Topeka shiner (*Notropis topeka*) monitoring in Eastern South Dakota streams (2010-2012) #T2-9-R-1

NOTE: Table 3 has been removed from this document to protect the security of specific locations.

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EXECUTIVE SUMMARY

The Topeka shiner (*Notropis topeka*) was listed as endangered in 1999 due to a 90% reduction in its range, which encompasses portions of six Midwestern states including South Dakota. However, more recent studies have shown that the Topeka shiner is more widespread within South Dakota than other portions of its range. Because of the prevalence of the Topeka shiner in South Dakota, the Department of Game, Fish and Parks developed a state management plan (Shearer 2003) with the goal of maintaining the habitat integrity of Topeka shiner streams in South Dakota while contributing towards national recovery efforts. Monitoring and assessment is a critical step in the implementation and evaluation of this goal.

The purpose of this study was to implement a long-term Topeka shiner monitoring program to determine progress toward the State Plan management goals. The monitoring plan was designed to assess the hydrologic and geomorphic parameters that may influence stream physical habitat, and ultimately fish community composition, and also to collect Topeka shiner and fish community data in tributaries potentially inhabited by Topeka shiners in the Big Sioux, Vermillion and James River Basins.

Specific objectives were to:

1) Classify each stream reach according to the Rosgen classification system (Rosgen 1996).
2) Produce a longitudinal profile of each stream reach illustrating pool/riffle sequences.
3) Produce a substrate composition profile for each stream reach.
4) Summarize aquatic habitat (riparian, bank and instream habitat) for each stream reach.
5) Calculate fish metrics for monitoring fish community structure.

A total of 33 sites were evaluated from 2010 to2012. Eleven streams were assessed with three sites per stream. Streams sampled included: Sixmile Creek, Peg Munky Run, Stray Horse Creek, West Pipestone Creek, and Medary Creek in the Big Sioux River Basin; the West Fork Vermillion River, Turkey Ridge Creek, and Long Creek from the Vermillion River Basin; and Middle Pearl Creek, Enemy Creek, and Twelvemile Creek from the James River Basin. Cross section, thalweg, substrate, habitat and fish community data were collected to calculate metrics to assess stream condition and the status of Topeka shiners.

Topeka shiners were found in all streams surveyed and at 58% (18 of 31) of sites sampled. Two sites were dry and could not be sampled. The number of Topeka shiners caught at sample sites ranged from 0 to 144. Three new sites were selected because permission could not be obtained to sample existing sites. Replacement sites were within close proximity to original sites and were located on Sixmile Creek, Medary Creek, and Peg Munky Run. Topeka shiners were collected at all of these sites. Two sites each from Long Creek and the West Fork Vermillion have limited data because the drought created intermittent pools. Additionally, fish were sampled from two sites on these steams. Poor environmental conditions ranging from flooding in 2010 to drought in 2012 made sampling difficult. Thus, the information presented in this report should be interpreted conservatively as sampling efforts may have lowered detection probabilities. During periods of intermittency fish often seek refuge in places of persistent water and flow. Topeka shiner may have been present, but not detected due to adverse conditions at sampling locations during the current period.

Since 2004, we have observed a shift in stream classification within several of the Topeka shiner monitoring sites, as well as a shift towards larger particle sizes. We found streams to fall within typical stream classifications as either "C" or "E" types for eastern South Dakota, however we observed shifts towards "G" type streams currently. Shifts towards "G" type streams and the associated probability of Topeka shiner presence is unknown.

Minimal changes in thalweg were observed between the 2004-2006 and 2010-2012 sampling periods. Sites on Stray Horse Creek and Medary Creek continued to have high gradient, heterogeneity and larger dominant particle sizes. Additionally, a single site on West Pipestone Creek continued to be homogeneous, flat-bottomed and dominated by silt substrates.

There were no differences between the time periods in bank cover, instream cover or index of biological integrity (IBI) between the different drainages. There were no changes in habitat metrics or IBI scores from the early to late sampling periods within the Big Sioux or James River Basins. However, there was a significant drop in bank cover within Long Creek from the Vermillion River Drainage between sampling periods. This drop did not correspond to a decline in IBI fish scores. Interestingly, there was no correlation between IBI scores and habitat metrics, suggesting the variables chosen to quantify stream habitat did not correspond to changes in the biotic community.

The purpose of this study was to provide a second round of sampling to be used in conjunction and for comparison with baseline data collected by Wall and Thomson (2007), in monitoring Topeka shiners and their habitat in eastern South Dakota. Streams clearly displayed a range of community and habitat conditions from relatively good (e.g., Stray Horse Creek, Medary Creek), to relatively poor (e.g., West Pipestone Creek). The metrics provided by this study were designed for detecting quantifiable differences in habitat and fish quality by comparing values at a site amongst years, however, we found some problems with the current methodology while doing the sampling this summer. Monitoring identical sites was not always feasible because we could not obtain landowner permission at several locations. Additionally, some methodology was found to be subjective and therefore, we recommend re-evaluating the current protocol to make adjustments that will limit bias and provide a more practical and repeatable monitoring program. With a revised approach, monitoring changes can be analyzed by individual site, stream, and/or basin over time.

TABLE OF CONTENTS

INTRODUCTION 7

METHODS 8
- Sample sites 8
- Data Collection 9
  - Stream habitat 9
  - Fish community 11
- Data Analysis 11
  - Stream Classification 11
  - Substrate Composition 12
  - Thalweg Profile 12
  - Instream Habitat 12
  - Fish Community Metrics 13
  - Statistical Analysis 15

RESULTS 15
  - Stream Classification 16
  - Substrate Composition 17
  - Thalweg Profile 17
  - Instream Habitat 17
  - Fish Community Metrics 18
  - Statistical Analysis 18

DISCUSSION 19
  - Stream Classification 19
  - Substrate Composition 21
  - Thalweg Profile 22
  - Instream Habitat 22
  - Fish Community Metrics 23

RECOMMENDATIONS 24

REFERENCES 26

LIST OF TABLES

Table 1. Topeka shiner sampling streams and site codes 29
Table 2. Fish community metrics chosen for evaluation of monitoring sites. 30
Table 3. Number of Topeka shiners caught at each sample site 32
Table 4. Rosgen classification for stream types at each monitoring site. 34
Table 5. Instream habitat scores at each monitoring site 36
Table 6. Fish community score for monitoring sites 38

LIST OF FIGURES

Figure 1. Sample sites for Topeka shiner monitoring 41
Figure 2. Key to the Rosgen classification of natural streams 42
Figure 3. Example of thalweg profile showing residual pools 43
Figure 4. D-50 plot of pebble count data 44
Figure 5. Thalweg profile.. 45
Figure 6. Differences between time periods within habitat and IBI scores among drainages 46
Figure 7. Differences between time periods within habitat and IBI scores among Big Sioux Drainage streams 47
Figure 8. Differences between time periods within habitat and IBI scores among James Drainage streams 48
Figure 9. Differences between time periods within habitat and IBI scores among Vermillion Drainage streams 49
Figure 10. Correlation matrix to examine patterns between habitat metrics and biological fish community IBI scores 50

LIST OF APPENDICES

Table A01. Numbers of fish caught at each monitoring site (by watershed) 51
Table A02. Fish metrics (by watershed) 55
Figure A01-a, -b. 6MC-01 Sampled site physical habitat 59
Figure A02-a, -b. 6MC-02 Sampled site physical habitat 60
Figure A03-a, -b. 6MC-03 Sampled site physical habitat 61
Figure A04-a, -b. MEC-01 Sampled site physical habitat 62
Figure A05-a, -b. MEC-02 Sampled site physical habitat 63
Figure A06-a, -b. MEC-03 Sampled site physical habitat 64
Figure A07-a, -b. PMR-01 Sampled site physical habitat 65
Figure A08-a, -b. PMR-02 Sampled site physical habitat 66
Figure A09-a, -b. PMR-03 Sampled site physical habitat 67
Figure A10-a, -b. STR-01 Sampled site physical habitat 68
Figure A11-a, -b. STR-02 Sampled site physical habitat 69
Figure A12-a, -b. STR-03 Sampled site physical habitat 70
Figure A13-a, -b. WPC-01 Sampled site physical habitat. 71
Figure A14-a, -b. WPC-02 Sampled site physical habitat 72
Figure A15-a, -b. WPC-03 Sampled site physical habitat 73

Figure A16-a, -b. ENC-01 Sampled site physical habitat.....74
Figure A17-a, -b. ENC-02 Sampled site physical habitat.....75
Figure A18-a, -b. ENC-03 Sampled site physical habitat.....76
Figure A19-a, -b. MPC-01 Sampled site physical habitat 77
Figure A20-a, -b. MPC-02 Sampled site physical habitat 78
Figure A21-a, -b. MPC-03 Sampled site physical habitat 79
Figure A22-a, -b. TMC-01 Sampled site physical habitat. 80
Figure A23-a, -b. TMC-02 Sampled site physical habitat. 81
Figure A24-a, -b. TMC-03 Sampled site physical habitat. 82
Figure A25-a, -b. LOC-01 Sampled site physical habitat.....83
Figure A26-a, -b. TUR-01 Sampled site physical habitat 84
Figure A27-a, -b. TUR-02 Sampled site physical habitat 85
Figure A28-a, -b. TUR-03 Sampled site physical habitat 86
Figure A29-a, -b. WFV-03 Sampled site physical habitat.....87

INTRODUCTION

The Topeka shiner (*Notropis topeka*) was listed as endangered in 1999 due to an estimated 90% reduction of occurrence in its range (USFWS 1998, 2001). At the time of listing, knowledge about the historic and current distribution of Topeka shiner was lacking in South Dakota. Recent studies have found that Topeka shiners appear prevalent in eastern South Dakota (Cunningham and Hickey 1997, Cunningham 1999, Blausey 2001, Wall et al. 2001, Deb Springman East Dakota Water Development District, *personal communication*).

The intact range and distribution of Topeka shiners in South Dakota prompted interest in managing the species at the state level. The "Topeka Shiner (*Notropis topeka*) Management Plan for the State of South Dakota" (Shearer 2003; "State Plan") was developed in cooperation with South Dakota Game, Fish and Parks and multiple federal, state and local entities. The intent of the State Plan was to allow the State of South Dakota to proactively manage Topeka shiner while reducing some federal regulatory requirements associated with the Endangered Species Act. The goal of the State Plan is to maintain the habitat integrity of Topeka shiner streams while contributing towards national recovery efforts. Monitoring and assessment is a critical step in the implementation and evaluation of this goal. A specific objective of the State Plan is to establish a monitoring and assessment protocol to evaluate the State's recovery goals.

The purpose of this study was to implement a long-term Topeka shiner monitoring program, which is necessary to evaluate the management goals outlined in the State Plan. The monitoring program was designed to assess physical habitat, Topeka shiner and fish community data in representative streams within the Big Sioux, Vermillion and James River Basins. According to the State Plan, these representative streams are to be assessed every three years in order to monitor stream conditions over time. This study represents the second round of data

collection, collected during a three-year period from 2010 to 2012. Results of this study provide habitat and fish metrics which can be used for comparison to data collected in 2004-2006 and subsequent years (i.e., three-year intervals) at "identical" sample locations.

Specific objectives were to:

1) Classify each stream reach according to the Rosgen classification system (Rosgen 1996).
2) Produce a longitudinal profile of each stream reach illustrating pool/riffle sequences.
3) Produce a substrate composition profile for each stream reach.
4) Summarize aquatic habitat (riparian, bank and instream habitat) for each stream reach.
5) Calculate fish metrics for monitoring fish community structure.

METHODS

Sample Sites

This study represents the second round of Topeka shiner monitoring since development of the state management plan, collected during a three-year period from 2010 to 2012 in; three tributaries of the James, three tributaries of the Vermillion, and five tributaries of the Big Sioux River Basins. These tributaries had established Topeka shiner populations and were selected to evaluate the watershed health of Topeka shiner streams within each respective river basin. A total of 33 sample sites were evaluated within eastern South Dakota over the course of three years (Figure 1). Eleven streams were assessed and three monitoring sites per stream were sampled (Table 1). Initial monitoring sites were selected based upon: 1) a qualitative evaluation of stream reach habitat to locate reaches with stream and riparian conditions typical of Topeka shiner habitat (Blausey 2001, Wall and Berry 2006), 2) stream flow (i.e., water present), 3)

previous records of Topeka shiner occurrence, and 4) permission from landowners for access. Subsequent sampling in subsequent years (2010-2012) was designed to monitor identical sampling locations. However, during the second round of sampling, landowner permission was not granted at a select number of sites, therefore, new sites were selected on the same stream in close proximity to the original monitoring site.

Data Collection

Stream Habitat

Stream habitat measurements were based upon Rosgen (1996). Stream mean bankfull width (BFW) was determined by measuring stream width between left and right bankfull at ten locations spaced $\geq$10 meters apart along each stream. A study reach was delineated equal to 40 times mean BFW or 100-m minimum/500-m maximum. The study reach was divided into 10, evenly spaced "subreaches". Each subreach was marked along the stream bank from downstream (subreach 1) to upstream (subreach 10).

A cross-sectional profile was taken within the study reach, typically at a riffle or a shallow run. Bankfull width was measured to the nearest centimeter using a tape measure that was strung across the reach perpendicular to the stream flow. Ten depth measurements from channel bottom to bankfull height (BFH) were taken at equal distances along the tape measure. From these measurements we calculated; mean depth, maximum depth, width to depth ratio (BFW/mean depth), and cross-sectional area (BFW x mean depth).

A Trimble Spectra Precision® Laser LL600 laser level and Spectra Precision® Laser HR500 laser receiver were used to measure elevation levels within the study reach and floodplain. The laser level was positioned in the floodplain to insure an unobstructed view from any point within the study reach and provide clear transmission to the level receiver. The laser

level receiver was attached to a bed rod and set to a precision of 6 mm. Flood-prone elevation was calculated as: 2 x (maximum depth) + BFH. To determine flood-prone width, the laser level receiver was set to a height (H) equal to BFH – (2 x maximum depth) on the bed rod. The bed rod was moved across the floodplain perpendicular to the stream while touching the ground until level with the laser. This was done for each side of the stream and the points on the ground that were level with H were marked. The distance between the marks was measured to the nearest 1/10 meter and was recorded as flood-prone width. Entrenchment ratio was calculated as (flood-prone width)/(BFW).

Water and relative elevation levels were measured along the thalweg of the study reach to develop a thalweg profile. Elevation levels were measured to the nearest 1/100 meter across the ten equally spaced subreaches from subreach 1 to 10. The laser level was used to determine relative elevation with the receiver set to a precision of 6 mm. Habitat type (lateral pool, backwater pool, glide/run, riffle) was recorded within each of the ten subreaches. Instream habitat (macrophytes, woody debris, live trees/roots, overhanging vegetation, undercut banks, boulders/cobble, artificial structures) was recorded within each subreach as; absent (0% of subreach area), sparse (<10% of subreach area), moderate (10%-40% subreach area), heavy (41%-75% of subreach area) and very heavy (>75% of subreach area). Substrate composition was estimated by randomly selecting and measuring 10 substrate particles within each subreach (1-10) from left bankfull (LBF) to right bankfull (RBF), for a total of 100 particles sampled across the study reach. Substrate particles were classed as silt/clay, sand, very fine to coarse gravel, small to large cobble and small to very large boulders according to the particle classification system of Wolman (1954). Longitudinal percent slope of the study reach was

calculated as: ((the elevation at the bottom of subreach 1 – the elevation at the top of subreach 10) / (reach length) x 100), to a precision of .001%. Elevation was measured at LBF.

Fish Community

Fish were sampled within the study reach using 15-ft or 30-ft wide by 4-foot deep 3/16-inch mesh seines. Seines were hauled from bank to bank where possible. One pass seine hauls were conducted within each subreach from downstream (subreach 1) to upstream (subreach 10) with block nets at each subreach. Where seine hauls were impractical (e.g. the stream was too narrow, had large cobble or boulders, large amounts of vegetation, or was a fast flowing riffle), kick seining was used. The length of seine hauls was determined by habitat type (i.e. one habitat type was seined in a haul) and by areas along the bank that provided low slopes to allow efficient pulling-up of the seine. Captured fish were kept in holding pens placed in the stream until identified and counted. After processing, all fish were released downstream to minimize recapture.

Data Analysis

Stream Classification

Each sampling reach was classified to stream type according to Rosgen (1996; Figure 2). Rosgen classifications are based on channel cross section profile measurements of; entrenchment ratio (flood-prone width / BFW), width/depth ratio (BFW/mean depth), sinuosity, longitudinal slope, and substrate material (Figure 2). Stream types (e.g. C4 to G4) are associated with morphological variables which typically change in response to disturbances (Rosgen 1996). The Rosgen classification system has been used by several agencies to monitor stream condition and stability and has been used to discern stream improvement or degradation over time (e.g. Watershed Assessment and River Stability and Sediment Supply [WARSSS] – EPA 2006).

Substrate Composition

Substrate particle data was plotted on a cumulative frequency graph (cumulative percent particles vs. log of particle size) to determine median substrate particle size frequency or D50 particle index value as used in the Rosgen classification system (Rosgen 1996). A change in median particle size frequency over time can indicate stream disturbance. For example a shift in such a graph over time towards finer materials would suggest a disturbance causing siltation of the stream.

Thalweg Profile

The thalweg profile has been used to monitor stream condition related to habitat heterogeneity (Lisle 1987, Lisle 1995, Madej 1999), and has also been related to fish density (Mossop and Bradford 2006). Thalweg profiles for each study reach were graphed using elevation and water level measurements taken in the field. Thalweg profiles illustrate channel bed variability, a measure of habitat heterogeneity and quality, and pool abundance (Lisle 1987, Madej 1999, Mossop and Bradford 2006). Changes in thalweg profiles over time can indicate changing stream condition (i.e., an increase in channel variation suggests an increase in habitat quality, a decrease in channel variability may represent a decrease in habitat quality; Lisle 1995, Madej 1999, Mossop and Bradford 2006). In a stable stream the location of pools and riffles may change over time, but the overall heterogeneity should remain the same.

Instream Habitat

Stream habitat was divided into two groups, instream cover and bank cover, for each monitoring site. Instream cover included the variables; woody debris, boulders/cobble, macrophytes and artificial structures. Bank cover included the variables overhanging vegetation, undercut banks and tree roots. Each variable was given a score from 0 to 4 relative to its

occurrence within each subreach according to the percent occurrence in each subreach: 0 = 0% subreach area, 1 = 1 to < 10% subreach area, 2 = 10% to 40% subreach area, 3 = 41% to 75% subreach area, 4 = >75% subreach area. For artificial structures each value was given a negative (i.e., 0 = 0% subreach area, -1 =1% to < 10% subreach area, -2 = 10% to 40% subreach area, -3 = 41% to 75% subreach area, -4 = >75% subreach area), because artificial structures such as dams and culverts are considered as negative factors affecting stream habitat. Scores were summed for each variable and an overall score was given for the two habitat groups. Future comparison can be made for each monitoring site as scores increase, decrease, or stay the same.

Fish Community Metrics

Data collected from fish sampling was organized into a fish community index of biological integrity (IBI) score for each sampling site (Karr et al. 1986, Barbour et al. 1999). Fish community and individual metrics were selected to be sensitive to regional disturbance regimes. Metrics are selected to respond either positively or negatively to disturbance. Typically, higher IBI scores indicate a healthier fish community and thus a healthier stream, whereas lower IBI scores indicate less healthy fish communities and streams. Temporal changes in IBI scores provide a means to monitor fish community and stream health through time. The IBI developed for sampling streams in the Big Sioux and Vermillion River Basins, which are located in the sub-humid climate zone, was based primarily on previous work in these basins by Milewski et al. (2001; Table 2). The IBI for the James River basin, which is located in the semi-arid climate zone, was developed largely from work by Shearer and Berry (2002; Table 2). Modifications to Milewski et al. (2001) and Shearer and Berry (2002) were as follows:

1. Northern redbelly dace (*Chrosomus eos*) were added to the intolerant species list for the Big Sioux Basin sites as this fish is on the edge of its range. Plains topminnow

(*Fundulus sciadicus*) was added to the intolerant species list for the James River Basin sites.

2. Blackside darter (*Percina maculata*) was added to the benthic invertebrate trophic guild list for the Big Sioux River Basin sites. Stone cat (*Noturus flavus*) was added to the benthic invertebrate trophic guild for all sites.
3. A metric for "proportion of insectivorous cyprinids" was included as an indicator of pool habitat (Karr 1986), replacing "number of green sunfish (*Lepomis cyanellus*) and orangespotted sunfish (*Lepomis humilis*)".
4. A metric for "log of the number of sunfish caught" was retained as a specific indicator of Topeka shiner presence and abundance (Blausey 2001, Wall and Berry 2006, Thomson and Berry 2007). For sites where no sunfish were caught, this metric was given a value of "zero". The metric, "Log of the number of Topeka shiners" was also created as an indicator of Topeka shiner abundance at all sites.
5. A metric quantifying "Fisher's alpha" was included as an additional measure of species diversity with species richness (Magurran 1988). Although species richness is commonly used in IBI metrics, it ignores species dominance and is affected by sample size. Values for Fishers alpha have been found to be more robust across species abundances and sample sizes (Hoagstrom 2006).

Metric scores were based upon a continuous scale ranging from 0 to 100 (Shearer and Berry 2002). Continuous scoring reduces variability in metric scores caused by scoring gaps and small differences in scores that can occur when using ordinal or categorical scoring scales (Shearer and Berry 2002). Threshold values for each metric (Table 2) were based upon Shearer and Berry (2006) or estimated using the range of conditions represented. For metrics represented by

proportions, values representing the 5th and 95th percentiles were used as threshold values representing impairment (Barbour et al. 1999). Metric values were included in an overall index of integrity by standardizing scores as; (measured metric value) / (standard best value) * 100 = standardized score for metrics that decrease in response to impairment, and (100 - measured metric value) / (100 - standardized best value) * 100 = standardized score for those metrics increasing with impairment. The best score achievable for each metric was 100. The total score awarded to each site was calculated as the mean of individual metric scores (n=12).

Statistical Analysis

We examined habitat and fish community indices between the two time periods using two-way ANOVA. We first compared bank cover, instream cover and IBI scores between the early (2004-2006) and late (2010-2012) time periods. Because we used multiple comparisons, we used a bonferroni correction value and set $\alpha=0.017$. Data met normality assumptions when comparing bank cover, instream cover and IBI scores (Shapiro-Wilk Test; P=0.116, P=0.645, and P=0.120, respectively) so data were not transformed prior to analysis. We then compared individual stream trends between the early and late time periods. Again, we compared bank cover, instream cover and IBI scores using a two-way ANOVA with an adjusted alpha level. Data met normality requirements for bank cover, instream cover and IBI (Shapiro-Wilk test; P=0.802, P=0.141, and P=0.951, respectively) so data were not transformed prior to analysis. To determine the explanatory power of the habitat variables of IBI variation, we ran a simple correlation matrix (Pearson Product Moment Correlation) to examine patterns between habitat and biological data.

RESULTS

Topeka shiners were found in all streams surveyed and at 58% or 18 of 31 sites sampled (Table 3; Two sites were dry with no fish). Numbers of Topeka shiners caught at sample sites ranged from 0 to 144. Three new sites were selected to replace identical sampling locations due to lack of landowner permission. New sites were within close proximity to original monitoring sites and were located on the same streams. New sites were located on Sixmile Creek, Medary Creek, and Peg Munky Run (Table 3). Topeka shiners were found at all three new sites (Table 3). Two sites each from Long Creek and West Fork of the Vermillion have limited data due to the drought creating intermittent pools. Two of the intermittent streams (LOC-02 and WFV-01) had no fish. Poor environmental conditions ranging from flooding in 2010 to drought in 2012 made sampling difficult.

Stream Classification

Stream valley classifications were typical of eastern South Dakota ("E" or "C" type streams; Rosgen 1996; Table 4). Substrate varied widely across monitoring sites with dominant substrates composed of a range of materials from silt/clay to cobble, which was reflected in the classification type (Table 4). Four sites (LOC-02, LOC-03, WFV-01, WFV-02) within the Vermillion River basin were dry with marginal pools, and therefore, stream classification was not calculated. Some streams showed signs of impairment. One monitoring site each on West Pipestone Creek (WPC-02), Enemy Creek (ENC-01), and West Fork Vermillion River (WFV-03) were moderately entrenched and transitioning from "C" type streams to "G" type streams. Additionally, one monitoring site each on Long Creek (LOC-01) and Turkey Ridge Creek (TUR-01) were moderately entrenched and transitioning from "E" type streams to "G" type streams. A monitoring site on West Pipestone Creek (WPC-03) had evidence of entrenchment and low sinuosity, transitioning to a "C" type stream from an "E" type. Topeka shiners appeared to have

equal probability of being found in either “E” type or “C” type streams.

Substrate Composition

Data collected from substrate surveys were plotted on graphs to determine D-50 values and illustrate substrate distributions (Figure 4). Substrate profiles for each sampling site are provided in the appendix (Figures A01-a to A29-a). Dominant substrate type varied across monitoring sites from; silt/clay (9 or 31%) or sand (5 or 17%), to gravel (14 or 48%) and cobble (1 or 4%).

Thalweg Profile

Qualitative differences amongst thalweg profiles are evident in the plotted graphs (Figure 3). Thalweg profiles for each sampling site are provided in the appendix (Figures A01-b to A29-b). Four sites (LOC-02, LOC-03, WFV-01, WFV-02) within the Vermillion River basin were dry with marginal pools and, therefore, profiles were not graphed. Medary Creek (MEC-01; Figure A04-b) and Stray Horse Creek (STR-01; Figure A10-b) are typical of relatively higher gradient reaches with frequent pool riffle complexes, high heterogeneity, and coarser substrate (Figures A04-a and A10-a respectively). In contrast, West Pipestone Creek (WPC-02; Figure A14-b) shows a homogeneous profile with low gradient and a relatively flat bottom. This stream type is typically dominated by silt substrates (Figure A14-a). Remaining profiles fell within this range.

Instream Habitat

Bank cover scores ranged from 3 to 81 (Table 5). Scores for bank cover were higher, on average, for monitoring sites in the Big Sioux River Basin (mean ± SD bank cover; 51.6±17), followed by the Vermillion River Basin (46.2±24.2) and the James River Basin (38.7±21.6; Table 5). Instream cover scores ranged from -2 to 57 (Table 5). Average scores for instream

cover at monitoring sites were similar across basins with the highest in the Big Sioux River Basin (25.5±18.0), followed by the James River Basin (24.7±16.0) and finally the Vermillion River Basin (19.8±20.7). Variation in scores was higher in the Big Sioux River Basin than in the other basins (Table 5). Four sites (LOC-02, LOC-03, WFV-01, WFV-02) within the Vermillion River basin were dry with marginal pools so instream habitat was not classified. WPC-02 had very low scores for bank cover (19) and instream cover (5). This site also had a relatively homogeneous thalweg profile and small particle size (silt/clay) which is reflected in its poor habitat score.

Fish Community Metrics

Fish community metric scores ranged from 15/100 to 85/100 (Table 6). James River Basin sites had higher average scores (mean=62) than Big Sioux (mean=47) and Vermillion River Basin (mean=53) sites. Additionally, scores varied less by site in the James River Basin (CV = 0.23) than in the Vermillion River (CV=29) and Big Sioux River basins (CV=36; Table 6). Monitoring sites dominated by intolerant species included PMR-03, WPC-03, ENC-02, ENC-03, TMC-02, LOC-01, LOC-03, TUR-03 (Appendix Table A01, Table A02). Topeka shiners were listed as the dominant species at three monitoring sites (ENC-02, ENC-03, WPC-03) and second most-dominant species at three other sites (ENC-01, TMC-03, STR-01; Appendix Table A01, Table A02). No fish were sampled at two monitoring sites (LOC-02, WFV-01) most likely due to the drought creating intermittent pools so their scores were not calculated (Table 6).

Statistical Analysis

There were no differences between the time periods (2004-2006 to 2010-2012) in bank cover, instream cover or IBI's between the different drainages (Figure 6). There were no changes

in habitat metrics or IBI scores from the early (2004-2006) to late (2010-2012) sampling periods in the Big Sioux River (Figure 7) or James River Drainages (Figure 8). However, there was a substantial drop in bank cover in Long Creek from the Vermillion River Drainage from the early (2004-2006) to late (2010-2012) sampling time periods ($F_{10,41}$=3.479; P=0.002; Figure 9). This significant drop did not correspond to a decline in IBI scores. Interestingly, there was no correlation between the IBI scores and either bank cover (r=0.113) or instream cover (0.051) suggesting the variables chosen to quantify stream habitat did not correspond to changes in the biotic community.

DISCUSSION

Topeka shiners remained extant in the eleven streams monitored under this project. Results from this sampling effort (2010-2012) indicated an 18% reduction in the number of locations currently supporting Topeka shiner populations (18 of 31 sites, 2 sites were dry). This reduction in the number of locations having Topeka shiners may have been, in part, related to the difficult sampling conditions from flooding to drought during the current monitoring period. These factors should be taken into consideration when comparing current findings with those from 2004-2006. The drought of 2012 created intermittent pools forcing fish to seek refuge in places of persistent water and flow (Magoulick and Kobza 2003). Topeka shiner detection probabilities may have been reduced due to these unfavorable conditions. Thus, the information presented in this report should be interpreted conservatively as conditions may have favored false negatives.

Stream Classification

Rivers generally do not change instantaneously; rather they undergo a more consistent series of channel adjustments over time to accommodate changes following either natural or

imposed alterations (Rosgen 1996). The rate and direction of change in stream classification is a matter of the magnitude of change in land use, climate and stream type involved. Some stream types change and evolve rapidly whole others are slow in response to changes (Rosgen 1996).

Stream valley classifications in eastern South Dakota are typically classified as either "C" or "E" types. The "C" type streams are located in valleys with well-developed floodplains (slightly entrenched) and exhibit a sequence of riffles and pools. Channels of "C" type streams can be significantly altered and rapidly de-stabilized when changes in bank stability, watershed condition, or flow regime are combined (Rosgen 1996). The "E" type streams designated as evolutionary in terms of fluvial process and morphology develop following floodplain development and are slightly entrenched. While "E" type streams are considered as highly stable systems, they are very sensitive to disturbance and can be rapidly converted to other stream types, including a "G" type stream, in a relatively short time period (Rosgen 1996). "G" type streams are entrenched, narrow, and contain a deep riffle/pool channel. "G" type streams are characteristic of having very high bank erosion rates and high sediment supplies.

Since 2004, some streams have displayed signs of change and impairment. We have observed a shift in stream classification within several of the Topeka shiner monitoring sites. Sites within West Pipestone Creek (WPC-02), Enemy Creek (ENC-01), and West Fork Vermillion River (WFV-03) were moderately entrenched and transitioning from "C" type streams to "G" type streams. Additionally, sites on Long Creek (LOC-01) and Turkey Ridge Creek (TUR-01) were moderately entrenched and transitioning from "E" type streams to "G" type streams. Topeka shiners appeared to have equal probability of being found in either "E" or "C" type streams, however, shifts towards "G" type streams and the associated probability of Topeka shiner detection is unknown. Characteristics of "G" type streams including entrenched,

narrow banks with high erosion rates and a deep riffle/pool channel complex may not be favorable to Topeka shiners.

Habitat unit classification can be a useful descriptive tool in stream classification. This tool is often applied inappropriately to quantify aquatic habitat in order to monitor the response of individual streams to human activities. This technique is not particularly repeatable, highly subjective and susceptible to variation among observers, over time, and between sites (Poole et al. 1997; Simon et al. 2007). It is possible that the shifts in stream classification toward "G" type streams were due to subjective variation among observers over time. Monitoring instead should focus on direct, repeatable, cost-effective and quantitative measures of selected physical, chemical, and biological components. These processes should span several scales (Poole et al. 1997). Future Topeka shiner stream monitoring should use a combination of a modified version of the stream Environmental Monitoring and Assessment Program (EMAP) to better assess habitat (Barbour et al. 1999).

Substrate Composition

Substrate sizes along with other physical properties of a stream play an important role in determining the type and diversity of organisms that a stream can support. These attributes provide useful information on ecosystem function and stream health. Human activities, which disturb stream banks or increase erosion, increase the supply of sediments (EPA 2006). Topeka shiner prefer pools of clear, clean water with gravel, rock or sand bottoms free from siltation (Pflieger 1997).

Since 2004, a shift towards larger particle sizes was observed. Wall and Thomson (2007) found the highest percentage of monitoring sites (43%) to contain silt/clay as the dominant particle size. A shift towards gravel (48%) as the dominant particle size was observed during the

2010-2012 sampling period, which Topeka shiners were found to currently favor (75% of current sites with Topeka shiner presence). It is unknown exactly why a shift toward larger particle sizes was observed. It could be partially due to scouring from recent flooding (2010) or the subjectivity of field crews. A revised and standardized protocol is needed in future monitoring efforts.

Thalweg Profile

Thalweg profiles are used to monitor stream condition related to habitat heterogeneity (Lisle 1987, Lisle 1995, Madej 1999). Thalweg profiles illustrate channel bed variability and over time, can indicate changes in stream morphology resulting from disturbance. An increase in channel variation suggests an increase in habitat quality whereas a decrease in channel variability may represent a decrease in habitat quality.

Minimal changes in thalweg were observed between the 2004-2006 and 2010-2012 sampling periods. Streams where Wall and Thomson (2007) observed high gradient and heterogeneity (STR-01 and MEC-01) retained those conditions which were reflected in a larger dominant particle size. Additionally streams with homogeneous profiles (WPC-02) were again classified as flat-bottomed and dominated by silt substrates.

Monitoring thalweg profiles is a relatively simple, rapid and inexpensive technique that is easily repeatable. It is well suited to monitor channel features such as residual pool depth and frequency, which is a favored habitat to Topeka shiners. Thalweg profiles provide a good measure of physical habitat and way of assessing and monitoring fish habitat over time.

Instream Habitat

Scoring fish habitat for each variable and summing them to determine an overall score for the two different habitat groups (instream cover and bank cover) can serve as a useful tool to

make future comparisons at monitoring sites over time. However, some subjectivity and personal biases even among trained biologists is possible. A total of ten habitat parameters were scored and given a rank from 0 to 4 at each sub-reach within each study reach. Generally, the greater variety in habitat parameters and higher the overall score the better the aquatic habitat for the fishery. Decreases in habitat score over time can indicate a decline in aquatic habitat. Habitat indices are an established means of monitoring changes in stream health over time (Barbour et al. 1999).

