addition to the multitude of ecological and recreational benefits achieved.

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5.1.1 DATA REFERENCES

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Sunset Alternative Design Modeling, 04 Dec 09

Angora Sewerline Design Grade HEC-RAS model; GMA 2004

Middle Reach, 08 Sep 04

Angora SEZ Existing Grade 2004

Angora SEZ Design Grade 2004

DESIGN PLANS

Airport Reach: 100%, ENTRIX, 2008

Middle Reaches 1 & 2: 75%, ENTRIX, 2008

Sunset Reach 5: 100% Stream Solutions, 2010

Sunset Reach 6: 75% Stream Solutions, 2008

AERIAL IMAGERY

NAIP Aerial Imagery, Summer 2012

IKONOS Satellite Imagery, 2002

APPENDIX A. SLRTV2 USER GUIDANCE

SLRTv2 User Guidance can be downloaded here: http://www.2ndnaturellc.com/reports/

APPENDIX B. SITE DESCRIPTIONS AND SLRTV2 RESULTS

Angora SEZ Project Summary

Current Conditions: The Angora SEZ restoration was completed in 2006. The project was carried out to restore stream function and improve riparian habitat along 2000 ft segment of Angora Creek. Prior to restoration, this section of creek was channelized and actively eroding. A large headcut with ran through the meadow with bank heights averaging between five and 12 feet which was likely created as a result of nearby urban development. The project intended to create a geomorphically stable with a functioning floodplain.

Restored reach and adjacent floodplain of Angora Creek SEZ above View Circle, looking upstream. 2013.

Upper section of restored reach and adjacent floodplain of Angora Creek SEZ, looking downstream. 2013.

View of incised section of Angora SEZ in pre-restoration condition. Note the poor floodplain conditions. 2004.

Rock grade control structure on restored reach of angora SEZ. 2013.

Plans and Modeling: Pre-restoration channel was rapidly eroding resulting in steep, exposed banks and the incised channel resulted in minimal to no overbank events. Signficant bank protection and grade controls were added to protect against future erosion and incision, represented in the BSTEM modeling by a post-restoration Manning's value of 0.07. The channel capacity at the site was reduced from 1,500 cfs to 15 cfs with minimal change in channel length.

STREAM LOAD REDUCTION TOOL (SLRTv2)

User Inputs

META DATA

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	Angora
REACH NAME	**Angora SEZ**
Date of Estimate	1/7/2014

CATCHMENT CHARACTERISTICS

CATCHMENT TYPE	Non Urban	
REGION	Southshore	
SUB-REGION	Southwest	
CATCHMENT AREA	2.6	
AREA UNITS	Sq-miles	
CATCHMENT % IMPERVIOUS		Urban Only
CATCHMENT LAND USE CONDITION		Urban Only

SEZ ATTRIBUTES

	PRE-RESTORATION		POST-RESTORATION
Channel length (m)	580.6	l_c	526.4
Channel slope (m/m)	0.0133	s	0.0147
Outside BEND length (m)	207.9	l_{ob}	192.9
BEND bank height (m)	2.6	h_{ob}	0.8
BEND bank angle (degrees)	42	a_{ob}	81
BEND toe length (m)	1.5	tl_{ob}	0.3
BEND toe angle (degrees)	10	ta_{ob}	9
STRAIGHT length (m)	372.6	l_{str}	333.4
Bank height of STRAIGHT reaches (m)	1.9	h_{str}	0.7
Bank angle of STRAIGHT reaches (degrees)	23	a_{str}	61
STRAIGHT reach toe length (m)	0.7	tl_{str}	0.2
STRAIGHT reach toe angle (degrees)	3	ta_{str}	3
Manning's roughness value of channel	0.03	*n*	0.07
Fines to bulk sediment ratio (0-1 value)	0.0174	FSP:BS	0.0174
Channel capacity (cfs)	1500	Q_{cc}	15
Floodplain length (m)	446	l_{fp}	446
Floodplain condition score	1	FPC	5
Effective cohesion (kPa)	3.8	c'	3.8
Angle of internal friction (degrees)	30.9	ϕ'	30.9
Bulk unit weight (kN/m^3)	17.1	γ	17.1
Matric suction parameter (degrees)	10.0	ϕ^b	10.0
Bank - Critical shear stress (Pa)	3.00	τ_c	3.00
Bank - Erodibility coefficient (cm^3/Ns)	0.645	*k*	0.645
Toe - Critical shear stress (Pa)	21.4	τ_c	21.4
Toe - Erodibility coefficient (cm^3/Ns)	0.127	*k*	0.127

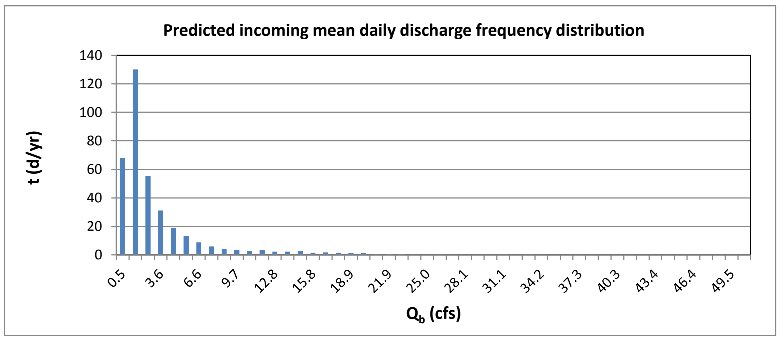
BSTEM Dynamic OUTPUT

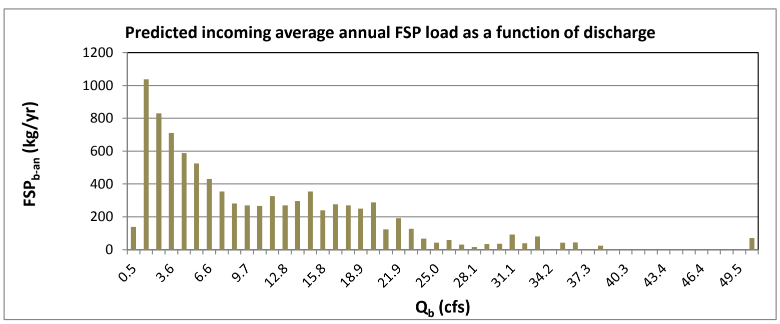
	PRE-RESTORATION		POST-RESTORATION	Q_{md-p}
Outside bend unit erosion rate (m^3/m/yr)	0	e_{ob-99}	0.011	99th
	0	e_{ob-75}	0.002	75th
	0	e_{ob-50}	0	50th
	0	e_{ob-25}	0	25th
Straight reach unit erosion rate (m^3/m/yr)	0.381	e_{str-99}	0.026	99th
	0.094	e_{str-75}	0.002	75th
	0	e_{str-50}	0	50th
	0	e_{str-25}	0	25th

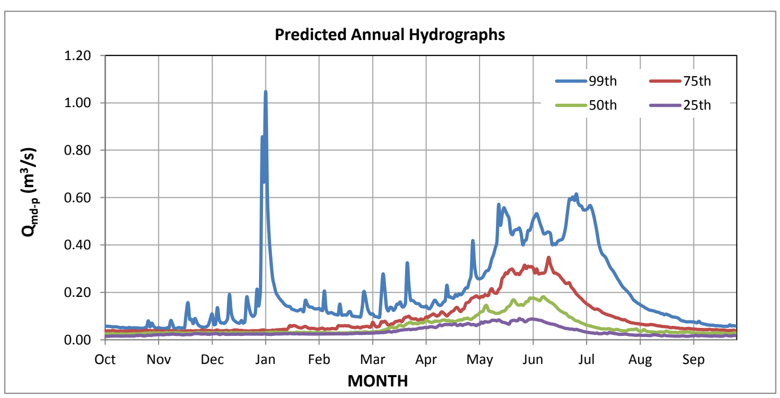
STREAM LOAD REDUCTION TOOL (SLRTv2)
Predicted catchment hydrology and FSP loads

SEZ NAME: **Angora SEZ**

CALCULATIONS		
NAME	VALUE	VARIABLE
Mean Annual Precip (in)	29.91	P
Total Area (sq mi or acres)	2.6	A
Total Impervious Area (acres)- urban only	0.0	A_i
Bin Interval (cfs)	1.021	Q_{bi}
Regional Coefficient	0.0008	R
Max Mean Daily Q (cfs)	55.01	Q_{max}
Bin 50 Value (cfs)	52.51	Q_{b-50}
FSP CRC (mg/L) - Urban only	n/a	V_{in}
Bin Interval (cfs)	1.02	Q_{bi}
FSP CRC (mg/L) - Urban only	n/a	FSP_C
Average annual discharge volume (ac-ft/yr)	2534.3	V_{in}
Average annual FSP load into SEZ (MT/yr)	9.1	FSP_{in}







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FAX: 831.426.7092
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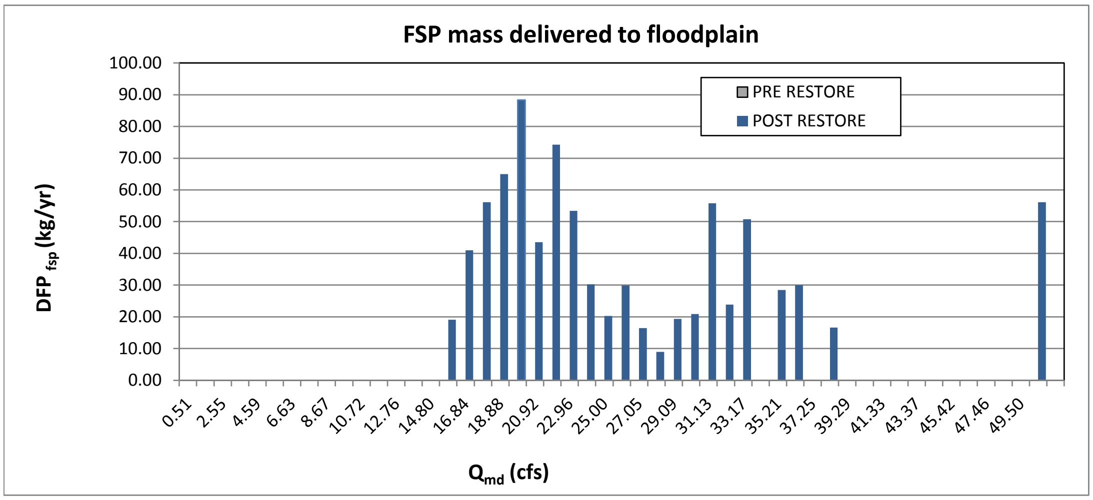
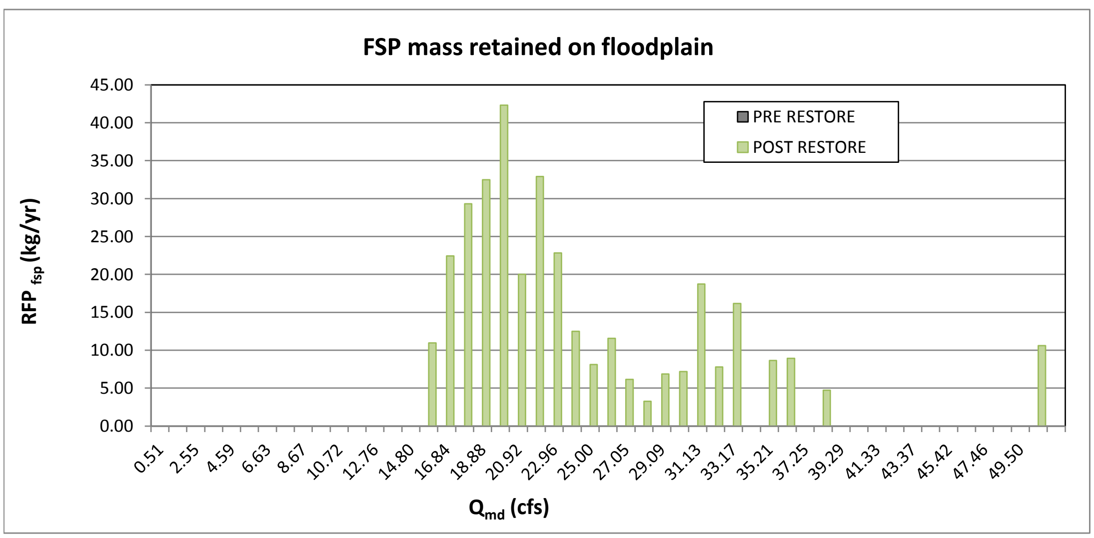
ANGORA SEZ

HYD FSP IN

STREAM LOAD REDUCTION TOOL (SLRTv2)
FLOODPLAIN RETENTION ESTIMATES

REACH NAME	Angora SEZ		
Date of estimate	1/7/2014		
	PRE RESTORE	POST RESTORE	VARIABLES
Channel length (m)	580.6	526.4	l
Channel slope (m/m)	0.0133	0.0147	s
Channel capacity (cfs)	1500	15	Q_{cc}
Floodplain condition score	1	5	FPC
Average days overbank (d/yr)	0.0	12.0	t_{ob}
Channel FSP load (kg/d)	639	133	FSP_{cc}
Catchment FSP load (MT/yr)	9.13		FSP_{in}
Delivered to floodplain (MT/yr)	0.00	0.85	DFP_{fsp}
Retained on floodplain (MT/yr)	0.00	0.34	RFP_{fsp}





SLRTv2 created by 2NDNATURE LLC (2014)

Average annual floodplain retention estimates [2/7/2014]

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STREAM LOAD REDUCTION TOOL (SLRTv2)
SEZ CHANNEL EROSION ESTIMATES

REACH NAME	**Angora SEZ**	
Date of estimate	1/7/2014	
	PRE RESTORE	**POST RESTORE**
Channel length (m)	580.6	526.4
Outside BEND length (m)	207.9	192.9
STRAIGHT length (m)	372.6	333.4
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174

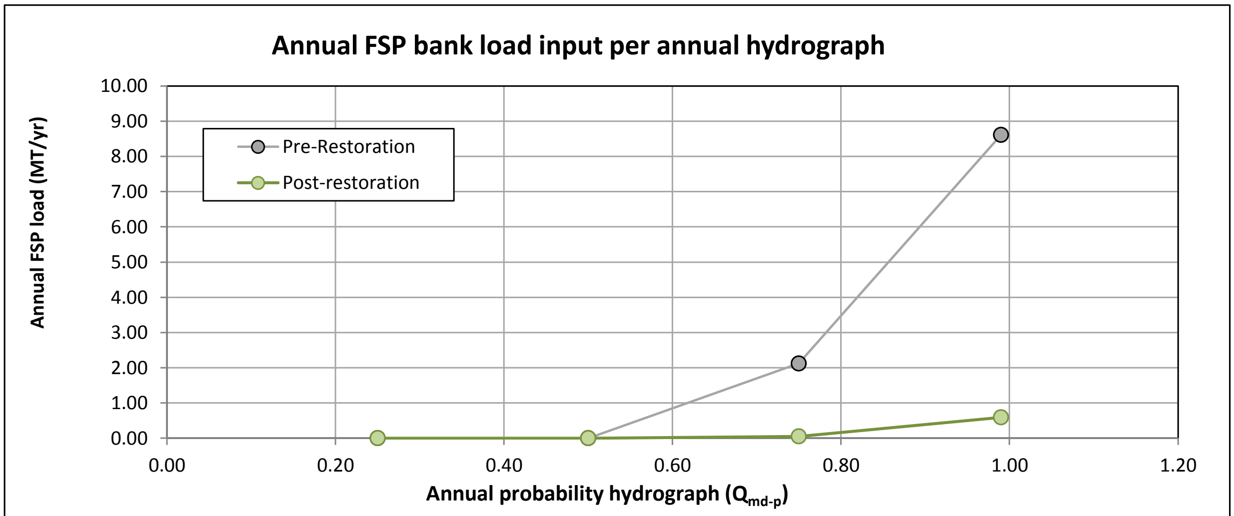
Dynamic BSTEM results

	PRE RESTORE	POST RESTORE	Q_{md-p}
Bulk sediment Outside bend unit erosion rate (m3/m/yr)	0.0000	0.0110	99th
	0.0000	0.0020	75th
	0.0000	0.0000	50th
	0.0000	0.0000	25th
Bulk sediment Straight reach unit erosion rate (m3/m/yr)	0.3810	0.0260	99th
	0.0940	0.0020	75th
	0.0000	0.0000	50th
	0.0000	0.0000	25th

	PRE RESTORE	POST RESTORE
Average annual bank erosion rate (m^3/km/yr)	18.63	1.02

SEZ Channel Erosion Results

	PRE RESTORE	POST RESTORE	% reduction
Average annual bulk sediment generated (MT/yr)	18.86	1.03	95%
Average annual FSP load generated (MT/yr)	0.328	0.018	
Average annual FSP load reduction (MT/yr)	0.310		



SLRTv2 created by 2NDNATURE LLC and A. Simon 2014

Average annual channel erosion estimates [2/10/2014]

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STREAM LOAD REDUCTION TOOL (SLRTv2)
Results Summary

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	Angora
REACH NAME	Angora SEZ
Date of Estimate	1/7/2014
CATCHMENT TYPE	Non Urban
REGION	Southshore
SUB-REGION	Southwest
CATCHMENT AREA	2.6
AREA UNITS	Sq-miles
CATCHMENT % IMPERVIOUS	
CATCHMENT LAND USE CONDITION	0

USER INPUTS

	PRE-RESTORATION	POST-RESTORATION	*CHANGE*	*% CHANGE*
Channel length (m)	580.6	526.4	-54.2	-9%
Channel slope (m/m)	0.0133	0.0147	0.0014	11%
Outside BEND length (m)	207.9	192.9	-15	-7%
BEND bank height (m)	2.6	0.8	-1.8	-69%
BEND bank angle (degrees)	42	81	39	93%
STRAIGHT length (m)	372.6	333.4	-39.2	-11%
Bank height of STRAGHT reaches (m)	1.9	0.7	-1.2	-63%
Bank angle of STRAIGHT reaches (degrees)	23	61	38	165%
Manning's roughness value of channel	0.03	0.07	0.04	133%
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174	0	0%
Channel capacity (cfs)	1500	15	-1485	-99%
Floodplain length (m)	446	446	0	0%
Floodplain condition score	1	5	4	2

SLRT OUTPUTS

AVERAGE ANNUAL ESTIMATES	PRE-RESTORATION	POST-RESTORATION	*CHANGE*	*% CHANGE*	
Predicted FSP catchment load (MT/yr)	9.13	9.13	0	0%	IN_{fsp} (MT/yr)
Predicted FSP load delivered to floodplain (MT/yr)	0.00	0.85	0.8	INCREASE	DFP_{fsp} (MT/yr)
Predicted FSP load retained on floodplain (MT/yr)	0.00	0.34	0.3	INCREASE	RFP_{fsp} (MT/yr)
Predicted FSP load from channel erosion (MT/yr)	0.33	0.02	-0.31	-95%	SCE_{fsp} (MT/yr)
Predicted FSP load at downstream boundary (MT/yr)	9.46	8.80	-0.65	-7%	OUT_{fsp} (MT/yr)

0.65 **Average annual FSP Load Reduction (MT/yr)** SEZ LR_{fsp} (MT/yr)

1.24 **Average annual FSP Load Reduction (MT/yr/km)**

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2NDNATURE LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

Angora Sewer Project Summary

Current Conditions: Restoration efforts were completed in 2002. Prior to restoration, Angora Creek was impacted by the placement of a linear sewer line constructed in the meadow in the 1960's. The result was a straightened and incised channel. Restoration efforts were to reconstruct the channel within the meadow to restore a functioning meadow system. The restored reach has a lower slope, improved sinuosity, and better interaction with the floodplain.

Lower section of restored reach and adjacent floodplain of Angora Sewer, looking upstream. 2013.

Upper section of restored reach and adjacent floodplain of Angora Sewer, looking downstream. 2013.

View of typical bank morphology of Angora Creek Sewer with level staff for scale. 2013.

