Flood Recovery Project Monitoring Methods

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The CWCB flood recovery project monitoring program

The Colorado Front Range flood recovery effort is unprecedented in size and scope. More than 100 projects were conceived and built with the primary goals of (1) reducing hazards and protecting life, safety, and property, and (2) enhancing the health and resilience of watersheds and stream corridors. CWCB recognizes this effort as an excellent opportunity to study the long-term effectiveness of flood recovery projects and to advance the science of stream restoration by monitoring the response to treatments.

CWCB is working with Colorado Watershed Assembly and its team of stream scientists and monitoring specialists from Alba Watershed Consulting, Johnson Environmental Consulting, and EcoMetrics to facilitate stream health and resilience monitoring by completing the following tasks.

- Classify and prioritize project reaches for monitoring
- Compile project background information and existing as-built data
- Perform field surveys at select sites to facilitate repeatable empirical measures
- Assess baseline stream health condition and trends at select sites

Results and deliverables from these efforts are being assembled in a set of data folders hosted by CWCB. This report is an overview of methods employed to meet these tasks.

Classification and prioritization

Classification

The flood recovery project reaches span a range of stream sizes and a variety of stream types that were affected very differently by the flood. For instance, small narrow canyon reaches were most often scoured or overcome by mass erosion. Larger streams on broad floodplains or alluvial fans, on the other hand, were more often overwhelmed by sediment deposition and avulsion. The reason for this is that Front Range streams vary in the types of processes that underlie their resiliency, health, and function. Recovery processes are also very different for different stream types, and we need to take this diversity into account when assessing baseline condition and evaluating recovery efforts. Treatments that help one stream recover may be wholly inappropriate on other types of streams that operate under different hydrological, geomorphic, and biological processes.

We classified project reaches into six stream categories, called stream styles, based on the dominant process domain (Table 1). This simple classification scheme considers stream order, valley confinement, geologic origin, substrate materials, slope, and stability mechanism. It incorporates the Stream Evolution Model, and the Rosgen and Montgomery-Buffington classification systems into a set of categories inspired by the RiverStyles framework. Each stream “style” represents a unique system that responds to disturbance and physical treatments according to its process domain.

Prioritization

CWCB prioritized 80 flood recovery project reaches into three tiers that define monitoring intent and activities to be completed by the CWCB team (Table 2). Priorities were selected to reflect the breadth of stream styles, different design philosophies, and a variety of treatment types. Practical considerations like land access also played a key role.

For low-priority (tier 0) project reaches, we compiled existing data provided to CWCB from outside sources, but did not perform any additional assessment, monitoring, or data collection. Long-term monitoring is not being contemplated by CWCB, but local project sponsors may choose to monitor these projects. On medium-priority (tier 1) reaches we used existing data to assess baseline condition, but we did not do any additional field work. These reaches are recommended for qualitative monitoring by local sponsors or citizen science groups. On high-priority (tier 2) reaches, we compiled existing information and performed field surveys to define baseline conditions in more detail and to set up sites for long-term field-based monitoring. These sites are scoped for long-term professional monitoring. Table 3 is a list of high-priority project reaches for which baseline monitoring, assessment, and field survey set-up was completed in 2017. Table 4 lists project reaches for which these tasks are scheduled in 2018. This list is tentative and subject to change.

Table 1: Stream style categories used for classifying Colorado Front Range flood recovery project reaches.

<table>
<tr><th colspan="14">Colorado Front Range EWP Project Stream Styles</th></tr>
<tr><th>Code</th><th>Stream Style</th><th>Valley confine-ment</th><th>Geologic origin</th><th>Rosgen valley type</th><th>Valley description</th><th>Valley slope</th><th>Stream order</th><th>Sediment transport & stability mechanism</th><th>Rosgen stream type (reference)</th><th>Montgomery - Buffington stream type</th><th>Material (range)</th><th>Description</th><th>Note</th></tr>
<tr><td>SC</td><td>Small confined stream</td><td rowspan="2">Confined</td><td rowspan="2">Colluvial</td><td rowspan="2">II</td><td rowspan="2">Confined valley with narrow or no floodplain</td><td rowspan="2">2-5%</td><td>1-2</td><td rowspan="2">Threshold - Resistance</td><td rowspan="2">B (A or G if very confined)</td><td rowspan="2">step-pool</td><td rowspan="2">bedrock - boulder</td><td rowspan="2">Steep-walled canyon with little to no floodplain and narrow riparian zone. Steep step-pool threshold streams with planform defined by valley walls.</td><td rowspan="2">Many of these streams are artificially channelized to accommodate roads and other infrastructure on valley floor.</td></tr>
<tr><td>MC</td><td>Medium confined stream</td><td>3-4</td></tr>
<tr><td>SMA</td><td>Small meandering alluvial stream</td><td rowspan="2">Partially-confined</td><td rowspan="2">Alluvial fill</td><td rowspan="2">$VIII_C$</td><td rowspan="2">Alluvial-filled valley with floodplains</td><td rowspan="3">< 2%</td><td>1-2</td><td rowspan="4">Alluvial - Dynamic equilibrium and resilience</td><td>D_B (E or C if no beavers)</td><td>beaver-dominated</td><td rowspan="2">cobble - gravel</td><td rowspan="2">Alluvial-filled canyon segment with floodplain and moderately-wide riparian zone. Low-gradient meandering or anastomosed alluvial streams in dynamic equilibrium.</td><td rowspan="4">Many of these streams are artificially channelized and/or leveed to accommodate floodplain development, infrastructure, etc.</td></tr>
<tr><td>MMA</td><td>Medium meandering alluvial stream</td><td>3-4</td><td>C</td><td rowspan="2">meandering riffle-pool or dune-ripple</td></tr>
<tr><td>MMP</td><td>Medium meandering plains stream</td><td rowspan="2">Un-confined</td><td>Alluvial plain</td><td>$VIII_U$</td><td>Unconfined plains</td><td>3-5</td><td>C or D</td><td rowspan="2">gravel - sand</td><td>Unconfined alluvial floodplains with wide riparian zones. Low-gradient meandering or braided alluvial streams in dynamic equilibrium.</td></tr>
<tr><td>MAF</td><td>Medium alluvial fan stream</td><td>Alluvial fan or outwash</td><td>III</td><td>Unconfined alluvial fan or outwash</td><td>2-5%</td><td>3-4</td><td>D</td><td>braided</td><td>Alluvial fan, typically at the mouth of a canyon on the foothills. Depositional areas with braided streams in dynamic equilibrium or actively aggrading.</td></tr>
</table>

Table 2: Project reach priorities

Priority Category		Monitoring intent	CWCB Monitoring Activity	Number of project reaches by stream style						
				SC	MC	SMA	MMA	MMP	MAF	TOTAL
2	High	• Intensive long-term quantitative monitoring by professionals.	• Compile existing project reports, design, as-built, and close-out documents. • Routine baseline stream health assessment (COSHAF level 2-3) and SVAP2. • Conduct baseline field surveys to supplement existing as-built data. • Set up sites for professional long-term monitoring.	10	0	3	4	5	3	25
1	Medium	• Qualitative monitoring by watershed groups and/or citizens. • Quantitative monitoring could be accomplished in future using pre-existing data for baseline.	• Compile existing project reports, design, as-built, and close-out documents. • Reconnaissance baseline stream health assessment (COSHAF level 1-2). • Rely on existing as-built data for baseline (no additional field surveys). • No site set-up for professional long-term monitoring.	8	6	1	5	14	1	35
0	Low	• No monitoring planned. • Quantitative or qualitative monitoring could be accomplished in future using pre-existing data for baseline.	• Compile existing project reports, design, as-built, and close-out documents. • No baseline stream health/functional assessment. • Rely on existing as-built data for baseline (no additional field surveys). • No site set-up for professional long-term monitoring.							20
Total project reaches										**80**

Table 3 List of high-priority project reaches where baseline monitoring, assessment, and field survey set-up completed in 2017

ID	Name	Stream Style	Watershed
BT24	North Fork	SC	Big T
BT31	Fox Creek	SC	Big T
BT30	West Creek	SMA	Big T
CC08	Area 2	SC	Coal Creek
EV01	Morten Reach	SC	Estes
EV12	Hydroplant	SC	Estes
EV6	Cheley Camp	SMA	Estes
EV15	Upper Fish Reach 4	SMA	Estes
LH20	Ranch Property	MAF	Lefthand
LH21	Streamcrest	MAF	Lefthand
LH01	Reach 3b	MMA	Lefthand
LT14	83rd Street Bridge	MAF	Little T

Table 4 List of high-priority project reaches scheduled for baseline monitoring, assessment, and field survey set-up in 2018

ID	Name	Stream Style	Watershed
FCC3	Wagon Wheel Gap	SC	4-Mi Canyon
BT22	Jasper Lake	MMA	Big T
BT26	West Drake	MMA	Big T
EV17	Elkhorn	SC	Estes
EV20	River's Edge	SC	Estes
FM35	Ingram Gulch	SC	Fourmile
FM37	Wall Street	SC	Fourmile
LH12	Bielins-Hock	MMA	Lefthand
LT16	Stagecoach Trail	MMP	Little T
MSP3	Latham Diversion	MMP	MS Platte
MSP6	Highway 60	MMP	MS Platte
SV29/28	Hall Ranch/Triangle	MMP	St Vrain
SV14/15	Lyons Rehabilitation	MMP	St Vrain

Background information and as-built data

Background information and as-built survey data were obtained from watershed coalitions, project sponsors, and design teams. We used a standard form to request information and checked off items as they were received (Table 5).

Table 5 Project information request list

Pre-project Conditions	
1	Pre-project photographs
2	Pre-project SVAP Assessment
Project Planning and Design	
3	Design narrative
4	General project goals
5	Clean Water Act permit from USACE, including special conditions, performance standards, and monitoring requirements
6	Wetland delineation report
7	Monitoring plan
8	Vegetation plan
9	What flow was the design built to?
10	Is the project on schedule?
11	What is the construction actual/planned start date? **(Indicate which)**
12	What is the construction actual / planned end date ? **(Indicate which)**
As-built Conditions	
13	Construction completion report to sponsor
14	Construction completion report to USACE
15	As-built drawings including structure locations, treatments, channel alignment, cross-sections and other important features
16	As-built drawings in CAD or Shapefile format (**Indicate which)**
17	As-built narrative description
18	Cross-section points as x,y,z coordinates
19	Charted as-built cross section, with end point coordinates.
20	Drone footage? Indicate pre-, during- or post-project

Field surveys

Field surveys were conducted on high-priority project reaches. The purpose of field work is to gather baseline data and to outfit the sites so that surveys can be repeated to track progress and changes in the future. Our selection of survey methods was guided by the basic stream health factors that are deemed to be most important at the site and most likely to be affected by the treatments employed. Field surveys fall into the categories outlined in Table 6, and each is described in detail in Appendix 1. Data and results from these surveys are housed with CWCB. For each site, we prepared a list of all baseline field surveys performed. We also prepared site maps with location data so that future parties can relocate survey monuments and repeat surveys efficiently. Our selection of which surveys to perform at which sites was guided by efficiency and utility. For each project reach we were limited to what we could accomplish with a crew of four people in one day during periods of low flow.

Table 6 Field surveys

Field surveys

Aerial imagery: Publicly available images or aerial photos taken in the field

Photo-points: Ground photos from recorded points that can be repeated

Cross-section surveys: Monumented station-elevation surveys across the floodplain and stream channel

Topographic surveys: Topographic map generated from surveyed points, photogrammetry, and/or LiDAR data

Vegetation transects: Monumented transects to measure vegetation cover by species and/or functional guild

Facet delineation/mapping: In-stream aquatic habitat type delineation based on velocity and depth

Pool area surveys/mapping: Aerial map of pools meeting specific depth or residual depth criteria

Substrate surveys: Wolman pebble counts on stream substrate

Wood counts: Quantitative counts of large wood and woody material

Test banks: Monumented stream bank locations to measure lateral accretion using bank pins and/or profiles

Baseline assessment

A baseline stream health assessment was performed on all medium-priority and high-priority project reaches using the stream health assessment framework outlined in Table 7. Each of the 11 variables in the framework were evaluated using the best available evidence according to the grading guidelines in Appendix 2 and summarized in a reach report card (see Appendix 3, Report Card sheet). Grades represent the degree of impairment compared to natural reference condition and can be converted to numerical scores that follow the academic grading scale (Table 8).

Table 7 Stream health assessment framework used in evaluating project reaches

Colorado Stream Health Assessment Framework		
Watershed	**Flow Regime**	Amount and timing of water supply.
	Sediment Regime	Amount, timing, and type of sediment supply.
	Water Quality	Physicochemical properties of water.
	Landscape	Buffer capacity and aquatic and terrestrial habitat connectivity.
Reach	**Floodplain Connectivity**	Frequency, extent, and duration of floodplain saturation or inundation.
	Riparian Condition	Riparian habitat condition, including vegetation structure and diversity.
	Organic Materials	Supply of wood and detritius to the reach.
	Morphology	Reach morphology including stream evolutionary state, planform, dimension, and profile.
	Stability	Ability of the reach to maintain form via resistance, dynamic equilibrium, and resilience.
	Physical Structure	Physical habitat including water depth, velocity, structural components, and substrate.
	Trophic Structure	Community and trophic structure of the organisms that inhabit the reach.

Table 8 Grading scale and scoring conversions used in baseline stream health assessments

Impairment	Negligible				Mild			Significant			Severe			Profound			
Grade	A++	A+	A	A-	B+	B	B-	C+	C	C-	D+	D	D-	F+	F	F-	F--
Score	100	98	95	92	88	85	82	78	75	72	68	65	62	58	55	52	50

Variable grades are accompanied by a narrative description to explain the rationale and evidence supporting them (see Appendix 3, COSHAF sheet). A narrative description is also provided for the level of confidence in assigned grades, and the confidence rating is summarized as high, moderate, or low. Assessment level indicates the level of effort, typical strategies, and types of evidence that are used when evaluating variables as outlined in Table 9. On medium-priority project reaches, we evaluated all variables using existing data at the reconnaissance level (level 1). On high-priority reaches, some variables were evaluated at the routine/rapid assessment level (level 2). Assessment level is indicated for all variables scored.

For all reach-scale variables evaluated at level 2, we made predictions about future trends (positive, level, negative, or questionable).

Table 9 Assessment levels used in baseline stream health assessments

Level	Category	Level of effort	Typical strategies	Types of evidence
1	Recon-naissance	1-2 person-hours	Aerial imagery observations, web-based investigation, "windshield surveys"	Documentation of stressors, existing summary data, simple indicators
2	Routine/ Rapid	8-10 person-hours	Level 1 plus rapid assessment field survey	Level 1 information plus field documentation of stressors, ecological indicators, direct observations, simple measures.
3	Intensive	Multiple people and/or multiple days	Level 2 plus additional site visits, targeted intensive, usually quantitative monitoring and analysis	Level 1 and 2 evidence plus historical aerial photograph analysis, quantitative models, reference-based parameters, quantitative monitoring

We also followed the NRCS Stream Visual Assessment Protocol (SVAP2 for Colorado Streams) to assess high-priority project reaches. For each of the SVAP2 variables, we provided a score based on routine site evaluation, narrative explanation of scoring, and a prediction of trend (see Appendix 3, SVAP2 sheet).