There were no differences between time periods (2004-2006 to 2010-2012) in bank cover or instream cover among drainages. There were no changes in habitat metrics from the early (2004-2006) to late (2010-2012) sampling periods in the Big Sioux or James River drainages. However, there was a significant drop in bank cover in Long Creek from the Vermillion River Drainage among sampling periods. We observed the Big Sioux River Basin to have the highest bank cover scores on average, which differed from Wall and Thomson (2007), as they found the Vermillion River Basin to have the highest bank cover scores. Instream cover scores remained similar among basins with no significant differences. West Pipestone Creek (WPC-02) remained one of the lowest ranked sites for habitat, which again was supported by a relatively homogenous thalweg profile and small substrate size.

Fish Community Metrics

Biological indices are an established means of monitoring changes in stream health over time (Karr et al. 1986). Metrics within the fish community IBI score were selected to respond either positively or negatively to disturbance. Generally, the higher the IBI score the healthier the fish community and thus the healthier the stream.

Differences between the time periods were not detected in fish community IBI scores among basins. Although not significant, the largest change in average IBI scores was observed within the James River Basin. Wall and Thompson (2007) assigned the lowest average IBI score (mean±SD, 48±14) to the James River Basin sites while we ranked it highest (62±17) during the current sampling period. Higher variability in fish IBI scores were observed in the Vermillion River Basin than the James River Basin which Wall and Thomson (2007) observed as higher. Topeka shiner remained the dominant species found at two sites on Enemy Creek (ENC-02 and ENC-03) and a single site on West Pipestone Creek (WPC-03). Additionally, two new sites on Enemy Creek (ENC-01) and Twelvemile Creek (TMC-03) were found to support Topeka shiner as the second most dominant species. However, Topeka shiners were absent from a Long Creek site (LOC-01) where they were the second most dominant species in the previous monitoring period (Wall and Thomson 2007). This could potentially be due to the drought and only intermittent pools being sampled.

RECOMMENDATIONS

We found some problems with the current methodology while sampling this summer. Monitoring identical sites was not always feasible because we could not obtain landowner permission at several locations. Additionally, some methodology was found to be subjective, therefore, we recommend re-evaluating the current protocol to make adjustments that will limit bias and provide a more practical and repeatable monitoring program. Additionally, adjustments to the habitat metrics and fish community IBI protocols may need to be adjusted. We tested to see if there was a positive correlation between habitat metrics and fish community IBI scores, but found no correlation. The observed decline in Long Creek habitat scores were not reflected in a lower fish community IBI score. We will need to test to see if there are correlations between

each habitat score metric with fish community IBI scores to see if a correlation exists. Adjustments to habitat metrics will help us to better monitor habitat and fish community over time. We need to continue to monitor habitat because it is more proactive and cost effective than strictly monitoring Topeka shiner distribution and abundance (Missouri Department of Conservation 1999). Differences in metrics can be analyzed by individual site, stream, and/or basin over time.

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Table 1. Topeka shiner sampling streams and site codes (1-3 = up-downstream).

River Basin	Sampling Stream	Stream Code	Site Code
Big Sioux River	Six-mile Creek	6MC	6MC-01
Big Sioux River	Six-mile Creek	6MC	6MC-02
Big Sioux River	Six-mile Creek	6MC	6MC-03
Big Sioux River	Medary Creek	MEC	MEC-01
Big Sioux River	Medary Creek	MEC	MEC-02
Big Sioux River	Medary Creek	MEC	MEC-03
Big Sioux River	Peg Munky Run	PMR	PMR-01
Big Sioux River	Peg Munky Run	PMR	PMR-02
Big Sioux River	Peg Munky Run	PMR	PMR-03
Big Sioux River	Stray Horse Creek	STR	STR-01
Big Sioux River	Stray Horse Creek	STR	STR-02
Big Sioux River	Stray Horse Creek	STR	STR-03
Big Sioux River	West Pipestone Creek	WPC	WPC-01
Big Sioux River	West Pipestone Creek	WPC	WPC-02
Big Sioux River	West Pipestone Creek	WPC	WPC-03
James River	Enemy Creek	ENC	ENC-01
James River	Enemy Creek	ENC	ENC-02
James River	Enemy Creek	ENC	ENC-03
James River	Middle Pearl Creek	MPC	MPC-01
James River	Middle Pearl Creek	MPC	MPC-02
James River	Middle Pearl Creek	MPC	MPC-03
James River	Twelvemile Creek	TMC	TMC-01
James River	Twelvemile Creek	TMC	TMC-02
James River	Twelvemile Creek	TMC	TMC-03
Vermillion River	Long Creek	LOC	LOC-01
Vermillion River	Long Creek	LOC	LOC-02
Vermillion River	Long Creek	LOC	LOC-03
Vermillion River	Turkey Ridge Creek	TUR	TUR-01
Vermillion River	Turkey Ridge Creek	TUR	TUR-02
Vermillion River	Turkey Ridge Creek	TUR	TUR-03
Vermillion River	West Fork Vermillion River	WFV	WFV-01
Vermillion River	West Fork Vermillion River	WFV	WFV-02
Vermillion River	West Fork Vermillion River	WFV	WFV-03

Table 2. Fish community metrics chosen for evaluation of monitoring sites. For threshold values; B = Big Sioux River Bain, V = Vermillion River Basin, J = James River Basin.

Code	Metric	Definition	Threshold values	Response to disturbance
SPPRCH	Species richness	Total number of all species	4 - 20 B,V 0 – 16 J	Decrease
SPPDIV	Species diversity	Fisher's alpha for species diversity	0.5 - 3.4 B,V 1.0 – 2.7 J	Decrease
#SF	Number of native sunfish	Log (total number of green and orange-spotted sunfish) + 1 (*Lepomis cyanellus and L. humilis*)	0 - 3.4	Decrease
#CYPCAT	Number of Cyprinids & Catostomids	Total number of Cyprinid species and Catostomid species	0 – 15 B,V 0 – 11 J	Decrease
#INTOL	Number of disturbance intolerant species	Intolerant species included: • Topeka shiner (*Notropis topeka*) • brook stickleback (*Culaea inconstans*) • blacknose dace (*Rhinichthys atratulus*) • tadpole madtom (*Noturus gyrinus*) • Iowa darter (*Etheostoma exile*) • sand shiner (*Notropis stramineus*) • plains topminnow (*Fundulus sciadicus*) – James River only • northern redbelly dace (*Chrosomus eos*) - Big Sioux only • shorthead redhorse (*Moxostoma macrolepidotum*)	0 – 8 B 0 – 7 V 0 – 4 J	Decrease
%TOL	Proportion disturbance tolerant species	% Abundance of tolerant species. Tolerant species included: • green sunfish • white sucker (*Catostomus commersonii*) • red shiner (*Cyprinella lutrensis*) • black bullhead (*Ameiurus melas*) • fathead minnow (*Pimephales promelas*) • common carp (*Cyprinus carpio*) • bluntnose minnow (*Pimephales notatus*) – Big Sioux & Vermillion Basins only	3 – 93 B,V 1 – 82 J	Increase

Table 2. (continued).

Code	Metric	Definition	Threshold values	Response to disturbance
#TOS	Number of Topeka shiners	Log (total number of Topeka shiners) + 1	0 – 3.4	Decrease
%OMNIV	Proportion omnivore species	% Abundance of omnivorous species. Omnivores included: • red shiner • white sucker • common carp • black bullhead • brassy minnow (*Hybognathus hankinsoni*) • fathead minnow • river carpsucker (*Carpiodes carpio*) • gizzard shad (*Dorosoma cepedianum*) – James River Basin only • bluntnose minnow (*Pimephales notatus*) – Big Sioux & Vermillion Basins only	8 – 95 B,V 8 – 94 J	Increase
%INSCYP	Proportion cyprinids that are insectivores	% Abundance of cyprinid insectivores. Species included: • sand shiner • Emerald shiner (*Notropis atherinoides*) • blacknose dace • bigmouth shiner (*Notropis dorsalis*) • common shiner (*Luxilus cornutus*) • creek chub (*Semotilus atromaculatus*)	2 – 80 B,V 0 – 61 J	Decrease
%BENINS	Proportion benthic insectivores	% Abundance of benthic insectivore species. Species included: • sand shiner • tadpole madtom • blacknose dace • Iowa darter • shorthead redhorse • Johnny darter (*Etheostoma nigrum*) • blackside darter (*Percina maculata*)-Big Sioux Basin only	3 – 60 B 0 – 50 V 0 – 53 J	Decrease
%DOM 1&2	Proportion of two dominant species	% Abundance of two most numerically dominant species. (species varied across monitoring site)	43 – 95 B,V 70 – 92 J	Increase
%EXOTIC	Proportion of exotic species	% Abundance of exotic species. Species included: • common carp • largemouth bass (*Micropterus salmoides*) • bluegill (*Lepomis macrochirus*)	0 – 4 B,V 0 – 61 J	Increase

Table 4. Rosgen classification for stream types at each monitoring site.

Site Code	River Basin	Reach Length	Entrenchment Ratio	Width/Depth Ratio	Sinuosity	Channel Slope	Substrate 50th Percentile	Rosgen Classification
6MC-01	Big Sioux River	137.2	8.4	4.6	1.01	0.003	Gravel	E4
6MC-02	Big Sioux River	159.1	5.9	6.9	1.09	0.005	Gravel	E4
6MC-03	Big Sioux River	404.8	5.4	8.8	1.14	0.004	Gravel	E4
MEC-01	Big Sioux River	150	30.4	19.5	1.21	0.005	Gravel	C4
MEC-02	Big Sioux River	224	2.3	12.9	1.76	0.003	Cobble	C3
MEC-03	Big Sioux River	311	4.0	12.0	1.20	<0.001	Silt	C6c-
PMR-01	Big Sioux River	100	6.1	4.9	1.06	0.003	Gravel	E4
PMR-02	Big Sioux River	100	4.4	14.0	1.10	0.005	Gravel	C4
PMR-03	Big Sioux River	100	9.4	12.0	0.54	0.007	Sand	C5
STR-01	Big Sioux River	499.9	2.8	10.4	1.00	0.002	Gravel	E4
STR-02	Big Sioux River	150	11.5	7.8	1.11	0.004	Gravel	E4
STR-03	Big Sioux River	210	6.6	19.1	1.20	<0.001	Gravel	C4c-
WPC-01	Big Sioux River	487.7	8.7	14.7	1.59	<0.001	Silt	C6c-
WPC-02	Big Sioux River	361.8	1.9	12.5	1.00	<0.001	Silt	C6c-*
WPC-03	Big Sioux River	252	2.4	15.9	1.01	0.002	Gravel	C4
ENC-01	James River	499.9	1.5	41.6	1.07	<0.001	Silt	C6c-*
ENC-02	James River	192	2.6	14.2	1.06	0.001	Sand	C5c-
ENC-03	James River	235.9	2.6	14.4	1.03	<0.001	Silt	C6c-

Table 4. (continued).

Site Code	River Basin	Reach Length	Entrenchment Ratio	Width/Depth Ratio	Sinuosity	Channel Slope	Substrate 50th Percentile	Rosgen Classification
MPC-01	James River	267.6	6.6	11.3	1.81	<0.001	Silt	E6
MPC-02	James River	312.7	9.2	11.4	1.86	<0.001	Gravel	E4
MPC-03	James River	259.1	13.8	7.3	1.63	0.002	Sand	E5
TMC-01	James River	101.8	2.3	7.4	1.68	0.002	Gravel	E4
TMC-02	James River	295.1	4.7	13.7	1.26	<0.001	Sand	C5c-
TMC-03	James River	150	2.4	10.4	1.89	<0.001	Silt	E6
LOC-01	Vermillion River	235.9	1.9	7.0	1.79	<0.001	Gravel	E4*
LOC-02	Vermillion River	--	--	--	--	--	--	--
LOC-03	Vermillion River	--	--	--	--	--	--	--
TUR-01	Vermillion River	107	1.7	7.5	1.18	<0.001	Silt	E6*
TUR-02	Vermillion River	150	34.0	4.7	1.13	0.003	Sand	E5
TUR-03	Vermillion River	399.9	24.3	7.7	1.57	<0.001	Silt	E6
WFV-01	Vermillion River	--	--	--	--	--	--	--
WFV-02	Vermillion River	--	--	--	--	--	--	--
WFV-03	Vermillion River	297.2	1.8	21.9	1.30	<0.001	Gravel	C4c-*

*= moderately entrenched

Table 5. Instream habitat scores at each monitoring site.

Site Code	River Basin	Macrophytes	Woody Debris >0.3 m	Wood Debris <0.3 m	Live Trees & Roots	Overhanging Vegetation	Undercut Bank	Boulders & Coble	Artificial Structures	Bank Cover	Instream Cover
6MC-01	Big Sioux River	0	0	0	4	39	38	0	-2	81	-2
6MC-02	Big Sioux River	22	16	16	13	25	7	3	0	45	57
6MC-03	Big Sioux River	1	2	2	2	28	29	1	0	59	6
MEC-01	Big Sioux River	0	0	0	0	16	26	0	0	42	0
MEC-02	Big Sioux River	12	2	1	0	24	27	27	-1	51	41
MEC-03	Big Sioux River	15	0	0	0	23	21	0	0	44	15
PMR-01	Big Sioux River	17	0	0	0	23	27	16	0	50	33
PMR-02	Big Sioux River	23	0	0	0	30	25	12	0	55	35
PMR-03	Big Sioux River	31	0	0	0	38	31	0	0	69	31
STR-01	Big Sioux River	15	2	2	5	38	31	10	0	74	29
STR-02	Big Sioux River	38	0	0	0	39	25	4	0	64	42
STR-03	Big Sioux River	36	2	2	0	36	21	7	0	57	47
WPC-01	Big Sioux River	17	0	0	0	26	15	0	0	41	17
WPC-02	Big Sioux River	5	0	0	0	14	5	0	0	19	5
WPC-03	Big Sioux River	2	5	2	3	12	9	21	-3	24	27
ENC-01	James River	40	5	5	3	0	0	1	0	3	51
ENC-02	James River	20	2	2	0	32	25	1	0	57	25
ENC-03	James River	36	4	4	0	9	0	1	0	9	45
MPC-01	James River	34	0	0	0	28	24	3	0	52	37
MPC-02	James River	10	0	0	0	12	19	1	0	31	11
MPC-03	James River	10	0	0	0	21	16	1	0	37	11
TMC-01	James River	6	3	3	0	36	32	2	0	68	14
TMC-02	James River	0	6	6	1	20	20	8	0	41	20
TMC-03	James River	6	0	0	0	34	16	2	0	50	8

Table 5. (continued).

Site Code	River Basin	Macrophytes	Woody Debris >0.3 m	Wood Debris <0.3 m	Live Trees & Roots	Overhanging Vegetation	Undercut Bank	Boulders & Coble	Artificial Structures	Bank Cover	Instream Cover
LOC-01	Vermillion River	0	8	8	4	0	9	8	0	13	24
LOC-02	Vermillion River	--	--	--	--	--	--	--	--	--	--
LOC-03	Vermillion River	--	--	--	--	--	--	--	--	--	--
TUR-01	Vermillion River	39	6	6	1	40	40	3	0	81	54
TUR-02	Vermillion River	0	3	3	11	13	26	0	0	50	6
TUR-03	Vermillion River	0	1	1	2	18	25	1	0	45	3
WFV-01	Vermillion River	--	--	--	--	--	--	--	--	--	--
WFV-02	Vermillion River	--	--	--	--	--	--	--	--	--	--
WFV-03	Vermillion River	0	0	0	0	8	34	12	0	42	12

Table 6. Fish community score for monitoring sites. (SCORE = ∑ metrics/12 for maximum score of 100).

Big Sioux River Basin	Species Richness	Species Diversity	# Sunfish	# Cyprinids & Catostomids	# Intolerant Species	% Tolerant Species	% Omnivore Species	% Insectivore Cyprinids	% Benthic Insectivore	% Dominant 2 Species	% Exotic Species	# Topeka Shiners	SCORE
6MC-01	75	100	44	60	38	30	35	22	19	52	100	29	50.3
6MC-01 Resampled	65	86	29	53	25	31	33	7	12	95	98	0	44.6
6MC-02	60	100	71	47	0	40	67	18	27	100	100	0	52.5
6MC-03	45	59	0	60	38	71	74	77	23	43	100	61	54.2
MEC-01	40	76	0	47	25	73	77	86	27	41	100	0	49.4
MEC-01 Resampled	85	83	0	80	63	58	62	51	34	94	99	0	59.0
MEC-02	100	96	0	93	88	73	77	60	31	97	100	29	70.3
MEC-03	80	90	0	67	50	44	46	46	37	66	100	0	52.0
PMR-01	80	84	0	67	75	76	60	27	17	100	99	81	63.7
PMR-02	85	84	29	73	88	84	82	43	26	100	100	81	72.8
PMR-03	55	59	0	47	63	83	87	81	97	45	100	0	59.6
STR-01	80	73	38	67	50	24	25	15	13	39	100	93	51.3
STR-01 Resampled	50	65	79	33	25	33	35	1	1	26	100	44	41.0
STR-02	70	33	29	7	0	28	33	0	0	9	100	0	25.7
STR-02 Resampled	25	19	0	13	13	2	2	0	3	4	99	0	14.8
STR-03	45	100	38	27	25	19	22	6	19	36	100	0	36.4
WPC-01	30	56	0	27	25	5	5	3	8	17	100	0	23.0
WPC-02	15	0	0	13	0	34	36	0	0	0	100	0	16.6
WPC-03	70	94	29	60	25	56	59	14	17	75	100	86	57.1

Table 6. (continued).

James River Basin	Species Richness	Species Diversity	# Sunfish	# Cyprinids & Catostomids	# Intolerant Species	% Tolerant Species	% Omnivore Species	% Insectivore Cyprinids	% Benthic Insectivore	% Dominant 2 Species	% Exotic Species	# Topeka Shiners	SCORE
ENC-01	81	100	50	73	50	83	22	2	2	72	99	76	59.2
ENC-02	100	100	50	100	75	82	81	39	10	100	93	84	76.1
ENC-03	94	100	65	91	75	82	74	11	23	100	97	90	75.1
MPC-01	63	71	50	64	50	10	26	34	13	92	99	0	47.6
MPC-02	94	100	79	64	50	21	14	1	2	100	89	0	51.1
MPC-03	100	92	90	100	75	48	9	3	2	77	87	52	61.3
TMC-01	88	89	57	91	50	69	39	45	5	100	100	75	67.3
TMC-02	100	100	52	100	75	67	75	98	64	100	99	82	84.5
TMC-02 Resampled	31	79	0	36	0	35	43	57	9	50	100	0	36.9
TMC-03	69	79	52	64	50	42	41	17	16	94	100	84	59.1

Table 6. (continued).

Vermillion River Basin	Species Richness	Species Diversity	# Sunfish	# Cyprinids & Catostomids	# Intolerant Species	% Tolerant Species	% Omnivore Species	% Insectivore Cyprinids	% Benthic Insectivore	% Dominant 2 Species	% Exotic Species	# Topeka Shiners	SCORE
LOC-01	60	59	54	53	29	64	52	57	85	45	99.75	0	54.8
LOC-02	--	--	--	--	--	--	--	--	--	--	--	--	--
LOC-03	25	41	0	33	29	64	67	75	100	18	100	29	48.4
TUR-01	35	40	0	40	29	61	64	73	4	29	100	0	39.5
TUR-02	60	100	38	73	29	84	89	86	28	77	92.47	0	63.1
TUR-02 Resampled	25	26	0	33	14	0	0	100	9	16	100	0	27.0
TUR-03	40	79	38	20	29	45	50	40	72	35	100	0	45.7
TUR-03 Resampled	65	73	76	47	43	70	80	48	100	88	100	78	72.2
WFV-01	--	--	--	--	--	--	--	--	--	--	--	--	--
WFV-02	80	74	79	73	29	25	23	19	5	50	99.27	76	52.6
WFV-03	80	71	76	80	57	98	96	100	36	39	99.56	57	74.1

Figure 1. Sample sites for Topeka shiner monitoring.

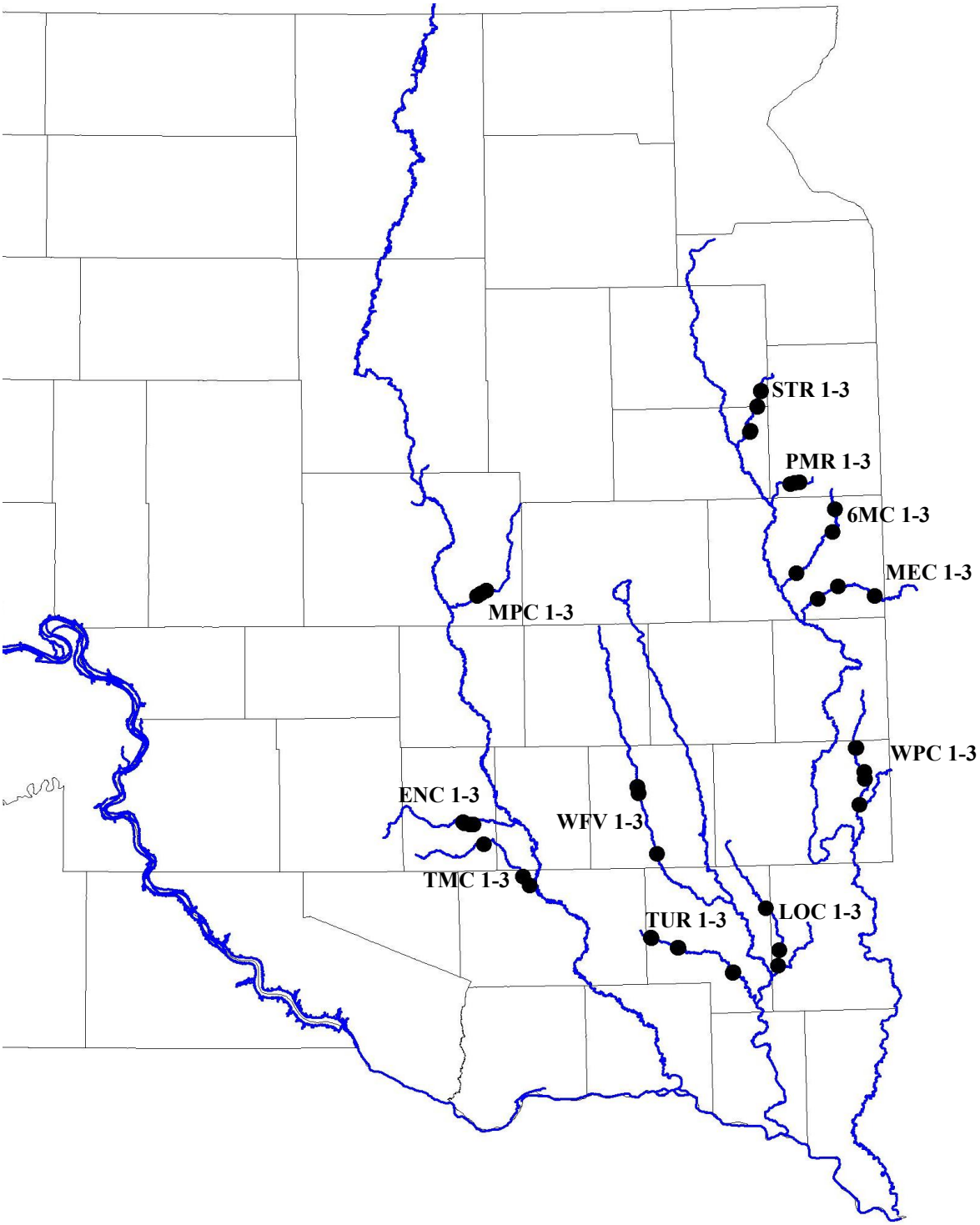


Figure 2. Key to the Rosgen classification of natural streams (from Rosgen 1996: page 5-6).

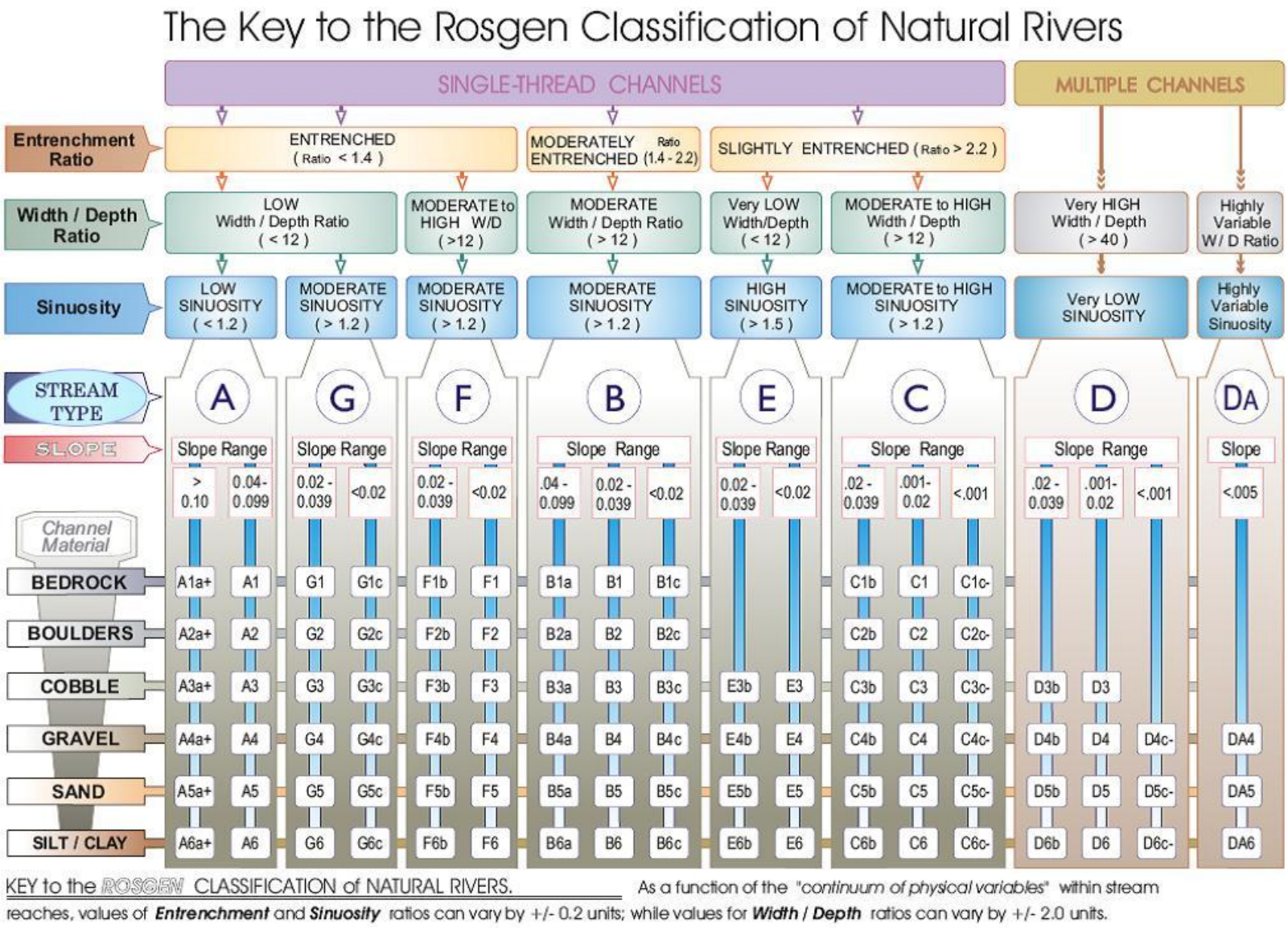


Figure 3. Example of thalweg profile showing residual pools (A, B, C, D). Horizontal lines represent residual pool lengths. Dashed vertical lines represent residual pool maximum depths. Red line represents linear regression line fit to thalweg profile with equation.

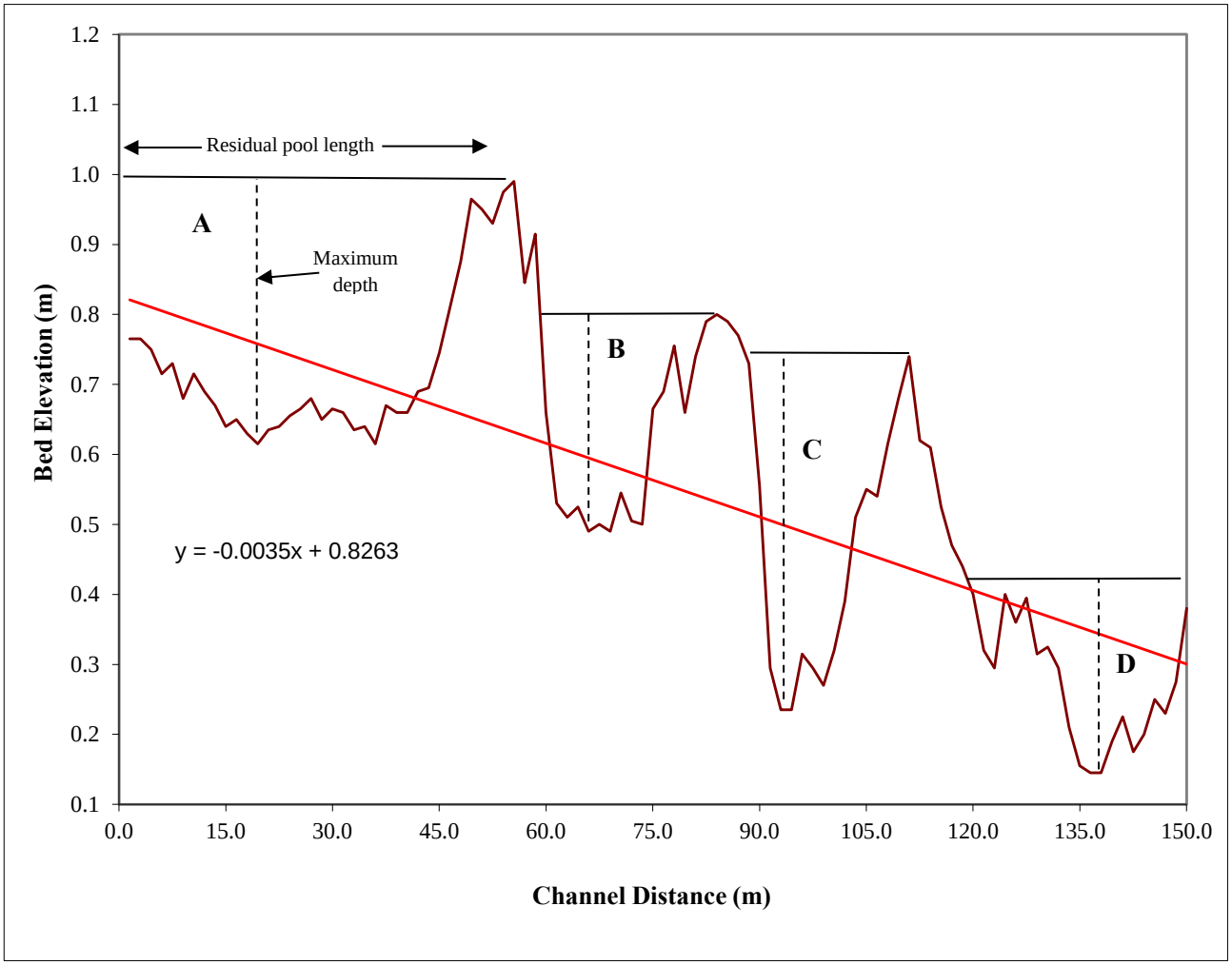


Figure 4. D-50 plot of pebble count data. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size).

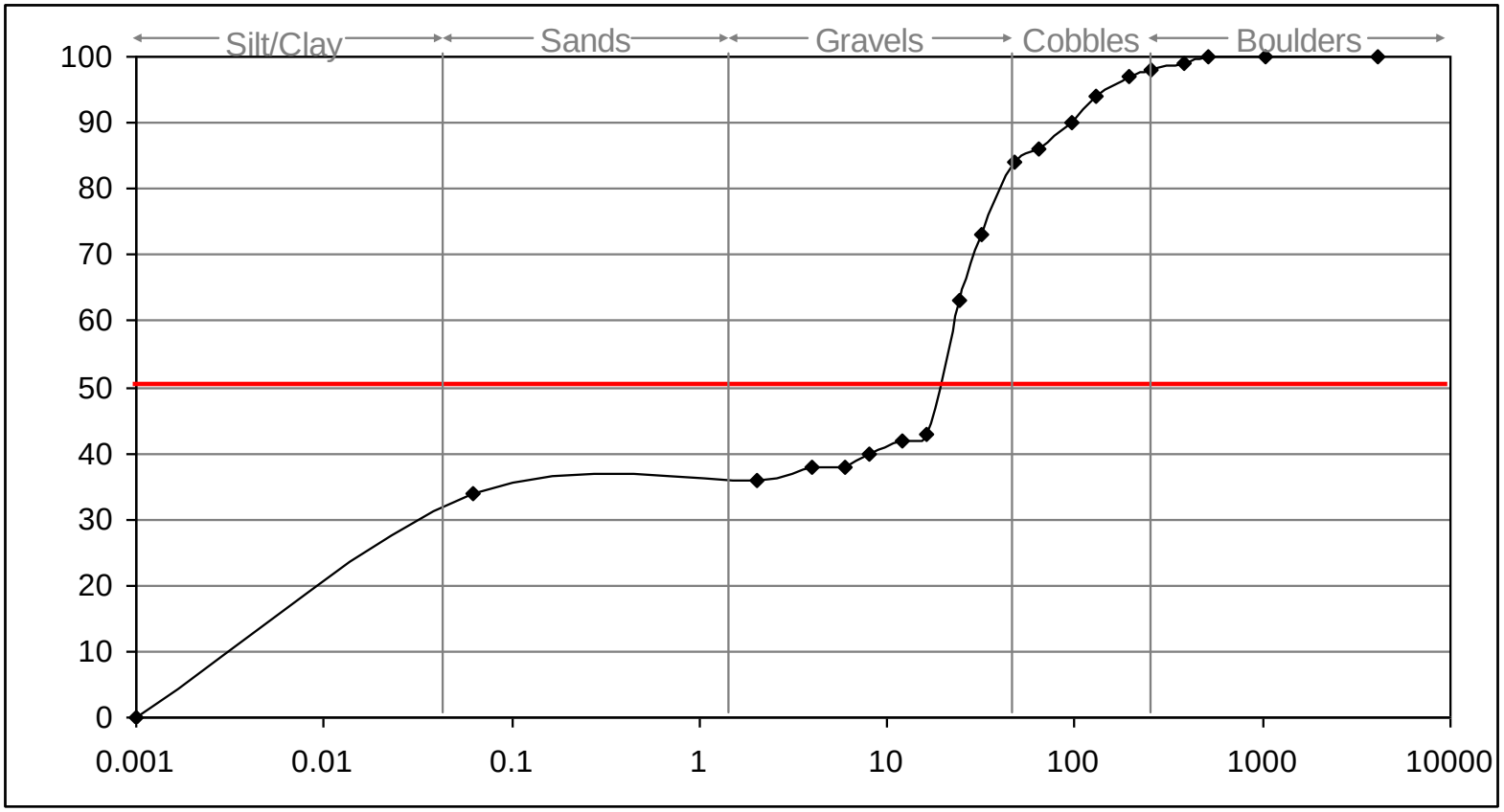


Figure 5. Thalweg profile.

