EXETER RIVER STUDY
2008 ACTIVITIES

RIVERBANK SCOUR ANALYSIS AND DISCHARGE GATE DESIGN IMPACTS TO WATER QUALITY

for the
TOWN OF EXETER, NH

April, 2008



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FOR THE

TOWN OF EXETER, NH

APRIL 2008

Prepared By:

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EXETER RIVER STUDY
2008 ACTIVITIES

RIVERBANK SCOUR ANALYSIS AND DISCHARGE GATE DESIGN IMPACTS TO WATER QUALITY

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SECTION 1

INTRODUCTION

This report presents the results of two tasks conducted in 2008 as part of the on-going Exeter River Study. These tasks, namely, a riverbank scour analysis and a discharge gate design impacts to water quality analysis, were performed to supplement information obtained during two larger studies conducted in 2005 and 2006. The 2008 Exeter River Study activities were selected to produce information that will eventually be needed to design dam modifications that were determined to be necessary from the 2005 and 2006 river study activities

Activities in 2005 were presented in a report titled "Exeter River Study - Interim 2005 Report" dated February 3, 2006. Activities in 2006 were presented in a report titled "Exeter River Study - Phase I Final Report" dated March, 2007.

The major 2005 Phase I activities included the following tasks:

- A field survey of each dam to produce input data for the hydraulic model;
- A backwater analysis of the Great Dam;
- Dissolved oxygen and temperature monitoring of the Exeter River;
- Assessment of funding opportunities for Exeter River infrastructure improvements;
- Develop a hydraulic model that predicts river profiles at 1, 10, 50 and 100-year storm events;
- Evaluate the feasibility and costs of automated impoundment level monitoring equipment; and
- Conduct a hydraulic analysis of the Great Dam low-level gate.

The major 2006 Phase I activities included the following tasks:

- Conduct a bathymetry survey of the Great Dam impoundment;
- Conduct a visual inspection of the Great Dam;

- Develop conceptual modifications to the Great Dam that would meet NHDES discharge requirements;

- Develop cost estimates for dam modification options, including complete removal of the Great Dam and fish passage; and

- Build a hydraulic model of the Exeter River in the impoundment area. Use model to select and evaluate adequacy of potential dam modifications. Use model to predict upstream flood water elevations of various storm events (10-year, 50-year, etc.).

The 2005 and 2006 Exeter River Study reports are available on-line at:
http://town.exeter.nh.us/NewPublications.cfm

A summary of the riverbank scour analysis and the discharge gate design impacts to water quality analysis are presented in Section 2, Executive Summary.

Section 2

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SECTION 2

EXECUTIVE SUMMARY AND RECOMMENDATIONS

As discussed in Section 1, Introduction, this report presents the results of a riverbank scour analysis and an analysis on how the discharge gate design could impact water quality in the impoundment. These activities were performed to supplement information obtained during two larger studies conducted in 2005 and 2006. See the Introduction section for a summary of activities conducted in previous reports. A summary of this report's findings is as follows.

2.1 RIVERBANK SCOUR ANALYSIS

A scour analysis was performed to better understand how dam modification options, identified in previous studies, could affect river bank stability downstream of the dam. A hydraulic model was used that incorporated the physical characteristics of the river channel and the individual characteristics of the three contemplated dam modification options.

The scour analysis modeling results indicated that all three dam modification options would not significantly alter the river flow velocities downstream of the dam during 100-year and 1-year flood flow events. However, because existing river flow velocities near the northeast embankment from String Bridge to the confluence of the Squamscott River are in the 8 to 12-foot per second range during the 100-year flood, additional channel armoring and maintenance of existing armoring is recommended in this area. Stone armoring of river banks is typically warranted when flow velocities exceed 10 feet per second. See Appendix A of this report for plans that depict the areas where armoring is recommended. If rip-rap were the chosen method of armoring, stones with an average diameter (D_{50}) 2.0 to 2.5 feet are recommended to protect the embankments during a 100-year flood event.

Field inspections noted an area of significant active bank erosion, likely due to eddies, at the confluence of the Exeter and Squamscott Rivers, near the Exeter Mill Apartments. It is recommended that this area be armored as well, using rip-rap of similar size.

It is also recommended that the existing rock retaining wall/ledge armoring on the northeast bank downstream of String Bridge be maintained.

The configuration of the low level discharge gate on the future modified dam should be similar in orientation to the existing outlet to prevent the possibility of bank erosion or scour immediately downstream of the dam.

2.2 DISCHARGE GATE DESIGN IMPACTS TO WATER QUALITY

During water quality studies conducted in 2005, low concentrations of dissolved oxygen were noted to exist in the lower levels of the impoundment (an area known as the hypolimnion) immediately upstream of the dam. Temperature measurements conducted at the same time also noted that during the warmer months, the impoundment became thermally stratified, in that water at the surface is warmer than the water at the bottom. This condition can reduce vertical mixing in the water column and contribute to poor water quality. This is exemplified by the occurrence of reduced dissolved oxygen concentrations (i.e., hypoxia) in the hypolimnion.

An analysis was preformed to determine whether a discharge gate that releases water from the base of the dam could provide discharges of water from the hypolimnion and, thus, potentially improve water quality. Section 3 of this report, Discharge Gate Design Impacts to Water Quality, presents an analysis of the expected water quality benefits of locating the discharge gate at the base of dam.

The analysis concluded that locating the discharge gate discharge point at the base of the dam would have a minimal impact to improve water quality. The analysis was completed by comparing the water's buoyancy forces (tendency of the water to move up or down based on water densities) to the water's own resistance to flow, or shear forces. This ratio of buoyancy forces to shear forces is know as the Richardson number (R_i) When R_i is greater than .25, the water layers are considered to be stable and, therefore, amenable to "slab flow". Stable water layers are necessary to be able move only the poor quality water in the hypolimnion. As the value of R_i increases, the water column becomes more stable and more condusive to "slab flow".

The analysis was conducted using three flow rates and three widths of flow. The Richardson numbers for these combinations ranged from 0.01 to 0.27. These low Richardson number values indicate a discharge gate at the base of the dam would be releaseing water from throughout the water column and, therefore, have little impact on improving water quality in the hypoliminion. The complete analysis can be found in Section 3 of this report, Discharge Gate Design Impacts to Water Quality.

2.3 RECOMMENDATIONS

We recommend the findings of this report be considered during the selection and design of the Great Dam modifications. As the scour analysis in this report made several final dam design assumptions, an update to the scour analysis should be performed when the design of the Great Dam modification are complete.

Section 3

WRIGHT-PIERCE
Engineering a Better Environment

April 10, 2008

James Hewitt
Wright Pierce
230 Commerce Way
Suite 302
Portsmouth, NH 03801

RE: Preliminary Analysis of Discharge Gate Design on Impoundment Water Quality
Great Dam, Exeter River, New Hampshire

Dear James:

A preliminary analysis of potential water quality benefits associated with alternative discharge gate release elevations at Great Dam on the Exeter River was performed. The purpose of this analysis was to evaluate the potential for improving dissolved oxygen concentrations in the Great Dam impoundment by discharging flows from a discharge gate that releases water from the base of the dam.

Previous studies have documented dissolved oxygen concentrations in the Great Dam impoundment in the summer. While previous data documents reduced dissolved oxygen concentrations throughout the water column in the impoundment, particularly low concentrations have been recorded in the bottom of the water column (i.e., hypolimnion) when the impoundment is thermally stratified in the summer. This analysis therefore evaluated the potential to withdraw water from the hypolimnion during low-flow (i.e. summer) conditions when reduced levels of dissolved oxygen in the hypolimnion adversely affect water quality in the Great Dam impoundment.

This analysis was performed using water temperature data and bathymetry data obtained from previous Exeter River Study activities. The analysis methodology was based on proposed flows through the low-level outlet and water column stability based on calculated flow speeds and the Richardson number, which represents the ratio of buoyancy to shear forces.

Review of Existing Data

Data obtained in 2005 and 2006 as part of this of this study was reviewed for this analysis. This data included water temperature and dissolved oxygen measurements at monitoring stations in the Exeter and Little Rivers in 2005 and bathymetric data collected in 2006.

Flow data for the Exeter River obtained from the United States Geological Survey (USGS) stream gaging station on the Exeter River near Brentwood, New Hampshire (USGS No. 01073587) was also used to quantitatively evaluate variations in the water quality data obtained between early-August and early-November 2005.

Hydrology

Hydrologic data for this analysis was obtained from the USGS stream gaging station on the Exeter River in Brentwood. This information includes mean and median daily-averaged flows by month in cubic-feet-per-second (cfs) (Table 1). Of particular interest are the low flow months of July, August, and September.

While daily average flows are relatively low in October, data obtained in 2005 indicates that the Great Dam impoundment experiences thermal turnover in early-October, along with cooler temperatures and increased dissolved oxygen concentrations.

Table 1: Monthly Flows, Exeter River at Brentwood

YEAR	Monthly Flow in cfs (Calculation Period: 1996-07-01 -> 2007-09-30)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996							40	6	15	335	132	304
1997	131	135	172	321	128	28	7	1	2	2	33	43
1998	133	252	304	103	169	361	80	7	4	26	29	37
1999	111	192	209	80	55	13	6	3	55	59	77	100
2000	89	110	269	279	136	66	30	30	13	17	66	92
2001	52	56	376	336	43	62	19	4	2	2	4	13
2002	17	37	92	114	148	114	14	2	2	6	44	110
2003	80	73	294	240	112	78	9	25	13	49	86	151
2004	69	48	100	413	160	82	27	46	49	42	63	178
2005	156	164	192	308	275	147	61	14	8	323	219	251
2006	260	215	89	110	598	379	108	68	32	119	299	151
2007	159	41	175	498	162	140	18	5	3			
Mean Discharge	114	120	207	255	180	134	35	18	16	89	96	130
Median Discharge	111	110	192	279	148	82	23	7	10	42	66	110

Thermal Stratification

This analysis was performed using data collected by Wright-Pierce on August 2, 2005, at Station No. 4 on the Exeter River (reference Table 5-1.1, Exeter River Interim 2005 Report for the Town of Exeter, NH [February 3, 2006]). This data set was selected for use here as Station No. 4 is the closest of the "full-depth" monitoring stations upstream from the Great Dam and the August 2, 2005, and shows a defined thermal gradient in the water column. This data, including calculated water densities based on temperature, is shown in Table 2.

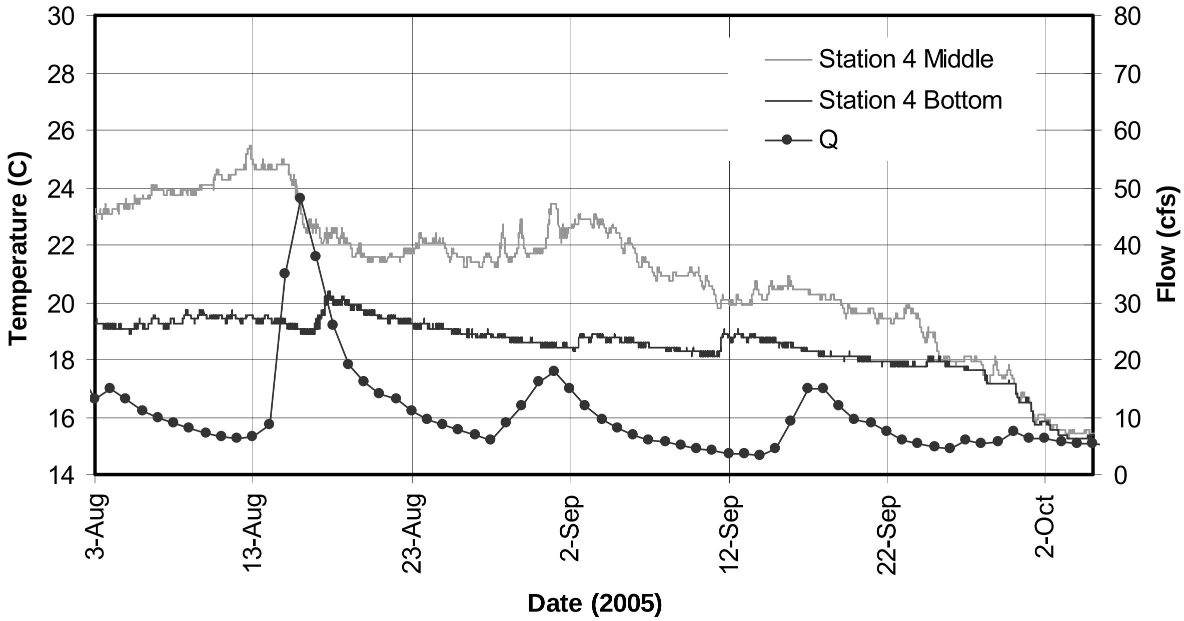
Table 2: Water Quality Data

Depth Below Water Surface (ft)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Temperature (degrees Celsius)	Water Density (kg/m^3)
0.5	5.00	60.0	25.1	997.022
3.5	3.80	44.5	23.1	997.022
6.5	3.33	38.0	22.6	997.517
9.5	2.21	26.1	22.4	997.635
12.5	0.43	4.7	19.4	997.681

Mg/L = milligrams per litre
Kg/m^3 = kilograms/cubic meter

The data in Table 2 documents the presence of both thermal stratification and reduced dissolved oxygen concentrations in the water column. Figure 1 depicts water temperature data obtained at Station No. 4 between early-August and early-October of 2005 and water flow in the Exeter River at the upstream USGS gaging station. Of note in this figure is the difference in measured water temperature between the middle and the bottom of the water column ("4 Middle" and "4 Bottom", respectively), and apparent effect of increased flow on the temperature difference. In particular, the higher flow of approximately 50 cfs on August 16, 2005, reduced the temperature gradient from approximately 5 to 2 degrees Celsius. Similar, though less pronounced reductions in thermal stratification are apparent during other periods of increased flow in the river.

Figure 1: Water Temperature and Flow



Analysis

The potential to discharge relatively dense water from the hypolimnion of the Great Dam impoundment was performed using the data presented above and an analysis of the ratio of buoyancy to shear forces, as represented by the Richardson number (R_i) (Equation 1). The Richardson number stability criteria for this analysis was 0.25, with a value greater than this representing a potentially stable regime suitable for withdrawal of denser water from the hypolimnion.

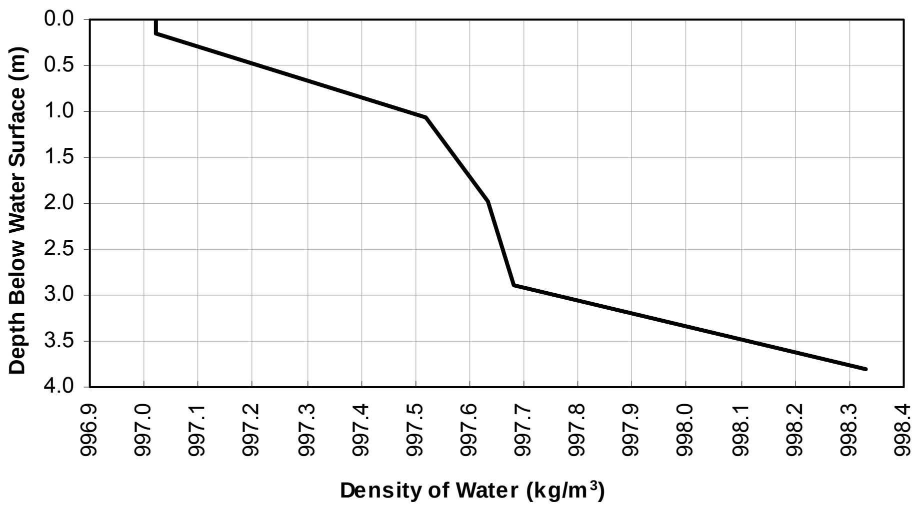
Equation 1: Richardson Number

$$R_i = \frac{\text{bouyancy}}{\text{shear}} = \frac{(g/\rho g)\,(\partial\rho/\partial z)}{(\partial u/\partial z)^2}$$

$$\text{density gradient} : \partial\rho/\rho z$$
$$\text{velocity gradient} : \partial u/\rho z$$

The density gradient was calculated using water temperature data presented in Table 1, which is shown in Figure 2. The density gradient was calculated as the absolute value of slope of the individual segments of the curve shown in Figure 2. The velocity gradient was calculated as gradient of streamwise scalar speed for a variety of flows and cross sections assuming a minimum velocity gradient defined by a linearly increasing flow with a speed of zero at the top of the water column and a maximum speed at the bottom of the water column. This velocity profile was selected as being reasonable for the proposed purpose of withdrawal of water from the hypolimnion. While uniform vertical profile would provide for vertical stability of the water column, this does not appear to be a reasonable assumption.

Figure 2: Water Density



The Richardson number was calculated for a variety of flow conditions, including varying widths of flow path and flow. The depth of the water column remained constant at 10 feet for this analysis. The results of this analysis are presented in Table 3.

Table 3: Calculated Richardson Number

Flow Width (ft)	Flow (cfs)	Richardson Number
10	1	0.02
	5	<0.01*
	10	<0.01
20	1	0.07
	5	<0.01
	10	<0.01
40	1	0.27
	5	0.01
	10	<0.01

*Note: Value less than 0.01

Discussion and Conclusions

The results of this analysis indicate that withdrawal of water from the hypolimnion of the Great Dam impoundment through a low-level outlet at the Great Dam would not result in discharge of only water from the hypolimnion, as the results presented in Table 3 show calculated Richardson numbers below the stability criteria used here for eight of the nine evaluated scenarios. The single case where the calculated Richardson number is greater than the stability criteria of 0.25 is for a relatively small flow and a scenario that assumes a larger degree of uniformity within the impoundment upstream of the dam.

In particular, the presence of bedrock outcroppings in this area would likely result in some confinement of the flow and disruption of stability in the far-field environment in the reach of the river upstream from the dam. The variability of the channel morphology of the Exeter River within the Great Dam impoundment was considered as part of this analysis using bathymetric data collected in 2006. This data documents the presence of riverine morphology within the impoundment, as indicated by the presence of relatively deep areas interspersed between shallower reaches of the river. The deeper areas typically occur at bends in the impoundment, which is characteristic of riverine morphology. That these pools have not filled with sediment suggests that some scour of these areas persists during periods of higher flow. The presence of shallower areas, or bars between the deeper areas could also disrupt density currents intended to be released through a low-level outlet at Great Dam.

Potential for disturbance of stratified flow may also occur in the near-field environment immediately adjacent to the low-level outlet. Unless entrance flow speeds are relatively low, entrainment of overlying water would likely occur. Increasing the discharge flow to compensate for the entrainment of water from above the hypolimnion would likely increase entrainment of water from the higher portion of the water column.

The withdrawal of water from the upstream base of the Great Dam through a low-level outlet at the dam is not considered to be a practical means to improving reduced dissolved oxygen levels in the impoundment hypolimnion. The primary factors considered in this determination are a) the relatively shallow depth of the impoundment adjacent to the dam, and 2) the relatively weak vertical density gradient in the water column.

Sincerely,
Stantec Consulting

Michael Chelminski
Senior Associate

Project Number 105071

Section 4

SECTION 4

RIVERBANK SCOUR ANALYSIS

4.1 INTRODUCTION AND BACKGROUND

This section presents the results of a scour analysis that was conducted to determine whether new discharged gate configurations contemplated for the Great Dam could cause downstream scour and bank erosion. The Great Dam is presently in violation of New Hampshire Department of Environmental Service (NHDES) rules that require all dams be able to pass the 50-year flood event with one foot of freeboard. Therefore, in 2005 and 2006 studies were conducted to identify, among other things, dam modifications that would satisfy NHDES Dam Bureau requirements. The most recent phase of Exeter River Study activities concluded in early 2007 with the preparation of a report titled "Exeter River Study Phase I Final Report" (Final Report).

The Final Report presented three separate discharge gate configuration options for the Great Dam, all of which could pass the NHDES 50-year flood flow with the one foot freeboard requirement. However, recent floods have damaged the northeast banks of the Exeter River downstream of the Great Dam near the library and the Exeter Mill Apartments. Proposed dam modifications could alter the flow of water downstream of the dam in a manner that may adversely affect riverbank stability and other structures in or near the river.

The three proposed Great Dam modifications outlined the Final Report are:

Concept 1:

- Remove the 1-foot high concrete "cap" along the entire length of the spillway
- Install a 1-foot high crest gate along the spillway length
- Increase height of southwest abutment 1.3 feet to match height of northeast abutment
- Install a new discharge low-level tainter gate (8 feet tall x 16 feet wide)

Concept 2:

- Remove 3 feet of dam crest along the entire length of the spillway
- Install a 3-foot high crest gate along the spillway length
- Increase height of southwest abutment 1.3 feet to match height of northeast abutment
- Install a new discharge low-level sluice gate (6 feet tall x 8 feet wide)

Concept 3:

- Replace the existing dam with a "labyrinth weir" style dam
- Increase height of southwest abutment 1.3 feet to match height of northeast abutment
- Install a new discharge low-level sluice gate (6 feet tall x 8 feet wide)

This scour analysis builds on the Final Report and investigates how the proposed dam discharge gate configurations may affect downstream scour and bank erosion. The following tasks were completed by Wright-Pierce to address potential scour and bank erosion issues:

- Conduct an inspection of the existing river banks and armoring and note signs of active riverbank erosion, vegetation, bank slopes, existing rip-rap undermining, rip-rap sizes, and current flow patterns.
- Conduct field survey activities to obtain river cross-section elevations downstream of String Bridge for use in the hydraulic model.
- Modify the existing Hydraulic Engineering Center-River Analysis System (HEC-RAS) hydraulic model of the Exeter River to evaluate conditions downstream of the Great Dam and downstream of String Bridge. Use the model to predict 100-year flood water velocity downstream of the Great Dam. The 100-year flood was used for these analyses to determine the worst case scenario flood flows and velocities expected through the Exeter River downstream of the Great Dam. Higher velocities create a greater potential for downstream scour and bank erosion to occur.
- Evaluate the adequacy of the existing river bank armoring and provide recommendations for improvements to mitigate potential erosion during a 100-year storm event for each of the three conceptual dam medication designs.
- Evaluate the potential for scour under String Bridge and immediately downstream of the discharge gates during a 100-year flood event for each of the three conceptual designs.

A plan view of the Exeter River through the project site is shown in Appendix A - Figure 3.

4.2 DATA COLLECTION

4.2.1 Site Visit

On January 22, 2008, Wright-Pierce staff conducted a site visit of the project area in order to understand the current flow patterns of the Exeter River downstream of the Great Dam. According to a USGS flow gage located upstream in Brentwood, NH, the average daily flow rate for January 22 was approximately 75 cubic feet per second (cfs). This indicates that flow rates downstream at the Great Dam on that day could have been 75 to 100 cfs, resulting in a flow depth over the fish weir of 4.5 to 5.5 inches. Figure 4, which is a photo of flow over the fish weir on January 22, shows a flow depth of about 5 inches over the weir.

Under these flow conditions, the following observations were made:

- The right channel under String Bridge, looking downstream, has a lower channel invert and carries more flow than the left channel;
- The right channel downstream of String Bridge contains a bend before entering the Squamscott River. This location was flagged as having a high risk of erosion due to the higher velocities typically found on the outside of a river bend. (Figure 3, Area A);
- The retaining wall just upstream of the bend in the right channel appeared to be leaning in toward the River, possibly due to undercutting of the river channel (Figure 3, Area B);
- A location of possible past erosion was found just upstream of String Bridge near the northwest corner of the library building corner (Figure 3, Area C). The embankment was covered with medium sized stone (6 to 10 inches in diameter), possibly placed after a significant high river flow event. Figure 5 is a photo taken of this area;

- Active embankment erosion was discovered on the Exeter Mill Apartments property just after the river bend downstream of String Bridge (Figure 3, Area D), possibly caused by eddying currents exiting into the Squamscott River. Figure 6 is a photo of the eroded area and Figure 7 is an aerial photo clearly showing the eddying currents downstream of the bend.
- Scour under String Bridge was not evident;
- Scour at the low flow gate was not evident;
- The right embankment just downstream of the Great Dam contains a rip-rap wall, with stones 18 to 24 inches in diameter that appear to be in good condition. Continuing downstream, between the fish weir and String Bridge, the right embankment contains some large rip-rap (18 to 24 inches in diameter) near the base of the embankment. Figures 8 and 9 show the existing armored embankments;
- The right embankment at the bend (Figure 3, Area A) is armored with 12 to 18-inch diameter rip-rap and appears to be adequately protecting the bank. However, some erosion above the armoring was evident and could have been caused by elevated river flows or overland flow from the Exeter Mill Apartments;
- Scrub brush vegetation was noted growing through the rip-rap downstream of the Great Dam and along the right embankment up to String Bridge. The tops of the right embankments were covered with grassy vegetation;
- The right embankment contained grassy vegetation above the retaining wall and a row of pine shrubs was growing above the rip-rap through the bend.
- Embankment slopes were noted as approximately 1 foot horizontal (H) to 1 foot vertical (V) downstream of the Great Dam, transitioning to approximately a 4H to 1V slope just upstream of String Bridge;
- Embankments downstream of String Bridge are vertical retaining walls up to the bend where the rip-rap has been place at approximately a 2H to 1V slope.

4.2.2 Existing Hydraulic Model

Wright-Pierce consulted with Exeter River Study project team member Stantec (formerly Woodlot Alternatives) and obtained the existing HEC-RAS hydraulic model used in Final Report. The existing model contained executed runs for baseline (existing) conditions and all three dam improvement concepts. It did not, however, contain detailed cross-section data for the Exeter River downstream of the Great Dam. The model was supplemented with cross-sections from an existing FEMA Flood Insurance Study (FIS) and a Wright-Pierce field survey of river cross-sections.

4.2.3 Field Survey

On March 3, 2008, Wright-Pierce conducted a field survey of the Exeter River downstream of the Great Dam to its confluence with the Squamscott River. During the field survey, it was estimated that the Exeter River was flowing at a rate of 200 to 250 cfs and depth of flow over the fish weir was 8.5 to 10 inches. Cross-sections to supplement the hydraulic model were collected through the divided channel created by the String Bridge center island. This information was used to further define the hydraulic model along areas of the Exeter River where the potential for bank erosion was high.

4.3 METHOD

4.3.1 HEC-RAS Hydraulic Modeling

The baseline conditions configuration and the three conceptual dam modification options were evaluated with the U.S. Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS) version 3.1.3. HEC-RAS is computer software designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. The system is capable of performing steady and unsteady flow water surface profile calculations. Because HEC-RAS is a one-dimensional program, it cannot account for changes in direction of flow and, as a result, it is not capable of analyzing changes in gate alignments. HEC-RAS is a good tool to analyze the expected velocities downstream of the Great Dam, but not changes in local flow patterns near the dam. Further scour analysis near the dam will need to be completed once a final dam modification design has been completed.

<u>Model Hydrology</u>
The 100-year flood flow was used for these analyses to determine the worst case scenario velocities expected through the Exeter River downstream of the Great Dam. Higher velocities create a greater potential for downstream scour and bank erosion to occur. The 100-year flood flow rate of 4,949 cfs was used in the Final Report for existing conditions and conceptual analyses. This flood flow rate was verified by checking against New Hampshire Department of Environmental Services (NHDES) files on the Great Dam.

A model run using a 1-year flood flow rate of 1000 cfs was also conducted to verify that velocities and erosion potential is reduced during lower flood flows.

<u>Existing Conditions Model</u>
The first step in the analysis, after obtaining the existing conditions model, was to update the model to include cross-sections downstream of the Great Dam, including String Bridge and cross-sections through the area of concern. The existing conditions model had two approximated cross-sections downstream of the Great Dam and did not include the fish weir. These two cross-sections were removed and replaced by five original FEMA FIS HEC-2 model cross-sections and one cross-section obtained during the field survey. The five original cross sections included the fish weir. These cross-sections were inserted to obtain a more accurate representation of flow patterns between the Great Dam and String Bridge.

Cross-sections downstream of String Bridge were obtained through a combination of field survey and interpolation. High velocities at the time of the survey produced unsafe conditions through the separated channel; therefore, limited the areas where survey shots could be taken. To resolve this issue, cross-sections were interpolated between the furthest downstream original HEC-2 cross section invert (Section 7) and the first well-defined survey cross-section downstream of the divided channel (Section 2). Interpolation was used to obtain a realistic channel definition for the model and is often an accepted practice to fill data gaps in river models. Figure 3 shows the cross-section locations.

The existing conditions model was then run for the 100-year and 1-year flood flow events. The resulting channel velocities were summarized for comparison with the conceptual model runs.

