Design Memorandum

Upper Fourmile Creek Stream Restoration 30% Design

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August 2016

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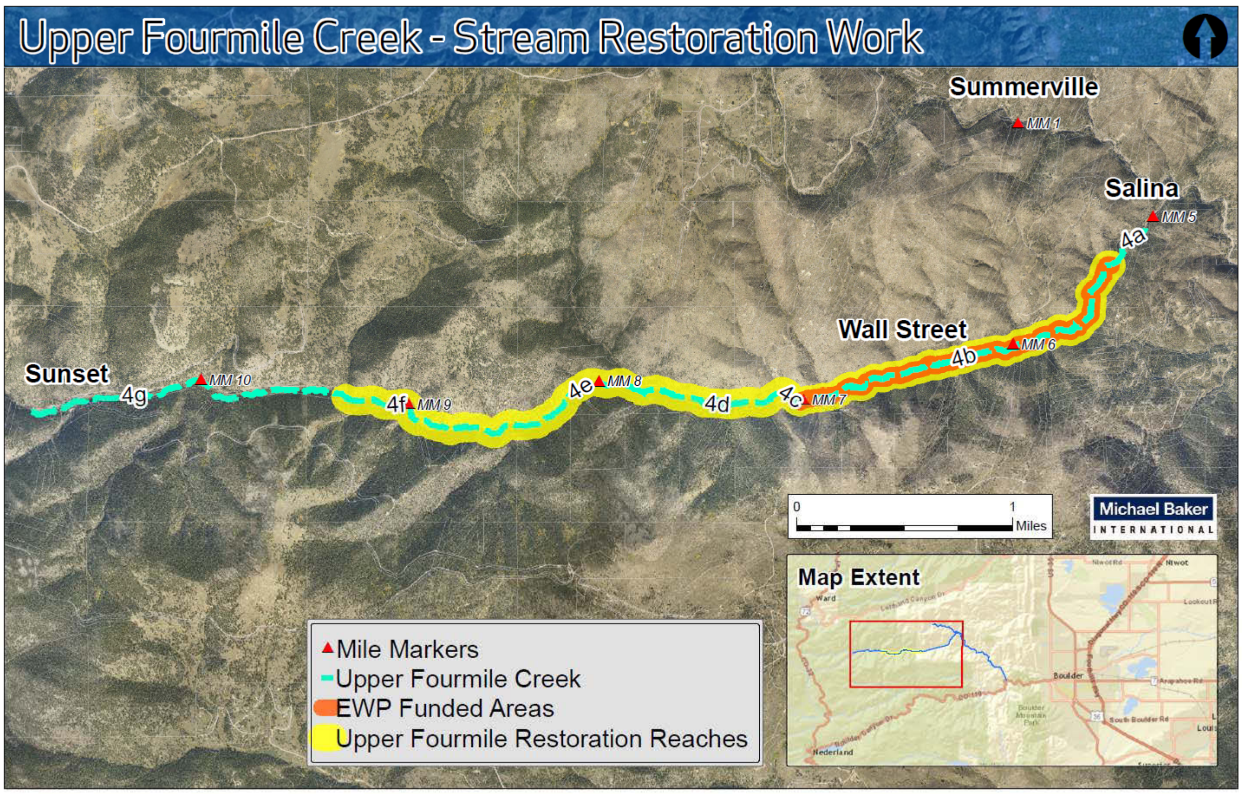
Project Location & General Watershed Description

Fourmile Creek is a perennial stream located within the Fourmile Watershed, which is approximately 2.5 miles west of the City of Boulder on Highway 119. The extents of the Upper Fourmile Creek Stream Restoration project are shown in Figure 1. The project begins approximately 2,500 feet upstream of the intersection of Gold Run Road and Fourmile Canyon Drive and extends upstream to a point approximately 6,600 feet downstream of the intersection of Fourmile Canyon Drive and the Switzerland Trail. The total length of this project is approximately 4.2 miles.

Figure 1 - Upper Fourmile Creek Stream Restoration Project Limits



The project stream length was broken into three reaches based on significant changes in drainage area. Reach 1 begins at the upstream extents of the project and extends downstream to the confluence of the Long Gulch tributary. Reach 2 begins at the end of Reach 1 and extends downstream to the confluence of the Emerson Gulch tributary. Reach 3 begins at the downstream end of Reach 2 and extends approximately 8,600 feet downstream. The drainage areas of Reaches 1, 2, and 3 are 11.2 square miles, 13.8 square miles, and 15.9 square miles, respectively. The watershed elevation varies between 6,700 feet at the downstream end of the project to 11,500 feet at the headwaters, approximately 2 miles west of the Peak to Peak Highway. The mean annual precipitation for this portion of the watershed is approximately 23 inches per year. No major hydrologic controls are present within this watershed.

Fourmile Canyon Fire

The Fourmile Canyon Fire (September 6-10, 2010) burned 23 percent of the Fourmile Creek Watershed, destroyed more than 160 homes, and was one of the costliest wildfires in Colorado history. The wildfire left the watershed at significant risk of flooding, substantial erosion and debris flows, and water quality degradation. 'Typical' summer thunderstorms in 2011 and 2012 produced flash floods that transported a significant amount of sediment and debris providing clear evidence of the updated risk in the watershed. While post-fire vegetation establishment was favorable by 2013 (pre-flood), the flood risk within the watershed was still elevated because of the lengthy time required for tree regeneration.

September 2013 Flood

Beginning on September 11th, 2013, significant flash flooding occurred in north-central Colorado on the eastern side of the Continental Divide. The September 2013 flood revealed infrastructure limitations as well as areas of significant risk. Larimer, Weld, and Boulder counties were among the most devastated of the 18 Colorado counties included in the September 24, 2013 Presidential Disaster Declaration. The historic rainfall, which reached over 17 inches of rain recorded by September 15th, brought yearly precipitation levels to over 30 inches (the most rain recorded in 120 years of hydrological record).

Along the Fourmile Creek corridor the flood destroyed large sections of local roads, residential properties, and private residential accesses. A high percentage of local residents were heavily affected by the flood and some were stranded for extended periods of time. Together, the high peak flows, the long duration of the event, and the sediment and debris inputs from landslides/debris flows resulted in significant infrastructure damage, both public and private. In addition to damaged infrastructure, the flood impacts on the creek corridor included migrations of the stream and significant in-stream and off-channel deposition and erosion.

These changes included damaging debris flows from fire-affected hillsides, destruction of tributary culverts, heavy erosion and deposition of material in tributaries, and the conveyance and deposition of debris included rocks, cobble, sand, trees, and trash throughout the stream corridor.

Geology & Soils

Upper Fourmile Creek had been mapped as a part of the Gold Run Quadrangle.

The geology of the Upper Fourmile Creek watershed is defined in the by extensive deposits of Precambrian biotite gneiss. As well, the watershed has extensive Precambrian intrusions of Precambrian Granodiorite with dots and lenses of mafic material. The watershed is bisected by a significant mafic dike of the middle Proterozoic which is evident in the large step pool features in Reach 2. The valley is filled with an irregular layering of sand, gravel, boulders, and granodiorite in various stages of weathering deposited during the Holocene period.

Geology in the watershed consists mostly of granite, with some siltstone and sandstone. This watershed is comprised of alluvial valleys with ranging widths. Most of the soils in the watershed can be classified as loamy or sandy alluvium and are typically well-drained soils meaning that they have a high rate of infiltration.

Ecology

This portion of Fourmile Creek is in the Crystalline Mid-Elevation Forests portion of the Southern Rockies Ecoregion, which is characterized by partially glaciated low mountain ridges and slopes with moderate to high-gradient streams (Chapman, et al. 2006). This steep, rugged watershed is generally dominated by lodgepole pine (Pinus contorta) forest in the upper elevations and ponderosa pine (Pinus ponderosa) woodland in the lower elevations. Substantial pockets of Douglas fir (Pseudotsuga menziesii) and quaking aspen (Populus tremuloides) are also found in some locations. Major wildlife species found in the watershed include mule deer, elk, black bear, coyote, and fox. The watershed also includes substantial areas of riparian habitat (including wetlands) along Fourmile Creek, especially in areas where a wider floodplain is present.

Aquatic Resources

The fishery objectives for this restoration project are habitat improvement and bi-directional fish passage throughout the reach for Brook Trout and other resident coldwater species. Brook Trout were chosen as the target species, as numerous Brook Trout were observed within the Project site during initial surveys. Macroinvertebrates were observed during field work, but specific species were not identified. All recommendations for improving native fish habitat are also conducive to the restoration of macroinvertebrate habitat. A summary of the aquatic resources assessment and recommendations is provided below. The complete memorandum of findings is provided in Appendix A.

Project Background

Fourmile Creek incurred significant damage during the September 2013 Flood. The flood and debris flow straightened the entire creek alignment, over widened the channel cross section, and modified the channel profile through the cutting and depositing of sediment. A heat map showing zones of erosion and deposition is provided in Appendix A. Aquatic and terrestrial habitat was severely impacted and/or destroyed and most riparian vegetation was removed by the flood.

This change in channel dimension (cross-section), pattern (planform), and profile (slope) has resulted in unstable channel conditions throughout the extents of this project. The resulting impact of these changes is a general inability of the existing channel to move water and sediment efficiently through the system without resulting in channel degradation, aggradation, and bank erosion.

Riparian and upland vegetation provides a substantial amount of natural earth stabilization for both the channel, floodplain, and valley. Much of this natural vegetation adjacent to Fourmile Creek was stripped during the flood event, which further reduced the overall stability of the existing stream system. Above average precipitation was received in the watershed, and along the Front Range of Colorado, during the summer of 2015. As a result, both natural and invasive vegetation has begun to grow back faster than expected. However, there is still a general lack of riparian vegetation in this system.

This project was derived from the adjacent Fourmile Canyon Drive roadway project. Fourmile Canyon Drive was also severely damaged during the September 2013 Flood and Boulder County (County) secured funding to do both the design and reconstruction of Fourmile Canyon Drive upstream of the confluence with Gold Run. The County decided to develop restoration plans for this section of Upper Fourmile Creek for two reasons:

1. There is a high degree of interaction between the road and creek and making site-specific improvements only at locations where the road crosses the creek puts these isolated improvements at risk of failing due to adjacent, unaddressed, instabilities in the creek.
2. The Fourmile Creek Watershed Master Plan (Master Plan) identified Reaches 4c through 4f as needing restoration designs in order to expedite recovery of the system.

The Master Plan outlined recommendations for restoring the stream geometry of Fourmile Creek along with recommended locations for channel bank stabilization and sediment removal for Reaches 4c through 4f. During the development of the Master Plan it was noted that Reach 4b was in good condition and no channel improvements were recommended. The reasoning for this was because it was expected that vegetation would reestablish over time and in-stream habitat would continue to improve as the channel continued to heal through natural processes. However, since completion of the Master Plan, Fourmile Creek experienced two heavy runoff events in the spring of 2014 and 2015. These events caused damage to Reach 4b in the form of channel erosion and deposition, lateral channel migration, and vertical degradation leaving this section of Fourmile Creek in a state of instability. If unaddressed, ongoing channel adjustment could adversely impact adjacent homes and Fourmile Canyon Drive. As a result, Reach 4b was added to the scope of this project.

Funding has recently been secured for the construction of Fourmile Creek by both the County and the Fourmile Coalition. The Fourmile Coalition will be responsible for implementing approximately one-mile segment of Reach 4b and the County will be implementing the remainder of the project. It is the intent of the County to construct Fourmile Creek along with Fourmile Canyon Drive. The goal for constructing both projects at once is to minimize disturbance in the watershed by having only one construction process versus two, take advantage of cost savings by having one contractor manage both projects, and optimize the interaction between the road and creek by constructing both at once.

Goals & Objectives

The general philosophy towards restoring Fourmile Creek was to implement the principles of natural channel design. The definition of natural channel design is to establish the physical, chemical, and biological functions of the river system that are self-regulating and emulate the natural stable form within the constraints imposed by the larger landscape conditions (Wildland Hydrology, 2006). It is important to restore all components of a stream system that are required to make it sustainable, rather than just focusing on what is visible. A river system includes not only the river channel but also its related components, including adjacent floodplains, wetlands, and associated riparian and biological communities. Defining the natural, stable form of a river involves re-establishing a physical stability that integrates the processes responsible for creating and maintaining the dimension, pattern and profile of river channels.

This project focused on the restoration of the bankfull channel and adjacent floodplain. Increasing major flood conveyance capacity within Fourmile Creek was not a design objective of this project, however, an objective of this project is to not increase the flood risk compared to what is defined on the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM). Fourmile Creek resides in a confined canyon along with many private residences and Fourmile Canyon Drive. Substantially increasing the flood-carrying capacity within Fourmile Creek would significantly impact many private residences and also require that the footprint of Fourmile Canyon Drive be reduced, which conflicts with many of Boulder County's objectives for flood recovery. However, it is important to note that flood risk will be reduced with this design as described throughout this memorandum.

A project kickoff meeting was held with the County on March 10th, 2015 to discuss project goals and objectives, which are in alignment with the definition of natural channel design, and consist of:

- Restoring the natural channel to the extent practical and within the current watershed setting
- Restoring aquatic and terrestrial habitat
- Restoring ecological connectivity
- Restoring wetland and riparian areas

- Reducing flood risk
- Integrating the above restoration strategies with the adjacent Fourmile Canyon Drive project
- Removing and mitigating mine tailings where possible

Stream Assessments

Project Reach

Project reach assessments were performed over a period of ten days using protocols outlined in Watershed Assessment of River Stability and Sediment Supply (Wildland Hydrology, 2006) to quantify the degree of impairment for the existing creek system related to hydrologic, geomorphic, ecologic, and biologic conditions. The project was divided into three major sub-reaches based on notable changes in drainage area at the confluence of incoming tributaries. Sub-reach delineations are shown on the Fourmile Creek 30% Stream Restoration Plans.

General project reach assessments included:

- Initial site assessment to document existing conditions with field notes and photographs.
- Identification of major geomorphic and sediment transport tendencies including transport and deposition zones along with potential sediment sources and sinks.
- A review of historical, pre- and post-flood aerial photography to evaluate changes in channel and floodplain conditions over time.
- A review of pre- and post-flood LiDAR data to evaluate changes in channel and floodplain conditions over time along with zones of channel erosion and deposition.
- Identification of vertical and lateral controls, such as roadways and utilities, in the vicinity of the project reach.
- Identification of flood debris.

Detailed project reach assessments consisted of the following:

- Hydrologic – To evaluate flow regime and peak flow characteristics.
- Geomorphic – To evaluate existing channel dimension, pattern, and profile characteristics including sediment samples and classification of existing and potential stream type.
- Ecologic – To evaluate riparian and upland vegetation along with the identification of wetlands.
- Biologic – To evaluate quality of in-stream habitat, presence of fish species, and presence of macroinvertebrates.
- Stability – To evaluate vertical and lateral channel stability processes that are leading to erosion, deposition, and bank erosion.
- Sediment Competence – To evaluate aggradation and degradation tendencies within each reach. Calculations were performed using riffle pebble count information and point bar samples of maximum particle size.

A gradation analysis on point bar material is typically performed to estimate material gradation, size, and weight that is transported during bankfull flow events. This analysis was not completed because the alluvium in the valley became distorted during the flood and enough time hasn't elapsed for natural sorting to occur. Therefore, a gradation analysis on point bar material is likely not representative of the sediment that is transported during bankfull flow events and was not performed for this project.

Additionally, a subsequent field assessment was conducted to identify other opportunities and constraints for consideration during design. These items consist of:

- Existing trees
- In-stream and riparian habitat features such as well-established pools and wetlands
- Private culvert and bridge crossings
- Areas of well-established vegetation that should be preserved to the extent possible
- Locations for potential wetland creation and fish rearing habitat
- Locations for potential sediment storage
- On-site materials that can be used for construction
- Opportunities for improved channel alignment

Project reach assessment information was compiled for all three reaches and is provided in Appendix A. Due to the size and scope of this project, existing conditions assessments were based on an average of observations throughout each reach. Representative riffle cross sections were also selected within each reach to evaluate bankfull hydraulics and sediment transport conditions. The estimated bankfull flows were used to evaluate existing conditions within each cross section. A summary of the project reach assessments is provided in Table 1. An overall assessment of channel condition was made using the Pfankuch Channel Stability Rating Procedure.

Table 1: Project Reach Assessment Summary

Reach	Channel Stability Rating	Rosgen Stream Type	Profile Bedform Classification	Entrenchment	Reach Avg. Slope (ft/ft)	Competence Analysis	W/D @ Bankfull Stage
1	Fair	C4b	Riffle-Pool	5.57	0.034	Degrading	12
2	Poor	B4	Riffle-Pool/Cascade-Pool	2.11	0.042	Degrading	22
3	Poor	B4	Riffle-Pool	2.20	0.032	Degrading	12

Ecologic Assessment

Based on field visits conducted in spring and summer 2016, much of the riparian habitat was impaired as a result of the 2013 Flood since it was buried under debris or sediment, washed downstream, or left high above a degraded channel without a sustainable water source. Although impaired, the riparian vegetation is still relatively widespread and can be found along most portions of the immediate channel banks and in secondary channels. However, most of these areas have lost their herbaceous understory to erosion and have been left with very steep and exposed banks, making them very vulnerable to future erosion. Generally, the mature deciduous trees on the floodplain survived the flood, while many of the conifers close to the main channel died as a result of altered hydrology or being partially buried. There are substantial off-channel wetlands present, especially in wider floodplain areas that were less damaged by the flood. Many of these areas have recovered well and don't appear to be substantially impaired.

The most common woody riparian species found along the channel and in secondary channel areas are water birch (Betula occidentalis) and speckled alder (Alnus incana), including many areas with an overstory of narrowleaf cottonwood (Populus angustifolia) and/or ponderosa pine. Other common riparian shrubs on the lower floodplain include red-osier (Cornus alba) and various willows (Salix spp.). The willows most often include sandbar willow (Salix exigua), strapleaf willow (S. liguilfolia), dewystem willow (S. irrorata), park willow (S. monticola), Drummond's willow (S. drummondiana), and gray willow (S. bebbiana). Other riparian shrubs present in slightly drier parts of the valley bottom often include Woods' rose (Rosa woodsii), chokecherry (Prunus virginiana), common red raspberry (Rubus idaeus), and gooseberry (Ribes spp.).

Herbaceous riparian vegetation along this portion of Fourmile Creek is often naturally somewhat limited due to shading, but is even sparser in some areas as a result of the 2013 Flood. The most common species found along the channel and in secondary channel areas include bluejoint (Calamagrostis canadensis), black bent (Agrostis gigantea), field horsetail (Equisetum arvense), and American cow parsnip (Heracleum maximum). Other species common in slightly drier parts of the valley bottom include many non-native pasture grasses like smooth brome (Bromus inermis), common timothy (Phleum pratense), orchard grass (Dactylis glomerata), creeping wildrye (Elymus repens), fescue (Festuca spp.), flatstem bluegrass (Poa compressa), and Kentucky bluegrass (Poa pratensis). Common native species observed in these areas include slender wildrye (Elymus trachycaulus), nodding wildrye (Elymus canadensis), common yarrow (Achillea millefolium), goldenrod (Solidago spp.), and black-eyed Susan (Rudbeckia hirta).

Many Colorado-listed noxious weeds are also present in the watershed, especially along the watercourses and roadways. The most common noxious weeds observed along this reach of Fourmile Creek during field visits include, creeping wildrye (Elymus repens), musk thistle (Carduus nutans), diffuse knapweed (Centaurea diffusa), Canada thistle (Cirsium arvense), bull thistle (Cirsium vulgare), oxeye daisy (Chrysanthemum leucanthemum), Chinese clematis (Clematis orientalis), myrtle spurge (Euphorbia myrsinites), St. John's wort (Hypericum perforatum), yellow toadflax (Linaria vulgaris), scentless chamomile (Matricaria perforata), bouncing bet (Saponaria officinalis), and common mullein (Verbascum thapsus).

Aquatic Resources Survey

A habitat survey was performed in November and December 2015 to evaluate existing habitat conditions and limiting factors within the scope of this project. A formal habitat survey was conducted at four sites on Fourmile Creek to represent four different distinct geomorphic conditions found within the Project site: partially healed, aggraded areas, incising/downcutting, and overwidened/homogenous. The habitat survey methods were based on protocols developed by the U.S. Forest Service (Overton 1997) and modified for use in small Colorado streams. The modified surveys use the same basic methods as the U.S. Forest Service inventory, but characteristics that are not relevant to small Colorado streams were not measured. Habitat units (riffles, runs, glides, and pools) were identified and measured individually. Pools were subclassified by formative structures (meanders, large woody debris, or boulders), and riffles were subclassified by gradient (low, high). Cascades and step pools were not present within the surveyed areas, although both were found within the Project site. Length, wetted width, average and maximum depth, substrate type, percentages of undercut and eroding banks, and the type of bank vegetation were measured within each habitat unit.

A summary of observed limiting factors is outlined below:

- A high frequency of bank erosion
- Channel disconnection from the floodplain
- Lack of pool habitat
- High percentage of fine substrates

Fourmile Creek is disconnected from its floodplain throughout much of the Project site, especially in areas bordered by roads. While limited connectivity with the floodplain is natural in canyon reaches, a total lack of access to the floodplain for extended distances is not. Restoring floodplain access in lower-gradient areas could provide temporary refugia for trout during high flows and increase system productivity by allowing the exchange of materials and nutrients between terrestrial and aquatic habitats.

Fourmile Creek lacks deep pools throughout most of the Project site, particularly the reaches adjacent to Alpine Gulch Road. Pools serve as important habitat for adult trout. They offer thermal refugia during the summer and winter, when temperature extremes limit the suitability of shallower habitats, and the greater water depths found in pools help to protect larger, adult fish from terrestrial predators. Providing a mix of habitats, including pools of varying depth and complexity, in addition to the riffles, runs, and glides already found in most reaches, will greatly increase habitat quality within the Project Site.

Additionally, Fourmile Creek would benefit from bank stabilization. Extensive erosion has resulted in a near-total loss of undercut bank habitat, which provides cover for all life stages of trout. These unstable banks could also serve as a source of fine sediment to the stream. Fine sediments can fill in spaces between larger substrates, decreasing habitat suitability for some benthic macroinvertebrates and spawning habitat for trout. Excess sediments can also reduce pool depths, thus decreasing their quality. Increasing bank stability can both provide better fish habitat in the form of undercut banks, while simultaneously reducing possible inputs of fine sediments.

Reference Reach

Reference reach information was obtained, and used as a starting point, for developing design parameters for restoring impaired reaches. A reference reach is a stable stream that has adjusted to existing watershed conditions in such a way as to be self-maintaining. Reference reaches do not need to be pristine systems, rather, they need to have been stable over a long period of time and in a similar hydro-physiographic region as the project reach. A hydro-physiographic region is an area where the hydrology, geology, and vegetation are relatively similar. A map of the physiographic regions in Colorado is provided in Figure 2. The yellow dots in this figure depict the locations where reference reach information was obtained and the blue star shows the location of this project. A map of the physiographic regions in the United States is provided in Figure 3, which shows the clear distinction and uniqueness of the physiographic region for this project and reference sites compared to adjacent regions. It is also recommended that reference reaches with within one order of magnitude of the project width, in terms of bankfull width (Wildland Hydrology 2013).

Figure 2 - USGS Map of Colorado Physiographic Provinces

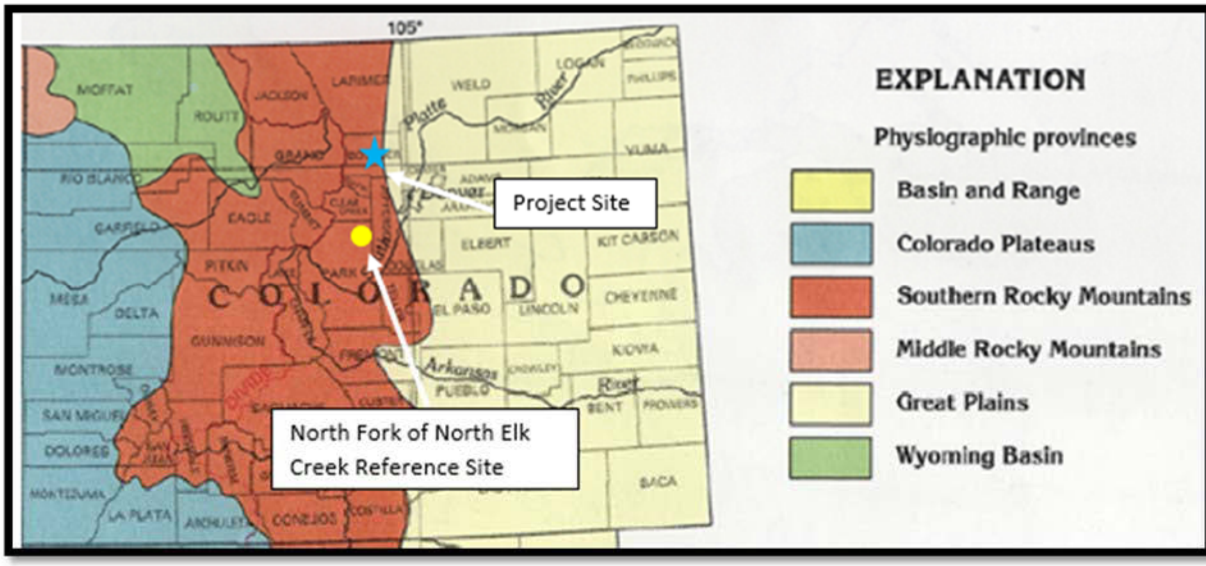
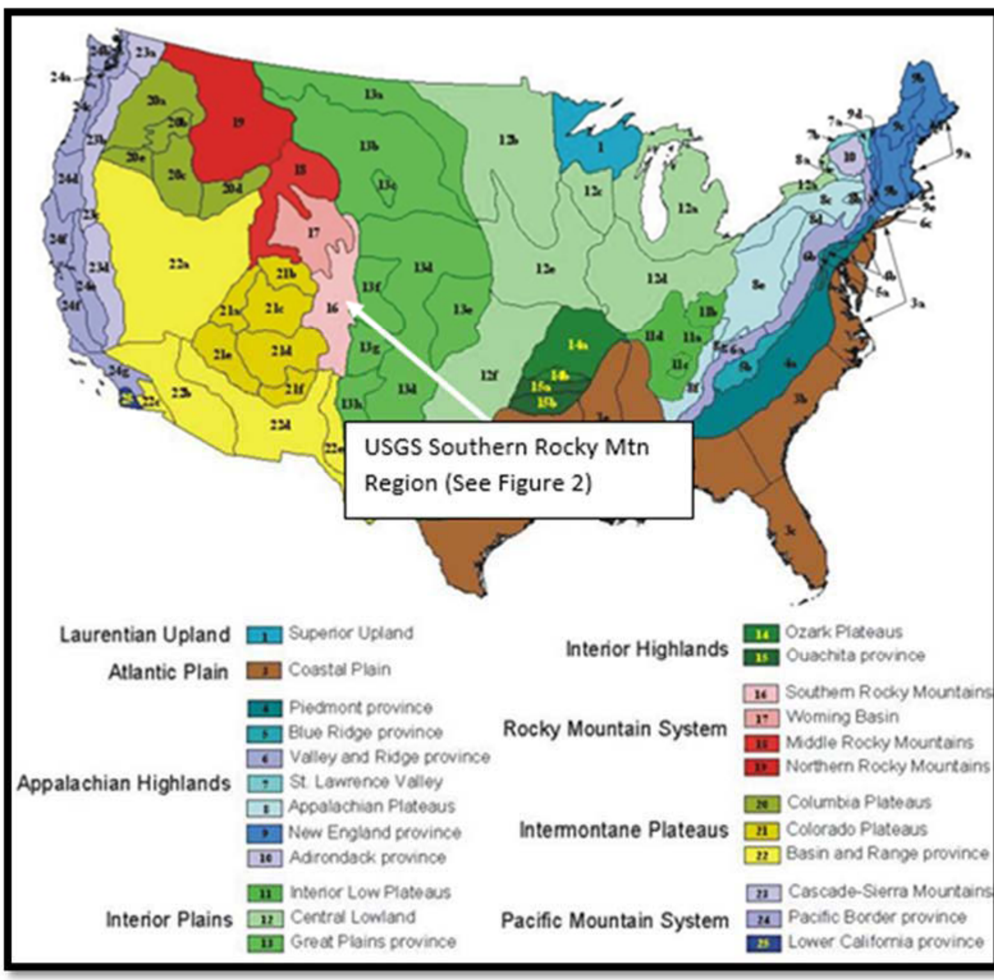


Figure 3 - NRCS Map of Physiographic Provinces in the United States



All assessment information that is collected for the project reach is also collected for the reference reach. Then, both data sets are compared, and scaled design parameters are developed for use as a starting point for restoring stable channel geometry for the project reach. Reference reach information can be obtained from the following locations, in order of preference:

1. Immediately upstream or downstream of the project reach
2. In same watershed as the project reach
3. In the same hydro-physiographic region as the project reach

Although Upper Fourmile Creek was severely impacted by the September 2013 flood, there are some small areas of reference information within the corridor that can be used for design purposes. During the assessment phase, our team collected cross section and profile information for portions of Upper Fourmile Creek that are in relatively stable condition. Reference information from Upper Fourmile Creek that was obtained and incorporated into our design includes:

- Bankfull channel cross section area
- Low flow channel width, depth, and area
- Point bar slopes
- Stable channel bank angles
- Riffle slope and pool slope
- Pool depths
- Pool spacing

Note that the above list is not an all-inclusive list of geomorphic information that is required to fully develop a restoration design for an impaired system. This list above only represents the stable geomorphic reference characteristics that were observed and measured in Upper Fourmile Creek.

In addition to collecting reference reach information, a pre-flood assessment of Upper Fourmile Creek geometry was performed. This assessment was performed using pre-flood LiDAR and aerial photographs to quantify approximate stable planform geometry, channel width, and slope that existed prior to the September 2013 flood and was used as an additional reference during the design process. This assessment is provided in Appendix A.

Reference reach assessment information was collected from the North Fork of North Elk Creek. This system is in stable condition, exists in the same physiographic region as Fourmile Creek, and contain similar watershed characteristics as Fourmile Creek. Additionally, the mean annual precipitation for this project and this reference reache is similar, as shown in Table 2. This information was used as a reference point for determining design parameters for restoring natural channel geometry in Fourmile Creek. Reference reach information is summarized in Appendix A.

Table 2: Comparison of Mean Annual Precipitation

Location	**Mean Annual Precipitation (inches)**
Project Site	23.1
North Fork of North Elk Creek (Reference Site)	25.5

Design Hydrology

Fourmile Creek, within the extents of this project, is not hydrologically controlled. There is a small water supply reservoir in the upper portion of the watershed, but it sits very near the watershed boundary and has very little influence on watershed hydrology.

A summary of the hydrologic analyses performed for this project is provided below. Bankfull flows and flood flows were evaluated, but the channel design was based on bankfull flow. Flood flow values were used for structure sizing, scour calculations, and floodplain modeling.

Flood Flow Estimation

USGS StreamStats

The United States Geological Survey (USGS) StreamStats was used to calculate a range of peak flows that could be expected to occur in this watershed. This analysis estimates peak flows by using regression equations developed for different geographic areas. In this case, regression equations are available for both Mountain Regions and Plains Regions. Since portions of the Fourmile Creek watershed exist in both regions, an area-averaged peak flow was calculated. The error associated with the regression equations in applicable to this project area ranges between 50% and 180%. A summary of this analysis is provided in Appendix A and summarized in Table 3.

Table 3: Summary of USGS StreamStats Analysis

Recurrence	Reach 1 (cfs)	Reach 2 (cfs)	Reach 3 (cfs)
	DA=11.2mi^2	DA=13.8mi^2	DA=15.9mi^2
2-year	78	90	99
5-year	118	137	158
10-year	145	171	203
25-year	181	218	269
50-year	221	268	337
100-year	252	310	404

Data from USGS StreamStats was used for reference when estimating bankfull flow for this watershed and comparison to FEMA regulatory 100-year flows.

FEMA Regulatory Flows

The regulatory flows for this project were obtained from a report published by the United States Army Corps of Engineers (USACE). A summary of the regulatory flows for this project are provided in Table 4. The FEMA Flood Insurance Rate Map (FIRM) is provided in Appendix A for reference.

Table 4: Summary of FEMA Regulatory Flows

Location	Peak Flow (cfs)			
	10-Year	50-year	100-Year	500-Year
U/S Limit of Study	490	1,320	1,850	3,700
Pennsylvania Gulch	520	1,780	2,510	4,750
Todd Gulch	580	2,020	2,860	4,750
Bear Gulch	580	2,020	2,860	5,420
Spring Gulch	670	2,310	3,270	6,160
Unnamed Gulch	790	2,670	3,750	7,060
Long Gulch	810	2,760	3,910	7,340
Unnamed Gulch	920	3,170	4,470	8,400
Between Schoolhouse Gulch and Melvina Gulch	990	3,370	4,720	8,850
U/S of Gold Run confluence	1,020	3,460	4,870	9,110

Note: Source: United States Army Corps of Engineers (USACE), Omaha District. 1977. Water and Related Land Resources Management Study, Metropolitan Denver and South Platte River and Tributaries, Colorado, Wyoming, and Nebraska, Volume V – Supporting Technical Reports Appendices, Appendix H – Hydrology. Also available at https://www-static.bouldercolorado.gov/docs/boulder-creek-floodplainoriginal-hydrologic-report-1-201304161054.pdf.

Bankfull Flow Estimation

Channel forming flow is the flow most responsible for shaping the channel cross section over time. There are several methods for estimating the channel forming flow including effective discharge, known recurrence interval, and bankfull flow. Effective discharge is the mean discharge that moves the largest fraction of annual sediment load over time and is estimated by the integration of the flow duration curve and sediment transport rating curve. Calculating effective discharge requires a long history of gage data and sediment transport data. The closest gage to the project site is USGS 06727500 (FOURMILE CREEK AT ORODELL, CO.). This gage is far downstream of the project site on Foumile Creek. Gage data at this location is limited and has been influenced by the 2010 fire and September 2013 flood and sediment transport data is not available at this gage. As a result, effective discharge was not calculated or used to estimate the channel forming flow. Alternately, estimates of bankfull flow and known recurrence interval were used to estimate the channel forming flow for Fourmile Creek.

Bankfull flow is a frequently occurring peak flow that occurs at a stage within the channel that corresponds to the incipient point of flooding. Bankfull flow is generally associated with a flood return period of 1-2 years and is generally responsible for moving the most sediment within the channel system over time. The role of the bankfull discharge in shaping the morphology of all alluvial channels is the fundamental principle behind natural channel design (Wildland Hydrology, 2006) and, therefore, needs to be estimated prior to beginning any design work. Estimations of bankfull flow, and bankfull cross section area, were made using the following methods:

1. Regional curves developed for Central Colorado that provide a means to estimate bankfull flow.
2. Field-based estimations that rely on presence of bankfull indicators and measurements of channel slope and cross section area. Bankfull stage indicators include:
    - The point at which the stream begins to spread out on the floodplain (requires knowledge of how the geomorphic floodplain should be configured)

- Highest active depositional feature
- Slope breaks in the channel bank/floodplain
- Change in particle size distribution
- Change in vegetation type
- Staining of rocks

3. Statistical analysis of gage data.
4. Comparison to the Elk Creek Reference Reach site.

Regional Curves

Regional curves of Drainage Area vs. Cross Section Area and Drainage Area vs. Bankfull Flow were obtained for Central Colorado (Wildland Hydrology 2007) to estimate bankfull flow and bankfull channel cross section area. A summary of estimated bankfull flow and cross section area are provided in Table 5. Regional curves are provided in Appendix A. Note that there are two regional curves that represent different precipitation regimes. The high precipitation curve is valid for areas that receive between 18 to 40 inches of rainfall per year. The Fourmile Creek watershed within the extents of this project receives about 21 inches of rainfall per year so the high precipitation curve is valid for this watershed.

Table 5: Central Colorado Regional Curve Estimations of Bankfull Flow & Area

Location	Bankfull Flow (cfs)	Bankfull Cross Section Area (ft^2)
Reach 1 (DA=11.2mi^2)	100-160	29-45
Reach 2 (DA=13.8mi^2)	120-180	30-48
Reach 3 (DA=15.9mi^2)	130-190	33-50

Field-Based Estimation

In damaged stream systems bankfull indicators are difficult to identify, and in some cases may not be present. Furthermore, only two years have elapsed since the September 2013 flood which is at the upper limit for the return period on a typical bankfull flow event meaning that statistically very few bankfull flow events could have been experienced since the flood. As a result, bankfull features may not have had a significant amount of time to reestablish since the flood. Regardless of this, observed bankfull features were surveyed and estimations of bankfull flow and cross section area were made at several locations along Fourmile Creek. Collected survey measurements were compared against regional curves of Drainage Area vs. Cross Section Area and Drainage Area vs. Bankfull Flow for the Central Colorado Mountains, both of which are provided in Appendix A. One data point from the field survey correlated fairly well with the regional curve data which confirmed applicability of the regional curve data to this project and further provided basis for determining the appropriate bankfull flow and bankfull cross section area as shown in Table 6.

Table 6: Field-Based Estimations of Bankfull Flow & Area

Location	Bankfull Flow (cfs)	Bankfull Cross Section Area (ft^2)
Reach 2 (DA=13.8mi^2)	156	36

Statistical Analysis of Gage Data

A statistical analysis of gage data was performed using the USGS PeakFQ software to calculate peak flows for the flood recurrences typically associated with the bankfull flow. This analysis was performed at gages in similar hydro-physiographic regions with a sufficient period of record to estimate the 1.25- to 2-year flow events. A total of ten gages were used to develop a regression equation of Drainage Area vs. Peak Flow. The results of the analysis were then applied to this project and are presented in Table 7. The regression analysis of the gage data, along with a comparison to the Central Colorado regional curve, is provided in Appendix A.

Table 7: Peak Flows Derived from Regression Analysis

Location	1.25-Year (cfs)	1.50-Year (cfs)	2-Year (cfs)
Reach 1 (DA=11.2mi^2)	155	178	206
Reach 2 (DA=13.8mi^2)	173	200	232
Reach 3 (DA=15.9mi^2)	186	216	251

Comparison to Reference Reach Survey

Bankfull flow estimations were made during the reference reach survey performed at the North Fork of North Elk Creek. This reference reach was selected because it is in a similar hydro-physiographic region as Fourmile Creek and both receive similar precipitation on an average-annual basis. Typical bankfull characteristics of the reference reach site are provided in Table 8 and are similar to what is predicted using the Central Colorado regional curves. Estimations of bankfull flow and bankfull cross section were plotted against the regional curves for Central Colorado and are provided in Appendix A.

Table 8: North Fork of North Elk Creek Typical Bankfull Characteristics

Location	Bankfull Flow (cfs)	Bankfull Cross Section Area (ft^2)
North Fork of North Elk Creek	110	18.3

Bankfull Flow Summary

A flood recurrence between the 1- and 2-year return intervals is typically associated with the bankfull flow (EWP Project Engineering Guidance 2013). The bankfull flow for the reference reach survey performed at the North Fork of North Elk Creek closely corresponds with the 1.25-year flood recurrence and the field-based estimation of bankfull flow is slightly lower than the 1.25-year flood recurrence estimated for Reach 2 in Table 7. As a result, it is assumed that the 1.25-year flood recurrence closely approximates the bankfull flow for Fourmile Creek.

Field-based estimations of bankfull flow are nearly the same as what is predicted by the Central Colorado regional curve, however, both of these data points are slightly lower than the 1.25-year flood recurrence. Field-based estimations of bankfull area are also nearly the same as what is predicted by the Central Colorado regional curve.

The bankfull flows for the proposed channel cross sections were selected based on closely matching field-based estimates of bankfull flow, the Central Colorado regional curve, and the 1.25-year flood recurrence. The selected bankfull flow and bankfull cross section area for the design of Fourmile Creek are provided in Table 9.

Table 9: Proposed Bankfull Channel Cross Section

Location	Avg. Design Slope (ft/ft)	Avg. Design Velocity (ft/s)	Bankfull Cross Section Area (ft^2)	Bankfull Flow (cfs)
Reach 1 (DA=11.2mi^2)	0.034	5.2	27.5	145
Reach 2 (DA=13.8mi^2)	0.042	5.7	29	160
Reach 3 (DA=15.9mi^2)	0.032	5.3	32.5	175

The proposed design contains several changes in channel slope in order to minimize earthwork, connect to critical floodplain elevations, and to match adjacent infrastructure elevations. Given that the length of this project is 4.2 miles and the scope is limited to 30% design, the average slopes for each of the design reaches was used for designing the proposed bankfull cross section.

Baseflow

The baseflow channel is important for providing habitat to aquatic organism throughout the year and allowing for aquatic organism passage. The baseflow channel also plays in important role in transporting the annual bedload for a stream system. The baseflow channel is embedded in the bottom of the bankfull channel section and is part of the multi-stage channel design. The average monthly flow for Fourmile Creek was obtained from USGS StreamStats and found to be between 2.5 and 4.3 cubic feet per second. These values reflect the average monthly flow for all months except for May through July, which are typically peak runoff months. Monthly average stream flow estimates are provided in Appendix A.

Natural Channel Design

A primary objective in the natural channel design process is to restore a channel geometry that can remain stable in the current watershed setting, and under the present constraints, with minimal structure. However, as previously discussed, there are many constraints in the Fourmile Creek watershed that prohibit the implementation of an ideal bankfull channel geometry and floodplain configuration. As a result, a design approach based on natural channel design principles, structural elements consistent with natural channel design objectives, ecological restoration, and hydraulic engineering was employed to develop a design solution for Fourmile Creek.

Approach

The approach towards restoring Fourmile Creek was to:

- Restore Fourmile Creek in the post-flood channel corridor, to the extent practical, in order to minimize earthwork and disturbance to vegetation that has become established since the 2013 Flood.
- Restore the natural channel dimension (cross section), pattern (planform), and profile (slope) to the extent practical to maximize stream stability at a lower cost, improve aquatic and terrestrial habitat, and optimize sediment transport and flood conveyance.

- Reconnect the channel to the adjacent floodplain to restore ecological connectivity and improve flood conveyance.
- Revegetate the channel and riparian zone with ecotypic plant species to restore habitat and ecological connectivity.
- Implement structure only where necessary to stabilize channel banks at risk of erosion, provide additional aquatic habitat, and protect the adjacent roadway and infrastructure.

Constraints

Ideally, when restoring a stream system, there are no limitations on what modifications can be made to channel geometry. The intent is that if the channel geometry can be fully restored to a stable state then additional structural stabilization may not be required. However, numerous constraints exist within the Fourmile Creek watershed that limit the ability to make changes to exiting channel geometry. These constraints include:

- Preserving existing, well-established trees
- Preserving existing, well-established vegetation
- Preserving existing well-heads and septic systems adjacent to the the creek corridor
- Minimizing impact to existing and proposed roadway infrastructure
- Aligning the creek (vertically and horizontally) with existing and proposed roadway crossings
- Minimizing impact to private property and protecting homes
- A desire to restore the creek in the post-flood channel corridor to the extent practical

These constraints mostly impact the ability to add sinuosity to the stream and fully restore the required floodplain width. The result is a channel with higher than desirable channel slopes and narrower floodplain than needed which leads to higher channel velocity, shear stress, and stream power. As a result, structure in the form of bank protection and in-stream features were added in areas of extreme hydraulic risk, which is further discussed later in his report. Structures were also added to improve stream complexity and aquatic habitat conditions. All structures consist of natural materials found within this watershed.

Channel Geometry

Multi-stage channels, as observed in natural rivers, are a key component to a natural channel design project and help reduce flood risk. Multi-stage channels accommodate a wide range of streamflows, including baseflow, bankfull discharge, and flood flows. The proposed design geometry was based on reference reach survey data, pre- and post-flood surveys of stable channel features, and sediment transport modeling. All pertinent design information is shown on the plan set and also provided in Appendix A. Other references that were consulted when designing stream geometry include:

- Applied River Geomorphology, Wildland Hydrology, 1996
- Design Criteria for Restoring Headwater Mountain Streams, Stream Mechanics, 2013
- Emergency Watershed Protection Program, 2013 Colorado Flood Recovery Phase 2, Project Engineering Guidance, 2015
- NRCS National Engineering Handbook Part 654, 2007

Bankfull Channel Cross Section

Three riffle bankfull channel cross sections were designed for this project for use in Reach 1, Reach 2, and Reach 3. The width and cross section area of these cross sections can be modified to accommodate discrete changes in channel slope in all sub reaches in order to preserve the intended bankfull flow capacity. It is recommended that the design of these cross sections be revisited after construction begins and when there is a better understanding of what the actual channel slopes will be. Current estimations of existing topography is based on LiDAR flown November 2013 and may not accurately reflect existing conditions. A summary of bankfull channel design parameters is provided in Table 10.

Table 10: Bankfull Channel Design

Bankfull Channel	**Sub-Reach**		
	Reach 1	**Reach 2**	**Reach 3**
Bankfull Discharge (cfs)	145	160	175
Width (ft)	22.5	22.5	24
Avg. Depth (ft)	1.2	1.3	1.4
Area (ft^2)	27.5	29	32.5
Width/Avg. Depth	18	18	18
Slope (ft/ft)	0.034	0.042	0.032
Calculated Velocity (ft/s)	5.2	5.7	5.3
Entrenchment Ratio	B4 Stream (1.3-2.2) C4 Stream (2.2-9.6)		
Stream Type(s)	B4/C4	B4/C4	B4/C4

The restored channel will be consistent with a B4 and C4 stream types in most locations with the exception of where step-pool features are recommended. The recommended width-to-depth ratio of the restored bankfull section is 18, which is suitable for both a B4 and C4 stream type (NEH 654 2007) and is approximately what was measured from stable riffle cross sections within the project limits.

Baseflow Channel Cross Section

The baseflow channel, termed the inner berm, is a small channel that sits within the bankfull channel. The baseflow channel for this project was designed to be approximately 20% of the bankfull cross section area. The design and construction of inner berms provide deep, low flow channel discharges for habitat and also transport a higher rate of annual bedload when present. A summary of baseflow channel design parameters is provided in Table 11. The baseflow channel design for this project was designed based on:

- Measurements of stable baseflow channel cross sections within the vicinity of this project (provided in Appendix A)
- Average monthly flow statistics obtained from USGS StreamStats
- Minimum depth and maximum velocity requirements for in-stream design species (Brook Trout)
- Sediment transport capacity and competence requirements (described later in this report)

Table 11: Baseflow Channel Design

Baseflow Channel Dimensions	Max Baseflow Capacity			Baseflow Channel at Low-Flow Conditions		
	Reach 1	**Reach 2**	**Reach 3**	**Reach 1**	**Reach 2**	**Reach 3**
Width (ft)	10.5	10.5	11.5	10.5	10.5	11.5
Avg. Depth (ft)	0.5	0.5	0.6	0.17	0.18	0.23
Area (ft^2)	5.3	5.3	7	1.8	1.9	2.6
Slope (ft/ft)	0.034	0.042	0.032	0.034	0.042	0.032
Calculated Velocity (ft/s)	2.7	3	3	1.4	1.6	1.6
Calculated Flow (cfs)	14.2	15.8	20.4	2.5	3.1	4.3

Flood Prone Cross Section

Incorporating different flood stages outside of the bankfull channel helps convey the frequent and infrequent floods events while preserving the bankfull channel integrity. The erosive forces associated with flood flows are dissipated on floodplain benches by spreading out onto floodplain benches at different stages. The secondary benefit of this multi-stage channel design approach is the addition of ecological function and species richness. The multi-stage channel also allows for the greatest diversity and complexity of both aquatic and terrestrial habitats and appropriate riparian systems.

The floodplain and flood-prone area features were incorporated at different stages outside of the bankfull channel cross section. These features were designed and implemented to accommodate a variety of existing site conditions and generally fell within three categories:

1. Partially Healed Channel – Recommendations in this condition consist of reforming the base flow and bankfull channel cross section in order to expedite recovery. These reaches generally connected to the floodplain and contain three different channel stages.
2. Incised Channel – The approach to restoring incised reaches consists of reforming the base flow and bankfull channel cross section within the incised reach. A flat bankfull bench will be graded and then sloped up to the existing floodplain elevation for a total of four channel stages.
3. Aggraded Channel – The approach to restoring aggraded reaches consists of excavating a baseflow and bankfull channel cross section. This process directly connects the bankfull channel to the floodplain for a total of three flood stages.

Channel Pattern

The average proposed sinuosity is approximately 1.06 which is approximately the same sinuosity that existed prior to the flood. The riffle-pool, cascade-pool, and step-pool sequences shown on the proposed plans are consistent with what was observed during reference reach surveys and assessment of pre- and post-flood channel conditions. Pool spacing varies between 1 to 6 bankfull widths. Small sections of step-pool sections were designed with a pool spacing of 0.5 to 2 bankfull widths. Refer to the Fourmile Creek 30% Stream Restoration Plans for additional planform design information.

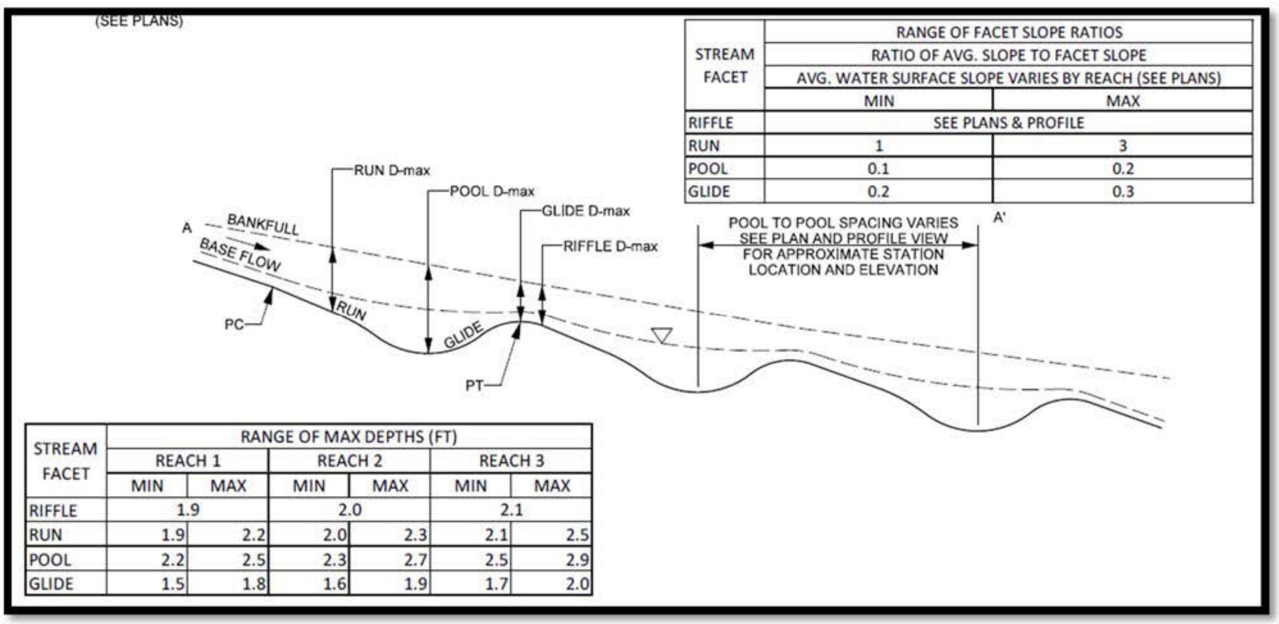
Channel Profile

As previously mentioned, the proposed design contains several changes in channel slope in order to minimize earthwork, connect to critical floodplain elevations, and to match adjacent infrastructure elevations. Average channel design slopes for each reach are as follows:

- Reach 1 = 0.034 ft/ft
- Reach 2 = 0.042 ft/ft
- Reach 3 = 0.032 ft/ft

In order to accommodate discrete changes in channel slope during the construction process, the design ratios in Figure 4 were developed in order to quantify the slopes for individual channel profile features when a deviation in average channel slope is encountered.