Overview of riparian area and floodplain conditions. 2013.

Plans and Modeling: Restoration of Angora Sewer reduced channel capacity and channel slope and increased channel length. The successful increase in the channel grade has resulted in a well vegetated floodplain and geomorphically stable channel with frequent floodplain inundation.

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2NDNATURE | LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

STREAM LOAD REDUCTION TOOL (SLRTv2)
User Inputs

META DATA

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	Angora
REACH NAME	**Angora Sewer**
Date of Estimate	1/7/2014

CATCHMENT CHARACTERISTICS

CATCHMENT TYPE	Non Urban	
REGION	Southshore	
SUB-REGION	Southwest	
CATCHMENT AREA	4.4	
AREA UNITS	Sq-miles	
CATCHMENT % IMPERVIOUS		Urban Only
CATCHMENT LAND USE CONDITION		Urban Only

SEZ ATTRIBUTES

	PRE-RESTORATION		POST-RESTORATION
Channel length (m)	804	l_c	1084
Channel slope (m/m)	0.0042	s	0.0031
Outside BEND length (m)	225.5	l_{ob}	556.4
BEND bank height (m)	1	h_{ob}	1
BEND bank angle (degrees)	45	a_{ob}	66
BEND toe length (m)	0.7	tl_{ob}	0.2
BEND toe angle (degrees)	20	ta_{ob}	2
STRAIGHT length (m)	578.5	l_{str}	527.6
Bank height of STRAIGHT reaches (m)	0.6	h_{str}	0.5
Bank angle of STRAIGHT reaches (degrees)	62	a_{str}	70
STRAIGHT reach toe length (m)	0.7	tl_{str}	0.3
STRAIGHT reach toe angle (degrees)	16	ta_{str}	15
Manning's roughness value of channel	0.03	n	0.03
Fines to bulk sediment ratio (0-1 value)	0.0174	FSP:BS	0.0174
Channel capacity (cfs)	25	Q_{cc}	15
Floodplain length (m)	659	l_{fp}	659
Floodplain condition score	3	FPC	5
Effective cohesion (kPa)	3.8	c'	3.8
Angle of internal friction (degrees)	30.9	ϕ'	30.9
Bulk unit weight (kN/m^3)	17.1	γ	17.1
Matric suction parameter (degrees)	10.0	ϕ^b	10.0
Bank - Critical shear stress (Pa)	3.00	τ_c	3.00
Bank - Erodibility coefficient (cm^3/Ns)	0.645	k	0.645
Toe - Critical shear stress (Pa)	21.4	τ_c	21.4
Toe - Erodibility coefficient (cm^3/Ns)	0.127	k	0.127

BSTEM Dynamic OUTPUT

	PRE-RESTORATION		POST-RESTORATION	Q_{md-p}
Outside bend unit erosion rate (m^3/m/yr)	0.163	e_{ob-99}	0.021	99th
	0.005	e_{ob-75}	0.0159	75th
	0	e_{ob-50}	0.0049	50th
	0	e_{ob-25}	0	25th
Straight reach unit erosion rate (m^3/m/yr)	0.039	e_{str-99}	0.0006	99th
	0.012	e_{str-75}	0.00057	75th
	0.001	e_{str-50}	0.00057	50th
	0	e_{str-25}	0	25th

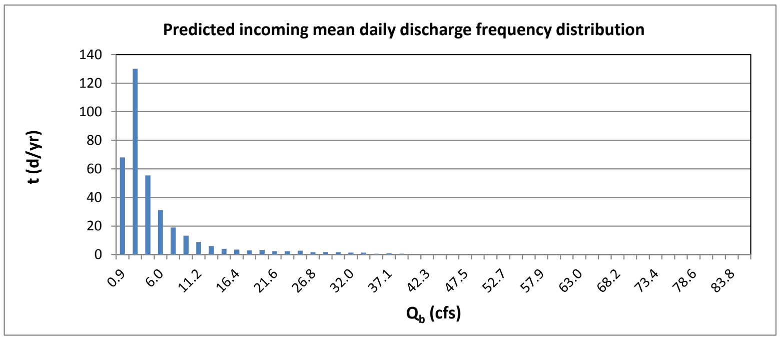
SLRTv2 created by 2NDNATURE LLC 2014

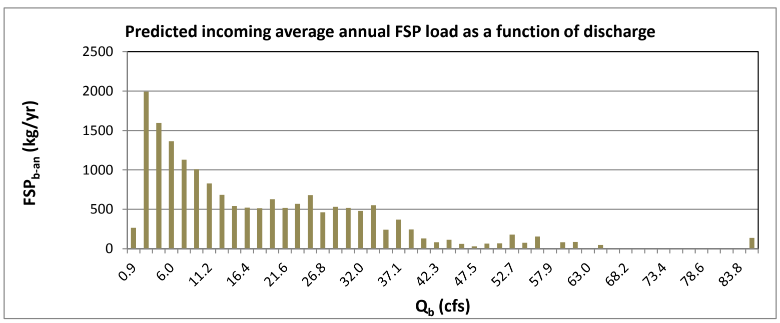
USER INPUT [3/20/2014]

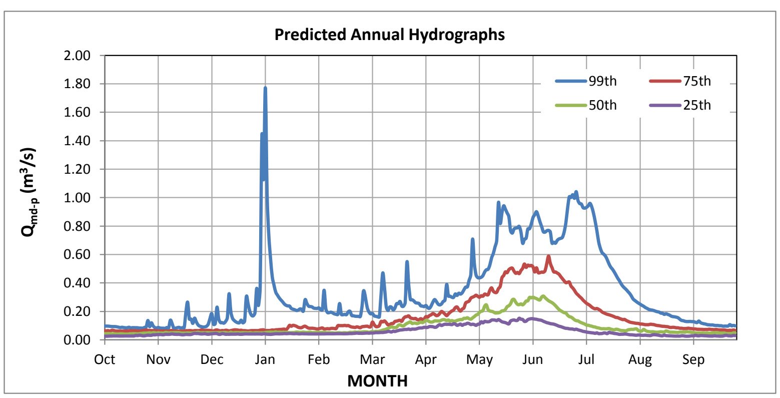
STREAM LOAD REDUCTION TOOL (SLRTv2)
Predicted catchment hydrology and FSP loads

SEZ NAME: **Angora Sewer**

CALCULATIONS		
NAME	VALUE	VARIABLE
Mean Annual Precip (in)	29.91	P
Total Area (sq mi or acres)	4.4	A
Total Impervious Area (acres)- urban only	0.0	A_i
Bin Interval (cfs)	1.727	Q_{bi}
Regional Coefficient	0.0008	R
Max Mean Daily Q (cfs)	93.09	Q_{max}
Bin 50 Value (cfs)	88.86	Q_{b-50}
FSP CRC (mg/L) - Urban only	n/a	V_{in}
Bin Interval (cfs)	1.73	Q_{bi}
FSP CRC (mg/L) - Urban only	n/a	FSP_C
Average annual discharge volume (ac-ft/yr)	4288.8	V_{in}
Average annual FSP load into SEZ (MT/yr)	17.5	FSP_{in}







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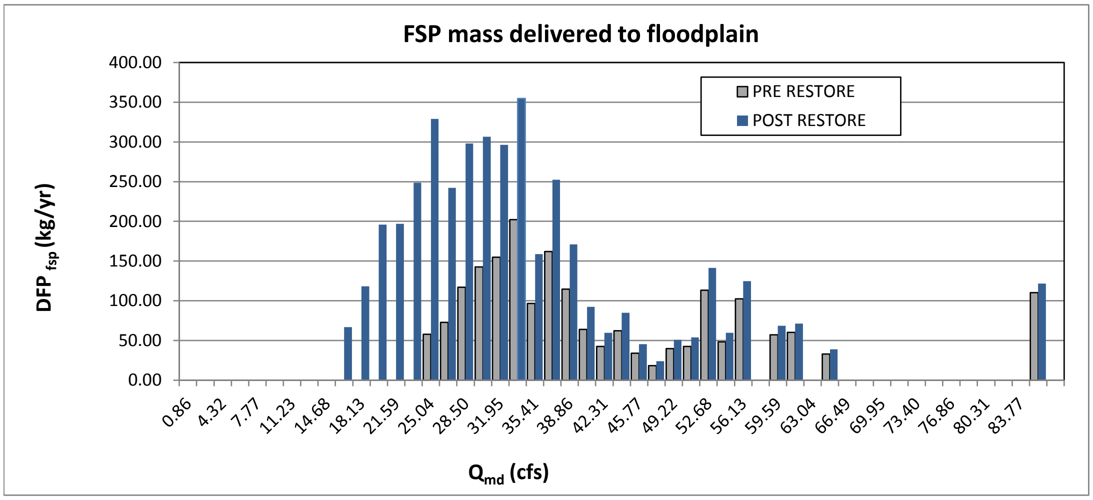
2NDNATURE | LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

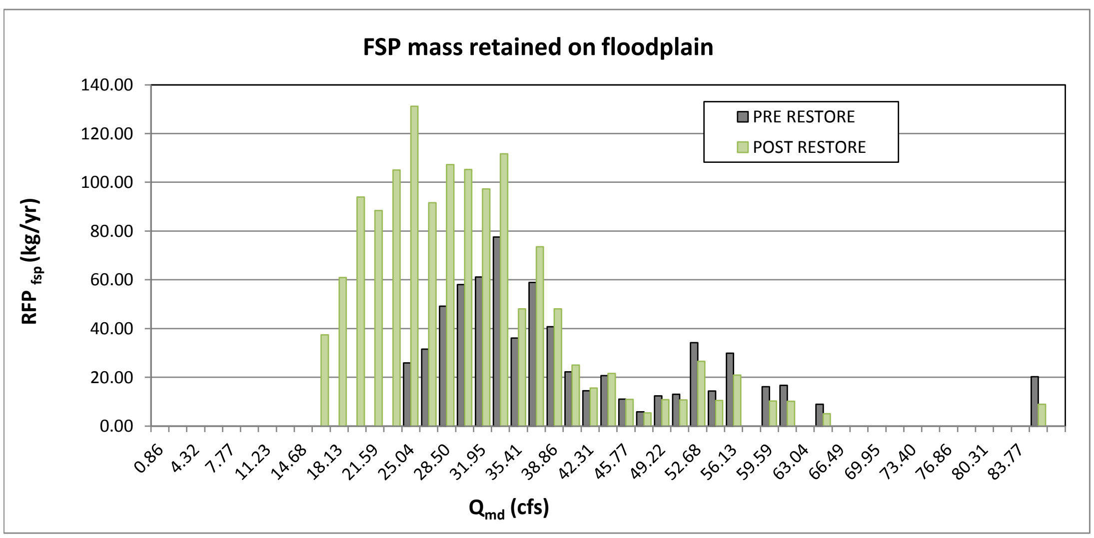
ANGORA SEWER

HYD FSP IN

STREAM LOAD REDUCTION TOOL (SLRTv2)
FLOODPLAIN RETENTION ESTIMATES

REACH NAME	Angora Sewer		
Date of estimate	1/7/2014		
	PRE RESTORE	**POST RESTORE**	VARIABLES
Channel length (m)	804	1084	l
Channel slope (m/m)	0.0042	0.0031	s
Channel capacity (cfs)	25	15	Q_{cc}
Floodplain condition score	3	5	FPC
Average days overbank (d/yr)	14.7	29.3	t_{ob}
Channel FSP load (kg/d)	233	131	FSP_{cc}
Catchment FSP load (MT/yr)	17.53		FSP_{in}
Delivered to floodplain (MT/yr)	1.95	4.27	DFP_{fsp}
Retained on floodplain (MT/yr)	0.68	1.39	RFP_{fsp}





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Average annual floodplain retention estimates [2/7/2014]

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2NDNATURE LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

STREAM LOAD REDUCTION TOOL (SLRTv2)
SEZ CHANNEL EROSION ESTIMATES

REACH NAME	Angora Sewer	
Date of estimate	1/7/2014	
	PRE RESTORE	POST RESTORE
Channel length (m)	804	1084
Outside BEND length (m)	225.5	556.4
STRAIGHT length (m)	578.5	527.6
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174

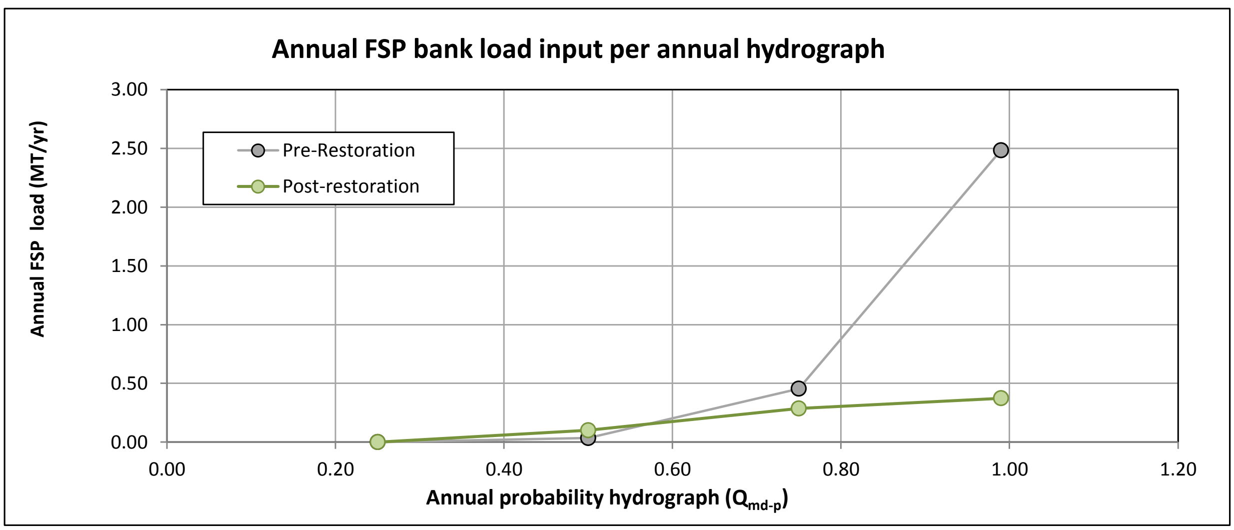
Dynamic BSTEM results

	PRE RESTORE	POST RESTORE	Q_{md-p}
Bulk sediment Outside bend unit erosion rate (m3/m/yr)	0.1630	0.0210	99th
	0.0050	0.0159	75th
	0.0000	0.0049	50th
	0.0000	0.0000	25th
Bulk sediment Straight reach unit erosion rate (m3/m/yr)	0.0390	0.0006	99th
	0.0120	0.0006	75th
	0.0010	0.0006	50th
	0.0000	0.0000	25th

	PRE RESTORE	POST RESTORE
Average annual bank erosion rate (m^3/km/yr)	3.63	1.18

SEZ Channel Erosion Results

	PRE RESTORE	POST RESTORE	% reduction
Average annual bulk sediment generated (MT/yr)	5.10	1.66	68%
Average annual FSP load generated (MT/yr)	0.089	0.029	
Average annual FSP load reduction (MT/yr)	0.060		



SLRTv2 created by 2NDNATURE LLC and A. Simon 2014

Average annual channel erosion estimates [2/10/2014]

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2NDNATURE LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

STREAM LOAD REDUCTION TOOL (SLRTv2)
Results Summary

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	Angora
REACH NAME	Angora Sewer
Date of Estimate	1/7/2014
CATCHMENT TYPE	Non Urban
REGION	Southshore
SUB-REGION	Southwest
CATCHMENT AREA	4.4
AREA UNITS	Sq-miles
CATCHMENT % IMPERVIOUS	
CATCHMENT LAND USE CONDITION	0

USER INPUTS

	PRE-RESTORATION	POST-RESTORATION	*CHANGE*	*% CHANGE*
Channel length (m)	804	1084	280	35%
Channel slope (m/m)	0.0042	0.0031	-0.0011	-26%
Outside BEND length (m)	225.5	556.4	330.9	147%
BEND bank height (m)	1	1	0	0%
BEND bank angle (degrees)	45	66	21	47%
STRAIGHT length (m)	578.5	527.6	-50.9	-9%
Bank height of STRAGHT reaches (m)	0.6	0.5	-0.1	-17%
Bank angle of STRAIGHT reaches (degrees)	62	70	8	13%
Manning's roughness value of channel	0.03	0.03	0	0%
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174	0	0%
Channel capacity (cfs)	25	15	-10	-40%
Floodplain length (m)	659	659	0	0%
Floodplain condition score	3	5	2	2

SLRT OUTPUTS

AVERAGE ANNUAL ESTIMATES	PRE-RESTORATION	POST-RESTORATION	*CHANGE*	*% CHANGE*	
Predicted FSP catchment load (MT/yr)	17.53	17.53	0	0%	IN_{fsp} (MT/yr)
Predicted FSP load delivered to floodplain (MT/yr)	1.95	4.27	2.3	119%	DFP_{fsp} (MT/yr)
Predicted FSP load retained on floodplain (MT/yr)	0.68	1.39	0.7	105%	RFP_{fsp} (MT/yr)
Predicted FSP load from channel erosion (MT/yr)	0.09	0.03	-0.06	-68%	SCE_{fsp} (MT/yr)
Predicted FSP load at downstream boundary (MT/yr)	16.94	16.17	-0.77	-5%	OUT_{fsp} (MT/yr)

0.77 **Average annual FSP Load Reduction (MT/yr)** SEZ LR_{fsp} (MT/yr)

0.71 **Average annual FSP Load Reduction (MT/yr/km)**

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TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

UTR Golf Course Reach Project Summary

Current Conditions: The UTR Golf Course is in the pre-restored condition and the restoration is in the preliminary design phase. The current reach has a significant amount of bank erosion and channel incision. Current floodplain inundation events are unlikely due to the large channel capacity.

Lower section of Upper Truckee River Golf Course Reach, looking downstream. 2013.

Lower section of Upper Truckee River Golf Course Reach and adjacent floodplain, looking across channel. 2013.

View of exposed bank, loose bank material along eroding outer bend section of UTR Golf Course. 2013.

View of bank erosion on outside bend of UTR Golf Course, toe morphology is also evident. 2013.

Plans and Modeling: Post-restoration morphology attributes were provided by CA State Parks. The planned project will decrease channel capacity, channel slope, and substantially reduce bank heights. Pre-restoration bank erosion rates from the BSTEM modeling were compared to Simon et al. (2003) annual bank erosion rate estimates produced from the CA State Parks long-term cross-section monitoring program. These estimates best aligned when the bank toe was modeled as a separate layer. The post restoration floodplain conditions are expected to be a mix of natural meadow and golf course turf.