Conceptual Models

The three conceptual models were updated with the same cross-sections that were inserted into the existing conditions model downstream of the Great Dam. Each of the three conceptual models was run for the 100-year and 1-year flood flow events. The resulting 100-year flood flow channel velocities for each conceptual model are summarized in the following section.

4.4 RESULTS

4.4.1 Existing Conditions Model

Table 4 shows the results of the existing conditions model run for a 100-year flood event. The table presents the velocities experienced along each river bank. A maximum embankment velocity of 11.7 feet per second (fps) was predicted at Cross-Section 4.

The model run for the 1-year flood event predicted a maximum embankment velocity of 7.9 fps. Since the 100-year flood flow resulted in a larger velocity than the 1-year flood flow, the 100-year velocity will govern the bank stabilization design.

TABLE 4
EXISTING CONDITIONS
100-YEAR FLOOD VELOCITIES

		South (Left) Channel Velocities (fps)		North (Right) Channel Velocities (fps)	
Cross Section Location	Cross Section Name	Baseline Left Bank	Baseline Right Bank	Baseline Left Bank	Baseline Right Bank
Downstream of Great Dam[1]	13	3.5	2.8	-	-
Upstream of Weir[1]	12	3.5	2.8	-	-
Downstream of Weir[1]	10	4.4	5.4	-	-
Upstream of String Bridge[1]	9	4.6	3.0	-	-
1' Upstream of String Bridge	7	7.9	9.0	10.6	10.6
1' Downstream of String Bridge	5	8.8	8.3	11.6	10.7
Entrance to Bend	4	10.5	9.6	7.2	11.7
Bend at Bay Entrance	3	8.2	9.4	10.0	10.1
Exit of Bend[1]	2	4.9	4.4	-	-
Bay Entrance[1]	1	4.3	2.9	-	-

[1]Cross-Section geometry contains one channel only, appropriate velocities listed in "South Channel" section

4.4.2 Dam Modification Concepts 1 Through 3

Table 5 shows the results of the model runs for Concepts 1 through 3 for a 100-year flood event. The model results for each concept are the same because the HEC-RAS cross-sections downstream of the dam are the same for each concept. The table presents the velocities experienced along each river bank. A maximum embankment velocity of 11.7 fps was predicted at Cross-Section 4. Figure 10 is a plan view that shows the velocities predicted along the river embankments.

TABLE 5
DAM MODIFICATION CONCEPTS 1 THROUGH 3
100-YEAR FLOOD VELOCITIES

		South (Left) Channel Velocities (fps)		North (Right) Channel Velocities (fps)	
Cross Section Location	Cross Section Name	Baseline		Baseline	
		Left Bank	Right Bank	Left Bank	Right Bank
Downstream of Great Dam[1]	13	3.5	2.8	-	-
Upstream of Weir[1]	12	3.5	2.8	-	-
Downstream of Weir[1]	10	4.4	5.4	-	-
Upstream of String Bridge[1]	9	4.6	3.0	-	-
1' Upstream of String Bridge	7	7.9	9.0	10.6	10.6
1' Downstream of String Bridge	5	8.8	8.3	11.6	10.7
Entrance to Bend	4	10.5	9.6	7.2	11.7
Bend at Bay Entrance	3	8.2	9.4	10.0	10.1
Exit of Bend[1]	2	4.9	4.4	-	-
Bay Entrance[1]	1	4.3	2.9	-	-

[1]Cross-Section geometry contains one channel only, appropriate velocities listed in "South Channel" section

The model runs for the 1-year event predicted a maximum embankment velocity of 7.9 fps. Since the 100-year flood flow resulted in a larger velocity than the 1-year flood flow, the 100-year velocity will govern the bank stabilization design.

See Appendix B for the HEC-RAS model output.

4.4.3 Low Flow Gate Analyses

In addition to determining the potential impacts of each concept on river bank erosion, the potential for scour at the low flow gate was also analyzed. It is important to minimize scour at the low flow gate to avoid possible undercutting of the river bed near the dam structure. Excessive scour at the low flow gate could lead to structural stability issues at the dam. Velocities through the low flow gates were predicted for existing conditions and the three dam concepts. Results of the velocity analysis are presented in Table 6.

TABLE 6
LOW FLOW GATE VELOCITY

Dam Configuration	Flow Rate Through Gate (cfs)	Velocity Through Gate (fps)
Existing Conditions	132	11.0
Concept 1	1680	13.1
Concept 2	657	13.7
Concept 3	651	13.6

As shown in Table 6, significant velocities are predicted through the low flow gates when the water surface elevation is at the dam crest. It is important to protect the river channel in the immediate vicinity of the low flow gate for each of the alternatives to avoid potential structural stability issues at the dam. In order to prevent additional bank erosion and scour, the low flow gates proposed for Concepts 1 through 3 should be oriented in the same direction as the existing low flow gate. This will ensure that the new gates do not redirect flows towards adjacent river banks. Since scour was not evident at the existing low flow gate, a new gate oriented in the same direction as the existing gate is not expected to cause additional scour.

4.4.4 Channel Armoring

The highest 100-year flood velocities were predicted along the right side of the northern channel, downstream of String Bridge (between 8 and 12 fps). This area appears to have a high risk for bank erosion. Additional embankment armoring should be required along that embankment.

Rip-rap channel armoring is recommended for this area. A maximum velocity of 11.7 fps, determined by HEC-RAS, and a unit weight of 135 pounds per cubic foot (pcf), was used to size the rip-rap armoring. The Ishbash method of stream bank rip-rap design was used to determine the required rip-rap size. The computer program Riprap 2.0 was used to verify the required rip-rap sizing. A D_{50} of 2.0 to 2.5 feet is recommended. See Appendix C for rip-rap calculations.

It is recommended that the armoring be placed at the base of the retaining wall just downstream of String Bridge, and along the embankment slope around the river bend, extending from just downstream of the retaining wall through the area of active bank erosion near the Exeter Mill apartments. It is also recommended that the existing rock wall/ledge armoring be maintained along the left embankment of the northern channel and along both embankments of the southern channel. Figure 11 shows the recommended locations for armoring and Figure 12 provides a detail for the typical placement of rip-rap along river banks.

4.5 CONCLUSION AND RECOMMENDATIONS

The analysis of the three contemplated modification options to Great Dam and their potential for downstream scour and bank erosion indicate all options would not significantly alter the downstream velocities during 100-year and 1-year flood flow events. This conclusion assumes the low flow gate orientation will remain as it exists now. However, because velocities from String Bridge to the confluence of the Squamscott River are in the 8 to 12 fps range during the 100-year flood, additional channel armoring is recommended in this area. If rip-rap were the chosen method of armoring, a D_{50} of 2.0 to 2.5 feet is recommended to protect the embankments during a 100-year flood event.

Field inspections noted an area of significant active bank erosion, due to eddies, downstream of the bend after String Bridge, near the Exeter Mill Apartments. It is recommended that this area be armored as well, using rip-rap of similar size.

It is also recommended that the existing rock retaining wall/ledge armoring be maintained downstream of String Bridge.

The proposed configurations for the low level outlet should be similar in orientation to the existing outlet to prevent the possibility of bank erosion or scour immediately downstream of the dam.

APPENDIX A

TOWN OF EXETER, NH

EXETER RIVER EROSION ANALYSIS

CROSS SECTION LOCATIONS

PROJ NO:	10613D	Wright-Pierce	FIGURE: 3
DATE:	APRIL 2008		
SCALE:	AS NOTED		

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Exeter, NH
Riverbank Scour Analysis and
Discharge Gate Design Impacts to Water Quality
Project #10613D

FIGURE 4
Flow over the fish weir on January 22, 2008

FIGURE 5
Stone near northwest corner of Library

Exeter, NH
Riverbank Scour Analysis and
Discharge Gate Design Impacts to Water Quality
Project #10613D

FIGURE 6
Erosion downstream of river bend caused by eddies

Exeter, NH
Riverbank Scour Analysis and
Discharge Gate Design Impacts to Water Quality
Project #10613D

FIGURE 7
Aerial showing eddies near Exeter Mill
Apartments downstream of String Bridge

FIGURE 8
Embankment armoring immediately
downstream of the Great Dam

FIGURE 9
Embankment armoring between the Great
Dam and String Bridge

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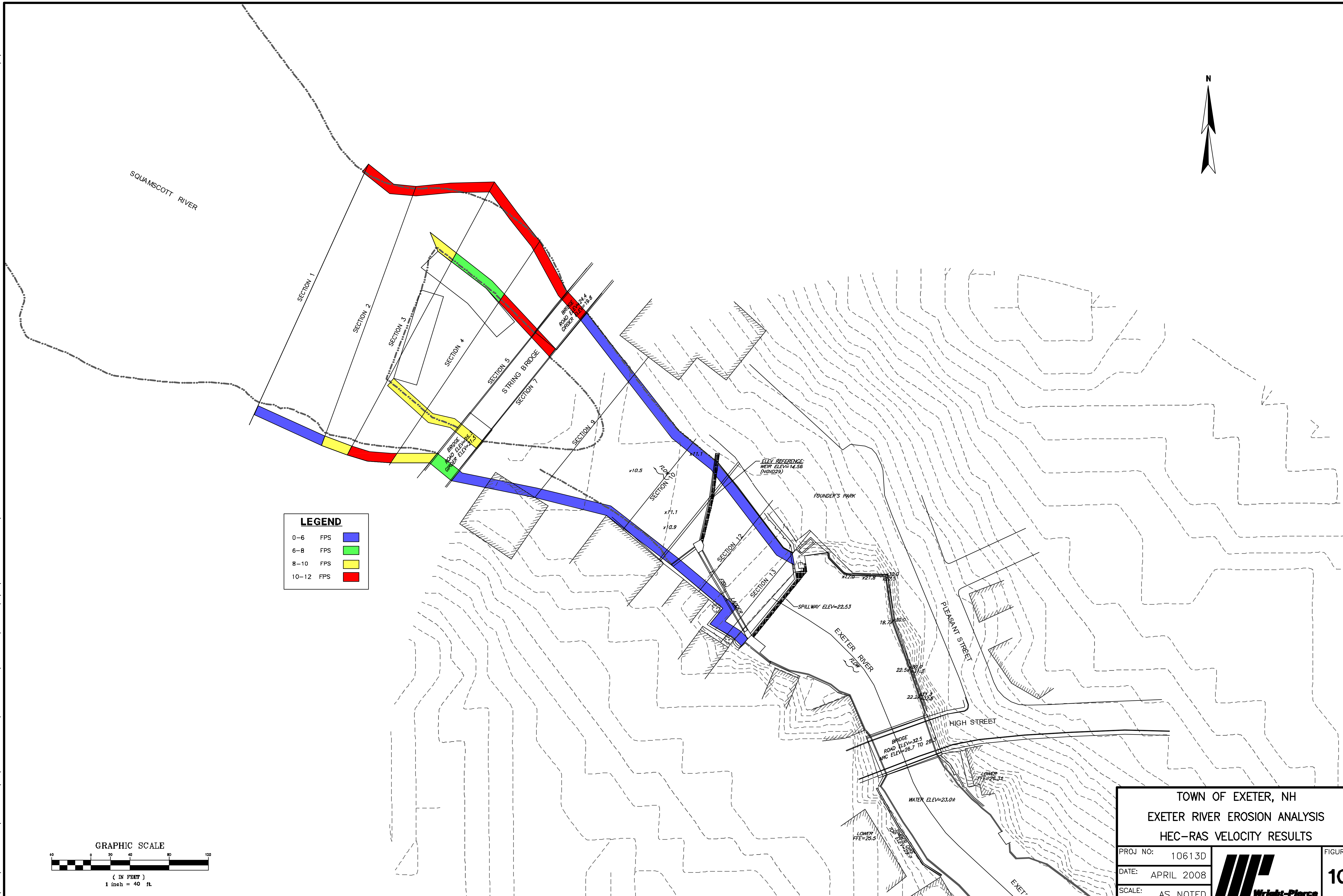


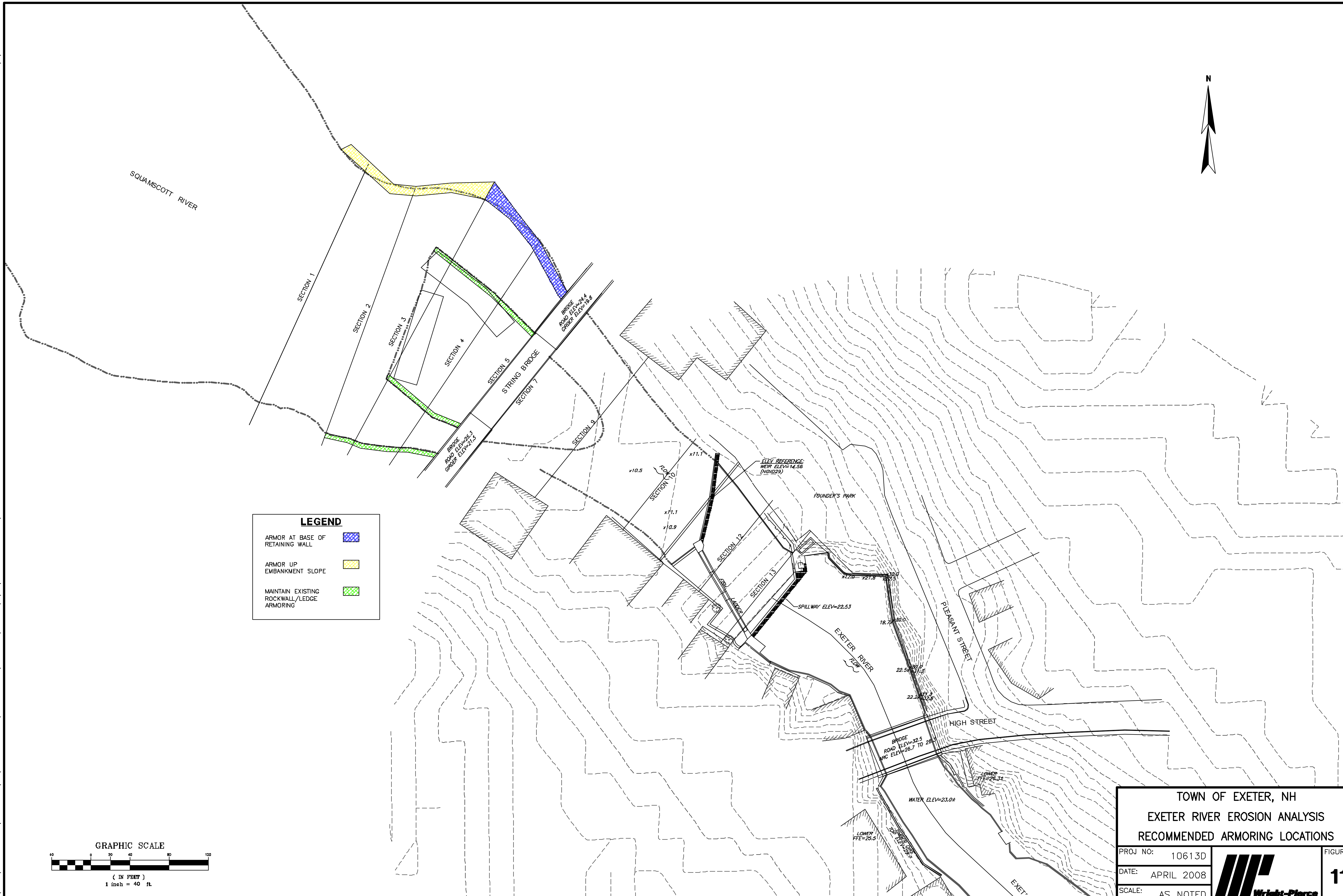
TOWN OF EXETER, NH

EXETER RIVER EROSION ANALYSIS

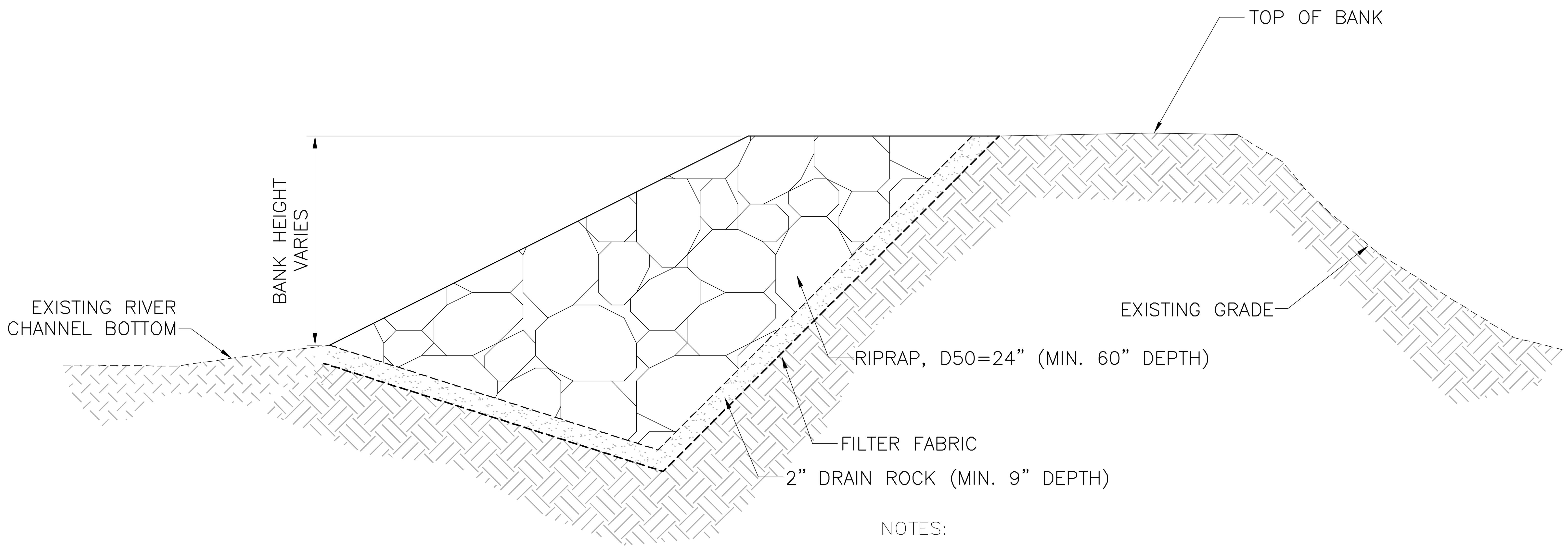
HEC-RAS VELOCITY RESULTS

PROJ NO: 10613D	Wright-Pierce	FIGURE: 10
DATE: APRIL 2008		
SCALE: AS NOTED		

G:\DWGS\10613-EXETER\10613D-FD\FIG\0613AFIG-8.DWG | 0613aFIG-10 | 1:2.1437 | ---- | 4/15/2008 12:03:57 PM | CGH



N
SQUAMSCOTT RIVER
SECTION 1
SECTION 2
SECTION 3
SECTION 4
SECTION 5
STRING BRIDGE
SECTION 7
SECTION 9
SECTION 10
SECTION 12
SECTION 13
BRIDGE ROAD ELEV=24.4 GIRDER ELEV=19.6
BRIDGE ROAD ELEV=25.3 GIRDER ELEV=21.5
ELEV REFERENCE: WEIR ELEV=14.56 (NGVD29)
FOUNDER'S PARK
FISH LADDER
SPILLWAY ELEV=22.53
EXETER RIVER
FLOW
PLEASANT STREET
HIGH STREET
BRIDGE ROAD ELEV=32.5 ARC ELEV=26.7 TO 28
WATER ELEV=23.0±
LOWER FFE=25.5
LOWER FFE=26.3±
LEGEND
ARMOR AT BASE OF RETAINING WALL
ARMOR UP EMBANKMENT SLOPE
MAINTAIN EXISTING ROCKWALL/LEDGE ARMORING
GRAPHIC SCALE
40 0 20 40 80 120
(IN FEET)
1 inch = 40 ft.
TOWN OF EXETER, NH
EXETER RIVER EROSION ANALYSIS
RECOMMENDED ARMORING LOCATIONS
PROJ NO: 10613D
DATE: APRIL 2008
SCALE: AS NOTED
FIGURE: 11
Wright-Pierce



NOTES:

1. RIPRAP SHALL BE A MINIMUM D50=24 INCHES, PLACED ON FILTER FABRIC.
2. RIPRAP STONE SHALL CONSIST OF SUB-ANGULAR FIELD STONE OR ROUGH, UNHEWN QUARRY STONE OF APPROXIMATELY RECTANGULAR SHAPE.
3. STONES SMALLER THAN 12 INCHES SHALL BE MORTARED IN PLACE.
4. RIPRAP SHALL BE PLACED ON THE SIDE SLOPES TO THE TOP OF THE BANKS, UNLESS OTHERWISE INDICATED ON THE PLANS.

TYPICAL RIPRAP SLOPE PROTECTION

NTS

TOWN OF EXETER, NH EXETER RIVER BANK EROSION ANALYSIS SLOPE PROTECTION DETAIL		
PROJ NO: 10613D	DATE: MARCH 2007	FIGURE:
WRIGHT-PIERCE Engineering a Better Environment		12

