TRANSCANADA HYDRO NORTHEAST INC.

ILP Study 8
Channel Morphology and Benthic Habitat Study

Revised Study Report

In support of Federal Energy Regulatory Commission Relicensing of:

Wilder Hydroelectric Project (FERC Project No. 1892-026)
Bellows Falls Hydroelectric Project (FERC Project No. 1855-045)
Vernon Hydroelectric Project (FERC Project No. 1904-073)

Prepared for

TransCanada Hydro Northeast Inc.
4 Park Street, Suite 402
Concord, NH 03301

Prepared by

Stantec Consulting Services Inc.
136 West Street, Suite 203
Northampton, Massachusetts 01060-3711

and

Normandeau Associates, Inc.
25 Nashua Road
Bedford NH 03110

May 16, 2016

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Executive Summary

The goal of the Channel Morphology and Benthic Habitat Study (Study 8) was to understand how operations of the Wilder, Bellows Falls, and Vernon projects affect bedload distribution, particle size, and composition in relation to habitat availability for different life-history stages of invertebrates and anadromous and riverine fish. The Study 8 Revised Study Plan identified that the specific objectives of this study were to:

- Assess the distribution and extent of the existing substrate types including gravel and cobble bars within the project-affected areas; and
- Identify the current conditions of the channel and determine the stability of the present substrate/benthic habitat and potential project-related effects on these habitats.

This study was initiated in 2014, during which study sites were selected in the study area, which extended from the upstream limit of the Wilder impoundment to approximately 1.5 miles downstream from Vernon dam and included tributaries that discharge to the Connecticut River within the study area. Twelve mainstem and six tributary sites were identified in the project area, and these sites were visited during two rounds of site visits in 2014.

The site visits included evaluation of coarse-grained substrates and associated quality of associated benthic habitat at the 18 sites. Information obtained during the site visits was subsequently evaluated using information obtained as part of this and other studies. Evaluations of coarse-grained substrate stability indicate that most of the evaluated coarse-grained substrates are stable at flows less than the applicable project's maximum nominal generating flows (MGF). The conclusion of this study is that flows greater than the project MGF are the dominant factors that contribute to the availability and stability of coarse-grained benthic habitat.

Based on the presence and stability of the identified coarse-grained substrates, these substrates appear to provide persistent habitat for coarse-grain-substrate dependent fauna, including different life-history stages of anadromous and riverine fish, and aquatic invertebrates. Information and evaluations performed as part of this study, and available information and evaluations performed as part of other studies, indicate that project operations do not substantially affect the distribution and extent of coarse-grained benthic habitat in the study area.

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cfs	cubic-feet-per-second
CRWC	Connecticut River Watershed Council
D50	Median particle size
DS	Downstream
FERC	Federal Energy Regulatory Commission
FGS	Field Geology Services, LLC.
GPS	Global Positioning System
HEC-RAS	Hydrologic Engineering Center River Analysis System
HEC-SSP	Hydrologic Engineering Center Statistical Software Package
ILP	Integrated Licensing Process
MGF	Maximum nominal generating flow
NHDES	New Hampshire Department of Environmental Services
NHGFD	New Hampshire Fish and Game Department
Normandeau	Normandeau Associates, Inc.
RSP	Revised Study Plan
SSR	Site Selection Report
SPD	Study Plan Determination
Stantec	Stantec Consulting Services Inc.
TransCanada	TransCanada Hydro Northeast Inc.
US	Upstream
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VANR	Vermont Agency of Natural Resources
WSE/WSEL	Water Surface Elevation

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1.0 INTRODUCTION

This report presents the findings of the 2014 Channel Morphology and Benthic Habitat Study (ILP Study 8) conducted in support of Federal Energy Regulatory Commission (FERC) relicensing of the TransCanada Hydro Northeast Inc. (TransCanada) Wilder Hydroelectric Project (FERC Project No. 1892), Bellows Falls Hydroelectric Project (FERC No. 1855), and Vernon Hydroelectric Project (FERC No. 1904). TransCanada has initiated the Integrated Licensing Process (ILP) for these projects in order to renew their operating licenses beyond the current expiration date of April 30, 2019 for each project.

In their study requests, New Hampshire Department of Environmental Services (NHDES), New Hampshire Fish and Game Department (NHFGD), Vermont Agency of Natural Resource (VANR), and Connecticut River Watershed Council (CRWC) expressed concerns regarding the potential for the Wilder, Bellows Falls, and Vernon Project facilities and operations to affect fluvial processes related to movement of coarse sediment (e.g., gravel and cobble) in the project-affected areas. Specific concerns were identified related to sediment supply, sediment composition and transport, and associated effects on fluvial processes including channel formation. Potentially affected resources include habitat for resident and anadromous fish and benthic habitat for aquatic invertebrates.

The Revised Study Plan (RSP) for this study was approved without modification in FERC's September 13, 2013 Study Plan Determination (SPD), except to change to original study report due date to March 1, 2015. An initial Study Report was filed with FERC on March 2, 2015 (the next business day) and this Revised Study Report includes originally reported results as well as new results based on additional study work.

This Revised Study Report includes information in the initial Study Report, including distribution of coarse-grained substrates within the study area; apparent influences on the characteristics, distribution, and mobility of coarse-grained sediment within the study area; availability of coarse-grained benthic habitat for relevant life-stages of dependent aquatic biota; and as part of the report revision, an assessment of potential effects of project operations on availability and stability of coarse-grained benthic habitat. This report also includes revisions based on stakeholder comments received by May 2, 2016.

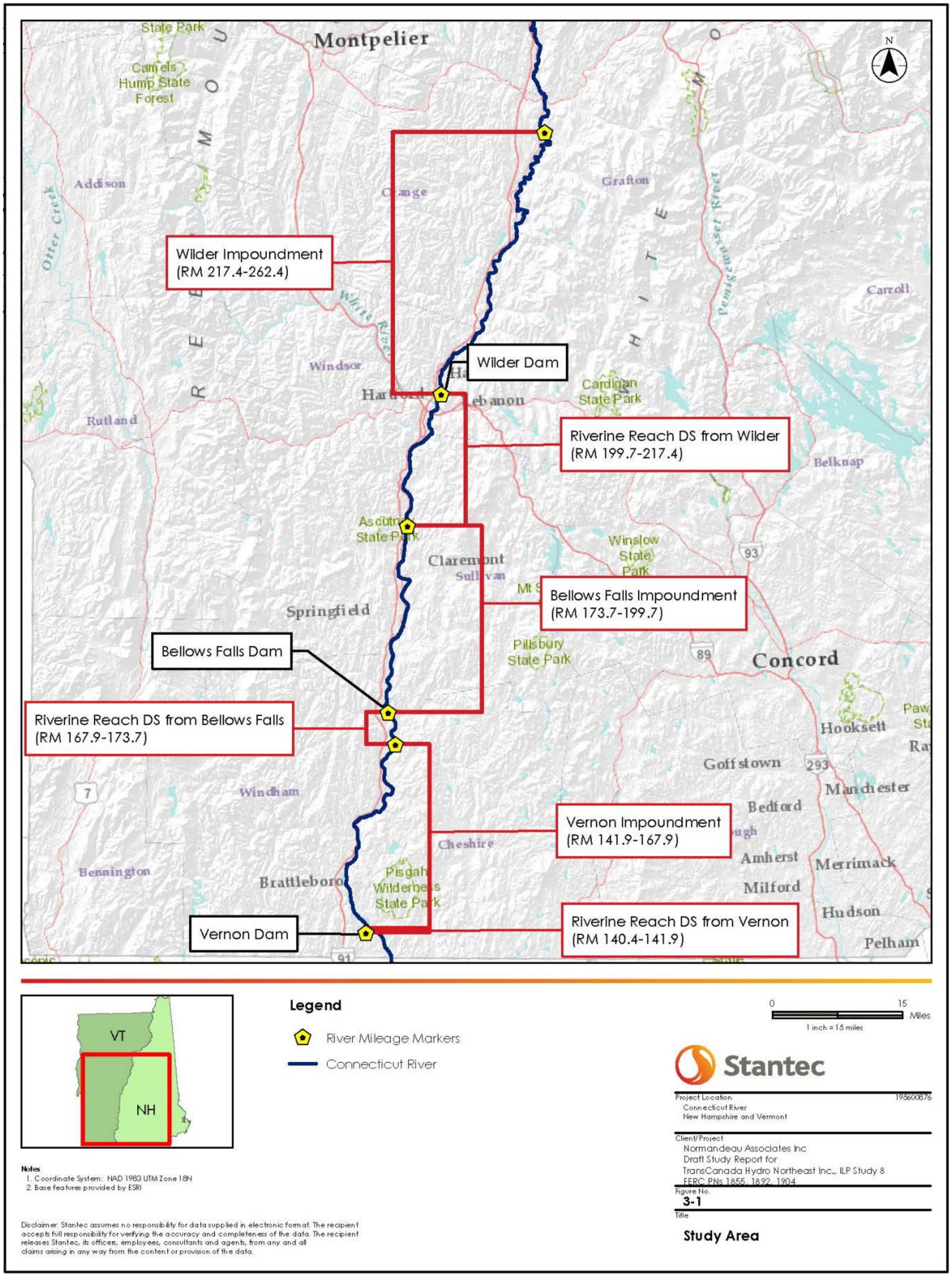
2.0 STUDY GOALS AND OBJECTIVES

As described in the RSP, the goal of this study was to understand how operations of the Wilder, Bellows Falls, and Vernon projects affect bedload distribution, particle size, and composition in relation to habitat availability for different life-history stages of invertebrates and anadromous and riverine fish. The RSP identified that the specific objectives of this study were to:

- Assess the distribution and extent of the existing substrate types including gravel and cobble bars within the project-affected areas; and
- Identify the current conditions of the channel and determine the stability of the present substrate/benthic habitat and potential project-related effects on these habitats.

3.0 STUDY AREA

The study area included twelve sites in the riverine reaches in the project-affected areas as well as six sites in tributaries that are within the project-affected areas from the upstream limit of the Wilder impoundment to approximately 1.5 miles downstream of Vernon dam. The study area excluded the portions of tributaries outside of project influence as these are influenced by non-project-related inflow. The approximate 1.5-mile reach downstream from Vernon dam was included in the study area, consistent with the geographic scope of other ILP studies (Figure 3.1).



Source: Base map features provided by ESRI

Figure 3.1. Study area.

Eighteen study sites were located within the study area, including twelve sites along the mainstem of the Connecticut River (mainstem study sites) and six sites along tributaries to the project-affected reaches of the Connecticut River (tributary study sites). Mainstem sites included eight sites in the riverine reach downstream of Wilder dam, three sites in the riverine reach downstream of Bellows Falls dam, and one site in the riverine reach downstream of Vernon dam. Tributary sites were located on the Ompompanoosuc River and on the five tributaries suggested by the aquatics working group during development of the RSP, including the White River, Mascoma River, Williams River, Saxtons River, and Cold River. Mainstem and tributary sites are summarized in Table 3.1 and Table 3.2, respectively, and depicted in Figures 3.2 through 3.4 (see also Section 4.1). Geo-referenced site locations were filed with FERC as part of the Initial Study Report filing on September 15, 2014.

Table 3.1. Mainstem study sites.

Study Site ID	Coordinates		Reach	Distance (river miles) from Project Dam	Site Position (MC / RR / RL)	Site Description	Site Notes	# of Transects
	Long.	Lat.						
08-M01	-72.304398	43.666479	Riverine reach below Wilder	0.05 DS from Wilder	RL	Mid-channel bar	Adjacent to Wilder spillway	1
08-M04	-72.331375	43.622827	Riverine reach below Wilder	2.91 DS from Wilder	MC	DS end of island	Adjacent to Johnston Island	2
08-M05	-72.339288	43.59342	Riverine reach below Wilder	6.28 DS from Wilder	MC	US end of Burnaps Island	0.36 mi US from Ottauquechee River; 1.13 mi DS from Bloods Brook	3
08-M07	-72.378234	43.573896	Riverine reach below Wilder	8.67 DS from Wilder	MC	Mid-channel bar	0.67 mi US from Sumner Falls	2
08-M08	-72.379872	43.54648	Riverine reach below Wilder	10.7 DS from Wilder	MC	Mid-channel bar	1.20 mi DS from Sumner Falls	3
08-M10	-72.386584	43.502201	Riverine reach below Wilder	14.2 DS from Wilder	RR	Point bar	0.85 mi DS from Bashan Brook	2
08-M12	-72.390753	43.466903	Riverine reach below Wilder	16.9 DS from Wilder	MC	US end of Chase Island	0.39 mi DS from Mill Brook (VT) and Mill Brook (NH)	3
08-M13	-72.389651	43.456049	Riverine reach below Wilder	17.7 DS from Wilder	MC	Mid-channel bar	0.37 mi DS from Chase Island; in vicinity of US limit of Bellows Falls impoundment	2
08-M15	-72.438594	43.129847	Riverine reach below Bellows Falls	0.83 DS from Bellows Falls	RL	Side bar	0.15 mi DS from Bellows Falls bypass reach	1
08-M16	-72.43217	43.113009	Riverine reach below Bellows Falls	2.19 DS from Bellows Falls	RL	Point bar	0.44 mi. DS from Cold River	2
08-M17	-72.434228	43.085665	Riverine reach below Bellows Falls	4.34 DS from Bellows Falls	RR	Point bar	0.10 mi US from Dwinnell Street bridge; in vicinity of US limit of Vernon impoundment	1
08-M20	-72.505433	42.768868	Riverine reach below Vernon	1.0 DS from Vernon	MC	US end and RL side of Stebbins Island	0.83 - 1.10 mi DS from Vernon	3

Note: The 12 mainstem study sites are a subset of the 20 potential mainstem sites identified as a part of the site selection process. For this reason, site numbers are not sequential. See Section 4 for additional information.

Abbreviations: DS (Downstream); mi. (mile); MC (Mid Channel); RL (River Left); RR (River Right); Long. (longitude); Lat. (latitude). Directionals “right” and “left” are based on an observer facing downstream.

Table 3.2. Tributary study sites.

Study Site ID	Coordinates		Reach	Distance from Project Dam (river miles)	Site Position (MC / RR / RL)	Site Description	Site Notes	# of Transects
	Long.	Lat.						
08-T01	-72.2392	43.765942	Impounded reach above Wilder	7.78 US from Wilder	RR of tributary	Point bar	Ompompanoosuc River; 1.34 mi US from confluence with Connecticut River	3
08-T02	-72.315542	43.648778	Riverine reach below Wilder	1.46 DS from Wilder	MC of tributary	Mid-channel bar	White River; at confluence with Connecticut River	3
08-T04	-72.322871	43.635913	Riverine reach below Wilder	2.71 DS from Wilder	MC of tributary	Mid-channel bar	Mascoma River; 0.16 mi US from confluence with Connecticut River	2
08-T12	-72.46574	43.184855	Impounded reach above Bellows Falls	2.71 US from Bellows Falls	MC of tributary	Point bar on island	Williams River; 1.1 mi US from confluence with Connecticut River	2
08-T14	-72.437139	43.124782	Riverine reach below Bellows Falls	1.21 DS from Bellows Falls	RR of mainstem	Delta bar	Saxtons River; at confluence with Connecticut River	3
08-T16	-72.431758	43.117739	Riverine reach below Bellows Falls	1.79 DS from Bellows Falls	RL of mainstem	Delta bar	Cold River; at confluence with Connecticut River	3

Note: The 6 tributary study sites are a subset of the 18 potential tributary sites identified as a part of the site selection process. For this reason, site numbers are not sequential. See Section 4 for additional information.

Abbreviations: DS (Downstream); mi. (mile); MC (Mid Channel); RL (River Left); RR (River Right); Long.(longitude); Lat. (latitude). Directionals “right” and “left” are based on an observer facing downstream.

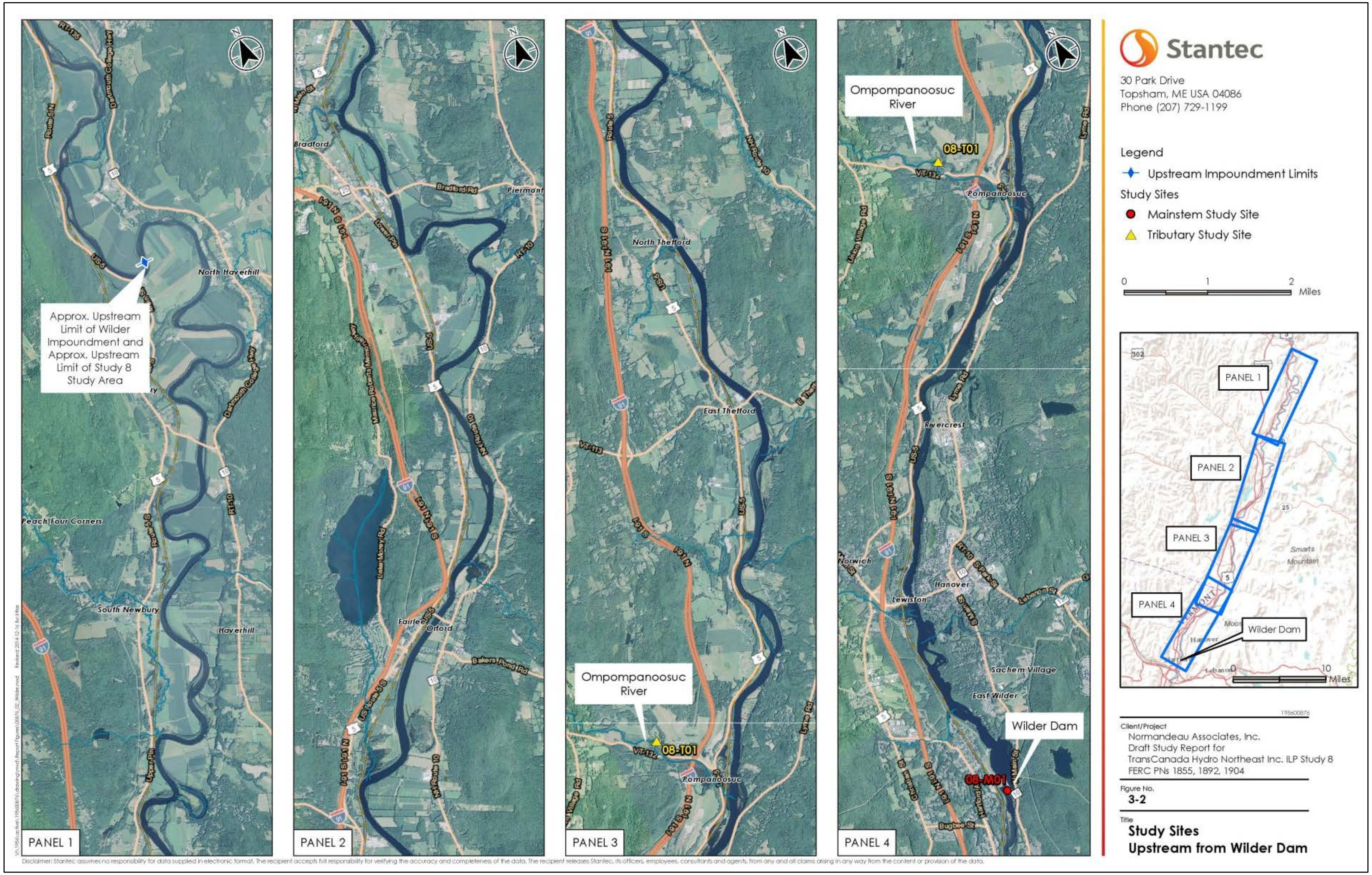


Figure 3.2. Study sites upstream of Wilder dam.

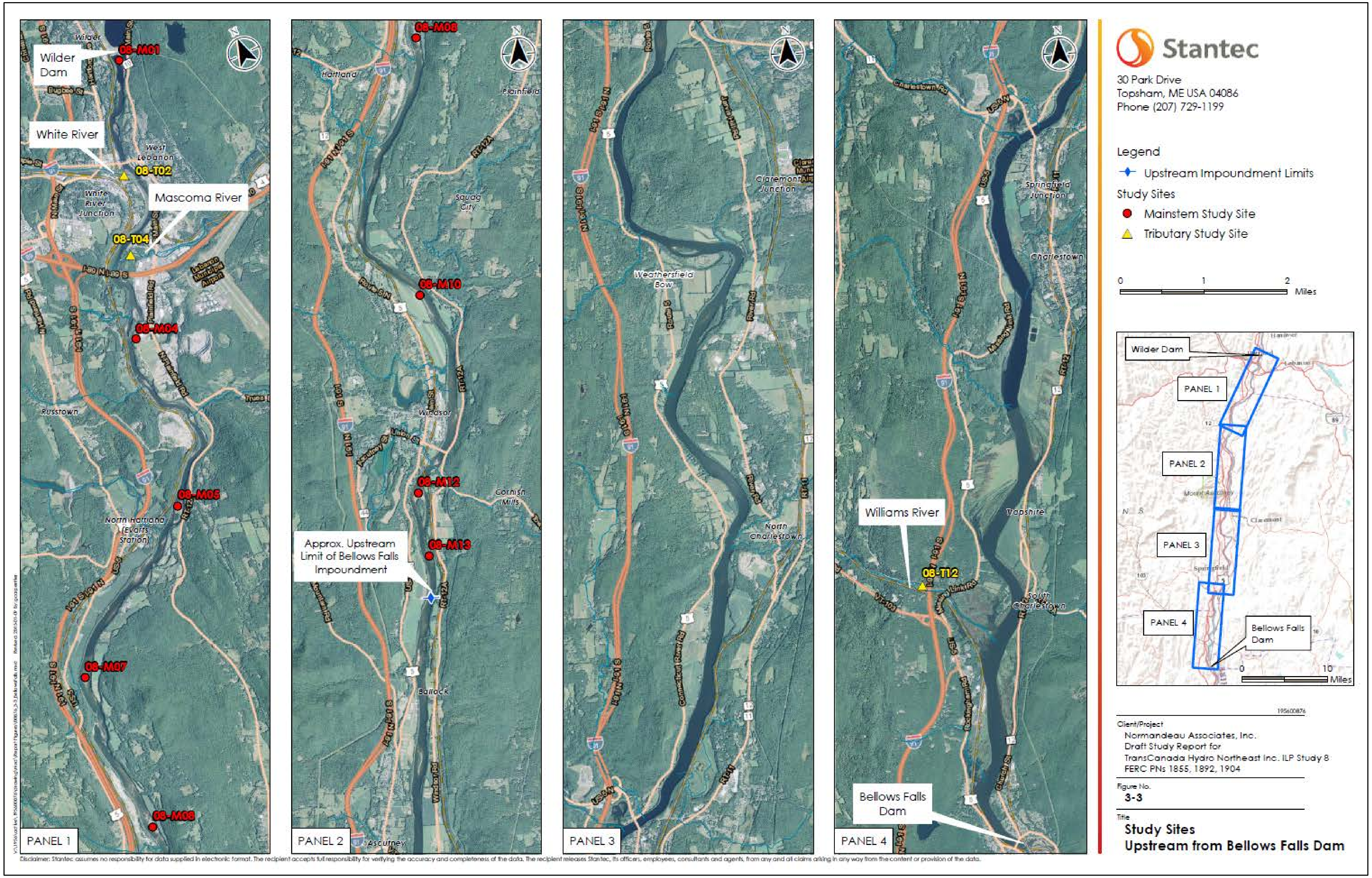


Figure 3.3. Study sites upstream of Bellows Falls dam.

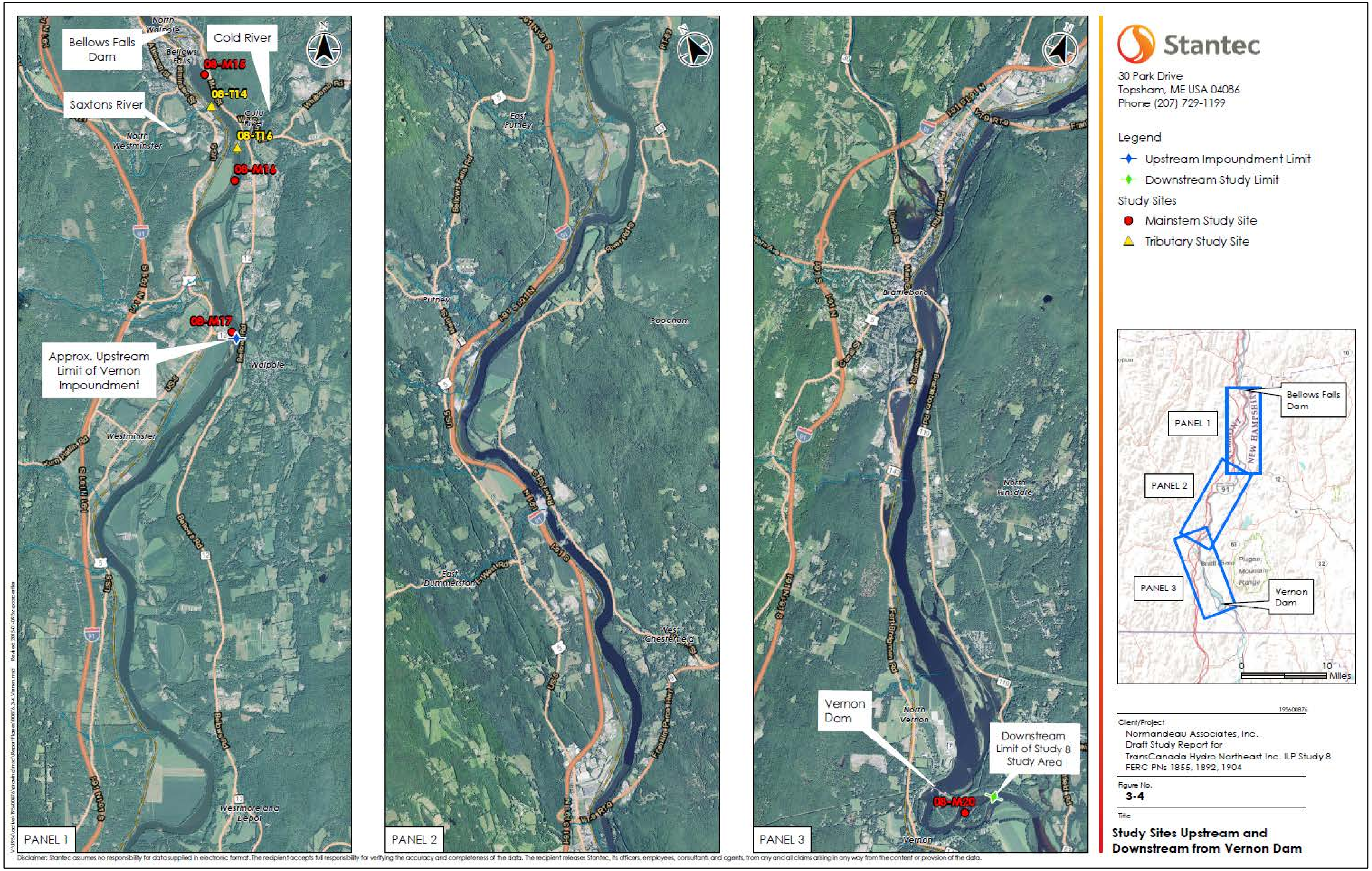


Figure 3.4. Study sites upstream and downstream of Vernon dam.

The mainstem sites included a variety of geomorphic features, including mid-channel bars (Photo 3.1), point bars, and side bars. Many of these features appeared to be persistent based on review of aerial photographs, and included named islands in the Connecticut River (Photo 3.2). The exposed extent of the mainstem sites varied between sites and with water levels.

Photo 3.1. Mainstem Site 08-M07 (mid-channel bar located upstream from Sumner Falls). Photograph taken facing upstream along the Connecticut River. (Stantec 10/8/2014)

Photo 3.2. Mainstem Site 08-M05, facing across the upstream end of Burnaps Island, towards the right bank of the Connecticut River. (Stantec 10/8/2014)

The six tributary sites included one tributary that discharges to the Wilder impoundment, one tributary that discharges to the Bellows Falls impoundment, and four tributaries that discharge to riverine reaches of the Connecticut River downstream of the project dams. The sites on impoundment tributaries (08-T01 and 08-T12) were located near the upstream limit of the project influence on each tributary. These sites were selected to obtain information on coarse-grained sediments expected to accrete in the vicinity of the confluence of the tributary with the impoundment (Photo 3.3). The four sites at tributaries that discharge to riverine reaches of the Connecticut River (08-T02, 08-T04, 08-T14, and 08-T16) are located at or immediately adjacent to the Connecticut River (Photo 3.4).

Photo 3.3. Tributary Site 08-T12 facing downstream along the Williams River. (Stantec 10/31/2014)

Photo 3.4. Tributary Site 08-T14 facing downstream across the confluence of the Saxtons River with the Connecticut River. (Stantec 10/9/2014)

4.0 METHODS

4.1 Site Selection

The RSP described three types of study sites located in three general areas:

- Upstream (US)-type study sites, located on riverine reaches of the Connecticut River upstream from the TransCanada Project impoundments;
- Downstream (DS)-type study sites, located on riverine reaches of the Connecticut River downstream from the Wilder and Bellows Falls dams; and
- Tributary study sites, located on select tributaries to the Connecticut River in the riverine reaches downstream from the Wilder and Bellows Fall dams and in tributaries to the TransCanada Project impoundments.

The RSP called for establishing approximately twelve US- and DS-type study sites (collectively referred to as mainstem sites) and up to six tributary study sites, including tributaries with and without flood control dams. Five tributaries were also specifically suggested by the working group, including the White River, Mascoma River, Williams River, Saxtons River, and Cold River.

Site selection was based on desktop studies, including review of:

- Aerial photographic imagery;

- U.S. Geological Survey (USGS) topographic maps;
- Data collected as part of Study 2 – Riverbank Transect Study;
- Flood control facilities on tributaries to the Connecticut River within the study area; and
- Available, applicable substrate data collected as part of Study 7 – Aquatic Habitat Mapping.

The primary method for study site selection was identification of areas with accumulations of apparently coarse sediment using aerial photographs. Aerial photographs depicting periods of lower water surface elevations were used to identify sites expected to be exposed or having shallow depths (less than knee deep) to allow for field sampling. Preliminary data collected as a part of Study 2, including site photographs, was also reviewed to inform site selection and corroborate assumptions developed based on review of aerial photography. Following desktop identification of potential sites, available substrate information collected as a part of Study 7 was reviewed to qualitatively evaluate the identified sites and confirm their apparent suitability in relation to the relevant Study 8 substrate criteria.

The primary selection criterion included observation of apparent depositional areas of coarse-grain sediments. Additional criteria included apparent site access, ability to obtain relevant information, and site safety. The site selection process also considered selection of a suite of sites that, as a whole, appeared generally spatially and physically representative of the study area. Potential tributary site identification also included consideration of the five tributaries listed in the RSP; the apparent sediment supply based on the presence of exposed bars and submerged bedforms on aerial photographs; observation of locations where accumulated sediment appear to have been deposited by tributaries; and the presence of flood control facilities.

Using the methodology described in the RSP and the Site Selection Report (SSR) (Stantec and Normandeau, 2014), a total of 38 potential study sites were identified, including 20 mainstem sites and 18 tributary sites. The SSR presented recommendations for twelve mainstem sites and six tributary sites and recommended that the balance of the potential study sites be identified as contingency sites, for use in the event that a recommended site was deemed unsuitable for use in the course of implementation of field work.

The SSR was presented to the aquatics working group in a consultation meeting on May 23, 2014. The working group made no requests for changes to the SSR and approved the recommended and contingency sites.

4.2 Field Methods

Field methods for this study included verification of site suitability, establishment of survey transects, documentation of transect locations, and performance of two rounds of sampling along each transect. Field data was recorded on standardized field forms (Appendix A).

4.2.1 Confirmation of Study Site Suitability

The suitability of each recommended site was evaluated during the first round of site visits by visual assessment of the presence of coarse-grained sediment. Contingency sites in close proximity to the recommended sites were also assessed. The field evaluation of one of the recommended mainstem sites (Site 08-M15) determined that this site was poorly suited for study. This site is located along the river left (New Hampshire) side of the Connecticut River approximately 800 ft downstream of the Bellow Falls bypassed reach and consists of a homogeneous mix of sand and finer material, rather than coarse-grained sediment. A survey was performed to identify a potentially more suitable, representative mainstem study site immediately downstream of Bellows Falls, but one was not identified. Based on the objectives of this study, it was determined that the recommended mainstem site would therefore be used.

The suitability of five of the six recommended tributary sites was confirmed as part of the field evaluation. During the first round of field data collection, one contingency tributary site (08-T04) was selected to replace a recommended tributary site (08-T03). Both sites are located in the vicinity of the confluence of the Mascoma River with the Connecticut River. Field observations and comparison of the sites indicated that the depositional feature at Site 08-T04 consisted of a more heterogeneous mix of coarse-grained sediments than Site 08-T03 (which was composed primarily of sand). Based on these observations, Site 08-T04 was determined to be better suited for study and was selected to replace Site 08-T03.

Following the confirmation of each site for study, the approximate limits of each site were established and the locations recorded using a Global Positioning System (GPS) receiver. The recorded limits of each site generally included the upstream and downstream limits and lateral (perpendicular to flow) limits. Photographs were obtained at each of the demarked limits, including photographs facing upstream and downstream at both the upstream and downstream limits, and photographs facing towards the site from the lateral limits of the site.

4.2.2 Establishment of Survey Transects

Survey transects were established at each study site prior to implementation of detailed field surveys. Transects were established following visual surveys of each site and were, in most cases, established along the upstream ends of bars to provide information on coarser-grained material since the downstream ends of bars and islands had, in some cases, large accumulations of homogeneous, sand-size material.

The number of survey transects was determined based on a preliminary characterization of each site. In general, a single transect was established at sites with homogeneous characteristics and multiple transects were established at sites with heterogeneous characteristics. The length of survey transects was established to obtain a representative sampling of coarse-grained sediment based on observed conditions. Transect lengths ranged from 100 to 300 feet.

Transects were generally aligned either parallel to the channel ("stream-wise transects") or perpendicular to the channel ("perpendicular transects"). Stream-wise transects were used in areas where the elevation may vary but the feature has a consistent geometry, such as along the crest of bars of accumulated sediment; or, along lines of similar elevation relative to the water surface, including along the sides of bars and around the upstream edge of bars. Perpendicular transects were used only along relatively flat bars. At sites where multiple transects were established at varying elevations, transects were numbered progressing from the water/water's edge to higher elevations at each site (i.e., Transect 1 [T1] generally is the lowest transect).

The locations of transects were limited by the depth of water that could be effectively sampled (e.g., less than 1.5 ft). For this reason, data collection was coordinated with TransCanada Operations to provide for low-flow conditions during data collection. The start and end locations of each transect were recorded with a GPS during the first site visit. During both rounds of data collection, photographs were taken along each transection from the start and end points of each transect and a representative photograph was taken of the substrate along each transect. Transect locations at each study site are depicted in the figures in Appendix B and photographs are provided in Appendix C.

4.2.3 Pebble Count Method

Coarse-grained substrates were quantified at each site using pebble counts. The pebble count methodology is based on Wolman (1954). The applied pebble count method included measurement of the median axis of 100 random samples collected at regular intervals along each survey transect. Pebble sizes were categorized based on a simplified Wentworth scale (Wentworth, 1922) (Table 4.1). The field sampling team was comprised of two people, with one person performing the sampling and the other person recording sample measurements. For consistency, the same person performed the sampling at every transect at each site during each site visit.

The pebble count method was performed based on the first particle touched by the sampler with the exception of sites where algal mats were present on top of coarse grained substrates. In this case, substrate particles underlying the algal mat were selected in lieu of fine-grained material (e.g., silt, sand) that was loosely embedded in the algal mat. Pebble count data was recorded on a standardized field data form (Appendix A).

Table 4.1. Simplified Wentworth scale.

Wentworth Class		Size Range (mm)
Silt/Clay	Silt/Clay	<0.062
Sand	Sand	0.062 - 2.0
Gravel	Very Fine	2-4
	Fine	4-8
	Medium	8-16
	Coarse	16-32
	Very Coarse	32-64
Cobble	Small	64-128
	Large	128-256
Boulder	Small	256-512
	Medium	512-1024
	Large - Very Large	1024-4096
Bedrock	Bedrock	-

4.2.4 Embeddedness Method

Embeddedness was quantified using methods as generally described in Chapter 5 of "Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers" (Barbour et al., 1999) that was prepared on behalf of the U.S. Environmental Protection Agency. Embeddedness was defined as the fraction of a gravel, cobble, or boulder particle surface that is surrounded by sand or finer sediments. Embeddedness was not evaluated for sand and finer particles.

Embeddedness was visually estimated at 10 sample points at decile intervals (e.g., 10%, 20% of the total transect length) along each survey transect. At each sample plot, percent embeddedness of gravel, cobble, and boulder particles was evaluated and an embeddedness score between 1 and 20 was recorded (Table 4.2).

Table 4.2. Embeddedness scores and condition categories.

Condition Category	Poor	Marginal	Suboptimal	Optimal
Embeddedness Score	1–5	6–10	11–15	16–20
% Embeddedness	>75%	75–50%	50–25%	25–0%
Description	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50–75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 25–50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 0–25% surrounded by fine sediment.

Embeddedness surveys were performed coincident with the pebble counts. In addition to the 10 visual embeddedness estimates along each transect, an overall visual estimate of embeddedness was recorded following completion of each transect. The overall estimate was made by the person performing the embeddedness estimates, and is intended to provide a single estimate of embeddedness generally representative of embeddedness along the entire transect. Embeddedness data was recorded on a standardized field data form (Appendix A).

4.2.5 Sampling Rounds

Study field work was conducted in two rounds during the summer and fall of 2014. The summer sampling round was conducted on July 11–15 and August 12, 2014; and the fall sampling round on October 6–9 and 31, 2014. Table 4.3 and Table 4.4 present sampling dates for the mainstem and tributary sites, respectively.

Table 4.3. Mainstem study site sampling dates.

Study Site ID	Summer 2014 Site Visit	Fall 2014 Site Visit
08-M01	7/12	10/8
08-M04	7/12	10/8
08-M05	7/12	10/8
08-M07	7/12	10/8
08-M08	7/13	10/7
08-M10	7/13	10/7
08-M12	7/15	10/6
08-M13	7/15	10/6
08-M15	7/14	10/6
08-M16	7/14	10/9
08-M17	7/14	10/9
08-M20	8/12	10/31

Table 4.4. Tributary study site sampling dates.

Study Site ID	Summer 2014 Site Visit	Fall 2014 Site Visit
08-T01	7/11	10/7
08-T02	7/12	10/7
08-T04	7/12	10/8
08-T12	7/13	10/31
08-T14	7/14	10/9
08-T16	7/14	10/9

4.3 Field Data Reduction and Analysis

Field data reduction included transcription of field data into standardized electronic forms (Microsoft Excel spreadsheet format) and analysis of the pebble count and embeddedness data.

Material size gradation curves were developed from the pebble count data and an average embeddedness was calculated based on the 10 individual embeddedness scores for each transect and site visit. Qualitative evaluation of the pebble count data was facilitated by comparison of material size gradation curves for each transect during the two site visits; and material size gradation curves for each transect at each site. The former comparison is intended to provide insight into potential temporal variations in sediment size along a given transect that may have occurred between the two site visits. The latter comparison is intended to provide insight into spatial variation of sediment at each site.

Tables and gradation curves of the reduced pebble count data are provided in Appendix D.

4.4 Desktop Analyses

Desktop analyses were performed to develop information for evaluation as part of this study. These analyses included development of 1) peak-flow statistics for the project-affected areas of the Connecticut River, and 2) critical shear stress criteria for coarse-grained substrate.

4.4.1 Peak-Flow Hydrologic Statistics

Peak-flow hydrologic statistics were developed to provide information for comparison of the projects' maximum nominal generating flows (MGFs) with high-flow events in the Connecticut River in the study area. These statistics were developed using peak flow data for the period-of-record at the USGS stream gaging stations at West Lebanon, NH (USGS Station No. 01144500) and North Walpole, NH (USGS Station No. 01154500). The statistical analyses were performed with the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center Statistical Software Package (HEC-SSP) using the Bulletin 17B flow frequency analysis method.

Results of the statistical analyses are presented in Table 4.5, which includes the reported flow statistics from HEC-SSP. For reference, the MGFs at the Wilder, Bellows Falls, and Vernon projects are 10,700, 11,400, and 17,100 cubic feet per second (cfs), respectively.

Table 4.5. Peak flow statistics.

Percent Chance Exceedance (%)	Return-Interval (years)	Expected Probability Flow (cfs)	
		West Lebanon (USGS Sta. No. 01144500)	North Walpole (USGS Sta. No. 01154500)
99	1.01	24,770	34,344
95	1.05	29,084	41,404
90	1.11	31,949	45,534
80	1.25	36,082	50,912
67	1.49	40,666	56,205
50	2	46,752	62,472
20	5	62,957	75,974
10	10	74,824	83,939
5	20	87,129	91,058
2	50	104,639	99,706
1	100	119,070	105,890
0.5	200	134,760	118,863

4.4.2 Critical Shear Stress Criteria

Critical shear stress (τ_{critical}) is calculated using a linear relationship presented in Julien (1995) for cohesionless sediment. This relation is presented for units that are consistent with the field sampling of substrate (millimeters [mm]) and Hydrologic Engineering Center River Analysis System (HEC-RAS) model output (lb/ft^2) and is noted as approximately valid for median participate size (D50) greater than 0.3 mm. The equation used for calculating critical shear stress is provided below.

$$\boldsymbol{\tau}_{\textbf{critical}}\left(\frac{\boldsymbol{lb}}{\boldsymbol{ft^2}}\right) = \mathbf{0.0164}\ \boldsymbol{d_{50}}(\boldsymbol{mm})$$

Table 4.6 includes the classes in the simplified Wentworth scale used for categorizing pebble size and the corresponding critical shear stress to the lower and upper size limits and average shear stress for the median particle size of each class. Critical shear stress for silt/clay material is not provided in Table 4.6 as this material class is comprised entirely of particles that are smaller than 0.062 mm. Similarly, the calculated shear stress for the lower size limit in the sand class is based on a particle diameter of 0.3 mm in lieu of 0.062mm. Bedrock is not included in Table 4.6.

Table 4.6. Simplified Wentworth Scale with critical shear stress.

Wentworth Class		Size Range (mm)	Critical Shear Stress (lb/ft^2)		
			Lower Bound	Upper Bound	Average
Silt/Clay	Silt/Clay	<0.062	n/a	n/a	n/a
Sand	Sand	0.062 - 2.0	0.0049	0.033	0.019
Gravel	Very Fine	2-4	0.033	0.066	0.049
	Fine	4-8	0.066	0.13	0.098
	Medium	8-16	0.13	0.26	0.20
	Coarse	16-32	0.26	0.52	0.39
	Very Coarse	32-64	0.52	1.0	0.79
Cobble	Small	64-128	1.0	2.1	1.6
	Large	128-256	2.1	4.2	3.1
Boulder	Small	256-512	4.2	8.4	6.3
	Medium	512-1024	8.4	17	13
	Large - Very Large	1024-4096	17	67	42

4.5 Evaluations Based on Other Studies

Evaluations as part of this study draw on information obtained from other studies, including sediment supply information from the Historical Riverbank Position and Erosion Study (Study 1), Riverbank Transect Study (Study 2) and Riverbank Erosion Study (Study 3); information regarding flow speed, depth, shear stress, and sediment mobility from the Hydraulic Modeling Study (Study 4); and information regarding substrate characterization in the riverine reaches from the Aquatic Habitat Mapping Study (Study 7). This review of other studies regarding potential sediment sources, mobility, and distribution is summarized below.

4.5.1 Riverbank Erosion (Studies 1 - 3)

Information developed as part of the Studies 1, 2, and 3 was reviewed to qualitatively assess potential impacts of riverbank erosion on bedload distribution, particle size, and composition in relation to availability and stability of coarse-grained benthic habitat. Specifically, available information from these studies was used to assess potential sources of fine-grained and coarse-grained sediment. The objectives of this assessment were to evaluate whether riverbank erosion is a potential source of 1) course-grained substrate that provides benthic habitat, and/or 2) fine-grained sediment that could result in increased embeddedness of coarse-grained sediment in the study area.

Study 1 documented areas of historical erosion along the Connecticut River in the study area. Study 1 was completed prior to the development of, and was reviewed as part of, this report revision.

Study 2 (in progress at the time of this report revision) evaluates the current stability and rates of erosion at riverbanks in the study area. Study 2 GIS data identifying the locations of study sites was available and was reviewed to compare the locations of Study 2 sites relative to this study's sites. The authors of this study report also corresponded with the author of Study 2 to discuss preliminary findings of Study 2 that may be relevant to this study. Information obtained from the author of Study 2 that is relevant to Study 8 is that riverbanks in the study area are largely composed of fine-grained material (e.g., sand) and do not contribute substantial amounts of coarse-grained substrate.

Study 3 (in progress at the time of this report revision) evaluates the location of riverbank erosion in the study area, compares this information with information obtained as part of previous studies, characterizes erosion processes, characterizes likely causes of erosion, and identifies potential effects of riverbank erosion on other resources. The authors of this study corresponded with the author of Study 3 to discuss preliminary findings of Study 3 that may be relevant to this study. Information obtained from the author of Study 3 that is relevant to Study 8 is that riverbank erosion is not a significant source of coarse-grained substrate to the study area.

4.5.2 Hydraulic Model Study (Study 4)

Information obtained from Study 4, including stage-shear stress and stage-discharge curves, was used to evaluate the stability of coarse-grained substrates over a range of water surface elevations (WSEs) and flows in the vicinity of each mainstem site and applicable tributary sites. The range of evaluated flows included flows greater than the project facility MGFs. Incipient motion criteria presented in Table 4.6 were compared to calculated shear stresses based on stage-shear stress data obtained from Study 4 at each mainstem site. This comparison was developed to evaluate the stability of the median particle size class(es) at these sites.

Information from Study 4 was obtained in the vicinity of the twelve mainstem sites and four of the tributary sites (08-T02, 08-T04, 08-T14, and 08-T16) which are located in close proximity to modeled areas of the Connecticut River. The two additional tributary sites (08-T01 and 08-T12) are located upstream from the limits of the hydraulic model developed as a part of Study 4 and as a result hydraulic model data is not available for these tributary sites.

Information from Study 4 was obtained for between two and seven hydraulic model cross sections for the mainstem sites, with the requested number of cross sections dependent on the spatial extent of each site relative to the location of adjacent hydraulic model cross sections. Similarly, information from Study 4 was obtained for between one and six hydraulic model cross sections for the four tributary sites for which information from Study 4 is used.

Study 4 initially modeled a range of flows from approximately 1,000 to 25,000 cfs. Based on the peak flow statistics presented in Table 4.5, the upper limit of this range (i.e., 25,000 cfs) corresponds with the approximately 1-year return-interval (99% chance exceedance) event. Based on a preliminary review of the Study 4 information and peak-flow, return-interval statistics presented in Section 4.4.1 of this report, additional information was obtained from Study 4 up to a maximum modeled flow of 100,000 cfs. Based on the peak flow statistics presented in Table 4.5, 100,000 cfs corresponds approximately with the 50-year return-interval (2% chance exceedance) event.

The Study 4 information included data from HEC-RAS model cross sections located in the vicinity of each mainstem site. The Study 4 data was developed using multiple downstream boundary conditions (applied WSEs) to account for variability of impoundment WSEs within the range of project operations and hydraulic discharge characteristics at the project dams. Evaluations presented herein are based on the lowest WSE boundary condition for each flow based on the expectation that this boundary condition would result in the largest calculated shear stress. The WSEs used for these boundary conditions are provided in Table 4.7.

Table 4.7. Study 4 downstream boundary condition WSEs.

Reach	Downstream Facility	Water Surface Elevation (ft NAVD88)
Wilder to Bellows Falls	Bellows Falls	288.2
Bellows Falls to Vernon	Vernon	211.6
Vernon to Turners Falls	Turners Falls	175.6

Figure 4.1 depicts the flow (discharge)-shear stress curves for seven of the Study 4 hydraulic model transects adjacent to Site 08-M20, with flow as the independent variable on the vertical axis and shear stress as the dependent variable on the horizontal axis.

As depicted in Figure 4.1, modeled shear stress varies between adjacent HEC-RAS model cross sections. This variability likely results from the spatial locations of each cross section as well as other factors, including available bathymetric data and boundary conditions used for the Study 4 hydraulic model.

Based on variability of the Study 4 information and the variability of conditions that result in incipient motion of sediment, a single representative cross section was selected for evaluations at each site. The selection of a single cross section at each site was based on qualitative evaluation of information at each site, including the shape of the flow-shear stress curve and the proximity of each cross section to the site transects. In particular, some of the Study 4 information indicated non-monotonic flow-shear stress curves and maximum shear stresses at very low flows (e.g., 2,000 cfs). Cross sections with strongly non-monotonic flow-shear stress curves were not used unless all of the cross-section data at that site had similar, non-monotonic curves. Data from cross section node 128 of the hydraulic model was selected as the representative shear stress data at this site.

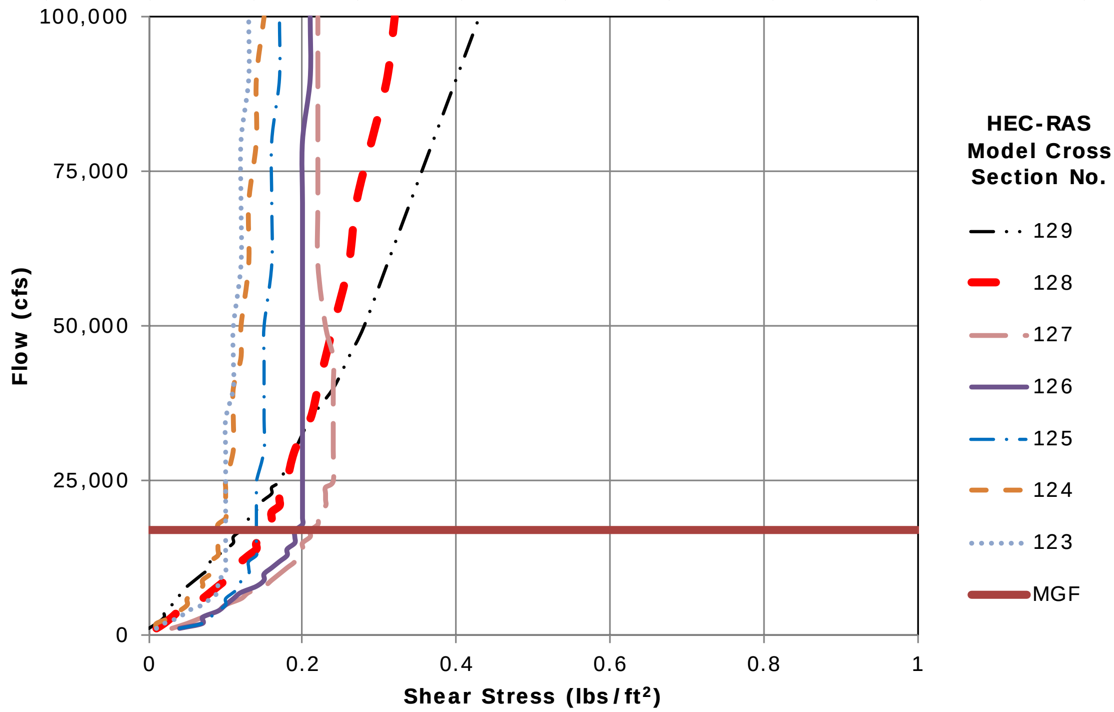


Figure 4.1. Sample of flow-shear stress curves plotted for model cross sections located in the vicinity of Site 08-M20.

Following selection of a representative HEC RAS model cross section at each of the mainstem and tributary sites included in this analysis, flow-shear stress information at the selected cross sections was compared to the critical shear stress data for identified substrate sizes (Table 4.6) to inform the assessment of potential effects of project operations on the stability of coarse-grained substrates at each site. Table 4.8 presents the maximum shear stress and associated flow at the sites where information from Study 4 was used.

Table 4.8. Maximum shear stress and associated flow at selected Study 4 cross sections.

Study Site ID	Study 4 Node Number	Wilders to Bellows Falls (MGF: 10,700 cfs)		Bellows Falls to Vernon (MGF: 11,400 cfs)		Vernon to Turners Falls (MGF: 17,100 cfs)	
		Max Flow (cfs)	Max shear (lb / ft^2)	Max Flow (cfs)	Max shear (lb / ft^2)	Max Flow (cfs)	Max shear (lb / ft^2)
08-M01	868	100,000	0.22	-	-	-	-
08-M04	836	6,000/ 100,000	1.06/.2	-	-	-	-
08-M05	807	100,000	0.37	-	-	-	-
08-M07	786	100,000	0.3	-	-	-	-
08-M08	768	100,000	0.18	-	-	-	-
08-M10	733	100,000	0.34	-	-	-	-
08-M12	710	100,000	0.29	-	-	-	-
08-M13	699	100,000	0.34	-	-	-	-
08-M15	495	-	-	100,000	0.07	-	-
08-M16	475	-	-	100,000	0.54	-	-
08-M17	450	-	-	100,000	0.26	-	-
08-M20	22/128	-	-	-	-	100,000	0.32
08-T02	852	100,000	0.17	-	-	-	-
08-T04	844	100,000	0.17	-	-	-	-
08-T14	489	-	-	100,000	0.46	-	-
08-T16	480	-	-	100,000	0.57	-	-

The Tributary and Backwater Fish Access and Habitats Study (Study 13) provides some information on fluctuations in water surface at mostly smaller tributary sites (stream order 1 – 3), but the broader spectrum of modeled flows in Study 4 provided more relevant information for this study, including high flow conditions that are not affected by project operations.

Study 4 provided information that may be used to evaluate whether fluctuations in WSEs associated with project operations may affect sediment delivery from tributaries. This potential effect was evaluated at the four tributary sites located on the riverine sections downstream of each project. Shear stress and WSE data obtained from Study 4 was used to evaluate the stability of coarse-grained substrate in the vicinity of the confluence of the tributaries with the Connecticut River.

4.5.3 Aquatic Habitat Mapping Study (Study 7)

Study 7 included mapping of aquatic habitat and substrates in the Connecticut River throughout the study area. This mapping included acquisition of remote-sensing imagery of the bottom in the three project impoundments and information from visual observations and manual probing of substrates in the riverine reaches.

Characterization of substrates in the riverine reaches of the Connecticut River in the study area is presented in tables in Appendix A of the Study 7 Final Study Report filed March 2, 2015. This information documents the presence of course-grained substrates in the study area and is used in this study to inform an understanding of the distribution and extent of coarse-grained substrates within the study area.

4.5.4 Dependent Biota

This study evaluated the availability of benthic habitat for relevant life-history stages of coarse-substrate-dependent aquatic invertebrates and anadromous and resident fish. As described below, the selection of species for consideration in this study included a review of the specific, coarse-substrate-dependent biota that were identified in study requests and in other ILP studies.

Aquatic Invertebrates

Invertebrates identified in study requests and in other studies include:

- Freshwater mussels including Dwarf Wedgemussel (*Alasmidonta heterodon*), (Study 24);
- Dragonflies and damselflies (Study 25); and
- Cobblestone and Puritan Tiger Beetles (*Cicindela marginipennis* and *C. puritana*) (Study 26).

Freshwater mussel species, including Dwarf Wedgemussel, are not specifically dependent on coarse-grained habitat; thus coarse-grained habitat availability for freshwater mussel species is not evaluated as a part of this study.Cobblestone and Puritan Tiger Beetles are not aquatic invertebrates; thus benthic habitat availability for these species is not evaluated as part of this study.