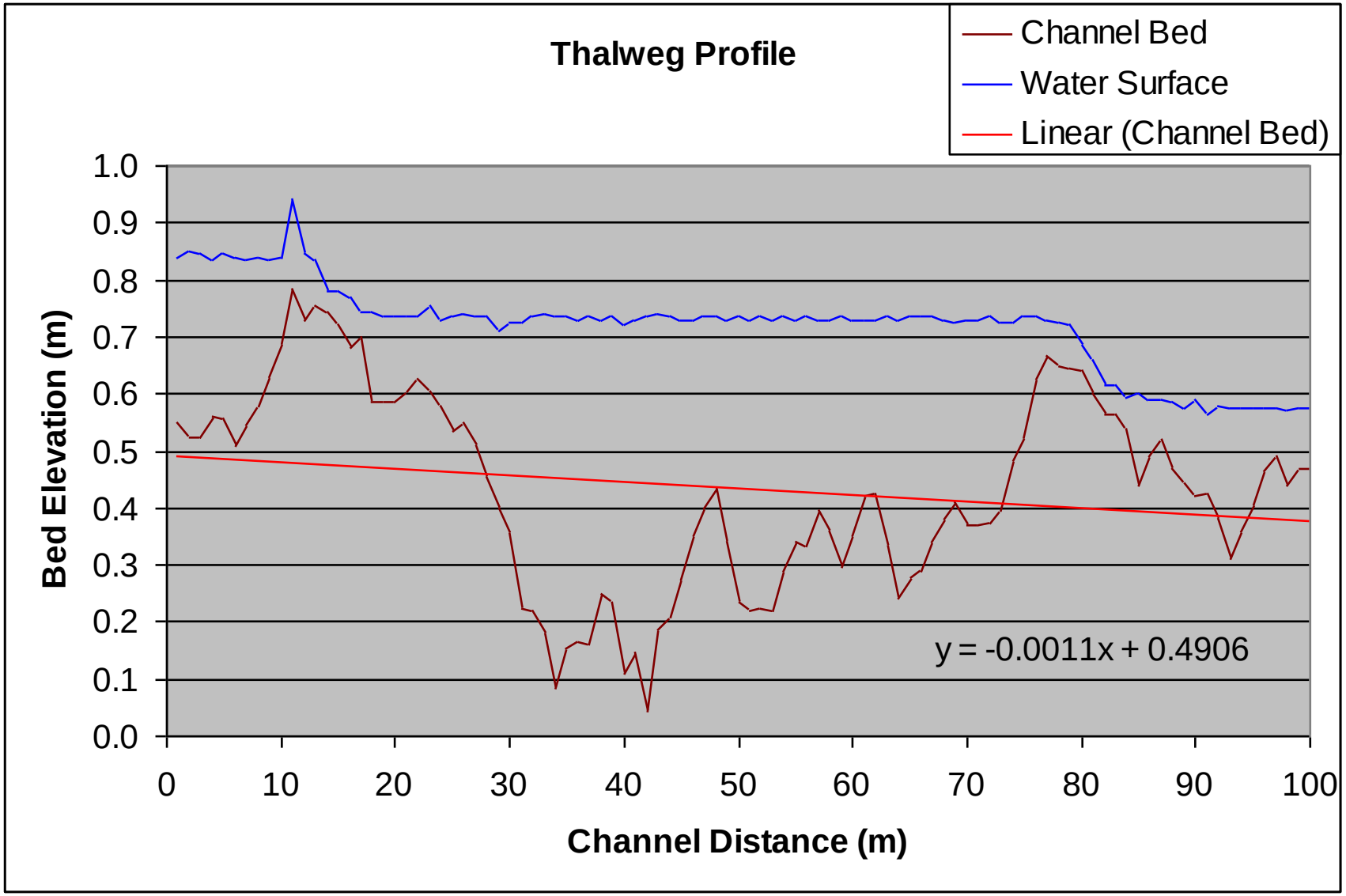


Figure 6. Differences between time periods (2004-2006 to 2010-2012) within habitat and IBI scores among drainages.

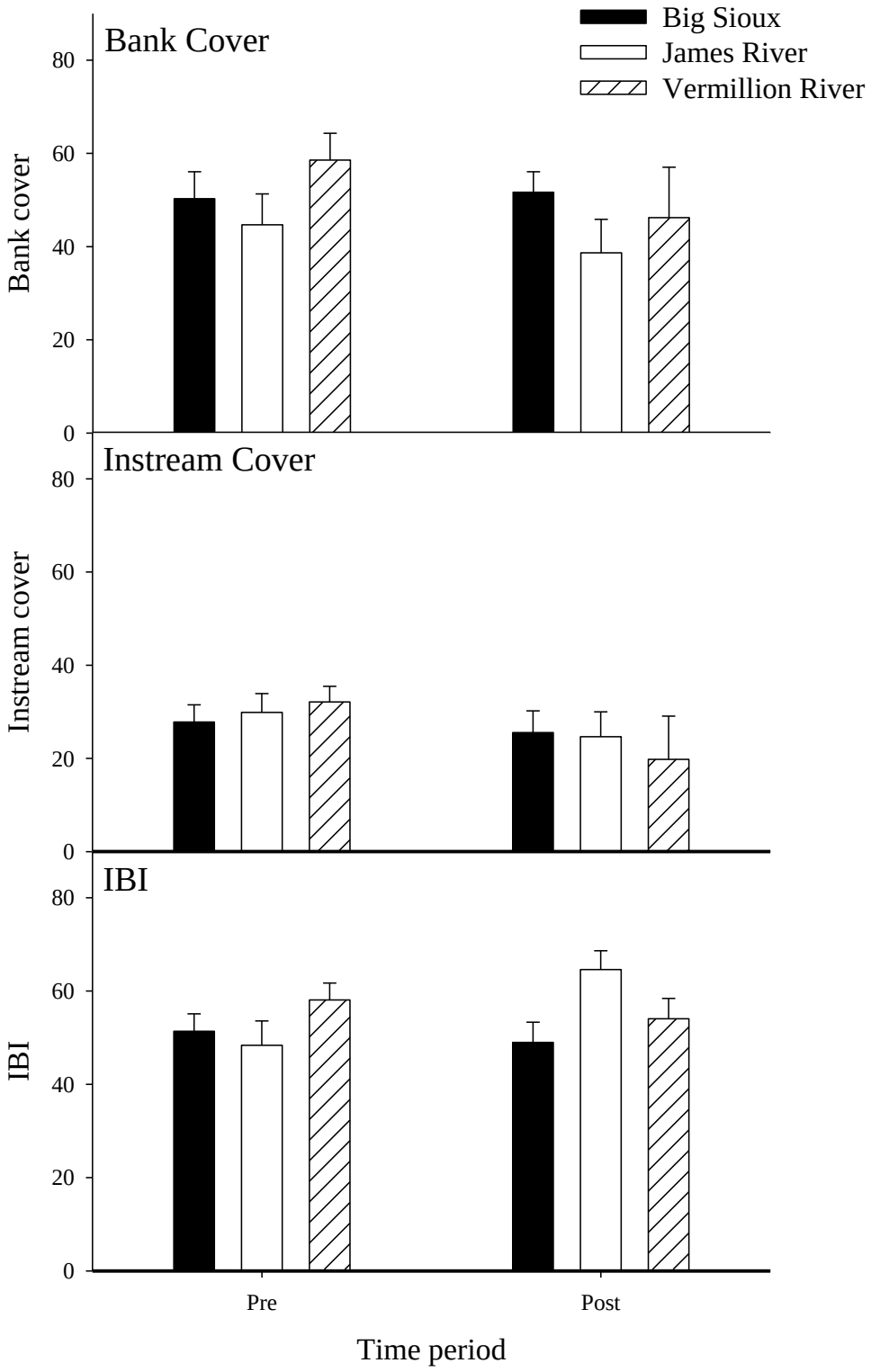


Figure 7. Differences between time periods (2004-2006 to 2010-2012) within habitat and IBI scores within the Big Sioux Drainage streams.

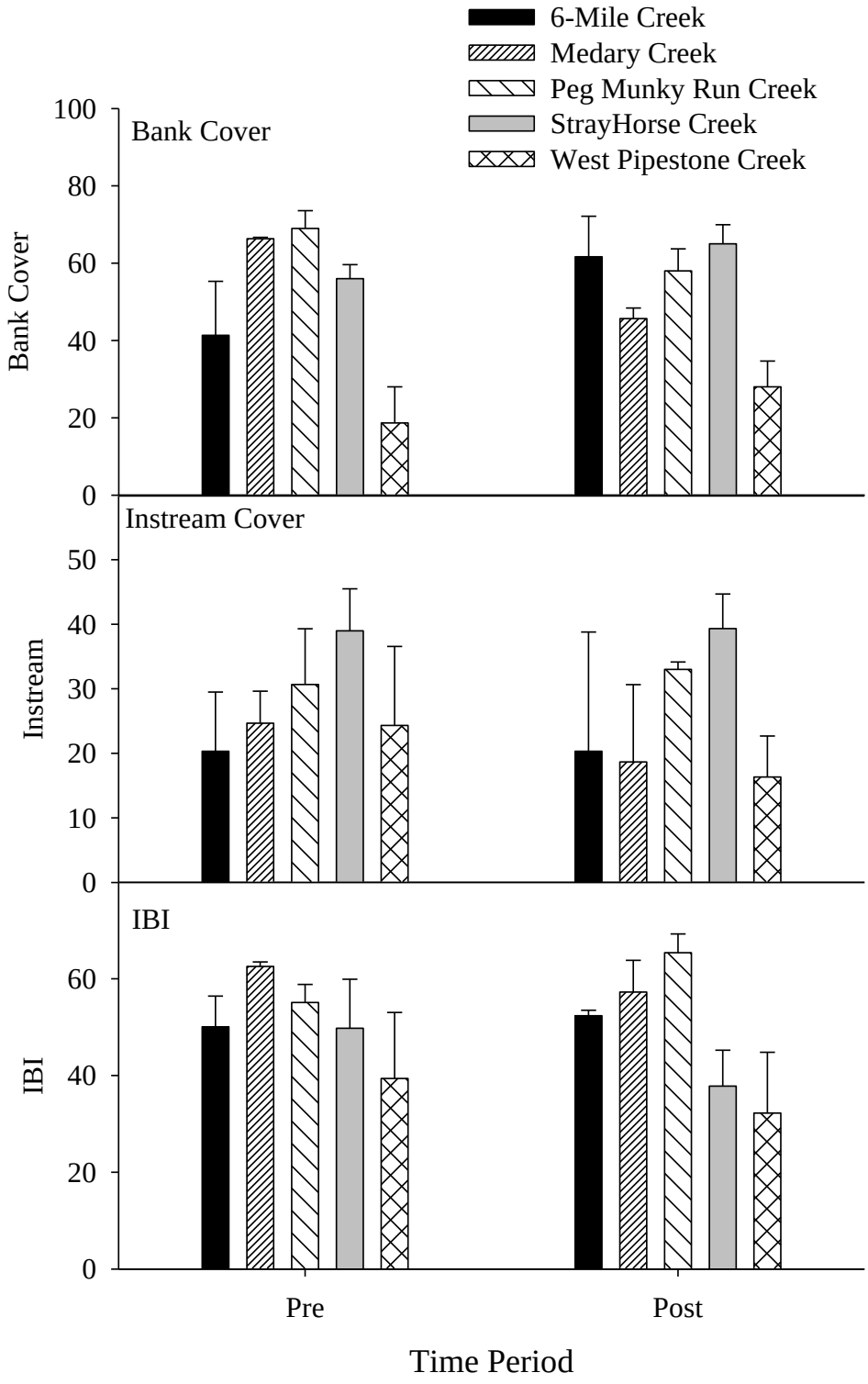


Figure 8. Differences between time periods (2004-2006 to 2010-2012) within habitat and IBI scores within the James Drainage streams.

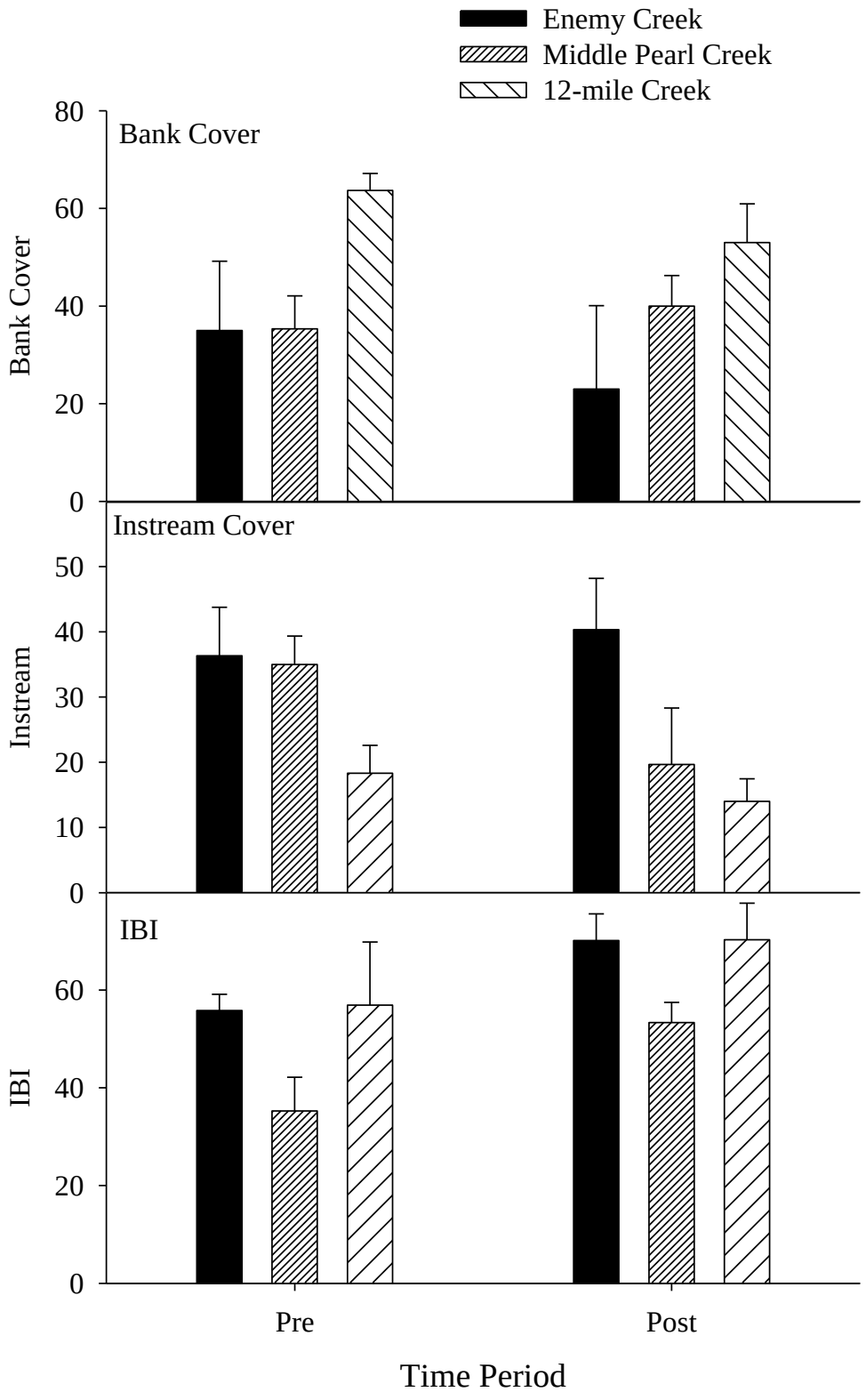


Figure 9. Differences between time periods (2004-2006 to 2010-2012) within habitat and IBI scores within the Vermillion Drainage streams.

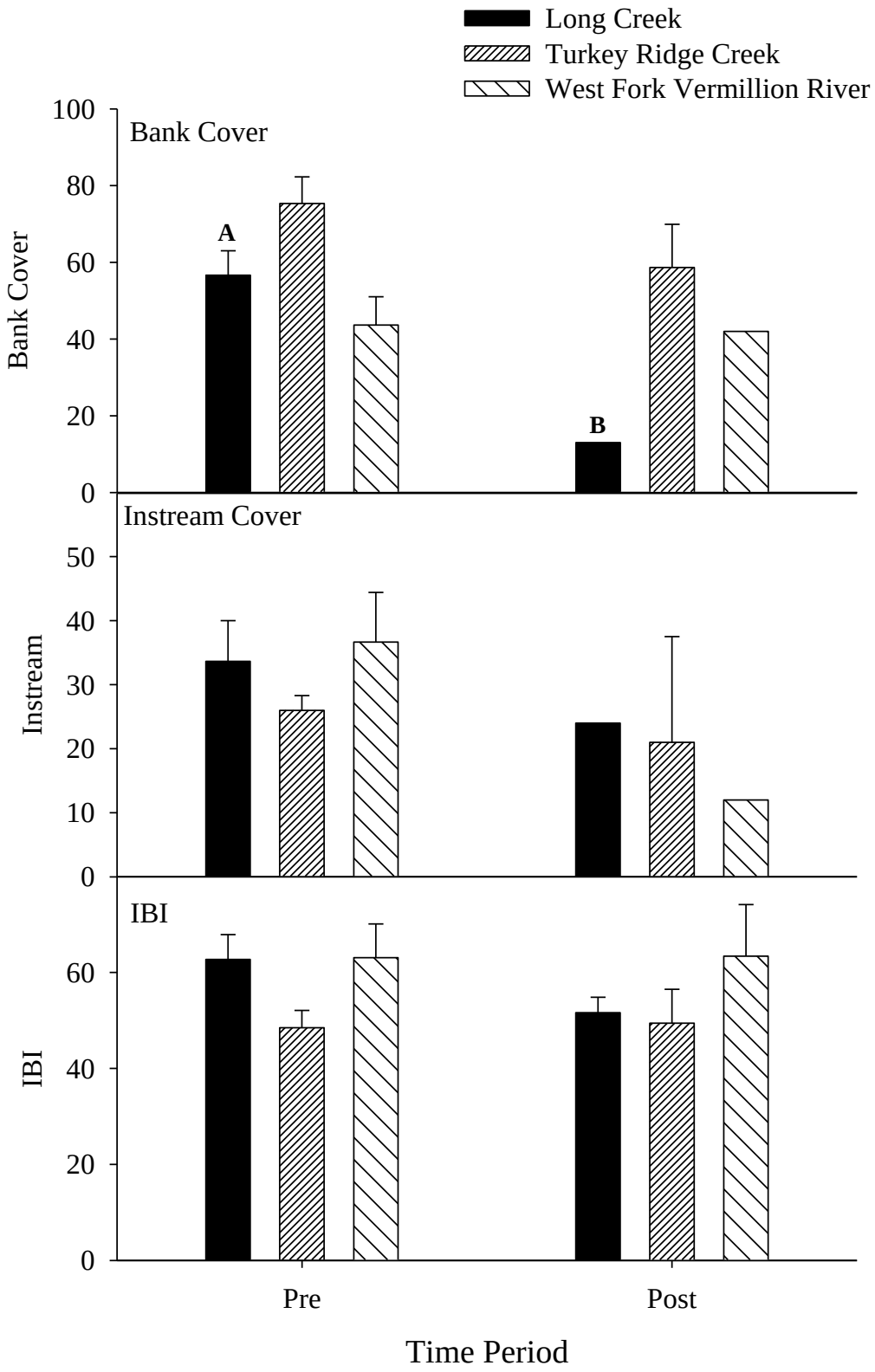
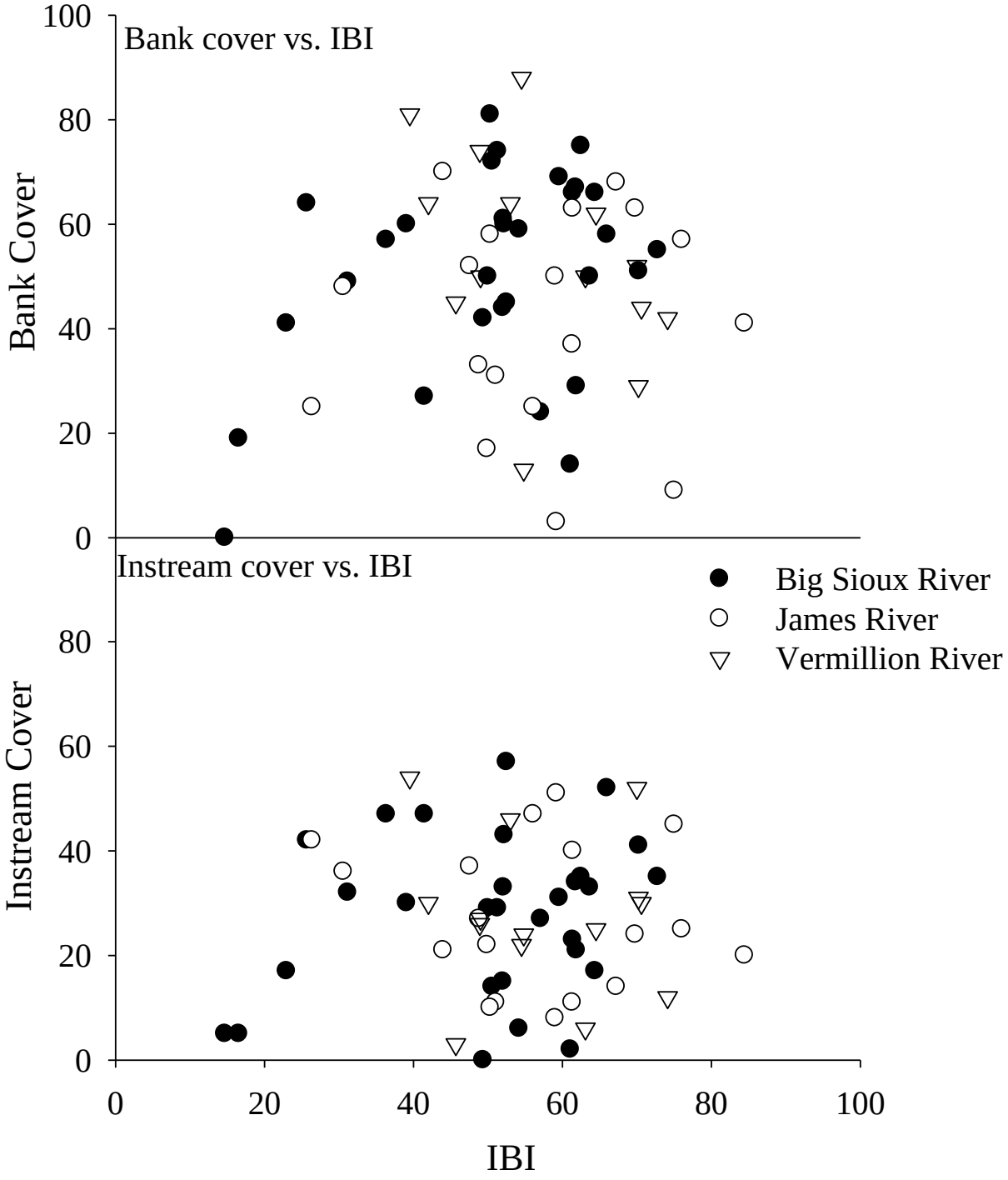


Figure 10. Correlation matrix to examine patterns between habitat metrics and biological fish community IBI scores.



APPENDIX

Table A01. Numbers of fish caught at each monitoring site (by watershed).

Big Sioux River Basin	6MC-01	6MC-01 (Resampled 2012)	6MC-02	6MC-03	MEC-01	MEC-01 (Resampled 2012)	MEC-02	MEC-03	PMR-01	PMR-02	PMR-03	STR-01	STR-01 (Resampled 2012)	STR-02	STR-02 (Resampled 2012)	STR-03	WPC-01	WPC-02	WPC-03
Topeka Shiner	1	0	0	12	0	0	1	0	57	55	0	144	3	0	0	0	0	0	82
Bigmouth Shiner	3	0	2	3	2	21	51	69	0	22	0	59	0	0	0	0	0	0	8
Black Bullhead	2	25	16	0	0	25	23	5	111	0	0	7	13	27	12	0	37	0	2
Blacknose Dace	1	0	0	3	6	55	123	0	55	60	271	0	1	0	0	1	0	0	0
Blackside Darter	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0
Bluntnose Minnow	0	17	0	0	0	108	159	30	0	0	0	0	0	0	0	0	1	0	15
Brassy Minnow	0	0	1	1	0	0	2	0	147	64	0	6	0	0	0	0	0	0	0
Brook Stickleback	0	0	0	0	0	0	4	1	16	31	27	0	0	0	0	0	0	0	0
Central Stoneroller	0	0	2	0	0	43	214	0	175	309	29	5	0	0	0	0	0	0	3
Channel Catfish	0	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Common Carp	0	5	0	0	0	13	2	1	8	0	0	0	0	0	19	0	0	0	0
Common Shiner	1	0	2	85	27	253	555	3	20	83	2	31	0	0	0	1	0	0	0
Creek Chub	1	1	10	0	1	94	231	42	88	171	41	9	0	0	0	0	0	0	7
Fathead Minnow	2	62	10	53	15	288	52	2	42	109	92	1099	121	0	1715	27	1	1	0
Green Sunfish	2	1	23	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0
Iowa Darter	0	0	0	0	0	1	8	1	8	9	3	3	0	0	22	0	0	0	0
Johnny Darter	0	0	16	0	1	122	183	26	1	52	4	22	0	0	5	1	0	0	13
Northern Pike	4	0	3	0	0	0	0	0	0	0	0	1	3	11	0	1	0	0	0

Table A01. (continued).

Big Sioux River Basin	6MC-01	6MC-01 (Resampled 2012)	6MC-02	6MC-03	MEC-01	MEC-01 (Resampled 2012)	MEC-02	MEC-03	PMR-01	PMR-02	PMR-03	STR-01	STR-01 (Resampled 2012)	STR-02	STR-02 (Resampled 2012)	STR-03	WPC-01	WPC-02	WPC-03
Northern Redbelly Dace	0	0	0	0	0	0	0	0	0	1	9	0	0	0	0	0	0	0	0
Orange Spotted Sunfish	1	0	2	0	0	0	0	0	0	0	0	2	49	0	0	1	0	0	1
Red Shiner	47	50	0	2	0	2	3	33	0	0	0	29	1	0	0	0	0	1	35
River Carpsucker	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Sand Shiner	8	13	0	22	2	53	31	99	7	49	0	88	0	0	0	0	1	0	13
Shorthead Redhorse	0	4	0	0	0	2	6	1	0	0	0	0	0	0	0	0	0	0	0
Shortnose Gar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Smallmouth Bass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Stonecat	1	5	0	0	0	0	9	1	0	0	0	0	7	0	0	0	0	0	0
Tadpole Madtom	0	0	0	0	0	5	28	0	9	2	5	7	0	0	0	3	1	0	0
White Sucker	2	11	10	2	1	68	364	263	51	103	4	82	1	1	0	8	1	0	61
Yellow Bullhead	2	2	0	0	0	11	7	3	0	0	0	0	1	0	0	0	0	0	0

Table A01. (continued).

James River Basin	ENC-01	ENC-02	ENC-03	MPC-01	MPC-02	MPC-03	TMC-01	TMC-02	TMC-02 (Resampled 2012)	TMC-03
Topeka Shiner	40	69	113	0	0	6	35	60	0	74
Bigmouth Shiner	0	0	11	0	0	1	5	80	0	0
Black Bullhead	1	6	23	56	259	1020	23	22	0	5
Brassy Minnow	178	8	43	6	20	756	294	81	0	21
Central Stoneroller	3	33	26	0	0	0	14	5	0	0
Common Carp	2	17	10	2	46	294	0	7	0	0
Common Shiner	3	6	1	50	0	17	23	128	1	1
Creek Chub	1	40	6	3	1	3	190	40	6	28
Emerald Shiner	0	4	0	0	0	23	0	152	0	0
Fathead Minnow	37	5	22	5	1	27	183	47	11	193
Gizzard Shad	0	0	0	0	11	0	0	9	0	0
Green Sunfish	3	4	9	5	43	118	3	2	0	5
Johnny Darter	2	4	22	0	0	7	10	12	1	23
Largemouth Bass	0	0	0	0	3	4	0	0	0	0
Northern Pike	0	0	0	0	3	0	0	0	0	0
Orange Spotted Sunfish	2	1	7	0	4	0	6	4	0	1
Red Shiner	0	20	0	191	54	3	7	249	1	12
River Carpsucker	0	0	0	0	0	0	0	1	0	0
Sand Shiner	0	4	2	17	3	4	14	410	0	9
Shortnose Gar	0	0	0	0	1	0	0	0	0	0
Tadpole Madtom	1	4	14	6	1	8	0	40	0	0
Walleye	0	0	0	0	0	1	0	1	0	0
White Sucker	5	2	2	0	2	15	30	2	0	0

Table A01. (continued).

Vermillion River Basin	LOC-01	LOC-02	LOC-03	TUR-01	TUR-02	TUR-02 (Resampled 2012)	TUR-03	TUR-03 (Resampled 2012)	WFV-01	WFV-02	WFV-03
Topeka Shiner	0	--	1	0	0	0	0	45	--	37	9
Bigmouth Shiner	2	--	0	0	5	46	0	24	--	26	7
Black Bullhead	0	--	0	0	0	0	0	7	--	750	2
Blacknose Dace	0	--	0	5	2	0	0	0	--	0	0
Brassy Minnow	113	--	0	1	2	0	0	0	--	0	133
Brook Stickleback	0	--	0	1	0	0	0	0	--	0	0
Central Stoneroller	0	--	0	0	10	11	0	0	--	0	4
Channel Catfish	6	--	0	0	0	0	1	0	--	0	0
Common Carp	2	--	0	0	7	0	0	0	--	11	8
Common Shiner	27	--	1	1	5	2	0	1	--	141	1099
Creek Chub	1	--	3	126	41	197	0	0	--	24	125
Fathead Minnow	46	--	19	64	1	0	0	84	--	327	15
Gizzard Shad	0	--	0	0	0	0	0	0	--	1	0
Green Sunfish	0	--	0	0	2	0	1	30	--	24	9
Johnny Darter	1	--	0	0	0	0	0	74	--	0	0
Orange Spotted Sunfish	7	--	0	0	0	0	1	10	--	23	31
Red Shiner	259	--	0	0	4	0	24	39	--	14	60
River Carpsucker	0	--	0	0	0	0	0	0	--	69	0
Sand Shiner	338	--	26	0	11	12	16	166	--	39	327
Shorthead Redhorse	0	--	0	0	0	0	0	0	--	0	1
Shortnose Gar	0	--	0	0	0	0	2	0	--	0	0
Smallmouth Buffalo	0	--	0	0	0	0	0	0	--	1	0
Stonecat	0	--	0	0	0	0	0	1	--	7	0
Tadpole Madtom	2	--	0	0	0	0	2	17	--	0	1
White Sucker	0	--	0	29	3	0	3	3	--	16	3

Table A02. Fish metrics (by watershed).

Big Sioux River Basin	**6MC-01**	**6MC-01 (Resampled 2012)**	**6MC-02**	**6MC-03**	**MEC-01**	**MEC-01 (Resampled 2012)**	**MEC-02**	**MEC-03**	**PMR-01**	**PMR-02**	**PMR-03**
Species Richness	15	13	12	9	8	17	21	16	16	17	11
# Individuals	78	245	97	183	55	1164	2056	580	796	1124	487
Species Diversity	5.52	2.93	3.61	1.99	2.57	2.82	3.26	3.05	2.84	2.84	2.00
# Sunfish	3	1	25	0	0	0	0	0	0	1	0
Log (# Sunfish)	0.48	0	1.40	0	0	0	0	0	0	0	0
Log (# Sunfish) + 1	1.48	1.00	2.40	0	0	0	0	0	0	1.00	0
# Cyprinids & Catostomids	9	8	7	9	7	12	14	10	10	11	7
# Intolerant Species	3	2	0	3	2	5	7	4	6	7	5
% Tolerant Species	70.51	69.80	60.82	31.15	29.09	43.30	29.33	57.59	26.63	18.95	19.71
% Omnivorous Species	67.95	69.39	38.14	31.69	29.09	43.30	29.43	57.59	45.10	24.56	19.71
% Insectivorous Cyprinids	17.95	5.71	14.43	61.75	69.09	40.89	48.20	36.72	21.36	34.25	64.48
% Benthic Insectivores	11.54	6.94	16.49	13.66	16.36	20.45	18.43	21.90	10.18	15.57	58.11
% Dominant Species	60.26	25.31	23.71	46.45	49.09	24.74	26.99	45.34	21.98	27.49	55.65
Dominant Species	RES	FHM	GSF	CNS	CNS	FHM	CNS	WHS	STC	STC	BLD
% Second Dominant Species	10.26	20.41	16.49	28.96	27.27	21.74	17.70	17.07	18.47	15.21	18.89
Second Dominant Species	SAS	RES	BLB	FHM	FHM	CNS	WHS	SAS	BRM	CRC	FHM
% Two Dominant Species	70.51	45.71	40.21	75.41	76.36	46.48	44.70	62.41	40.45	42.70	74.54
% Exotic Species	0	2.04	0	0	0	1.12	0.10	0.17	1.01	0	0
# Topeka shiners	1	0	0	12	0	0	1	0	57	55	0
Log (# Topeka shiners)	0	0	0	1.08	0	0	0	0	1.76	1.74	0
Log (# Topeka shiners) + 1	1.00	0	0	2.08	0	0	1.00	0	2.76	2.74	0

Table A02. (continued).