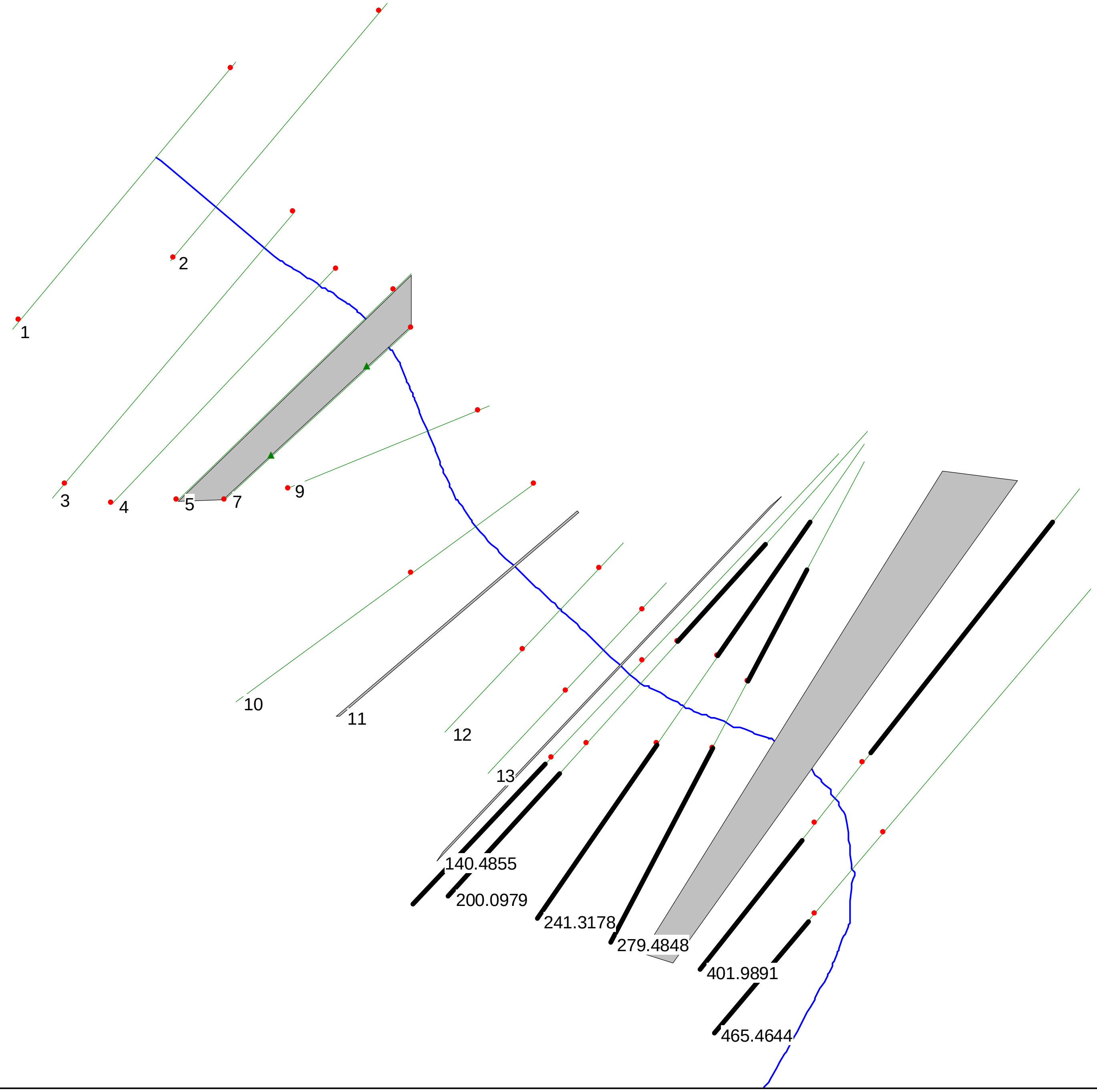
APPENDIX B

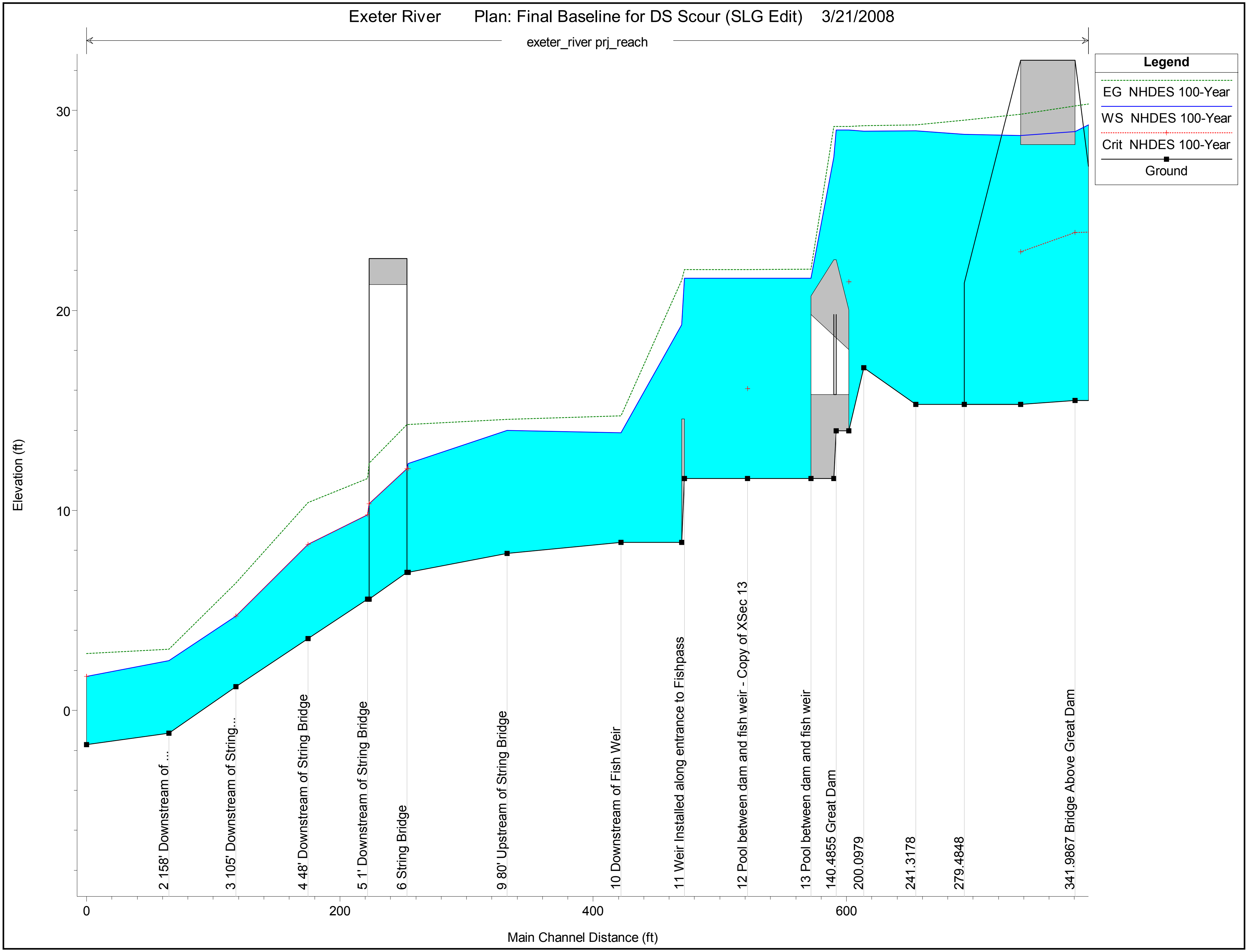
APPENDIX B
HEC RAS Model Results

HEC RAS

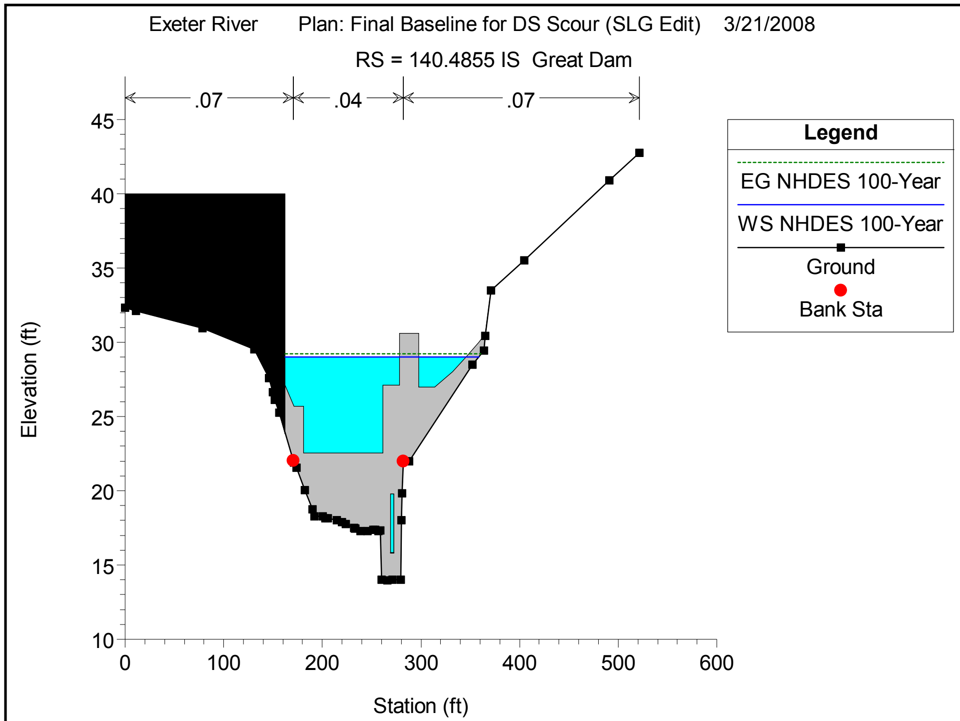
Existing Conditions Results

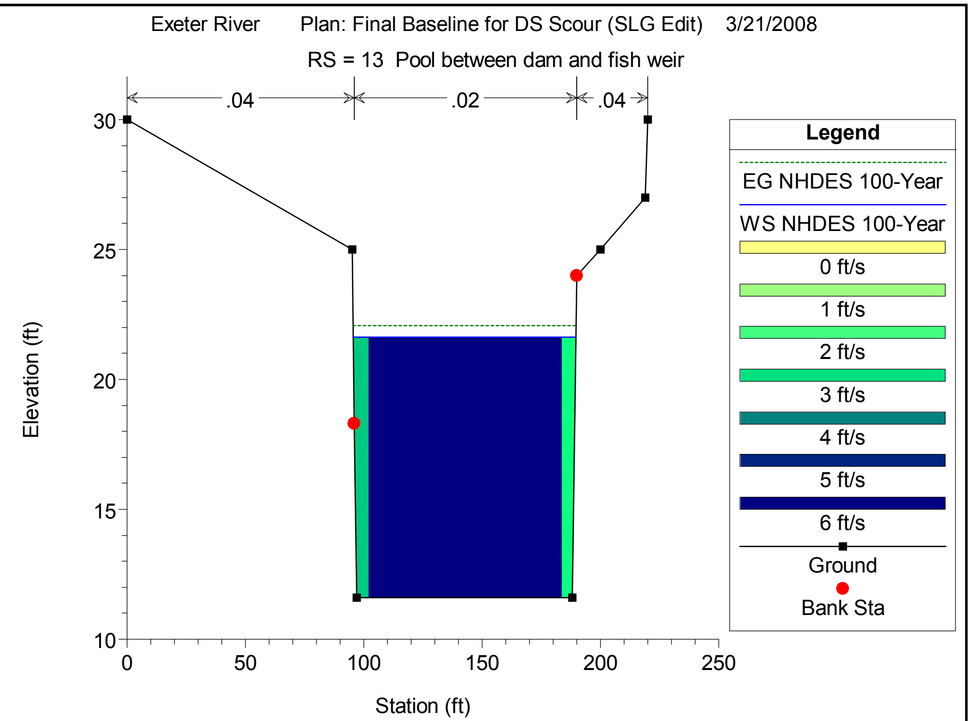
Exeter River Analysis: HEC-RAS Geometric Plan View
Final Baseline for DS Scour (SLG Edit)

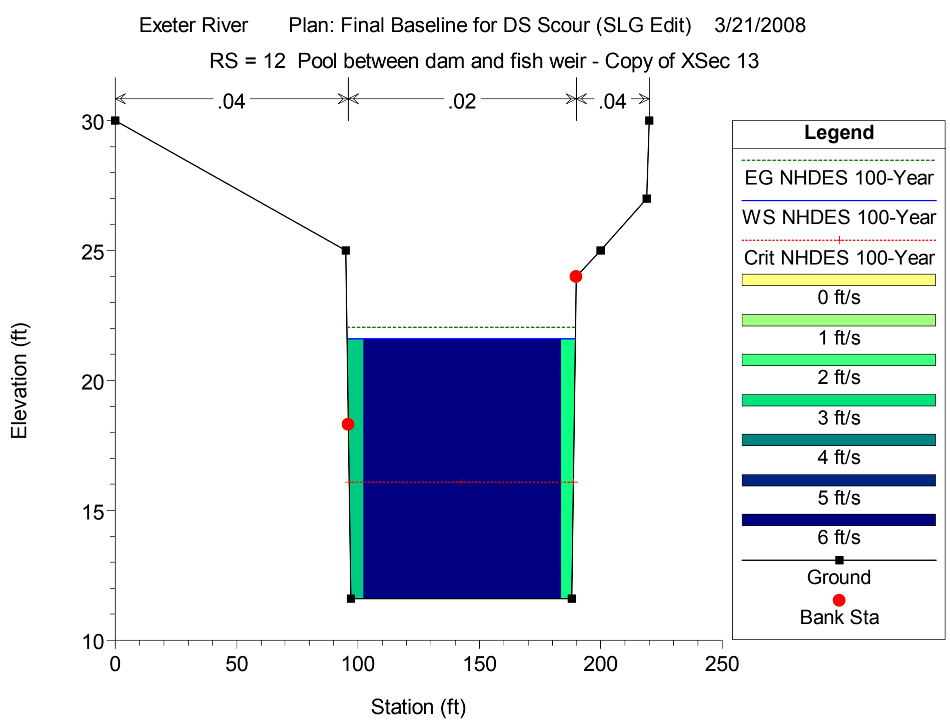


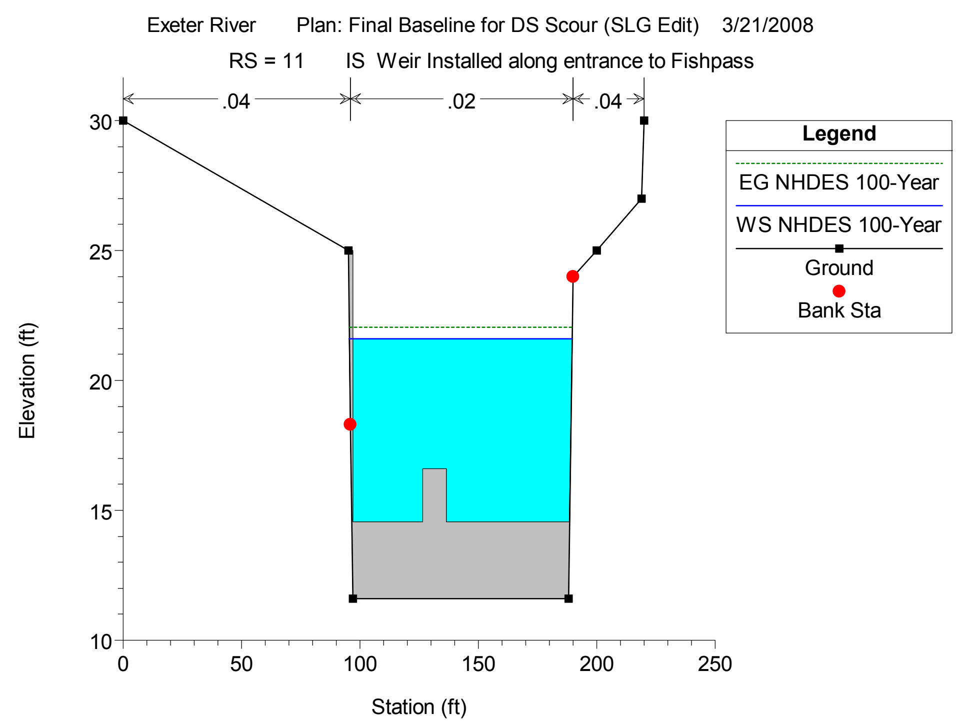


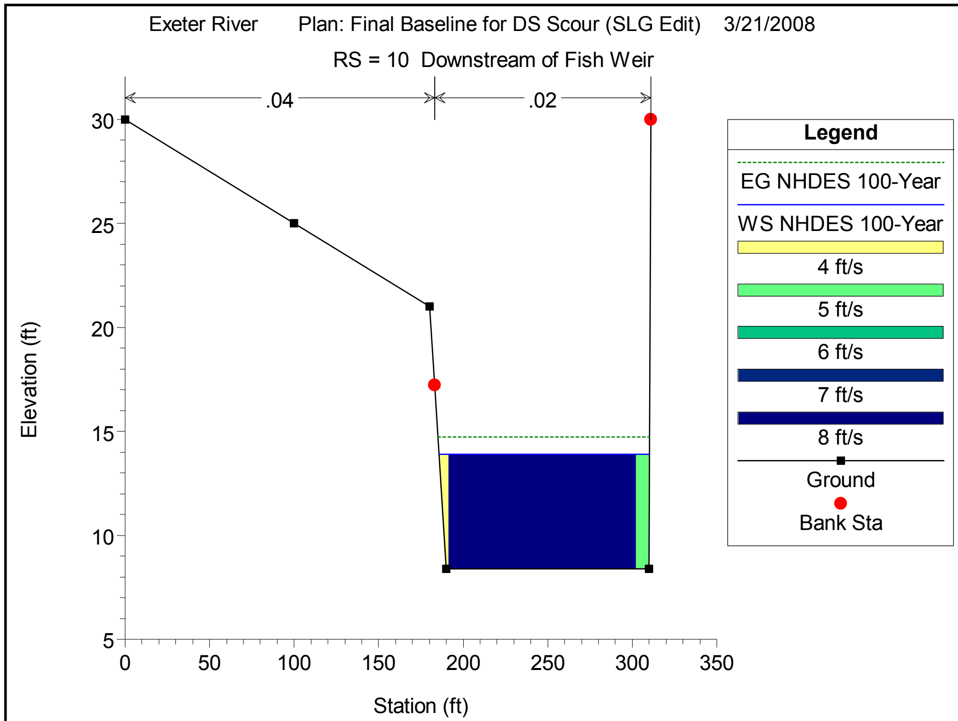
Exeter River Plan: Final Baseline for DS Scour (SLG Edit) 3/21/2008
exeter_river prj_reach
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
Ground
Elevation (ft)
Main Channel Distance (ft)
2 158' Downstream of ...
3 105' Downstream of String...
4 48' Downstream of String Bridge
5 1' Downstream of String Bridge
6 String Bridge
9 80' Upstream of String Bridge
10 Downstream of Fish Weir
11 Weir Installed along entrance to Fishpass
12 Pool between dam and fish weir - Copy of XSec 13
13 Pool between dam and fish weir
140.4855 Great Dam
200.0979
241.3178
279.4848
341.9867 Bridge Above Great Dam
0
200
400
600
10
20
30


Exeter River Plan: Final Baseline for DS Scour (SLG Edit) 3/21/2008
RS = 140.4855 IS Great Dam
.07
.04
.07
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Ground
Bank Sta

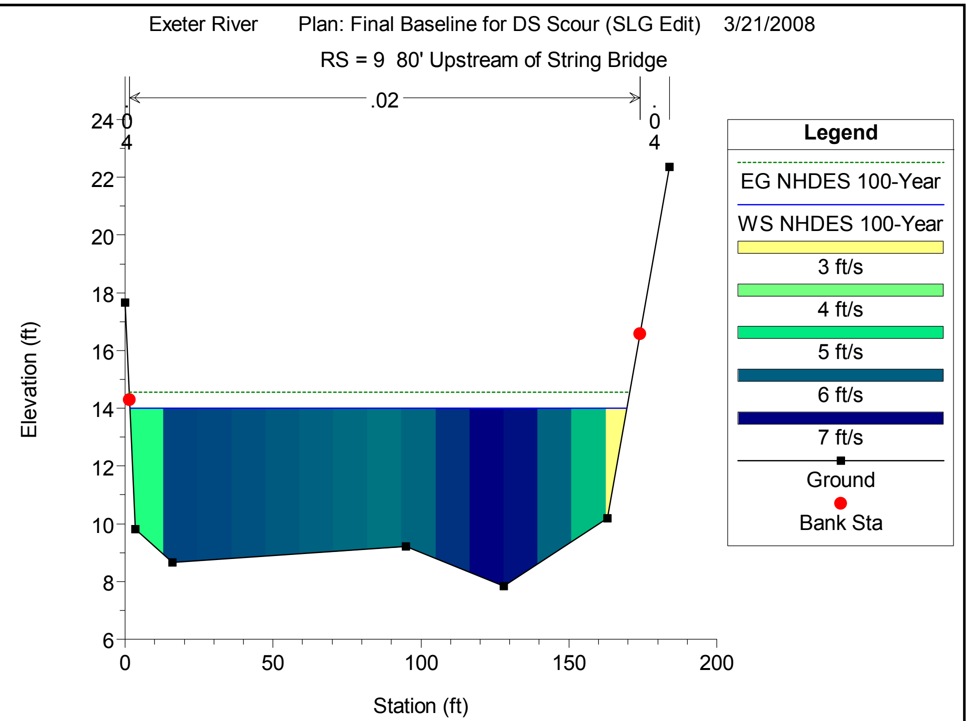

Exeter River Plan: Final Baseline for DS Scour (SLG Edit) 3/21/2008
RS = 13 Pool between dam and fish weir
.04
.02
.04
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
Ground
Bank Sta


Exeter River Plan: Final Baseline for DS Scour (SLG Edit) 3/21/2008
RS = 12 Pool between dam and fish weir - Copy of XSec 13
.04
.02
.04
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
Ground
Bank Sta

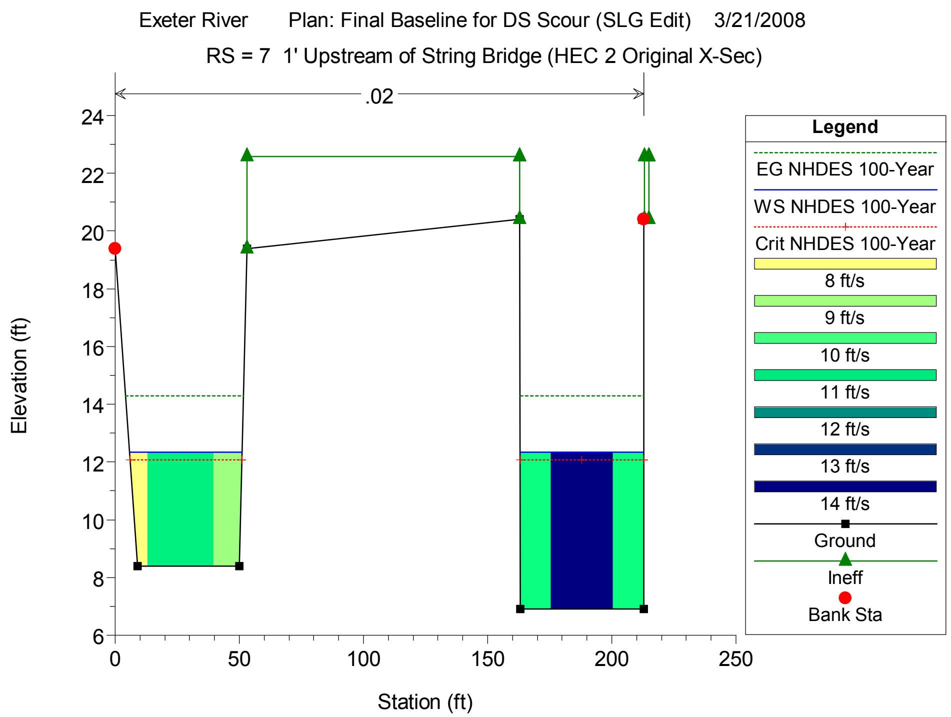

Exeter River Plan: Final Baseline for DS Scour (SLG Edit) 3/21/2008
RS = 11 IS Weir Installed along entrance to Fishpass
.04
.02
.04
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Ground
Bank Sta



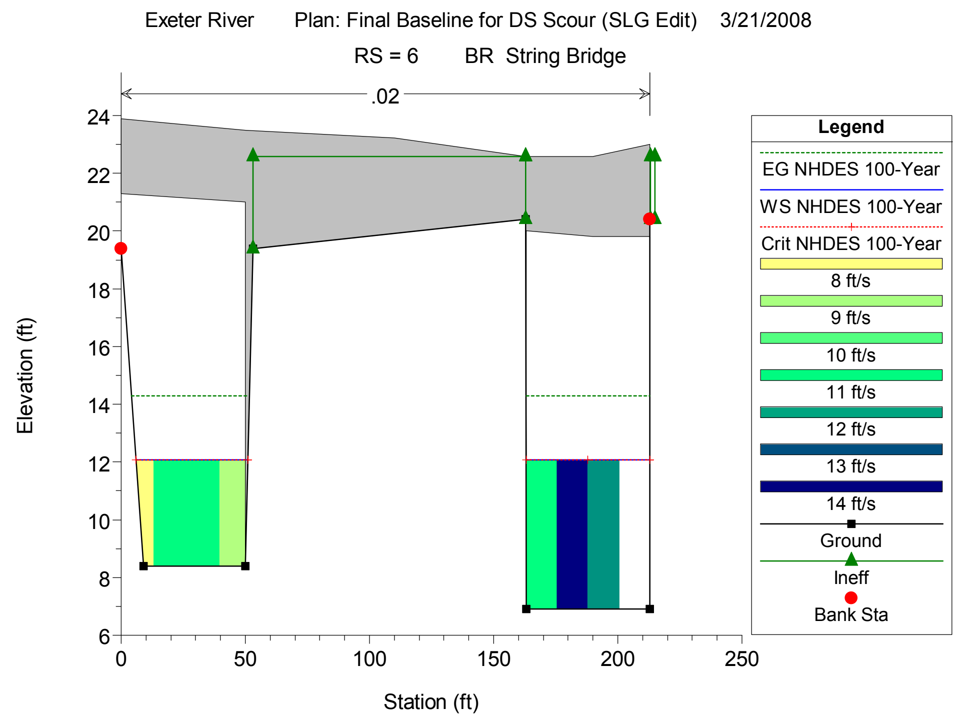
Exeter River Plan: Final Baseline for DS Scour (SLG Edit) 3/21/2008
RS = 10 Downstream of Fish Weir
.04
.02
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
Ground
Bank Sta



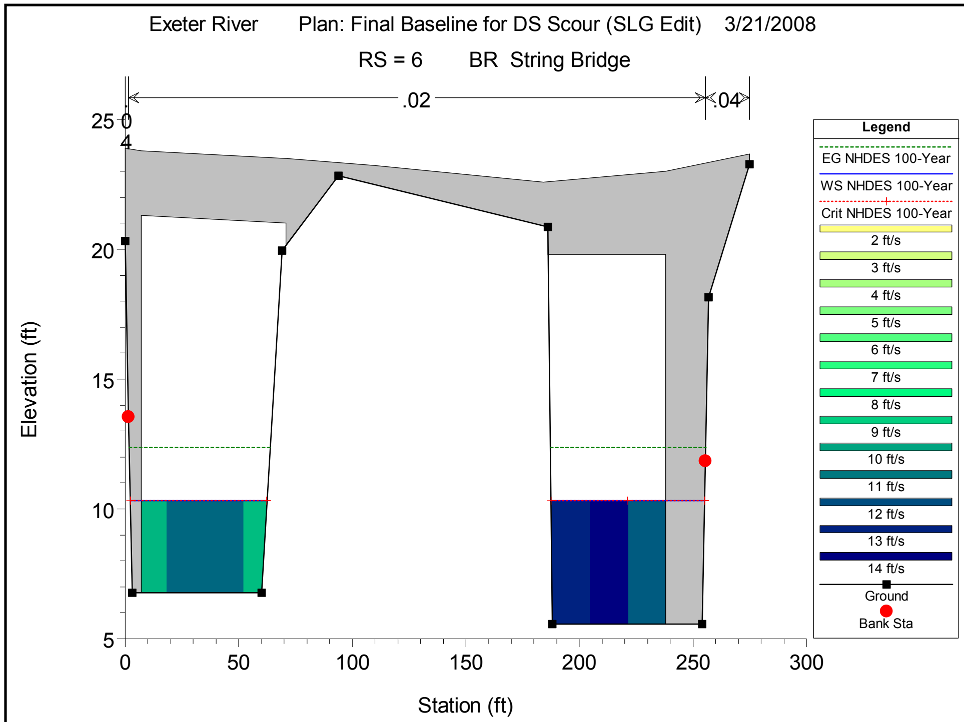
Exeter River Plan: Final Baseline for DS Scour (SLG Edit) 3/21/2008
RS = 9 80' Upstream of String Bridge
.02
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
Ground
Bank Sta

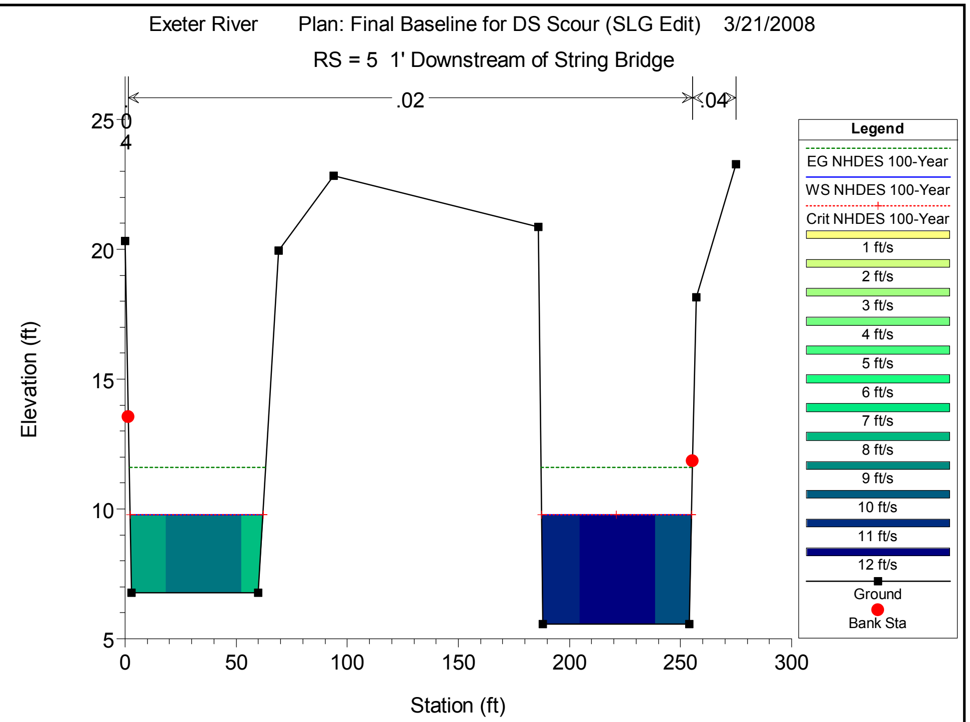


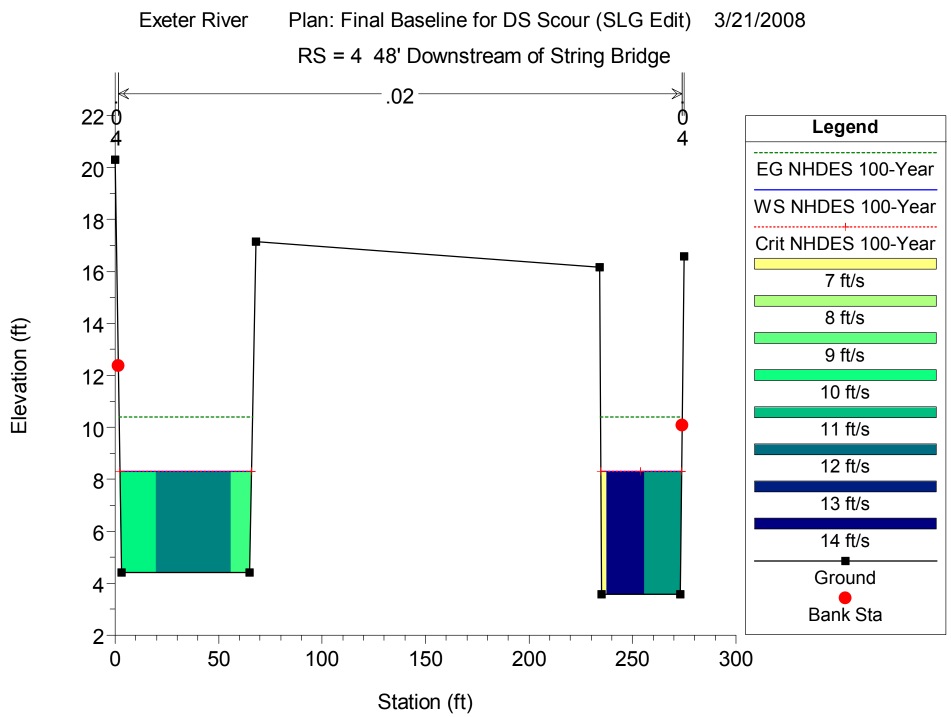
Exeter River Plan: Final Baseline for DS Scour (SLG Edit) 3/21/2008
RS = 7 1' Upstream of String Bridge (HEC 2 Original X-Sec)
.02
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
13 ft/s
14 ft/s
Ground
Ineff
Bank Sta

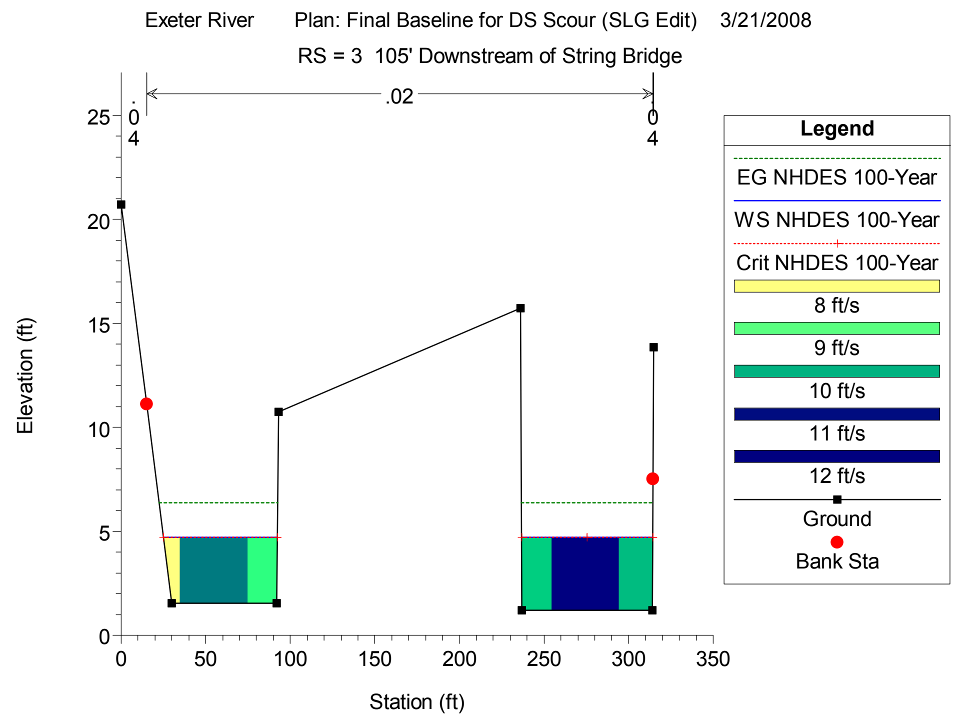


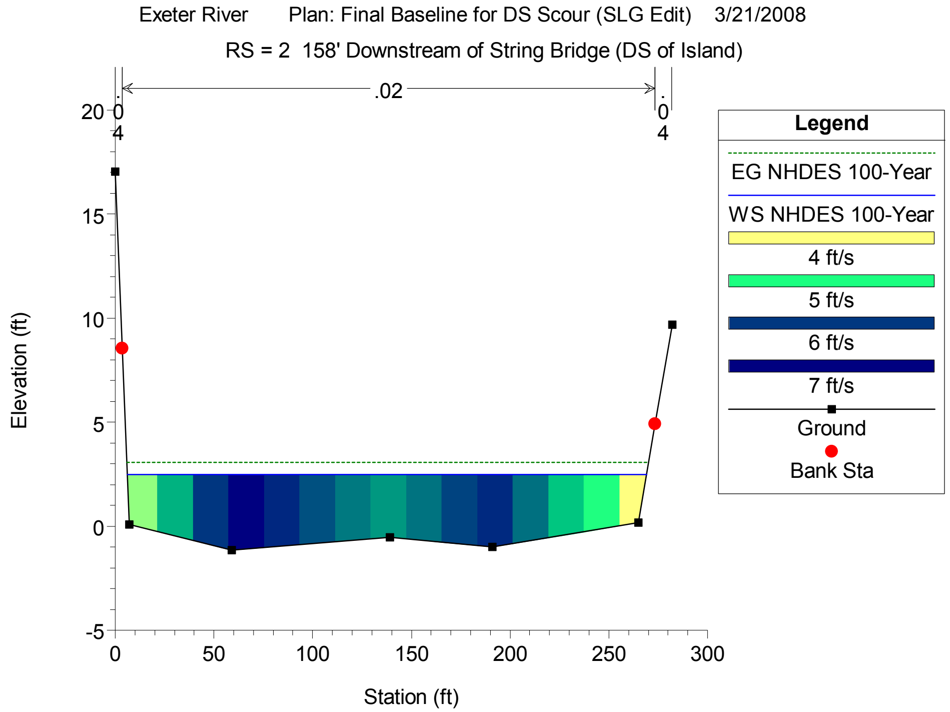
Exeter River Plan: Final Baseline for DS Scour (SLG Edit) 3/21/2008
RS = 6 BR String Bridge
.02
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
13 ft/s
14 ft/s
Ground
Ineff
Bank Sta