Aquatic life-stages of the species included in the order Odonata (i.e., dragonflies and damselflies), have a range of aquatic habitat requirements, but are not solely dependent on habitat comprised of coarse-grained substrates. Coarse-grained substrate does provide benthic habitat for certain species in the order Odonata and, more generally, for a wide range of benthic macroinvertebrates (e.g., Plecoptera [stonefly] nymphs) that are not specifically addressed in the study requests or other studies. For these reasons, this study’s evaluation of coarse-grained habitat for aquatic invertebrates focused on the general availability and characteristics (e.g., grain size and embeddedness) of coarse-grained substrate for use by benthic macroinvertebrates within the study area. Evaluation of habitat suitability for benthic macroinvertebrates used the substrate habitat suitability criteria (HSC) provided in the draft Study 9 (Instream Flow Study) HSC Selection Report (dated

December 15, 2014). The macroinvertebrate substrate HSC define increased suitability for coarse-grained substrates relative to finer-grained substrates, including cobble substrate representing optimal conditions as defined by a suitability index of 1.0.

Fish Species

Selection of resident riverine and anadromous fish species for consideration in this study was based on review of habitat-specific needs relative to coarse-grained substrate using information presented in other studies. Evaluated fish species (and the associated study) included:

- American Shad (*Alosa sapidissima*), (Study 21);
- American Eel (*Anguilla rostrat*e), (Study 11);
- Fallfish (*Semotilus corporalis*), (Study 15);
- Walleye (*Sander vitreus*), (Study 15);
- White Sucker (*Catostomus commersonii*), (Study 15);
- Smallmouth Bass (*Micropterus dolomieu*), (Study 15);
- Tessellated Darter (*Etheostoma olmstedi*), (Study 12); and
- Sea Lamprey (*Petromyzon marinus*), (Study 16).

Coarse-grained substrate dependence of these species was evaluated based on review of information in the above-referenced study plans and the Study 9 draft HSC. Dependency on coarse-grained substrates was identified for this study if substrate suitability indices greater than 0.5 were limited to gravel, cobble, or boulder material based on the habitat suitability criteria presented in Appendix A of the Study 9 HSC Selection Report.

Dependence on coarse-grained substrate was identified for Fallfish, Walleye, White Sucker, and Smallmouth Bass. The life-stage-specific dependence of these fish species on coarse-grained substrates is described in Study 15 based on suitable spawning habitat, and the Study 9 HSC Selection Report provides life-stage-specific HSC for these species. Consistent with Study 15, these four species are assigned into the following two “species groups”, for evaluation of coarse-substrate-dependent habitat needs:

- Early-Spring Riffle Spawners (Walleyes and White Suckers); and
- Late-Spring Island/Bar Spawners (Smallmouth Bass and Fallfish).

Dependence on coarse-grained substrate was also identified for Sea Lamprey based on the Study 9 HSC Selection Report. Dependence on coarse-grained substrate was not identified for American Shad, American Eel, or Tessellated Darter; therefore, this study does not evaluate habitat availability for these species.

5.0 RESULTS AND DISCUSSION

The following sections summarize the distribution and extent of coarse-grained substrate at the study sites; evaluate potential sediment sources, including erosion of streambanks in the study area and sediment supply from tributaries; assess the stability of coarse-grained substrates in the study area; and evaluate the availability and stability of habitat for coarse-grained substrate-dependent aquatic invertebrates and anadromous and resident fish.

5.1 Distribution and Extent of Existing Coarse-Grained Substrates

The primary reference for information on distribution and extent of coarse-grained substrates is Study 7, which documented the presence of coarse-grained substrates in much of the riverine sections of the Connecticut River in the study area. The Study 7 report indicated that in the riverine reach downstream from Wilder dam, the dominant substrate trends from cobble to gravel, moving downstream. Dominant substrates in the riverine reach downstream from Bellows Falls dam were also identified to trend generally from cobble to gravel. Similarly, dominant substrates in the riverine reach below Vernon dam (i.e., between Vernon dam and the downstream end of Stebbins Island) generally trend from cobble to gravel, with localized areas dominated by sand identified in pools. Data from Study 7 that addressed coarse-grained substrate are presented in Appendix A of the Study 7 Final Study Report dated March 2, 2015.

5.2 Substrate Gradation at Study Sites

Pebble count data obtained as part of this study's field work corroborate the general findings of dominant substrate types presented in Study 7, documenting the presence of coarse-grained substrates at eleven of the twelve mainstem sites and five of the six tributary sites distributed throughout riverine reaches within the study area.

Pebble count data collected along each transect provided information on the grain size of substrate including the distribution (gradation) of substrate sizes. This information was used to characterize the presence and composition of coarse-grained substrates and indirectly to characterize benthic habitat and stability of coarse-grained substrates using information obtained as part of other studies.

Pebble count measurements were collected using the simplified Wentworth scale described in Section 4.2.3. Use of this scale provides for ready comparison of the pebble count data based on general classes (i.e., sand, gravel, cobble, boulder) and refinement within classes (e.g., "very fine gravel"). This approach provides for qualitative description of the pebble count data (e.g., "medium gravel") in lieu of quantitative descriptions (e.g., 15 mm).

Table 5.1 presents median particle classes based on the pebble count data at the mainstem sites. It is apparent in this table that coarse gravel is the dominant median substrate size at mainstem sites between Wilder dam and Bellows Falls dam, and that very coarse gravel is the dominant median substrate size at mainstem sites downstream from Bellows Falls dam. Two mainstem sites had markedly different substrate characteristics, however. The median substrate size at Site 08-M01, which is immediately downstream from Wilder dam, was cobble-sized material along with numerous boulders. Substrate at this site appears to be stable and may be comprised of rock that was excavated and/or placed as part of dam construction. The median substrate size at Site 08-M15, which is along the New Hampshire side of the Connecticut River downstream from Bellows Falls dam and upstream from the first tributary (Saxtons River) is sand.

Table 5.1. Median particle class for mainstem study sites.

Study Site ID	Transect 1		Transect 2		Transect 3	
	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
08-M01	Small Cobble	Large Cobble	-	-	-	-
08-M04	Coarse Gravel	Coarse Gravel	Coarse Gravel	Very Coarse Gravel	-	-
08-M05	Medium Gravel	Fine Gravel	Coarse Gravel	Coarse Gravel	Coarse Gravel	Very Coarse Gravel
08-M07	Coarse Gravel	Medium Gravel	Medium Gravel	Coarse Gravel	-	-
08-M08	Coarse Gravel	Coarse Gravel	Coarse Gravel	Coarse Gravel	Coarse Gravel	Coarse Gravel
08-M10	Coarse Gravel	Coarse Gravel	Coarse Gravel	Coarse Gravel	-	-
08-M12	Coarse Gravel	Coarse Gravel	Coarse Gravel	Medium Gravel	Coarse Gravel	Coarse Gravel
08-M13	Coarse Gravel	Coarse Gravel	Coarse Gravel	Coarse Gravel	-	-
08-M15	Sand	Sand	-	-	-	-
08-M16	Very Coarse Gravel	Very Coarse Gravel	Very Coarse Gravel	Very Coarse Gravel	-	-
08-M17	Coarse Gravel	Very Coarse Gravel	-	-	-	-
08-M20	Very Coarse Gravel	Very Coarse Gravel	Very Coarse Gravel	Very Coarse Gravel	Coarse Gravel	Coarse Gravel

Table 5.2 presents median particle classes based on the pebble count data at the tributary study sites. The median substrate size at these sites varied from silt/clay (Site 08-T01, Ompompanoosuc River) to very coarse gravel (Site 08-T16, Cold River). The variability of sediment sizes observed at the tributary sites may be due to multiple factors, including watershed size, topography and surficial geology; anthropogenic influences in the watersheds; and recent storm events. Examples of anthropogenic influences include the presence of the project impoundment and the

Union Village Dam Flood Risk Management Project on the Ompompanoosuc River in Thetford, Vermont upstream from Site 08-T01.

Table 5.2. Median particle class for tributary study sites.

Study Site ID	Transect 1		Transect 2		Transect 3	
	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
08-T01	Silt/Clay	Silt/Clay	Very Fine Gravel	Sand	Sand	Sand
08-T02	Medium Gravel	Coarse Gravel	Silt/Clay	Medium Gravel	Medium Gravel	Coarse Gravel
08-T04	Sand	Sand	Very Fine Gravel	Fine Gravel	-	-
08-T12	Coarse Gravel	Coarse Gravel	Very Coarse Gravel	Coarse Gravel	-	-
08-T14	Small Cobble	Small Cobble	Very Coarse Gravel	Small Cobble	Medium Gravel	Coarse Gravel
08-T16	Very Coarse Gravel	Very Coarse Gravel	Very Coarse Gravel	Very Coarse Gravel	Medium Gravel	Sand

Figure 5.1 presents a histogram of the median particle sizes that are presented in Table 5.1 and Table 5.2. The median-diameter particle sizes in Figure 5.1 indicate similarity of particle sizes at sites between the Wilder and Bellows Falls dams, and between the Bellows Falls and Vernon dams. It is apparent from the figure that the median particle size is larger at sites downstream of the Bellows Falls dam relative to the sites upstream of the dam. Apparent causes of the larger size material downstream of the Bellows Falls dam are the input of sediment from the Saxtons and Cold rivers. The median particle size downstream of Vernon dam is similar to the median particle size at sites downstream of Bellows Falls.

Observed conditions and information obtained at the study sites suggest that sediment delivery from tributary streams varies, and that effects on the distribution of coarse-grained substrates in the adjacent reach of the Connecticut River are similarly variable. Information obtained at sites 08-T14 (Saxtons River) and 08-T16 (Cold River) indicated that the median particle size classes at these sites are similar to those at downstream mainstem sites (08-M16, 08-M17), whereas information obtained at sites 08-T02 (White River) and 08-T04 (Mascoma River) indicated that the median particle size class is smaller than the downstream mainstem sites (08-M04, 08-M05, 08-M07, 08-M08, 08-M10, 08-M12, and 08-M13) that are upstream of Bellows Falls. The differences between observed conditions at these sites indicate variability in the contribution of sediment from tributaries in the study area.

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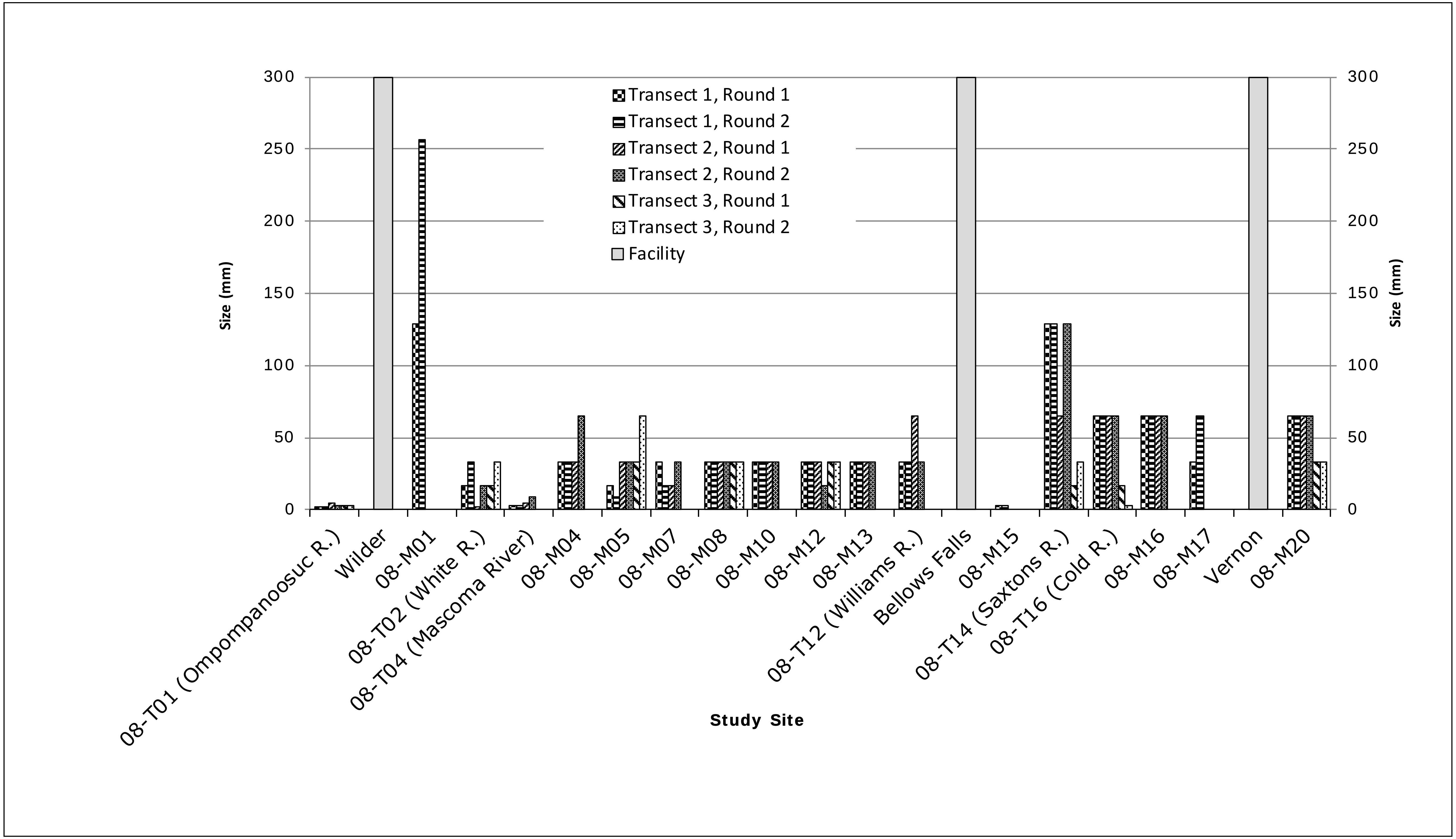

Note: The study sites and locations of the three project dams are presented from upstream to downstream.

Figure 5.1. Median-diameter particle sizes for study sites.

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Observations and analysis of data collected during the summer and fall 2014 site visits indicate little inter-site variability in coarse-grained substrate at the eighteen study sites. Apparent changes along specific sample transects that are apparent in Figure 5.1 are limited to differences between adjacent Wentworth size classes; and such differences between adjacent size classes are not within the resolution of the sampling method.

5.3 Potential Sediment Sources

Observations during site visits indicated that tributaries to the study area are a primary source of coarse-grained substrate. This finding is based on observations of large accumulations of coarse-grained substrate adjacent to the confluences of tributaries. Example sites include 08-T14 at the confluence of the Saxtons River and 08-T16 at the confluence of the Cold River. Existing coarse-grained substrate in the Connecticut River observed in the study area is also potentially mobile and redistributed during high-flow conditions.

Information obtained as part of Studies 1 - 3 identifies additional potential sources of sediments in the study area. Information developed as part of Study 1 documented historical records of riverbank erosion for the period examined in the study area. Preliminary information developed as part of Study 2 indicates that fine-grained (sand-sized and smaller) material is the dominant material in riverbanks where erosion was documented and that riverbank erosion is not a substantial source of coarse-grained substrate. Based on these preliminary findings, it is inferred that historical riverbank erosion documented in Study 1 was not a likely source of coarse-grained substrate in the study area. Similarly, preliminary information developed as part of Study 3 does not identify riverbank erosion as a significant source of coarse-grained substrate to the study area.

Conversely, preliminary information developed as part of Study 2 indicates that fine-grained material is the dominant material in riverbanks of the Connecticut River within the study area. It is inferred from this information that historical bank erosion evaluated in Study 1 was a source of fine-grained material. Similarly, preliminary information developed as part of Study 3 indicates that ongoing riverbank erosion is currently a source of fine-grained material. Based on information developed as part of Studies 1 – 3, riverbank erosion is an ongoing source of fine-grained material, which can contribute to increased embeddedness of coarse-grained substrates in the study area.

5.4 Embeddedness of Coarse-Grained Substrates at Study Sites

Embeddedness refers to the extent to which coarse-grained substrates are surrounded by fine-grained sediment, such as silt and sand. Generally, increased embeddedness of coarse-grained substrates reduces the interstitial habitat available to benthic macroinvertebrates and fish for shelter, spawning, and egg incubation. Table 5.3 presents the average embeddedness condition categories at the mainstem sites.

Table 5.3. Average embeddedness condition categories for mainstem study sites.

Study Site ID	Transect 1		Transect 2		Transect 3	
	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
08-M01	Optimal	Optimal	-	-	-	-
08-M04	Optimal	Optimal	Optimal	Suboptimal	-	-
08-M05	Suboptimal	Marginal	Suboptimal	Marginal	Suboptimal	Suboptimal
08-M07	Marginal	Poor	Marginal	Marginal	-	-
08-M08	Suboptimal	Marginal	Optimal	Suboptimal	Optimal	Suboptimal
08-M10	Suboptimal	Suboptimal	Suboptimal	Suboptimal	-	-
08-M12	Suboptimal	Suboptimal	Marginal	Marginal	Marginal	Marginal
08-M13	Suboptimal	Suboptimal	Suboptimal	Suboptimal	-	-
08-M15	N/A[a]	N/A	-	-	-	-
08-M16	Optimal	Suboptimal	Suboptimal	Marginal	-	-
08-M17	Suboptimal	Suboptimal	-	-	-	-
08-M20	Suboptimal	Suboptimal	Marginal	Marginal	Suboptimal	Optimal

a. Where the condition category is listed as N/A, the dominant substrate was sand or finer and embeddedness was not assessed (see section 4.2.4).

Inter-site spatial variability in embeddedness was apparent in some of the mainstem site transects but consistent trends related to the respective elevations of the transects were not apparent. Embeddedness was not assessed along Transect 1 at tributary Site 08-M15 because substrates along this transect were comprised of sand or finer material.

The embeddedness data indicates a small temporal shift from the summer site visits relative to the fall site visits at the mainstem sites. Reduced embeddedness scores (i.e., increased embeddedness) were observed at nine of the 25 mainstem site transects, whereas improved embeddedness scores (i.e., decreased embeddedness) were observed at one mainstem site transect. Apparent conditions that may have contributed to reductions in embeddedness scores observed during the fall site visit included observed algal mats and accumulations of finer sediment (e.g., sand) and lower flow conditions between the summer and fall 2014 site visits.

Tributary Sites 08-T01 and 08-T04 had consistently “poor” and “marginal” embeddedness condition categories. These embeddedness condition categories are consistent with the dominance of finer-grained substrates observed at these sites as noted in Table 5.2 . Embeddedness was not assessed along Transect 1 at tributary Site 08-T01 because substrates along this transect were comprised of sand or finer material. Table 5.4 presents the average embeddedness condition categories at each of the six tributary sites.

Table 5.4. Average embeddedness condition categories for tributary study sites.

Study Site ID	Transect 1		Transect 2		Transect 3	
	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
08-T01	N/A[a]	N/A	Poor	Poor	Poor	Poor
08-T02	Optimal	Suboptimal	Marginal	Marginal	Suboptimal	Suboptimal
08-T04	Poor	Poor	Poor	Marginal	-	-
08-T12	Marginal	Suboptimal	Optimal	Suboptimal	-	-
08-T14	Optimal	Optimal	Suboptimal	Suboptimal	Suboptimal	Suboptimal
08-T16	Optimal	Optimal	Optimal	Suboptimal	Suboptimal	Marginal

a. Where the condition category is listed as N/A, the dominant substrate was sand or finer and embeddedness was not assessed (see section 4.2.4).

Inter-site spatial variability in embeddedness was apparent in four of the six tributary sites (08-T02, 08-T12, 08-T14, and 08-T16) with transects located at lower elevations having higher embeddedness scores (i.e., decreased embeddedness). At sites with multiple transects embeddedness scores were generally lower (i.e., embeddedness increased) at the higher-elevation transects.

At the tributary sites, the embeddedness data indicated small temporal shifts from the summer site visits to the fall site visits. Reduced embeddedness scores (i.e., increased embeddedness) were observed at four of the 16 tributary site transects, and increased embeddedness scores (i.e., reduced embeddedness) were observed at two tributary site transects. Apparent conditions that may have contributed to reductions in embeddedness condition at tributary site transects during the fall site visit included accumulation of finer sediment (e.g., sand) during lower-flow conditions between the summer and fall 2014 site visits. Figure 5.2 presents a histogram of embeddedness scores. A consistent trend of spatial variability in embeddedness at the sites is not apparent.

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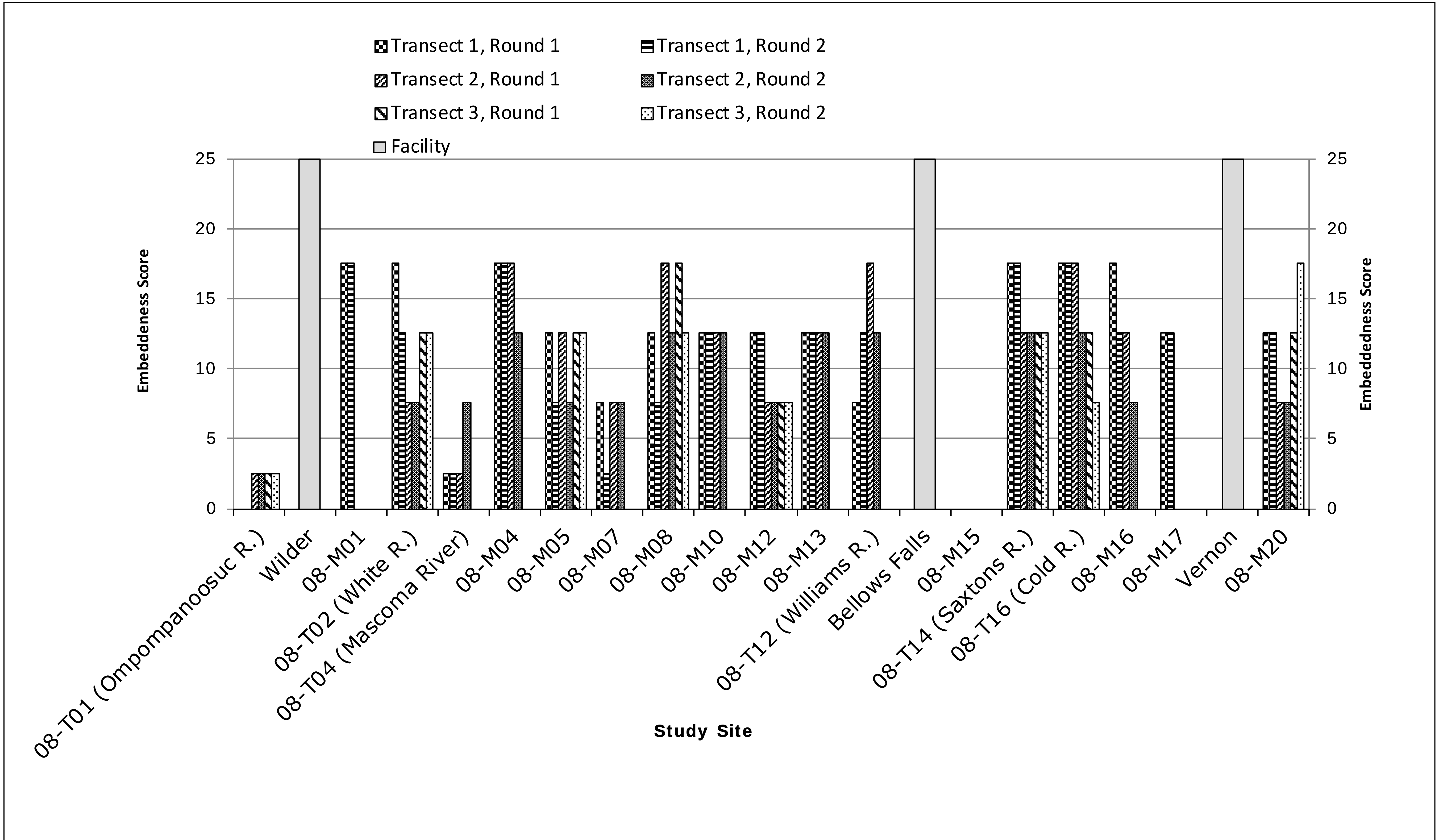

Note: The study sites and locations of the three project dams are presented from upstream to downstream.

Figure 5.2. Embeddedness scores for study sites.

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5.5 Stability of Coarse-Grained Substrates

Stability of coarse-grained substrates was evaluated using information obtained from Study 4 as described in Section 4.5.2. Stability of substrates at the mainstem sites and the four tributary sites included in the model-based analysis was evaluated by comparing the critical shear stress for the median particle size at each transect with shear stress information from the selected Study 4 hydraulic model cross section. These comparisons are presented in graphical presentations depicting flow, shear stress, and water surface elevation (WSE) in Appendix E**.**

Figure 5.3 is a sample presentation of this information for Site 08-M07. The primary (left) vertical axis has flow as the primary independent axis and corresponding WSEs as a dependent variable on the secondary (right) vertical axis. Shear stress is provided in the primary (bottom) horizontal axis, and calculated values of shear stress are represented by the blue line on this figure. The secondary (top) horizontal axis corresponds to the critical shear stress for incipient motion (mobilization) for each of the particle size classes. Note that the maximum depicted particle class is “Very Coarse Gravel”, as the shear stress values obtained from the HEC-RAS model did not exceed the critical shear stress for larger material. The median particle size at each transect is represented by red vertical lines (labeled by transect) and the applicable project’s MGF is represented by the green horizontal line.

Information presented in Figure 5.3 includes the median particle sizes at the two sample transects during both rounds of sampling (red vertical lines). The median substrate at Transect 1 is coarse gravel during the first round of sampling (“T1R1”) and medium gravel during the second round of sampling (“T1R2”). Similar information is presented for Transect 2.

Comparison of the transect data with the shear stress curve in Figure 5.3 indicates that the critical shear stress for medium gravel (the median particle size for T1R2 and T2R1) occurs at a flow of approximately 40,000 cfs, which is almost four times greater than the MGF (10,700 cfs) in this study area.

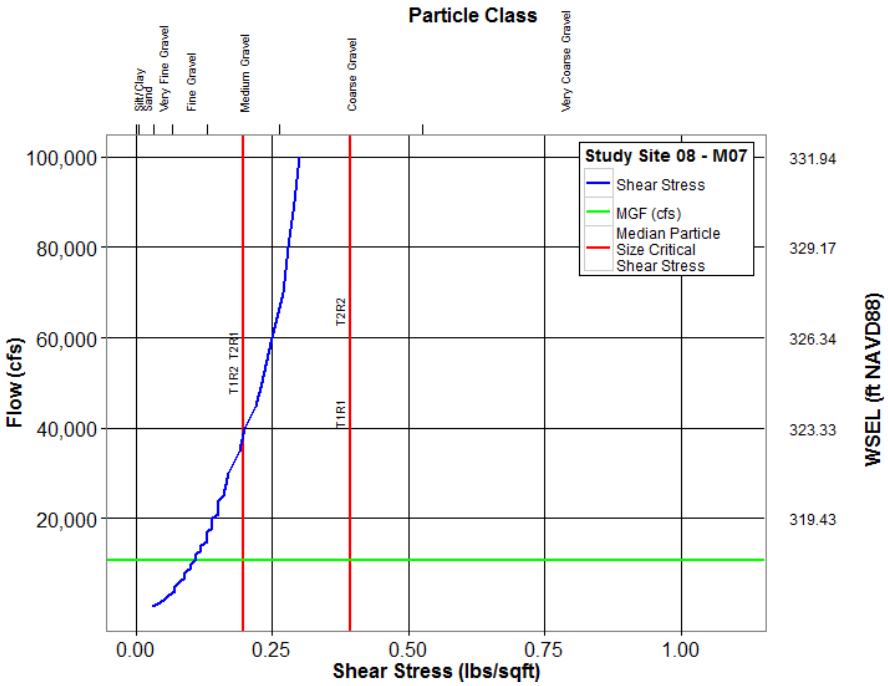

Figure 5.3. Sample shear stress plot (Site 08-M07).

Information obtained from Study 4 and evaluations conducted as part of this study indicate that shear stresses up to the MGFs are less than the critical shear stress for coarse-grained substrates at most of the mainstem sites.

5.5.1 Stability of Coarse-Grained Substrates at Mainstem Study Sites

Comparison of shear stress data obtained from Study 4 with critical shear stresses for median particle sizes at mainstem sites indicates that coarse-grained substrates are stable at flows less than the MGF for all transects and both study rounds at ten of the twelve mainstem sites (08-M01[1], 08-M07, 08-M08, 08-M10, 08-M12, 08-M13, 08-M15, 08-M16, 08-M17, and 08-M20; Appendix E).

[1] Note that the plot in Appendix E for Site 08-M01 does not depict the single transect and two study rounds at this site. The relatively large size of the median substrate at this site (small cobble and large cobble during the sample rounds 1 and 2, respectively) result in a large critical shear stress that is greater than the maximum scale presented on the data analysis figures.

Evaluation of shear stress data for Site 08-M04 (Figure 5.4) indicates that the maximum shear stress occurs at a flow of approximately 6,000 cfs, which is less than the MGF of 10,700 cfs at this location. This shear stress exceeds the critical shear stress for the median substrate sizes (coarse gravel and very coarse gravel) identified during field surveys at this site. The flow-shear stress data (curve) at this location is not single-valued (i.e., a vertical line may intersect the curve at more than one point [non-monotonic]). It is expected that the complex geometry at this site, including an island that divides the river into two channels, contributes to the non-monotonic flow-shear stress curve at this location. Shear stress data for Site 08-M05 is also not single-valued, but not as strongly as the data for Site 08-M04.

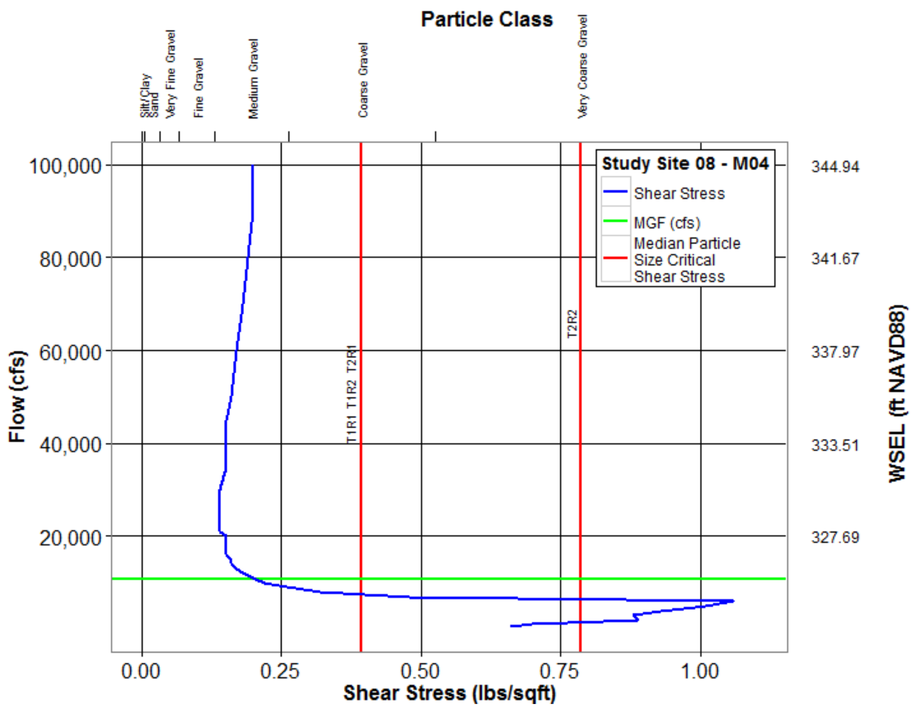

Figure 5.4. Sample shear stress plot (Site 08-M04).

Evaluation of shear stress data for Site 08-M05 indicates that the median substrate at Transect 1 (identified as medium gravel and fine gravel based on the results of the Round 1 and 2 sampling, respectively) are potentially mobile at flows less than or equal to the MGF. Median substrates at the two other transects at this mainstem site are stable based on comparison of the critical shear stress with the shear stress information obtained from Study 4.

Shear stress data indicates that substrate at site 08-M15 is stable at the MGF of 11,400 cfs at this location; however, observations during the site visits suggest that the median substrate at this site (sand) is apparently mobile at flows less than the MGF. This site is a side bar located along the New Hampshire side of the river adjacent to an eroding shoreline that is largely comprised of sand-sized and smaller material, and an upstream-flowing (back) eddy was observed at this site during the site visits. Observed conditions at Site 08-M15 suggest that flow speeds and associated shear stress in this back eddy may be sufficient to mobilize sediment.

5.5.2 Stability of Coarse-Grained Substrates at Tributary Study Sites

Information obtained from Study 4 was used for evaluation of substrate stability at four of the six tributary sites (08-T02, 08-T04, 08-T14, and 08-T16).

Site 08-T02 is a mid-channel bar in the White River at its confluence with the Connecticut River. Comparison of the Study 4 shear stress data with critical shear stress indicates that substrate is stable at flows less than the MGF of 10,700 cfs at this location with the exception of the median particle size (silt/clay) that was identified along Transect 2 during the Round 1 sampling event. Shear stress data from the Study 4 model is not expected to be a good predictor of substrate stability at this tributary site; based on the location of this site, it is expected that the flows in the White River are the dominant factor that affects substrate stability at this site.

Site 08-T04 is a mid-channel bar in the Mascoma River approximately 1,000 ft upstream from the confluence of the Mascoma River with the Connecticut River. Similar to Site 08-T02, shear stress data from the Study 4 model is not expected to be a good predictor of substrate stability at this tributary site. Comparison of the Study 4 shear stress data with critical shear stress at both transects for both sampling rounds indicates that substrate is susceptible to remobilization at flows less than or approximately equal to the MGF of 10,700 cfs at this location. Based on the location of this site upstream from the confluence of the Mascoma River with the Connecticut River, it is expected that the flows in the Mascoma River are the primary factor that affects substrate stability at this site.

Site 08-T14 is a delta bar in the Connecticut River at the confluence of the Saxtons River. Based on its location, shear stress data from the Study 4 model is expected to be a good predictor of substrate stability at this site. Comparison of the Study 4 shear stress data with critical shear stress indicates that the median substrate size at Transects 1 and 2 is stable for both study sampling rounds and that the median substrate size identified at Transect 3 during the Round 2 sampling is stable. Comparison of the Study 4 shear stress data with critical shear stress indicates that the median substrate size (medium gravel) at Transect 3 based on the Round 2 sampling event is susceptible to remobilization at flows approximately equal to the MGF of 11,400 cfs at this location.

Sites 08-T01 and 08-T12 are located on tributaries to the Wilder and Bellows Falls impoundments, respectively. Both of these sites are located well upstream from the tributaries' respective confluences with the Connecticut River and shear stress data from Study 4 is therefore not available for evaluation of substrate stability at these tributary sites.

5.6 Habitat Availability

Coarse-grained substrates may provide habitat for coarse-grain-substrate dependent biota, including habitat for the two fish species groups described in Section 4.5.4 (Early-Spring Riffle Spawners and Late-Spring Island/Bar Spawners), spawning habitat for Sea Lamprey, and habitat for aquatic macroinvertebrates based on the substrate HSC developed as part of Study 9. This study assessed benthic habitat availability and stability for relevant life-stages of these coarse-grain-substrate dependent biota.

Information developed as part of Study 7 (Aquatic Habitat Mapping) indicated that coarse-grained substrates are generally present throughout the riverine reaches of the study area, including in areas that were not evaluated as part of Study 8. Data collected as a part of Study 8 indicated that coarse-grained habitat was present at the majority of study sites and that gravel and cobble are the median substrate size at eleven mainstem sites and at the two tributary sites that consist of delta bars in the Connecticut River (08-T14 [Saxtons River], and 08-T16 [Cold River]). The two tributary sites with mid-channel bars (08-T02 [White River] and 08-T04 [Mascoma River]) have median substrate sizes that varied in size from silt/clay to coarse gravel. The dominance of finer-grained substrate at these two sites relative to the two tributary sites with delta bars appears to reflect sediment loading characteristics and backwater effects from the adjacent reach of the Connecticut River that influence depositional characteristics.

Information obtained from Study 4, informs this study's evaluation of habitat stability. As described in Section 5.4, evaluations of shear stress data from Study 4 and critical shear stresses for median substrates at the mainstem sites and the two tributary sites on delta bars that are directly affected by mainstem flows in the Connecticut River indicate that most of the coarse-grained substrates at these sites are stable at flows less than the MGF. Information obtained from Studies 1, 2, and 3 indicate that riverbank material in the study area is largely fine-grained material, and therefore indicates that riverbank erosion is not a significant source of coarse-grained substrate. Rates and volumes of riverbank erosion were not available for evaluation as part of this study.

Embeddedness data collected as a part of Study 8 also provides information that can be used to evaluate the availability of habitat associated with coarse-grained sediment. While coarse-grained substrate may be present at a given location, high embeddedness can reduce access to interstitial habitat between coarse-grained substrates. Review of data presented in Figure 5.2 does not indicate a spatial trend in embeddedness in the study area.

Table 5.3 presents embeddedness condition categories identified at each transect for each of the two rounds of data collection conducted at the eleven mainstem sites where embeddedness data was collected. The 48 embeddedness condition categories include 34 condition categories of "optimal" or "suboptimal", 13 condition categories of "marginal", and one condition category of "poor". Based on the dominance of "optimal" and "suboptimal" embeddedness condition categories, the embeddedness conditions identified indicate availability of habitat for coarse-grain-substrate dependent biota along Connecticut River in the study area.

Table 5.4 presents embeddedness condition categories identified at each transect for each of the two rounds of data collection conducted at the tributary sites. The 30 embeddedness condition categories include 18 condition categories of "optimal" or "suboptimal", five condition categories of "marginal", and seven condition categories of "poor". Embeddedness condition categories varied substantially between the tributary sites. Embeddedness at the tributary sites was highly dependent on the location of each site and localized factors that affect deposition of fine- and coarse-grained sediment. Primary identified factors that contribute to embeddedness at the tributary sites are sediment discharge from the tributary waterway and backwater influences from the Connecticut River.

The two tributary sites where the dominant embeddedness condition categories were "poor" or "marginal" are 08-T01 and 08-T04. Site 08-T01 is located on the Ompompanoosuc River in the vicinity of the upstream limit of normal backwater effects from the Wilder impoundment. Observations at this tributary site indicated that it is in a depositional area. Site 08-T04 is located on the Mascoma River upstream from its confluence with the Connecticut River downstream from Wilder dam and from the confluence of the White River with the Connecticut River. The primary identified factors expected to contribute to increased embeddedness at this site are discharge of fine-grained sediment from the Mascoma River and backwater effects from the Connecticut River during high-flow events (i.e., flows that exceed the MGF).

6.0 ASSESSMENT OF PROJECT EFFECTS

The distribution and characteristics of coarse-grained benthic habitat in the study area are related to, and affected by, fluvial processes. This study assessed the potential for Wilder, Bellows Falls, and Vernon operations to affect fluvial processes related to movement of coarse sediment (e.g., gravel and cobble) in the project-affected area as it relates to the availability and stability of coarse-grained benthic habitat. The study area extended from the upstream limit of the Wilder impoundment to approximately 1.5 miles downstream from Vernon dam and included tributaries that discharge to the Connecticut River within the study area.

This study identified the presence of coarse-grained substrates throughout the study area along riverine sections of the Connecticut River and at the confluence of tributaries in the study area. Evaluations of coarse-grained substrate stability using information collected as part of this and other available ILP studies indicate that most of the evaluated coarse-grained substrates are stable at flows less than the applicable project's MGF. This study concludes that flows greater than the projects' MGFs are the dominant factors that contribute to the availability and stability of coarse-grained benthic habitat in the study area.

Availability of habitat for coarse-grain-substrate dependent biota was also evaluated based on embeddedness condition. This study identified embeddedness conditions that indicate habitat for coarse-grain-substrate dependent biota is available along the Connecticut River in the study area. Based on the presence and stability of the identified coarse-grained substrates, these substrates appear to provide persistent habitat for coarse-grain-substrate dependent fauna, including different life-history stages of anadromous and riverine fish, and aquatic invertebrates. Information and evaluations performed as part of this study, and available information and evaluations performed as part of other studies, indicate that project operations do not substantially affect the distribution and extent of coarse-grained benthic habitat in riverine reaches of the study area and in tributaries that are within the project-affected areas.

7.0 LITERATURE CITED

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Julien, P.Y., 1995. *Erosion and Sedimentation.* Cambridge University Press, Cambridge, U.K.

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Wolman, M.G., 1954. A Method of Sampling Coarse River-Bed Material. Transactions of the American Geophysical Union 35(6):951-956.

Wentworth, C.K., 1922. A Scale of Grade and Class Terms for Clastic Sediments. The Journal of Geology 30(5): 377-392.

APPENDIX A

Field Data Form

STUDY 8 DATA FORM

Study Site # ___________

Field Staff: ____ **Date:** ______________

PEBBLE COUNT (Tally By Transect)					
Wentworth Size Class		**Size range** (mm)	**Transect**		
			#: ____	**#: ____**	**#:____**
Silt/Clay	Silt/Clay	<0.062 (By touch)			
Sand	Sand	0.062 - 2.0			
Gravel	Very Fine	2-4			
	Fine	4-8			
	Medium	8-16			
	Coarse	16-32			
	Very Coarse	32-64			
Cobble	Small	64-128			
	Large	128-256			
Boulder	Small	256-512			
	Medium	512-1024			
	Large - Very Large	1024-4096			
Bedrock	Bedrock	-			

NOTES:

STUDY 8 DATA FORM

Study Site # ___________

EMBEDDEDNESS (% by Transect Station and Total Visual Estimate)

Transect Station	Transect			Notes
	#: ____	#: ____	#: ____	
1				
10				
20				
30				
40				
50				
60				
70				
80				
90				
100				
Visual Estimate:				

Instructions: Embeddedness is defined as the fraction of a gravel/cobble/boulder particle surface that is surrounded by sand or finer sediments. Embeddedness is not evaluated for sand and finer particles. Evaluate embeddedness at every 10th pebble count sample point along pebble count transects. At each sample point, evaluate particles in a 10-cm-diameter circle surrounding the sampling point. For each particle evaluated, enter the embeddedness score indicated on the table below.

"Condition Category":	**N/A**	**Poor**	**Marginal**	**Suboptimal**	**Optimal**
Embeddedness Score:	**N/A**	**1-5**	**6-10**	**11-15**	**16-20**
% Embeddedness:	100%	>75%	75-50%	50-25%	25-0%
Description:	Substrate characterized by lack of gravel, cobble, boulder material.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment.

SITE SKETCH & NOTES

Include in sketch: north arrow, major landmarks, study site boundaries, transect / plot locations, and photopoint locations.

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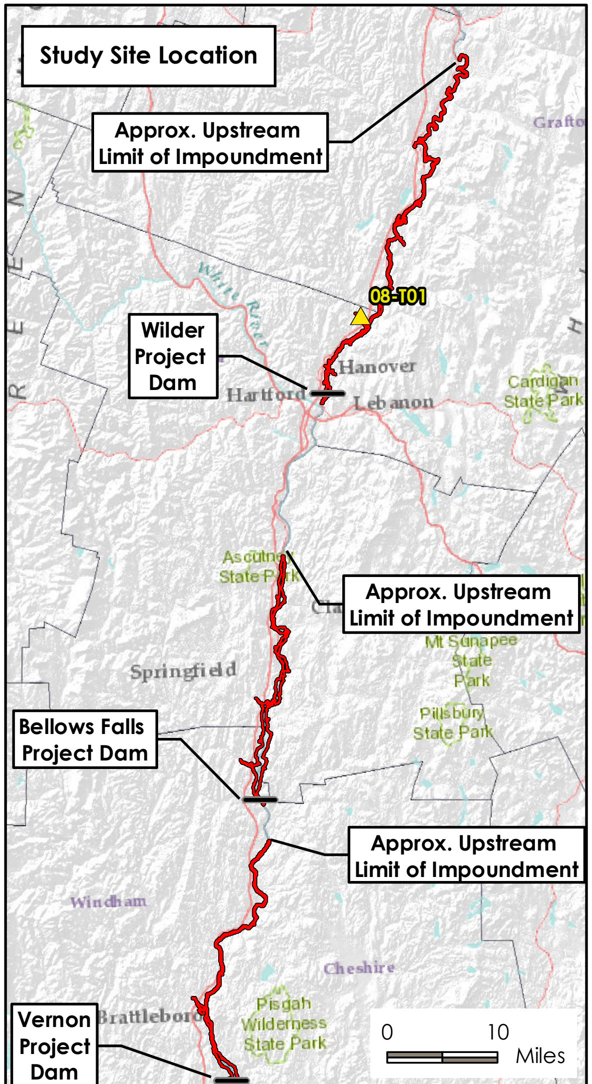
APPENDIX B

Figures



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Phone (207) 729-1199

Legend

- Mainstem Study Site
- Tributary Study Site
- Project Boundary

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Figure No.
B.1

Title
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1/9/2015

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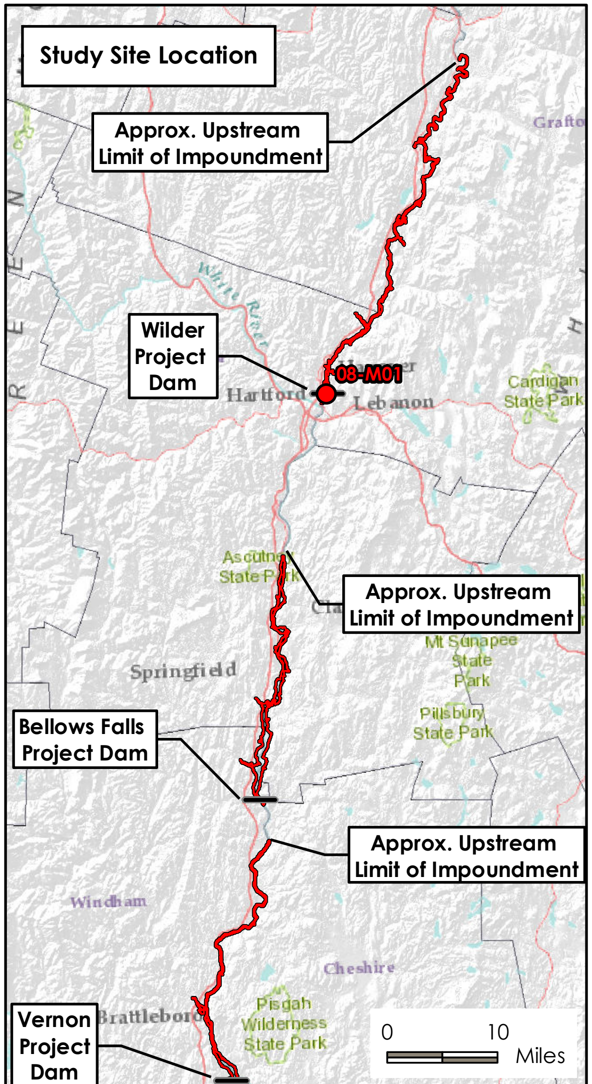

Aerial Photography: U.S. Imaging, Inc (April and May, 2013) and ESRI World Imagery Web Mapping Service (April 2011).

Note: Where sediment deposits are not visible in the vicinity of a depicted Potential Study Site (PSS), this may be due to relatively high water levels during procurement of the aerial photography used here.

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Study Site 08-M01

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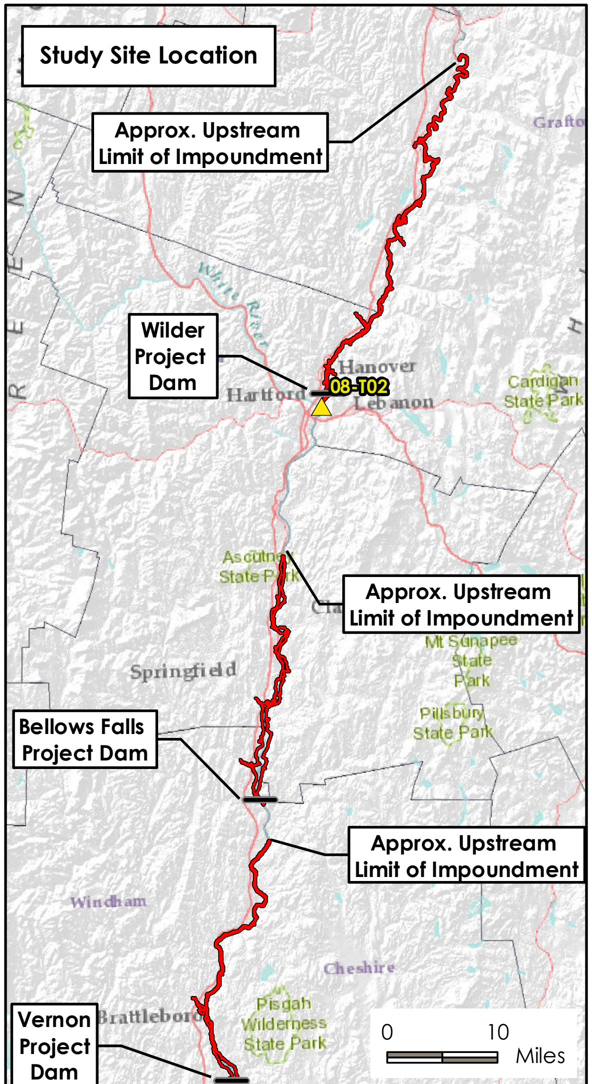

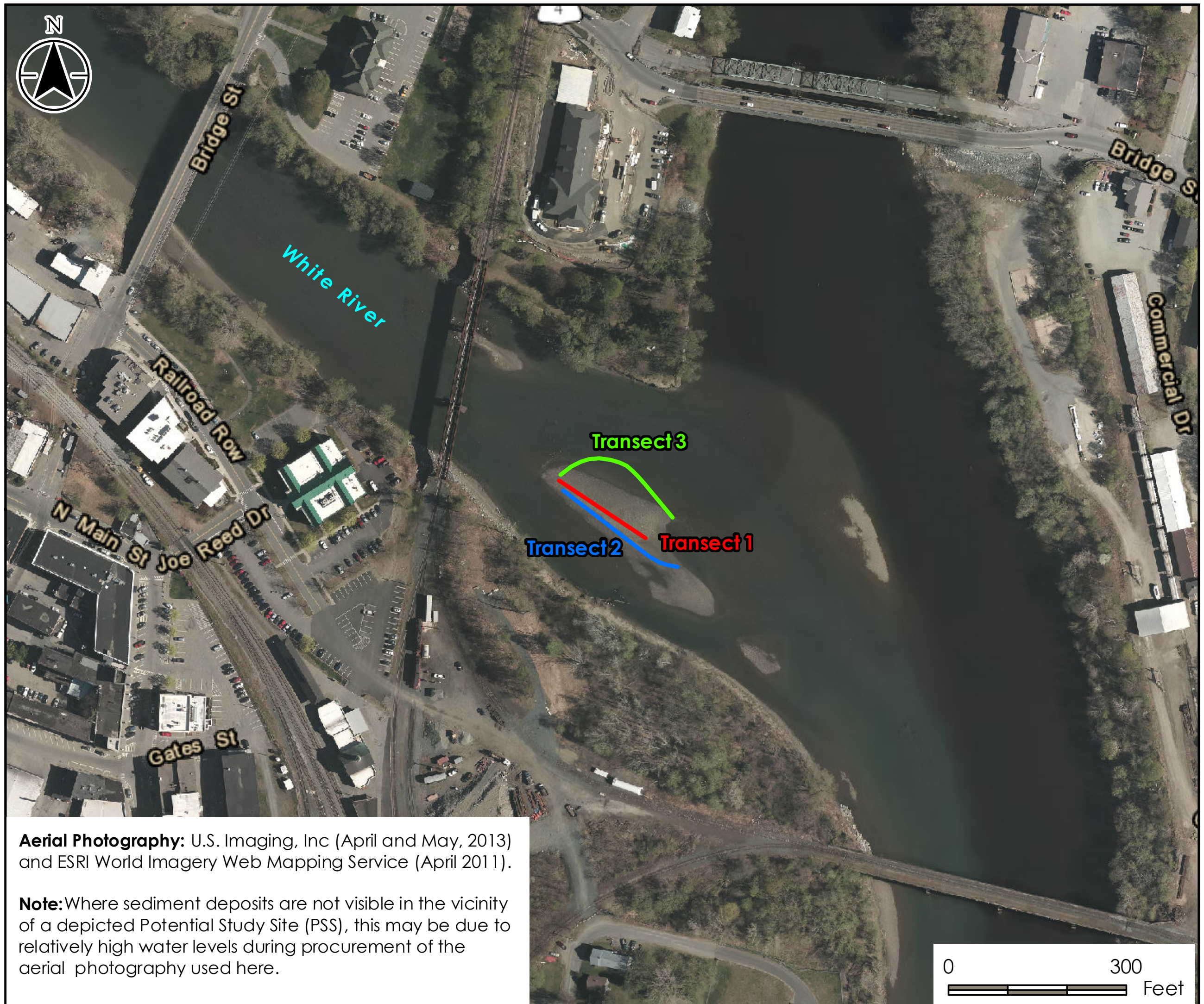

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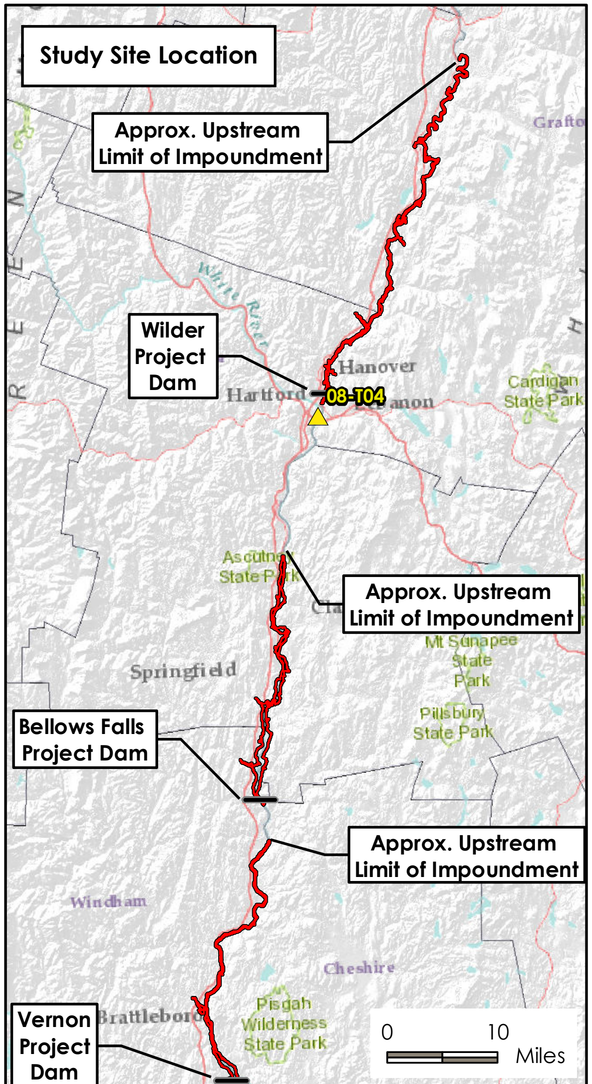

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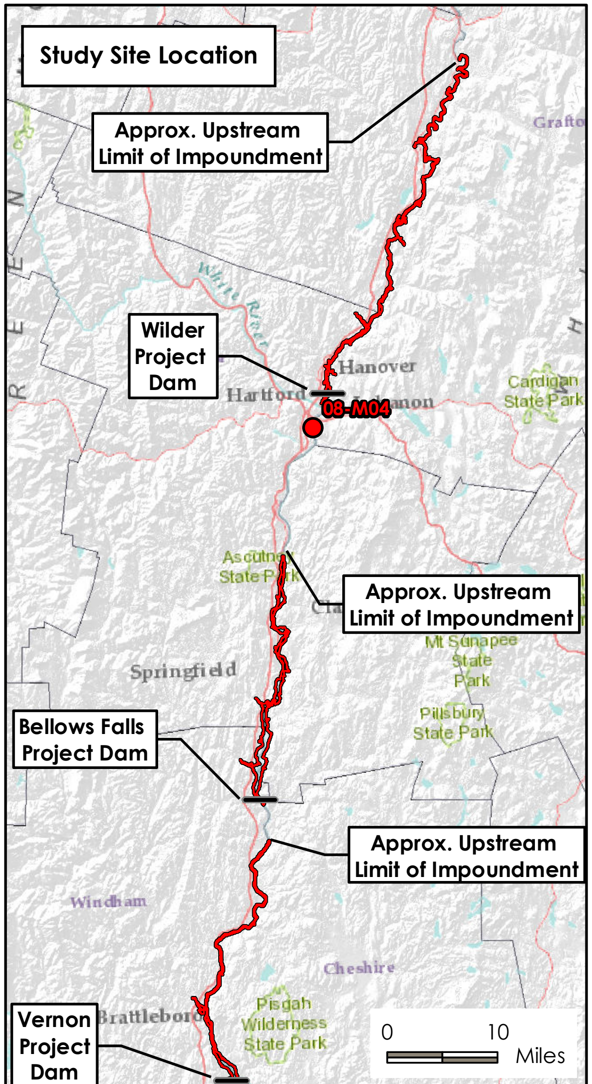