STREAM LOAD REDUCTION TOOL (SLRTv2)
User Inputs

META DATA

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	UPPER TRUCKEE RIVER
REACH NAME	**UTR GOLF COURSE**
Date of Estimate	2/7/2014

CATCHMENT CHARACTERISTICS

CATCHMENT TYPE	Non Urban	
REGION	Mainstem UTR	
SUB-REGION	Southwest	
CATCHMENT AREA	42.4	
AREA UNITS	Sq-miles	
CATCHMENT % IMPERVIOUS		Urban Only
CATCHMENT LAND USE CONDITION		Urban Only

SEZ ATTRIBUTES

	PRE-RESTORATION		POST-RESTORATION
Channel length (m)	1829	l_c	2143
Channel slope (m/m)	0.0021	s	0.0018
Outside BEND length (m)	841	l_{ob}	984
BEND bank height (m)	2.8	h_{ob}	1.3
BEND bank angle (degrees)	50	a_{ob}	18
BEND toe length (m)	1	tl_{ob}	0.9
BEND toe angle (degrees)	39	ta_{ob}	6
STRAIGHT length (m)	988	l_{str}	1159
Bank height of STRAIGHT reaches (m)	1.9	h_{str}	0.6
Bank angle of STRAIGHT reaches (degrees)	23	a_{str}	31
STRAIGHT reach toe length (m)	3	tl_{str}	2.3
STRAIGHT reach toe angle (degrees)	4	ta_{str}	6
Manning's roughness value of channel	0.03	*n*	0.03
Fines to bulk sediment ratio (0-1 value)	0.0174	FSP:BS	0.0174
Channel capacity (cfs)	1900	Q_{cc}	550
Floodplain length (m)	1221	l_{fp}	1221
Floodplain condition score	3	FPC	5
Effective cohesion (kPa)	3.8	c'	3.8
Angle of internal friction (degrees)	30.9	ϕ'	30.9
Bulk unit weight (kN/m^3)	17.1	γ	17.1
Matric suction parameter (degrees)	10.0	ϕ^b	10.0
Bank - Critical shear stress (Pa)	3.00	τ_c	3.00
Bank - Erodibility coefficient (cm^3/Ns)	0.645	*k*	0.645
Toe - Critical shear stress (Pa)	21.4	τ_c	21.4
Toe - Erodibility coefficient (cm^3/Ns)	0.127	*k*	0.127

BSTEM Dynamic OUTPUT

	PRE-RESTORATION		POST-RESTORATION	Q_{md-p}
Outside bend unit erosion rate (m^3/m/yr)	18.18	e_{ob-99}	1.04	99th
	0.139	e_{ob-75}	0.478	75th
	0.057	e_{ob-50}	0.239	50th
	0	e_{ob-25}	0.103	25th
Straight reach unit erosion rate (m^3/m/yr)	7.67	e_{str-99}	0.27	99th
	0.24	e_{str-75}	0.06	75th
	0.146	e_{str-50}	0.04	50th
	0.036	e_{str-25}	0.01	25th

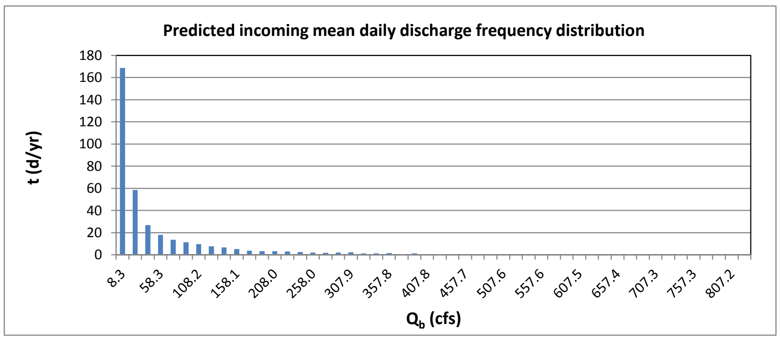
SLRTv2 created by 2NDNATURE LLC 2014

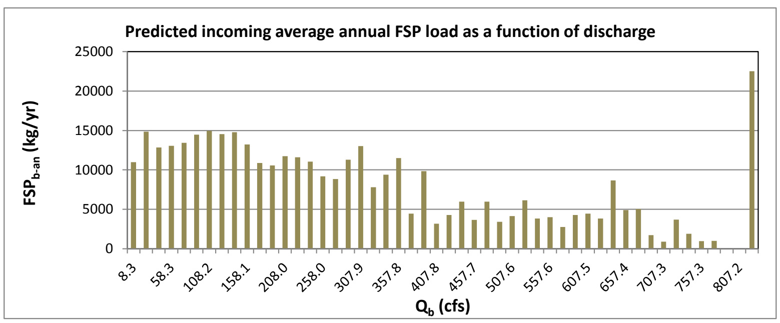
USER INPUT [3/20/2014]

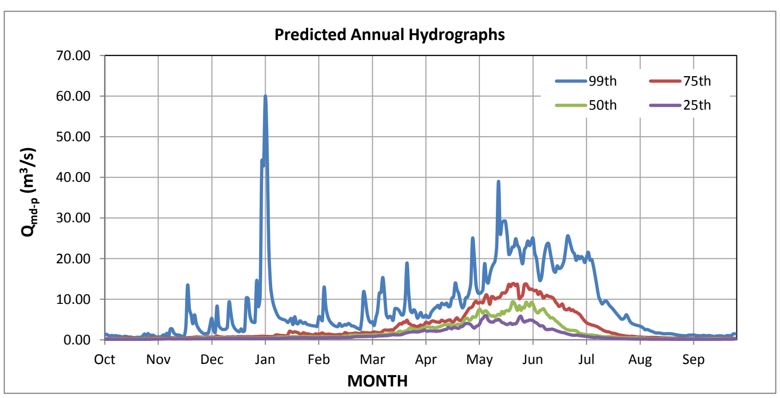
STREAM LOAD REDUCTION TOOL (SLRTv2)
Predicted catchment hydrology and FSP loads

SEZ NAME: **UTR GOLF COURSE**

CALCULATIONS		
NAME	VALUE	VARIABLE
Mean Annual Precip (in)	29.91	P
Total Area (sq mi or acres)	42.4	A
Total Impervious Area (acres)- urban only	0.0	A_i
Bin Interval (cfs)	16.643	Q_{bi}
Regional Coefficient	0.003	R
Max Mean Daily Q (cfs)	2434.91	Q_{max}
Bin 50 Value (cfs)	1625.22	Q_{b-50}
FSP CRC (mg/L) - Urban only	n/a	V_{in}
Bin Interval (cfs)	16.64	Q_{bi}
FSP CRC (mg/L) - Urban only	n/a	FSP_C
Average annual discharge volume (ac-ft/yr)	42854.0	V_{in}
Average annual FSP load into SEZ (MT/yr)	389.3	FSP_{in}







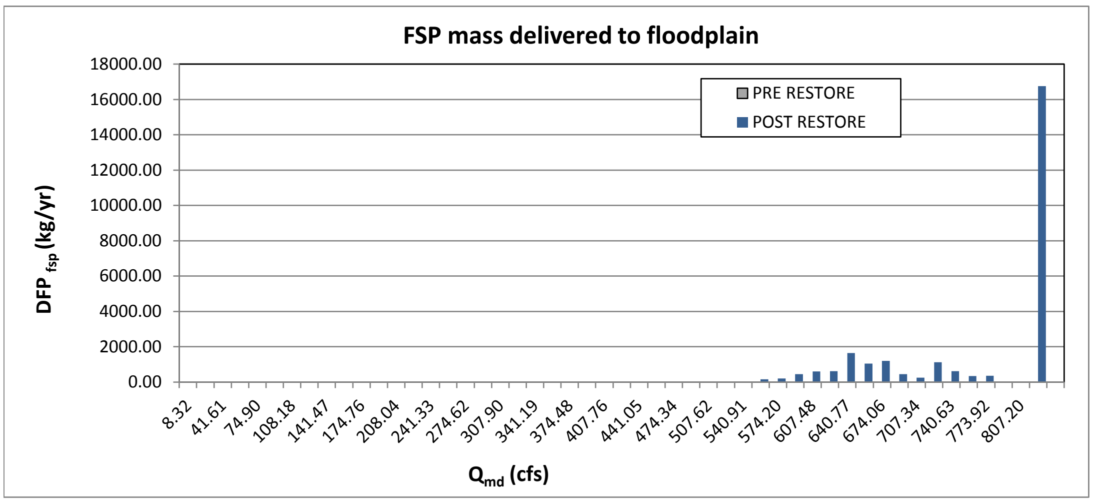
DESIGNED BY
2NDNATURE LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

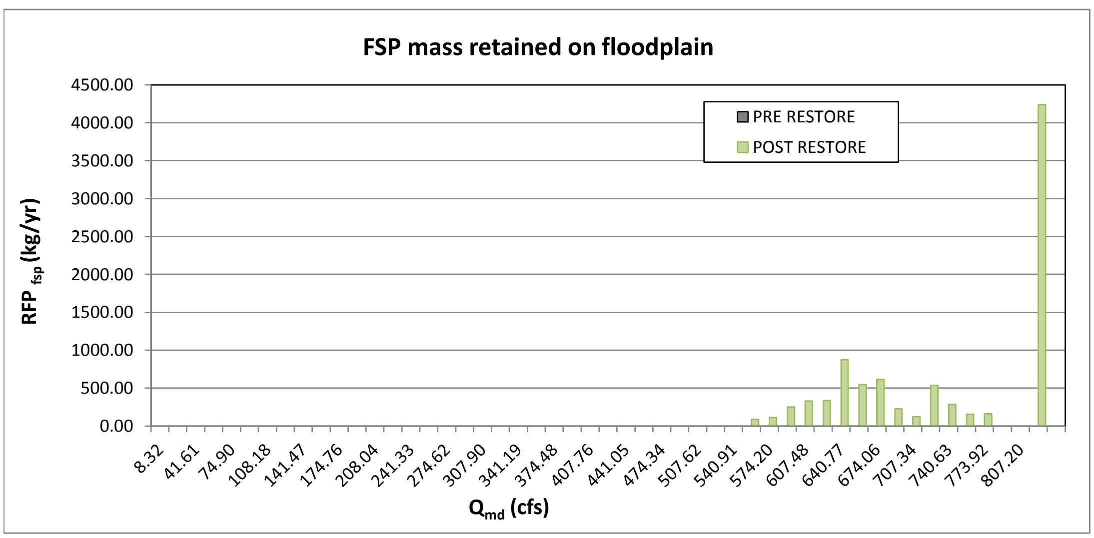
UTR GOLF COURSE

HYD FSP IN

STREAM LOAD REDUCTION TOOL (SLRTv2)
FLOODPLAIN RETENTION ESTIMATES

REACH NAME	UTR GOLF COURSE		
Date of estimate	2/7/2014		
	PRE RESTORE	**POST RESTORE**	VARIABLES
Channel length (m)	1829	2143	l
Channel slope (m/m)	0.0021	0.0018	s
Channel capacity (cfs)	1900	550	Q_{cc}
Floodplain condition score	3	5	FPC
Average days overbank (d/yr)	0.0	3.9	t_{ob}
Channel FSP load (kg/d)	45043	11513	FSP_{cc}
Catchment FSP load (MT/yr)	389.25		FSP_{in}
Delivered to floodplain (MT/yr)	0.00	25.77	DFP_{fsp}
Retained on floodplain (MT/yr)	0.00	8.88	RFP_{fsp}





SLRTv2 created by 2NDNATURE LLC (2014)

Average annual floodplain retention estimates [2/24/2014]

STREAM LOAD REDUCTION TOOL (SLRTv2)
SEZ CHANNEL EROSION ESTIMATES

REACH NAME	**UTR GOLF COURSE**	
Date of estimate	2/7/2014	
	PRE RESTORE	**POST RESTORE**
Channel length (m)	1829	2143
Outside BEND length (m)	841	984
STRAIGHT length (m)	988	1159
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174

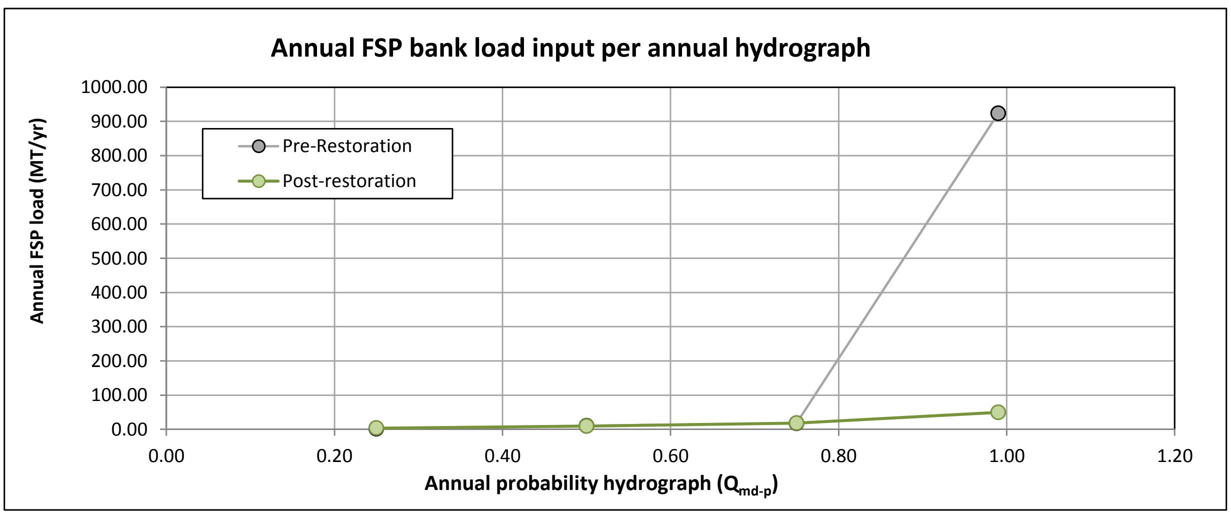
Dynamic BSTEM results

	PRE RESTORE	POST RESTORE	Q_{md-p}
Bulk sediment Outside bend unit erosion rate (m3/m/yr)	18.1800	1.0400	99th
	0.1390	0.4780	75th
	0.0570	0.2390	50th
	0.0000	0.1030	25th
Bulk sediment Straight reach unit erosion rate (m3/m/yr)	7.6700	0.2700	99th
	0.2400	0.0600	75th
	0.1460	0.0400	50th
	0.0360	0.0100	25th

	PRE RESTORE	POST RESTORE
Average annual bank erosion rate (m^3/km/yr)	459.77	52.14

SEZ Channel Erosion Results

	PRE RESTORE	POST RESTORE	% reduction
Average annual bulk sediment generated (MT/yr)	1466.33	166.29	89%
Average annual FSP load generated (MT/yr)	25.514	2.893	
Average annual FSP load reduction (MT/yr)	22.621		



SLRTv2 created by 2NDNATURE LLC and A. Simon 2014

Average annual channel erosion estimates [2/24/2014]

STREAM LOAD REDUCTION TOOL (SLRTv2)
Results Summary

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	UPPER TRUCKEE RIVER
REACH NAME	UTR GOLF COURSE
Date of Estimate	2/7/2014
CATCHMENT TYPE	Non Urban
REGION	Mainstem UTR
SUB-REGION	Southwest
CATCHMENT AREA	42.4
AREA UNITS	Sq-miles
CATCHMENT % IMPERVIOUS	
CATCHMENT LAND USE CONDITION	0

USER INPUTS

	PRE-RESTORATION	POST-RESTORATION	*CHANGE*	*% CHANGE*
Channel length (m)	1829	2143	314	17%
Channel slope (m/m)	0.0021	0.0018	-0.0003	-14%
Outside BEND length (m)	841	984	143	17%
BEND bank height (m)	2.8	1.3	-1.5	-54%
BEND bank angle (degrees)	50	18	-32	-64%
STRAIGHT length (m)	988	1159	171	17%
Bank height of STRAGHT reaches (m)	1.9	0.6	-1.3	-68%
Bank angle of STRAIGHT reaches (degrees)	23	31	8	35%
Manning's roughness value of channel	0.03	0.03	0	0%
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174	0	0%
Channel capacity (cfs)	1900	550	-1350	-71%
Floodplain length (m)	1221	1221	0	0%
Floodplain condition score	3	5	2	2

SLRT OUTPUTS

AVERAGE ANNUAL ESTIMATES	PRE-RESTORATION	POST-RESTORATION	*CHANGE*	*% CHANGE*	
Predicted FSP catchment load (MT/yr)	389.25	389.25	0	0%	IN_{fsp} (MT/yr)
Predicted FSP load delivered to floodplain (MT/yr)	0.00	25.77	25.8	#DIV/0!	DFP_{fsp} (MT/yr)
Predicted FSP load retained on floodplain (MT/yr)	0.00	8.88	8.9	#DIV/0!	RFP_{fsp} (MT/yr)
Predicted FSP load from channel erosion (MT/yr)	25.51	2.89	-22.62	-89%	SCE_{fsp} (MT/yr)
Predicted FSP load at downstream boundary (MT/yr)	414.77	383.27	-31.50	-8%	OUT_{fsp} (MT/yr)

31.50 **Average annual FSP Load Reduction (MT/yr)** SEZ LR_{fsp} (MT/yr)

14.70 **Average annual FSP Load Reduction (MT/yr/km)**

DESIGNED BY
2NDNATURE LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

UTR Sunset Reach 6 Project Summary

Current Conditions: The restoration efforts on UTR Sunset Reach 6 are currently in the preliminary design phase. Restoration efforts intend to improve the riparian function of the channel.

Upper section of UTR Sunset Reach 6, looking downstream. 2013.

Lower section of UTR Sunset Reach 6, looking downstream. 2013.

View of high topographic complexity and low vegetation structure on the floodplain on UTR Sunset Reach 6. 2013.

Typical bend segment of UTR Sunset Reach 6 near the downstream project boundary. 2013.

Plans and Modeling: UTR Sunset Reach 6 was predicted to have minimal channel erosion in both pre-restoration and post-restoration models. The changes in channel capacity from 700 to 500 along with improvement in FPC score were estimated to increase the FSP load retained on the floodplain by 122%. The combined restoration efforts are predicted to cause an FSP load reduction of 10.39 (MT/yr).

STREAM LOAD REDUCTION TOOL (SLRTv2)
User Inputs

META DATA

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	Upper Truckee
REACH NAME	**UTR Sunset reach 6**
Date of Estimate	1/7/2014

CATCHMENT CHARACTERISTICS

CATCHMENT TYPE	Non Urban	
REGION	Mainstem UTR	
SUB-REGION	Southwest	
CATCHMENT AREA	50.3	
AREA UNITS	Sq-miles	
CATCHMENT % IMPERVIOUS		Urban Only
CATCHMENT LAND USE CONDITION		Urban Only

SEZ ATTRIBUTES

	PRE-RESTORATION		POST-RESTORATION
Channel length (m)	1163	l_c	1472
Channel slope (m/m)	0.001	s	0.0008
Outside BEND length (m)	457.8	l_{ob}	831.5
BEND bank height (m)	1	h_{ob}	1.2
BEND bank angle (degrees)	51	a_{ob}	25
BEND toe length (m)	0.9	tl_{ob}	1
BEND toe angle (degrees)	16	ta_{ob}	0
STRAIGHT length (m)	705.5	l_{str}	640.9
Bank height of STRAIGHT reaches (m)	1.1	h_{str}	1.2
Bank angle of STRAIGHT reaches (degrees)	21	a_{str}	28
STRAIGHT reach toe length (m)	0.3	tl_{str}	1
STRAIGHT reach toe angle (degrees)	37	ta_{str}	0
Manning's roughness value of channel	0.03	*n*	0.03
Fines to bulk sediment ratio (0-1 value)	0.0174	FSP:BS	0.0174
Channel capacity (cfs)	700	Q_{cc}	450
Floodplain length (m)	930	l_{fp}	930
Floodplain condition score	3	FPC	5
Effective cohesion (kPa)	3.8	c'	3.8
Angle of internal friction (degrees)	30.9	ϕ'	30.9
Bulk unit weight (kN/m^3)	17.1	γ	17.1
Matric suction parameter (degrees)	10.0	ϕ^b	10.0
Bank - Critical shear stress (Pa)	3.00	τ_c	3.00
Bank - Erodibility coefficient (cm^3/Ns)	0.645	*k*	0.645
Toe - Critical shear stress (Pa)	21.4	τ_c	21.4
Toe - Erodibility coefficient (cm^3/Ns)	0.127	*k*	0.127

BSTEM Dynamic OUTPUT

	PRE-RESTORATION		POST-RESTORATION	Q_{md-p}
Outside bend unit erosion rate (m^3/m/yr)	0.010	e_{ob-99}	0	99th
	0	e_{ob-75}	0	75th
	0	e_{ob-50}	0	50th
	0	e_{ob-25}	0	25th
Straight reach unit erosion rate (m^3/m/yr)	0.015	e_{str-99}	0	99th
	0.014	e_{str-75}	0	75th
	0	e_{str-50}	0	50th
	0	e_{str-25}	0	25th