Exeter River Plan: Final Baseline for DS Scour (SLG Edit) 3/21/2008
RS = 6 BR String Bridge
.02
.04
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
13 ft/s
14 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)

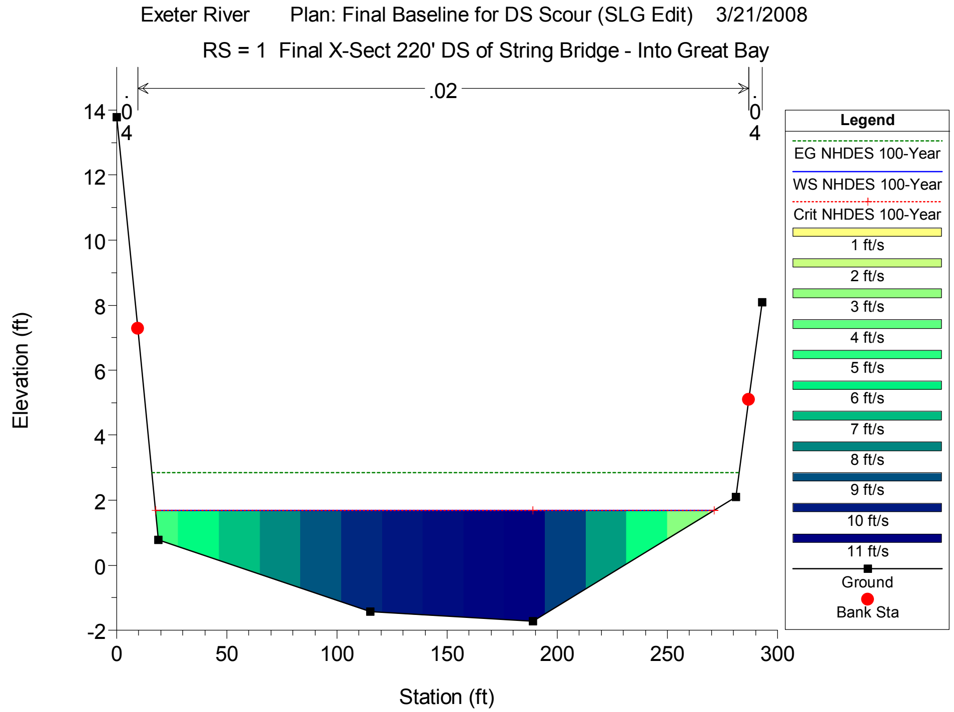

Exeter River Plan: Final Baseline for DS Scour (SLG Edit) 3/21/2008
RS = 5 1' Downstream of String Bridge
.02
.04
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)


Exeter River Plan: Final Baseline for DS Scour (SLG Edit) 3/21/2008
RS = 4 48' Downstream of String Bridge
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
7 ft/s
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
13 ft/s
14 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)


Exeter River Plan: Final Baseline for DS Scour (SLG Edit) 3/21/2008
RS = 3 105' Downstream of String Bridge
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)



Exeter River Plan: Final Baseline for DS Scour (SLG Edit) 3/21/2008
RS = 2 158' Downstream of String Bridge (DS of Island)
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)



Exeter River Plan: Final Baseline for DS Scour (SLG Edit) 3/21/2008
RS = 1 Final X-Sect 220' DS of String Bridge - Into Great Bay
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
11 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)

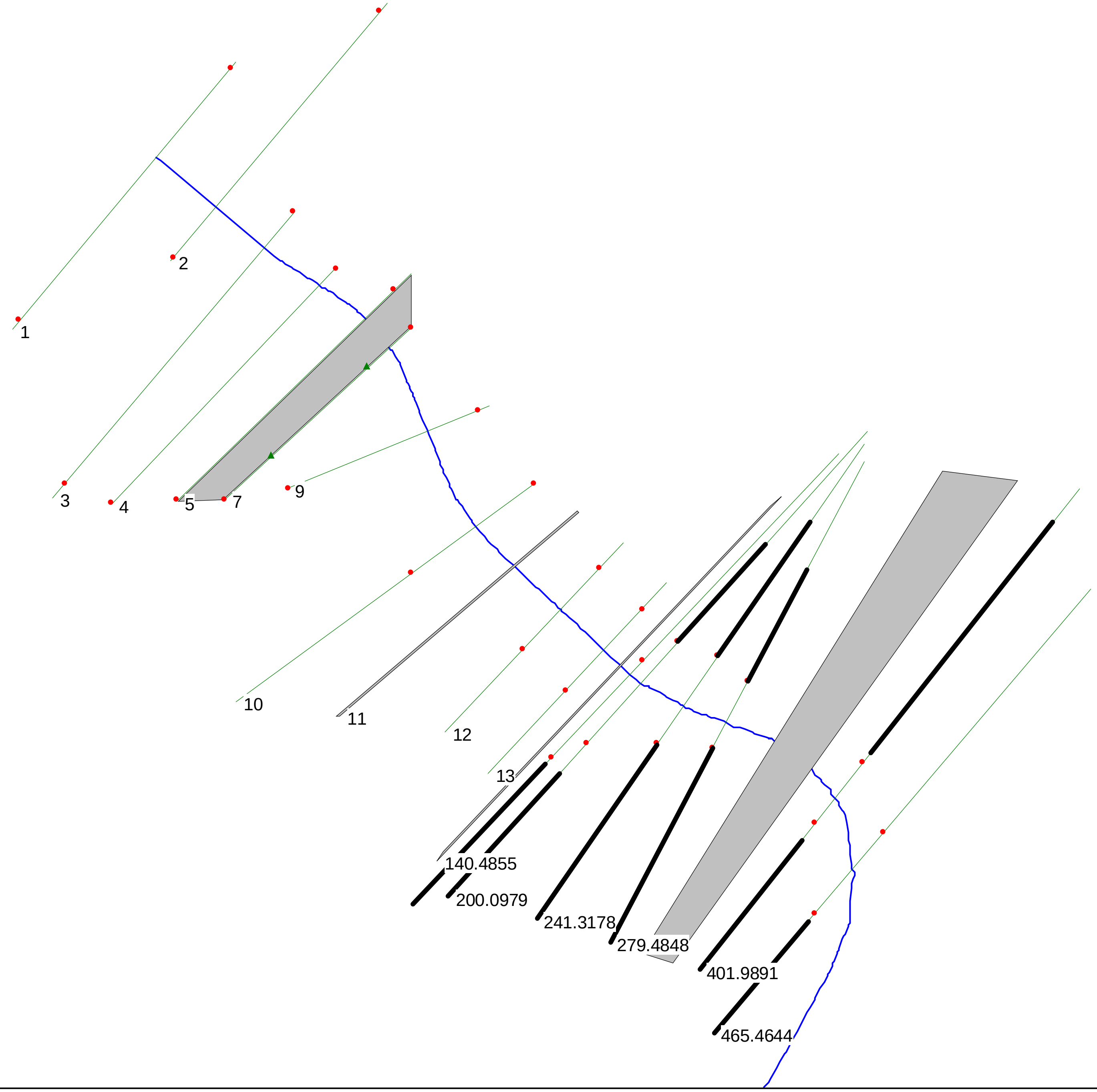
HEC-RAS Plan: FinalScour Locations: User Defined Profile: NHDES 100-Year

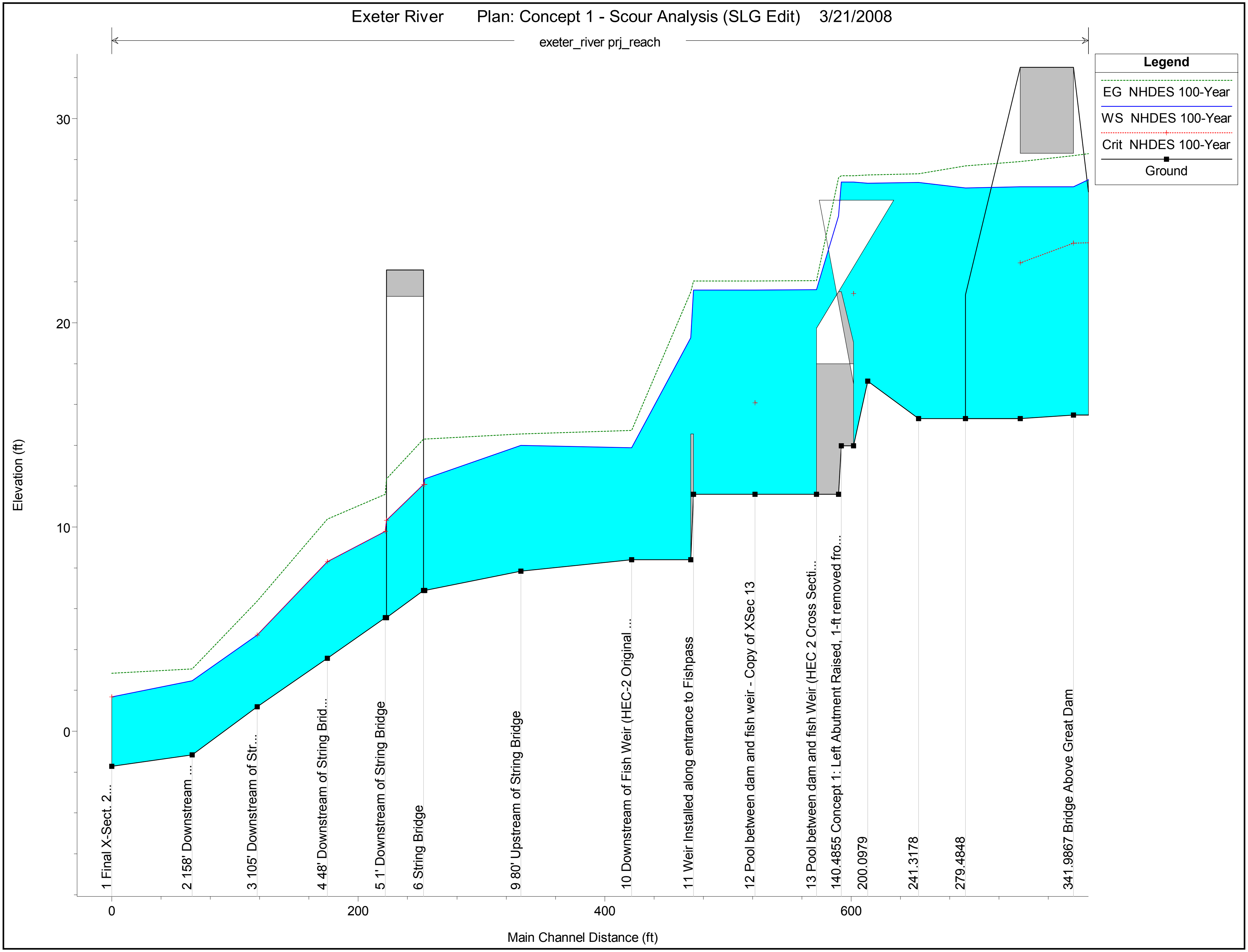
River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Flow Area	Top Width	Froude # Chl	Vel Left	Vel Chnl	Vel Right	Vel Total
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(sq ft)	(ft)		(ft/s)	(ft/s)	(ft/s)	(ft/s)
exeter_river	prj_reach	401.9891	NHDES 100-Year	4949.00	15.49	30.02	23.94	30.53	0.000973	975.87	92.94	0.30	1.98	5.94	1.82	5.07
exeter_river	prj_reach	341.9867		Bridge												
exeter_river	prj_reach	279.4848	NHDES 100-Year	4949.00	15.30	28.80		29.51	0.001523	733.93	63.14	0.35	0.52	6.77		6.74
exeter_river	prj_reach	241.3178	NHDES 100-Year	4949.00	15.30	28.97		29.28	0.000565	1123.28	89.90	0.22	0.30	4.42		4.41
exeter_river	prj_reach	200.0979	NHDES 100-Year	4949.00	17.14	28.97		29.23	0.000644	1192.28	114.28	0.23		4.15		4.15
exeter_river	prj_reach	188.4948	NHDES 100-Year	4949.00	13.98	29.02	21.43	29.20	0.000403	1612.87	196.35	0.19	1.01	3.60	1.02	3.07
exeter_river	prj_reach	140.4855		Inl Struct												
exeter_river	prj_reach	13	NHDES 100-Year	4949.00	11.60	21.62		22.06	0.000294	926.97	94.11	0.30	0.25	5.34		5.34
exeter_river	prj_reach	12	NHDES 100-Year	4949.00	11.60	21.60	16.09	22.04	0.000296	925.43	94.11	0.30	0.25	5.35		5.35
exeter_river	prj_reach	11		Inl Struct												
exeter_river	prj_reach	10	NHDES 100-Year	4949.00	8.40	13.88		14.73	0.001135	670.75	124.61	0.56		7.38		7.38
exeter_river	prj_reach	9	NHDES 100-Year	4949.00	7.84	14.01		14.56	0.000785	831.37	167.94	0.47		5.95		5.95
exeter_river	prj_reach	7	NHDES 100-Year	4949.00	6.90	12.35	12.08	14.30	0.003611	441.10	95.06	0.92		11.22		11.22
exeter_river	prj_reach	6		Bridge												
exeter_river	prj_reach	5	NHDES 100-Year	4949.00	5.56	9.78	9.78	11.60	0.004313	457.12	127.28	1.01		10.83		10.83
exeter_river	prj_reach	4	NHDES 100-Year	4949.00	3.58	8.30	8.30	10.39	0.004387	426.03	102.75	1.01		11.62		11.62
exeter_river	prj_reach	3	NHDES 100-Year	4949.00	1.19	4.71	4.71	6.38	0.004348	477.48	144.84	1.01		10.36		10.36
exeter_river	prj_reach	2	NHDES 100-Year	4949.00	-1.15	2.48		3.05	0.001516	811.79	263.13	0.61		6.10		6.10
exeter_river	prj_reach	1	NHDES 100-Year	4949.00	-1.72	1.69	1.69	2.84	0.004501	575.60	253.68	1.01		8.60		8.60

HEC RAS

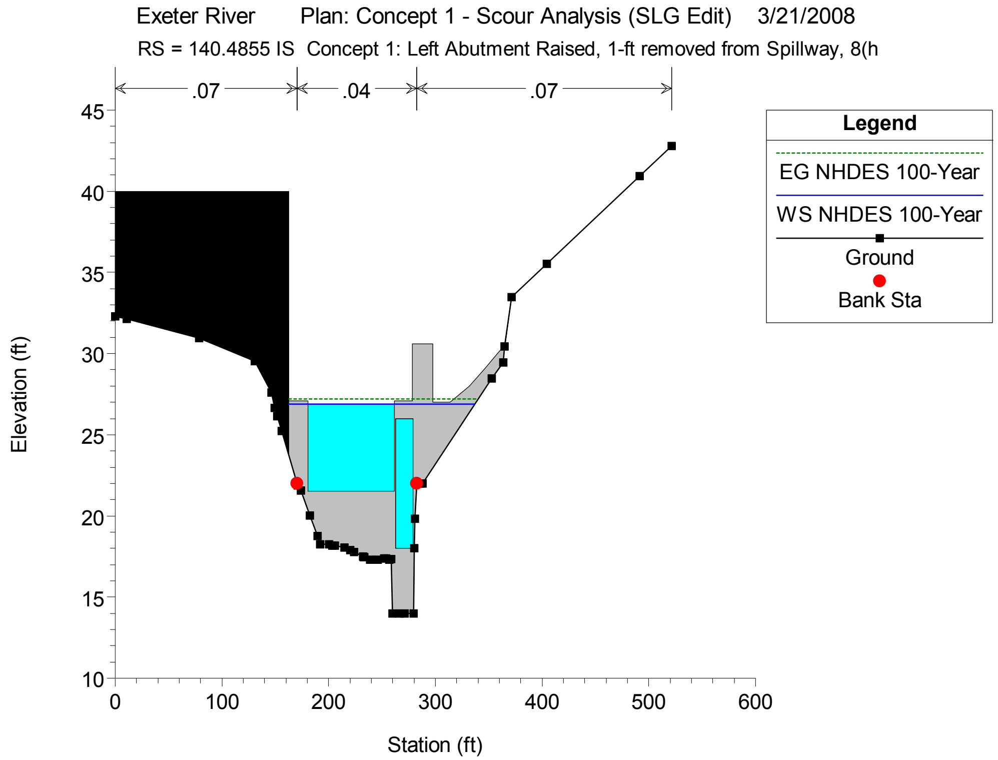
Concept 1 Results

Exeter River Analysis: HEC-RAS Geometric Plan View
Concept 1 - Scour Analysis (SLG Edit)

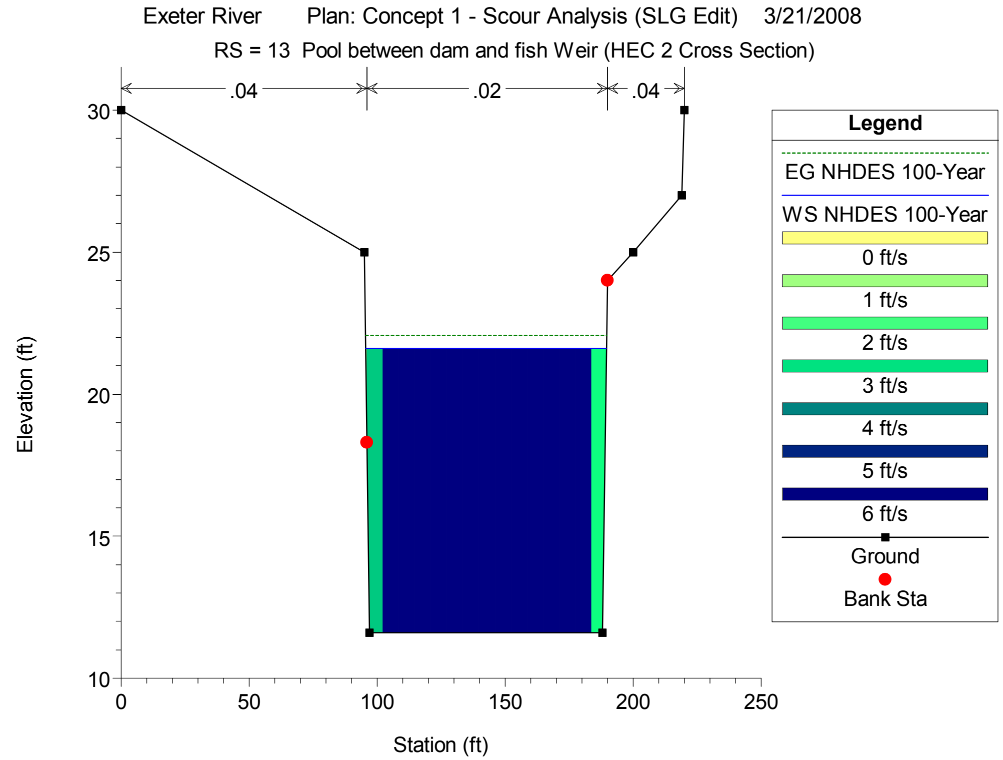




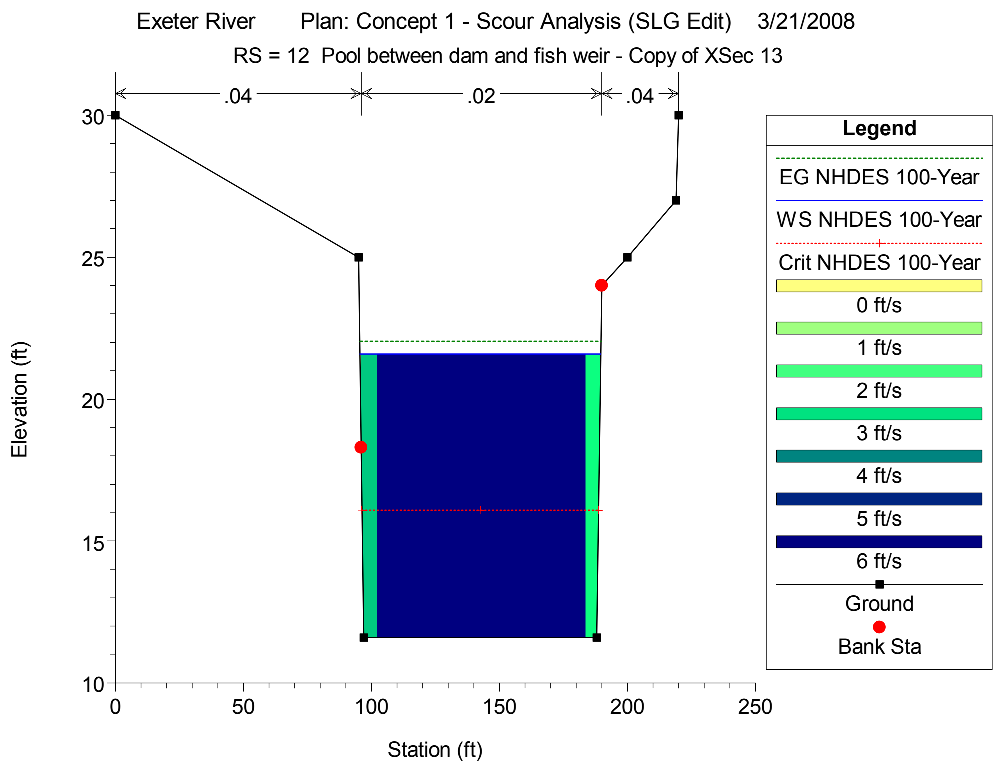
Exeter River Plan: Concept 1 - Scour Analysis (SLG Edit) 3/21/2008
exeter_river prj_reach
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
Ground
Elevation (ft)
30
20
10
0
Main Channel Distance (ft)
0
200
400
600
1 Final X-Sect. 2...
2 158' Downstream ...
3 105' Downstream of Str...
4 48' Downstream of String Brid...
5 1' Downstream of String Bridge
6 String Bridge
9 80' Upstream of String Bridge
10 Downstream of Fish Weir (HEC-2 Original ...
11 Weir Installed along entrance to Fishpass
12 Pool between dam and fish weir - Copy of XSec 13
13 Pool between dam and fish Weir (HEC 2 Cross Secti...
140.4855 Concept 1: Left Abutment Raised, 1-ft removed fro...
200.0979
241.3178
279.4848
341.9867 Bridge Above Great Dam



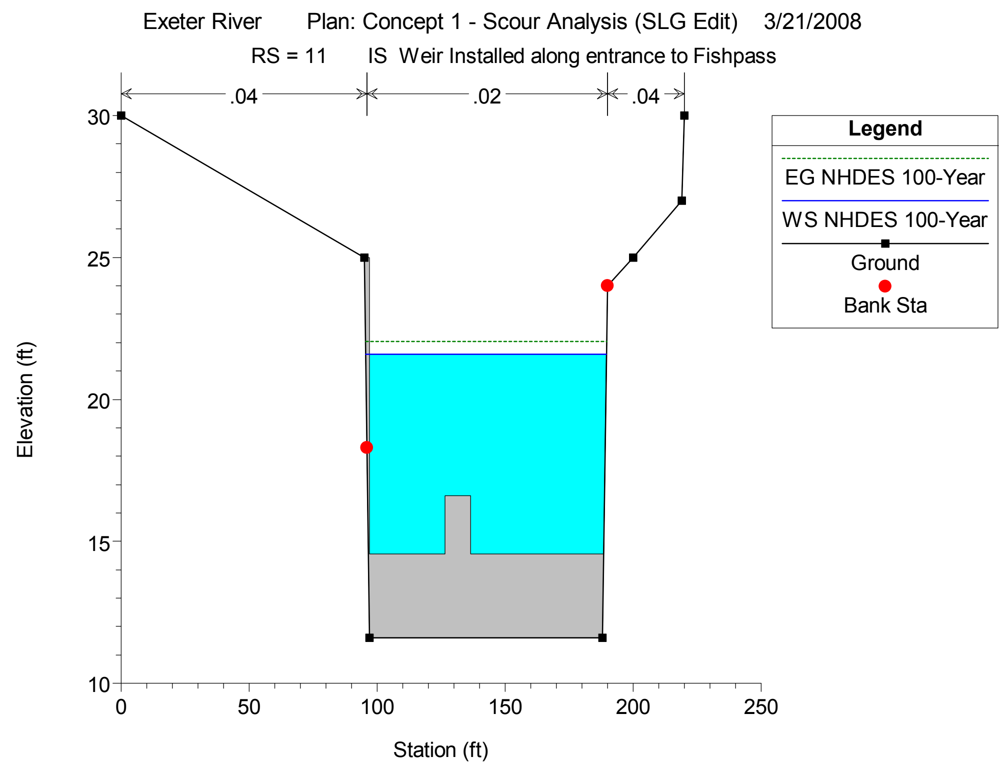
Exeter River Plan: Concept 1 - Scour Analysis (SLG Edit) 3/21/2008
RS = 140.4855 IS Concept 1: Left Abutment Raised, 1-ft removed from Spillway, 8(h
.07
.04
.07
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Ground
Bank Sta



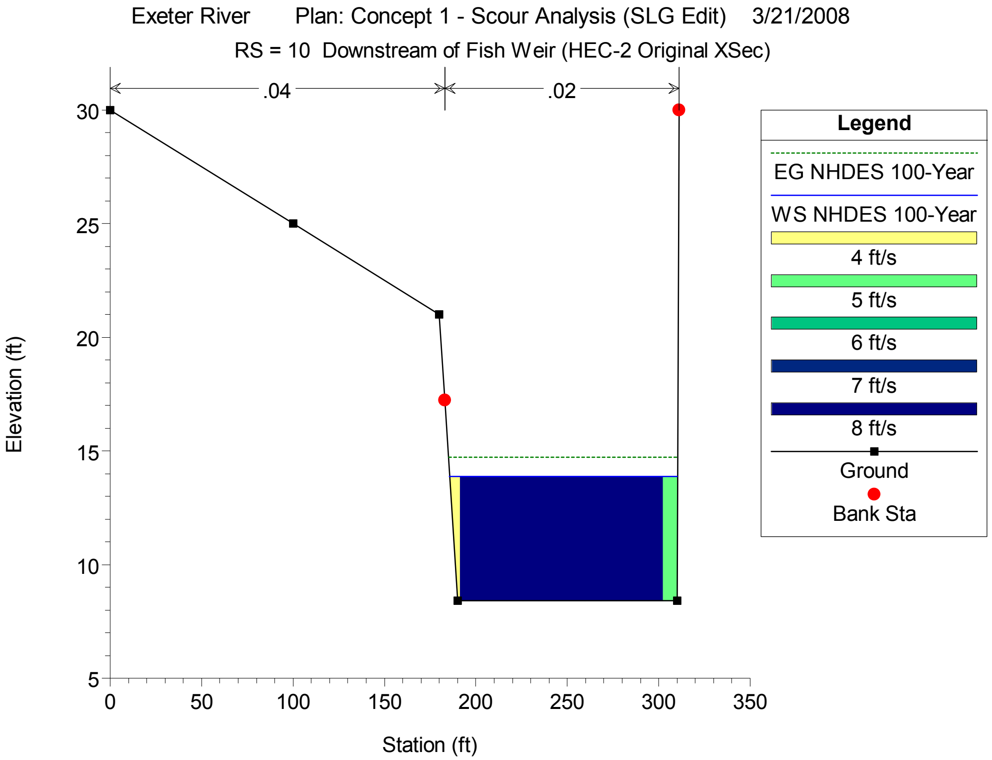
Exeter River Plan: Concept 1 - Scour Analysis (SLG Edit) 3/21/2008
RS = 13 Pool between dam and fish Weir (HEC 2 Cross Section)
.04
.02
.04
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
Ground
Bank Sta