Big Sioux River Basin	**STR-01**	**STR-01 (Resampled 2012)**	**STR-02**	**STR-02 (Resampled 2012)**	**STR-03**	**WPC-01**	**WPC-02**	**WPC-03**
Species Richness	16	10	4	5	9	6	3	14
# Individuals	1594	200	40	1773	44	42	3	249
Species Diversity	2.47	2.22	1.11	0.63	3.42	1.92	0	3.21
# Sunfish	2	49	1	0	2	0	0	1
Log (# Sunfish)	0.30	1.69	0	0	0.30	0	0	0
Log (# Sunfish) + 1	1.30	2.69	1.00	0	1.30	0	0	1.00
# Cyprinids & Catostomids	10	5	1	2	4	4	2	9
# Intolerant Species	4	2	0	1	2	2	0	2
% Tolerant Species	76.35	68.00	72.50	98.48	81.82	95.24	66.67	45.38
% Omnivorous Species	76.73	68.00	70.00	98.48	79.55	95.24	66.67	46.18
% Insectivorous Cyprinids	11.73	0.50	0	0	4.55	2.38	0	11.24
% Benthic Insectivores	7.53	0.50	0	1.52	11.36	4.76	0	10.44
% Dominant Species	68.95	60.50	67.50	96.73	61.36	88.10	0	32.93
Dominant Species	FHM	FHM	BLB	FHM	FHM	BLB	0	TOS
% Second Dominant Species	9.03	24.50	27.50	1.24	18.18	2.38	0	24.50
Second Dominant Species	TOS	OSF	NOP	IOD	WHS	FHM	0	WHS
% Two Dominant Species	77.98	85.00	95.00	97.97	79.55	90.48	0	57.43
% Exotic Species	0	0	0	1.07	0	0	0	0
# Topeka shiners	144	3	0	0	0	0	0	82
Log (# Topeka shiners)	2.16	0.48	0	0	0	0	0	1.91
Log (# Topeka shiners) + 1	3.16	1.48	0	0	0	0	0	2.91

Table A02. (continued).

James River Basin	ENC-01	ENC-02	ENC-03	MPC-01	MPC-02	MPC-03	TMC-01	TMC-02	TMC-02 (Resampled 2012)	TMC-03
Species Richness	13	16	15	10	15	17	14	20	5	11
# Individuals	278	227	311	341	452	2306	837	1352	20	372
Species Diversity	2.83	3.93	3.29	1.93	2.98	2.49	2.39	3.33	2.14	2.13
# Sunfish	5	5	16	5	47	118	9	6	0	6
Log (# Sunfish)	0.70	0.70	1.20	0.70	1.67	2.07	0.95	0.78	0	0.78
Log (# Sunfish) + 1	1.70	1.70	2.20	1.70	2.67	3.07	1.95	1.78	0	1.78
# Cyprinids & Catostomids	8	11	10	7	7	11	10	13	4	7
# Intolerant Species	2	3	3	2	2	3	2	3	0	2
% Tolerant Species	17.63	18.94	18.33	90.03	79.42	52.01	32.14	33.28	65.00	58.06
% Omnivorous Species	80.22	25.55	32.15	76.25	86.95	91.69	64.16	30.92	60.00	62.10
% Insectivorous Cyprinids	1.44	23.79	6.43	20.53	0.88	2.08	27.72	59.91	35.00	10.22
% Benthic Insectivores	1.08	5.29	12.22	6.74	0.88	0.82	2.87	34.17	5.00	8.60
% Dominant Species	64.03	30.40	36.33	56.01	57.30	44.22	35.13	30.33	55.00	51.88
Dominant Species	BRM	TOS	TOS	RES	BLB	BLB	BRM	SAS	FHM	FHM
% Second Dominant Species	14.39	17.62	13.83	16.42	11.95	32.78	22.70	18.42	30.00	19.89
Second Dominant Species	TOS	CRC	BRM	BLB	RES	BRM	CRC	RES	CRC	TOS
% Two Dominant Species	78.42	48.02	50.16	72.43	69.25	76.99	57.83	48.74	85.00	71.77
% Exotic Species	0.72	7.49	3.22	0.59	10.84	12.92	0	0.52	0	0
# Topeka shiners	40	69	113	0	0	6	35	60	0	74
Log (# Topeka shiners)	1.60	1.84	2.05	0	0	0.78	1.54	1.78	0	1.87
Log (# Topeka shiners) + 1	2.60	2.84	3.05	0	0	1.78	2.54	2.78	0	2.87

Table A02. (continued).

Vermillion River Basin	**LOC-01**	**LOC-02**	**LOC-03**	**TUR-01**	**TUR-02**	**TUR-02 (Resampled 2012)**	**TUR-03**	**TUR-03 (Resampled 2012)**	**WFV-01**	**WFV-02**	**WFV-03**
Species Richness	12	--	5	7	12	5	8	13	--	16	16
# Individuals	804	--	50	227	93	268	50	501	--	1510	1834
Species Diversity	2.00	--	1.38	1.37	3.67	0.87	2.69	2.48	--	2.50	2.41
# Sunfish	7	--	0	0	2	0	2	40	--	47	40
Log (# Sunfish)	0.85	--	0	0	0.30	0	0.30	1.60	--	1.67	1.60
Log (# Sunfish) + 1	1.85	--	0	0	1.30	0	1.30	2.60	--	2.67	2.60
# Cyprinids & Catostomids	8	--	5	6	11	5	3	7	--	11	12
# Intolerant Species	2	--	2	2	2	1	2	3	--	2	4
% Tolerant Species	38.18	--	38.00	40.97	18.28	0	56.00	32.53	--	75.63	5.29
% Omnivorous Species	52.24	--	38.00	41.41	18.28	0	54.00	26.55	--	78.61	12.05
% Insectivorous Cyprinids	45.77	--	60.00	58.15	68.82	95.90	32.00	38.12	--	15.23	84.95
% Benthic Insectivores	42.41	--	52.00	2.20	13.98	4.48	36.00	51.30	--	2.58	17.94
% Dominant Species	42.04	--	52.00	55.51	44.09	73.51	48.00	33.13	--	49.67	59.92
Dominant Species	SAS	--	SAS	CRC	CRC	CRC	RES	SAS	--	BLB	CNS
% Second Dominant Species	32.21	--	38.00	28.19	11.83	17.16	32.00	16.77	--	21.66	17.83
Second Dominant Species	RES	--	FHM	FHM	SAS	BIS	SAS	FHM	--	FHM	SAS
% Two Dominant Species	74.25	--	90.00	83.70	55.91	90.67	80.00	49.90	--	71.32	77.75
% Exotic Species	0.25	--	0	0	7.53	0	0	0	--	0.73	0.44
# Topeka shiners	0	--	1	0	0	0	0	45	--	37	9
Log (# Topeka shiners)	--	--	0	0	0	0	0	1.65	--	1.57	0.95
Log (# Topeka shiners) + 1	--	--	1	0	0	0	0	2.65	--	2.57	1.95

Figure A01-a, -b. 6MC-01 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

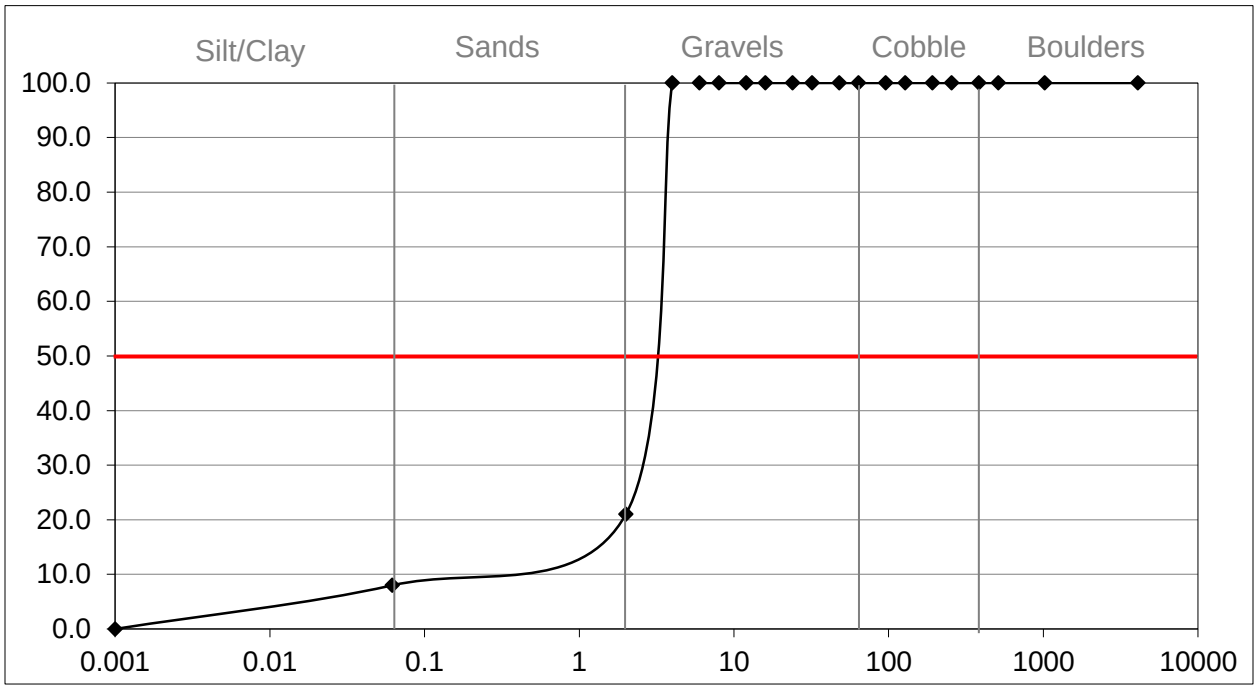


Figure A01 –a.

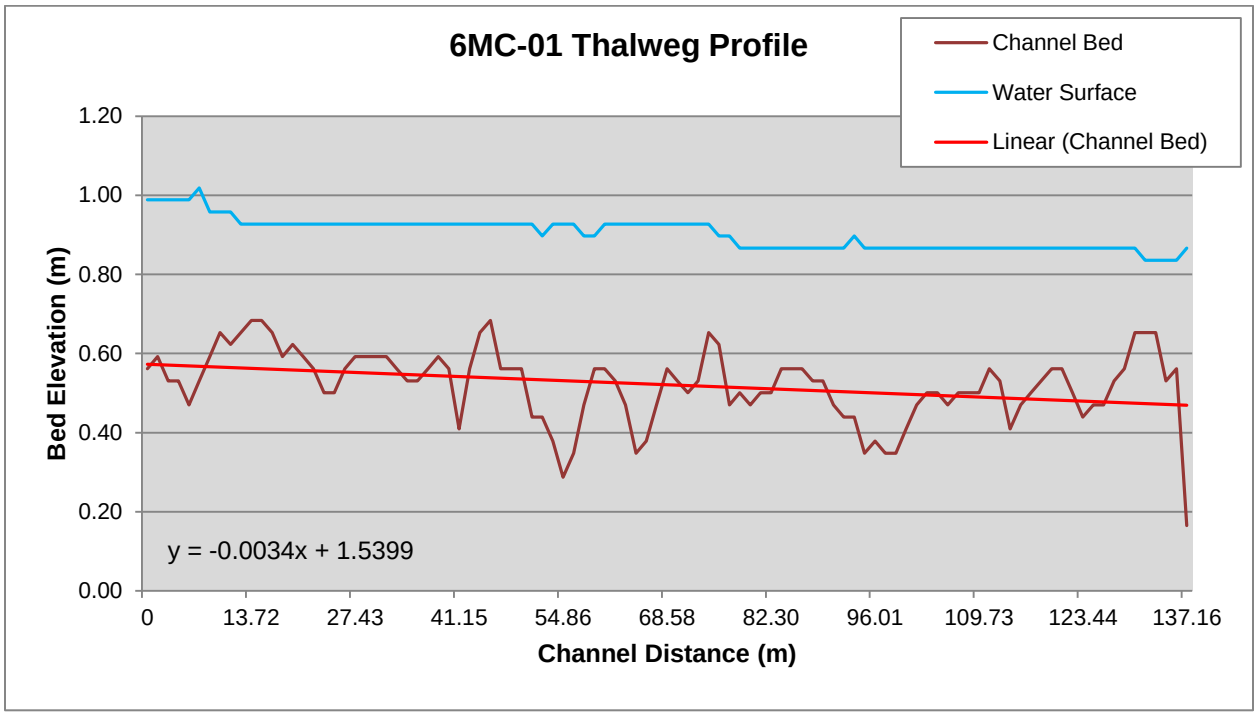


Figure A01 –b.

Figure A02 –a, -b. 6MC-02 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

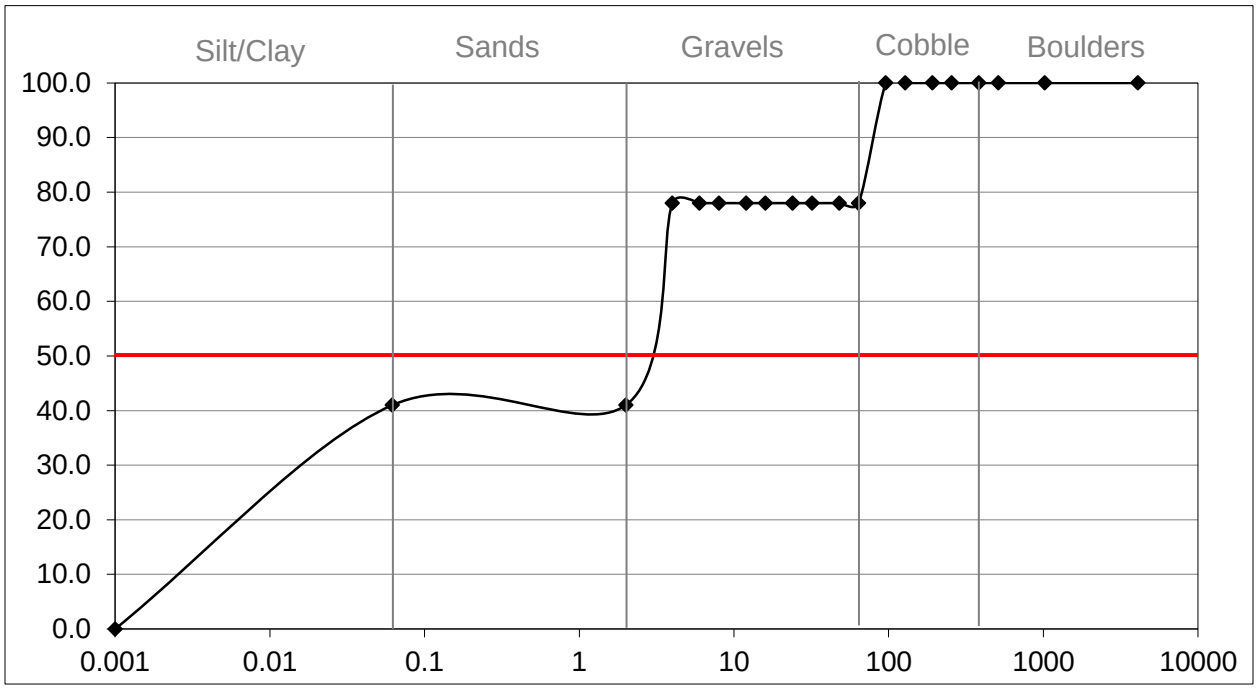


Figure A02 –a.

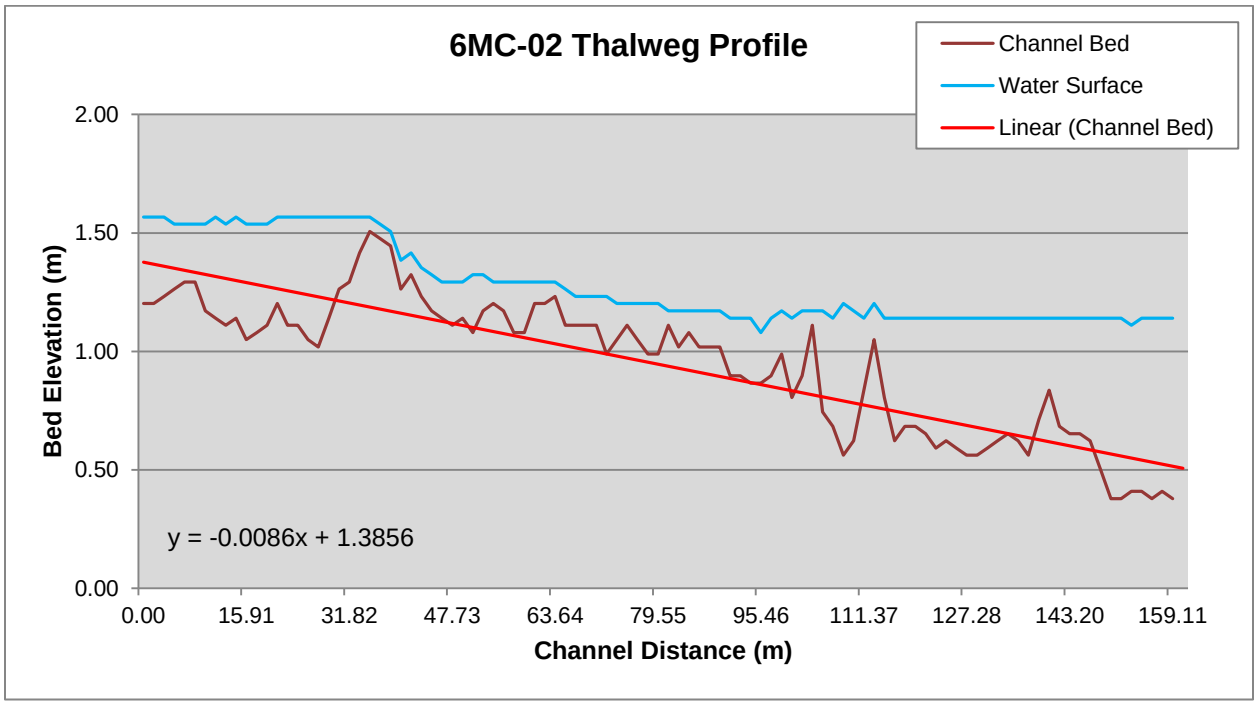


Figure A02 –b.

Figure A03 –a, -b. 6MC-03 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

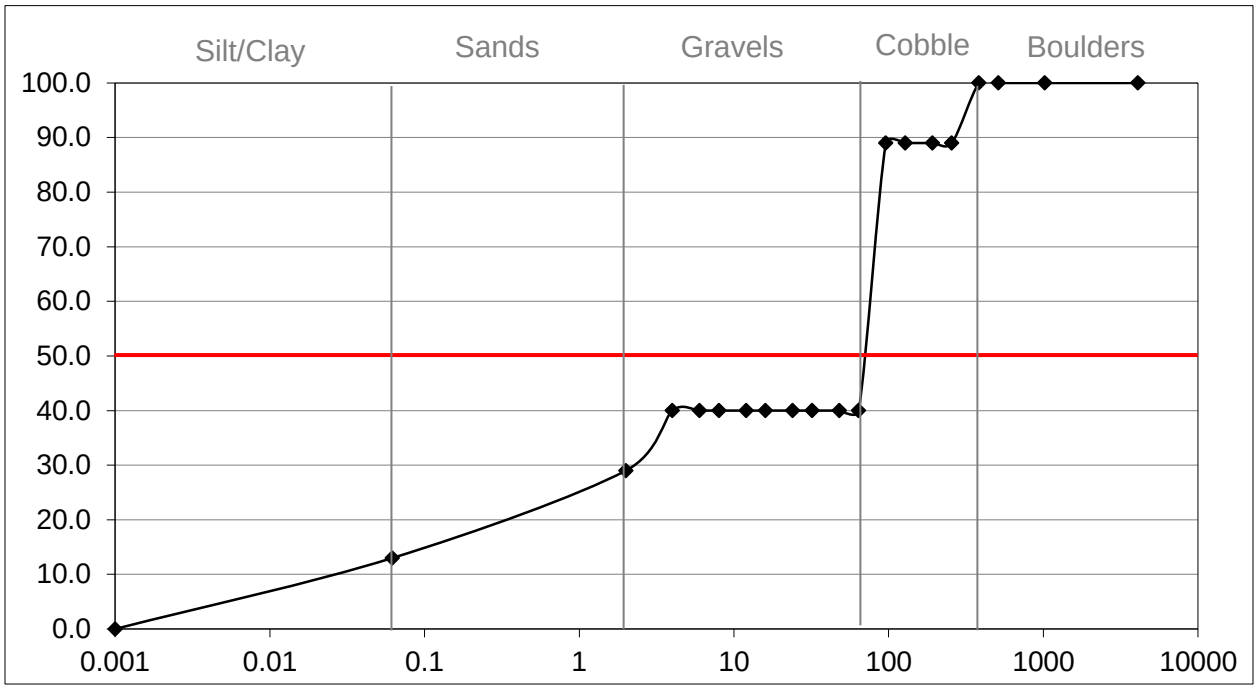


Figure A03 –a.

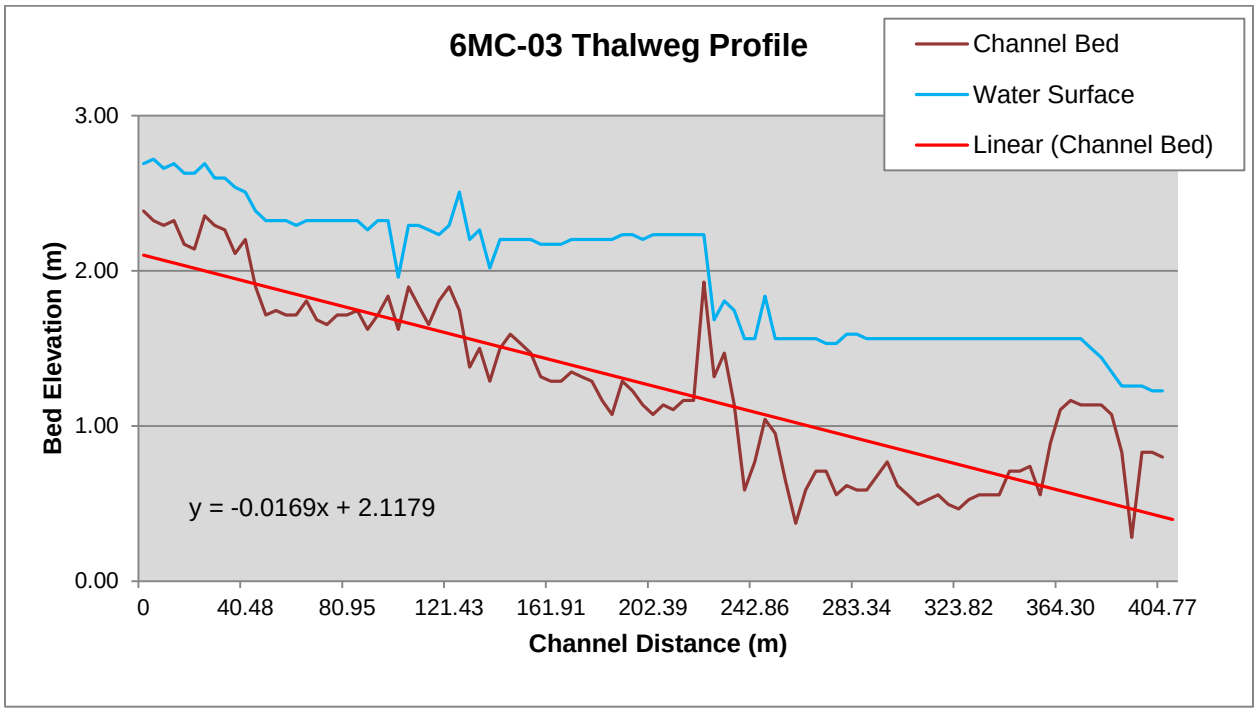


Figure A03 –b.

Figure A04 –a, -b. MEC-01 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

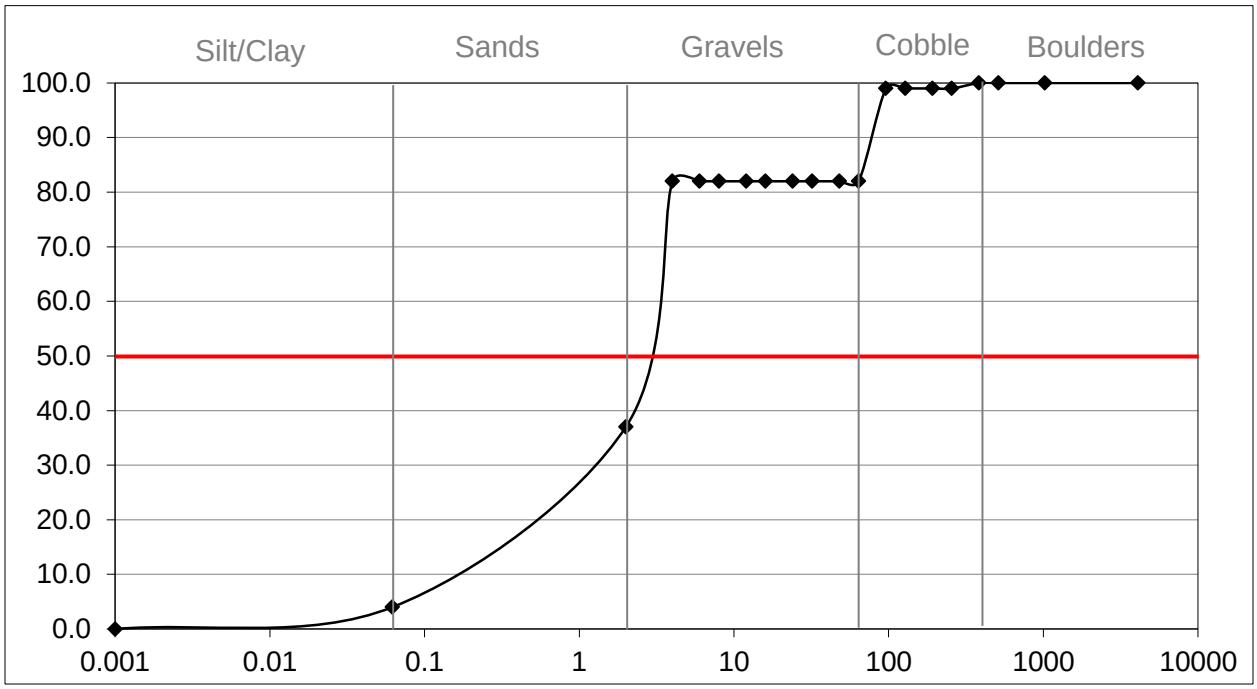


Figure A04 –a.

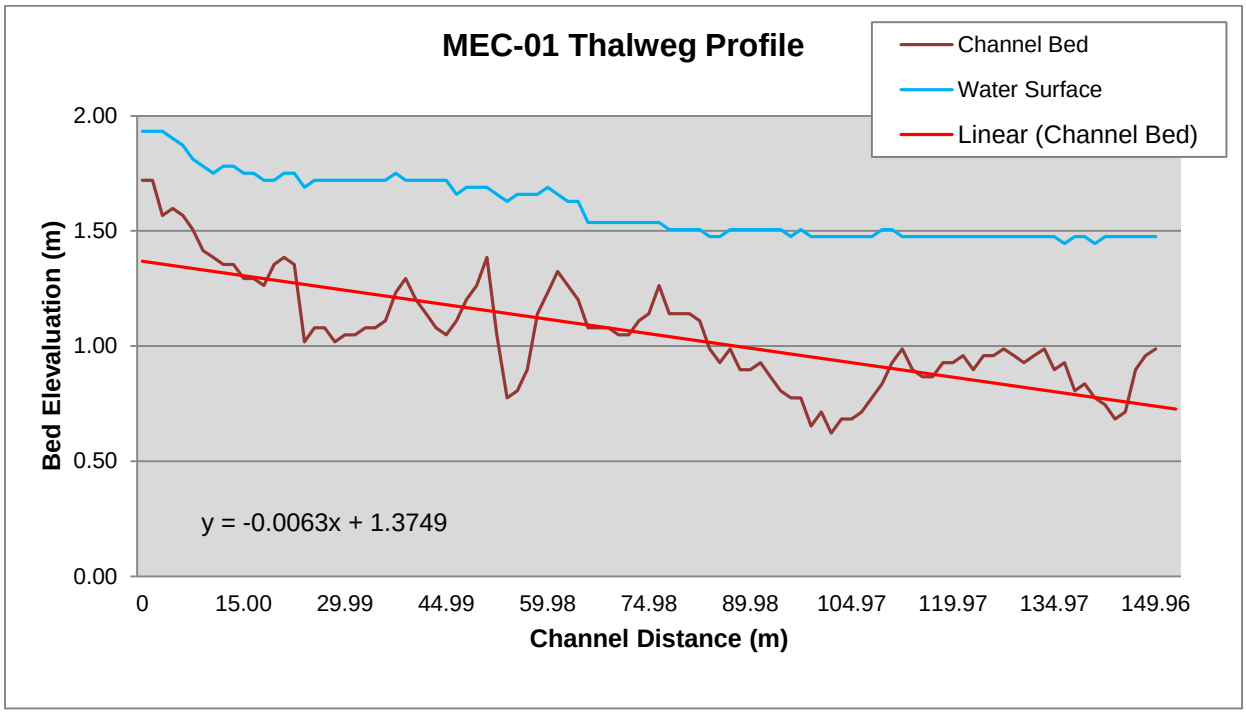


Figure A04 –b.

Figure A05 –a, -b. MEC-02 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

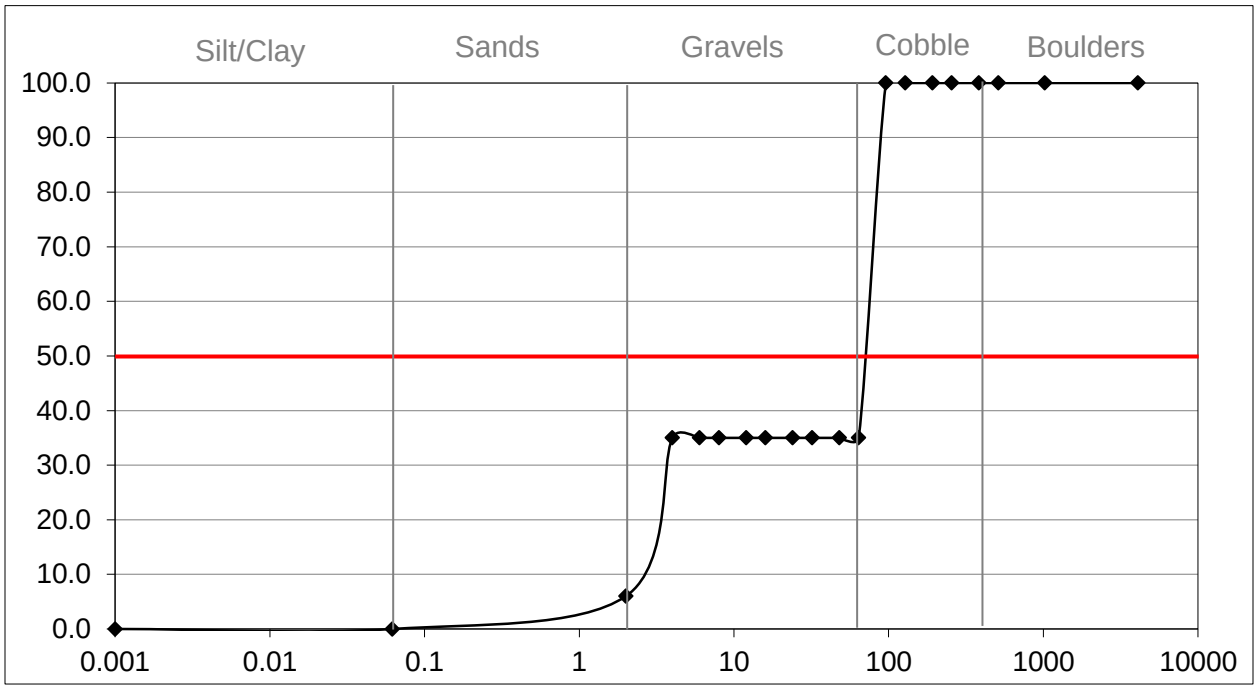


Figure A05 –a.

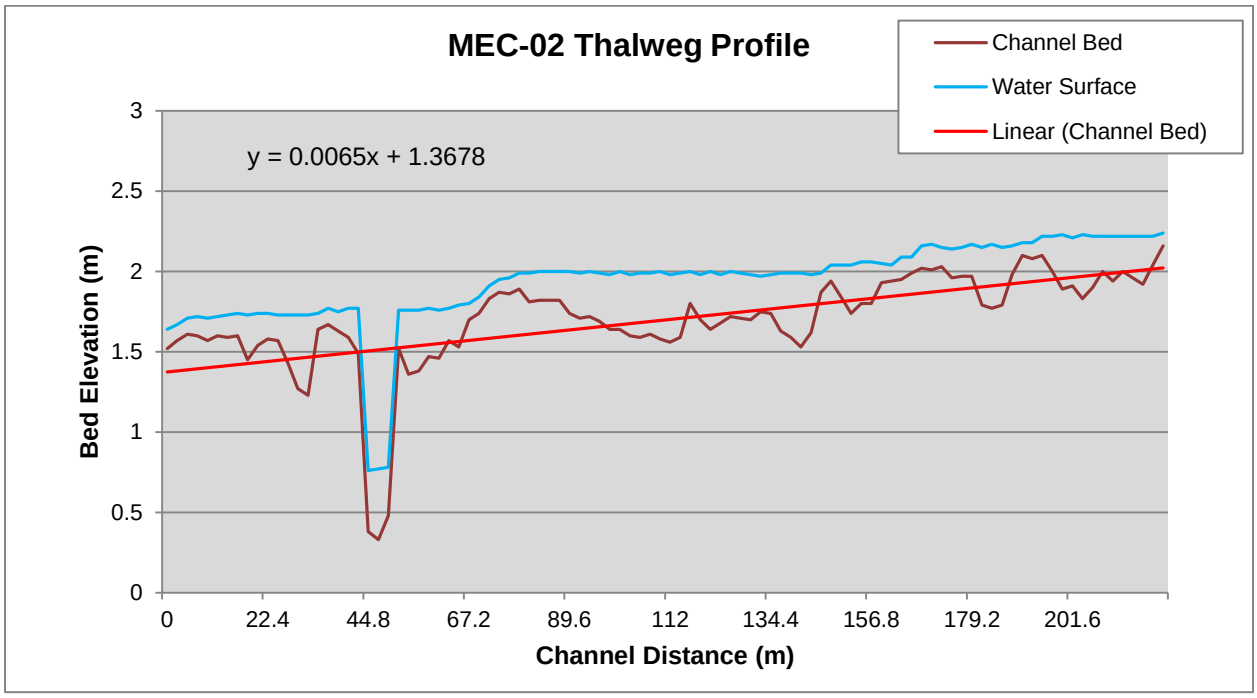


Figure A05 –b.