Figure 4 - Ratios for Channel Profile Features



STREAM FACET	RANGE OF FACET SLOPE RATIOS RATIO OF AVG. SLOPE TO FACET SLOPE AVG. WATER SURFACE SLOPE VARIES BY REACH (SEE PLANS)	
	MIN	MAX
RIFFLE	SEE PLANS & PROFILE	
RUN	1	3
POOL	0.1	0.2
GLIDE	0.2	0.3

STREAM FACET	RANGE OF MAX DEPTHS (FT)					
	REACH 1		REACH 2		REACH 3	
	MIN	MAX	MIN	MAX	MIN	MAX
RIFFLE	1.9		2.0		2.1	
RUN	1.9	2.2	2.0	2.3	2.1	2.5
POOL	2.2	2.5	2.3	2.7	2.5	2.9
GLIDE	1.5	1.8	1.6	1.9	1.7	2.0

All riffle and pool locations are shown on the planset and are intended to be constructed with native, in-stream channel bed material only. In other words, the import of additional material is not required to construct these features. Pool locations are shown on both the outside and middle of channel bend to add complexity and based on in-stream structures being used adjacent to the pool.

Structures

Stream restoration projects that utilize the natural channel design approach are rarely designed and implemented without stabilization and enhancement structures (Wildland Hydrology 2013). Structures are used to meet multiple objectives such as protecting areas of extreme hydraulic risk and to improve in-stream habitat conditions. All structures recommended for this design are compatible with the existing and proposed stream types and with the natural boundary conditions found along the creek corridor. Proposed structures will be constructed with materials found within the watershed and similar imported material that matches existing watershed conditions.

A summary of structure applicability by stream type is provided in Table 12.

Table 12: Structure Applicability by Stream Type

Table 9-2. Summary of suitability guidelines of various structures by stream type.

Stream Type	Toe Wood	Toe Wood Lunker	Rock J-Hook Vane	Root Wad, Log Vane, J-Hook	Cross-Vane	W-Weir	Conver-ging Rock Clusters	Rock & Roll Logs	Log & Rock Step-Pool	Stacked Sod Mats	Root Wads Banks
A1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
A2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
A3	Poor	Poor	Poor	Poor	Fair	Poor	Fair	Good	Excellent	Poor	Poor
A4	Poor	Poor	Poor	Poor	Fair	Poor	Fair	Good	Excellent	Poor	Poor
A5	Poor	Poor	Poor	Poor	Fair	Poor	Poor	Fair	Fair	Poor	Poor
A6	Poor	Poor	Poor	Poor	Fair	Poor	Poor	Fair	Fair	Poor	Poor
B1	N/A	N/A	N/A	N/A	Good	N/A	N/A	N/A	N/A	N/A	N/A
B2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
B3	Excellent	Good	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent
B4	Excellent	Good	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Excellent
B5	Excellent	Fair	Fair	Good	Good	Good	Poor	Good	Good	Good	Excellent
B6	Excellent	Fair	Fair	Good	Good	Good	Poor	Good	Good	Good	Excellent
C1	Excellent	N/A	Good	Poor	Good	N/A	N/A	N/A	N/A	N/A	N/A
C2	Excellent	N/A	Good	Good	N/A	N/A	N/A	N/A	N/A	N/A	N/A
C3	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Good	Excellent	Excellent
C4	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Good	Good	Excellent	Excellent
C5	Excellent	Good	Fair	Excellent	Good	Good	Poor	Good	Fair	Excellent	Excellent
C6	Excellent	Good	Fair	Excellent	Good	Good	Poor	Good	Fair	Excellent	Excellent
D3	Good	Poor	Poor	Fair	Poor	Poor	N/A	Poor	N/A	Fair	Fair
D4	Good	Poor	Poor	Fair	Poor	Poor	N/A	Poor	N/A	Fair	Fair
D5	Good	Poor	Poor	Fair	Poor	Poor	N/A	Poor	N/A	Fair	Fair
D6	Good	Poor	Poor	Fair	Poor	Poor	N/A	Poor	N/A	Fair	Fair
DA4	Excellent	Excellent	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Excellent	Excellent
DA5	Excellent	Excellent	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Excellent	Excellent
DA6	Excellent	Excellent	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Excellent	Excellent
E3	Good	Excellent	Good	Good	Good	N/A	N/A	N/A	Good	Excellent	Good
E4	Good	Excellent	Good	Good	Good	N/A	N/A	N/A	Good	Excellent	Good
E5	Good	Excellent	Poor	Good	Good	N/A	N/A	N/A	Fair	Excellent	Good
E6	Good	Excellent	Poor	Good	Good	N/A	N/A	N/A	Fair	Excellent	Good
F1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F3	Fair	Fair	Poor	Fair	Good	Fair	Fair	Poor	Poor	Fair	Good
F4	Fair	Fair	Poor	Fair	Good	Fair	Fair	Poor	Poor	Fair	Good
F5	Fair	Poor	Poor	Fair	Good	Fair	Poor	Poor	Poor	Fair	Good
F6	Fair	Poor	Poor	Fair	Good	Fair	Poor	Poor	Poor	Fair	Good
G1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G3	Poor	Poor	Poor	Poor	Good	Poor	Good	Fair	Excellent	Poor	Fair
G4	Poor	Poor	Poor	Poor	Good	Poor	Good	Fair	Excellent	Poor	Fair
G5	Poor	Poor	Poor	Poor	Good	Poor	Poor	Fair	Fair	Poor	Fair
G6	Poor	Poor	Poor	Poor	Good	Poor	Poor	Fair	Fair	Poor	Fair

The in-stream features listed below were included in the restoration of Fourmile Creek. All structures were designed to be passable by aquatic organisms in this system.

- Cross Vane – Used in areas of straight sections to promote pool formation and potentially extreme hydraulic conditions to reduce near bank stress, channel bank erosion, grade control, and assist with controlling the channel thalweg. Rock cross vanes were used instead of log

vanes in confined areas which tend to have more extreme hydraulic conditions that could lead to logs becoming mobilized. These structures typically require imported boulders, but can be constructed with on-site material if available.
- J-Hook (Rock & Log) - Used in areas of sharp channel bends and potentially extreme hydraulic conditions to reduce near bank stress, channel bank erosion, and assist with turning the channel thalweg. The structures can also be used for grade control. Log vanes also provide aquatic habitat through the formation of scour pools and in-stream cover. These structures can be made with on-site material where available.
- Step-Pool (Rock & Log) – Used in segments of steep channel slopes to transition channel grade, provide grade control, and allow for aquatic organism passage. These structures can be made with on-site material where available, but sometimes require imported materials be used.
- Converging Boulder Clusters – Placed at the head of riffles where additional grade control would be beneficial. These features also provide in-stream complexity, and aquatic habitat. These structures can be made with on-site material where available. These structures are particularly useful in areas where the channel will be realigned into unconsolidated alluvium as they help stabilize riffle sections from eroding.

Well-graded backfill material is recommended in areas where a filter system needs to be implemented in order to prevent piping. Geotextile can be used as an alternative to well-graded material, but is not recommended for use in Fourmile Creek because it impede fish passage. While adult Brook Trout can navigate over the crests of the proposed in-stream structure, juvenile Brook Trout may not be able to. Alternately, these juvenile fish navigate upstream through these structures by squeezing through the interstitial space between boulders. This type of navigation is not possible with geotextile is used, therefore a well-graded mix of native alluvium is recommended as an alternative.

Channel Bank Protection

The following bank protection features were included in the restoration of Fourmile Creek. Note that bank protection was not added in areas where channel bank erosion will likely not cause an adverse impact to infrastructure and/or private residences. Additionally, channel bank protection was not added adjacent to steep geologic features and areas dominated by boulders and cobble due to the low risk of failure and potential challenges with construction.

- Boulder Bank Protection – Used in confined corridors and tight channel bends close to infrastructure and private residences.
- Toe Wood – Used in most places where bank protection is needed because of its proven effectiveness and benefit to in-stream habitat. This is also the most cost effective bank stabilization method compared to other options suitable for this watershed.
- Root Wads – Used only in areas where sufficient room adjacent to the creek exists for construction and where channel bank materials are conducive to easy excavation.

The use of soil lifts will also likely be used during construction where the bankfull channel is being restored in an incised reach and where transitioning from the bankfull elevation to existing floodplain results in a steep side slope that can’t be sustained with native soils (typically side slopes steeper than 2 horizontal to 1 vertical).

Channel Hydraulics

Channel hydraulics were calculated with a variety of models depending on specific design objectives. The HEC-RAS model was used to develop an existing and proposed condition hydraulic model for the ultimate purpose of preparing a Conditional Letter of Map Revision (CLOMR). The results of these analyses are not provided in this memorandum, but will be included as a part of the CLOMR submittal which will be completed at a future date.

The Federal Highway Administration (FHWA) Hydraulic Toolbox software provides a hydraulic model that was used to evaluate hydraulic conditions at channel bends. The data from this model was ultimately used to calculate scour depths and boulder sizing. These calculations are provided in Appendix A.

The RIVERMorph® software contains a velocity and discharge calculation model for the purposes of calculating hydraulic conditions for both the existing and proposed channel cross sections. The proposed channel cross section was designed using this model because the data generated is referenced, and required, for the subsequent sediment modeling routines performed by this model, which are described later in this memo. These calculations are provided in Appendix A.

Private Bridge Crossing Design

Some of the private bridges that were damaged or destroyed by the September 2013 flood have either already been replaced or are in the process of being designed and repaired through a different project. However, there are 13 crossings that are still damaged and in need of replacement or that were destroyed during the September 2013 flood and have been replaced with a temporary crossing. The hydraulic opening and general configuration for each of these crossings was designed using HEC-RAS with the following design objectives:

- Span the bankfull channel in order to maintain efficient sediment transport through the crossing.
- Implement a soft-bottom system with natural alluvium to help promote aquatic organism passage.
- Avoid abrupt vertical transitions upstream and/or downstream of the crossings in order to maintain aquatic organism passage.
- Convey the 10-year flow per Boulder County criteria where possible. Where this is not possible, crossing conveyance was optimized based on site constraints.
- Provide additional, smaller, floodplain culverts through embankments encroaching into the floodplain to allow for additional flood relief and redundancy and also help sustain ecological connectivity.

It is important to note that these crossings will not be constructed as a part of the Upper Fourmile Creek Restoration because they are private infrastructure that needs to be paid for, and constructed, separately. The purpose of completing the design of these crossings was to provide preliminary designs for use with future design and construction efforts. As a result, these crossings were not included in the CLOMR model. The model results are provided in Appendix A and the structure detail is provided in the Fourmile Creek 30% Stream Restoration Plans.

Pond Diversions

There are two private water diversions that were damaged during the September 2013 Flood located at stream Station 181+00 and 200+00. In both of these locations the stream down-cut during the flood and the diversion became separated from the water supply that feeds the pond. Preliminary designs were developed to replace these diversions in a sustainable location in the proposed channel pattern and profile while allowing the appropriate connectivity to the privately owned water storage ponds. The proposed diversion structures are slide gates the feed a closed conduit system. Boulder bank protection is recommended upstream and downstream of each diversion along with a cross-vane structure near each point of diversion to help maintain a constant head into the diversion structure. The following general criteria was used for the

- Minimum slope of 2%
- Pipe outlet at mean pond water surface elevation

At the request of the Fourmile Coalition, the diversion structures were designed to be identical to the diversion structure designed by the NRCS for the pond owned by the Fourmile Fire Station in Sunset. The reason for this was to allow for consistent operation of each facility in the event of an emergency.

Scour Analyses

Scour depths were calculated at channel bends using the protocol outlined in the FHWA Hydraulic Engineering Circular 23. Scour depths were calculated to determine the required depth that channel bank protection needed to be keyed in below the channel surface to protect against channel scour. Scour depths were computed for bankfull flow conditions at the locations with greatest scour potential. The results of this analysis were extrapolated to all channel bends where bank protection was installed. Results of the scour analysis are provided in Appendix A.

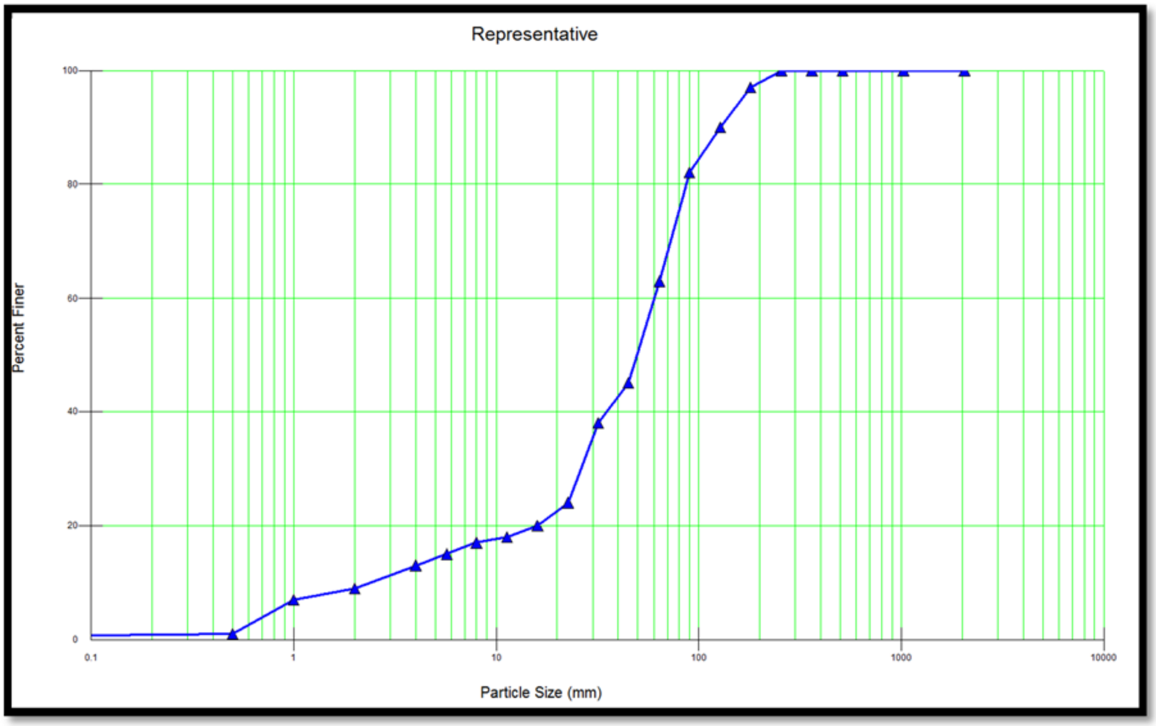
Boulder Sizing

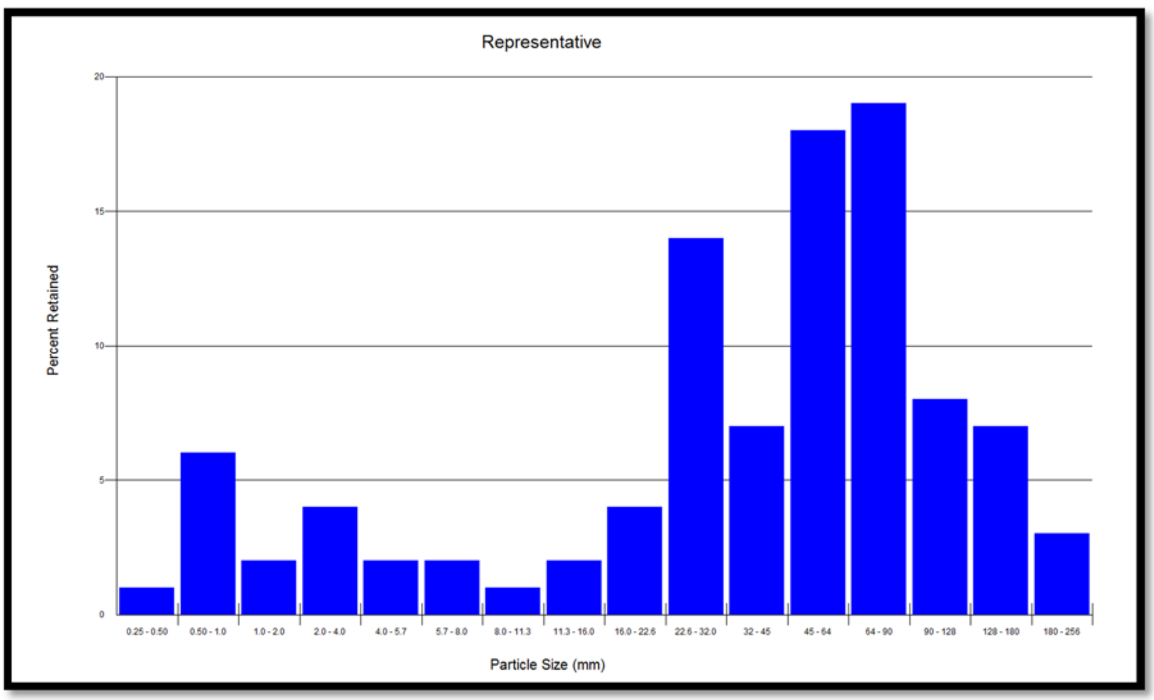
Boulders are used in a variety of structures recommended in this design. Boulders that are used to resist hydraulic forces and provide permanent structure were sized with bankfull flows using the criteria outlined in the United States Army Corps of Engineers (USACE) EM 1110-2-1601 and Urban Drainage & Flood Control District (UDFCD) Drainage Criteria Manual, Volume 2. Boulder sizes were calculated at locations of highest expected hydraulic forces. The resultant boulder size was used throughout the project. Boulder sizing calculations are provided in Appendix A.

Sediment Transport Modeling

Data collected during the reference reach and project reach survey serves as a starting point for the design of the proposed channel geometry. Sediment transport modeling is then performed to evaluate the sediment transport characteristics of the propose design and used to inform refinements in the proposed channel geometry. Preliminary sediment transport modeling was performed to evaluate the ability of the proposed to convey the anticipated sediment load. The sediment transport analyses were partially based on sediment data gathered during field work. Both pebble count and bar sample data was obtained in multiple locations, however, it is important to note that the size and gradation of these samples were impacted by the September 2013 flood and may not represent the sediment regime, size, and gradation that will eventually form as the watershed continues to recover from the flood. As a result, there is an unknown degree of uncertainty with the sediment transport modeling results. A representative particle size distribution for Upper Fourmile Creek is shown in Figure 5.

Figure 5 - Representative Particle Size Distribution





The bi-modal distribution shown in the second graphic in Figure 5 means that finer sediment particles have become intermixed with the dominant channel bed material. This indicates that there are instabilities in the upstream contributing watershed and could be the result of eroding channel banks and/or fine sediments entering the system from burn scars.

Two different types of preliminary sediment transport analyses were performed: competence analysis and capacity analysis. Both analyses were performed with the RIVERMorph® software using protocols outlined in NRCS National Engineering Handbook Part 654. Sediment competence is determined by comparing the size of a particle that the channel can move compared to the material found in the streambed. A channel is considered competent if it can move the D84 size particle. The results of the sediment competence analysis are shown in Table 13.

Table 13 - Sediment Competence Results

Reach	Largest Bar Sample (mm)	Predicted Largest Moveable Particle (mm)		Predicted Channel Adjustment
		Shields Eqn.	Colorado Eqn.	
1	203	215	311	Slight Degradation
2	203	288	352	Slight Degradation
3	203	225	335	Slight Degradation

The capacity analysis evaluates the ability of the creek to move the total volume of sediment coming into the system and reveals whether the system will have the tendency to aggrade or degrade. Suspended load and bed load information was estimated from regional curves developed for Central Colorado (Wildland Hydrology 2007). A flow duration curve was developed based on scaled mean-daily flow data obtained from USGS 06721500, North St. Vrain Near Alans Park. This gage was selected because it is one of the only gages in the vicinity of this site with an ample period of mean daily flow records. Scaling mean-daily flow data from a nearby gage in a different watershed is an acceptable approach to developing a flow duration curve as documented in to develop a flow duration curve (NRCS NEH 654). The results of the sediment capacity analysis are shown in Table 14.

Table 14 - Sediment Capacity Results

Reach	Incoming Sediment Load (tons)	Bankfull Channel Capacity (tons)	Difference (%)
1	94	104	+10% Excess Capacity
2	224	264	+18% Excess Capacity
3	133	146	+10% Excess Capacity

The proposed design is competent and has the capacity to move the anticipated volume of sediment entering the system. The proposed channel section was designed with a small amount of excess capacity to account for additional, and unforeseen, sediment loading entering the stream system as the watershed continues to heal from damage caused by the 2010 fire and the September 2013 flood. This excess capacity will allow for the channel section to naturally adjust over time while preserving the needed capacity to move the expected incoming sediment load. Additional capacity also serves as a small safety factor to mitigate the uncertainty associated with the sediment modeling results. Without a slight amount of excess capacity, any increase in sediment loading could cause the channel to aggrade, and potentially avulse and form a new channel. Detailed results of the sediment competence and capacity analysis are provided in Appendix A.

Ecologic Restoration

A custom wetland/riparian restoration design was developed for the restoration of Fourmile Creek. The design maximized the size of lower floodplain benches whenever possible. These benches were be designed to frequently flood during high flow events or be positioned low enough to consistently receive alluvial groundwater, which will provide the appropriate water regime to support a diverse and productive wetland and riparian system. The restored system will mimic the natural system that was lost or impaired during the flood event and is comprised of three vegetation "zones." These zones generally include channel edge (mainly herbaceous plants or emergent wetland), lower riparian (shrub-dominated, often wetlands, typically willow), and upper riparian (shrubs and trees--mainly willow and cottonwood but usually non-wetland). These habitats are essential for the health of any watershed and are mainly supported by high alluvial groundwater or regular overbank flooding. They provide key habitat for a myriad of wildlife species (including endangered species), serve as movement corridors to link areas of larger habitats, provide bank protection and overall channel stability, enhance water quality, reduce flooding in downstream areas, and promote groundwater recharge.

All of the wetland and riparian areas will be seeded and/or planted with plants native to the Fourmile Creek watershed, with a particular focus on plants sourced locally (local ecotypes). Introducing containerized plant material with living and robust root systems is the quickest way to stabilize each project and "jump start" the establishment of native plant communities. The use of local ecotypes ensures the presence of plant material that is adapted to the local environment while also avoiding the introduction of unknown genetics into the system.

Aquatic Resource Considerations

Recommendations for improving aquatic habitat are as follows:

- During low water periods later in the year, habitats with depths greater than 15 cm and velocities less than 15 cm/sec. are known to be important to both adult and juvenile Brook Trout, but are particularly important for juveniles (Raleigh 1982). Similarly, adult Brook Trout are known to utilize habitats with depths of greater than 30 cm and velocities less than 30 cm/sec when available (Bovee 1978). Deep, slow water habitat should be augmented where geomorphically appropriate.
- Large wood should be used to create habitat structures where possible. Large wood also increases stream productivity by providing high-quality habitat for macroinvertebrates and a source of organic matter for stream food webs. When practical, leave leaves/needles and small branches on the trees used to create habitat features.
- Floodplain reconnection should be facilitated where appropriate, and when feasible given the existing infrastructure in the watershed. Seasonal flooding also increases stream productivity by increasing the input of terrestrial materials that fuel the food web (i.e., Bowen et al. 2003).
- Riparian restoration would increase fish habitat quality in the future by facilitating formation of undercut banks and by providing vegetative shading and input of terrestrial material (including insects, Baxter et al. 2005) into the stream.
- Modify existing avulsions to create side channels for Brook Trout fry and juveniles when feasible. Shallow, slow water areas of side channels and pools are important habitat utilized by Brook Trout fry (Raleigh 1982). Depths at bankfull should be 6 – 8”. Seasonal drying of these channels is acceptable as long as vegetation encroachment will not occur as a result.

- Ensure connectivity throughout the restoration reach. Because salmonids such as Brook Trout require a complex mix of habitats to carry out their life cycles (Fausch et al. 2002), connectivity between diverse reaches is essential to robust populations.

Depth and velocity requirements for juvenile and adult Brook Trout were obtained from Raleigh (1982) to assist in the design of habitat in the primary and side channels. Additional habitat information was also obtained from sources reviewed in Ficke et al. (2009). Information on Brook Trout habitat preferences were used to ensure that stream restoration designs were suitable for the resident species in Fourmile Creek. Habitat survey data and site visit notes were compared to habitat suitability data to determine limiting factors to habitat and to guide future rehabilitation activities.

Flood Debris

A tremendous amount of flood debris was deposited throughout this creek corridor. Due to survey data limitations, all locations of flood debris were not identified on the plan set. However, it is the intent of this project to remove flood debris from the creek corridor or repurpose it for a different use within this project. For example, excess alluvium could be used to fill relic channels and woody debris could be used for toe wood bank protection. The management of flood debris removal, or repurposing, will take place during construction as a part of the design-build process and will be directed by the on-site engineer.

Fire Considerations

As previously mentioned the Fourmile Watershed was impacted by the Fourmile Canyon Fire in September 2010. Wildfires destroy both overstory and understory vegetation leaving native soils exposed and prone to exacerbated erosional processes. It is out of the scope of this project to predict sediment loading from burn scars in the Fourmile Watershed. However, sediment storage areas have been incorporated into the proposed restoration design knowing that increased sediment loading from these burn areas will continue until vegetation becomes reestablished. Sediment storage areas have been incorporated into this design in two ways:

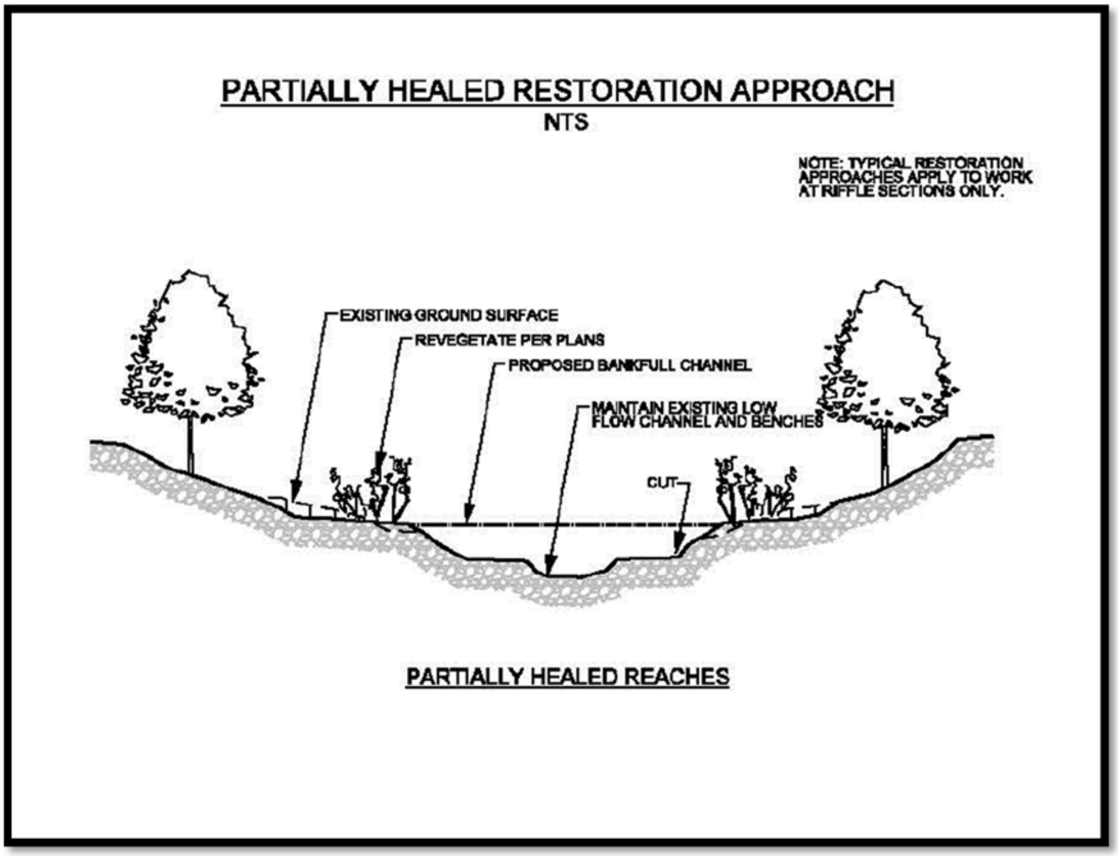
1. As previously mentioned the proposed channel section was designed with a small amount of excess capacity to account for additional sediment entering the stream system.
2. Sediment storage areas were incorporated into the floodplain restoration designs and are identified on the Fourmile Creek 30% Stream Restoration Plans.

Reach Description

The Upper Fourmile Creek stream restoration project was broken into three reaches based on significant changes in drainage area. All reaches are defined on the Fourmile Creek 30% Stream Restoration Plans. Upper Fourmile Creek exists in an alluvial valley through the entire extent of this project. There are four separate types of channel conditions that exist in each of the three design reaches:

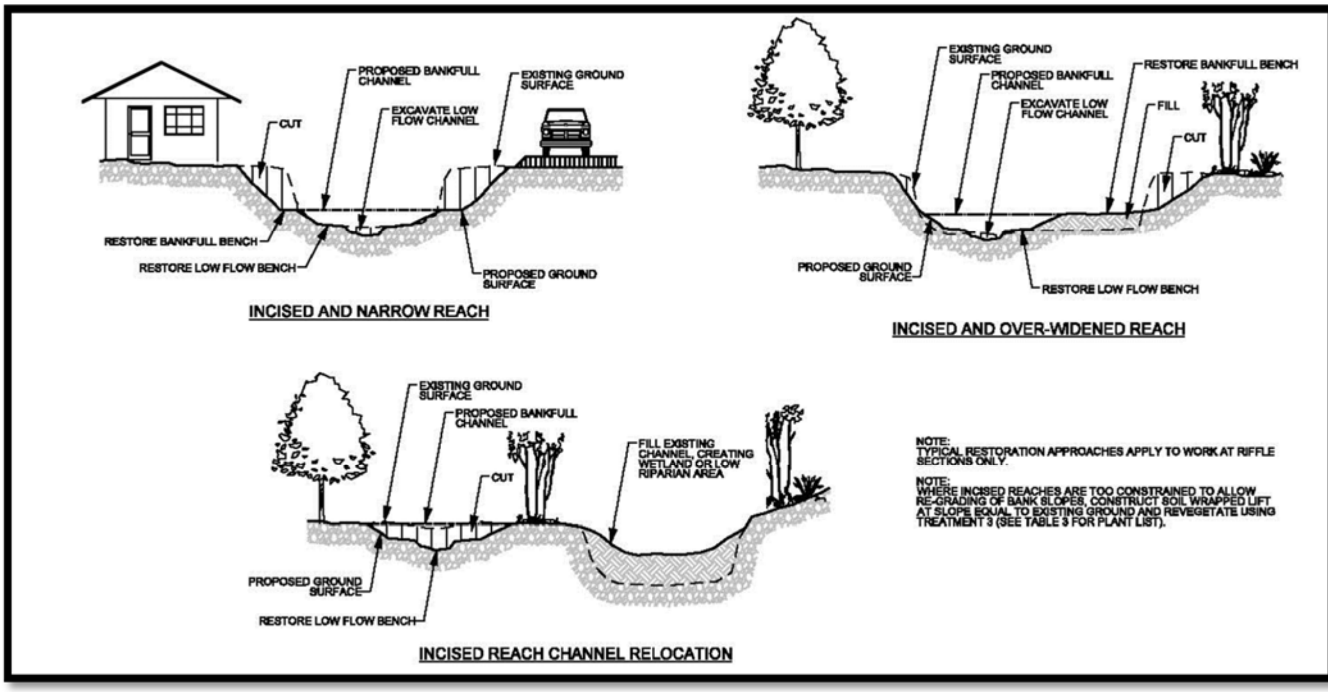
Partially Healed Channel – This channel type is generally in good condition and may require minor work to reshape channel cross section geometry in order to expedite recovery. A general approach to restoring these reaches is depicted in Figure 6. Note that many of these locations have continued to heal and additional improvements may not be necessary once construction begins. Some of these areas have been identified on the plans as areas where no work is required. Additional locations may be identified by the on-site engineer during construction.

Figure 6 - Partially Healed Channel Restoration Approach



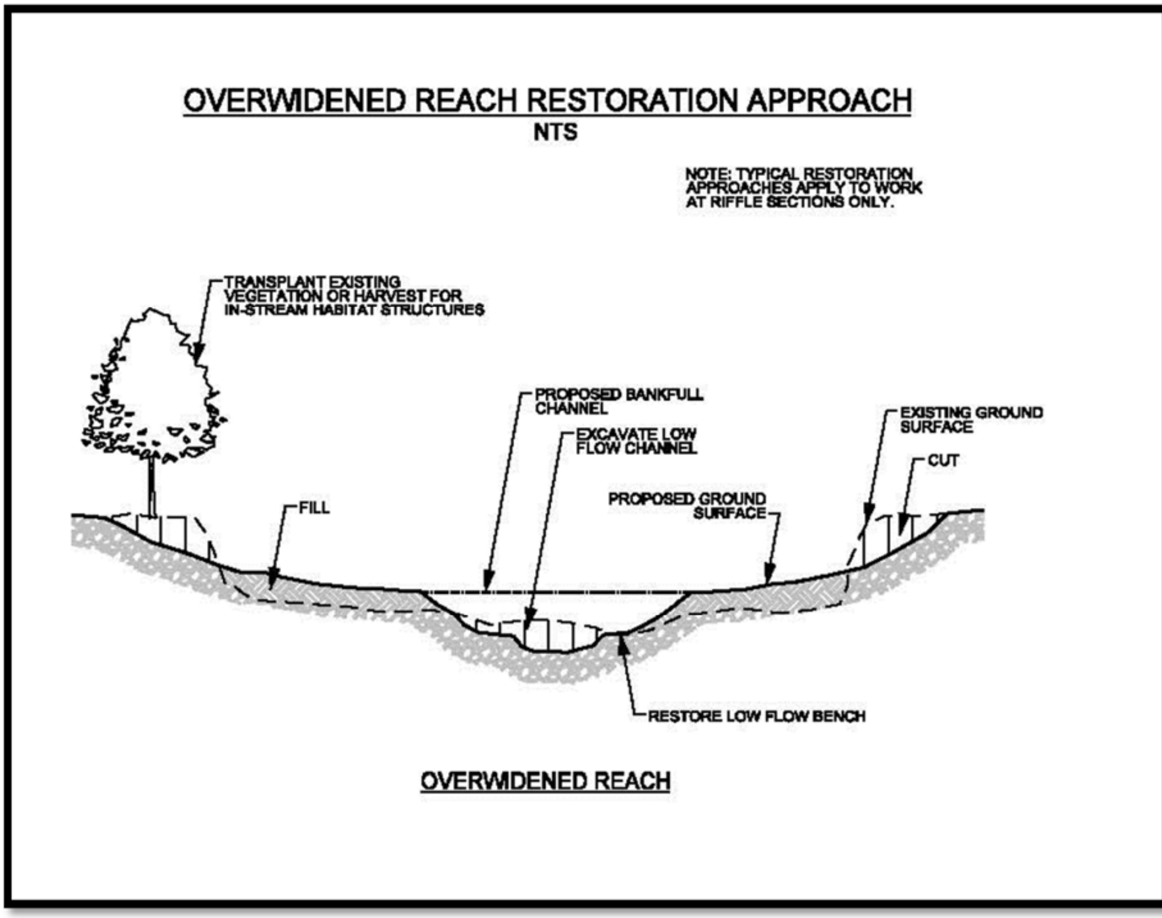
Incised Channel – This channel type has experienced downcutting and has become disconnected from the adjacent floodplain. Incised channels within Upper Fourmile Creek exist in many forms ranging from very narrow channels to channels to over-widened and incised channels. The approach to restoring these reaches is to essentially create a multi-stage channel within the incised reach or move the channel to a new location. Additional guidance on restoring incised reaches is provided in the section below. A general approach to restoring these reaches is depicted in Figure 7.

Figure 7 - Incised Channel Restoration Approach



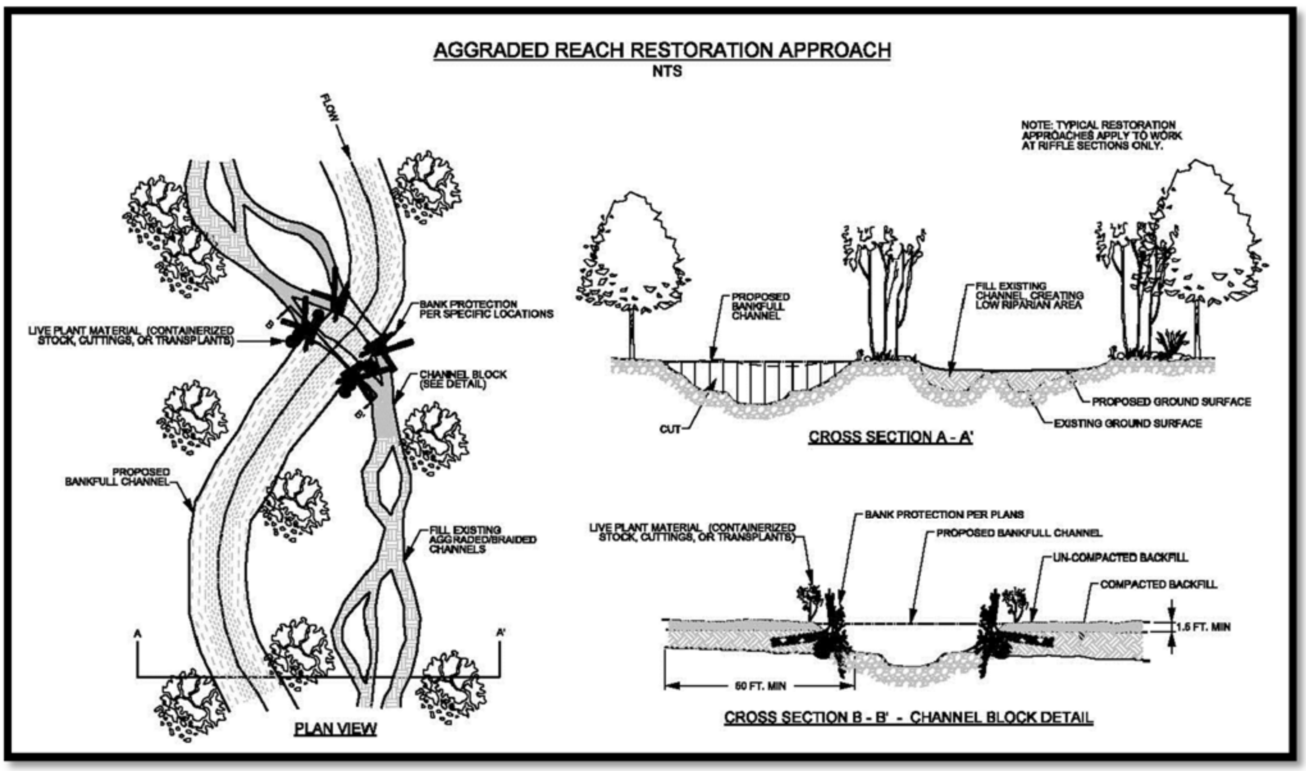
Over-widened Channel – This channel type has experienced local deposition causing the channel to adjust laterally. This process has resulted in a very wide channel section with shallow flow depth. The approach to restoring these reaches is similar to restoring incised channels in that the objective is to create a multi-stage channel within the over-widened reach. A general approach to restoring these reaches is depicted in Figure 8.

Figure 8 – Overwidened Channel Restoration Approach



Aggraded Channel – This channel type has experienced systemic deposition causing the channel to completely fill in with sediment. These zones of aggradation were formed by debris jams or at constrictions in the valley width. There are several channel threads in all of these locations. The approach to restoring these reaches is to excavate a bankfull channel into the deposition zone at the appropriate slope to maintain efficient sediment transport so additional aggradation does not occur. The new channel will be directly connected to the adjacent floodplain which will allow for additional floodplain restoration opportunities. A general approach to restoring these reaches is depicted in Figure 9.

Figure 9 – Aggraded Channel Restoration Approach



Reach 1 Photos

Picture 1 - Partially Healed Channel in Reach 1

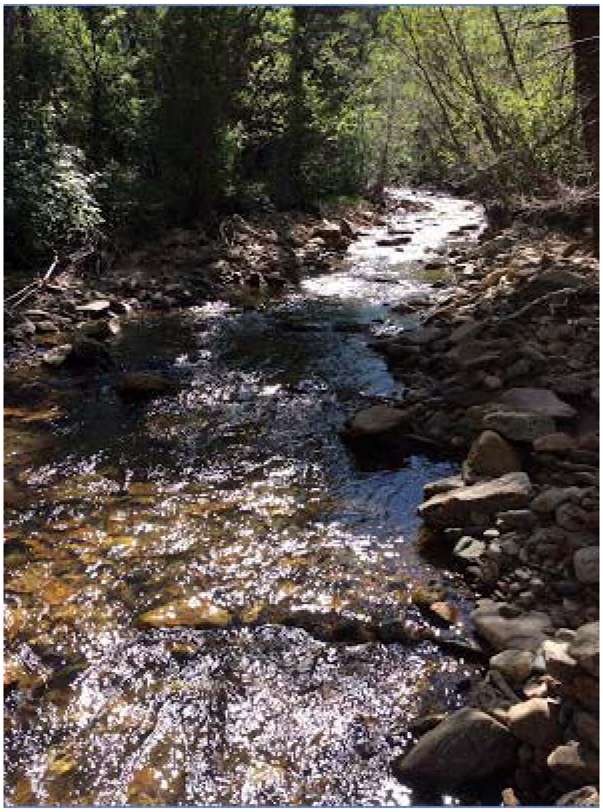
Picture 2 – Over-Widened Channel in Reach 1

Picture 3 – Incised Channel in Reach 1

Picture 4 – Aggraded Channel in Reach 1

Reach 2 Photos

Picture 5 - Partially Healed Channel in Reach 2



Picture 6 – Over-Widened Channel in Reach 2

Picture 7 – Incised Channel in Reach 2

Picture 8 – Aggraded Channel in Reach 2

Reach 3 Photos

Picture 9 - Partially Healed Channel in Reach 3

Picture 10 – Over-Widened Channel in Reach 3

Picture 11 – Incised Channel in Reach 3

Picture 12 – Aggraded Channel in Reach 3

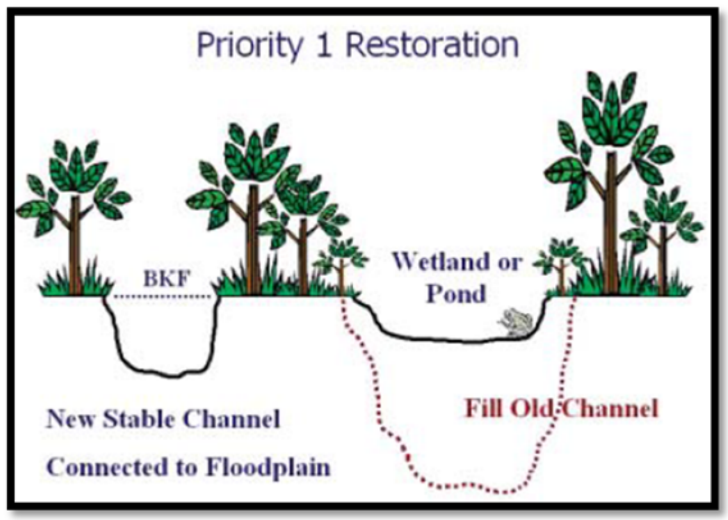
Restoring Incised Reaches

When restoring incised channels, such as most of Fourmile Creek, there are four different approaches (Priority 1 through Priority 4) for doing so as outlined in Stream Restoration – A Natural Channel Design Handbook (NC State University) and summarized below. This methodology is also further described, and referenced, in River Restoration & Natural Channel Design (Wildland Hydrology, 2013). All restoration approaches discussed below do not require import of fill material, and both Priority 1 and Priority 3 approaches do not require exporting material. The Priority 2 restoration approach may generate excess material that needs to be exported, however, in most instances the material can be disposed of on-site to fill the relic channel and/or avulsions that exist within the valley bottom. The Priority 4 restoration approach is to stabilize channel banks-in place. This method was not used in Fourmile Creek.

Earthwork is typically the most expensive component of a channel restoration project. As a result, the proposed channel profile and cross section were designed so that earthwork was minimized. Every attempt was made to balance earthwork quantities resulting from profile and cross section modifications. However, most of the proposed design was based on post-flood LiDAR information obtained in November 2014. As a result, there are associated inaccuracies with the use of LiDAR which could result in a difference in earthwork quantities compared to what is reported for this project.

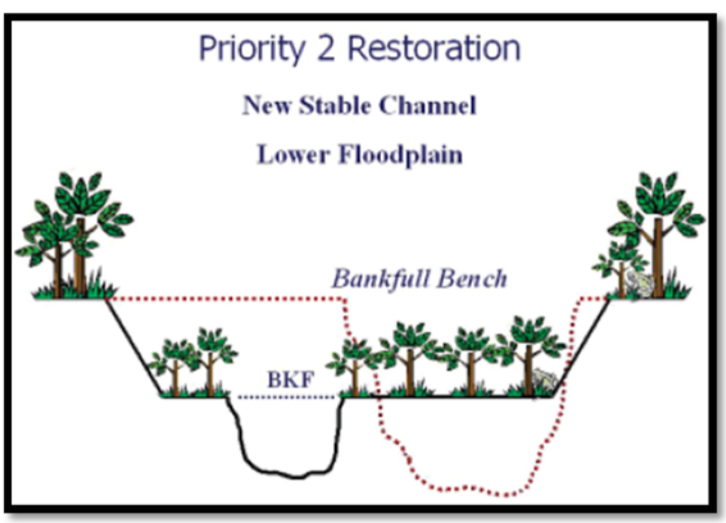
Priority 1 – Establish Bankfull Stage at the Historical Floodplain Elevation

The objective of a Priority 1 project is to replace the incised channel with a new, stable stream at a higher elevation. This is accomplished by excavating a new channel with the appropriate dimension, pattern and profile (based on reference reach data) to fit the watershed and valley type. The bankfull stage of the new channel is located at the ground surface of the original floodplain. The increase in streambed elevation also will raise the water table, in many cases restoring or enhancing wetland conditions in the floodplain. Surrounding land uses can limit the use of a Priority 1 approach if there are concerns about increased flooding or widening of the stream corridor. Most Priority 1 projects will result in higher flood stages above bankfull discharge in the immediate vicinity of the project and possibly downstream.



Priority 2 – Create a New Floodplain and Pattern with Stream Bed Remaining at the Existing Elevation

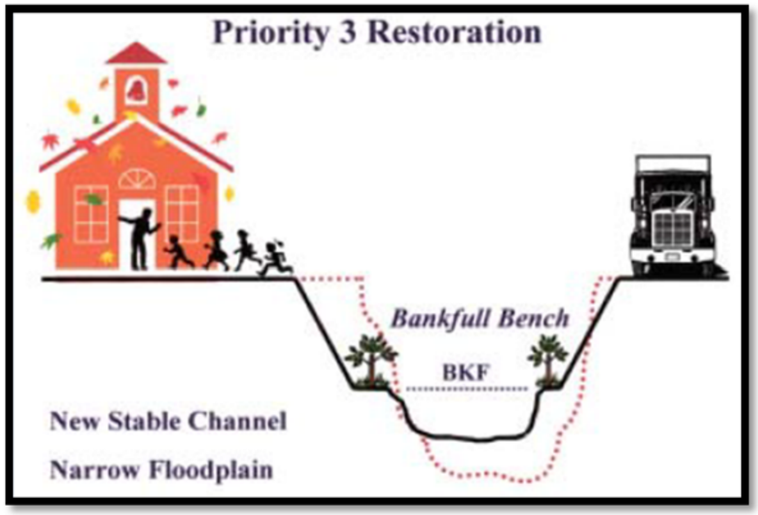
The objective of a Priority 2 project is to create a new, stable stream and floodplain at the existing channel-bed elevation. This is accomplished by excavating a new floodplain and stream channel at the elevation of the existing incised stream. The new channel is designed with the appropriate dimension, pattern and profile (based on reference reach data) to fit the watershed. The bankfull stage of the new channel is located at the elevation of the newly excavated floodplain. Because the new floodplain is excavated at a lower elevation, Priority 2 projects do not increase—and



may decrease—the potential for flooding.

Priority 3 – Widen the Floodplain at the Existing Bankfull Elevation

Priority 3 is similar to Priority 2 in its objective to widen the floodplain at the existing channel elevation to reduce shear stress. This is accomplished by excavating a floodplain bench on one or both sides of the existing stream channel at the elevation of the existing bankfull stage. The existing channel may be modified to enhance its dimension and profile based on reference reach data. The bankfull stage of the new channel is located at the elevation of the newly widened floodplain. Priority 3 projects typically do not increase sinuosity to a large extent because of land constraints. These projects typically have little impact on flooding potential unless there are large changes in channel dimension.



Opinion of Probable Construction Cost

Opinion of probable construction costs were based on an Association for the Advancement of Cost Engineering (AACE) International CLASS 3 Cost Estimate. Class 3 estimates are generally prepared to form the basis for budget authorization, appropriation, and/or funding. Typically engineering is from 10% to 40% complete, and would comprise a minimum of process flow diagrams, utility flow diagrams, preliminary piping and instrumentation diagrams, plot plan, developed layout drawings, and essentially complete engineered process and utility equipment lists. They are typically prepared to support full project funding requests, and become the first of the project phase "control estimates" against which all actual costs and resources will be monitored for variation to budget. Most Class 3 estimates involve more deterministic estimating methods than stochastic methods. Typical accuracy ranges for Class 3 estimates are from +/- 10% to 30% (sometimes higher), depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination.

The opinion of probable construction costs assume that some on-site material will be available for constructing channel features and in-stream structures. The availability of on-site material could impact the actual costs. Additionally, earthwork quantities were based on LiDAR information and actual quantities could differ significantly.

Next Steps

The proposed design for Fourmile Creek is at the 30% design level. The intent of this plan set was to identify all major design components and provide sufficient detail for a contractor to begin construction. If this plan is carried forward into construction the design engineer will need to be on-site daily to ensure the plans are being interpreted correctly, make field-fit modifications, and make design modifications.