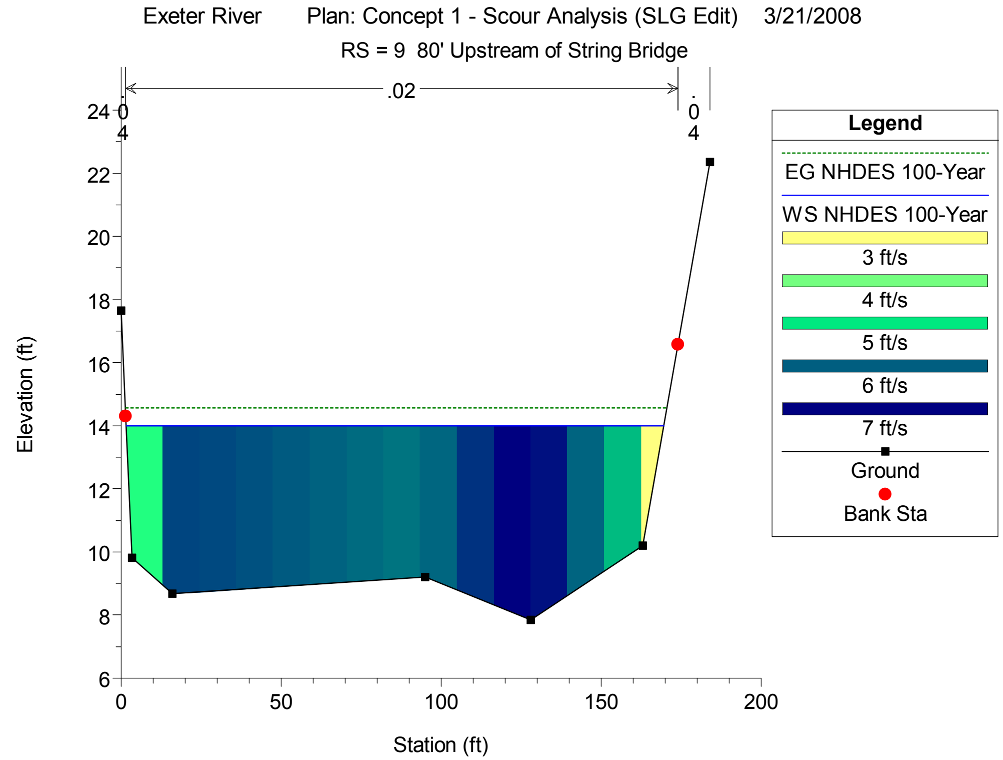


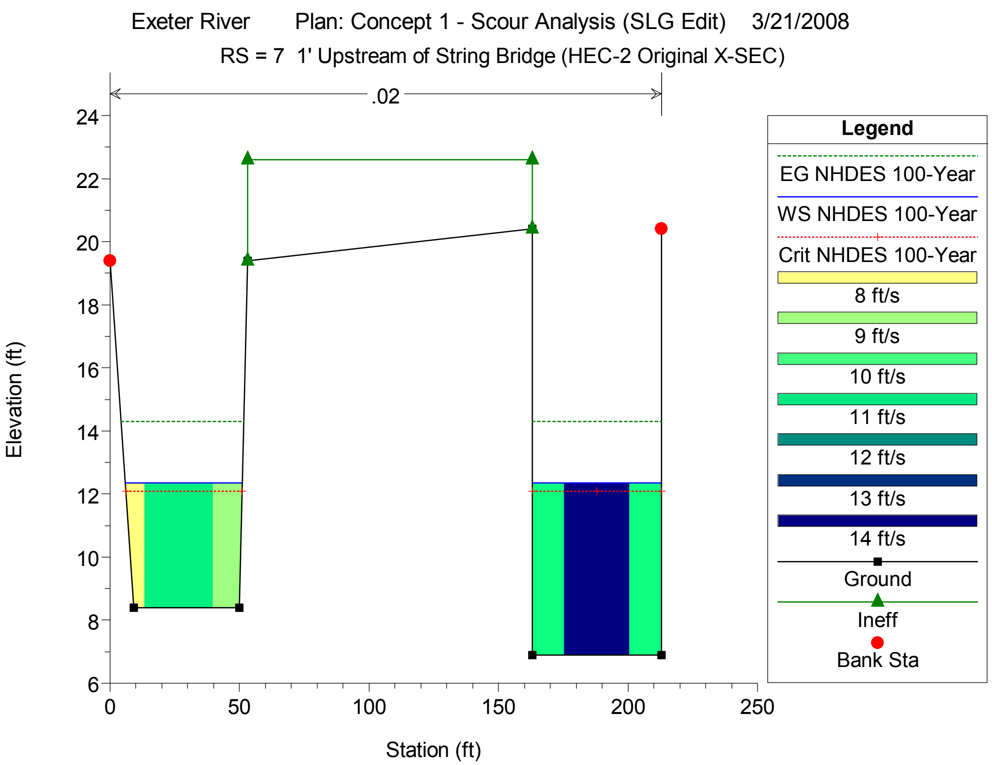
Exeter River Plan: Concept 1 - Scour Analysis (SLG Edit) 3/21/2008
RS = 12 Pool between dam and fish weir - Copy of XSec 13
.04
.02
.04
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
Ground
Bank Sta

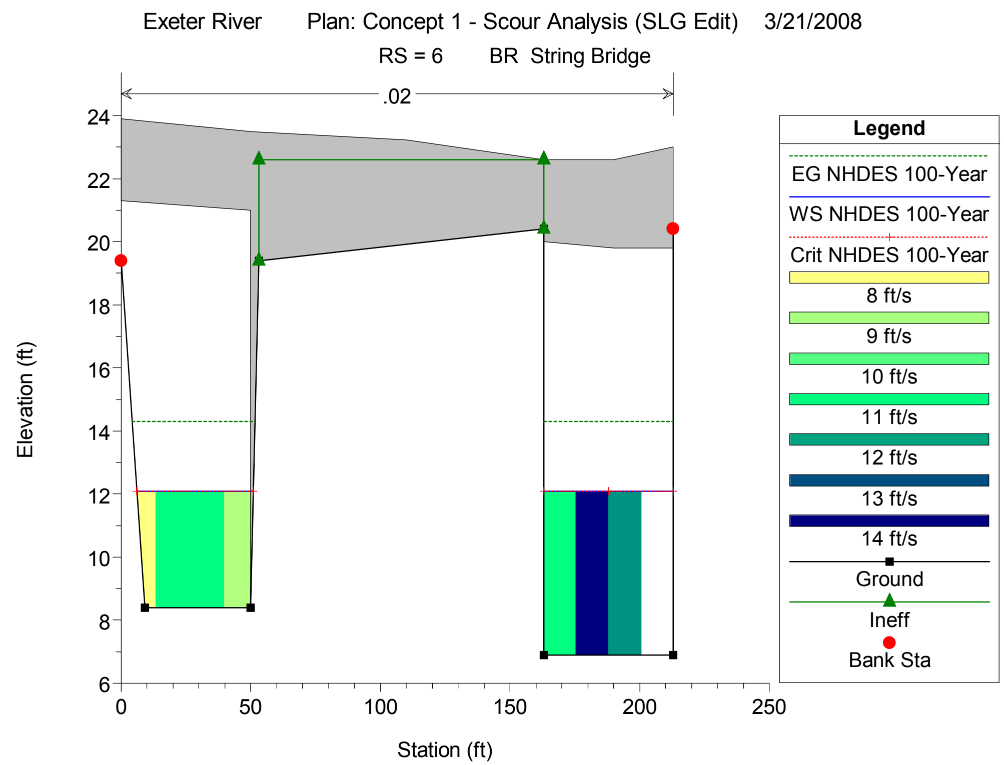


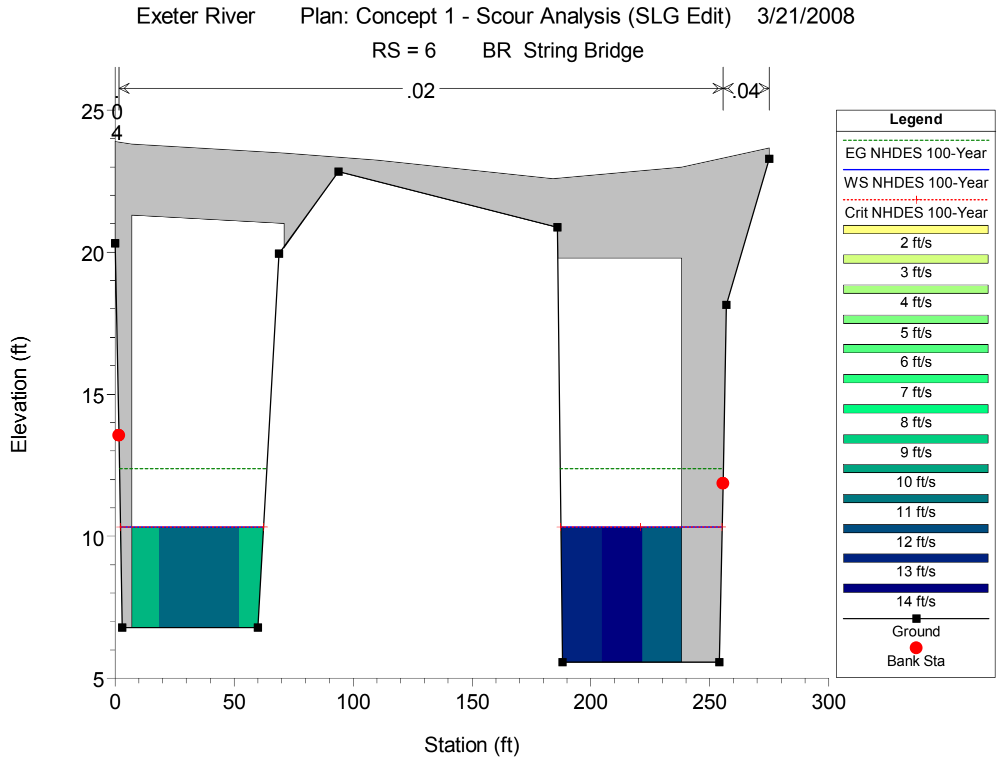
Exeter River Plan: Concept 1 - Scour Analysis (SLG Edit) 3/21/2008
RS = 11 IS Weir Installed along entrance to Fishpass
.04
.02
.04
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Ground
Bank Sta

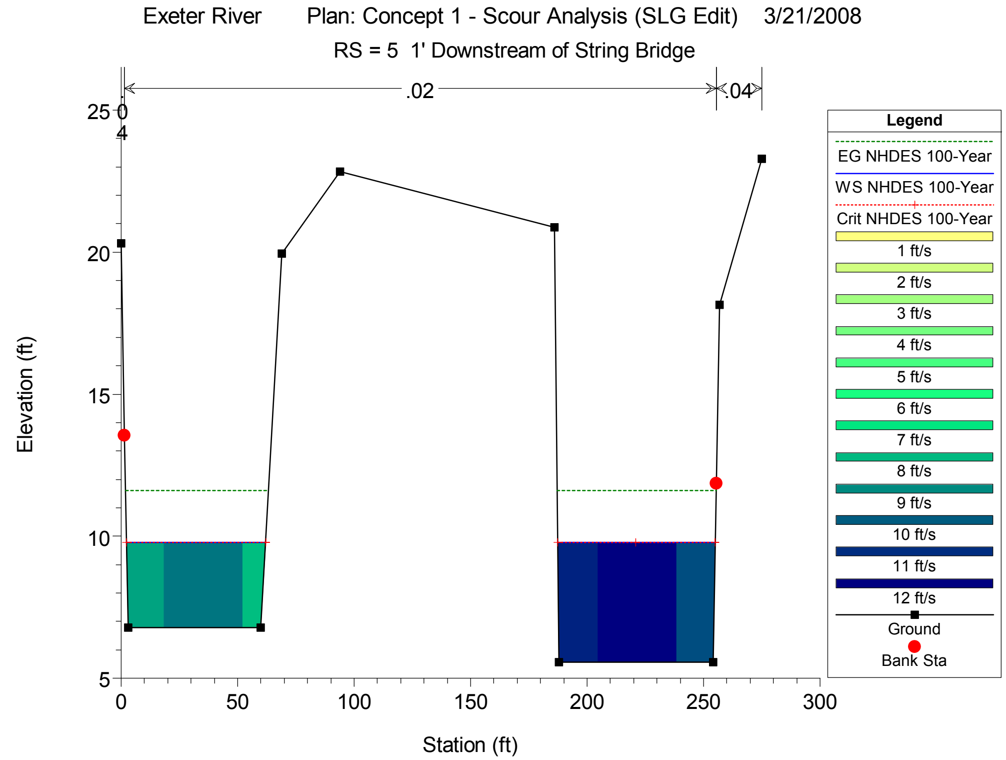

Exeter River Plan: Concept 1 - Scour Analysis (SLG Edit) 3/21/2008
RS = 10 Downstream of Fish Weir (HEC-2 Original XSec)
.04
.02
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
Ground
Bank Sta

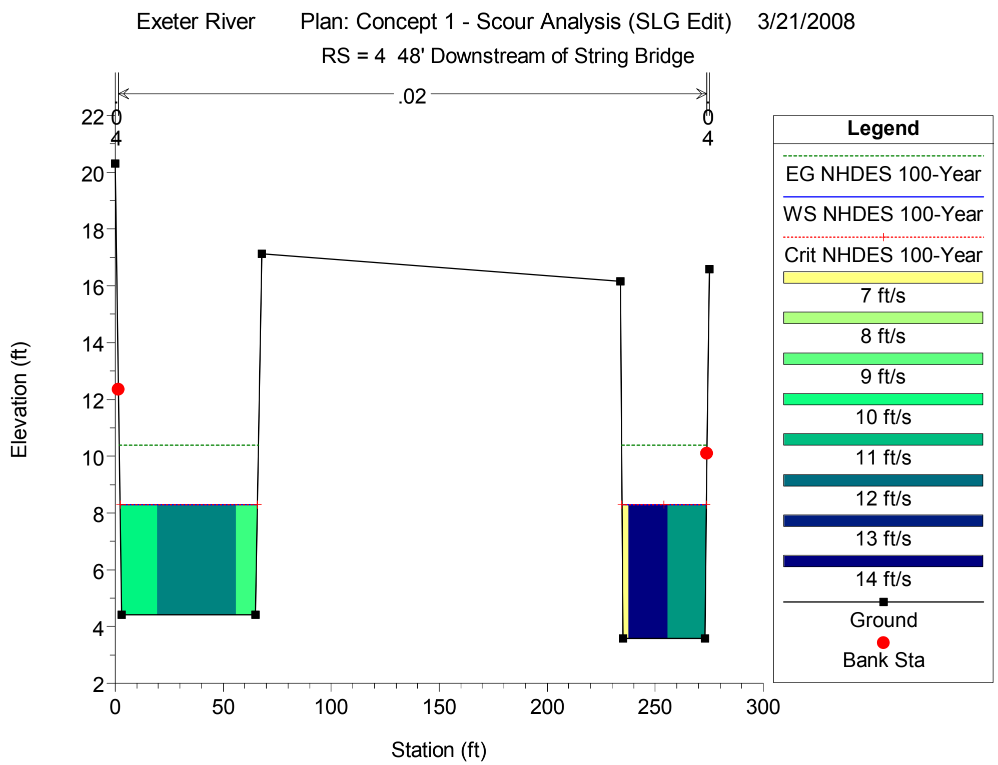

Exeter River Plan: Concept 1 - Scour Analysis (SLG Edit) 3/21/2008
RS = 9 80' Upstream of String Bridge
.02
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
Ground
Bank Sta

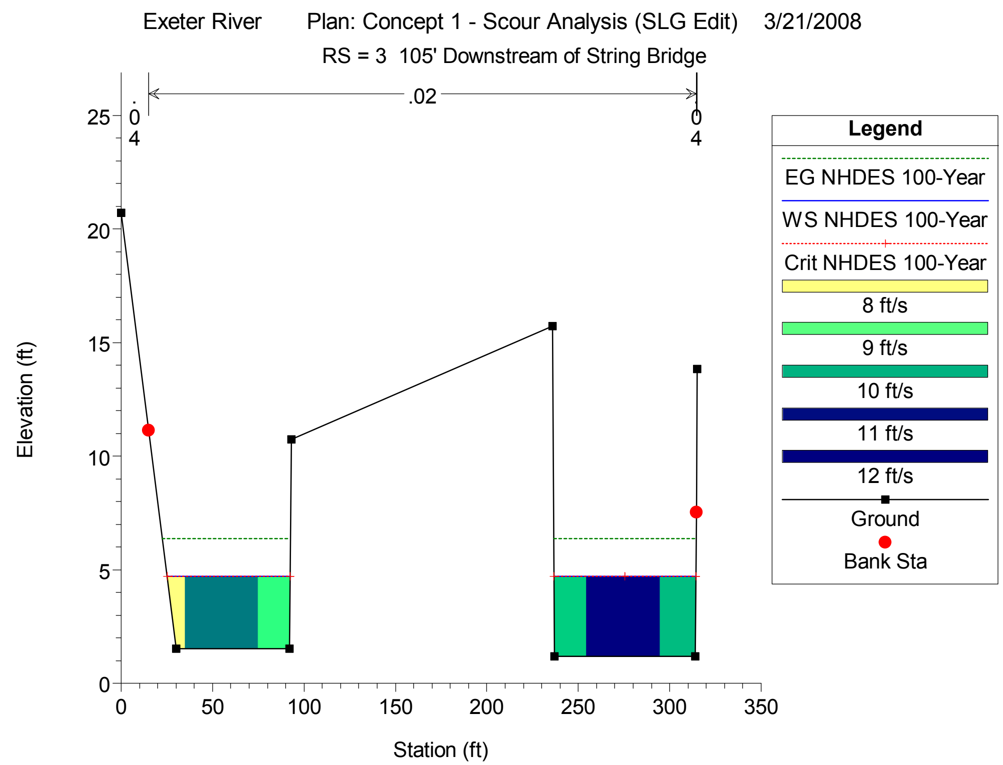

Exeter River Plan: Concept 1 - Scour Analysis (SLG Edit) 3/21/2008
RS = 7 1' Upstream of String Bridge (HEC-2 Original X-SEC)
.02
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
13 ft/s
14 ft/s
Ground
Ineff
Bank Sta

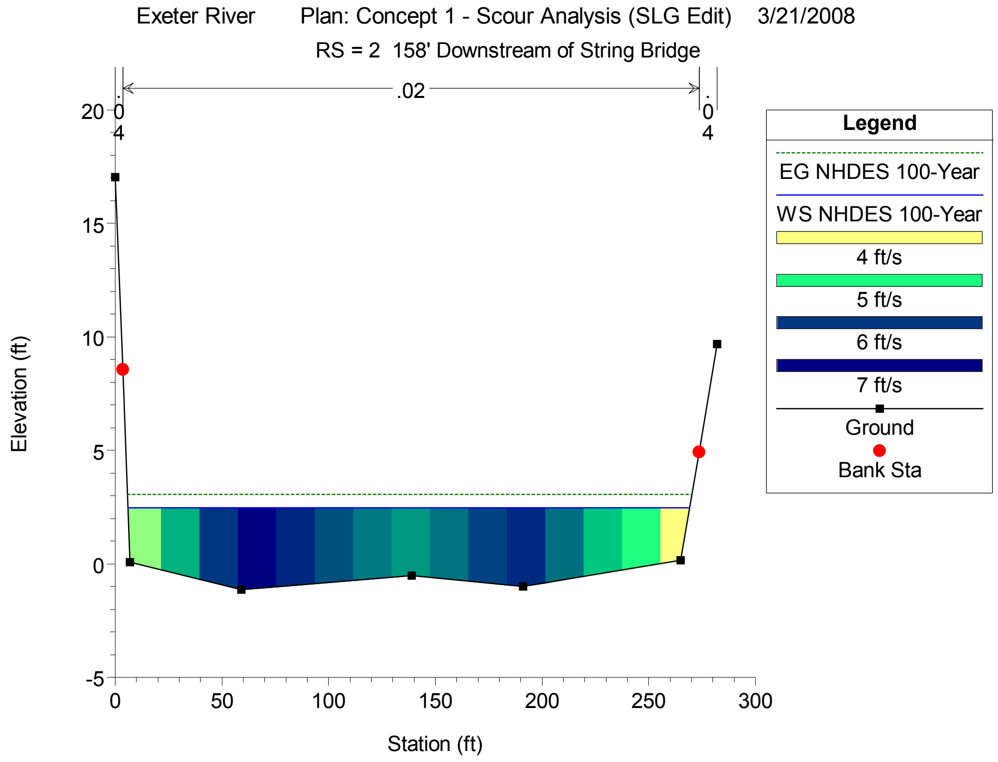

Exeter River Plan: Concept 1 - Scour Analysis (SLG Edit) 3/21/2008
RS = 6 BR String Bridge
.02
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
13 ft/s
14 ft/s
Ground
Ineff
Bank Sta


Exeter River Plan: Concept 1 - Scour Analysis (SLG Edit) 3/21/2008
RS = 6 BR String Bridge
.02
.04
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
13 ft/s
14 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)

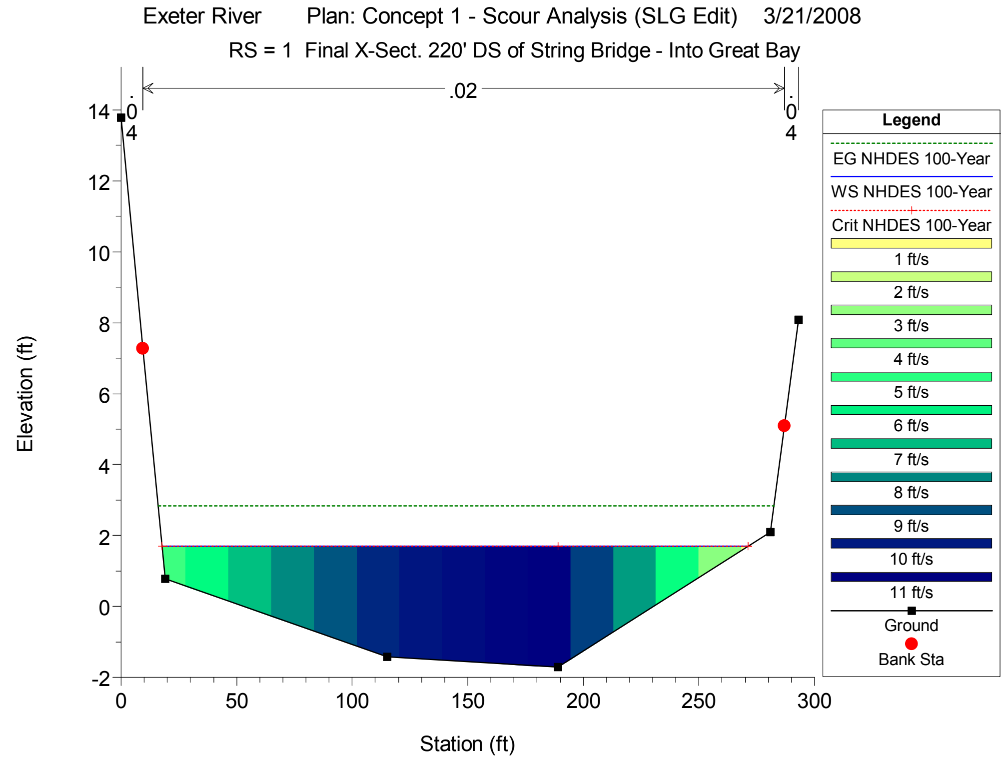

Exeter River Plan: Concept 1 - Scour Analysis (SLG Edit) 3/21/2008
RS = 5 1' Downstream of String Bridge
.02
.04
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)


Exeter River Plan: Concept 1 - Scour Analysis (SLG Edit) 3/21/2008
RS = 4 48' Downstream of String Bridge
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
7 ft/s
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
13 ft/s
14 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)


Exeter River Plan: Concept 1 - Scour Analysis (SLG Edit) 3/21/2008
RS = 3 105' Downstream of String Bridge
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)



Exeter River Plan: Concept 1 - Scour Analysis (SLG Edit) 3/21/2008
RS = 2 158' Downstream of String Bridge
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)



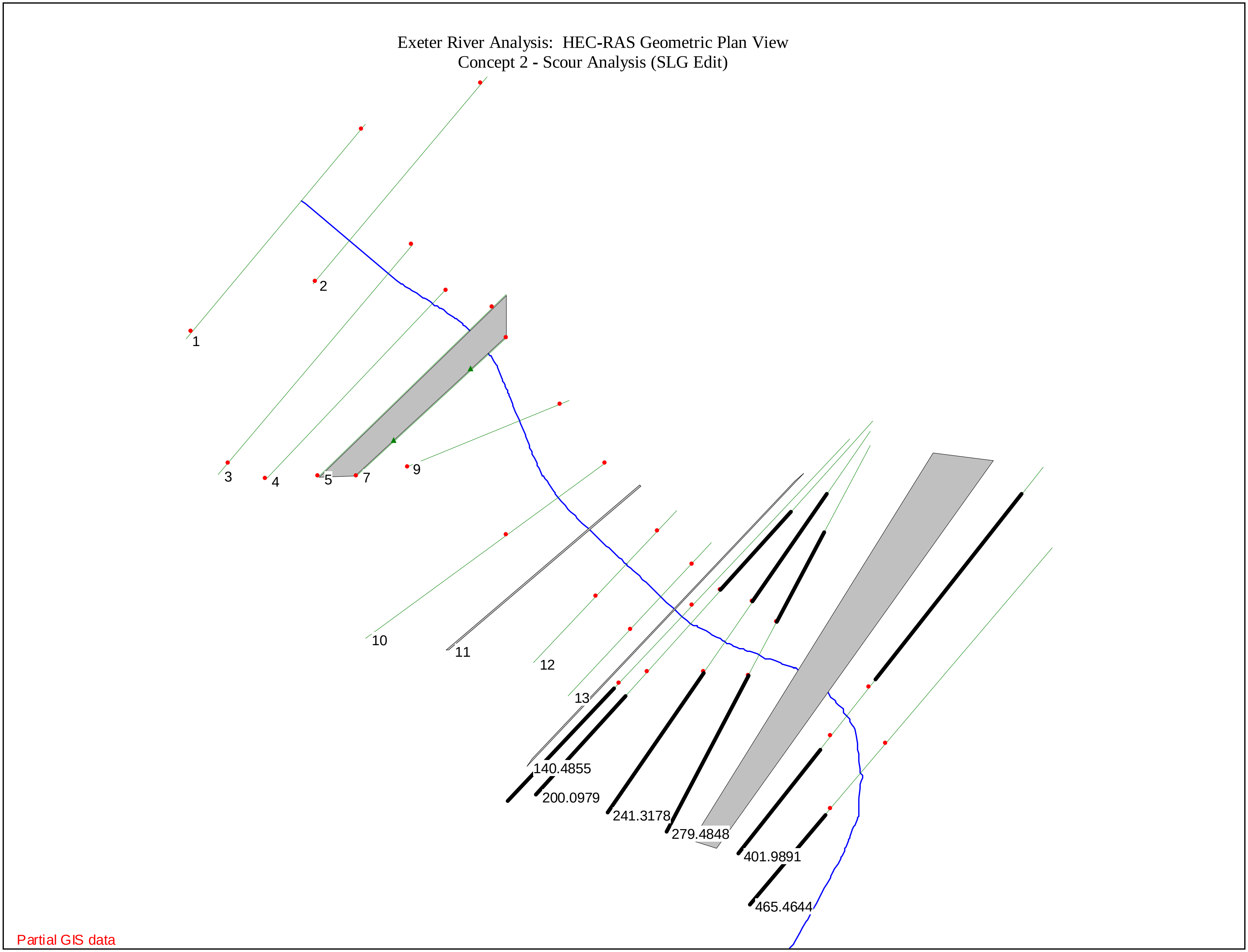
Exeter River Plan: Concept 1 - Scour Analysis (SLG Edit) 3/21/2008
RS = 1 Final X-Sect. 220' DS of String Bridge - Into Great Bay
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
11 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)