Figure A06 –a, -b. MEC-03 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

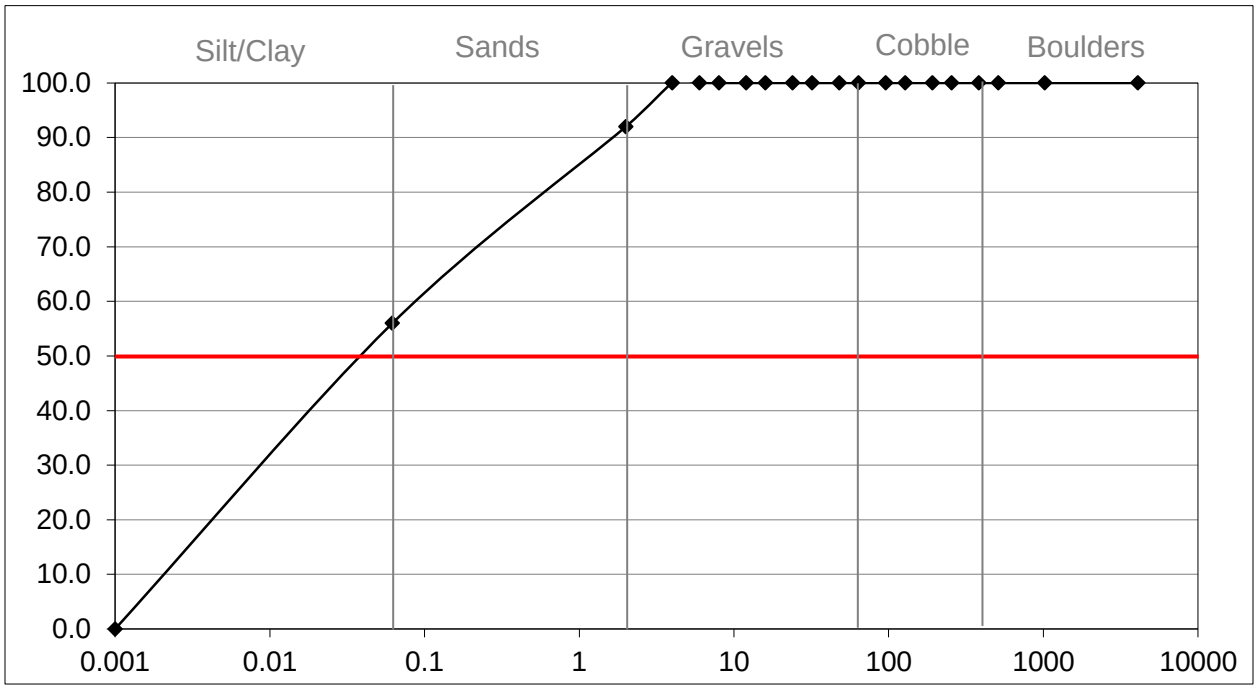


Figure A06 –a.

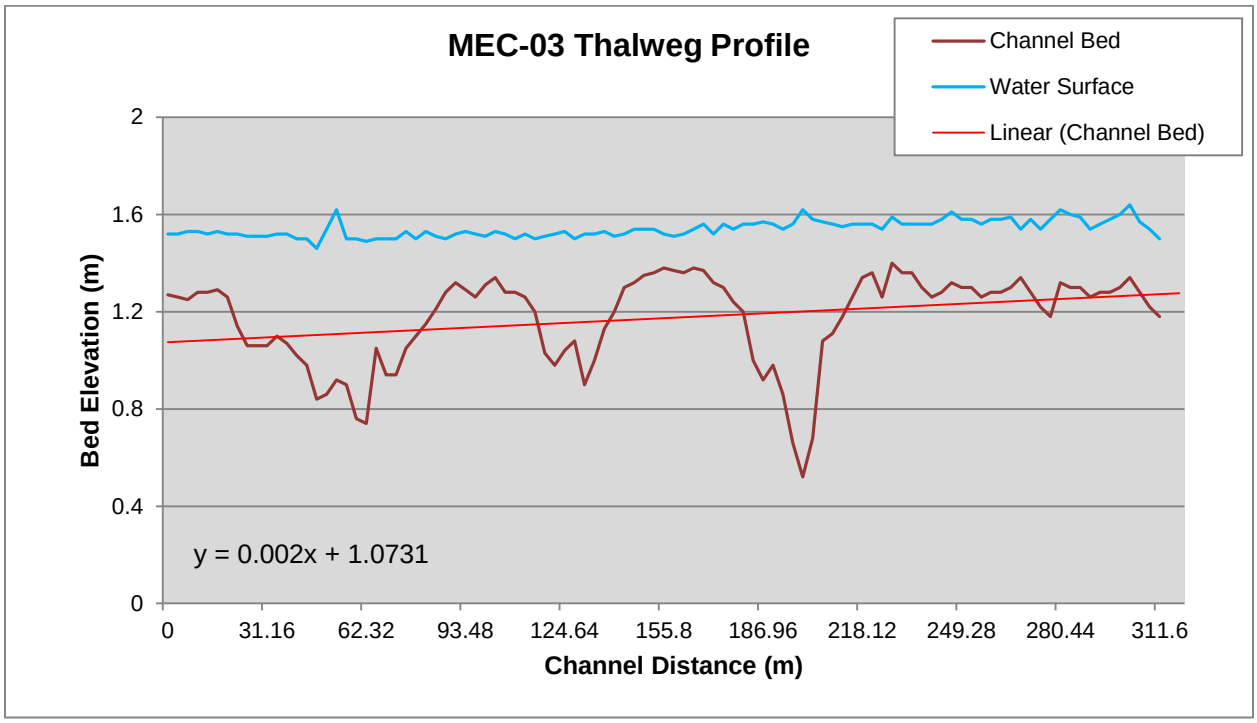


Figure A06 –b.

Figure A07 –a, -b. PMR-01 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

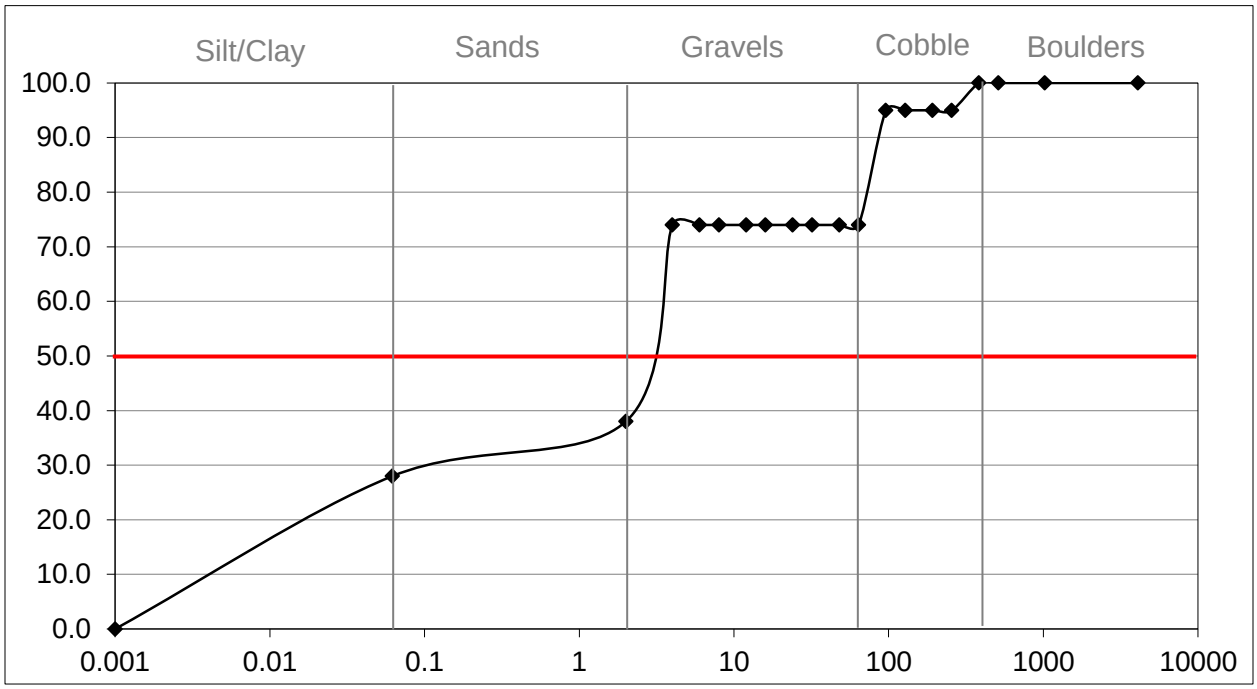


Figure A07 –a.

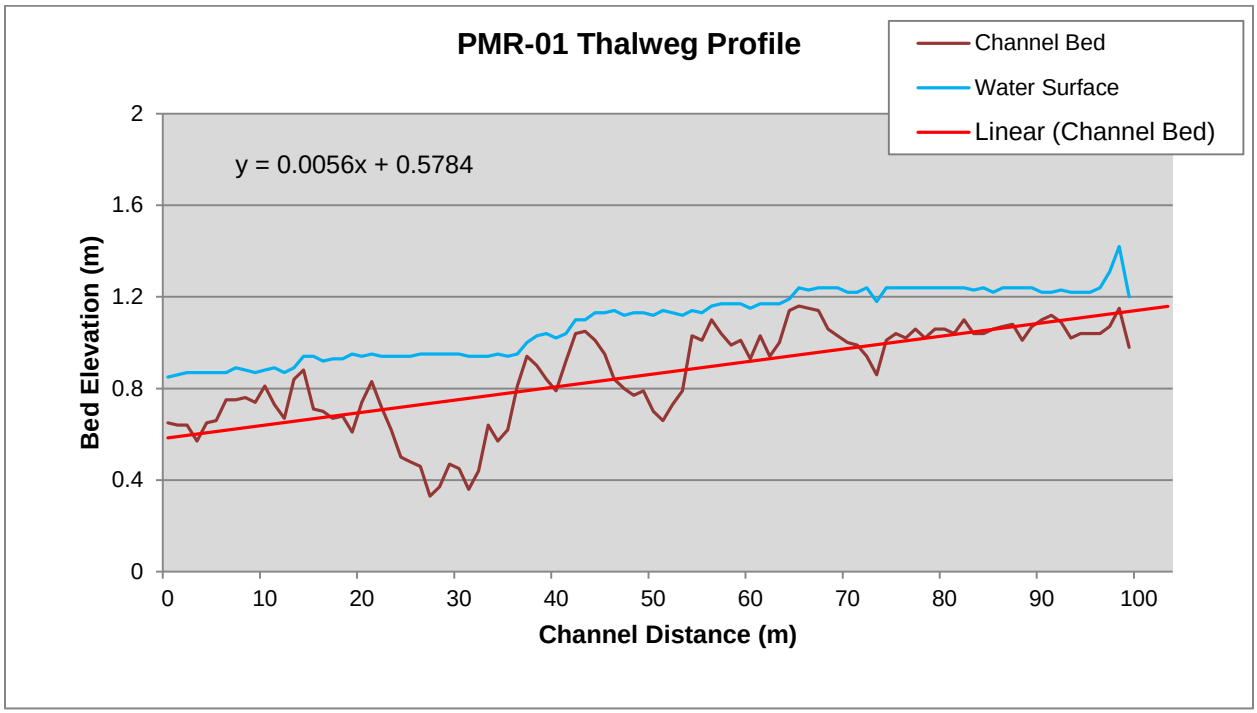


Figure A07 –b.

Figure A08 –a, -b. PMR-02 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

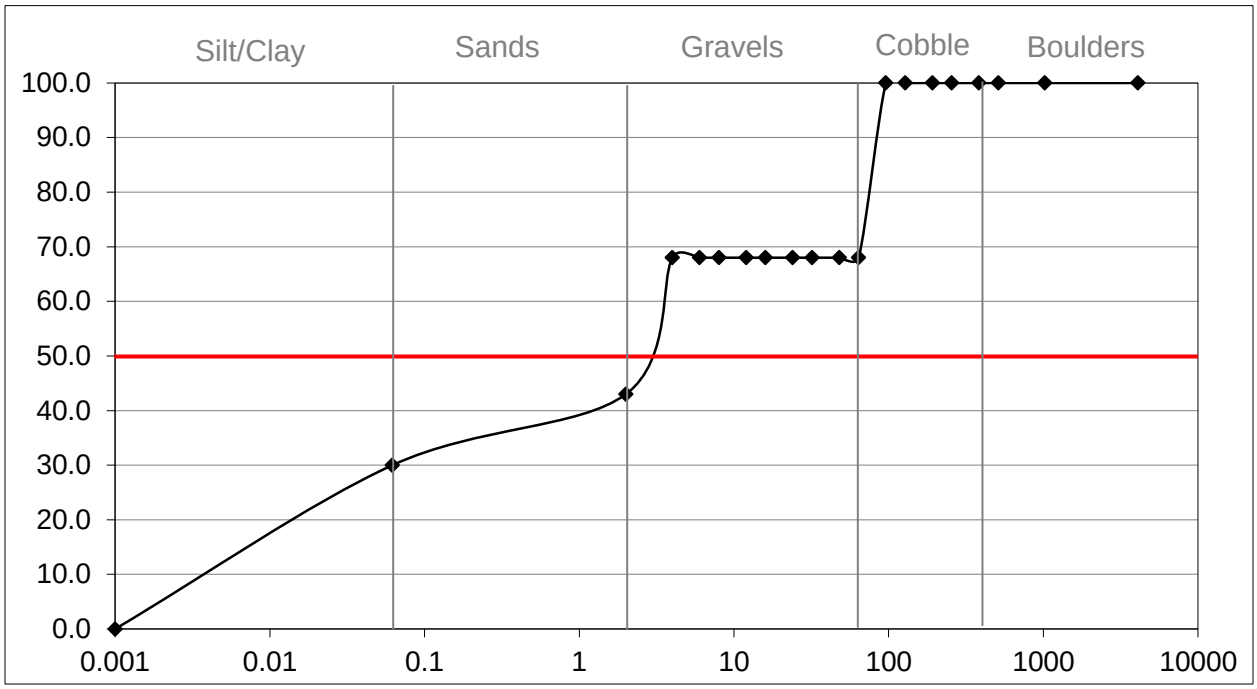


Figure A08 –a.

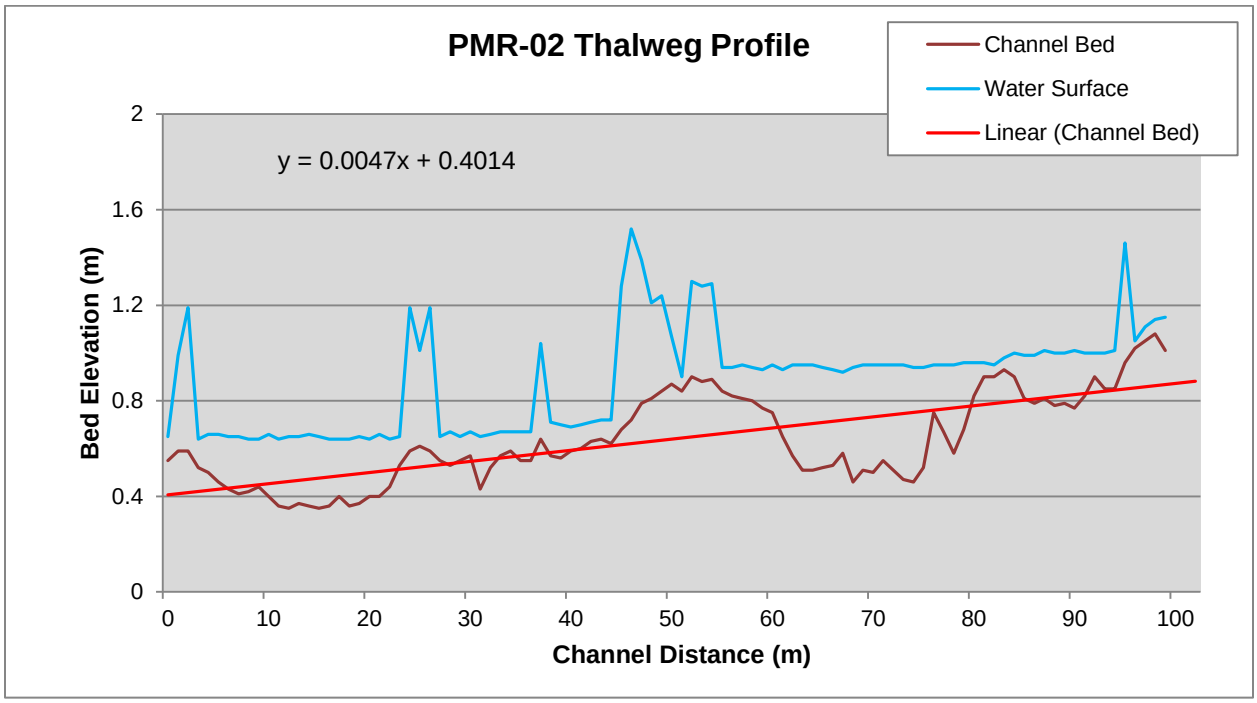


Figure A08 –b.

Figure A09 –a, -b. PMR-03 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

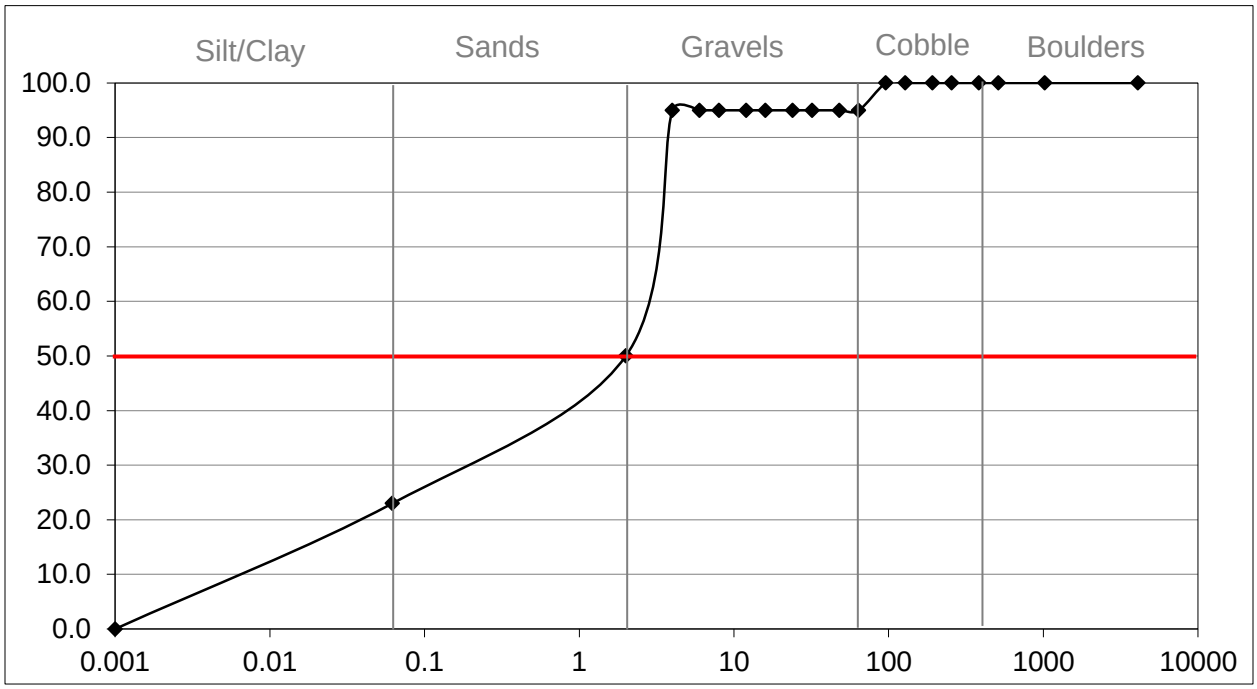


Figure A09 –a.

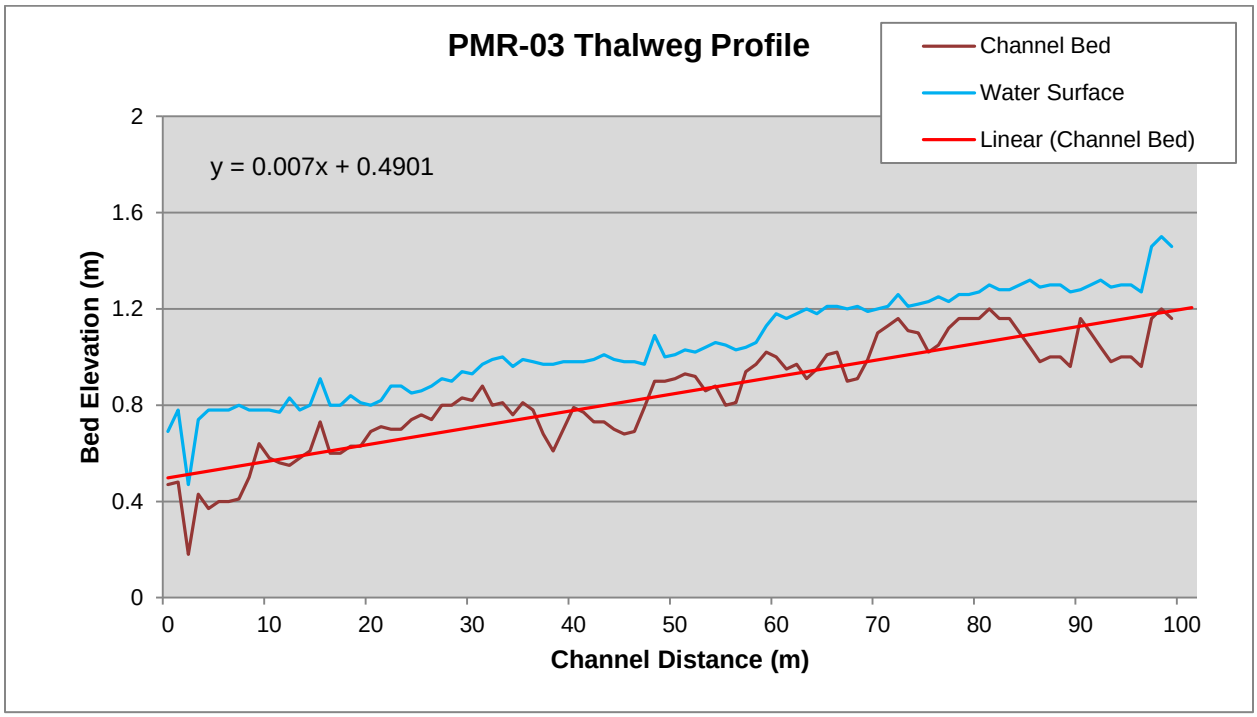


Figure A09 –b.

Figure A10 –a, -b. STR-01 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

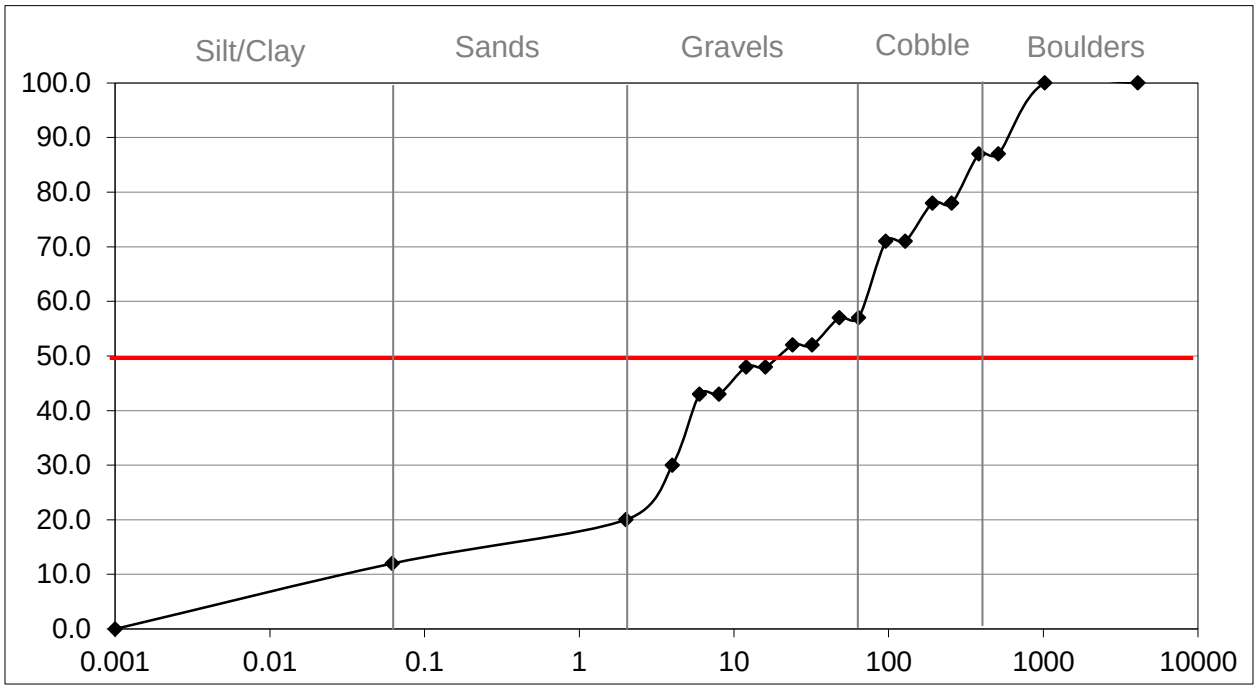


Figure A10 –a.

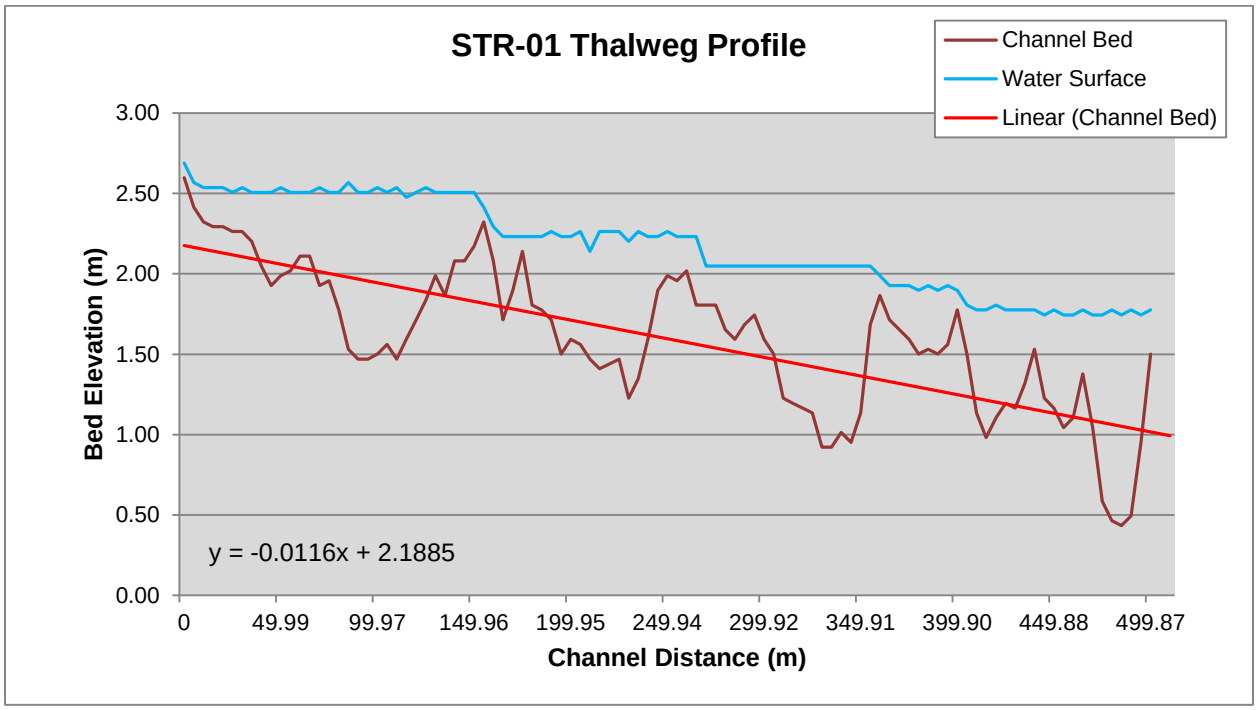


Figure A10 –b.

Figure A11 –a, -b. STR-02 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

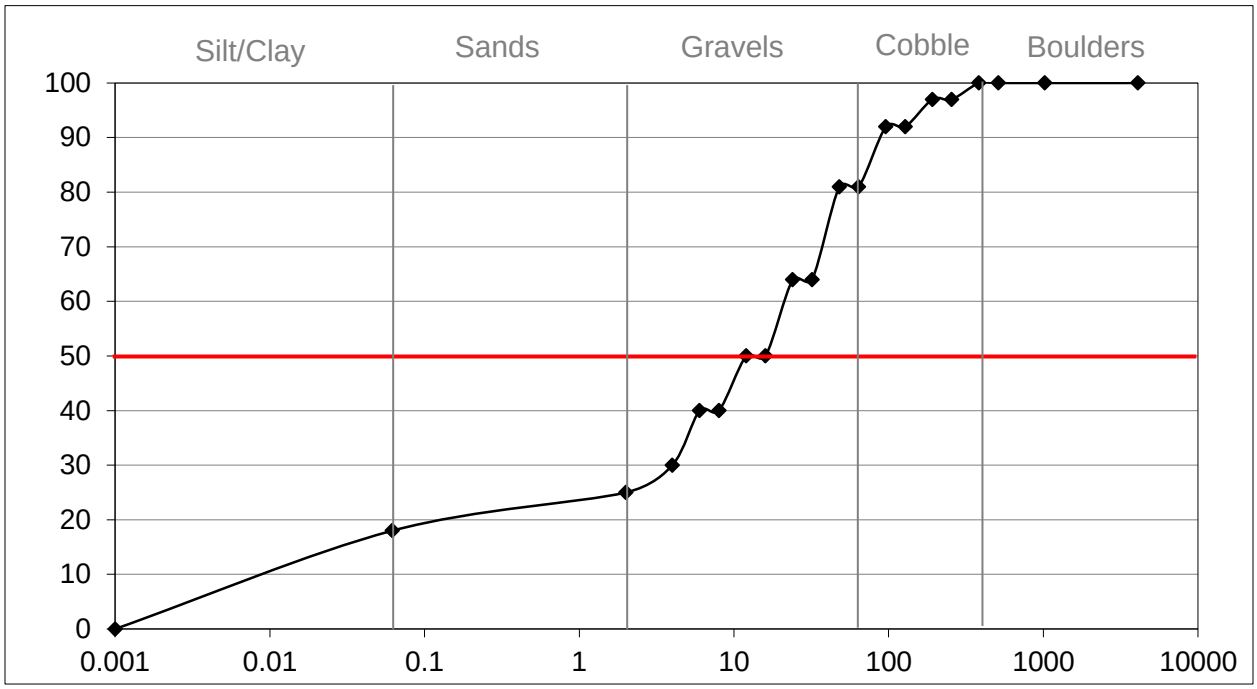


Figure A11 –a.

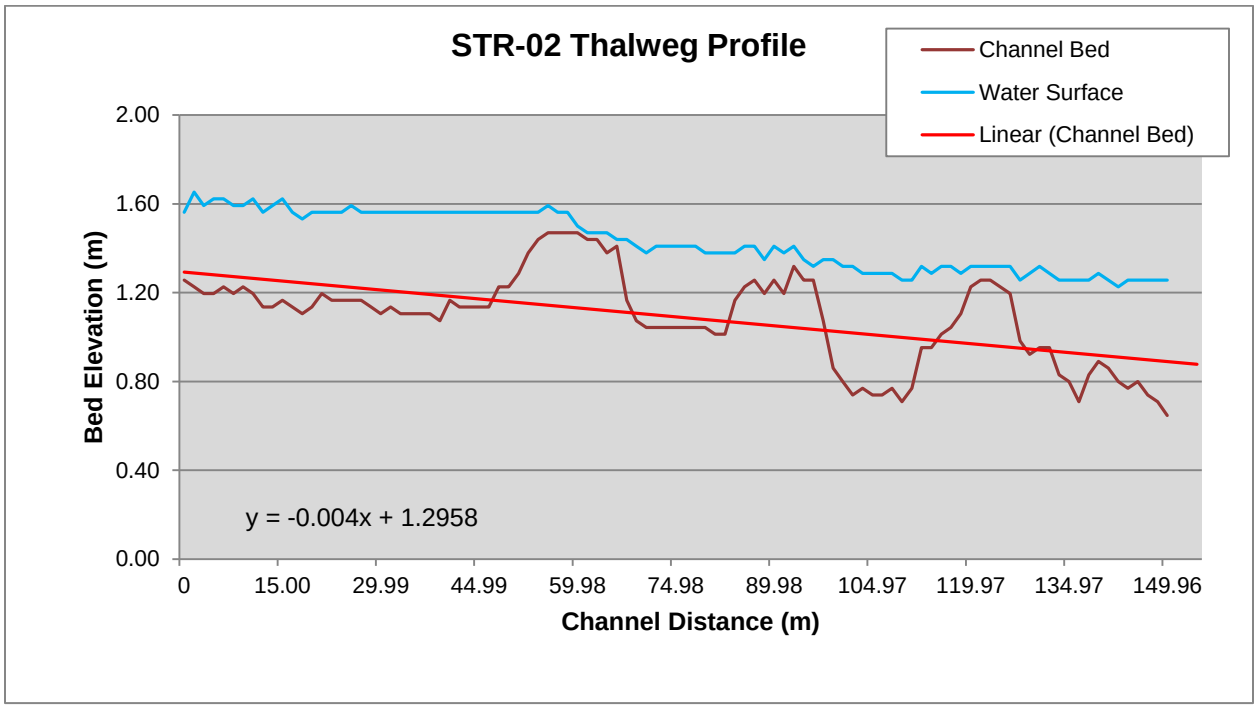


Figure A11 –b.