The following tasks are being completed under different task orders for this project and the Wagonwheel Gap Road project, all of which will be completed prior to construction.

- Final hydraulic modeling and submittal of the Conditional Letter of Map Revision.
- A monitoring plan will need to be prepared that includes both implementation monitoring and effectiveness monitoring.
- Development report
- Engineering memo with earthwork calculations
- Landscape erosion control memorandum
- Specifications
- Quality assurance plan
- Operations and maintenance plan

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Wildland Hydrology (2009): Watershed Assessment of River Stability & Sediment Supply

Appendix A

- Habitat Data Analysis and Reporting: Fourmile Creek Restoration Project
- Project Reach Assessment
  - Heat Map
  - Assessment Data
- Reference Reach Data & Design Geometry
  - Post-Flood Survey of Stable Channel Features
  - North Fork of North Elk Creek
  - Pre-Flood Assessment of Fourmile Creek
- USGS StreamStats Summary
- FEMA FIRM
- Regional Curves
- Statistical Analysis of USGS Gage Data
- Hydraulic Modeling Results
  - Scour calculations
  - Boulder sizing
  - Proposed channel cross section
  - Private bridge
- Sediment Transport Modeling Results
  - Competence
  - Capacity

Habitat Data Analysis and Reporting: Fourmile Creek Restoration Project

Technical Memorandum

Habitat Data Analysis and Reporting: Fourmile Creek Restoration Project

This technical memo details recommendations for improvement of fish habitat on Fourmile Creek as part of a larger restoration project design developed by Michael Baker International (Baker). The scope of work submitted to for this project included two days of fieldwork, a set of semi-quantitative habitat surveys, data analysis, and resulting recommendations for fish habitat restoration for resident fishes in Fourmile Creek. These recommendations are primarily qualitative but have been developed for incorporation into engineering designs.

1.0 Introduction

1.1 Fourmile Creek

Fourmile Creek is a small tributary that flows into Boulder Creek in Boulder Canyon, upstream of the town of Boulder, CO. Fourmile Creek is characterized by a snowmelt-dominated hydrograph, with monthly average flows from 2011 to 2015 ranging from 7 to 40 cfs from April through July, while in August and September, flows averaged less than 2 cfs. From 2011 through 2015, mean annual flows ranged from 9 to 29 cfs (USGS gage 06727500, Fourmile Creek @ Orodell, CO).

Fourmile Creek and its riparian corridor have been impacted by extensive anthropogenic activities. Numerous private bridges, culverts, small diversions, and small recreational ponds are fairly common within the Project area. Similarly, roads parallel the stream for portions of the Project site. These roads channelize the stream in some areas, and traction sand and material from unpaved road surfaces act as sources of fine sediments.

In September 2013, floods caused extensive property damage and major changes in channel morphology on streams throughout the Front Range, including Fourmile Creek. Major flooding occurred across the Colorado Front Range, and peak flows exceeded 300 cfs in Fourmile Creek. Within the project site, four major geomorphic conditions were observed: over-widened, homogenous reaches, depositional reaches with braided channels, incised or downcutting reaches, and partially recovered reaches.

Michael Baker International (Baker) has been retained by the Boulder County Department of Transportation to restore selected sections of Fourmile Creek. The fishery objectives for this restoration project are habitat improvement and bi-directional fish passage throughout the reach for Brook Trout and other resident coldwater species. The Project site is located on two reaches of Fourmile Creek and includes approximately 4,000 linear feet of Fourmile Creek and its adjacent floodplain (**Error! Reference source not found.**).

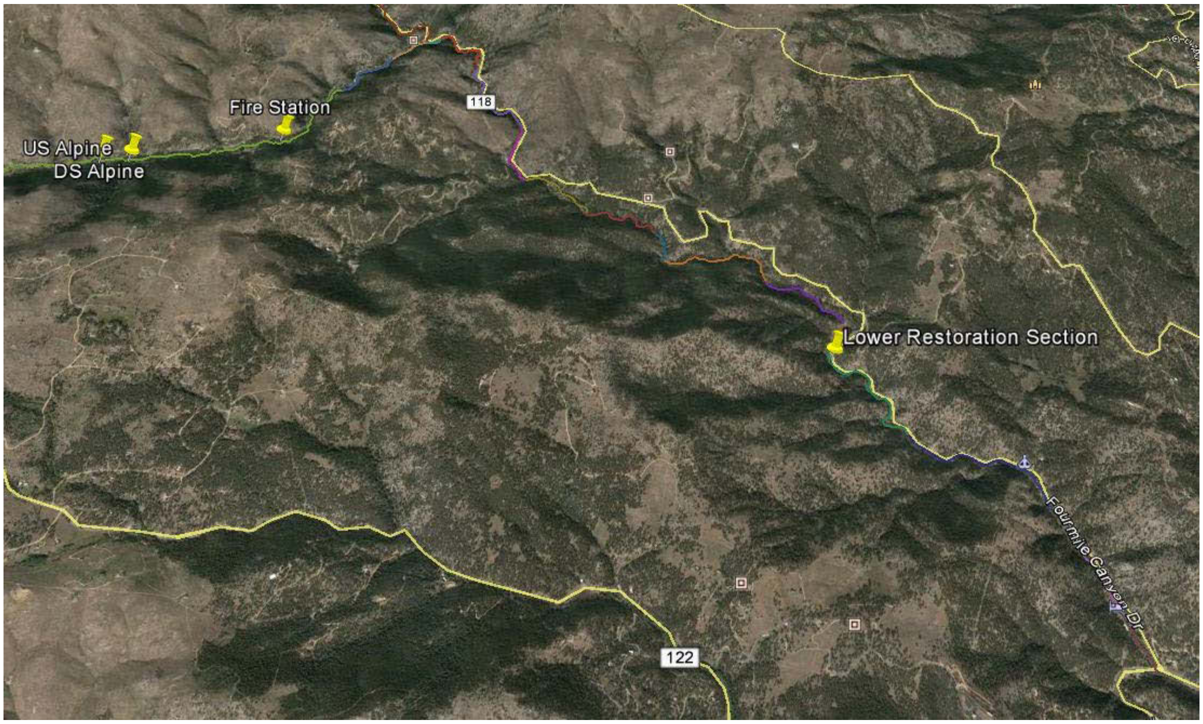

Figure 1: Google Earth image of the four habitat sampling sites on Fourmile Creek.

2.0 Methods

2.1 Habitat Surveys

A site visit was conducted on December 3 and 4, 2015. The majority of the site was walked, but some sections were observed from the road due to inaccessibility and/or time limitations. In both cases, existing conditions were noted and photographed.

A formal habitat survey was conducted at four sites on Fourmile Creek: Upstream of Alpine Road, downstream of Alpine Road, a depositional area near the fire station in upper Fourmile Canyon, and the lower restoration section. These sites were chosen to represent four different distinct geomorphic conditions found within the Project site: partially recovered, depositional/braided, incising/downcutting, and overwidened/homogenous. GEI's habitat survey methods are based on protocols developed by the U.S. Forest Service (Overton 1997) and modified for use in small Colorado streams. The modified surveys use the same basic methods as the U.S. Forest Service inventory, but characteristics that are not relevant to small Colorado streams were not measured. Habitat units (riffles, runs, glides, and pools) were identified and measured individually. Pools were subclassified by formative structures (meanders, large woody debris, or boulders), and riffles were subclassified by gradient (low, high). Cascades and step pools were not present within the surveyed areas, although both were found within the Project site. Length, wetted width, average and maximum depth, substrate type, percentages of undercut and eroding banks, and the type of bank vegetation were measured within each habitat unit. Bankfull widths were not measurable due to recent flooding, but were estimated at 6.5 m. Information such as the percentage of area taken up by each habitat unit type (e.g., pools, riffles, runs, etc.), the average depth of the habitat unit types, and the total number of habitat units were calculated from the information collected in these surveys and used to describe existing conditions before rehabilitation.

2.2 Fisheries Data for Habitat Recommendations

Brook Trout were chosen as the target species, as numerous Brook Trout were observed within the Project site during initial surveys. Depth and velocity requirements for juvenile and adult Brook Trout were obtained from Raleigh (1982) to assist in the design of habitat in the primary and side channels. Additional habitat information was also obtained from sources reviewed in Ficke et al. (2009). Information on Brook Trout habitat preferences were used to ensure that stream restoration designs were suitable for the resident species in Fourmile Creek. Habitat survey data and site visit notes were compared to habitat suitability data to determine limiting factors to habitat and to guide future rehabilitation activities.

3.0 Results

3.1 Habitat Analyses

The aquatic habitat throughout Fourmile Creek has been affected by anthropogenic modifications and the September 2013 floods. However, pronounced differences also exist between the reaches represented by the four surveyed sites.

3.1.1 Lower Restoration Section (Reach 1f)

The Lower Restoration Section represents a partially recovered reach. The Lower Restoration Section contained a mix of habitat units: glides, riffles, runs, and pools formed by lateral scour. It contained the second highest number of habitat units and the second highest number of habitat unit types of the three sites (Table 1). The Lower Restoration Section is comprised of only 5% pool habitat, but does contain several glides that serve as deeper, slow water habitat. The pools in the Lower Restoration Site provide a small amount of holding water for large-bodied fishes, but this site is dominated by fast water habitat types such as runs and riffles. The percentages of surface fines were somewhat high within the site, and were higher in the glides and pool than in the fast water habitat units. Sixty-two percent of the banks at this site were classified as eroding (Table 1). The remaining banks were armored by large boulders. Undercut banks were generally absent. Average site width was 3.0 m, and average depth was 16 cm. Maximum depths in pool and glide habitats were 35 to 40 cm.

Table 1: Summary habitat characteristics for the four surveyed sites on Fourmile Creek, December 3 and 4, 2015.

Habitat Attribute	Upstream of Alpine Gulch Road	Downstream of Alpine Gulch Road	Depositional Area near Fire Station	Lower Restoration Section
No. of Habitat Units	1	6	10	9
No. of Habitat Unit Types	1	4	7	5
% Pool area	0	8	30	5
% Surface Fines	15	20	33	23
% Undercut	0	0	2	0
% Eroding Bank	100	100	2	62
Average site width (m)	2.6	2.8	2.8	3.0
Average site depth (cm)	12	17	19	16

3.1.1.1 Limiting Factors

The primary limiting factors in the Lower Restoration Section are a high frequency of bank erosion, disconnection from the floodplain, a lack of pool habitat, and a relatively high percentage of fine substrates. Stream incision has resulted in the disconnection of the main channel and the floodplain, which limits juvenile habitat and low velocity refugia for juvenile and adult fish during high flows. Disconnection of the main channel and the floodplain also limits the exchange of materials between the terrestrial and aquatic environment, a process that increases the productivity of both environments (Baxter et al. 2005). Although the Lower Restoration Section contains some slow water habitat in the form of two glides, pools are rare. The deep and slow water habitat provided by pools serves as important habitat for large, adult trout, and it provides them with refuge from predators. A higher proportion of fine substrates limits habitat for aquatic invertebrates and the spawning success of salmonids such as Brook Trout (Waters 1995).

3.1.2 Depositional Area near the Fire Station (Reach 4a)

The Depositional Area near the Fire Station is representative of the depositional, braided reaches in Fourmile Creek. This site contains the highest number of habitat units and number of habitat types of the four sites surveyed in December 2015 (Table 1). Approximately 30% of the section is comprised of pool habitat, and riffles and runs are also found throughout the site. The percent surface fines in this site was the highest of the four sites. However, this is partially due to the lower gradient of this site and the higher proportion of pools and glides (Table 1). These slow water habitat units allow fine sediments to settle out of the water column and onto the bottom of the stream due to the lower water velocity. A very small amount (2%) of undercut banks was found within the reach, limiting this type of refuge habitat. However, this was the largest percentage of undercut banks within any of the sites. The percentage of eroding banks was also low (2%). Average width and depth were comparable to widths and depths at other sections surveyed in December 2015. This site is braided and lacks a well-defined stream channel because of the extensive sediment deposition that occurred during the September 2013 floods.

3.1.2.1 Limiting Factors

Habitat quality in the Depositional Area is limited. Although the Depositional Area has a higher number of pools and a slightly higher average depth than the other sites, pool quality is low, and the entire reach is fairly unstable. Fine sediments are relatively high within this reach, especially within the pools and glides. This limits favorable spawning habitat for trout, and limits the interstitial spaces between large substrate particles that provide habitat for aquatic macroinvertebrates. A significant headcut exists just downstream of this site. If this headcut migrates upstream through this site, a low-gradient area with floodplain connectivity and the potential to provide habitat for juvenile and spawning adult brook trout will be lost.

3.1.3 Downstream of Alpine Gulch Road (Reach 4b)

The site downstream of Alpine Gulch Road represents an incising or downcutting reach. This site contains fewer habitat units (n = 6) and habitat unit types (n = 4) than the Depositional Area near the Fire Station and the Lower Restoration Section. Only one pool was measured within this section, and it accounted for 8% of total area within the site (Table 1). The remainder of the site was comprised of runs, low gradient riffles, and high gradient riffles. No undercut banks were surveyed, and 100% of the streambank was classified as eroding. Average widths ranged from 1.6 m to 4.0 m, and average depths ranged from 12 to 25 cm, which are comparable to the other sites. The percent surface fines (20%) within this site was also similar to other sites. Some unvegetated sections of streambank, which may be vulnerable to further erosion, were also observed.

3.1.3.1 Limiting Factors

The primary limiting factors to habitat quality in the section Downstream of Alpine Gulch Road are a low proportion of pool habitat, a lack of undercut banks, and a high proportion of eroding banks. This incised channel is also disconnected from the floodplain. Pools and glides are generally absent from this site, which limits the amount of slow, deep water habitat available to adult trout. Similarly, the lack of undercut banks and riparian vegetation limit the amount of overhead cover, which serves as protection from predators for larger trout. The prevalence of eroding banks can increase sedimentation in the future, which limits habitat for some aquatic macroinvertebrates and decreases the suitability of spawning habitat for trout. Also, this sediment can deposit in pools and other slow water habitats, decreasing available deep water habitats. The Downstream of Alpine Gulch Road section is bordered by a small road and channelized, which limits the potential for the stream to meander and create pools. A headcut within this reach indicates vertical instability, and threatens both aquatic habitat and the Alpine Gulch Road crossing. As the habitat structures within this reach are relatively new and unstable, their quality is limited. The habitat quality will likely improve as time passes.

3.1.4 Upstream of Alpine Gulch Road (Reach 4b)

The section upstream of Alpine Road is comprised of a single, 100 m long, low gradient riffle. This site is representative of an overwidened, homogenous reach. Average and maximum depths were relatively low, and widths were comparable to other sections surveyed. The percent surface fines (15%) was relatively low, which is likely due, in part, to the lack of slow water habitat within the reach. No undercut banks were observed, and 100% of the banks were classified as eroding. Habitat diversity within this reach was very low, and no pools or glides were present.

3.1.4.1 Limiting Factors

The Upstream of Alpine Road section is largely limited by the lack of habitat diversity, high levels of erosion, a lack of undercut banks, low depths, and disconnection from the floodplain. During low flows, this long riffle may act as a migration barrier to larger fish due to the shallow water and potential exposure to predators. The absence of slow water habitat at the Upstream of Alpine Road section severely limits the suitability of this segment for adult trout. However, low gradient riffles do serve as favorable habitat for benthic macroinvertebrates, many of which utilize interstitial spaces in riffles and runs.

3.1.5 Summary: Limiting Factors to Fish Habitat

Fourmile Creek is disconnected from its floodplain throughout much of the Project site, especially in areas bordered by roads. While limited connectivity with the floodplain is natural in canyon reaches, a total lack of access to the floodplain for extended distances is not. Restoring floodplain access in lower-gradient areas could provide temporary refugia for trout during high flows and increase system productivity by allowing the exchange of materials and nutrients between terrestrial and aquatic habitats.

Fourmile Creek lacks deep pools throughout most of the Project site, particularly the reaches adjacent to Alpine Gulch Road. Pools serve as important habitat for adult trout. They offer thermal refugia during the summer and winter, when temperature extremes limit the suitability of shallower habitats, and the greater water depths found in pools help to protect larger, adult fish from terrestrial predators. Providing a mix of habitats, including pools of varying depth and complexity, in addition to the riffles, runs, and glides already found in most reaches, will greatly increase habitat quality within the Project Site.

Additionally, Fourmile Creek would benefit from bank stabilization. Extensive erosion has resulted in a near-total loss of undercut bank habitat, which provides cover for all life stages of trout. These unstable banks could also serve as a source of fine sediment to the stream. Fine sediments can fill in spaces between larger substrates, decreasing habitat suitability for some benthic macroinvertebrates and spawning habitat for trout. Excess sediments can also reduce pool depths, thus decreasing their quality. Increasing bank stability can both provide better fish habitat in the form of undercut banks, while simultaneously reducing possible inputs of fine sediments.

4.0 Recommendations

4.1 Geomorphically Distinct Reaches

4.1.1 Lower Restoration Section

The Lower Restoration Section already contains some habitat diversity in the form of riffles, runs, pools, and glides. Addition of pools or enlargement of existing pool habitat through the addition of large boulders and woody debris, where appropriate, would increase habitat quality in this reach. Banks should be stabilized to prevent unnatural inputs of fine sediments into Fourmile Creek. Streambank revegetation should be encouraged where appropriate, to stabilize banks and to encourage the formation of undercut banks in the future. Streamside vegetation can also act as overhead cover for fish where it overhangs the stream, and can facilitate inputs of terrestrial or adult aquatic insects back into the stream, where they serve as a source of food for trout and other insectivorous fish. Although reconnecting the stream channel with the floodplain would be beneficial, spatial constraints such as road embankments and natural features such as canyon walls may make this infeasible. Fine sediments within the reach will likely flush out over time during seasonal high flows.

4.1.2 Depositional Area near the Fire Station

The Depositional Area already contains a favorable level of habitat diversity, with a variety of pools, riffles, and runs found in this section. This diversity should be maintained. The new habitat structures in this reach could be allowed to form more fully via natural processes, especially if the flow was directed into a single channel instead of a multi-thread channel. Existing pools could also be augmented with large boulders or woody debris, where appropriate. If the natural flow regime can be expected to flush some of the existing fine sediment out of this reach over time, few physical repairs would be required to enhance habitat. However, the headcut at the lower end of this reach should be stabilized, perhaps with a step-pool structure, to prevent future, sudden changes in bed elevation. The depositional areas such as the one near the Fire Station provide an opportunity to create productive areas because they are low-gradient and because the channel and the floodplain are closely connected. Stream channel incision in this area would prevent the opportunity to create high-quality fish habitat and a highly productive area in the stream corridor.

4.1.3 Downstream of Alpine Gulch Road

The Downstream of Alpine Gulch Road section is limited by a lack of pool habitat and a high proportion of eroding banks. Pool formation should be facilitated using boulders and the existing large woody debris in the reach. The creation of a step-pool system would increase the holding water in this reach and prevent further habitat loss through future channel incision. Because this reach is highly incised, it may be more practical to provide holding water (in the form of step-pool complexes) and to ensure that this reach is passable, instead of reconnecting the stream channel to the floodplain. If the gradient in the reach does not exceed 7 percent, it will continue to provide suitable habitat for Brook Trout (Fausch 1989). Higher gradients are are also acceptable; slopes of up to 13 percent do not appear to restrict upstream movement of this species (Adams et al. 2000). Revegetation should be considered within this reach, because of the benefits provided by overhead cover and input of leaf litter and terrestrial insects. The benefits of bank stabilization would include lack of further sedimentation. If large boulders are useful for armoring banks in steep step-pool complexes, they can also serve a similar function to undercut banks, because they provide some cover for Brook Trout.

4.1.4 Upstream of Alpine Gulch Road

This site is completely lacking in habitat diversity, and is comprised of one continuous riffle. Increased structural complexity, through construction of a "two stage" channel and the addition of boulders or large woody debris, would increase the habitat quality in the reach and provide refuge for fishes during low and high flows. If appropriate, reaches like this one could be converted to pool-riffle sequences so some deep, slow water habitat would be available for adult trout. The two-stage channel will also deepen riffles to allow fish passage during low flows. The eroded banks throughout this reach should be stabilized to prevent further habitat degradation through sedimentation. If practical, reestablishing a small floodplain within this reach would increase stream productivity.

4.2 General Recommendations

- During low water periods later in the year, habitats with depths greater than 15 cm and velocities less than 15 cm/sec. are known to be important to both adult and juvenile Brook Trout, but are particularly important for juveniles (Raleigh 1982). Similarly, adult Brook Trout are known to utilize habitats with depths of greater than 30 cm and velocities less than 30 cm/sec when available (Bovee 1978). Deep, slow water habitat should be augmented where geomorphically appropriate.

- Large wood should be used to create habitat structures where possible. Large wood also increases stream productivity by providing high-quality habitat for macroinvertebrates and a source of organic matter for stream food webs. When practical, leave leaves/needles and small branches on the trees used to create habitat features.

- Floodplain reconnection should be facilitated where appropriate, and when feasible given the existing infrastructure in the watershed. Seasonal flooding also increases stream productivity by increasing the input of terrestrial materials that fuel the food web (i.e., Bowen et al. 2003).

- Riparian restoration would increase fish habitat quality in the future by facilitating formation of undercut banks and by providing vegetative shading and input of terrestrial material (including insects, Baxter et al. 2005) into the stream.

- Modify existing avulsions to create side channels for Brook Trout fry and juveniles when feasible. Shallow, slow water areas of side channels and pools are important habitat utilized by Brook Trout fry (Raleigh 1982). Depths at bankfull should be 6 –

8". Seasonal drying of these channels is acceptable as long as vegetation encroachment will not occur as a result.

- Ensure connectivity throughout the restoration reach. Because salmonids such as Brook Trout require a complex mix of habitats to carry out their life cycles (Fausch et al. 2002), connectivity between diverse reaches is essential to robust populations.

5.0 References

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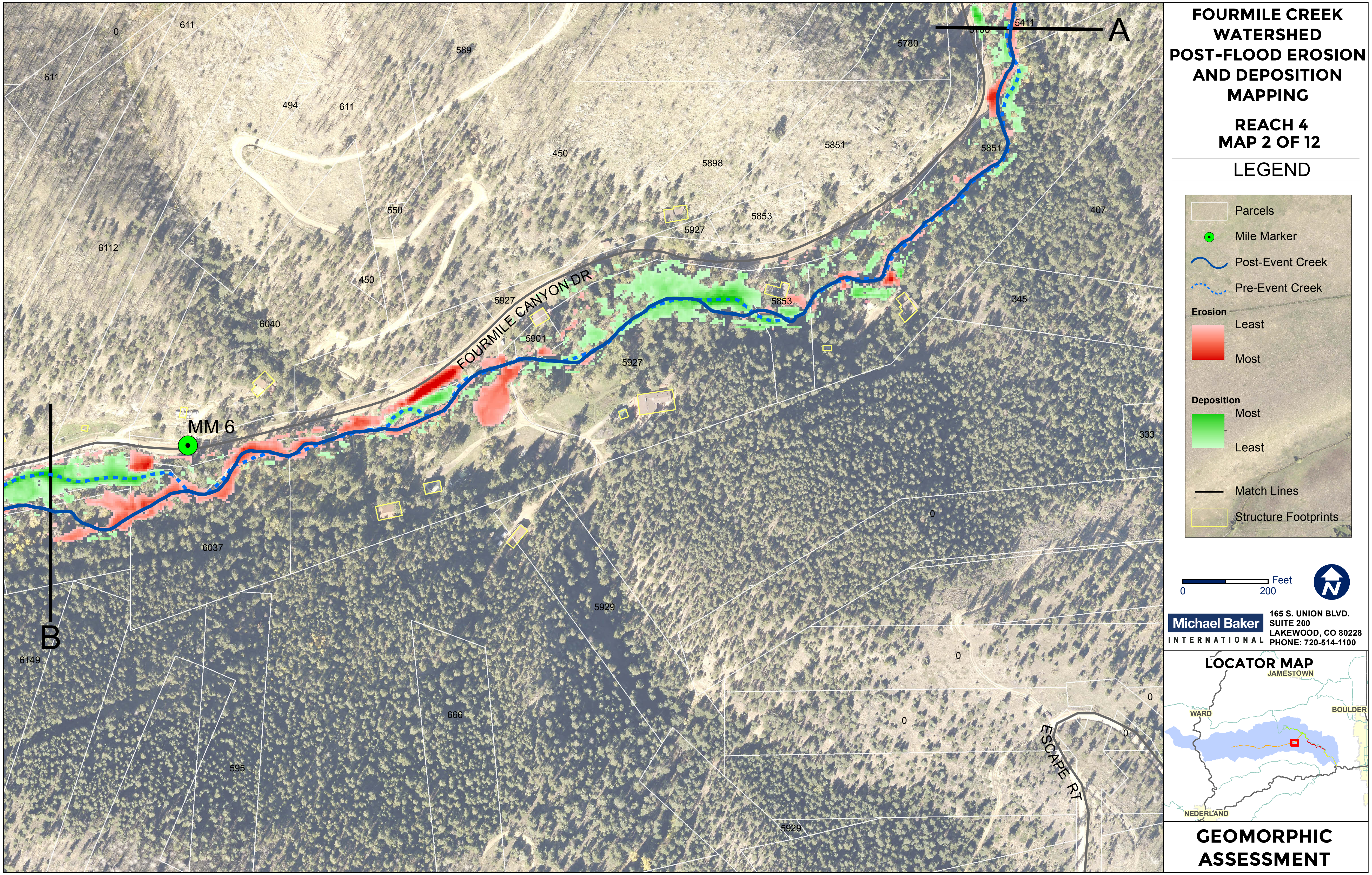
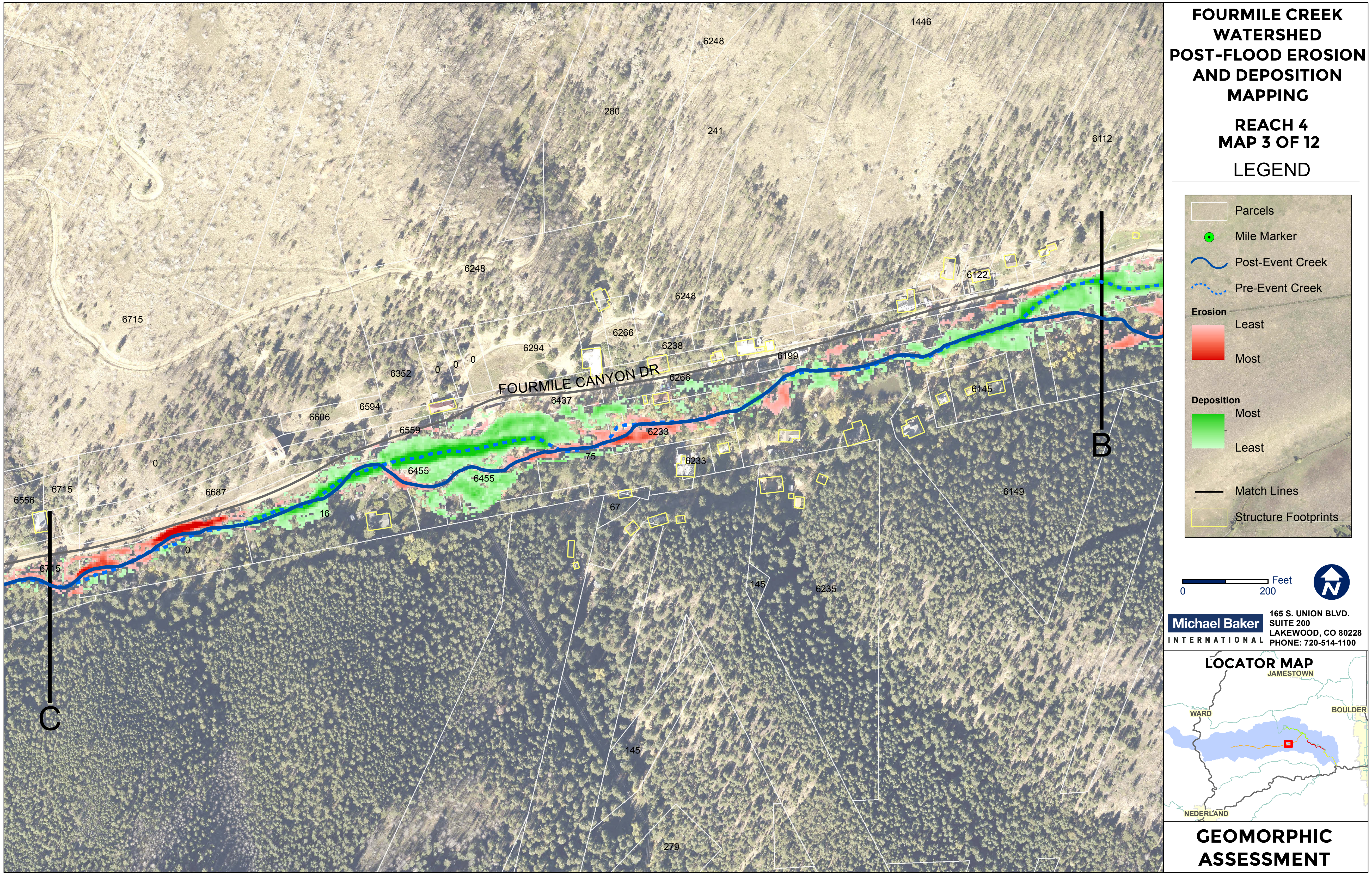
Project Reach Assessment



FOURMILE CREEK WATERSHED POST-FLOOD EROSION AND DEPOSITION MAPPING
REACH 4
MAP 2 OF 12
LEGEND
Parcels
Mile Marker
Post-Event Creek
Pre-Event Creek
Erosion
Least
Most
Deposition
Most
Least
Match Lines
Structure Footprints
Feet
0
200
Michael Baker INTERNATIONAL
165 S. UNION BLVD. SUITE 200 LAKEWOOD, CO 80228 PHONE: 720-514-1100
LOCATOR MAP
JAMESTOWN
WARD
BOULDER
NEDERLAND
GEOMORPHIC ASSESSMENT
FOURMILE CANYON DR
ESCAPE RT
MM 6
A
B


FOURMILE CREEK WATERSHED POST-FLOOD EROSION AND DEPOSITION MAPPING
REACH 4
MAP 3 OF 12
LEGEND
Parcels
Mile Marker
Post-Event Creek
Pre-Event Creek
Erosion
Least
Most
Deposition
Most
Least
Match Lines
Structure Footprints
Feet
0
200
Michael Baker INTERNATIONAL
165 S. UNION BLVD.
SUITE 200
LAKEWOOD, CO 80228
PHONE: 720-514-1100
LOCATOR MAP
JAMESTOWN
WARD
BOULDER
NEDERLAND
GEOMORPHIC ASSESSMENT
FOURMILE CANYON DR
B
C

FOURMILE CREEK WATERSHED POST-FLOOD EROSION AND DEPOSITION MAPPING

REACH 4
MAP 4 OF 12

LEGEND

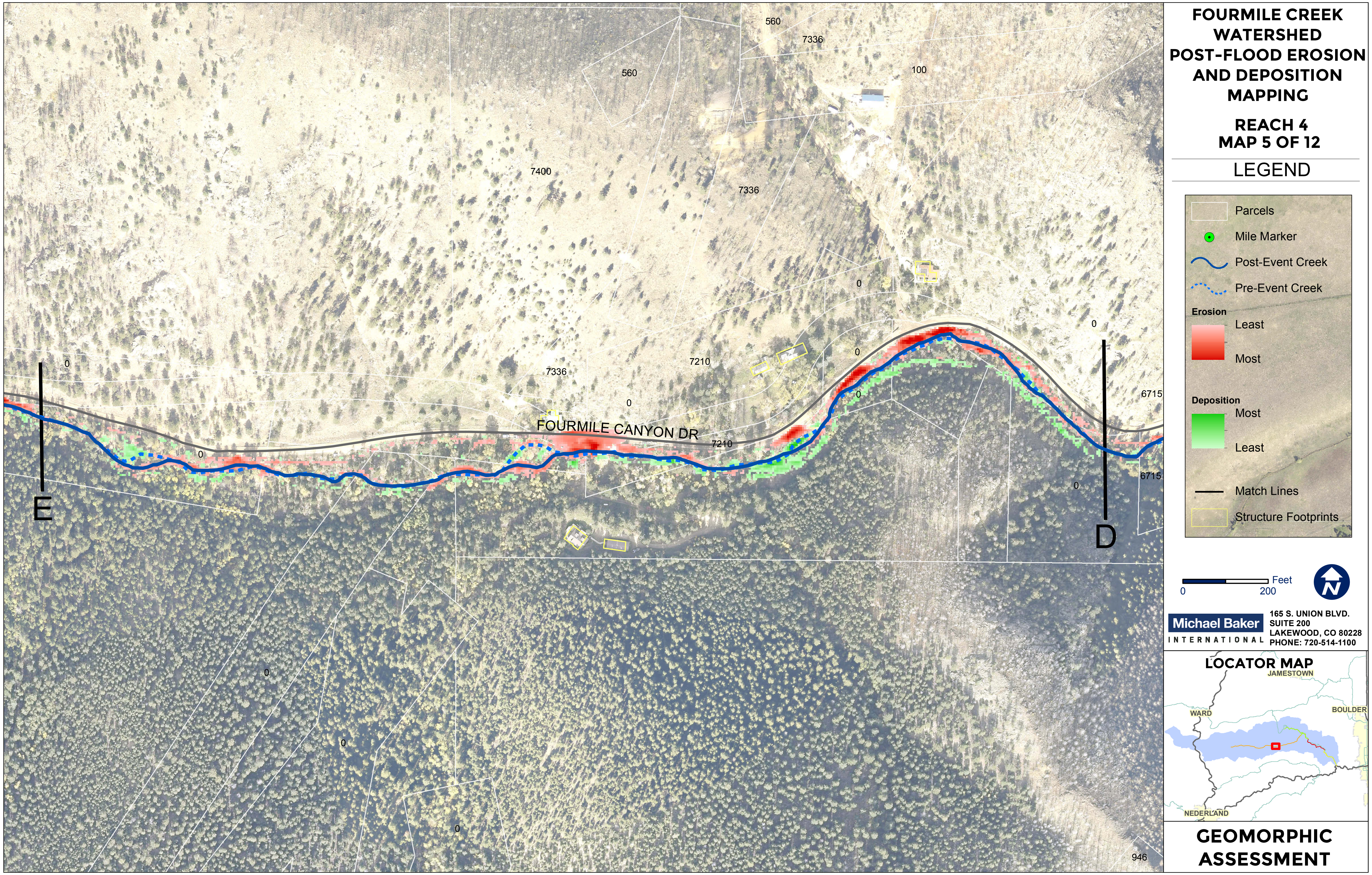
- Parcels
- Mile Marker
- Post-Event Creek
- Pre-Event Creek
- **Erosion**: Least – Most
- **Deposition**: Most – Least
- Match Lines
- Structure Footprints

Feet 0 200

Michael Baker INTERNATIONAL
165 S. UNION BLVD.
SUITE 200
LAKEWOOD, CO 80228
PHONE: 720-514-1100

LOCATOR MAP

GEOMORPHIC ASSESSMENT


FOURMILE CANYON DR
E
D
560
7336
100
7400
7210
6715
946
FOURMILE CREEK WATERSHED POST-FLOOD EROSION AND DEPOSITION MAPPING
REACH 4
MAP 5 OF 12
LEGEND
Parcels
Mile Marker
Post-Event Creek
Pre-Event Creek
Erosion
Least
Most
Deposition
Most
Least
Match Lines
Structure Footprints
Feet
0
200
Michael Baker INTERNATIONAL
165 S. UNION BLVD.
SUITE 200
LAKEWOOD, CO 80228
PHONE: 720-514-1100
LOCATOR MAP
JAMESTOWN
WARD
BOULDER
NEDERLAND
GEOMORPHIC ASSESSMENT


FOURMILE CREEK WATERSHED POST-FLOOD EROSION AND DEPOSITION MAPPING
REACH 4
MAP 6 OF 12
LEGEND
Parcels
Mile Marker
Post-Event Creek
Pre-Event Creek
Erosion
Least
Most
Deposition
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Least
Match Lines
Structure Footprints
Feet
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Michael Baker INTERNATIONAL
165 S. UNION BLVD. SUITE 200 LAKEWOOD, CO 80228 PHONE: 720-514-1100
LOCATOR MAP
JAMESTOWN
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GEOMORPHIC ASSESSMENT
MM 8
FOURMILE CANYON DR
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7860
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7893
0


FOURMILE CREEK WATERSHED POST-FLOOD EROSION AND DEPOSITION MAPPING
REACH 4
MAP 7 OF 12
LEGEND
Parcels
Mile Marker
Post-Event Creek
Pre-Event Creek
Erosion
Least
Most
Deposition
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Match Lines
Structure Footprints
Feet
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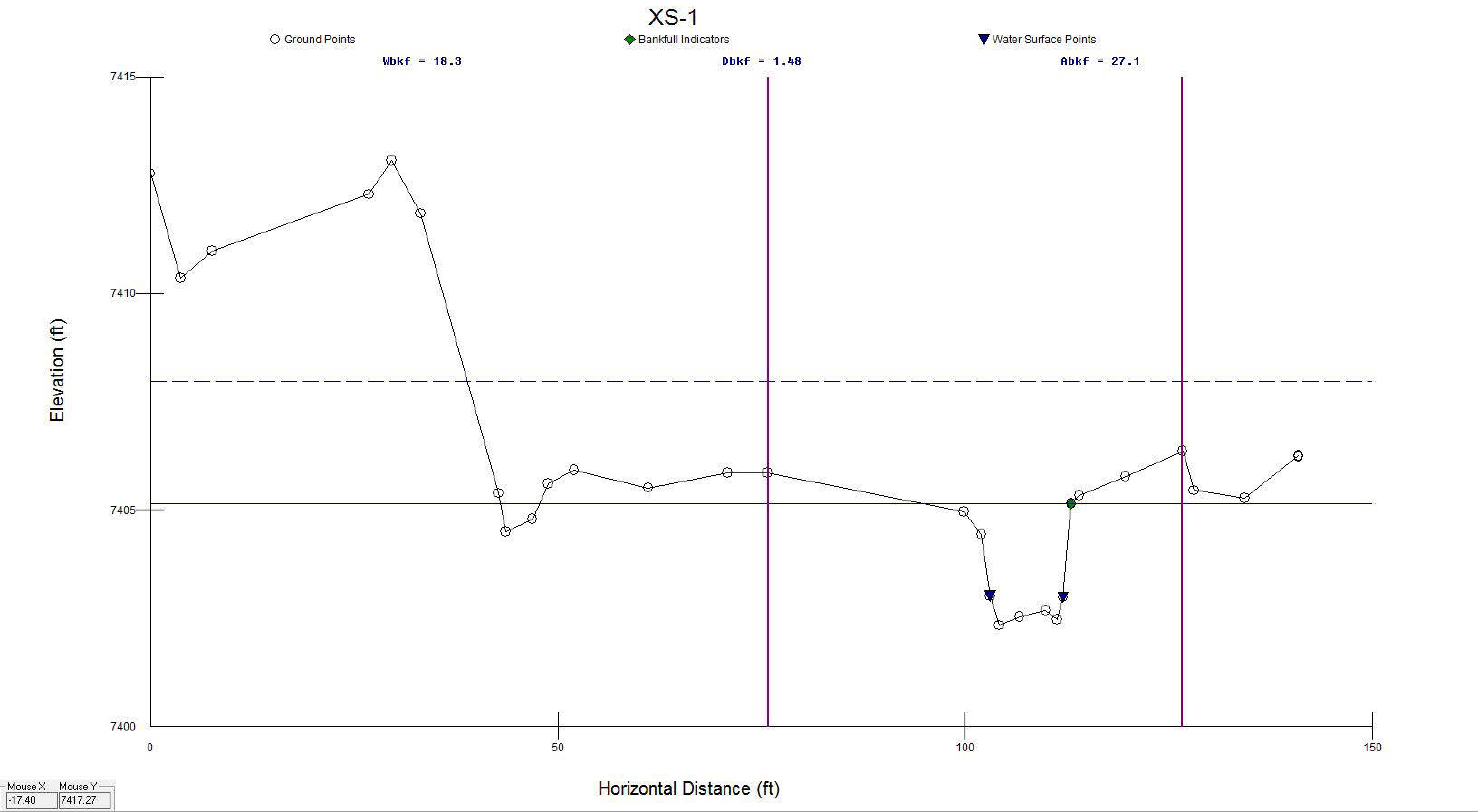
Reach 1 – Existing Conditions Assessment



XS-1
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 18.3
Dbkf = 1.48
Abkf = 27.1
7415
7410
7405
7400
Elevation (ft)
0
50
100
150
Horizontal Distance (ft)
Mouse X
Mouse Y
-17.40
7417.27

RIVERMORPH PARTICLE SUMMARY

River Name: Fourmile Creek
Reach Name: 4f
Sample Name: Riffle-1
Survey Date: 10/15/2015

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	0	0.00	0.00
0.062 - 0.125	0	0.00	0.00
0.125 - 0.25	2	2.00	2.00
0.25 - 0.50	10	10.00	12.00
0.50 - 1.0	9	9.00	21.00
1.0 - 2.0	10	10.00	31.00
2.0 - 4.0	3	3.00	34.00
4.0 - 5.7	1	1.00	35.00
5.7 - 8.0	2	2.00	37.00
8.0 - 11.3	2	2.00	39.00
11.3 - 16.0	2	2.00	41.00
16.0 - 22.6	6	6.00	47.00
22.6 - 32.0	10	10.00	57.00
32 - 45	9	9.00	66.00
45 - 64	10	10.00	76.00
64 - 90	9	9.00	85.00
90 - 128	3	3.00	88.00
128 - 180	11	11.00	99.00
180 - 256	1	1.00	100.00
256 - 362	0	0.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

D16 (mm)	0.72
D35 (mm)	5.7
D50 (mm)	25.42
D84 (mm)	87.11
D95 (mm)	161.09
D100 (mm)	255.99
Silt/Clay (%)	0
Sand (%)	31
Gravel (%)	45
Cobble (%)	24
Boulder (%)	0
Bedrock (%)	0

Total Particles = 100.

RIVERMORPH PFANKUCH SUMMARY

River Name: 4f
Reach Name: Assesments
Survey Date: 10/15/2015

Upper Bank

Landform Slope:	2
Mass Wasting:	7
Debris Jam Potential:	6
Vegetative Protection:	6

Lower Bank

Channel Capacity:	2
Bank Rock Content:	6
Obstructions to Flow:	6
Cutting:	12
Deposition:	12

Channel Bottom

Rock Angularity:	3
Brightness:	3
Consolidation of Particles:	6
Bottom Size Distribution:	12
Scouring and Deposition:	18
Aquatic Vegetation:	3

Channel Stability Evaluation

Sediment Supply:	High
Stream Bed Stability:	
W/D Condition:	Normal
Stream Type:	C4B

Rating - 104
Condition - Fair

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Fourmile Creek
Reach Name: 4f <-- This is not a Reference Reach
Drainage Area: 10.1 sq mi
State: Colorado
County: Boulder
Latitude: 40.035
Longitude: -105.439
Survey Date: 07/24/2015

Classification Data

Valley Type:	Type VIII(b)
Valley Slope:	0.0366 ft/ft
Number of Channels:	Single
Width:	18.32 ft
Mean Depth:	1.48 ft
Flood-Prone Width:	101.99 ft
Channel Materials D50:	50.28 mm
Water Surface Slope:	0.02651 ft/ft
Sinuosity:	1.22
Discharge:	141.845 cfs
Velocity:	5.238 fps
Cross Sectional Area:	27.08 sq ft
Entrenchment Ratio:	5.57
Width to Depth Ratio:	12.38
Rosgen Stream Classification:	C 4b

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY & DISCHARGE Estimates

Stream:	**Fourmile Creek**	Location:	**Reach - 4f**
Date:		Stream Type: **C4**	Valley Type: **VIII**
Observers:	**Abel, Aragon**	HUC:	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Riffle Cross-Sectional AREA	27.08	A_{bkf} (ft^2)	Bankfull Riffle Mean DEPTH	1.48	d_{bkf} (ft)
Bankfull Riffle WIDTH	18.32	W_{bkf} (ft)	Wetted PERIMETER ~ (2 * d_{bkf}) + W_{bkf}	20.85	W_p (ft)
D_{84} at Riffle	87.11	Dia. (mm)	D_{84} (mm) / 304.8	0.29	D_{84} (ft)
Bankfull SLOPE	0.0265	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	1.30	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R(ft) / D_{84} (ft)	4.55	R / D_{84}
Drainage Area	10.1	DA (mi^2)	Shear Velocity $u^* = (gRS)^{½}$	1.053	u* (ft/sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 * Log\{R / D_{84}\}] u^*$	6.90	ft / sec	186.80	cfs
2. Roughness Coefficient: a) Manning's *n* from Friction Factor / Relative Roughness (Figs. 2-18, 2-19) $u = 1.49*R^{2/3}*S^{1/2}/n$ n = 0.055	5.24	ft / sec	141.85	cfs
2. Roughness Coefficient: b) Manning's *n* from Stream Type (Fig. 2-20) $u = 1.49*R^{2/3}*S^{1/2}/n$ n = 0.055	5.24	ft / sec	141.85	cfs
2. Roughness Coefficient: c) Manning's *n* from Jarrett (USGS): $u = 1.49*R^{2/3}*S^{1/2}/n$; $n = 0.39*S^{0.38}*R^{-0.16}$ n = 0.094. Note: This equation is applicable to **steep, step/pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for Stream Types A1, A2, A3, B1, B2, B3, C2 & E3	3.06	ft / sec	82.92	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) Darcy-Weisbach (Leopold, Wolman and Miller)	7.79	ft / sec	210.93	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) Chezy C	0.00	ft / sec	0.00	cfs
4. Continuity Equations: a) Regional Curves u = Q / A; Return Period for Bankfull Discharge Q = 0.0 year	0.00	ft / sec	0.00	cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A	0.00	ft / sec	0.00	cfs

Protrusion Height Options for the D_{84} Term in the Relative Roughness Relation (R/D_{84}) – Estimation Method 1

Option 1.	For **sand-bed** channels: Measure 100 **"protrusion heights"** of sand dunes from the downstream side of feature to the top of feature. Substitute the D_{84} sand dune protrusion height in ft for the D_{84} term in method 1.
Option 2.	For **boulder-dominated** channels: Measure 100 **"protrusion heights"** of boulders on the sides from the bed elevation to the top of the rock on that side. Substitute the D_{84} boulder protrusion height in ft for the D_{84} term in method 1.
Option 3.	For **bedrock-dominated** channels: Measure 100 **"protrusion heights"** of rock separations, steps, joints or uplifted surfaces above channel bed elevation. Substitute the D_{84} bedrock protrusion height in ft for the D_{84} term in method 1.
Option 4.	For **log-influenced** channels: Measure "**protrusion heights**" proportionate to channel width of log diameters or the height of the log on upstream side if embedded. Substitute the D_{84} protrusion height in ft for the D_{84} term in method 1.

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Fourmile Creek**			Stream Type:	**C 4b**
Location:	**4f**			Valley Type:	**VIIIb**
Observers:	**Sean Abel, Daniel Aragon**			Date:	**07/24/2015**
Enter Required Information for Existing Condition					
25.4	D_{50}	Median particle size of riffle bed material (mm)			
N/A	$\hat{D}_{50}$	Median particle size of bar or sub-pavement sample (mm)			
0.666	D_{max}	Largest particle from bar sample (ft)	**203**	**(mm)**	304.8 mm/ft
0.02651	S	Existing bankfull water surface slope (ft/ft)			
1.48	d	Existing bankfull mean depth (ft)			
1.65	$\gamma_s - \gamma / \gamma$	Immersed specific gravity of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress				
0.00	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\ (D_{50}/\hat{D}_{50})^{-0.872}$
7.99	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\ (D_{max}/D_{50})^{-0.887}$
N/A	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**N/A**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample				
N/A	d	Required bankfull mean depth (ft)	$d = \frac{\tau^*(\gamma_s - 1)D_{max}}{S}$	(use D_{max} in ft)
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample				
N/A	S	Required bankfull water surface slope (ft/ft)	$S = \frac{\tau^*(\gamma_s - 1)D_{max}}{d}$	(use D_{max} in ft)
		Check: ☐ Stable ☐ Aggrading ☐ Degrading		

Sediment Competence Using Dimensional Shear Stress			
2.448		Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
Shields **198.2**	CO **293.7**	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
Shields **2.505**	CO **1.482**	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
Shields **1.51**	CO **0.90**	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \frac{\tau}{\gamma S}$
Shields **0.0271**	CO **0.0160**	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \frac{\tau}{\gamma d}$
		Check: ☐ Stable ☐ Aggrading ☑ Degrading	

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Fourmile Creek** Location: **4f**

Observers: **Sean Abel, Daniel Aragon** Date: **7/24/2015**

List ALL COMBINATIONS that APPLY............... ☞	P	1	2	8				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
S	Subterranean stream channel: Flows parallel to and near the surface for various seasons - a sub-surface flow that follows the stream bed.
I	Intermittent stream channel: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
P	Perennial stream channels: Surface water persists yearlong.

Specific Category

1	Seasonal variation in streamflow dominated primarily by snowmelt runoff.
2	Seasonal variation in streamflow dominated primarily by stormflow runoff.
3	Uniform stage and associated streamflow due to spring-fed condition, backwater, etc.
4	Streamflow regulated by glacial melt.
5	Ice flows/ice torrents from ice dam breaches.
6	Alternating flow/backwater due to tidal influence.
7	Regulated streamflow due to diversions, dam release, dewatering, etc.
8	Altered due to development, such as urban streams, cut-over watersheds or vegetation conversions (forested to grassland) that change flow response to precipitation events.
9	Rain-on-snow generated runoff.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Fourmile Creek**
Location:	**4f**
Observers:	**Sean Abel, Daniel Aragon**
Date:	**7/24/2015**
Stream Size Category and Order ☞	**S4 (3)**

Category	STREAM SIZE: Bankfull width		Check (✓) appropriate category
	meters	feet	
S-1	0.305	<1	☐
S-2	0.3 – 1.5	1 – 5	☐
S-3	1.5 – 4.6	5 – 15	☐
S-4	4.6 – 9	15 – 30	☐
S-5	9 – 15	30 – 50	☐
S-6	15 – 22.8	50 – 75	☐
S-7	22.8 – 30.5	75 – 100	☐
S-8	30.5 – 46	100 – 150	☐
S-9	46 – 76	150 – 250	☐
S-10	76 – 107	250 – 350	☐
S-11	107 – 150	350 – 500	☐
S-12	150 – 305	500 – 1000	☐
S-13	>305	>1000	☐

Stream Order

Add categories in parenthesis for specific stream order of reach. For example a third order stream with a bankfull width of 6.1 meters (20 feet) would be indexed as: S-4(3).