The primary purpose for evaluating baseline stream health at this stage of the monitoring program is to guide our selection of field surveys and parameters. Project summary reports identify which surveys are useful for informing stream health variables and stated project objectives (see Appendix 3, Survey sheet). Table 10 is a list of parameters that are commonly used to monitor stream health and resilience indicating which of the reach-scale stream health variables that the parameter directly or indirectly informs. For each project reach, we provide a checklist showing which parameters could be calculated using data from baseline field surveys (see Appendix 3, Parameter sheet).

Some common montoring parameters and the stream health factors they most directly inform Black = direct indicator Grey = strong indirect indicator White = weakor no indicator	Floodplain connectivity	Riparian condition	Organic materials	Morphology	Stability	Physical structure	Trophic structure
Floodplain width (Q_{bkf}, Q_2, Q_{10}, etc)	■	░	░	░	░		
Floodplain area (Q_{bkf}, Q_2, Q_{10}, etc)	■	░	░	░	░		
Overbank return interval	■	░	░	░	░		
Riparian wetland area (delineation)	░	■					
Prevalence Index (hydric plants)	░	■					
Species diversity/richness index		■					
Percent woody cover		■	░	░	░	░	░
Percent cover by guild		■	░	░			
Percent cover by species		■					
NRCS Root strength index		■			░		
Noxious weed cover		■					
In-stream wood (number, volume,			■			░	
Floodplain wood (number, volume,			■				
Detritus (volume, mass)			■				░
Stream type/evolutionary stage	░	░	░	■	░	░	░
Sinuosity (stream length/valley	░			■		░	
Branching rate, bifurcation ratio	░			■		░	
Meander width (or ratio)	░			■			
Cross sectional area (capacity)	░			■	░		
Entrenchment Ratio	░			■	░		
Bank Height Ratio	░			■	░		
Cross section area	░			■	░		
Width/depth ratio				■	░	░	░
Slope (bankfull, water surface)				■	░		
Aggradation rate					■		
Degradation rate					■		
Shear stress/critical shear stress					■		
Lateral accretion rate					■		
Erosion per length (volume, mass)					■		
Length or area by depth/velocity						■	░
Pool area (RPD>1.0, 1.5, 2.0)						■	░
Overhead cover (length or area)						■	░
Substrate (size, distribution, % fines)					░	■	░
Embeddedness						■	░
Fish biomass/number by							■
Invertebrate biomass/number by							■
Invertebrate impact indices							■

Table 10 Some common monitoring parameters and the reach-scale stream health parameters they inform. Direct indicators are shaded in black and indirect indicators are shaded in grey.

Products

The product of these efforts is a set of project data folders being assembled and hosted by CWCB. Project folders contain the following:

Baseline summary report – a spreadsheet report for the reach with the following pages (Appendix 3):

1. Summary sheet – general project data.
2. Report card sheet – a summary of the baseline stream health assessment with grades, predicted trends, and assessment levels for stream health factors.
3. Assessment sheet – details of the baseline stream health evaluation with variable grades, predicted trends, assessment levels, confidence ratings, and notes.
4. SVAP2 sheet – details of the baseline SVAP2 evaluation with element scores, predicted trends, notes, and suspected causes for low scoring elements.
5. Survey sheet – a sheet listing the available data sources including public sources, as-built surveys provided by implementation crews, and baseline field surveys performed by the CWCB/CWA team. Matrices indicate how surveys align with reach-scale stream health factors and stated project objectives.
6. Parameters sheet – a checklist showing which parameters could be calculated from available baseline and as-built survey data.
7. Background information sheet – checklist and notes showing which of the requested project design and as-built information was provided.

Site maps – a site map for each high-priority project reach that shows the location of field surveys, monuments, and control points. We also provide a table of survey data to help relocate surveys, monuments, and control points in the field.

Data files – Files containing data obtained in field surveys. File formats vary by survey type and include spreadsheets, shapefiles, photo files, etc.

GIS files – Shapefiles and GIS project files for sites evaluated in the field.

Background information – Project design and as-built reports and information provided to CWCB.

Appendix 1:

Field Survey Sheets

Field-acquired aerial imagery

Field survey

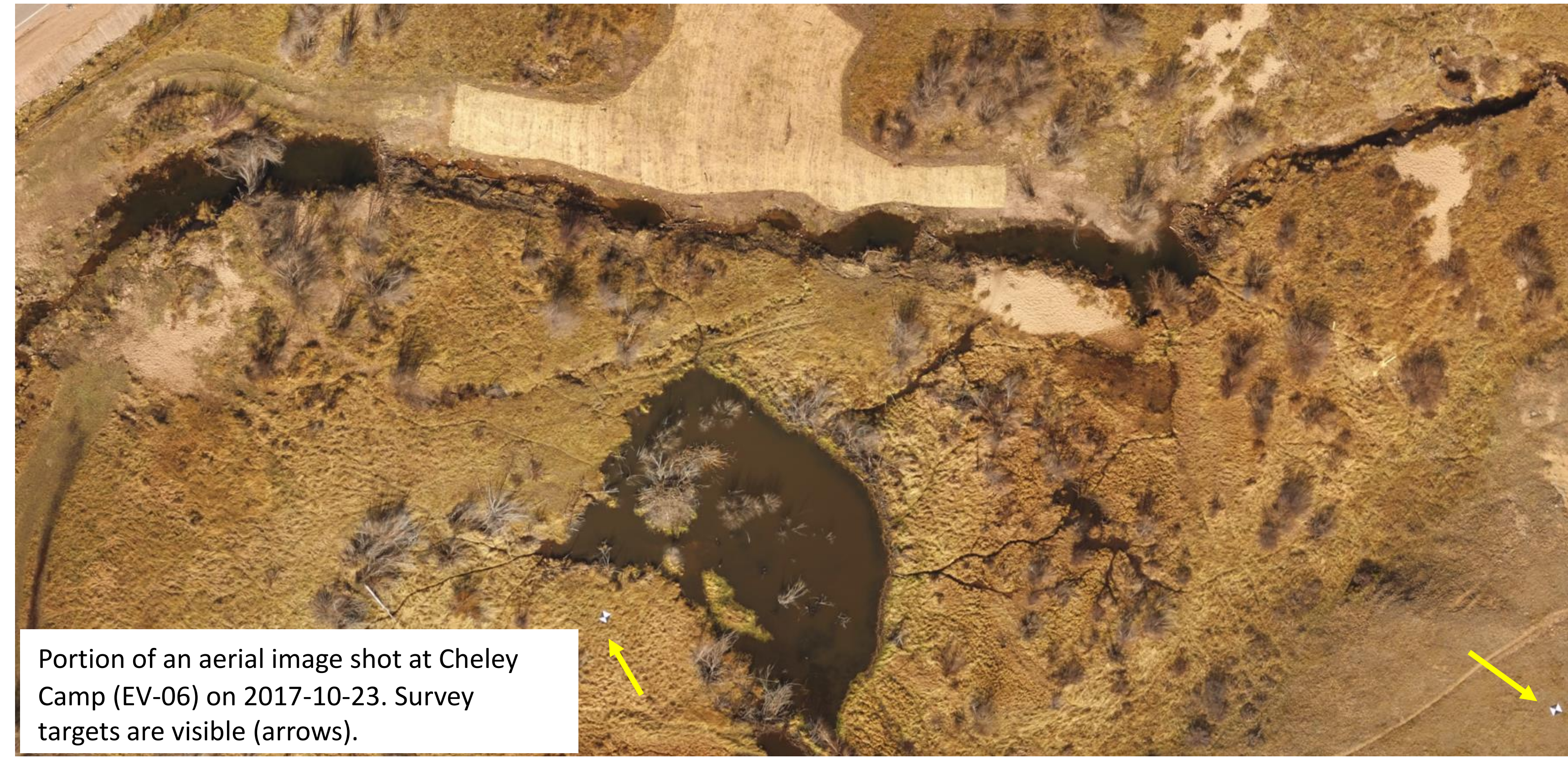
Field-acquired aerial imagery is obtained using unmanned aerial vehicles (UAVs), otherwise known as drones. For large areas, we fly program the drone to take multiple photos in a systematic grid and stitch them together into a single image mosaic using software such as Pix4D. Surveying visible targets in the field makes it so they can be orthorectified.

Data products

Aerial images (digital photo files)
Orthoimages (if digitally rectified using surveyed targets)

Comments

Aerial images are extremely useful for monitoring, especially on reaches in unconfined valleys, multi-channel streams, and wide riparian zones. They can be used for mapping, qualitative observations, and measuring quantitative stream and riparian parameters. Field-acquired images are higher resolution than public aerial images (e.g. Google Earth) and can be scheduled for specific dates. Orthorectifying is very helpful to enable quantitative measures and to assure that images can be overlaid.



Portion of an aerial image shot at Cheley Camp (EV-06) on 2017-10-23. Survey targets are visible (arrows).

Portion of an aerial image shot at Upper Fish Creek (EV-15) on 2017-10-24
Survey targets are visible (yellow arrows).

Photo-points

<u>Field survey</u>
The value of photopoints lies in the ability to recreate images from the same point over time. The locations of photos taken in the field are recorded using handheld GPS. We also record the direction the camera is pointed in degrees relative to true north. Having this information on the image is helpful.

<u>Data products</u>
Photos (digital photo files) with accompanying location and direction information
Shapefile of photopoints (shown on site map)

<u>Comments</u>
Next to aerial imagery, repeatable field-acquired photos may be your most valuable long-term monitoring tool. They provide a good qualitative record of changes to stream and riparian parameters, and they are also useful for verifying mapped parameters and making quantitative measurements. We choose locations and compose our photos to capture features of interest in the stream, floodplain, and riparian area. Broader photos from higher vantage points are usually more useful for long-term monitoring, unless the purpose is to track a specific feature like a single pool, structure, or bank line. Plan ahead to avoid photo-points that will be soon obscured by growing vegetation. Panorama shots are very useful, but be aware that panorama features on cameras and smartphones may distort your images, so we recommend taking simple images as well.

Field photos are almost useless unless they can be repeated over time and easily compared with past/future photos to detect change. It is extremely important to occupy the exact position and direction. It is also important to take photos when there is good light—high-noon on a clear day is best to eliminate glare. Repeating photo-points several times a year at different seasons is helpful for capturing phenology, vegetation development, stream stage, floodplain activation, and other season-dependent attributes of the reach. A picture is worth a thousand words. How many data points is one worth? A lot, in our experience. Don't neglect the simple but powerful photo-point!

Photo-points locations are shown on reach site maps. This example is from the 83rd Street project on Little Thompson (LT-14).

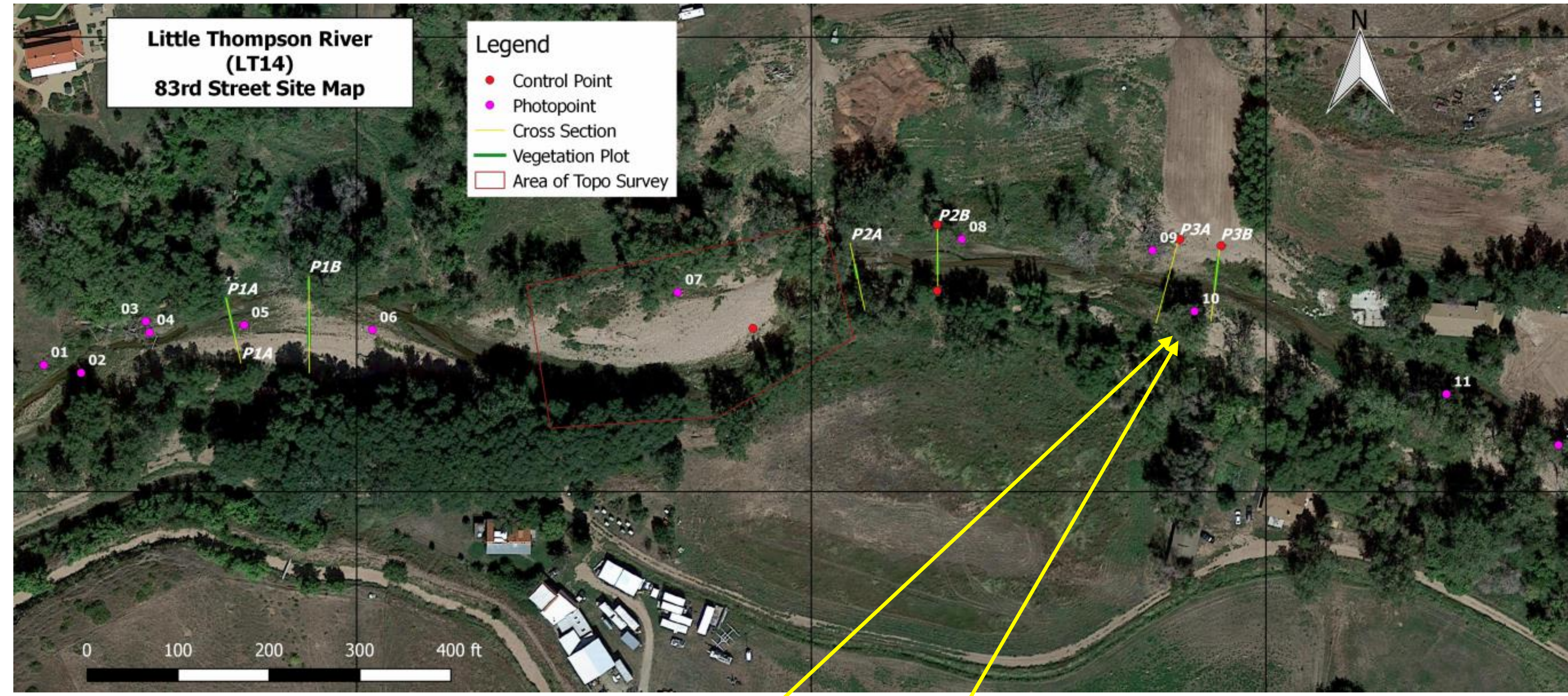


Photo-point 10a, looking upstream from point 10 on the 83rd Street project on Little Thompson (LT-14).

Photo-point 10b, looks downstream from point 10 on the 83rd Street project on Little Thompson (LT-14).

Cross-section surveys

Field survey

Cross section (XS) surveys are linear arrays of land-surface point data aligned perpendicularly across the stream, floodplain, and riparian area. We monument end points with survey markers (usually capped rebar pins) and record the locations using GPS or other survey methods. XS data are presented in station-elevation form, where station is distance along the line from the river-left in decimal feet. Elevation is vertical height (feet) relative to control points on site (which are usually also tied to common datum). XS surveys may be shot using any appropriate survey gear (tape and level, GPS, total station, etc.) to shoot points along a tape or line pulled tight between the end pins. Wherever possible, we use an RTK GPS system to survey end pin locations and elevations precisely. It is important to shoot enough points to accurately capture terrain changes, with points at all grade changes.