Figure A12 –a, -b. STR-03 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

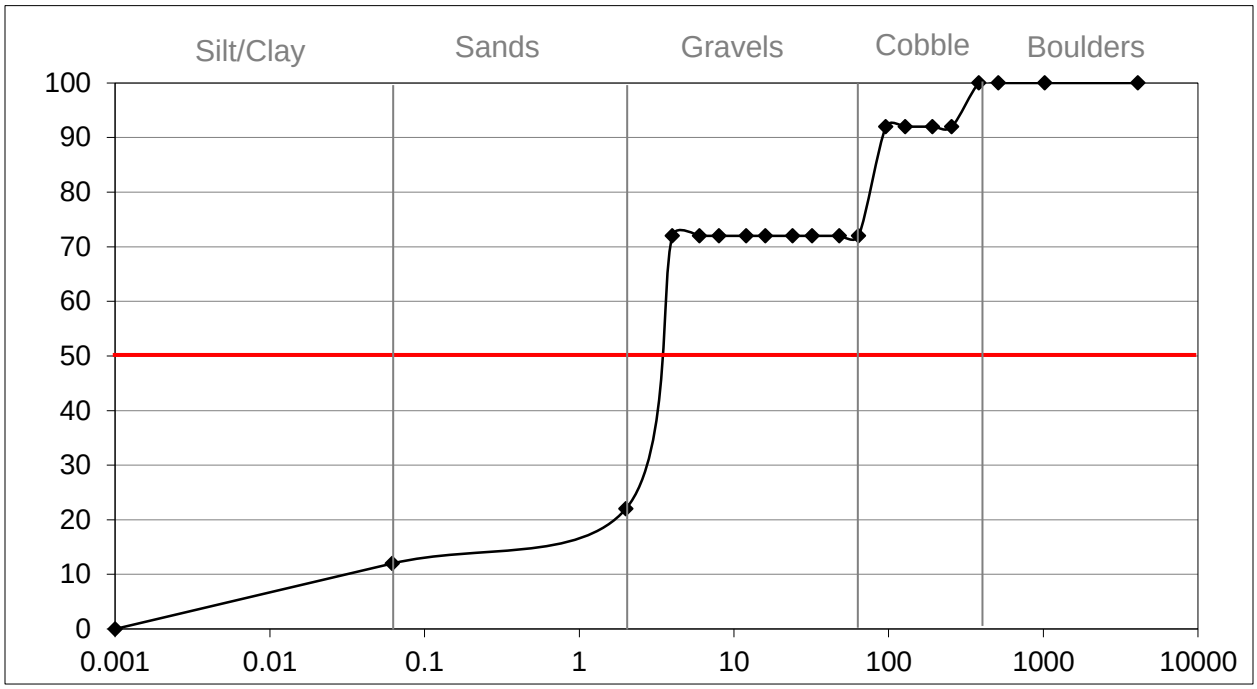


Figure A12 –a.

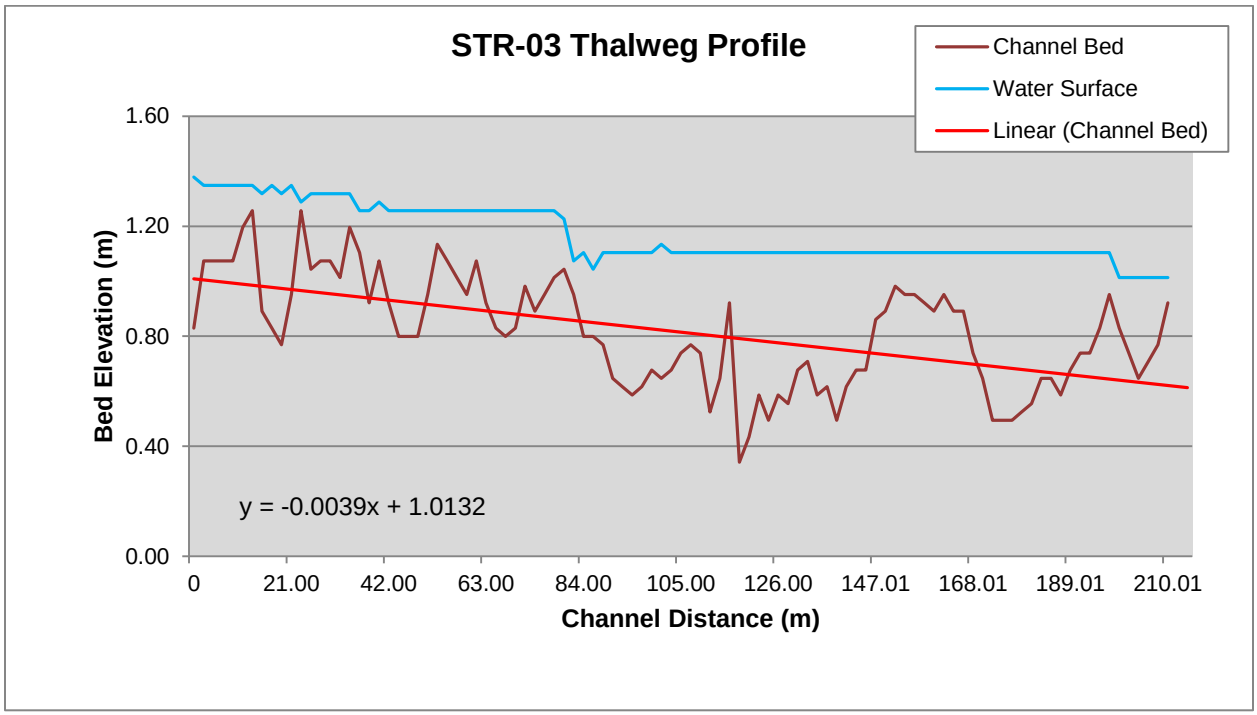


Figure A12 –b.

Figure A13 –a, -b. WPC-01 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

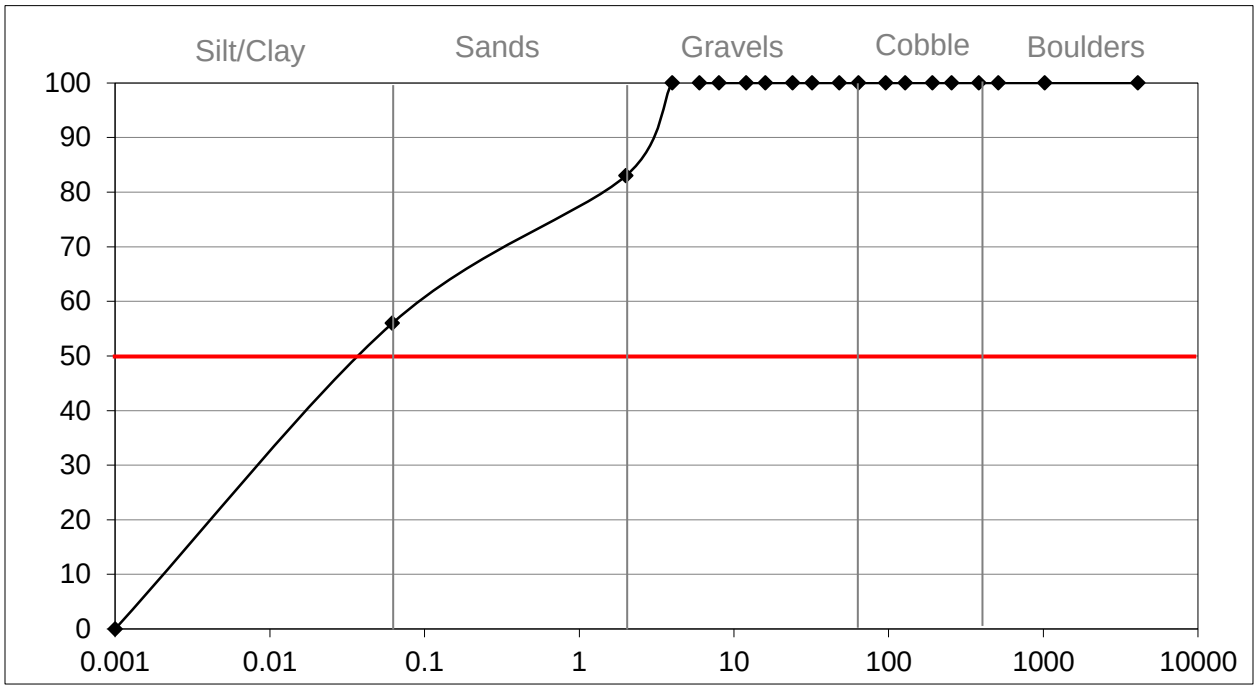


Figure A13 –a.

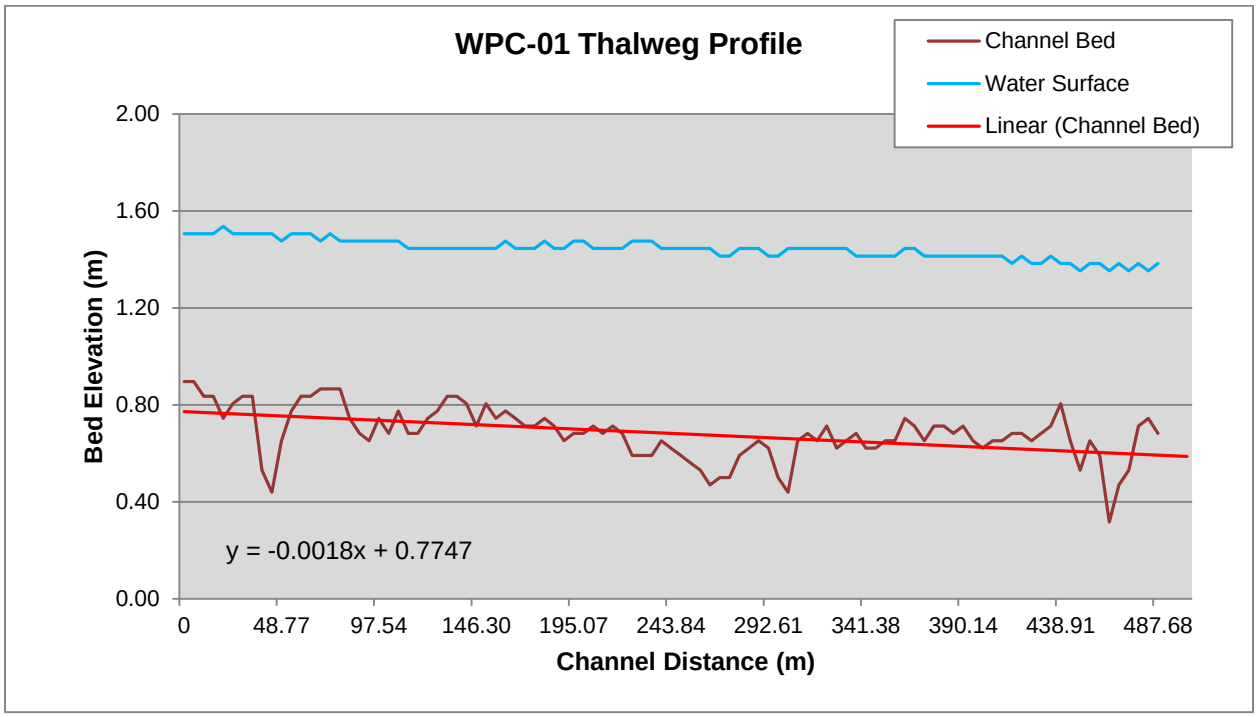


Figure A13 –b.

Figure A14 –a, -b. WPC-02 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

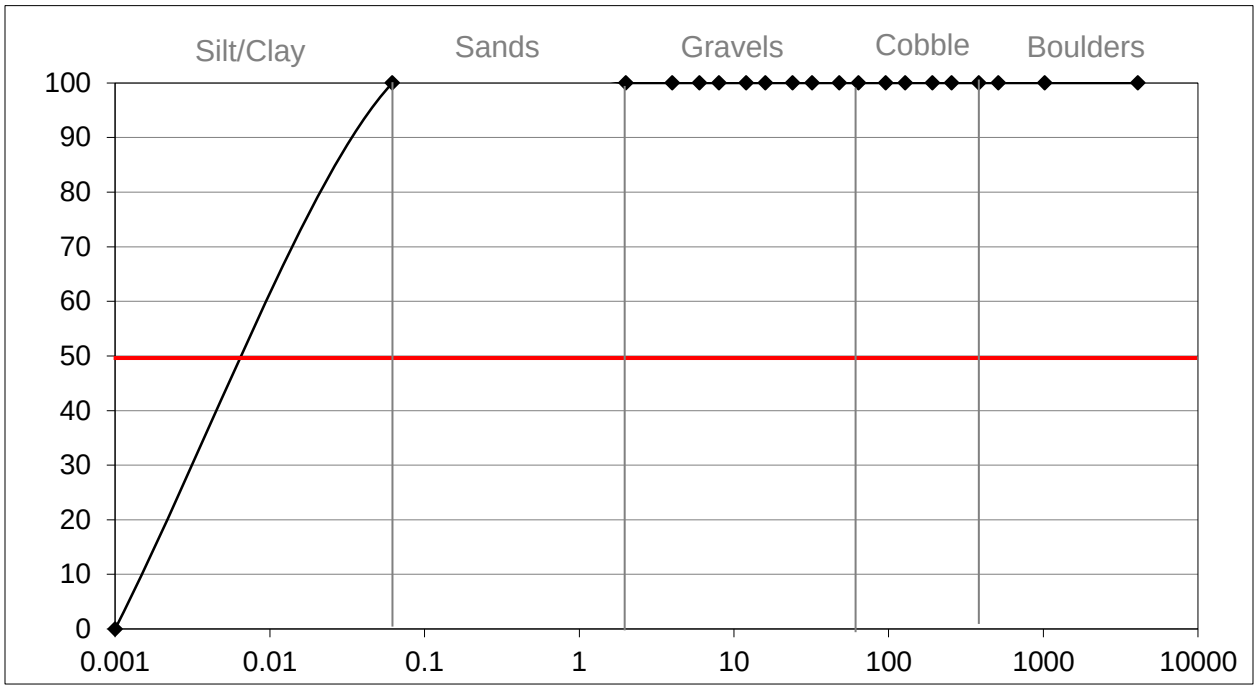


Figure A14 –a.

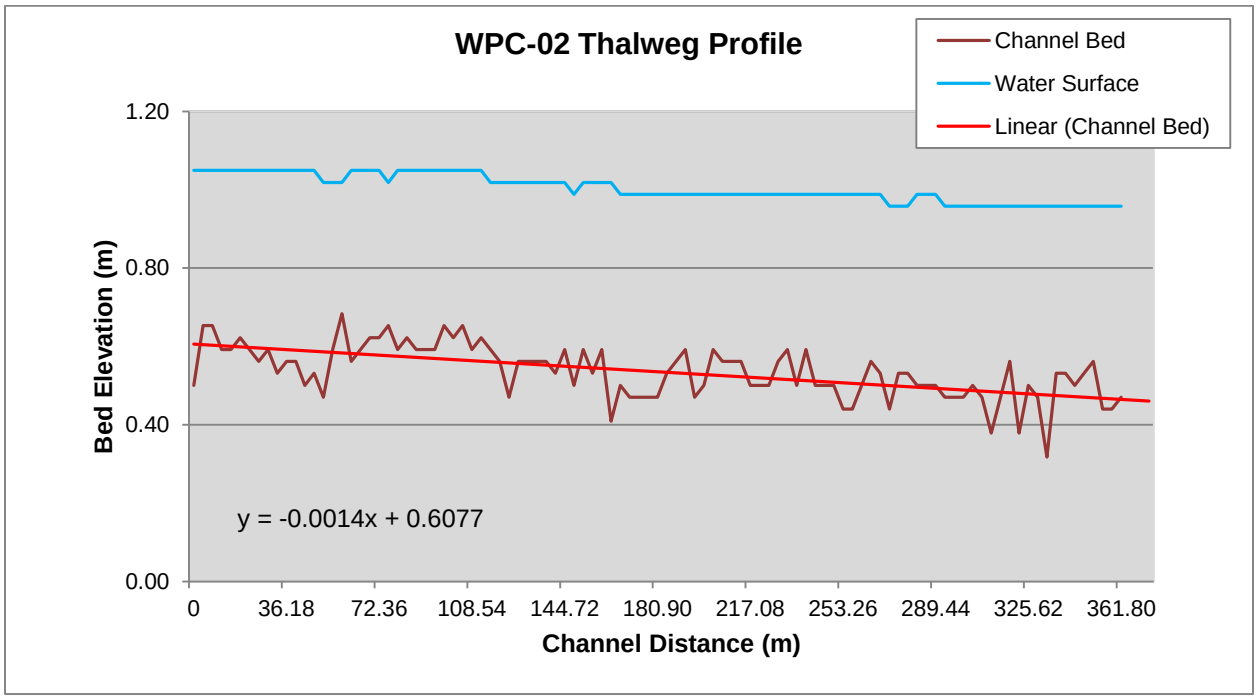


Figure A14 –b.

Figure A15 –a, -b. WPC-03 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

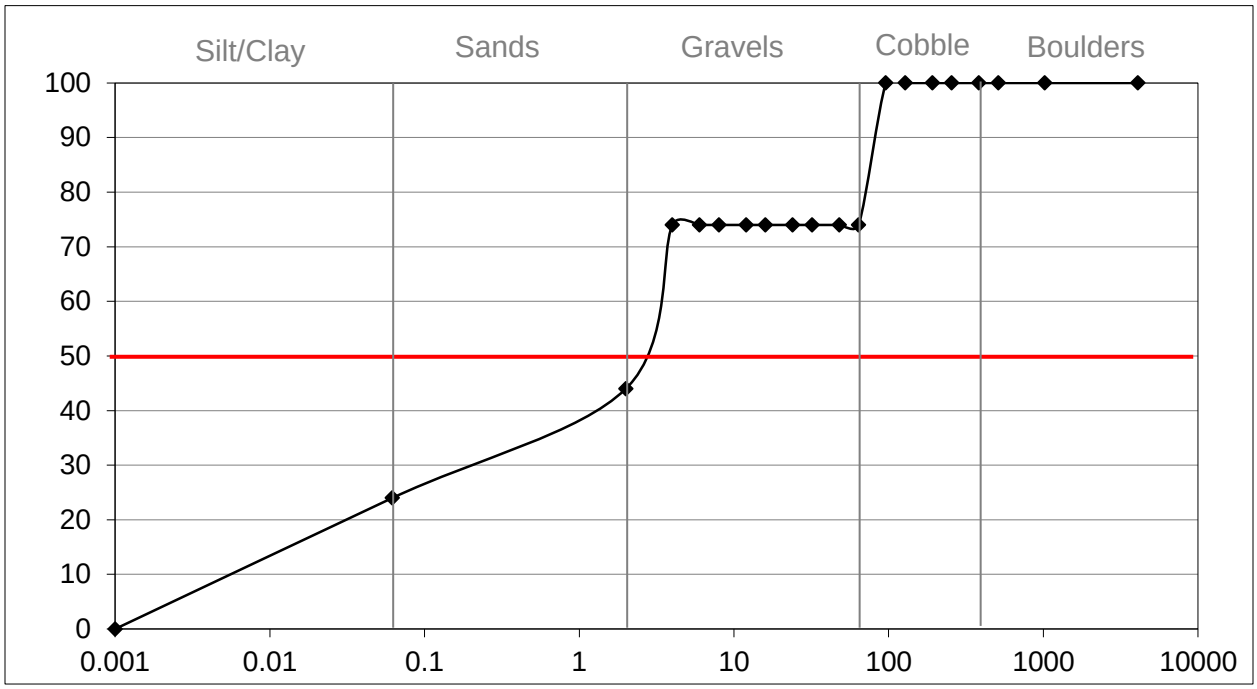


Figure A15 –a.

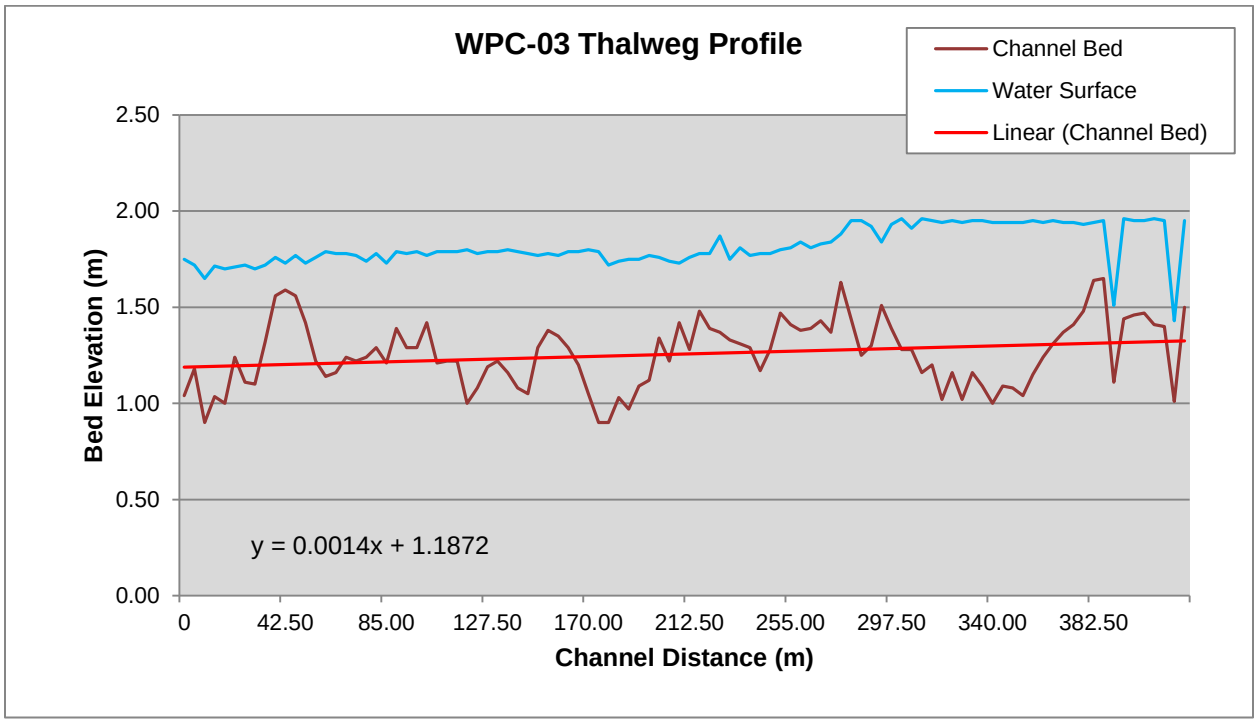


Figure A15 –b.

Figure A16 –a, -b. ENC -01 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

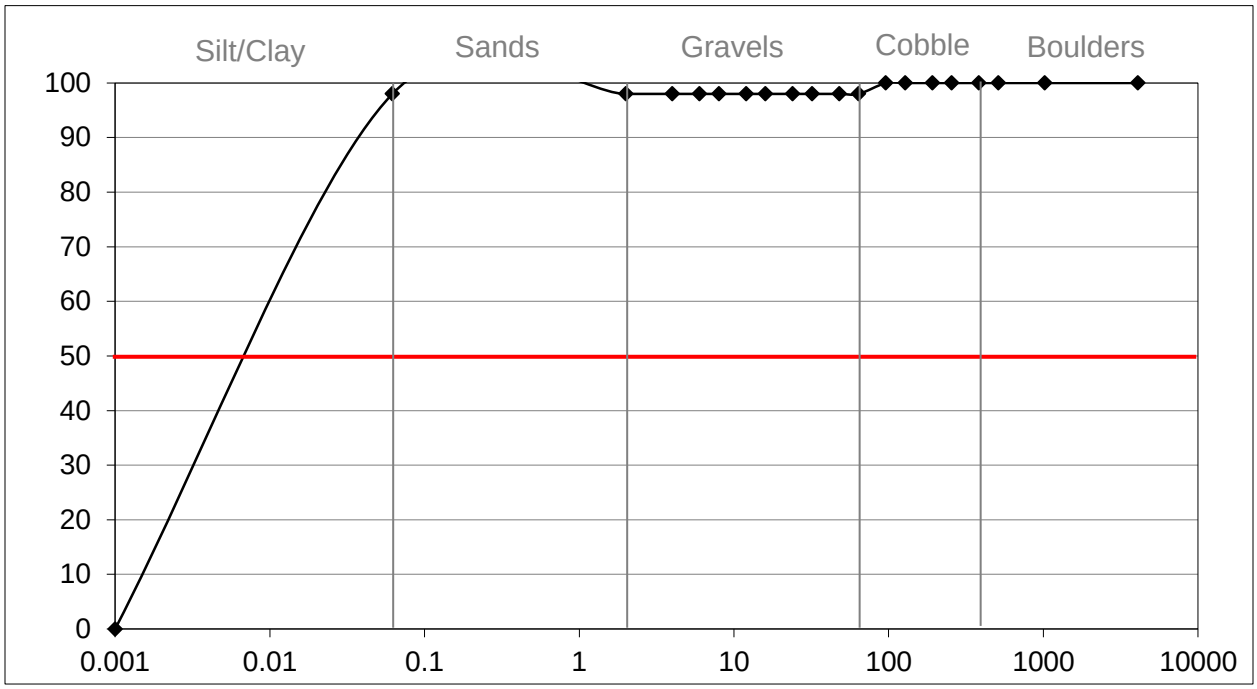


Figure A16 –a.

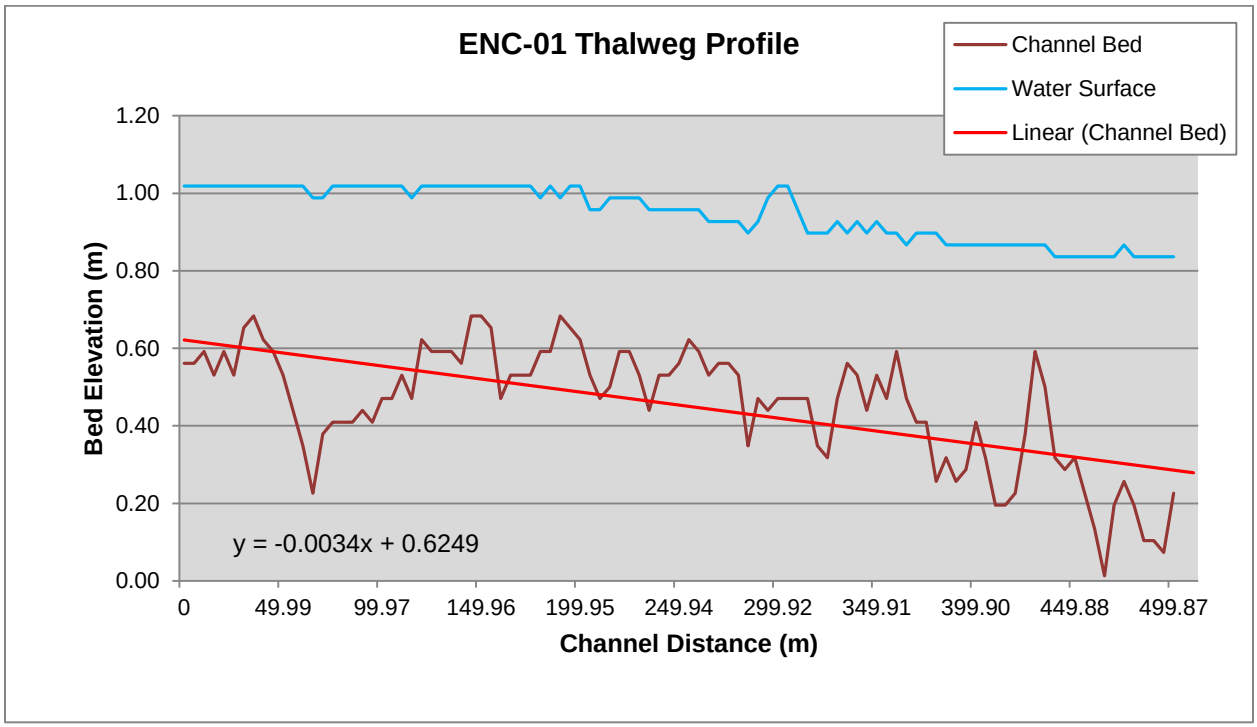


Figure A16 –b.

Figure A17 –a, -b. ENC-02 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

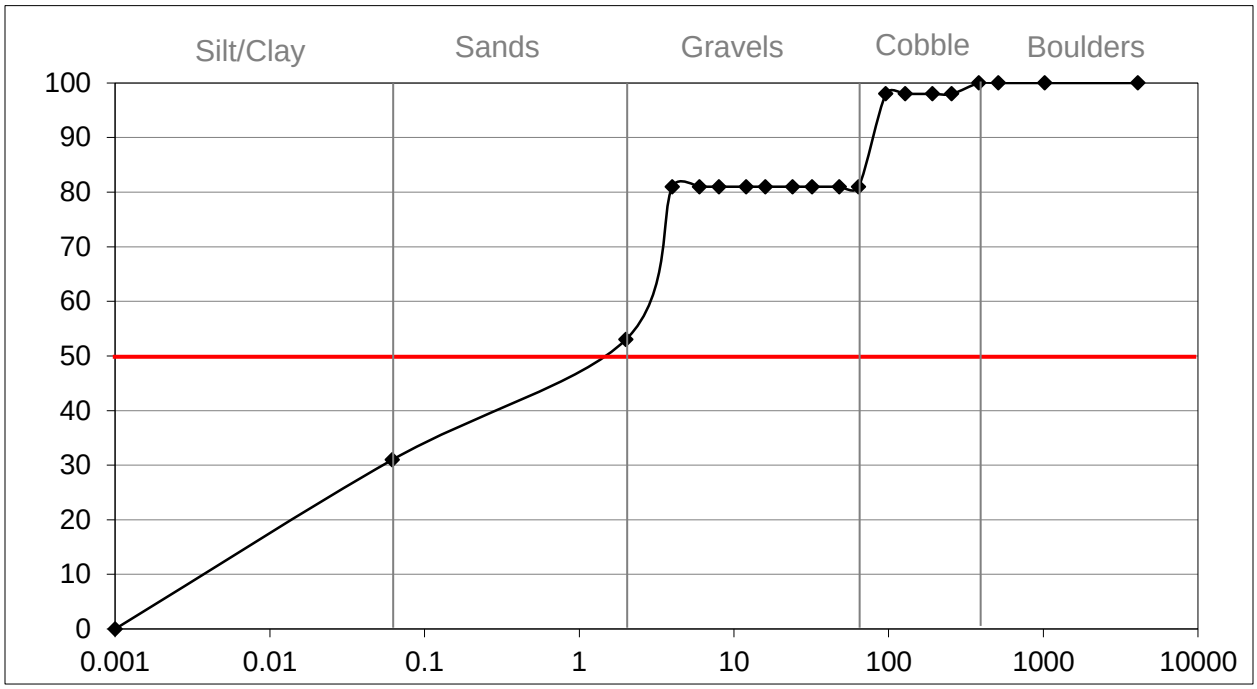


Figure A17 –a.

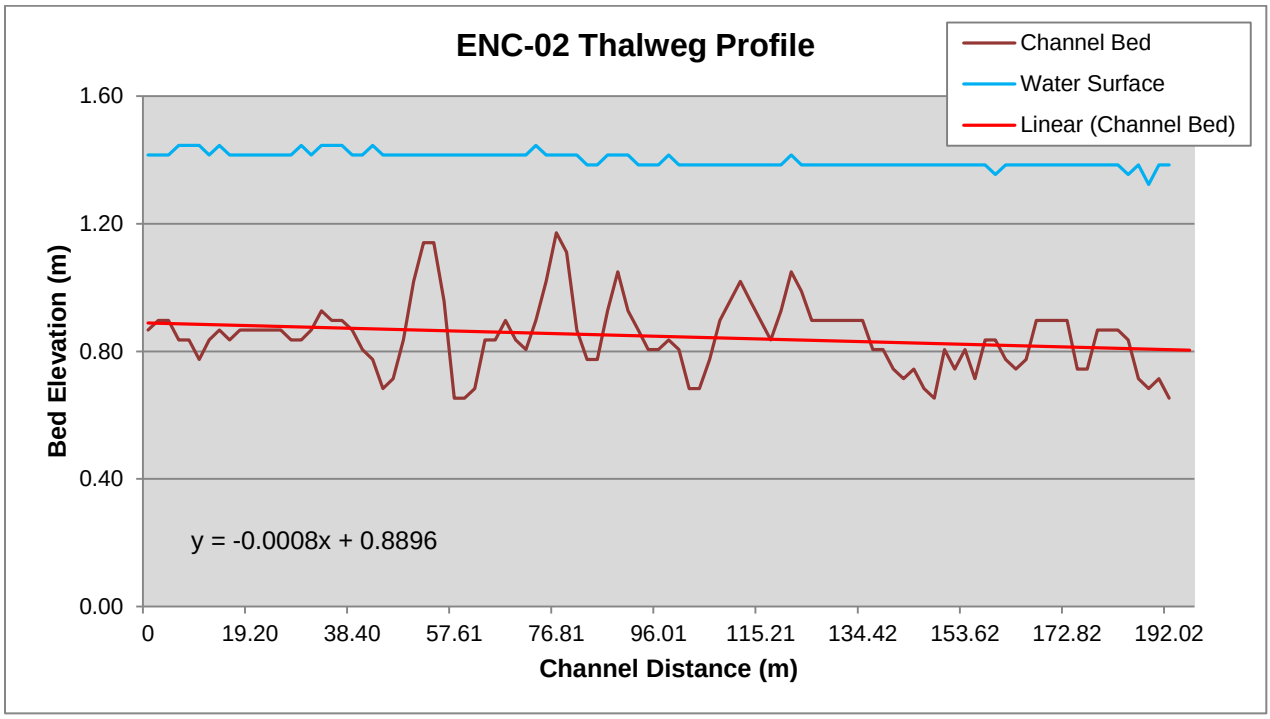


Figure A17 –b.