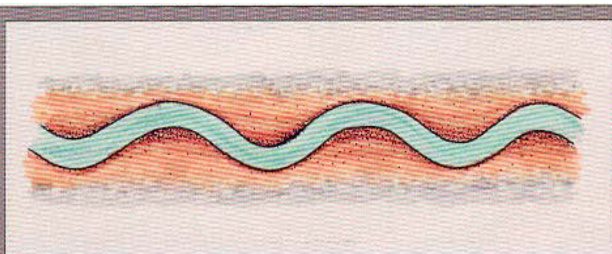
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream: **Fourmile Creek**	Reach: **4f**
Observers: **Sean Abel, Daniel Aragon**	Date: **7/24/2015**

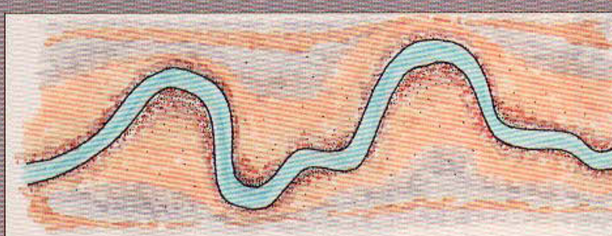
List ALL CATEGORIES that APPLY ☞	M1	M3	M4		

Various Meander Pattern variables modified from Galay et al. (1973)

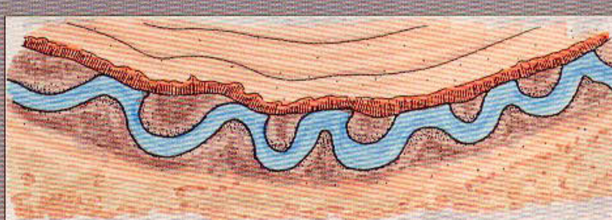


M1 REGULAR MEANDERS

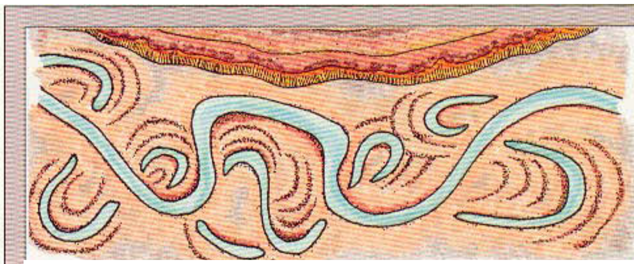
M2 TORTUOUS MEANDERS



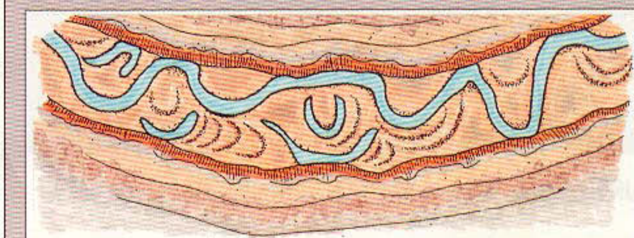
M3 IRREGULAR MEANDERS



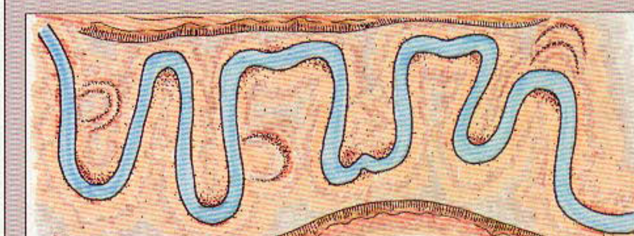
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

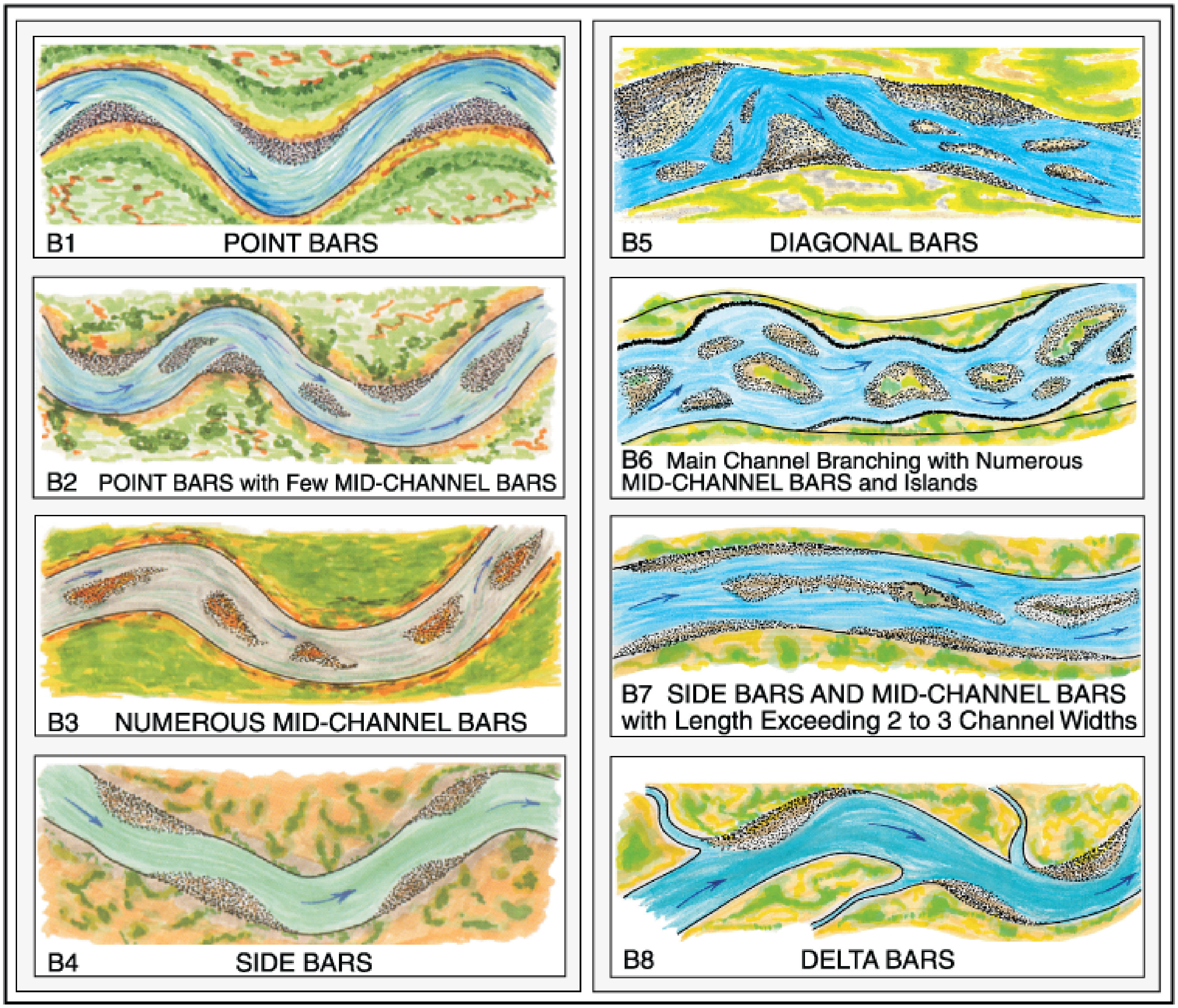
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Fourmile Creek**	Reach:	**4f**
Observers:	**Sean Abel, Daniel Aragon**	Date:	**7/24/2015**

List ALL CATEGORIES that APPLY ☞	**B1**	**B2**	**B4**	**B5**	

Various Depositional Features modified from Galay et al. (1973)

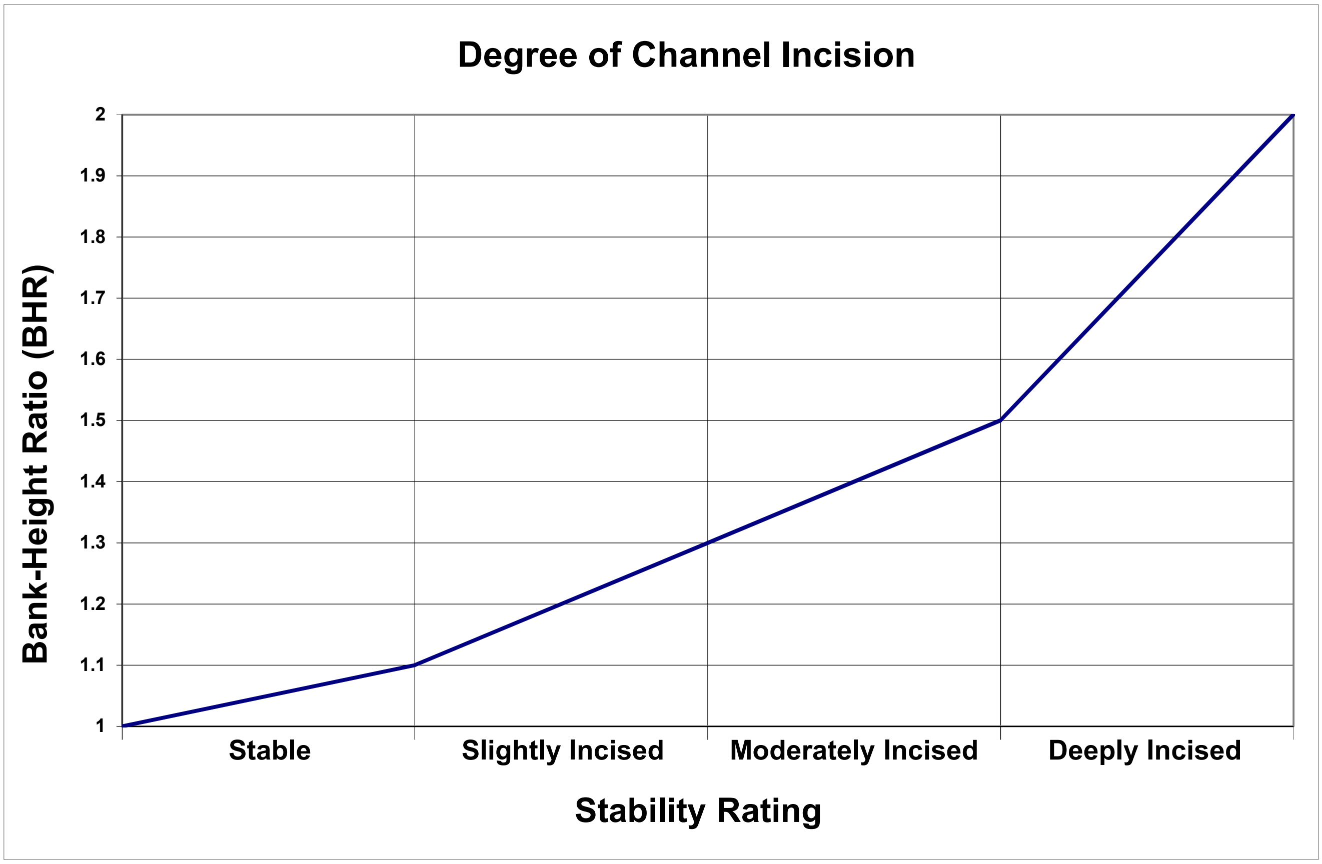


Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Fourmile Creek**		Location: **4f**	
Observers: **Sean Abel, Daniel Aragon**		Date: **7/24/2015**	
Description/extent		**Materials that upon placement into the active channel or flood-prone area may cause adjustments in channel dimensions or conditions due to influences on the existing flow regime.**	**Check (✓) all that apply**
D1	None	Minor amounts of small, floatable material.	☐
D2	Infrequent	Debris consists of small, easily moved, floatable material, e.g., leaves, needles, small limbs and twigs.	☐
D3	Moderate	Increasing frequency of small- to medium-sized material, such as large limbs, branches and small logs, that when accumulated, affect 10% or less of the active channel cross-section area.	☑
D4	Numerous	Significant build-up of medium- to large-sized materials, e.g., large limbs, branches, small logs or portions of trees that may occupy 10–30% of the active channel cross-section area.	☐
D5	Extensive	Debris "dams" of predominantly larger materials, e.g., branches, logs and trees, occupying 30–50% of the active channel cross-section area, often extending across the width of the active channel.	☐
D6	Dominating	Large, somewhat continuous debris "dams," extensive in nature and occupying over 50% of the active channel cross-section area. Such accumulations may divert water into the flood-prone areas and form fish migration barriers, even when flows are at less than bankfull.	☑
D7	Beaver dams: Few	An infrequent number of dams spaced such that normal streamflow and expected channel conditions exist in the reaches between dams.	☐
D8	Beaver dams: Frequent	Frequency of dams is such that backwater conditions exist for channel reaches between structures where streamflow velocities are reduced and channel dimensions or conditions are influenced.	☐
D9	Beaver dams: Abandoned	Numerous abandoned dams, many of which have filled with sediment and/or breached, initiating a series of channel adjustments, such as bank erosion, lateral migration, avulsion, aggradation and degradation.	☐
D10	Human influences	Structures, facilities or materials related to land uses or development located within the flood-prone area, such as diversions or low-head dams, controlled by-pass channels, velocity control structures and various transportation encroachments that have an influence on the existing flow regime, such that significant channel adjustments occur.	☐

Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision			
Low Bank Height:	3.6	Bank-Height Ratio:	1.3
Max Bankfull Depth:	2.8		
Degree of Channel Incision Stability Rating ☞			Slightly Incised

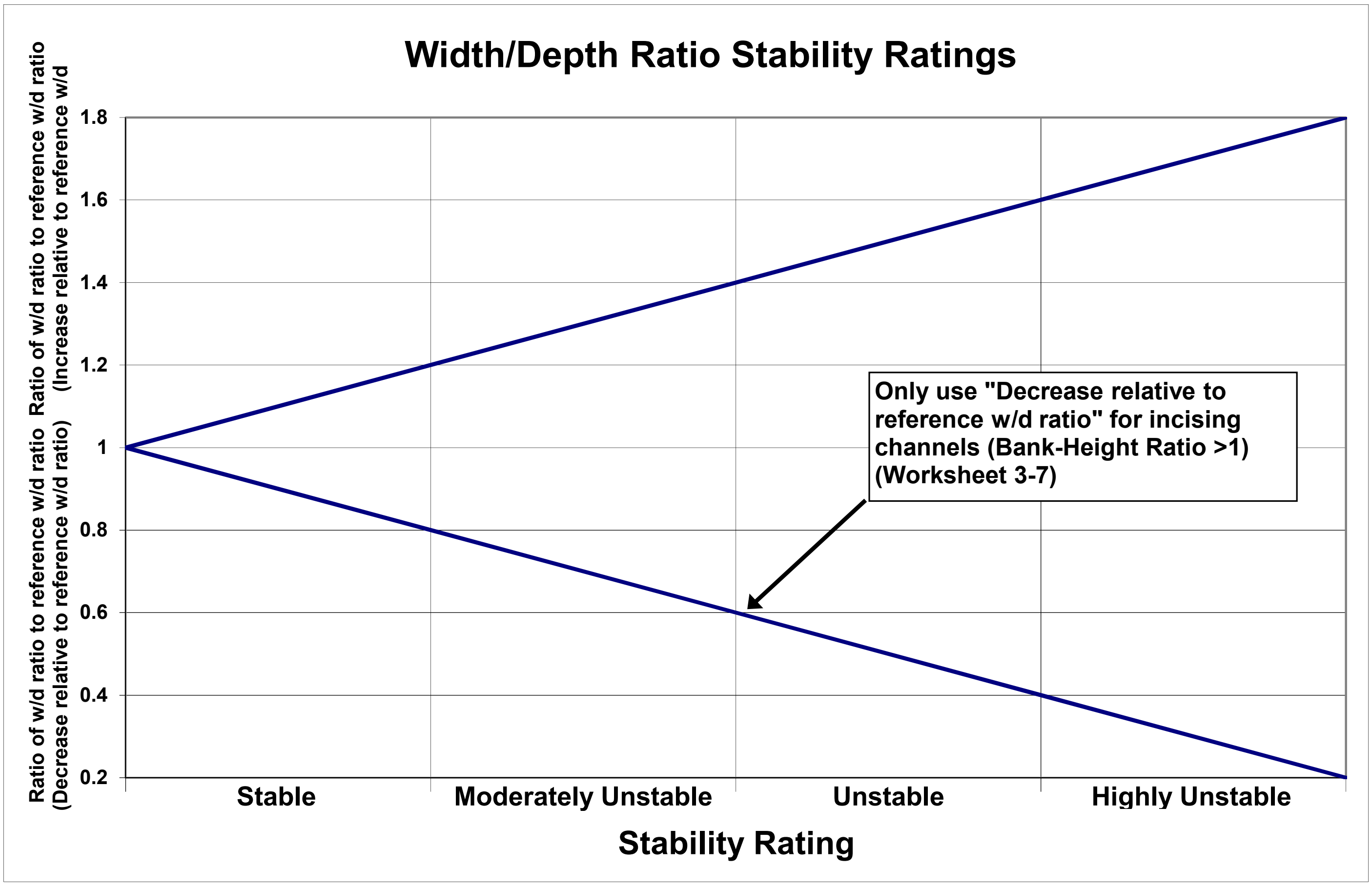


Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State

Existing Width/Depth Ratio:	**12.38**	Ratio of existing W/d to reference W/d:	**0.69**
Reference Width/Depth Ratio:	**18**		

Width/Depth Ratio State Stability Rating ☞ **Moderately Unstable**

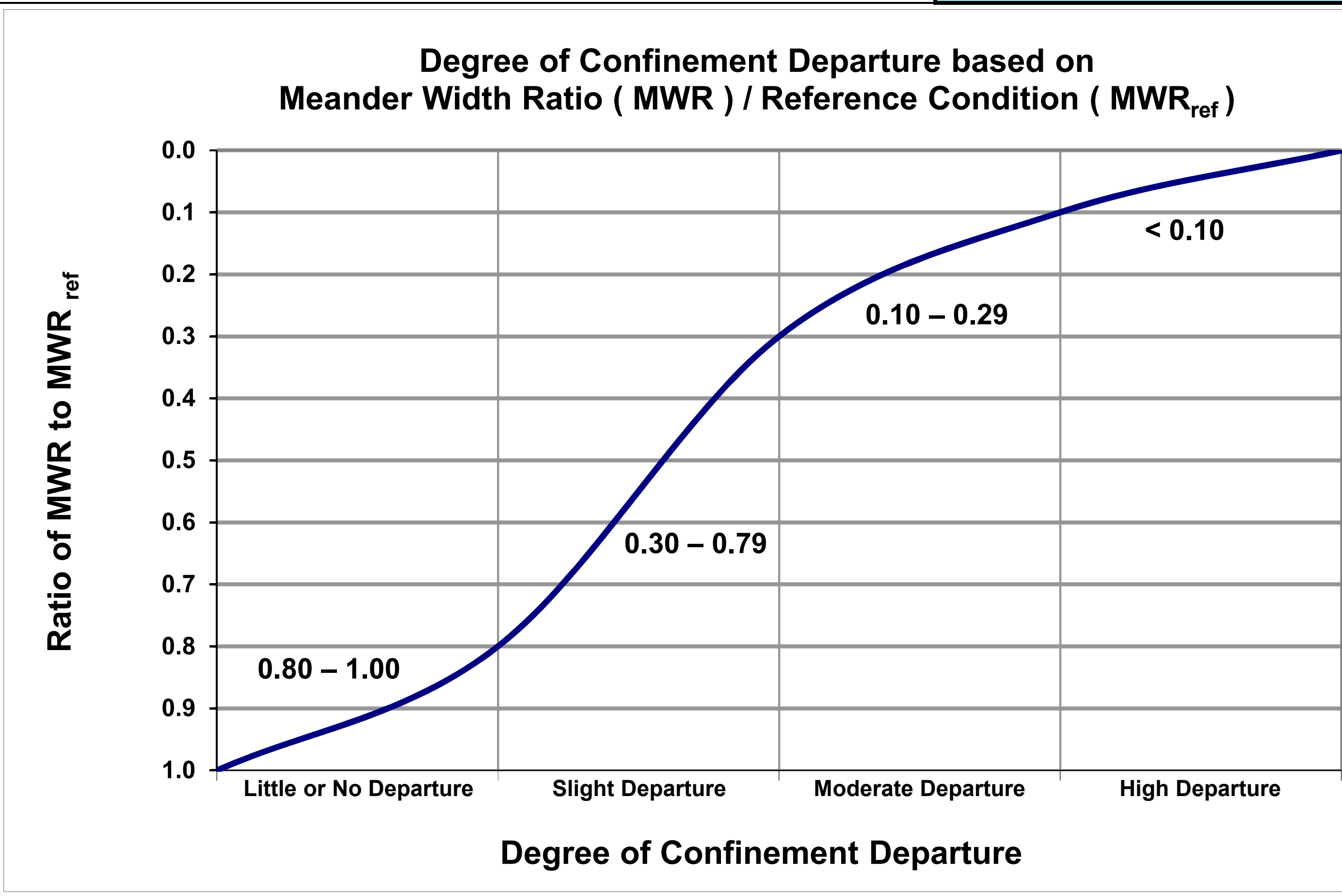


Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement

Existing Meander Width Ratio (MWR):	1.1	Ratio of MWR to MWR_{ref}:	0.46
Reference Meander Width Ratio (MWR_{ref}):	2.4		

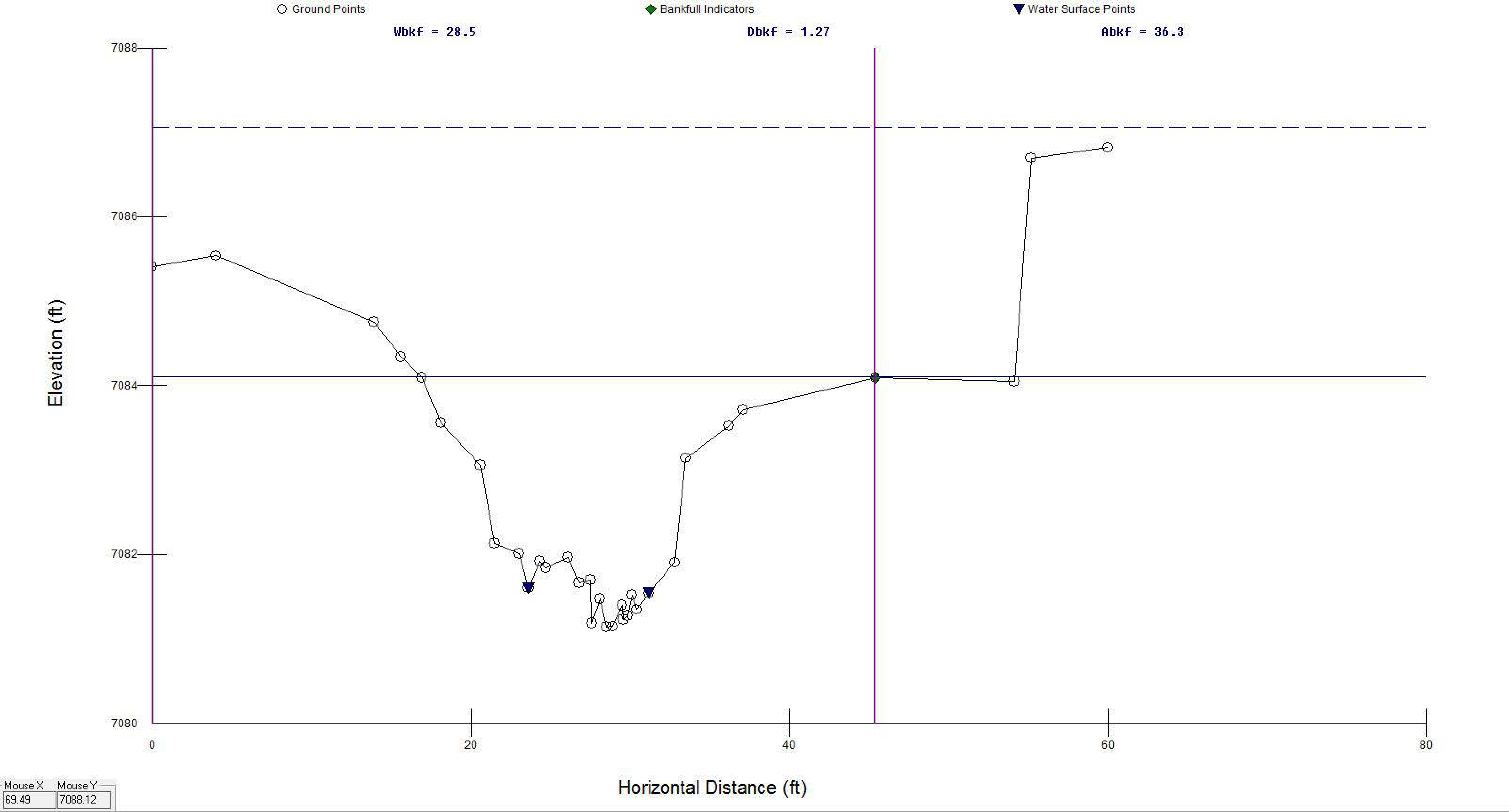
Degree of Confinement Stability Rating ☞ **Moderately Confined**



Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: Fourmile Creek	Stream Type: C 4b
Location: 4f	Valley Type: VIIIb
Observers: Sean Abel, Daniel Aragon	Date: 07/24/2015
Stream Type Stage Shifts (Figure 3-14)	**Stability Rating (Check Appropriate Rating)**
Stream Type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C)	☐ Stable
(E→C), (B→High W/d B), (C→High W/d C)	☑ Moderately Unstable
(G_c→F), (G→F_b), (F→D), (C→F)	☐ Unstable
(C→D), (A→G), (B→G), (D→G), (C→G), (E→G), (E→A)	☐ Highly Unstable

Reach 2 – Existing Conditions Assessment


Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 28.5
Dbkf = 1.27
Abkf = 36.3
7088
7086
7084
7082
7080
Elevation (ft)
0
20
40
60
80
Horizontal Distance (ft)
Mouse X
69.49
Mouse Y
7088.12

RIVERMORPH PARTICLE SUMMARY

River Name: Fourmile Creek
Reach Name: 4d
Sample Name: 4DriffleCount
Survey Date: 10/23/2015

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	0	0.00	0.00
0.062 - 0.125	1	0.97	0.97
0.125 - 0.25	6	5.83	6.80
0.25 - 0.50	3	2.91	9.71
0.50 - 1.0	6	5.83	15.53
1.0 - 2.0	11	10.68	26.21
2.0 - 4.0	10	9.71	35.92
4.0 - 5.7	4	3.88	39.81
5.7 - 8.0	9	8.74	48.54
8.0 - 11.3	14	13.59	62.14
11.3 - 16.0	4	3.88	66.02
16.0 - 22.6	6	5.83	71.84
22.6 - 32.0	7	6.80	78.64
32 - 45	3	2.91	81.55
45 - 64	6	5.83	87.38
64 - 90	2	1.94	89.32
90 - 128	2	1.94	91.26
128 - 180	3	2.91	94.17
180 - 256	2	1.94	96.12
256 - 362	3	2.91	99.03
362 - 512	1	0.97	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

D16 (mm)	1.04
D35 (mm)	3.81
D50 (mm)	8.35
D84 (mm)	52.98
D95 (mm)	212.35
D100 (mm)	511.98
Silt/Clay (%)	0
Sand (%)	26.21
Gravel (%)	61.17
Cobble (%)	8.74
Boulder (%)	3.88
Bedrock (%)	0

Total Particles = 103.

RIVERMORPH PFANKUCH SUMMARY

River Name: 4d
Reach Name: Assesments
Survey Date: 08/23/2016

Upper Bank

Landform Slope:	2
Mass Wasting:	6
Debris Jam Potential:	6
Vegetative Protection:	6

Lower Bank

Channel Capacity:	2
Bank Rock Content:	6
Obstructions to Flow:	6
Cutting:	12
Deposition:	12

Channel Bottom

Rock Angularity:	3
Brightness:	3
Consolidation of Particles:	6
Bottom Size Distribution:	12
Scouring and Deposition:	18
Aquatic Vegetation:	3

Channel Stability Evaluation

Sediment Supply:	High
Stream Bed Stability:	
W/D Condition:	
Stream Type:	B4

Rating - 103
Condition - Poor

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name:	Fourmile Creek
Reach Name:	4d <-- This is not a Reference Reach
Drainage Area:	13.5 sq mi
State:	Colorado
County:	Boulder
Latitude:	40.036
Longitude:	105.411
Survey Date:	07/24/2015

Classification Data

Valley Type:	Type VIII(b)
Valley Slope:	0.0404 ft/ft
Number of Channels:	Single
Width:	28.5 ft
Mean Depth:	1.27 ft
Flood-Prone Width:	60 ft
Channel Materials D50:	55.69 mm
Water Surface Slope:	0.02478 ft/ft
Sinuosity:	1.15
Discharge:	156.6 cfs
Velocity:	4.32 fps
Cross Sectional Area:	36.25 sq ft
Entrenchment Ratio:	2.11
Width to Depth Ratio:	22.44
Rosgen Stream Classification:	B 4

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY & DISCHARGE Estimates

Stream:	Fourmile Creek	Location:	Reach - 4d
Date:	8/28/2015	Stream Type: B4	Valley Type: VIIIb
Observers:	Abel, Aragon	HUC:	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Riffle Cross-Sectional AREA	36.25	A_{bkf} (ft^2)	Bankfull Riffle Mean DEPTH	1.27	d_{bkf} (ft)
Bankfull Riffle WIDTH	28.50	W_{bkf} (ft)	Wetted PERIMETER ~ (2 * d_{bkf}) + W_{bkf}	31.09	W_p (ft)
D_{84} at Riffle	52.98	Dia. (mm)	D_{84} (mm) / 304.8	0.17	D_{84} (ft)
Bankfull SLOPE	0.0248	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	1.17	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R(ft) / D_{84} (ft)	6.72	R / D_{84}
Drainage Area	0.0	DA (mi^2)	Shear Velocity $u^* = (gRS)^{½}$	0.966	u* (ft/sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness — $u = [2.83 + 5.66 * Log \{ R / D_{84} \}] u^*$	7.24	ft / sec	262.53	cfs
2. Roughness Coefficient: a) Manning's *n* from Friction Factor / Relative Roughness (Figs. 2-18, 2-19) — $u = 1.49*R^{2/3}*S^{1/2}/n$ — *n* = 0.06	4.32	ft / sec	156.60	cfs
2. Roughness Coefficient: b) Manning's *n* from Stream Type (Fig. 2-20) — $u = 1.49*R^{2/3}*S^{1/2}/n$ — *n* = 0.06	4.32	ft / sec	156.60	cfs
2. Roughness Coefficient: c) Manning's *n* from Jarrett (USGS): $u = 1.49*R^{2/3}*S^{1/2}/n$; $n = 0.39*S^{0.38}*R^{-0.16}$ — *n* = 0.093. Note: This equation is applicable to **steep, step/pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for Stream Types A1, A2, A3, B1, B2, B3, C2 & E3	2.78	ft / sec	100.59	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) — Darcy-Weisbach (Leopold, Wolman and Miller)	7.84	ft / sec	284.21	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) — Chezy C	0.00	ft / sec	0.00	cfs
4. Continuity Equations: a) Regional Curves — u = Q / A — Return Period for Bankfull Discharge Q = 0.0 year	0.00	ft / sec	0.00	cfs
4. Continuity Equations: b) USGS Gage Data — u = Q / A	0.00	ft / sec	0.00	cfs

Protrusion Height Options for the D_{84} Term in the Relative Roughness Relation (R/D_{84}) – Estimation Method 1

Option 1.	For **sand-bed** channels: Measure 100 **"protrusion heights"** of sand dunes from the downstream side of feature to the top of feature. Substitute the D_{84} sand dune protrusion height in ft for the D_{84} term in method 1.
Option 2.	For **boulder-dominated** channels: Measure 100 **"protrusion heights"** of boulders on the sides from the bed elevation to the top of the rock on that side. Substitute the D_{84} boulder protrusion height in ft for the D_{84} term in method 1.
Option 3.	For **bedrock-dominated** channels: Measure 100 **"protrusion heights"** of rock separations, steps, joints or uplifted surfaces above channel bed elevation. Substitute the D_{84} bedrock protrusion height in ft for the D_{84} term in method 1.
Option 4.	For **log-influenced** channels: Measure "**protrusion heights**" proportionate to channel width of log diameters or the height of the log on upstream side if embedded. Substitute the D_{84} protrusion height in ft for the D_{84} term in method 1.

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Fourmile Creek**			Stream Type:	**B 4**
Location:	**4d**			Valley Type:	**VIIIb**
Observers:	**Sean Abel, Daniel Aragon**			Date:	**07/24/2015**
Enter Required Information for Existing Condition					
8.4	D_{50}	Median particle size of riffle bed material (mm)			
N/A	$\hat{D}_{50}$	Median particle size of bar or sub-pavement sample (mm)			
0.666	D_{max}	Largest particle from bar sample (ft)	**203**	**(mm)**	304.8 mm/ft
0.02478	S	Existing bankfull water surface slope (ft/ft)			
1.27	d	Existing bankfull mean depth (ft)			
1.65	$\gamma_s - \gamma / \gamma$	Immersed specific gravity of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress				
0.00	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\ (D_{50}/\hat{D}_{50})^{-0.872}$
24.31	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\ (D_{max}/D_{50})^{-0.887}$
N/A	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**N/A**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample				
N/A	**d**	Required bankfull mean depth (ft)	$d = \frac{\tau^* (\gamma_s - 1) D_{max}}{S}$	(use D_{max} in ft)
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample				
N/A	**S**	Required bankfull water surface slope (ft/ft)	$S = \frac{\tau^* (\gamma_s - 1) D_{max}}{d}$	(use D_{max} in ft)
	Check: ☐ Stable ☐ Aggrading ☐ Degrading			

Sediment Competence Using Dimensional Shear Stress			
1.964		Bankfull shear stress $\tau = \gamma dS$ (lbs/ft²) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
Shields **157.5**	CO **249.7**	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
Shields **2.505**	CO **1.482**	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
Shields **1.62**	CO **0.96**	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \frac{\tau}{\gamma S}$
Shields **0.0316**	CO **0.0187**	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \frac{\tau}{\gamma d}$
		Check: ☐ Stable ☐ Aggrading ☑ Degrading	

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Fourmile Creek**	Location: **4d**							
Observers: **Sean Abel, Daniel Aragon**	Date: **7/24/2015**							
List ALL COMBINATIONS that APPLY...............☞	**P**	**1**	**2**	**8**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
S	Subterranean stream channel: Flows parallel to and near the surface for various seasons - a sub-surface flow that follows the stream bed.
I	Intermittent stream channel: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
P	Perennial stream channels: Surface water persists yearlong.

Specific Category

1	Seasonal variation in streamflow dominated primarily by snowmelt runoff.
2	Seasonal variation in streamflow dominated primarily by stormflow runoff.
3	Uniform stage and associated streamflow due to spring-fed condition, backwater, etc.
4	Streamflow regulated by glacial melt.
5	Ice flows/ice torrents from ice dam breaches.
6	Alternating flow/backwater due to tidal influence.
7	Regulated streamflow due to diversions, dam release, dewatering, etc.
8	Altered due to development, such as urban streams, cut-over watersheds or vegetation conversions (forested to grassland) that change flow response to precipitation events.
9	Rain-on-snow generated runoff.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Fourmile Creek**
Location:	**4d**
Observers:	**Sean Abel, Daniel Aragon**
Date:	**7/24/2015**
Stream Size Category and Order ☞	**S4 (3)**

Category	STREAM SIZE: Bankfull width		Check (✓) appropriate category
	meters	feet	
S-1	0.305	<1	☐
S-2	0.3 – 1.5	1 – 5	☐
S-3	1.5 – 4.6	5 – 15	☐
S-4	4.6 – 9	15 – 30	☐
S-5	9 – 15	30 – 50	☐
S-6	15 – 22.8	50 – 75	☐
S-7	22.8 – 30.5	75 – 100	☐
S-8	30.5 – 46	100 – 150	☐
S-9	46 – 76	150 – 250	☐
S-10	76 – 107	250 – 350	☐
S-11	107 – 150	350 – 500	☐
S-12	150 – 305	500 – 1000	☐
S-13	>305	>1000	☐

Stream Order

Add categories in parenthesis for specific stream order of reach. For example a third order stream with a bankfull width of 6.1 meters (20 feet) would be indexed as: S-4(3).

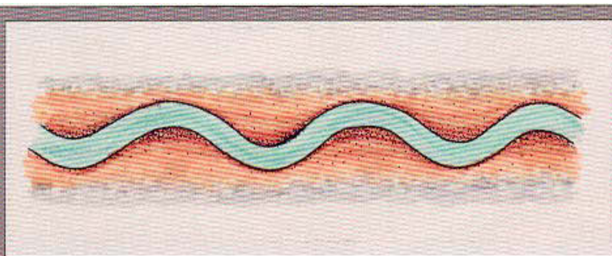
Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream:	**Fourmile Creek**	Reach:	**4d**
Observers:	**Sean Abel, Daniel Aragon**	Date:	**7/24/2015**

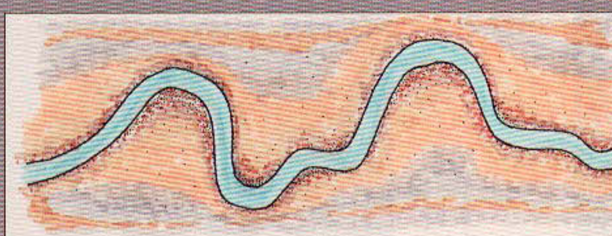
List ALL CATEGORIES that APPLY ☞	M1	M3	M4		

Various Meander Pattern variables modified from Galay et al. (1973)

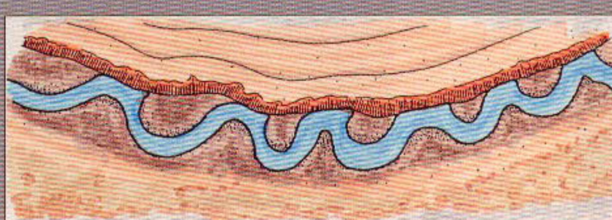


M1 REGULAR MEANDERS

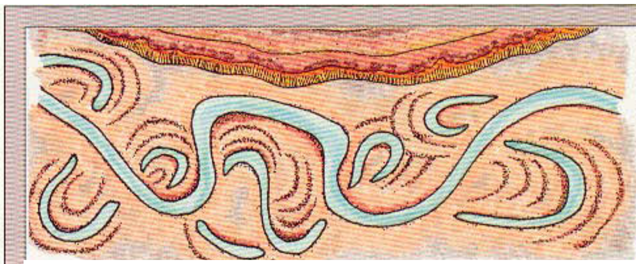
M2 TORTUOUS MEANDERS



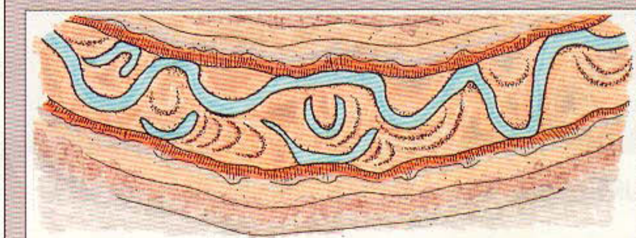
M3 IRREGULAR MEANDERS



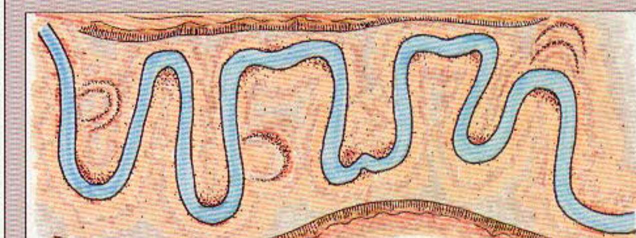
M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS



M6 CONFINED MEANDER SCROLLS



M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

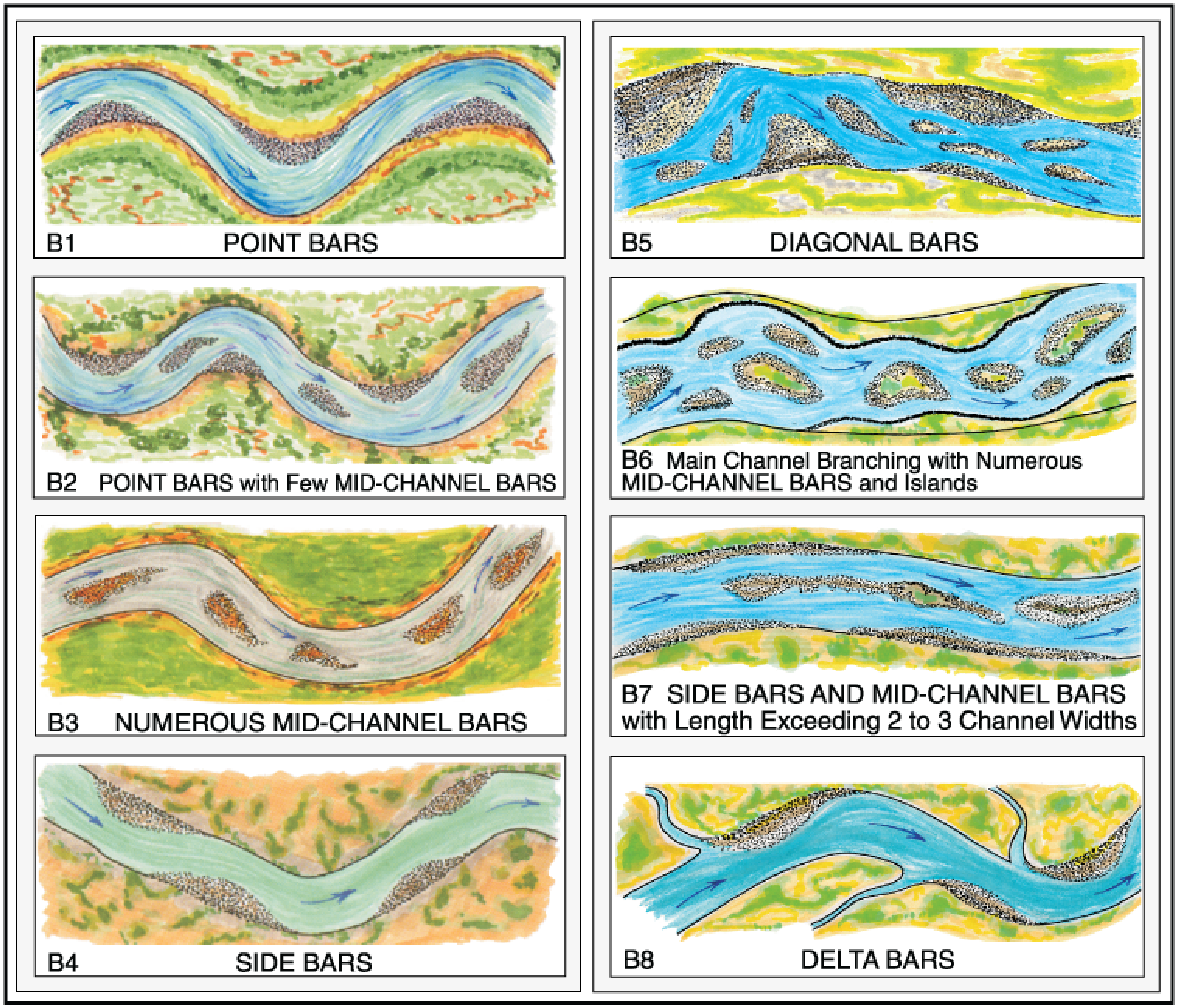
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Fourmile Creek**	Reach:	**4d**
Observers:	**Sean Abel, Daniel Aragon**	Date:	**7/24/2015**

List ALL CATEGORIES that APPLY ☞	**B1**	**B2**	**B4**	**B5**	

Various Depositional Features modified from Galay et al. (1973)

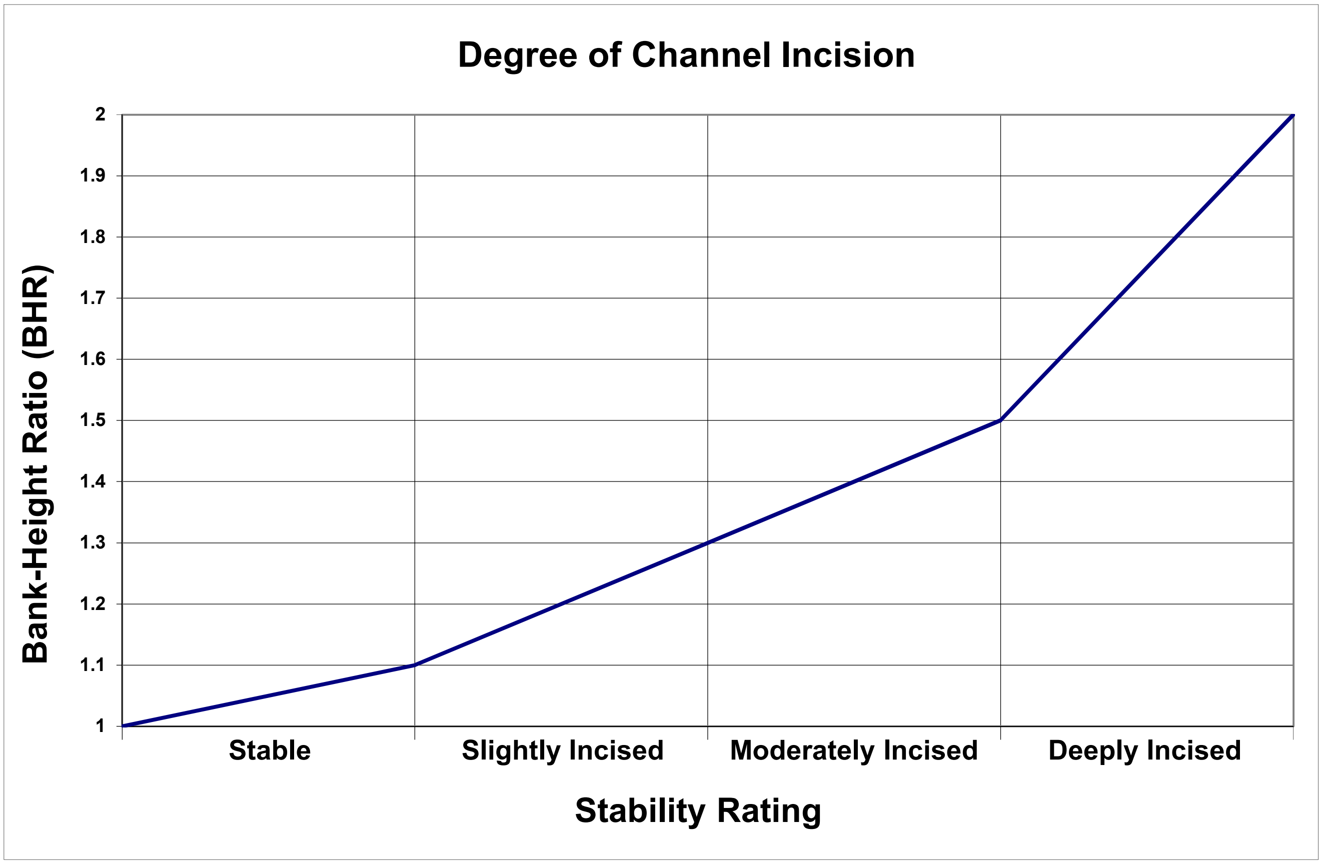


Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Fourmile Creek**		Location: **4d**	
Observers: **Sean Abel, Daniel Aragon**		Date: **7/24/2015**	
Description/extent		**Materials that upon placement into the active channel or flood-prone area may cause adjustments in channel dimensions or conditions due to influences on the existing flow regime.**	**Check (✓) all that apply**
D1	None	Minor amounts of small, floatable material.	☐
D2	Infrequent	Debris consists of small, easily moved, floatable material, e.g., leaves, needles, small limbs and twigs.	☐
D3	Moderate	Increasing frequency of small- to medium-sized material, such as large limbs, branches and small logs, that when accumulated, affect 10% or less of the active channel cross-section area.	☑
D4	Numerous	Significant build-up of medium- to large-sized materials, e.g., large limbs, branches, small logs or portions of trees that may occupy 10–30% of the active channel cross-section area.	☐
D5	Extensive	Debris "dams" of predominantly larger materials, e.g., branches, logs and trees, occupying 30–50% of the active channel cross-section area, often extending across the width of the active channel.	☐
D6	Dominating	Large, somewhat continuous debris "dams," extensive in nature and occupying over 50% of the active channel cross-section area. Such accumulations may divert water into the flood-prone areas and form fish migration barriers, even when flows are at less than bankfull.	☑
D7	Beaver dams: Few	An infrequent number of dams spaced such that normal streamflow and expected channel conditions exist in the reaches between dams.	☐
D8	Beaver dams: Frequent	Frequency of dams is such that backwater conditions exist for channel reaches between structures where streamflow velocities are reduced and channel dimensions or conditions are influenced.	☐
D9	Beaver dams: Abandoned	Numerous abandoned dams, many of which have filled with sediment and/or breached, initiating a series of channel adjustments, such as bank erosion, lateral migration, avulsion, aggradation and degradation.	☐
D10	Human influences	Structures, facilities or materials related to land uses or development located within the flood-prone area, such as diversions or low-head dams, controlled by-pass channels, velocity control structures and various transportation encroachments that have an influence on the existing flow regime, such that significant channel adjustments occur.	☐