Data products

Spreadsheet of point data (station-elevation format) with notes
Photos of XS (digital photo files)
Shapefile of XS pin locations (shown on site map)

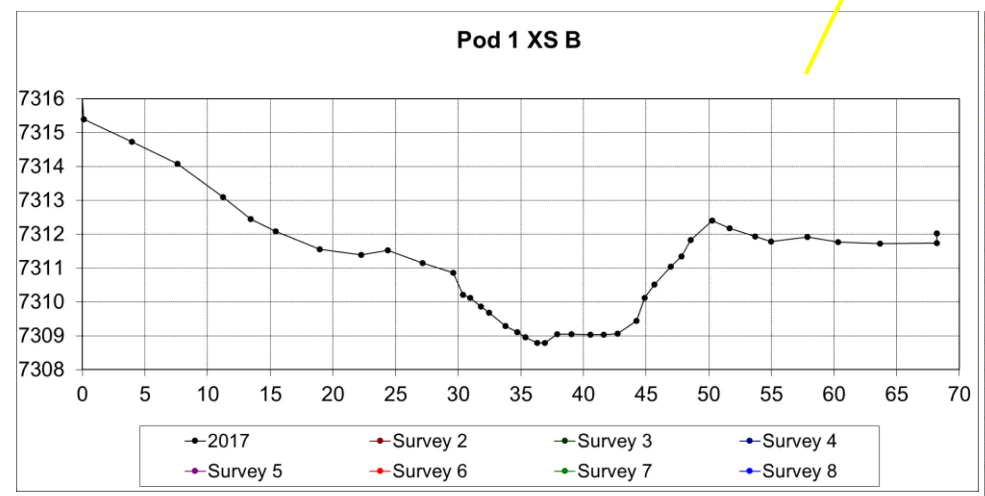
Comments

Overlaying XS surveys over time is a powerful way to track changes in channel dimensional shape and size, migration, bank erosion an lateral accretion, bed scour and incision, deposition and aggradation, and other processes. You can also use them to calculate channel dimension parameters like XS area, width, depth, W/D, bank height, bank height ratio, etc., but keep in mind that most channel dimension parameters must be defined relative to stage (e.g. Q_2, "bankfull", etc.) or a specified geomorphic feature.

When repeating out XS surveys, be prepared to locate the pins. Accurate GPS and metal detectors are helpful since the pins are often installed low to the ground and may be grown-over by vegetation. In some cases the pins will have been removed or buried, so be prepared to relocate end points using survey-grade GPS or other survey tools. Use care to make sure the line between end points is straight and aligned properly. This can be especially difficult in windy conditions and on long XS.

You can use the point density (number of points shot along the XS) in our baseline survey as a rough guide for the minimum number of points. Be sure to capture all grade changes and, when in doubt, shoot more points. See the test bank sheet for more detail about how to deal with steep banks and overhangs.

XS locations are identified on reach site maps. This example is from West Creek at Glen Haven (BT-30). Note that the stream was moved since the time of the last available aerial imagery. (Another good reason to get aerial photos in the field when you can!)



Example plot of station-elevation data from XS1b on West Creek at Glen Haven (above). These data are stored in a file with photos (right) that is prepared to overlay additional surveys. The original point data and field notes are recorded separately.

X	Y
0.00	7316.01
0.11	7315.39
3.94	7314.72
7.61	7314.07
11.21	7313.10
13.42	7312.45
15.42	7312.08
18.95	7311.55
22.27	7311.39
24.40	7311.52
27.15	7311.14
29.62	7310.85
30.40	7310.21
30.97	7310.11
31.83	7309.85
32.46	7309.67
33.78	7309.28
34.73	7309.10
35.36	7308.95
36.30	7308.79
36.90	7308.78
37.89	7309.04
39.04	7309.04
40.55	7309.03
41.60	7309.02
42.70	7309.06
44.25	7309.43
44.87	7310.12
45.68	7310.50
46.97	7311.03
47.84	7311.34
48.58	7311.82
50.28	7312.39
51.65	7312.17
53.69	7311.93
54.96	7311.78
57.89	7311.91
60.34	7311.76
63.67	7311.72
68.20	7311.74
68.21	7312.02

Looking downstream at XS1b

Looking downstream and across at XS1b from left bank

Topographic surveys

<u>Field survey</u>

We use a DJI drone and Pix4D software to create orthoimages and a photgrammetric topographic model (digital surface model). Topographic data is rectified to target points and control points that are surveyed with GPS RTK. Topographic mapping in the field is a highly technical and specialized field and must be conducted by experts.

<u>Data products</u>

DSM (digital surface model) GIS raster layer
Aerial photos (set of tiled images)
Orthophoto mosaic (rectified aerial photo of site)

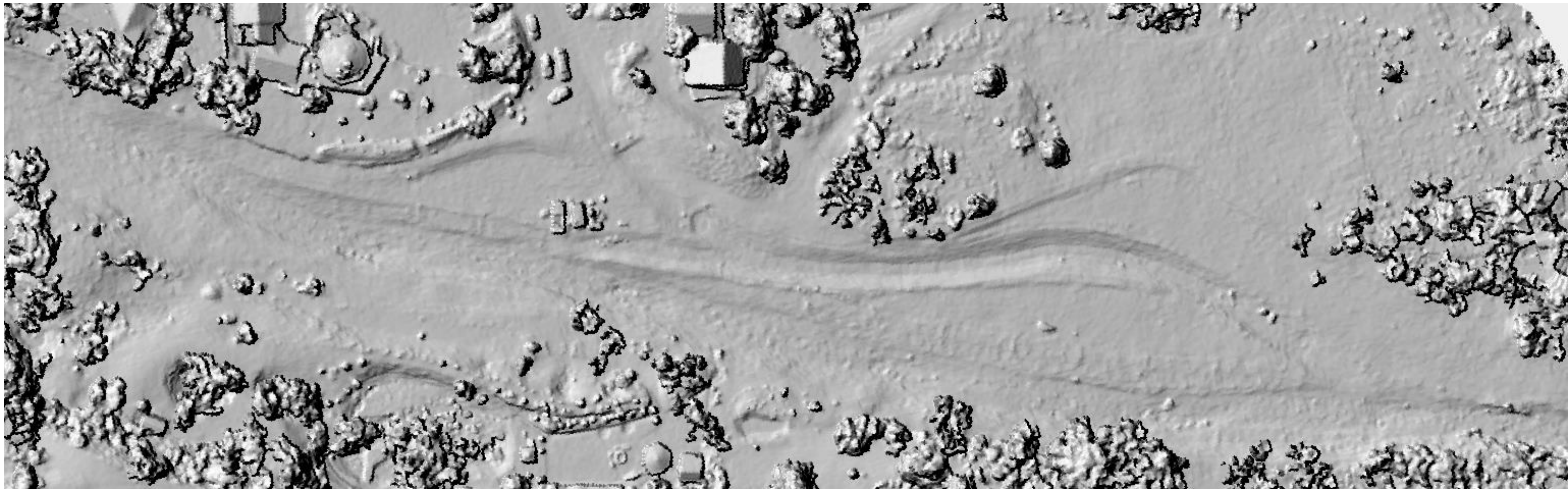
<u>Comments</u>

Photogrammetric topography is a very powerful monitoring tool. If done correctly, repeat surveys allow you to track changes in topography such as erosion and deposition down to scales of tenths of a foot on areas with sparse vegetation. You can essentially “pull a cross-section or transect” anywhere once the DSM is made. It can also be used to track vegetation heights and to measure numerous useful geomorphic and ecological parameters.

The major limitation is that the surface model created by photogrammetry is the top of dense vegetation, and not necessarily the ground. This is a plus if you are monitoring vegetation, but a limitation if you want to track ground elevation in dense trees, shrubs, or grass.

Powerful? Yes. Practical? Oftentimes not. Although it is a much less expensive option for detailed topographic mapping than other methods (e.g. LiDAR), it is still expensive, and the quality of the data is only as good as the surveyors that do the work. Sites obscured by trees or other structures are problematic, and commercial drone flights are restricted in some areas.

Orthophoto layer (above) and shaded relief map (below) created from digital surface model for a segment on Streamcrest (LH-21), Lefthand Creek



Vegetation transect surveys

Field survey

Our vegetation monitoring is based on evaluating plots placed along transects. Two sampling layouts were used to meet the demands of different site layouts. Whenever possible, plots were arrayed along channel XS transects, so that vegetation composition and development can analyzed in relation to floodplain position. At sites with only a narrow riparian bench, a vegetation specific transect was installed parallel to the channel, with the start at the upstream pin. Vegetation transects are monumented at either end with survey markers (usually capped rebar pins). End points are also located with GPS or other survey methods.

To sample vegetation, a tape measure is stretched between the end pins. Vegetation sampling occurs from landward extent of the floodplain to the edge of water (at about baseflow levels). Our sampling units are elongated plots 4m-wide, with the transect tape defining the plot center. The length of plots along the transects vary. In 2017, monitoring sites were all freshly restored and largely devoid of vegetation. Therefore, vegetation plots began and stopped where breaks in vegetation composition were evident, if any. Often only one plot was created on the given side of the river. Creating coarse (long) plots of homogenous vegetation like this will allow plots to be subdivided in the future in response to site development.

At each plot the following information was recorded: Dominant and subdominant herbaceous functional "guilds" (e.g., grasses, sedges, forbs, mixed ruderal species); Percent herbaceous coverage; dominant and subdominant shrub species or genera (e.g., willows); percent shrub coverage; number and type of individual shrubs.

Data products

Spreadsheet of vegetation data by station (for each transect)
Photos of transect (digital photo files)
Shapefile of transect pin locations (shown on site map)

Comments

There are many approaches to vegetation sampling. Pick the way that makes senses for your application. Our approach was designed to be adaptable to the spectrum of site configurations we encountered and adaptable to unknown developmental trajectories of new restoration sites. It guides the evaluator to collecting critical data, but it does not require the evaluator to have an in-depth knowledge of plant identification.

In designing a vegetation monitoring approach, keep in mind vegetation development and its effect on sampling effort – an intensive method can be a breeze on a freshly restored site, but time prohibitive in future years. Making plots of the same size between transects and sites allows a valid comparison of species richness but there may be reasons to vary plot size according to site conditions. Also, make sure you always run transect tapes in the same direction, between transects, sites and sample years.

Vegetation transect on Fox Creek (BT-31), Big Thompson

Vegetation transect at Streamcrest (LH-21), Lefthand

Stationing														
Tape reading START	Tape reading END	photo ID	section	description	herb cover %	herb dom	herb sub	shrub cover %	shrub dom	shrub sub	number of willows	number of alders	number of shrubs	notes
0	15	1:28	left		20%	Mixed rud		0%	no		0		0	
15	18		left		3%	Mixed wet		5%	S exigua		6	0	6	
18	40		stream	stream channel									0	stream channel
40	42		right		3%	Grasses	Wet forb	5%	S exigua		6	0	6	

A view of some raw vegetation data

Facet delineation and mapping

Field survey

We used 5 categories of low-flow water depth-velocity combinations to delineate stream segments into facet types.

Cascade: very fast and shallow
Riffle: fast and shallow
Run: fast and deep
Pool: slow and deep
Glide: slow and shallow

	Depth	Velocity
Cascade	< 1 ft	>> 1 ft/s
Riffle	< 1 ft	> 1 ft/s
Run	> 1 ft	> 1 ft/s
Pool	> 1 ft	< 1 ft/s
Glide	< 1 ft	< 1 ft/s

Reaches were delineated into segments based on these classes by walking the reach during low flow and taking GPS points at breaks classes. Clearly, streams are not uniform across their width, so facet delineations are necessarily a generalization representing the dominant class for each segment. We took photos of representative facet types on each reach delineated.

Data products

Photos of representative facets
Shapefile of facet segments (as points or polygons)
Map of reach segmented into facet types

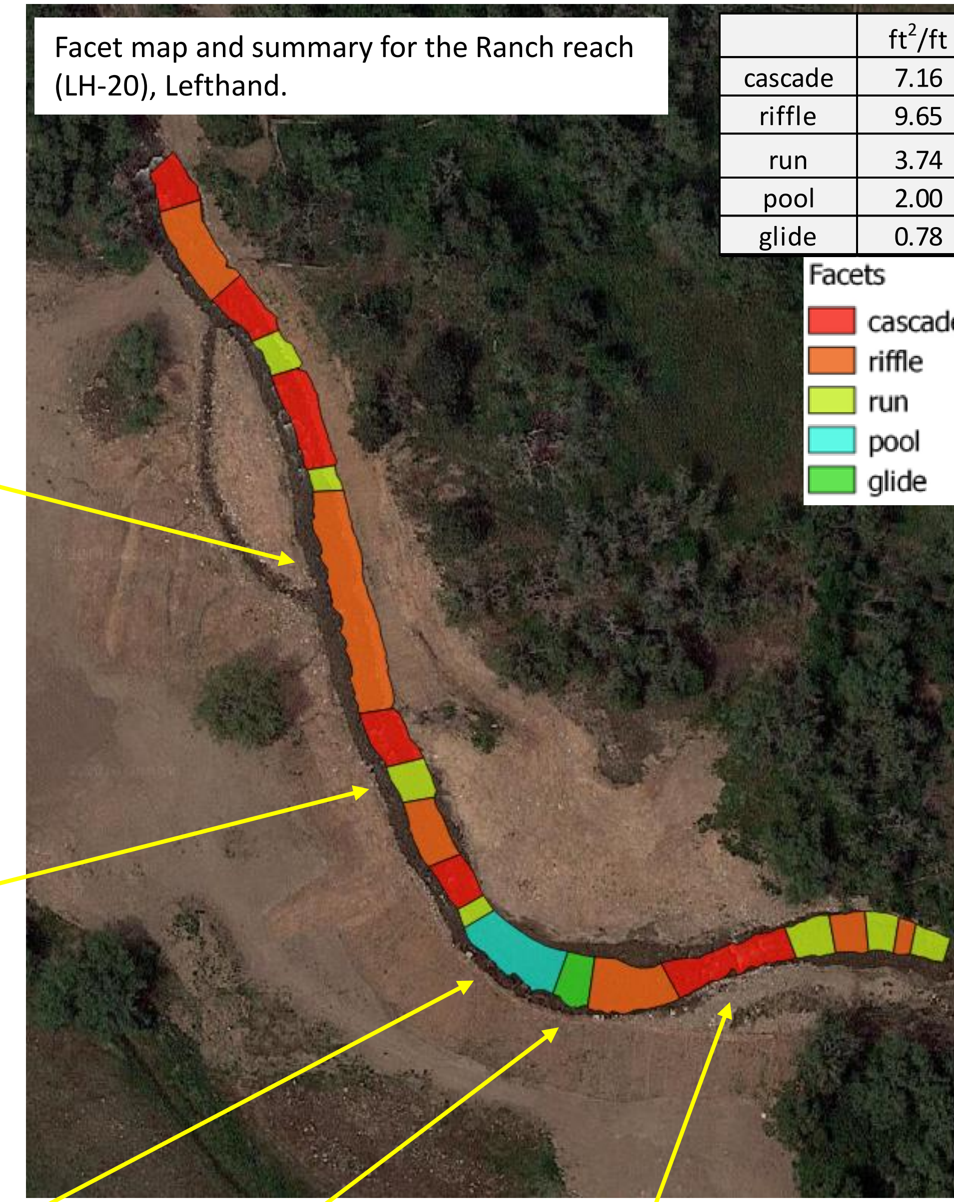
Comments

Facet delineation is a coarse but useful method for quantifying lotic aquatic habitat and geomorphic features. While the facet definitions are objectively defined and can be verified with a stadia rod and velocity meter, delineations necessarily require subjective judgment since velocity and depth are not consistent across stream width. Future surveyors should look to verify and look for obvious changes to baseline delineations to detect change rather than remapping to reduce error from different observers. Facet delineations by stream segment are coarse measures that are not sensitive to subtle geomorphic changes. Its primary value is in comparing reaches and documenting major changes. Be careful not to confuse these facet definitions with similar terms used to describe planform locations on Rosgen C-type streams which can be different.