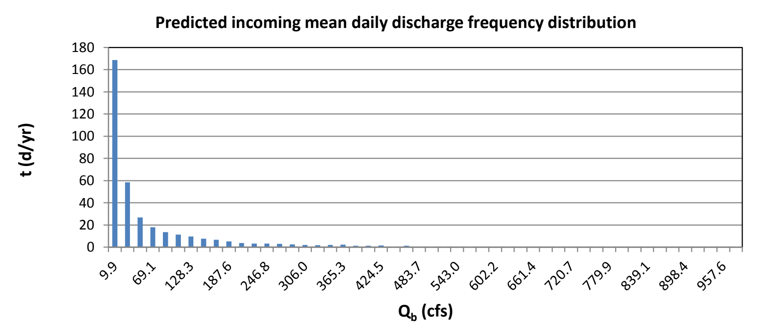
SLRTv2 created by 2NDNATURE LLC 2014

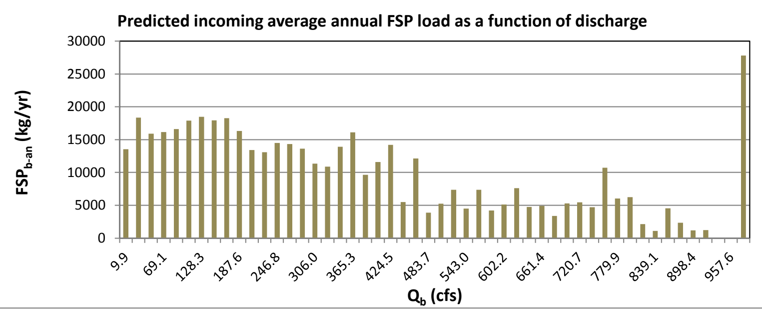
USER INPUT [3/20/2014]

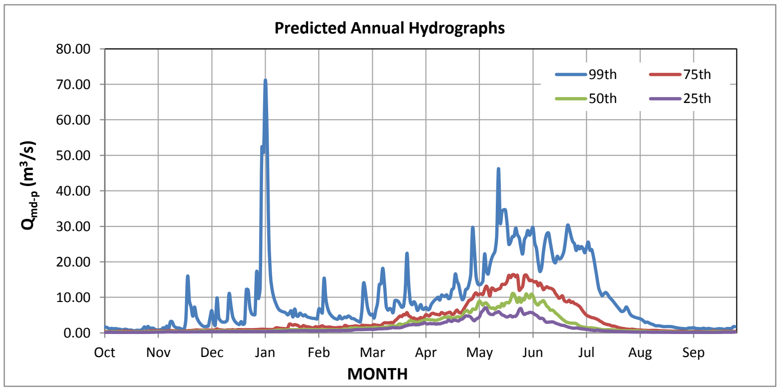
STREAM LOAD REDUCTION TOOL (SLRTv2)
Predicted catchment hydrology and FSP loads

SEZ NAME: **UTR Sunset reach 6**

CALCULATIONS		
NAME	VALUE	VARIABLE
Mean Annual Precip (in)	29.91	P
Total Area (sq mi or acres)	50.3	A
Total Impervious Area (acres)- urban only	0.0	A_i
Bin Interval (cfs)	19.744	Q_{bi}
Regional Coefficient	0.003	R
Max Mean Daily Q (cfs)	2888.59	Q_{max}
Bin 50 Value (cfs)	1928.03	Q_{b-50}
FSP CRC (mg/L) - Urban only	n/a	V_{in}
Bin Interval (cfs)	19.74	Q_{bi}
FSP CRC (mg/L) - Urban only	n/a	FSP_C
Average annual discharge volume (ac-ft/yr)	50838.6	V_{in}
Average annual FSP load into SEZ (MT/yr)	481.1	FSP_{in}







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2NDNATURE LLC

TEL: 831.426.9119 FAX: 831.426.7092

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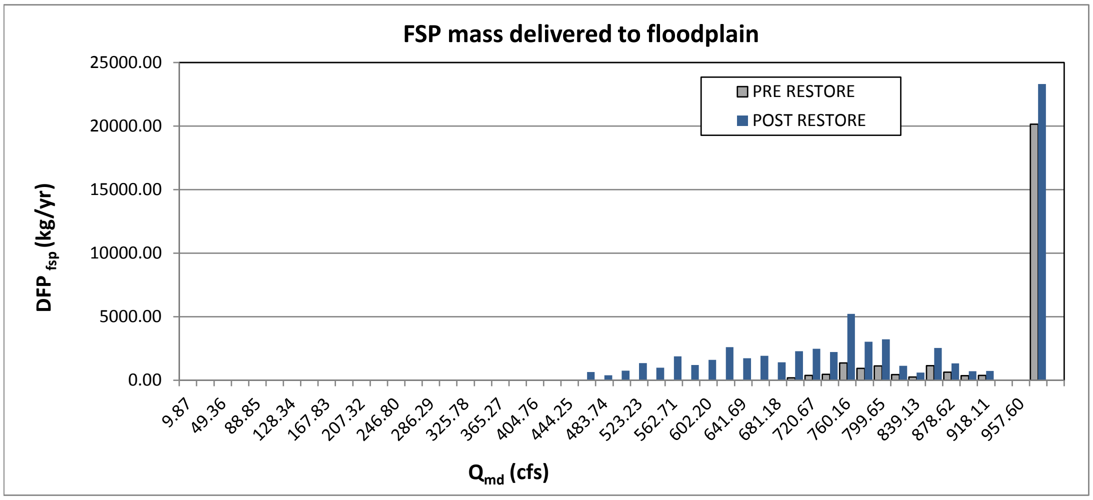
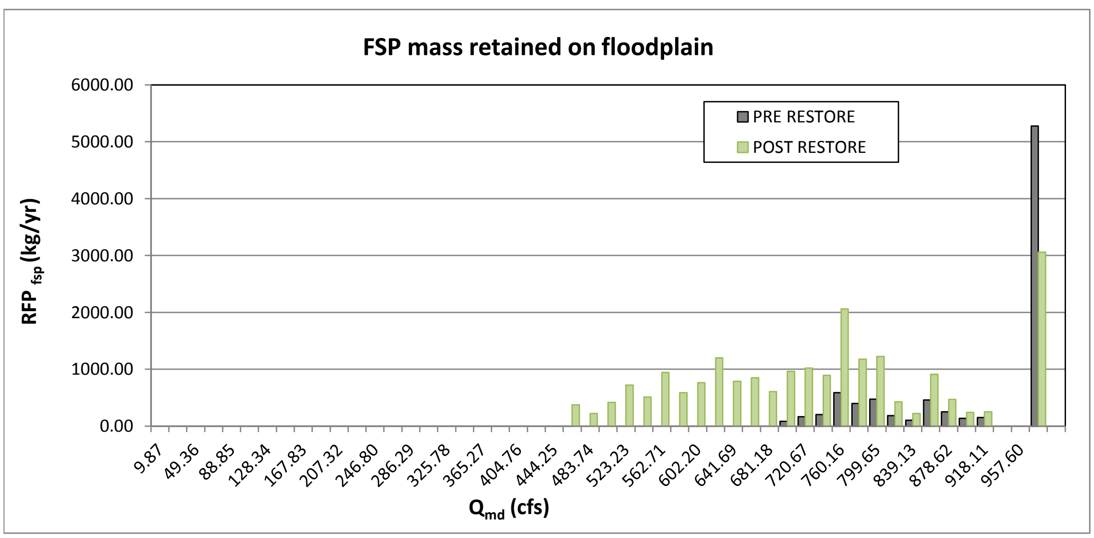
STREAM LOAD REDUCTION TOOL (SLRTv2)
FLOODPLAIN RETENTION ESTIMATES

REACH NAME	**UTR Sunset reach 6**		
Date of estimate	1/7/2014		
	PRE RESTORE	**POST RESTORE**	VARIABLES
Channel length (m)	1163	1472	*l*
Channel slope (m/m)	0.001	0.0008	*s*
Channel capacity (cfs)	700	450	Q_{cc}
Floodplain condition score	3	5	FPC
Average days overbank (d/yr)	3.3	9.3	t_{ob}
Channel FSP load (kg/d)	15323	9019	FSP_{cc}
Catchment FSP load (MT/yr)	481.11		FSP_{in}
Delivered to floodplain (MT/yr)	27.78	65.24	DFP_{fsp}
Retained on floodplain (MT/yr)	8.46	20.87	RFP_{fsp}





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Average annual floodplain retention estimates [3/20/2014]

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2NDNATURE LLC
TEL: 831.426.9119 FAX: 831.426.7092
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STREAM LOAD REDUCTION TOOL (SLRTv2)
SEZ CHANNEL EROSION ESTIMATES

REACH NAME	**UTR Sunset reach 6**	
Date of estimate	1/7/2014	
	PRE RESTORE	**POST RESTORE**
Channel length (m)	1163	1472
Outside BEND length (m)	457.8	831.5
STRAIGHT length (m)	705.5	640.9
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174

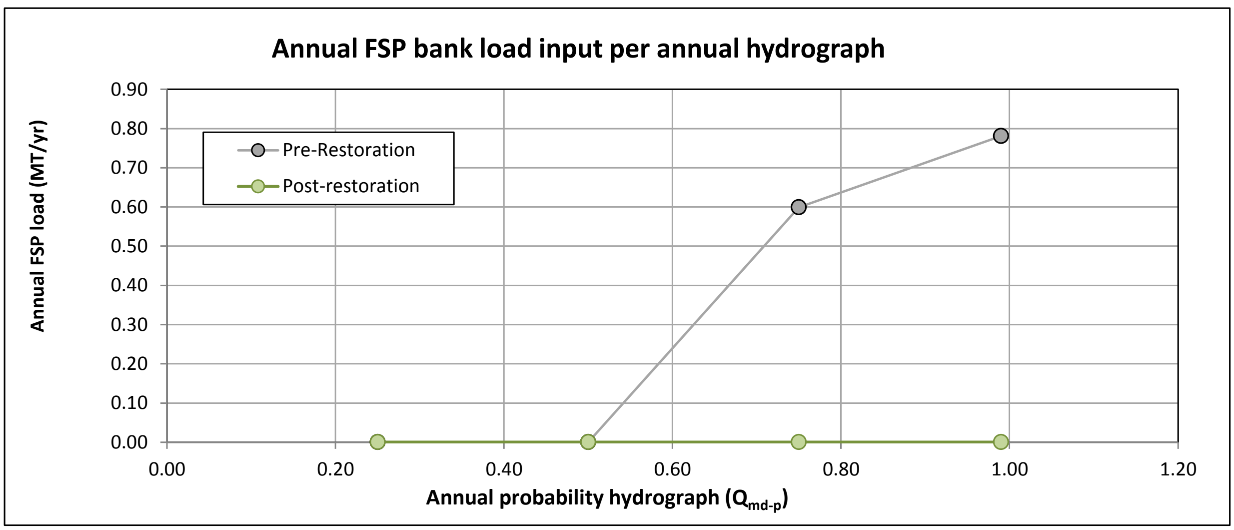
Dynamic BSTEM results

	PRE RESTORE	POST RESTORE	Q_{md-p}
Bulk sediment Outside bend unit erosion rate (m3/m/yr)	0.0100	0.0000	99th
	0.0000	0.0000	75th
	0.0000	0.0000	50th
	0.0000	0.0000	25th
Bulk sediment Straight reach unit erosion rate (m3/m/yr)	0.0150	0.0000	99th
	0.0140	0.0000	75th
	0.0000	0.0000	50th
	0.0000	0.0000	25th

	PRE RESTORE	POST RESTORE
Average annual bank erosion rate (m^3/km/yr)	1.41	0.00

SEZ Channel Erosion Results

	PRE RESTORE	POST RESTORE	% reduction
Average annual bulk sediment generated (MT/yr)	2.85	0.00	100%
Average annual FSP load generated (MT/yr)	0.050	0.000	
Average annual FSP load reduction (MT/yr)	0.050		



STREAM LOAD REDUCTION TOOL (SLRTv2)
Results Summary

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	Upper Truckee
REACH NAME	UTR Sunset reach 6
Date of Estimate	1/7/2014
CATCHMENT TYPE	Non Urban
REGION	Mainstem UTR
SUB-REGION	Southwest
CATCHMENT AREA	50.3
AREA UNITS	Sq-miles
CATCHMENT % IMPERVIOUS	
CATCHMENT LAND USE CONDITION	0

USER INPUTS

	PRE-RESTORATION	POST-RESTORATION	*CHANGE*	*% CHANGE*
Channel length (m)	1163	1472	309	27%
Channel slope (m/m)	0.001	0.0008	-0.0002	-20%
Outside BEND length (m)	457.8	831.5	373.7	82%
BEND bank height (m)	1	1.2	0.2	20%
BEND bank angle (degrees)	51	25	-26	-51%
STRAIGHT length (m)	705.5	640.9	-64.6	-9%
Bank height of STRAIGHT reaches (m)	1.1	1.2	0.1	9%
Bank angle of STRAIGHT reaches (degrees)	21	28	7	33%
Manning's roughness value of channel	0.03	0.03	0	0%
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174	0	0%
Channel capacity (cfs)	700	450	-250	-36%
Floodplain length (m)	930	930	0	0%
Floodplain condition score	3	5	2	2

SLRT OUTPUTS

AVERAGE ANNUAL ESTIMATES	PRE-RESTORATION	POST-RESTORATION	*CHANGE*	*% CHANGE*	
Predicted FSP catchment load (MT/yr)	481.11	481.11	0	0%	IN_{fsp} (MT/yr)
Predicted FSP load delivered to floodplain (MT/yr)	27.78	65.24	37.5	135%	DFP_{fsp} (MT/yr)
Predicted FSP load retained on floodplain (MT/yr)	8.46	20.87	12.4	147%	RFP_{fsp} (MT/yr)
Predicted FSP load from channel erosion (MT/yr)	0.05	0.00	-0.05	-100%	SCE_{fsp} (MT/yr)
Predicted FSP load at downstream boundary (MT/yr)	472.70	460.24	-12.46	-3%	OUT_{fsp} (MT/yr)

12.46 **Average annual FSP Load Reduction (MT/yr)** SEZ LR_{fsp} (MT/yr)

8.46 **Average annual FSP Load Reduction (MT/yr/km)**

SLRTv2 created by 2NDNATURE LLC (2014) SLRT RESULTS SUMMARY [3/20/2014]

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2NDNATURE | LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

UTR Sunset Reach 5 Project Summary

Current Conditions: The restoration efforts on UTR Sunset Reach 5 are currently in the process of being implemented. The project intent is to increase the frequency and duration of out of bank events and reduce channel erosion.

Lower section of UTR Sunset Reach 5, looking downstream. 2013.

Lower section of UTR Sunset Reach 5, looking upstream. 2013.

View of erosion on outer bend of UTR on Sunset Reach 5. 2013.

View of eroded bank on UTR Sunset Reach 5. 2013.

Plans and Modeling: UTR Sunset Reach 5 models estimated an 85% reduction in predicted FSP load from channel erosion. Geomporphic changes in the channel reducing the channel capacity and improving floodplain conditions are predicted to result in the floodplain retention of an additional 26.1 MT/yr of FSP.

STREAM LOAD REDUCTION TOOL (SLRTv2)
User Inputs

META DATA

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	Upper Truckee
REACH NAME	**UTR Sunset reach 5**
Date of Estimate	1/7/2014

CATCHMENT CHARACTERISTICS

CATCHMENT TYPE	Non Urban	
REGION	Mainstem UTR	
SUB-REGION	Southwest	
CATCHMENT AREA	51.3	
AREA UNITS	Sq-miles	
CATCHMENT % IMPERVIOUS		Urban Only
CATCHMENT LAND USE CONDITION		Urban Only

SEZ ATTRIBUTES

	PRE-RESTORATION		POST-RESTORATION
Channel length (m)	2261.7	l_c	2261.5
Channel slope (m/m)	0.0011	s	0.0011
Outside BEND length (m)	1165.8	l_{ob}	1137.1
BEND bank height (m)	1.5	h_{ob}	0.9
BEND bank angle (degrees)	72	a_{ob}	23
BEND toe length (m)	1.6	tl_{ob}	1.2
BEND toe angle (degrees)	11	ta_{ob}	7
STRAIGHT length (m)	1096	l_{str}	1124.4
Bank height of STRAIGHT reaches (m)	1.5	h_{str}	1.2
Bank angle of STRAIGHT reaches (degrees)	6	a_{str}	66
STRAIGHT reach toe length (m)	1.6	tl_{str}	1
STRAIGHT reach toe angle (degrees)	7	ta_{str}	2
Manning's roughness value of channel	0.03	*n*	0.03
Fines to bulk sediment ratio (0-1 value)	0.0174	FSP:BS	0.0174
Channel capacity (cfs)	900	Q_{cc}	370
Floodplain length (m)	1213	l_{fp}	1213
Floodplain condition score	3	FPC	5
Effective cohesion (kPa)	3.8	c'	3.8
Angle of internal friction (degrees)	30.9	ϕ'	30.9
Bulk unit weight (kN/m^3)	17.1	γ	17.1
Matric suction parameter (degrees)	10.0	ϕ^b	10.0
Bank - Critical shear stress (Pa)	3.00	τ_c	3.00
Bank - Erodibility coefficient (cm^3/Ns)	0.645	*k*	0.645
Toe - Critical shear stress (Pa)	21.4	τ_c	21.4
Toe - Erodibility coefficient (cm^3/Ns)	0.127	*k*	0.127

BSTEM Dynamic OUTPUT

	PRE-RESTORATION		POST-RESTORATION	Q_{md-p}
Outside bend unit erosion rate (m^3/m/yr)	0.249	e_{ob-99}	0.033	99th
	0.101	e_{ob-75}	0.028	75th
	0.139	e_{ob-50}	0.003	50th
	0.050	e_{ob-25}	0.039	25th
Straight reach unit erosion rate (m^3/m/yr)	1.994	e_{str-99}	0.060	99th
	0	e_{str-75}	0.049	75th
	0	e_{str-50}	0.046	50th
	0	e_{str-25}	0.019	25th

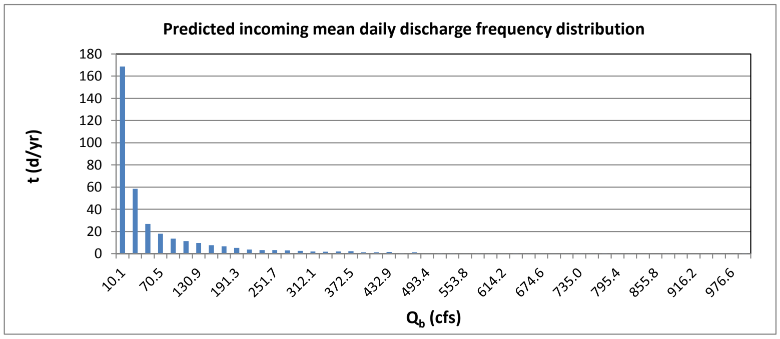
SLRTv2 created by 2NDNATURE LLC 2014

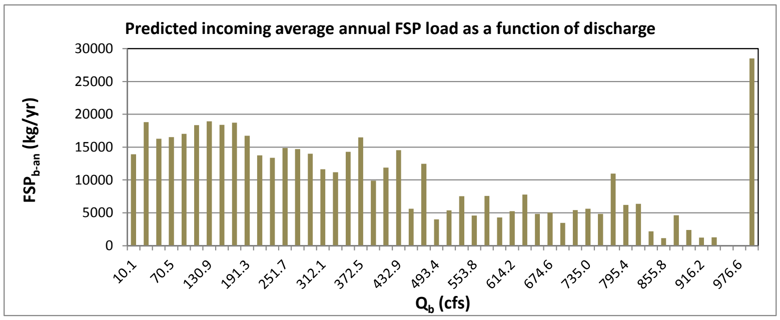
USER INPUT [3/20/2014]