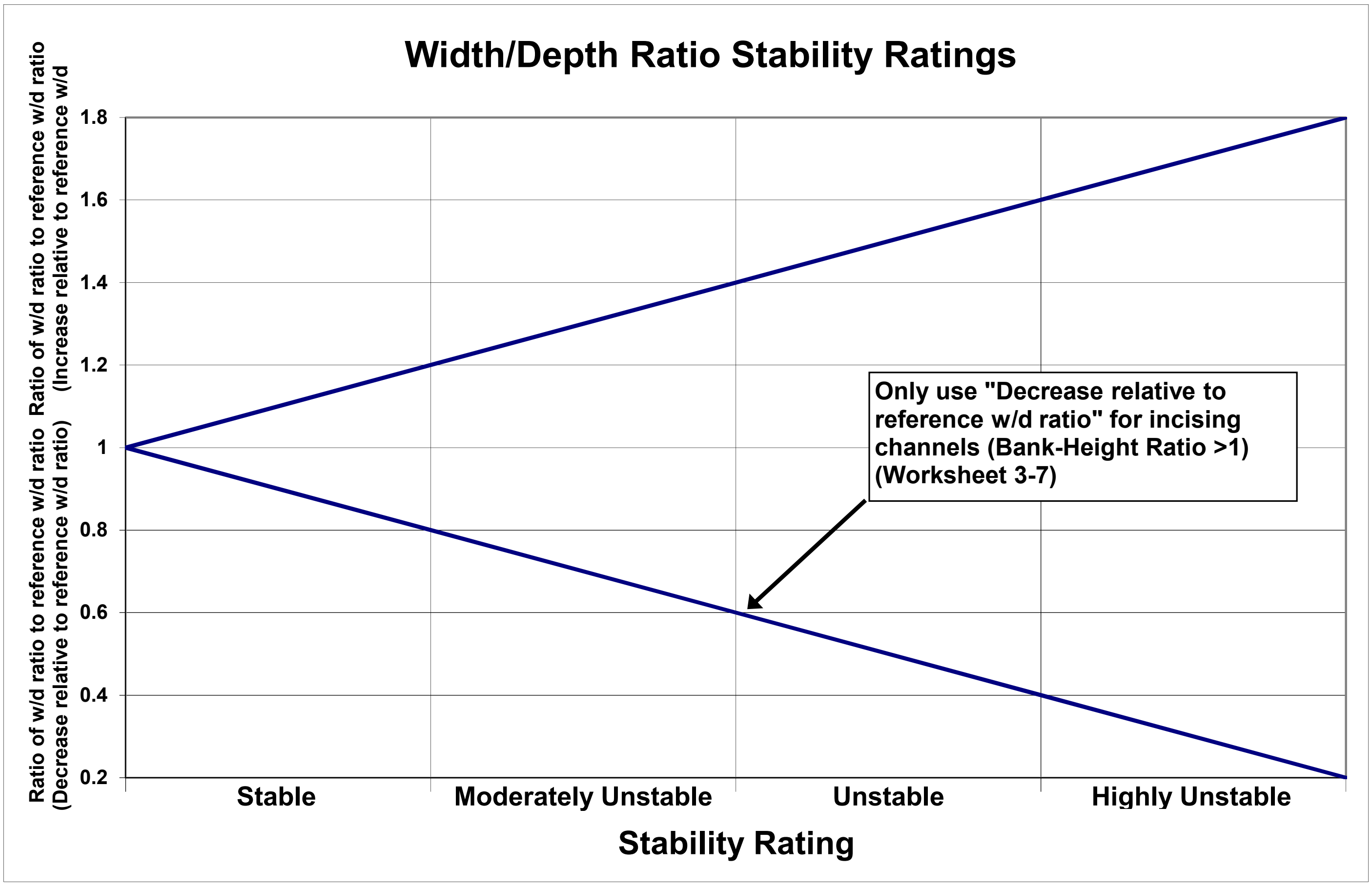
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision			
Low Bank Height:	4.4	Bank-Height Ratio:	1.5
Max Bankfull Depth:	3		
Degree of Channel Incision Stability Rating ☞			Moderately Incised



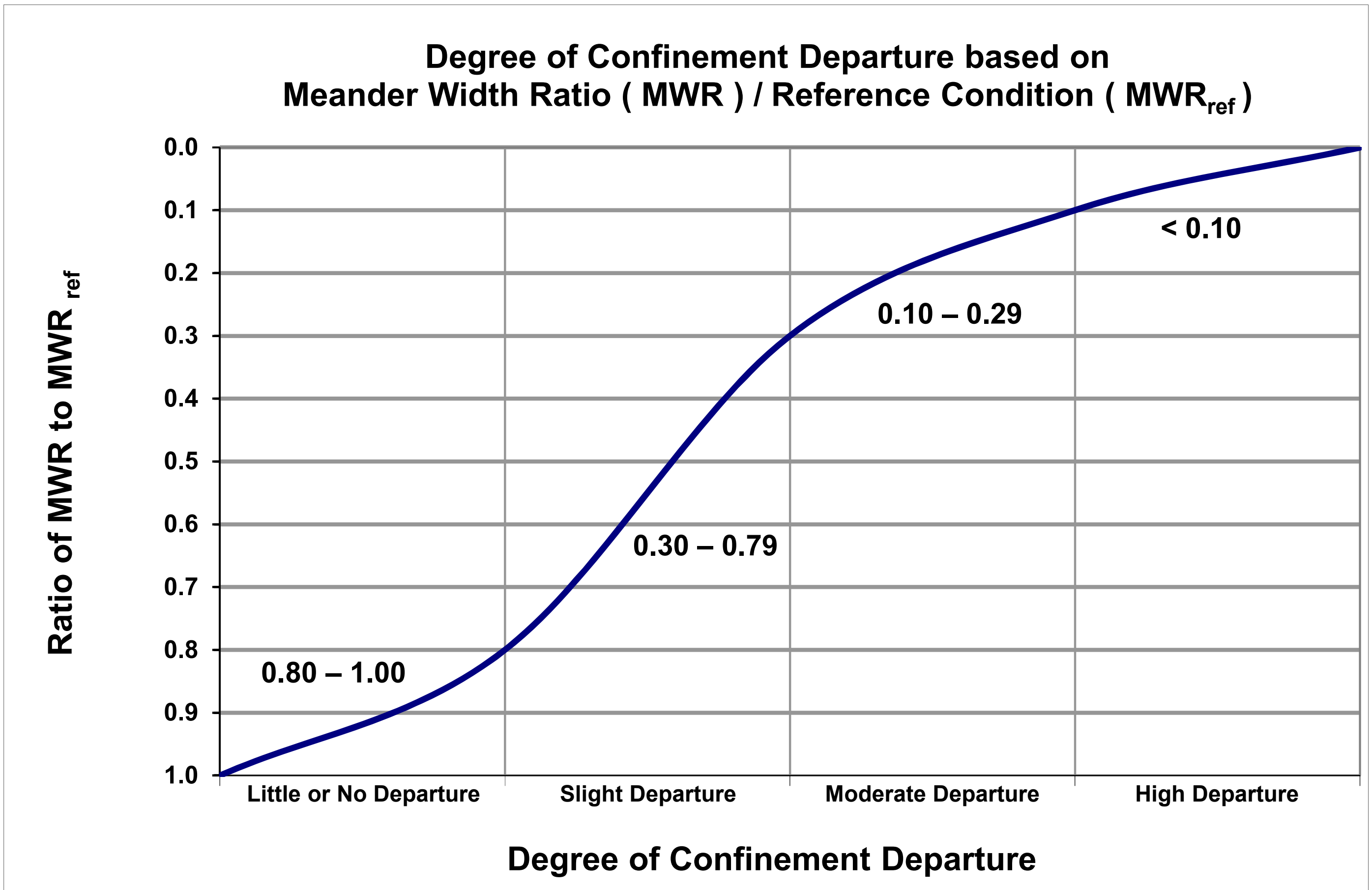
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	**22.44**	Ratio of existing W/d to reference W/d:	**1.25**
Reference Width/Depth Ratio:	**18**		
Width/Depth Ratio State Stability Rating ☞		**Moderately Unstable**	



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

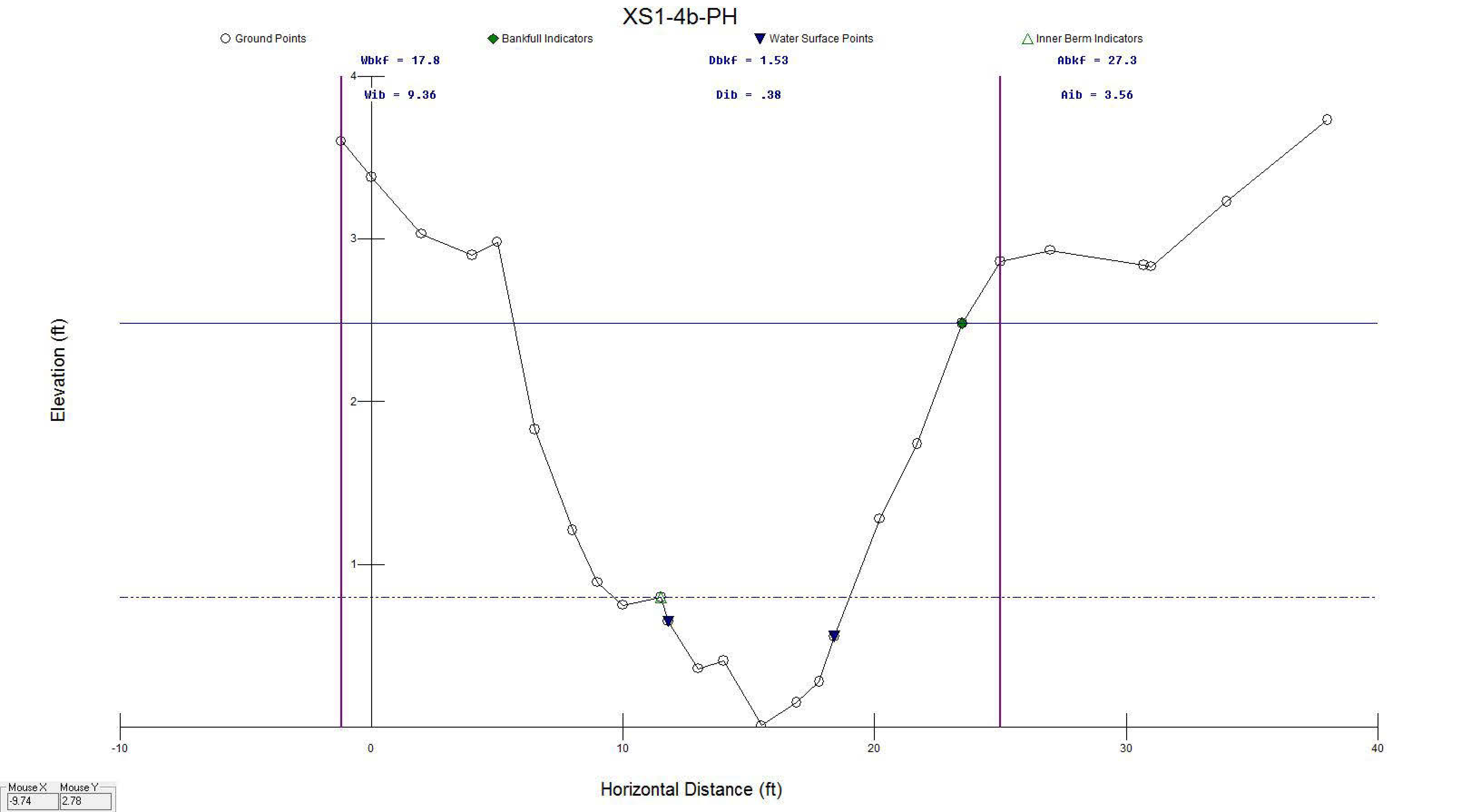
Degree of Confinement			
Existing Meander Width Ratio (MWR):	1.8	Ratio of MWR to MWR_{ref}:	0.75
Reference Meander Width Ratio (MWR_{ref}):	2.4		
Degree of Confinement Stability Rating ☞		Moderately Confined	



Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Fourmile Creek**	Stream Type: **B 4**
Location: **4d**	Valley Type: **VIIIb**
Observers: **Sean Abel, Daniel Aragon**	Date: **07/24/2015**
Stream Type Stage Shifts (Figure 3-14)	**Stability Rating (Check Appropriate Rating)**
Stream Type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C)	☐ Stable
(E→C), (B→High W/d B), (C→High W/d C)	☑ Moderately Unstable
(G_c→F), (G→F_b), (F→D), (C→F)	☐ Unstable
(C→D), (A→G), (B→G), (D→G), (C→G), (E→G), (E→A)	☐ Highly Unstable

Reach 3 – Existing Conditions Assessment



XS1-4b-PH
Ground Points
Bankfull Indicators
Water Surface Points
Inner Berm Indicators
Wbkf = 17.8
Dbkf = 1.53
Abkf = 27.3
Wib = 9.36
Dib = .38
Aib = 3.56
Elevation (ft)
Horizontal Distance (ft)
-10
0
10
20
30
40
1
2
3
4
Mouse X
Mouse Y
-9.74
2.78

RIVERMORPH PARTICLE SUMMARY

River Name:	Fourmile Creek
Reach Name:	4f
Sample Name:	Riffle-1
Survey Date:	10/15/2015

Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062	0	0.00	0.00
0.062 - 0.125	0	0.00	0.00
0.125 - 0.25	2	2.00	2.00
0.25 - 0.50	10	10.00	12.00
0.50 - 1.0	9	9.00	21.00
1.0 - 2.0	10	10.00	31.00
2.0 - 4.0	3	3.00	34.00
4.0 - 5.7	1	1.00	35.00
5.7 - 8.0	2	2.00	37.00
8.0 - 11.3	2	2.00	39.00
11.3 - 16.0	2	2.00	41.00
16.0 - 22.6	6	6.00	47.00
22.6 - 32.0	10	10.00	57.00
32 - 45	9	9.00	66.00
45 - 64	10	10.00	76.00
64 - 90	9	9.00	85.00
90 - 128	3	3.00	88.00
128 - 180	11	11.00	99.00
180 - 256	1	1.00	100.00
256 - 362	0	0.00	100.00
362 - 512	0	0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

D16 (mm)	0.72
D35 (mm)	5.7
D50 (mm)	25.42
D84 (mm)	87.11
D95 (mm)	161.09
D100 (mm)	255.99
Silt/Clay (%)	0
Sand (%)	31
Gravel (%)	45
Cobble (%)	24
Boulder (%)	0
Bedrock (%)	0

Total Particles = 100.

RIVERMORPH PFANKUCH SUMMARY

River Name: 4b
Reach Name: Assesments
Survey Date: 08/04/2016

Upper Bank

Landform Slope:	2
Mass Wasting:	6
Debris Jam Potential:	6
Vegetative Protection:	6

Lower Bank

Channel Capacity:	2
Bank Rock Content:	6
Obstructions to Flow:	6
Cutting:	12
Deposition:	12

Channel Bottom

Rock Angularity:	3
Brightness:	3
Consolidation of Particles:	6
Bottom Size Distribution:	12
Scouring and Deposition:	18
Aquatic Vegetation:	3

Channel Stability Evaluation

Sediment Supply:	High
Stream Bed Stability:	
W/D Condition:	
Stream Type:	B4

Rating - 103
Condition - Poor

RIVERMORPH STREAM CHANNEL CLASSIFICATION

River Name: Fourmile Creek
Reach Name: 4b <-- This is not a Reference Reach
Drainage Area: 15.9 sq mi
State: Colorado
County: Boulder
Latitude: 0
Longitude: 0
Survey Date: 01/27/2016

Classification Data

Valley Type:	Type VIII(b)
Valley Slope:	0.037 ft/ft
Number of Channels:	Single
Width:	17.85 ft
Mean Depth:	1.53 ft
Flood-Prone Width:	39.2 ft
Channel Materials D50:	50 mm
Water Surface Slope:	0.035 ft/ft
Sinuosity:	1.06
Discharge:	170.941 cfs
Velocity:	6.257 fps
Cross Sectional Area:	27.32 sq ft
Entrenchment Ratio:	2.2
Width to Depth Ratio:	11.67
Rosgen Stream Classification:	B 4

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY & DISCHARGE Estimates

Stream:	Fourmile Creek		Location:	Reach - 4b	
Date:		Stream Type: B4	Valley Type:	VIIIb	
Observers:			HUC:		

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Riffle Cross-Sectional AREA	27.32	A_{bkf} (ft^2)	Bankfull Riffle Mean DEPTH	1.53	d_{bkf} (ft)
Bankfull Riffle WIDTH	17.85	W_{bkf} (ft)	Wetted PERIMETER ~ (2 * d_{bkf}) + W_{bkf}	18.81	W_p (ft)
D_{84} at Riffle	87.11	Dia. (mm)	D_{84} (mm) / 304.8	0.29	D_{84} (ft)
Bankfull SLOPE	0.0350	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	1.45	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R(ft) / D_{84} (ft)	5.07	R / D_{84}
Drainage Area	15.9	DA (mi^2)	Shear Velocity $u^* = (gRS)^{½}$	1.278	u* (ft/sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 * Log\{R / D_{84}\}] u^*$	8.73	ft / sec	238.59	cfs
2. Roughness Coefficient: a) Manning's *n* from Friction Factor / Relative Roughness (Figs. 2-18, 2-19) $u = 1.49 * R^{2/3} * S^{1/2} / n$ *n* = 0.057	6.26	ft / sec	170.94	cfs
2. Roughness Coefficient: b) Manning's *n* from Stream Type (Fig. 2-20) $u = 1.49 * R^{2/3} * S^{1/2} / n$ *n* = 0.057	6.26	ft / sec	170.94	cfs
2. Roughness Coefficient: c) Manning's *n* from Jarrett (USGS): $u = 1.49 * R^{2/3} * S^{1/2} / n$ $n = 0.39 * S^{0.38} * R^{-0.16}$ *n* = 0.103 Note: This equation is applicable to **steep, step/pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for Stream Types A1, A2, A3, B1, B2, B3, C2 & E3	3.47	ft / sec	94.80	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) Darcy-Weisbach (Leopold, Wolman and Miller)	9.21	ft / sec	251.59	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) Chezy C	0.00	ft / sec	0.00	cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 0.0 year	0.00	ft / sec	0.00	cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A	0.00	ft / sec	0.00	cfs

Protrusion Height Options for the D_{84} Term in the Relative Roughness Relation (R/D_{84}) – Estimation Method 1

Option 1.	For **sand-bed** channels: Measure 100 **"protrusion heights"** of sand dunes from the downstream side of feature to the top of feature. Substitute the D_{84} sand dune protrusion height in ft for the D_{84} term in method 1.
Option 2.	For **boulder-dominated** channels: Measure 100 **"protrusion heights"** of boulders on the sides from the bed elevation to the top of the rock on that side. Substitute the D_{84} boulder protrusion height in ft for the D_{84} term in method 1.
Option 3.	For **bedrock-dominated** channels: Measure 100 **"protrusion heights"** of rock separations, steps, joints or uplifted surfaces above channel bed elevation. Substitute the D_{84} bedrock protrusion height in ft for the D_{84} term in method 1.
Option 4.	For **log-influenced** channels: Measure "**protrusion heights**" proportionate to channel width of log diameters or the height of the log on upstream side if embedded. Substitute the D_{84} protrusion height in ft for the D_{84} term in method 1.

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Fourmile Creek**		Stream Type: **B 4**		
Location:	**4b**		Valley Type: **VIIIb**		
Observers:			Date: **01/27/2016**		
Enter Required Information for Existing Condition					
25.4	D_{50}	Median particle size of riffle bed material (mm)			
N/A	$\hat{D}_{50}$	Median particle size of bar or sub-pavement sample (mm)			
0.666	D_{max}	Largest particle from bar sample (ft)	**203**	**(mm)**	304.8 mm/ft
0.03450	S	Existing bankfull water surface slope (ft/ft)			
1.53	d	Existing bankfull mean depth (ft)			
1.65	$\gamma_s - \gamma / \gamma$	Immersed specific gravity of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress				
N/A	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$	
7.99	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$	
N/A	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**N/A**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample				
N/A	**d**	Required bankfull mean depth (ft)	$d = \frac{\tau^*(\gamma_s - 1)D_{max}}{S}$	(use D_{max} in ft)
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample				
N/A	**S**	Required bankfull water surface slope (ft/ft)	$S = \frac{\tau^*(\gamma_s - 1)D_{max}}{d}$	(use D_{max} in ft)
		Check: ☐ Stable ☐ Aggrading ☐ Degrading		

Sediment Competence Using Dimensional Shear Stress		
3.294		Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope
Shields **270**	CO **365.3**	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**
Shields **2.505**	CO **1.482**	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**
Shields **1.16**	CO **0.69**	Predicted mean depth required to initiate movement of measured D_{max} (mm) $d = \frac{\tau}{\gamma S}$ τ = predicted shear stress, γ = 62.4, S = existing slope
Shields **0.0262**	CO **0.0155**	Predicted slope required to initiate movement of measured D_{max} (mm) $S = \frac{\tau}{\gamma d}$ τ = predicted shear stress, γ = 62.4, d = existing depth
		Check: ☐ Stable ☐ Aggrading ☑ Degrading

Worksheet 3-16. Stability ratings for corresponding successional stage shifts of stream types. Check the appropriate stability rating.

Stream: **Fourmile Creek**	Stream Type: **B 4**
Location: **4b**	Valley Type: **VIIIb**
Observers:	Date: **01/27/2016**
Stream Type Stage Shifts (Figure 3-14)	**Stability Rating (Check Appropriate Rating)**
Stream Type at potential, (C→E), (F_b→B), (G→B), (F→B_c), (F→C), (D→C)	☐ Stable
(E→C), (B→High W/d B), (C→High W/d C)	☑ Moderately Unstable
(G_c→F), (G→F_b), (F→D), (C→F)	☐ Unstable
(C→D), (A→G), (B→G), (D→G), (C→G), (E→G), (E→A)	☐ Highly Unstable

Worksheet 3-2. Flow regime variables that influence channel characteristics, sediment regime and biological interpretations.

FLOW REGIME

Stream: **Fourmile Creek**	Location: **4b**							
Observers:	Date: **1/27/2016**							
List ALL COMBINATIONS that APPLY...............☞	**P**	**1**	**2**	**8**				

General Category

E	Ephemeral stream channels: Flows only in response to precipitation
S	Subterranean stream channel: Flows parallel to and near the surface for various seasons - a sub-surface flow that follows the stream bed.
I	Intermittent stream channel: Surface water flows discontinuously along its length. Often associated with sporadic and/or seasonal flows and also with Karst (limestone) geology where losing/gaining reaches create flows that disappear then reappear farther downstream.
P	Perennial stream channels: Surface water persists yearlong.

Specific Category

1	Seasonal variation in streamflow dominated primarily by snowmelt runoff.
2	Seasonal variation in streamflow dominated primarily by stormflow runoff.
3	Uniform stage and associated streamflow due to spring-fed condition, backwater, etc.
4	Streamflow regulated by glacial melt.
5	Ice flows/ice torrents from ice dam breaches.
6	Alternating flow/backwater due to tidal influence.
7	Regulated streamflow due to diversions, dam release, dewatering, etc.
8	Altered due to development, such as urban streams, cut-over watersheds or vegetation conversions (forested to grassland) that change flow response to precipitation events.
9	Rain-on-snow generated runoff.

Worksheet 3-3. Stream order and stream size categories for stratification by stream type.

Stream Size and Order

Stream:	**Fourmile Creek**
Location:	**4b**
Observers:	
Date:	**1/27/2016**
Stream Size Category and Order ☞	**S4 (3)**

Category	STREAM SIZE: Bankfull width		Check (✓) appropriate category
	meters	feet	
S-1	0.305	<1	☐
S-2	0.3 – 1.5	1 – 5	☐
S-3	1.5 – 4.6	5 – 15	☐
S-4	4.6 – 9	15 – 30	☐
S-5	9 – 15	30 – 50	☐
S-6	15 – 22.8	50 – 75	☐
S-7	22.8 – 30.5	75 – 100	☐
S-8	30.5 – 46	100 – 150	☐
S-9	46 – 76	150 – 250	☐
S-10	76 – 107	250 – 350	☐
S-11	107 – 150	350 – 500	☐
S-12	150 – 305	500 – 1000	☐
S-13	>305	>1000	☐

Stream Order

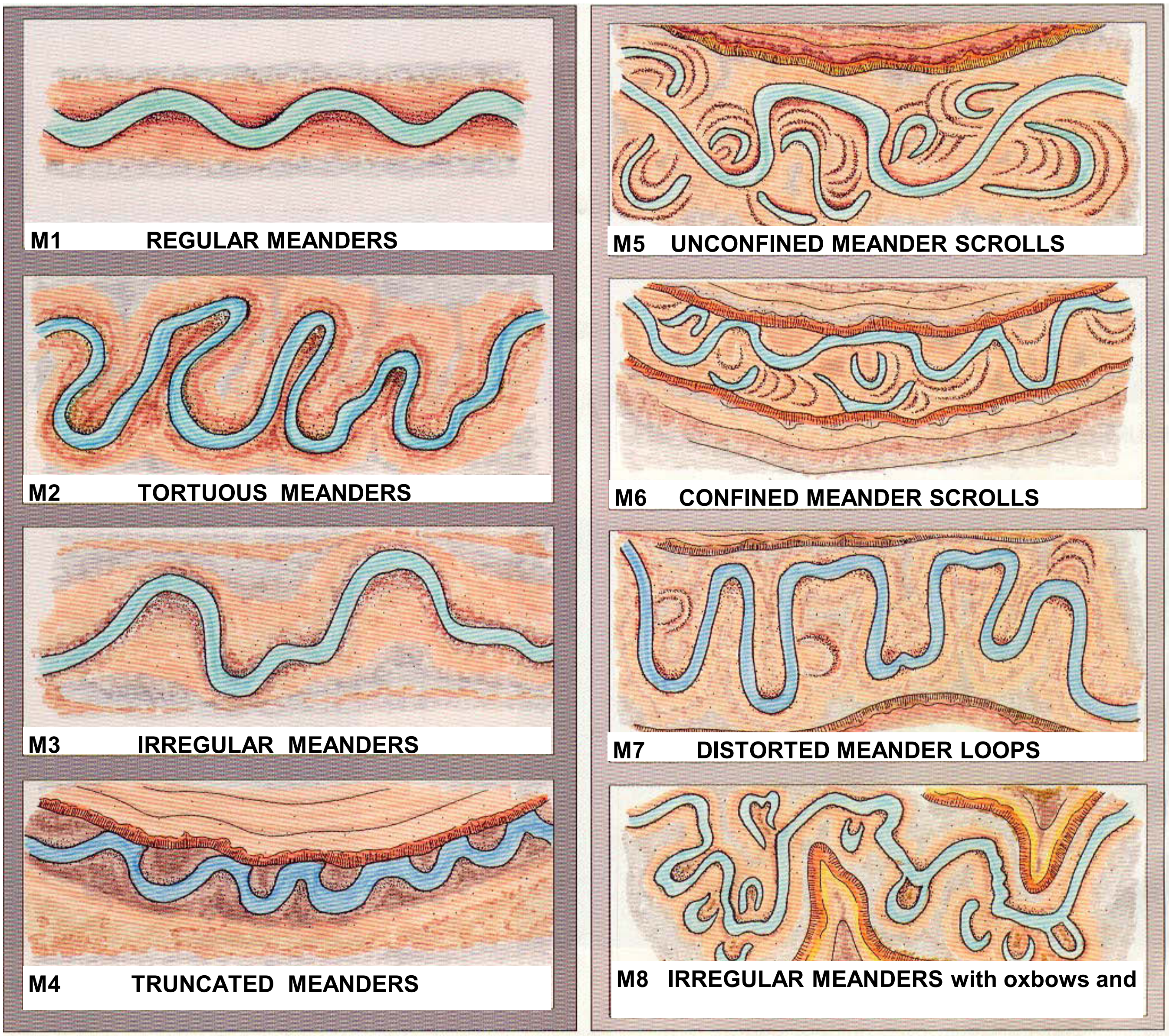
Add categories in parenthesis for specific stream order of reach. For example a third order stream with a bankfull width of 6.1 meters (20 feet) would be indexed as: S-4(3).

Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

Meander Patterns

Stream: **Fourmile Creek**			Reach: **4b**		
Observers:			Date: **1/27/2016**		
List ALL CATEGORIES that APPLY ☞	**M1**	**M3**	**M4**		

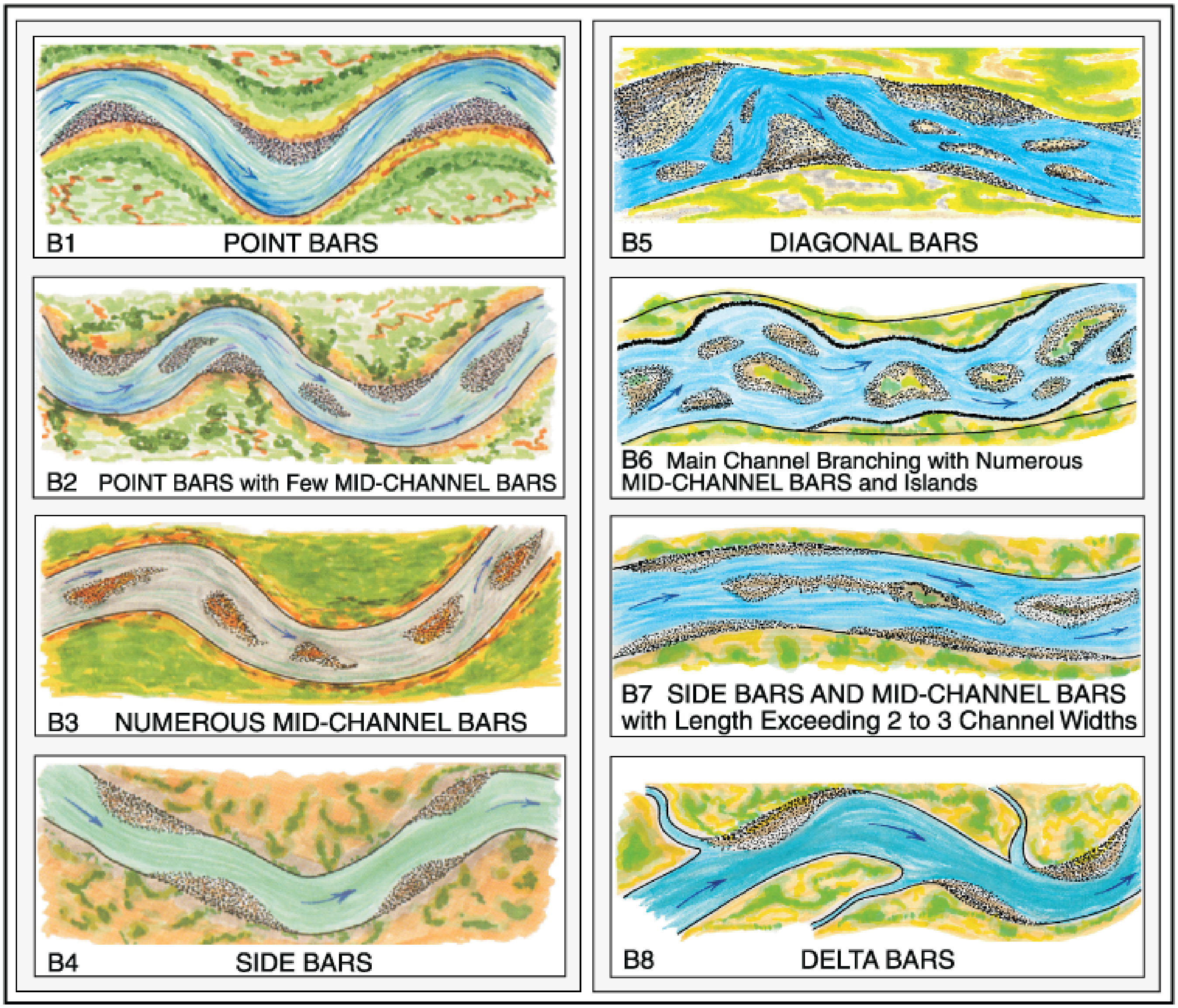
Various Meander Pattern variables modified from Galay et al. (1973)



Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns						
Stream:	**Fourmile Creek**		Reach:	**4b**		
Observers:			Date:	**1/27/2016**		
List ALL CATEGORIES that APPLY ☞	**B1**	**B2**	**B4**	**B5**		

Various Depositional Features modified from Galay et al. (1973)

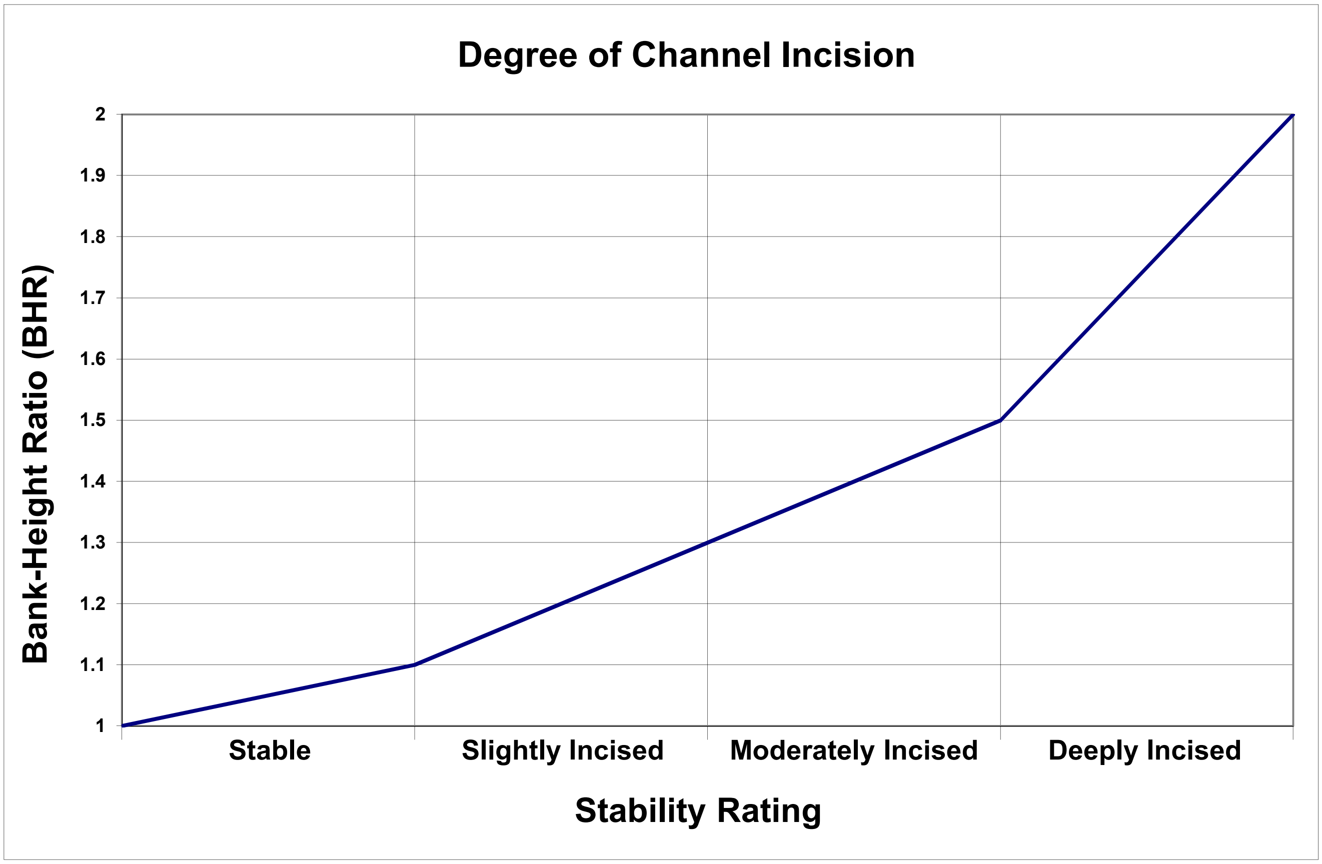


Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages				
Stream:	**Fourmile Creek**	Location: **4b**		
Observers:		Date: **1/27/2016**		
Description/extent		**Materials that upon placement into the active channel or flood-prone area may cause adjustments in channel dimensions or conditions due to influences on the existing flow regime.**	**Check (✓) all that apply**
D1	None	Minor amounts of small, floatable material.	☐
D2	Infrequent	Debris consists of small, easily moved, floatable material, e.g., leaves, needles, small limbs and twigs.	☐
D3	Moderate	Increasing frequency of small- to medium-sized material, such as large limbs, branches and small logs, that when accumulated, affect 10% or less of the active channel cross-section area.	☑
D4	Numerous	Significant build-up of medium- to large-sized materials, e.g., large limbs, branches, small logs or portions of trees that may occupy 10–30% of the active channel cross-section area.	☐
D5	Extensive	Debris "dams" of predominantly larger materials, e.g., branches, logs and trees, occupying 30–50% of the active channel cross-section area, often extending across the width of the active channel.	☐
D6	Dominating	Large, somewhat continuous debris "dams," extensive in nature and occupying over 50% of the active channel cross-section area. Such accumulations may divert water into the flood-prone areas and form fish migration barriers, even when flows are at less than bankfull.	☑
D7	Beaver dams: Few	An infrequent number of dams spaced such that normal streamflow and expected channel conditions exist in the reaches between dams.	☐
D8	Beaver dams: Frequent	Frequency of dams is such that backwater conditions exist for channel reaches between structures where streamflow velocities are reduced and channel dimensions or conditions are influenced.	☐
D9	Beaver dams: Abandoned	Numerous abandoned dams, many of which have filled with sediment and/or breached, initiating a series of channel adjustments, such as bank erosion, lateral migration, avulsion, aggradation and degradation.	☐
D10	Human influences	Structures, facilities or materials related to land uses or development located within the flood-prone area, such as diversions or low-head dams, controlled by-pass channels, velocity control structures and various transportation encroachments that have an influence on the existing flow regime, such that significant channel adjustments occur.	☐

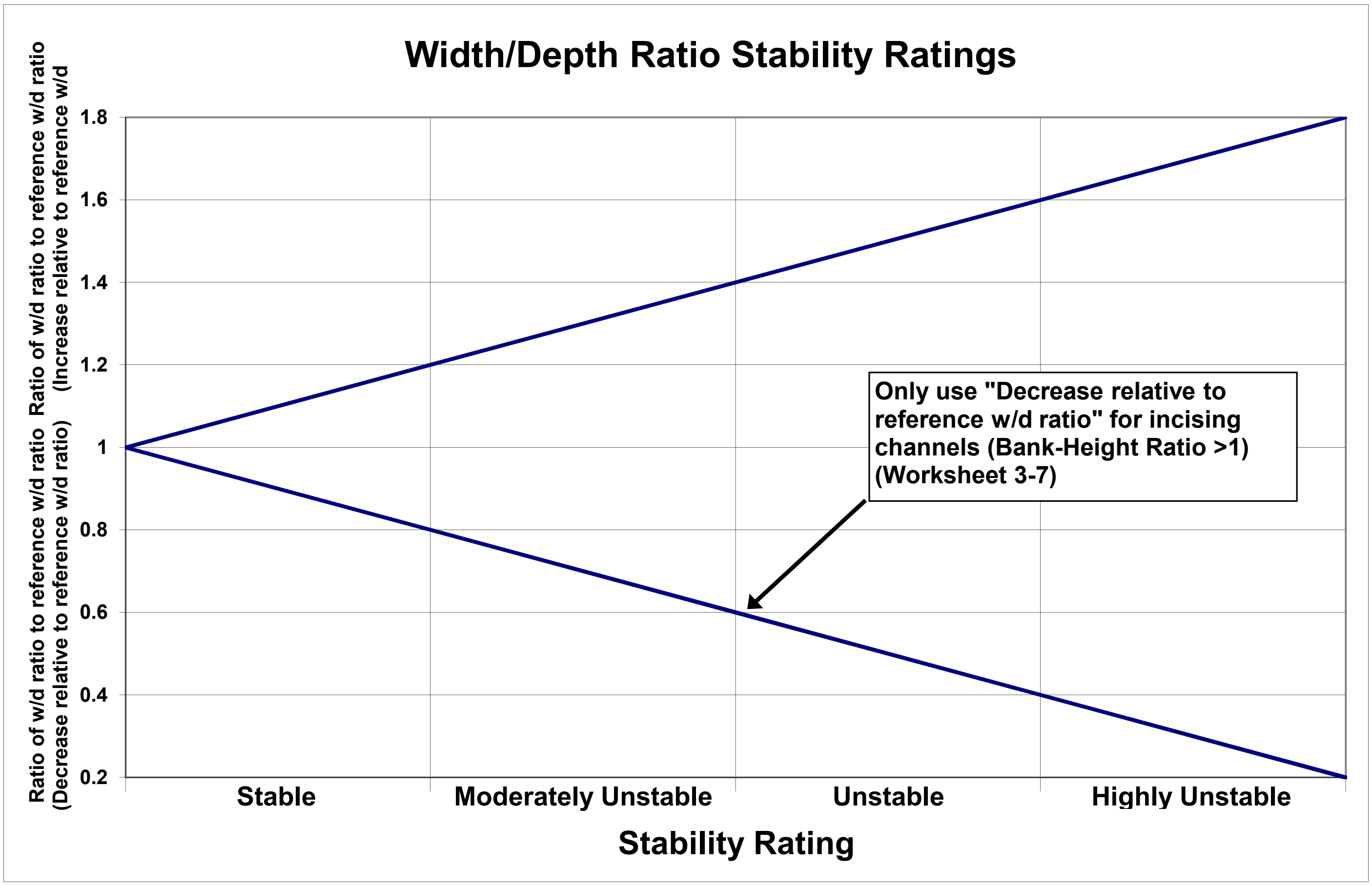
Worksheet 3-7. Relationship of Bank-Height Ratio (BHR) ranges to corresponding stream stability ratings.

Degree of Channel Incision			
Low Bank Height:	2.9	Bank-Height Ratio:	1.2
Max Bankfull Depth:	2.47		
Degree of Channel Incision Stability Rating ☞		Slightly Incised	



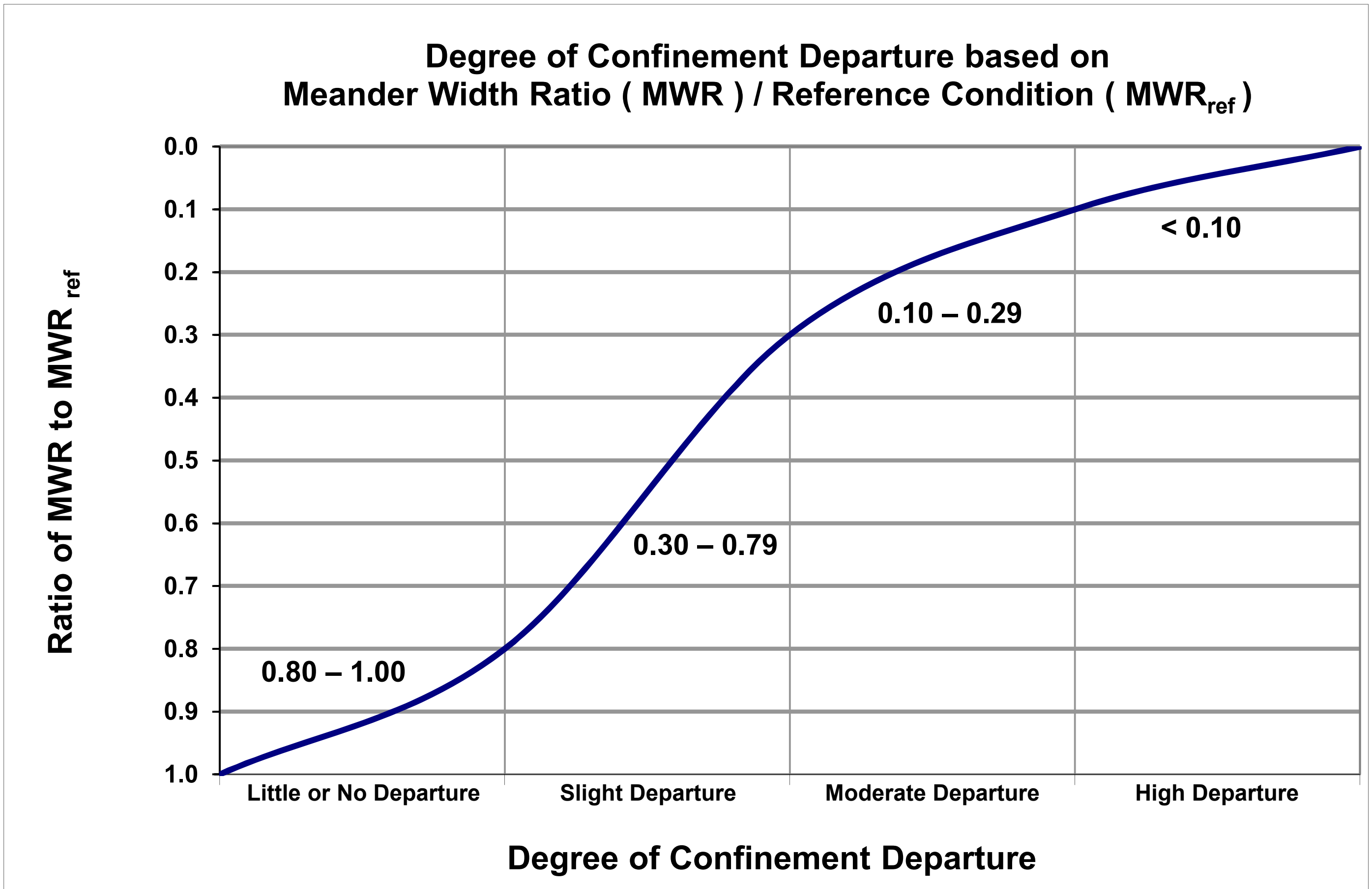
Worksheet 3-8. Stability ratings based on departure of width/depth ratio from reference condition.

Width/Depth Ratio State			
Existing Width/Depth Ratio:	**11.67**	Ratio of existing W/d to reference W/d:	**0.65**
Reference Width/Depth Ratio:	**18**		
Width/Depth Ratio State Stability Rating ☞		**Moderately Unstable**	



Worksheet 3-9. Degree of confinement based on Meander Width Ratio (MWR) divided by reference condition Meander Width Ratio (MWR_{ref}).