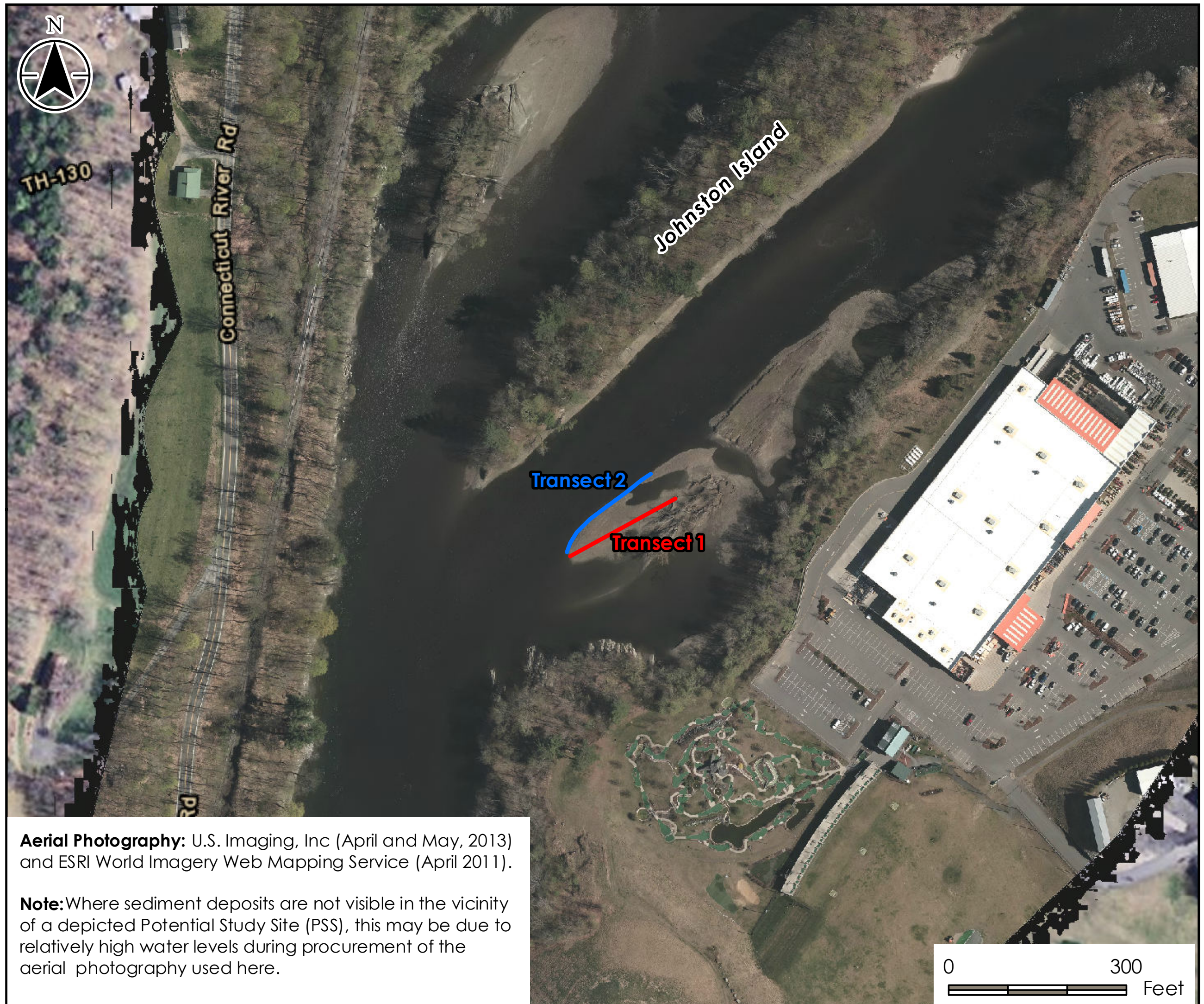

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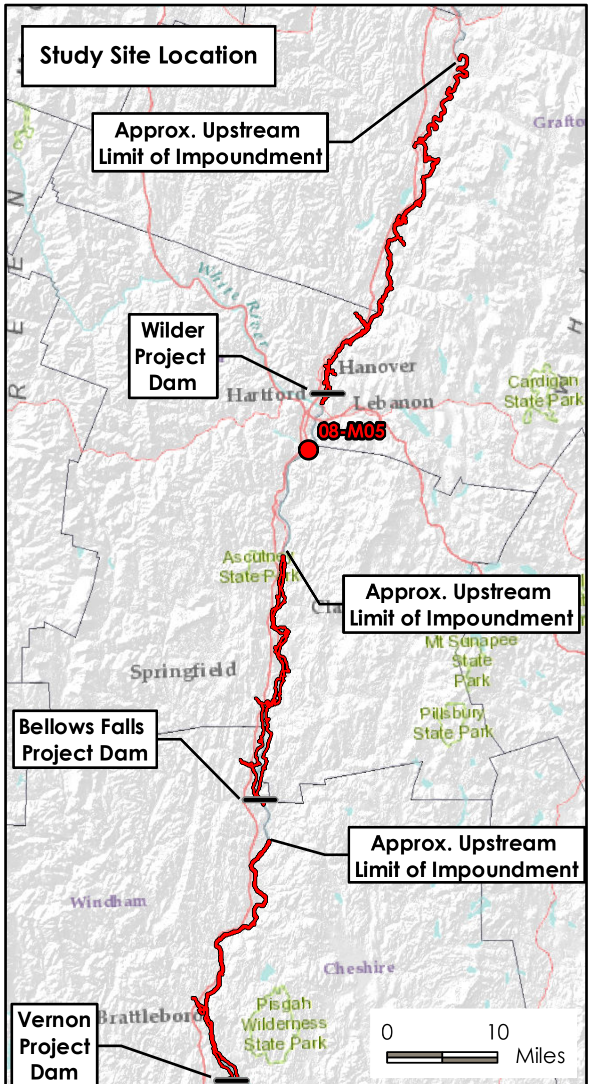

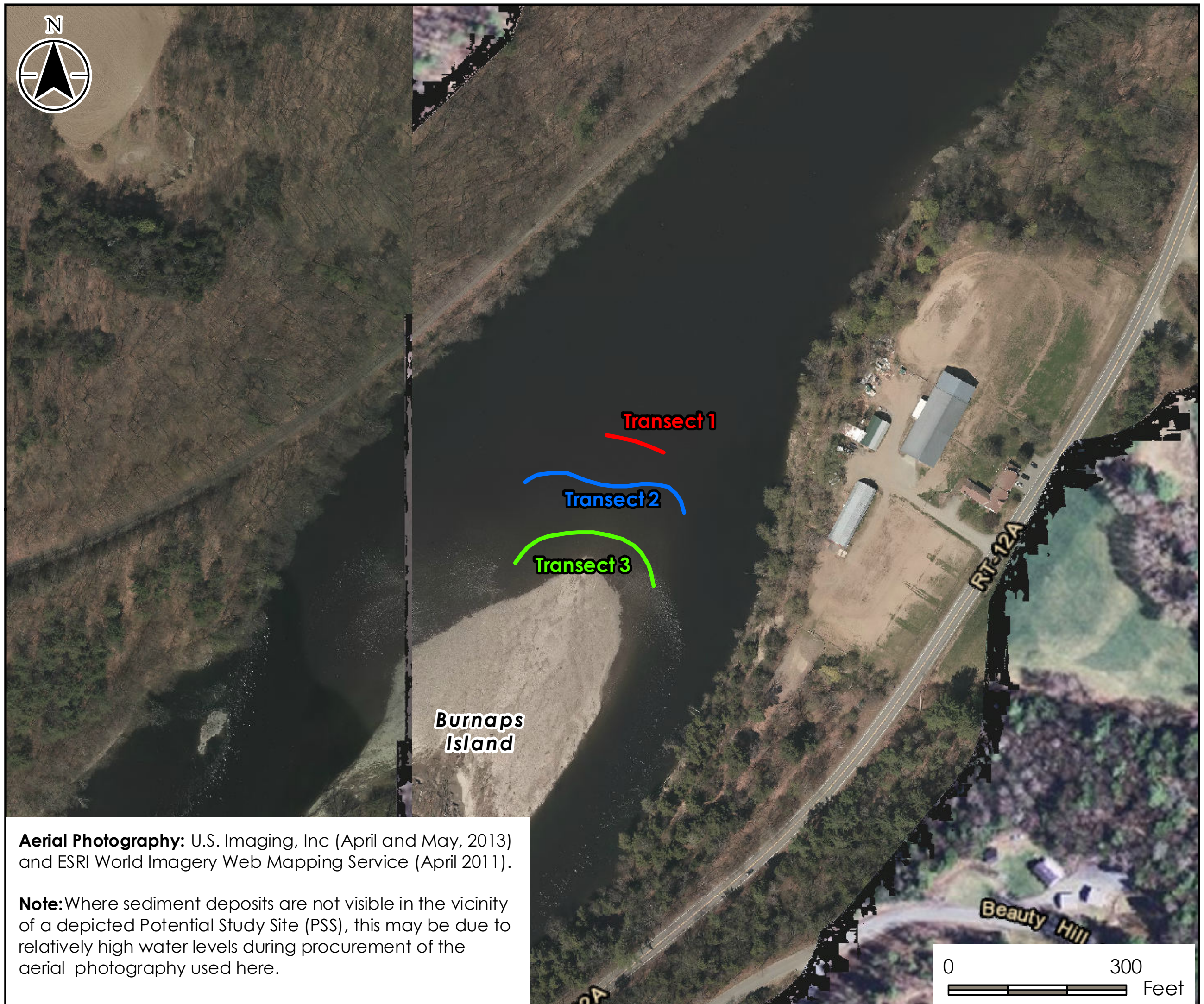

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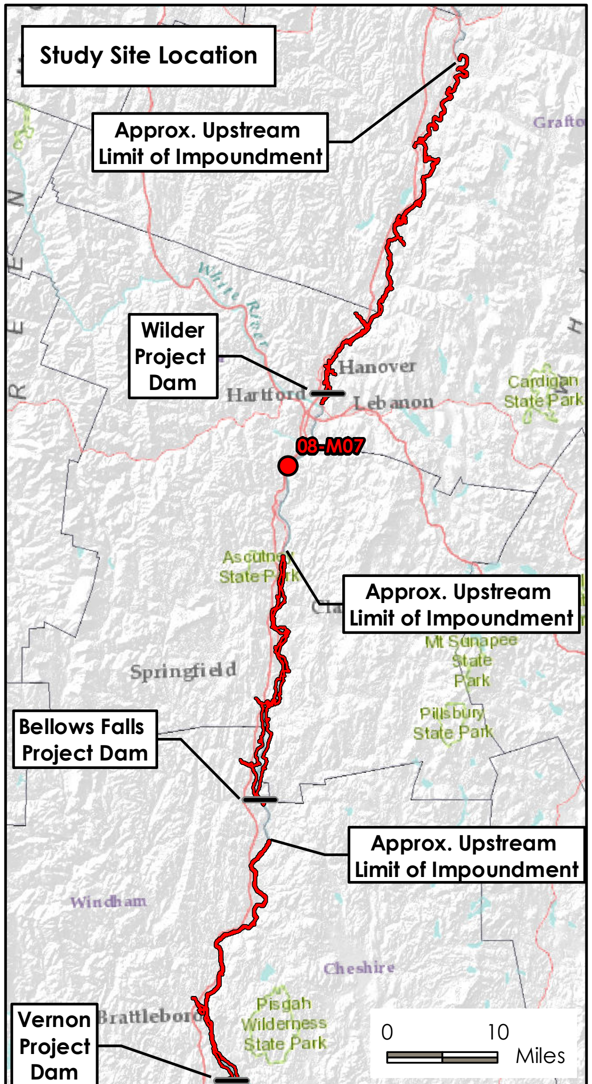

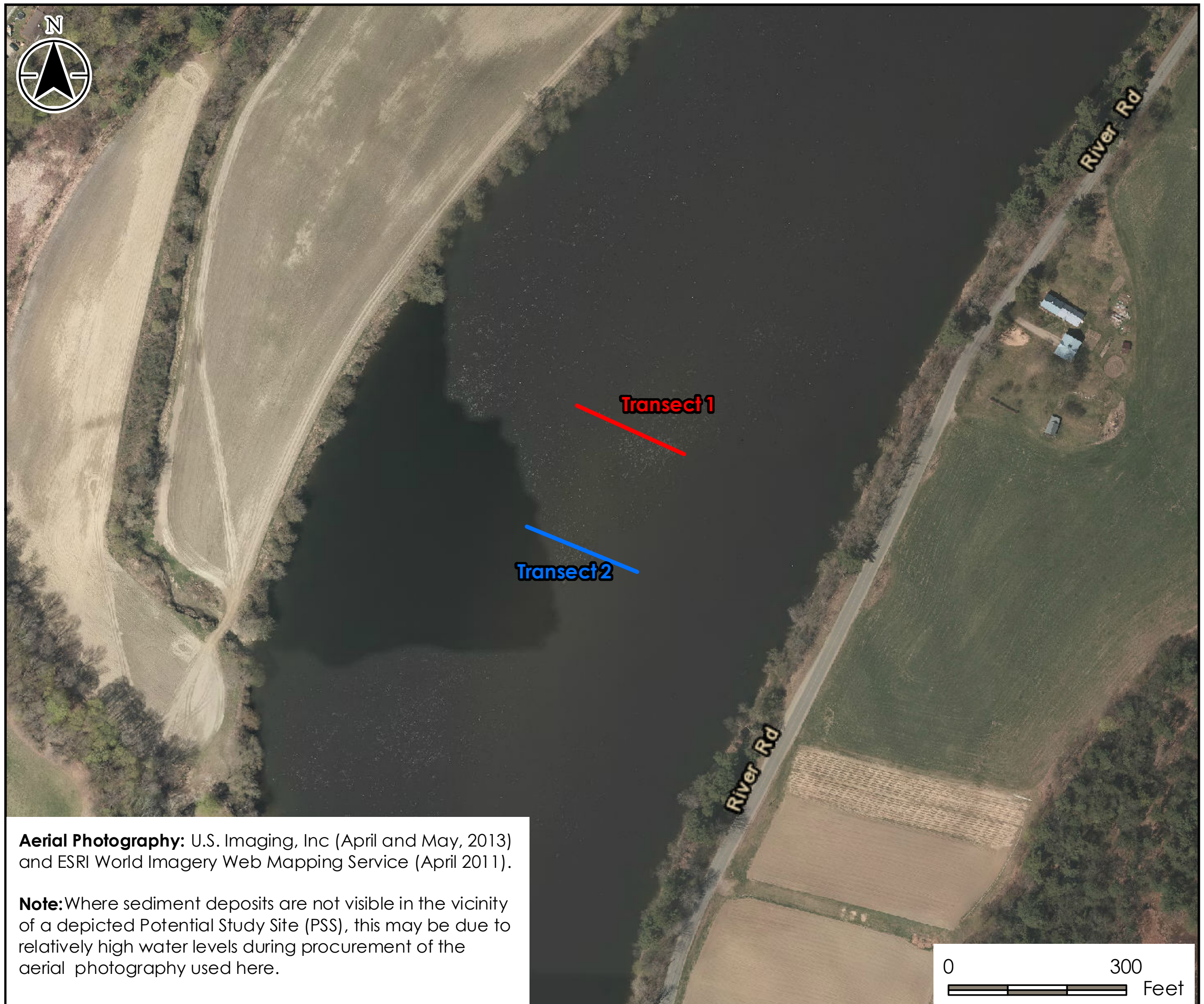

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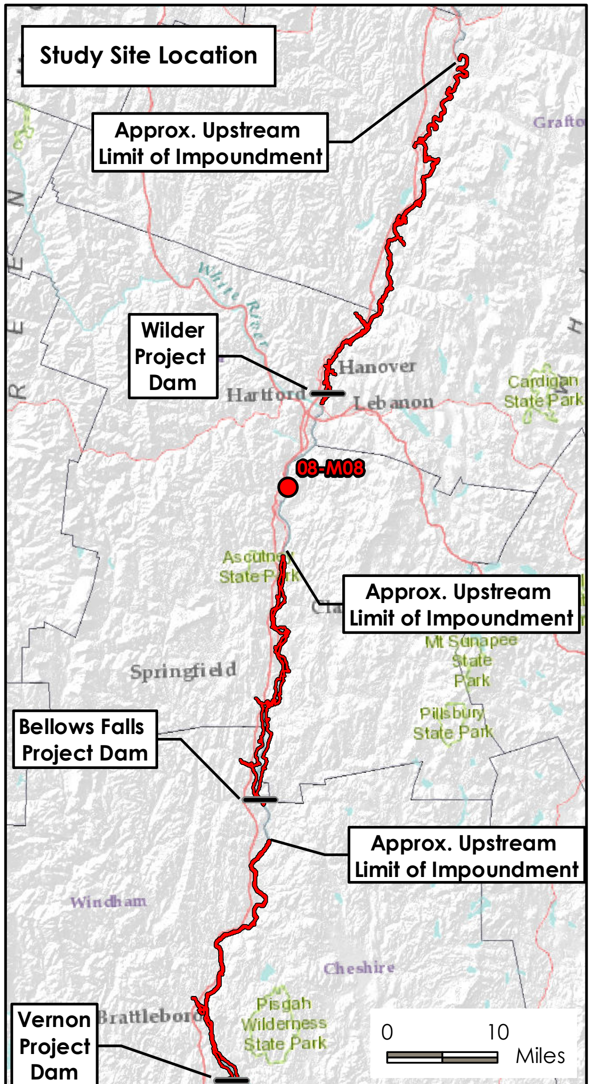

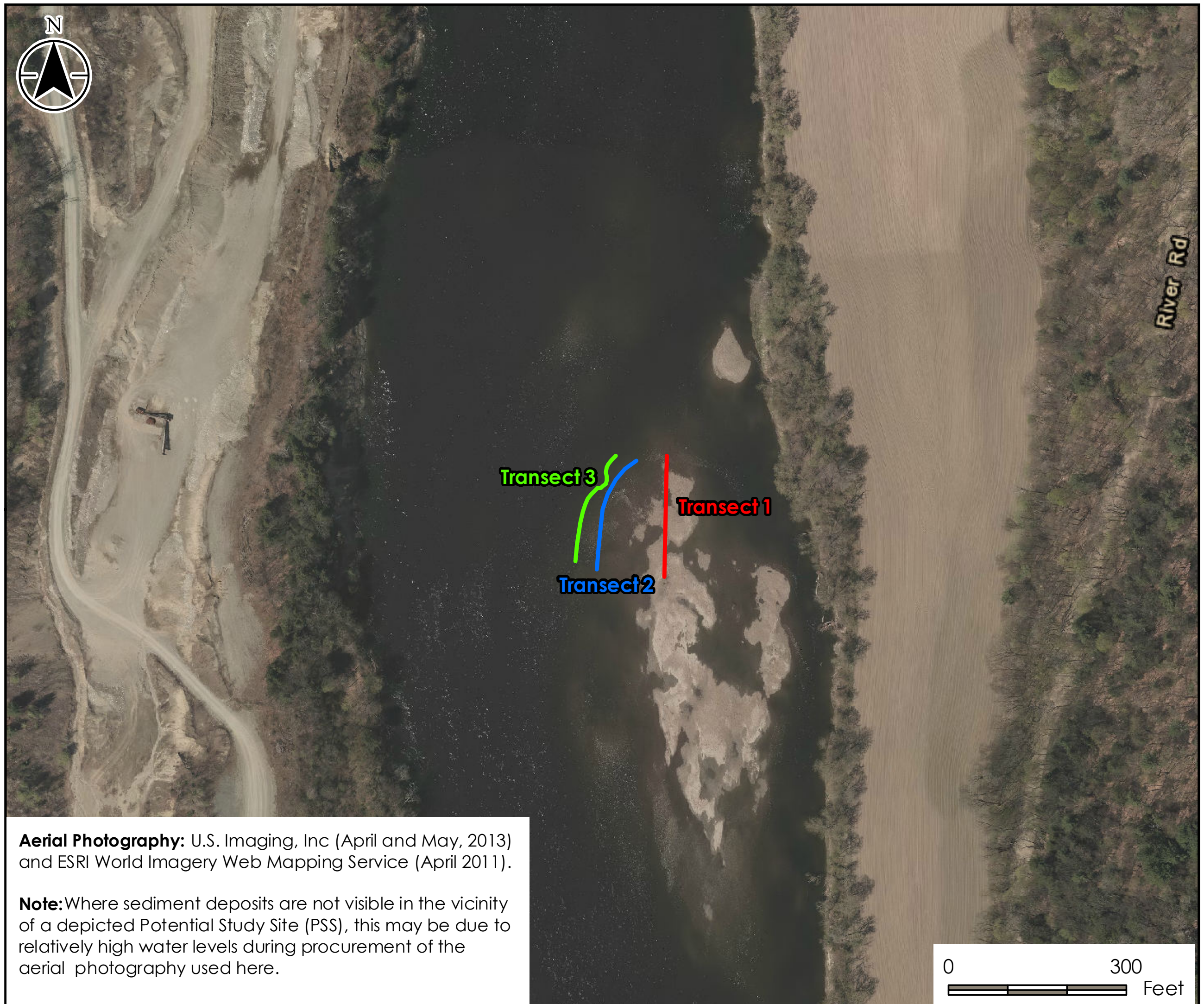

Aerial Photography: U.S. Imaging, Inc (April and May, 2013) and ESRI World Imagery Web Mapping Service (April 2011).

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Study Site 08-M08

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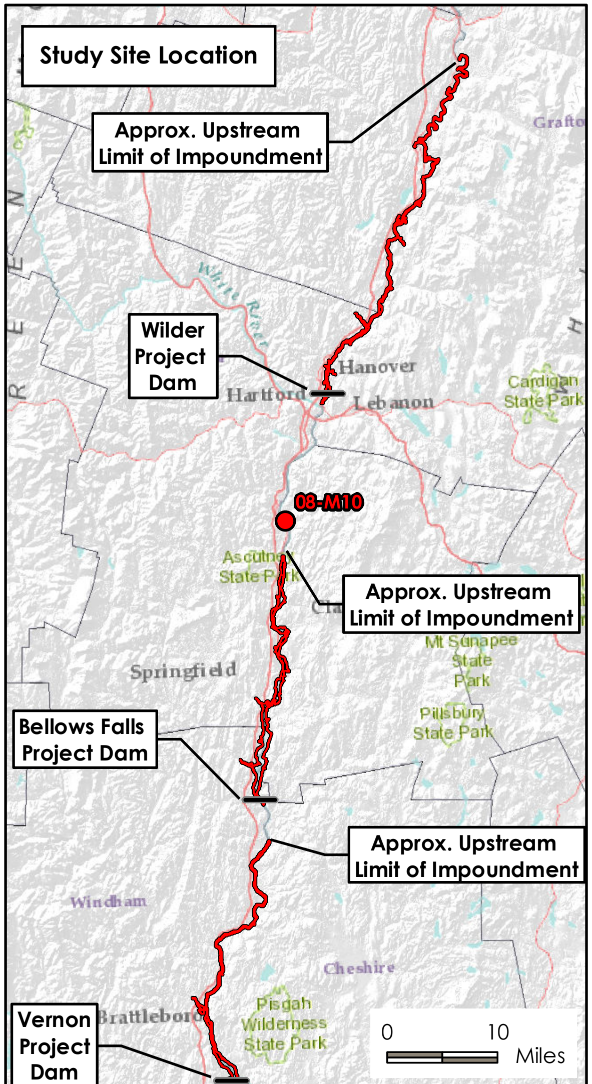

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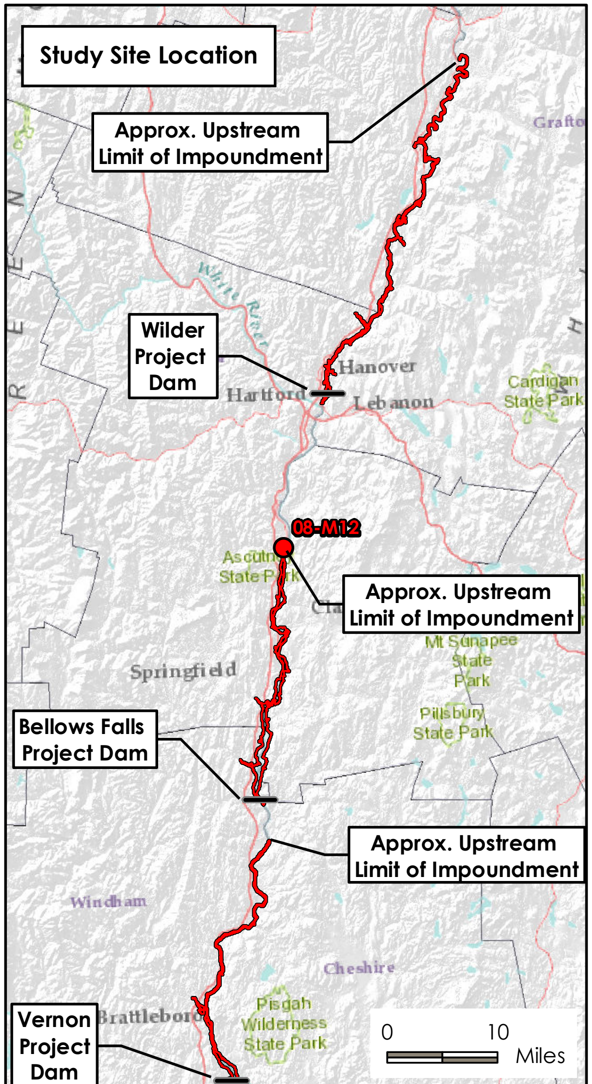

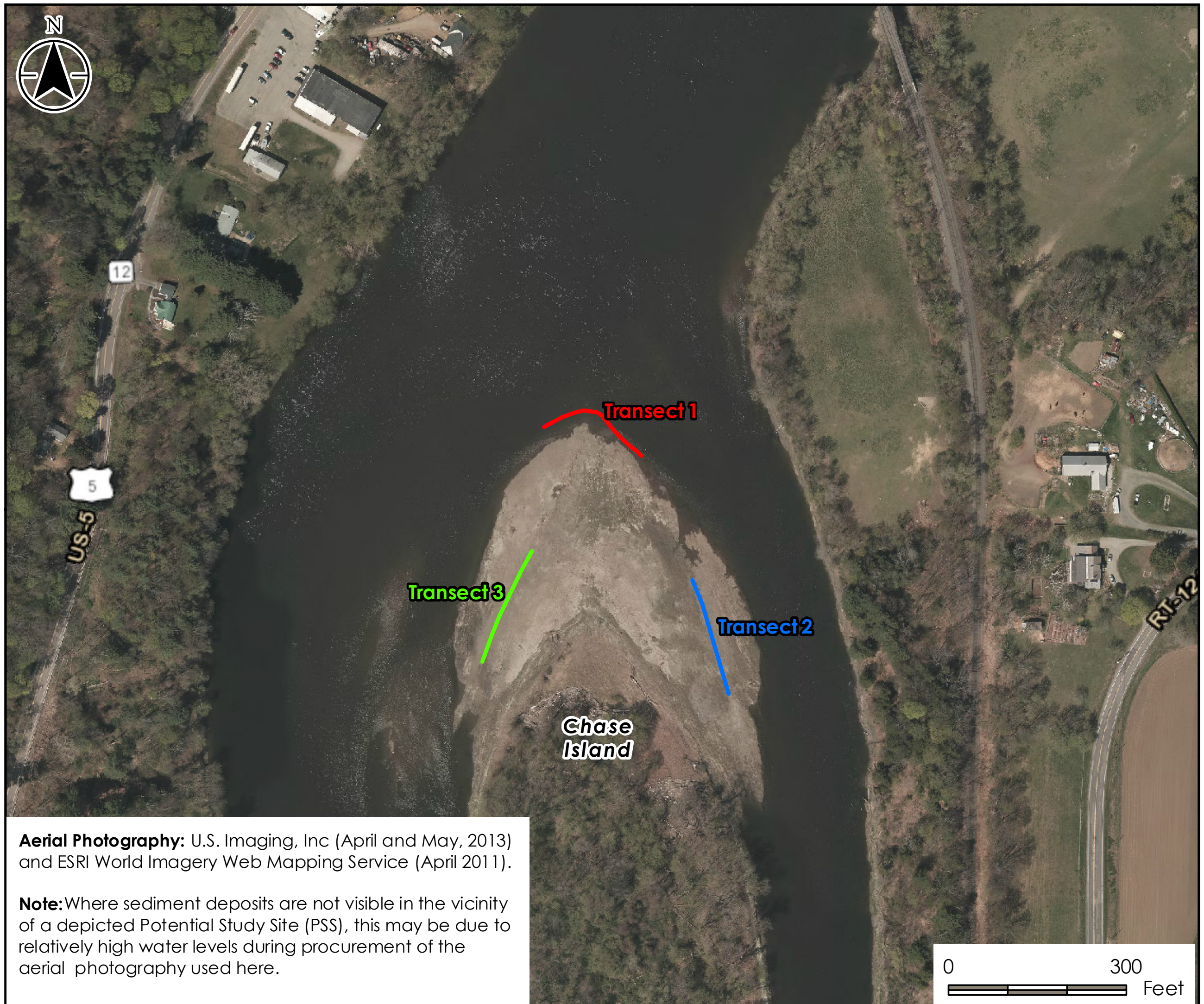

Aerial Photography: U.S. Imaging, Inc (April and May, 2013) and ESRI World Imagery Web Mapping Service (April 2011).

Note: Where sediment deposits are not visible in the vicinity of a depicted Potential Study Site (PSS), this may be due to relatively high water levels during procurement of the aerial photography used here.

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Figure No.

B.10

Title

Study Site 08-M12

1/13/2015

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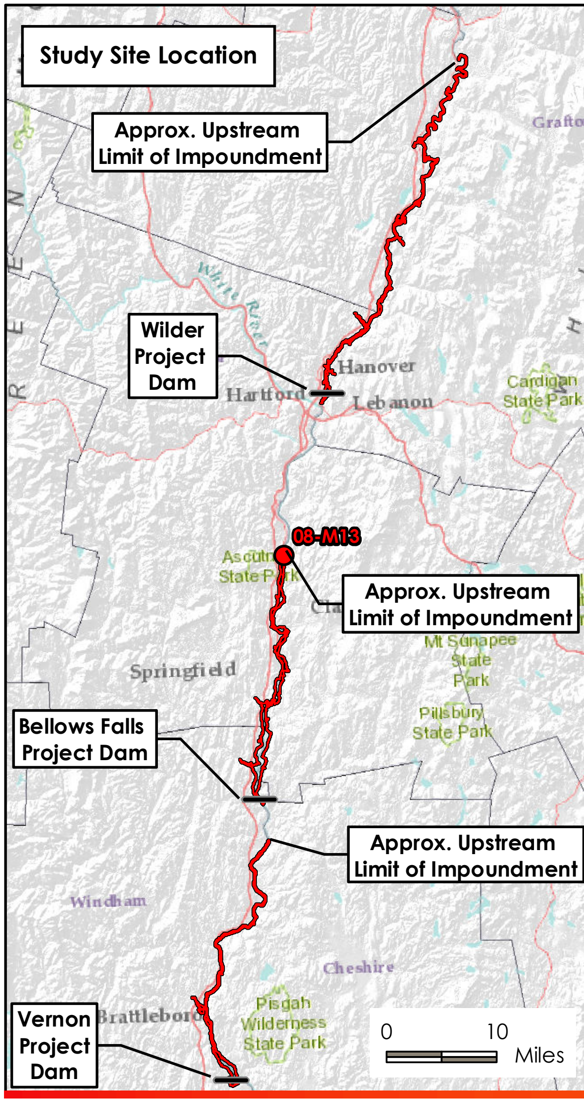

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Figure No.

B.11

Title

Study Site 08-M13

1/9/2015

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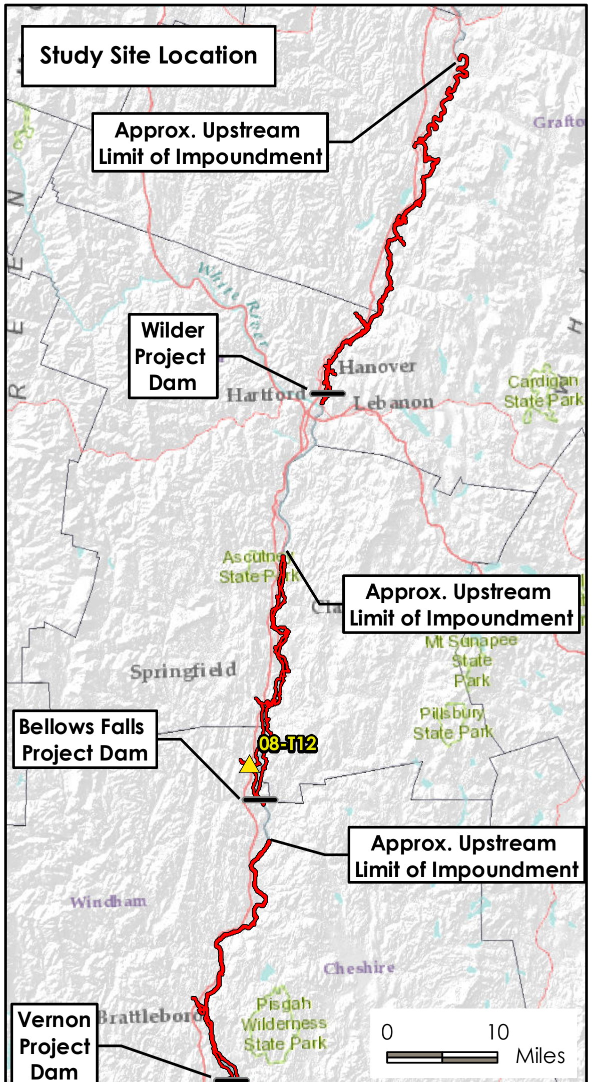

Aerial Photography: U.S. Imaging, Inc (April and May, 2013) and ESRI World Imagery Web Mapping Service (April 2011).

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Figure No.

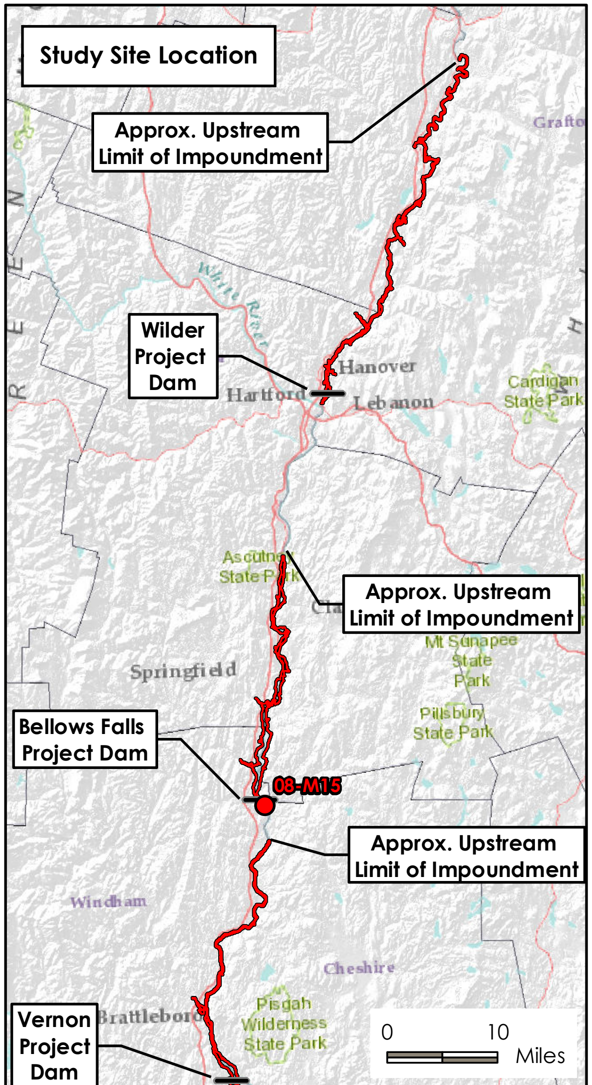
B.12

Title

Study Site 08-T12

1/9/2015

00876_AppA_StudySites.mxd



Aerial Photography: U.S. Imaging, Inc (April and May, 2013) and ESRI World Imagery Web Mapping Service (April 2011).

Note: Where sediment deposits are not visible in the vicinity of a depicted Potential Study Site (PSS), this may be due to relatively high water levels during procurement of the aerial photography used here.

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Figure No.

B.13

Title

Study Site 08-M15

1/9/2015

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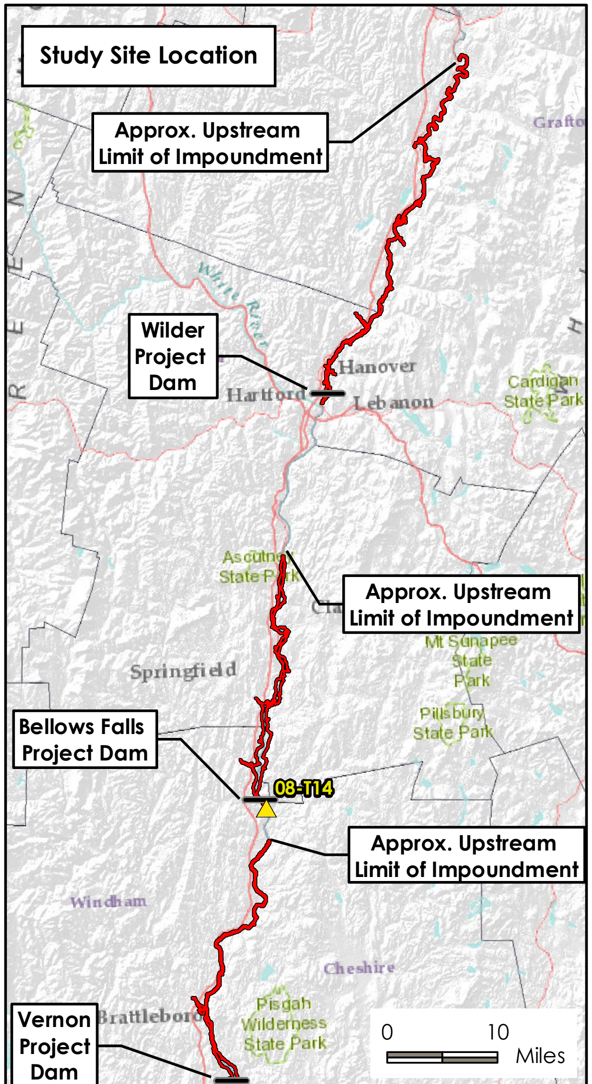

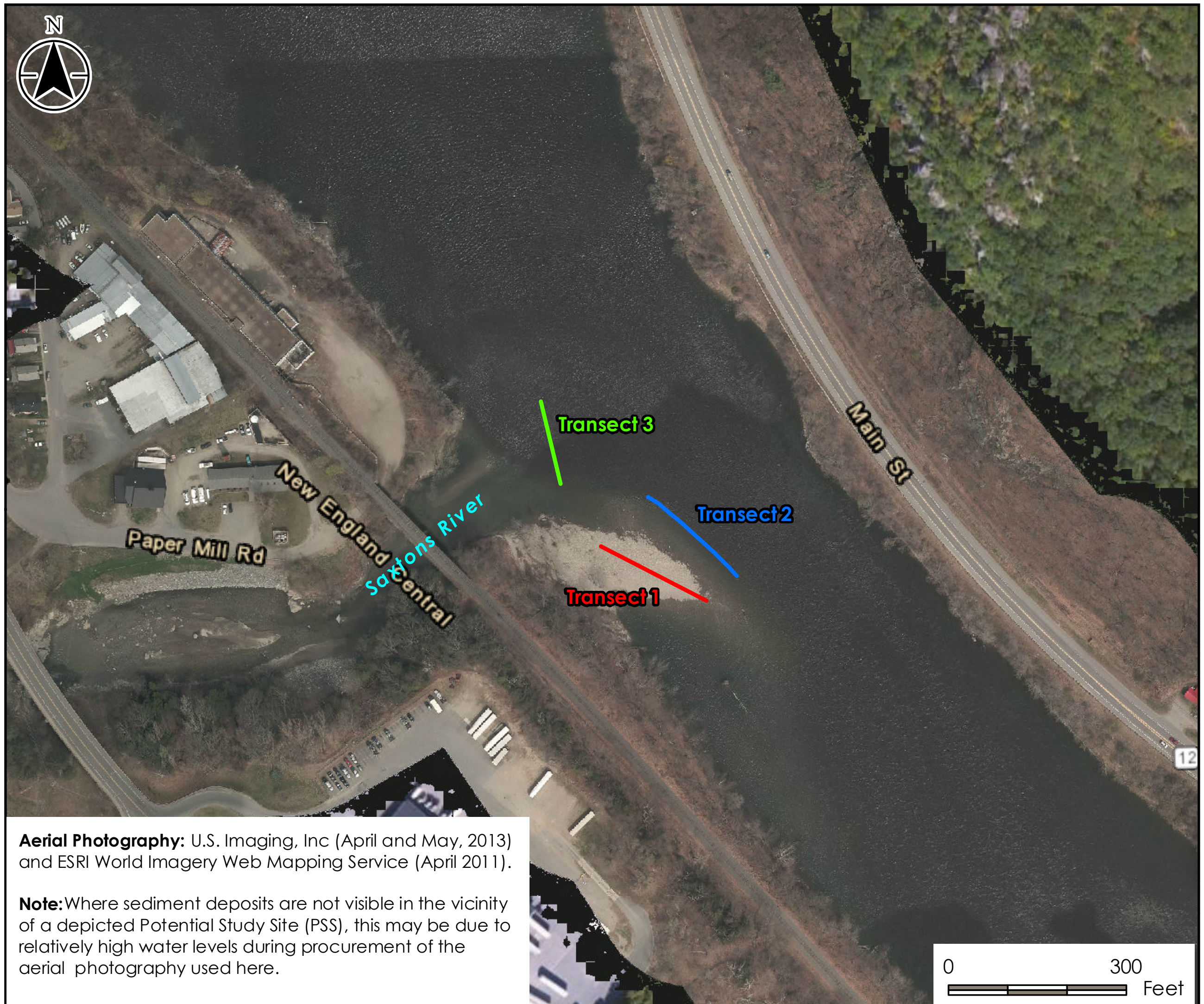

Aerial Photography: U.S. Imaging, Inc (April and May, 2013) and ESRI World Imagery Web Mapping Service (April 2011).

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Figure No.

B.14

Title

Study Site 08-T14

1/9/2015

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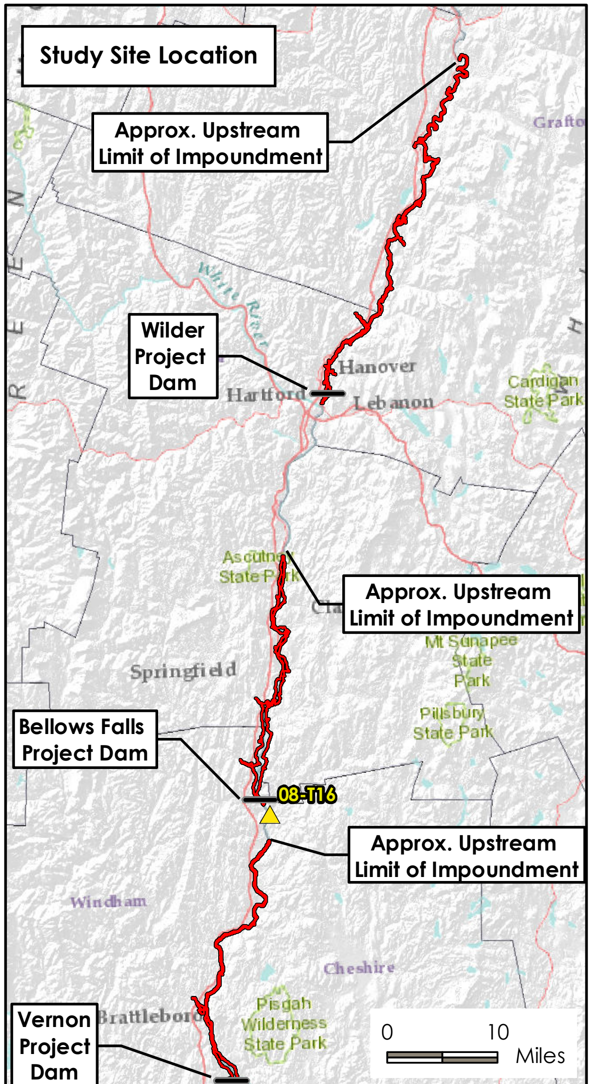

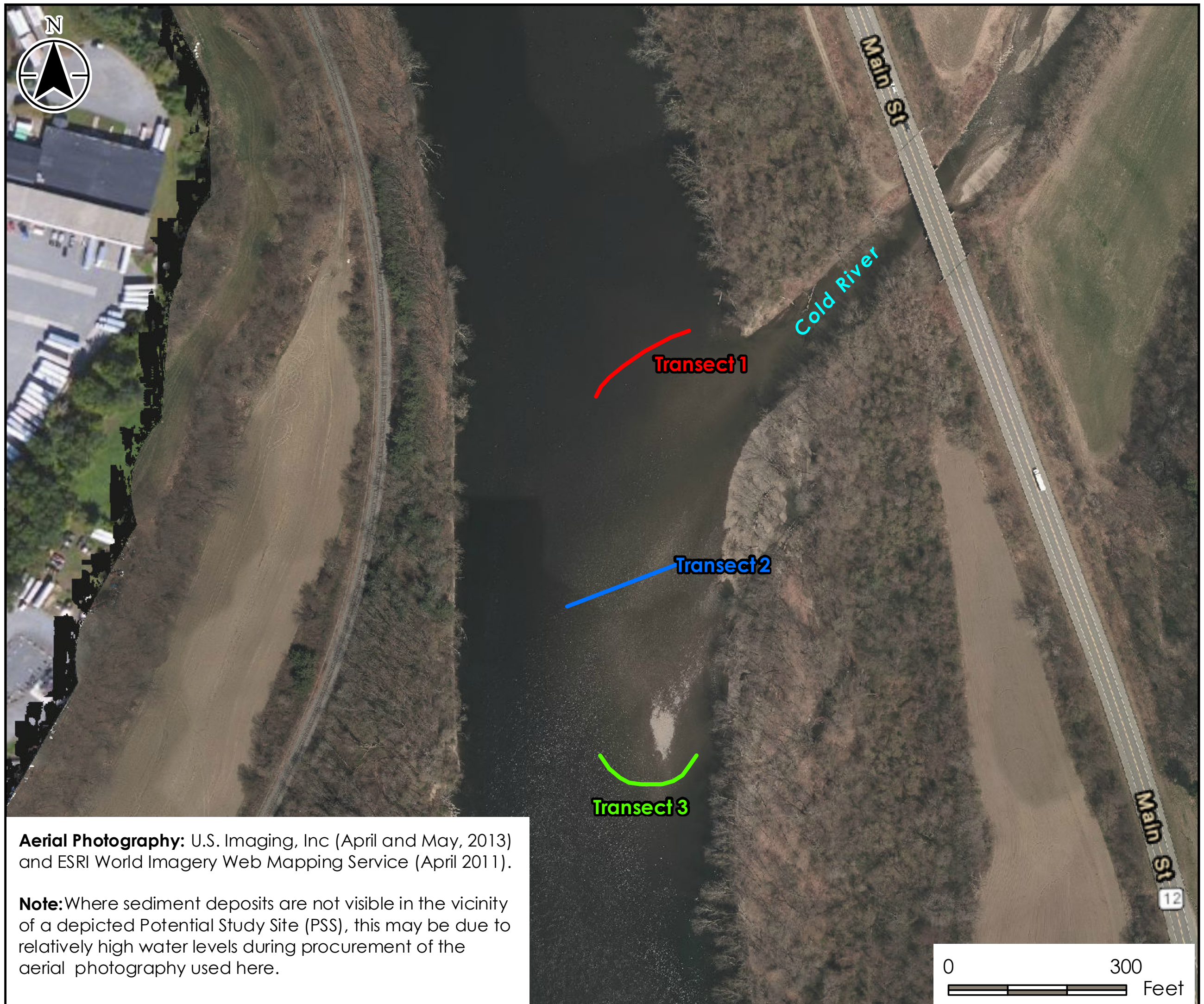

Aerial Photography: U.S. Imaging, Inc (April and May, 2013) and ESRI World Imagery Web Mapping Service (April 2011).

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Figure No.
B.15

Title
Study Site 08-T16
1/9/2015

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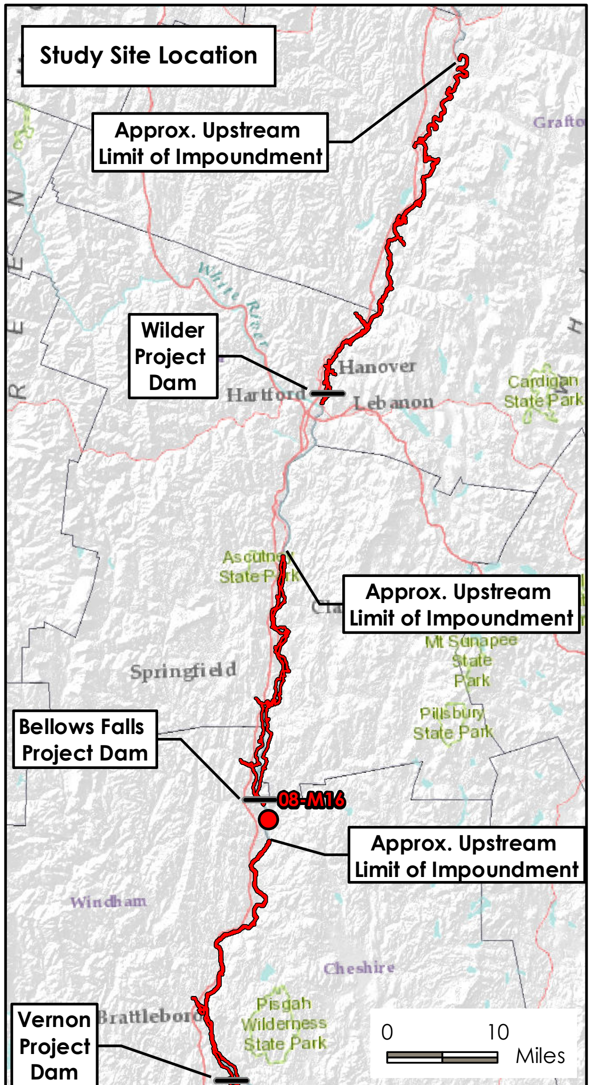

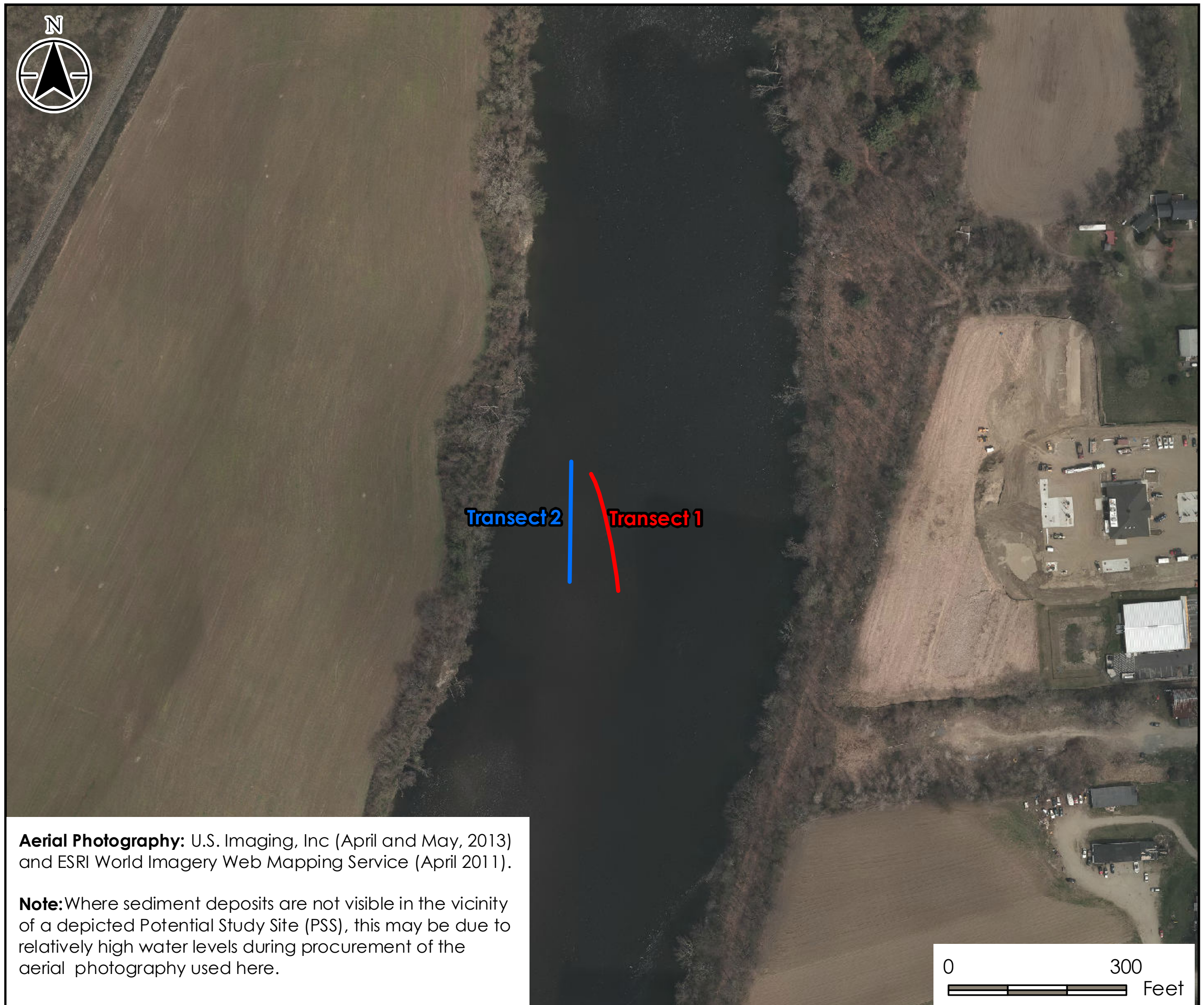

Aerial Photography: U.S. Imaging, Inc (April and May, 2013) and ESRI World Imagery Web Mapping Service (April 2011).

Note: Where sediment deposits are not visible in the vicinity of a depicted Potential Study Site (PSS), this may be due to relatively high water levels during procurement of the aerial photography used here.

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Figure No.