HEC-RAS Plan: C-1 Scour Locations: User Defined Profile: NHDES 100-Year

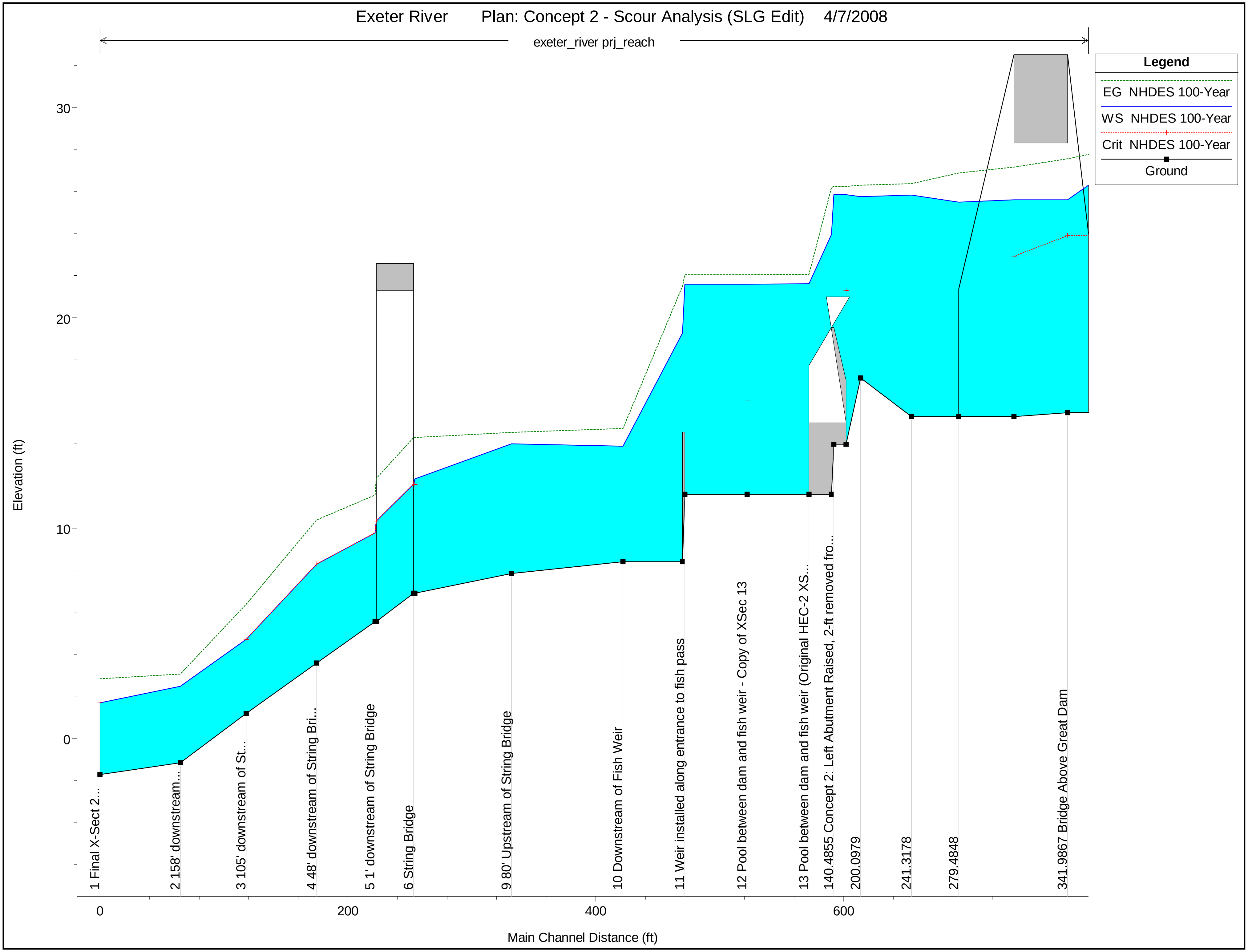
River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Flow Area	Top Width	Froude # Chl	Vel Left	Vel Chnl	Vel Right	Vel Total
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(sq ft)	(ft)		(ft/s)	(ft/s)	(ft/s)	(ft/s)
exeter_river	prj_reach	401.9891	NHDES 100-Year	4949.00	15.49	27.67	23.95	28.49	0.002093	756.94	92.94	0.43	2.37	7.52	2.32	6.54
exeter_river	prj_reach	341.9867		Bridge												
exeter_river	prj_reach	279.4848	NHDES 100-Year	4949.00	15.30	26.61		27.69	0.002929	595.27	63.14	0.48	0.70	8.35		8.31
exeter_river	prj_reach	241.3178	NHDES 100-Year	4949.00	15.30	26.87		27.30	0.001015	933.83	89.90	0.29	0.39	5.31		5.30
exeter_river	prj_reach	200.0979	NHDES 100-Year	4949.00	17.14	26.84		27.24	0.001216	1000.18	135.48	0.31	1.31	5.14		4.95
exeter_river	prj_reach	188.4948	NHDES 100-Year	4949.00	13.98	26.89	21.43	27.20	0.000844	1220.24	174.31	0.26	1.23	4.54	1.19	4.06
exeter_river	prj_reach	140.4855		Inl Struct												
exeter_river	prj_reach	13	NHDES 100-Year	4949.00	11.60	21.62		22.06	0.000294	926.97	94.11	0.30	0.25	5.34		5.34
exeter_river	prj_reach	12	NHDES 100-Year	4949.00	11.60	21.60	16.09	22.04	0.000296	925.43	94.11	0.30	0.25	5.35		5.35
exeter_river	prj_reach	11		Inl Struct												
exeter_river	prj_reach	10	NHDES 100-Year	4949.00	8.40	13.88		14.73	0.001135	670.75	124.61	0.56		7.38		7.38
exeter_river	prj_reach	9	NHDES 100-Year	4949.00	7.84	14.01		14.56	0.000785	831.37	167.94	0.47		5.95		5.95
exeter_river	prj_reach	7	NHDES 100-Year	4949.00	6.90	12.35	12.08	14.30	0.003611	441.10	95.06	0.92		11.22		11.22
exeter_river	prj_reach	6		Bridge												
exeter_river	prj_reach	5	NHDES 100-Year	4949.00	5.56	9.78	9.78	11.60	0.004313	457.12	127.28	1.01		10.83		10.83
exeter_river	prj_reach	4	NHDES 100-Year	4949.00	3.58	8.30	8.30	10.39	0.004387	426.03	102.75	1.01		11.62		11.62
exeter_river	prj_reach	3	NHDES 100-Year	4949.00	1.19	4.71	4.71	6.38	0.004348	477.48	144.84	1.01		10.36		10.36
exeter_river	prj_reach	2	NHDES 100-Year	4949.00	-1.15	2.48		3.05	0.001516	811.79	263.13	0.61		6.10		6.10
exeter_river	prj_reach	1	NHDES 100-Year	4949.00	-1.72	1.69	1.69	2.84	0.004501	575.60	253.68	1.01		8.60		8.60

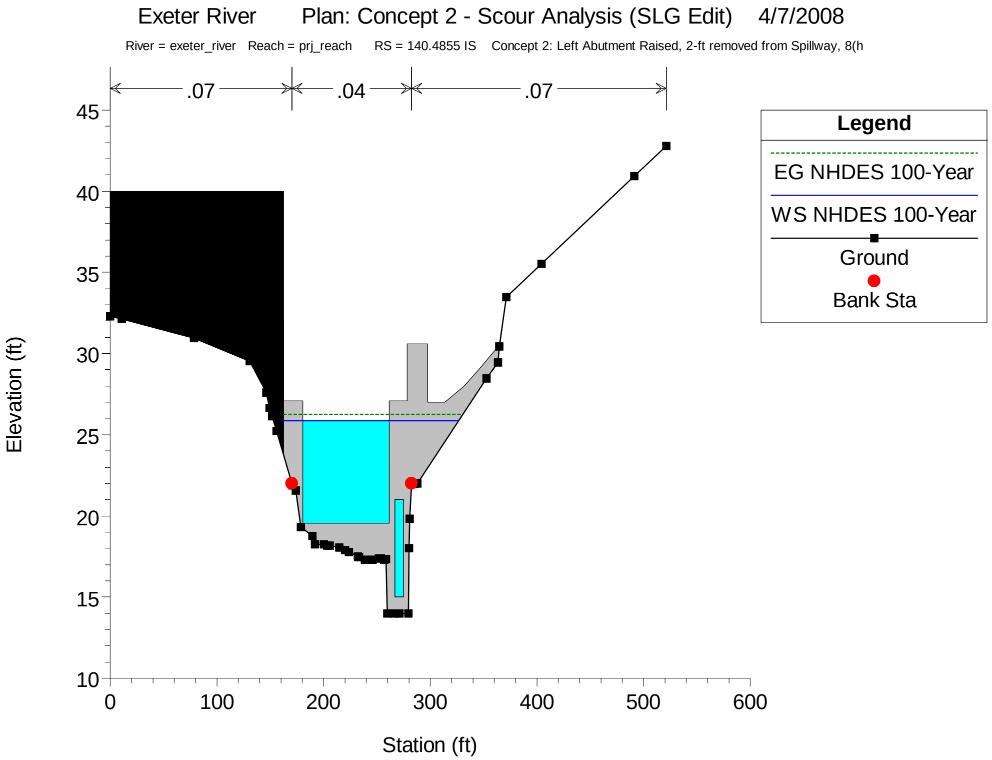
HEC RAS

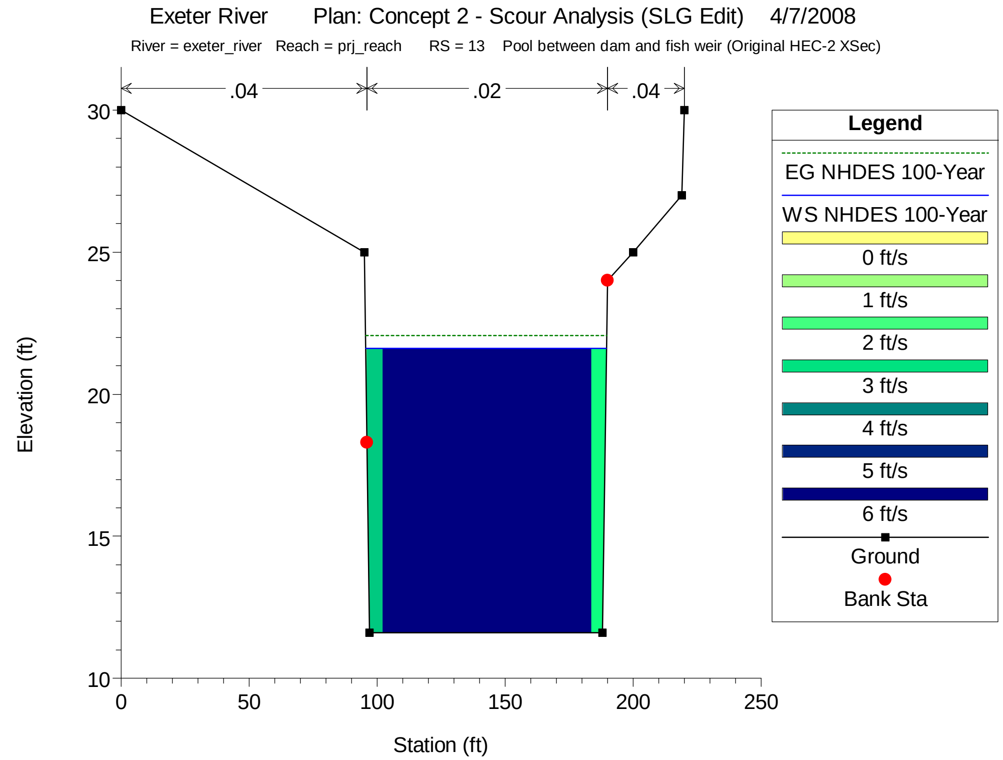
Concept 2 Results

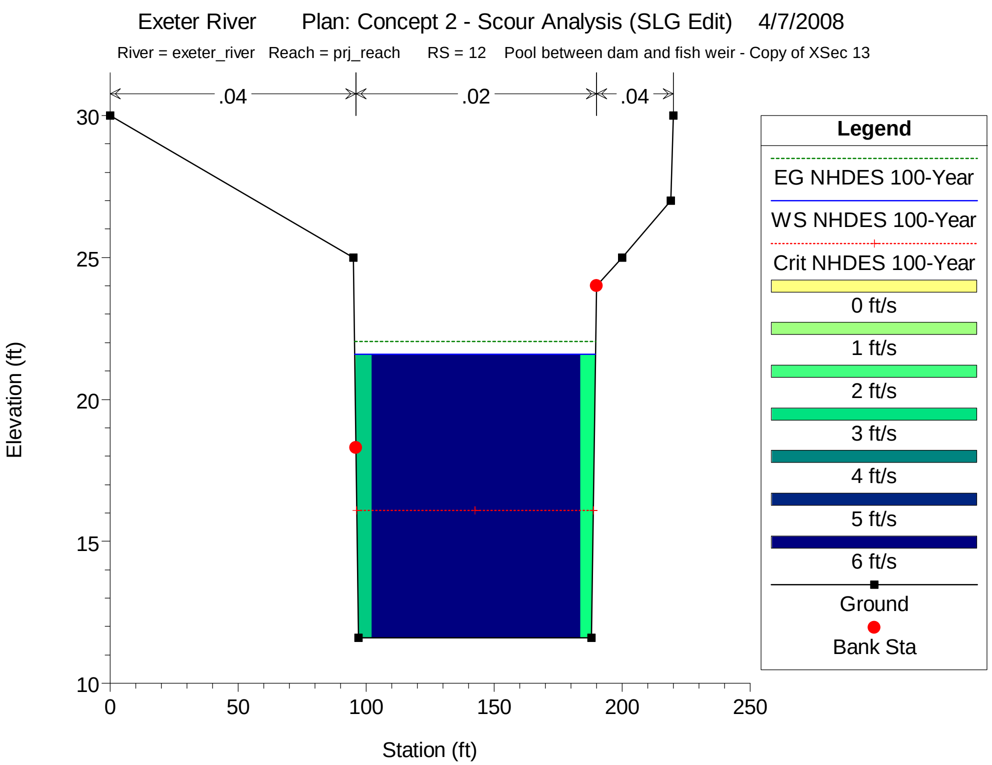


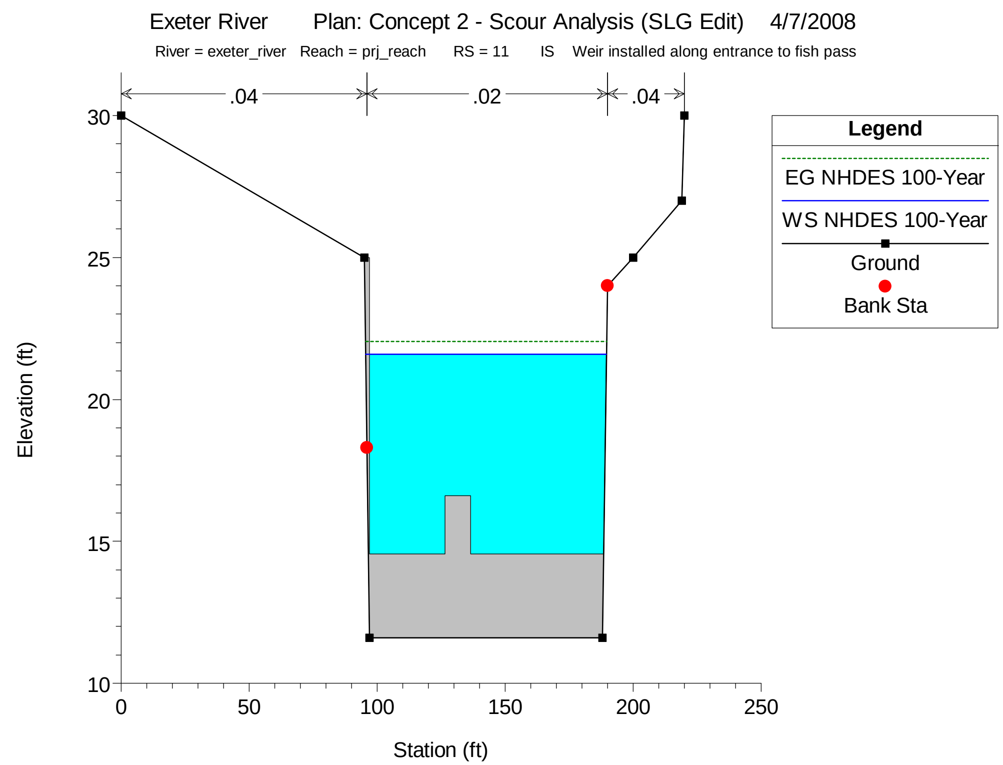
Exeter River Analysis: HEC-RAS Geometric Plan View
Concept 2 - Scour Analysis (SLG Edit)
1
2
3
4
5
7
9
10
11
12
13
140.4855
200.0979
241.3178
279.4848
401.9891
465.4644
Partial GIS data

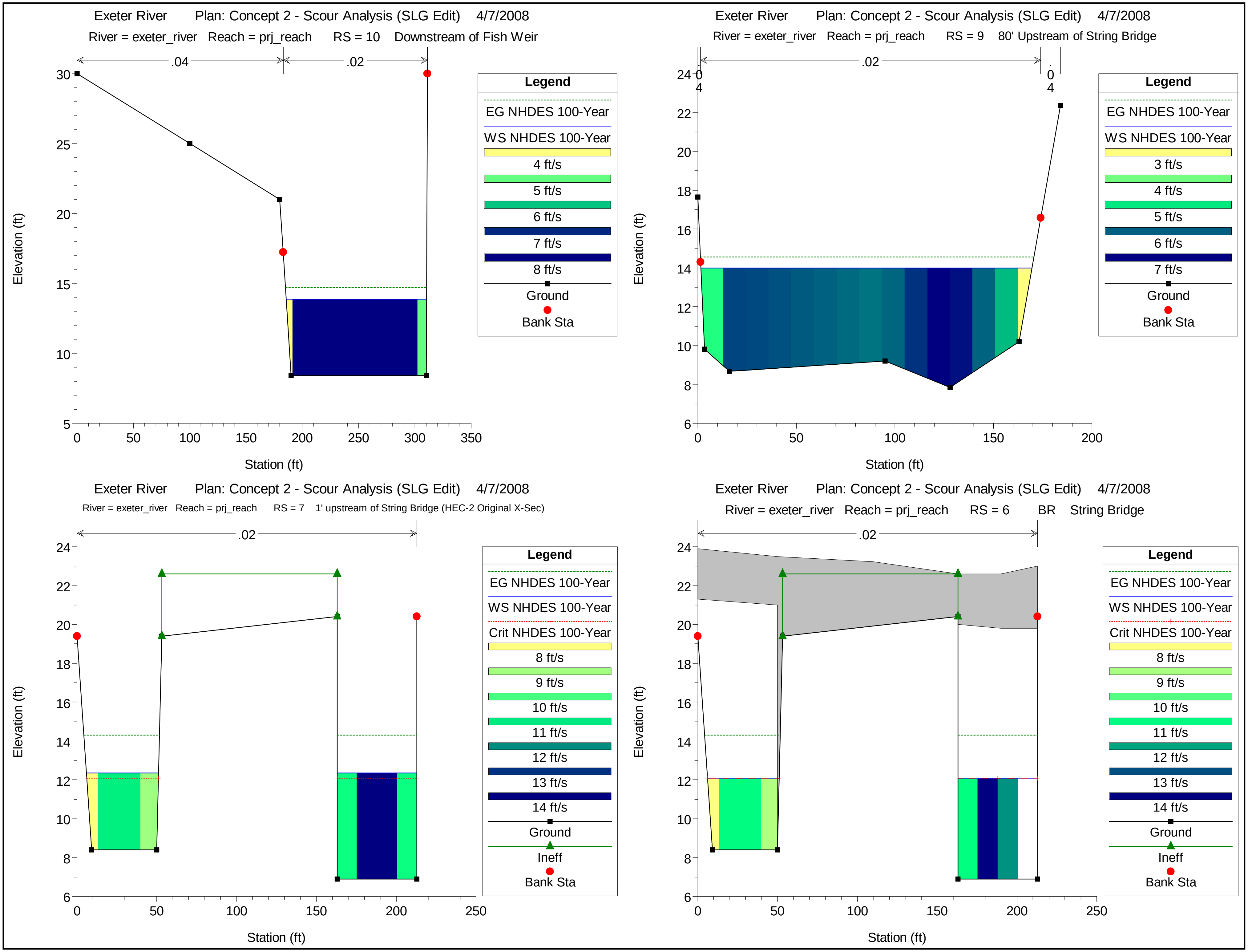

Exeter River Plan: Concept 2 - Scour Analysis (SLG Edit) 4/7/2008
exeter_river prj_reach
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
Ground
Elevation (ft)
30
20
10
0
1 Final X-Sect 2...
2 158' downstream...
3 105' downstream of St...
4 48' downstream of String Bri...
5 1' downstream of String Bridge
6 String Bridge
9 80' Upstream of String Bridge
10 Downstream of Fish Weir
11 Weir installed along entrance to fish pass
12 Pool between dam and fish weir - Copy of XSec 13
13 Pool between dam and fish weir (Original HEC-2 XS...
140.4855 Concept 2: Left Abutment Raised, 2-ft removed fro...
200.0979
241.3178
279.4848
341.9867 Bridge Above Great Dam
0
200
400
600
Main Channel Distance (ft)


Exeter River Plan: Concept 2 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 140.4855 IS Concept 2: Left Abutment Raised, 2-ft removed from Spillway, 8(h
.07
.04
.07
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Ground
Bank Sta

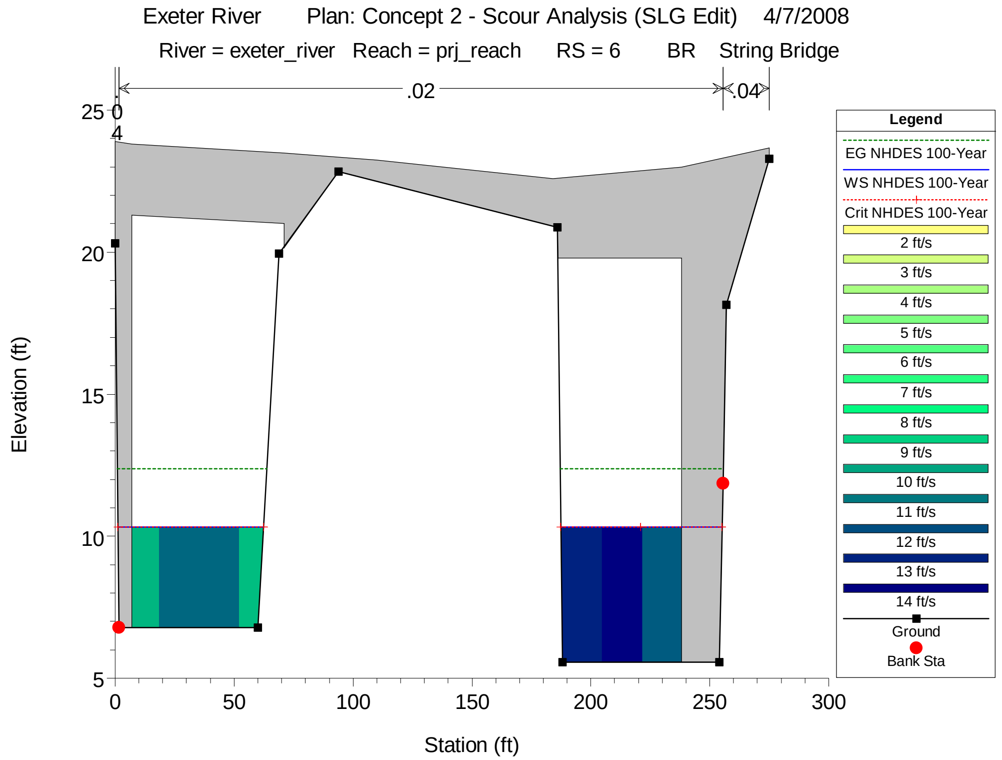

Exeter River Plan: Concept 2 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 13 Pool between dam and fish weir (Original HEC-2 XSec)
.04
.02
.04
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
Ground
Bank Sta

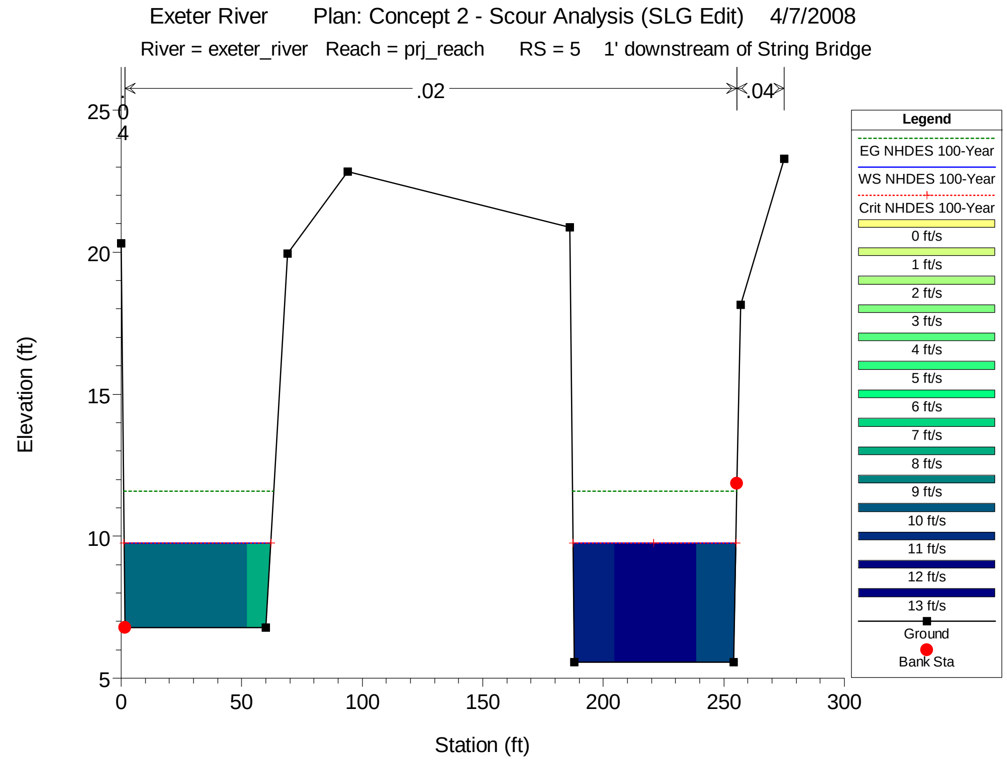

Exeter River Plan: Concept 2 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 12 Pool between dam and fish weir - Copy of XSec 13
.04
.02
.04
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
Ground
Bank Sta