LH20 typical riffle


LH20 typical run


LH20 typical pool and glide



Facet map and summary for the Ranch reach (LH-20), Lefthand.

	ft^2/ft
cascade	7.16
riffle	9.65
run	3.74
pool	2.00
glide	0.78


LH20 typical cascade

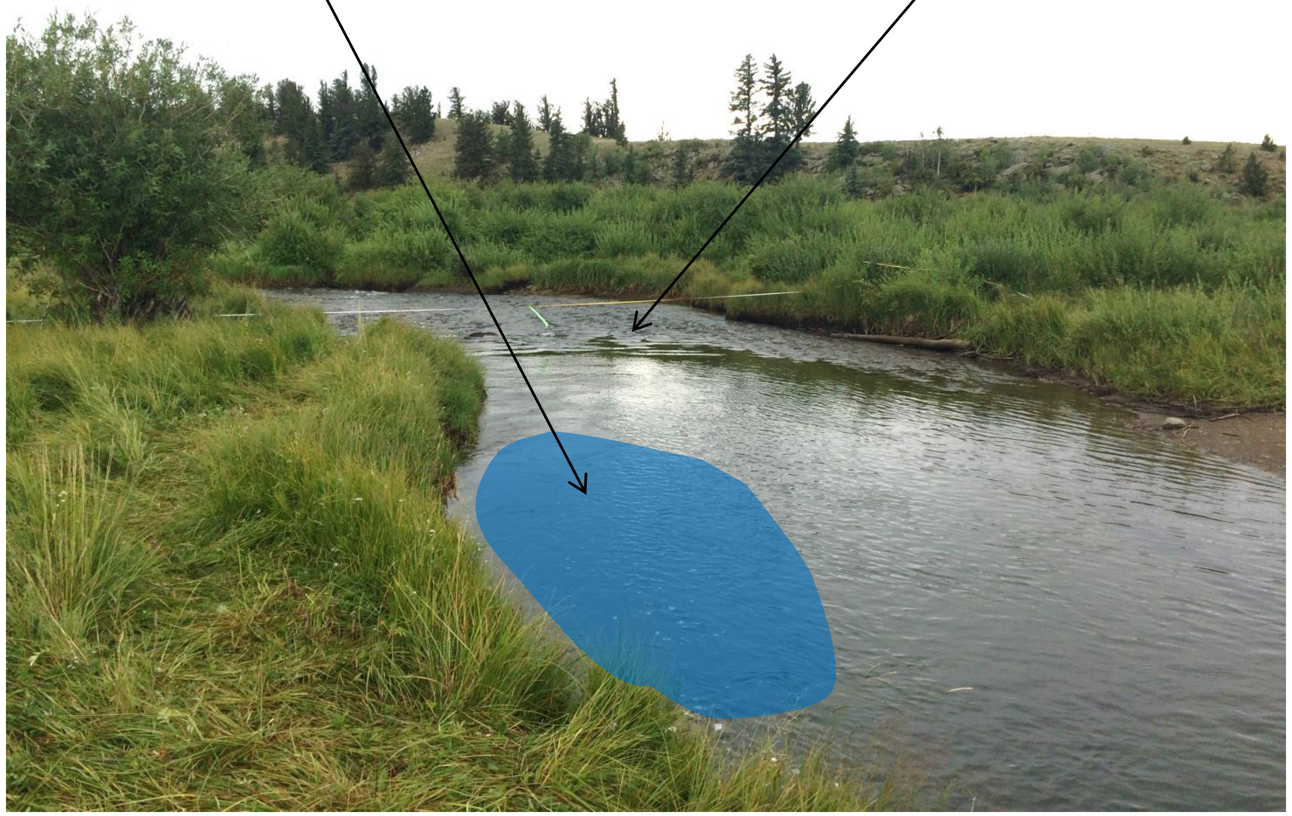
Pool area surveys and mapping

Field survey

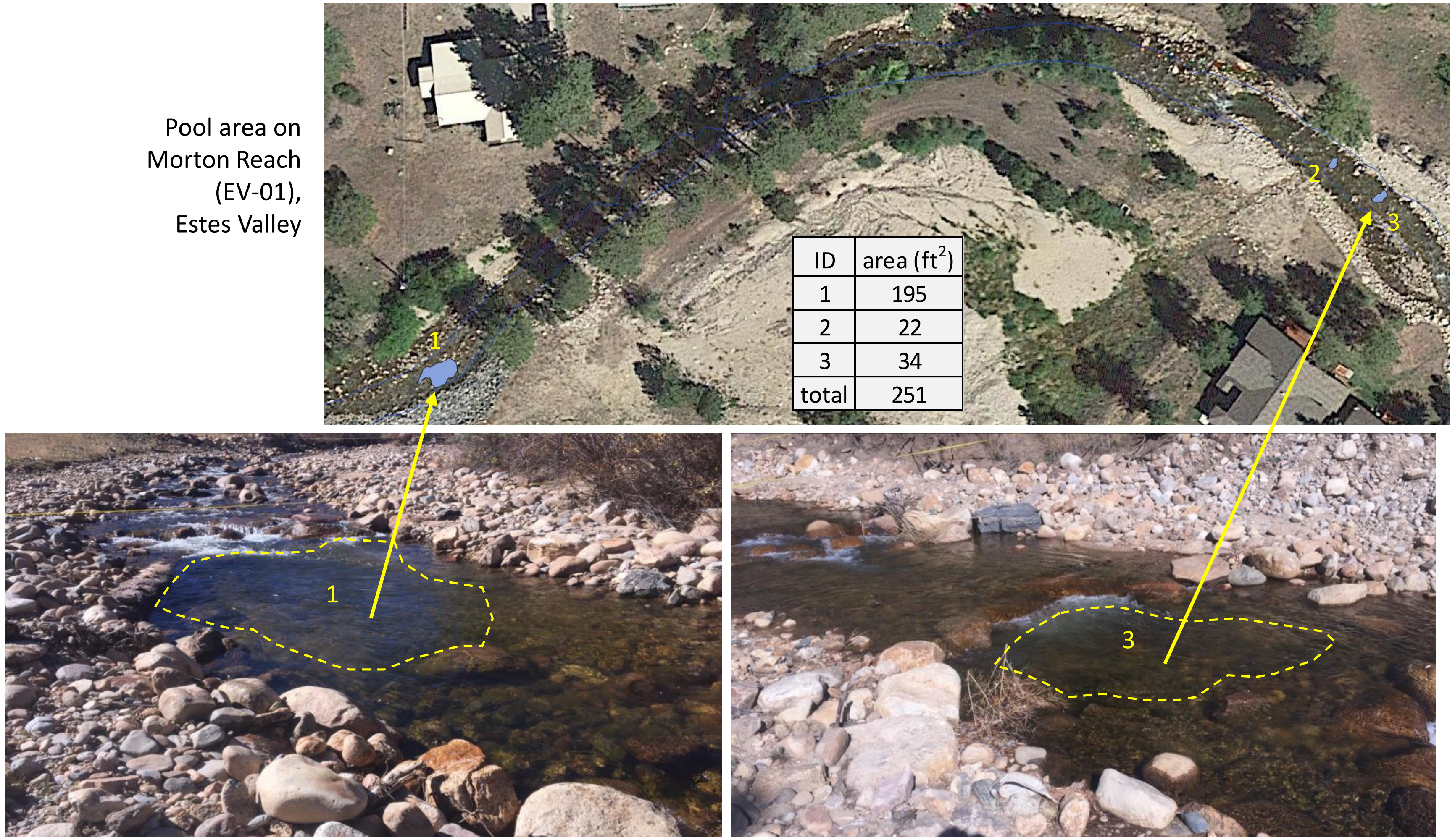
Pools meeting any specified depth requirement could potentially be surveyed and mapped. For these projects the depth criterion we used is residual pool depth >1.5 ft unless otherwise specified. To map 1.5-ft residual pool depth (RPD) in the field, we survey during low-flow periods and delineate the perimeter of areas that are deeper than 1.5 + d ft, where d is the mean depth of water over the stage-controlling feature immediately downstream of the pool.

Pools are delineated in the field by tracing the perimeter of area that meets depth criteria (1.5 + d ft unless otherwise specified).

Downstream stage control (e.g. riffle crest, beaver dam, etc.) Mean depth over this feature is equal to d.

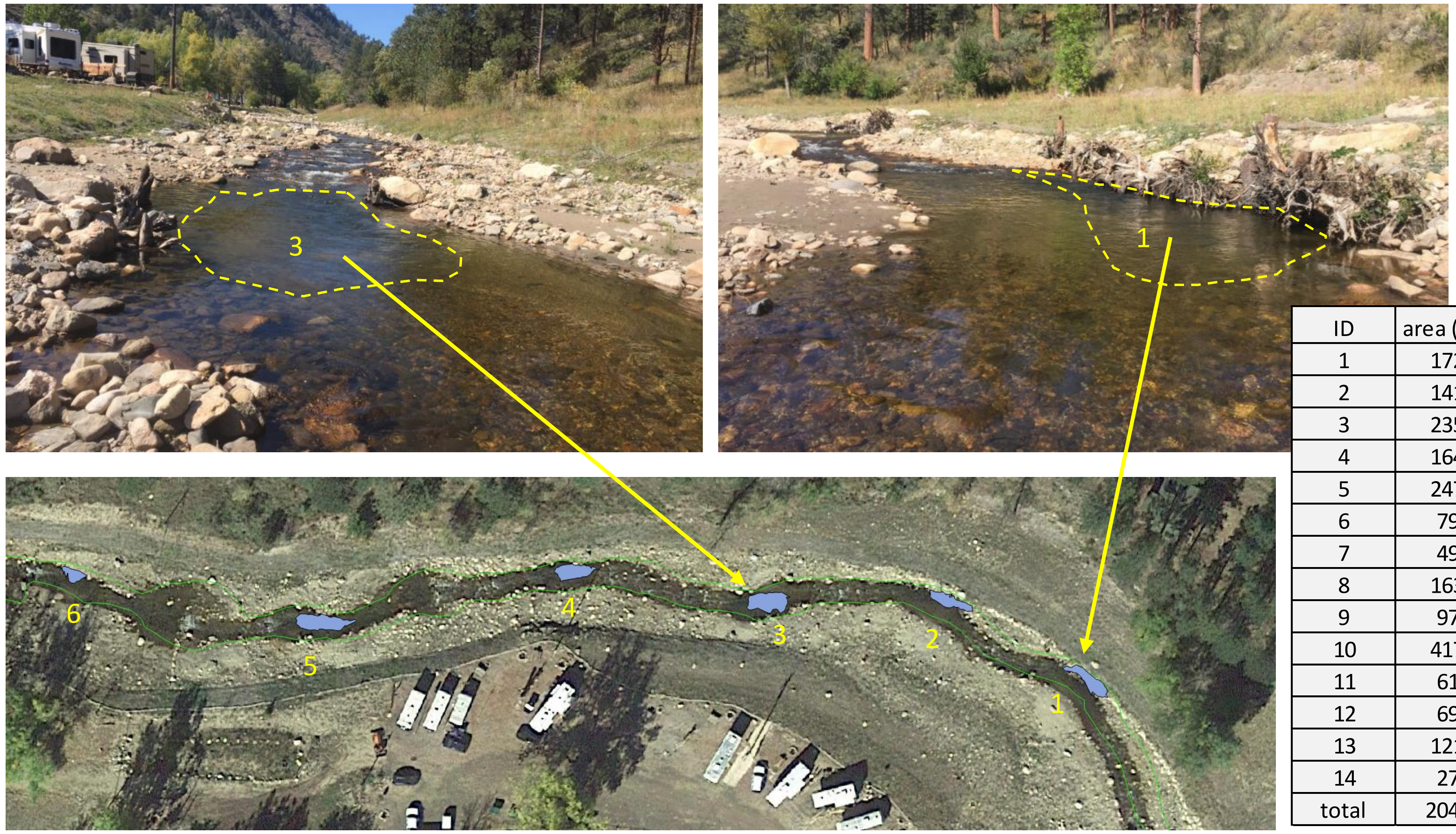


Pool area on Morton Reach (EV-01), Estes Valley



ID	area (ft^2)
1	195
2	22
3	34
total	251

Pool area on North Fork Reach (BT-24), Big Thompson



ID	area (ft^2)
1	172
2	141
3	235
4	164
5	247
6	79
7	49
8	163
9	97
10	417
11	61
12	69
13	121
14	27
total	2042

Data products

Spreadsheet with calculated area of mapped pools

Shapefile of mapped pool area

Comments

Pool area may be an important limiting habitat factor, and this method is the best and most objective method for quantifying pool area that we know of. The methods are repeatable and able to detect at least moderate changes as pool area. Mapping pool area on a reach scale is preferable to simple measuring pool depth or tracking the fate of individual pools if your primary concern is habitat.

Substrate surveys

Field survey

Substrate surveys were made using standard Wolman pebble counts on transects. Materials were sampled on regular intervals (heel-toe or short steps) across the active stream bed and recorded by size class based on the length of the intermediate axis. Material smaller than 1 mm was combined to a single class.

Data products

Spreadsheet of size distribution with statistics, locations (XS) identified

Comments

Pebble count data is useful for monitoring gross changes to stream bed composition.

Root wad on the Ranch Reach (LH-20), Lefthand

Pebble count data for a riffle (photo to left) on the Ranch Reach (LH-20), Lefthand

Riffle

Material	Size Range (mm	Count
silt/clay	0 - 0.062	
very fine sand	0.062 - 0.125	
fine sand	0.125 - 0.25	
medium sand	0.25 - 0.5	
coarse sand	0.5 - 1	16
very coarse sand	1 - 2	7
very fine gravel	2 - 4	6
fine gravel	4 - 6	2
fine gravel	6 - 8	0
medium gravel	8 - 11	2
medium gravel	11 - 16	3
coarse gravel	16 - 22	7
coarse gravel	22 - 32	15
very coarse gravel	32 - 45	14
very coarse gravel	45 - 64	10
small cobble	64 - 90	12
medium cobble	90 - 128	5
large cobble	128 - 180	5
very large cobble	180 - 256	1
small boulder	256 - 362	
small boulder	362 - 512	
medium boulder	512 - 1024	
large boulder	1024 - 2048	
very large boulder	2048 - 4096	
	total particle count:	105

Wood counts

Field survey

Field crews counted large woody material within the bankfull stream width. For our surveys, we divided wood into two classes: logs and jams. Logs are individual pieces of wood greater than 0.4 ft diameter and 3 ft long. Jams are any conglomerate of wood pieces with gross volume greater than 10 ft^3. Logs are solid wood. Jams are a matrix of wood and space. For each log encountered, we recorded (1) length, (2) mean diameter, and (3) percent submerged at low flow. For each jam, we recorded (1) length, (2) width, (3) height, (4) estimated density (% wood versus space), and (5) percent submerged at low flow. Embedded wood that is buried in bank or substrate material is not counted.