B.16

Title

Study Site 08-M16

1/9/2015

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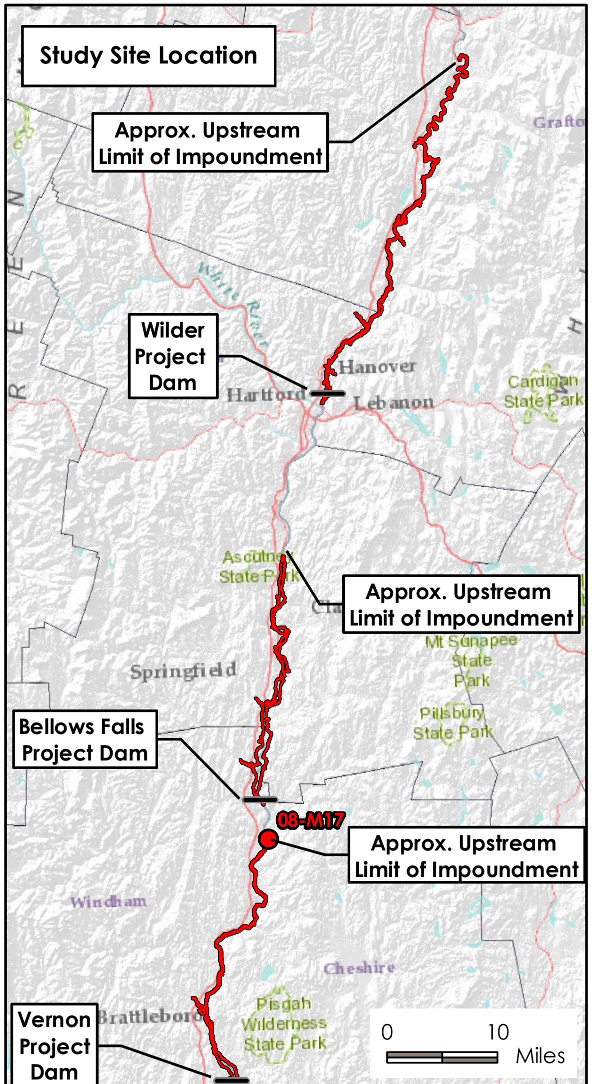

Aerial Photography: U.S. Imaging, Inc (April and May, 2013) and ESRI World Imagery Web Mapping Service (April 2011).

Note: Where sediment deposits are not visible in the vicinity of a depicted Potential Study Site (PSS), this may be due to relatively high water levels during procurement of the aerial photography used here.

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Figure No.
B.17

Title
Study Site 08-M17
1/9/2015

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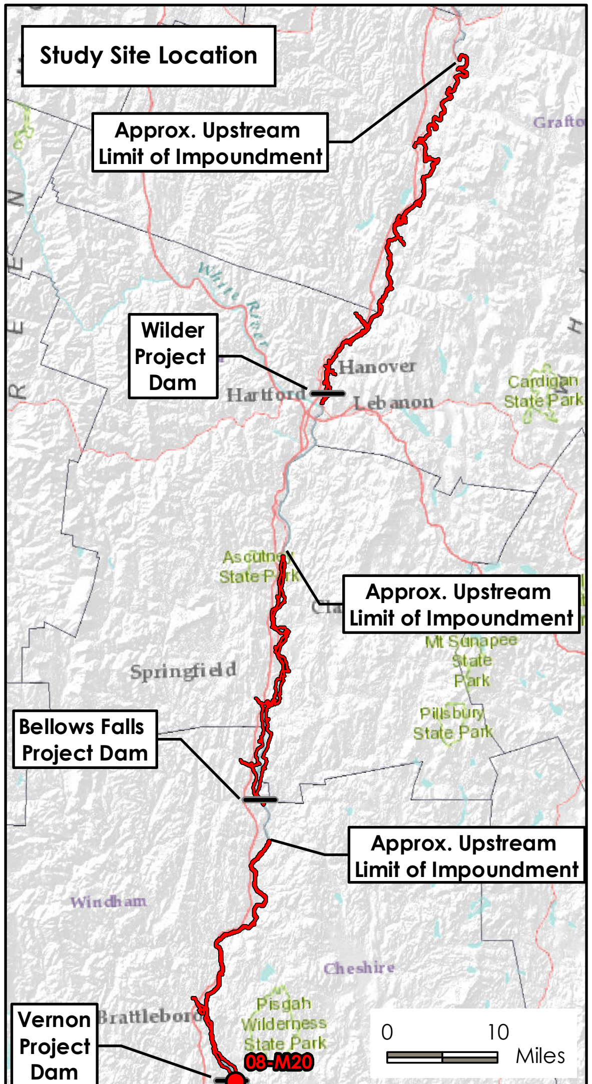

Aerial Photography: U.S. Imaging, Inc (April and May, 2013) and ESRI World Imagery Web Mapping Service (April 2011).

Note: Where sediment deposits are not visible in the vicinity of a depicted Potential Study Site (PSS), this may be due to relatively high water levels during procurement of the aerial photography used here.

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Figure No.
B.18

Title
Study Site 08-M20
1/9/2015

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APPENDIX C

Photographs

Transect Locations and Representative Photographs
Mainstem Study Site 08-M01

Figure C.1. Location of Study Site **08-M01** transect below Wilder Dam. [1, 2]

Photo C.1. View across Study Site 08-M01, facing upstream towards Wilder Dam. The location of Transect 1 is indicated by the tape measure visible in the midground of the photograph. (Stantec 07/12/14)

Photo C.2. View across Study Site 08-M01, facing northwest towards the left bank of the Connecticut River (visible in the background of the photo). The location of Transect 1 is indicated by the tape measure in the center of the photograph. (Stantec 07/12/14)

Photo C.3. Representative substrate along Transect 1 (the end point of Transect 1 is located at the end of the tape measure visible in the photograph). (Stantec 07/12/14)

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[1] All Appendix C figures are oriented with north at the top of the page.
[2] Aerial imagery source for all figures in Appendix C: U.S. Imaging, Inc. (April and May, 2013) and ESRI World Imagery Web Mapping Service (April 2011).

Transect Locations and Representative Photographs
Mainstem Study Site 08-M04

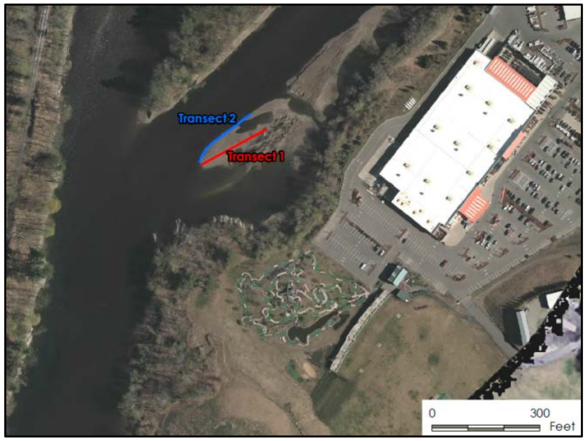

Figure C.2. Location of Study Site **08-M04** transects adjacent to Johnston Island (visible at upper left of photograph).

Photo C.4. View across Study Site 08-M04, facing southeast. The right bank of the Connecticut River is visible in the background of the photograph. (Stantec 07/12/14)

Photo C.5. View across Study Site 08-M04 facing downstream from the end (upstream limit) of Transect 1. The location of Transect 1 is indicated by the tape measure in the center of the photograph. (Stantec 07/12/14)

Photo C.6. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure in the middle of the photograph. (Stantec 07/12/14)

Photo C.7. View along Study Site 08-M04 facing upstream from the start (downstream limit) of Transect 2. The location of Transect 2 is indicated by the tape measure visible at edge-of-water in the photograph. (Stantec 07/12/14)

Photo C.8. Representative substrate along Transect 2. Location of Transect 2 is indicated by the tape measure in the middle of the photograph. (Stantec 07/12/14)

Transect Locations and Representative Photographs
Mainstem Study Site 08-M05

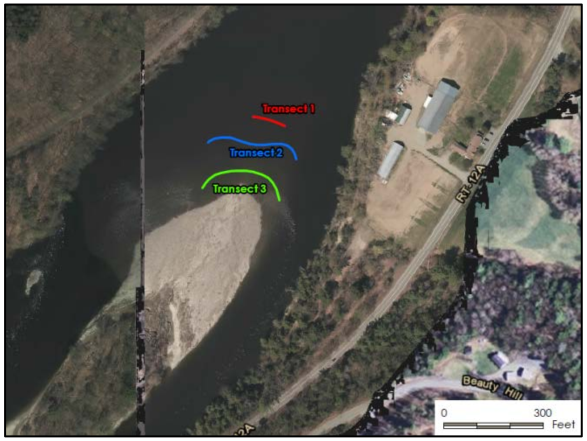

Figure C.3. Location of Study Site **08-M05** transects at upstream end of Burnaps Island.

Photo C.9. View across Study Site 08-M05, facing downstream towards Burnaps Island. Photograph is taken from approximate location of Transect 1. (Stantec 10/08/14)

Photo C.10. View across Study Site 08-M05, facing west. Photograph is taken from the start (east limit) of Transect 1. The location of Transect 1 is indicated by the tape measure in the center of the photograph. (Stantec 10/08/14)

Photo C.11. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure in the center of the photograph. Note algae present on substrate. (Stantec 10/08/14)

Photo C.12. View across Study Site 08-M05, facing east. Photograph is taken from the end (west limit) of Transect 2. The location of Transect 2 is indicated by the tape measure in the center of the photograph. (Stantec 10/08/14)

Photo C.13. Representative substrate along Transect 2. Location of Transect 2 is indicated by the tape measure in the center of the photograph. Note algae present on substrate. (Stantec 10/08/14)

Transect Locations and Representative Photographs
Mainstem Study Site 08-M05 (continued)

Photo C.14. View across Study Site 08-M05, facing northwest (the right bank of the Connecticut River is visible in the background of the photograph. Photograph is taken from the start point (east limit) of Transect 3. The location of Transect 3 is indicated by the tape measure in the center of the photograph. (Stantec 10/08/14)

Photo C.15. Representative substrate along Transect 3. Location of Transect 3 is indicated by the tape measure in center of the photograph. (Stantec 10/08/14)

Transect Locations and Representative Photographs
Mainstem Study Site 08-M07

Figure C.4. Location of Study Site **08-M07** transects at mid-channel bar upstream from Sumner Falls.

Photo C.16. View across Study Site 08-M07, facing downstream towards Sumner Falls. The photograph is taken from the approximate vicinity of Transect 1. (Stantec 07/12/14)

Photo C.17. View across Study Site 08-M07, facing west from the start (east limit) of Transect 1. The location of Transect 1 is indicated by the tape measure in the center of the photograph. (Stantec 10/08/14)

Photo C.18. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure in the middle of the photograph. (Stantec 07/12/14)

Photo C.19. View across Study Site 08-M07, facing east towards end (west limit) of Transect 2. The location of Transect 2 is indicated by the tape measure in the center of the photograph. (Stantec 10/08/14)

Photo C.20. Representative substrate along Transect 2. Location of Transect 2 is indicated by the tape measure in the middle of the photograph. (Stantec 07/12/14)

Transect Locations and Representative Photographs
Mainstem Study Site 08-M08

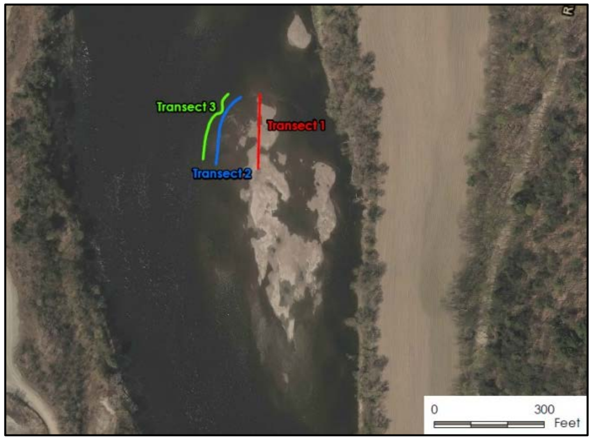

Figure C.5. Location of Study Site **08-M08** transects at mid-channel bar downstream from Sumner Falls.

Photo C.21. View across Study Site 08-M08, facing downstream. (Stantec 07/13/14)

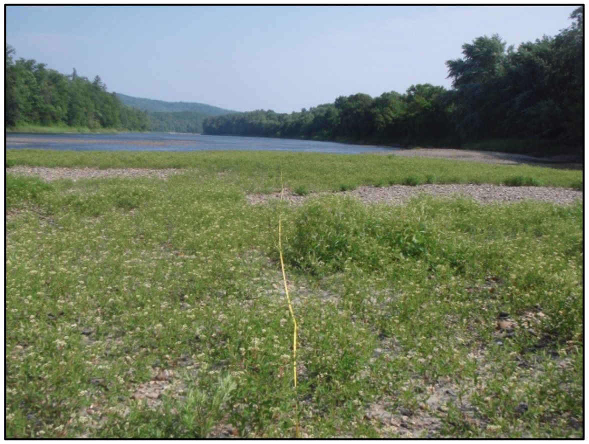

Photo C.22. View across Study Site 08-M08, facing upstream from the start (downstream limit) of Transect 1. The location of Transect 1 is indicated by the tape measure in the middle of the photograph. (Stantec 07/13/14)

Photo C.23. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure in the middle of the photograph. (Stantec 07/13/14)

Photo C.24. View across Study Site 08-M08, facing upstream from the start (downstream limit) of Transect 2. The location of Transect 2 is indicated by the tape measure in the center of the photograph. (Stantec 07/13/14)

Photo C.25. Representative substrate along Transect 2. Location of Transect 2 is indicated by the tape measure in the middle of the photograph. (Stantec 07/13/14)

Transect Locations and Representative Photographs
Mainstem Study Site 08-M08 (continued)

Photo C.26. View across Study Site 08-M08, facing downstream from the end (upstream limit) of Transect 3. The location of Transect 3 is indicated by the tape measure in the center of the photograph. (Stantec 07/13/14)

Photo C.27. Representative substrate along Transect 3. Location of Transect 3 is indicated by the tape measure in the photograph. (Stantec 07/13/14)

Transect Locations and Representative Photographs
Mainstem Study Site 08-M10

Figure C.6. Location of Study Site **08-M10** transects at point bar on right side of channel.

Photo C.28. View across Study Site 08-M10, facing northeast towards the left bank of the Connecticut River. (Stantec 07/13/14)

Photo C.29. View across Study Site 08-M10, facing upstream the start (downstream limit) of Transect 1. The location of Transect 1 is indicated by the tape measure in the center of the photograph. (Stantec 07/13/14)

Photo C.30. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure in the center of the photograph. (Stantec 07/13/14)

Photo C.31. View across Study Site 08-M10, facing downstream from the end (upstream limit) of Transect 2. The location of Transect 2 is indicated by the tape measure in the center of the photograph. (Stantec 07/13/14)

Photo C.32. Representative substrate along Transect 2. Location of Transect 2 is indicated by the tape measure in the middle of the photograph. (Stantec 07/13/14)

Transect Locations and Representative Photographs
Mainstem Study Site 08-M12

Figure C.7. Location of Study Site **08-M12** transects at upstream end of Chase Island.

Photo C.33. View across Study Site 08-M12, facing downstream towards Chase Island from the upstream end of Chase Island. (Stantec 07/15/14)

Photo C.34. View across Study Site 08-M12, facing east towards the left bank of the Connecticut River. Photograph taken from end (west limit) of Transect 1. Location of Transect 1 is indicated by the tape measure in the center of the photograph. (Stantec 07/15/14)

Photo C.35. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure in the middle of the photograph. (Stantec 07/15/14)

Photo C.36. View across Study Site 08-M12, facing south from the end (upstream limit) of Transect 2. Location of Transect 2 is indicated by the tape measure in the center of the photograph. (Stantec 07/15/14)

Photo C.37. Representative substrate along Transect 2. Location of Transect 2 is indicated by the tape measure in the middle of the photograph. (Stantec 07/15/14)

Transect Locations and Representative Photographs
Mainstem Study Site 08-M12 (continued)

Photo C.38. View across Study Site 08-M12, facing south (downstream) from the end (upstream limit) of Transect 3. Location of Transect 3 is indicated by the tape measure in the center of the photograph. (Stantec 07/15/14)

Photo C.39. Representative substrate along Transect 3. Location of Transect 3 is indicated by the tape measure in the middle of the photograph. (Stantec 07/15/14)

Transect Locations and Representative Photographs
Mainstem Study Site 08-M13

Figure C.8. Location of Study Site **08-M13**, downstream from Chase Island, in the vicinity of the upstream limit of the Bellows Falls impoundment.

Photo C.40. View across Study Site 08-M13, facing west towards the right bank of the Connecticut River. (Stantec 07/15/14)

Photo C.41. View across Study Site 08-M13, facing upstream from the start (downstream limit) of Transect 1. Location of Transect 1 is indicated by the tape measure in the center of the photograph. (Stantec 07/15/14)

Photo C.42. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure in the middle of the photograph. (Stantec 07/15/14)

Photo C.43. View across Study Site 08-M13, facing downstream from the end (upstream limit) of Transect 2. Location of Transect 2 is indicated by the tape measure in the center of the photograph. (Stantec 07/15/14)

Photo C.44. Representative substrate along Transect 2. Location of Transect 2 is indicated by the tape measure in the middle of the photograph. (Stantec 07/15/14)

Transect Locations and Representative Photographs
Mainstem Study Site 08-M15

Figure C.9. Location of Study Site **08-M15** transects below Bellows Falls Dam.

Photo C.45. View across Study Site 08-M15, facing upstream. The Bellows Falls facility is visible in the background of the photograph. (Stantec 10/09/14)

Photo C.46. View across Study Site 08-M15, facing downstream from the end (upstream limit) of Transect 1. Location of Transect 1 is indicated by the tape measure in the center of the photograph. (Stantec 10/09/14)

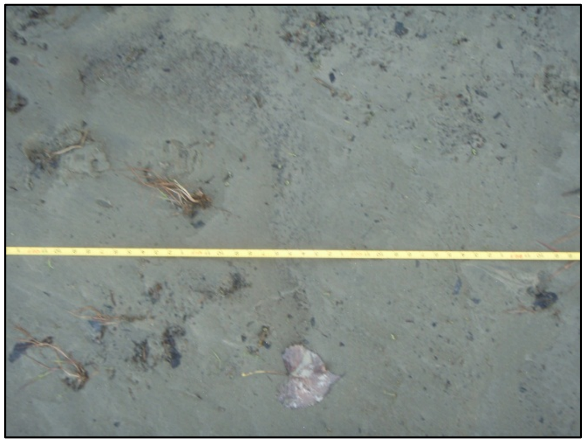

Photo C.47. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure in the middle of the photograph. (Stantec 10/09/14)

Transect Locations and Representative Photographs
Mainstem Study Site 08-M16

Figure C.10. Location of Study Site **08-M16** transects at point bar on river right.

Photo C.48. View across Study Site 08-M16, facing west towards the left bank of the Connecticut River. (Stantec 07/14/14)

Photo C.49. View across Study Site 08-M16, facing downstream from the end (upstream limit) of Transect 1. Location of Transect 1 is indicated by the tape measure in the center of the photograph. (Stantec 07/14/14)

Photo C.50. Representative substrate of Transect 1. Location of Transect 1 is indicated by the tape measure in the middle of the photograph. (Stantec 07/14/14)

Photo C.51. View across Study Site 08-M16, facing downstream from the end (upstream limit) of Transect 2. Location of Transect 2 is indicated by the tape measure in the center of the photograph. (Stantec 07/14/14)

Photo C.52. Representative substrate along Transect 2. Location of Transect 2 is indicated by the tape measure in the middle of the photograph. (Stantec 07/14/14)

Transect Locations and Representative Photographs
Mainstem Study Site 08-M17

Figure C.11. Location of Study Site **08-M17** transect at point bar on river right near the upstream limit of the Vernon impoundment.

Photo C.53. View across Study Site 08-M17, facing downstream towards the Dwinnell Street Bridge. (Stantec 07/12/14)

Photo C.54. View across Study Site 08-M17, facing upstream from the start (downstream limit) of Transect 1. Location of Transect 1 is indicated by the tape measure in the center of the photograph. (Stantec 07/14/14)

Photo C.55. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure in the middle of the photograph. (Stantec 07/14/14)

Transect Locations and Representative Photographs
Mainstem Study Site 08-M20

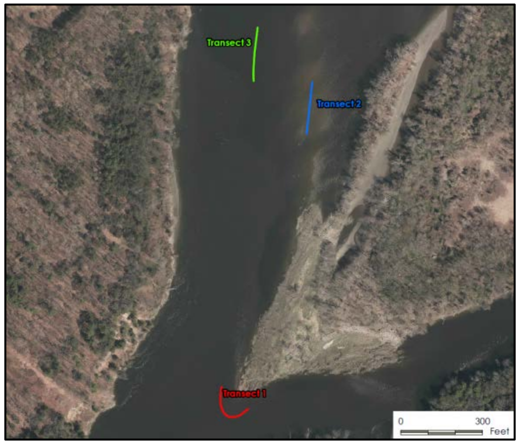

Figure C.12. Location of Study Site **08-M20** transects at Stebbins Island below Vernon Dam.

Photo C.56. View across Study Site 08-M20, facing downstream towards Stebbins Island. The location of Transect 1 is indicated by the tape measure visible in the midground of the photograph. (Stantec 08/12/14)

Photo C.57. View across Study Site 08-M20, facing upstream from the end (downstream limit) of Transect 1. Location of Transect 1 is indicated by the tape measure in the center of the photograph. (Stantec 08/14/14)

Photo C.58. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure in the middle of the photograph. (Stantec 08/14/14)

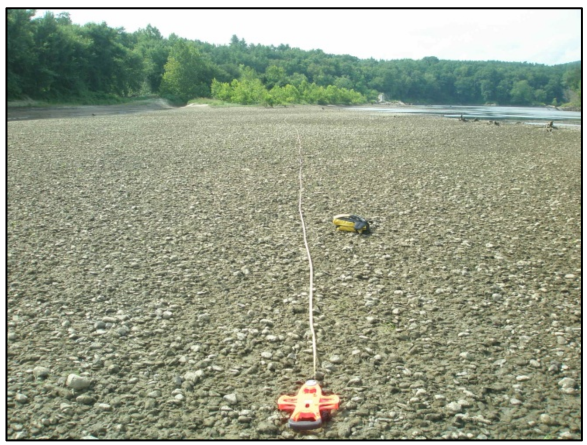

Photo C.59. View across Study Site 08-M20, facing upstream from the start (downstream limit) of Transect 2. Location of Transect 2 is indicated by the tape measure in the center of the photograph. (Stantec 08/14/14)

Photo C.60. Representative substrate along Transect 2. Location of Transect 2 is indicated by the tape measure in the middle of the photograph. (Stantec 08/14/14)

Transect Locations and Representative Photographs
Mainstem Study Site 08-M20 (continued)

Photo C.61. View across Study Site 08-M20, facing downstream from the end (upstream limit) of Transect 3. Location of Transect 3 is indicated by the tape measure in the center of the photograph. (Stantec 10/31/14)

Photo C.62. Representative substrate along Transect 3. Location of Transect 3 is indicated by the tape measure in the middle of the photograph. (Stantec 08/14/14)

Transect Locations and Representative Photographs
Tributary Study Site 08-T01

Figure C.13. Location of Study Site **08-T01** transects on the Ompompanoosuc River.

Photo C.63. View across Study Site 08-T01, facing upstream. (Stantec 07/11/14)

Photo C.64. View across Study Site 08-T01, facing upstream from the start (downstream limit) of Transect 1. The alignment of Transect 1 is indicated by the tape measure visible in the center of the photograph. (Stantec 07/11/14)

Photo C.65. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure visible in the photograph. (Stantec 07/11/14)

Photo C.66. View across Study Site 08-T01, facing downstream from the end (upstream limit) of Transect 2. The alignment of Transect 2 is indicated by the tape measure visible in foreground of photograph. (Stantec 07/11/14)

Photo C.67. Representative substrate along Transect 2. Location of Transect 2 is indicated by the tape measure visible in the photograph. (Stantec 07/11/14)

Transect Locations and Representative Photographs
Tributary Study Site 08-T01 (continued)

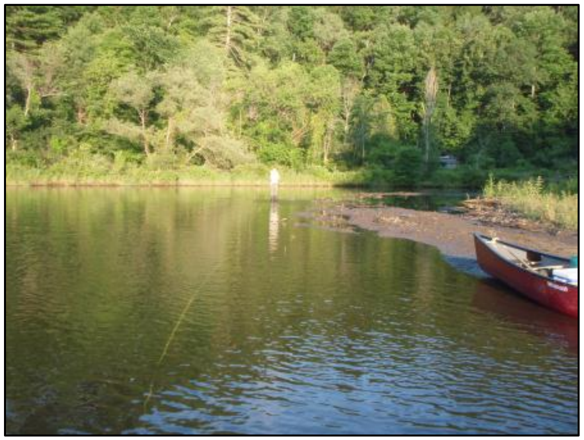

Photo C.68. View across Study Site 08-T01, facing downstream from the end (upstream limit) of Transect 3. The alignment of Transect 3 is indicated by the tape measure visible in foreground of photograph. (Stantec 07/11/14)

Photo C.69. Representative substrate along Transect 3. Location of Transect 3 is indicated by the tape measure in the middle of the photograph. (Stantec 07/11/14)

Transect Locations and Representative Photographs
Tributary Study Site 08-T02

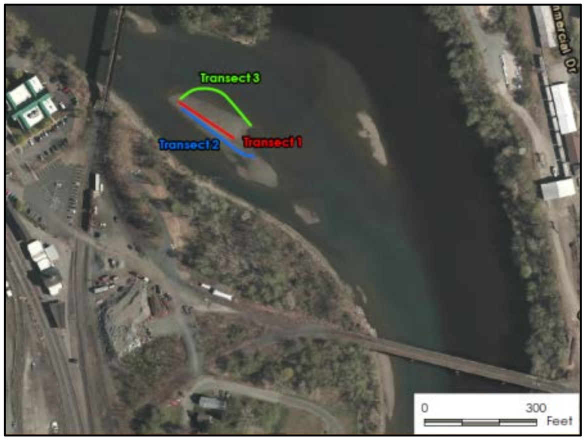

Figure C.14. Location of Study Site **08-T02** transects at the confluence of the White River and Connecticut rivers.

Photo C.70. View across Study Site 08-T02, facing upstream towards railroad and road bridges over the White River. (Stantec 07/12/14)

Photo C.71. View across Study Site 08-T02, facing downstream from the end (upstream limit) of Transect 1. The alignment of Transect 1 is indicated by the tape measure visible in foreground of photograph. (Stantec 07/12/14)

Photo C.72. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure in the middle of the photograph. (Stantec 07/12/14)

Photo C.73. View across Study Site 08-T02, facing upstream from the start (downstream limit) of Transect 2. The alignment of Transect 2 is indicated by the tape measure visible in foreground of photograph. (Stantec 07/12/14)

Photo C.74. Representative substrate along Transect 2. Location of Transect 2 is indicated by the tape measure in the center of the photograph. (Stantec 07/12/14)

Transect Locations and Representative Photographs
Tributary Study Site 08-T02 (continued)

Photo C.75. View across Study Site 08-T02, facing upstream from the start (downstream limit) of Transect 3. The alignment of Transect 3 is indicated by the tape measure visible in foreground of photograph. (Stantec 07/12/14)

Photo C.76. Representative substrate along Transect 3. Location of Transect 3 is indicated by the tape measure in the center of the photograph. (Stantec 10/07/14)

Transect Locations and Representative Photographs
Tributary Study Site 08-T04

Figure C.15. Location of Study Site **08-T04** transects on Mascoma Brook.

Photo C.77. View across Study Site 08-T04, facing upstream along Mascoma Brook. (Stantec 07/12/14)

Photo C.78. View across Study Site 08-T04, facing south from the end (river-right limit) of Transect 1. The alignment of Transect 1 is indicated by the tape measure visible in foreground of photograph. (Stantec 07/12/14)

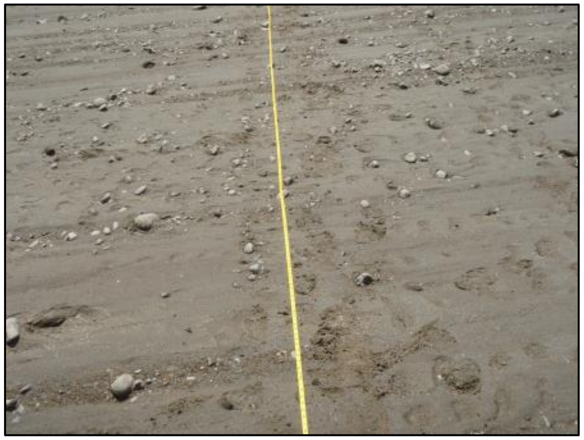

Photo C.79. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure in the center of the photograph. (Stantec 07/12/14)

Photo C.80. View across Study Site 08-T04, facing north from the start (river-left limit) of Transect 2. The alignment of Transect 2 is indicated by the tape measure visible in foreground of photograph. (Stantec 07/12/14)

Photo C.81. Representative substrate along Transect 2. The location of Transect 2 is indicated by the tape measure in the center of the photograph. (Stantec 07/12/14)

Transect Locations and Representative Photographs
Tributary Study Site 08-T12

Figure C.16. Location of Study Site **08-T12** transects on the Williams River.

Photo C.82. View downstream across Study Site 08-T12 along Williams River with Interstate 91 Bridge in background. (Stantec 10/31/14)

Photo C.83. View across Study Site 08-T12, facing upstream from the start (downstream limit) of Transect 1. The alignment of Transect 1 is indicated by the tape measure visible in foreground of photograph. (Stantec 10/31/14)

Photo C.84. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure in the center of the photograph. (Stantec 10/31/14)

Photo C.85. View across Study Site 08-T12, facing downstream from the end (upstream limit) of Transect 2. The alignment of Transect 2 is indicated by the tape measure visible in foreground of photograph. (Stantec 07/13/14)

Photo C.86. Representative substrate along Transect 2. Location of Transect 2 is indicated by the tape measure in the middle of the photograph. (Stantec 07/13/14)

Transect Locations and Representative Photographs
Tributary Study Site 08-T14

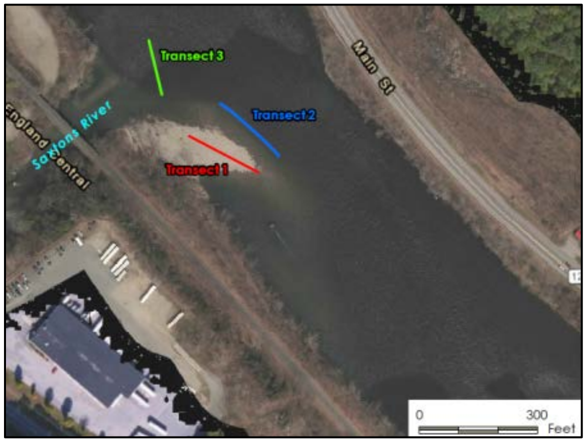

Figure C.17. Location of Study Site **08-T14** transects at the confluence of the Saxtons and Connecticut rivers.

Photo C.87. View across Study Site 08-T14, facing south across the delta bar. The Saxtons River is visible in the midground of the photograph, and its confluence with the Connecticut River is visible at the left side of the photograph. (Stantec 10/9/14)

Photo C.88. View across Study Site 08-T14, facing downstream from the end (upstream limit) of Transect 1. The alignment of Transect 1 is indicated by the tape measure visible in foreground of photograph. (Stantec 10/9/14)

Photo C.89. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure in the center of the photograph. (Stantec 10/9/14)

Photo C.90. View across Study Site 08-T14, facing upstream from the start (downstream limit) of Transect 2. The location of Transect 2 is indicated by the tape measure. The Bellows Falls facility is visible in the background. (Stantec 07/14/14)

Photo C.91. Representative substrate along Transect 2. Location of Transect 2 is indicated by the tape measure in the middle of the photograph. (Stantec 07/14/14)

Transect Locations and Representative Photographs
Tributary Study Site 08-T14 (continued)

Photo C.92. View across Study Site 08-T14, facing across the Saxtons River (visible in the middle of the photograph) at its confluence with the Connecticut River (visible in the background of the photograph). The start (southern limit) of Transect 3 is represented by the blue flagging visible in the foreground of the photograph. The end (northern limit) of Transect 3 is in the location of the person visible standing on the bar in the midground of the photograph. The Bellows Falls facility is visible in the background of the photograph. (Stantec 07/14/14)

Photo C.93. Representative substrate along Transect 3. (Stantec 07/14/14)

Transect Locations and Representative Photographs
Tributary Study Site 08-T16

Figure C.18. Location of Study Site **08-T16** transects at the confluence of the Cold and Connecticut rivers.

Photo C.94. View facing south across Study Site 08-T16 from the vicinity of Transect 1. The Cold River is visible in the midground of the photograph, and the right bank of the Connecticut River is visible at the right side of the photograph. (Stantec 10/9/14)

Photo C.95. View across Study Site 08-T16, facing west from the start of Transect 1. The location of Transect 1 is indicated by the tape measure. The right bank of the Connecticut River is visible in the background of the photograph. (Stantec 07/14/14)

Photo C.96. Representative substrate along Transect 1. Location of Transect 1 is indicated by the tape measure in the middle of the photograph. (Stantec 07/14/14)

Photo C.97. View across Study Site 08-T16, facing west from the start of Transect 2. The location of Transect 2 is indicated by the tape measure. The right bank of the Connecticut River is visible in the background of the photograph. (Stantec 07/14/14)

Photo C.98. Representative substrate along Transect 2. Location of Transect 2 is indicated by the tape measure in the middle of the photograph. (Stantec 07/14/14)

Transect Locations and Representative Photographs
Tributary Study Site 08-T16 (continued)

Photo C.99. View across Study Site 08-T16, facing southwest from the start of Transect 3. The location of Transect 3 is indicated by the tape measure. The right bank of the Connecticut River is visible in the background of the photograph. (Stantec 07/14/14)

Photo C.100. Representative substrate along Transect 3. Location of Transect 3 is indicated by the tape measure in visible in the photograph. (Stantec 07/14/14)

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APPENDIX D

Particle Size Distribution

Appendix D.1. Study Site 08-M01

Table D.1-1. Study site 08-M01 particle size distribution.

PERCENT FINER (By Transect)								
Wentworth Size Class		Size range (mm)	TRANSECT 1		TRANSECT 2		TRANSECT 3	
			Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%				
Sand	Sand	0.062 - 2.0	0%	0%				
Gravel	Very Fine	2-4	0%	0%				
	Fine	4-8	0%	0%				
	Medium	8-16	1%	0%				
	Coarse	16-32	3%	2%				
	Very Coarse	32-64	22%	6%				
Cobble	Small	64-128	43%	12%				
	Large	128-256	59%	30%				
Boulder	Small	256-512	74%	59%				
	Medium	512-1024	88%	90%				
	Large - Very Large	1024-4096	92%	99%				
Bedrock	Bedrock	-	92%	99%				

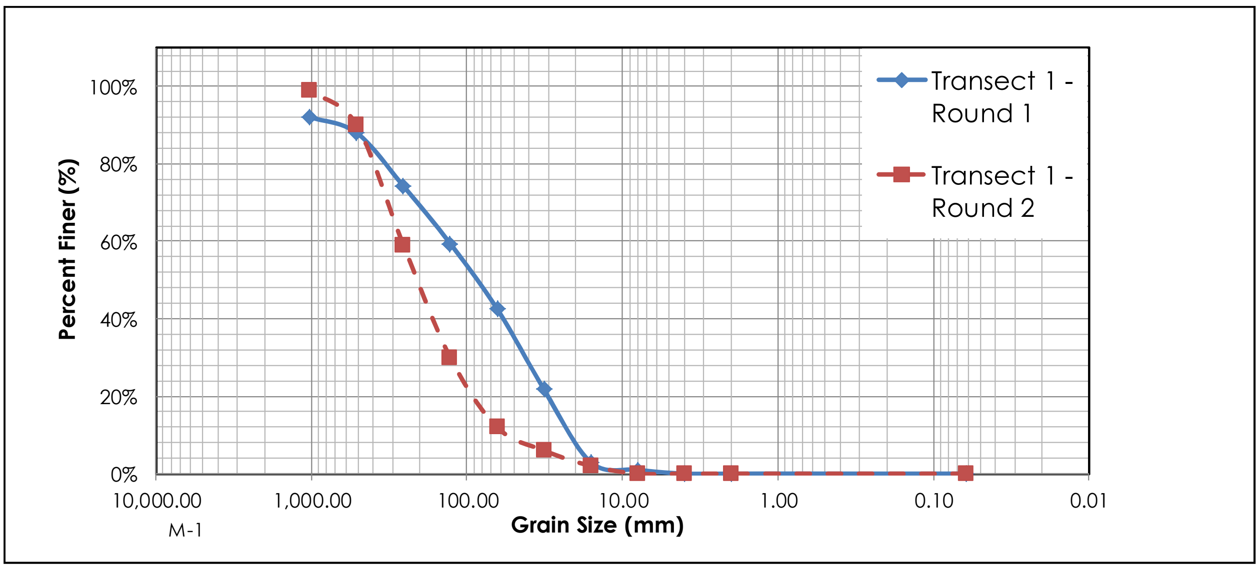

Figure D.1-1. Study site 08-M01 Transect 1 gradation curves.

Appendix D-2. Study Site 08-M04

Table D.2-1. Study site 08-M04 particle size distribution.

PERCENT FINER (By Transect)								
Wentworth Size Class		Size range (mm)	TRANSECT 1		TRANSECT 2		TRANSECT 3	
			Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%	0%	0%		
Sand	Sand	0.062 - 2.0	0%	0%	0%	0%		
Gravel	Very Fine	2-4	6%	30%	0%	4%		
	Fine	4-8	6%	30%	1%	5%		
	Medium	8-16	9%	31%	3%	6%		
	Coarse	16-32	23%	39%	13%	13%		
	Very Coarse	32-64	58%	62%	55%	47%		
Cobble	Small	64-128	86%	87%	85%	88%		
	Large	128-256	99%	99%	100%	100%		
Boulder	Small	256-512	100%	100%	100%	100%		
	Medium	512-1024	100%	100%	100%	100%		
	Large - Very Large	1024-4096	100%	100%	100%	100%		
Bedrock	Bedrock	-	100%	100%	100%	100%		

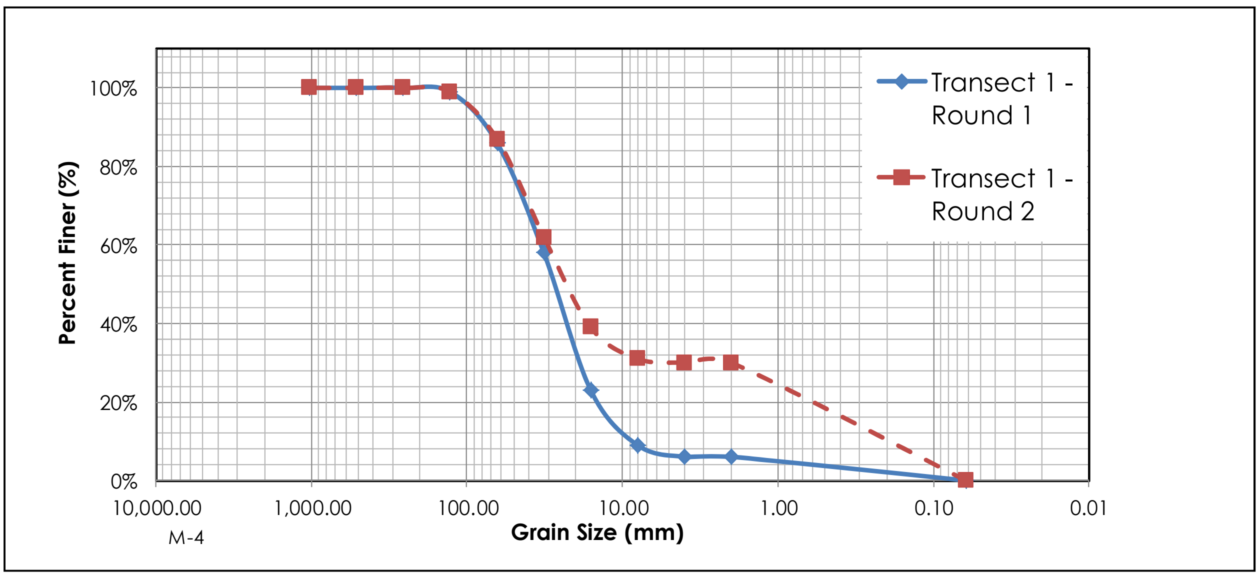

Figure D.2-1. Study site 08-M04 Transect 1 gradation curves.

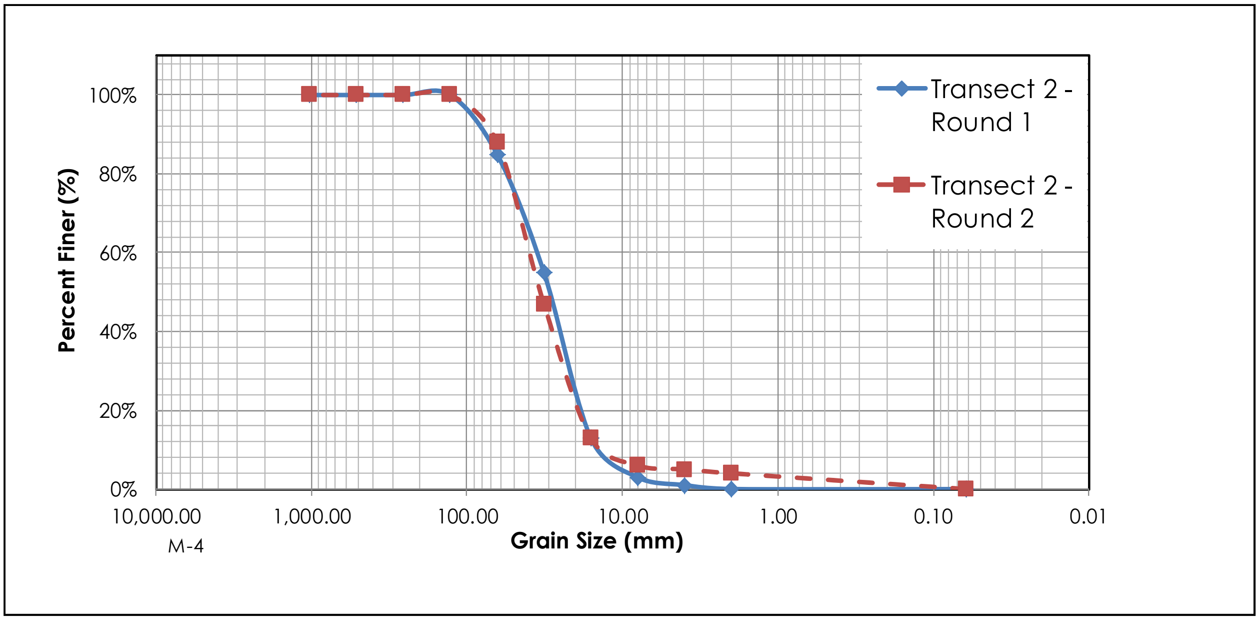

Figure D.2-2. Study site 08-M04 Transect 2 gradation curves.

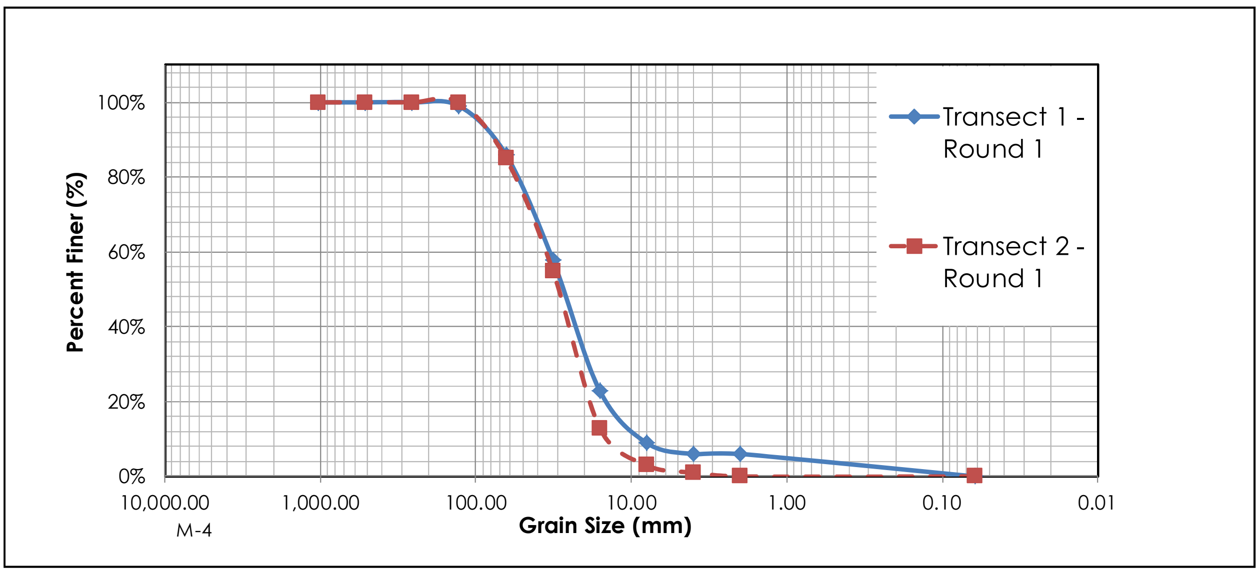

Figure D.2-3. Study site 08-M04 Transects 1 and 2, Round 1 gradation curves.

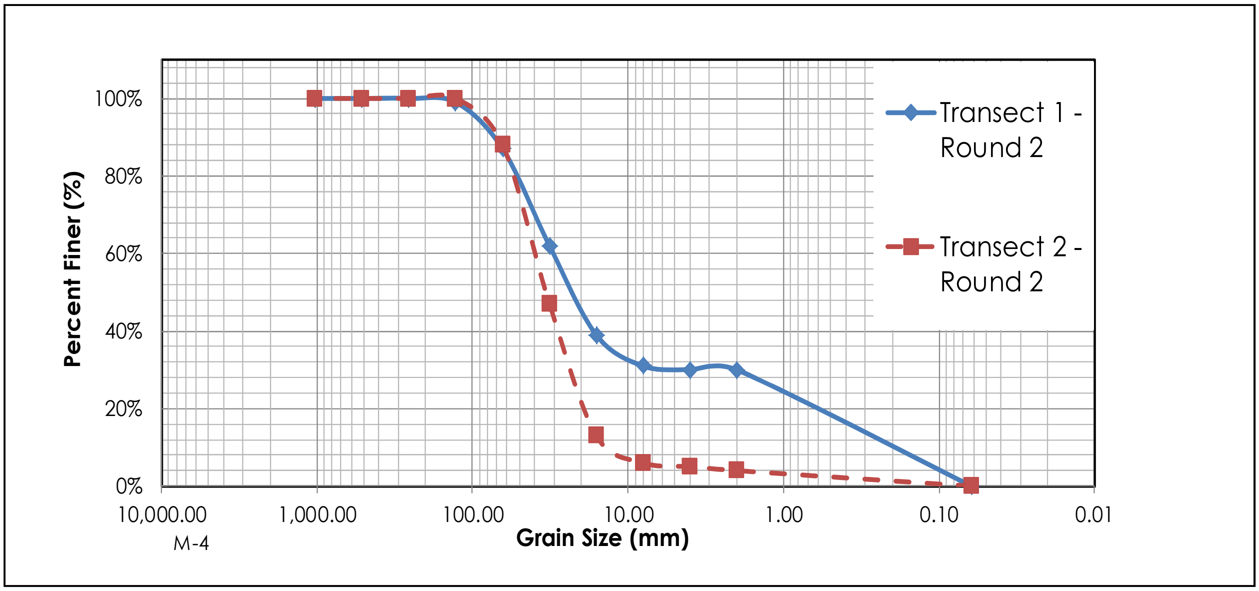

Figure D.2-4. Study site 08-M04 Transects 1 and 2, Round 2 gradation curves.

Appendix D-3. Study Site 08-M05

Table D.3-1. Study site 08-M05 particle size distribution.

PERCENT FINER (By Transect)									
Wentworth Size Class		Size range (mm)	TRANSECT 1		TRANSECT 2		TRANSECT 3	
			Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%	0%	0%	0%	0%
Sand	Sand	0.062 - 2.0	0%	0%	0%	0%	0%	0%
Gravel	Very Fine	2-4	19%	44%	18%	31%	24%	2%
	Fine	4-8	23%	49%	18%	33%	25%	3%
	Medium	8-16	33%	54%	31%	37%	31%	11%
	Coarse	16-32	53%	64%	46%	42%	42%	23%
	Very Coarse	32-64	68%	72%	62%	57%	58%	46%
Cobble	Small	64-128	79%	90%	76%	73%	81%	72%
	Large	128-256	95%	99%	95%	97%	96%	96%
Boulder	Small	256-512	100%	100%	99%	100%	100%	100%
	Medium	512-1024	100%	100%	100%	100%	100%	100%
	Large - Very Large	1024-4096	100%	100%	100%	100%	100%	100%
Bedrock	Bedrock	-	100%	100%	100%	100%	100%	100%

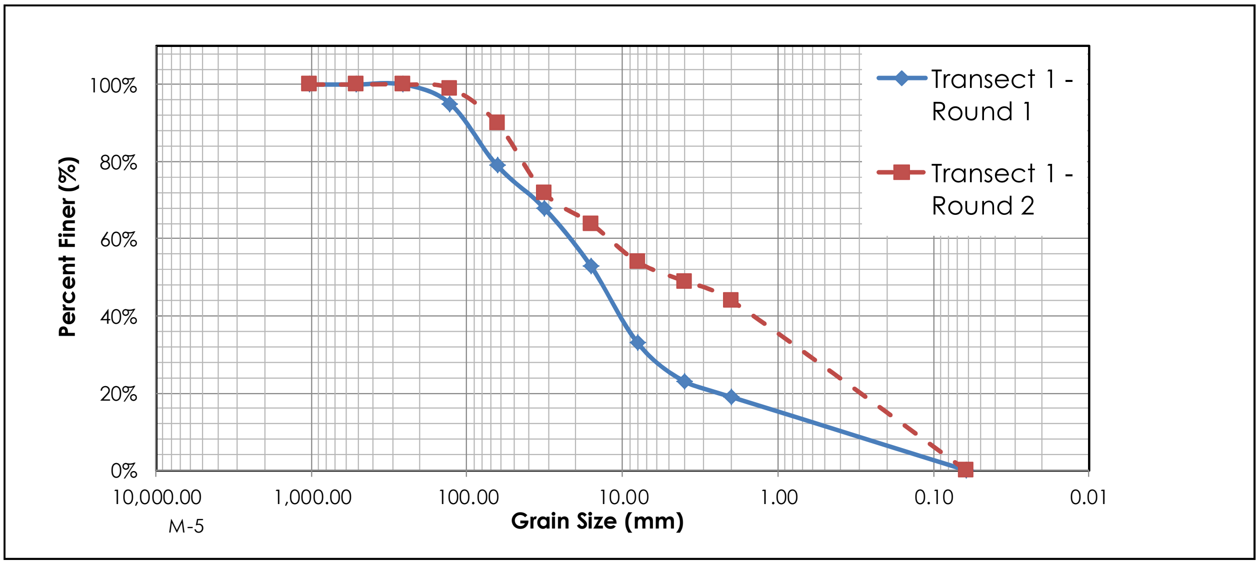

Figure D.3-1. Study site 08-M05 Transect 1 gradation curves.

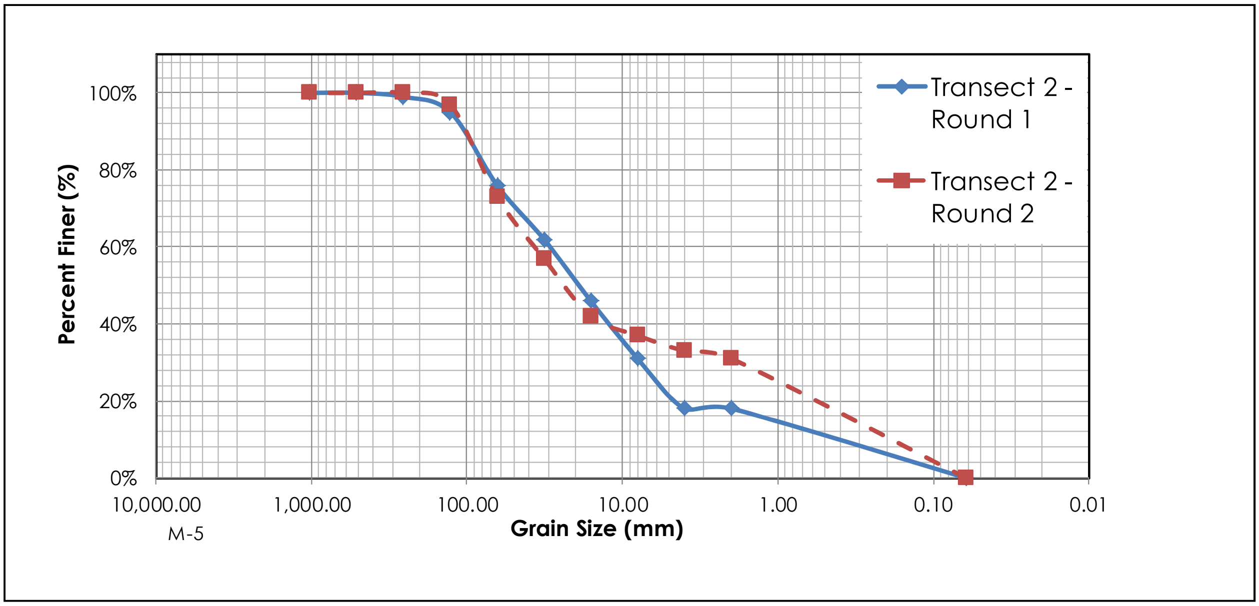

Figure D.3-2. Study site 08-M05 Transect 2 gradation curves.

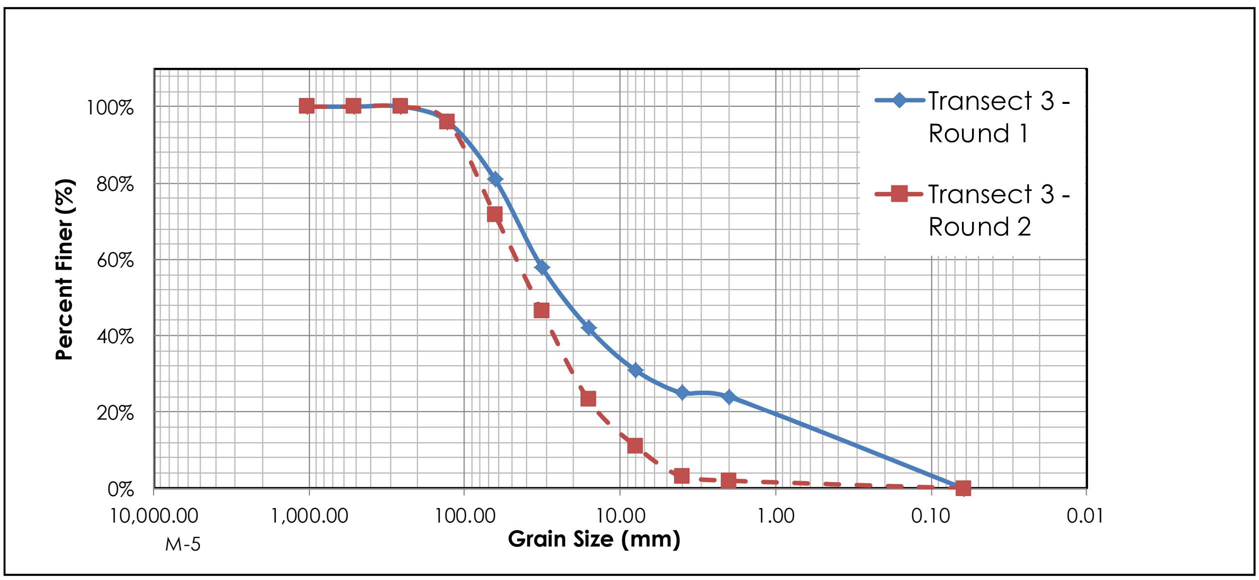

Figure D.3-3. Study site 08-M05 Transect 3 gradation curves.