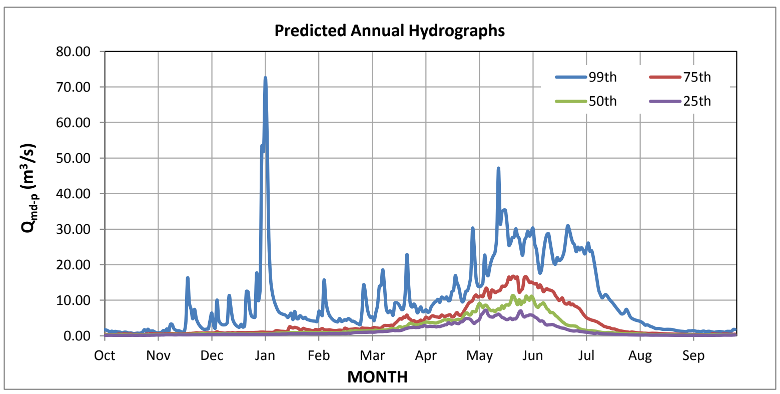
STREAM LOAD REDUCTION TOOL (SLRTv2)
Predicted catchment hydrology and FSP loads

SEZ NAME: **UTR Sunset reach 5**

CALCULATIONS		
NAME	VALUE	VARIABLE
Mean Annual Precip (in)	29.91	P
Total Area (sq mi or acres)	51.3	A
Total Impervious Area (acres)- urban only	0.0	A_i
Bin Interval (cfs)	20.137	Q_{bi}
Regional Coefficient	0.003	R
Max Mean Daily Q (cfs)	2946.02	Q_{max}
Bin 50 Value (cfs)	1966.36	Q_{b-50}
FSP CRC (mg/L) - Urban only	n/a	V_{in}
Bin Interval (cfs)	20.14	Q_{bi}
FSP CRC (mg/L) - Urban only	n/a	FSP_C
Average annual discharge volume (ac-ft/yr)	51849.3	V_{in}
Average annual FSP load into SEZ (MT/yr)	493.0	FSP_{in}

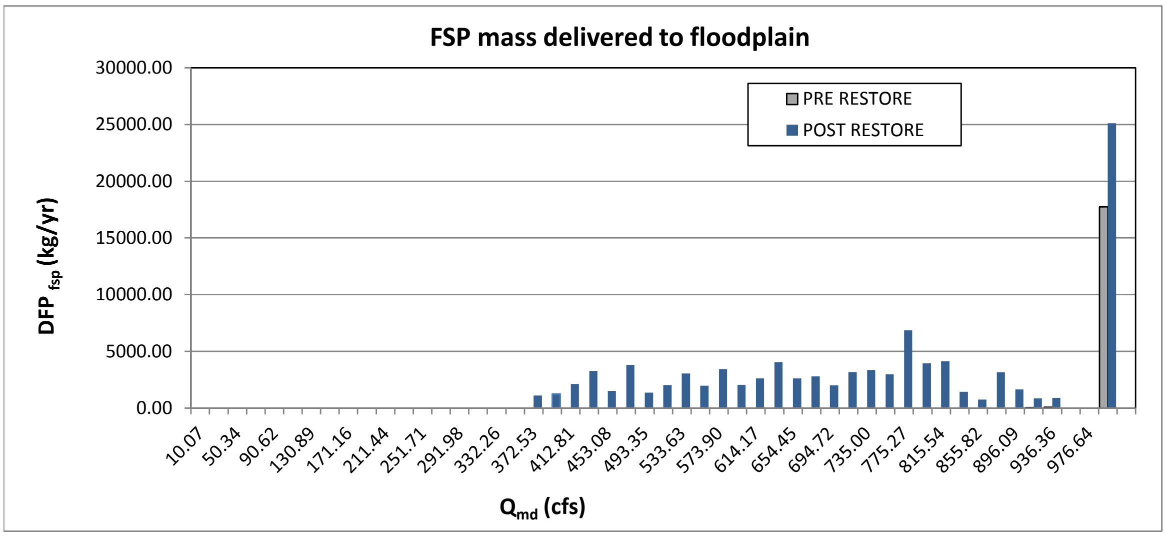


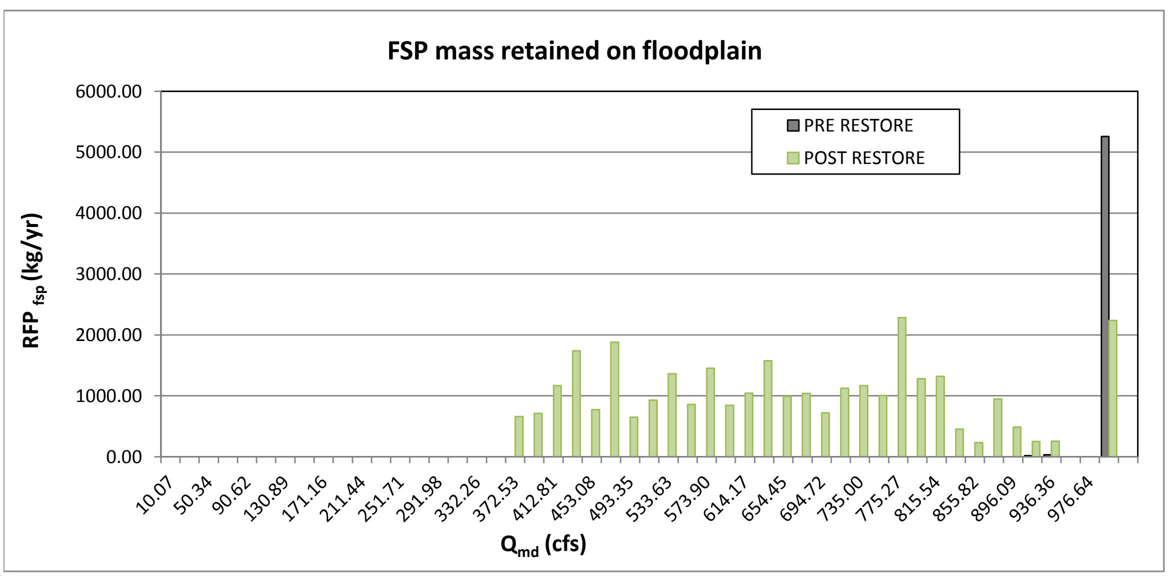




STREAM LOAD REDUCTION TOOL (SLRTv2)
FLOODPLAIN RETENTION ESTIMATES

REACH NAME	**UTR Sunset reach 5**		
Date of estimate	1/7/2014		
	PRE RESTORE	**POST RESTORE**	VARIABLES
Channel length (m)	2261.7	2261.5	*l*
Channel slope (m/m)	0.0011	0.0011	*s*
Channel capacity (cfs)	900	370	Q_{cc}
Floodplain condition score	3	5	FPC
Average days overbank (d/yr)	0.6	16.6	t_{ob}
Channel FSP load (kg/d)	21529	6767	FSP_{cc}
Catchment FSP load (MT/yr)	493.00		FSP_{in}
Delivered to floodplain (MT/yr)	17.85	99.18	DFP_{fsp}
Retained on floodplain (MT/yr)	5.30	31.41	RFP_{fsp}





STREAM LOAD REDUCTION TOOL (SLRTv2)
SEZ CHANNEL EROSION ESTIMATES

REACH NAME	**UTR Sunset reach 5**	
Date of estimate	1/7/2014	
	PRE RESTORE	**POST RESTORE**
Channel length (m)	2261.7	2261.5
Outside BEND length (m)	1165.8	1137.1
STRAIGHT length (m)	1096	1124.4
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174

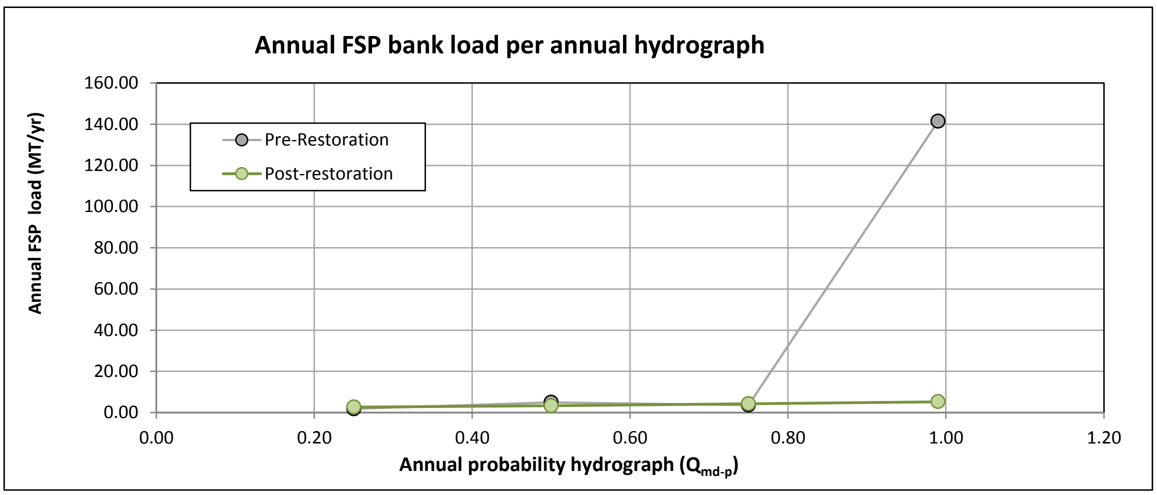
Dynamic BSTEM results

	PRE RESTORE	POST RESTORE	Q_{md-p}
Bulk sediment Outside bend unit erosion rate (m3/m/yr)	0.2490	0.0334	99th
	0.1010	0.0277	75th
	0.1390	0.0034	50th
	0.0500	0.0390	25th
Bulk sediment Straight reach unit erosion rate (m3/m/yr)	1.9940	0.0602	99th
	0.0000	0.0490	75th
	0.0000	0.0460	50th
	0.0000	0.0190	25th

	PRE RESTORE	POST RESTORE
Average annual bank erosion rate (m^3/km/yr)	61.01	9.36

SEZ Channel Erosion Results

	PRE RESTORE	POST RESTORE	% reduction
Average annual bulk sediment generated (MT/yr)	240.59	36.91	85%
Average annual FSP load generated (MT/yr)	4.186	0.642	
Average annual FSP load reduction (MT/yr)	3.544		



SLRTv2 created by 2NDNATURE LLC and A. Simon 2014

Average annual channel erosion estimates [2/24/2014]

STREAM LOAD REDUCTION TOOL (SLRTv2)
Results Summary

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	Upper Truckee
REACH NAME	UTR Sunset reach 5
Date of Estimate	1/7/2014
CATCHMENT TYPE	Non Urban
REGION	Mainstem UTR
SUB-REGION	Southwest
CATCHMENT AREA	51.3
AREA UNITS	Sq-miles
CATCHMENT % IMPERVIOUS	
CATCHMENT LAND USE CONDITION	0

USER INPUTS

	PRE-RESTORATION	POST-RESTORATION	*CHANGE*	*% CHANGE*
Channel length (m)	2261.7	2261.5	-0.2	0%
Channel slope (m/m)	0.0011	0.0011	0	0%
Outside BEND length (m)	1165.8	1137.1	-28.7	-2%
BEND bank height (m)	1.5	0.9	-0.6	-40%
BEND bank angle (degrees)	72	23	-49	-68%
STRAIGHT length (m)	1096	1124.4	28.4	3%
Bank height of STRAGHT reaches (m)	1.5	1.2	-0.3	-20%
Bank angle of STRAIGHT reaches (degrees)	6	66	60	1000%
Manning's roughness value of channel	0.03	0.03	0	0%
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174	0	0%
Channel capacity (cfs)	900	370	-530	-59%
Floodplain length (m)	1213	1213	0	0%
Floodplain condition score	3	5	2	2

SLRT OUTPUTS

AVERAGE ANNUAL ESTIMATES	PRE-RESTORATION	POST-RESTORATION	*CHANGE*	*% CHANGE*	
Predicted FSP catchment load (MT/yr)	493.00	493.00	0	0%	IN_{fsp} (MT/yr)
Predicted FSP load delivered to floodplain (MT/yr)	17.85	99.18	81.3	456%	DFP_{fsp} (MT/yr)
Predicted FSP load retained on floodplain (MT/yr)	5.30	31.41	26.1	492%	RFP_{fsp} (MT/yr)
Predicted FSP load from channel erosion (MT/yr)	4.19	0.64	-3.54	-85%	SCE_{fsp} (MT/yr)
Predicted FSP load at downstream boundary (MT/yr)	491.88	462.23	-29.65	-6%	OUT_{fsp} (MT/yr)

29.65 **Average annual FSP Load Reduction (MT/yr)** SEZ LR_{fsp} (MT/yr)

13.11 **Average annual FSP Load Reduction (MT/yr/km)**

DESIGNED BY
2NDNATURE LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

UTR Airport Project Summary

Current Conditions: The UTR Airport reach restoration construction was completed in 2011. The previous channel was a straight and incised adjacent to the South Lake Tahoe Airport. The channel capacity and sinuosity of the restored channel are much closer to expected functional conditions given incoming hydrology and sediment loads. Wood structures and depressions were created on the floodplain in an effort to increase the topographic complexity. It is expected that the meadow vegetation will transition into a more mesic meadow complex following some above average water years.


Upper section of Upper Truckee River Airport Reach, looking downstream. Post-project condition.


Upper section of Upper Truckee River Airport Reach, looking upstream. Post-project condition.


Restoration planting and stabilized bank. Post-project condition.


Bank stabilization along restored channel. Post-project condition.

Plans and Modeling: Bank erosion was reduced on the pre-restored channel using placement of significant rip rap.The pre-project was modeled with a higher Mannings number to simulate these stable bank conditions. The restoration reduced the hardness of the banks resulting in an increase in stream bank input post project, which is desired and expected. Given the lateral confinement of the floodplain by a hillslope right and airport left, the post restoration floodplain condition is expected to be moderate.

STREAM LOAD REDUCTION TOOL (SLRTv2)

User Inputs

META DATA

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	Upper Truckee
REACH NAME	**UTR Airport**
Date of Estimate	1/7/2014

CATCHMENT CHARACTERISTICS

CATCHMENT TYPE	Non Urban	
REGION	Mainstem UTR	
SUB-REGION	Southwest	
CATCHMENT AREA	52.3	
AREA UNITS	Sq-miles	
CATCHMENT % IMPERVIOUS		Urban Only
CATCHMENT LAND USE CONDITION		Urban Only

SEZ ATTRIBUTES

	PRE-RESTORATION		POST-RESTORATION
Channel length (m)	1126.5	l_c	1259.8
Channel slope (m/m)	0.0008	s	0.0007
Outside BEND length (m)	196.6	l_{ob}	762.2
BEND bank height (m)	1.8	h_{ob}	1.7
BEND bank angle (degrees)	22	a_{ob}	19
BEND toe length (m)	1	tl_{ob}	1
BEND toe angle (degrees)	1	ta_{ob}	2
STRAIGHT length (m)	930	l_{str}	497.6
Bank height of STRAIGHT reaches (m)	2	h_{str}	1.3
Bank angle of STRAIGHT reaches (degrees)	22	a_{str}	30
STRAIGHT reach toe length (m)	1	tl_{str}	2.2
STRAIGHT reach toe angle (degrees)	1	ta_{str}	3
Manning's roughness value of channel	0.07	*n*	0.03
Fines to bulk sediment ratio (0-1 value)	0.0174	FSP:BS	0.0174
Channel capacity (cfs)	1200	Q_{cc}	590
Floodplain length (m)	1050	l_{fp}	1050
Floodplain condition score	1	FPC	3
Effective cohesion (kPa)	3.8	c'	3.8
Angle of internal friction (degrees)	30.9	ϕ'	30.9
Bulk unit weight (kN/m^3)	17.1	γ	17.1
Matric suction parameter (degrees)	10.0	ϕ^b	10.0
Bank - Critical shear stress (Pa)	3.00	τ_c	3.00
Bank - Erodibility coefficient (cm^3/Ns)	0.645	*k*	0.645
Toe - Critical shear stress (Pa)	21.4	τ_c	21.4
Toe - Erodibility coefficient (cm^3/Ns)	0.127	*k*	0.127

BSTEM Dynamic OUTPUT

	PRE-RESTORATION		POST-RESTORATION	Q_{md-p}
Outside bend unit erosion rate (m^3/m/yr)	0	e_{ob-99}	0.150	99th
	0	e_{ob-75}	0.030	75th
	0	e_{ob-50}	0.049	50th
	0	e_{ob-25}	0	25th
Straight reach unit erosion rate (m^3/m/yr)	0	e_{str-99}	0.145	99th
	0	e_{str-75}	0.032	75th
	0	e_{str-50}	0.049	50th
	0	e_{str-25}	0	25th

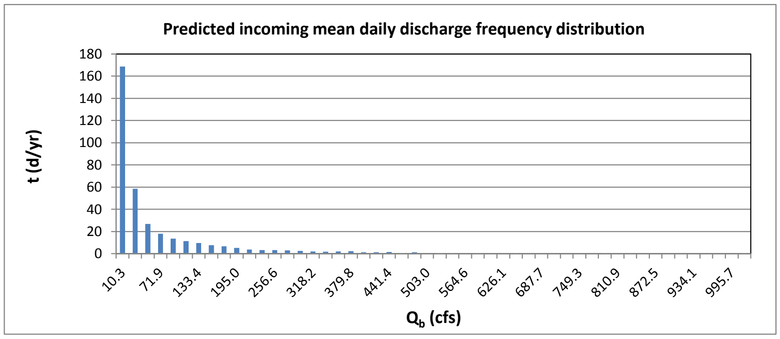
SLRTv2 created by 2NDNATURE LLC 2014

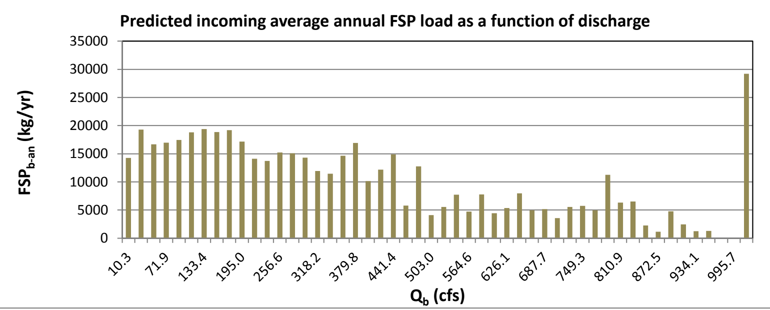
USER INPUT [3/20/2014]

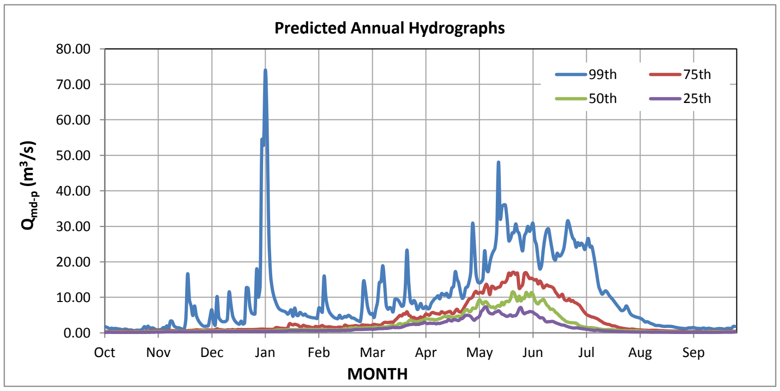
STREAM LOAD REDUCTION TOOL (SLRTv2)
Predicted catchment hydrology and FSP loads

SEZ NAME: **UTR Airport**

CALCULATIONS		
NAME	VALUE	VARIABLE
Mean Annual Precip (in)	29.91	P
Total Area (sq mi or acres)	52.3	A
Total Impervious Area (acres)- urban only	0.0	A_i
Bin Interval (cfs)	20.529	Q_{bi}
Regional Coefficient	0.003	R
Max Mean Daily Q (cfs)	3003.44	Q_{max}
Bin 50 Value (cfs)	2004.69	Q_{b-50}
FSP CRC (mg/L) - Urban only	n/a	V_{in}
Bin Interval (cfs)	20.53	Q_{bi}
FSP CRC (mg/L) - Urban only	n/a	FSP_C
Average annual discharge volume (ac-ft/yr)	52860.0	V_{in}
Average annual FSP load into SEZ (MT/yr)	504.9	FSP_{in}