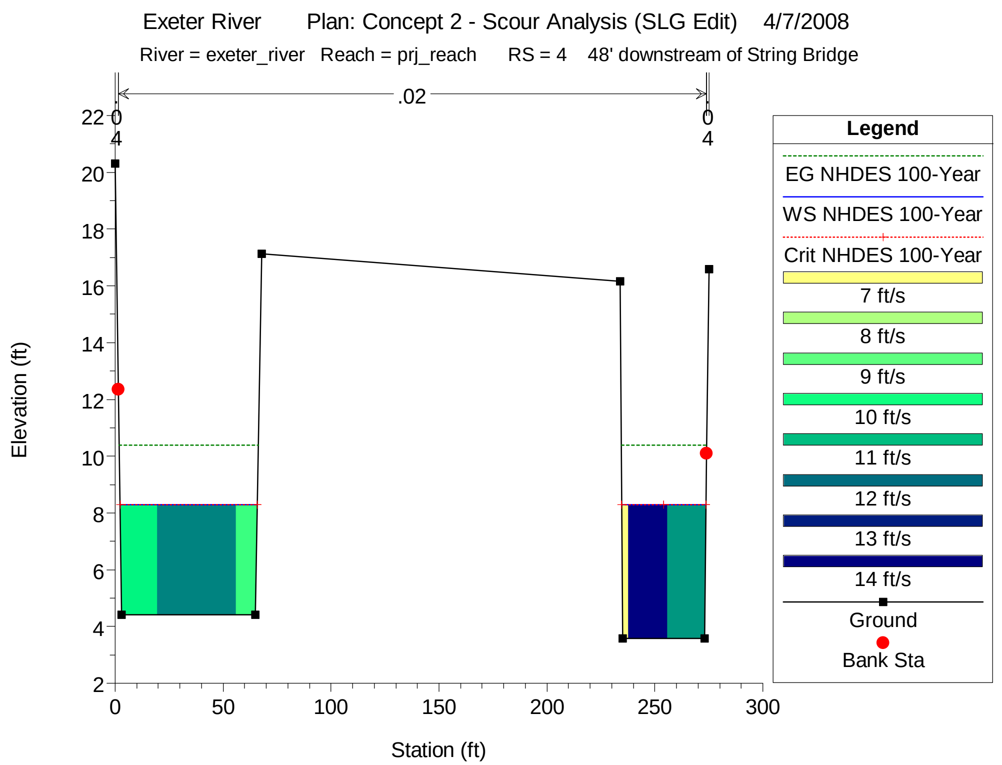

Exeter River Plan: Concept 2 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 11 IS Weir installed along entrance to fish pass
.04
.02
.04
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Ground
Bank Sta

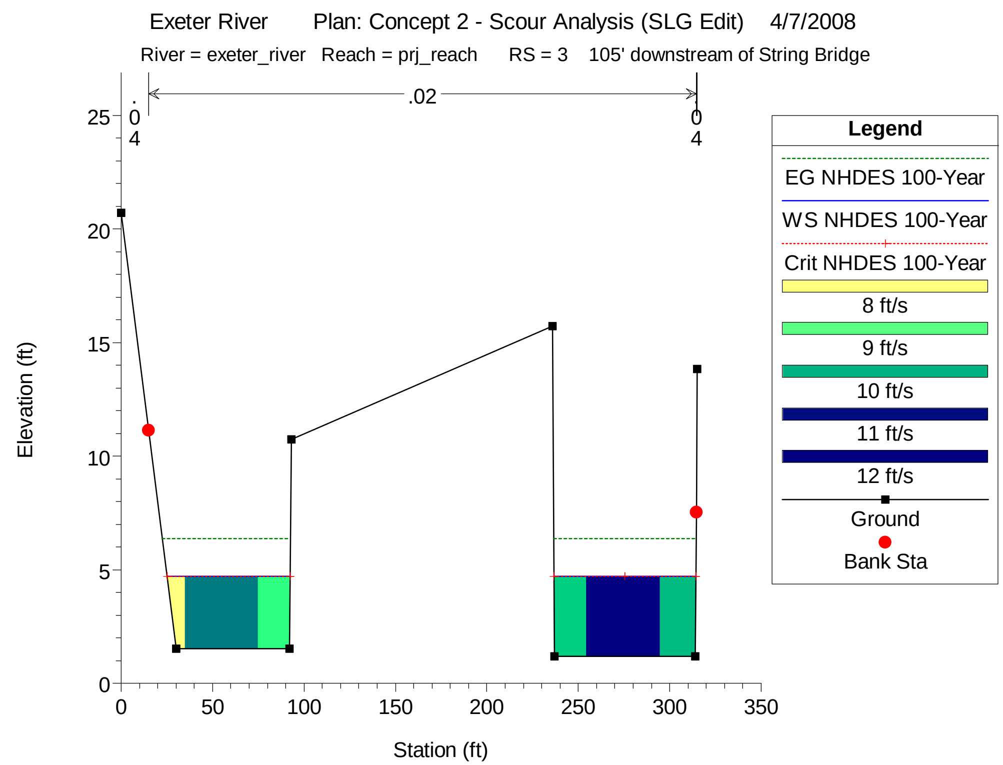


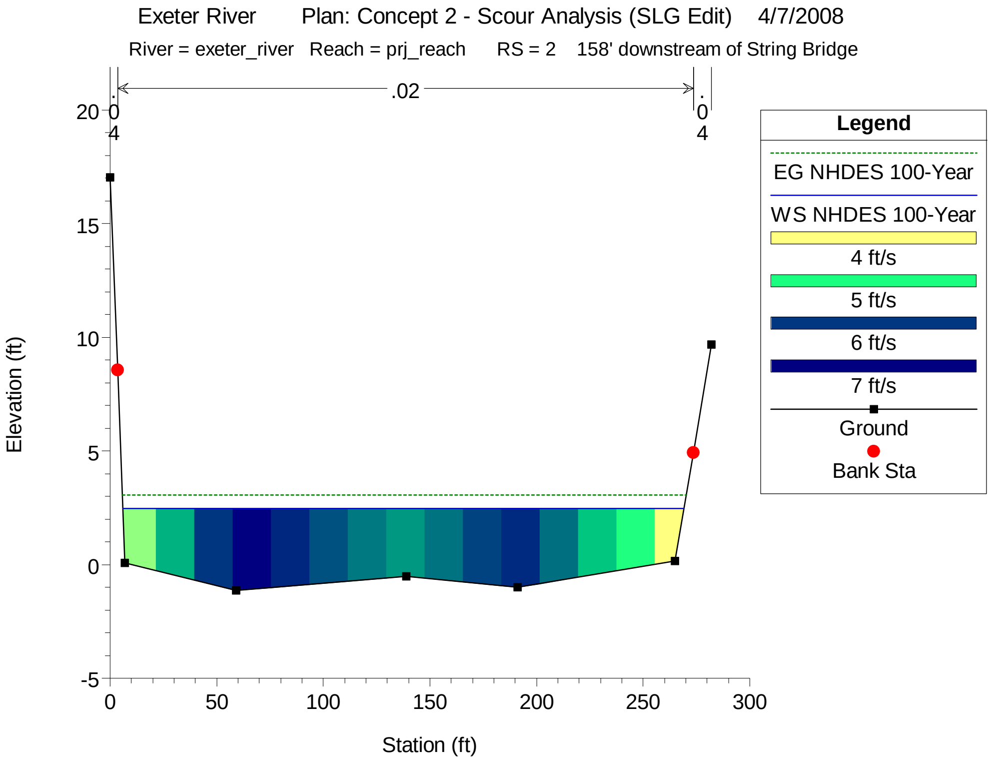
Exeter River Plan: Concept 2 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 10 Downstream of Fish Weir
.04
.02
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
Ground
Bank Sta
Exeter River Plan: Concept 2 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 9 80' Upstream of String Bridge
.02
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
Ground
Bank Sta
Exeter River Plan: Concept 2 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 7 1' upstream of String Bridge (HEC-2 Original X-Sec)
.02
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
13 ft/s
14 ft/s
Ground
Ineff
Bank Sta
Exeter River Plan: Concept 2 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 6 BR String Bridge
.02
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
13 ft/s
14 ft/s
Ground
Ineff
Bank Sta


Exeter River Plan: Concept 2 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 6 BR String Bridge
.02
.04
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
13 ft/s
14 ft/s
Ground
Bank Sta

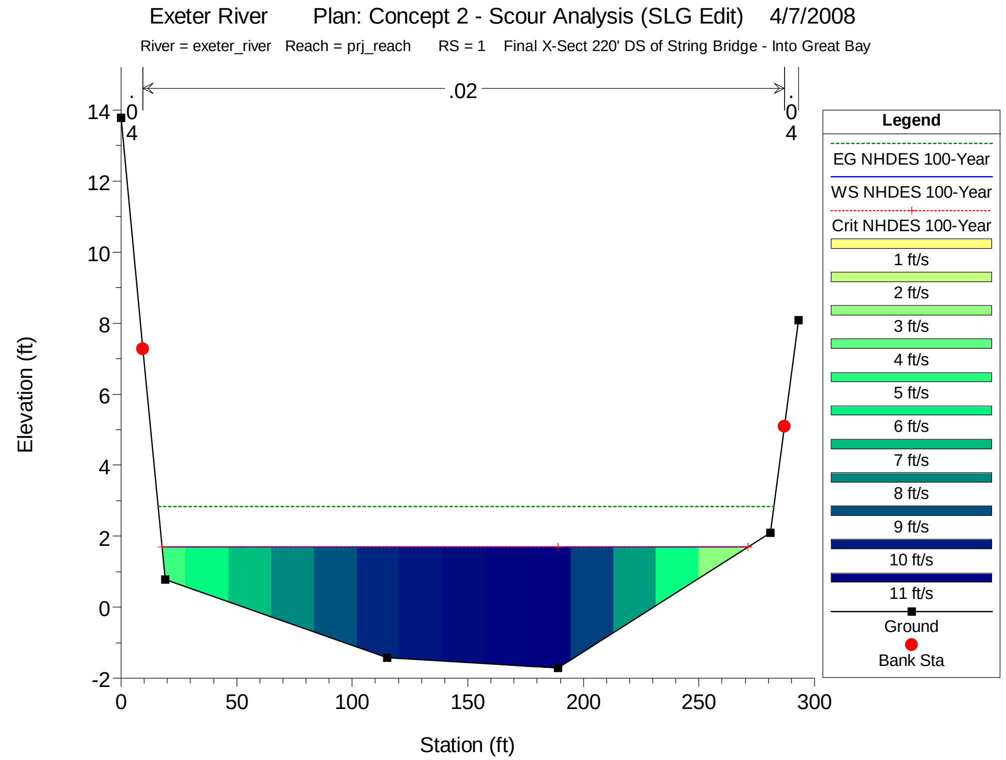

Exeter River Plan: Concept 2 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 5 1' downstream of String Bridge
.02
.04
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
13 ft/s
Ground
Bank Sta


Exeter River Plan: Concept 2 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 4 48' downstream of String Bridge
.02
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
7 ft/s
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
13 ft/s
14 ft/s
Ground
Bank Sta


Exeter River Plan: Concept 2 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 3 105' downstream of String Bridge
.02
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
Ground
Bank Sta



Exeter River Plan: Concept 2 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 2 158' downstream of String Bridge
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)



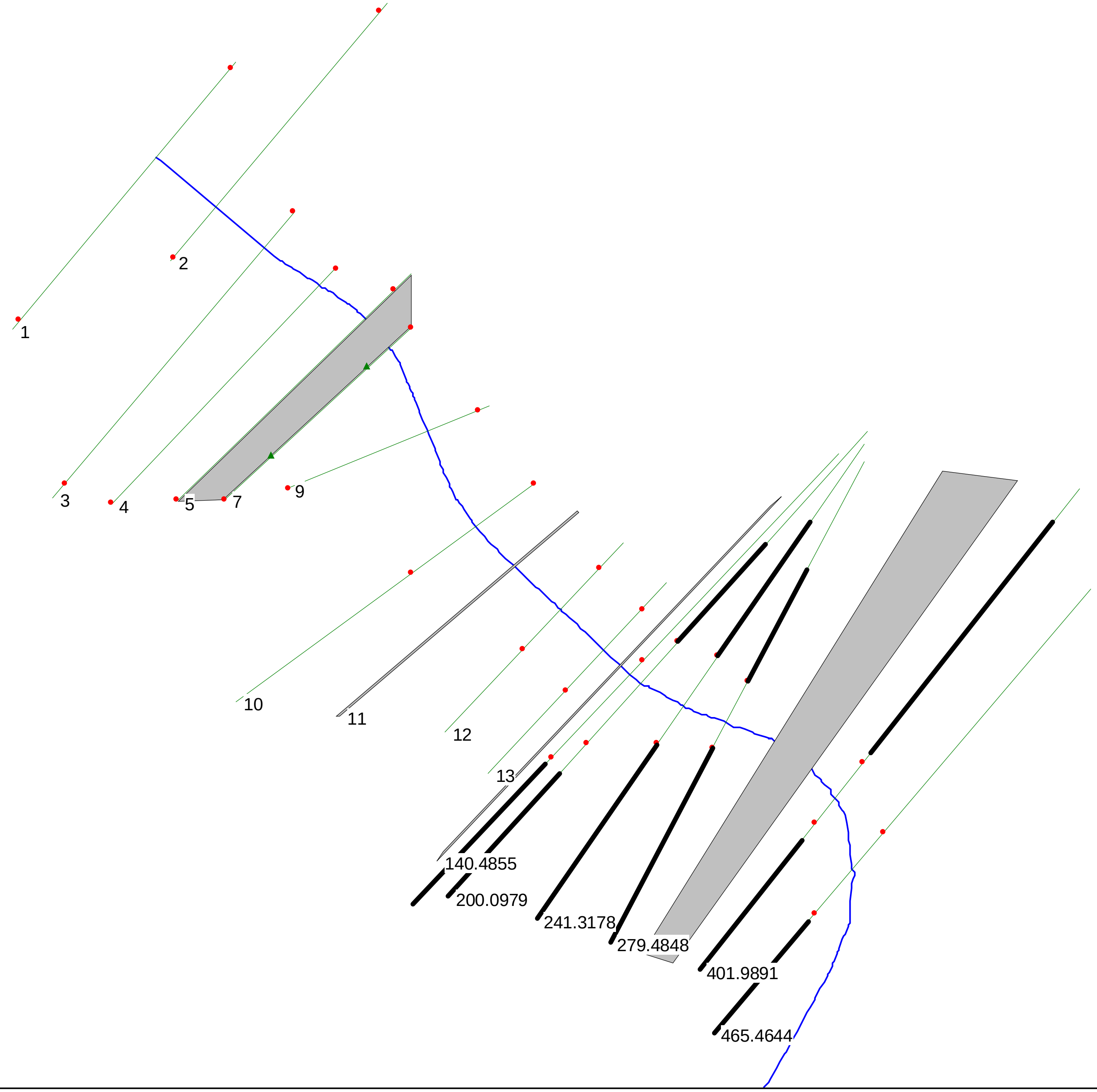
Exeter River Plan: Concept 2 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 1 Final X-Sect 220' DS of String Bridge - Into Great Bay
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
11 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)

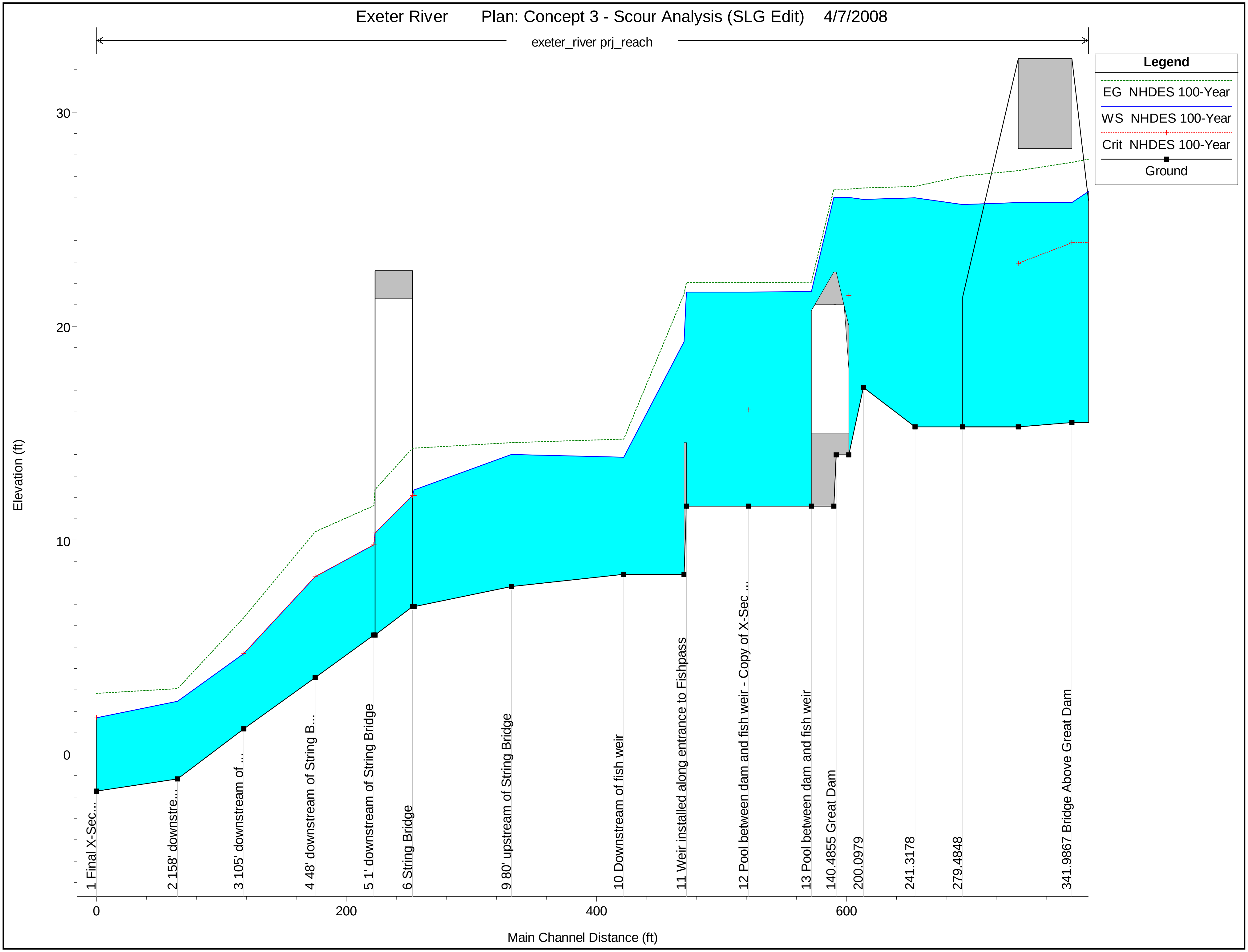
HEC-RAS Plan: C-2 Scour Locations: User Defined Profile: NHDES 100-Year

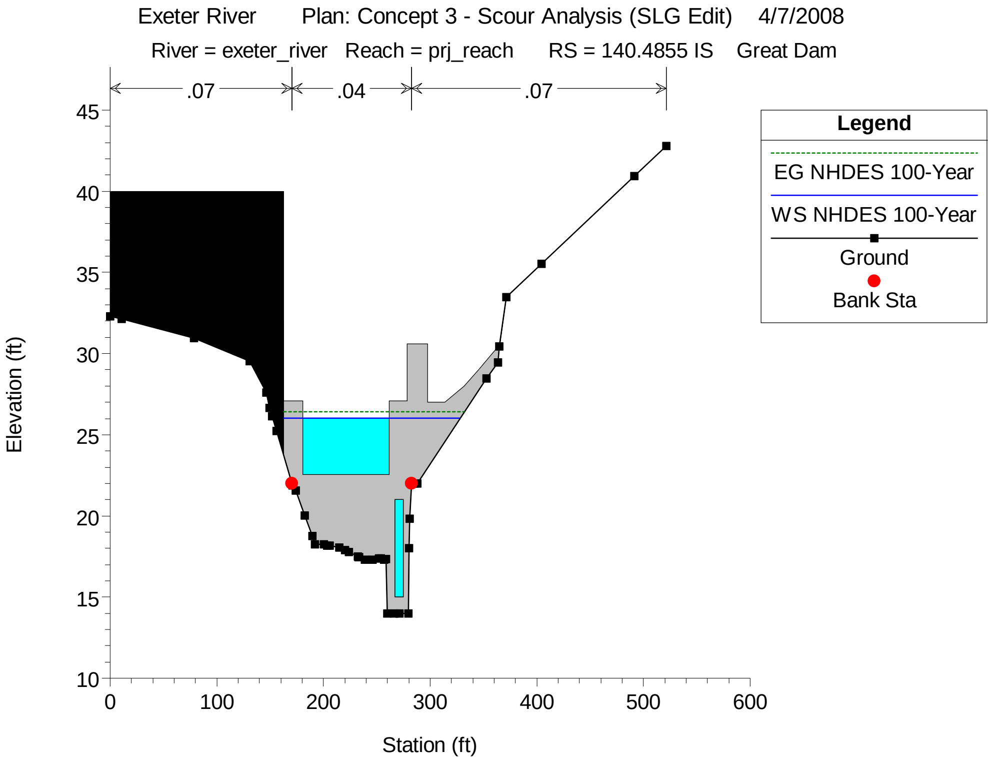
River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Flow Area	Top Width	Froude # Chl	Vel Left	Vel Chnl	Vel Right	Vel Total
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(sq ft)	(ft)		(ft/s)	(ft/s)	(ft/s)	(ft/s)
exeter_river	prj_reach	401.9891	NHDES 100-Year	4949.00	15.49	27.03	23.96	27.99	0.002666	697.80	92.94	0.48	2.47	8.10	2.48	7.09
exeter_river	prj_reach	341.9867		Bridge												
exeter_river	prj_reach	279.4848	NHDES 100-Year	4949.00	15.30	25.50		26.88	0.004344	525.27	63.14	0.58	0.83	9.45		9.42
exeter_river	prj_reach	241.3178	NHDES 100-Year	4949.00	15.30	25.83		26.37	0.001418	840.95	89.90	0.34	0.45	5.90		5.88
exeter_river	prj_reach	200.0979	NHDES 100-Year	4949.00	17.14	25.76		26.31	0.001926	857.17	130.77	0.39	1.40	5.94		5.77
exeter_river	prj_reach	188.4948	NHDES 100-Year	4949.00	13.98	25.85	21.31	26.24	0.001246	1053.99	163.84	0.31	1.30	5.13	1.25	4.70
exeter_river	prj_reach	140.4855		Inl Struct												
exeter_river	prj_reach	13	NHDES 100-Year	4949.00	11.60	21.62		22.06	0.000294	926.98	94.11	0.30	0.25	5.34		5.34
exeter_river	prj_reach	12	NHDES 100-Year	4949.00	11.60	21.60	16.09	22.04	0.000296	925.43	94.11	0.30	0.25	5.35		5.35
exeter_river	prj_reach	11		Inl Struct												
exeter_river	prj_reach	10	NHDES 100-Year	4949.00	8.40	13.88		14.73	0.001135	670.75	124.61	0.56		7.38		7.38
exeter_river	prj_reach	9	NHDES 100-Year	4949.00	7.84	14.01		14.56	0.000785	831.37	167.94	0.47		5.95		5.95
exeter_river	prj_reach	7	NHDES 100-Year	4949.00	6.90	12.35	12.08	14.30	0.003611	441.10	95.06	0.92		11.22		11.22
exeter_river	prj_reach	6		Bridge												
exeter_river	prj_reach	5	NHDES 100-Year	4949.00	5.56	9.76	9.76	11.57	0.004216	458.54	128.42	1.01	0.72	10.80		10.79
exeter_river	prj_reach	4	NHDES 100-Year	4949.00	3.58	8.30	8.30	10.39	0.004387	426.03	102.75	1.01		11.62		11.62
exeter_river	prj_reach	3	NHDES 100-Year	4949.00	1.19	4.71	4.71	6.38	0.004348	477.48	144.84	1.01		10.36		10.36
exeter_river	prj_reach	2	NHDES 100-Year	4949.00	-1.15	2.48		3.05	0.001516	811.79	263.13	0.61		6.10		6.10
exeter_river	prj_reach	1	NHDES 100-Year	4949.00	-1.72	1.69	1.69	2.84	0.004501	575.60	253.68	1.01		8.60		8.60

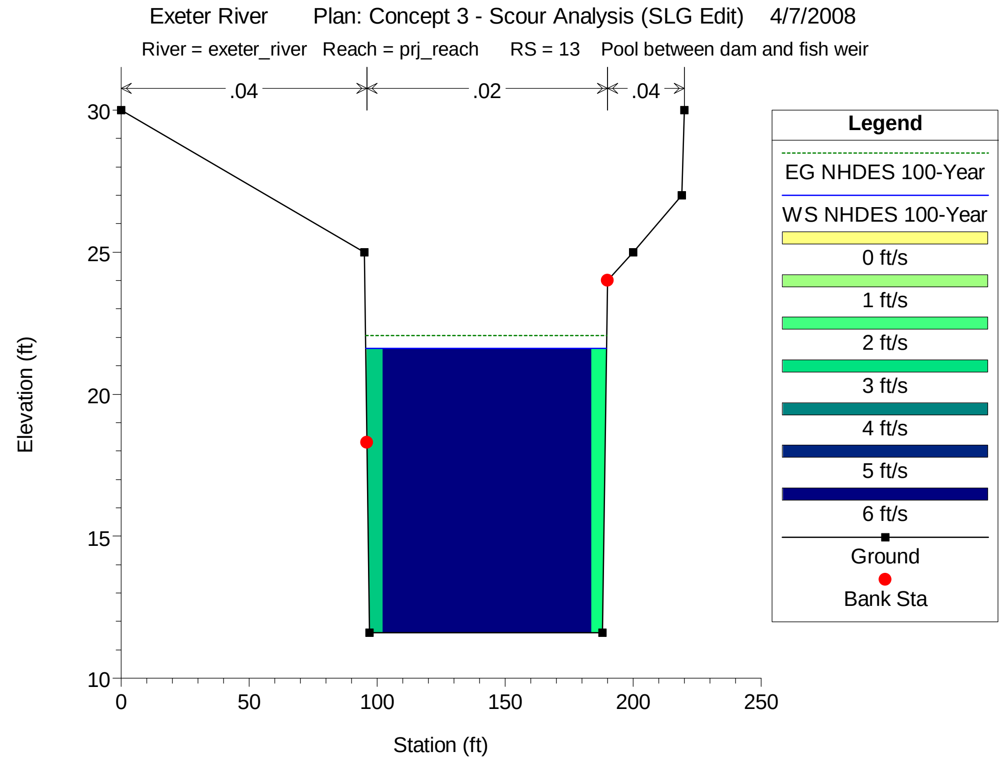
HEC RAS
Concept 3 Results

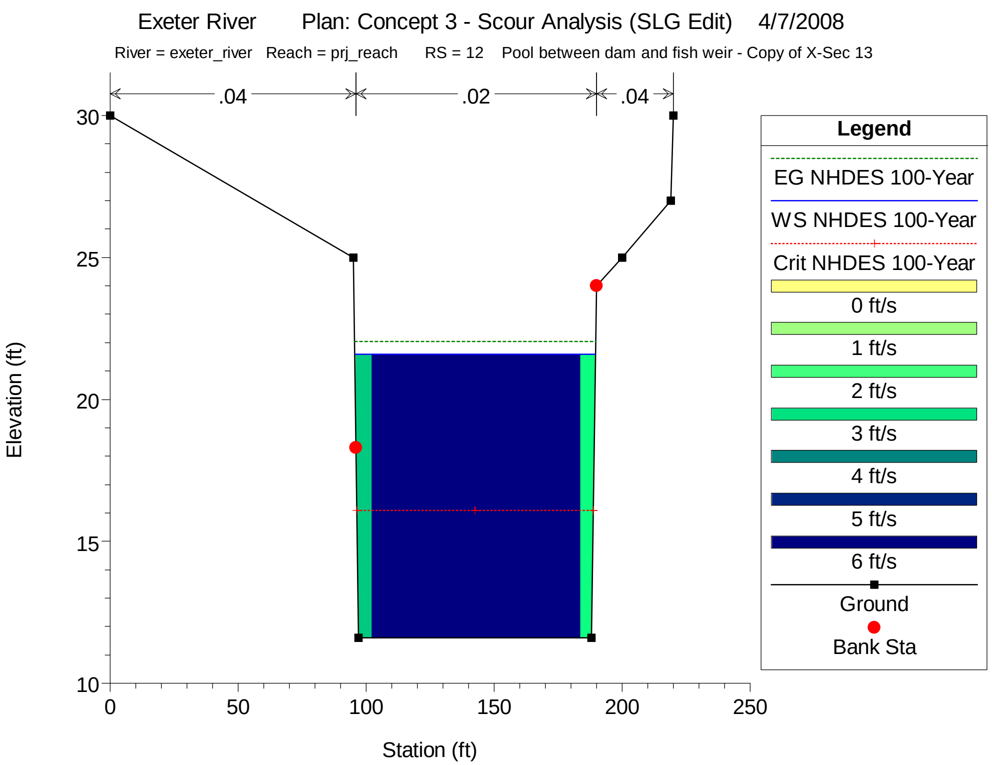
Exeter River Analysis: HEC-RAS Geometric Plan View
Concept 3 - Scour Analysis (SLG Edit)