Data products

Spreadsheet of raw wood count data

Shapefile of recorded wood (some sites)

Comments

Wood is an important geomorphic and habitat component of Front Range streams. It is also a factor that is heavily managed. Wood was routinely removed from streams as unwanted debris following the 2103 floods, and many recovery projects purposely tried to reincorporate stream wood in their restoration plans. While it may seem simple (until you try it) quantifying wood is streams has proven notoriously difficult in research experiments. While these data are coarse, they do present a quantitative approach that can be used to track many wood-related parameters.

Example of a field form for quantifying in-stream LWM

point ID	Type	Length	Diameter (Width for jams)	Height (for jams only)	Estimated density (for jams only)	% submerged at low flow
5	log	4	0.5			0%
6	log	15	0.6			60%
7	JAM	10	5.0	4.0	40%	60%
8	JAM	6	3.0	3.0	60%	60%

Wood in small streams at Cheley Camp EV06) and Upper Fish Creek (EV15), Estes Valley

Root wad/log jam revetment on the North Fork Reach (BT-24), Big Thompson

Test banks

Field survey

Test banks are positions along the bank set up to measure lateral accretion (movement of the bank caused by erosion and channel migration). Accretion can be measured by surveying the profile of the bank repeatedly over time or by installing bank pins. Bank pins are rods pounded horizontally into a bank until the end is flush with the edge of the bank. If the bank erodes and the pin does not move, then accretion is measured by the length of the pin. Profiles are usually surveyed on banks with cross-sections. Sometimes additional survey markers (besides the XS end points) are placed near the bank and surveyed to assure precise positioning. Low-angle banks are surveyed similar to cross-sections with careful leveling of the survey rod to assure proper station readings. Steep or overhanging banks are surveyed vertically by measuring horizontal distance from a leveled rod set at a known station.

Data products

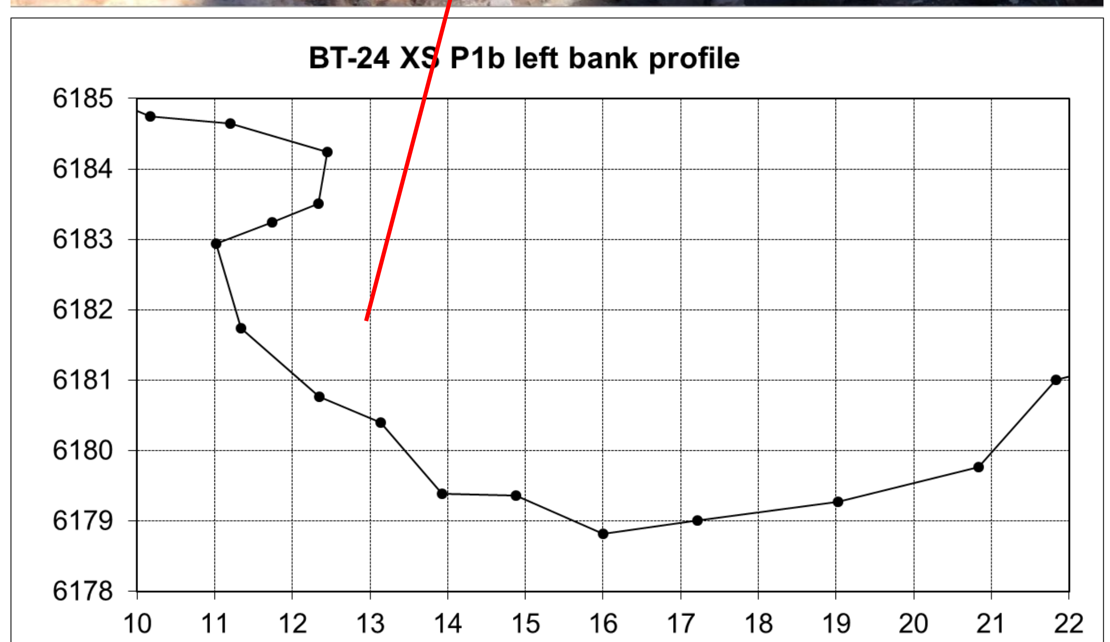
Spreadsheet of point data with notes for bank profiles (accretion distance for pins)
Photos of test banks
Shapefile of test bank locations (if separate from XS)

Comments

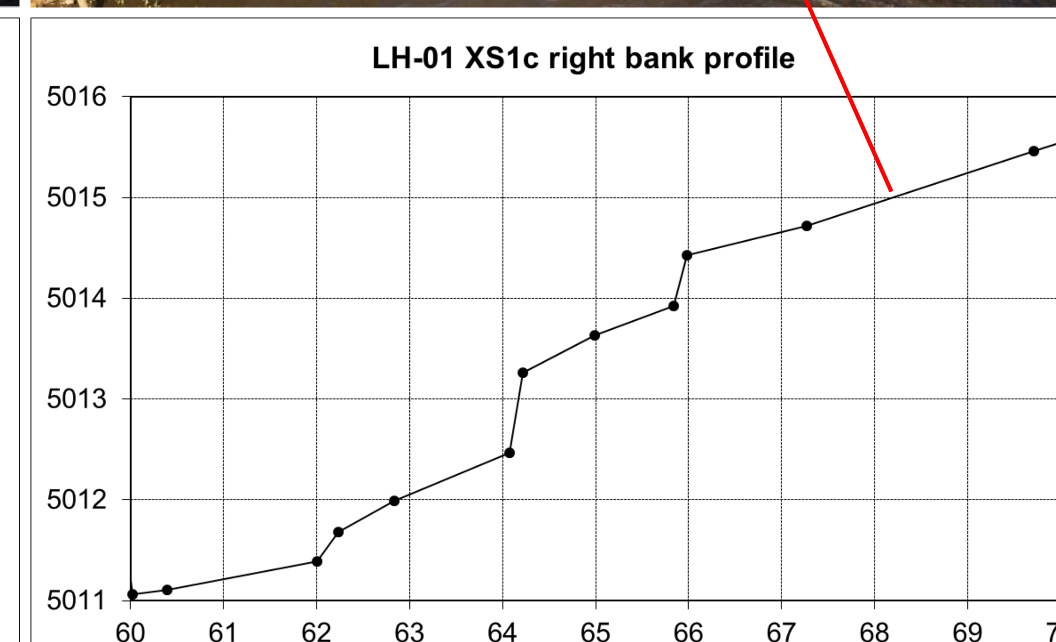
Test banks are useful for quantifying erosion, lateral accretion, and migration.
The advantage of pins is that they are simple. They are also visually impressive because you can see the amount of accretion right then and there in the field without having to go home and interpret it from a graph. The disadvantage is that it measures only one point along the profile of the bank. Pins are also sometimes difficult to install, they may become hazards, and they only work for relatively slow accretion rates.

Measuring accretion on a set of bank pins

Bank profile on a test bank on the North Fork reach (BT-30), Big Thompson.



Bank profile on a test bank on the Ranch reach (LH-01), Lefthand Creek.



Appendix 2:

Stream Health Assessment

Variable Grading Guidelines

Watershed-scale Variables

Flow Regime

Water is supplied to a reach from its contributing watershed in a characteristic pattern, or flow regime, represented by a hydrograph, and flow regime is a primary determinant of the structure and function of streams and rivers. Land and water uses in the watershed may affect the total net volume of water supplied to the reach or impact the pattern of the hydrograph by impacting peak flows, low flows, and rates of change. The **Total Volume** subvariable rates the net annual change in water volume caused by depletions and/or augmentation as a percentage of natural. **Peak Flow** rates impairment to the magnitude, timing, and duration of high-flow events. Grading criteria are based on changes to the pattern of peaks in the hydrograph and deviation of annual net peak flow discharge compared to geomorphically relevant thresholds. Similarly, the **Base Flow** subvariable rates impairment to the magnitude, timing, and duration of low-flow events. Grading criteria are based on changes to the pattern of dips, or low flow periods, in the hydrograph and deviation of annual net base flow discharge compared to biologically relevant thresholds. **Rate of Change** considers impacts to the rate at which discharge varies over time, with grading criteria based on the degree to which changing flows stress native plants and animals. The **Flow Regime** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Flow\ Regime = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines for $V_{hyd}1$: Flow Regime - Total Volume			
A	≥ 90	Negligible	Net change from augmentations and depletions less than 5% of the total annual volume.
B	≥ 80	Mild	Net change from augmentations and depletions between 5% and 15% of the total annual volume.
C	≥ 70	Significant	Net change from augmentations and depletions between 15% and 30% of the total annual volume.
D	≥ 60	Severe	Net change from augmentations and depletions between 30% and 50% of the total annual volume.
F	≥ 50	Profound	Net change from augmentations and depletions more than 50% of the total annual volume.

Scoring Guidelines for $V_{hyd}2$: Flow Regime - Peak Flows			
A	≥ 90	Negligible	Magnitude and duration of annual discharge peaks closely resembles natural hydrograph. Departure from natural peak flow magnitude less than 10%.
B	≥ 80	Mild	Hydrograph has a natural seasonal pattern, but peaks are attenuated, elevated, extended, or shortened. Departure from natural peak flow magnitude 10-20%.
C	≥ 70	Significant	Hydrograph has a natural seasonal pattern, but peaks are attenuated, elevated, extended, or shortened. Departure from natural peak flow magnitude 20-33%.
D	≥ 60	Severe	Disrupted seasonal hydrograph patterns and/or departure from natural peak flow magnitude 33-50%.
F	≥ 50	Profound	Disrupted seasonal hydrograph patterns and/or departure from natural peak flow magnitude greater than 50%.

Scoring Guidelines for Flow Regime - Base Flows			
A	≥ 90	Negligible	Magnitude and duration of base flows closely resembles the natural hydrograph. Departure from natural seasonal minimum discharge less than 10%.
B	≥ 80	Mild	Hydrograph has a natural seasonal low-flow pattern. Seasonal minimum discharge diminished 10-20% or increased by 10-50%.
C	≥ 70	Significant	Periods of biologically critical low flows occur occasionally. Seasonal minimum discharge diminished 20-33% or increased by more than 50%.
D	≥ 60	Severe	Periods of biologically critical low flows are frequent. Seasonal minimum discharge diminished 33-50%.
F	≥ 50	Profound	Frequent and extended periods of biologically critical low flows and/or periods of no flow occur. Seasonal minimum discharge diminished by more than 50%.

Scoring Guidelines for Flow Regime – Rate of Change			
A	≥ 90	Negligible	Flow rates of change closely resemble natural hydrograph. Departure in rise and/or fall rates less than 10%
B	≥ 80	Mild	No rapid artificial flow changes. Departure in rise and/or fall rates 10-20%.
C	≥ 70	Significant	Occasional rapid artificial flow changes. Departure in rise and/or fall rates 20-33%.
D	≥ 60	Severe	Frequent rapid artificial flow changes. Departure in rise and/or fall rates 33-50%.
F	≥ 50	Profound	Artificially uniform hydrograph or hydrographs in which rapid daily fluctuations are common. Departure in rise and/or fall rates greater than 50%.

Sediment Regime

Streams and rivers tend to be naturally adapted to the characteristic flow and sediment regime of their watersheds. Like changes to flow regime, an altered sediment regime may cause a cascade of impacts to stream form and function. The **Sediment Regime** variable reflects the net combined impact to amount and timing of sediment supply to a reach from all sources. The sources of sediment to the reach are land erosion in the contributing watershed and channel erosion on reaches upstream and tributary to it. The **Land Sources** subvariable rates impairment to the amount of sediment produced via land erosion in the contributing watershed with grading criteria based on the extent of land use and unnatural bare ground in the watershed. **Channel Sources** rates impairment to the amount of sediment produced by human-induced channel erosion and incision on main stem and tributary reaches upstream of the reach. While some portion of sediment enters directly from valley side slopes, most of it is discharged to the reach as bedload and suspended sediment by the stream. **Continuity** rates impairment to the natural transport of sediment from its sources in the contributing watershed to the reach. Grading criteria are based on the number and size of unnatural impediments to sediment transport and on the proportion of the watershed from which sediment transport is blocked. The **Sediment Regime** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Sediment\ Regime = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines for $V_{sed}1$: Sediment Regime - Land Sources			
A	≥ 90	Negligible	The amount and timing of sediment production from land erosion is relatively unaffected by human land use.
B	≥ 80	Mild	Stressors are present, and rates of surface erosion and mass erosion events minimally impacted. Examples include watersheds with low road or development density or grazing practices that do not deplete vegetation cover.
C	≥ 70	Significant	Land uses in the watershed are causing significant changes to the amount of land erosion. Examples include overgrazed slopes with increased bare ground, high density of unimproved roads, or evidence of past human-caused mass erosion.
D	≥ 60	Severe	Greatly increased land erosion caused by human activity or land use is evident. Examples include widespread overgrazed or clear-cut slopes, erosion associated with roads adjacent to the stream, or evidence of recent human-caused mass erosion.
F	≥ 50	Profound	Land uses in the watershed are causing an overwhelming amount of sediment from land erosion. Examples include widespread loss of ground cover on adjacent slopes with rill or gully formation or very large or frequent human-caused mass erosion.

Scoring Guidelines for $V_{sed}2$: Sediment Regime - Channel Sources			
A	≥ 90	Negligible	Main stem and tributaries in the contributing drainage network have natural rates of erosion. Total net sediment supply from channel erosion is increased by less than 10% over natural rate.
B	≥ 80	Mild	Some main stem and tributary reaches have areas of accelerated channel erosion. Total net sediment supply from channel erosion is increased by 10-20% or is artificially low.
C	≥ 70	Significant	Accelerated channel erosion is common in the watershed, or there are localized reaches with major instability, incision, and/or gully formation. Total net sediment supply from channel erosion is increased by 20-33%.
D	≥ 60	Severe	Anthropogenic channel erosion is a major source of sediment to the reach. Total net sediment supply from channel erosion is increased by 33-50%.
F	≥ 50	Profound	Anthropogenic channel erosion is an overwhelming source of sediment to the reach. Total net sediment supply from channel erosion is increased by more than 50%.

Scoring Guidelines for $V_{sed}3$: Sediment Regime - Continuity			
A	≥ 90	Negligible	Impediments to sediment continuity block sediment from less than 10% of the contributing watershed.
B	≥ 80	Mild	Impediments to sediment continuity block 10-25% of sediment supply from of the contributing watershed, or small impediments
C	≥ 70	Significant	Impediments to sediment continuity block 25-50% of sediment supply from of the contributing watershed.
D	≥ 60	Severe	Impediments to sediment continuity block more than 50% of sediment supply from of the contributing watershed.
F	≥ 50	Profound	Impediments to sediment continuity trap almost all incoming sediment, supplying the reach with clear water discharge.