Degree of Confinement			
Existing Meander Width Ratio (MWR):	1.3	Ratio of MWR to MWR_{ref}:	0.54
Reference Meander Width Ratio (MWR_{ref}):	2.4		
Degree of Confinement Stability Rating ☞		Moderately Confined	



Reference Reach Data & Design Geometry

		Entry Number & Variable	Design Reach 1	Reach 1 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Design Reach 2	Reach 2 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Design Reach 3	Reach 3 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Postflood Stable Cross Sections
	1	Valley Type (I–XII)	VIII			VIII				VIII				VIII	
	2	Valley Width (W_{val})													
	3	Stream Type	C4			C3b	B4/C4			C3b	C4			C3b	
	4	Drainage Area, mi^2 (DA)	11.20			4.4	13.80			4.4	15.90			4.4	
	5	Bankfull Discharge, cfs (Q_{bkf})	145.0			110.0	160.0			110.0	175.0			110.0	
Riffle Dimensions	6	Riffle Width, ft (W_{bkf})	Mean: 22.5	Mean:	Mean: 20.3	Mean: 15.1	Mean: 22.5	Mean:	Mean: 20.9	Mean: 15.1	Mean: 24.0	Mean:	Mean: 22.1	Mean: 15.1	Mean: 22.4
			Min: 22.5	Min:	Min: 15.7	Min: 12.8	Min: 22.5	Min:	Min: 16.1	Min: 12.8	Min: 24.0	Min:	Min: 17.0	Min: 12.8	Min: 19.8
			Max: 22.5	Max:	Max: 22.8	Max: 18.7	Max: 22.5	Max:	Max: 23.4	Max: 18.7	Max: 24.0	Max:	Max: 24.8	Max: 18.7	Max: 24.9
	7	Riffle Mean Depth, ft (d_{bkf})	Mean: 1.2	Mean:	Mean: 1.35	Mean: 1.1	Mean: 1.3	Mean:	Mean: 1.39	Mean: 1.1	Mean: 1.4	Mean:	Mean: 1.47	Mean: 1.1	Mean: 1.4
			Min: 1.2	Min:	Min: 1.21	Min: 0.8	Min: 1.3	Min:	Min: 1.24	Min: 0.8	Min: 1.4	Min:	Min: 1.31	Min: 0.8	Min: 1.0
			Max: 1.2	Max:	Max: 1.76	Max: 1.4	Max: 1.3	Max:	Max: 1.80	Max: 1.4	Max: 1.4	Max:	Max: 1.91	Max: 1.4	Max: 1.7
	8	Riffle Width/Depth Ratio (W_{bkf}/d_{bkf})	Mean: 18.4	Mean:	Mean: 15.0	Mean: 15.0	Mean: 17.5	Mean:	Mean: 15.0	Mean: 15.0	Mean: 17.7	Mean:	Mean: 15.0	Mean: 15.0	Mean: 16.5
			Min: 18.4	Min:	Min: 8.9	Min: 8.9	Min: 17.5	Min:	Min: 8.9	Min: 8.9	Min: 17.7	Min:	Min: 8.9	Min: 8.9	Min: 20.5
			Max: 18.4	Max:	Max: 18.9	Max: 18.9	Max: 17.5	Max:	Max: 18.9	Max: 18.9	Max: 17.7	Max:	Max: 18.9	Max: 18.9	Max: 14.3
	9	Riffle Cross-Sectional Area, ft^2 (A_{bkf})	Mean: 27.5	Mean:	Mean: 27.5	Mean: 15.9	Mean: 29.0	Mean:	Mean: 29.0	Mean: 15.9	Mean: 32.5	Mean:	Mean: 32.5	Mean: 15.9	Mean: 29.3
			Min: 27.5	Min:		Min: 10.8	Min: 29.0	Min:		Min: 10.8	Min: 32.5	Min:		Min: 10.8	Min: 24.2
			Max: 27.5	Max:		Max: 18.6	Max: 29.0	Max:		Max: 18.6	Max: 32.5	Max:		Max: 18.6	Max: 34.5
	10	Riffle Maximum Depth (d_{max})	Mean: 1.9	Mean:	Mean: 2.76	Mean: 2.1	Mean: 2.0	Mean:	Mean: 2.83	Mean: 2.1	Mean: 2.1	Mean:	Mean: 3.00	Mean: 2.1	Mean: 2.2
			Min: 1.9	Min:	Min: 2.35	Min: 1.8	Min: 2.0	Min:	Min: 2.42	Min: 1.8	Min: 2.1	Min:	Min: 2.56	Min: 1.8	Min: 1.6
			Max: 1.9	Max:	Max: 3.03	Max: 2.5	Max: 2.0	Max:	Max: 3.11	Max: 2.5	Max: 2.1	Max:	Max: 3.30	Max: 2.5	Max: 2.9
	11	Riffle Maximum Depth to Riffle Mean Depth (d_{max}/d_{bkf})	Mean: 1.6	Mean:	Mean: 2.038	Mean: 2.0	Mean: 1.6	Mean:	Mean: 2.038	Mean: 2.0	Mean: 1.5	Mean:	Mean: 2.038	Mean: 2.0	Mean: 1.6
			Min: 1.6	Min:	Min: 1.741	Min: 1.7	Min: 1.6	Min:	Min: 1.741	Min: 1.7	Min: 1.5	Min:	Min: 1.741	Min: 1.7	Min: 1.7
			Max: 1.6	Max:	Max: 2.241	Max: 2.2	Max: 1.6	Max:	Max: 2.241	Max: 2.2	Max: 1.5	Max:	Max: 2.241	Max: 2.2	Max: 1.6
	12	Width of Flood-Prone Area at Elevation of 2 * d_{max}, ft (W_{fpa})	Mean: 58.9	Mean:	Mean: 84.79	Mean: 59.3	Mean: 52.7	Mean:	Mean: 87.07	Mean: 59.3	Mean: 68.9	Mean:	Mean: 92.21	Mean: 59.3	Mean: 33.7
			Min: 30.0	Min:	Min: 50.38	Min: 46.4	Min: 24.3	Min:	Min: 51.74	Min: 46.4	Min: 23.3	Min:	Min: 54.79	Min: 46.4	Min: 28.2
			Max: 130.0	Max:	Max: 126.51	Max: 79.4	Max: 97.0	Max:	Max: 129.91	Max: 79.4	Max: 230.0	Max:	Max: 137.58	Max: 79.4	Max: 39.2
	13	Entrenchment Ratio (W_{fpa}/W_{bkf})	Mean: 2.6	Mean:	Mean: 4.2	Mean: 4.2	Mean: 2.3	Mean:	Mean: 4.2	Mean: 4.2	Mean: 2.9	Mean:	Mean: 4.2	Mean: 4.2	Mean: 1.5
			Min: 1.3	Min:	Min: 2.5	Min: 2.5	Min: 1.1	Min:	Min: 2.5	Min: 2.5	Min: 1.0	Min:	Min: 2.5	Min: 2.5	Min: 1.4
			Max: 5.8	Max:	Max: 6.2	Max: 6.2	Max: 4.3	Max:	Max: 6.2	Max: 6.2	Max: 9.6	Max:	Max: 6.2	Max: 6.2	Max: 1.6
Riffle Inner Berm Dimensions	14	Riffle Inner Berm Width, ft (W_{ib})	Mean: 10.5	Mean:	Mean: 13.6	Mean: 10.2	Mean: 10.5	Mean:	Mean: 13.9	Mean: 10.2	Mean: 11.5	Mean:	Mean: 14.8	Mean: 10.2	Mean: 13.1
			Min: 10.5	Min:	Min: 10.4	Min: 7.0	Min: 10.5	Min:	Min: 10.6	Min: 7.0	Min: 11.5	Min:	Min: 11.3	Min: 7.0	Min: 9.4
			Max: 10.5	Max:	Max: 16.1	Max: 14.8	Max: 10.5	Max:	Max: 16.5	Max: 14.8	Max: 11.5	Max:	Max: 17.5	Max: 14.8	Max: 16.8
	15	Riffle Inner Berm Width to Riffle Width (W_{ib}/W_{bkf})	Mean: 0.5	Mean: -	Mean: 0.667	Mean: 0.7	Mean: 0.5	Mean: -	Mean: 0.667	Mean: 0.7	Mean: 0.5	Mean: -	Mean: 0.667	Mean: 0.7	Mean: 0.6
			Min: 0.5	Min: -	Min: 0.509	Min: 0.5	Min: 0.5	Min: -	Min: 0.509	Min: 0.5	Min: 0.5	Min: -	Min: 0.509	Min: 0.5	Min: 0.5
			Max: 0.5	Max: -	Max: 0.792	Max: 0.8	Max: 0.5	Max: -	Max: 0.792	Max: 0.8	Max: 0.5	Max: -	Max: 0.792	Max: 0.8	Max: 0.7
	16	Riffle Inner Berm Mean Depth, ft (d_{ib})	Mean: 0.5	Mean:	Mean: 0.83	Mean: 0.7	Mean: 0.5	Mean:	Mean: 0.85	Mean: 0.7	Mean: 0.6	Mean:	Mean: 0.90	Mean: 0.7	Mean: 0.3
			Min: 0.5	Min:	Min: 0.79	Min: 0.5	Min: 0.5	Min:	Min: 0.81	Min: 0.5	Min: 0.6	Min:	Min: 0.86	Min: 0.5	Min: 0.3
			Max: 0.5	Max:	Max: 0.90	Max: 0.8	Max: 0.5	Max:	Max: 0.93	Max: 0.8	Max: 0.6	Max:	Max: 0.98	Max: 0.8	Max: 0.4
	17	Riffle Inner Berm Mean Depth to Riffle Mean Depth (d_{ib}/d_{bkf})	Mean: 0.4	Mean: -	Mean: 0.612	Mean: 0.6	Mean: 0.4	Mean: -	Mean: 0.612	Mean: 0.6	Mean: 0.5	Mean: -	Mean: 0.612	Mean: 0.6	Mean: 0.3
			Min: 0.4	Min: -	Min: 0.582	Min: 0.6	Min: 0.4	Min: -	Min: 0.582	Min: 0.6	Min: 0.5	Min: -	Min: 0.582	Min: 0.6	Min: 0.3
			Max: 0.4	Max: -	Max: 0.667	Max: 0.7	Max: 0.4	Max: -	Max: 0.667	Max: 0.7	Max: 0.5	Max: -	Max: 0.667	Max: 0.7	Max: 0.2
	18	Riffle Inner Berm Width/Depth Ratio (W_{ib}/d_{ib})	Mean: 20.3	Mean: -	Mean: 16.5	Mean: 16.5	Mean: 20.3	Mean: -	Mean: 16.5	Mean: 16.5	Mean: 18.8	Mean: -	Mean: 16.5	Mean: 16.5	Mean: 37.9
			Min: 20.3	Min: -	Min: 10.7	Min: 10.7	Min: 20.3	Min: -	Min: 10.7	Min: 10.7	Min: 18.8	Min: -	Min: 10.7	Min: 10.7	Min: 30.2
			Max: 20.3	Max: -	Max: 25.5	Max: 25.5	Max: 20.3	Max: -	Max: 25.5	Max: 25.5	Max: 18.8	Max: -	Max: 25.5	Max: 25.5	Max: 44.2
	19	Riffle Inner Berm Cross-Sectional Area (A_{ib})	Mean: 5.4	Mean:	Mean: 11.1	Mean: 6.6	Mean: 5.4	Mean:	Mean: 11.7	Mean: 6.6	Mean: 7.0	Mean:	Mean: 13.1	Mean: 6.6	Mean: 4.4
			Min: 5.4	Min:	Min: 9.3	Min: 3.7	Min: 5.4	Min:	Min: 9.8	Min: 3.7	Min: 7.0	Min:	Min: 11.0	Min: 3.7	Min: 3.6
			Max: 5.4	Max:	Max: 12.8	Max: 8.6	Max: 5.4	Max:	Max: 13.5	Max: 8.6	Max: 7.0	Max:	Max: 15.1	Max: 8.6	Max: 5.2
	20	Riffle Inner Berm Cross-Sectional Area to Riffle Cross-Sectional Area (A_{ib}/A_{bkf})	Mean: 0.2	Mean: -	Mean: 0.403	Mean: 0.4	Mean: 0.2	Mean: -	Mean: 0.403	Mean: 0.4	Mean: 0.2	Mean: -	Mean: 0.403	Mean: 0.4	Mean: 0.1
			Min: 0.2	Min: -	Min: 0.338	Min: 0.3	Min: 0.2	Min: -	Min: 0.338	Min: 0.3	Min: 0.2	Min: -	Min: 0.338	Min: 0.3	Min: 0.1
			Max: 0.2	Max: -	Max: 0.465	Max: 0.5	Max: 0.2	Max: -	Max: 0.465	Max: 0.5	Max: 0.2	Max: -	Max: 0.465	Max: 0.5	Max: 0.1
	21	Pool Width, ft (W_{bkfp})	Mean: 23.5	Mean:	Mean: 14.8	Mean: 11.0	Mean: 24.0	Mean:	Mean: 15.2	Mean: 11.0	Mean: 25.0	Mean:	Mean: 16.1	Mean: 11.0	Mean:
			Min: 23.5	Min:	Min: 14.8	Min: 11.0	Min: 24.0	Min:	Min: 15.2	Min: 11.0	Min: 25.0	Min:	Min: 16.1	Min: 11.0	Min:
			Max: 23.5	Max:	Max: 14.8	Max: 11.0	Max: 24.0	Max:	Max: 15.2	Max: 11.0	Max: 25.0	Max:	Max: 16.1	Max: 11.0	Max:
	22	Pool Width to Riffle Width (W_{bkfp}/W_{bkf})	Mean: 1.0	Mean: -	Mean: 0.730	Mean: 0.7	Mean: 1.1	Mean: -	Mean: 0.730	Mean: 0.7	Mean: 1.0	Mean: -	Mean: 0.730	Mean: 0.7	Mean: -
			Min: 1.0	Min: -	Min: 0.730	Min: 0.7	Min: 1.1	Min: -	Min: 0.730	Min: 0.7	Min: 1.0	Min: -	Min: 0.730	Min: 0.7	Min: -
			Max: 1.0	Max: -	Max: 0.730	Max: 0.7	Max: 1.1	Max: -	Max: 0.730	Max: 0.7	Max: 1.0	Max: -	Max: 0.730	Max: 0.7	Max: -
	23	Pool Mean Depth, ft (d_{bkfp})	Mean: 1.4	Mean:	Mean: 1.36	Mean: 1.1	Mean: 1.4	Mean:	Mean: 1.40	Mean: 1.1	Mean: 1.6	Mean:	Mean: 1.48	Mean: 1.1	Mean:
			Min: 1.4	Min:	Min: 1.36	Min: 1.1	Min: 1.4	Min:	Min: 1.40	Min: 1.1	Min: 1.6	Min:	Min: 1.48	Min: 1.1	Min:
			Max: 1.4	Max:	Max: 1.36	Max: 1.1	Max: 1.4	Max:	Max: 1.40	Max: 1.1	Max: 1.6	Max:	Max: 1.48	Max: 1.1	Max:

Category	Entry	Variable	Stat	Design Reach 1	Reach 1 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Design Reach 2	Reach 2 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Design Reach 3	Reach 3 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Postflood Stable Cross Sections
Pool Dimensions	24	Pool Mean Depth to Riffle Mean Depth (d_{bkfp}/d_{bkf})	Mean:	1.1	-	1.009	1.0	1.1	-	1.009	1.0	1.2	-	1.009	1.0	-
			Min:	1.1	-	1.009	1.0	1.1	-	1.009	1.0	1.2	-	1.009	1.0	-
			Max:	1.1	-	1.009	1.0	1.1	-	1.009	1.0	1.2	-	1.009	1.0	-
	25	Pool Width/Depth Ratio (W_{bkfp}/d_{bkfp})	Mean:	17.3	-	10.2	10.2	17.2	-	10.2	10.2	15.8	-	10.2	10.2	-
			Min:	17.3	-	10.2	10.2	17.2	-	10.2	10.2	15.8	-	10.2	10.2	-
			Max:	17.3	-	10.2	10.2	17.2	-	10.2	10.2	15.8	-	10.2	10.2	-
	26	Pool Cross-Sectional Area, ft^2 (A_{bkfp})	Mean:	32.0		20.5	11.9	33.5		21.7	11.9	39.5		24.3	11.9	
			Min:	32.0		20.5	11.9	33.5		21.7	11.9	39.5		24.3	11.9	
			Max:	32.0		20.5	11.9	33.5		21.7	11.9	39.5		24.3	11.9	
	27	Pool Area to Riffle Area (A_{bkfp}/A_{bkf})	Mean:	1.2	-	0.747	0.7	1.2	-	0.747	0.7	1.2	-	0.747	0.7	-
			Min:	1.2	-	0.747	0.7	1.2	-	0.747	0.7	1.2	-	0.747	0.7	-
			Max:	1.2	-	0.747	0.7	1.2	-	0.747	0.7	1.2	-	0.747	0.7	-
	28	Pool Maximum Depth (d_{maxp})	Mean:	2.5		3.15	2.5	2.7		3.23	2.5	2.9		3.42	2.5	
			Min:	2.5		3.15	2.5	2.7		3.23	2.5	2.9		3.42	2.5	
			Max:	2.5		3.15	2.5	2.7		3.23	2.5	2.9		3.42	2.5	
	29	Pool Maximum Depth to Riffle Mean Depth (d_{maxp}/d_{bkf})	Mean:	2.0	-	2.327	2.3	2.1	-	2.327	2.3	2.1	-	2.327	2.3	-
			Min:	2.0	-	2.327	2.3	2.1	-	2.327	2.3	2.1	-	2.327	2.3	-
			Max:	2.0	-	2.327	2.3	2.1	-	2.327	2.3	2.1	-	2.327	2.3	-
	30	Point Bar Slope (S_{pb})	Mean:	10.0		5.620	5.6	10.0		5.620	5.6	9.0		5.620	5.6	
			Min:	10.0		10.000	10.0	10.0		10.000	10.0	9.0		10.000	10.0	
			Max:	10.0		2.500	2.5	10.0		2.500	2.5	9.0		2.500	2.5	
Pool Inner Berm Dimensions	31	Pool Inner Berm Width, ft (W_{ibp})	Mean:	10.3		5.5	4.1	9.7		5.7	4.1	11.0		6.0	4.1	
			Min:	10.3		5.5	4.1	9.7		5.7	4.1	11.0		6.0	4.1	
			Max:	10.3		5.5	4.1	9.7		5.7	4.1	11.0		6.0	4.1	
	32	Pool Inner Berm Width to Pool Width (W_{ibp}/W_{bkfp})	Mean:	0.4	-	0.374	0.4	0.4	-	0.374	0.4	0.4	-	0.374	0.4	-
			Min:	0.4	-	0.374	0.4	0.4	-	0.374	0.4	0.4	-	0.374	0.4	-
			Max:	0.4	-	0.374	0.4	0.4	-	0.374	0.4	0.4	-	0.374	0.4	-
	33	Pool Inner Berm Mean Depth, ft (d_{ibp})	Mean:	1.1		0.47	0.4	1.2		0.48	0.4	1.3		0.51	0.4	
			Min:	1.1		0.47	0.4	1.2		0.48	0.4	1.3		0.51	0.4	
			Max:	1.1		0.47	0.4	1.2		0.48	0.4	1.3		0.51	0.4	
	34	Pool Inner Berm Mean Depth to Pool Mean Depth (d_{ibp}/d_{bkfp})	Mean:	0.8	-	0.342	0.3	0.9	-	0.342	0.3	0.8	-	0.342	0.3	-
			Min:	0.8	-	0.342	0.3	0.9	-	0.342	0.3	0.8	-	0.342	0.3	-
			Max:	0.8	-	0.342	0.3	0.9	-	0.342	0.3	0.8	-	0.342	0.3	-
	35	Pool Inner Berm Width/Depth Ratio (W_{ibp}/d_{ibp})	Mean:	9.1	-	11.1	11.1	8.1	-	11.1	11.1	8.5	-	11.1	11.1	-
			Min:	9.1	-	11.1	11.1	8.1	-	11.1	11.1	8.5	-	11.1	11.1	-
			Max:	9.1	-	11.1	11.1	8.1	-	11.1	11.1	8.5	-	11.1	11.1	-
	36	Pool Inner Berm Cross-Sectional Area (A_{ibp})	Mean:	11.7		2.6	1.5	11.6		2.8	1.5	14.3		3.1	1.5	
			Min:	11.7		2.6	1.5	11.6		2.8	1.5	14.3		3.1	1.5	
			Max:	11.7		2.6	1.5	11.6		2.8	1.5	14.3		3.1	1.5	
	37	Pool Inner Berm Cross-Sectional Area to Pool Cross-Sectional Area (A_{ibp}/A_{bkfp})	Mean:	0.4	-	0.128	0.1	0.3	-	0.128	0.1	0.4	-	0.128	0.1	-
			Min:	0.4	-	0.128	0.1	0.3	-	0.128	0.1	0.4	-	0.128	0.1	-
			Max:	0.4	-	0.128	0.1	0.3	-	0.128	0.1	0.4	-	0.128	0.1	-
Run Dimensions	38	Run Width, ft (W_{bkfr})	Mean:			22.3	16.5			22.9	16.5			24.2	16.5	
			Min:			15.0	11.1			15.4	11.1			16.3	11.1	
			Max:			35.7	26.4			36.6	26.4			38.8	26.4	
	39	Run Width to Riffle Width (W_{bkfr}/W_{bkf})	Mean:	-	-	1.096	1.1	-	-	1.096	1.1	-	-	1.096	1.1	-
			Min:	-	-	0.738	0.7	-	-	0.738	0.7	-	-	0.738	0.7	-
			Max:	-	-	1.753	1.8	-	-	1.753	1.8	-	-	1.753	1.8	-
	40	Run Mean Depth, ft (d_{bkfr})	Mean:			0.95	0.8			0.97	0.8			1.03	0.8	
			Min:			0.52	0.4			0.53	0.4			0.56	0.4	
			Max:			1.50	1.2			1.54	1.2			1.64	1.2	
	41	Run Mean Depth to Riffle Mean Depth (d_{bkfr}/d_{bkf})	Mean:	-	-	0.701	0.7	-	-	0.701	0.7	-	-	0.701	0.7	-
			Min:	-	-	0.383	0.4	-	-	0.383	0.4	-	-	0.383	0.4	-
			Max:	-	-	1.112	1.1	-	-	1.112	1.1	-	-	1.112	1.1	-
	42	Run Width/Depth Ratio (W_{bkfr}/d_{bkfr})	Mean:	-	-	30.6	30.6	-	-	30.6	30.6	-	-	30.6	30.6	-
			Min:	-	-	15.9	9.3	-	-	15.9	9.3	-	-	15.9	9.3	-
			Max:	-	-	10.8	64.3	-	-	10.8	64.3	-	-	10.8	64.3	-
	43	Run Cross-Sectional Area, ft^2 (A_{bkfr})	Mean:			18.4	10.7			19.5	10.7			21.8	10.7	
			Min:			13.8	7.9			14.5	7.9			16.3	7.9	

Section	Entry Number & Variable		Stat	Design Reach 1	Reach 1 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Design Reach 2	Reach 2 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Design Reach 3	Reach 3 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Postflood Stable Cross Sections
			Max:			22.9	13.2			24.2	13.2			27.1	13.2	
	44	Run Area to Riffle Area (A_{bkfr}/A_{bkf})	Mean:	-	-	0.671	0.7	-	-	0.671	0.7	-	-	0.671	0.7	-
			Min:	-	-	0.500	0.5	-	-	0.500	0.5	-	-	0.500	0.5	-
			Max:	-	-	0.834	0.8	-	-	0.834	0.8	-	-	0.834	0.8	-
	45	Run Maximum Depth (d_{maxr})	Mean:			2.14	1.7			2.19	1.7			2.32	1.7	
			Min:			1.68	1.3			1.73	1.3			1.83	1.3	
			Max:			2.70	2.1			2.78	2.1			2.94	2.1	
	46	Run Maximum Depth to Riffle Mean Depth (d_{maxr}/d_{bkf})	Mean:	-	-	1.579	1.6	-	-	1.579	1.6	-	-	1.579	1.6	-
			Min:	-	-	1.243	1.2	-	-	1.243	1.2	-	-	1.243	1.2	-
			Max:	-	-	2.000	2.0	-	-	2.000	2.0	-	-	2.000	2.0	-
Glide Dimensions	47	Glide Width, ft (W_{bkfg})	Mean:			33.7	25.0			34.7	25.0			36.7	25.0	
			Min:			33.7	25.0			34.7	25.0			36.7	25.0	
			Max:			33.7	25.0			34.7	25.0			36.7	25.0	
	48	Glide Width to Riffle Width (W_{bkfg}/W_{bkf})	Mean:	-	-	1.659	1.7	-	-	1.659	1.7	-	-	1.659	1.7	-
			Min:	-	-	1.659	1.7	-	-	1.659	1.7	-	-	1.659	1.7	-
			Max:	-	-	1.659	1.7	-	-	1.659	1.7	-	-	1.659	1.7	-
	49	Glide Mean Depth, ft (d_{bkfg})	Mean:			0.51	0.4			0.52	0.4			0.55	0.4	
			Min:			0.51	0.4			0.52	0.4			0.55	0.4	
			Max:			0.51	0.4			0.52	0.4			0.55	0.4	
	50	Glide Mean Depth to Riffle Mean Depth (d_{bkfg}/d_{bkf})	Mean:	-	-	0.374	0.4	-	-	0.374	0.4	-	-	0.374	0.4	-
			Min:	-	-	0.374	0.4	-	-	0.374	0.4	-	-	0.374	0.4	-
			Max:	-	-	0.374	0.4	-	-	0.374	0.4	-	-	0.374	0.4	-
	51	Glide Width/Depth Ratio (W_{bkfg}/d_{bkfg})	Mean:	-	-	62.4	62.4	-	-	62.4	62.4	-	-	62.4	62.4	-
			Min:	-	-	62.4	62.4	-	-	62.4	62.4	-	-	62.4	62.4	-
			Max:	-	-	62.4	62.4	-	-	62.4	62.4	-	-	62.4	62.4	-
	52	Glide Cross-Sectional Area, ft^2 (A_{bkfg})	Mean:			17.1	9.9			18.1	9.9			20.3	9.9	
			Min:			17.1	9.9			18.1	9.9			20.3	9.9	
			Max:			17.1	9.9			18.1	9.9			20.3	9.9	
	53	Glide Area to Riffle Area (A_{bkfg}/A_{bkf})	Mean:	-	-	0.623	0.6	-	-	0.623	0.6	-	-	0.623	0.6	-
			Min:	-	-	0.623	0.6	-	-	0.623	0.6	-	-	0.623	0.6	-
			Max:	-	-	0.623	0.6	-	-	0.623	0.6	-	-	0.623	0.6	-
	54	Glide Maximum Depth (d_{maxg})	Mean:			2.03	1.6			2.09	1.6			2.21	1.6	
			Min:			2.03	1.6			2.09	1.6			2.21	1.6	
			Max:			2.03	1.6			2.09	1.6			2.21	1.6	
	55	Glide Maximum Depth to Riffle Mean Depth (d_{maxg}/d_{bkf})	Mean:	-	-	1.505	1.5	-	-	1.505	1.5	-	-	1.505	1.5	-
			Min:	-	-	1.505	1.5	-	-	1.505	1.5	-	-	1.505	1.5	-
			Max:	-	-	1.505	1.5	-	-	1.505	1.5	-	-	1.505	1.5	-
Glide Inner Berm Dimensions	56	Glide Inner Berm Width, ft (W_{ibg})	Mean:			6.2	4.6			6.4	4.6			6.8	4.6	
			Min:			6.2	4.6			6.4	4.6			6.8	4.6	
			Max:			6.2	4.6			6.4	4.6			6.8	4.6	
	57	Glide Inner Berm Width to Glide Width (W_{ibg}/W_{bkfg})	Mean:	-	-	0.184	0.2	-	-	0.184	0.2	-	-	0.184	0.2	-
			Min:	-	-	0.184	0.2	-	-	0.184	0.2	-	-	0.184	0.2	-
			Max:	-	-	0.184	0.2	-	-	0.184	0.2	-	-	0.184	0.2	-
	58	Glide Inner Berm Mean Depth, ft (d_{ibg})	Mean:			0.62	0.5			0.64	0.5			0.68	0.5	
			Min:			0.62	0.5			0.64	0.5			0.68	0.5	
			Max:			0.62	0.5			0.64	0.5			0.68	0.5	
	59	Glide Inner Berm Mean Depth to Glide Mean Depth (d_{ibg}/d_{bkfg})	Mean:	-	-	1.234	1.2	-	-	1.234	1.2	-	-	1.234	1.2	-
			Min:	-	-	1.234	1.2	-	-	1.234	1.2	-	-	1.234	1.2	-
			Max:	-	-	1.234	1.2	-	-	1.234	1.2	-	-	1.234	1.2	-
	60	Glide Inner Berm Width/Depth Ratio (W_{ibg}/d_{ibg})	Mean:	-	-	9.3	9.3	-	-	9.3	9.3	-	-	9.3	9.3	-
			Min:	-	-	9.3	9.3	-	-	9.3	9.3	-	-	9.3	9.3	-
			Max:	-	-	9.3	9.3	-	-	9.3	9.3	-	-	9.3	9.3	-
	61	Glide Inner Berm Cross-Sectional Area (A_{ibg})	Mean:			3.9	2.3			4.2	2.3			4.7	2.3	
			Min:			3.9	2.3			4.2	2.3			4.7	2.3	
			Max:			3.9	2.3			4.2	2.3			4.7	2.3	
	62	Glide Inner Berm Area to Glide Area (A_{ibg}/A_{bkfg})	Mean:	-	-	0.230	0.2	-	-	0.230	0.2	-	-	0.230	0.2	-
			Min:	-	-	0.230	0.2	-	-	0.230	0.2	-	-	0.230	0.2	-
			Max:	-	-	0.230	0.2	-	-	0.230	0.2	-	-	0.230	0.2	-
			Mean:			0.0	0.0			0.0	0.0			0.0	0.0	

Entry Number & Variable			Design Reach 1	Reach 1 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Design Reach 2	Reach 2 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Design Reach 3	Reach 3 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Postflood Stable Cross Sections
Step Dimensions	63	Step Width, ft (W_{bkfs})	Min:	Min:	Min: 0.0	Min: 0.0	Min:	Min:	Min: 0.0	Min: 0.0	Min:	Min:	Min: 0.0	Min: 0.0	Min:
			Max:	Max:	Max: 0.0	Max: 0.0	Max:	Max:	Max: 0.0	Max: 0.0	Max:	Max:	Max: 0.0	Max: 0.0	Max:
	64	Step Width to Riffle Width (W_{bkfs}/W_{bkf})	Mean: -	Mean: -	Mean: 0.000	Mean: 0.0	Mean: -	Mean: -	Mean: 0.000	Mean: 0.0	Mean: -	Mean: -	Mean: 0.000	Mean: 0.0	Mean: -
			Min: -	Min: -	Min: 0.000	Min: 0.0	Min: -	Min: -	Min: 0.000	Min: 0.0	Min: -	Min: -	Min: 0.000	Min: 0.0	Min: -
			Max: -	Max: -	Max: 0.000	Max: 0.0	Max: -	Max: -	Max: 0.000	Max: 0.0	Max: -	Max: -	Max: 0.000	Max: 0.0	Max: -
	65	Step Mean Depth, ft (d_{bkfs})	Mean:	Mean:	Mean: 0.00	Mean: 0.0	Mean:	Mean:	Mean: 0.00	Mean: 0.0	Mean:	Mean:	Mean: 0.00	Mean: 0.0	Mean:
			Min:	Min:	Min: 0.00	Min: 0.0	Min:	Min:	Min: 0.00	Min: 0.0	Min:	Min:	Min: 0.00	Min: 0.0	Min:
			Max:	Max:	Max: 0.00	Max: 0.0	Max:	Max:	Max: 0.00	Max: 0.0	Max:	Max:	Max: 0.00	Max: 0.0	Max:
	66	Step Mean Depth to Riffle Mean Depth (d_{bkfs}/d_{bkf})	Mean: -	Mean: -	Mean: 0.000	Mean: 0.0	Mean: -	Mean: -	Mean: 0.000	Mean: 0.0	Mean: -	Mean: -	Mean: 0.000	Mean: 0.0	Mean: -
			Min: -	Min: -	Min: 0.000	Min: 0.0	Min: -	Min: -	Min: 0.000	Min: 0.0	Min: -	Min: -	Min: 0.000	Min: 0.0	Min: -
			Max: -	Max: -	Max: 0.000	Max: 0.0	Max: -	Max: -	Max: 0.000	Max: 0.0	Max: -	Max: -	Max: 0.000	Max: 0.0	Max: -
	67	Step Width/Depth Ratio (W_{bkfs}/d_{bkfs})	Mean: -	Mean: -	Mean: 0.0	Mean: 0.0	Mean: -	Mean: -	Mean: 0.0	Mean: 0.0	Mean: -	Mean: -	Mean: 0.0	Mean: 0.0	Mean: -
			Min: -	Min: -	Min: 0.0	Min: 0.0	Min: -	Min: -	Min: 0.0	Min: 0.0	Min: -	Min: -	Min: 0.0	Min: 0.0	Min: -
			Max: -	Max: -	Max: 0.0	Max: 0.0	Max: -	Max: -	Max: 0.0	Max: 0.0	Max: -	Max: -	Max: 0.0	Max: 0.0	Max: -
	68	Step Cross-Sectional Area, ft^2 (A_{bkfs})	Mean:	Mean:	Mean: 0.0	Mean: 0.0	Mean:	Mean:	Mean: 0.0	Mean: 0.0	Mean:	Mean:	Mean: 0.0	Mean: 0.0	Mean:
			Min:	Min:	Min: 0.0	Min: 0.0	Min:	Min:	Min: 0.0	Min: 0.0	Min:	Min:	Min: 0.0	Min: 0.0	Min:
			Max:	Max:	Max: 0.0	Max: 0.0	Max:	Max:	Max: 0.0	Max: 0.0	Max:	Max:	Max: 0.0	Max: 0.0	Max:
	69	Step Area to Riffle Area (A_{bkfs}/A_{bkf})	Mean: -	Mean: -	Mean: 0.000	Mean: 0.0	Mean: -	Mean: -	Mean: 0.000	Mean: 0.0	Mean: -	Mean: -	Mean: 0.000	Mean: 0.0	Mean: -
			Min: -	Min: -	Min: 0.000	Min: 0.0	Min: -	Min: -	Min: 0.000	Min: 0.0	Min: -	Min: -	Min: 0.000	Min: 0.0	Min: -
			Max: -	Max: -	Max: 0.000	Max: 0.0	Max: -	Max: -	Max: 0.000	Max: 0.0	Max: -	Max: -	Max: 0.000	Max: 0.0	Max: -
	70	Step Maximum Depth (d_{maxs})	Mean:	Mean:	Mean: 0.00	Mean: 0.0	Mean:	Mean:	Mean: 0.00	Mean: 0.0	Mean:	Mean:	Mean: 0.00	Mean: 0.0	Mean:
			Min:	Min:	Min: 0.00	Min: 0.0	Min:	Min:	Min: 0.00	Min: 0.0	Min:	Min:	Min: 0.00	Min: 0.0	Min:
			Max:	Max:	Max: 0.00	Max: 0.0	Max:	Max:	Max: 0.00	Max: 0.0	Max:	Max:	Max: 0.00	Max: 0.0	Max:
	71	Step Maximum Depth to Riffle Mean Depth (d_{maxs}/d_{bkf})	Mean: -	Mean: -	Mean: 0.00	Mean: 0.0	Mean: -	Mean: -	Mean: 0.00	Mean: 0.0	Mean: -	Mean: -	Mean: 0.00	Mean: 0.0	Mean: -
			Min: -	Min: -	Min: 0.00	Min: 0.0	Min: -	Min: -	Min: 0.00	Min: 0.0	Min: -	Min: -	Min: 0.00	Min: 0.0	Min: -
			Max: -	Max: -	Max: 0.00	Max: 0.0	Max: -	Max: -	Max: 0.00	Max: 0.0	Max: -	Max: -	Max: 0.00	Max: 0.0	Max: -
Channel Pattern	72	Linear Wavelength, ft (λ)	Mean: 117.1	Mean: 135.9	Mean: 75.7	Mean: 56.0	Mean: 150.7	Mean: 148.0	Mean: 77.7	Mean: 56.0	Mean: 127.8	Mean: 289.8	Mean: 82.3	Mean: 56.0	Mean:
			Min: 65.3	Min: 41.5	Min: 56.8	Min: 42.0	Min: 69.7	Min: 56.1	Min: 58.3	Min: 42.0	Min: 58.0	Min: 124.5	Min: 61.7	Min: 42.0	Min:
			Max: 215.0	Max: 319.2	Max: 104.1	Max: 77.0	Max: 250.2	Max: 517.1	Max: 106.9	Max: 77.0	Max: 218.1	Max: 577.6	Max: 113.2	Max: 77.0	Max:
	73	Linear Wavelength to Riffle Width (λ/W_{bkf})	Mean: 5.2	Mean: 5.0	Mean: 3.721	Mean: 3.7	Mean: 6.7	Mean: 5.5	Mean: 3.721	Mean: 3.7	Mean: 5.3	Mean: 10.7	Mean: 3.721	Mean: 3.7	Mean: -
			Min: 2.9	Min: 1.5	Min: 2.791	Min: 2.8	Min: 3.1	Min: 2.1	Min: 2.791	Min: 2.8	Min: 2.4	Min: 4.6	Min: 2.791	Min: 2.8	Min: -
			Max: 9.6	Max: 11.8	Max: 5.116	Max: 5.1	Max: 11.1	Max: 19.2	Max: 5.116	Max: 5.1	Max: 9.1	Max: 21.4	Max: 5.116	Max: 5.1	Max: -
	74	Stream Meander Length, ft (L_m)	Mean: 119.6	Mean: 139.2	Mean: 87.8	Mean: 65.0	Mean: 154.6	Mean: 152.4	Mean: 90.2	Mean: 65.0	Mean: 132.2	Mean: 306.5	Mean: 95.5	Mean: 65.0	Mean:
			Min: 63.9	Min: 41.3	Min: 60.8	Min: 45.0	Min: 72.0	Min: 57.6	Min: 62.5	Min: 45.0	Min: 62.0	Min: 120.3	Min: 66.1	Min: 45.0	Min:
			Max: 221.4	Max: 322.7	Max: 108.1	Max: 80.0	Max: 256.4	Max: 591.3	Max: 111.0	Max: 80.0	Max: 229.4	Max: 602.8	Max: 117.6	Max: 80.0	Max:
	75	Stream Meander Length Ratio (L_m/W_{bkf})	Mean: 5.3	Mean: 5.2	Mean: 4.319	Mean: 4.3	Mean: 6.9	Mean: 5.6	Mean: 4.319	Mean: 4.3	Mean: 5.5	Mean: 11.4	Mean: 4.319	Mean: 4.3	Mean: -
			Min: 2.8	Min: 1.5	Min: 2.990	Min: 3.0	Min: 3.2	Min: 2.1	Min: 2.990	Min: 3.0	Min: 2.6	Min: 4.5	Min: 2.990	Min: 3.0	Min: -
			Max: 9.8	Max: 12.0	Max: 5.316	Max: 5.3	Max: 11.4	Max: 21.9	Max: 5.316	Max: 5.3	Max: 9.6	Max: 22.3	Max: 5.316	Max: 5.3	Max: -
	76	Belt Width, ft (W_{blt})	Mean: 50.0	Mean: 65.0	Mean: 55.4	Mean: 41.0	Mean: 55.0	Mean: 65.0	Mean: 56.9	Mean: 41.0	Mean: 55.0	Mean: 65.0	Mean: 60.3	Mean: 41.0	Mean:
			Min: 25.0	Min: 65.0	Min: 40.5	Min: 30.0	Min: 40.0	Min: 65.0	Min: 41.6	Min: 30.0	Min: 30.0	Min: 65.0	Min: 44.1	Min: 30.0	Min:
			Max: 80.0	Max: 65.0	Max: 74.3	Max: 55.0	Max: 70.0	Max: 65.0	Max: 76.3	Max: 55.0	Max: 85.0	Max: 65.0	Max: 80.8	Max: 55.0	Max:
	77	Meander Width Ratio (W_{blt}/W_{bkf})	Mean: 2.2	Mean: 2.4	Mean: 2.724	Mean: 2.7	Mean: 2.4	Mean: 2.4	Mean: 2.724	Mean: 2.7	Mean: 2.3	Mean: 2.4	Mean: 2.724	Mean: 2.7	Mean: -
			Min: 1.1	Min: 2.4	Min: 1.993	Min: 2.0	Min: 1.8	Min: 2.4	Min: 1.993	Min: 2.0	Min: 1.3	Min: 2.4	Min: 1.993	Min: 2.0	Min: -
			Max: 3.6	Max: 2.4	Max: 3.654	Max: 3.7	Max: 3.1	Max: 2.4	Max: 3.654	Max: 3.7	Max: 3.5	Max: 2.4	Max: 3.654	Max: 3.7	Max: -
	78	Radius of Curvature, ft (R_c)	Mean: 68.4	Mean: 102.2	Mean: 17.6	Mean: 13.0	Mean: 80.4	Mean: 113.1	Mean: 18.0	Mean: 13.0	Mean: 68.6	Mean: 131.3	Mean: 19.1	Mean: 13.0	Mean:
			Min: 25.9	Min: 6.1	Min: 5.4	Min: 4.0	Min: 30.2	Min: 12.1	Min: 5.6	Min: 4.0	Min: 25.0	Min: 36.6	Min: 5.9	Min: 4.0	Min:
			Max: 198.2	Max: 200.0	Max: 37.8	Max: 28.0	Max: 251.6	Max: 200.0	Max: 38.9	Max: 28.0	Max: 199.0	Max: 275.0	Max: 41.2	Max: 28.0	Max:
	79	Radius of Curvature to Riffle Width (R_c/W_{bkf})	Mean: 3.0	Mean: 3.8	Mean: 0.864	Mean: 0.9	Mean: 3.6	Mean: 4.2	Mean: 0.864	Mean: 0.9	Mean: 2.9	Mean: 4.9	Mean: 0.864	Mean: 0.9	Mean: -
			Min: 1.2	Min: 0.2	Min: 0.266	Min: 0.3	Min: 1.3	Min: 0.4	Min: 0.266	Min: 0.3	Min: 1.0	Min: 1.4	Min: 0.266	Min: 0.3	Min: -
			Max: 8.8	Max: 7.4	Max: 1.860	Max: 1.9	Max: 11.2	Max: 7.4	Max: 1.860	Max: 1.9	Max: 8.3	Max: 10.2	Max: 1.860	Max: 1.9	Max: -
	80	Arc Length, ft (L_a)	Mean: 22.4	Mean: 34.5	Mean: 35.1	Mean: 26.0	Mean: 30.1	Mean: 38.4	Mean: 36.1	Mean: 26.0	Mean: 25.5	Mean: 89.4	Mean: 38.2	Mean: 26.0	Mean:
			Min: 12.3	Min: 5.4	Min: 16.2	Min: 12.0	Min: 10.3	Min: 5.0	Min: 16.7	Min: 12.0	Min: 12.4	Min: 19.9	Min: 17.6	Min: 12.0	Min:
			Max: 91.9	Max: 135.6	Max: 62.2	Max: 46.0	Max: 88.3	Max: 127.5	Max: 63.8	Max: 46.0	Max: 88.4	Max: 369.0	Max: 67.6	Max: 46.0	Max:
	81	Arc Length to Riffle Width (L_a/W_{bkf})	Mean: 1.0	Mean: 1.3	Mean: 1.728	Mean: 1.7	Mean: 1.3	Mean: 1.4	Mean: 1.728	Mean: 1.7	Mean: 1.1	Mean: 3.3	Mean: 1.728	Mean: 1.7	Mean: -
			Min: 0.5	Min: 0.2	Min: 0.797	Min: 0.8	Min: 0.5	Min: 0.2	Min: 0.797	Min: 0.8	Min: 0.5	Min: 0.7	Min: 0.797	Min: 0.8	Min: -
			Max: 4.1	Max: 5.0	Max: 3.056	Max: 3.1	Max: 3.9	Max: 4.7	Max: 3.056	Max: 3.1	Max: 3.7	Max: 13.7	Max: 3.056	Max: 3.1	Max: -
	82	Riffle Length (L_r), ft	Mean: 37.3	Mean: 34.9	Mean: 22.6	Mean: 16.7	Mean: 47.8	Mean: 39.5	Mean: 23.2	Mean: 16.7	Mean: 40.7	Mean: 66.6	Mean: 24.6	Mean: 16.7	Mean:
			Min: 10.9	Min: 1.0	Min: 10.8	Min: 8.0	Min: 12.9	Min: 2.1	Min: 11.1	Min: 8.0	Min: 13.4	Min: 3.1	Min: 11.7	Min: 8.0	Min:
			Max: 96.2	Max: 182.4	Max: 42.0	Max: 31.1	Max: 95.7	Max: 329.8	Max: 43.2	Max: 31.1	Max: 105.0	Max: 141.3	Max: 45.7	Max: 31.1	Max:

	Entry Number & Variable		Design Reach 1	Reach 1 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Design Reach 2	Reach 2 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Design Reach 3	Reach 3 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Postflood Stable Cross Sections
	83	Riffle Length to Riffle Width (L_r/W_{bkf})	Mean: 1.7 Min: 0.5 Max: 4.3	Mean: 1.3 Min: 0.0 Max: 6.8	Mean: 1.112 Min: 0.531 Max: 2.066	Mean: 1.1 Min: 0.5 Max: 2.1	Mean: 2.1 Min: 0.6 Max: 4.3	Mean: 1.5 Min: 0.1 Max: 12.2	Mean: 1.112 Min: 0.531 Max: 2.066	Mean: 1.1 Min: 0.5 Max: 2.1	Mean: 1.7 Min: 0.6 Max: 4.4	Mean: 2.5 Min: 0.1 Max: 5.2	Mean: 1.112 Min: 0.531 Max: 2.066	Mean: 1.1 Min: 0.5 Max: 2.1	Mean: - Min: - Max: -
	84	Individual Pool Length, ft (L_p)	Mean: 15.7 Min: 8.6 Max: 64.3	Mean: 24.2 Min: 3.8 Max: 94.9	Mean: 24.0 Min: 8.6 Max: 82.4	Mean: 17.8 Min: 6.4 Max: 61.0	Mean: 21.1 Min: 7.2 Max: 61.8	Mean: 26.9 Min: 3.5 Max: 89.2	Mean: 24.7 Min: 8.8 Max: 84.6	Mean: 17.8 Min: 6.4 Max: 61.0	Mean: 17.9 Min: 8.7 Max: 61.9	Mean: 62.6 Min: 14.0 Max: 258.3	Mean: 26.1 Min: 9.3 Max: 89.6	Mean: 17.8 Min: 6.4 Max: 61.0	Mean: Min: Max:
	85	Pool Length to Riffle Width (L_p/W_{bkf})	Mean: 0.7 Min: 0.4 Max: 2.9	Mean: 0.9 Min: 0.1 Max: 3.5	Mean: 1.181 Min: 0.422 Max: 4.050	Mean: 1.2 Min: 0.4 Max: 4.1	Mean: 0.9 Min: 0.3 Max: 2.7	Mean: 1.0 Min: 0.1 Max: 3.3	Mean: 1.181 Min: 0.422 Max: 4.050	Mean: 1.2 Min: 0.4 Max: 4.1	Mean: 0.7 Min: 0.4 Max: 2.6	Mean: 2.3 Min: 0.5 Max: 9.6	Mean: 1.181 Min: 0.422 Max: 4.050	Mean: 1.2 Min: 0.4 Max: 4.1	Mean: - Min: - Max: -
	86	Pool-to-Pool Spacing, ft (P_s)	Mean: 59.6 Min: 30.5 Max: 122.6	Mean: 69.7 Min: 14.6 Max: 216.7	Mean: 59.9 Min: 16.2 Max: 119.3	Mean: 44.3 Min: 12.0 Max: 88.3	Mean: 77.7 Min: 29.8 Max: 135.4	Mean: 76.2 Min: 17.0 Max: 419.5	Mean: 61.5 Min: 16.6 Max: 122.6	Mean: 44.3 Min: 12.0 Max: 88.3	Mean: 66.1 Min: 26.8 Max: 135.2	Mean: 158.7 Min: 46.7 Max: 342.2	Mean: 65.1 Min: 17.6 Max: 129.8	Mean: 44.3 Min: 12.0 Max: 88.3	Mean: Min: Max:
	87	Pool-to-Pool Spacing to Riffle Width (P_s/W_{bkf})	Mean: 2.6 Min: 1.4 Max: 5.4	Mean: 2.6 Min: 0.5 Max: 8.0	Mean: 2.944 Min: 0.797 Max: 5.868	Mean: 2.9 Min: 0.8 Max: 5.9	Mean: 3.5 Min: 1.3 Max: 6.0	Mean: 2.8 Min: 0.6 Max: 15.5	Mean: 2.944 Min: 0.797 Max: 5.868	Mean: 2.9 Min: 0.8 Max: 5.9	Mean: 2.8 Min: 1.1 Max: 5.6	Mean: 5.9 Min: 1.7 Max: 12.7	Mean: 2.944 Min: 0.797 Max: 5.868	Mean: 2.9 Min: 0.8 Max: 5.9	Mean: - Min: - Max: -
Sinuosity and Slope	88	Stream Length (SL)	8310.0	8600.0		3420.0	5290.0	5200.0		3420.0	8599.0	8526.0		3420.0	
	89	Valley Length (VL)	7630.0	7630.0		3000.0	5055.0	5055.0		3000.0	8010.0	8010.0		3000.0	
	90	Valley Slope (S_{val})	0.0375	0.0381	#DIV/0!	0.0336	0.0000	0.0406	#DIV/0!	0.0336	0.0000	0.0371	#DIV/0!	0.0336	
	91	Sinuosity (k)	SL/VL: 1.09	SL/VL: 1.13	SL/VL:	SL/VL: 1.14 VS/S: 1.14	SL/VL: 1.05	SL/VL: 1.03	SL/VL:	SL/VL: 1.14 VS/S: 1.14	SL/VL: 1.07	SL/VL: 1.06	SL/VL:	SL/VL: 1.14 VS/S: 1.14	SL/VL: VS/S:
	92	Average Water Surface Slope (S)	0.0344		$S = S_{val}/k$ #DIV/0!	0.0294	0.0422		$S = S_{val}/k$ #DIV/0!	0.0294	0.0319		$S = S_{val}/k$ #DIV/0!	0.0294	
Floodplain	93	Floodplain Width, ft (W_f)	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 305.000 Min: 210.000 Max: 400.000	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 305.000 Min: 210.000 Max: 400.000	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 305.000 Min: 210.000 Max: 400.000	Mean: Min: Max:
	94	Floodplain Surface Depth Limit, ft (d_f)	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 2.0 Min: 1.8 Max: 2.2	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 2.0 Min: 1.8 Max: 2.2	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 2.0 Min: 1.8 Max: 2.2	Mean: Min: Max:
Low Terrace	95	Low Terrace Width, ft (W_{lt})	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 450.000 Min: 290.000 Max: 620.000	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 450.000 Min: 290.000 Max: 620.000	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 450.000 Min: 290.000 Max: 620.000	Mean: Min: Max:
	96	Low Terrace Surface Depth Limit, ft (d_{lt})	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 5.6 Min: 5.3 Max: 6.0	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 5.6 Min: 5.3 Max: 6.0	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 5.6 Min: 5.3 Max: 6.0	Mean: Min: Max:
Flood-Prone Area	97	Flood-Prone Area Width, ft (W_{fpa})	Mean: 52.720 Min: 24.300 Max: 97.000	Mean: Min: Max:	Mean: Min: Max:	Mean: 450.000 Min: 290.000 Max: 610.000	Mean: 52.720 Min: 24.300 Max: 97.000	Mean: Min: Max:	Mean: Min: Max:	Mean: 450.000 Min: 290.000 Max: 610.000	Mean: 68.929 Min: 23.300 Max: 230.000	Mean: Min: Max:	Mean: Min: Max:	Mean: 450.000 Min: 290.000 Max: 610.000	Mean: Min: Max:
	98	Flood-Prone Area Surface Depth Limit, ft (d_{fpa})	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 5.6 Min: 5.3 Max: 6.0	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 5.6 Min: 5.3 Max: 6.0	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 5.6 Min: 5.3 Max: 6.0	Mean: Min: Max:
Degree of Incision	99	Low Bank Height (LBH)	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 0.000 Min: 0.000 Max: 0.000	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 0.000 Min: 0.000 Max: 0.000	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 0.000 Min: 0.000 Max: 0.000	Mean: Min: Max:
	100	Maximum Bankfull Depth (d_{max}) at Same Location as Low Bank Height (LBH) Measurement	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 2.1 Min: 2.1 Max: 2.1	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 2.1 Min: 2.1 Max: 2.1	Mean: Min: Max:	Mean: Min: Max:	Mean: Min: Max:	Mean: 2.1 Min: 2.1 Max: 2.1	Mean: Min: Max:
	101	Bank-Height Ratio (LBH/d_{max})	Mean: - Min: - Max: -	Mean: Min: Max:	Mean: - Min: - Max: -	Mean: 0.000 Min: 0.000 Max: 0.000	Mean: - Min: - Max: -	Mean: Min: Max:	Mean: - Min: - Max: -	Mean: 0.000 Min: 0.000 Max: 0.000	Mean: - Min: - Max: -	Mean: Min: Max:	Mean: - Min: - Max: -	Mean: 0.000 Min: 0.000 Max: 0.000	Mean: Min: Max:
from Profile	102	Riffle Maximum Depth, ft (d_{max})	Mean: Min: Max:	Mean: Min: Max:	Mean: 2.0 Min: 0.5 Max: 2.6	Mean: 1.6 Min: 0.4 Max: 2.0	Mean: Min: Max:	Mean: Min: Max:	Mean: 2.1 Min: 0.5 Max: 2.6	Mean: 1.6 Min: 0.4 Max: 2.0	Mean: Min: Max:	Mean: Min: Max:	Mean: 2.2 Min: 0.5 Max: 2.8	Mean: 1.6 Min: 0.4 Max: 2.0	Mean: Min: Max:
	103	Riffle Maximum Depth to Riffle Mean Depth (d_{max}/d_{bkf})	Mean: - Min: - Max: -	Mean: Min: Max:	Mean: 1.505 Min: 0.355 Max: 1.897	Mean: 1.505 Min: 0.355 Max: 1.897	Mean: - Min: - Max: -	Mean: Min: Max:	Mean: 1.505 Min: 0.355 Max: 1.897	Mean: 1.505 Min: 0.355 Max: 1.897	Mean: - Min: - Max: -	Mean: Min: Max:	Mean: 1.505 Min: 0.355 Max: 1.897	Mean: 1.505 Min: 0.355 Max: 1.897	Mean: Min: Max:

Bed Feature Max Depth Measurements and Dimensionless Ratios

Entry Number & Variable			Design Reach 1	Reach 1 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference
104	Pool Maximum Depth, ft (d_{maxp})	Mean:			3.3	2.6
		Min:			2.3	1.8
		Max:			4.9	3.9
105	Pool Maximum Depth to Riffle Mean Depth (d_{maxp}/d_{bkf})	Mean:	-		2.467	2.467
		Min:	-		1.682	1.682
		Max:	-		3.607	3.607
106	Run Maximum Depth, ft (d_{maxr})	Mean:			2.5	1.9
		Min:			1.6	1.3
		Max:			3.4	2.7
107	Run Maximum Depth to Riffle Mean Depth (d_{maxr}/d_{bkf})	Mean:	-		1.813	1.813
		Min:	-		1.206	1.206
		Max:	-		2.486	2.486
108	Glide Maximum Depth, ft (d_{maxg})	Mean:			2.2	1.7
		Min:			1.0	0.8
		Max:			3.0	2.4
109	Glide Maximum Depth to Riffle Mean Depth (d_{maxg}/d_{bkf})	Mean:	-		1.607	1.607
		Min:	-		0.757	0.757
		Max:	-		2.215	2.215
110	Step Maximum Depth, ft (d_{maxs})	Mean:			0.0	0.0
		Min:			0.0	0.0
		Max:			0.0	0.0
111	Step Maximum Depth to Riffle Mean Depth (d_{maxs}/d_{bkf})	Mean:	-		0.000	0.000
		Min:	-		0.000	0.000
		Max:	-		0.000	0.000

Entry Number & Variable			Design Reach 2	Reach 2 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference
104	Pool Maximum Depth, ft (d_{maxp})	Mean:			3.4	2.6
		Min:			2.3	1.8
		Max:			5.0	3.9
105	Pool Maximum Depth to Riffle Mean Depth (d_{maxp}/d_{bkf})	Mean:	-		2.467	2.467
		Min:	-		1.682	1.682
		Max:	-		3.607	3.607
106	Run Maximum Depth, ft (d_{maxr})	Mean:			2.5	1.9
		Min:			1.7	1.3
		Max:			3.5	2.7
107	Run Maximum Depth to Riffle Mean Depth (d_{maxr}/d_{bkf})	Mean:	-		1.813	1.813
		Min:	-		1.206	1.206
		Max:	-		2.486	2.486
108	Glide Maximum Depth, ft (d_{maxg})	Mean:			2.2	1.7
		Min:			1.1	0.8
		Max:			3.1	2.4
109	Glide Maximum Depth to Riffle Mean Depth (d_{maxg}/d_{bkf})	Mean:	-		1.607	1.607
		Min:	-		0.757	0.757
		Max:	-		2.215	2.215
110	Step Maximum Depth, ft (d_{maxs})	Mean:			0.0	0.0
		Min:			0.0	0.0
		Max:			0.0	0.0
111	Step Maximum Depth to Riffle Mean Depth (d_{maxs}/d_{bkf})	Mean:	-		0.000	0.000
		Min:	-		0.000	0.000
		Max:	-		0.000	0.000

Entry Number & Variable			Design Reach 3	Reach 3 Preflood Assessment	Target Design Based on Reference	N. Fork of N. Elk Creek Reference	Postflood Stable Cross Sections
104	Pool Maximum Depth, ft (d_{maxp})	Mean:			3.6	2.6	
		Min:			2.5	1.8	
		Max:			5.3	3.9	
105	Pool Maximum Depth to Riffle Mean Depth (d_{maxp}/d_{bkf})	Mean:	-		2.467	2.467	
		Min:	-		1.682	1.682	
		Max:	-		3.607	3.607	
106	Run Maximum Depth, ft (d_{maxr})	Mean:			2.7	1.9	
		Min:			1.8	1.3	
		Max:			3.7	2.7	
107	Run Maximum Depth to Riffle Mean Depth (d_{maxr}/d_{bkf})	Mean:	-		1.813	1.813	
		Min:	-		1.206	1.206	
		Max:	-		2.486	2.486	
108	Glide Maximum Depth, ft (d_{maxg})	Mean:			2.4	1.7	
		Min:			1.1	0.8	
		Max:			3.3	2.4	
109	Glide Maximum Depth to Riffle Mean Depth (d_{maxg}/d_{bkf})	Mean:	-		1.607	1.607	
		Min:	-		0.757	0.757	
		Max:	-		2.215	2.215	
110	Step Maximum Depth, ft (d_{maxs})	Mean:			0.0	0.0	
		Min:			0.0	0.0	
		Max:			0.0	0.0	
111	Step Maximum Depth to Riffle Mean Depth (d_{maxs}/d_{bkf})	Mean:	-		0.000	0.000	
		Min:	-		0.000	0.000	
		Max:	-		0.000	0.000	

USGS StreamStats Summary

StreamStats Version 3.0

Flow Statistics Ungaged Site Report

Date: Mon Jan 25, 2016 4:27:59 PM GMT-7
Study Area: Colorado
NAD 1983 Latitude: 40.0375 (40 02 15)
NAD 1983 Longitude: -105.4195 (-105 25 10)
Drainage Area: 11.1999999999999 mi2

Peak-Flows Basin Characteristics

98% Mountain Region Peak Flow (11 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	11.2	1	1060
Mean Basin Slope from 10m DEM (percent)	34.3	7.6	60.2
Mean Annual Precipitation (inches)	23.09	18	47

2% Plains Region Peak Flow (0.17 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	11.2	0.5	2930
6 Hour 100 Year Precipitation (inches)	3.06	2.4	5.1

Low-Flows Basin Characteristics

100% Mountain Region Min Flow (11.2 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	11.2	1	1060
Mean Annual Precipitation (inches)	23.09	18	47
Mean Basin Elevation (feet)	8800	8600	12000

Flow-Duration Basin Characteristics

100% Mountain Region Flow Duration (11.2 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	11.2	1	1060
Mean Annual Precipitation (inches)	23.09	18	47

Maximum-Flows Basin Characteristics

100% Mountain Region Max Flow (11.2 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	11.2	1	1060
Mean Annual Precipitation (inches)	23.09	18	47

Mean-Flows Basin Characteristics			
100% Mountain Region Mean Flow (11.2 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	11.2	1	1060
Mean Annual Precipitation (inches)	23.09	18	47

Peak-Flows Statistics Area-Averaged						
Statistic	**Value**	**Unit**	**Prediction Error (percent)**	**Equivalent years of record**	**90-Percent Prediction Interval**	
					Min	**Max**
PK2	78.3	ft3/s	51			
PK5	118	ft3/s	45			
PK10	145	ft3/s	42			
PK25	181	ft3/s	41			
PK50	221	ft3/s	40			
PK100	252	ft3/s	38			
PK200	288	ft3/s	38			
PK500	337	ft3/s	35			

Peak-Flows Statistics Mountain_Region_Peak_Flow						
Statistic	**Value**	**Unit**	**Prediction Error (percent)**	**Equivalent years of record**	**90-Percent Prediction Interval**	
					Min	**Max**
PK2	78.1	ft3/s	49			
PK5	116	ft3/s	44			
PK10	143	ft3/s	41			
PK25	176	ft3/s	40			
PK50	214	ft3/s	39			
PK100	241	ft3/s	36			
PK200	266	ft3/s	36			
PK500	317	ft3/s	33			

Peak-Flows Statistics Plains_Region_Peak_Flow						
Statistic	**Value**	**Unit**	**Prediction Error (percent)**	**Equivalent years of record**	**90-Percent Prediction Interval**	
					Min	**Max**
PK2	94.5	ft3/s	180			
PK5	216	ft3/s	140			
PK10	326	ft3/s	140			
PK25	535	ft3/s	140			
PK50	717	ft3/s	140			
PK100	974	ft3/s	140			
PK200	1770	ft3/s	160			
PK500	1680	ft3/s	140			

http://pubs.usgs.gov/sir/2009/5136/# (http://pubs.usgs.gov/sir/2009/5136/#)

Capesius_ J.P._ and Stephens_ V. C._ Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136_ 32 p.