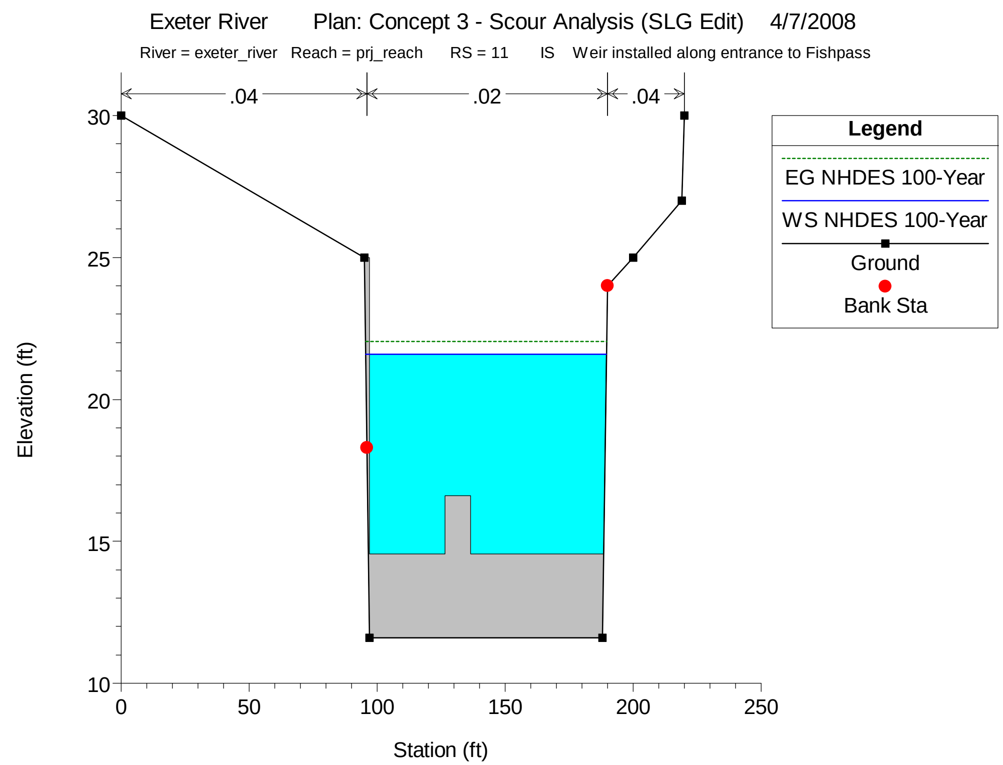


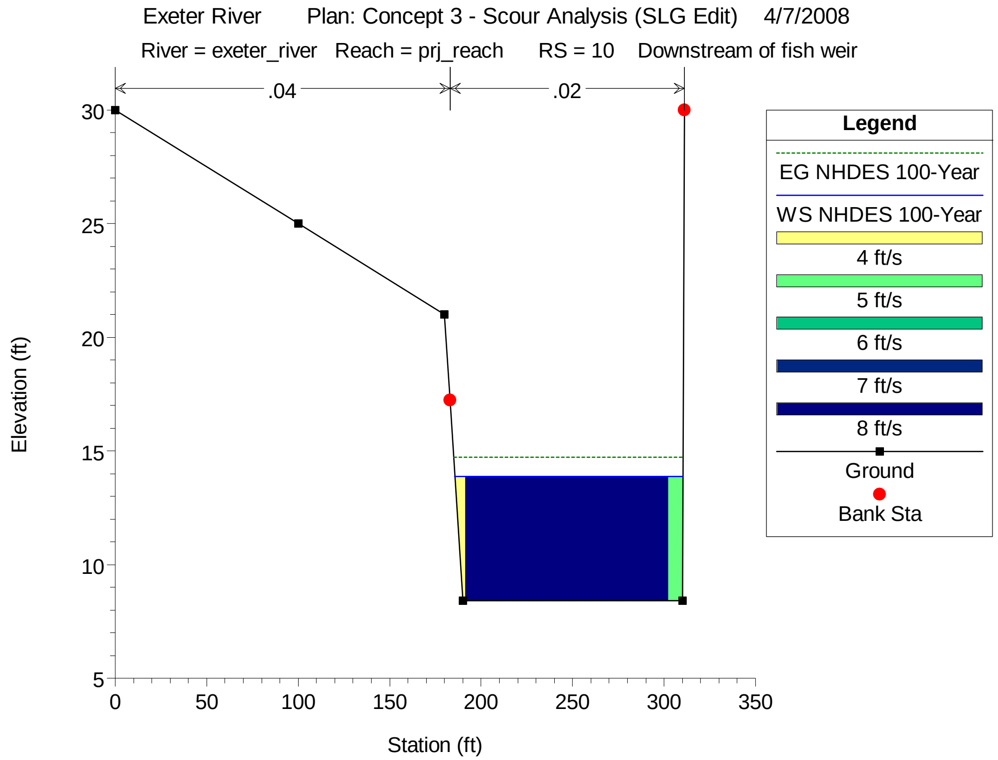

Exeter River Plan: Concept 3 - Scour Analysis (SLG Edit) 4/7/2008
exeter_river prj_reach
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
Ground
Elevation (ft)
Main Channel Distance (ft)
0
10
20
30
0
200
400
600
1 Final X-Sec...
2 158' downstre...
3 105' downstream of ...
4 48' downstream of String B...
5 1' downstream of String Bridge
6 String Bridge
9 80' upstream of String Bridge
10 Downstream of fish weir
11 Weir installed along entrance to Fishpass
12 Pool between dam and fish weir - Copy of X-Sec ...
13 Pool between dam and fish weir
140.4855 Great Dam
200.0979
241.3178
279.4848
341.9867 Bridge Above Great Dam

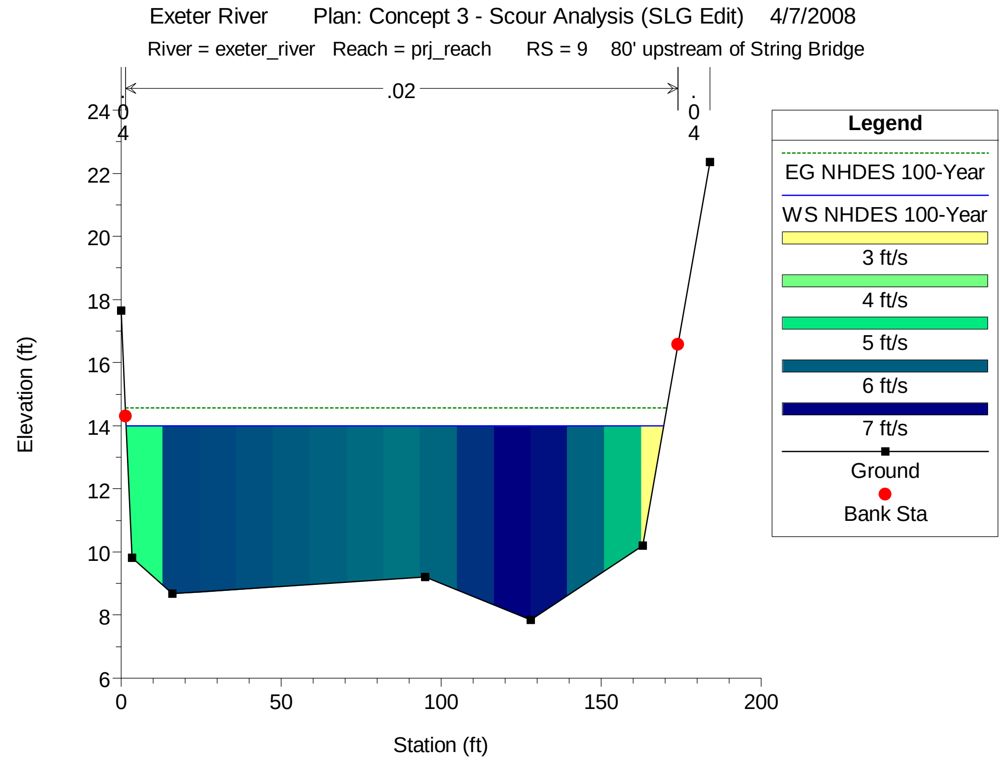

Exeter River Plan: Concept 3 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 140.4855 IS Great Dam
.07
.04
.07
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Ground
Bank Sta

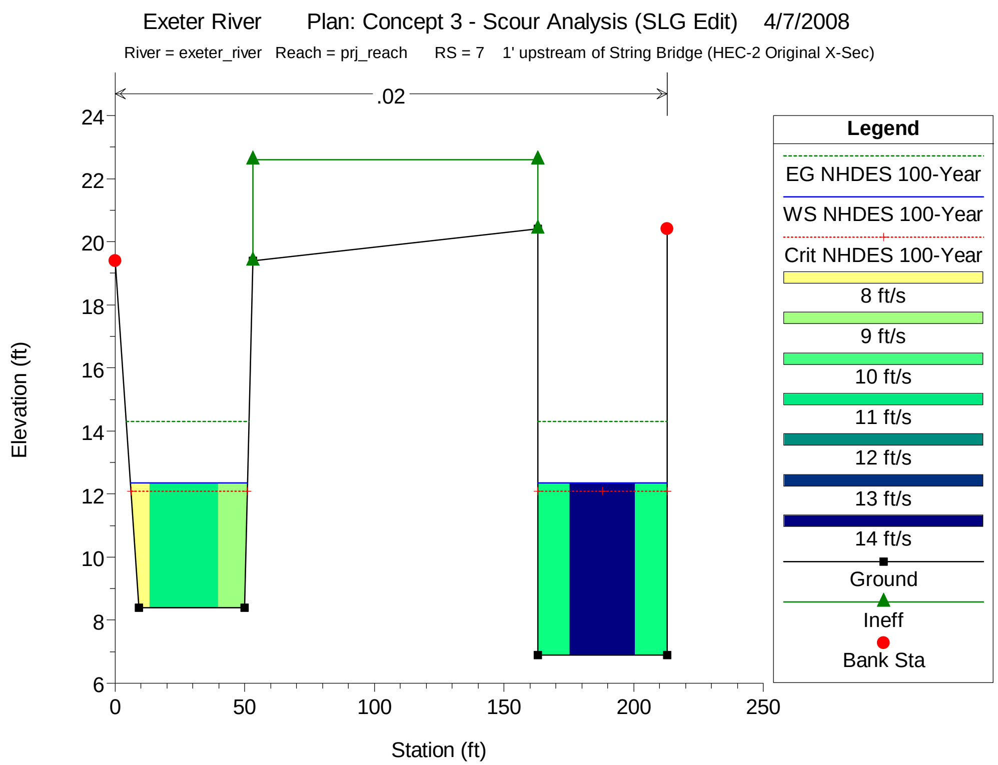

Exeter River Plan: Concept 3 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 13 Pool between dam and fish weir
.04
.02
.04
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
Ground
Bank Sta

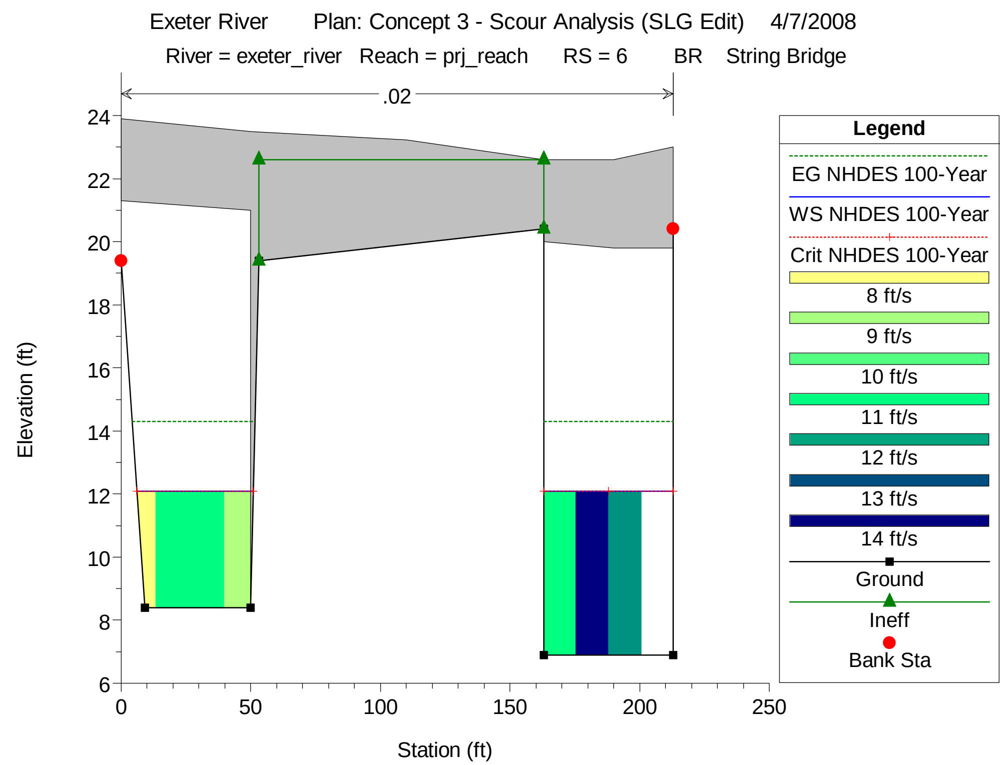

Exeter River Plan: Concept 3 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 12 Pool between dam and fish weir - Copy of X-Sec 13
.04
.02
.04
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
Ground
Bank Sta

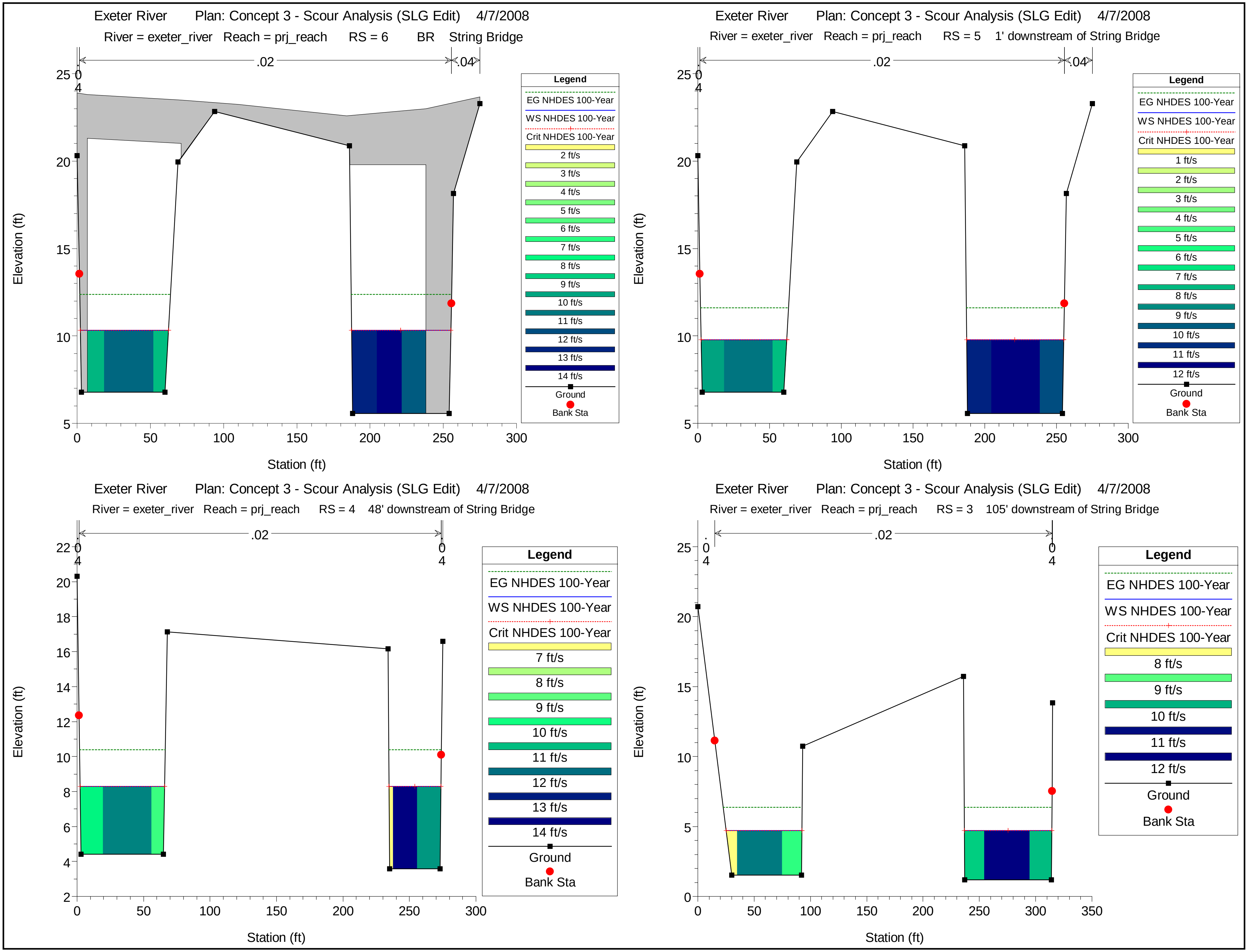

Exeter River Plan: Concept 3 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 11 IS Weir installed along entrance to Fishpass
.04
.02
.04
Elevation (ft)
Station (ft)
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Ground
Bank Sta

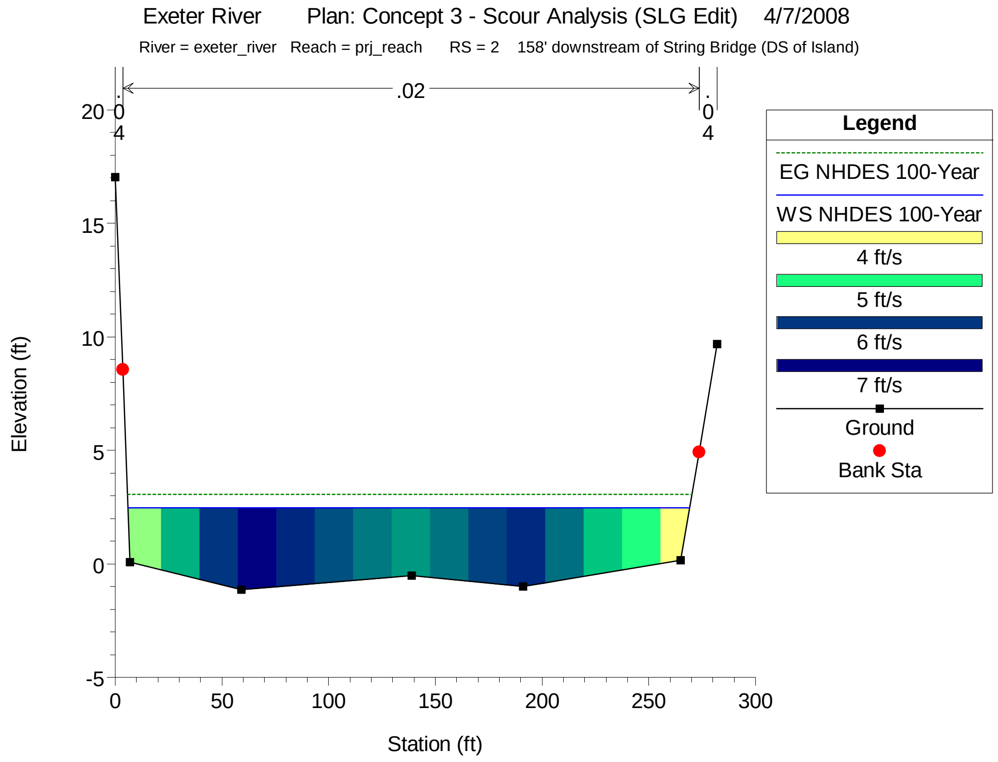

Exeter River Plan: Concept 3 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 10 Downstream of fish weir
.04
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)


Exeter River Plan: Concept 3 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 9 80' upstream of String Bridge
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)

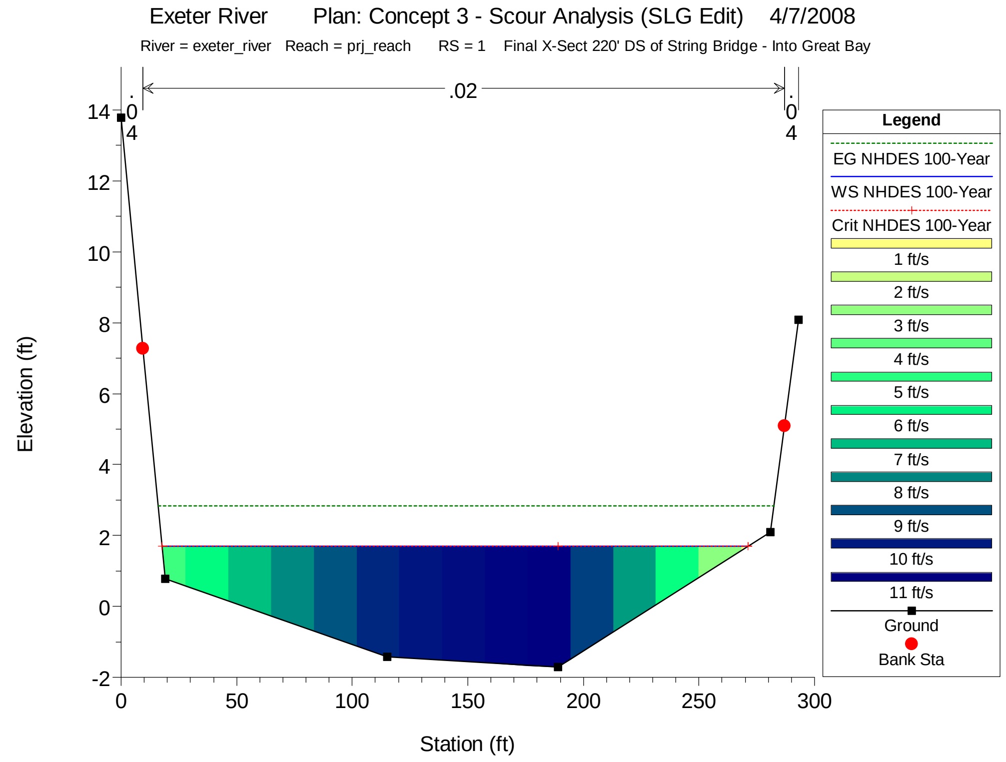

Exeter River Plan: Concept 3 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 7 1' upstream of String Bridge (HEC-2 Original X-Sec)
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
13 ft/s
14 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)


Exeter River Plan: Concept 3 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 6 BR String Bridge
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
8 ft/s
9 ft/s
10 ft/s
11 ft/s
12 ft/s
13 ft/s
14 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)


Exeter River Plan: Concept 3 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 6 BR String Bridge
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
Ground
Bank Sta
Elevation (ft)
Station (ft)
Exeter River Plan: Concept 3 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 5 1' downstream of String Bridge
Exeter River Plan: Concept 3 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 4 48' downstream of String Bridge
Exeter River Plan: Concept 3 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 3 105' downstream of String Bridge



Exeter River Plan: Concept 3 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 2 158' downstream of String Bridge (DS of Island)
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)



Exeter River Plan: Concept 3 - Scour Analysis (SLG Edit) 4/7/2008
River = exeter_river Reach = prj_reach RS = 1 Final X-Sect 220' DS of String Bridge - Into Great Bay
.02
Legend
EG NHDES 100-Year
WS NHDES 100-Year
Crit NHDES 100-Year
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
11 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)

HEC-RAS Plan: C-3 Scour Locations: User Defined Profile: NHDES 100-Year

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Flow Area	Top Width	Froude # Chl	Vel Left	Vel Chnl	Vel Right	Vel Total
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(sq ft)	(ft)		(ft/s)	(ft/s)	(ft/s)	(ft/s)
exeter_river	prj_reach	401.9891	NHDES 100-Year	4949.00	15.49	27.12	23.94	28.06	0.002575	706.03	92.94	0.47	2.45	8.01	2.46	7.01
exeter_river	prj_reach	341.9867		Bridge												
exeter_river	prj_reach	279.4848	NHDES 100-Year	4949.00	15.30	25.68		27.01	0.004049	537.08	63.14	0.56	0.81	9.25		9.21
exeter_river	prj_reach	241.3178	NHDES 100-Year	4949.00	15.30	26.01		26.53	0.001338	856.42	89.90	0.33	0.44	5.79		5.78
exeter_river	prj_reach	200.0979	NHDES 100-Year	4949.00	17.14	25.92		26.46	0.001904	844.66	114.28	0.38		5.86		5.86
exeter_river	prj_reach	188.4948	NHDES 100-Year	4949.00	13.98	26.01	21.43	26.40	0.001204	1069.77	165.46	0.31	1.31	5.08	1.26	4.63
exeter_river	prj_reach	140.4855		Inl Struct												
exeter_river	prj_reach	13	NHDES 100-Year	4949.00	11.60	21.62		22.06	0.000294	926.97	94.11	0.30	0.25	5.34		5.34
exeter_river	prj_reach	12	NHDES 100-Year	4949.00	11.60	21.60	16.09	22.04	0.000296	925.43	94.11	0.30	0.25	5.35		5.35
exeter_river	prj_reach	11		Inl Struct												
exeter_river	prj_reach	10	NHDES 100-Year	4949.00	8.40	13.88		14.73	0.001135	670.75	124.61	0.56		7.38		7.38
exeter_river	prj_reach	9	NHDES 100-Year	4949.00	7.84	14.01		14.56	0.000785	831.37	167.94	0.47		5.95		5.95
exeter_river	prj_reach	7	NHDES 100-Year	4949.00	6.90	12.35	12.08	14.30	0.003611	441.10	95.06	0.92		11.22		11.22
exeter_river	prj_reach	6		Bridge												
exeter_river	prj_reach	5	NHDES 100-Year	4949.00	5.56	9.78	9.78	11.60	0.004313	457.12	127.28	1.01		10.83		10.83
exeter_river	prj_reach	4	NHDES 100-Year	4949.00	3.58	8.30	8.30	10.39	0.004387	426.03	102.75	1.01		11.62		11.62
exeter_river	prj_reach	3	NHDES 100-Year	4949.00	1.19	4.71	4.71	6.38	0.004348	477.48	144.84	1.01		10.36		10.36
exeter_river	prj_reach	2	NHDES 100-Year	4949.00	-1.15	2.48		3.05	0.001516	811.79	263.13	0.61		6.10		6.10
exeter_river	prj_reach	1	NHDES 100-Year	4949.00	-1.72	1.69	1.69	2.84	0.004501	575.60	253.68	1.01		8.60		8.60

APPENDIX C

APPENDIX C
Rip Rap Calculations

BY SLG DATE 4/4/08

CHCKD. BY RTW DATE 4/7/8

Wright-Pierce

SHEET NO. 1 OF 1

PROJECT NO. 10613D

PROJECT EXETER RIVER STUDY

BOOK NO.

TASK: SIZE RIVER BANK ARMORING DOWNSTEAM OF STRING BRIDGE, USING ISHBASH METHOD.

REFERENCES: ISHBASH EQUATION

$$V = y\left[2g(G_s - S)/S\right]^{1/2} D_{50}^{1/2}$$

CACULATIONS:

$V = 11.66$ fps

G_s = specific gravity of riprap $= \frac{135}{62.4} = 2.16$

S = S.G. OF WATER $= 1$

y = ISHBASH COEFFICIENT $= 0.86$

$$D_{50} = \left(\frac{V}{y\left[2g(G_s-S)/S\right]^{1/2}}\right)^2 = \left(\frac{11.66}{.86\left[2\times 32.2(2.16-1)/1\right]^{1/2}}\right)^2 = \left(\frac{11.66}{7.43}\right)^2$$

$$\boxed{D_{50} = 2.45 \text{ ft.}}$$

04/04/08 WRIGHT-PIERCE Riprap 2.0
99 MAIN ST.

TOPSHAM, ME 04087

PROGRAM OUTPUT

USBR Method

Input Parameters:

Run Name: EXETER Description: EXETER DOWNSTREAM EMBANKMENT EROSION ANALYSIS

Average Channel Velocity, ft/sec 11.66

Output Results:

Computed D50, ft 1.92

*** Using FHWA Gradation ***

Gradation Class 1/2 ton
Layer Thickness, ft 3.38

Percent Smaller by Size	Rock Size, ft	Rock Size, lbs
D100	2.85	2,000
D50	2.25	1,000
D5	1.80	500

Isbash Method

Input Parameters:

Run Name: EXETER Description: EXETER DOWNSTREAM EMBANKMENT EROSION ANALYSIS

Average Channel Velocity, ft/sec 11.66
Unit Weight of Stone, lbs/cu ft 135.00
Turbulence Level High

Output Results:

Computed D50, ft 2.45

*** Using FHWA Gradation ***

Gradation Class 1 ton
Layer Thickness, ft 4.28

Percent Smaller by Size	Rock Size, ft	Rock Size, lbs

D100	3.60	4,000
D50	2.85	2,000
D5	2.25	1,000

WRIGHT-PIERCE

Engineering a Better Environment