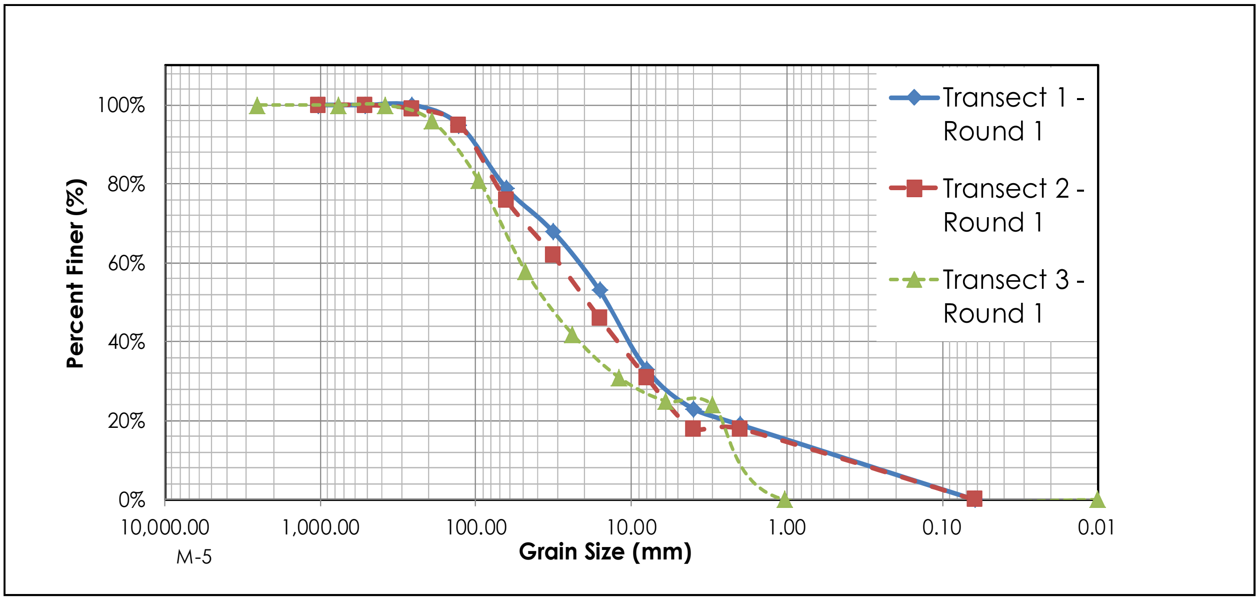

Figure D.3-4. Study site 08-M05 Transects 1, 2, and 3, Round 1 gradation curves.

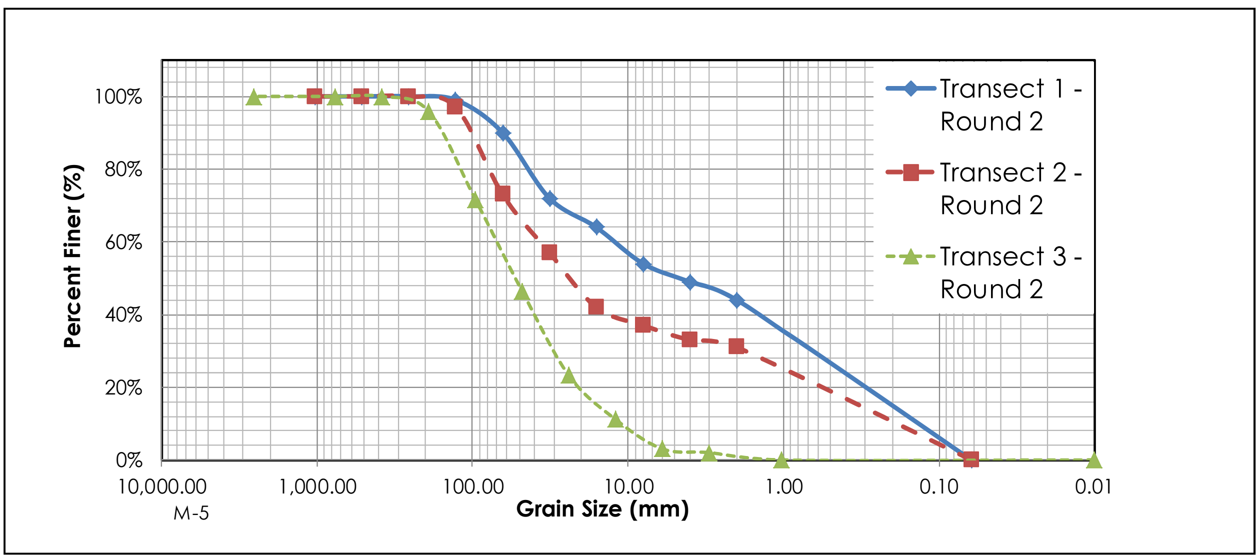

Figure D.3-5. Study site 08-M05 Transects 1, 2, and 3, Round 2 gradation curves.

Appendix D-4. Study Site 08-M07

Table D.4-1. Study site 08-M07 particle size distribution.

Wentworth Size Class		Size range (mm)	TRANSECT 1 Round 1	TRANSECT 1 Round 2	TRANSECT 2 Round 1	TRANSECT 2 Round 2	TRANSECT 3 Round 1	TRANSECT 3 Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%	0%	0%		
Sand	Sand	0.062 - 2.0	0%	1%	0%	0%		
Gravel	Very Fine	2-4	24%	57%	23%	42%		
	Fine	4-8	25%	57%	25%	43%		
	Medium	8-16	34%	57%	28%	45%		
	Coarse	16-32	49%	62%	50%	49%		
	Very Coarse	32-64	70%	73%	74%	67%		
Cobble	Small	64-128	91%	92%	94%	90%		
	Large	128-256	100%	100%	100%	100%		
Boulder	Small	256-512	100%	100%	100%	100%		
	Medium	512-1024	100%	100%	100%	100%		
	Large - Very Large	1024-4096	100%	100%	100%	100%		
Bedrock	Bedrock	-	100%	100%	100%	100%		

PERCENT FINER (By Transect)

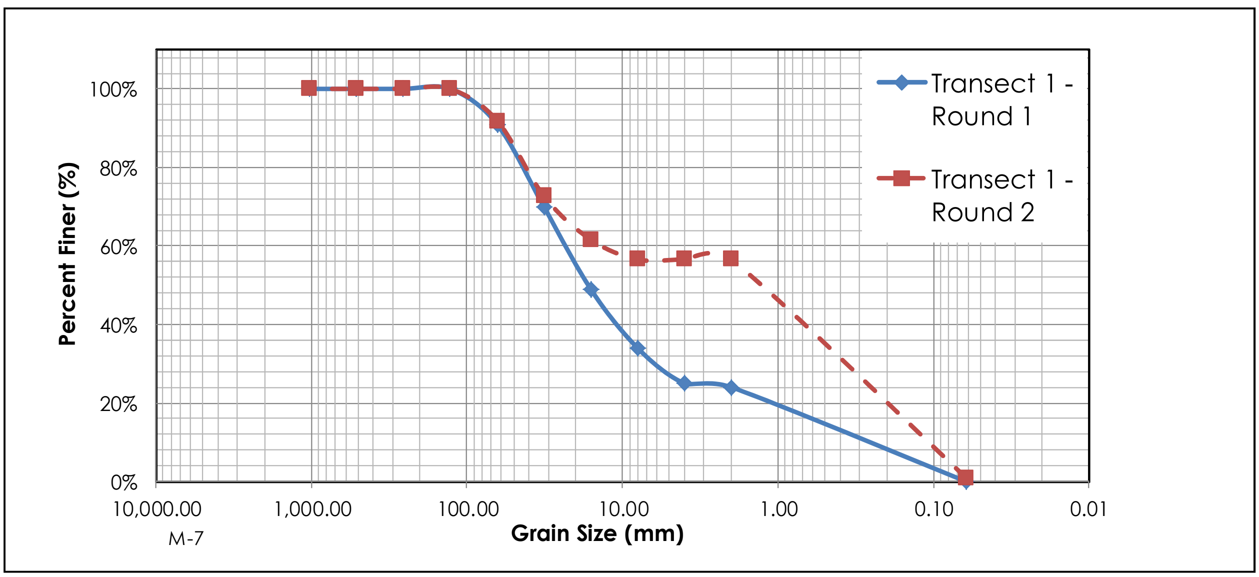

Figure D.4-1. Study site 08-M07 Transect 1 gradation curves.

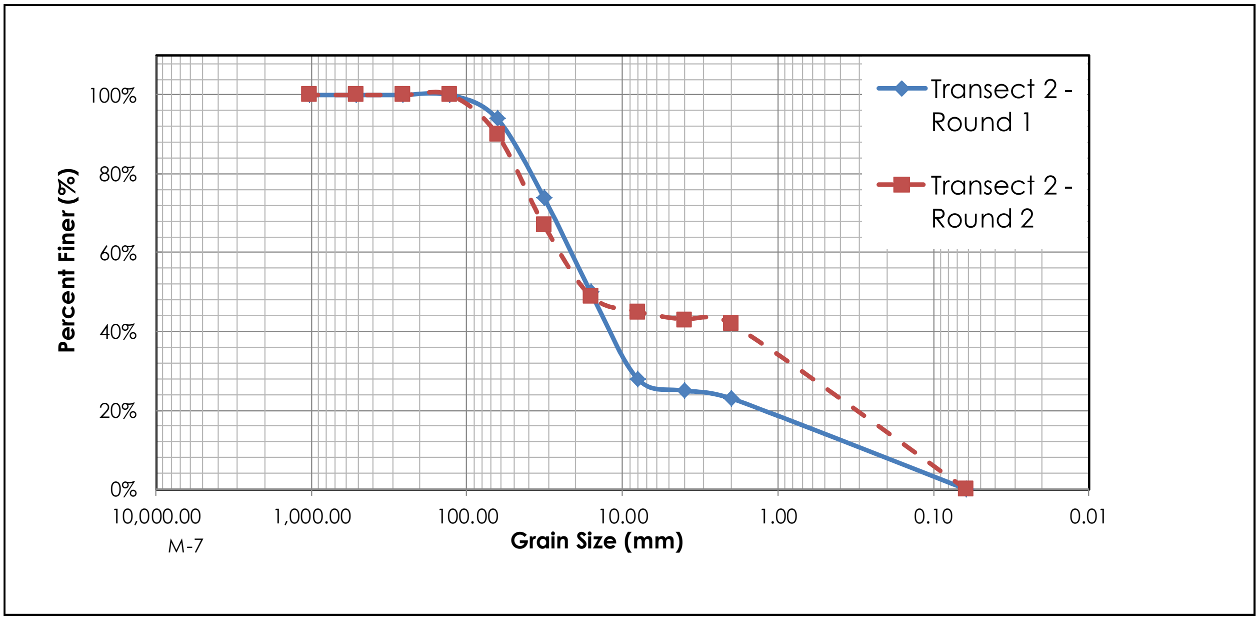

Figure D.4-2. Study site 08-M07 Transect 2 gradation curves.

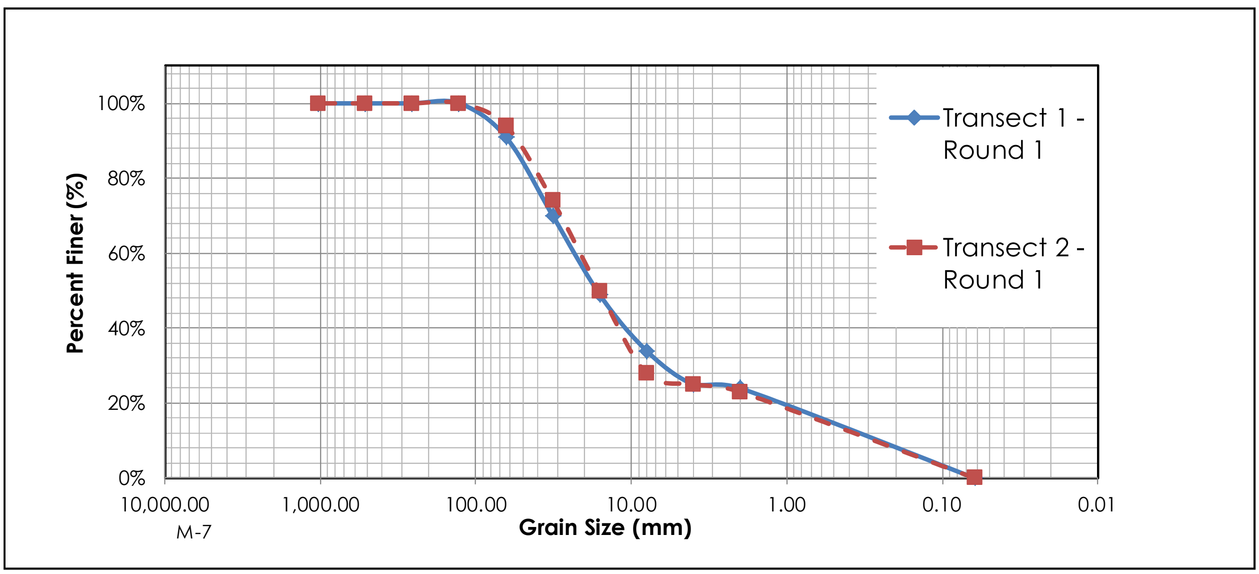

Figure D.4-3. Study site 08-M07 Transects 1 and 2, Round 1 gradation curves.

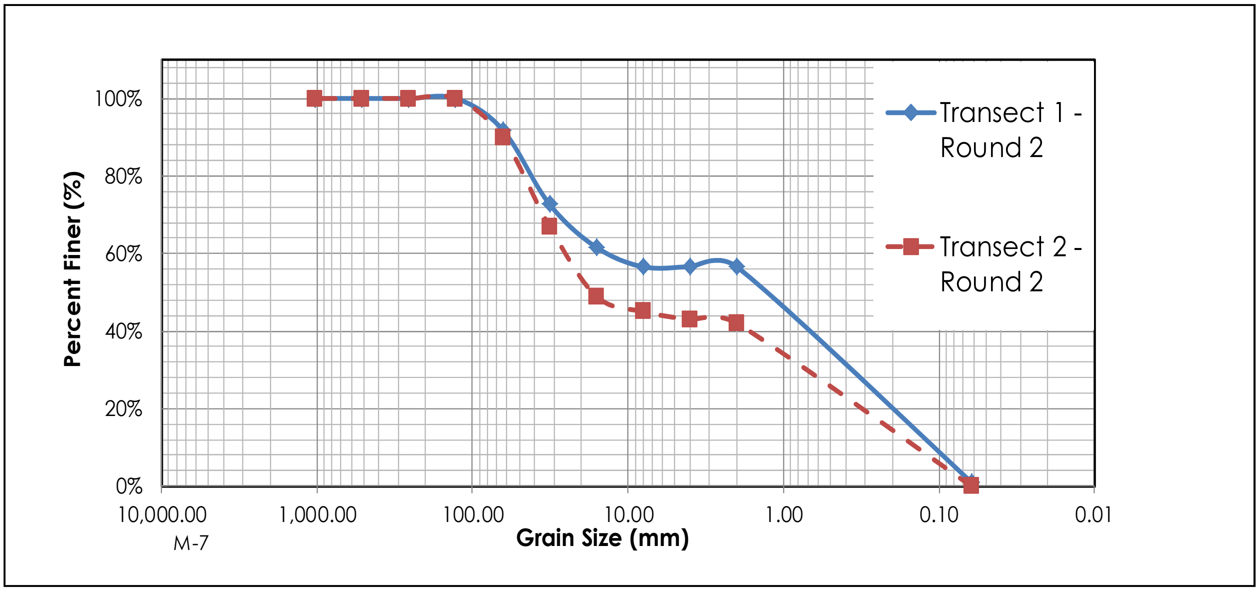

Figure D.4-4. Study site 08-M07 Transects 1 and 2, Round 2 gradation curves.

Appendix D-5. Study Site 08-M08

Table D.5-1. Study site 08-M08 particle size distribution.

Wentworth Size Class		Size range (mm)	TRANSECT 1 Round 1	TRANSECT 1 Round 2	TRANSECT 2 Round 1	TRANSECT 2 Round 2	TRANSECT 3 Round 1	TRANSECT 3 Round 2
			PERCENT FINER (By Transect)					
Silt/Clay	Silt/Clay	<0.062	0%	0%	0%	0%	0%	0%
Sand	Sand	0.062 - 2.0	0%	0%	0%	1%	0%	0%
Gravel	Very Fine	2-4	19%	19%	6%	3%	1%	1%
	Fine	4-8	19%	19%	6%	4%	1%	1%
	Medium	8-16	29%	24%	13%	10%	6%	7%
	Coarse	16-32	41%	39%	37%	29%	29%	22%
	Very Coarse	32-64	66%	72%	73%	61%	66%	55%
Cobble	Small	64-128	89%	91%	94%	92%	92%	96%
	Large	128-256	100%	100%	100%	100%	100%	100%
Boulder	Small	256-512	100%	100%	100%	100%	100%	100%
	Medium	512-1024	100%	100%	100%	100%	100%	100%
	Large - Very Large	1024-4096	100%	100%	100%	100%	100%	100%
Bedrock	Bedrock	-	100%	100%	100%	100%	100%	100%

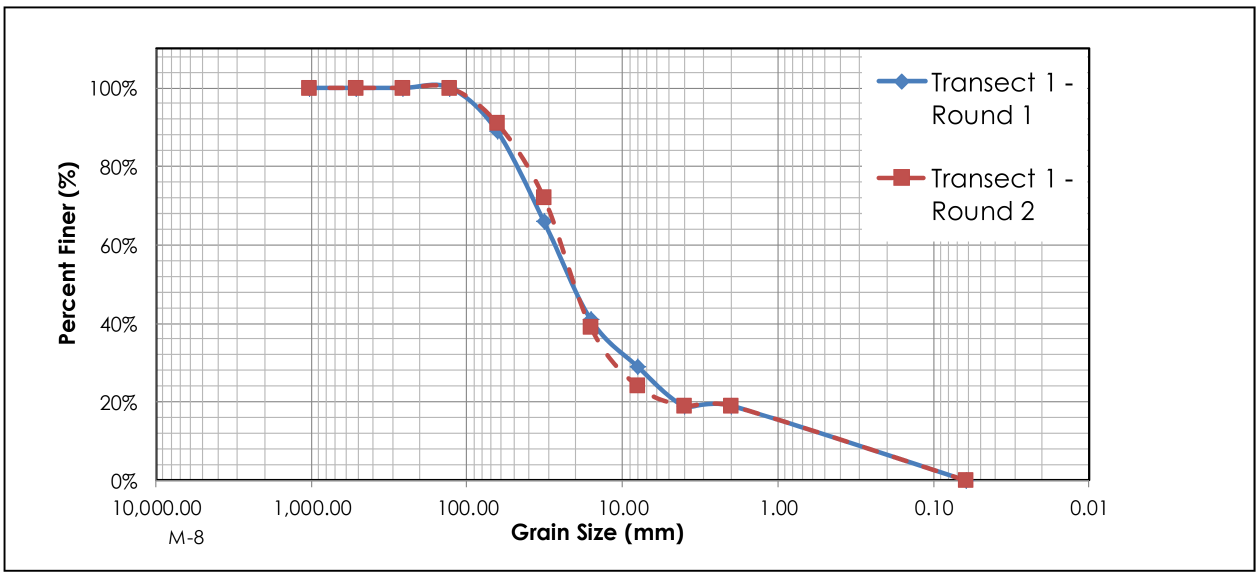

Figure D.5-1. Study site 08-M08 Transect 1 gradation curves.

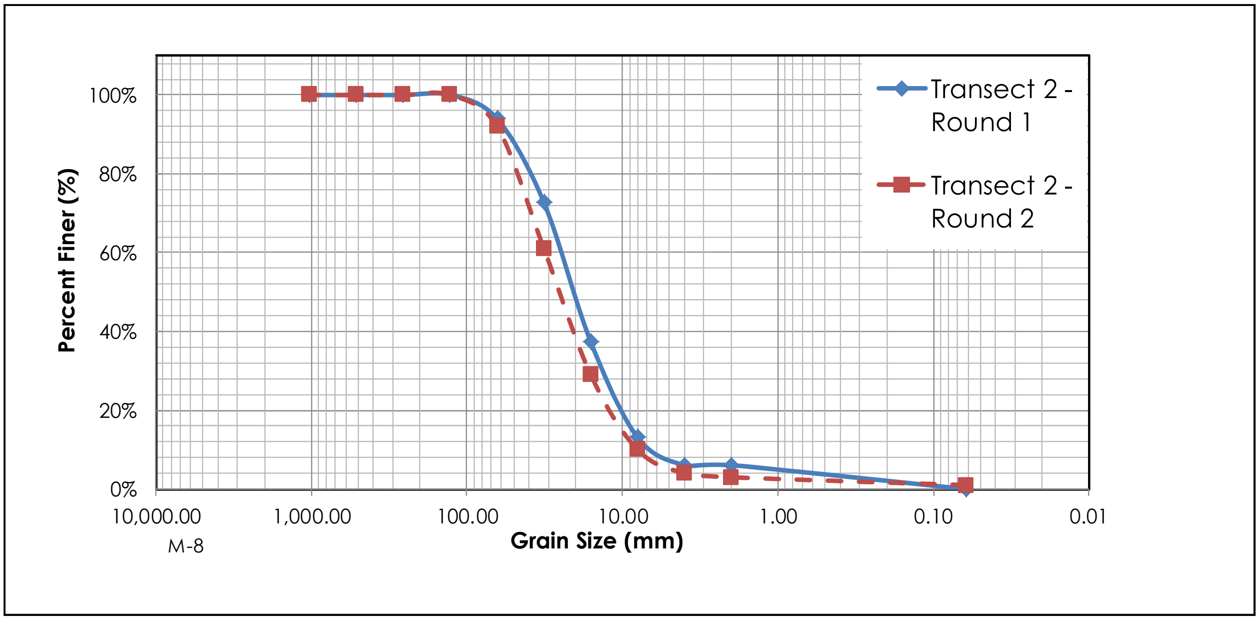

Figure D.5-2. Study site 08-M08 Transect 2 gradation curves.

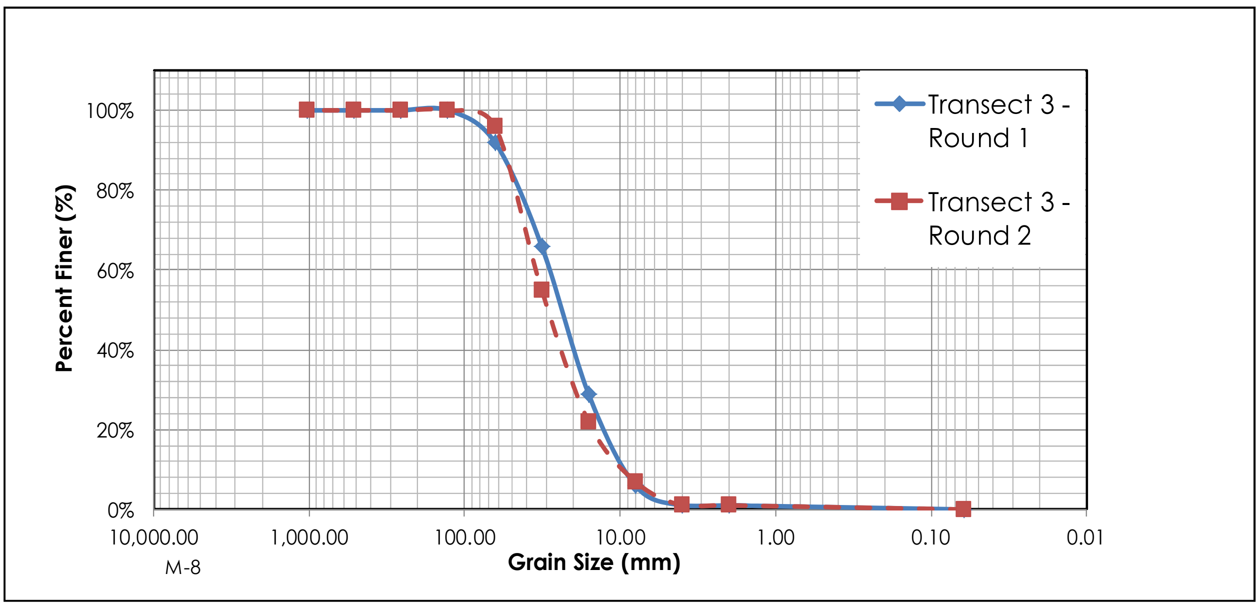

Figure D.5-3. Study site 08-M08 Transect 3 gradation curves.

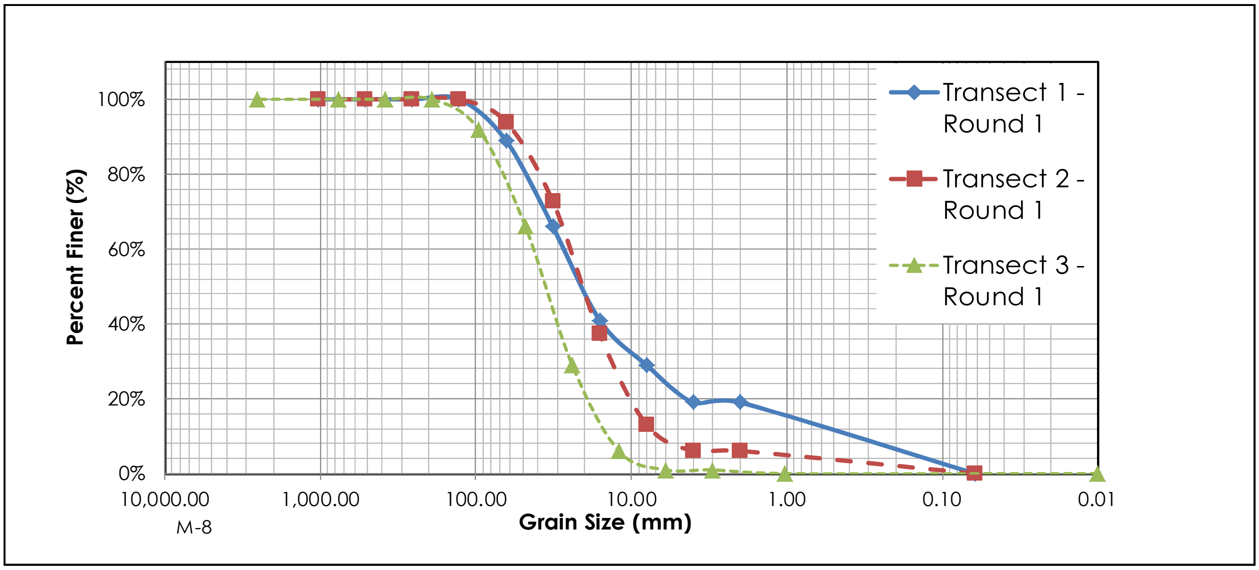

Figure D.5-4. Study site 08-M08 Transects 1, 2, and 3, Round 1 gradation curves.

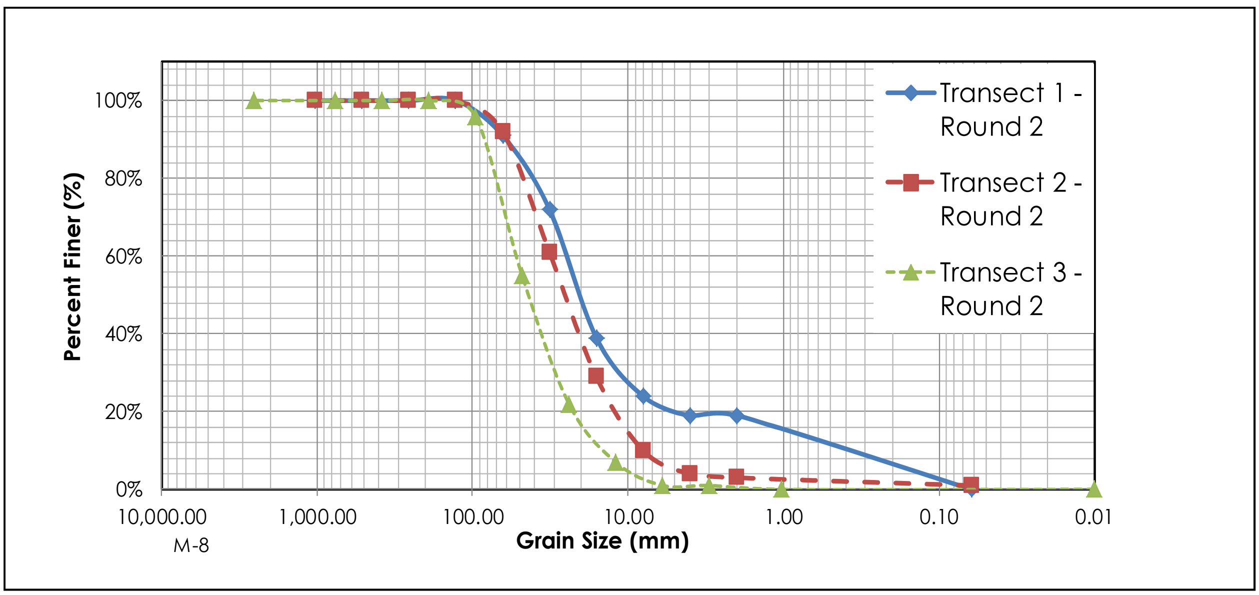

Figure D.5-5. Study site 08-M08 Transects 1, 2, and 3, Round 2 gradation curves.

Appendix D-6. Study Site 08-M10

Table D.6-1. Study site 08-M10 particle size distribution.

PERCENT FINER (By Transect)									
Wentworth Size Class		Size range (mm)	TRANSECT 1		TRANSECT 2		TRANSECT 3	
			Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%	0%	0%		
Sand	Sand	0.062 - 2.0	1%	4%	0%	0%		
Gravel	Very Fine	2-4	8%	4%	3%	5%		
	Fine	4-8	10%	4%	3%	5%		
	Medium	8-16	12%	6%	7%	7%		
	Coarse	16-32	26%	20%	22%	15%		
	Very Coarse	32-64	55%	51%	56%	51%		
Cobble	Small	64-128	92%	89%	84%	79%		
	Large	128-256	99%	99%	100%	99%		
Boulder	Small	256-512	100%	100%	100%	100%		
	Medium	512-1024	100%	100%	100%	100%		
	Large - Very Large	1024-4096	100%	100%	100%	100%		
Bedrock	Bedrock	-	100%	100%	100%	100%		

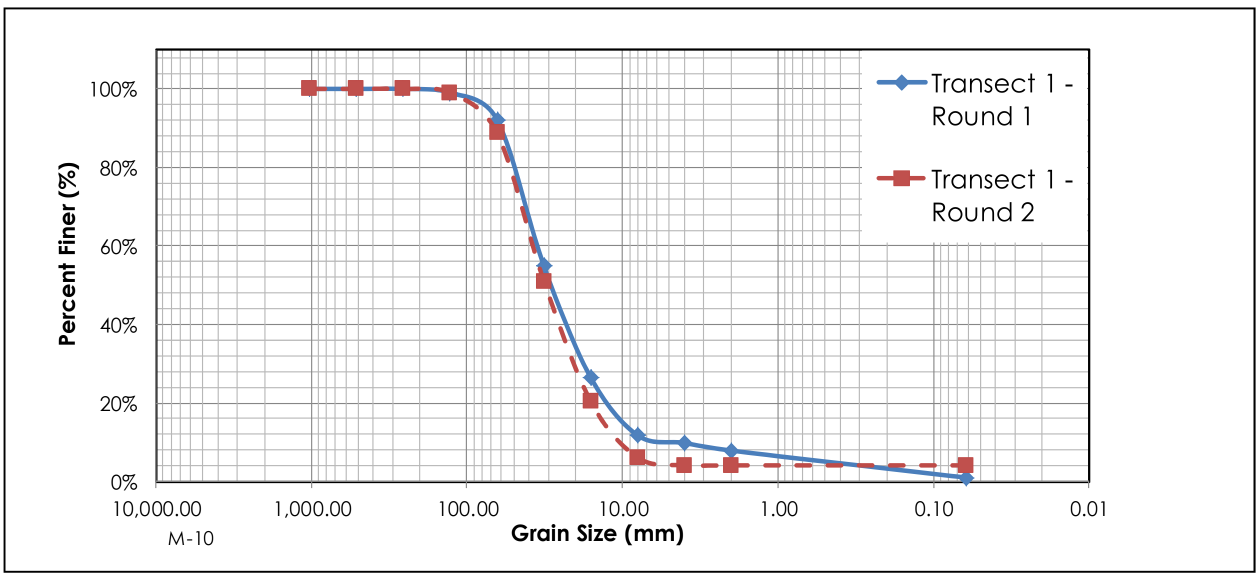

Figure D.6-1. Study site 08-M10 Transect 1 gradation curves.

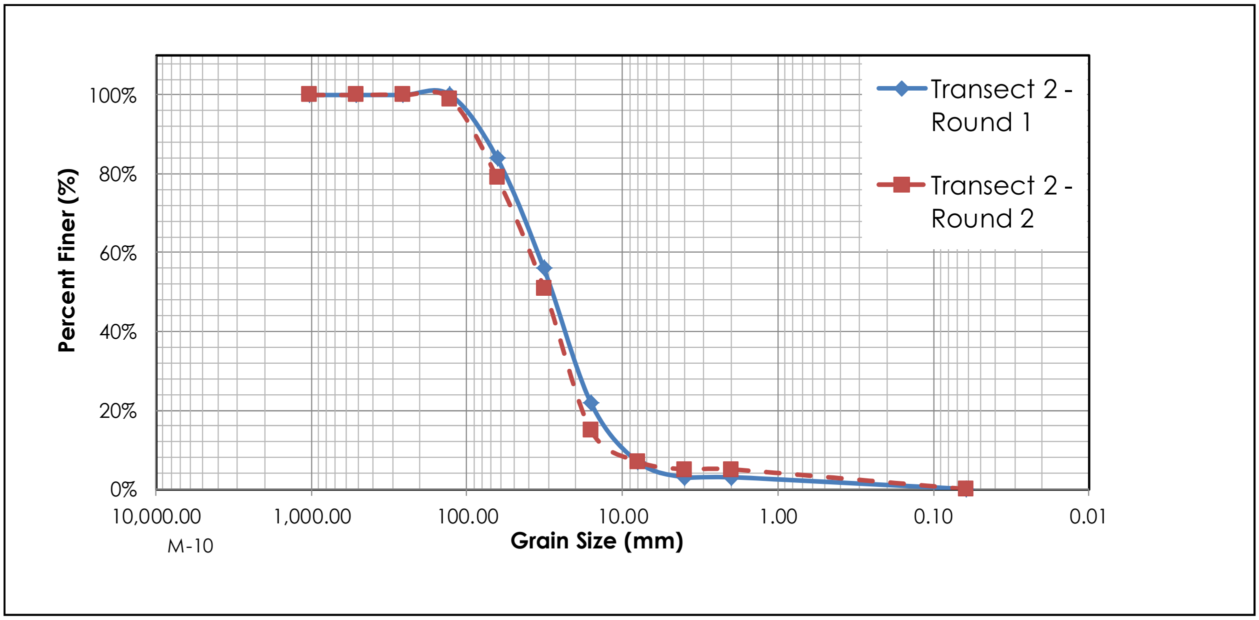

Figure D.6-2. Study site 08-M10 Transect 2 gradation curves.

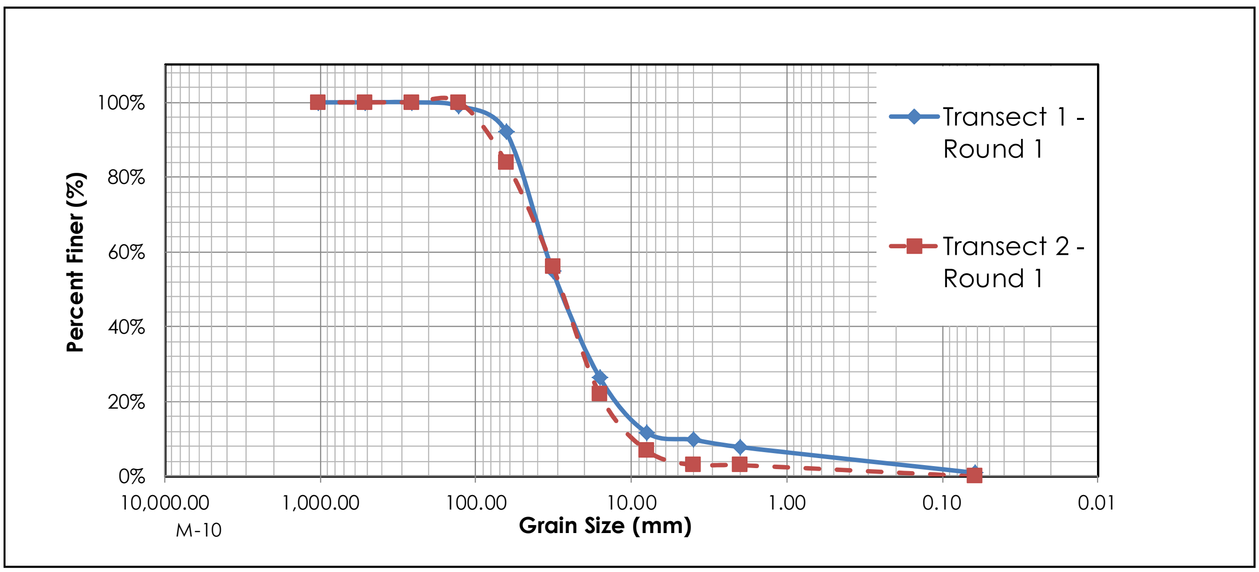

Figure D.6-3. Study site 08-M10 Transects 1 and 2, Round 1 gradation curves.

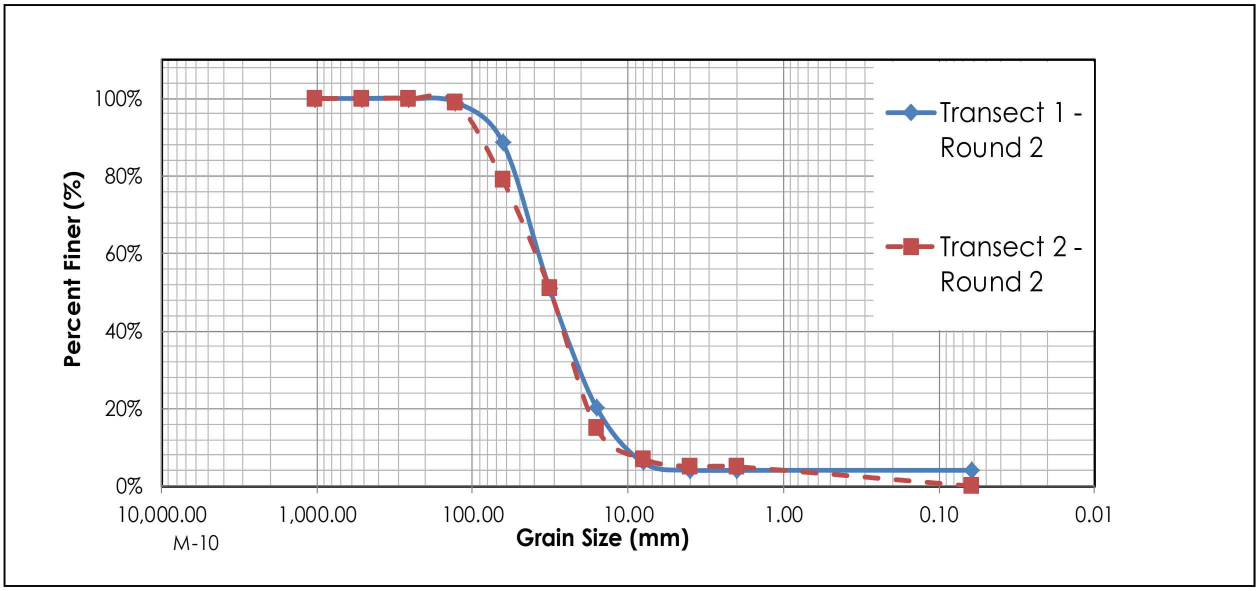

Figure D.6-4. Study site 08-M10 Transects 1 and 2, Round 2 gradation curves.

Appendix D-7. Study Site 08-M12

Table D.7-1. Study site 08-M12 particle size distribution.

Wentworth Size Class		Size range (mm)	PERCENT FINER (By Transect) TRANSECT 1 Round 1	TRANSECT 1 Round 2	TRANSECT 2 Round 1	TRANSECT 2 Round 2	TRANSECT 3 Round 1	TRANSECT 3 Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%	0%	0%	0%	0%
Sand	Sand	0.062 - 2.0	0%	6%	0%	0%	0%	0%
Gravel	Very Fine	2-4	8%	16%	22%	40%	15%	17%
	Fine	4-8	10%	18%	23%	40%	16%	17%
	Medium	8-16	16%	26%	33%	42%	22%	24%
	Coarse	16-32	30%	39%	48%	55%	42%	47%
	Very Coarse	32-64	69%	75%	74%	83%	73%	81%
Cobble	Small	64-128	93%	97%	99%	99%	97%	98%
	Large	128-256	100%	99%	100%	100%	100%	100%
Boulder	Small	256-512	100%	100%	100%	100%	100%	100%
	Medium	512-1024	100%	100%	100%	100%	100%	100%
	Large - Very Large	1024-4096	100%	100%	100%	100%	100%	100%
Bedrock	Bedrock	-	100%	100%	100%	100%	100%	100%

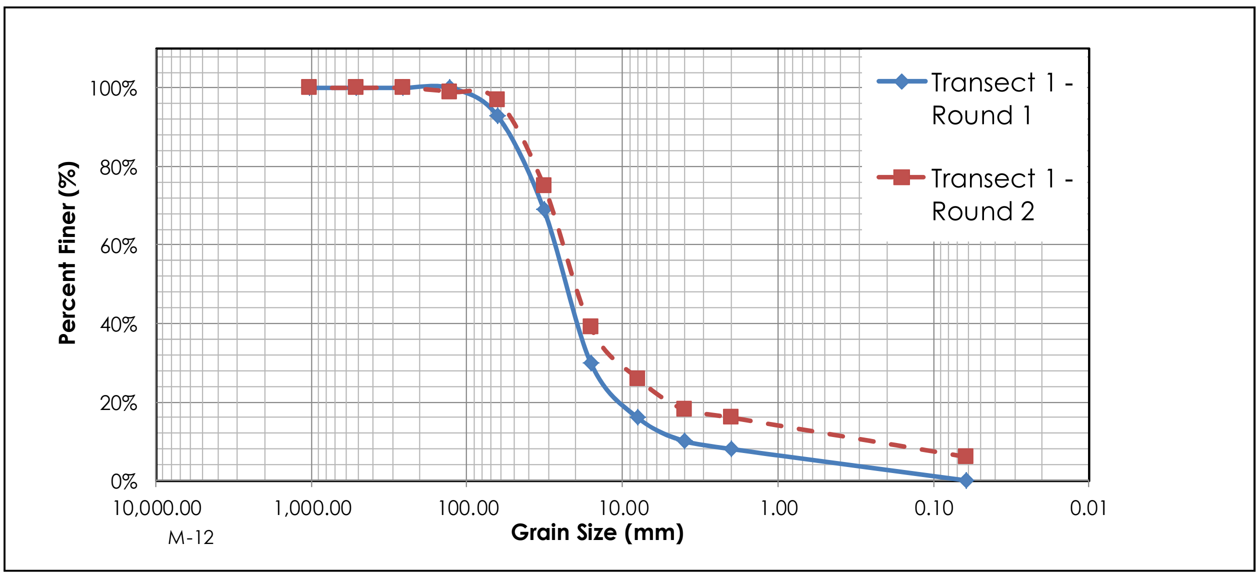

Figure D.7-1. Study site 08-M12 Transect 1 gradation curves.

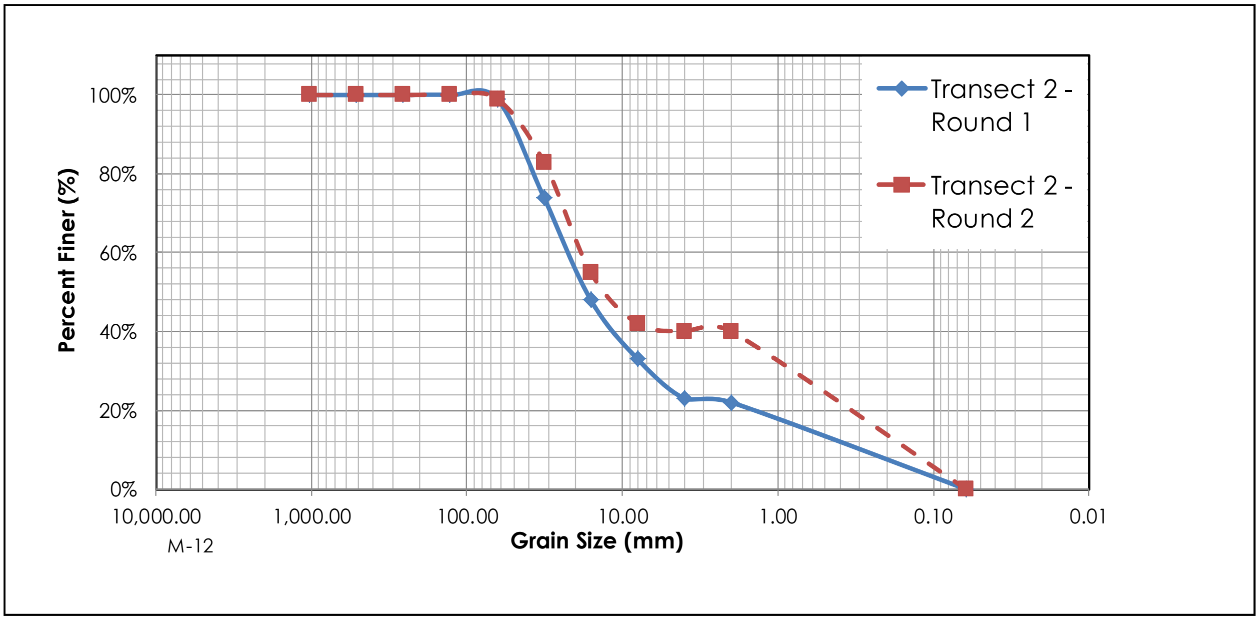

Figure D.7-2. Study site 08-M12 Transect 2 gradation curves.

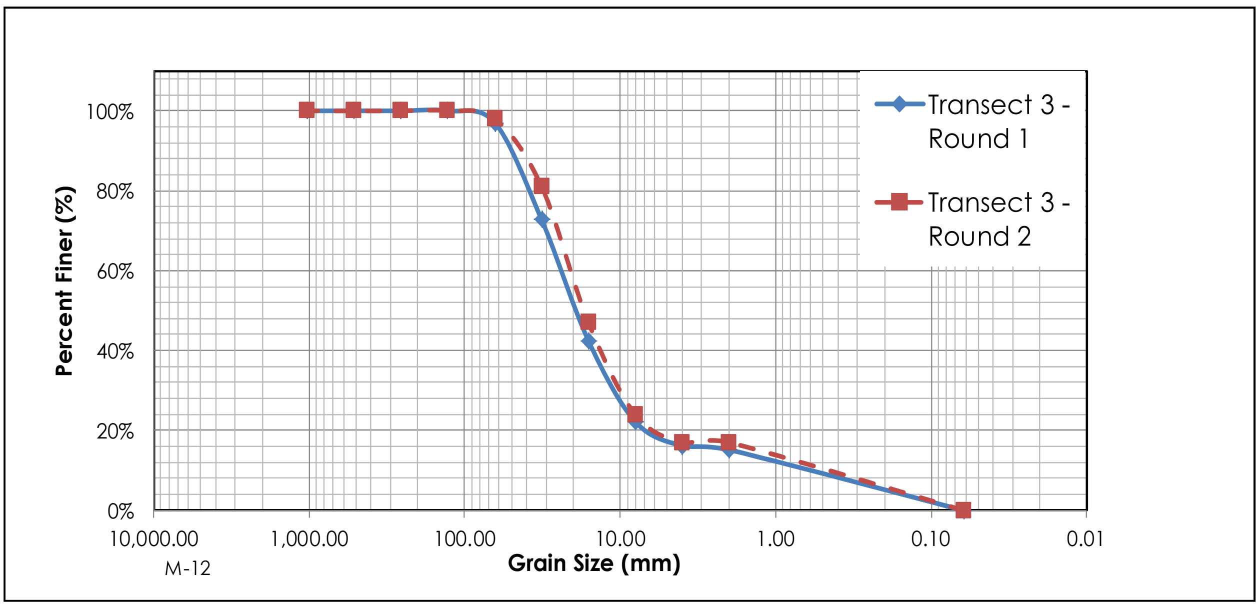

Figure D.7-3. Study site 08-M12 Transect 3 gradation curves.

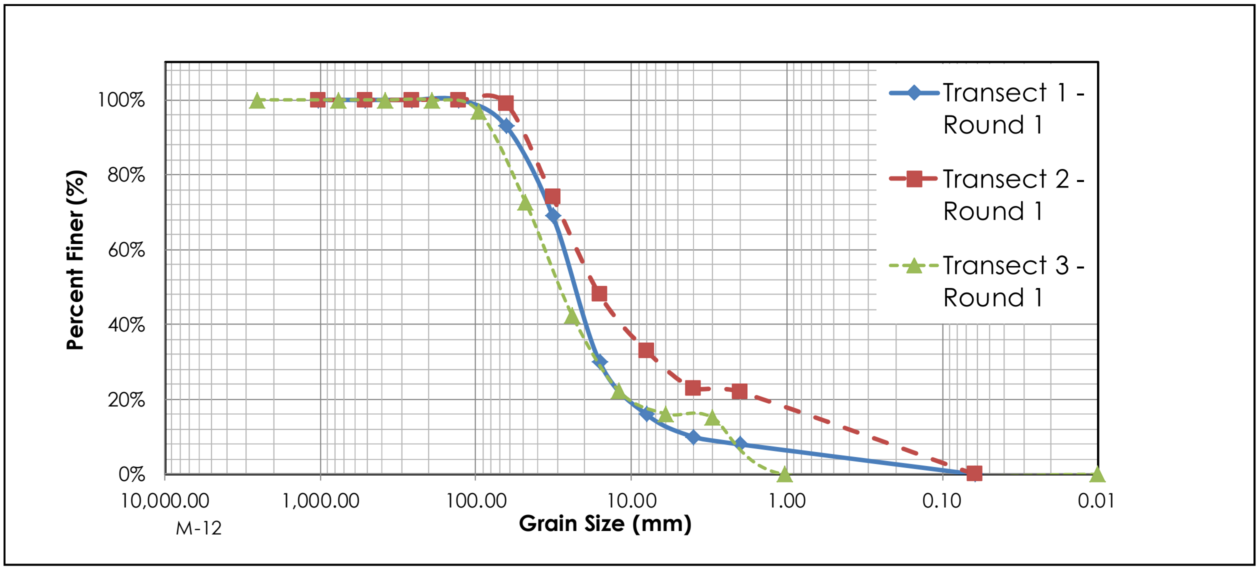

Figure D.7-4. Study site 08-M12 Transects 1, 2, and 3, Round 1 gradation curves.

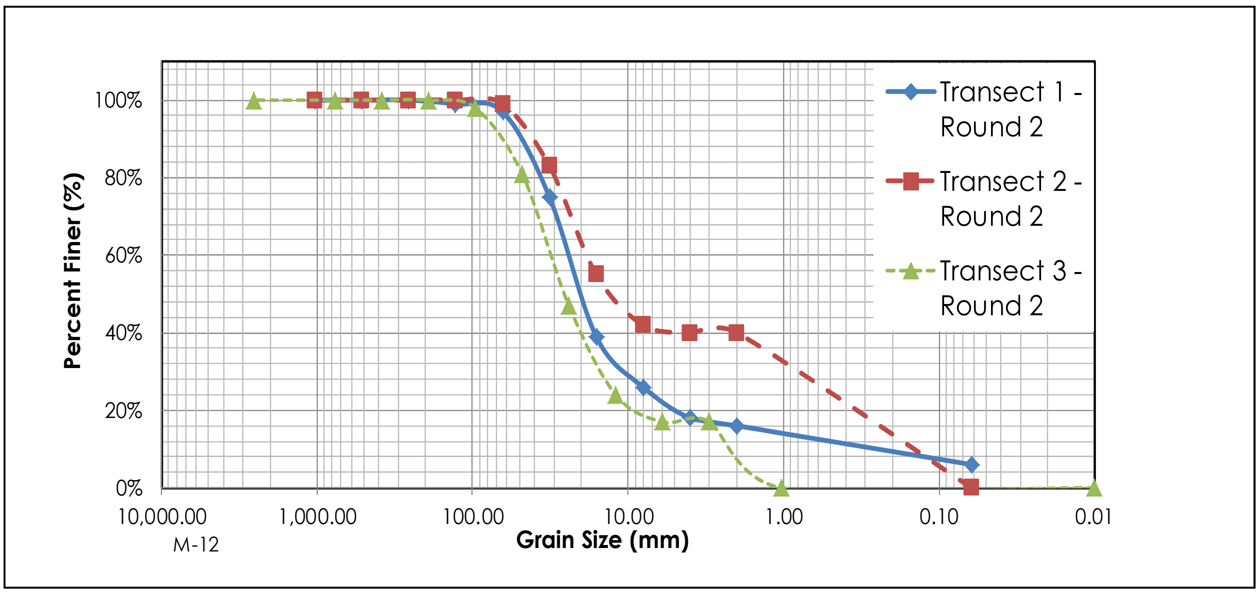

Figure D.7-5. Study site 08-M12 Transects 1, 2, and 3, Round 2 gradation curves.

Appendix D-8. Study Site 08-M13

Table D.8-1. Study site 08-M13 particle size distribution.

PERCENT FINER (By Transect)									
Wentworth Size Class		Size range (mm)	TRANSECT 1		TRANSECT 2		TRANSECT 3	
			Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%	0%	0%		
Sand	Sand	0.062 - 2.0	0%	0%	0%	0%		
Gravel	Very Fine	2-4	18%	2%	12%	9%		
	Fine	4-8	18%	2%	12%	11%		
	Medium	8-16	19%	7%	18%	17%		
	Coarse	16-32	34%	19%	35%	35%		
	Very Coarse	32-64	71%	61%	77%	78%		
Cobble	Small	64-128	91%	91%	98%	98%		
	Large	128-256	100%	100%	100%	100%		
Boulder	Small	256-512	100%	100%	100%	100%		
	Medium	512-1024	100%	100%	100%	100%		
	Large - Very Large	1024-4096	100%	100%	100%	100%		
Bedrock	Bedrock	-	100%	100%	100%	100%		

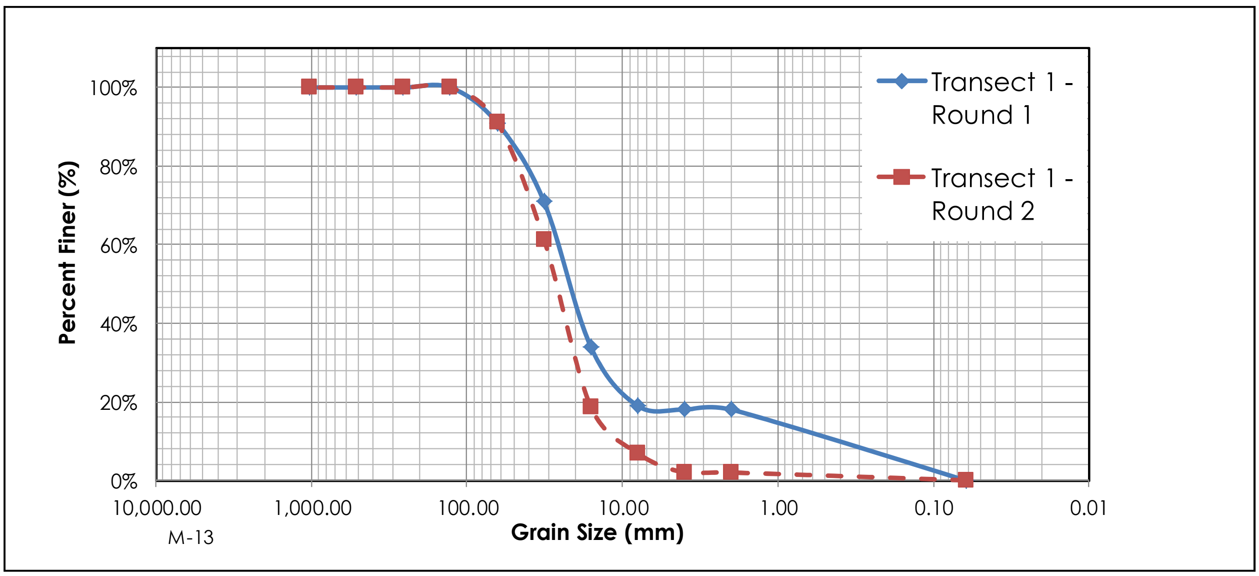

Figure D.8-1. Study site 08-M13 Transect 1 gradation curves.