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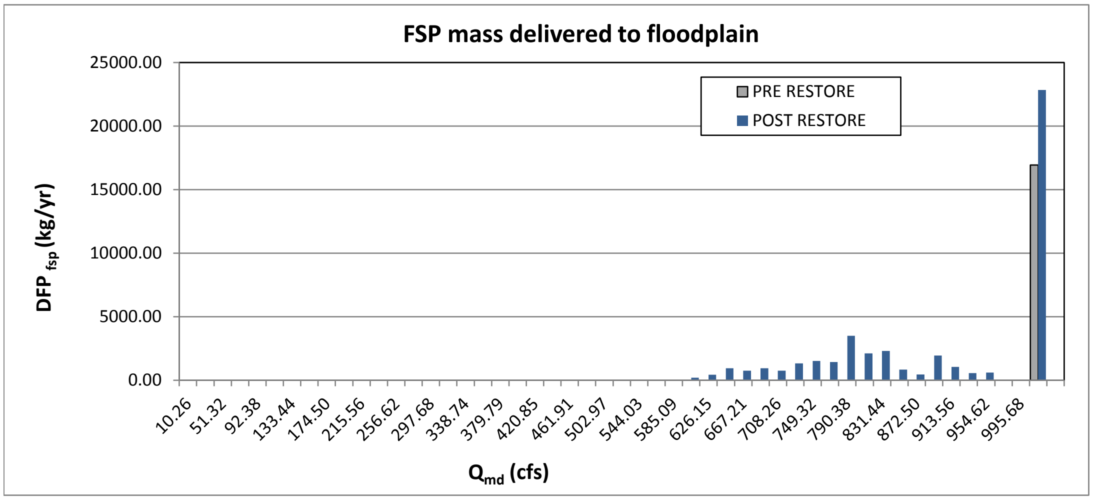
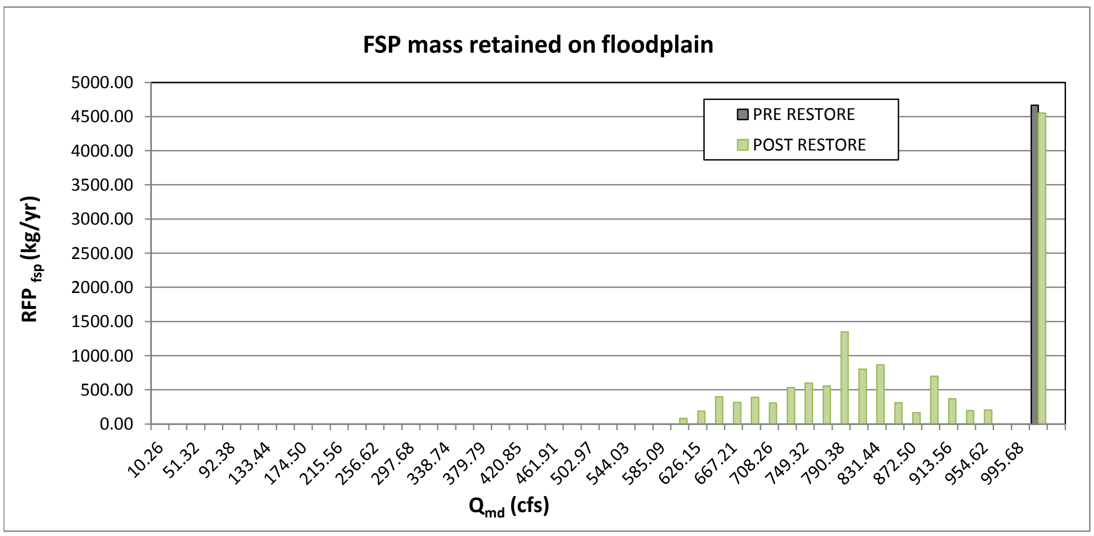
2NDNATURE LLC
TEL: 831.426.9119
FAX: 831.426.7092
www.2ndnaturellc.com

STREAM LOAD REDUCTION TOOL (SLRTv2)
FLOODPLAIN RETENTION ESTIMATES

REACH NAME	UTR Airport		
Date of estimate	1/7/2014		
	PRE RESTORE	POST RESTORE	VARIABLES
Channel length (m)	1126.5	1259.8	l
Channel slope (m/m)	0.0008	0.0007	s
Channel capacity (cfs)	1200	590	Q_{cc}
Floodplain condition score	1	3	FPC
Average days overbank (d/yr)	0.5	5.5	t_{ob}
Channel FSP load (kg/d)	24534	12690	FSP_{cc}
Catchment FSP load (MT/yr)	504.94		FSP_{in}
Delivered to floodplain (MT/yr)	16.94	44.45	DFP_{fsp}
Retained on floodplain (MT/yr)	4.67	12.88	RFP_{fsp}





SLRTv2 created by 2NDNATURE LLC (2014)

Average annual floodplain retention estimates [3/20/2014]

STREAM LOAD REDUCTION TOOL (SLRTv2)
SEZ CHANNEL EROSION ESTIMATES

REACH NAME	**UTR Airport**	
Date of estimate	1/7/2014	
	PRE RESTORE	**POST RESTORE**
Channel length (m)	1126.5	1259.8
Outside BEND length (m)	196.6	762.2
STRAIGHT length (m)	930	497.6
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174

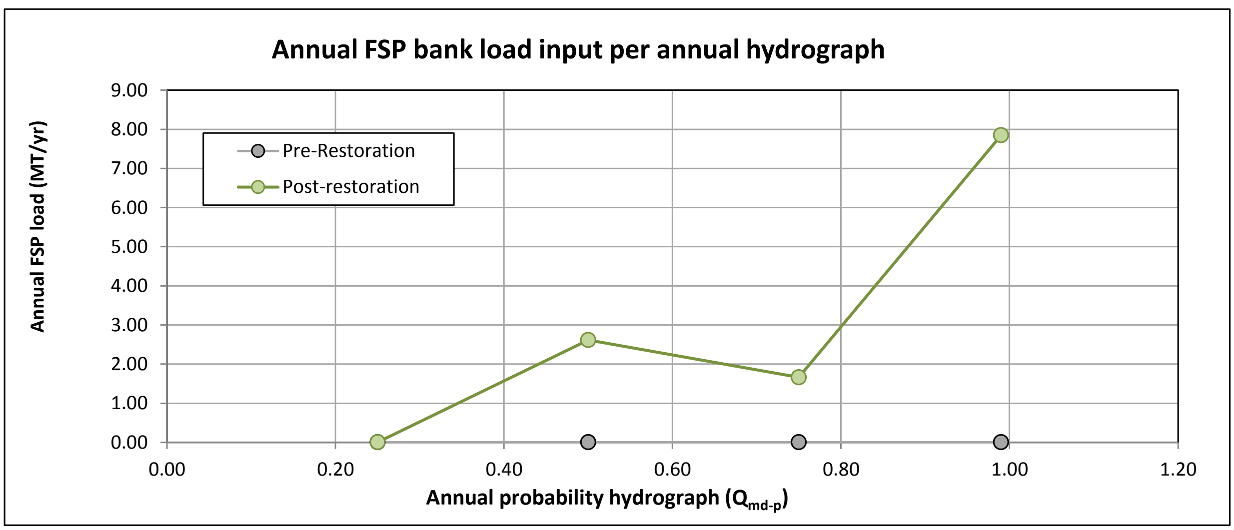
Dynamic BSTEM results

	PRE RESTORE	POST RESTORE	Q_{md-p}
Bulk sediment Outside bend unit erosion rate (m3/m/yr)	0.0000	0.1500	99th
	0.0000	0.0300	75th
	0.0000	0.0490	50th
	0.0000	0.0000	25th
Bulk sediment Straight reach unit erosion rate (m3/m/yr)	0.0000	0.1450	99th
	0.0000	0.0320	75th
	0.0000	0.0490	50th
	0.0000	0.0000	25th

	PRE RESTORE	POST RESTORE
Average annual bank erosion rate (m^3/km/yr)	0.00	12.17

SEZ Channel Erosion Results

	PRE RESTORE	POST RESTORE	% reduction
Average annual bulk sediment generated (MT/yr)	0.00	23.91	#DIV/0!
Average annual FSP load generated (MT/yr)	0.000	0.416	
Average annual FSP load reduction (MT/yr)	-0.416		



SLRTv2 created by 2NDNATURE LLC and A. Simon 2014

Average annual channel erosion estimates [2/10/2014]

STREAM LOAD REDUCTION TOOL (SLRTv2)
Results Summary

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	Upper Truckee
REACH NAME	UTR Airport
Date of Estimate	1/7/2014
CATCHMENT TYPE	Non Urban
REGION	Mainstem UTR
SUB-REGION	Southwest
CATCHMENT AREA	52.3
AREA UNITS	Sq-miles
CATCHMENT % IMPERVIOUS	
CATCHMENT LAND USE CONDITION	0

USER INPUTS

	PRE-RESTORATION	POST-RESTORATION	*CHANGE*	*% CHANGE*
Channel length (m)	1126.5	1259.8	133.3	12%
Channel slope (m/m)	0.0008	0.0007	-0.0001	-13%
Outside BEND length (m)	196.6	762.2	565.6	288%
BEND bank height (m)	1.8	1.7	-0.1	-6%
BEND bank angle (degrees)	22	19	-3	-14%
STRAIGHT length (m)	930	497.6	-432.4	-46%
Bank height of STRAIGHT reaches (m)	2	1.3	-0.7	-35%
Bank angle of STRAIGHT reaches (degrees)	22	30	8	36%
Manning's roughness value of channel	0.07	0.03	-0.04	-57%
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174	0	0%
Channel capacity (cfs)	1200	590	-610	-51%
Floodplain length (m)	1050	1050	0	0%
Floodplain condition score	1	3	2	2

SLRT OUTPUTS

AVERAGE ANNUAL ESTIMATES	PRE-RESTORATION	POST-RESTORATION	*CHANGE*	*% CHANGE*	
Predicted FSP catchment load (MT/yr)	504.94	504.94	0	0%	IN_{fsp} (MT/yr)
Predicted FSP load delivered to floodplain (MT/yr)	16.94	44.45	27.5	162%	DFP_{fsp} (MT/yr)
Predicted FSP load retained on floodplain (MT/yr)	4.67	12.88	8.2	176%	RFP_{fsp} (MT/yr)
Predicted FSP load from channel erosion (MT/yr)	0.00	0.42	0.42	#DIV/0!	SCE_{fsp} (MT/yr)
Predicted FSP load at downstream boundary (MT/yr)	500.28	492.48	-7.80	-2%	OUT_{fsp} (MT/yr)

7.80 **Average annual FSP Load Reduction (MT/yr)** SEZ LR_{fsp} (MT/yr)

6.19 **Average annual FSP Load Reduction (MT/yr/km)**

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2NDNATURE LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

UTR Middle Reach 1&2 Project Summary

Current Conditions: Middle Reach 1 & 2 is currently in the planning stage. Currently the UTR has a flow split at the upstream boundary, flowing into two separate channels: termed Main and Gully. The gully in particular is extremely incised and in existing conditions, overbank flows are rare. Recent field observations of the Gully suggest signficant amounts of bank failure and erosion. The restoration alternative modeled by SLRT assumes the Gully will be abandoned and filled and all flows at the upstream boundary will be routed through the Main channel.

Lower section of Upper Truckee River Middle Reach 1&2, looking downstream in Mainstem. 2013

Upper section of Upper Truckee River Middle Reach 1&2, looking upstream in Gully. 2013

Upper section of Upper Truckee River Middle Reach 1&2, looking upstream in Mainstem. 2013.

Middle section of Upper Truckee River Middle Reach 1&2, view of bank erosion in Gully. 2013.

Plans and Modeling: A 2004 HEC-RAS model provided by ENTRIX models the flow split as 60/40 between the mainstem and gully, respectively. The flow percentages were incorporated into BSTEM and SLRT flow modeling to reflect this flow divide for pre-restoration BSTEM runs. Each channel had its own respective SLRT input data processed similarly to other projects. The post-restoration modeling used the same input geometry for the mainstem channel, but did not distribute the incoming hydrology between the two reaches. The modeling results suggest substantial decreases in channel erosion along with much improved interaction with the floodplain.

STREAM LOAD REDUCTION TOOL (SLRTv2)
User Inputs

META DATA

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	Upper Truckee
REACH NAME	**UTR Middle Reaches 1 & 2 - Main**
Date of Estimate	1/17/2014

CATCHMENT CHARACTERISTICS

CATCHMENT TYPE	Non Urban	
REGION	Mainstem UTR	
SUB-REGION	Southwest	
CATCHMENT AREA	53.7	
AREA UNITS	Sq-miles	
CATCHMENT % IMPERVIOUS		Urban Only
CATCHMENT LAND USE CONDITION		Urban Only

SEZ ATTRIBUTES

	PRE-RESTORATION		POST-RESTORATION
Channel length (m)	1334	l_c	
Channel slope (m/m)	0.0015	s	
Outside BEND length (m)	514.6	l_{ob}	
BEND bank height (m)	1.2	h_{ob}	
BEND bank angle (degrees)	48	a_{ob}	
BEND toe length (m)	0.8	tl_{ob}	
BEND toe angle (degrees)	10	ta_{ob}	
STRAIGHT length (m)	819.5	l_{str}	
Bank height of STRAIGHT reaches (m)	1.4	h_{str}	
Bank angle of STRAIGHT reaches (degrees)	53	a_{str}	
STRAIGHT reach toe length (m)	1	tl_{str}	
STRAIGHT reach toe angle (degrees)	7	ta_{str}	
Manning's roughness value of channel	0.03	n	
Fines to bulk sediment ratio (0-1 value)	0.0174	FSP:BS	
Channel capacity (cfs)	500	Q_{cc}	
Floodplain length (m)	955	l_{fp}	
Floodplain condition score	3	FPC	
Effective cohesion (kPa)	3.8	c'	
Angle of internal friction (degrees)	30.9	ϕ'	
Bulk unit weight (kN/m^3)	17.1	γ	
Matric suction parameter (degrees)	10.0	ϕ^b	
Bank - Critical shear stress (Pa)	3.00	τ_c	
Bank - Erodibility coefficient (cm^3/Ns)	0.645	k	
Toe - Critical shear stress (Pa)	21.4	τ_c	
Toe - Erodibility coefficient (cm^3/Ns)	0.127	k	

BSTEM Dynamic OUTPUT

	PRE-RESTORATION		POST-RESTORATION	Q_{md-p}
Outside bend unit erosion rate (m^3/m/yr)	0.125	e_{ob-99}		99th
	0.088	e_{ob-75}		75th
	0.04	e_{ob-50}		50th
	0.01	e_{ob-25}		25th
Straight reach unit erosion rate (m^3/m/yr)	0.175	e_{str-99}		99th
	0.111	e_{str-75}		75th
	0.061	e_{str-50}		50th
	0.036	e_{str-25}		25th

SLRTv2 created by 2NDNATURE LLC 2014

USER INPUT [3/20/2014]

STREAM LOAD REDUCTION TOOL (SLRTv2)
User Inputs

META DATA

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	Upper Truckee
REACH NAME	**UTR Middle Reaches 1 & 2 - Gully**
Date of Estimate	1/7/2014

CATCHMENT CHARACTERISTICS

CATCHMENT TYPE	Non Urban	
REGION	Mainstem UTR	
SUB-REGION	Southwest	
CATCHMENT AREA	53.7	
AREA UNITS	Sq-miles	
CATCHMENT % IMPERVIOUS		Urban Only
CATCHMENT LAND USE CONDITION		Urban Only

SEZ ATTRIBUTES

	PRE-RESTORATION		POST-RESTORATION
Channel length (m)	1036.9	l_c	
Channel slope (m/m)	0.0019	s	
Outside BEND length (m)	400.3	l_{ob}	
BEND bank height (m)	2.7	h_{ob}	
BEND bank angle (degrees)	75	a_{ob}	
BEND toe length (m)	2.3	tl_{ob}	
BEND toe angle (degrees)	15	ta_{ob}	
STRAIGHT length (m)	636.6	l_{str}	
Bank height of STRAIGHT reaches (m)	1.8	h_{str}	
Bank angle of STRAIGHT reaches (degrees)	75	a_{str}	
STRAIGHT reach toe length (m)	2.1	tl_{str}	
STRAIGHT reach toe angle (degrees)	14	ta_{str}	
Manning's roughness value of channel	0.03	*n*	
Fines to bulk sediment ratio (0-1 value)	0.0174	FSP:BS	
Channel capacity (cfs)	1200	Q_{cc}	
Floodplain length (m)	955	l_{fp}	
Floodplain condition score	3	FPC	
Effective cohesion (kPa)	3.8	c'	
Angle of internal friction (degrees)	30.9	ϕ'	
Bulk unit weight (kN/m^3)	17.1	γ	
Matric suction parameter (degrees)	10.0	ϕ^b	
Bank - Critical shear stress (Pa)	3.00	τ_c	
Bank - Erodibility coefficient (cm^3/Ns)	0.645	*k*	
Toe - Critical shear stress (Pa)	21.4	τ_c	
Toe - Erodibility coefficient (cm^3/Ns)	0.127	*k*	

BSTEM Dynamic OUTPUT

	PRE-RESTORATION		POST-RESTORATION	Q_{md-p}
Outside bend unit erosion rate ($m^3/m/yr$)	5.170	e_{ob-99}		99th
	0.030	e_{ob-75}		75th
	0	e_{ob-50}		50th
	0	e_{ob-25}		25th
Straight reach unit erosion rate ($m^3/m/yr$)	5.040	e_{str-99}		99th
	0.019	e_{str-75}		75th
	0.008	e_{str-50}		50th
	0	e_{str-25}		25th

SLRTv2 created by 2NDNATURE LLC 2014

USER INPUT [3/20/2014]

STREAM LOAD REDUCTION TOOL (SLRTv2)
User Inputs

META DATA

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	Upper Truckee River
REACH NAME	**UTR Middle Reach 1&2**
Date of Estimate	1/8/2014

CATCHMENT CHARACTERISTICS

CATCHMENT TYPE	Non Urban	
REGION	Mainstem UTR	
SUB-REGION	Southwest	
CATCHMENT AREA	53.7	
AREA UNITS	Sq-miles	
CATCHMENT % IMPERVIOUS		Urban Only
CATCHMENT LAND USE CONDITION		Urban Only

SEZ ATTRIBUTES

	PRE-RESTORATION		POST-RESTORATION
Channel length (m)		l_c	1334
Channel slope (m/m)		s	0.0015
Outside BEND length (m)		l_{ob}	514.6
BEND bank height (m)		h_{ob}	1.2
BEND bank angle (degrees)		a_{ob}	48
BEND toe length (m)		tl_{ob}	0.8
BEND toe angle (degrees)		ta_{ob}	10
STRAIGHT length (m)		l_{str}	819.5
Bank height of STRAIGHT reaches (m)		h_{str}	1.4
Bank angle of STRAIGHT reaches (degrees)		a_{str}	53
STRAIGHT reach toe length (m)		tl_{str}	1
STRAIGHT reach toe angle (degrees)		ta_{str}	7
Manning's roughness value of channel		n	0.03
Fines to bulk sediment ratio (0-1 value)	0.0174	FSP:BS	0.0174
Channel capacity (cfs)		Q_{cc}	500
Floodplain length (m)		l_{fp}	955
Floodplain condition score		FPC	5
Effective cohesion (kPa)		c'	3.8
Angle of internal friction (degrees)		ϕ'	30.9
Bulk unit weight (kN/m^3)		γ	17.1
Matric suction parameter (degrees)		ϕ^b	10.0
Bank - Critical shear stress (Pa)		τ_c	3.00
Bank - Erodibility coefficient (cm^3/Ns)		k	0.645
Toe - Critical shear stress (Pa)		τ_c	21.4
Toe - Erodibility coefficient (cm^3/Ns)		k	0.127