Low-Flows Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
M7D2Y	0.26	ft3/s	89			
M7D10Y	0.0927	ft3/s	150			
M7D50Y	0.18	ft3/s	130			

http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#
(http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#)
Capesius_ J.P._ and Stephens_ V. C._ Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136_ 32 p.

Flow-Duration Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
D10	20.9	ft3/s	45			
D25	5.82	ft3/s	55			
D50	2.34	ft3/s	55			
D75	1.31	ft3/s	64			
D90	0.73	ft3/s	85			

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(http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#)
Capesius_ J.P._ and Stephens_ V. C._ Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136_ 32 p.

Maximum-Flows Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
V7D2Y	50.8	ft3/s	46			
V7D10Y	86.8	ft3/s	35			
V7D50Y	124	ft3/s	31			

http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#
(http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#)
Capesius_ J.P._ and Stephens_ V. C._ Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136_ 32 p.

Mean-Flows Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
Q1	1.47	ft3/s	50			
Q2	1.38	ft3/s	51			
Q3	1.51	ft3/s	49			
Q4	3.03	ft3/s	44			
Q5	22.4	ft3/s	46			

Q6	43.9	ft3/s	46			
Q7	13.2	ft3/s	76			
Q8	5.83	ft3/s	80			
Q9	3.5	ft3/s	59			
QA	8.81	ft3/s	33			
Q10	2.67	ft3/s	45			
Q11	2.07	ft3/s	46			
Q12	1.67	ft3/s	47			

http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#
(http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#)
Capesius_ J.P._ and Stephens_ V. C._ Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136_ 32 p.

StreamStats Version 3.0

Flow Statistics Ungaged Site Report

Date: Mon Jan 25, 2016 4:45:24 PM GMT-7
Study Area: Colorado
NAD 1983 Latitude: 40.0369 (40 02 13)
NAD 1983 Longitude: -105.4028 (-105 24 11)
Drainage Area: 13.8 mi2

Peak-Flows Basin Characteristics			
96% Mountain Region Peak Flow (13.2 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	13.8	1	1060
Mean Basin Slope from 10m DEM (percent)	35.9	7.6	60.2
Mean Annual Precipitation (inches)	22.65	18	47
4% Plains Region Peak Flow (0.57 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	13.8	0.5	2930
6 Hour 100 Year Precipitation (inches)	3.04	2.4	5.1

Low-Flows Basin Characteristics			
100% Mountain Region Min Flow (13.8 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	13.8	1	1060
Mean Annual Precipitation (inches)	22.65	18	47
Mean Basin Elevation (feet)	8660	8600	12000

Flow-Duration Basin Characteristics			
100% Mountain Region Flow Duration (13.8 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	13.8	1	1060
Mean Annual Precipitation (inches)	22.65	18	47

Maximum-Flows Basin Characteristics			
100% Mountain Region Max Flow (13.8 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	13.8	1	1060
Mean Annual Precipitation (inches)	22.65	18	47

Mean-Flows Basin Characteristics

100% Mountain Region Mean Flow (13.8 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	13.8	1	1060
Mean Annual Precipitation (inches)	22.65	18	47

Peak-Flows Statistics Area-Averaged

Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
PK2	89.6	ft3/s	55			
PK5	137	ft3/s	48			
PK10	171	ft3/s	45			
PK25	218	ft3/s	44			
PK50	268	ft3/s	43			
PK100	310	ft3/s	40			
PK200	374	ft3/s	41			
PK500	427	ft3/s	37			

Peak-Flows Statistics Mountain_Region_Peak_Flow

Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
PK2	88.9	ft3/s	49			
PK5	133	ft3/s	44			
PK10	163	ft3/s	41			
PK25	201	ft3/s	40			
PK50	245	ft3/s	39			
PK100	277	ft3/s	36			
PK200	305	ft3/s	36			
PK500	364	ft3/s	33			

Peak-Flows Statistics Plains_Region_Peak_Flow

Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
PK2	105	ft3/s	180			
PK5	241	ft3/s	140			
PK10	364	ft3/s	140			
PK25	597	ft3/s	140			
PK50	802	ft3/s	140			
PK100	1090	ft3/s	140			
PK200	1970	ft3/s	160			
PK500	1880	ft3/s	140			

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Low-Flows Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
M7D2Y	0.3	ft3/s	89			
M7D10Y	0.1	ft3/s	150			
M7D50Y	0.2	ft3/s	130			

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(http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#)
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Flow-Duration Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
D10	24.1	ft3/s	45			
D25	6.86	ft3/s	55			
D50	2.79	ft3/s	55			
D75	1.58	ft3/s	64			
D90	0.89	ft3/s	85			

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Maximum-Flows Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
V7D2Y	58	ft3/s	46			
V7D10Y	100	ft3/s	35			
V7D50Y	143	ft3/s	31			

http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#
(http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#)
Capesius_ J.P._ and Stephens_ V. C._ Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136_ 32 p.

Mean-Flows Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
Q1	1.76	ft3/s	50			
Q2	1.66	ft3/s	51			
Q3	1.83	ft3/s	49			
Q4	3.73	ft3/s	44			
Q5	26.5	ft3/s	46			

Q6	50.6	ft3/s	46			
Q7	15.1	ft3/s	76			
Q8	6.72	ft3/s	80			
Q9	4.09	ft3/s	59			
QA	10.2	ft3/s	33			
Q10	3.15	ft3/s	45			
Q11	2.45	ft3/s	46			
Q12	1.99	ft3/s	47			

http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#
(http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#)
Capesius_ J.P._ and Stephens_ V. C._ Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136_ 32 p.

StreamStats Version 3.0

Flow Statistics Ungaged Site Report

Date: Mon Jan 25, 2016 4:50:36 PM GMT-7
Study Area: Colorado
NAD 1983 Latitude: 40.0484 (40 02 54)
NAD 1983 Longitude: -105.3745 (-105 22 29)
Drainage Area: 15.9 mi2

Peak-Flows Basin Characteristics

89% Mountain Region Peak Flow (14.1 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	15.9	1	1060
Mean Basin Slope from 10m DEM (percent)	36.4	7.6	60.2
Mean Annual Precipitation (inches)	22.38	18	47

11% Plains Region Peak Flow (1.8 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	15.9	0.5	2930
6 Hour 100 Year Precipitation (inches)	3.04	2.4	5.1

Low-Flows Basin Characteristics

89% Mountain Region Min Flow (14.1 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	15.9	1	1060
Mean Annual Precipitation (inches)	22.38	18	47
Mean Basin Elevation (feet)	8490 (below min value 8600)	8600	12000

11% Undefined Region (1.8 mi2)

Warning: The selected watershed is partly in an area for which flow equations were not defined. Whole-watershed flow estimates have been provided using the regional equations that are available for other parts of the watershed. Weighted flows were not calculated. Users should be careful to evaluate the applicability of the provided estimates.
Some parameters are outside the suggested range. Estimates will be extrapolations with unknown errors.

Flow-Duration Basin Characteristics

89% Mountain Region Flow Duration (14.1 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	15.9	1	1060
Mean Annual Precipitation (inches)	22.38	18	47

11% Undefined Region (1.8 mi2)

Warning: The selected watershed is partly in an area for which flow equations were not defined. Whole-watershed flow estimates have been provided using the regional equations that are available for other parts of the watershed. Weighted flows were not calculated. Users should be careful to evaluate the applicability of the provided estimates.

Maximum-Flows Basin Characteristics			
89% Mountain Region Max Flow (14.1 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	15.9	1	1060
Mean Annual Precipitation (inches)	22.38	18	47
11% Undefined Region (1.8 mi2)			

Warning: The selected watershed is partly in an area for which flow equations were not defined. Whole-watershed flow estimates have been provided using the regional equations that are available for other parts of the watershed. Weighted flows were not calculated. Users should be careful to evaluate the applicability of the provided estimates.

Mean-Flows Basin Characteristics			
89% Mountain Region Mean Flow (14.1 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	15.9	1	1060
Mean Annual Precipitation (inches)	22.38	18	47
11% Undefined Region (1.8 mi2)			

Warning: The selected watershed is partly in an area for which flow equations were not defined. Whole-watershed flow estimates have been provided using the regional equations that are available for other parts of the watershed. Weighted flows were not calculated. Users should be careful to evaluate the applicability of the provided estimates.

Peak-Flows Statistics Area-Averaged						
Statistic	**Value**	**Unit**	**Prediction Error (percent)**	**Equivalent years of record**	**90-Percent Prediction Interval**	
					Min	**Max**
PK2	98.9	ft3/s	64			
PK5	158	ft3/s	55			
PK10	203	ft3/s	52			
PK25	269	ft3/s	51			
PK50	337	ft3/s	50			
PK100	404	ft3/s	48			
PK200	541	ft3/s	50			
PK500	587	ft3/s	45			

Peak-Flows Statistics Mountain_Region_Peak_Flow						
Statistic	**Value**	**Unit**	**Prediction Error (percent)**	**Equivalent years of record**	**90-Percent Prediction Interval**	
					Min	**Max**

PK5	145	ft3/s	44			
PK10	179	ft3/s	41			
PK25	220	ft3/s	40			
PK50	268	ft3/s	39			
PK100	303	ft3/s	36			
PK200	335	ft3/s	36			
PK500	400	ft3/s	33			

Peak-Flows Statistics Plains_Region_Peak_Flow						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
PK2	113	ft3/s	180			
PK5	261	ft3/s	140			
PK10	395	ft3/s	140			
PK25	651	ft3/s	140			
PK50	875	ft3/s	140			
PK100	1190	ft3/s	140			
PK200	2160	ft3/s	160			
PK500	2050	ft3/s	140			

http://pubs.usgs.gov/sir/2009/5136/# (http://pubs.usgs.gov/sir/2009/5136/#)
Capesius_ J.P._ and Stephens_ V. C._ Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136_ 32 p.

Low-Flows Statistics Mountain_Region_Min_Flow						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
M7D2Y	0.3	ft3/s				
M7D10Y	0.1	ft3/s				
M7D50Y	0.22	ft3/s				

http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/# (http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#)
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Flow-Duration Statistics Mountain_Region_Flow_Duration						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
D10	26.7	ft3/s	45			
D25	7.67	ft3/s	55			
D50	3.15	ft3/s	55			
D75	1.79	ft3/s	64			
D90	1.02	ft3/s	85			

http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/# (http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#)

Capesius_ J.P._ and Stephens_ V. C._ Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136_ 32 p.

Maximum-Flows Statistics Mountain_Region_Max_Flow						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
V7D2Y	63.5	ft3/s	46			
V7D10Y	111	ft3/s	35			
V7D50Y	159	ft3/s	31			

http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#
(http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#)
Capesius_ J.P._ and Stephens_ V. C._ Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136_ 32 p.

Mean-Flows Statistics Mountain_Region_Mean_Flow						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
Q1	2	ft3/s	50			
Q2	1.89	ft3/s	51			
Q3	2.09	ft3/s	49			
Q4	4.3	ft3/s	44			
Q5	29.7	ft3/s	46			
Q6	55.8	ft3/s	46			
Q7	16.6	ft3/s	76			
Q8	7.4	ft3/s	80			
Q9	4.56	ft3/s	59			
QA	11.4	ft3/s	33			
Q10	3.53	ft3/s	45			
Q11	2.75	ft3/s	46			
Q12	2.26	ft3/s	47			

http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#
(http://pubs.usgs.gov/sir/2009/5136/#http://pubs.usgs.gov/sir/2009/5136/#)
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FEMA FIRM

NOTES TO USERS

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To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) Report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS Report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study Report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study Report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study Report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) zone 13. The **horizontal datum** was NAD 83, GRS 1980 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

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Base map information shown on this FIRM was provided by the FEMA Map Service Centerand the Boulder Area Spatial Data Cooperative (BASIC). Additional input was provided by the Town of Erie and the City of Longmont. These data are current as of 2004

This map reflects more detailed and up-to-date **stream channel configurations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables for multiple streams in the Flood Insurance Study Report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map.

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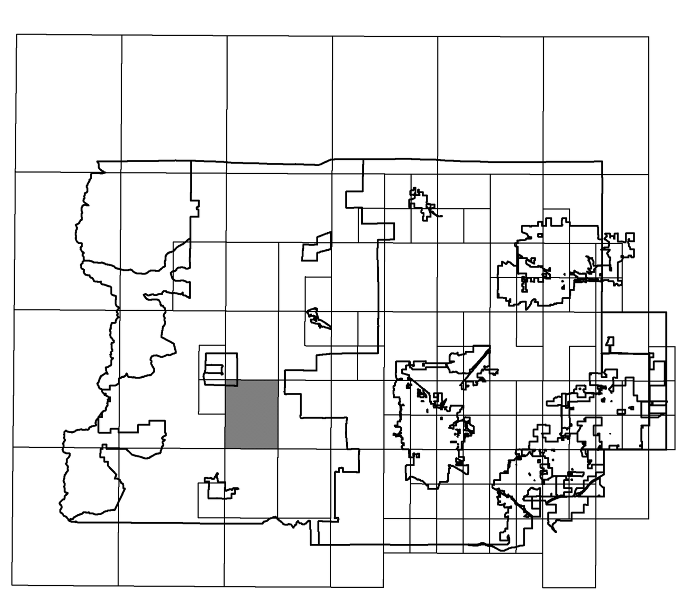
Boulder County Vertical Datum Offset Table

Flooding Source	Vertical Datum Offset (ft)	Flooding Source	Vertical Datum Offset (ft)
Fourmile Creek (Eldorado Drive and Artesian Road to uppermost point of reach)	4.6	Lefthand Creek (Lefthand Canyon Drive and Sawmill Road to uppermost point of reach)	4.7

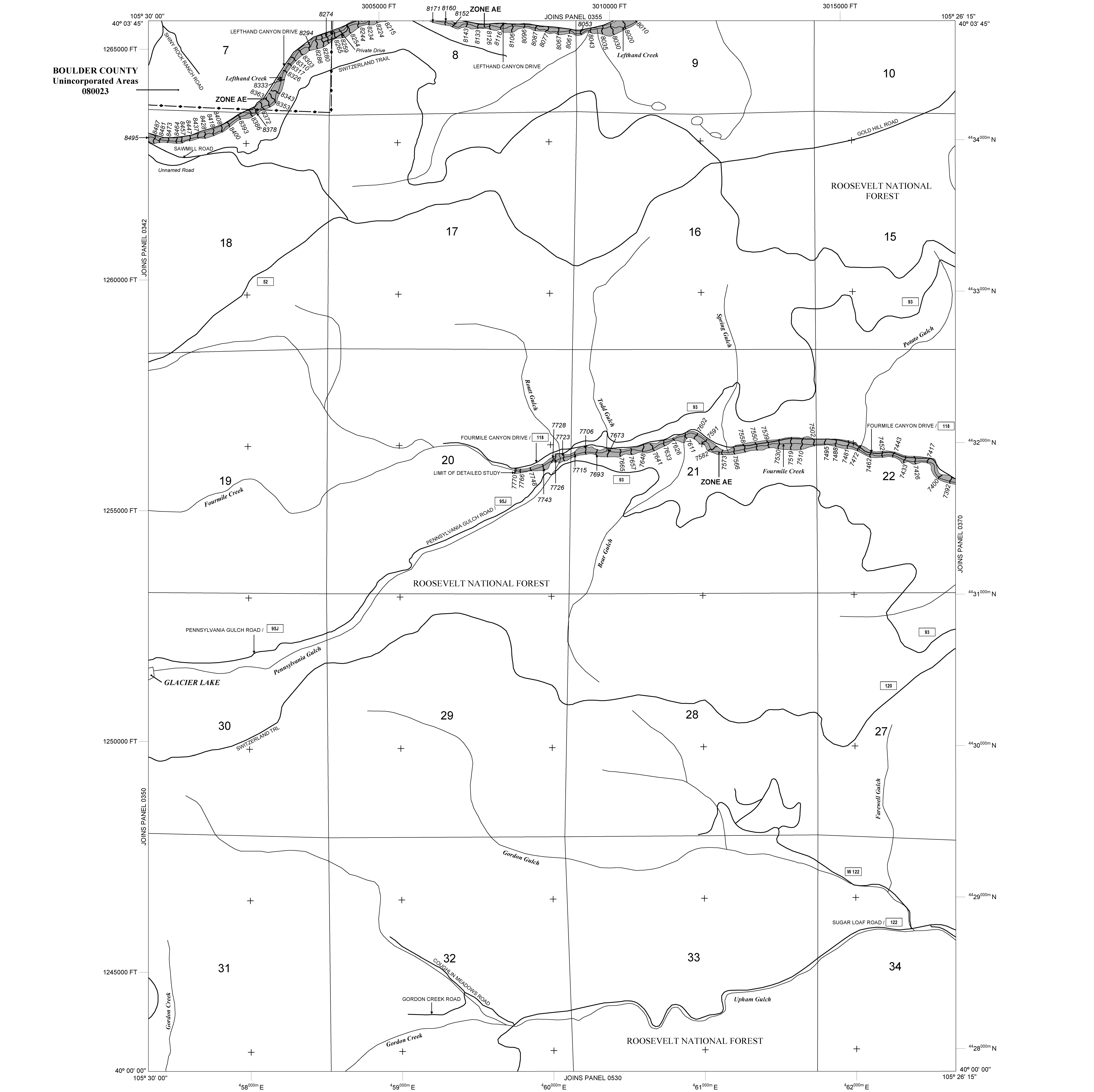
Example: To convert Fourmile Creek elevations to NAVD 88, 4.6 feet were added to the NGVD 29 elevations.

Panel Location Map



This digital Flood Insurance Rate map (FIRM) was produced through a cooperative partnership between the State of Colorado Water Conservation Board, the Urban Drainage and Flood Control District, and the Federal Emergency Management Agency (FEMA). The State of Colorado Water Conservation Board and the Urban Drainage and Flood Control District have implemented a long-term approach of floodplain management to reduce the costs associated with flooding. As part of this effort, both the State of Colorado and the Urban Drainage and Flood Control District have joined in Cooperating Technical Partner agreements with FEMA to produce this digital FIRM.

Additional Flood Hazard Information and resources are available from local communities, the Colorado Water Conservation Board, and the Urban Drainage and Flood Control District.



NOTE: MAP AREA SHOWN ON THIS PANEL IS LOCATED WITHIN TOWNSHIP 1 NORTH, RANGE 72 WEST.

LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Areas formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

Floodplain Boundary

Floodway boundary

Zone D boundary

CBRS and OPA boundary

Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.

513	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

A — A	Cross section line
23 - - - - - - 23	Transect line
45° 02' 08", 93° 02' 12"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83) Western Hemisphere
4989000m N	1000-meter Universal Transverse Mercator grid values, zone 13
3180000 FT	5000-foot ticks: Colorado State Plane North Zone (FIPS Zone 0501), Lambert Conformal Conic projection
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
• M1.5	River Mile

MAP REPOSITORY
Refer to listing of Map Repositories on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
June 2, 1995

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

May 6, 1996 - to incorporate previously issued Letters of Map Revision; to add roads and road names; and to update corporate limits.
October 4, 2002 - to change base flood elevations; to change special flood hazard areas; to change zone designations; to update roads and road names; to reflect updated topographic information; to incorporate previously issued Letters of Map Revision; and to change floodway.
December 18, 2012 - to update corporate limits; to update roads and road names; to add Special Flood Hazard Areas previously shown on Town of Erie, Colorado Flood Insurance Rate Map dated December 2, 2004; and to incorporate previously issued Letters of Map Revision.

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 1000'

500 0 1000 2000 FEET
300 0 300 600 METERS

NFIP
NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0365J

FIRM
FLOOD INSURANCE RATE MAP
BOULDER COUNTY, COLORADO
AND INCORPORATED AREAS

PANEL 365 OF 615

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BOULDER COUNTY	080023	0365	J

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
08013C0365J

MAP REVISED
DECEMBER 18, 2012

Federal Emergency Management Agency

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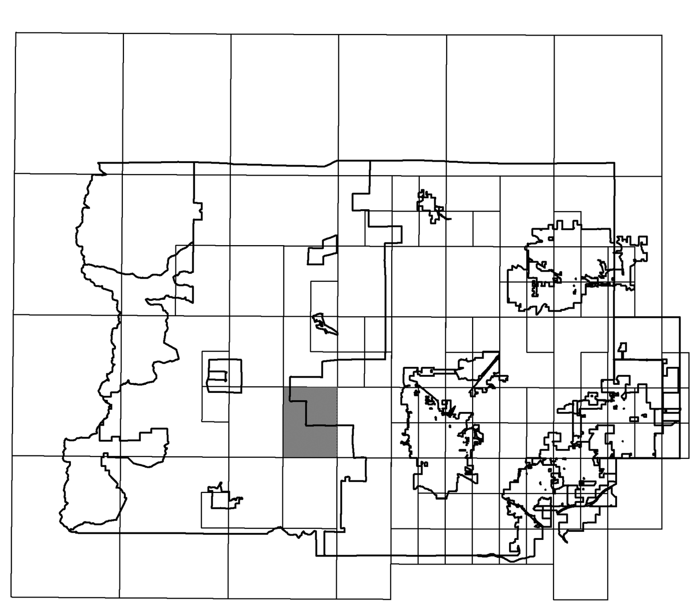
Boulder County Vertical Datum Offset Table

Flooding Source	Vertical Datum Offset (ft)	Flooding Source	Vertical Datum Offset (ft)
Boulder Creek (160,000 feet upstream of confluence of Fourmile Creek to uppermost point of reach)	4.2	Boulder Creek (Confluence of Fourmile Creek to 160,000 feet upstream of confluence of Fourmile Creek)	3.7

Example: To convert Boulder Creek elevations to NAVD 88, 4.2 feet were added to the NGVD 29 elevations.

Panel Location Map



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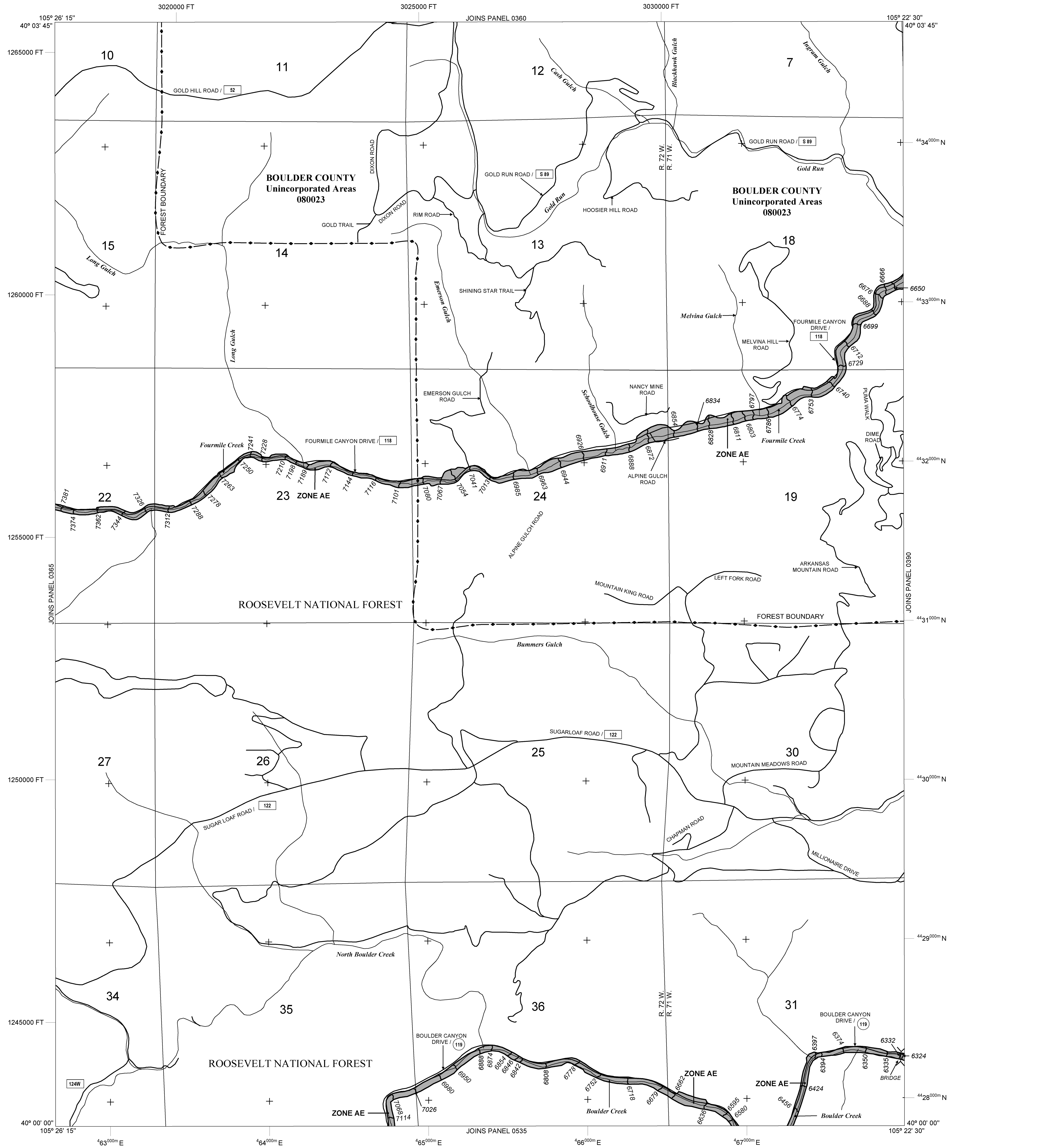

NOTE: MAP AREA SHOWN ON THIS PANEL IS LOCATED WITHIN TOWNSHIP 1 NORTH, RANGE 71 WEST, AND TOWNSHIP 1 NORTH, RANGE 72 WEST.

LEGEND

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ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Areas formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

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ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

Floodplain Boundary

Floodway boundary

Zone D boundary

CBRS and OPA boundary

Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.

513	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

A — A	Cross section line
23 - - - - - 23	Transect line
45° 02' 08", 93° 02' 12"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83) Western Hemisphere
$^{49}89^{000m}$ N	1000-meter Universal Transverse Mercator grid values, zone 13
3180000 FT	5000-foot ticks: Colorado State Plane North Zone (FIPS Zone 0501), Lambert Conformal Conic projection
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
• M1.5	River Mile

MAP REPOSITORY
Refer to listing of Map Repositories on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
June 2, 1995

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL
May 6, 1996 - to incorporate previously issued Letters of Map Revision; to add roads and road names; and to update corporate limits.
October 4, 2002 - to change base flood elevations; to change special flood hazard areas; to change zone designations; to update roads and road names; to reflect updated topographic information; to incorporate previously issued Letters of Map Revision; and to change floodway.
December 18, 2012 - to update corporate limits; to update roads and road names; to add Special Flood Hazard Areas previously shown on Town of Erie, Colorado Flood Insurance Rate Map dated December 2, 2004; and to incorporate previously issued Letters of Map Revision.

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 1000'

500 0 1000 2000 FEET
300 0 300 600 METERS

NFIP
NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0370J

FIRM
FLOOD INSURANCE RATE MAP
BOULDER COUNTY, COLORADO
AND INCORPORATED AREAS

PANEL 370 OF 615

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BOULDER COUNTY	080023	0370	J

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
08013C0370J

MAP REVISED
DECEMBER 18, 2012

Federal Emergency Management Agency

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) Report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS Report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study Report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study Report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study Report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) zone 13. The **horizontal datum** was NAD 83, GRS 1980 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713- 3242**, or visit its website at http://www.ngs.noaa.gov.

Base map information shown on this FIRM was provided by the FEMA Map Service Centerand the Boulder Area Spatial Data Cooperative (BASIC). Additional input was provided by the Town of Erie and the City of Longmont. These data are current as of 2004

This map reflects more detailed and up-to-date **stream channel configurations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables for multiple streams in the Flood Insurance Study Report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map.

Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

For information on available products associated with this FIRM visit the **Map Service Center (MSC)** website at http://msc.fema.gov. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the MSC website.

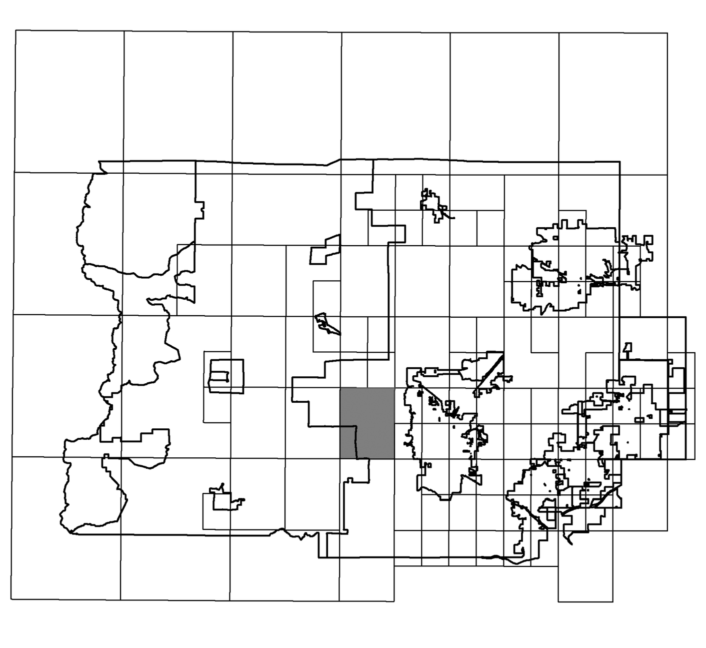
If you have **questions about this map,** how to order products, or the National Flood Insurance Program in general, please call the **FEMA Map Information eXchange (FMIX)** at **1-877-FEMA-MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/business/nfip.

Boulder County Vertical Datum Offset Table

Flooding Source	Vertical Datum Offset (ft)	Flooding Source	Vertical Datum Offset (ft)
Boulder Creek (East County Line Road to confluence of Fourmile Creek)	3.3	Fourmile Canyon Creek	3.7
Boulder Creek (confluence of Fourmile Creek to 60,000 feet upstream of confluence of Fourmile Creek	3.7	Fourmile Creek (Baseline Road to Confluence with Boulder Creek)	4.6

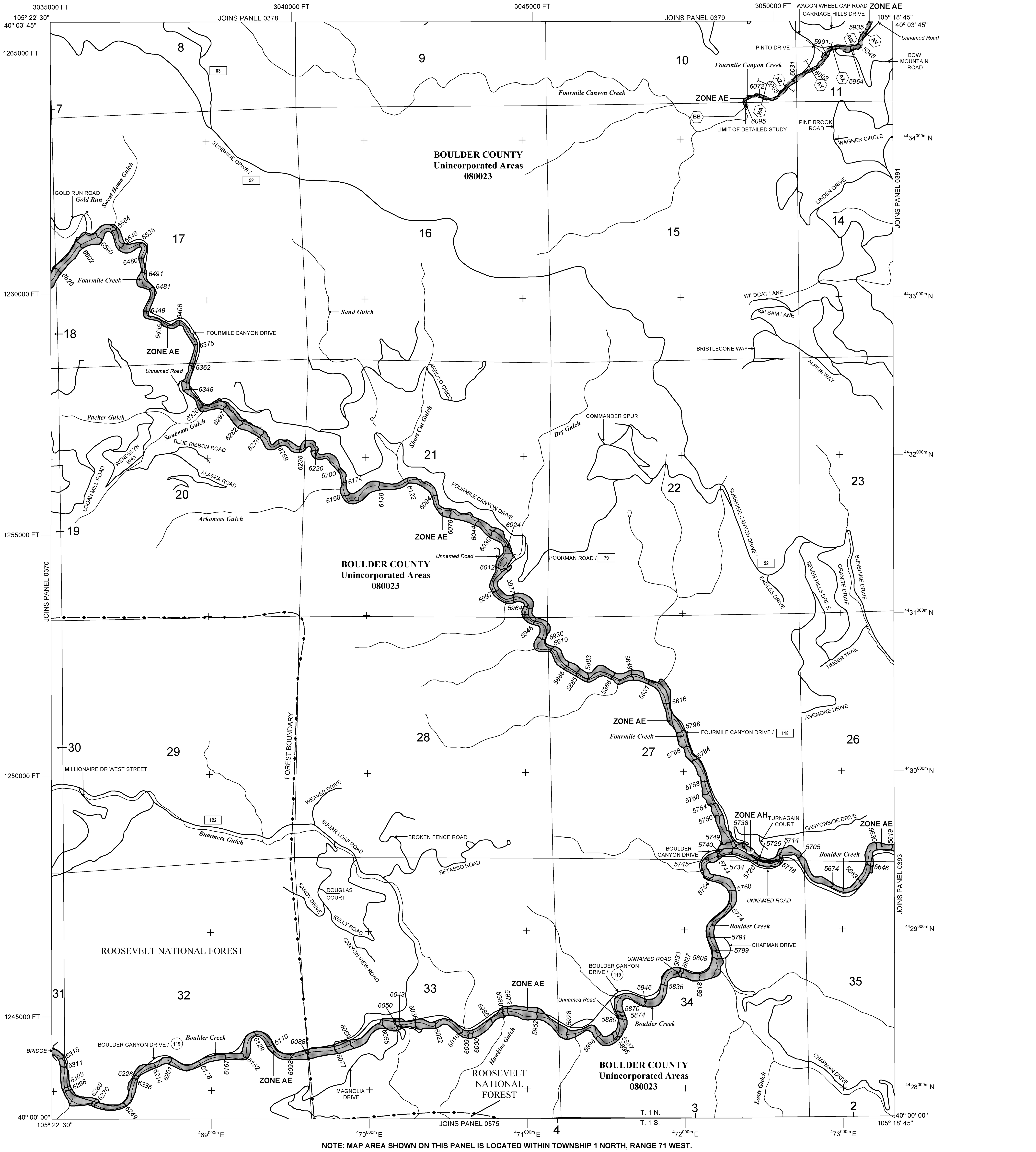
Example: To convert Fourmile Canyon Creek elevations to NAVD 88, 3.7 feet were added to the NGVD 29 elevations.

Panel Location Map



This digital Flood Insurance Rate map (FIRM) was produced through a cooperative partnership between the State of Colorado Water Conservation Board, the Urban Drainage and Flood Control District, and the Federal Emergency Management Agency (FEMA). The State of Colorado Water Conservation Board and the Urban Drainage and Flood Control District have implemented a long-term approach of floodplain management to reduce the costs associated with flooding. As part of this effort, both the State of Colorado and the Urban Drainage and Flood Control District have joined in Cooperating Technical Partner agreements with FEMA to produce this digital FIRM.

Additional Flood Hazard Information and resources are available from local communities, the Colorado Water Conservation Board, and the Urban Drainage and Flood Control District.



LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Areas formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X — Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X — Areas determined to be outside the 0.2% annual chance floodplain.

ZONE D — Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

Floodplain Boundary

Floodway boundary

Zone D boundary

CBRS and OPA boundary

Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.

513	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

A — A	Cross section line
23 - - - - - 23	Transect line
45° 02' 08", 93° 02' 12"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83) Western Hemisphere
4989000m N	1000-meter Universal Transverse Mercator grid values, zone 13
3180000 FT	5000-foot ticks: Colorado State Plane North Zone (FIPS Zone 0501), Lambert Conformal Conic projection
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
• M1.5	River Mile

MAP REPOSITORY
Refer to listing of Map Repositories on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
June 2, 1995

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL
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MAP SCALE 1" = 1000'

500 0 1000 2000 FEET
300 0 300 600 METERS

NFIP
NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0390J

FIRM
FLOOD INSURANCE RATE MAP
BOULDER COUNTY, COLORADO
AND INCORPORATED AREAS

PANEL 390 OF 615

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BOULDER COUNTY	080023	0390	J

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

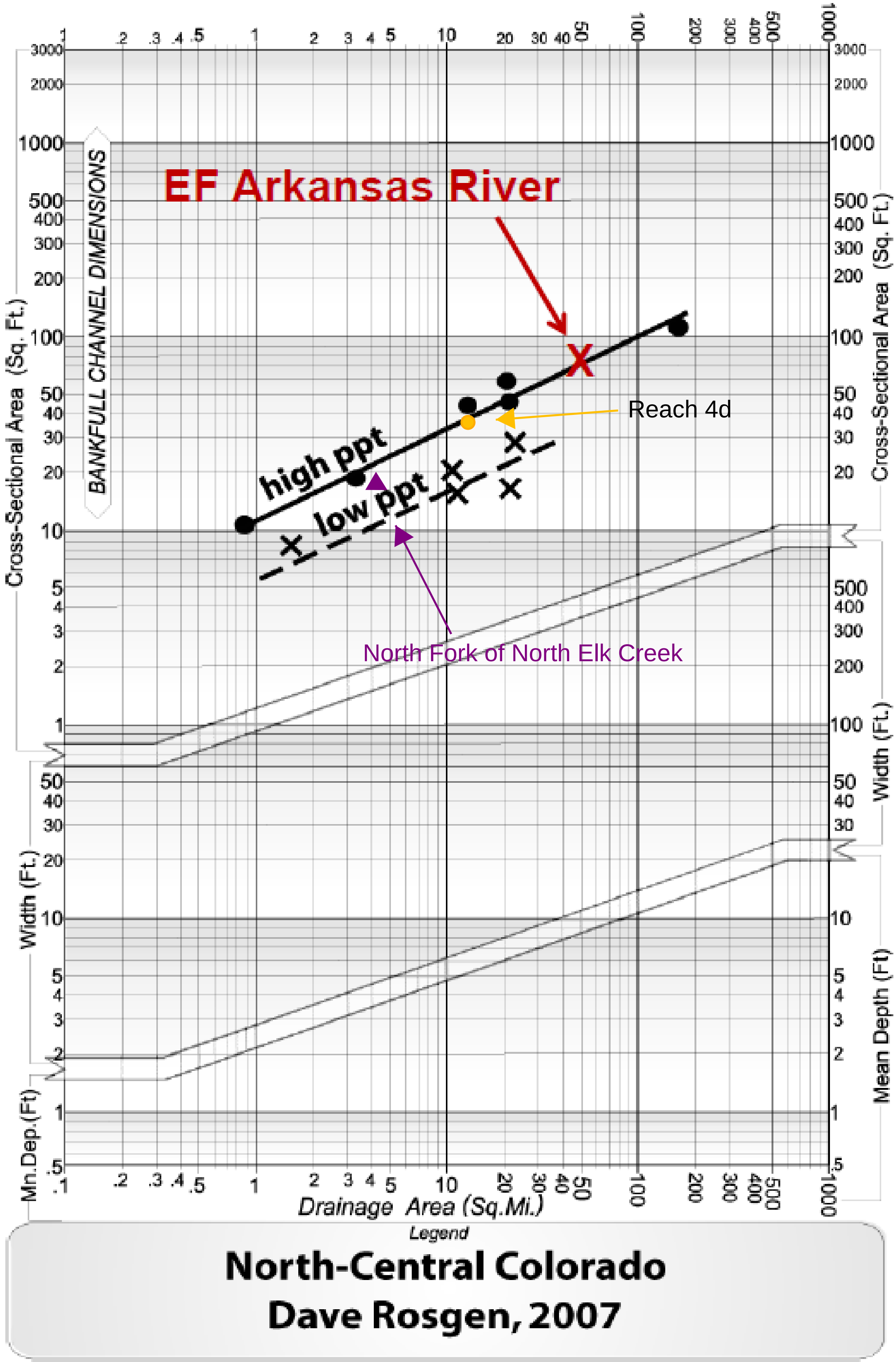
MAP NUMBER
08013C0390J

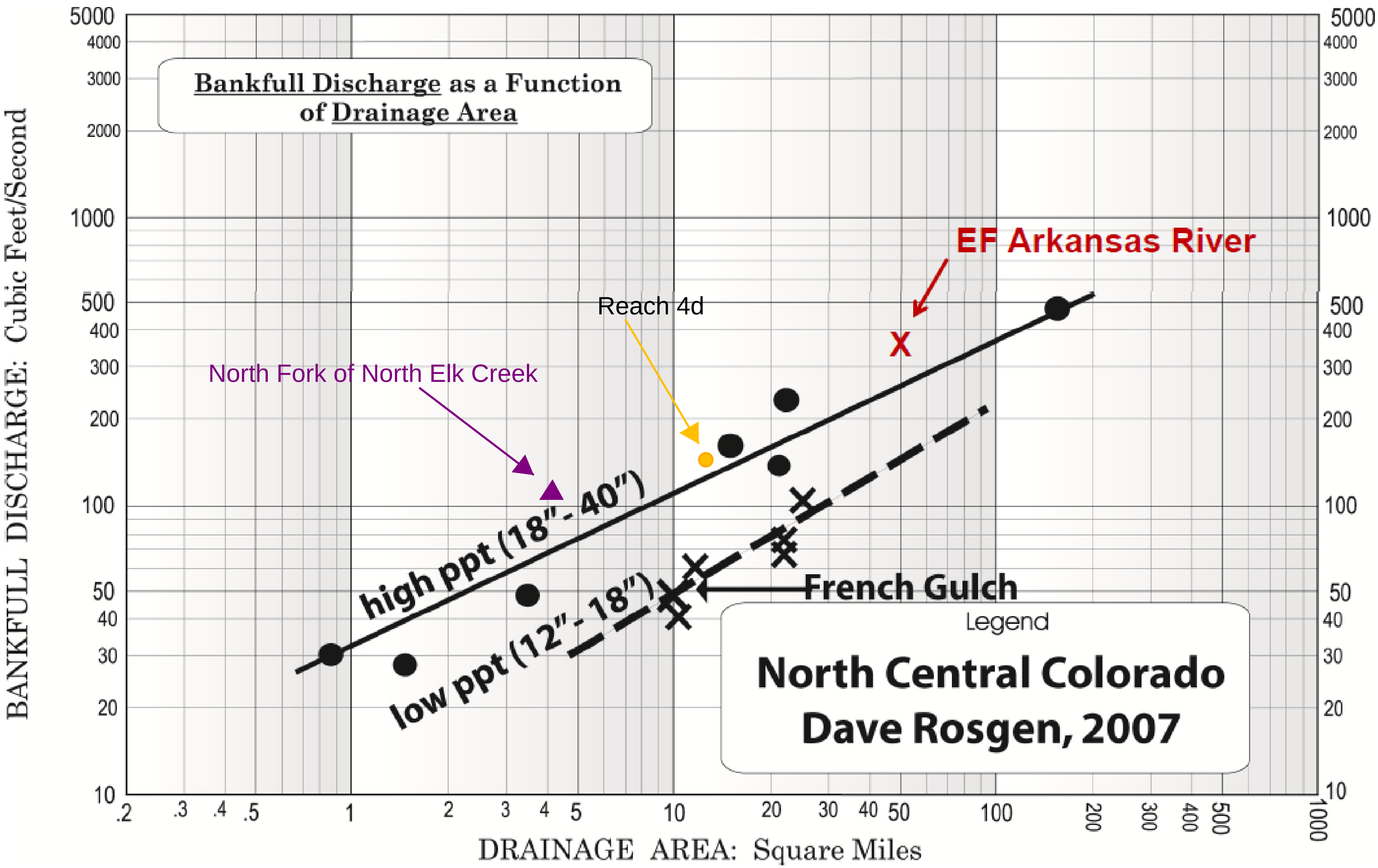
MAP REVISED
DECEMBER 18, 2012

Federal Emergency Management Agency

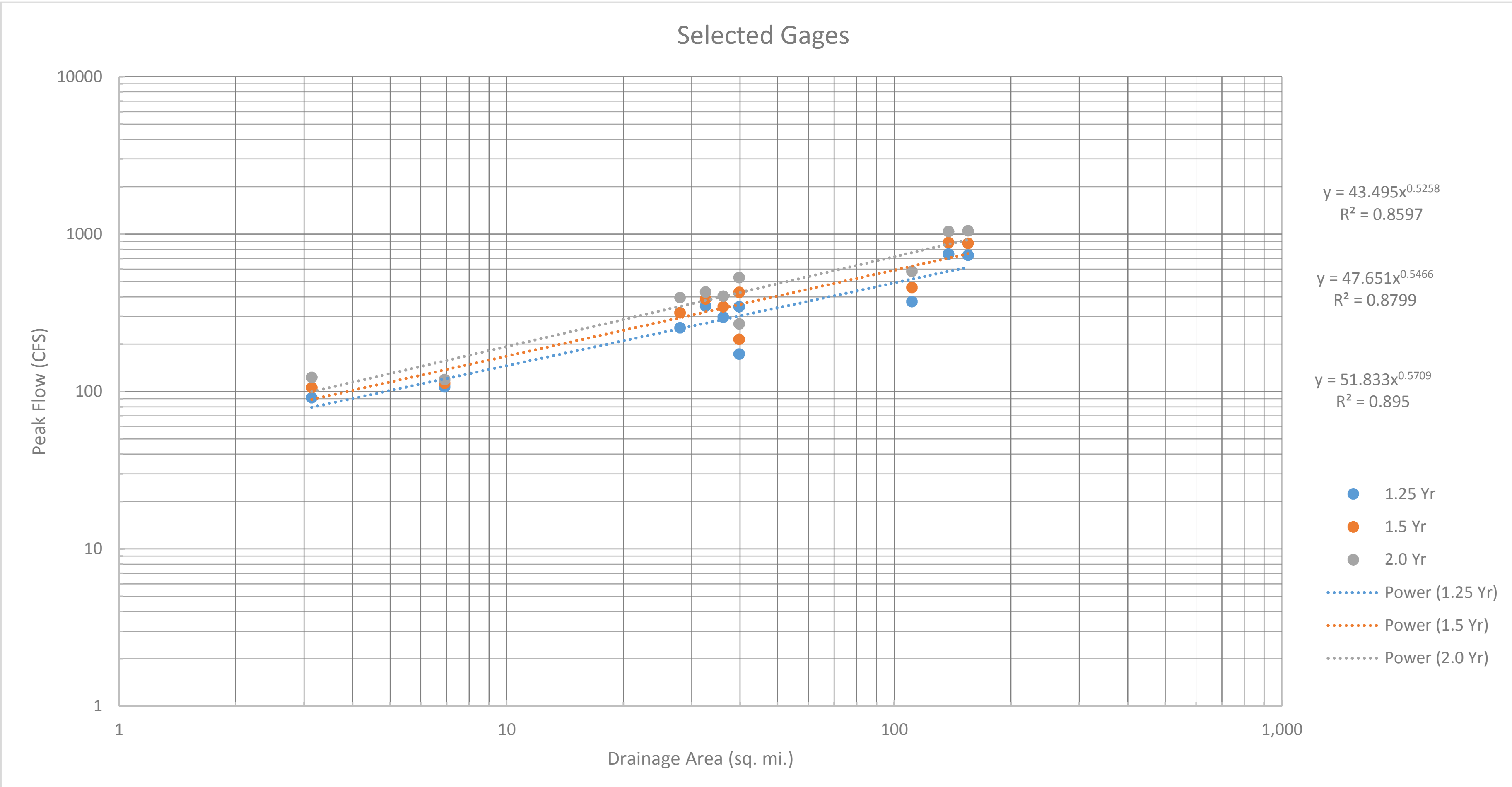
Regional Curves

Upper Fourmile Stream Survey Compared to Regional Curves

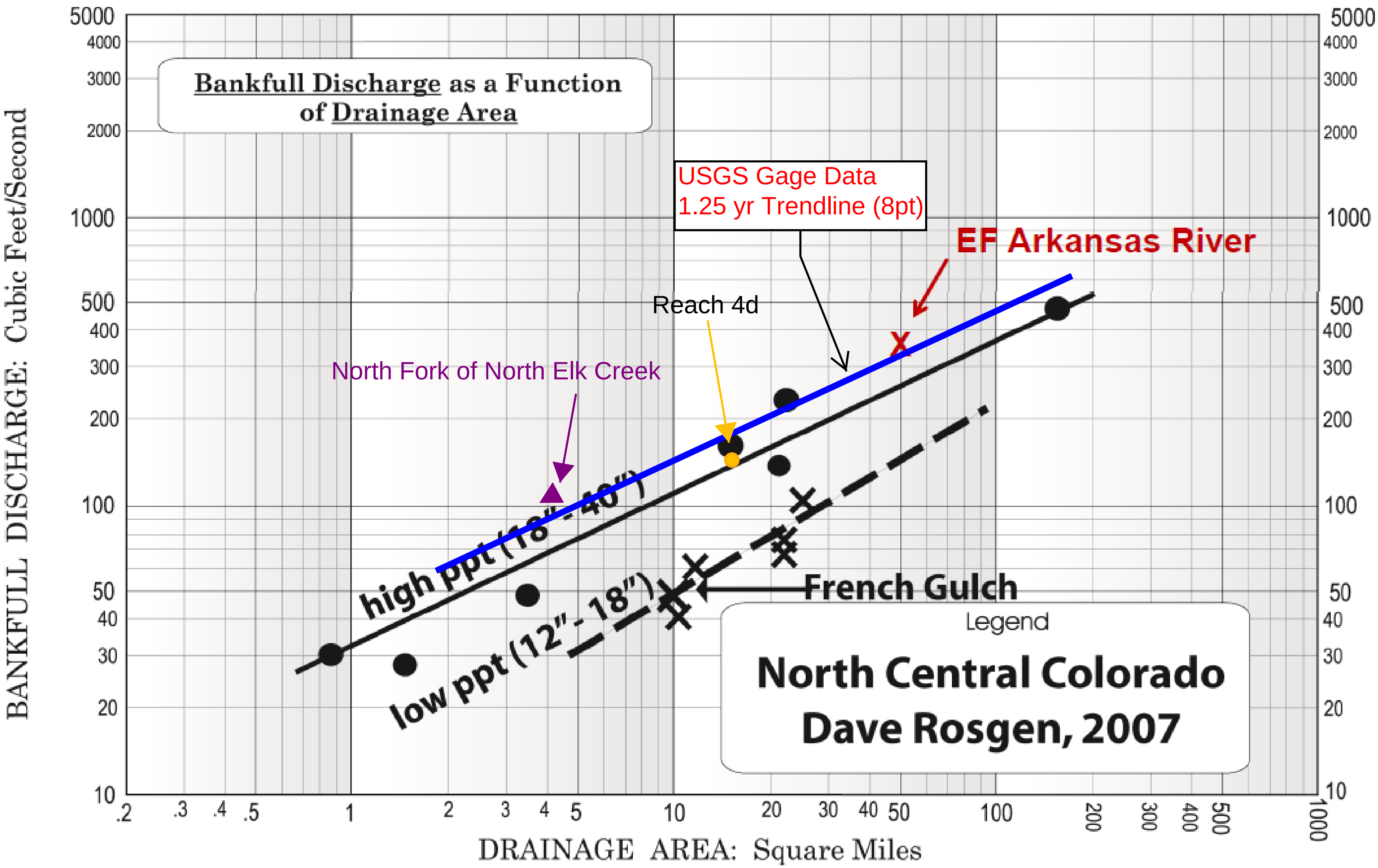



Bankfull Discharge as a Function of Drainage Area
EF Arkansas River
Reach 4d
North Fork of North Elk Creek
high ppt (18"-40")
low ppt (12"-18")
French Gulch
Legend
North Central Colorado
Dave Rosgen, 2007
BANKFULL DISCHARGE: Cubic Feet/Second
DRAINAGE AREA: Square Miles