Water Quality

Physicochemical properties are largely inherited to a reach from its contributing watershed, and water quality is determined by a combination of upstream land and water uses and biogeochemical processing. Water quality parameters are typically the most quantified and monitored aspects of stream health and regulatory standards play a role in scoring all the water quality subvariables. But from the perspective of holistic stream health, the departure from natural conditions is more important than tight adherence to standards. The **Temperature** subvariable rates impairment to water temperature regime, especially as it impacts native biota. The **Nutrients** subvariable deals with nutrient levels (especially nitrogen, potassium, and phosphorus) as well as dissolved and particulate organic material. Dissolved oxygen is closely tied to both temperature regime and nutrient levels. The **Chemical Conditions** subvariable accounts for all other potential biologically-limiting water quality parameters, especially inorganic compounds and metals. The **Water Quality** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Water\ Quality = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines for Water Quality - Temperature			
A	≥ 90	Negligible	Temperature regime is natural and appropriate for a well-functioning river in its process domain.
B	≥ 80	Mild	Temperature regime is within the range of natural variability, natural aquatic biota are minimally impaired and regulatory standards not exceeded.
C	≥ 70	Significant	Temperature regime is altered to a degree that could significantly affect natural aquatic biota and/or regulatory standards are occasionally exceeded. 303d M&E reaches.
D	≥ 60	Severe	Temperature regime is altered to a degree that is known to affect natural aquatic biota and/or regulatory standards are frequently exceeded. 303d listed reaches.
F	≥ 50	Profound	The temperature regime is fundamentally altered. Natural biota are severely impaired and/or regulatory standards are chronically exceeded.

Scoring Guidelines for Water Quality - Nutrients			
A	≥ 90	Negligible	Nutrient levels are natural and appropriate for a well-functioning river in its process domain.
B	≥ 80	Mild	Nutrient levels are within the range of natural variability, natural aquatic biota are minimally impaired and regulatory standards not exceeded.
C	≥ 70	Significant	Nutrient levels are altered to a degree that they significantly affect natural aquatic biota and/or regulatory standards are occasionally exceeded. 303d M&E reaches.
D	≥ 60	Severe	Nutrient levels are altered to a degree that is known to affect natural aquatic biota and/or regulatory standards are frequently exceeded. 303d listed reaches.
F	≥ 50	Profound	The physicochemical environment is fundamentally altered. Natural biota are severely impaired and/or regulatory standards are chronically exceeded.

Scoring Guidelines for Water Quality – Chemical Conditions			
A	≥ 90	Negligible	Chemical conditions are natural and appropriate for a well-functioning river in its process domain.
B	≥ 80	Mild	Chemical conditions are within the range of natural variability, natural aquatic biota are minimally impaired and regulatory standards not exceeded.
C	≥ 70	Significant	Chemical conditions are altered to a degree that could potentially limit natural aquatic biota and/or regulatory standards are occasionally exceeded. 303d M&E reaches.
D	≥ 60	Severe	Chemical conditions are altered to a degree that is known to be lethal or limiting to natural aquatic biota and/or regulatory standards are frequently exceeded. 303d listed reaches.
F	≥ 50	Profound	The chemical environment is fundamentally altered. Natural biota are severely impaired and/or regulatory standards are chronically exceeded.

Landscape Connectivity

The interaction and connectivity of a reach with its landscape and surrounding area is an important component of stream health. The **Buffer Capacity** subvariable rates the degree to which surrounding land area supports healthy stream and riparian function by buffering potential stressors in the contributing area. Grading criteria area based on the types and extent of land use within a buffer area extending 200 meters out from the riparian zone. **Terrestrial Connectivity** rates impairment to the migration and dispersal of terrestrial organisms into and out of the reach based on the loss of habitat and dispersal/migration barriers within a habitat connectivity envelope extending 500 meters out from the riparian zone. **Aquatic Connectivity** rates impairment to the migration and dispersal of aquatic organisms between the reach and adjacent segments of the stream and its tributaries. Grading criteria are based on the severity and proximity of migration barriers. The **Landscape Connectivity** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Landscape\ Connectivity\ = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines for Landscape – Buffer Capacity			
A	≥ 90	Negligible	No appreciable land use changes in the buffer area.
B	≥ 80	Mild	Land use in buffer area has minor impacts to its ability to buffer surrounding stressors. High-intensity land uses or development with impervious surfaces, bare soil, and structures covers less than 10% of the buffer area.
C	≥ 70	Significant	Land use in buffer area is responsible for a marked shift in land cover, diminishing its ability to buffer surrounding stressors. High-intensity land use or development with impervious surfaces, bare soil, and structures covers 10 – 40%.
D	≥ 60	Severe	Artificial land cover types dominate most of the buffer area and/or high-intensity land use or development with impervious surfaces, bare soil, and structures covers 40 – 75%. Buffer capacity is diminished but not totally extinguished.
F	≥ 50	Profound	High-intensity land use or development with impervious surfaces, bare soil, and structures covers more than 75% of the buffer area. The surrounding area has no capacity to buffer outside stressors and the buffer area itself may contribute ecological stress.

Scoring Guidelines for Landscape – Terrestrial Connectivity			
A	≥ 90	Negligible	Less than 10% habitat loss within the surrounding 500-meter habitat connectivity envelope (HCE) and no significant barriers to migration or dispersal of terrestrial organisms.
B	≥ 80	Mild	10-25% of habitat in the HCE is lost or isolated from the reach by impermeable barriers and/or permeable barriers affect a greater portion of surrounding habitat.
C	≥ 70	Significant	25-50% of habitat in the HCE is lost or isolated from the reach by impermeable barriers and/or permeable barriers affect a greater portion of surrounding habitat.
D	≥ 60	Severe	50-75% of habitat in the HCE is lost or isolated from the reach by impermeable barriers and/or permeable barriers affect a greater portion of surrounding habitat.
F	≥ 50	Profound	More than 75% of habitat in the HCE is lost or isolated from the reach by impermeable barriers and/or permeable barriers affect a greater portion of surrounding habitat.

Scoring Guidelines for Landscape – Aquatic Connectivity			
A	≥ 90	Negligible	There are no significant barriers that prevent migration or dispersal of aquatic organisms within the entire ecoregion and upstream to headwaters.
B	≥ 80	Mild	Impermeable migration/dispersal barriers are within 10 miles and/or there are minor migration/dispersal impediments on the reach or adjacent reaches.
C	≥ 70	Significant	Impermeable migration/dispersal barriers exist within 5 miles and/or there are multiple migration/dispersal impediments on the reach or adjacent reaches.
D	≥ 60	Severe	Impermeable migration/dispersal barriers exist within 2 miles and/or migration/dispersal is severely impeded on the reach or adjacent reaches.
F	≥ 50	Profound	The reach is effectively isolated. Impermeable migration/dispersal barriers exist within 1 miles and/or migration/dispersal is completely impeded on the reach or adjacent reaches.

Reach-scale Variables

Floodplain Connectivity

Floodplain connectivity describes the degree to which water accesses and hydrates the land. The amount and timing of flow interacts with channel and floodplain morphology to create a characteristic pattern of land saturation or inundation. This variable is used to rate the degree to which the aerial extent of effective floodplain is decreased due to either hydrologic impacts, channel impacts (e.g. enlargement, entrenchment, channelization), or land uses in the floodplain area (e.g. levees, drainage ditches, development, floodplain fill) that impede water access and aerial distribution. Scoring guidelines are based on the comparison of present day floodplain extent to historic natural conditions in three tiers. The **High-frequency Floodplain** subvariable rates impairment to the floodplain area regularly saturated or inundated during average annual high flow events with return interval of 1-2 years. **Medium-frequency Floodplain** considers the active floodplain during events with 5-10-year return interval. The **Floodplain Connectivity** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Floodplain\ Connectivity = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines for Floodplain Connectivity – High-frequency Floodplain			
A	≥ 90	Negligible	Natural pattern of floodplain activation during average annual flow regime. Area of land saturated or inundated at flows with return interval 1-2 years is natural and decreased less than 10%. (> 90% intact).
B	≥ 80	Mild	Area of land saturated or inundated at flows with return interval 1-2 years is decreased 10 - 25% (75 - 90% intact).
C	≥ 70	Significant	Area of land saturated or inundated at flows with return interval 1-2 years is decreased 25 – 50% (50 - 75% intact).
D	≥ 60	Severe	Area of land saturated or inundated at flows with return interval 1-2 years is decreased 50 - 70%. (30 - 50% intact).
F	≥ 50	Profound	Area of land saturated or inundated at flows with return interval 1-2 years is decreased 70%. (< 30% intact).

Scoring Guidelines for Floodplain Connectivity – Medium-frequency Floodplain			
A	≥ 90	Negligible	Natural pattern of floodplain activation during high flow events. Area of land saturated or inundated at flows with return interval 5-10 years is natural and decreased less than 10%. (> 90% intact).
B	≥ 80	Mild	Area of land saturated or inundated at flows with return interval 5-10 years is decreased 10 - 25% (75 - 90% intact).
C	≥ 70	Significant	Area of land saturated or inundated at flows with return interval 5-10 years is decreased 25 – 50% (50 - 75% intact).
D	≥ 60	Severe	Area of land saturated or inundated at flows with return interval 5-10 years is decreased 50 - 70%. (30 - 50% intact).
F	≥ 50	Profound	Area of land saturated or inundated at flows with return interval 5-10 years is decreased 70%. (< 30% intact).

Riparian Condition

Riparian areas are complex assemblages of plant species with characteristic structure, diversity, and processes that interact directly with the river. The **Riparian Condition** variable describes the degree to which riparian areas support river health and critical functions such as habitat for fish and wildlife populations, bank stabilization, flood energy dissipation, biogeochemical cycling, water temperature regulation. The variable rates the degree to which the supporting aspects of riparian vegetation structure, connectivity, and ecological processes are impaired by human impacts such as land conversion, land use, and management.

Scoring Guidelines for Riparian Condition			
A	≥ 90	Negligible	Native riparian conditions that are natural and appropriate for a well-functioning river in its process domain. Vegetation diversity is self-sustaining with intact hydrology and topography that supports a preponderance of native flora and fauna, without spread of aggressive or noxious species. Habitat is characteristically patchy, with strong interspersion of patches and good vertical structure. Full support of river health.
B	≥ 80	Mild	Riparian habitat resembles native conditions with detectable changes, connectivity to the river, and characteristic topography. Vegetation is self-sustaining, requiring little maintenance to preserve characteristic structure diversity. Native species predominate with only minor invasion by aggressive species. Noxious species do not threaten functioning. Habitat maintains a high degree of patchiness and interspersion, with little homogenization or loss of vertical structure. Minor reduction in the support of hiver health attributes.
C	≥ 70	Significant	Hydrologic alteration, disconnection from the river, decreased plant diversity, loss of structural complexity, and/or homogenization of vertical structure, patchiness and interspersion and are evident, but the riparian area is vegetated. Small populations of noxious species may occur, and a significant proportion of the species are exotic or aggressive natives. Examples include floodplain hayfields. Riparian land use contributes to the degradation of one or more river health attributes.
D	≥ 60	Severe	Hydrologic alteration, disconnection from the river, decreased plant diversity, loss of structural complexity, and/or homogenization of vertical structure, patchiness and interspersion and are severe. Riparian habitat may be isolated from the river and noxious weeds, aggressive species, or exotics are prevalent or dominant. Bare ground or impervious surfaces make up a significant portion of land cover. Vegetation tends to be unnatural, landscaped, or manicured. Examples include residential lawns, sports fields and golf courses. Riparian land use contributes to river dysfunction.
F	≥ 50	Profound	Riparian area is developed or wholly converted with predominantly bare ground, impervious surfaces or otherwise lacking in vegetation as a result of land use and management actions. Riparian habitat function is essentially extinguished and land use contributes substantially to river dysfunction

Organic Material

Organic material is the bodies and fragments of dead organisms, especially plants, that enter a stream. **Wood** is the coarsest organic material, functioning primarily as a structural component affecting stream morphology, stability, and physical structure. It occurs as individual pieces, such as logs, branches, and downed trees, or bunched together in wood jams or beaver dams. **Detritus** is smaller vegetative fragments such as leaves, needles, twigs, and grass, plus animal bodies and feces. Detritus is often the primary energy source for a stream reach, but it also functions in forming microhabitat and substrate structure. These two subvariables rate the degree of alteration to the supply and accumulation of organic materials. The **Organic Material** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Organic\ Material = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines for Organic Material - Wood			
A	≥ 90	Negligible	Wood supply is natural and appropriate for a well-functioning river in its process domain. Mean annual LWD volume is decreased less than 10%.
B	≥ 80	Mild	Wood volume is decreased 10 - 25%, or the river has unnaturally high input of wood from unnatural sources.
C	≥ 70	Significant	Wood volume is decreased 25 - 50%, or the river is occasionally clogged with debris from unnatural sources.
D	≥ 60	Severe	Wood volume is decreased 50 - 80%, or the river is chronically clogged with debris from unnatural sources.
F	≥ 50	Profound	Wood volume is decreased by more than 80%.

Scoring Guidelines for Organic Material - Detritus			
A	≥ 90	Negligible	Detritus supply is natural and appropriate for a well-functioning river in its process domain. Mean annual detritus mass is decreased less than 10%.
B	≥ 80	Mild	Mean annual detritus mass is decreased 10 - 25%, or the river has unnaturally high input of detritus from unnatural sources.
C	≥ 70	Significant	Mean annual detritus mass is decreased 25 - 50%, or the river has extremely high input of detritus from unnatural sources.
D	≥ 60	Severe	Mean annual detritus mass is decreased 50 - 80%.
F	≥ 50	Profound	Mean annual detritus mass is decreased more than 80%.

Stream Morphology

Streams exhibit characteristic patterns of morphology by process domain as a result of geomorphic processes such as dynamic equilibrium between hydrology and sediment, adaptations to natural disturbance, and response to biotic agents such as vegetation, beavers, and other animals. Morphology is also altered directly by humans. The **Planform** subvariable rates impairment to the aerial shape of a river reach, including patterns of branching, sinuosity, and curvature. Grading criteria area based on the extent of artificial impacts such floodplain encroachment, channelization, straightening, and bank armoring. **Dimension** deals with impairment to the cross-sectional shape and size, especially the degree of entrenchment, channel capacity, and width-depth ratio. The **Profile** subvariable rates impairment to the longitudinal shape (gradient or slope) of a river reach based on the degree of alteration to river bed profile and water surface slope. The **Stream Morphology** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Stream\ Morphology = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines for Stream Morphology - Planform			
A	≥ 90	Negligible	Planform is natural and appropriate for a well-functioning river in its process domain.
B	≥ 80	Mild	Localized impacts to sinuosity, branching, or meander patterns. Ratio of channel length to valley length departure less than 10%.
C	≥ 70	Significant	Reach-scale impacts to sinuosity, branching, or meander patterns and/or ratio of channel length to valley length departure 10-20%.
D	≥ 60	Severe	Widespread impacts sinuosity, branching, or meander patterns and/or ratio of channel length to valley length departure 20-40%.
F	≥ 50	Profound	Severely altered sinuosity, branching, or meander patterns and/or ratio of channel length to valley length departure greater than 40%.