Figure A18 –a, -b. ENC-03 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

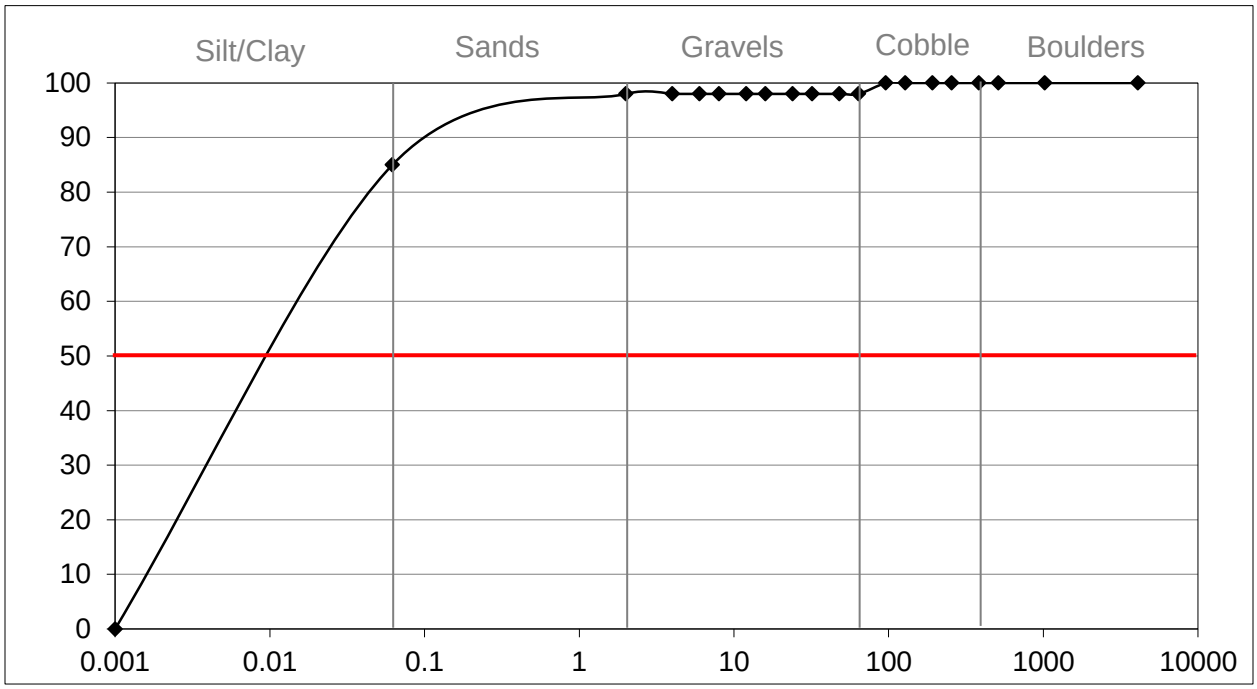


Figure A18 –a.

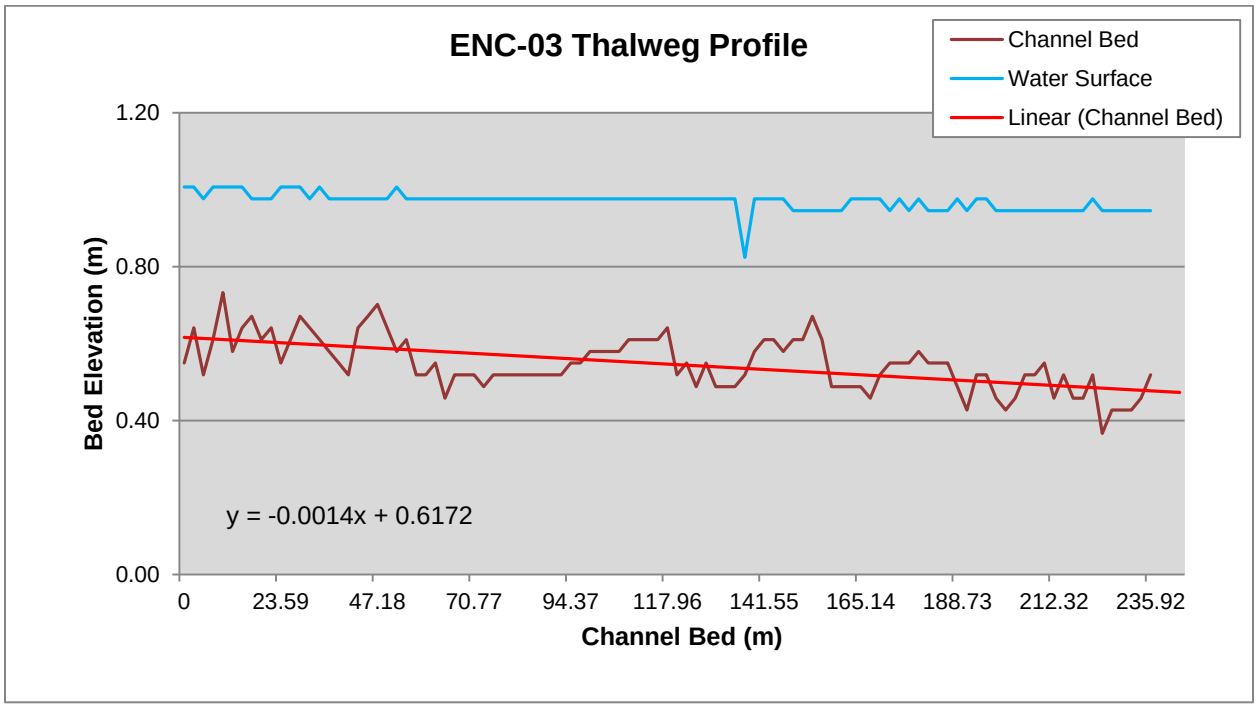


Figure A18 –b.

Figure A19 –a, -b. MPC-01 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

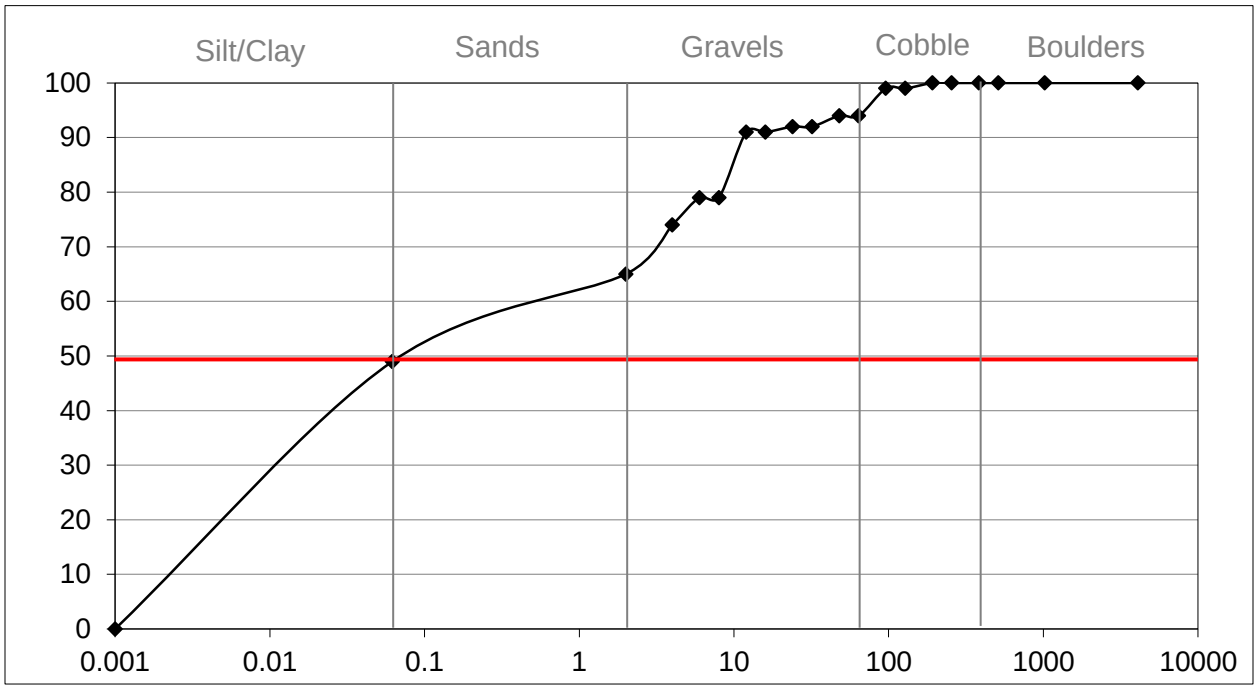


Figure A19 –a.

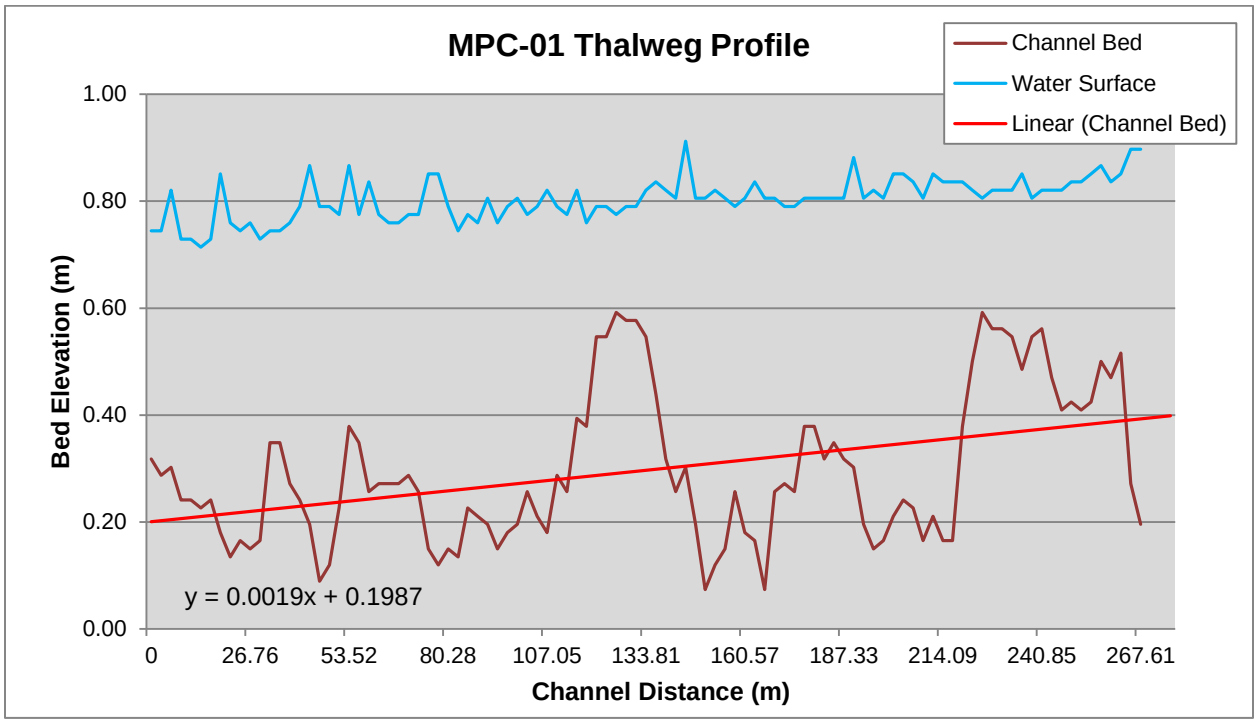


Figure A19 –b.

Figure A20 –a, -b. MPC-02 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

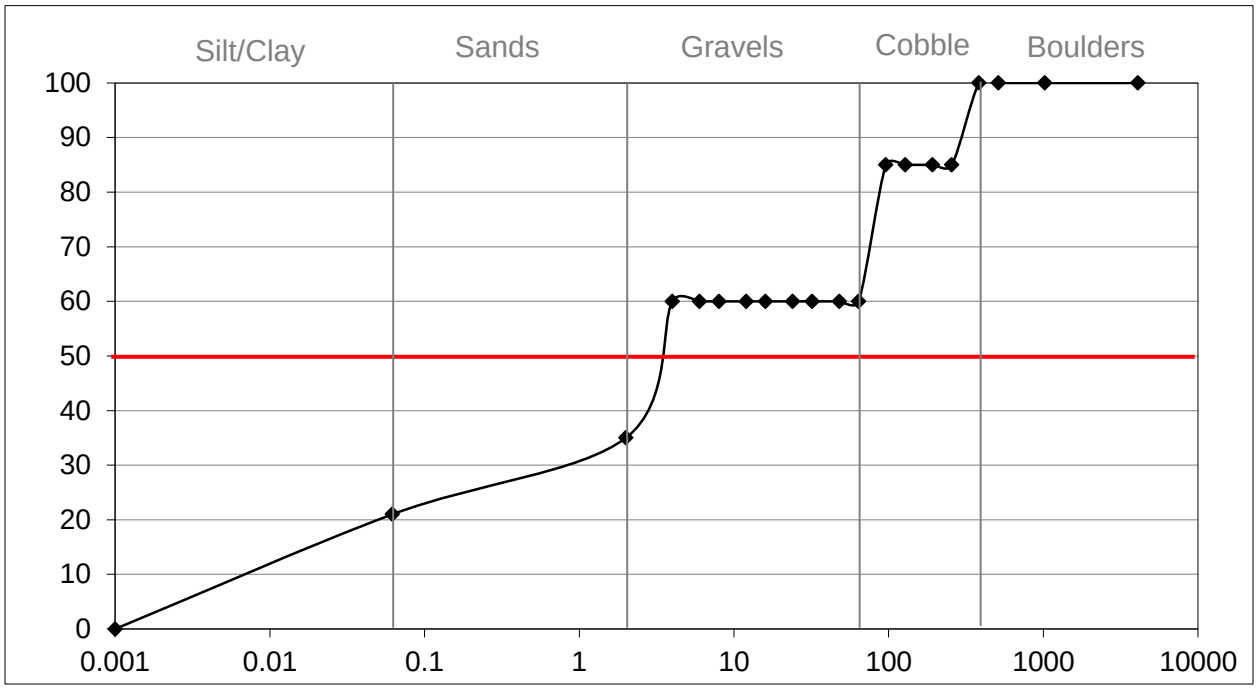


Figure A20 –a.

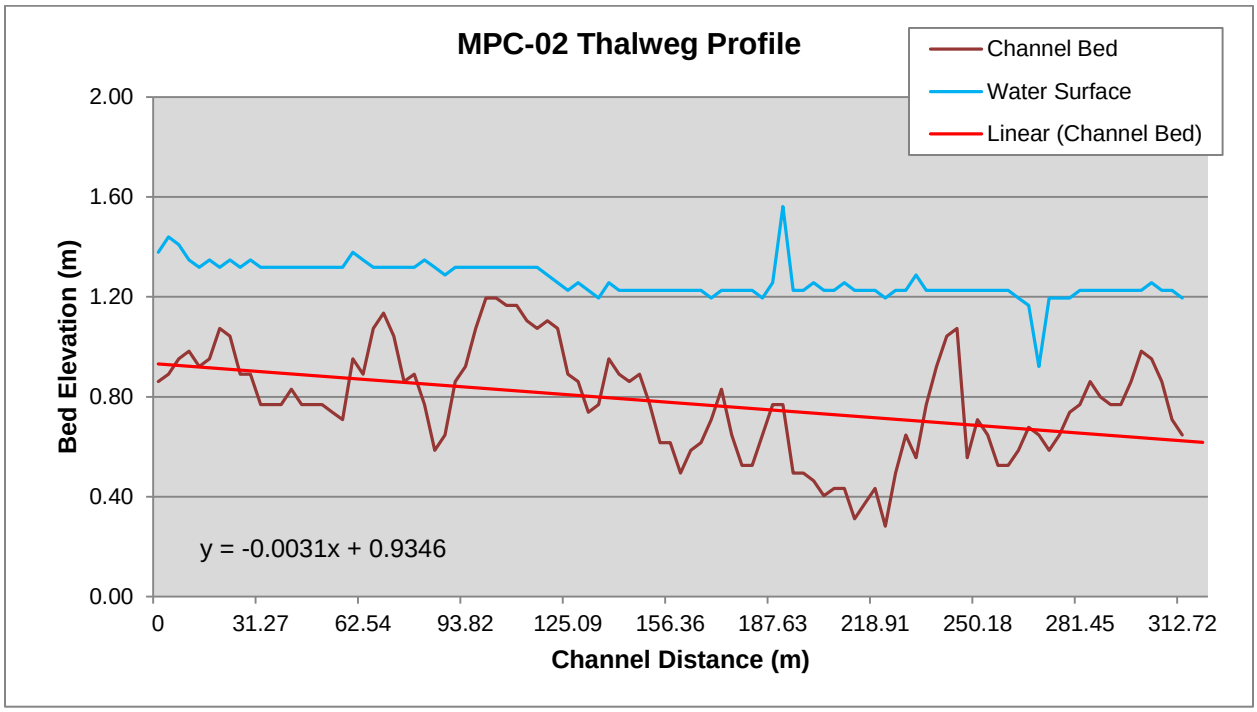


Figure A20 –b.

Figure A21 –a, -b. MPC-03 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

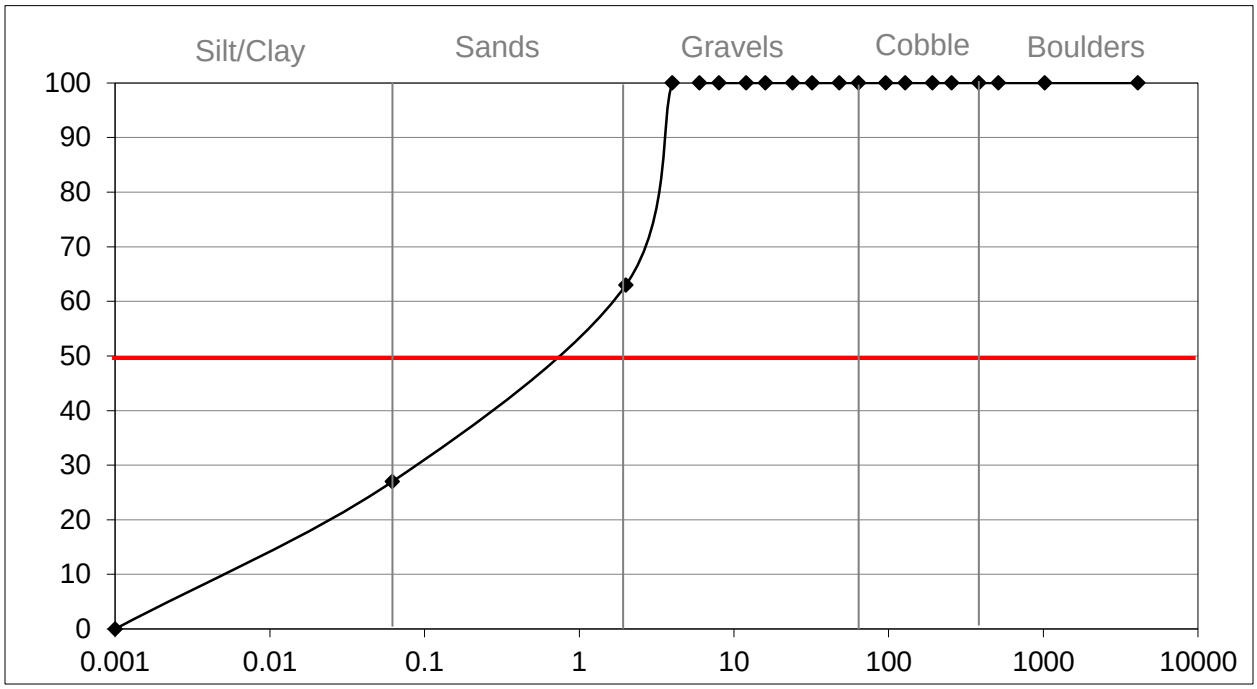


Figure A21 –a.

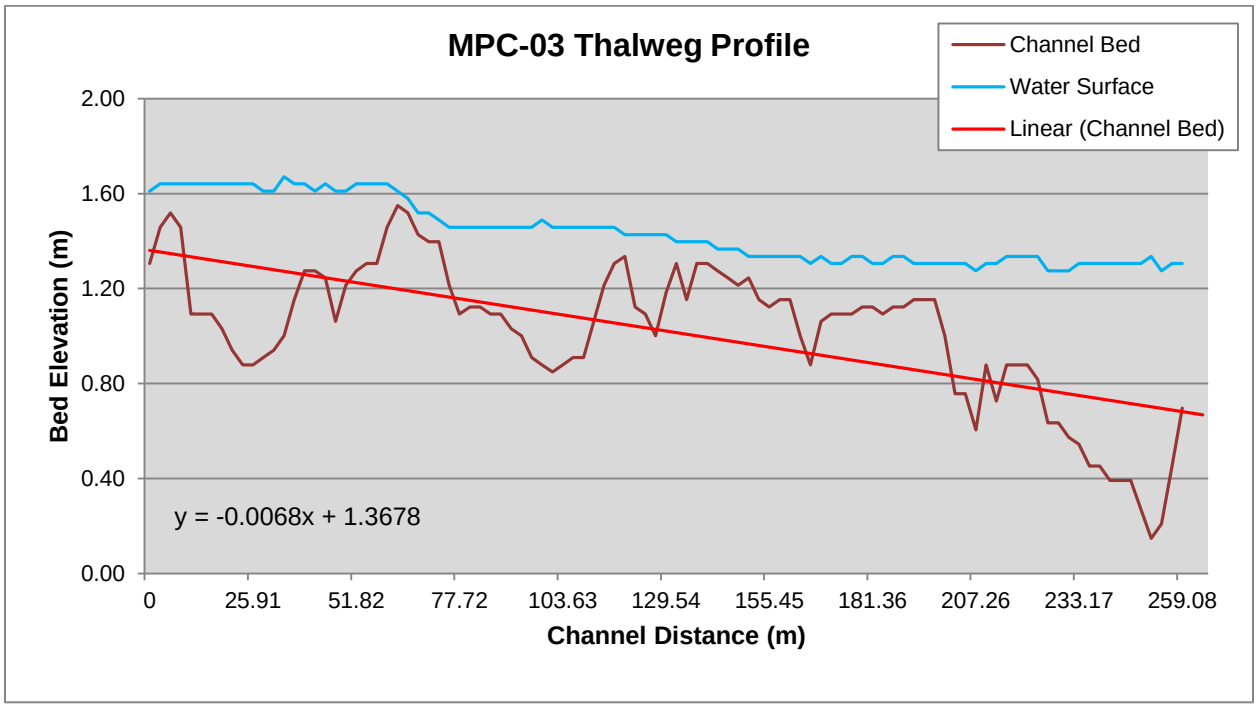


Figure A21 –b.

Figure A22 –a, -b. TMC-01 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

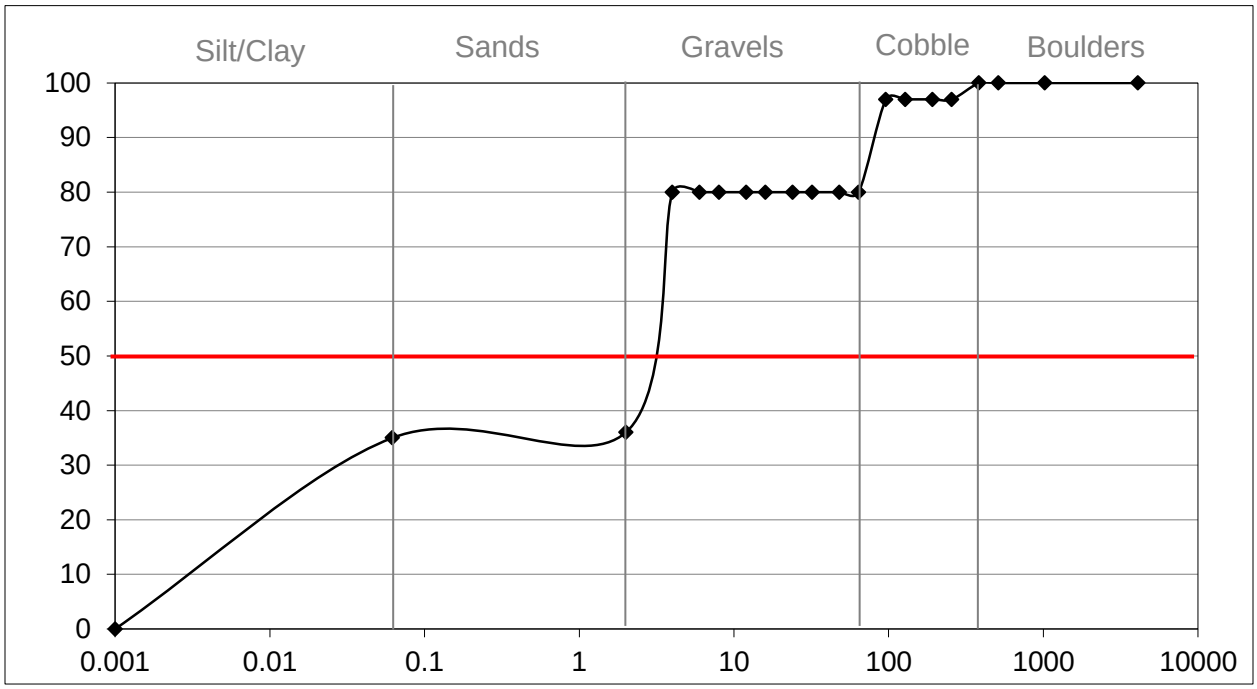


Figure A22 –a.

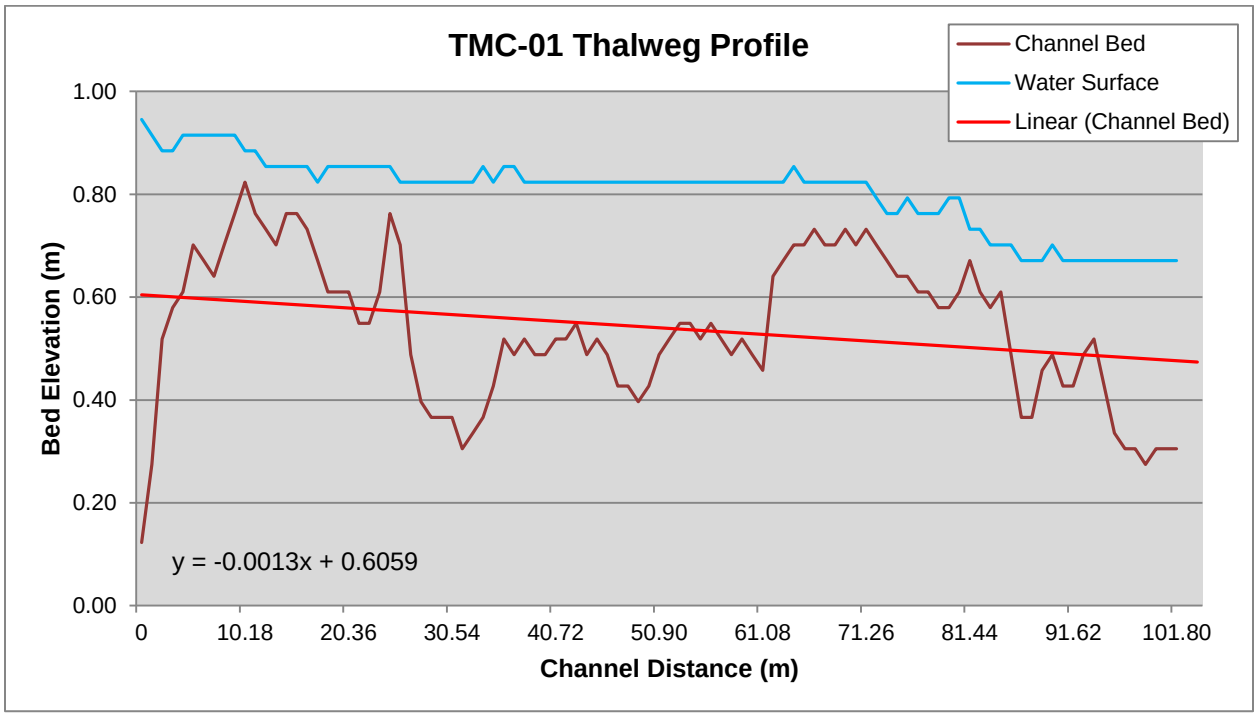


Figure A22 –b.

Figure A23 –a, -b. TMC-02 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

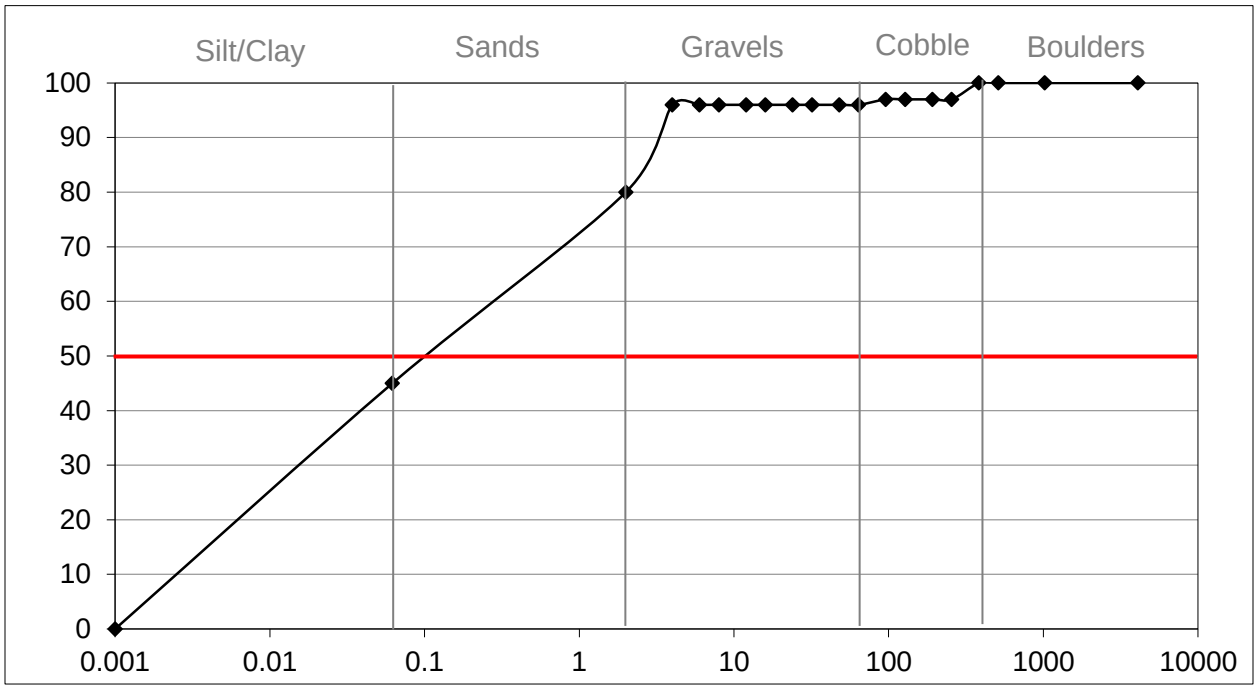


Figure A23 –a.

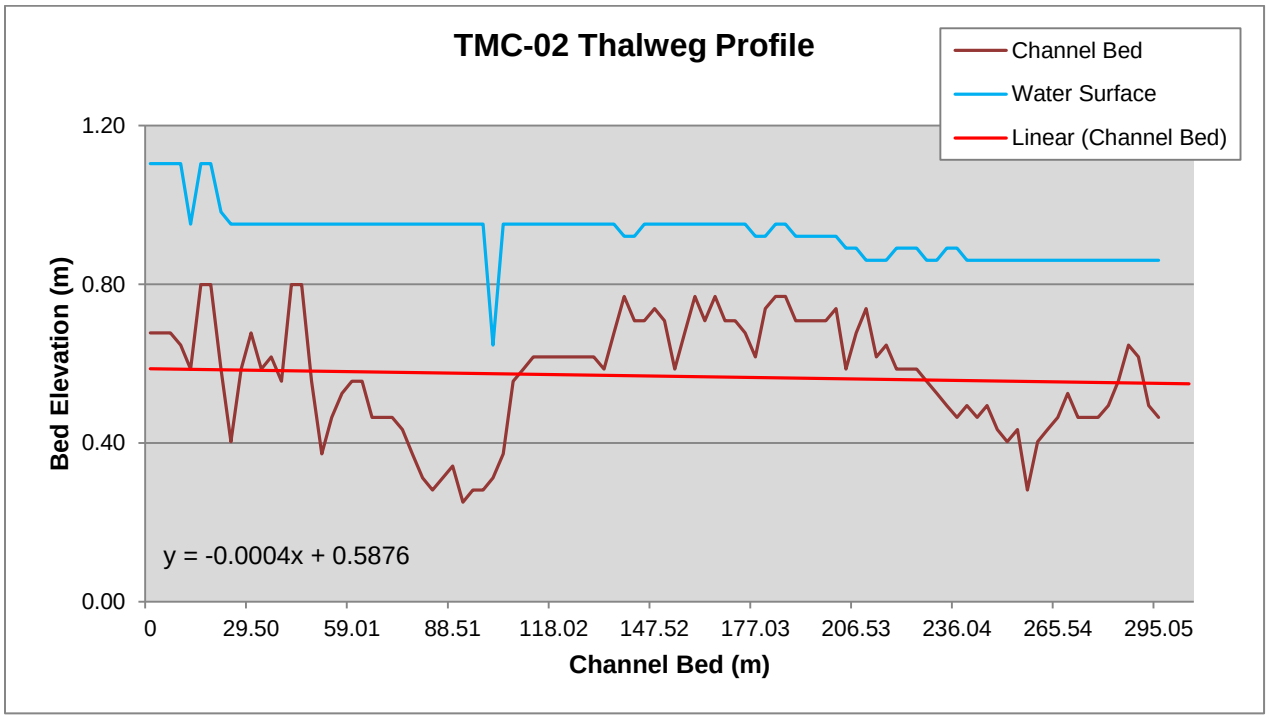


Figure A23 –b.