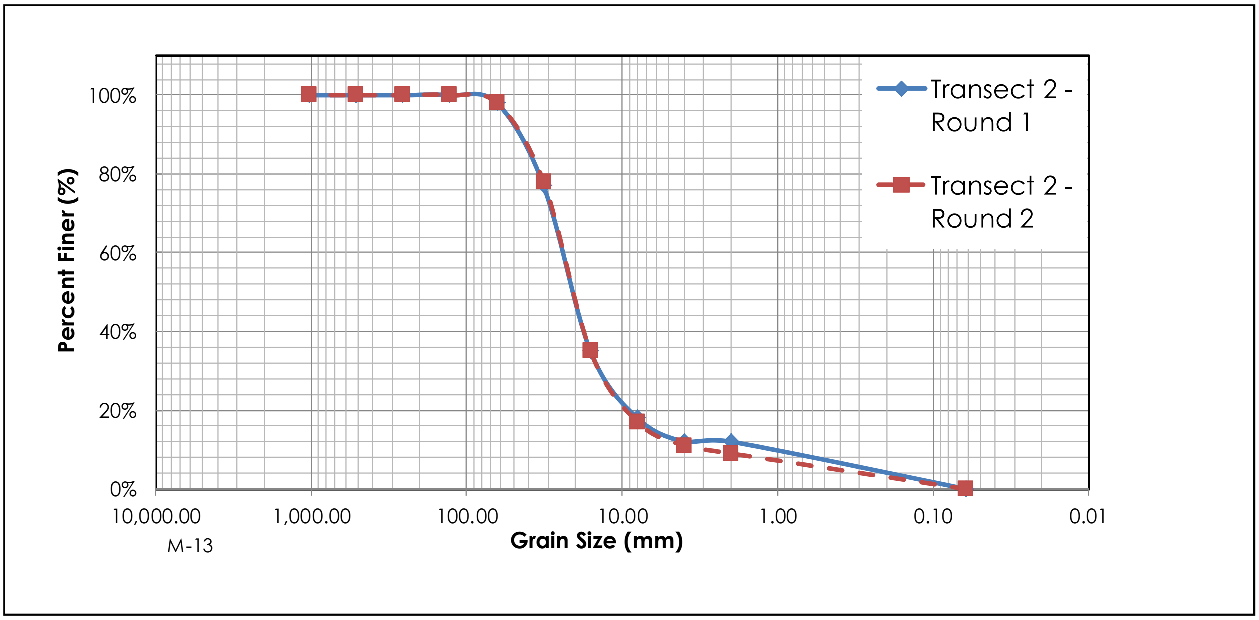

Figure D.8-2. Study site 08-M13 Transect 2 gradation curves.

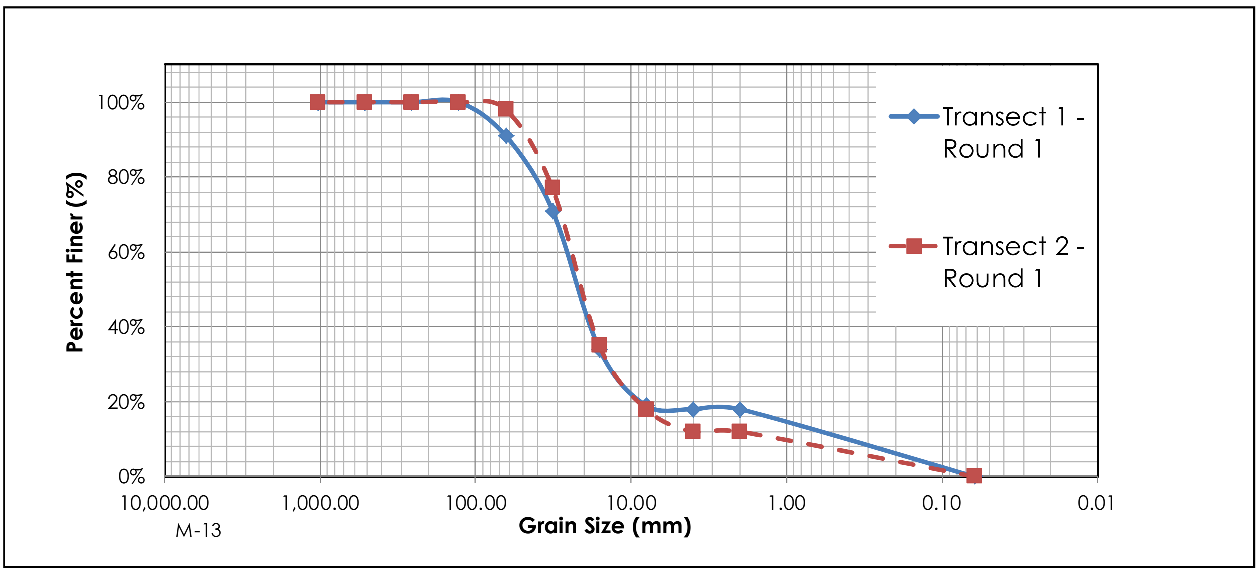

Figure D.8-3. Study site 08-M13 Transects 1 and 2, Round 1 gradation curves.

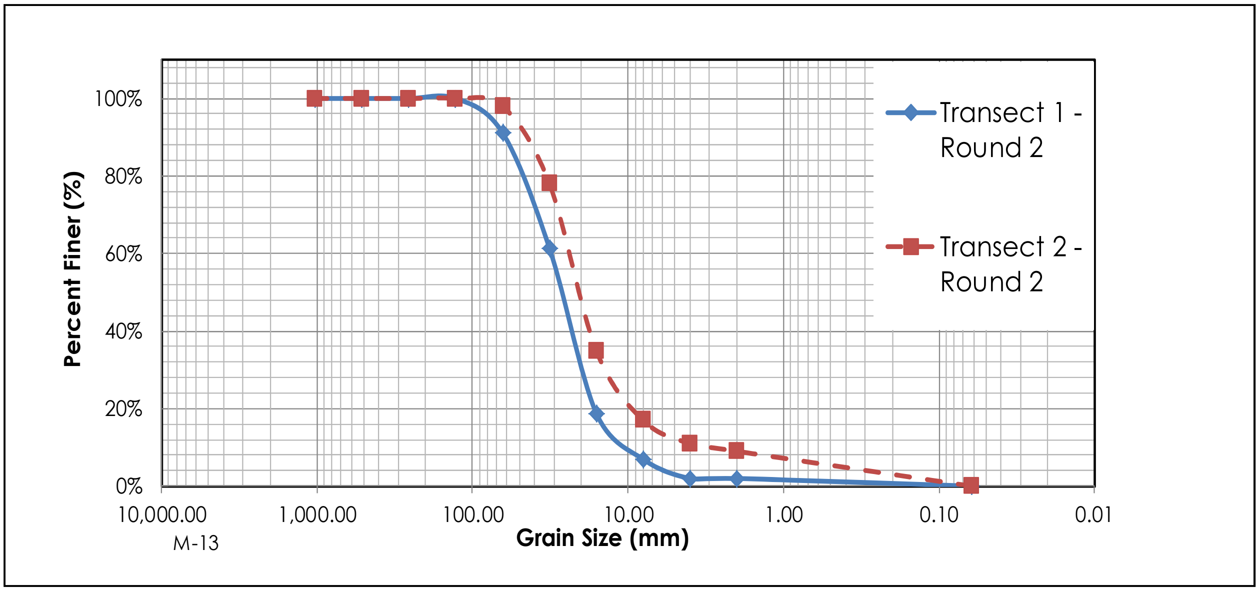

Figure D.8-4. Study site 08-M13 Transects 1 and 2, Round 2 gradation curves.

Appendix D-9. Study Site 08-M15

Table D.9-1. Study site 08-M15 particle size distribution.

PERCENT FINER (By Transect)								
Wentworth Size Class		Size range (mm)	TRANSECT 1		TRANSECT 2		TRANSECT 3	
			Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%				
Sand	Sand	0.062 - 2.0	0%	0%				
Gravel	Very Fine	2-4	100%	100%				
	Fine	4-8	100%	100%				
	Medium	8-16	100%	100%				
	Coarse	16-32	100%	100%				
	Very Coarse	32-64	100%	100%				
Cobble	Small	64-128	100%	100%				
	Large	128-256	100%	100%				
Boulder	Small	256-512	100%	100%				
	Medium	512-1024	100%	100%				
	Large - Very Large	1024-4096	100%	100%				
Bedrock	Bedrock	-	100%	100%				

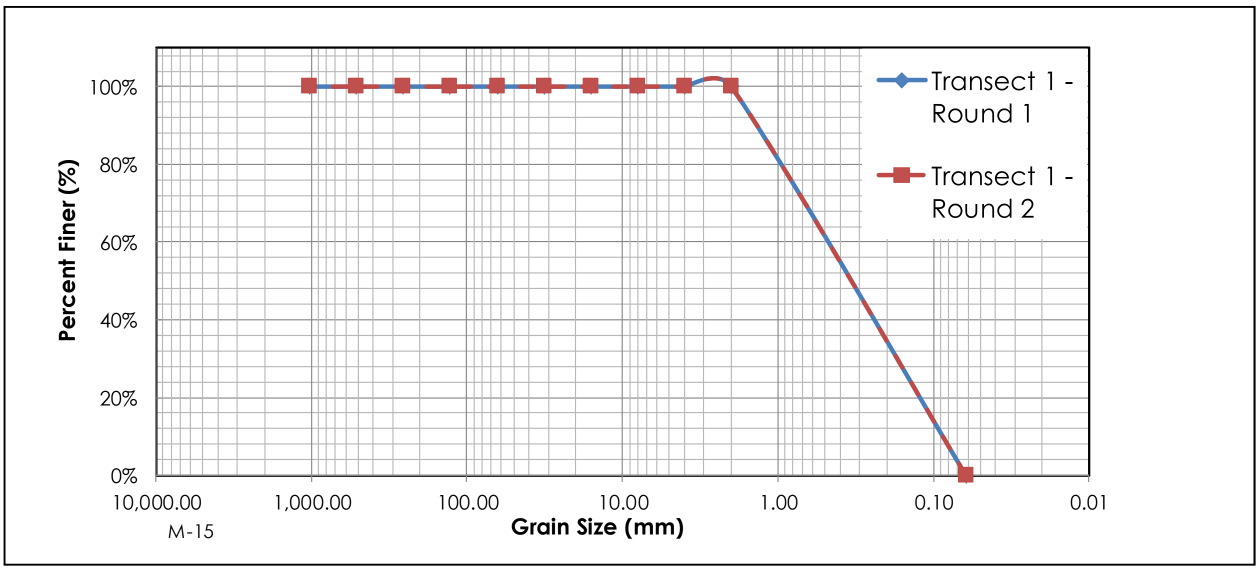

Figure D.9-1. Study site 08-M15 Transect 1 gradation curves.

Appendix D-10. Study Site 08-M16

Table D.10-1. Study site 08-M16 particle size distribution.

Wentworth Size Class		Size range (mm)	PERCENT FINER (By Transect) TRANSECT 1 Round 1	TRANSECT 1 Round 2	TRANSECT 2 Round 1	TRANSECT 2 Round 2	TRANSECT 3 Round 1	TRANSECT 3 Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%	0%	0%		
Sand	Sand	0.062 - 2.0	0%	0%	0%	0%		
Gravel	Very Fine	2-4	10%	9%	15%	35%		
	Fine	4-8	10%	9%	15%	35%		
	Medium	8-16	10%	9%	15%	35%		
	Coarse	16-32	14%	10%	17%	35%		
	Very Coarse	32-64	34%	24%	29%	36%		
Cobble	Small	64-128	69%	54%	63%	53%		
	Large	128-256	91%	93%	99%	94%		
Boulder	Small	256-512	100%	100%	100%	100%		
	Medium	512-1024	100%	100%	100%	100%		
	Large - Very Large	1024-4096	100%	100%	100%	100%		
Bedrock	Bedrock	-	100%	100%	100%	100%		

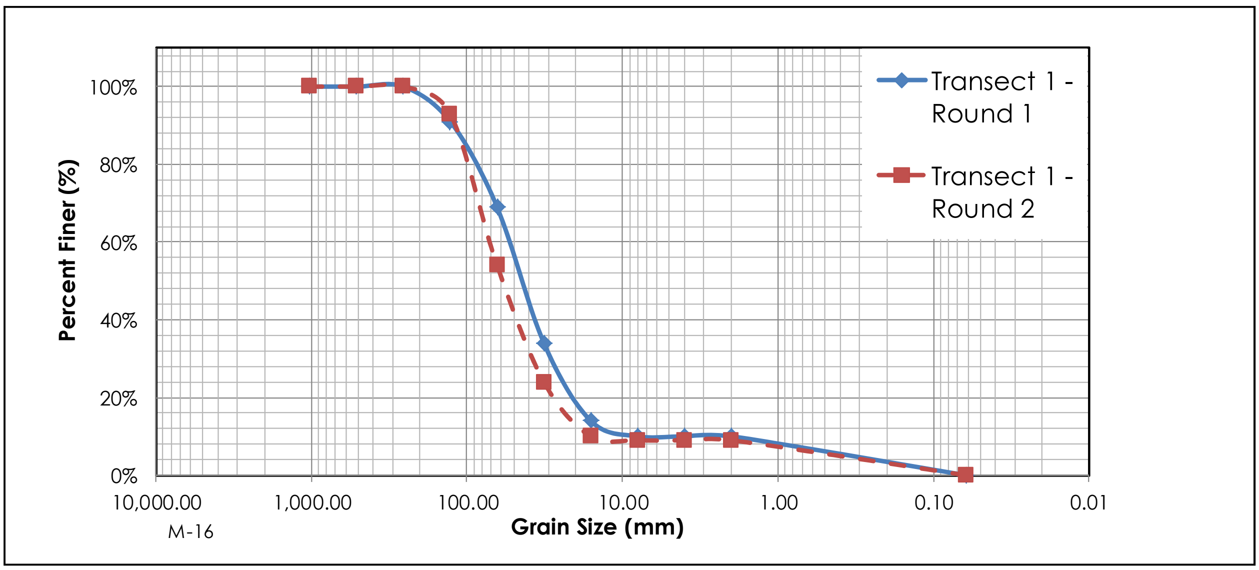

Figure D.10-1. Study site 08-M16 Transect 1 gradation curves.

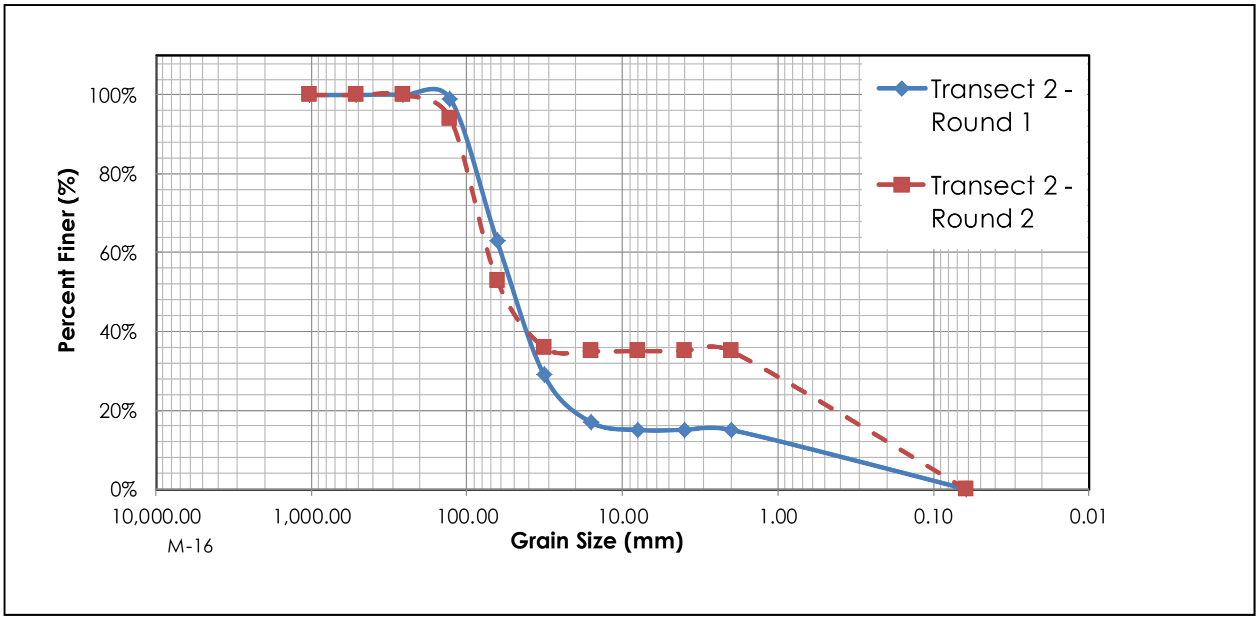

Figure D.10-2. Study site 08-M16 Transect 2 gradation curves.

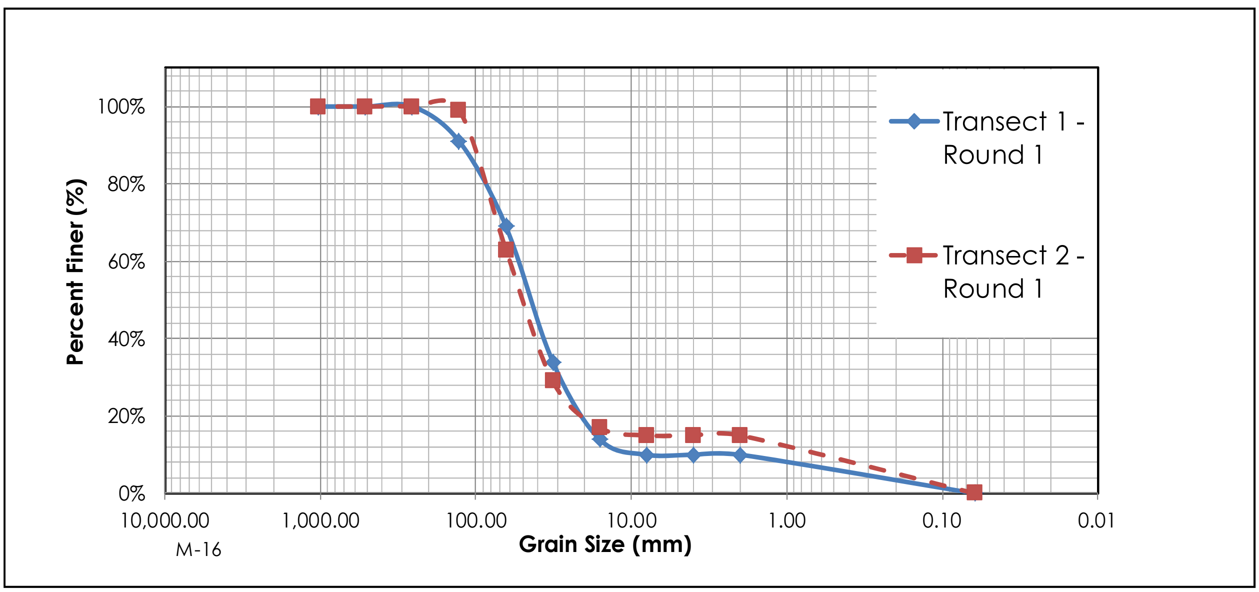

Figure D.10-3. Study site 08-M16 Transects 1 and 2, Round 1 gradation curves.

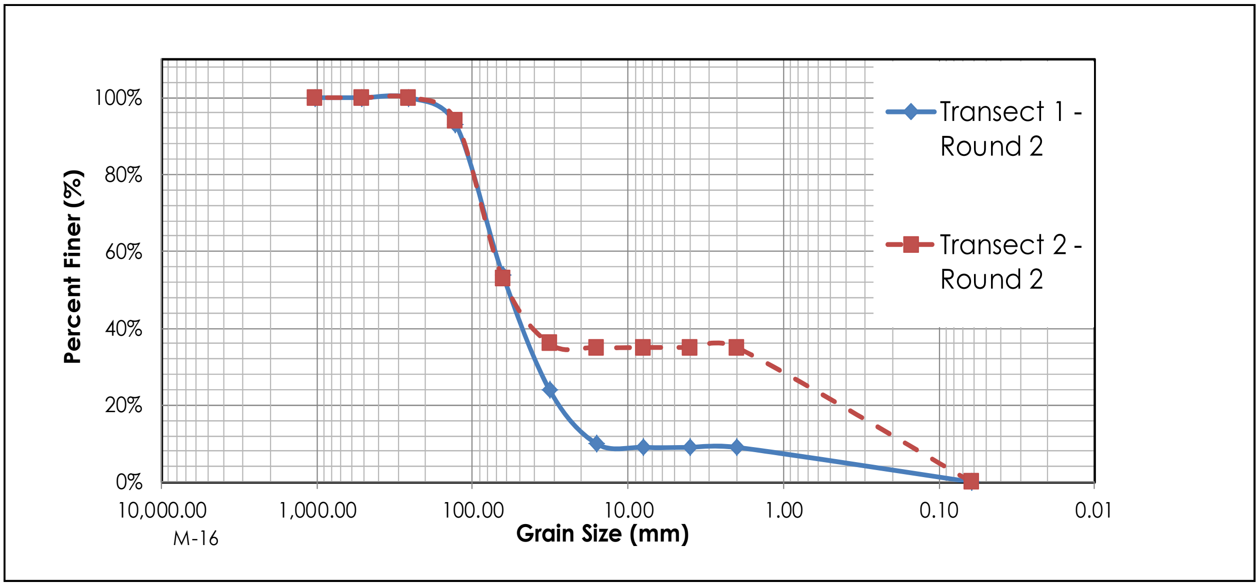

Figure D.10-4. Study site 08-M16 Transects 1 and 2, Round 2 gradation curves.

Appendix D-11. Study Site 08-M17

Table D.11-1. Study site 08-M17 particle size distribution.

PERCENT FINER (By Transect)									
Wentworth Size Class		Size range (mm)	TRANSECT 1		TRANSECT 2		TRANSECT 3	
			Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%				
Sand	Sand	0.062 - 2.0	1%	0%				
Gravel	Very Fine	2-4	6%	2%				
	Fine	4-8	6%	3%				
	Medium	8-16	9%	5%				
	Coarse	16-32	18%	14%				
	Very Coarse	32-64	58%	47%				
Cobble	Small	64-128	94%	97%				
	Large	128-256	100%	100%				
Boulder	Small	256-512	100%	100%				
	Medium	512-1024	100%	100%				
	Large - Very Large	1024-4096	100%	100%				
Bedrock	Bedrock	-	100%	100%				

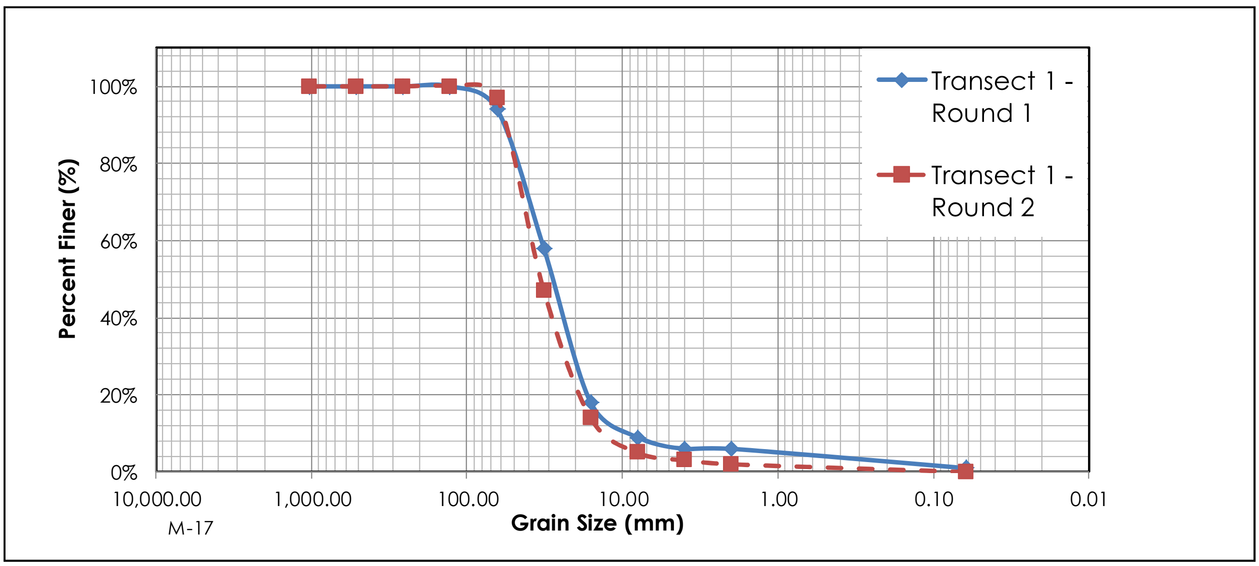

Figure D.11-1. Study site 08-M17 Transect 1 gradation curves.

Appendix D-12. Study Site 08-M20

Table D.12-1. Study site 08-M20 particle size distribution.

PERCENT FINER (By Transect)									
Wentworth Size Class		Size range (mm)	TRANSECT 1		TRANSECT 2		TRANSECT 3	
			Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%	0%	0%	0%	0%
Sand	Sand	0.062 - 2.0	1%	0%	7%	0%	0%	0%
Gravel	Very Fine	2-4	3%	1%	11%	28%	5%	2%
	Fine	4-8	3%	1%	11%	28%	5%	4%
	Medium	8-16	6%	5%	11%	29%	5%	14%
	Coarse	16-32	17%	13%	19%	32%	16%	30%
	Very Coarse	32-64	46%	30%	49%	49%	61%	54%
Cobble	Small	64-128	91%	81%	87%	84%	100%	97%
	Large	128-256	100%	99%	99%	100%	100%	100%
Boulder	Small	256-512	100%	100%	100%	100%	100%	100%
	Medium	512-1024	100%	100%	100%	100%	100%	100%
	Large - Very Large	1024-4096	100%	100%	100%	100%	100%	100%
Bedrock	Bedrock	-	100%	100%	100%	100%	100%	100%

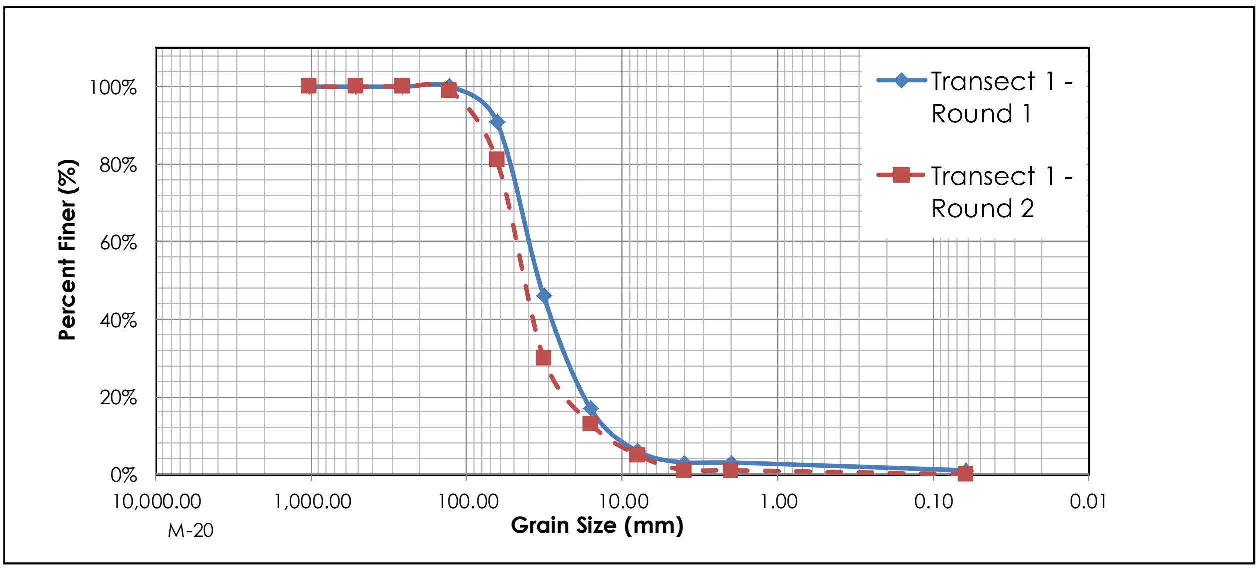

Figure D.12-1. Study site 08-M20 Transect 1 gradation curves.

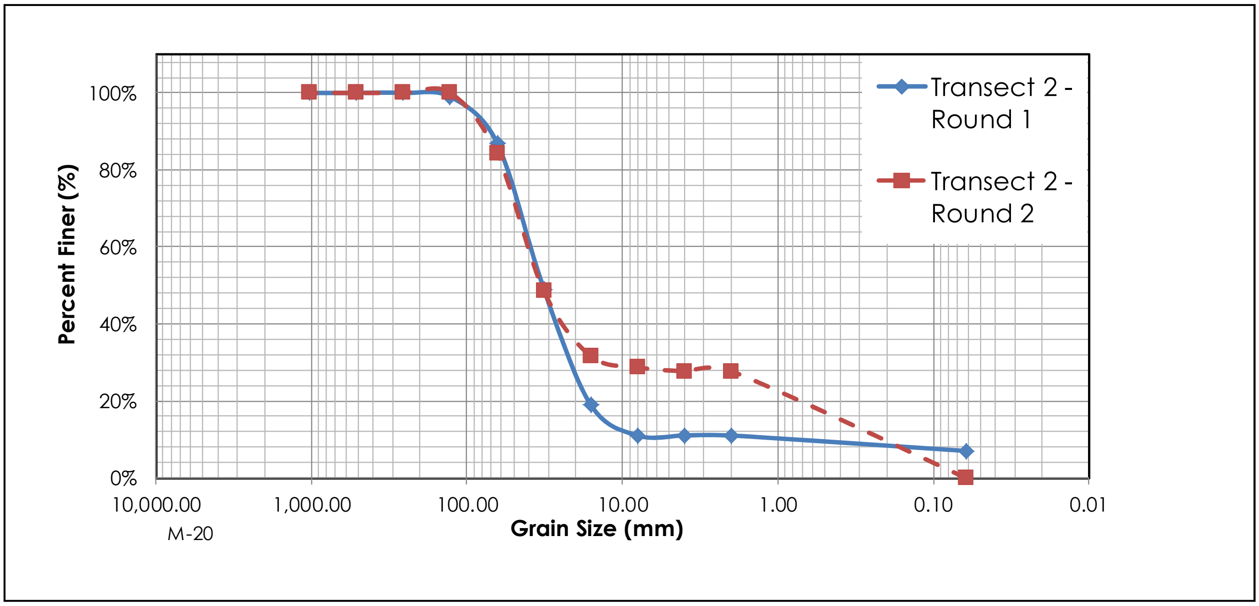

Figure D.12-2. Study site 08-M20 Transect 2 gradation curves.

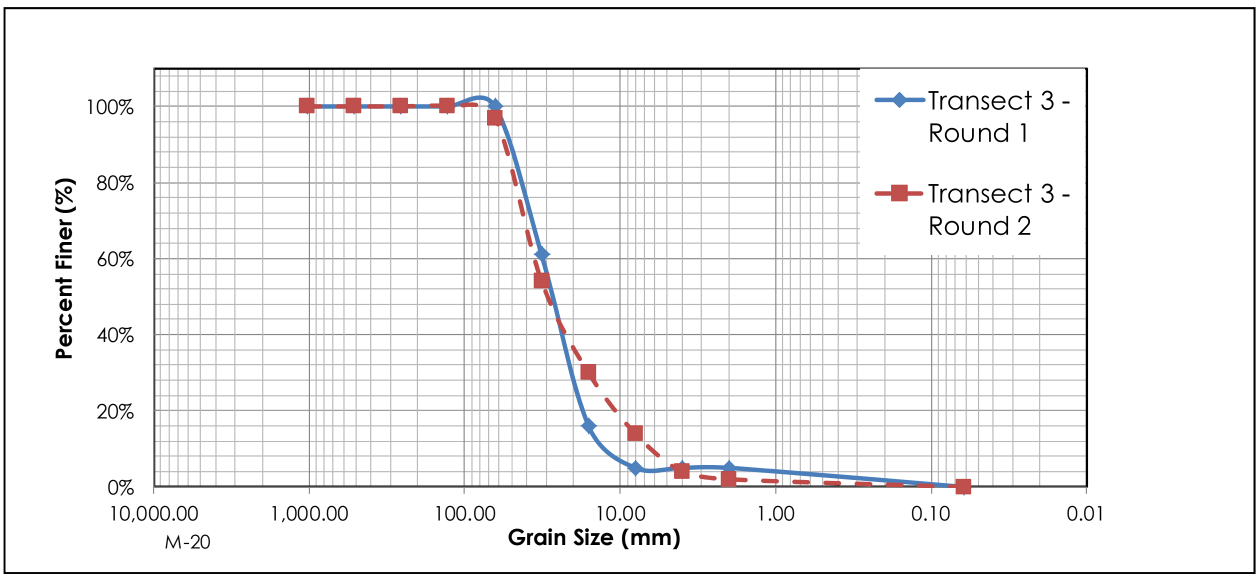

Figure D.12-3. Study site 08-M20 Transect 3 gradation curves.

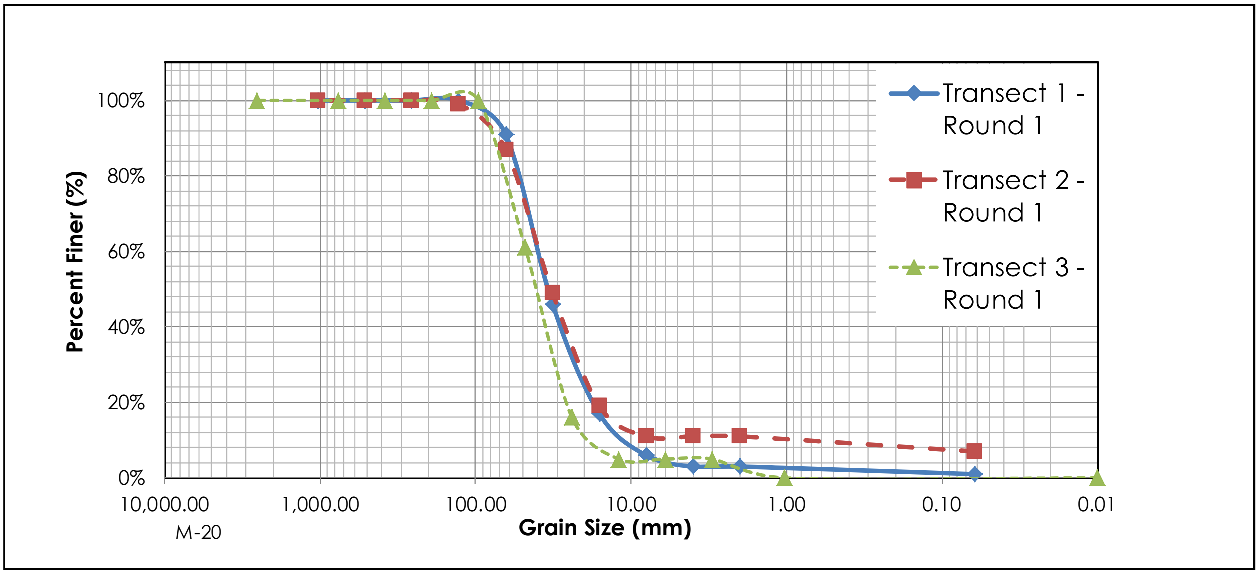

Figure D.12-4. Study site 08-M20 Transects 1, 2, and 3, Round 1 gradation curves.

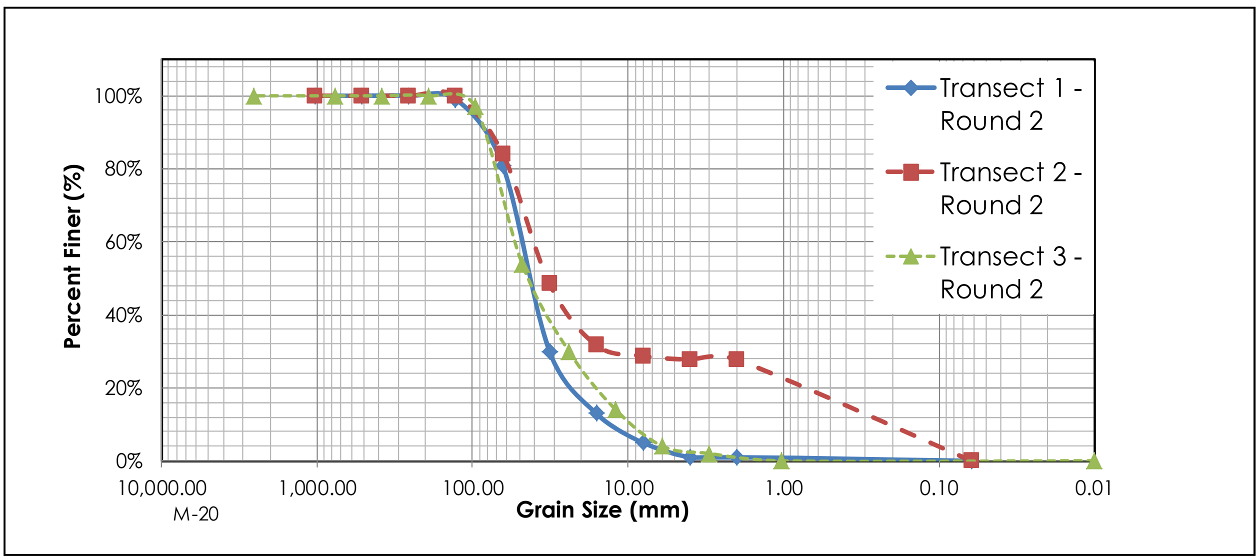

Figure D.12-5. Study site 08-M20 Transects 1, 2, and 3, Round 2 gradation curves.

Appendix D-13. Study Site 08-T01

Table D.13-1. Study site 08-T01 particle size distribution.

PERCENT FINER (By Transect)									
Wentworth Size Class		Size range (mm)	TRANSECT 1		TRANSECT 2		TRANSECT 3		
			Round 1	Round 2	Round 1	Round 2	Round 1	Round 2	
Silt/Clay	Silt/Clay	<0.062	0%	0%	0%	0%	0%	0%	
Sand	Sand	0.062 - 2.0	100%	100%	11%	28%	18%	6%	
Gravel	Very Fine	2-4	100%	100%	23%	73%	61%	64%	
	Fine	4-8	100%	100%	54%	75%	65%	67%	
	Medium	8-16	100%	100%	93%	92%	78%	90%	
	Coarse	16-32	100%	100%	100%	100%	97%	99%	
	Very Coarse	32-64	100%	100%	100%	100%	100%	100%	
Cobble	Small	64-128	100%	100%	100%	100%	100%	100%	
	Large	128-256	100%	100%	100%	100%	100%	100%	
Boulder	Small	256-512	100%	100%	100%	100%	100%	100%	
	Medium	512-1024	100%	100%	100%	100%	100%	100%	
	Large - Very Large	1024-4096	100%	100%	100%	100%	100%	100%	
Bedrock	Bedrock	-	100%	100%	100%	100%	100%	100%	

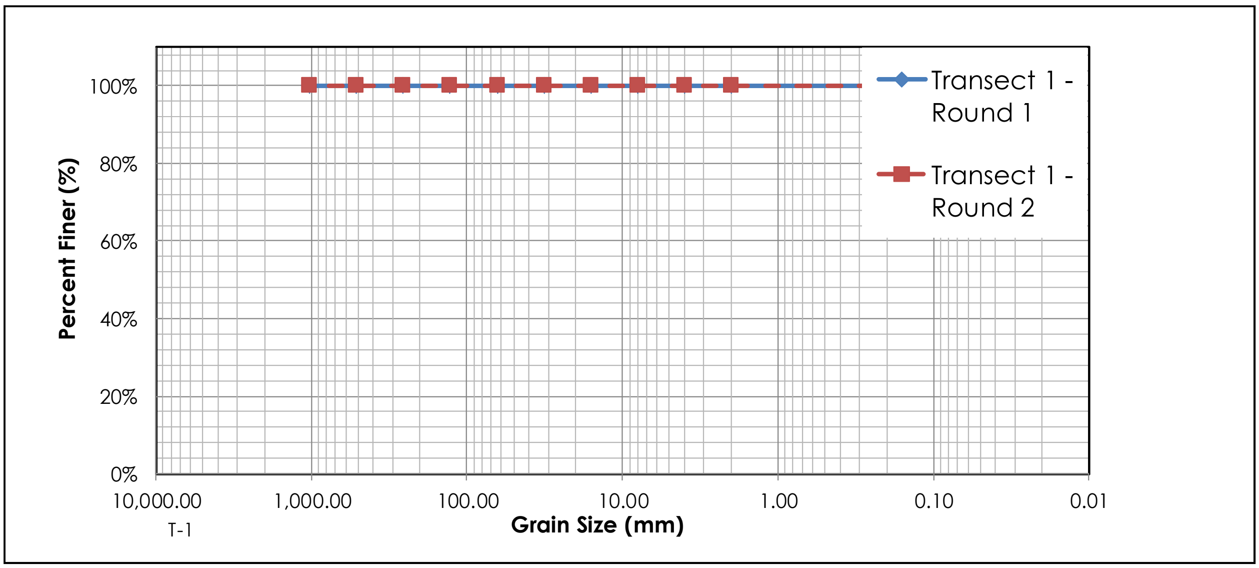

Figure D.13-1. Study site 08-T01 Transect 1 gradation curves.

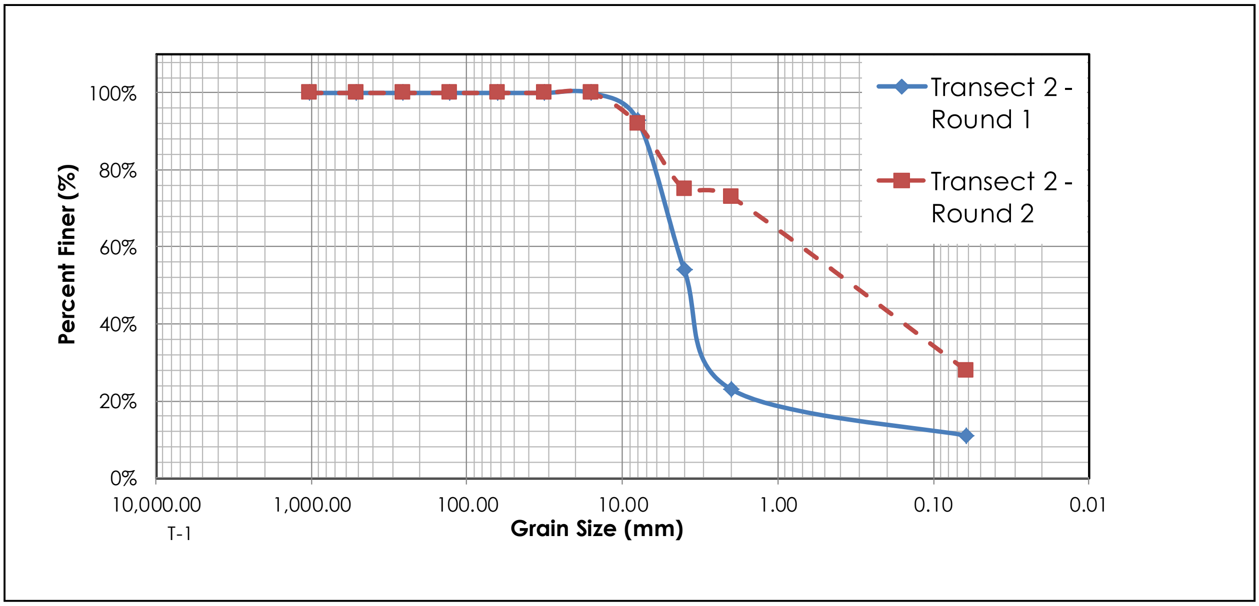

Figure D.13-2. Study site 08-T01 Transect 2 gradation curves.

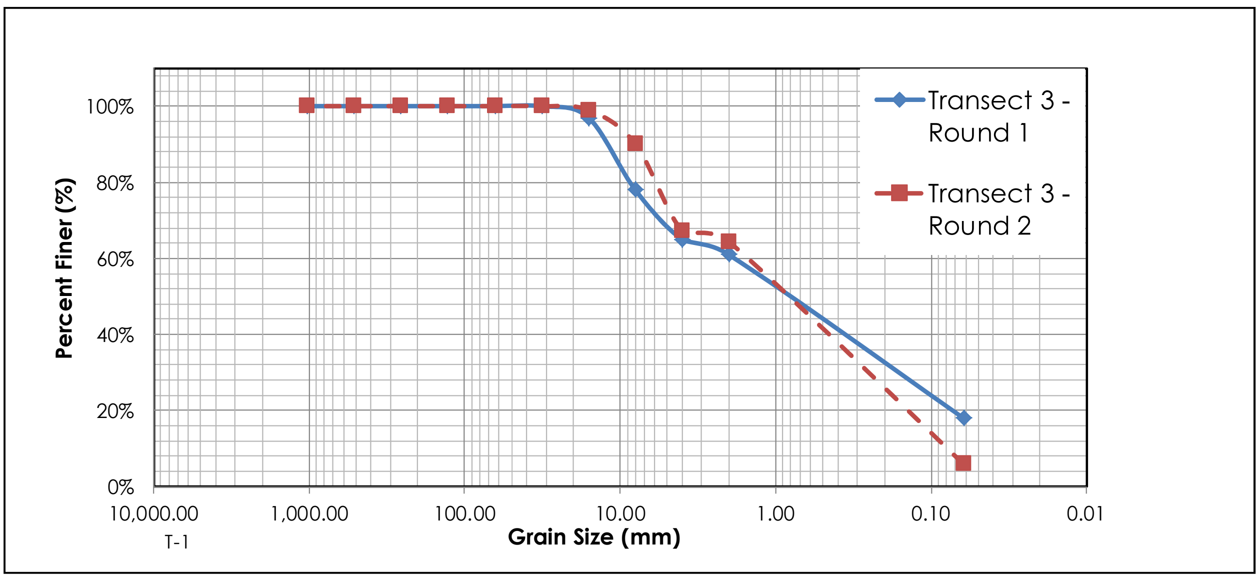

Figure D.13-3. Study site 08-T01 Transect 3 gradation curves.

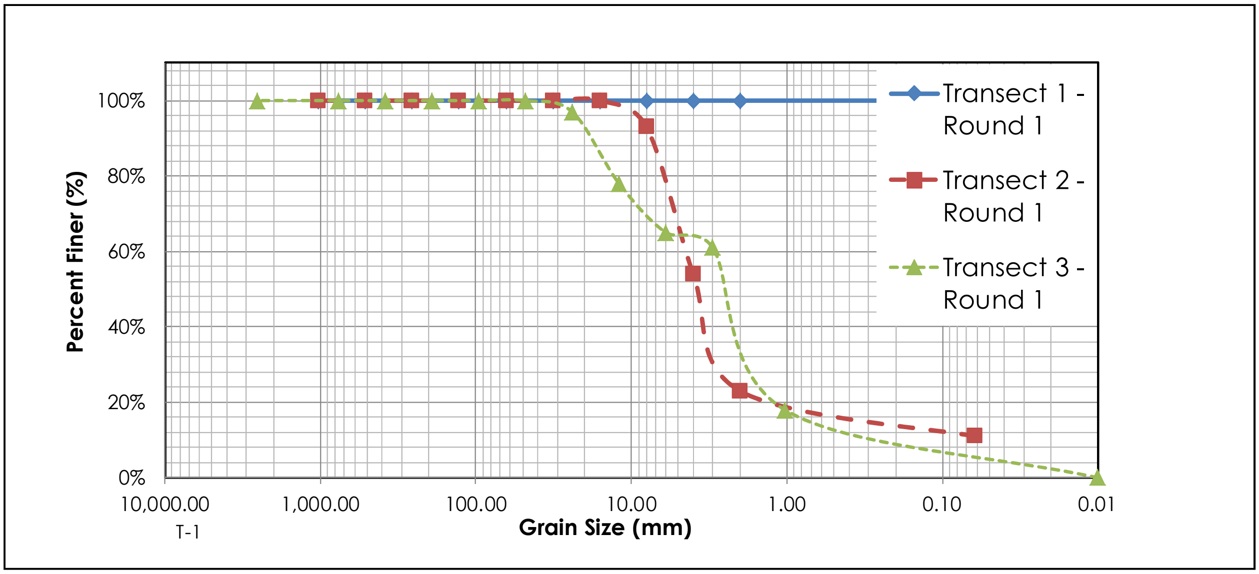

Figure D.13-4. Study site 08-T01 Transects 1, 2, and 3, Round 1 gradation curves.

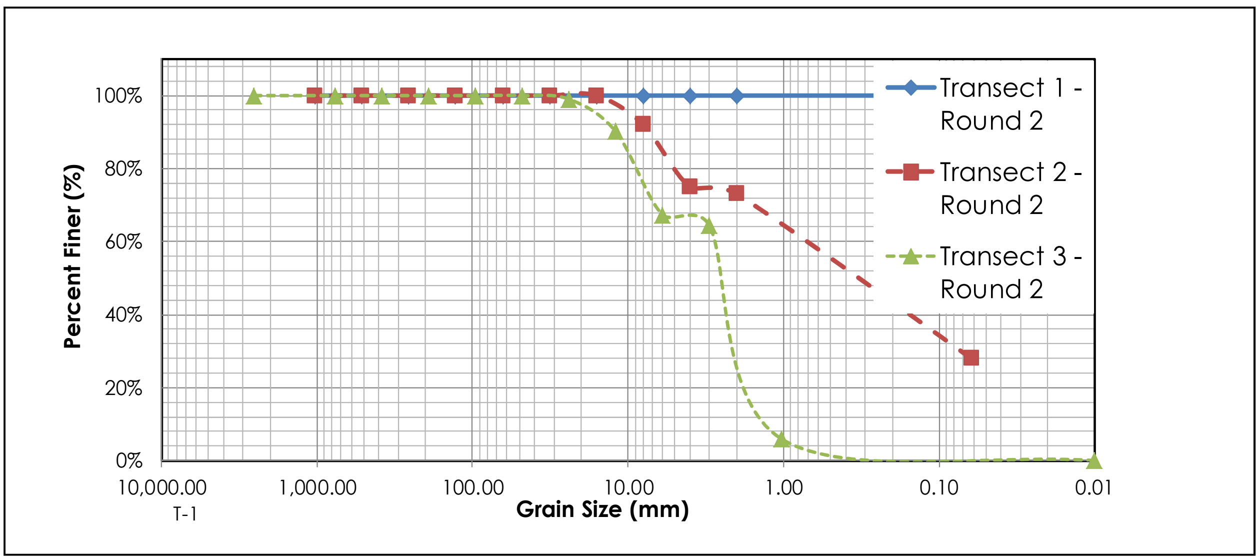

Figure D.13-5. Study site 08-T01 Transects 1, 2, and 3, Round 2 gradation curves.

Appendix D-14. Study Site 08-T02

Table D.14-1. Study site 08-T02 particle size distribution.

PERCENT FINER (By Transect)									
Wentworth Size Class		Size range (mm)	TRANSECT 1		TRANSECT 2		TRANSECT 3	
			Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%	0%	0%	0%	0%
Sand	Sand	0.062 - 2.0	0%	0%	65%	0%	0%	0%
Gravel	Very Fine	2-4	21%	10%	65%	42%	37%	23%
	Fine	4-8	21%	10%	66%	42%	39%	24%
	Medium	8-16	33%	12%	71%	46%	47%	26%
	Coarse	16-32	65%	29%	84%	55%	62%	41%
	Very Coarse	32-64	90%	63%	94%	87%	81%	60%
Cobble	Small	64-128	98%	93%	99%	97%	94%	85%
	Large	128-256	100%	99%	100%	100%	100%	95%
Boulder	Small	256-512	100%	100%	100%	100%	100%	98%
	Medium	512-1024	100%	100%	100%	100%	100%	100%
	Large - Very Large	1024-4096	100%	100%	100%	100%	100%	100%
Bedrock	Bedrock	-	100%	100%	100%	100%	100%	100%

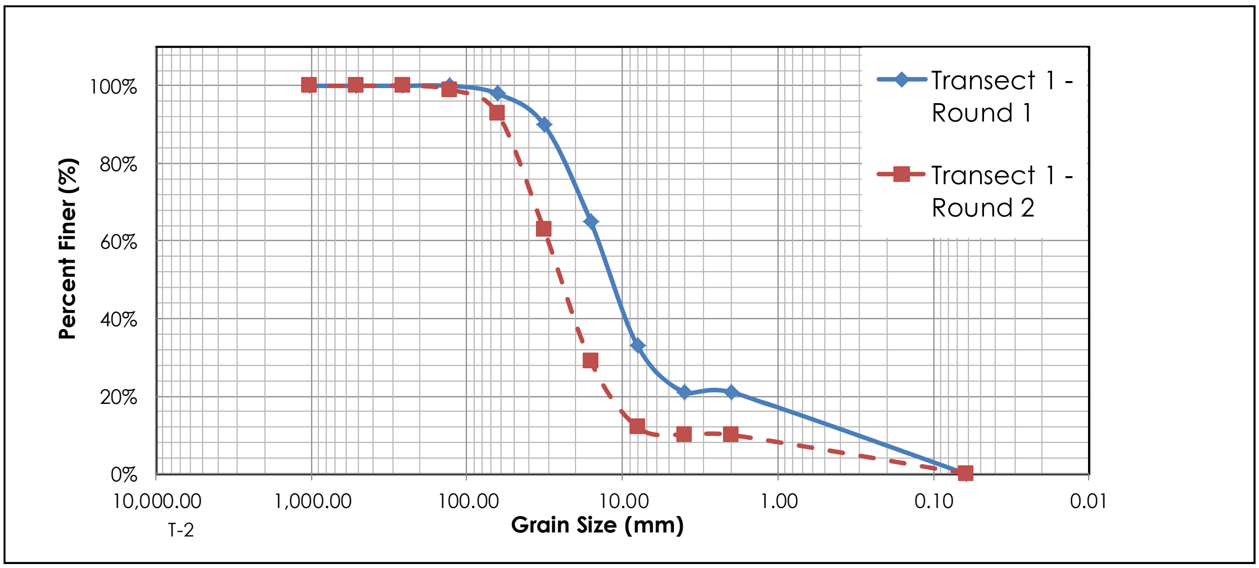

Figure D.14-1. Study site 08-T02 Transect 1 gradation curves.