Scoring Guidelines for Stream Morphology - Dimension			
A	≥ 90	Negligible	Dimension is natural and appropriate for a well-functioning river in its process domain.
B	≥ 80	Mild	Localized impacts to entrenchment, channel capacity, or width/depth. Departure less than 10%.
C	≥ 70	Significant	Reach-scale impacts to entrenchment, channel capacity, or width/depth. Departure 10-25%.
D	≥ 60	Severe	Widespread impacts to entrenchment, channel capacity, or width/depth. Departure 25-50%.
F	≥ 50	Profound	Severely altered entrenchment, channel capacity, or width/depth. Departure greater than 50%.

Scoring Guidelines for Stream Morphology - Profile			
A	≥ 90	Negligible	Water surface slope and bed profile variation are natural and appropriate for a well-functioning river in its process domain.
B	≥ 80	Mild	Localized bed profile or water surface slope impacts at low flows and/or bankfull slope departure up to 10%. Examples: reaches with small grade control structures, minimal planform changes.
C	≥ 70	Significant	Localized bed profile or water surface slope impacts at low to moderate flows and/or bankfull slope departure 10-20%. Examples: reaches with large grade control structures, moderate planform changes.
D	≥ 60	Severe	Widespread bed profile or water surface slope impacts at all flows and/or bankfull slope departure 20-40%. Examples: reaches with numerous large grade control structures, major planform changes.
F	≥ 50	Profound	Severe changes to water surface slope at all flows and/or bankfull slope departure greater than 40%.

Stability

Resistance, equilibrium, and resilience are considered together to rate the probability that the stream will maintain functional geomorphic and vegetation structure over time. **Resistance** rates impairment to the strength of streambed, banks, and floodplain compared to natural forces of scour and erosion. **Equilibrium** considers the dynamic balance between sediment supply and transport capacity represented by Lane's Balance. **Resilience** rates the ability of the system to recover after a large disturbance such as a large flood, wildfire, or mass erosion event based on its ability to move and adjust and the potential for riparian vegetation communities to recover. The **Stability** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Stability = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines for Stability - Resistance			
A	≥ 90	Negligible	There are no significant stressors that would impede the physical movement/adjustment of the stream or the recovery of critical components.
B	≥ 80	Mild	The reach has a minimally diminished floodplain connectivity, mostly native riparian vegetation, and few structural impediments to movement/adjustment.
C	≥ 70	Significant	Structural impediments to physical movement/adjustment are present, significantly diminished floodplain connectivity, or vegetation that is limited due to a lack of local source material, impediments to establishment, or exotics.
D	≥ 60	Severe	Limited resilience. Examples include reaches that depend upon artificial stabilization or structures to maintain form, limited floodplain connectivity, very poor riparian vegetation, or water source impairment that strongly affects peak flows and effective discharge.
F	≥ 50	Profound	Not resilient. Examples include artificially maintained threshold channels, reaches with severe floodplain disconnect, severely limited mechanism for vegetation recovery, or severely impaired water source.

Scoring Guidelines for Stability - Equilibrium			
A	≥ 90	Negligible	Pattern and rate of erosion, deposition, and migration are natural and appropriate for a well-functioning river in its process domain.
B	≥ 80	Mild	Reach-scale pattern and rate of erosion, deposition, and migration are within the natural range for the river type and process domain, but localized impacts are present.
C	≥ 70	Significant	Reach-scale impacts to the pattern and rate of erosion, deposition, and migration; reaches with excess deposition, scour, bank erosion, accelerated migration, pool filling, unnatural bars, over-widening, enlargement, or mild incision.
D	≥ 60	Severe	Severe reach-scale impacts to the pattern and rate of erosion, deposition, and migration; reaches with widespread bank erosion, avulsions, complete pool filling, reach-wide aggradation, recent head cuts, or artificially hardened channels in unconfined alluvial valleys.
F	≥ 50	Profound	Rapidly aggrading or degrading reaches where instability is actively expanding to adjacent reaches.

Scoring Guidelines for Stability - Resilience			
A	≥ 90	Negligible	The reach is fully resilient and capable of rapid recovery. There are no significant stressors that obstruct the physical movement or adjustment of the river within its historical migration zone, and no impediments to native plant source, dispersal, and establishment of critical components.
B	≥ 80	Mild	The reach is resilient to moderate events but may be slow to recover its functional potential from major disturbance. It retains most of its historical channel migration zone, few obstructions to movement and adjustment, and mostly native riparian vegetation.
C	≥ 70	Significant	The reach can likely recover its functional potential after moderate disturbance but may not recover from major disturbance without direct intervention. It has significantly diminished channel migration zone, obstructions to physical movement and adjustment, and/or vegetation that is limited due to a lack of local source material, dispersal barriers, impediments to establishment, or exotics.
D	≥ 60	Severe	The reach is unlikely to recover its functional potential after moderate disturbance without direct intervention. The reach has a severely limited channel migration zone and stability depends on artificial stabilization or structures. Natural recolonization and recovery of the riparian zone is improbable due to a lack of local source material, dispersal barriers, impediments to establishment, or exotics.
F	≥ 50	Profound	The reach depends entirely on artificial stabilization, engineered structures, or routine maintenance to maintain stability and functional condition. It has no capacity to recover naturally if these fail. Channel migration zone and the potential for natural vegetation recovery are nonexistent.

Physical Structure

Heterogeneity in the physical structure of a stream is the result of complex interactions between hydraulics and geomorphology via the processes of erosion, scour, and deposition that shape the form of bed, banks, and substrate. Biological drivers such as riparian vegetation, wood, beavers, aquatic vegetation and algae may also have a profound effect. The **Macrohabitat** subvariable, which is relevant as physical habitat for fish and larger animals, rates impairment to the distribution of and diversity of water depth, velocity, and physical cover, the shape of bed and bank features, and other large physical structure provided by wood, rock, vegetation, and debris dams and jams. **Microhabitat** rates impairment to the physical habitat relevant to aquatic organisms the size of macroinvertebrates or fish larvae, particularly the availability of interstitial space within the river bed substrate, degree of embeddedness, armoring, proportion of fine sediment, aquatic vegetation or algae cover, and patches of organic materials or detritus accumulation such as leaf packs and wood. The **Physical Structure** variable score is calculated as the average of the minimum and mean of subvariable scores.

$$Physical\ Structure = (Minimum\ of\ subvariables + Mean\ of\ subvariables)/2$$

Scoring Guidelines for Physical Structure - Macrohabitat			
A	≥ 90	Negligible	Macro-scale structural heterogeneity is natural and appropriate for a well-functioning river in its process domain. All velocity-depth combinations and structural components are present in characteristic distribution.
B	≥ 80	Mild	Most typical velocity-depth combinations are present, but distribution of features is slightly skewed due to dispersed stressors or minimal direct impacts.
C	≥ 70	Significant	Some typical velocity-depth combinations or characteristic structural elements are absent or limited. Examples include reaches with altered pool spacing, skewed riffle-pool ratio, or lack of bank structure. Reaches with artificial structure or revetted banks.
D	≥ 60	Severe	Some typical velocity-depth combinations or characteristic structural elements are absent making the reach uncharacteristically homogenous. Examples include reaches with graded or heavily revetted banks or features that are frequently limited by inundation or low flow.
F	≥ 50	Profound	Homogenous form with uniform velocity-depth pattern and lack of physical structure. Examples include reaches with severely homogenized physical characteristics such as unnatural plain-bed morphology.

Scoring Guidelines for Physical Structure - Microhabitat			
A	≥ 90	Negligible	Micro-scale structural heterogeneity is natural and appropriate for a well-functioning river in its process domain. Bed conditions similar to reference with all habitat types reflected in appropriate proportions.
B	≥ 80	Mild	All aspects of micro-scale structural diversity are present, but distribution of features is slightly skewed due to dispersed stressors or minimal direct impacts. Examples include reaches with fine sediment deposition, slightly decreased interstitial space (mild embeddedness).
C	≥ 70	Significant	Some aspects of micro-scale structural diversity are lacking or limited. Examples include reaches with altered bed material distribution, moderate embeddedness, patches of armoring, or increased cover of persistent algae/aquatic vegetation, or decreased detritus/organic accumulation patches.
D	≥ 60	Severe	Some aspects of micro-scale structural diversity are lacking or severely limited, making the reach uncharacteristically homogenous. Examples include reaches with severe embeddedness, widespread armoring, persistent algae/aquatic vegetation in riffles, or lack of any detritus/organic accumulation patches.
F	≥ 50	Profound	Completely static or homogenous armored micro-scale physical structure. Examples include gravel or cobble-bed streams that are aggrading with fine material or choked with algae, alluvial streams unnaturally scoured to bedrock, or grouted/ hardened artificial streambeds.

Trophic Structure

Biota is an essential element of functional condition due to the essential biochemical processing performed through a characteristic **Trophic Structure**. It is a core feature of reach health and an important factor to consider when rating the ability of a reach to perform other functions. The **Trophic Structure** variable is not broken down into subvariables, so all the trophic levels and taxonomic groups must be considered together.

Scoring Guidelines for Trophic Structure			
A	≥ 90	Negligible	Community structure is natural and appropriate for a well-functioning river in its process domain. It is representative of the native, undisturbed condition.
B	≥ 80	Mild	Community structure consists of mostly native species. Distribution, age structure, or overall biomass of species may be slightly altered, but all functional guilds are appropriately represented and filled by native species.
C	≥ 70	Significant	Community structure is altered. Exotic species may be common, diversity lacking, and/or species distributions skewed, but niches typical of natural niches. Important functional guilds are appropriately represented even when composed of nonnative species.
D	≥ 60	Severe	Community structure is severely altered and may include a preponderance of exotic species, major loss of diversity, or lacking keystone species. One or more important functional guilds is unfilled or poorly represented.
F	≥ 50	Profound	Community structure is fundamentally altered. Examples include communities dominated by exotic species and communities with multiple important functional guilds that are vacant or severely diminished.

Overall River Health Grade

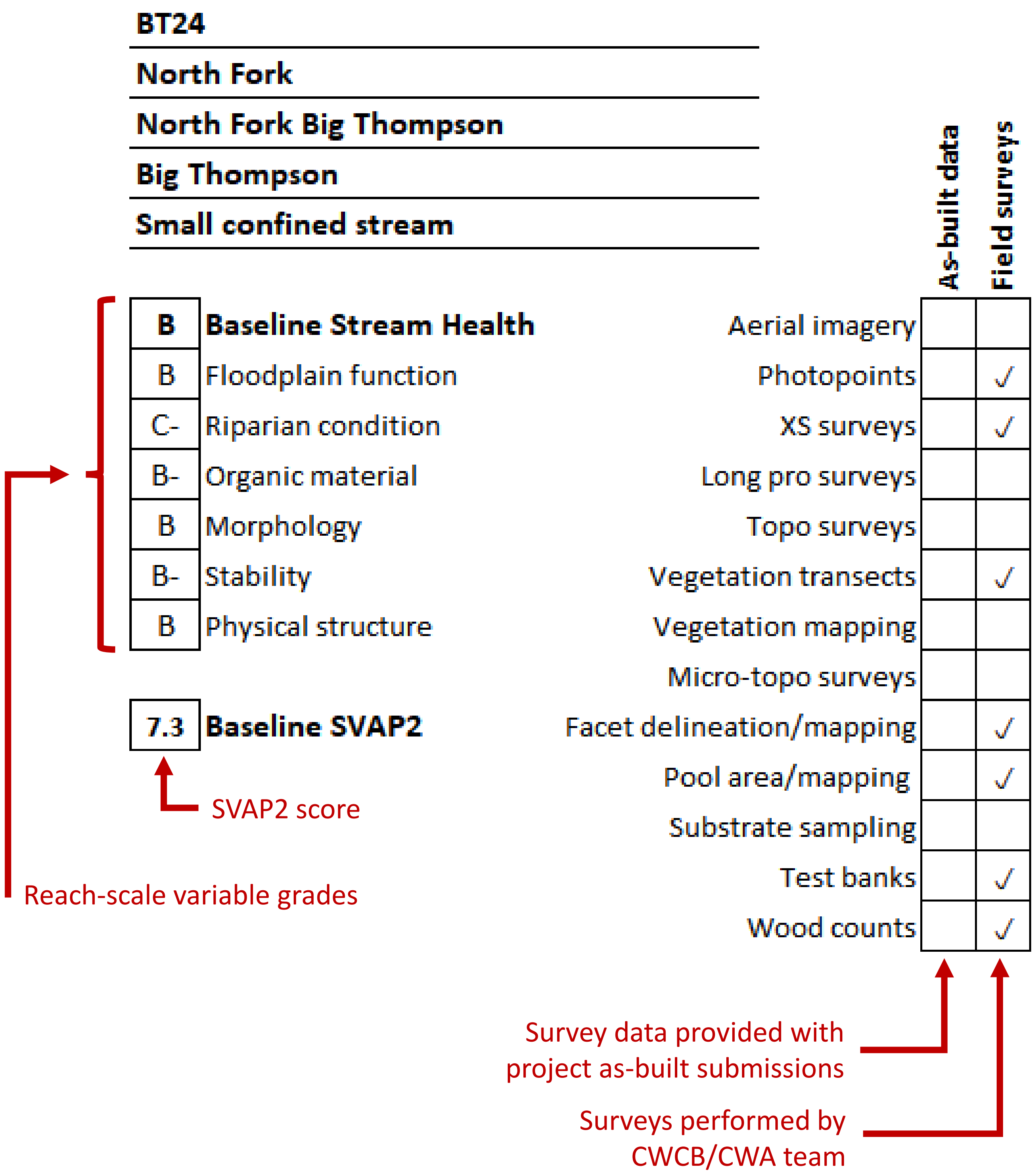
An overall grade for stream health is calculated as a weighted average of the variable scores for a reach variable scores using the following weights.