Figure A24 –a, -b. TMC-03 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

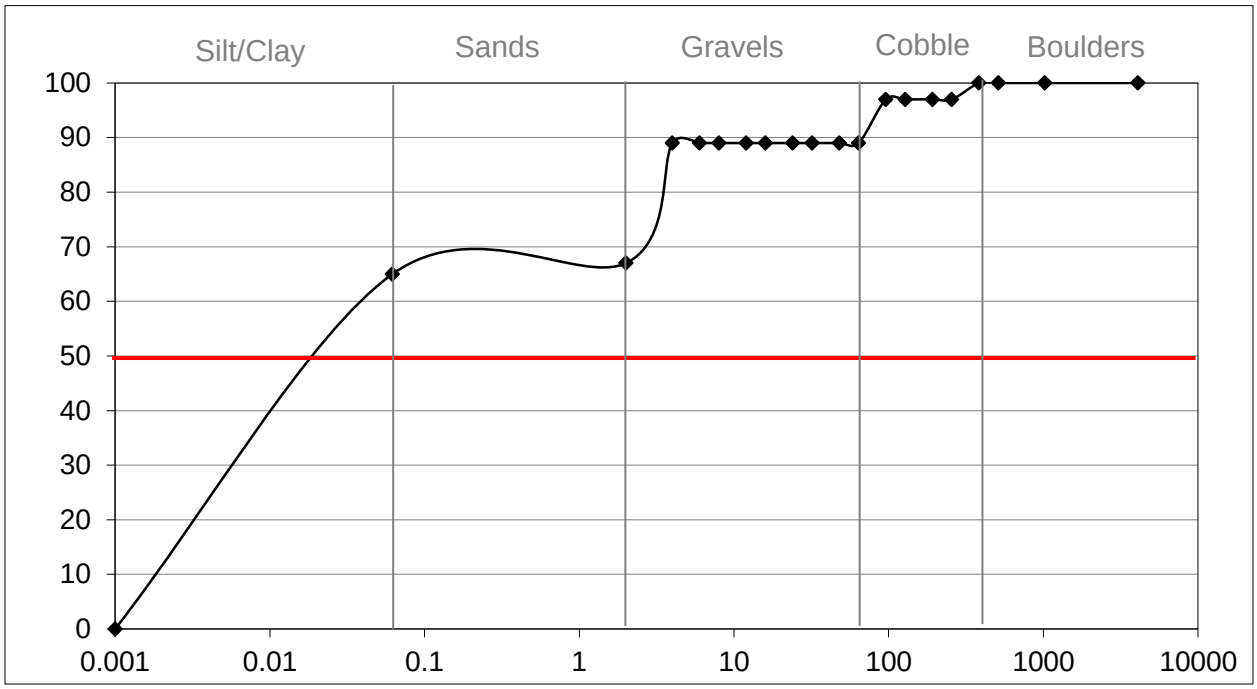


Figure A24 –a.

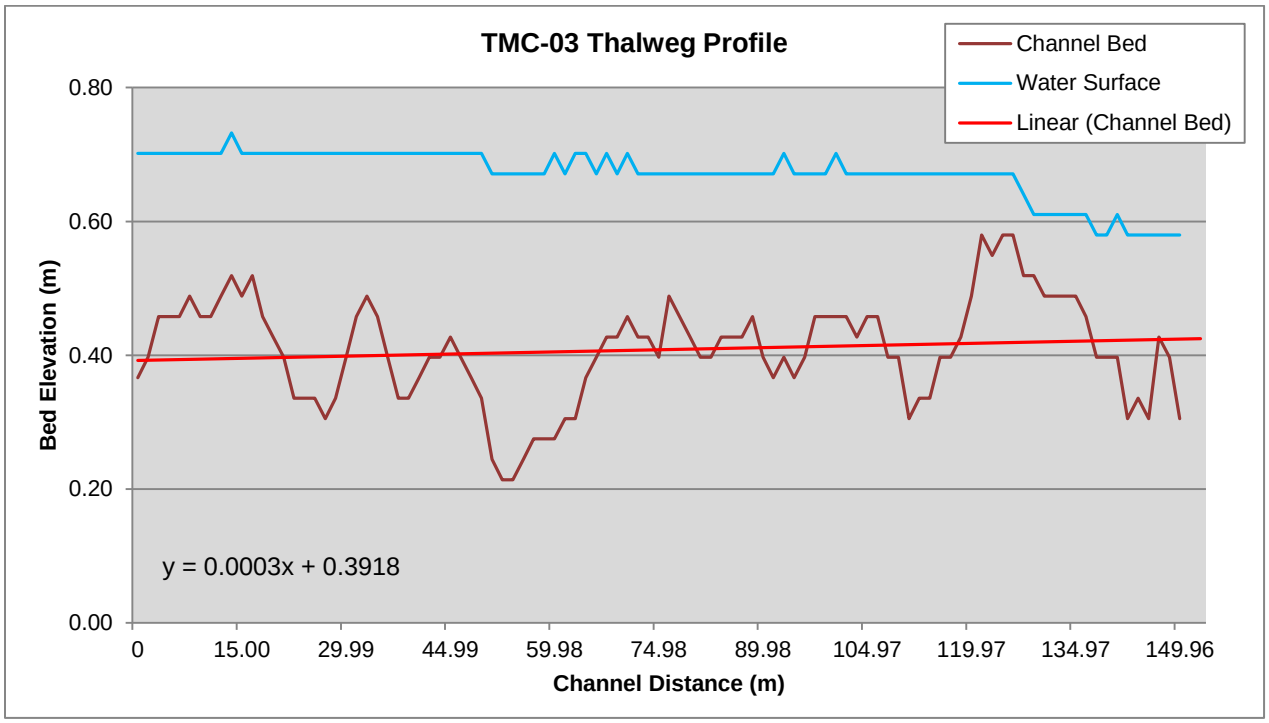


Figure A24 –b.

Figure A25 –a, -b. LOC-01 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

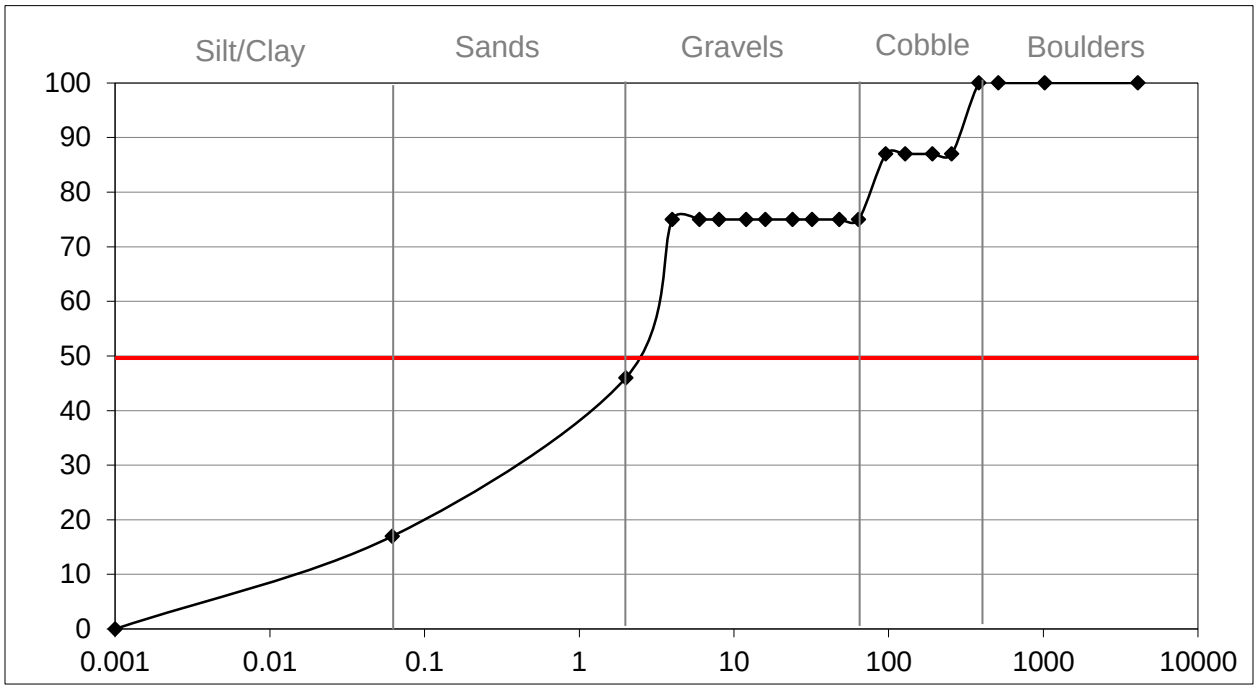


Figure A25 –a.

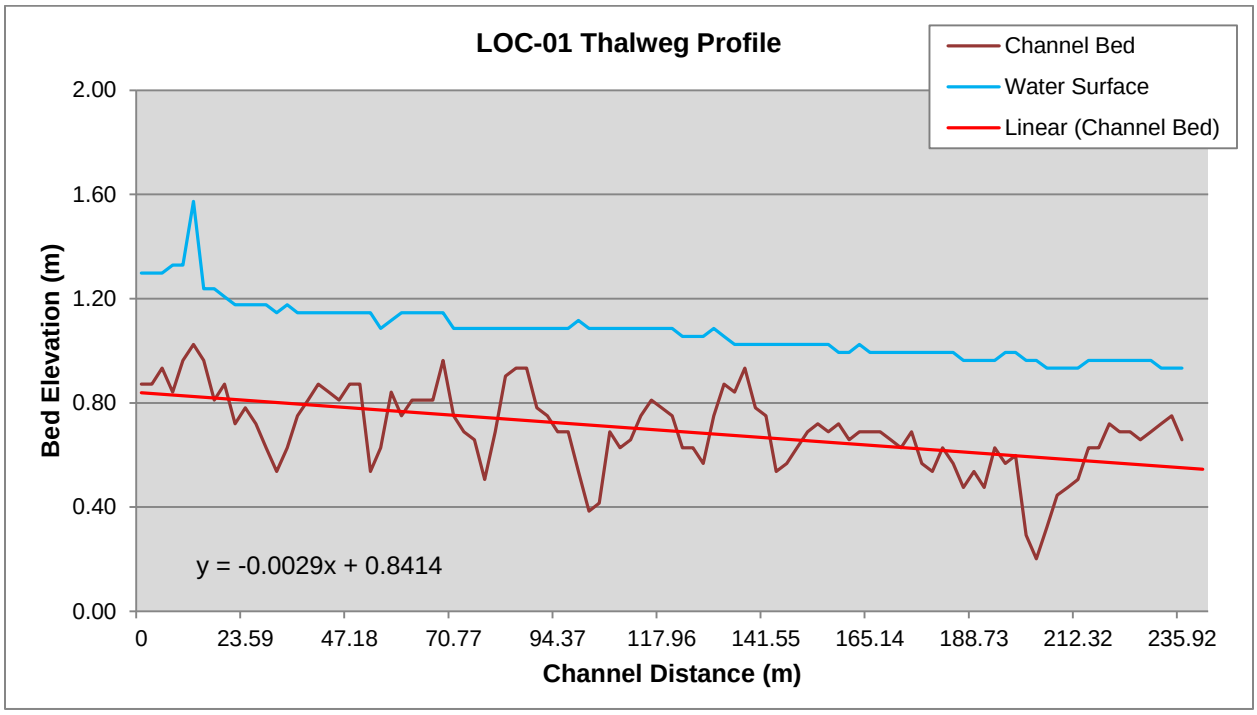


Figure A25 –b.

Figure A26 –a, -b.TUR-01 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

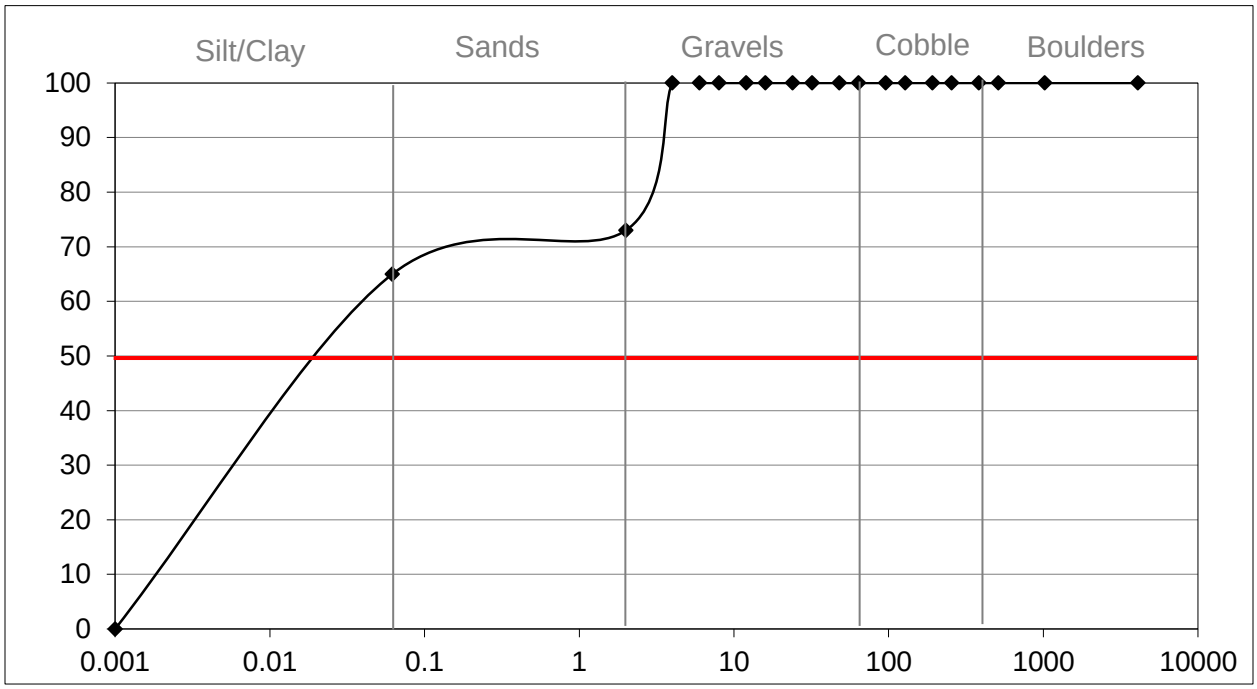


Figure A26 –a.

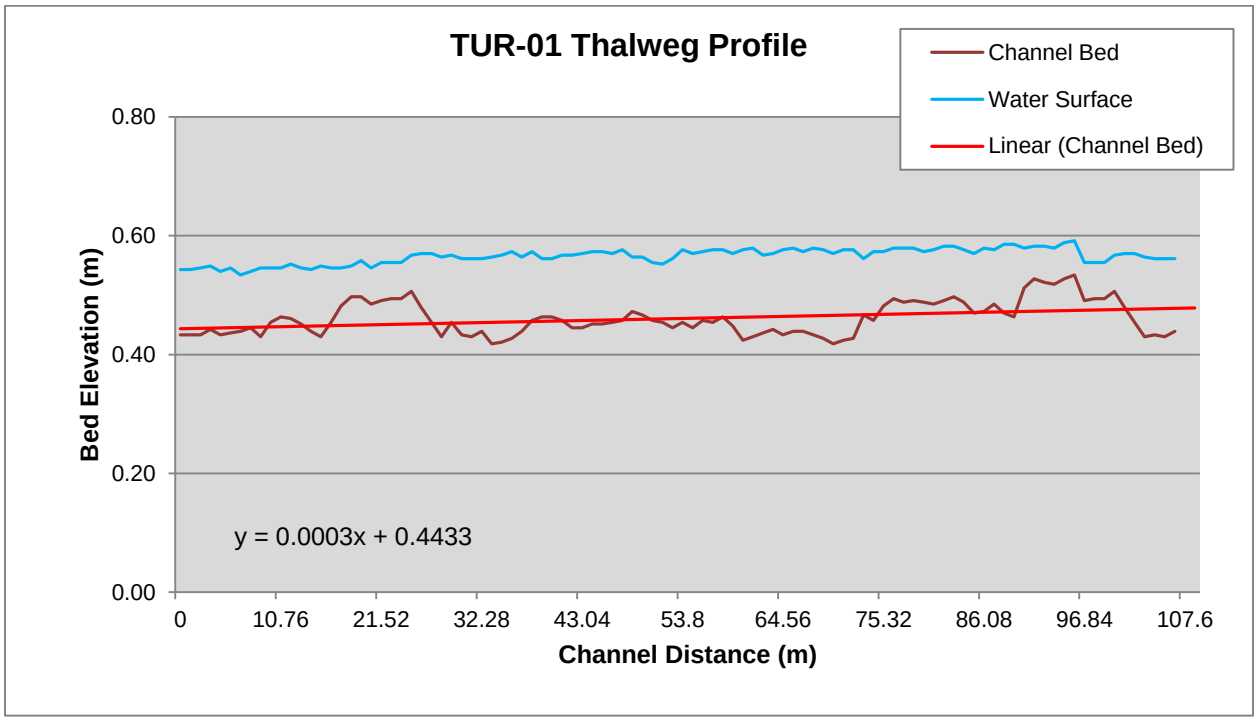


Figure A26 –b.

Figure A27 –a, -b. TUR-02 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

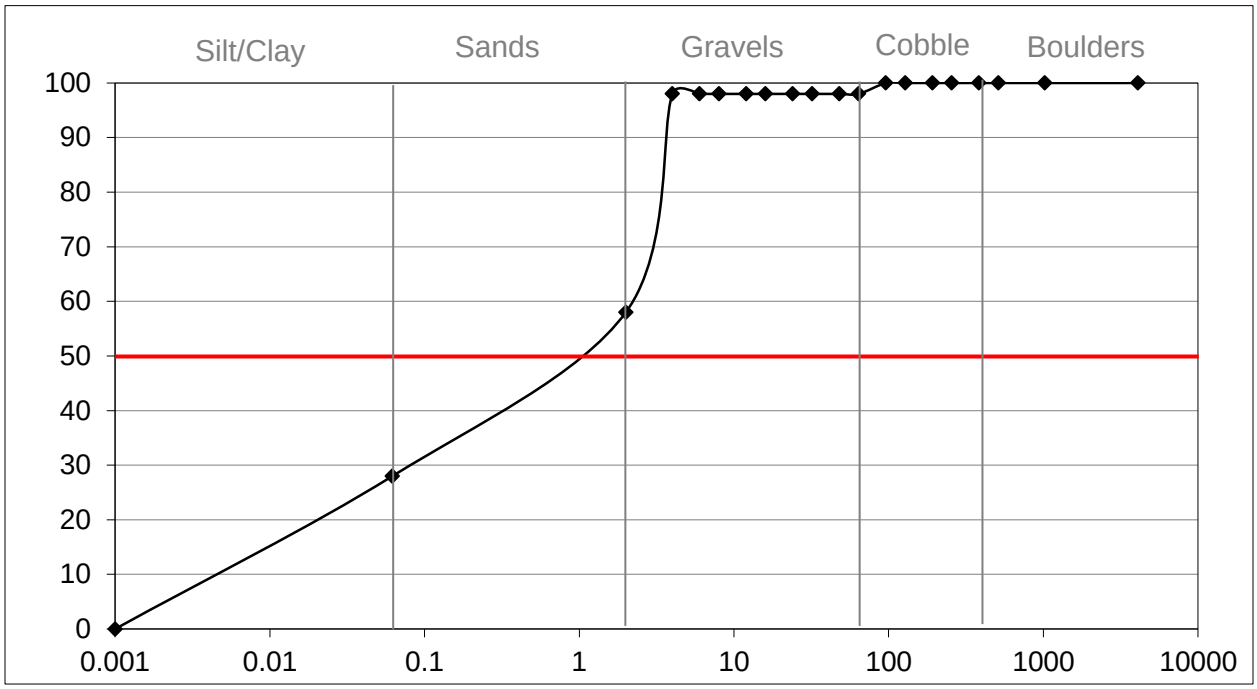


Figure A27 –a.

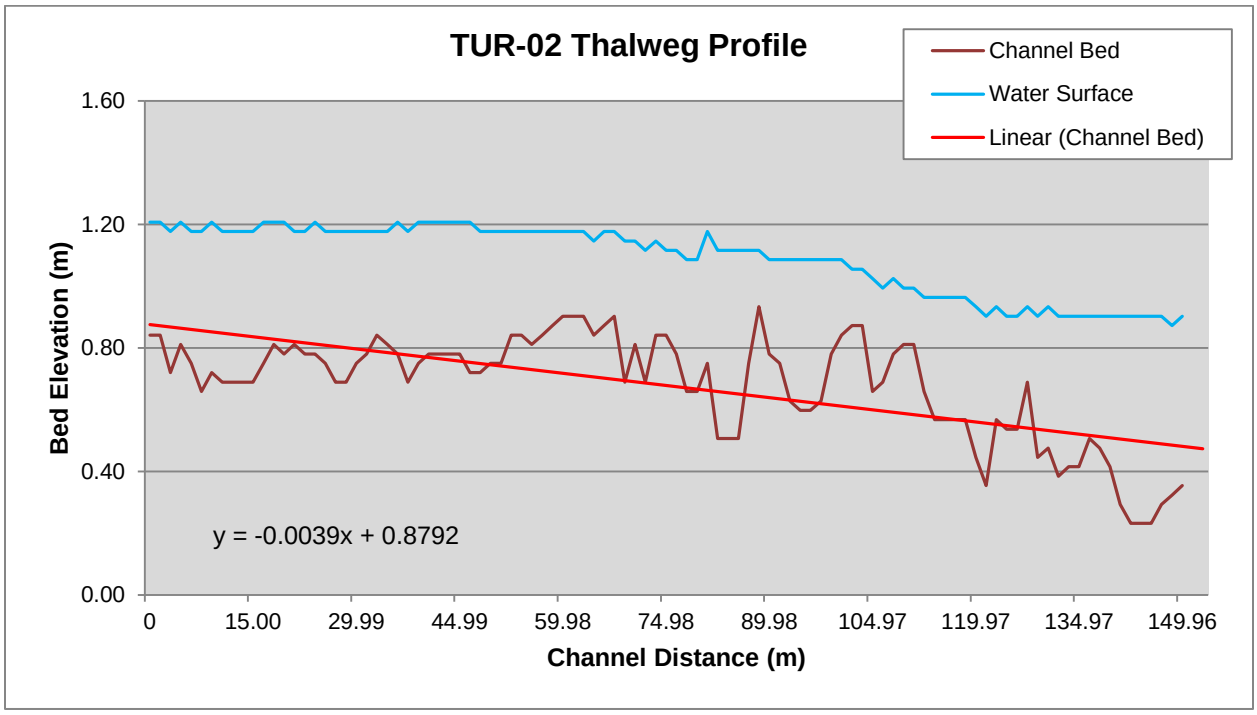


Figure A27 –b.

Figure A28 –a, -b. TUR-03 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

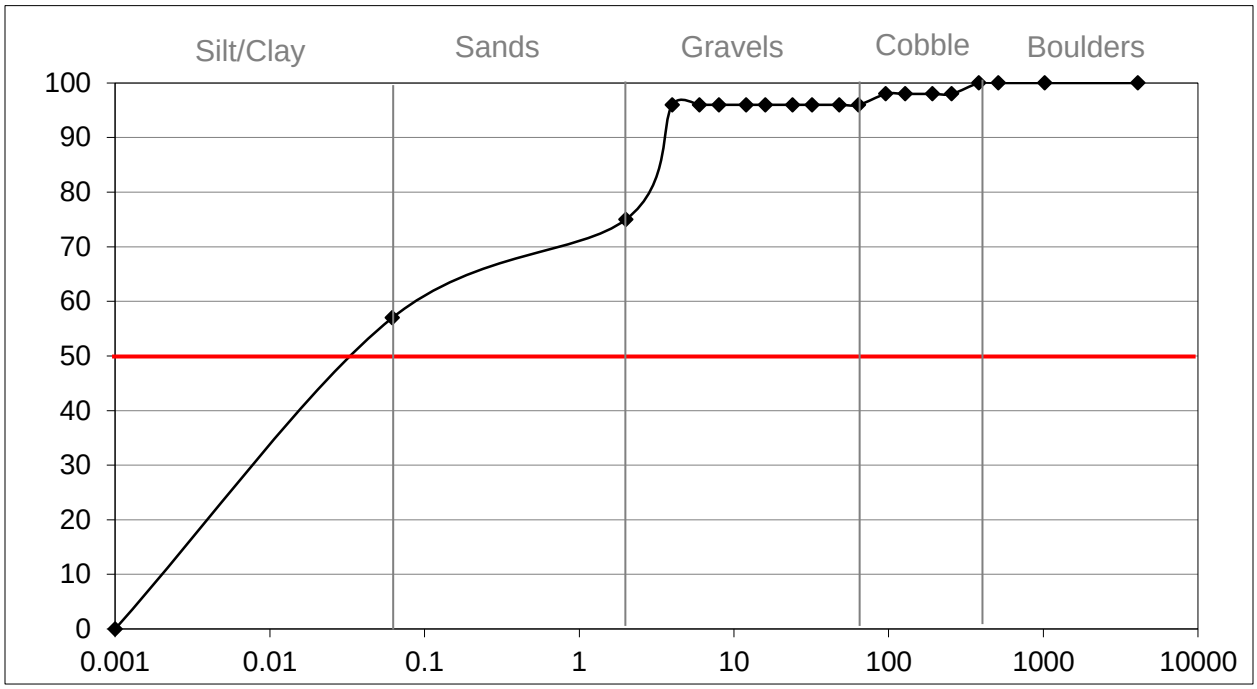


Figure A28 –a.

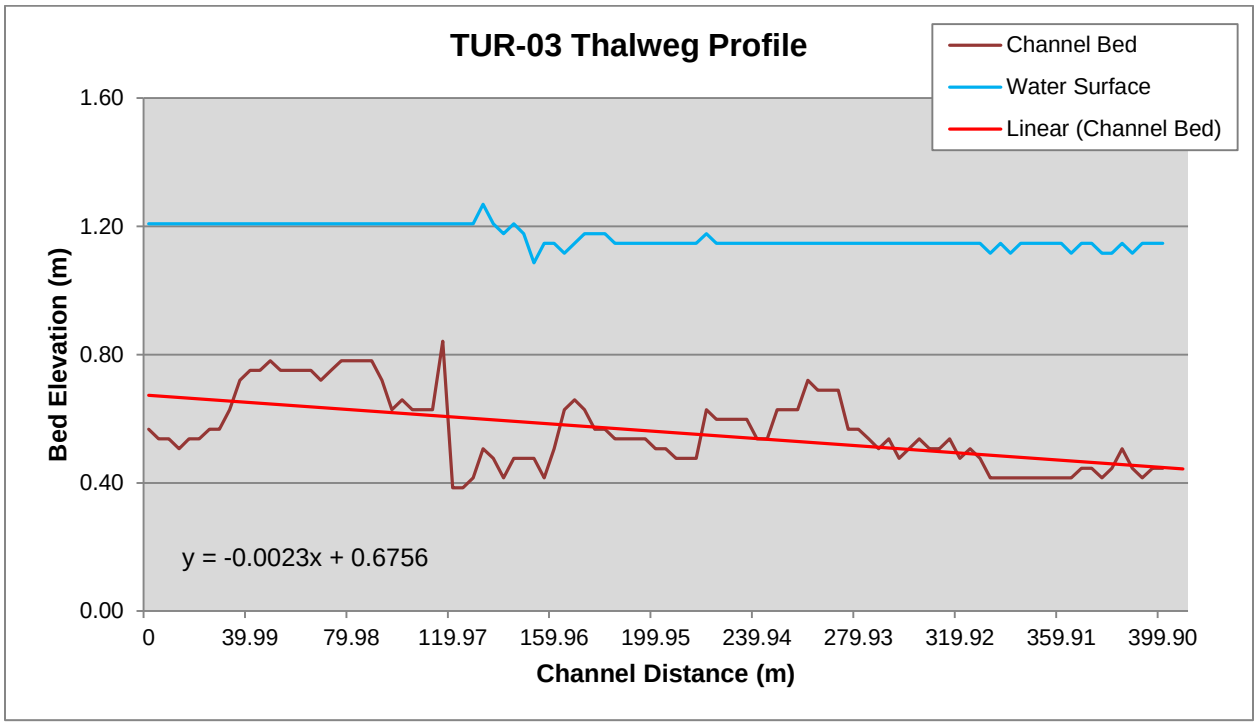


Figure A28 –b.

Figure A29 –a, -b. WFV-03 sampled site physical habitat. a: D-50 plot of pebble count data for all monitoring sites. Y-axis = Percent cumulative pebble class. X-axis = log (pebble size), b: Thalweg profile.

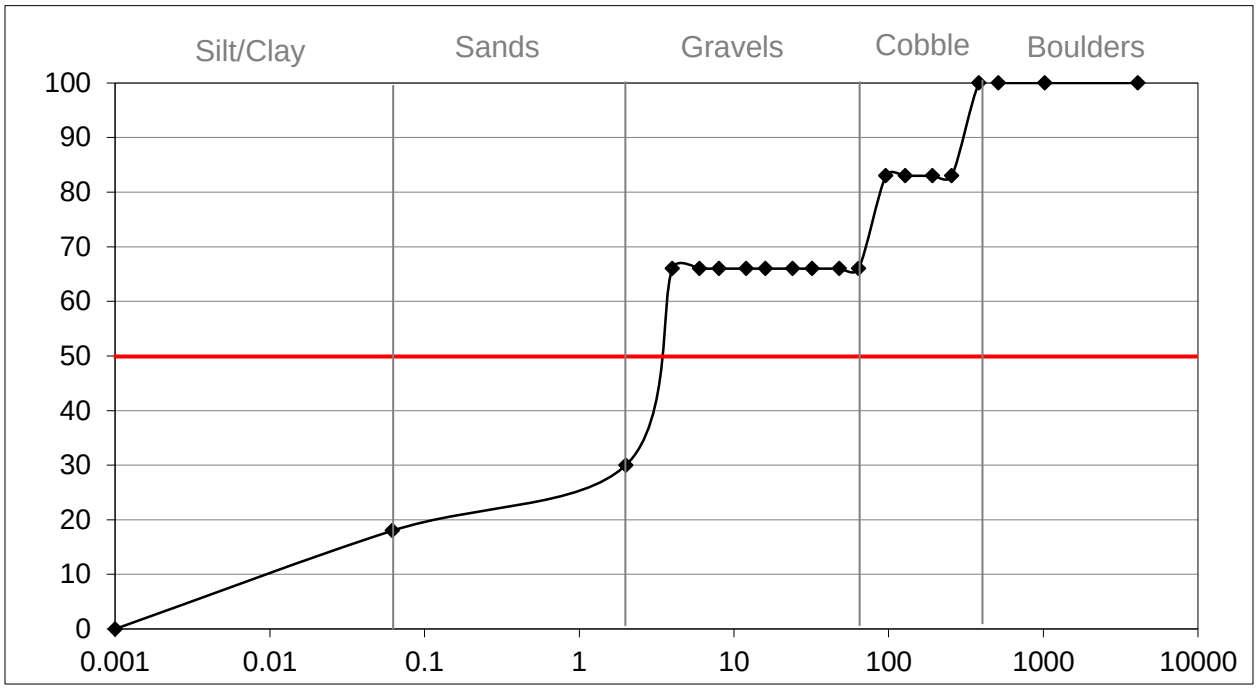


Figure A29 –a.

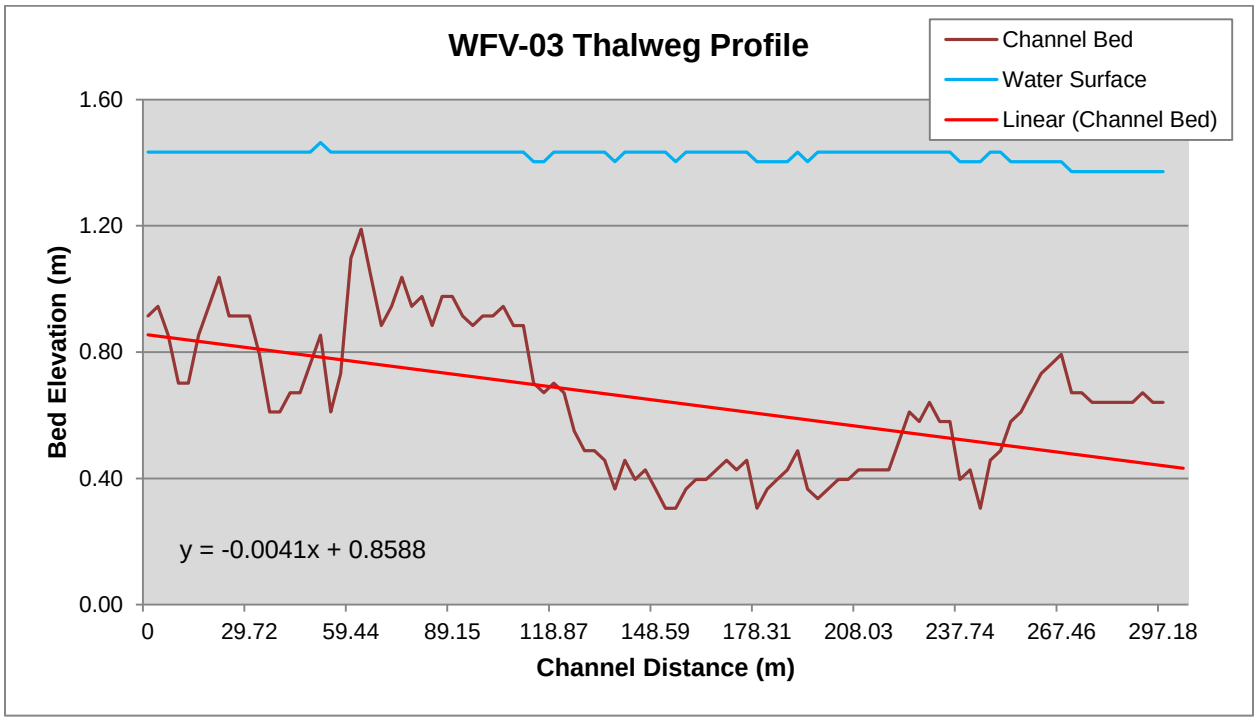


Figure A29 –b.