BSTEM Dynamic OUTPUT

	PRE-RESTORATION		POST-RESTORATION	Q_{md-p}
Outside bend unit erosion rate (m^3/m/yr)		e_{ob-99}	0.154	99th
		e_{ob-75}	0.115	75th
		e_{ob-50}	0.090	50th
		e_{ob-25}	0.046	25th
Straight reach unit erosion rate (m^3/m/yr)		e_{str-99}	0.152	99th
		e_{str-75}	0.109	75th
		e_{str-50}	0.106	50th
		e_{str-25}	0.070	25th

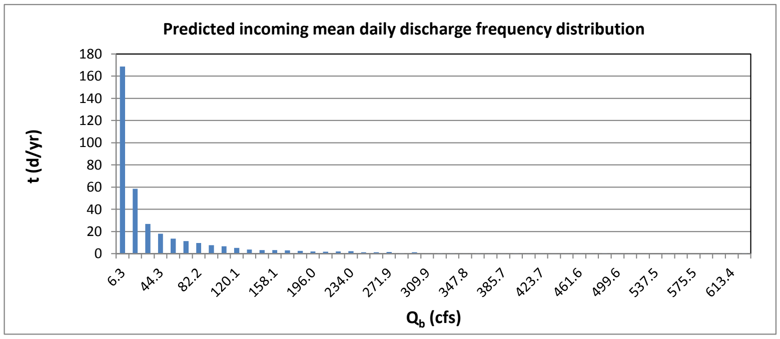
SLRTv2 created by 2NDNATURE LLC 2014

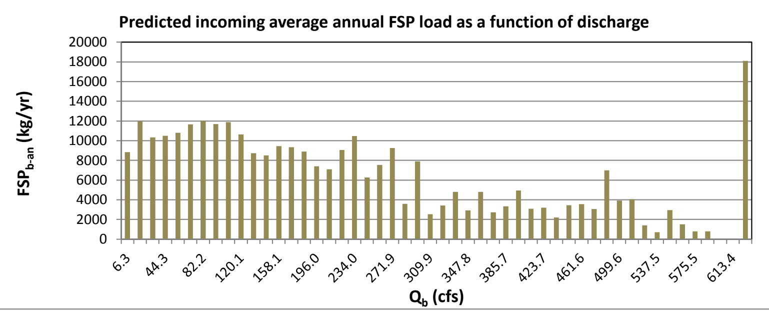
USER INPUT [3/20/2014]

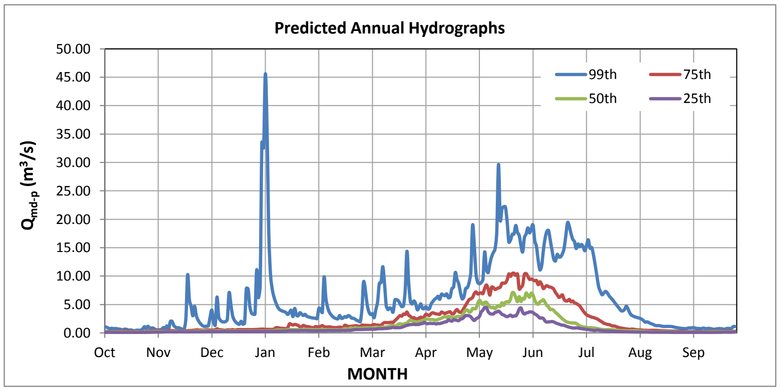
STREAM LOAD REDUCTION TOOL (SLRTv2)
Predicted catchment hydrology and FSP loads

SEZ NAME: **UTR Middle Reaches 1 & 2 - Main**

CALCULATIONS		
NAME	VALUE	VARIABLE
Mean Annual Precip (in)	29.91	P
Total Area (sq mi or acres)	53.7	A
Total Impervious Area (acres)- urban only	0.0	A_i
Bin Interval (cfs)	21.079	Q_{bi}
Regional Coefficient	0.003	R
Max Mean Daily Q (cfs)	3083.84	Q_{max}
Bin 50 Value (cfs)	2058.35	Q_{b-50}
FSP CRC (mg/L) - Urban only	n/a	V_{in}
Bin Interval (cfs)	21.08	Q_{bi}
FSP CRC (mg/L) - Urban only	n/a	FSP_C
Average annual discharge volume (ac-ft/yr)	31357.1	V_{in}
Average annual FSP load into SEZ (MT/yr)	313.1	FSP_{in}







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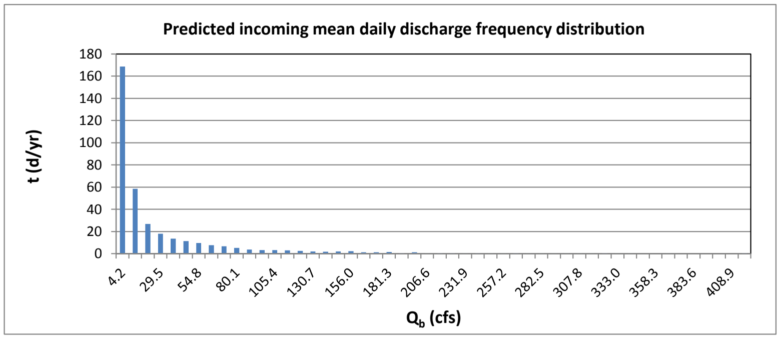
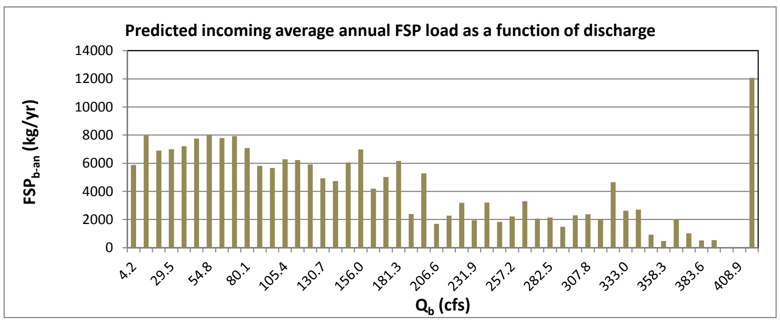
2NDNATURE LLC
TEL: 831.426.9119
FAX: 831.426.7092
www.2ndnaturellc.com

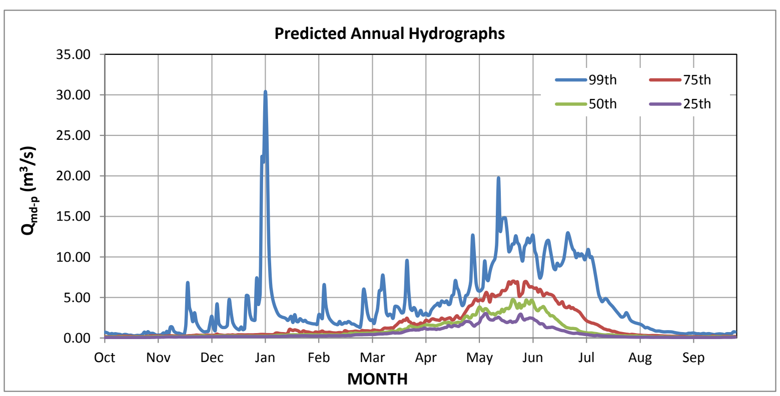
STREAM LOAD REDUCTION TOOL (SLRTv2)
Predicted catchment hydrology and FSP loads

SEZ NAME: **UTR Middle Reaches 1 & 2 - Gully**

CALCULATIONS		
NAME	VALUE	VARIABLE
Mean Annual Precip (in)	29.91	P
Total Area (sq mi or acres)	53.7	A
Total Impervious Area (acres)- urban only	0.0	A_i
Bin Interval (cfs)	21.079	Q_{bi}
Regional Coefficient	0.003	R
Max Mean Daily Q (cfs)	3083.84	Q_{max}
Bin 50 Value (cfs)	2058.35	Q_{b-50}
FSP CRC (mg/L) - Urban only	n/a	V_{in}
Bin Interval (cfs)	21.08	Q_{bi}
FSP CRC (mg/L) - Urban only	n/a	FSP_C
Average annual discharge volume (ac-ft/yr)	21710.0	V_{in}
Average annual FSP load into SEZ (MT/yr)	208.7	FSP_{in}







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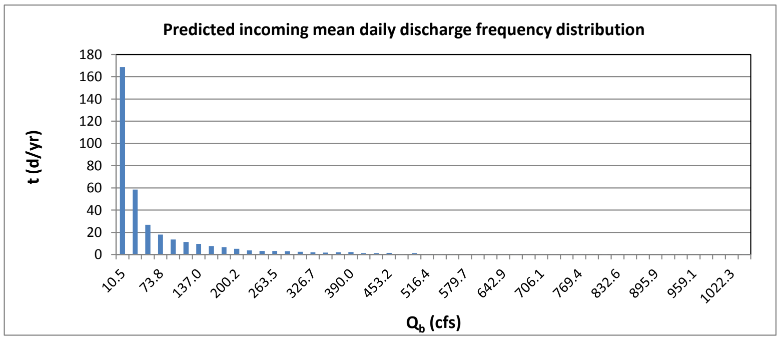
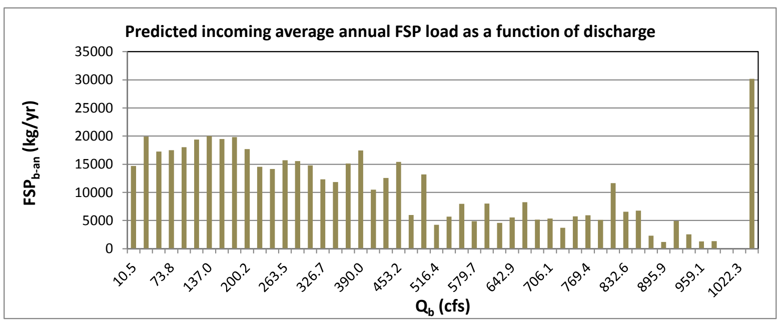
2NDNATURE LLC
TEL: 831.426.9119
FAX: 831.426.7092
www.2ndnaturellc.com

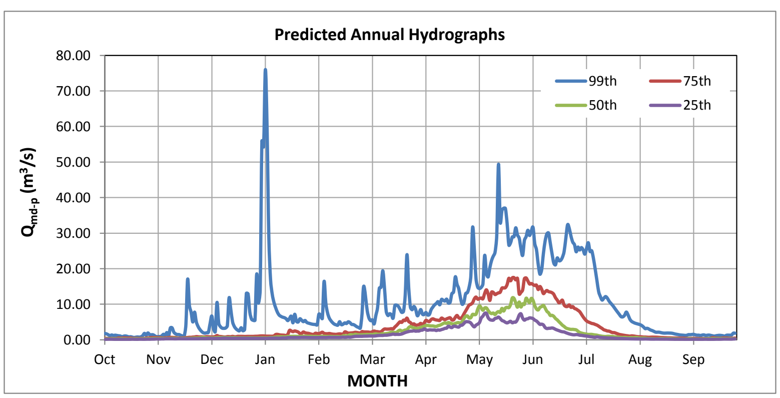
STREAM LOAD REDUCTION TOOL (SLRTv2)
Predicted catchment hydrology and FSP loads

SEZ NAME: **UTR Middle Reach 1&2**

CALCULATIONS		
NAME	VALUE	VARIABLE
Mean Annual Precip (in)	29.91	P
Total Area (sq mi or acres)	53.7	A
Total Impervious Area (acres)- urban only	0.0	A_i
Bin Interval (cfs)	21.079	Q_{bi}
Regional Coefficient	0.003	R
Max Mean Daily Q (cfs)	3083.84	Q_{max}
Bin 50 Value (cfs)	2058.35	Q_{b-50}
FSP CRC (mg/L) - Urban only	n/a	V_{in}
Bin Interval (cfs)	21.08	Q_{bi}
FSP CRC (mg/L) - Urban only	n/a	FSP_C
Average annual discharge volume (ac-ft/yr)	54275.0	V_{in}
Average annual FSP load into SEZ (MT/yr)	521.8	FSP_{in}







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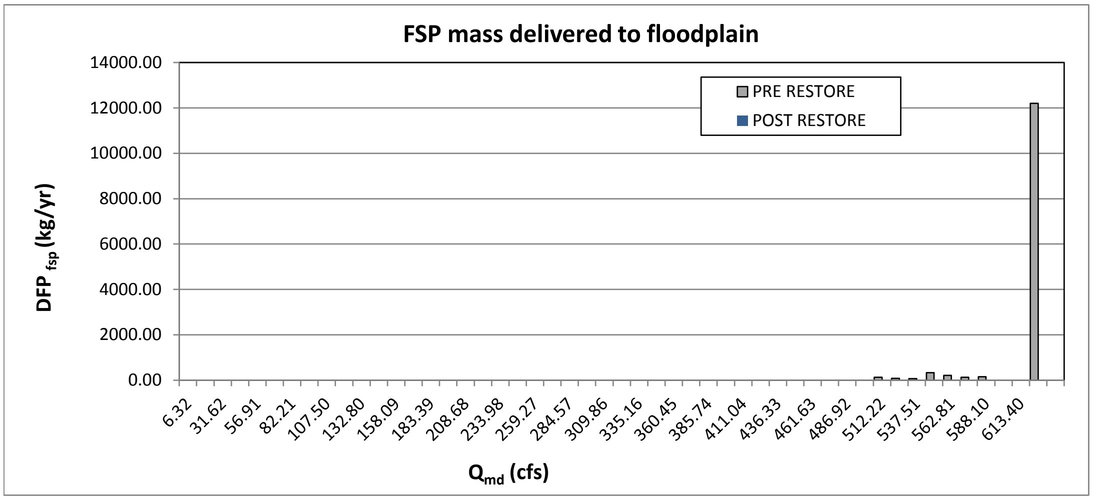
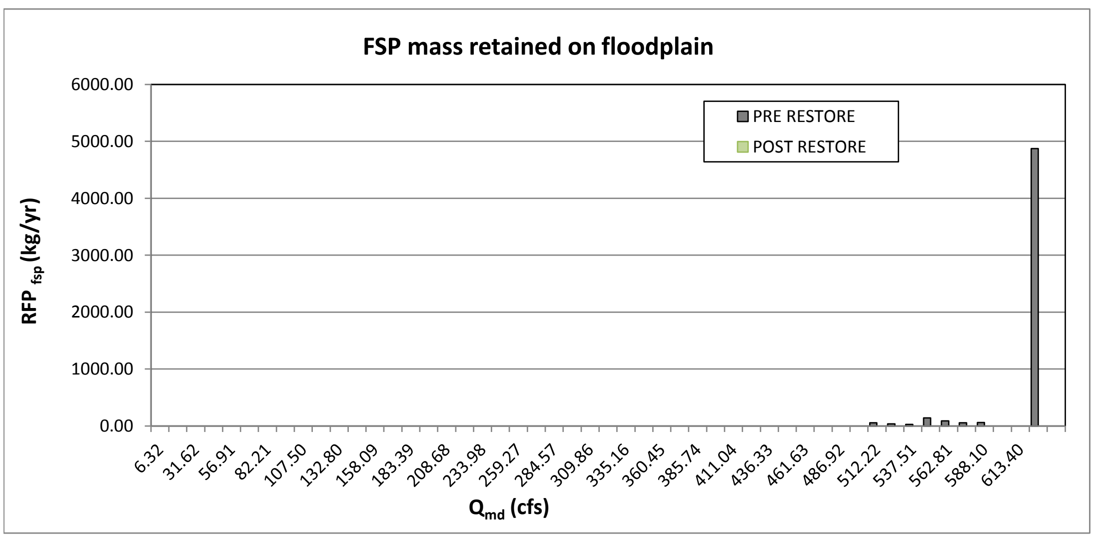
UTR MIDDLE REACHES 1 & 2 - MAIN (POST)

HYD FSP IN

STREAM LOAD REDUCTION TOOL (SLRTv2)
FLOODPLAIN RETENTION ESTIMATES

REACH NAME	UTR Middle Reaches 1 & 2 - Main		
Date of estimate	1/17/2014		
	PRE RESTORE	**POST RESTORE**	VARIABLES
Channel length (m)	1334	0	l
Channel slope (m/m)	0.0015	0	s
Channel capacity (cfs)	500	0	Q_{cc}
Floodplain condition score	3	0	FPC
Average days overbank (d/yr)	1.4	365.0	t_{ob}
Channel FSP load (kg/d)	11792	#N/A	FSP_{cc}
Catchment FSP load (MT/yr)	313.05		FSP_{in}
Delivered to floodplain (MT/yr)	13.29	#N/A	DFP_{fsp}
Retained on floodplain (MT/yr)	5.33	#DIV/0!	RFP_{fsp}





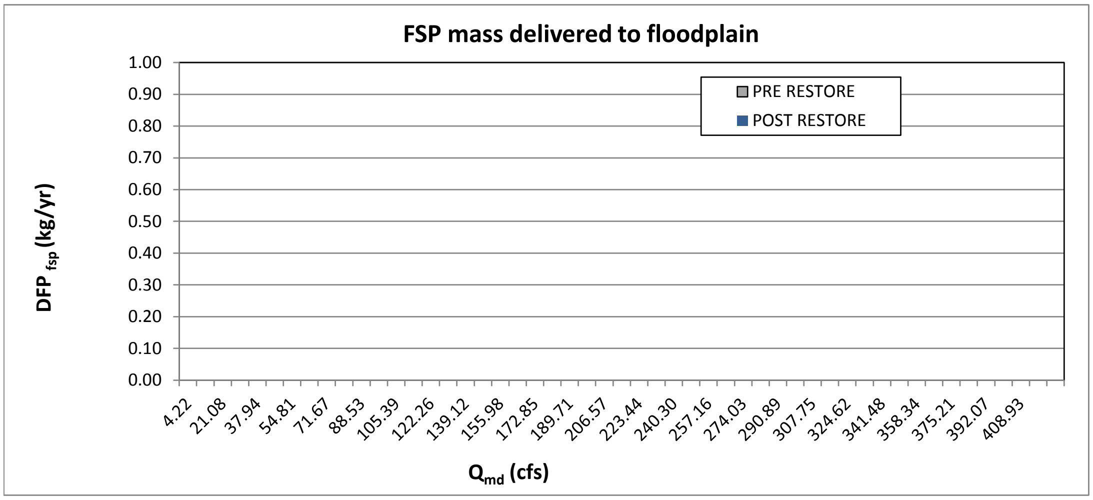
SLRTv2 created by 2NDNATURE LLC (2014)

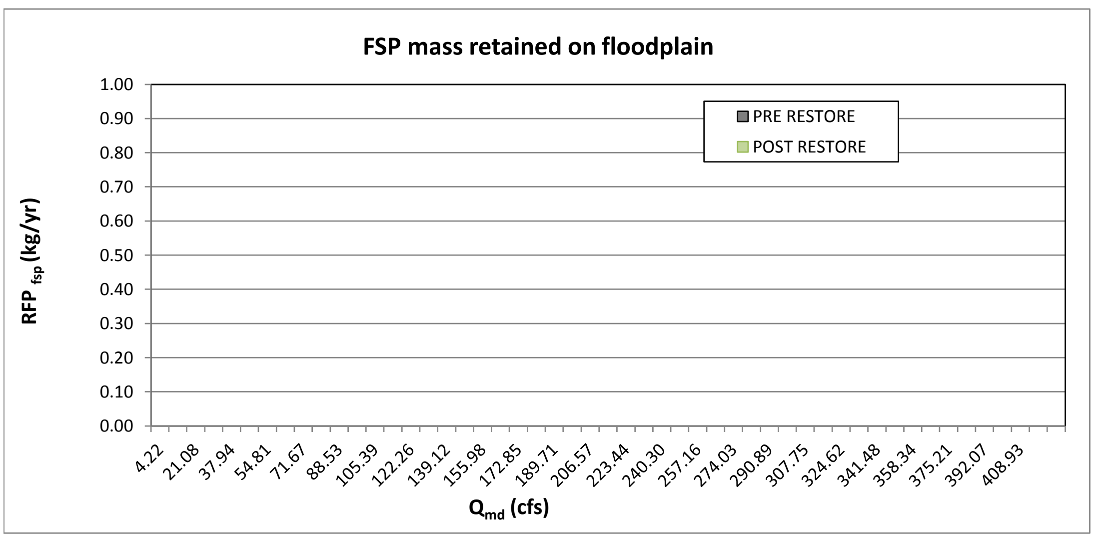
Average annual floodplain retention estimates [2/7/2014]