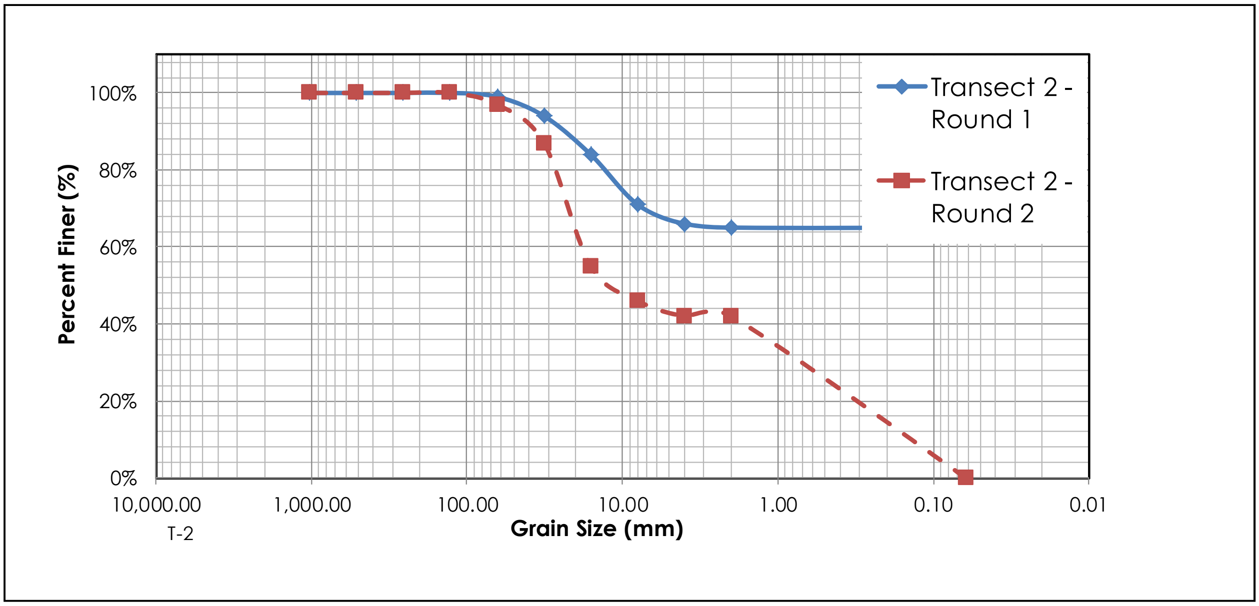

Figure D.14-2. Study site 08-T02 Transect 2 gradation curves.

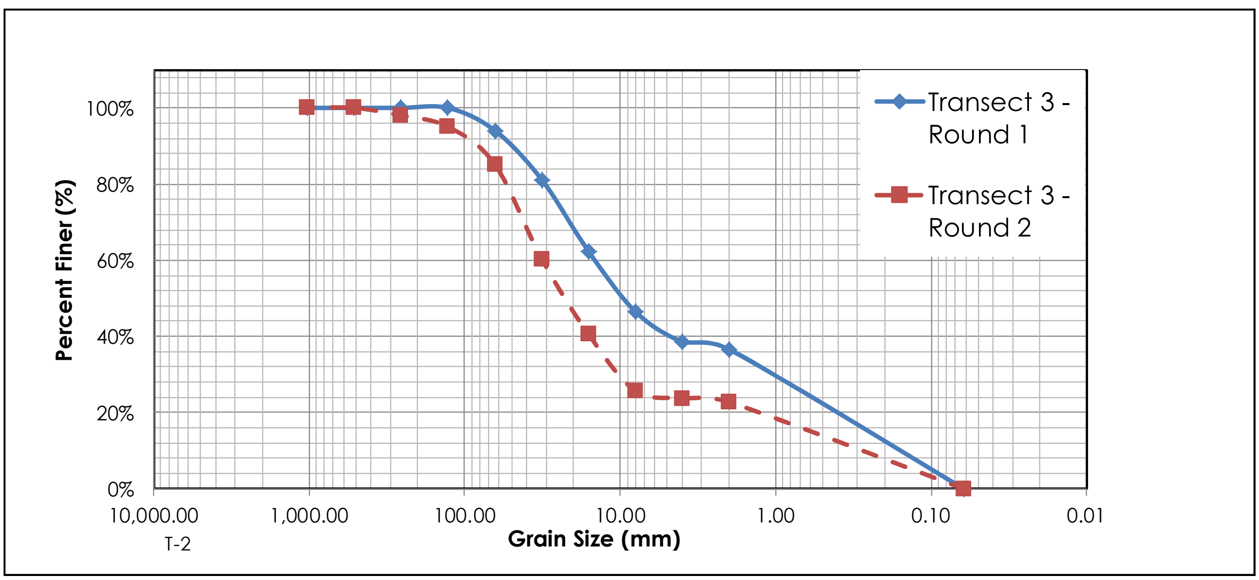

Figure D.14-3. Study site 08-T02 Transect 3 gradation curves.

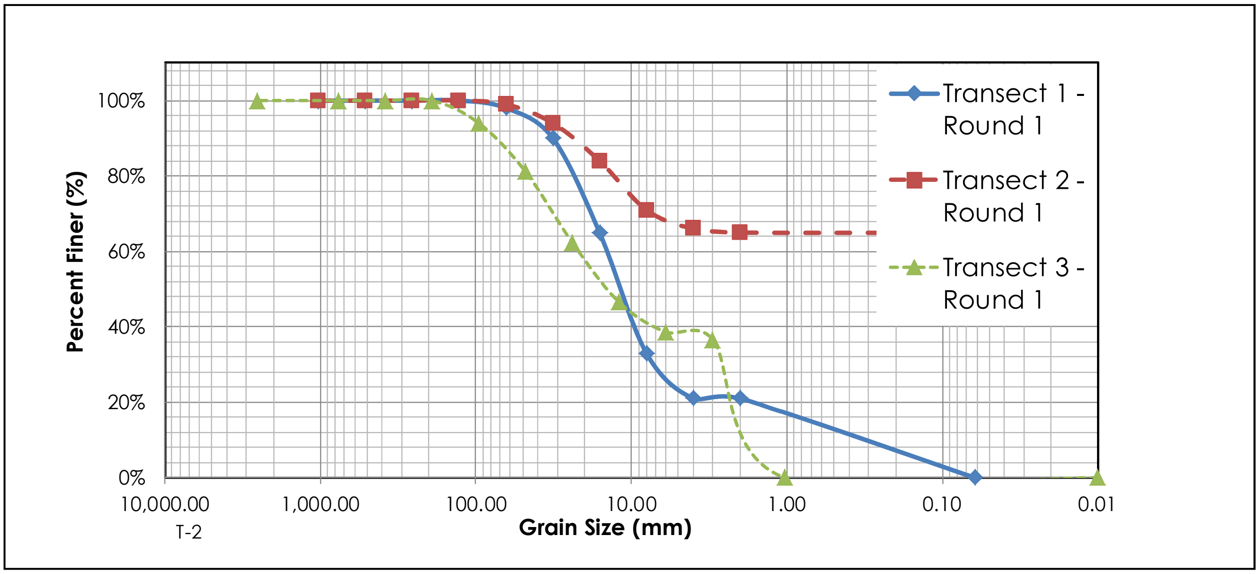

Figure D.14-4. Study site 08-T02 Transects 1, 2, and 3, Round 1 gradation curves.

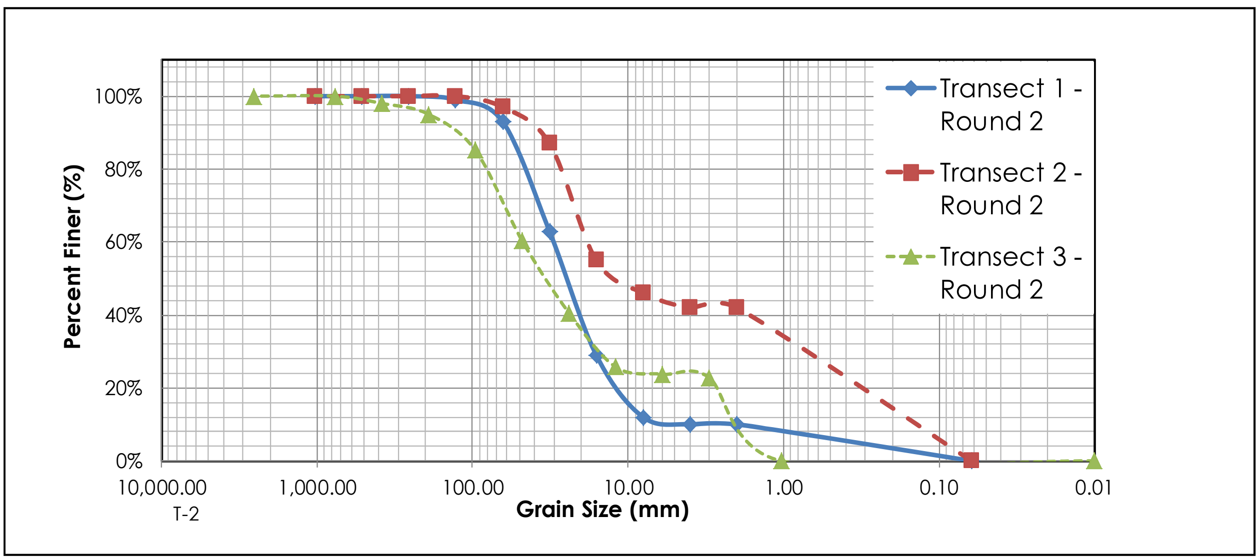

Figure D.14-5. Study site 08-T02 Transects 1, 2, and 3, Round 2 gradation curves.

Appendix D-15. Study Site 08-T04

Table D.15-1. Study site 08-T04 particle size distribution.

PERCENT FINER (By Transect)								
Wentworth Size Class		Size range (mm)	TRANSECT 1		TRANSECT 2		TRANSECT 3	
			Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%	0%	0%		
Sand	Sand	0.062 - 2.0	0%	2%	0%	2%		
Gravel	Very Fine	2-4	80%	63%	48%	41%		
	Fine	4-8	82%	71%	52%	46%		
	Medium	8-16	85%	86%	66%	56%		
	Coarse	16-32	91%	91%	78%	67%		
	Very Coarse	32-64	96%	96%	87%	81%		
Cobble	Small	64-128	99%	99%	95%	91%		
	Large	128-256	100%	100%	100%	99%		
Boulder	Small	256-512	100%	100%	100%	100%		
	Medium	512-1024	100%	100%	100%	100%		
	Large - Very Large	1024-4096	100%	100%	100%	100%		
Bedrock	Bedrock	-	100%	100%	100%	100%		

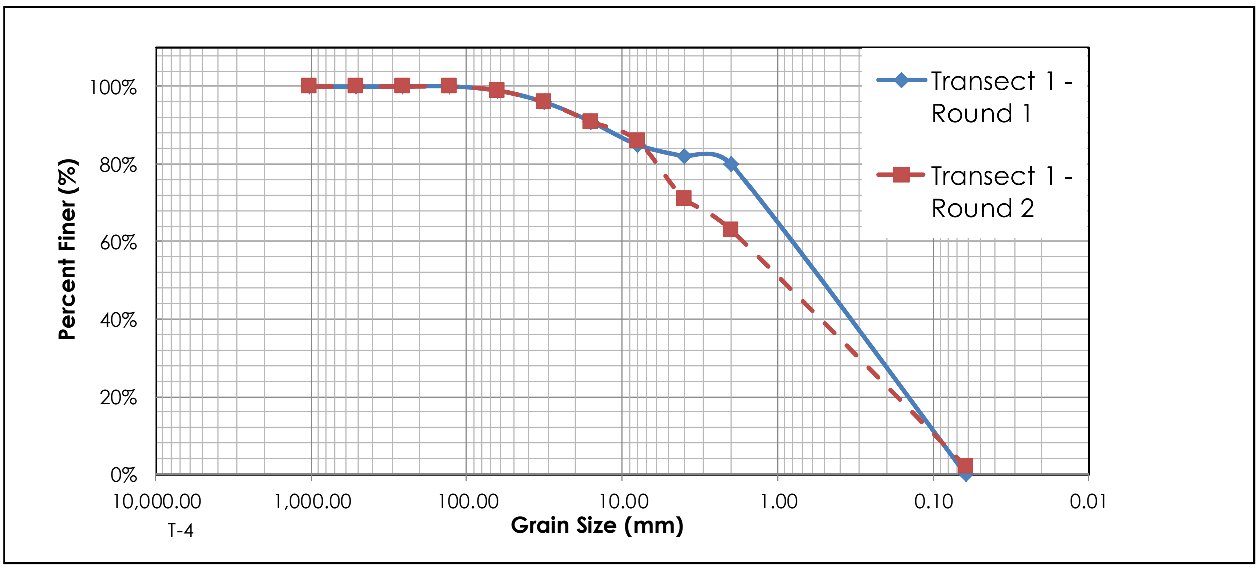

Figure D.15-1. Study site 08-T04 Transect 1 gradation curves.

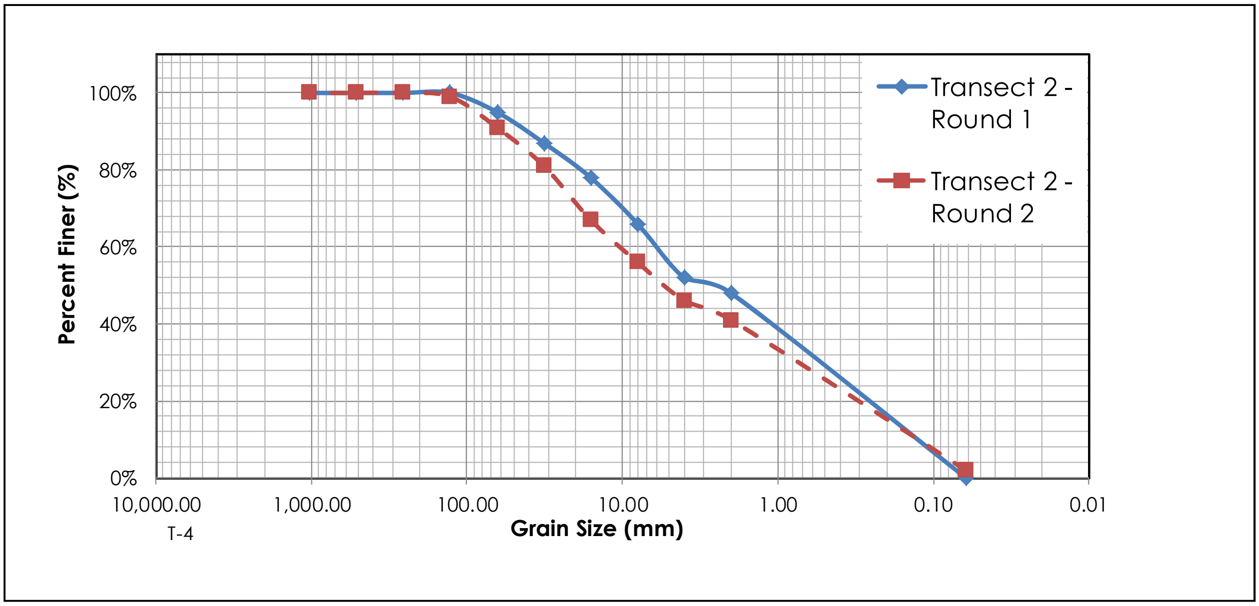

Figure D.15-2. **Study site 08-T04 Transect 2 gradation curves.**

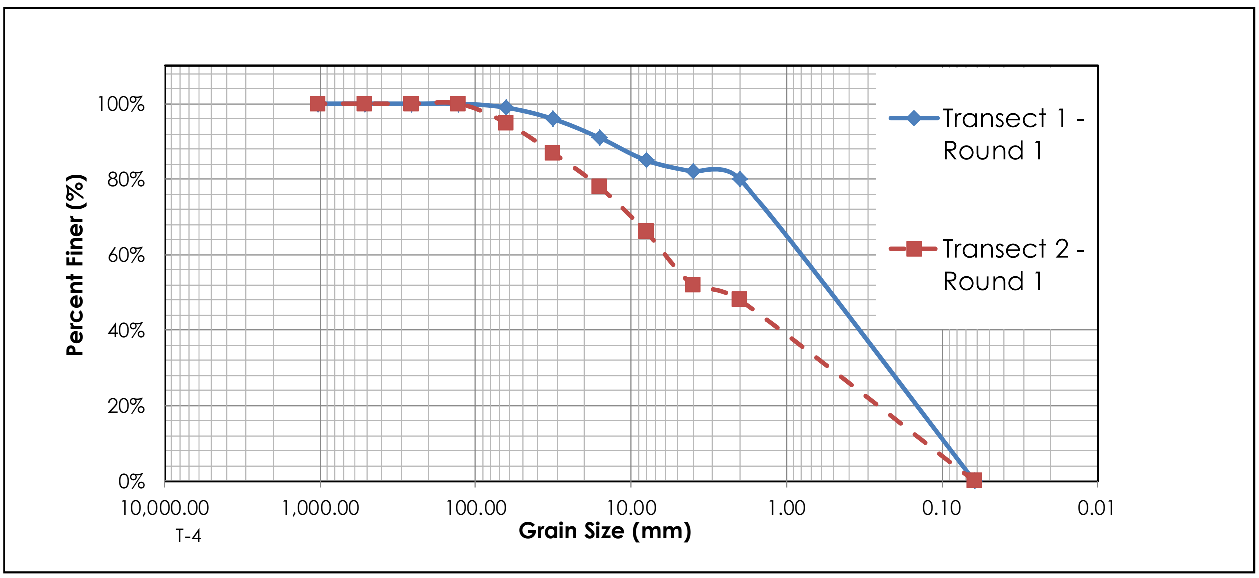

Figure D.15-3. **Study site 08-T04 Transects 1 and 2, Round 1 gradation curves.**

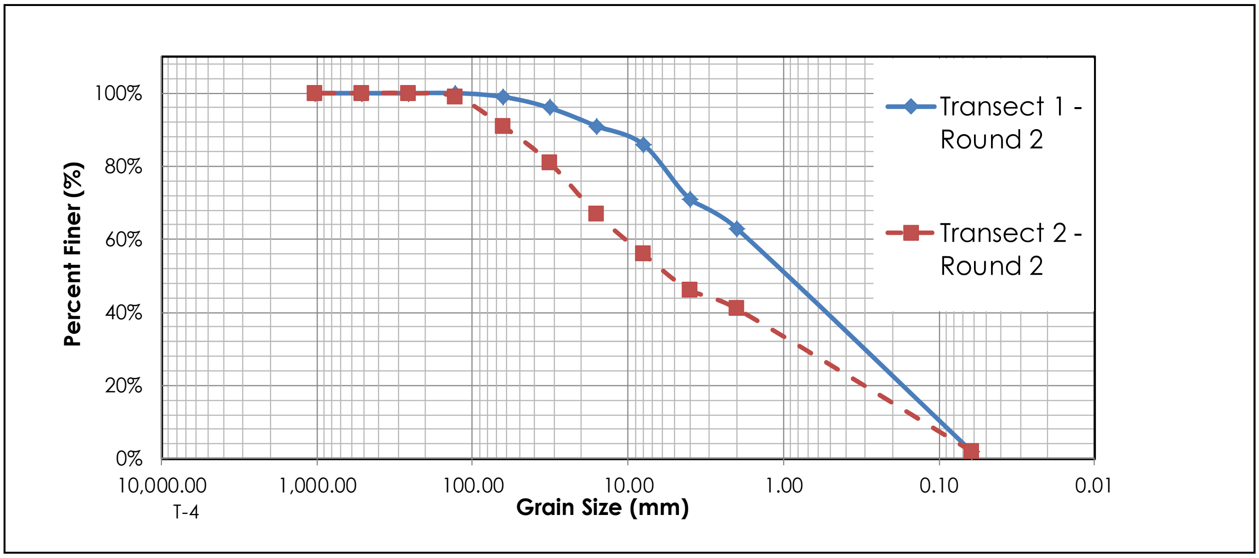

Figure D.15-4. Study site 08-T04 Transects 1 and 2, Round 2 gradation curves.

Appendix D-16. Study Site 08-T12

Table D.16-1. Study site 08-T12 particle size distribution.

Wentworth Size Class		Size range (mm)	PERCENT FINER (By Transect) TRANSECT 1 Round 1	TRANSECT 1 Round 2	TRANSECT 2 Round 1	TRANSECT 2 Round 2	TRANSECT 3 Round 1	TRANSECT 3 Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%	0%	0%		
Sand	Sand	0.062 - 2.0	0%	0%	0%	0%		
Gravel	Very Fine	2-4	21%	15%	12%	22%		
	Fine	4-8	21%	16%	12%	22%		
	Medium	8-16	22%	19%	14%	24%		
	Coarse	16-32	28%	27%	23%	29%		
	Very Coarse	32-64	62%	56%	42%	54%		
Cobble	Small	64-128	82%	87%	74%	83%		
	Large	128-256	94%	96%	96%	96%		
Boulder	Small	256-512	100%	100%	100%	100%		
	Medium	512-1024	100%	100%	100%	100%		
	Large - Very Large	1024-4096	100%	100%	100%	100%		
Bedrock	Bedrock	-	100%	100%	100%	100%		

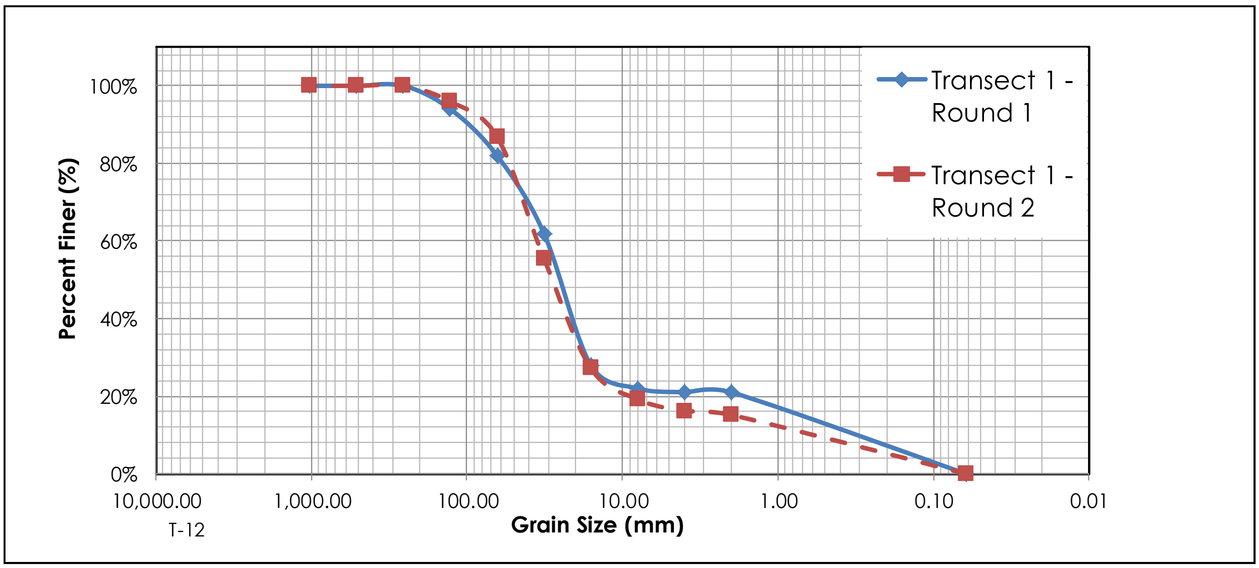

Figure D.16-1. Study site 08-T12 Transect 1 gradation curves.

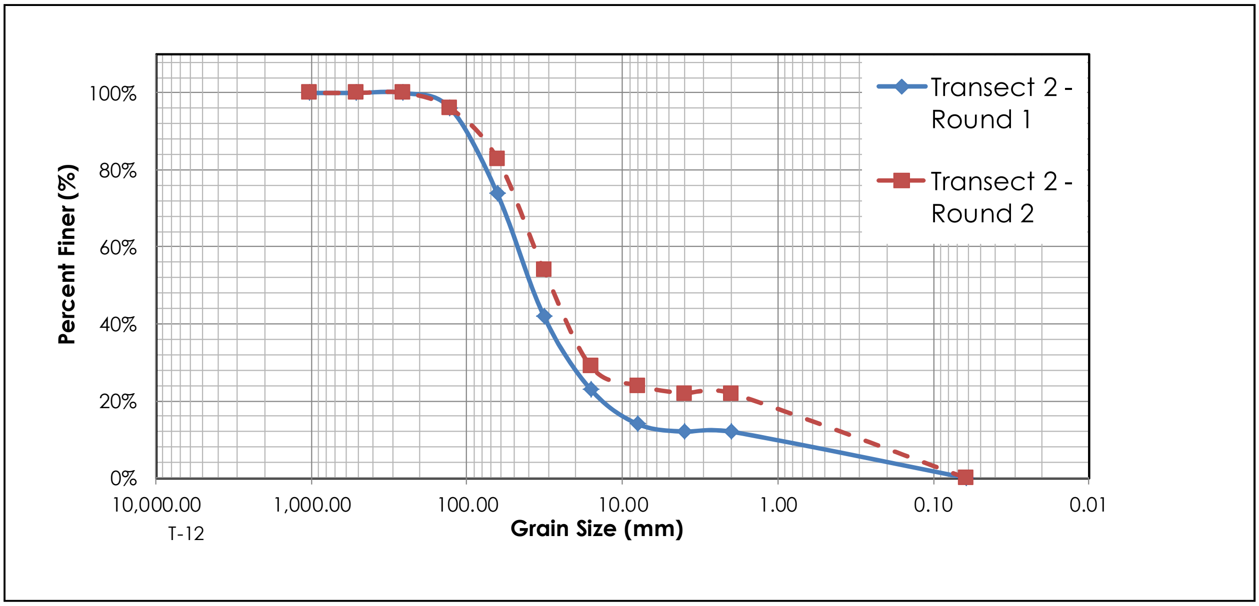

Figure D.16-2. Study site 08- T12 Transect 2 gradation curves.

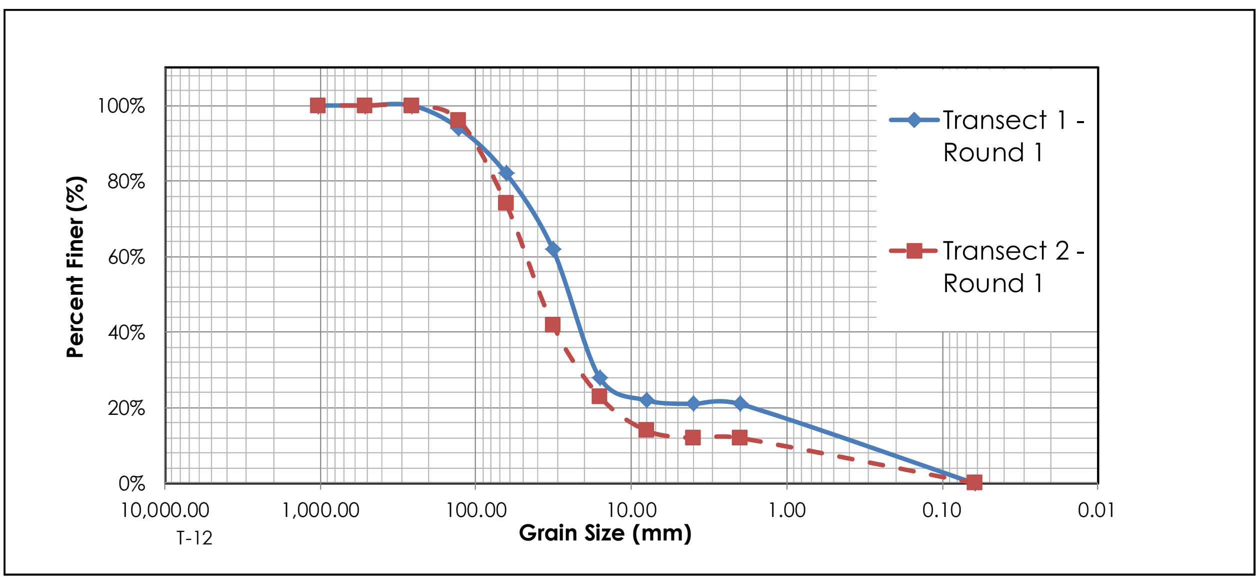

Figure D.16-3. Study site 08- T12 Transects 1 and 2, Round 1 gradation curves.

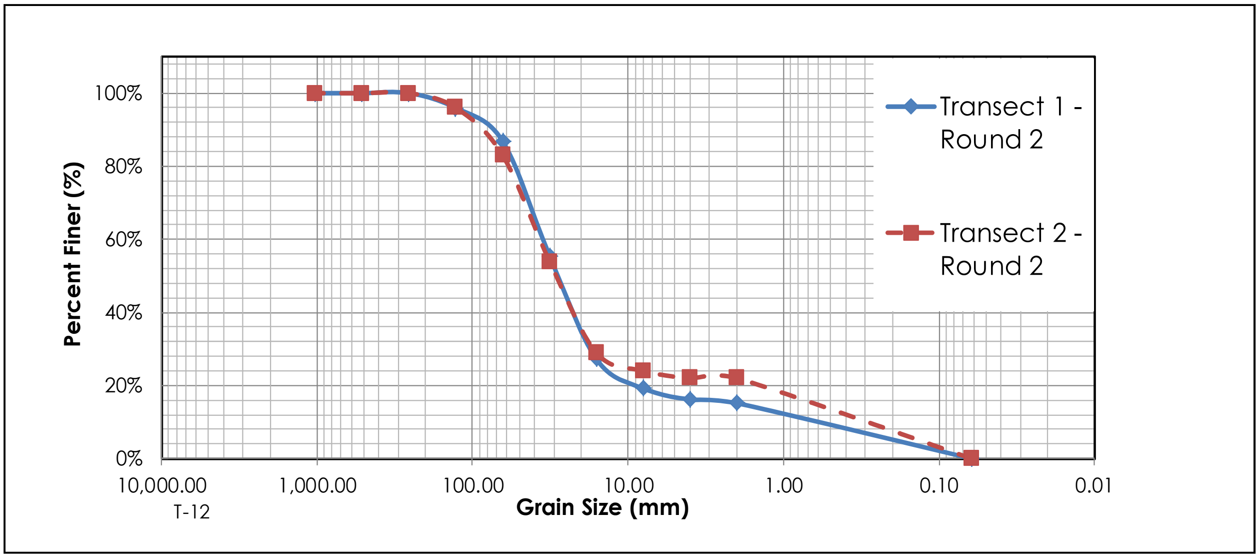

Figure D.16-4. Study site 08- T12 Transects 1 and 2, Round 2 gradation curves.

Appendix D-17. Study Site 08-T14

Table D.17-1. Study site 08-T14 particle size distribution.

Wentworth Size Class		Size range (mm)	PERCENT FINER (By Transect) TRANSECT 1		TRANSECT 2		TRANSECT 3	
			Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%	0%	0%	0%	0%
Sand	Sand	0.062 - 2.0	0%	0%	0%	0%	0%	0%
Gravel	Very Fine	2-4	4%	5%	15%	15%	17%	19%
	Fine	4-8	4%	5%	18%	16%	19%	19%
	Medium	8-16	5%	6%	20%	16%	25%	21%
	Coarse	16-32	8%	9%	24%	16%	50%	34%
	Very Coarse	32-64	13%	15%	34%	23%	71%	57%
Cobble	Small	64-128	37%	39%	65%	46%	89%	82%
	Large	128-256	87%	77%	95%	86%	99%	100%
Boulder	Small	256-512	96%	98%	100%	100%	100%	100%
	Medium	512-1024	100%	100%	100%	100%	100%	100%
	Large - Very Large	1024-4096	100%	100%	100%	100%	100%	100%
Bedrock	Bedrock	-	100%	100%	100%	100%	100%	100%

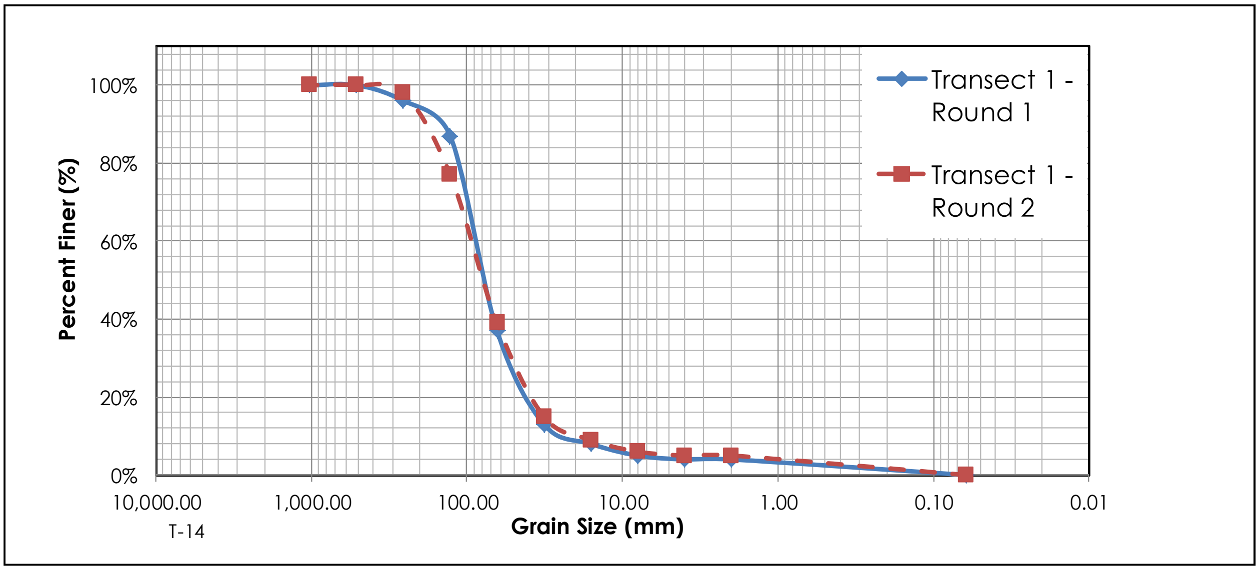

Figure D.17-1. Study site 08-T14 Transect 1 gradation curves.

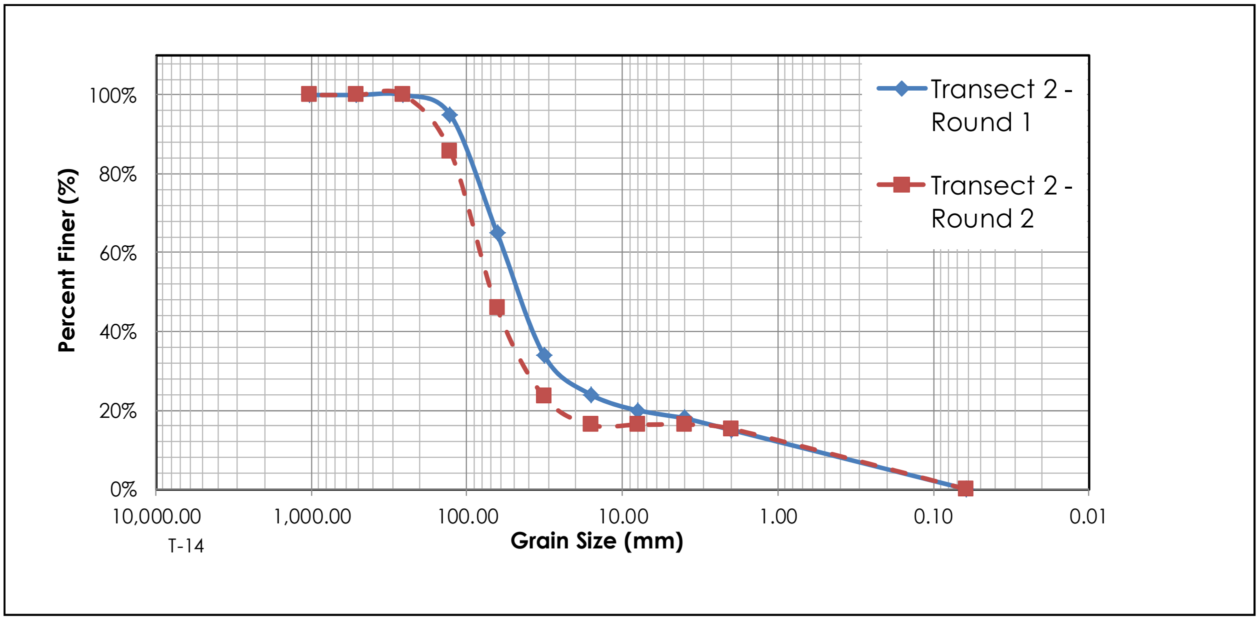

Figure D.17-2. Study site 08-T14 Transect 2 gradation curves.

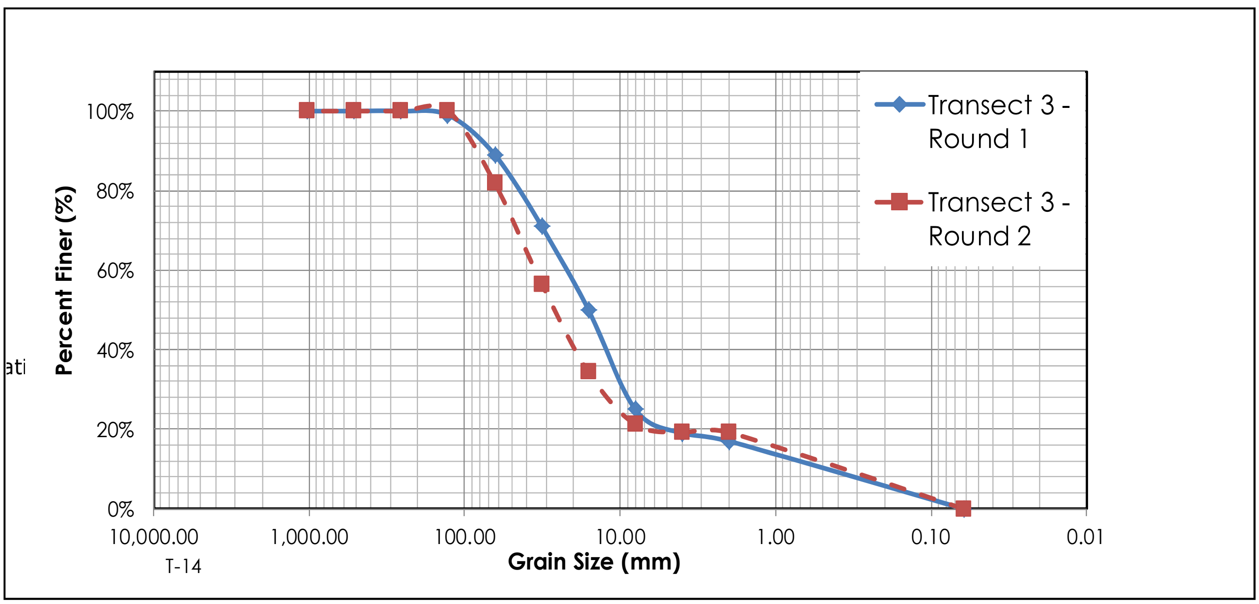

Figure D.17-3. Study site 08-T14 Transect 3 gradation curves.

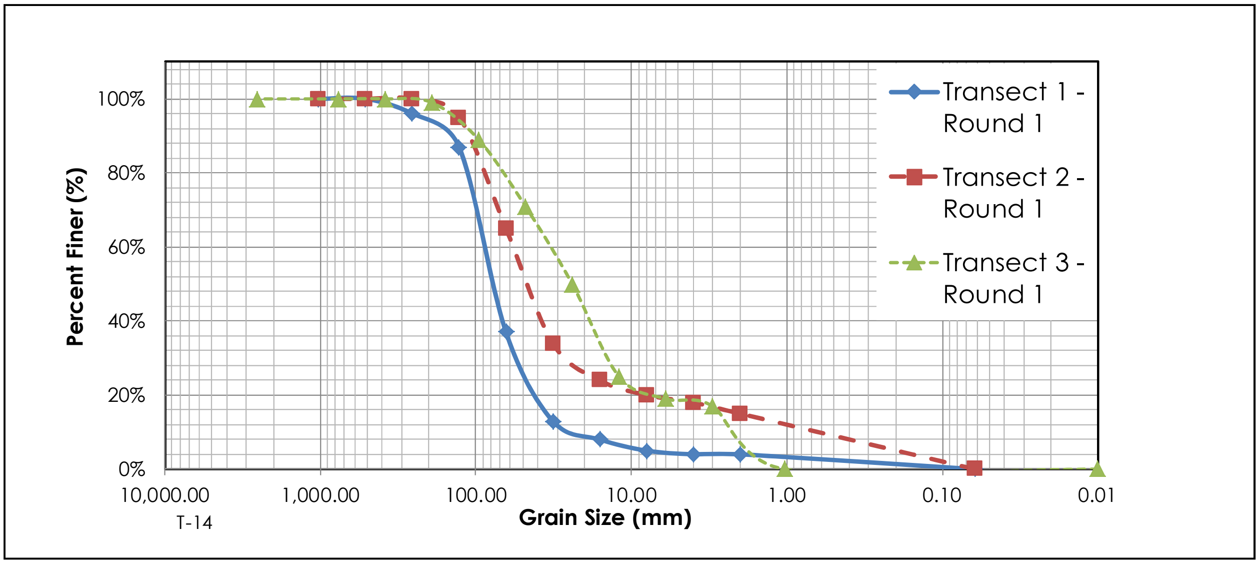

Figure D.17-4. Study site 08-T14 Transects 1, 2, and 3, Round 1 gradation curves.

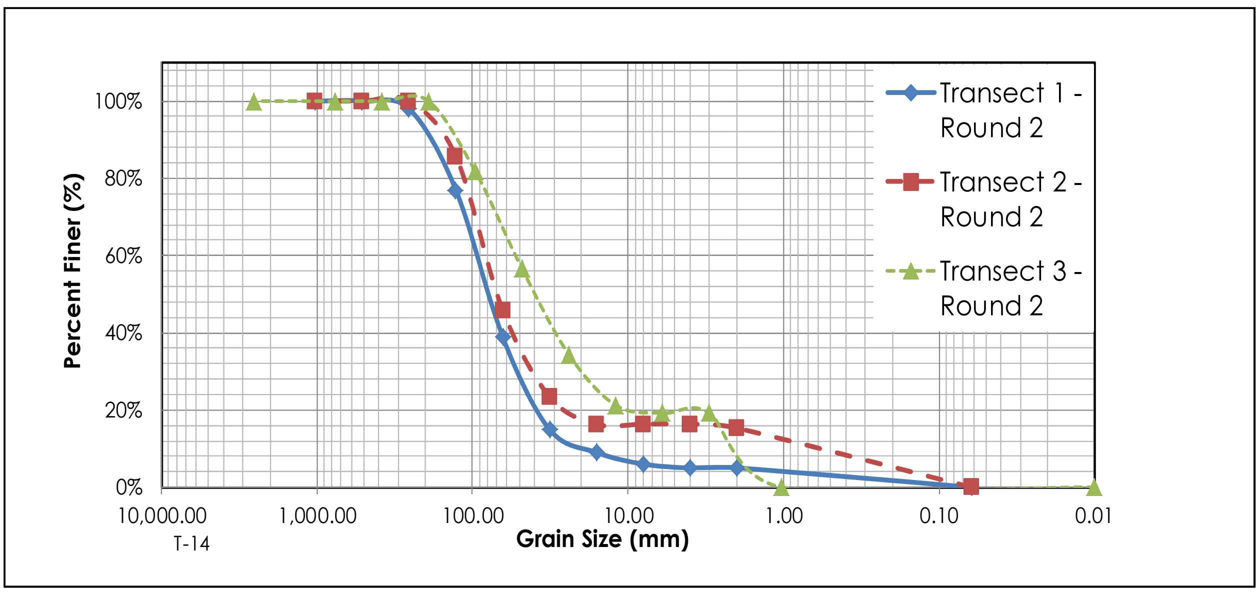

Figure D.17-5. Study site 08-T14 Transects 1, 2, and 3, Round 2 gradation curves.

Appendix D-18. Study Site 08-T16

Table D.18-1. Study site 08-T16 particle size distribution.

PERCENT FINER (By Transect)								
Wentworth Size Class		Size range (mm)	TRANSECT 1		TRANSECT 2		TRANSECT 3	
			Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Silt/Clay	Silt/Clay	<0.062	0%	0%	0%	0%	0%	0%
Sand	Sand	0.062 - 2.0	0%	0%	0%	0%	1%	0%
Gravel	Very Fine	2-4	0%	2%	2%	1%	15%	50%
	Fine	4-8	0%	4%	3%	1%	16%	54%
	Medium	8-16	2%	6%	8%	3%	24%	60%
	Coarse	16-32	8%	12%	16%	10%	50%	68%
	Very Coarse	32-64	39%	29%	31%	26%	75%	83%
Cobble	Small	64-128	79%	69%	55%	54%	96%	95%
	Large	128-256	96%	93%	89%	82%	98%	99%
Boulder	Small	256-512	100%	98%	100%	99%	100%	100%
	Medium	512-1024	100%	100%	100%	100%	100%	100%
	Large - Very Large	1024-4096	100%	100%	100%	100%	100%	100%
Bedrock	Bedrock	-	100%	100%	100%	100%	100%	100%

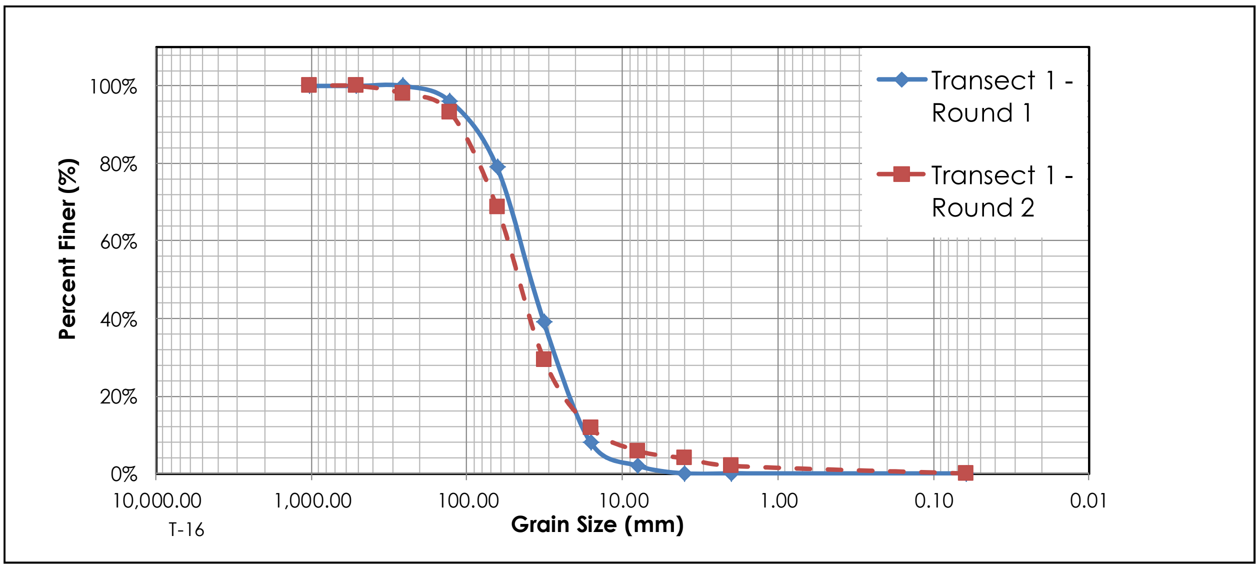

Figure D.18-1. Study site 08-T16 Transect 1 gradation curves.

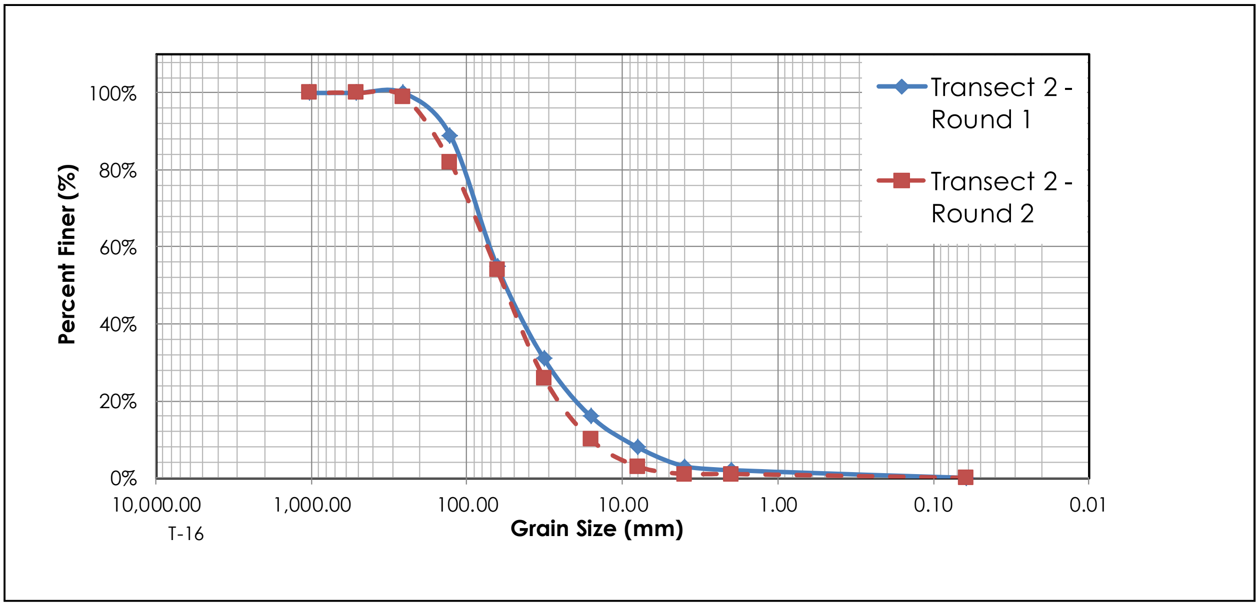

Figure D.18-2. Study site 08-T16 Transect 2 gradation curves.

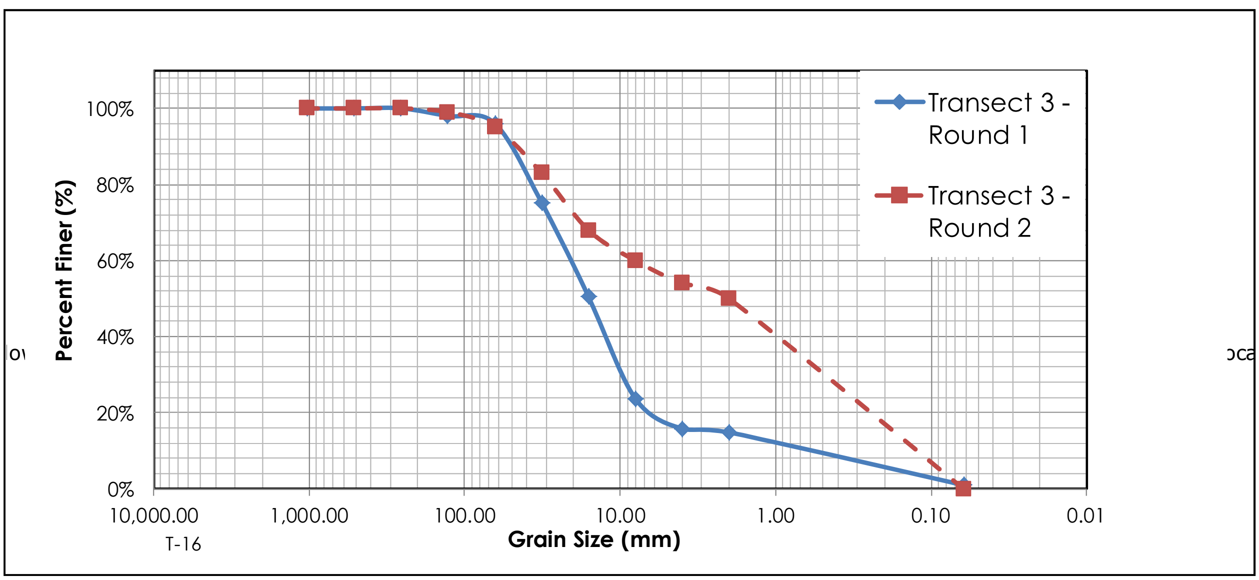

Figure D.18-3. Study site 08-T16 Transect 3 gradation curves.

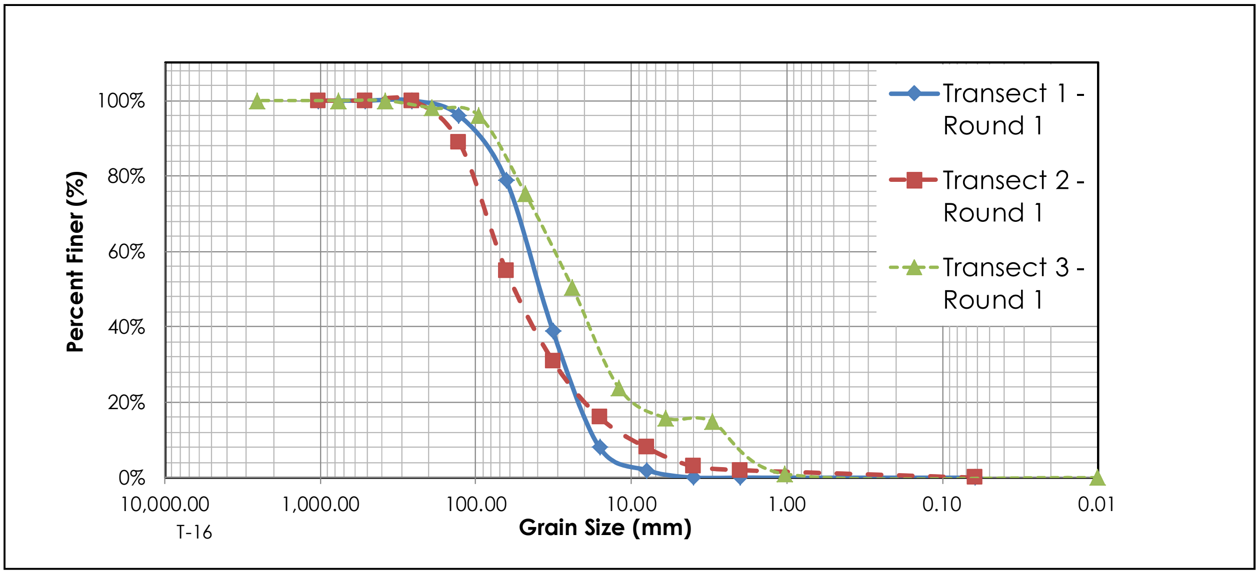

Figure D.18-4. Study site 08-T16 Transects 1, 2, and 3, Round 1 gradation curves.

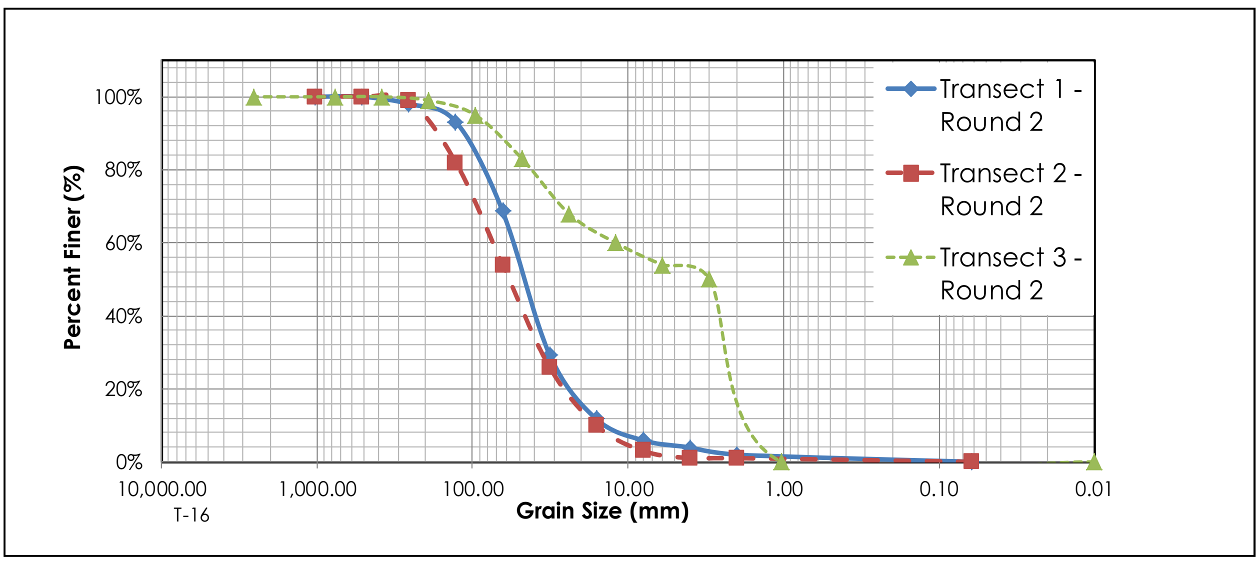

Figure D.18-5. Study site 08-T16 Transects 1, 2, and 3, Round 2 gradation curves.