Variable	%
Flow Regime	15
Sediment Regime	5
Water Quality	10
Landscape	5
Floodplain Connectivity	10
Riparian Condition	15
Organic Material	5
Morphology	10
Stability	10
Physical Structure	10
Trophic Structure	5

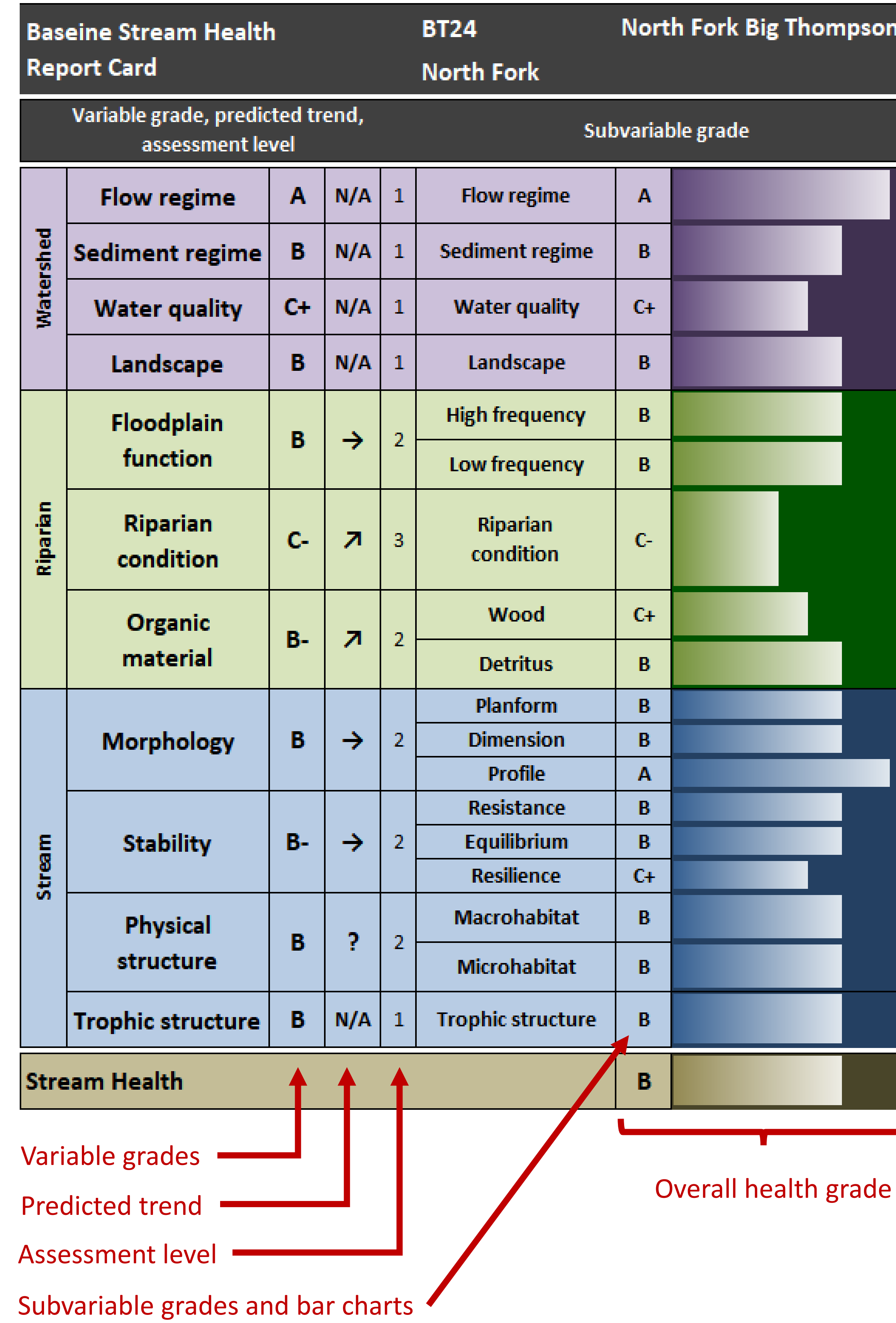
Appendix 3:

Project Baseline Summary Reports

These sheets are a guide to using the project baseline summary reports by walking through the parts of the report for the North Fork project reach (BT-24) Big Thompson



Summary Sheet



Report Card Sheet

Stream Health Assessment Worksheet		BT24 North Fork
Flow Regime	A	*Evaluated CDSS map and aerial imagery for watershed. No major dams or diversions upstream. No obvious induicators of flow regime alteration on site.*
Assessment level	1	*Purpose of assessment is baseline for monitoring reach-scale treatments that would not effect flow regime. Uncertainty OK.*
Confidence	Mod	
Sediment Regime	B	*Evaluated aerial imagery for watershed. No major land use changes. Channel erosion issues related to encroachment and crossings were evident in 2013 flood. No dams.*
Assessment level	1	*Purpose of assessment is baseline for monitoring reach-scale treatments that would not effect sediment supply. Uncertainty OK.*
Confidence	Mod	
Water Quality	C+	*Evaluated CDPHE WQCD map and list and aerial imagery of watershed. This reach is on segment COSPBT-07 which is on the 303d list as a high priority for copper.*
Assessment level	1	*Purpose of assessment is baseline for monitoring reach-scale treatments that do not effect quality of water supply. Uncertainty OK.*
Confidence	Mod	
Landscape connectivity	B	*Evaluated aerial imagery and on-site reconnaissance, CDSS to help locate potential migration barriers (diversion dams). Minor stressors present*
Assessment level	1	*Purpose of assessment is baseline for monitoring reach-scale treatments that have minimal effect on landscape connectivity. Uncertainty OK.*
Confidence	Mod	
Floodplain function	B	*Flood modeling available in as-builts. XS, routine site evaluation. Some encroachment on low-frequency floodplain. Constructed floodplain benches probably activate at Q1-2. This site is borderline confined - partially confined. Less confined at lower end.*
High-frequency floodplain	B	
Low-frequency floodplain	B	
Predicted trend	→	
Assessment level	2	*Q1-2 floodplain does not appear to be limited by bench elevation/bank height. Inundation/saturation could be verified in field and/or by vegetation types in future.*
Confidence	Mod	
Riparian Condition	C-	*New constructed riparian area is mostly bare, recently planted, detailed planting plan, some fine soil present, appropriate hydrology. Some good vegetation on undisturbed floodplain.*
Predicted trend	↗	
Assessment level	3	*Poor due to recent disturbance and construction. Predict rapid recovery due to soil and hydo conditions. Monitor vegetation.*
Confidence	Mod	
Organic Material	B-	*Channel wood and recruitment limited by debris removal and recent maintenance. Partially mitigated by wood installation in channel and scattred wood on floodplain.*
Wood	C+	
Detritus	B	
Predicted trend	↗	
Assessment level	2	*Debris removal evident after flood, expect improvement with inflows from upstream and development of riparian vegetation on site. Monitor wood.*
Confidence	Mod	
Morphology	B	*Planform, dimension, profile is generally appropriate to valley type and process domain. Generally step-pool B-type stream with some riffle-pool C-type in less confined areas. Hardened banks and structures common.*
Planform	B	
Dimension	B	
Profile	A	
Predicted trend	→	
Assessment level	2	*Monitor changes to morphology.*
Confidence	Mod	
Stability	B-	*Resistance and resilience predicted to increase as bank vegetation improves. Equilibrium assumed to be good based on design and resistant channel material (threshold regime) but should be monitoried. Resilience impacted by development in CMZ (situation similar to pre-2013 flood)*
Resistance	B	
Equilibrium	B	
Resilience	C+	
Predicted trend	→	
Assessment level	2	*Monitor stability.*
Confidence	High	
Physical Structure	B	*Complex habitat features present and range of velocity-depth combinations. Primarily step-pool and cascade system is similar to reference. Some deep pool area and overhead cover.*
Macrohabitat	B	
Microhabitat	B	
Predicted trend	?	
Assessment level	2	*Could improve confidence with quantitative phyical habitat/structure surveys and comparison to reference. Monitor pool area, pool-maintenance, and facet diversity.*
Confidence	Mod	
Trophic Structure	B	*Estimated based on physical and chemical habitat characteristics, connectivity, basic field obs.*
Assessment level	1	*Low confidence. Could evaluate past studies, consult CPW, biological surveys to improve confidence.*
Confidence	Low	

Variable grade

Subvariable grades

Predicted trend

Assessment level

Confidence rating

Grading notes explain the rationale for the grade relative to grading guidelines.

Confidence notes explain uncertainty in the grading.

Assessment Sheet

Baseine SVAP2	BT24 North Fork	North Fork Big Thompson		
Element score and predicted trend			**Scoring note**	**Suspected causes for scores less than 5**
Channel condition	N/A	N/A	*Not scored, criteria does not apply to confined streams*	*N/A*
Hydrlogic alteration	9	→	*No major diversions, dams, etc. Natural flow regime*	*N/A*
Bank stability	7	→	*Mostly armored by rock and wood.*	*N/A*
Riparian quantity	4	↗	*Vegetation gaps exceed 40%.*	*Encroachment, new construction.*
Riparian quality	4	↗	*Mostly bare area on recently constructed floodplain*	*New construction, recently re-planted*
Canopy cover	2	↗	*< 20% shaded*	*No mature canopy on recently constructed floodplain.*
Water appearance	9	→	*Clarity appropriate to site (though limited observation) no apparent sheen or precipitates*	*N/A*
Nutrient enrichment	9	→	*Clear water, little algal growth*	*N/A*
Manure	8	→	*No livestock access, some impact from adjacent campground?*	*N/A*
Pools	8	?	*Deep pools present, some bottom obscured by wood, shallow pools also present*	*N/A*
Barriers	9	→	*No significant artificial migration barriers*	*N/A*
Habitat complexity	8	?	*8-9 of listed habitat features present*	*N/A*
Invertebrates	N/A	N/A	*Not scored.*	*N/A*
Embeddedness	10	?	*Embeddednessless than 10%*	*N/A*
Salinity	N/A	N/A	*Not scored.*	*N/A*
Sum score	87			
# elements scored	12			
Overall score	7.3	Good		

Predicted trend

Scoring notes

Suspected causes

SVAP2 element scores

SVAP2 Sheet

Survey Sheet

Checklist showing baseline survey data availability for common stream monitoring parameters

Data sources	Aerial imagery	Photopoints	XS surveys	Long pro surveys	Topo surveys	Vegetation transects	Vegetation mapping	Facet delineation/mapping	Pool area/mapping	Substrate sampling/embeddedness	Test banks	Wood counts
Public	✓											
As-builts												
Baseline field surveys		✓	✓			✓		✓	✓		✓	✓

Data available from public sources

Data provided in background information

Data acquired in baseline field surveys

Stream Health Factors

Baseline condition (Grade)	Predicted Trend	Stream Health Factors	Aerial imagery	Photopoints	XS surveys	Long pro surveys	Topo surveys	Vegetation transects	Vegetation mapping	Facet delineation/mapping	Pool area/mapping	Substrate sampling/embeddedness	Test banks	Wood counts
B	→	Floodplain function	✓	✓	✓									
C-	↗	Riparian condition	✓	✓				✓						
B-	↗	Organic material		✓				✓						✓
B	→	Morphology	✓	✓	✓									
B-	→	Stability	✓	✓	✓								✓	
B	?	Physical structure		✓	✓					✓	✓		✓	✓
B	N/A	Trophic structure												

Matrix showing survey data availability for informing reach-scale stream health factors. (Variable grades and predicted trends are shown to left.)

Stated stream health and resilience objectives

Objectives	Aerial imagery	Photopoints	XS surveys	Long pro surveys	Topo surveys	Vegetation transects	Vegetation mapping	Facet delineation/mapping	Pool area/mapping	Substrate sampling/embeddedness	Test banks	Wood counts
Decreased sediment loading											✓	
Improved riparian habitat by adding vegetation	✓	✓	✓			✓	✓					
In-stream habitat complexity		✓	✓					✓	✓			✓

Matrix showing survey data availability for informing project objectives stated in design report

Notes

Many photos available in the as-built report, but locations not specified
Post-construction land survey data indicated on as-built report but not provided.

Notes about data availability

Parameter Sheet

Baseline data availability for common parameters	
Floodplain width (Q_{bkf}, Q_2, Q_{10}, etc)	✓
Floodplain area (Q_{bkf}, Q_2, Q_{10}, etc)	
Overbank return interval	✓
Riparian wetland area (delineation)	
Prevalence Index (hydric plants)	✓
Species diversity/richness index	✓
Percent woody cover	✓
Percent cover by guild	✓
Percent cover by species	✓
NRCS Root strength index	✓
Noxious weed cover	✓
In-stream wood (number, volume, mass)	✓
Floodplain wood (number, volume, mass)	
Detritus (volume, mass)	
Stream type/evolutionary stage	✓
Sinuosity (stream length/valley length)	✓
Branching rate, bifurcation ratio	✓
Meander width (or ratio)	✓
Cross sectional area (capacity)	✓
Entrenchment Ratio	✓
Bank Height Ratio	✓
Cross section area	✓
Width/depth ratio	✓
Slope (bankfull, water surface)	✓
Aggradation rate	✓
Degradation rate	✓
Shear stress/critical shear stress	
Lateral accretion rate	✓
Erosion per length (volume, mass)	
Length or area by depth/velocity class	✓
Pool area (RPD>1.0, 1.5, 2.0)	✓
Overhead cover (length or area)	
Substrate (size, distribution, % fines)	
Embeddedness	
Fish biomass/number by species/class	
Invertebrate biomass/number by species/class	
Invertebrate impact indices	

Background Information Sheet

	EWP Baseline Assessment Information Request - North Fork				
			Provided?		
	Information Item	Format	Yes	No	Comment/Answer
Pre-project Conditions					
1	Pre-project photographs	JPG	X		12/5/2016
2	Pre-project SVAP Assessment	PDF/Word	X		12/5/2016
Project Planning and Design					
3	Design narrative	PDF/Word	X		Section 3, Basis of Design Report (NFBigT_NF_EWP_Final Design Report.pdf)
4	General project goals	PDF/Word	X		Section 2, Basis of Design Report (NFBigT_NF_EWP_Final Design Report.pdf)
5	Clean Water Act permit from USACE, including special conditions, performance standards, and monitoring requirements	PDF/Word	X		PCN and USACE NWP verification
6	Wetland delineation report	PDF/Word		X	Have wetland map but no report
7	Monitoring plan	PDF/Word		X	D_North Fork OIM Plan.doc
8	Vegetation plan	PDF/Word	X		Appx C, Basis of Design Report (NFBigT_NF_EWP_Final Design Report.pdf) - pdf p 134
9	What flow was the design built to?		X		Table 7.1, Basis of Design Report (NFBigT_NF_EWP_Final Design Report.pdf)
10	Is the project on schedule?		X		Yes
11	What is the construction actual/planned start date? **(Indicate which)**		X		1/30/2017 (actual)
12	What is the construction actual / planned end date ? **(Indicate which)**		X		5/5/2017 (actual)
As-built Conditions					
13	Construction completion report to sponsor	PDF/Word	X		Final Construction Report (EWP_Final Construction Report Compiled.pdf)
14	Construction completion report to USACE	PDF/Word		X	Section 9 of Final Construction Report indicates that closeout of USACE permit is in process by Larimer County
15	As-built drawings including structure locations, treatments, channel alignment, cross-sections and other important features	PDF/Word	X		Appx C, Final Construction Report (EWP_Final Construction Report Compiled.pdf)
16	As-built drawings in CAD or Shapefile format (**Indicate which)**	.dwg or .shp		X	None
17	As-built narrative description	PDF/Word	X		In report
18	Cross-section points as x,y,z coordinates	text or excel file		X	None
19	Charted as-built cross section, with end point coordinates.	Spreadsheet		X	None
20	Drone footage? Indicate pre-, during- or post-project	Varies		X	None

This sheet lists the background information that was requested by CWCB. We used this information in baseline assessments and to plan monitoring strategies on project reaches.
All this information will be available to parties for use in monitoring programs.
The Comment/Answer column shows where to look for the information in the compiled documents.