DESIGNED BY
2NDNATURE | LLC
TEL: 831.426.9119
FAX: 831.426.7092
www.2ndnaturellc.com

STREAM LOAD REDUCTION TOOL (SLRTv2)
FLOODPLAIN RETENTION ESTIMATES

REACH NAME	UTR Middle Reaches 1 & 2 - Gully		
Date of estimate	1/7/2014		
	PRE RESTORE	**POST RESTORE**	VARIABLES
Channel length (m)	1036.9	0	*l*
Channel slope (m/m)	0.0019	0	*s*
Channel capacity (cfs)	1200	0	Q_{cc}
Floodplain condition score	3	0	FPC
Average days overbank (d/yr)	0.0	365.0	t_{ob}
Channel FSP load (kg/d)	24150	#N/A	FSP_{cc}
Catchment FSP load (MT/yr)	208.70		FSP_{in}
Delivered to floodplain (MT/yr)	0.00	#N/A	DFP_{fsp}
Retained on floodplain (MT/yr)	0.00	#DIV/0!	RFP_{fsp}





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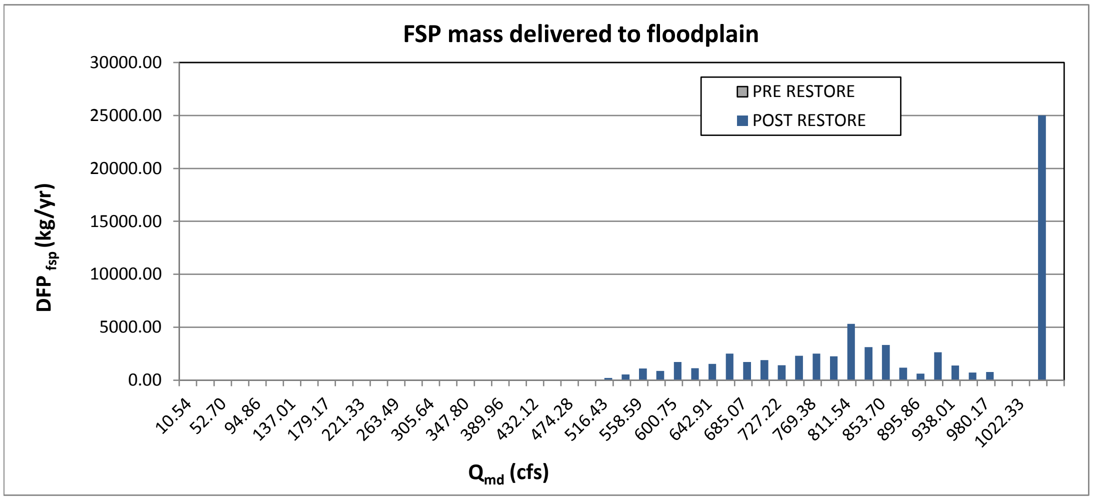
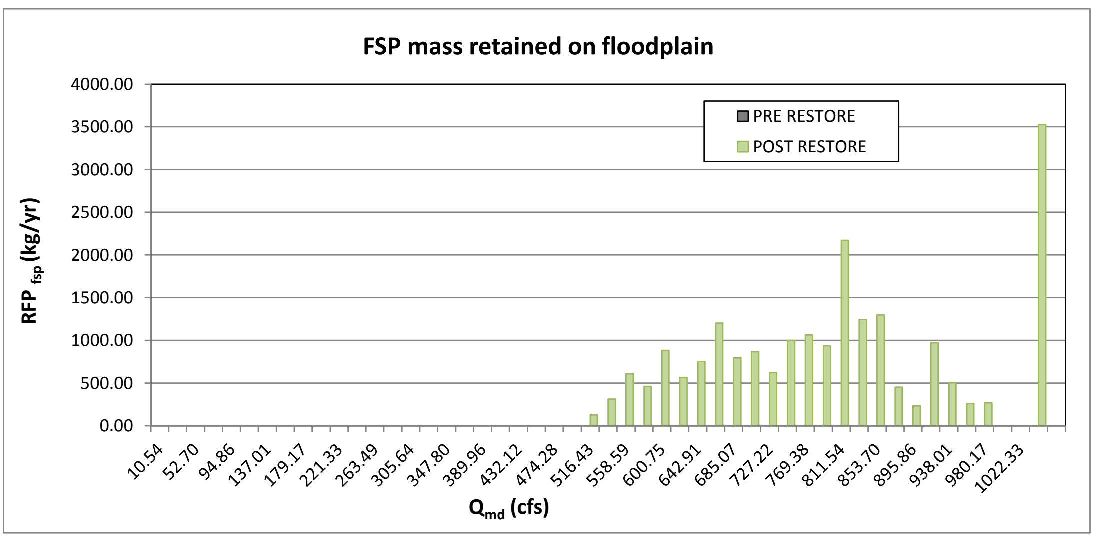
STREAM LOAD REDUCTION TOOL (SLRTv2)
FLOODPLAIN RETENTION ESTIMATES

REACH NAME	UTR Middle Reach 1&2		
Date of estimate	1/8/2014		
	PRE RESTORE	POST RESTORE	VARIABLES
Channel length (m)	0	1334	*l*
Channel slope (m/m)	0	0.0015	*s*
Channel capacity (cfs)	0	500	Q_{cc}
Floodplain condition score	0	5	FPC
Average days overbank (d/yr)	365.0	8.1	t_{ob}
Channel FSP load (kg/d)	#N/A	10323	FSP_{cc}
Catchment FSP load (MT/yr)	521.76		FSP_{in}
Delivered to floodplain (MT/yr)	#N/A	65.69	DFP_{fsp}
Retained on floodplain (MT/yr)	#DIV/0!	21.11	RFP_{fsp}





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STREAM LOAD REDUCTION TOOL (SLRTv2)
SEZ CHANNEL EROSION ESTIMATES

REACH NAME	**UTR Middle Reaches 1 & 2 - Main**	
Date of estimate	1/17/2014	
	PRE RESTORE	**POST RESTORE**
Channel length (m)	1334	0
Outside BEND length (m)	514.6	0
STRAIGHT length (m)	819.5	0
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174

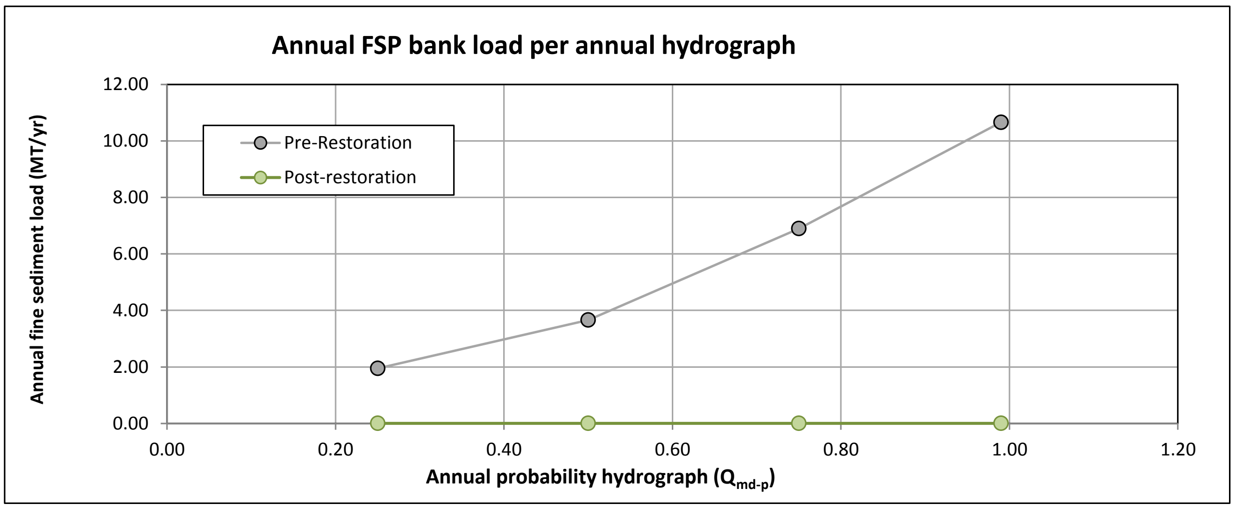
Dynamic BSTEM results

	PRE RESTORE	POST RESTORE	Q_{md-p}
Bulk sediment Outside bend unit erosion rate (m3/m/yr)	0.1250	0.0000	99th
	0.0880	0.0000	75th
	0.0400	0.0000	50th
	0.0100	0.0000	25th
Bulk sediment Straight reach unit erosion rate (m3/m/yr)	0.1750	0.0000	99th
	0.1110	0.0000	75th
	0.0610	0.0000	50th
	0.0360	0.0000	25th

	PRE RESTORE	POST RESTORE
Average annual bank erosion rate (m3/km/yr)	22.11	0.00

SEZ Channel Erosion Results

	PRE RESTORE	POST RESTORE	% reduction
Average annual bulk sediment generated (MT/yr)	51.44	0.00	100%
Average annual FSP load generated (MT/yr)	0.895	0.000	
Average annual FSP load reduction (MT/yr)	0.895		



SLRTv2 created by 2NDNATURE LLC and A. Simon 2014

Average annual channel erosion estimates [2/10/2014]

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2NDNATURE LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

STREAM LOAD REDUCTION TOOL (SLRTv2)
SEZ CHANNEL EROSION ESTIMATES

REACH NAME	**UTR Middle Reaches 1 & 2 - Gully**	
Date of estimate	1/7/2014	
	PRE RESTORE	**POST RESTORE**
Channel length (m)	1036.9	0
Outside BEND length (m)	400.3	0
STRAIGHT length (m)	636.6	0
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174

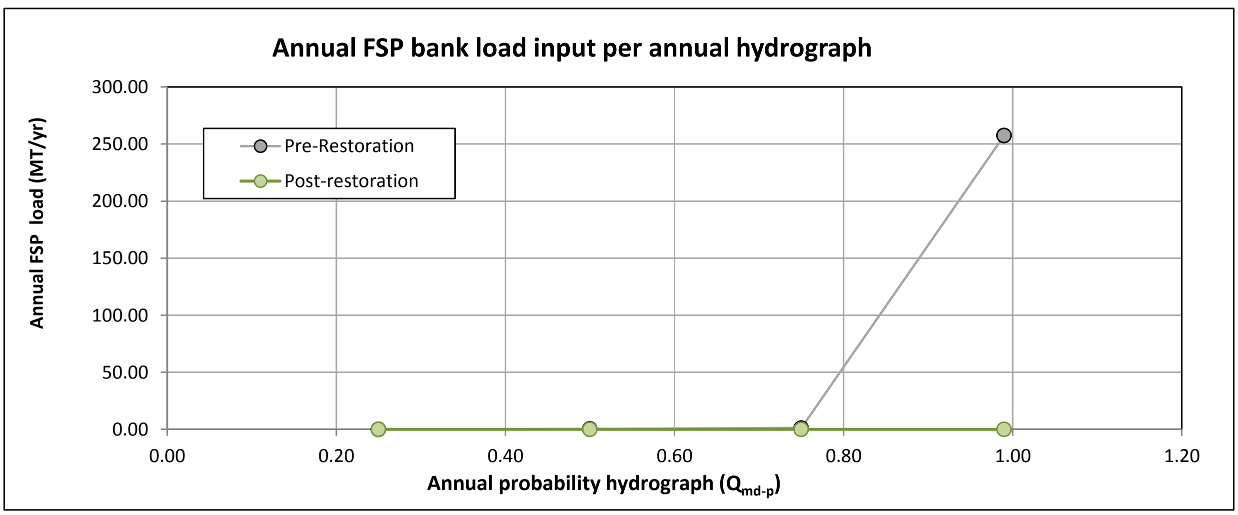
Dynamic BSTEM results

	PRE RESTORE	POST RESTORE	Q_{md-p}
Bulk sediment Outside bend unit erosion rate (m3/m/yr)	5.1700	0.0000	99th
	0.0300	0.0000	75th
	0.0000	0.0000	50th
	0.0000	0.0000	25th
Bulk sediment Straight reach unit erosion rate (m3/m/yr)	5.0400	0.0000	99th
	0.0190	0.0000	75th
	0.0079	0.0000	50th
	0.0000	0.0000	25th

	PRE RESTORE	POST RESTORE
Average annual bank erosion rate (m3/km/yr)	214.99	0.00

SEZ Channel Erosion Results

	PRE RESTORE	POST RESTORE	% reduction
Average annual bulk sediment generated (MT/yr)	388.72	0.00	100%
Average annual FSP load generated (MT/yr)	6.764	0.000	
Average annual FSP load reduction (MT/yr)	6.764		



SLRTv2 created by 2NDNATURE LLC and A. Simon 2014

Average annual channel erosion estimates [2/10/2014]

STREAM LOAD REDUCTION TOOL (SLRTv2)
SEZ CHANNEL EROSION ESTIMATES

REACH NAME	**UTR Middle Reach 1&2**	
Date of estimate	1/8/2014	
	PRE RESTORE	**POST RESTORE**
Channel length (m)	0	1334
Outside BEND length (m)	0	514.6
STRAIGHT length (m)	0	819.5
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174

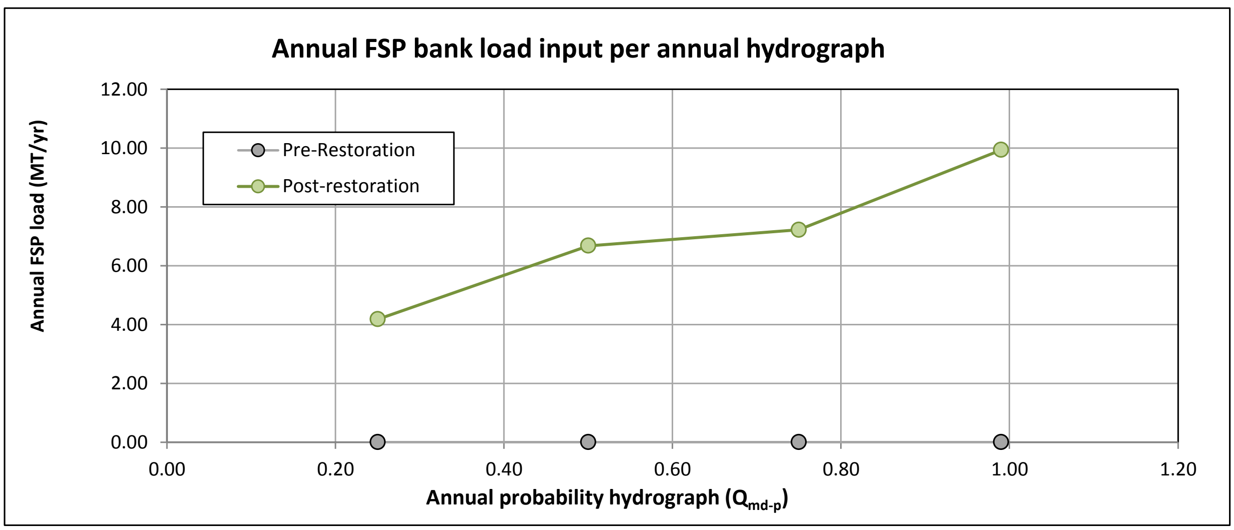
Dynamic BSTEM results

	PRE RESTORE	POST RESTORE	Q_{md-p}
Bulk sediment Outside bend unit erosion rate (m3/m/yr)	0.0000	0.1540	99th
	0.0000	0.1145	75th
	0.0000	0.0902	50th
	0.0000	0.0455	25th
Bulk sediment Straight reach unit erosion rate (m3/m/yr)	0.0000	0.1515	99th
	0.0000	0.1093	75th
	0.0000	0.1060	50th
	0.0000	0.0698	25th

	PRE RESTORE	POST RESTORE
Average annual bank erosion rate (m^3/km/yr)	#DIV/0!	28.55

SEZ Channel Erosion Results

	PRE RESTORE	POST RESTORE	% reduction
Average annual bulk sediment generated (MT/yr)	0.00	66.40	#DIV/0!
Average annual FSP load generated (MT/yr)	0.000	1.155	
Average annual FSP load reduction (MT/yr)	-1.155		



SLRTv2 created by 2NDNATURE LLC and A. Simon 2014

Average annual channel erosion estimates [2/13/2014]

STREAM LOAD REDUCTION TOOL (SLRTv2)
Results Summary

USER NAME	2NDNATURE
WATERSHED/CATCHMENT	Upper Truckee River
REACH NAME	UTR Middle Reach 1&2
Date of Estimate	1/8/2014
CATCHMENT TYPE	Non Urban
REGION	Mainstem UTR
SUB-REGION	Southwest
CATCHMENT AREA	53.7
AREA UNITS	Sq-miles
CATCHMENT % IMPERVIOUS	
CATCHMENT LAND USE CONDITION	0

NOTE; DUE TO THE PRE RESTORATION CONFIGURATION IN TWO SEPARATE CHANNELS SOME OF THE PRE POST RESTORATION ATTRIBUTE COMPARISONS ARE NOT USEFUL

USER INPUTS

	Main	Gully	Combined			
	PRE-RESTORATION	PRE-RESTORATION	PRE-RESTORATION	POST-RESTORATION	CHANGE	% CHANGE
Channel length (m)	1334.0	1036.9	2370.9	1334	0	0%
Channel slope (m/m)	0.0015	0.0019	0.0017	0.0015	0	0%
Outside BEND length (m)	514.6	400.3	914.9	514.6	0	0%
BEND bank height (m)	1.2	2.7	2.0	1.2	0	0%
BEND bank angle (degrees)	48	75	62	48	0	0%
STRAIGHT length (m)	819.5	636.6	1456.1	819.5	0	0%
Bank height of STRAGHT reaches (m)	1.4	1.8	1.6	1.4	0	0%
Bank angle of STRAIGHT reaches (degrees)	53.0	75.0	64.0	53	0	0%
Manning's roughness value of channel	0.03	0.03	0.03	0.04	0.01	33%
Fines to bulk sediment ratio (0-1 value)	0.0174	0.0174	0.0174	0.0174	0	0%
Channel capacity (cfs)	500	1200	1700	500	0	0%
Floodplain length (m)	955	955	955	955	0	0%
Floodplain condition score	3	3	3	5	2	67%

SLRT OUTPUTS

AVERAGE ANNUAL ESTIMATES	Main	Gully	Combined				
	PRE-RESTORATION	PRE-RESTORATION	PRE-RESTORATION	POST-RESTORATION	CHANGE	% CHANGE	
Predicted FSP catchment load (MT/yr)	313.05	208.70	521.76	521.76	0.00	0%	IN_{fsp} (MT/yr)
Predicted FSP load delivered to floodplain (MT/yr)	13.29	0.00	13.29	65.69	52.40	394%	DFP_{fsp} (MT/yr)
Predicted FSP load retained on floodplain (MT/yr)	5.33	0.00	5.33	21.11	15.78	296%	RFP_{fsp} (MT/yr)
Predicted FSP load from channel erosion (MT/yr)	0.90	6.76	7.66	1.16	-6.50	-85%	SCE_{fsp} (MT/yr)
Predicted FSP load at downstream boundary (MT/yr)	308.62	215.47	524.08	501.80	-22.28	-4%	OUT_{fsp} (MT/yr)

22.28 **Average annual FSP Load Reduction (MT/yr)** SEZ LR_{fsp} (MT/yr)

16.70 **Average annual FSP Load Reduction per reach length (MT/yr/km)**

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