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APPENDIX E

Shear Stress Comparison Figures

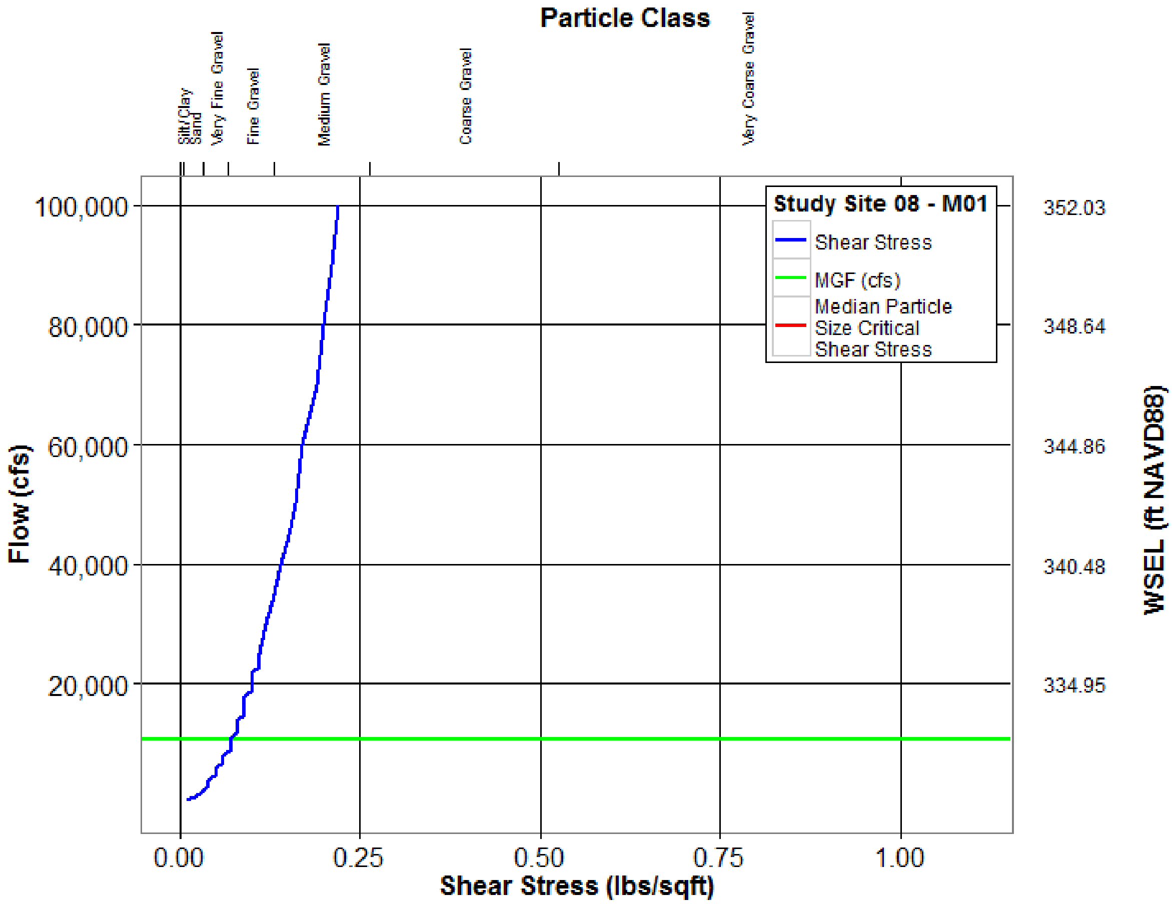

Figure E.1. Study site 08-M01. (Note that this figure does not depict the median particle size critical shear stress of the single transect and two study rounds conducted at this site. The relatively large median substrates at this site (small cobble and large cobble during the sample rounds 1 and 2, respectively) have critical shear stresses that are greater than the maximum scale presented on the figure.)

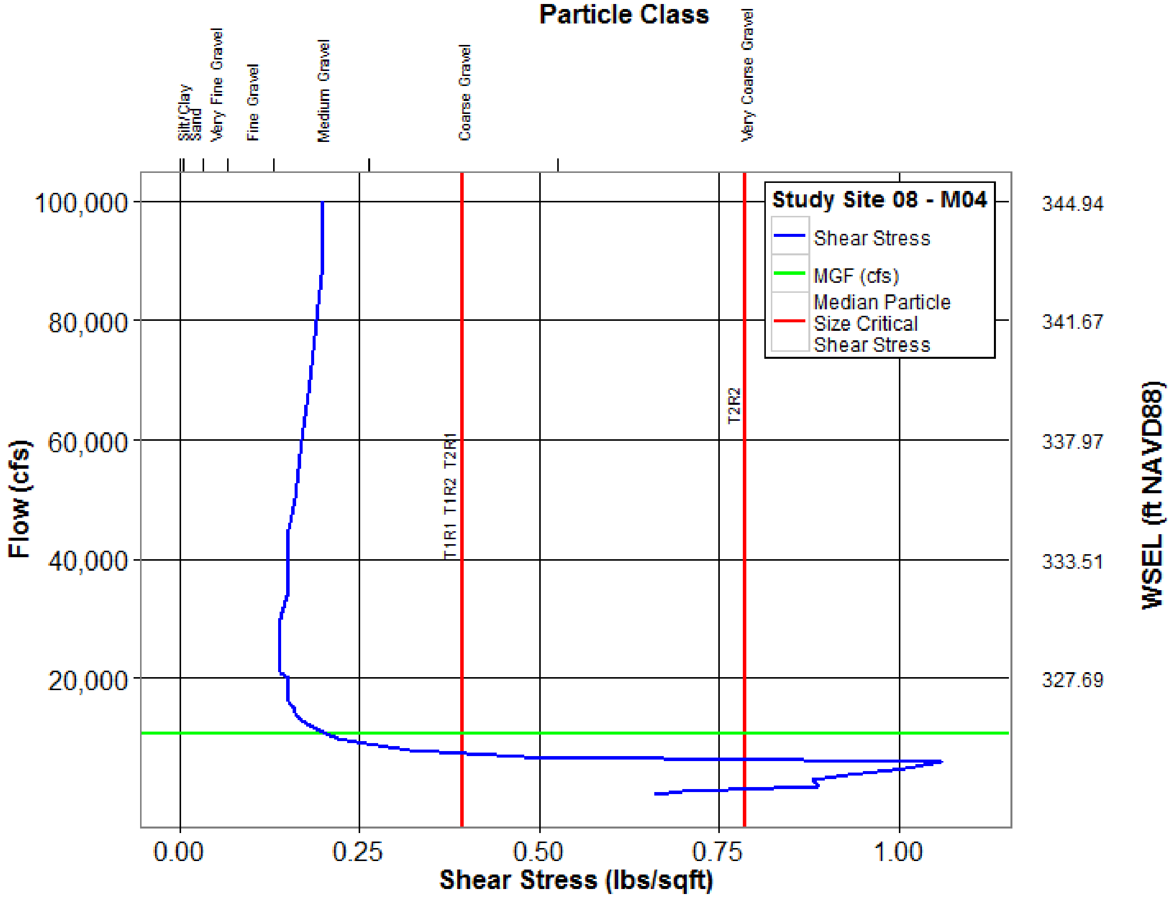

Figure E.2. Study site 08-M04.

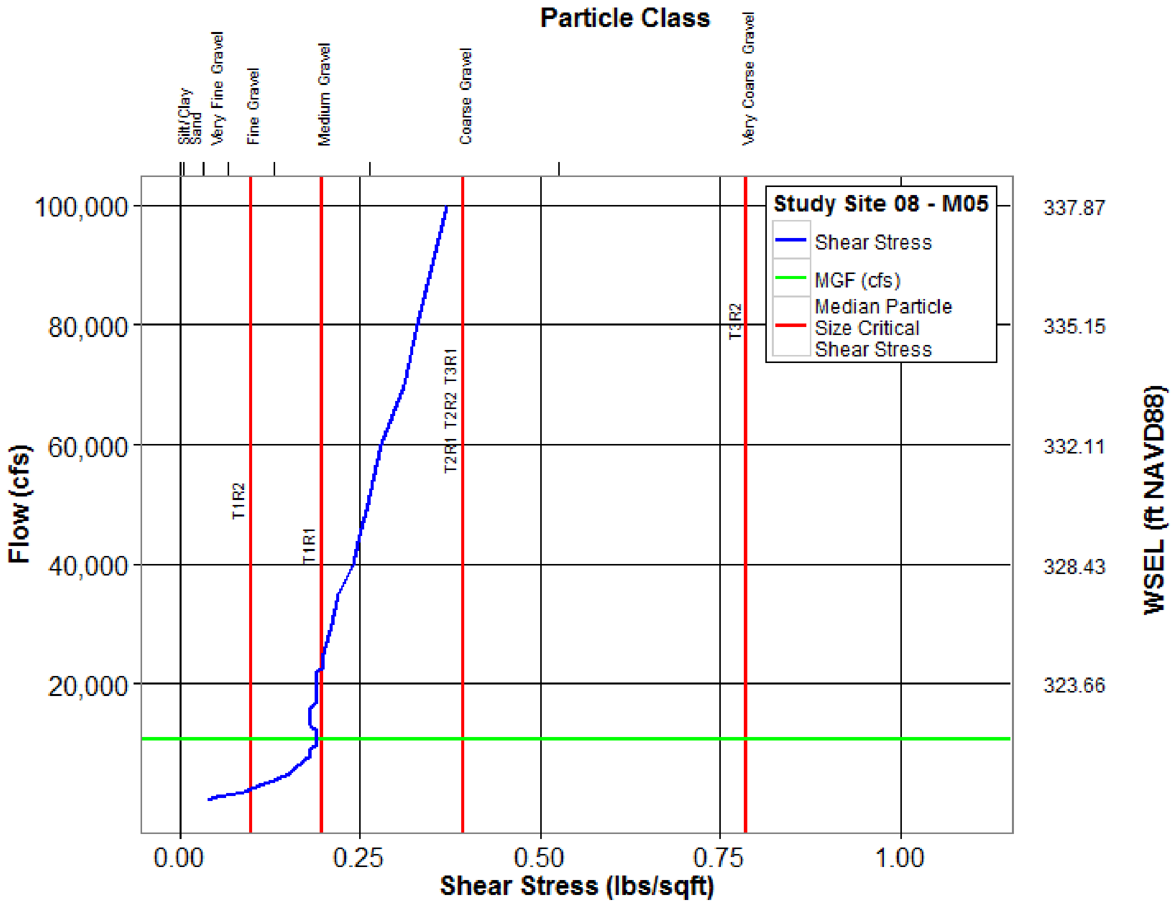

Figure E.3. Study site 08-M05.

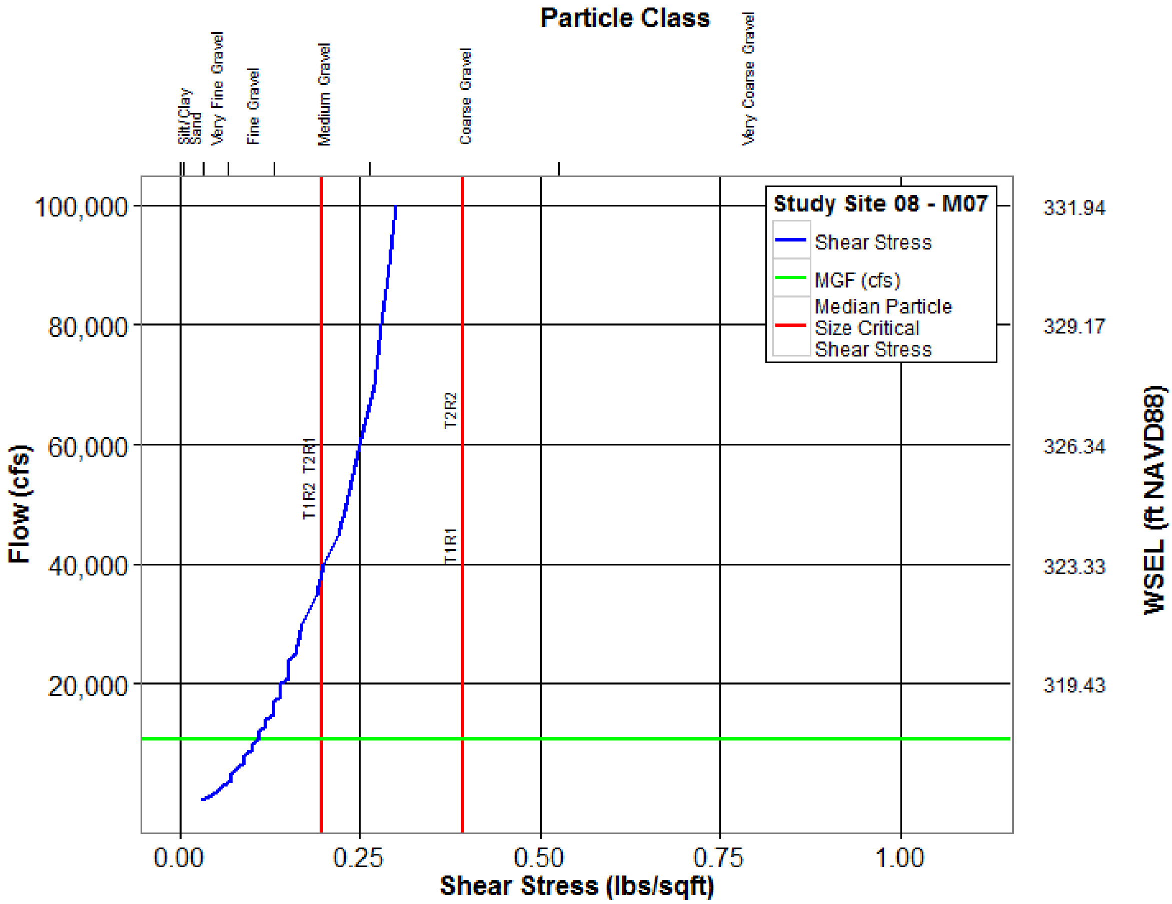

Figure E.4. Study site 08-M07.

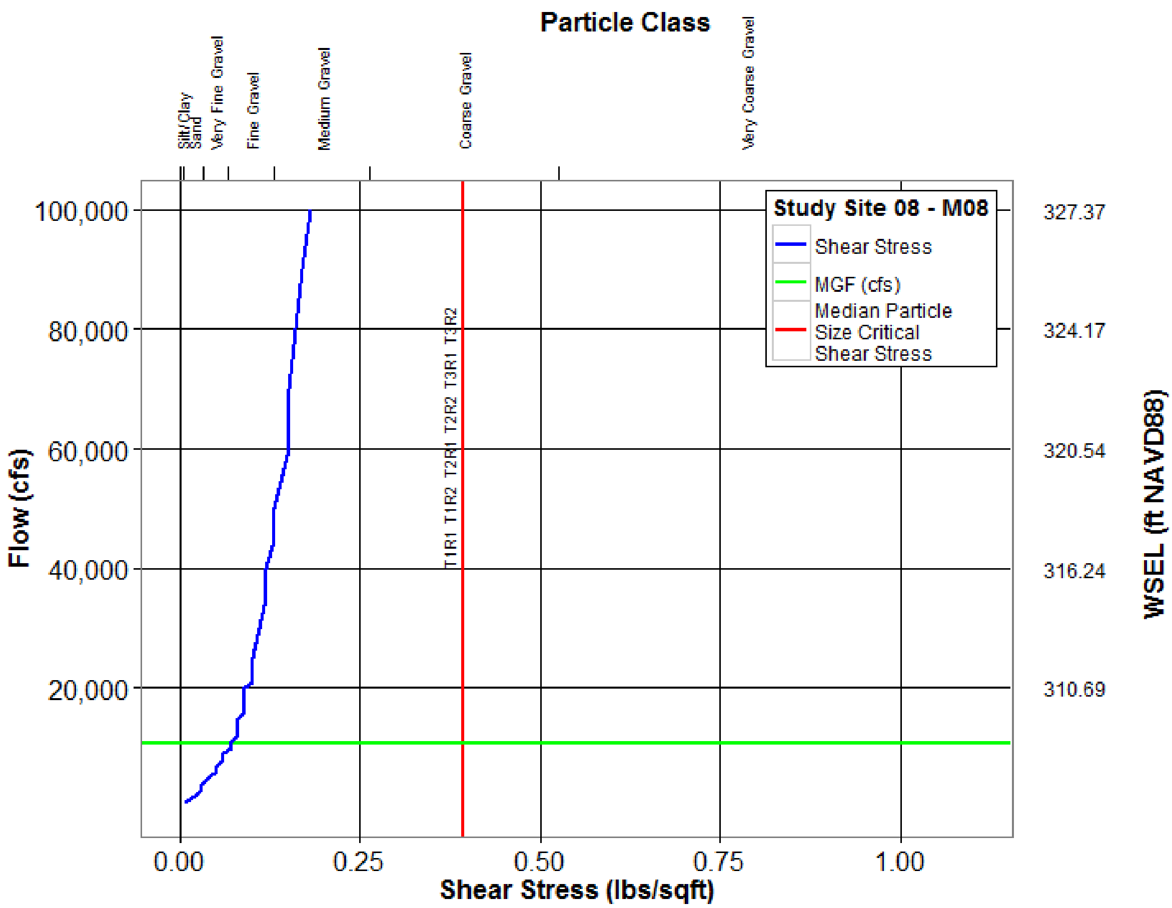

Figure E.5. Study site 08-M08.

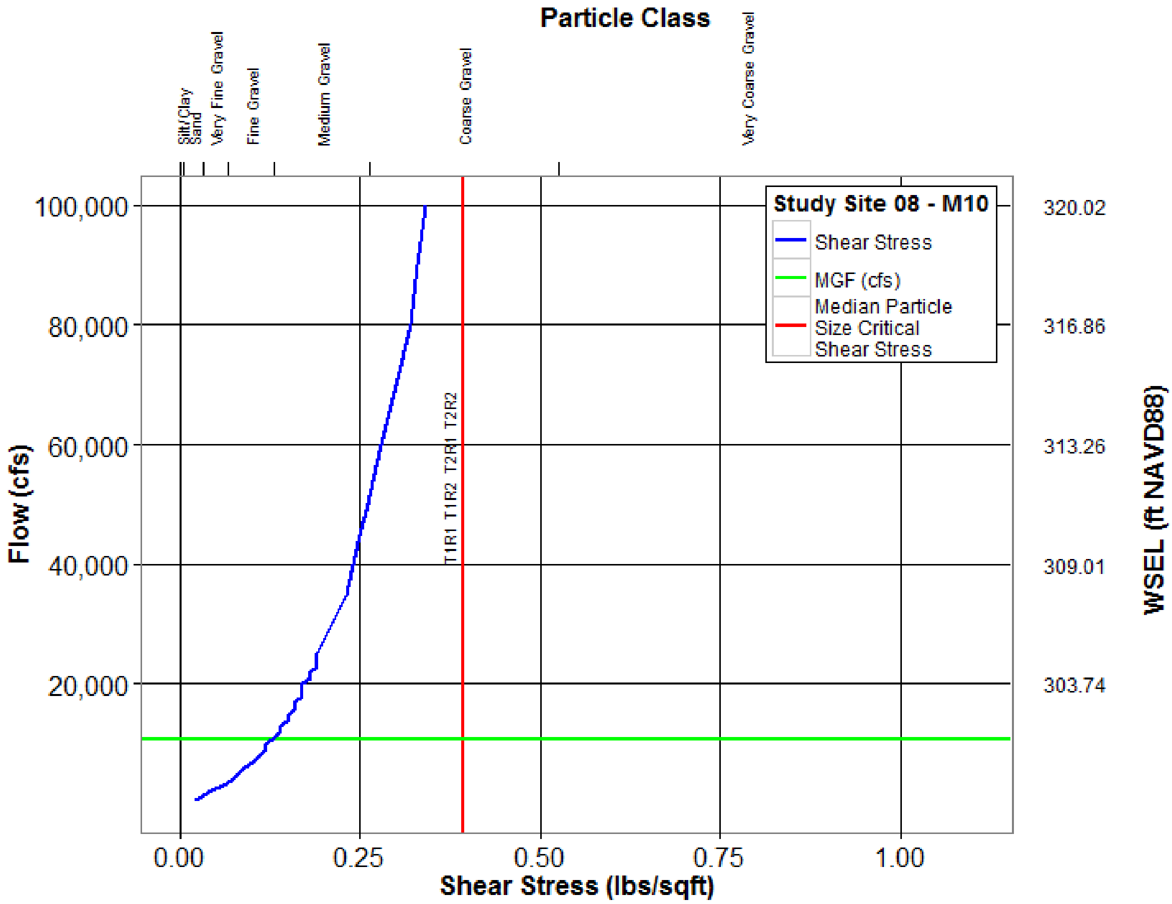

Figure E.6. Study site 08-M10.

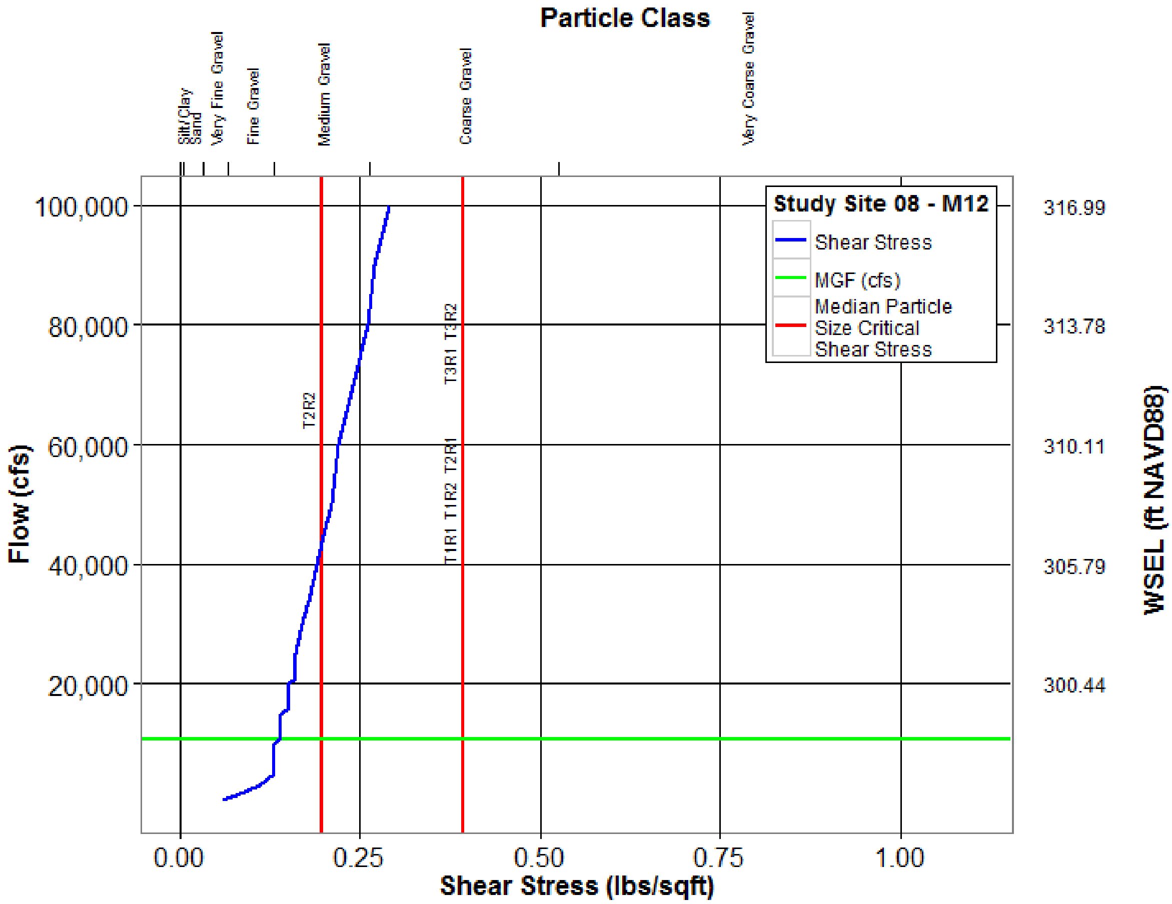

Figure E.7. Study site 08-M12.

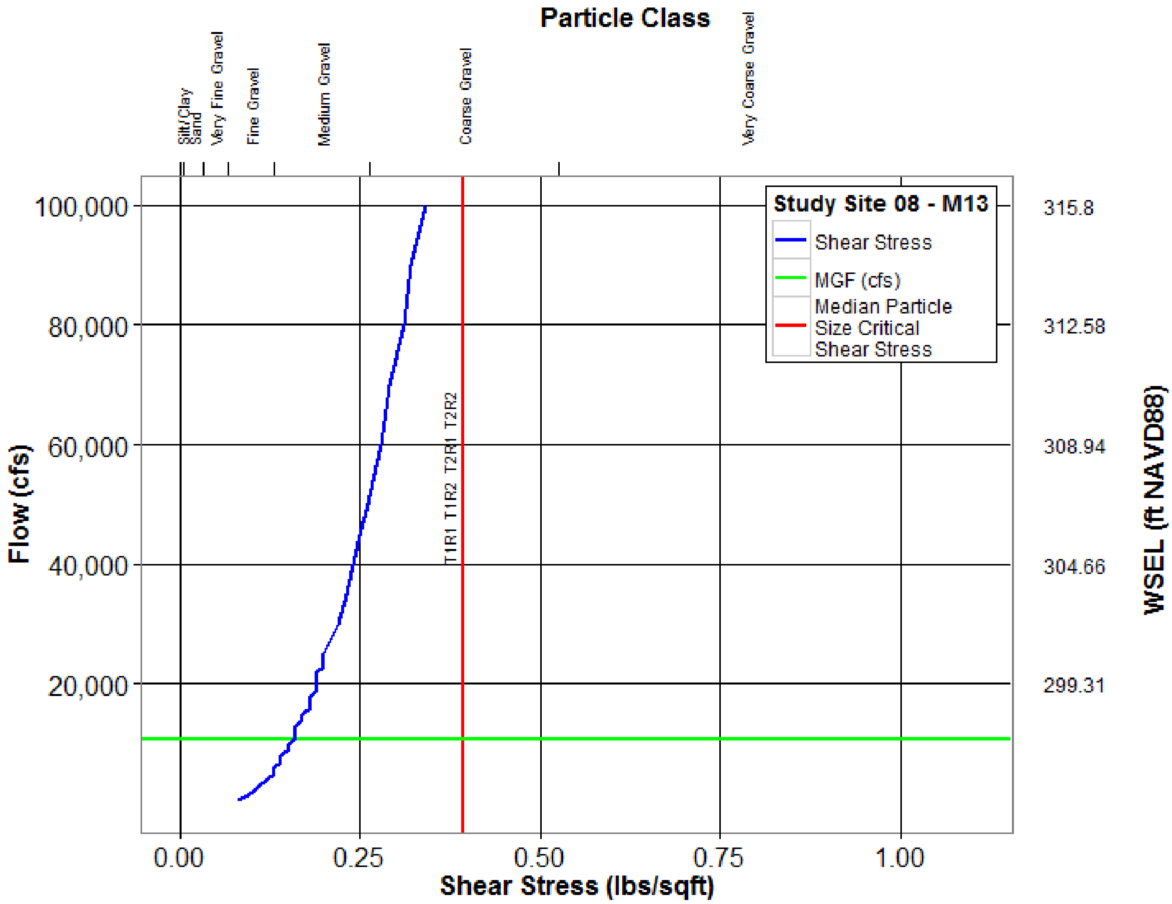

Figure E.8. Study site 08-M13.

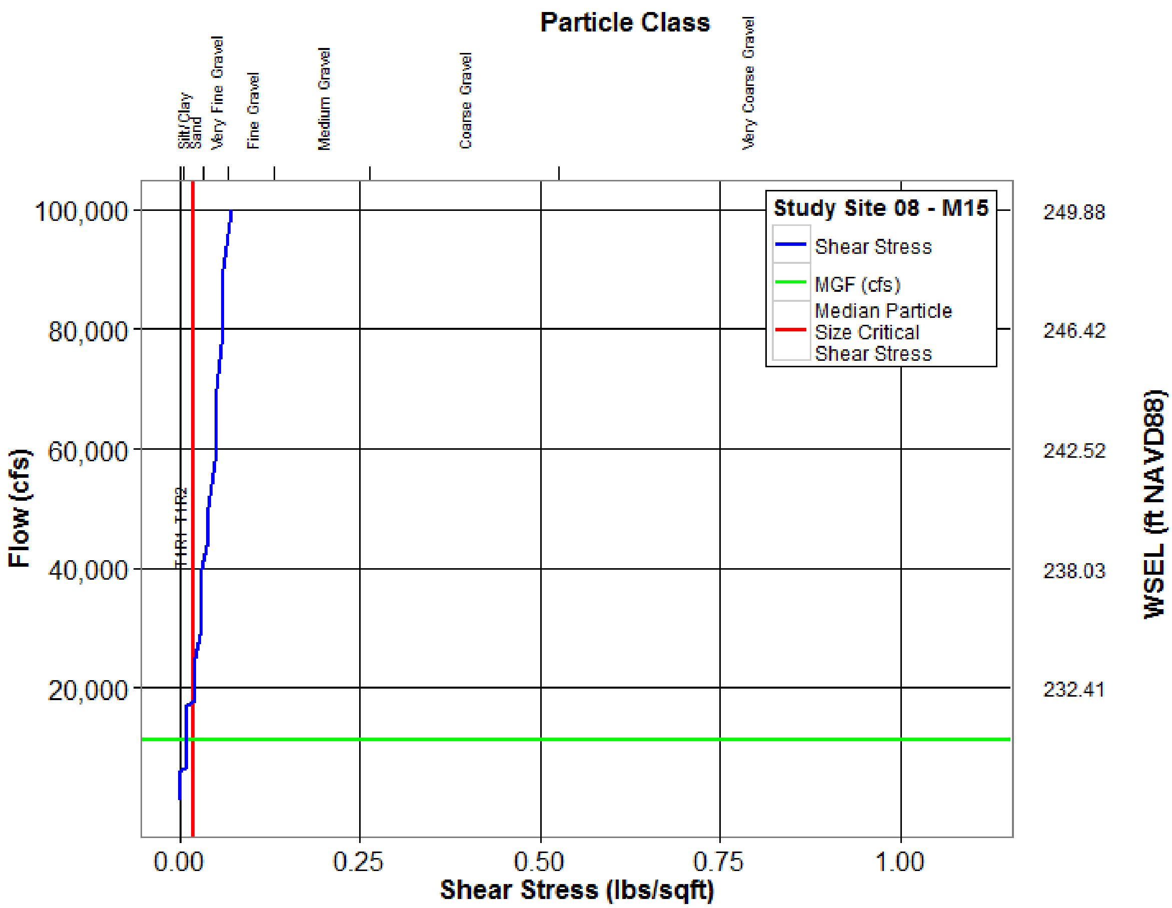

Figure E.9. Study site 08-M15.

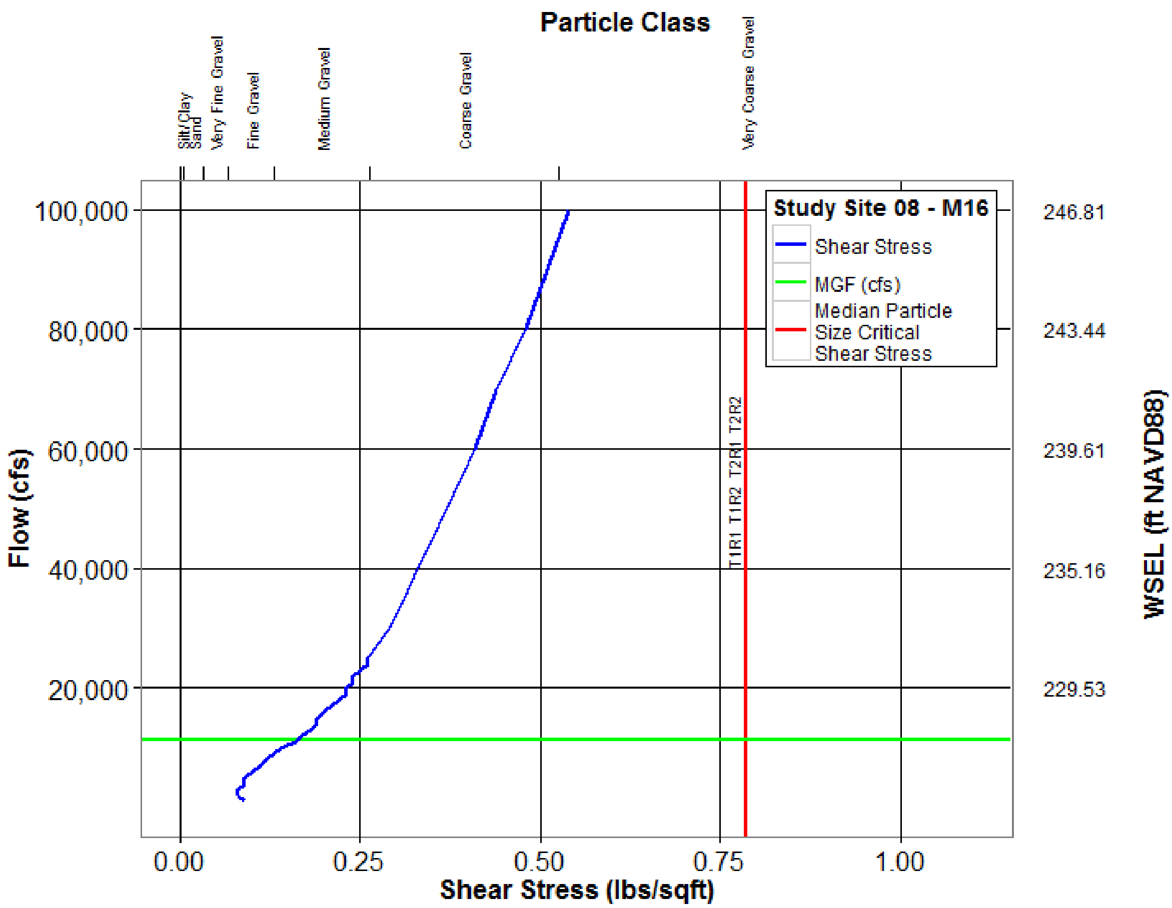

Figure E.10. Study site 08-M16.

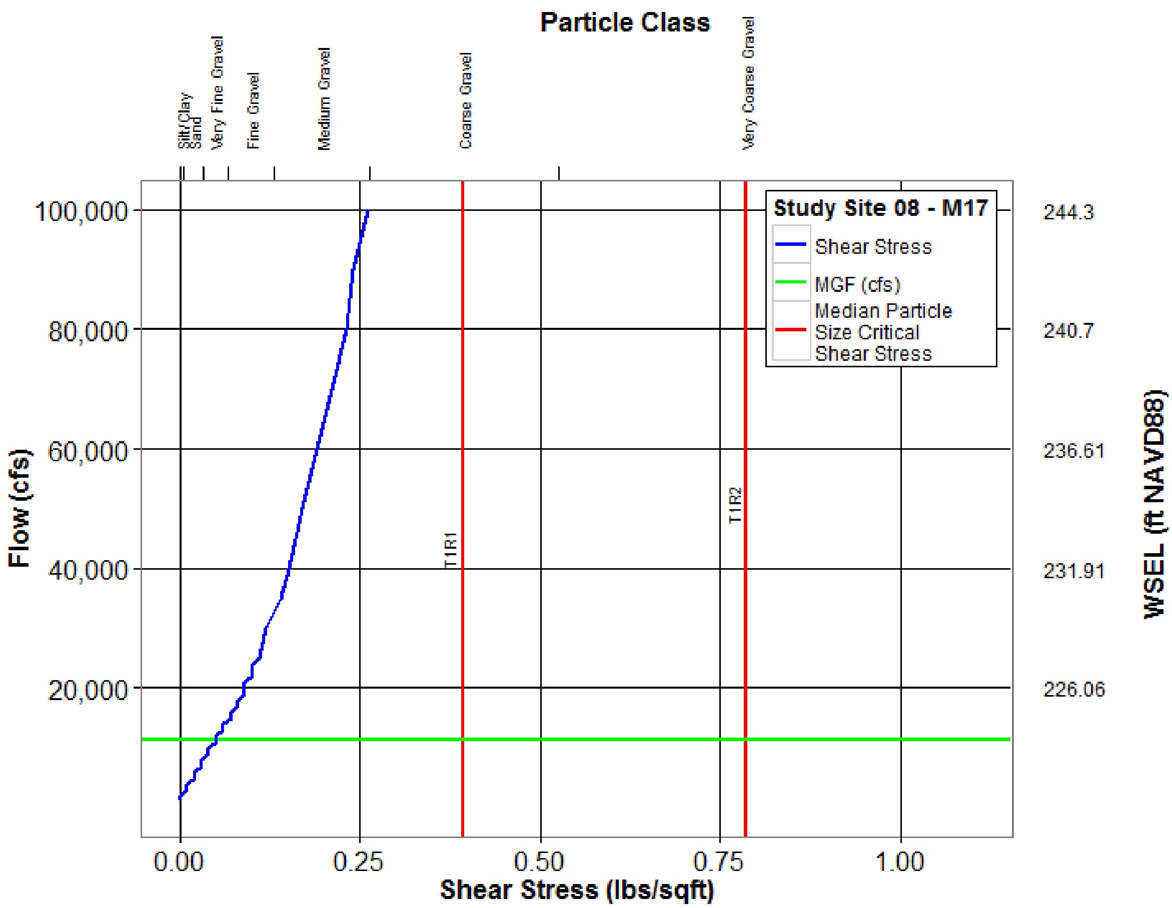

Figure E.11. Study site 08-M17.

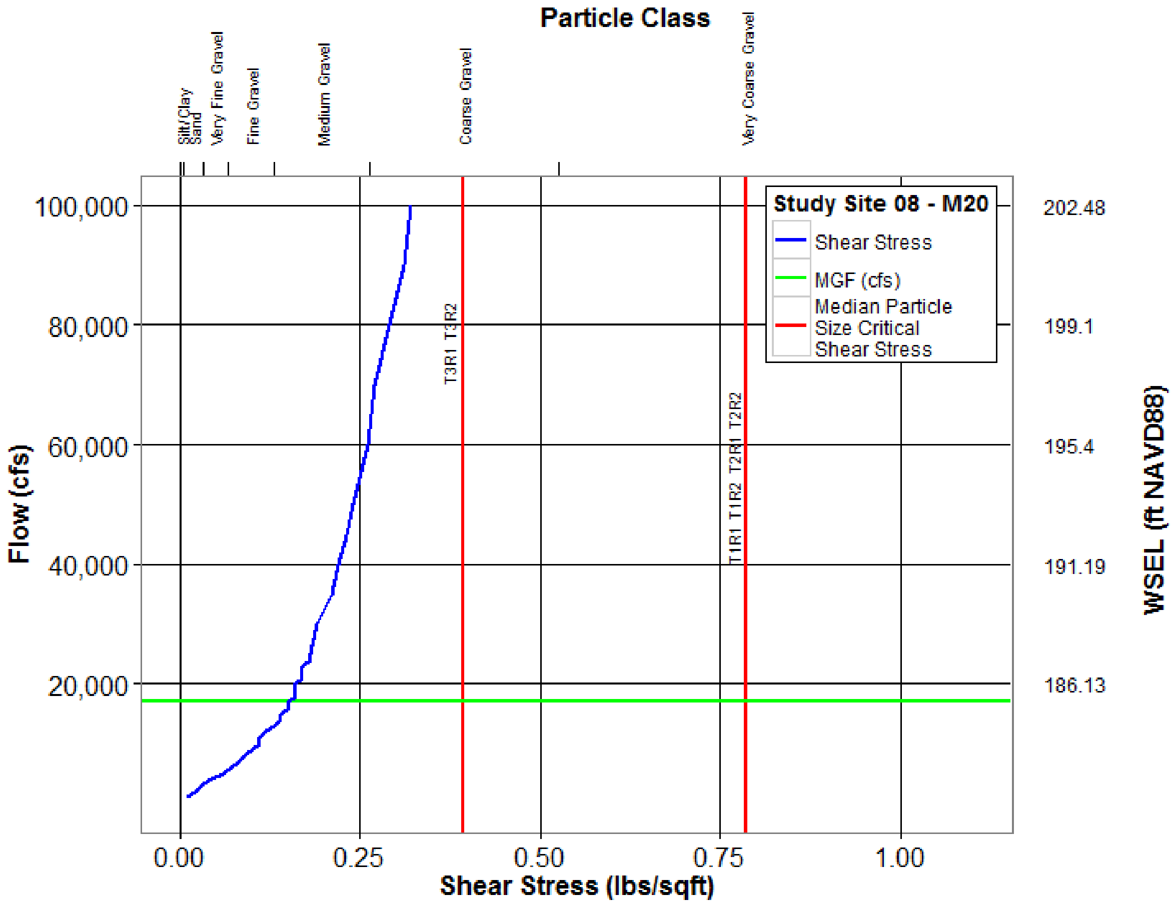

Figure E.12. Study site 08-M20.

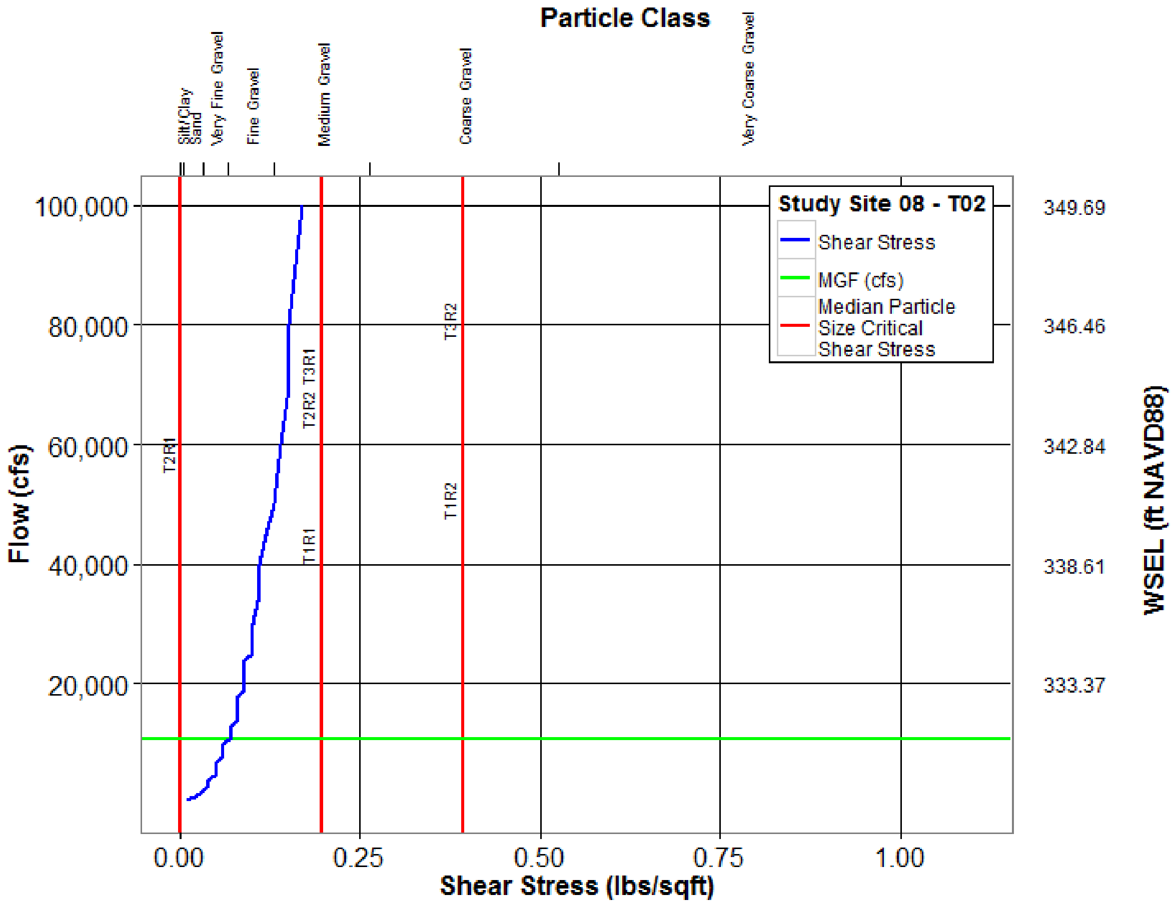

Figure E.13. Study site 08-T02.

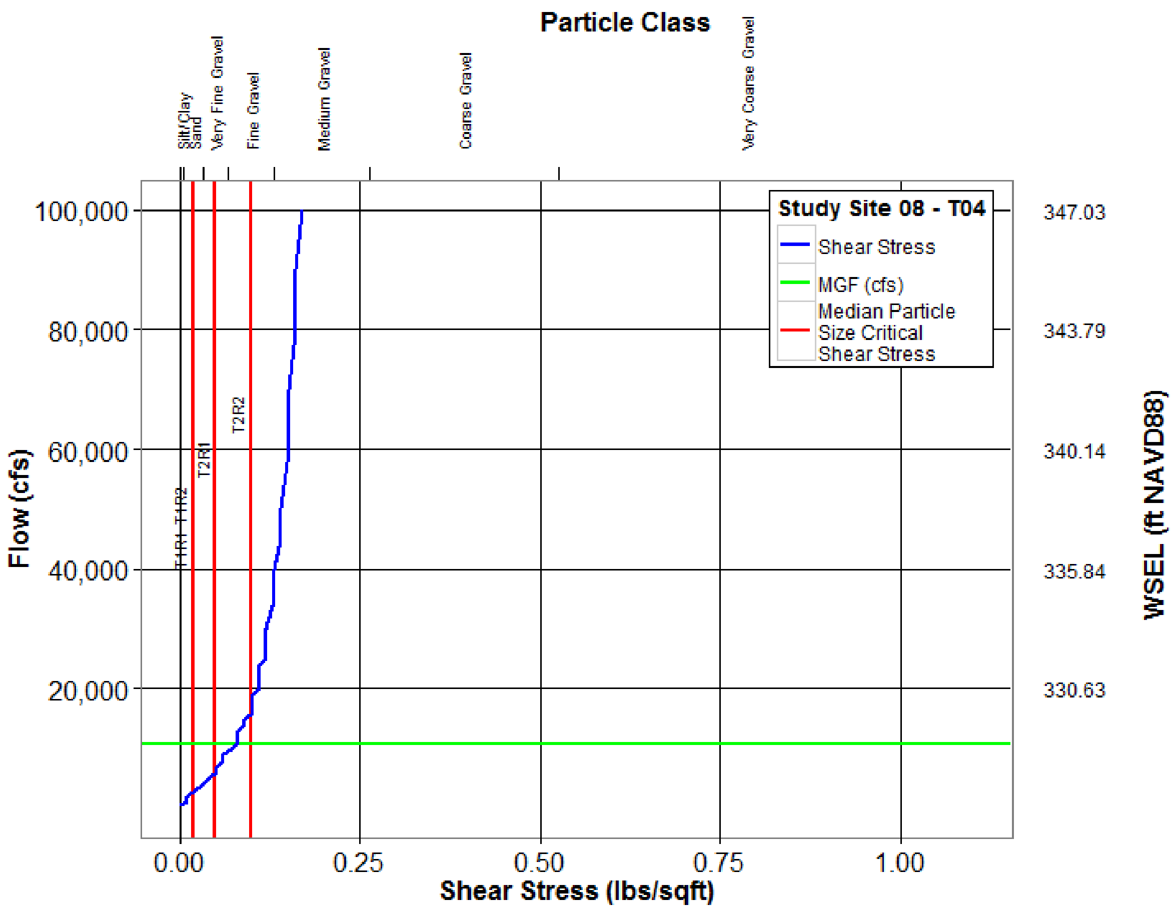

Figure E.14. Study site 08-T04.

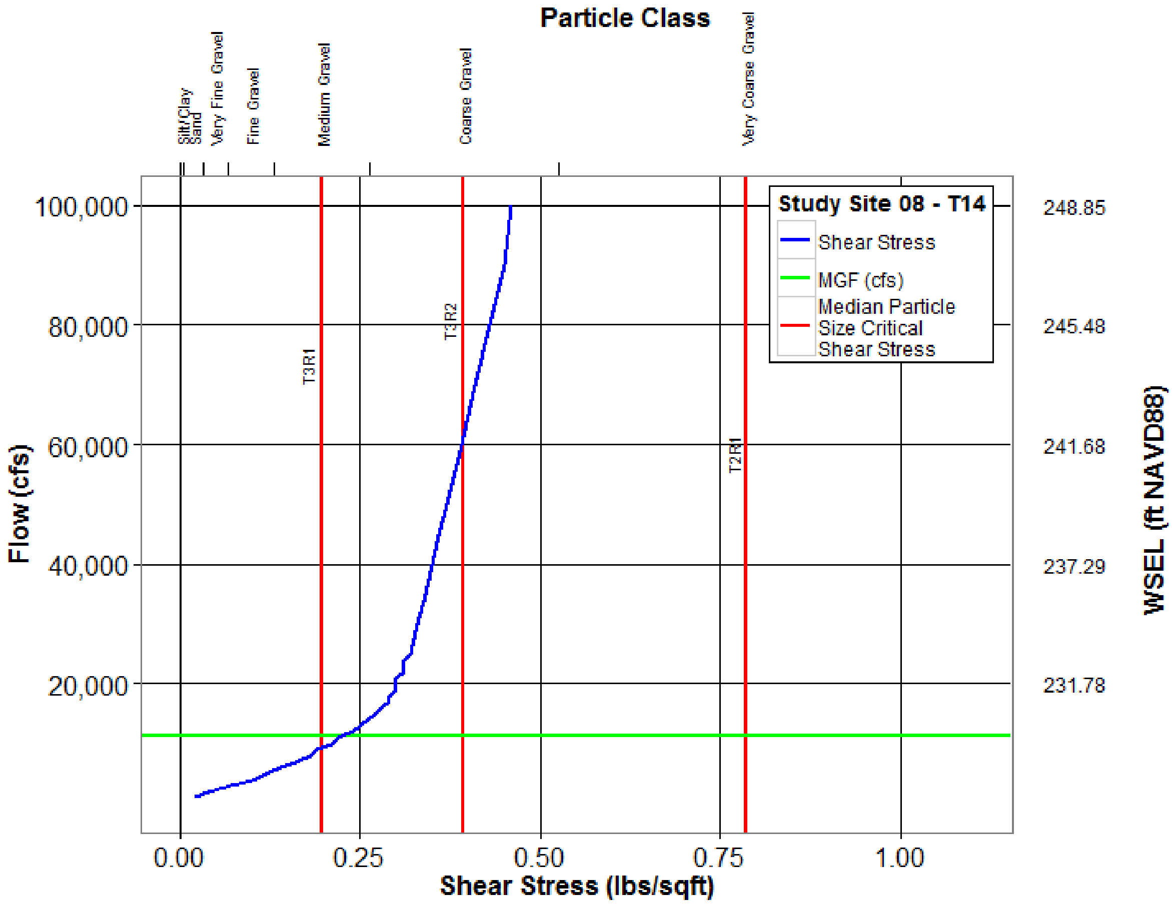

Figure E.15. Study site 08-T14. (Note that this figure does not depict the median particle size critical shear stress of Transect 1 for both sampling rounds or Transect 2 for the second sampling round. The relatively large median substrate at these sites (small cobble) has a critical sheer stress that is greater than the maximum scale presented on this figure.)

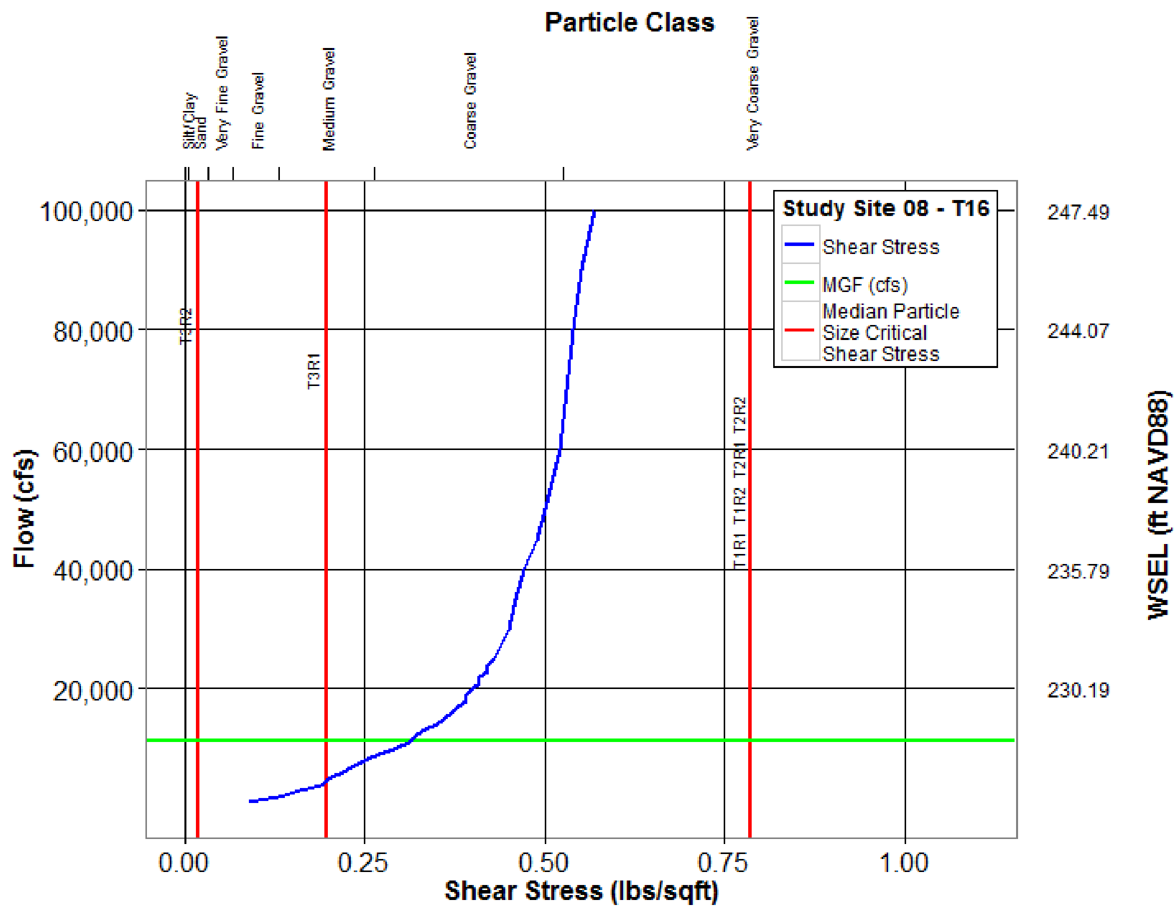

Figure E.16. Study site 08-T16.

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