Statistical Analysis of USGS Gage Data



Selected Gages
Peak Flow (CFS)
10000
1000
100
10
1
1
10
100
1,000
Drainage Area (sq. mi.)
y = 43.495x^0.5258
R² = 0.8597
y = 47.651x^0.5466
R² = 0.8799
y = 51.833x^0.5709
R² = 0.895
1.25 Yr
1.5 Yr
2.0 Yr
Power (1.25 Yr)
Power (1.5 Yr)
Power (2.0 Yr)



Bankfull Discharge as a Function of Drainage Area
USGS Gage Data 1.25 yr Trendline (8pt)
EF Arkansas River
Reach 4d
North Fork of North Elk Creek
high ppt (18"- 40")
low ppt (12"- 18")
French Gulch
Legend
North Central Colorado
Dave Rosgen, 2007
BANKFULL DISCHARGE: Cubic Feet/Second
DRAINAGE AREA: Square Miles

Hydraulic Modeling Results

Hydraulic Analysis Report

Project Data

Project Title: Upper Fourmile Creek

Designer:

Project Date: Thursday, February 11, 2016

Project Units: U.S. Customary Units

Notes:

Channel Analysis: Reach 1 Riffle

Notes:

Input Parameters

Channel Type: Custom Cross Section

Cross Section Data

Elevation (ft)	Elevation (ft)	Manning's n
0.00	5.00	0.0600
0.50	3.00	0.0600
3.50	2.90	0.0600
7.10	1.80	0.0600
9.50	1.70	0.0600
11.50	1.10	0.0600
14.75	1.00	0.0600
18.00	1.10	0.0600
20.00	1.70	0.0600
22.40	1.80	0.0600
26.00	2.90	0.0600
29.00	3.00	0.0600
29.50	5.00	-----

Longitudinal Slope: 0.0344 ft/ft

Depth: 1.9000 ft

Result Parameters

Flow: 142.2974 cfs

Area of Flow: 27.5050 ft^2

Wetted Perimeter: 23.0120 ft

Hydraulic Radius: 1.1952 ft

Average Velocity: 5.1735 ft/s

Top Width: 22.5000 ft

Froude Number: 0.8246

Critical Depth: 1.7303 ft

Critical Velocity: 5.9834 ft/s

Critical Slope: 0.0521 ft/ft

Critical Top Width: 21.39 ft

Calculated Max Shear Stress: 4.0785 lb/ft^2

Calculated Avg Shear Stress: 2.5657 lb/ft^2

Composite Manning's n Equation: Lotter method

Manning's n: 0.0600

Channel Analysis: Reach 2 Riffle

Notes:

Input Parameters

Channel Type: Custom Cross Section

Cross Section Data

Elevation (ft)	Elevation (ft)	Manning's n
0.00	5.10	0.0600
0.50	3.10	0.0600
3.50	3.00	0.0600
7.40	1.80	0.0600
9.50	1.70	0.0600
11.50	1.10	0.0600
14.75	1.00	0.0600
18.00	1.10	0.0600
20.00	1.70	0.0600
22.10	1.80	0.0600
26.00	3.00	0.0600
29.00	3.10	0.0600
29.50	5.10	-----

Longitudinal Slope: 0.0390 ft/ft

Depth: 2.0000 ft

Result Parameters

Flow: 165.3759 cfs

Area of Flow: 29.0050 ft^2

Wetted Perimeter: 23.0448 ft

Hydraulic Radius: 1.2586 ft

Average Velocity: 5.7016 ft/s

Top Width: 22.5000 ft

Froude Number: 0.8850

Critical Depth: 1.8837 ft

Critical Velocity: 6.2564 ft/s

Critical Slope: 0.0507 ft/ft

Critical Top Width: 21.74 ft

Calculated Max Shear Stress: 4.8672 lb/ft^2

Calculated Avg Shear Stress: 3.0630 lb/ft^2

Composite Manning's n Equation: Lotter method

Manning's n: 0.0600

Channel Analysis: Reach 3 Riffle

Notes:

Input Parameters

Channel Type: Custom Cross Section

Cross Section Data

Elevation (ft)	Elevation (ft)	Manning's n
0.00	5.20	0.0600
0.50	3.20	0.0600
3.50	3.10	0.0600
7.40	1.90	0.0600
9.75	1.80	0.0600
11.75	1.10	0.0600
15.50	1.00	0.0600
19.25	1.10	0.0600
21.25	1.80	0.0600
23.60	1.90	0.0600
27.50	3.10	0.0600
30.50	3.20	0.0600
31.00	5.20	-----

Longitudinal Slope: 0.0319 ft/ft

Depth: 2.1000 ft

Result Parameters

Flow: 173.3321 cfs

Area of Flow: 32.5300 ft^2

Wetted Perimeter: 24.6057 ft

Hydraulic Radius: 1.3221 ft

Average Velocity: 5.3284 ft/s

Top Width: 24.0000 ft

Froude Number: 0.8065

Critical Depth: 1.8904 ft

Critical Velocity: 6.2705 ft/s

Critical Slope: 0.0507 ft/ft

Critical Top Width: 22.64 ft

Calculated Max Shear Stress: 4.1802 lb/ft^2

Calculated Avg Shear Stress: 2.6316 lb/ft^2

Composite Manning's n Equation: Lotter method

Manning's n: 0.0600

Channel Analysis: Reach 1 Pool

Notes:

Input Parameters

Channel Type: Custom Cross Section

Cross Section Data

Elevation (ft)	Elevation (ft)	Manning's n
0.00	3.50	0.0600
12.00	2.30	0.0600
15.00	1.00	0.0600
18.00	1.00	0.0600
21.00	1.00	0.0600
22.30	2.30	0.0600
23.50	3.50	-----

Longitudinal Slope: 0.0344 ft/ft

Depth: 2.5000 ft

Result Parameters

Flow: 163.8451 cfs

Area of Flow: 30.8750 ft^2

Wetted Perimeter: 24.8649 ft

Hydraulic Radius: 1.2417 ft

Average Velocity: 5.3067 ft/s

Top Width: 23.5000 ft

Froude Number: 0.8159

Critical Depth: 2.2817 ft

Critical Velocity: 6.3001 ft/s

Critical Slope: 0.0529 ft/ft

Critical Top Width: 21.10 ft

Calculated Max Shear Stress: 5.3664 lb/ft^2

Calculated Avg Shear Stress: 2.6654 lb/ft^2

Composite Manning's n Equation: Lotter method

Manning's n: 0.0600

Channel Analysis: Reach 2 Pool

Notes:

Input Parameters

Channel Type: Custom Cross Section

Cross Section Data

Elevation (ft)	Elevation (ft)	Manning's n
0.00	3.70	0.0600
13.00	2.40	0.0600
15.30	1.00	0.0600
18.30	1.00	0.0600
21.30	1.00	0.0600
22.70	2.40	0.0600
24.00	3.70	-----

Longitudinal Slope: 0.0390 ft/ft

Depth: 2.7000 ft

Result Parameters

Flow: 190.2816 cfs

Area of Flow: 32.8950 ft^2

Wetted Perimeter: 25.5758 ft

Hydraulic Radius: 1.2862 ft

Average Velocity: 5.7845 ft/s

Top Width: 24.0000 ft

Froude Number: 0.8707

Critical Depth: 2.5427 ft

Critical Velocity: 6.5040 ft/s

Critical Slope: 0.0523 ft/ft

Critical Top Width: 22.27 ft

Calculated Max Shear Stress: 6.5707 lb/ft^2

Calculated Avg Shear Stress: 3.1300 lb/ft^2

Composite Manning's n Equation: Lotter method

Manning's n: 0.0600

Channel Analysis: Reach 3 Pool

Notes:

Input Parameters

Channel Type: Custom Cross Section

Cross Section Data

Elevation (ft)	Elevation (ft)	Manning's n
0.00	3.90	0.0600
12.60	2.50	0.0600
15.60	1.00	0.0600
18.85	1.00	0.0600
22.10	1.00	0.0600
23.60	2.50	0.0600
25.00	3.90	-----

Longitudinal Slope: 0.0319 ft/ft

Depth: 2.7000 ft

Result Parameters

Flow: 182.5886 cfs

Area of Flow: 33.5250 ft^2

Wetted Perimeter: 24.5389 ft

Hydraulic Radius: 1.3662 ft

Average Velocity: 5.4463 ft/s

Top Width: 23.0000 ft

Froude Number: 0.7950

Critical Depth: 2.4248 ft

Critical Velocity: 6.6219 ft/s

Critical Slope: 0.0518 ft/ft

Critical Top Width: 20.25 ft

Calculated Max Shear Stress: 5.3745 lb/ft^2

Calculated Avg Shear Stress: 2.7195 lb/ft^2

Composite Manning's n Equation: Lotter method

Manning's n: 0.0600

Channel Analysis: Boulder Pool

Notes:

Input Parameters

Channel Type: Custom Cross Section

Cross Section Data

Elevation (ft)	Elevation (ft)	Manning's n
0.00	3.70	0.0600
10.40	2.40	0.0600
13.60	1.00	0.0600
16.60	1.00	0.0600
19.60	1.00	0.0600
22.40	2.40	0.0600
25.00	3.70	-----

Longitudinal Slope: 0.0390 ft/ft

Depth: 2.7000 ft

Result Parameters

Flow: 225.2942 cfs

Area of Flow: 36.6500 ft^2

Wetted Perimeter: 26.0112 ft

Hydraulic Radius: 1.4090 ft

Average Velocity: 6.1472 ft/s

Top Width: 25.0000 ft

Froude Number: 0.8947

Critical Depth: 2.5671 ft

Critical Velocity: 6.7421 ft/s

Critical Slope: 0.0494 ft/ft

Critical Top Width: 23.67 ft

Calculated Max Shear Stress: 6.5707 lb/ft^2

Calculated Avg Shear Stress: 3.4290 lb/ft^2

Composite Manning's n Equation: Lotter method

Manning's n: 0.0600

MAYNORD METHOD FOR CHANNEL SCOUR AT A BEND

Ref: HEC-23 Page 4.10, method assumes bank is protected and that erosion potential will be directed at invert.

Bankfull Flow (subcritical flow condition)

D_{mnc}	1.4	ft	cross section area/topwidth upstream of bend	*Reach 1 Pool*
R_c	26	ft	centerline radius of bend	*From Reach 1 Proposed Alignment Min*
W	23.5	ft	topwidth in bend	*Reach 1 Pool*
D	2.5	ft	Flow depth in bend without scour	*Reach 1 Pool*

D_{mxb}	2.6	ft	Water depth at max scour
Ds	0.1	ft	Scour depth (below existing invert)
Ds X 2	0.2	ft	Scour depth (below existing invert) including recommended SF of 2

MAYNORD METHOD FOR CHANNEL SCOUR AT A BEND

Ref: HEC-23 Page 4.10, method assumes bank is protected and that erosion potential will be directed at invert.

Bankfull Flow (subcritical flow condition)

D_{mnc}	1.4	ft	cross section area/topwidth upstream of bend	*Reach 1 Pool*
R_c	68	ft	centerline radius of bend	*From Reach 1 Proposed Alignment Average*
W	23.5	ft	topwidth in bend	*Reach 1 Pool*
D	2.5	ft	Flow depth in bend without scour	*Reach 1 Pool*

D_{mxb}	2.5	ft	Water depth at max scour
Ds	0.0	ft	Scour depth (below existing invert)
Ds X 2	0.0	ft	Scour depth (below existing invert) including recommended SF of 2

MAYNORD METHOD FOR CHANNEL SCOUR AT A BEND
Ref: HEC-23 Page 4.10, method assumes bank is protected and that erosion potential will be directed at invert.

Bankfull Flow (subcritical flow condition)

D_{mnc}	1.5	ft	cross section area/topwidth upstream of bend	*Reach 2 Pool*
R_c	30	ft	centerline radius of bend	*From Reach 2 Proposed Alignment Min*
W	24	ft	topwidth in bend	*Reach 2 Pool*
D	2.7	ft	Flow depth in bend without scour	*Reach 2 Pool*

D_{mxb}	2.8	ft	Water depth at max scour
Ds	0.1	ft	Scour depth (below existing invert)
Ds X 2	0.1	ft	Scour depth (below existing invert) including recommended SF of 2

MAYNORD METHOD FOR CHANNEL SCOUR AT A BEND

Ref: HEC-23 Page 4.10, method assumes bank is protected and that erosion potential will be directed at invert.

Bankfull Flow (subcritical flow condition)

D_{mnc}	1.5	ft	cross section area/topwidth upstream of bend	*Reach 2 Pool*
R_c	80	ft	centerline radius of bend	*From Reach 2 Proposed Alignment Average*
W	24	ft	topwidth in bend	*Reach 2 Pool*
D	2.7	ft	Flow depth in bend without scour	*Reach 2 Pool*

D_{mxb}	2.6	ft	Water depth at max scour
Ds	-0.1	ft	Scour depth (below existing invert)
Ds X 2	-0.1	ft	Scour depth (below existing invert) including recommended SF of 2

MAYNORD METHOD FOR CHANNEL SCOUR AT A BEND

Ref: HEC-23 Page 4.10, method assumes bank is protected and that erosion potential will be directed at invert.

Bankfull Flow (subcritical flow condition)

D_{mnc}	1.6	ft	cross section area/topwidth upstream of bend	*Reach 3 Pool*
R_c	25	ft	centerline radius of bend	*From Reach 3 Proposed Alignment Min*
W	25	ft	topwidth in bend	*Reach 3 Pool*
D	2.9	ft	Flow depth in bend without scour	*Reach 3 Pool*

D_{mxb}	3.0	ft	Water depth at max scour
Ds	0.1	ft	Scour depth (below existing invert)
Ds X 2	0.2	ft	Scour depth (below existing invert) including recommended SF of 2

MAYNORD METHOD FOR CHANNEL SCOUR AT A BEND

Ref: HEC-23 Page 4.10, method assumes bank is protected and that erosion potential will be directed at invert.

Bankfull Flow (subcritical flow condition)

D_{mnc}	1.6	ft	cross section area/topwidth upstream of bend	*Reach 3 Pool*
R_c	69	ft	centerline radius of bend	*From Reach 3 Proposed Alignment Average*
W	25	ft	topwidth in bend	*Reach 3 Pool*
D	2.9	ft	Flow depth in bend without scour	*Reach 3 Pool*

D_{mxb}	2.9	ft	Water depth at max scour
Ds	0.0	ft	Scour depth (below existing invert)
Ds X 2	0.0	ft	Scour depth (below existing invert) including recommended SF of 2

MAYNORD METHOD FOR CHANNEL SCOUR AT A BEND

Ref: HEC-23 Page 4.10, method assumes bank is protected and that erosion potential will be directed at invert.

Bankfull Flow (subcritical flow condition)

D_{mnc}	1.6	ft	cross section area/topwidth upstream of bend	*Boulder Pool*
R_c	25	ft	centerline radius of bend	*From Proposed Alignment Min*
W	25	ft	topwidth in bend	*Boulder Pool*
D	2.7	ft	Flow depth in bend without scour	*Boulder Pool*

D_{mxb}	3.0	ft	Water depth at max scour
Ds	0.3	ft	Scour depth (below existing invert)
Ds X 2	0.6	ft	Scour depth (below existing invert) including recommended SF of 2

MAYNORD METHOD FOR CHANNEL SCOUR AT A BEND

Ref: HEC-23 Page 4.10, method assumes bank is protected and that erosion potential will be directed at invert.

Bankfull Flow (subcritical flow condition)

D_{mnc}	1.6	ft	cross section area/topwidth upstream of bend	*Boulder Pool*
R_c	80	ft	centerline radius of bend	*From Proposed Alignment Average*
W	25	ft	topwidth in bend	*Boulder Pool*
D	2.7	ft	Flow depth in bend without scour	*Boulder Pool*

D_{mxb}	2.9	ft	Water depth at max scour
Ds	0.2	ft	Scour depth (below existing invert)
Ds X 2	0.4	ft	Scour depth (below existing invert) including recommended SF of 2

Client: Boulder County | By: SMA
Project: Upper Fourmile Creek Stream Restoration | Date: 11-Aug-16
Description: **LPSTP Toe Protection for Bankfull Flow in Pool-1 at Maximum Velocity**

METHOD 1 - CORPS OF ENGINEERS

SOURCE: *U.S. Army Corps of Engineers. 1994. Hydraulic Design of Flood Control Channels. EM 1110-2-1601, Change 1. June 30.*
Revetment Method (Recommended for slopes < 2%)
Chapter 3 Section III

INPUT DATA

y = 2.5 Depth of Flow
Sf = 1.1 Safety Factor
Cs = 0.3 Stability Coefficient (0.3 for angular rock, 0.375 for rounded)

Calculate Cv for channel bend:
Rc = 25.9 radius of curvature (ft) From design pattern min
T = 23.5 Topwidth (ft) Bankfull
Cv = 1.27 Velocity Distribution Coeff. (Use 1.0 for Rc/T > 26)
Ct = 4.5 Blanket Thickness Coefficient

Calculate design velocity (Vss) for channel bend:
Vavg = 5.307 Avg Channel Velocity U/S of Bend (ft/s) Maximum of Reach 1
Vss = 9.1 Design velocity (bank area of bend in natural channel)

Theta = 45 Bank Angle in Degrees *Measured on outside of pool cross section from toe*
Phi = 90 Angle of repose (degrees) of riprap material (normally 40 degrees
Sg = 2.65 Rock Specific Gravity
g = 32.2 Gravity

COMPUTED DATA

K1 = 0.71 Side slope correction factor
D30 = 4.1 ft
D50 = 4.9 ft

Max D50 = 4.9 ft

METHOD 2 - UDFCD/SPRINGS

SOURCE: *Urban Storm Drainage Criteria Manual, Vol. 2*
Uban Drainage and Flood Control District, Denver, Colorado
Rev. April 2008

City of Colorado Springs/El Paso County Drainage Criteria Manual
12-Oct-94

INPUT DATA

V = 5.307 Mean channel flow velocity (ft/s) Maximum of Reach 1

Adjust Velocity for Bend (UDFCD EQ. MD-10, pg MD-47). No Adjustment for Rc/T > 8.
Rc = 25.9 radius of curvature (ft) From design pattern min
T = 23.5 Topwidth (ft) Bankfull
Va = 11 Velocity adjusted for bend (ft/s)

S = 0.055 Channel slope (ft/ft) from proposed grading
S_s = 2.65 Rock specific gravity

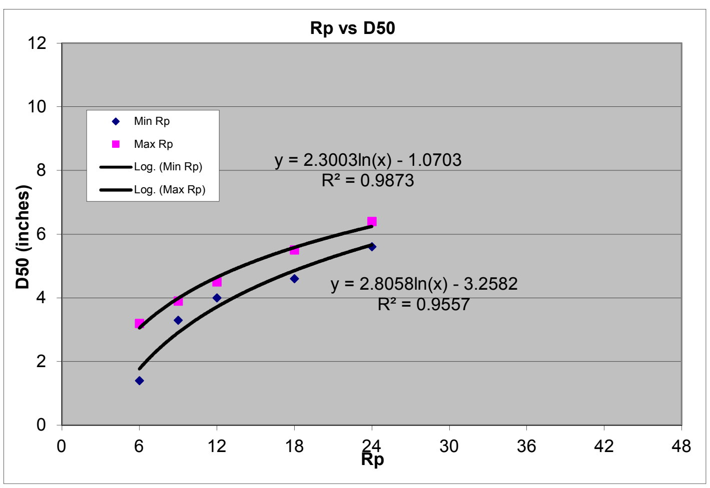
COMPUTED DATA

			Class/Type
	R_p =	4.7	
Riprap	**D50 (ft) =**	**1.50**	**H**
Boulder	**D50 (ft) =**	**1.50**	**B18**

Values in UDFCD Manual (rows 1.4–5.6); Extrapolated from UDFCD Values (See Curves Below) (rows 6.3–8.2)

Min Rp	Max Rp	Riprap Type	D50 (inches)
1.4	3.2	VL	6
3.3	3.9	L	9
4	4.5	M	12
4.6	5.5	H	18
5.6	6.4	VH	24
6.3	6.8		30
6.8	7.2		36
7.2	7.5		42
7.6	7.8		48
7.9	8.1		54
8.2	8.3		60

Min Rp	Max Rp	Boulder Class	D50 (inches)
4.6	5.5	B18	18
5.6	6.4	B24	24
6.5	7.1	B30	30
7.2	7.8	B36	36
7.9	8.4	B42	42
8.5	9.0	B48	48



Client: Boulder County
Project: Upper Fourmile Creek Stream Restoration
Description: **LPSTP Toe Protection for Bankfull Flow in Pool-2 at Maximum Velocity**

By: SMA
Date: 11-Aug-16

METHOD 1 - CORPS OF ENGINEERS

SOURCE: *U.S. Army Corps of Engineers. 1994. Hydraulic Design of Flood Control Channels. EM 1110-2-1601, Change 1. June 30.*
Revetment Method (Recommended for slopes < 2%)
Chapter 3 Section III

INPUT DATA

y =	2.7	Depth of Flow
Sf =	1.1	Safety Factor
Cs =	0.3	Stability Coefficient (0.3 for angular rock, 0.375 for rounded)

Calculate Cv for channel bend:

Rc =	30.2	radius of curvature (ft) From design pattern min
T =	24	Topwidth (ft) Bankfull
Cv =	1.26	Velocity Distribution Coeff. (Use 1.0 for Rc/T > 26)
Ct =	4.5	Blanket Thickness Coefficient

Calculate design velocity (Vss) for channel bend:

Vavg =	5.785	Avg Channel Velocity U/S of Bend (ft/s) Maximum of Reach 2
Vss =	9.8	Design velocity (bank area of bend in natural channel)

Theta =	45	Bank Angle in Degrees *Measured on outside of pool cross section from toe*
Phi =	90	Angle of repose (degrees) of riprap material (normally 40 degrees
Sg =	2.65	Rock Specific Gravity
g =	32.2	Gravity

COMPUTED DATA

K1 =	0.71	Side slope correction factor
D30 =	4.7	ft
D50 =	**5.6**	**ft**

Max D50 = 5.6 ft

METHOD 2 - UDFCD/SPRINGS

SOURCE: *Urban Storm Drainage Criteria Manual, Vol. 2*
Uban Drainage and Flood Control District, Denver, Colorado
Rev. April 2008

City of Colorado Springs/El Paso County Drainage Criteria Manual
12-Oct-94

INPUT DATA

V =	5.785	Mean channel flow velocity (ft/s) Maximum of Reach 2

Adjust Velocity for Bend (UDFCD EQ. MD-10, pg MD-47). No Adjustment for Rc/T > 8.

Rc =	30.2	radius of curvature (ft) From design pattern min
T =	24	Topwidth (ft) Bankfull
Va =	12	Velocity adjusted for bend (ft/s)

S =	0.055	Channel slope (ft/ft) from proposed grading
S_s =	2.65	Rock specific gravity

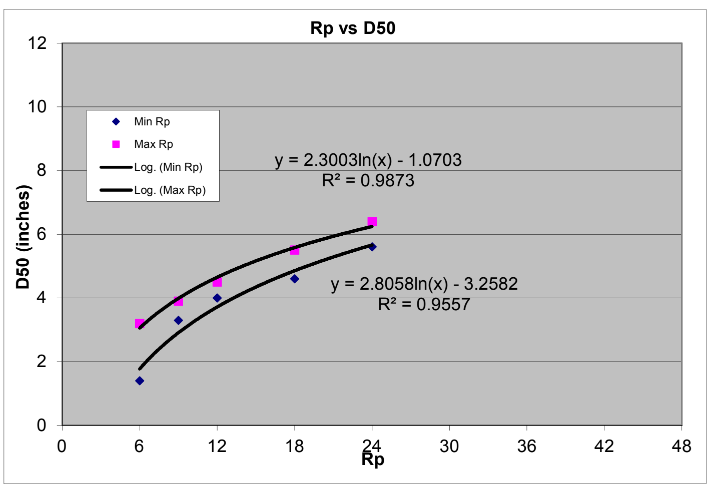
COMPUTED DATA

			Class/Type
	R_p =	5.1	
Riprap	**D50 (ft) =**	**1.50**	**H**
Boulder	**D50 (ft) =**	**1.50**	**B18**

Values in UDFCD Manual (rows 1.4–5.6); Extrapolated from UDFCD Values (See Curves Below) (rows 6.3–8.2)

Min Rp	Max Rp	Riprap Type	D50 (inches)
1.4	3.2	VL	6
3.3	3.9	L	9
4	4.5	M	12
4.6	5.5	H	18
5.6	6.4	VH	24
6.3	6.8		30
6.8	7.2		36
7.2	7.5		42
7.6	7.8		48
7.9	8.1		54
8.2	8.3		60

Min Rp	Max Rp	Boulder Class	D50 (inches)
4.6	5.5	B18	18
5.6	6.4	B24	24
6.5	7.1	B30	30
7.2	7.8	B36	36
7.9	8.4	B42	42
8.5	9.0	B48	48



Client: Boulder County
Project: Upper Fourmile Creek Stream Restoration
Description: **LPSTP Toe Protection for Bankfull Flow in Pool-3 at Maximum Velocity**

By: SMA
Date: 11-Aug-16

METHOD 1 - CORPS OF ENGINEERS

SOURCE: *U.S. Army Corps of Engineers. 1994. Hydraulic Design of Flood Control Channels. EM 1110-2-1601, Change 1. June 30.*
Revetment Method (Recommended for slopes < 2%)
Chapter 3 Section III

INPUT DATA

y = 2.9 Depth of Flow
Sf = 1.1 Safety Factor
Cs = 0.3 Stability Coefficient (0.3 for angular rock, 0.375 for rounded)

Calculate Cv for channel bend:
Rc = 25 radius of curvature (ft) From design pattern min
T = 25 Topwidth (ft) Bankfull
Cv = 1.28 Velocity Distribution Coeff. (Use 1.0 for Rc/T > 26)
Ct = 4.5 Blanket Thickness Coefficient

Calculate design velocity (Vss) for channel bend:
Vavg = 5.638 Avg Channel Velocity U/S of Bend (ft/s) Maximum of Reach 3
Vss = 9.8 Design velocity (bank area of bend in natural channel)

Theta = 45 Bank Angle in Degrees *Measured on outside of pool cross section from toe*
Phi = 90 Angle of repose (degrees) of riprap material (normally 40 degrees
Sg = 2.65 Rock Specific Gravity
g = 32.2 Gravity

COMPUTED DATA

K1 = 0.71 Side slope correction factor
D30 = 4.7 ft
D50 = 5.7 ft

Max D50 = 5.7 ft

METHOD 2 - UDFCD/SPRINGS

SOURCE: *Urban Storm Drainage Criteria Manual, Vol. 2*
Uban Drainage and Flood Control District, Denver, Colorado
Rev. April 2008

City of Colorado Springs/El Paso County Drainage Criteria Manual
12-Oct-94

INPUT DATA

V = 5.638 Mean channel flow velocity (ft/s) Maximum of Reach 3

Adjust Velocity for Bend (UDFCD EQ. MD-10, pg MD-47). No Adjustment for Rc/T > 8.
Rc = 25 radius of curvature (ft) From design pattern min
T = 25 Topwidth (ft) Bankfull
Va = 11 Velocity adjusted for bend (ft/s)

S = 0.055 Channel slope (ft/ft) from proposed grading
S_s = 2.65 Rock specific gravity

COMPUTED DATA

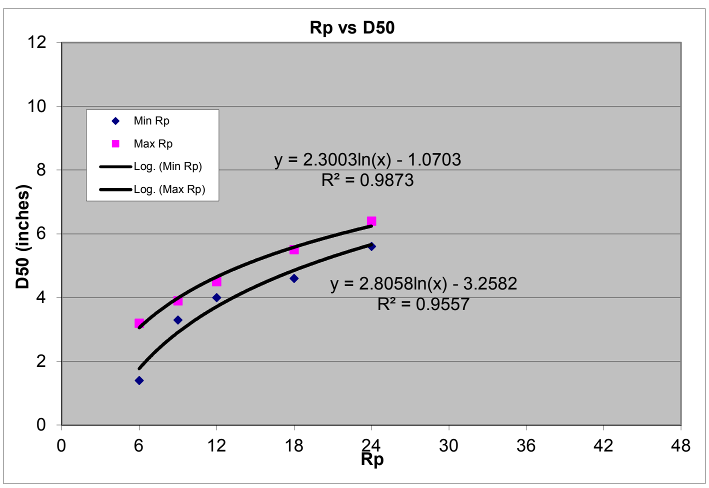
Class/Type
R_p = 5.0
Riprap **D50 (ft) = 1.50 H**
Boulder **D50 (ft) = 1.50 B18**

Values in UDFCD Manual

Extrapolated from UDFCD Values
(See Curves Below)

Min Rp	Max Rp	Riprap Type	D50 (inches)
1.4	3.2	VL	6
3.3	3.9	L	9
4	4.5	M	12
4.6	5.5	H	18
5.6	6.4	VH	24
6.3	6.8		30
6.8	7.2		36
7.2	7.5		42
7.6	7.8		48
7.9	8.1		54
8.2	8.3		60

Min Rp	Max Rp	Boulder Class	D50 (inches)
4.6	5.5	B18	18
5.6	6.4	B24	24
6.5	7.1	B30	30
7.2	7.8	B36	36
7.9	8.4	B42	42
8.5	9.0	B48	48



Client: Boulder County
Project: Upper Fourmile Creek Stream Restoration
Description: **LPSTP Toe Protection for Bankfull Flow in Boulder Bank Pool at Maximum Velocity**

By: SMA
Date: 11-Aug-16

METHOD 1 - CORPS OF ENGINEERS

SOURCE: *U.S. Army Corps of Engineers. 1994. Hydraulic Design of Flood Control Channels. EM 1110-2-1601, Change 1. June 30.*
Revetment Method (Recommended for slopes < 2%)
Chapter 3 Section III

INPUT DATA

y = 2.7 Depth of Flow
Sf = 1.1 Safety Factor
Cs = 0.3 Stability Coefficient (0.3 for angular rock, 0.375 for rounded)

Calculate Cv for channel bend:
Rc = 25 radius of curvature (ft) From design pattern min
T = 25 Topwidth (ft) Bankfull
Cv = 1.28 Velocity Distribution Coeff. (Use 1.0 for Rc/T > 26)
Ct = 4.5 Blanket Thickness Coefficient

Calculate design velocity (Vss) for channel bend:
Vavg = 6.147 Avg Channel Velocity U/S of Bend (ft/s) Maximum of All Reaches
Vss = 10.7 Design velocity (bank area of bend in natural channel)

Theta = 45 Bank Angle in Degrees *Measured on outside of pool cross section from toe*
Phi = 90 Angle of repose (degrees) of riprap material (normally 40 degrees
Sg = 2.65 Rock Specific Gravity
g = 32.2 Gravity

COMPUTED DATA

K1 = 0.71 Side slope correction factor
D30 = 6.0 ft
D50 = 7.2 ft

Max D50 = 7.2 ft

METHOD 2 - UDFCD/SPRINGS

SOURCE: *Urban Storm Drainage Criteria Manual, Vol. 2*
Uban Drainage and Flood Control District, Denver, Colorado
Rev. April 2008

City of Colorado Springs/El Paso County Drainage Criteria Manual
12-Oct-94

INPUT DATA

V = 6.147 Mean channel flow velocity (ft/s) Maximum of All Reaches

Adjust Velocity for Bend (UDFCD EQ. MD-10, pg MD-47). No Adjustment for Rc/T > 8.
Rc = 25 radius of curvature (ft) From design pattern min
T = 25 Topwidth (ft) Bankfull
Va = 12 Velocity adjusted for bend (ft/s)

S = 0.055 Channel slope (ft/ft) from proposed grading
S_s = 2.65 Rock specific gravity

COMPUTED DATA

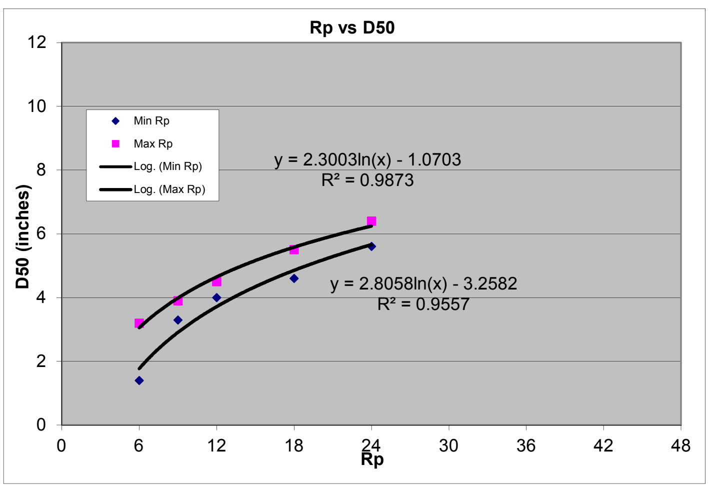
Class/Type
R_p = 5.5
Riprap **D50 (ft) = 1.50 H**
Boulder **D50 (ft) = 1.50 B18**

Values in UDFCD Manual

Extrapolated from UDFCD Values
(See Curves Below)

Min Rp	Max Rp	Riprap Type	D50 (inches)
1.4	3.2	VL	6
3.3	3.9	L	9
4	4.5	M	12
4.6	5.5	H	18
5.6	6.4	VH	24
6.3	6.8		30
6.8	7.2		36
7.2	7.5		42
7.6	7.8		48
7.9	8.1		54
8.2	8.3		60

Min Rp	Max Rp	Boulder Class	D50 (inches)
4.6	5.5	B18	18
5.6	6.4	B24	24
6.5	7.1	B30	30
7.2	7.8	B36	36
7.9	8.4	B42	42
8.5	9.0	B48	48



Client: Boulder County
Project: Upper Fourmile Creek Stream Restoration
Description: **LPSTP Toe Protection for Bankfull Flow in Riffle at Maximum Velocity in Reach 1**

By:
Date:

METHOD 1 - CORPS OF ENGINEERS

SOURCE: *U.S. Army Corps of Engineers. 1994. Hydraulic Design of Flood Control Channels. EM 1110-2-1601, Change 1. June 30.*
Revetment Method (Recommended for slopes < 2%)

INPUT DATA

y =	1.9	Depth of Flow
Sf =	1.1	Safety Factor
Cs =	0.3	Stability Coefficient (0.3 for angular rock, 0.375 for rounded)
Cv =	1	Velocity Distribution Coeff.
Ct =	4.5	Blanket Thickness Coefficient
Vdes =	5.174	Design Velocity
Theta =	30	Bank Angle in Degrees
Sg =	2.65	Rock Specific Gravity
g =	32.2	Gravity

COMPUTED DATA

K1 =	0.81	Side slope correction factor
D30 =	0.7	ft
D50 =	**0.8**	**ft**

METHOD 2 - UDFCD/SPRINGS

SOURCE: *Urban Storm Drainage Criteria Manual, Vol. 2*
Uban Drainage and Flood Control District, Denver, Colorado
Rev. April 2008

City of Colorado Springs/El Paso County Drainage Criteria Manual
12-Oct-94

INPUT DATA

V =	5.174	Mean channel flow velocity (ft/s)
S =	0.065	Channel slope (ft/ft)
S_s =	2.65	Rock specific gravity

COMPUTED DATA

R_p =	2.3	
D50 =	**0.50**	**ft**

Rp	**Riprap Type**	**D50 (inches)**
1.4 to 3.2	VL	6
3.3 to 3.9	L	9
4.0 to 4.5	M	12
4.6 to 5.5	H	18
5.6 to 6.4	VH	24

Client: Boulder County
Project: Upper Fourmile Creek Stream Restoration
Description: **LPSTP Toe Protection for Bankfull Flow in Riffle at Maximum Velocity in Reach 2**

By:
Date:

METHOD 1 - CORPS OF ENGINEERS

SOURCE: *U.S. Army Corps of Engineers. 1994. Hydraulic Design of Flood Control Channels. EM 1110-2-1601, Change 1. June 30.*
Revetment Method (Recommended for slopes < 2%)

INPUT DATA

y =	2	Depth of Flow
Sf =	1.1	Safety Factor
Cs =	0.3	Stability Coefficient (0.3 for angular rock, 0.375 for rounded)
Cv =	1	Velocity Distribution Coeff.
Ct =	4.5	Blanket Thickness Coefficient
Vdes =	5.702	Design Velocity
Theta =	30	Bank Angle in Degrees
Sg =	2.65	Rock Specific Gravity
g =	32.2	Gravity

COMPUTED DATA

K1 =	0.81	Side slope correction factor
D30 =	0.9	ft
D50 =	**1.1**	**ft**

METHOD 2 - UDFCD/SPRINGS

SOURCE: *Urban Storm Drainage Criteria Manual, Vol. 2*
Uban Drainage and Flood Control District, Denver, Colorado
Rev. April 2008

City of Colorado Springs/El Paso County Drainage Criteria Manual
12-Oct-94

INPUT DATA

V =	7.95	Mean channel flow velocity (ft/s)
S =	0.065	Channel slope (ft/ft)
S_s =	2.65	Rock specific gravity

COMPUTED DATA

R_p =	3.6	
D50 =	**0.75**	**ft**

Rp	Riprap Type	D50 (inches)
1.4 to 3.2	VL	6
3.3 to 3.9	L	9
4.0 to 4.5	M	12
4.6 to 5.5	H	18
5.6 to 6.4	VH	24

Client:	Boulder County		By:
Project:	Upper Fourmile Creek Stream Restoration		Date:
Description:	**LPSTP Toe Protection for Bankfull Flow in Riffle at Maximum Velocity in Reach 1**		

METHOD 1 - CORPS OF ENGINEERS

SOURCE: *U.S. Army Corps of Engineers. 1994. Hydraulic Design of Flood Control Channels. EM 1110-2-1601, Change 1. June 30.*
Revetment Method (Recommended for slopes < 2%)

INPUT DATA

y =	2.1	Depth of Flow
Sf =	1.1	Safety Factor
Cs =	0.3	Stability Coefficient (0.3 for angular rock, 0.375 for rounded)
Cv =	1	Velocity Distribution Coeff.
Ct =	4.5	Blanket Thickness Coefficient
Vdes =	5.328	Design Velocity
Theta =	30	Bank Angle in Degrees
Sg =	2.65	Rock Specific Gravity
g =	32.2	Gravity

COMPUTED DATA

K1 =	0.81	Side slope correction factor
D30 =	0.7	ft
D50 =	**0.9**	**ft**

METHOD 2 - UDFCD/SPRINGS

SOURCE: *Urban Storm Drainage Criteria Manual, Vol. 2*
Uban Drainage and Flood Control District, Denver, Colorado
Rev. April 2008

City of Colorado Springs/El Paso County Drainage Criteria Manual
12-Oct-94

INPUT DATA

V =	5.328	Mean channel flow velocity (ft/s)
S =	0.065	Channel slope (ft/ft)
S_s =	2.65	Rock specific gravity

COMPUTED DATA

R_p =	2.4	
D50 =	**0.50**	**ft**

Rp	Riprap Type	D50 (inches)
1.4 to 3.2	VL	6
3.3 to 3.9	L	9
4.0 to 4.5	M	12
4.6 to 5.5	H	18
5.6 to 6.4	VH	24

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY & DISCHARGE Estimates

Stream:	Fourmile Creek	Location:	Reach - 4f
Date:		Stream Type: B4	Valley Type: VIII
Observers:	Sean Abel	HUC:	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Riffle Cross-Sectional AREA	27.51	A_{bkf} (ft^2)	Bankfull Riffle Mean DEPTH	1.22	d_{bkf} (ft)
Bankfull Riffle WIDTH	22.50	W_{bkf} (ft)	Wetted PERMIMETER ~ (2 * d_{bkf}) + W_{bkf}	23.01	W_p (ft)
D_{84} at Riffle	122.15	Dia. (mm)	D_{84} (mm) / 304.8	0.40	D_{84} (ft)
Bankfull SLOPE	0.0344	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	1.20	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R(ft) / D_{84} (ft)	2.99	R / D_{84}
Drainage Area	10.1	DA (mi^2)	Shear Velocity $u^* = (gRS)^{1/2}$	1.153	u* (ft/sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 * Log \{ R / D_{84} \}] u^*$	6.35	ft / sec	174.65	cfs
2. Roughness Coefficient: a) Manning's *n* from Friction Factor / Relative Roughness (Figs. 2-18, 2-19) $u = 1.49 * R^{2/3} * S^{1/2} / n$ n = 0.06	5.18	ft / sec	142.39	cfs
2. Roughness Coefficient: b) Manning's *n* from Stream Type (Fig. 2-20) $u = 1.49 * R^{2/3} * S^{1/2} / n$ n = 0.06	5.18	ft / sec	142.39	cfs
2. Roughness Coefficient: c) Manning's *n* from Jarrett (USGS): $u = 1.49 * R^{2/3} * S^{1/2} / n$ $n = 0.39 * S^{0.38} * R^{-0.16}$ **Note:** This equation is applicable to **steep, step/pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for n = 0.105	2.95	ft / sec	81.13	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) Darcy-Weisbach (Leopold, Wolman and Miller)	6.52	ft / sec	179.26	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) Chezy C	0.00	ft / sec	0.00	cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 0.0 year	0.00	ft / sec	0.00	cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A	0.00	ft / sec	0.00	cfs

Protrusion Height Options for the D_{84} Term in the Relative Roughness Relation (R/D_{84}) – Estimation Method 1

Option 1.	For **sand-bed** channels: Measure 100 **"protrusion heights"** of sand dunes from the downstream side of feature to the top of feature. Substitute the D_{84} sand dune protrusion height in ft for the D_{84} term in method 1.
Option 2.	For **boulder-dominated** channels: Measure 100 **"protrusion heights"** of boulders on the sides from the bed elevation to the top of the rock on that side. Substitute the D_{84} boulder protrusion height in ft for the D_{84} term in method 1.
Option 3.	For **bedrock-dominated** channels: Measure 100 **"protrusion heights"** of rock separations, steps, joints or uplifted surfaces above channel bed elevation. Substitute the D_{84} bedrock protrusion height in ft for the D_{84} term in method 1.
Option 4.	For **log-influenced** channels: Measure "**protrusion heights**" proportionate to channel width of log diameters or the height of the log on upstream side if embedded. Substitute the D_{84} protrusion height in ft for the D_{84} term in method 1.

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY & DISCHARGE Estimates

Stream:	**Fourmile Creek**	Location:	**Reach - 4d**
Date:		Stream Type: **B4**	Valley Type: **VIII**
Observers:	**Sean Abel**	HUC:	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Riffle Cross-Sectional AREA	**29.01**	A_{bkf} (ft^2)	Bankfull Riffle Mean DEPTH	**1.29**	d_{bkf} (ft)
Bankfull Riffle WIDTH	**22.50**	W_{bkf} (ft)	Wetted PERMIMETER ~ $(2 * d_{bkf}) + W_{bkf}$	**23.04**	W_p (ft)
D_{84} at Riffle	**52.98**	Dia. (mm)	D_{84} (mm) / 304.8	**0.17**	D_{84} (ft)
Bankfull SLOPE	**0.0390**	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	**1.26**	R (ft)
Gravitational Acceleration	**32.2**	g (ft / sec^2)	Relative Roughness R(ft) / D_{84} (ft)	**7.24**	R / D_{84}
Drainage Area	**13.5**	DA (mi^2)	Shear Velocity $u^* = (gRS)^{1/2}$	**1.258**	u* (ft/sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 * \text{Log}\{R / D_{84}\}] u^*$	**9.68**	ft / sec	**280.79**	cfs
2. Roughness Coefficient: a) Manning's *n* from Friction Factor / Relative Roughness (Figs. 2-18, 2-19) $u = 1.49 * R^{2/3} * S^{1/2} / n$ $n =$ **0.06**	**5.71**	ft / sec	**165.50**	cfs
2. Roughness Coefficient: b) Manning's *n* from Stream Type (Fig. 2-20) $u = 1.49 * R^{2/3} * S^{1/2} / n$ $n =$ **0.06**	**5.71**	ft / sec	**165.50**	cfs
2. Roughness Coefficient: c) Manning's *n* from Jarrett (USGS): $u = 1.49 * R^{2/3} * S^{1/2} / n$; $n = 0.39 * S^{0.38} * R^{-0.16}$ **Note:** This equation is applicable to **steep, step/pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for $n =$ **0.110**	**3.12**	ft / sec	**90.60**	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) **Darcy-Weisbach (Leopold, Wolman and Miller)**	**9.96**	ft / sec	**289.02**	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) **Chezy C**	**0.00**	ft / sec	**0.00**	cfs
4. Continuity Equations: a) Regional Curves u = Q / A **Return Period for Bankfull Discharge** Q = **0.0** year	**0.00**	ft / sec	**0.00**	cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A	**0.00**	ft / sec	**0.00**	cfs

Protrusion Height Options for the D_{84} Term in the Relative Roughness Relation (R/D_{84}) – Estimation Method 1

Option 1.	For **sand-bed** channels: Measure 100 **"protrusion heights"** of sand dunes from the downstream side of feature to the top of feature. Substitute the D_{84} sand dune protrusion height in ft for the D_{84} term in method 1.
Option 2.	For **boulder-dominated** channels: Measure 100 **"protrusion heights"** of boulders on the sides from the bed elevation to the top of the rock on that side. Substitute the D_{84} boulder protrusion height in ft for the D_{84} term in method 1.
Option 3.	For **bedrock-dominated** channels: Measure 100 **"protrusion heights"** of rock separations, steps, joints or uplifted surfaces above channel bed elevation. Substitute the D_{84} bedrock protrusion height in ft for the D_{84} term in method 1.
Option 4.	For **log-influenced** channels: Measure "**protrustion heights**" proportionate to channel width of log diameters or the height of the log on upstream side if embedded. Substitute the D_{84} protrusion height in ft for the D_{84} term in method 1.

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY & DISCHARGE Estimates

Stream:	**Fourmile Creek**	Location:	**Reach - 4b**
Date:	Stream Type: **B4**	Valley Type:	**VIII**
Observers:	**Sean Abel**	HUC:	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Riffle Cross-Sectional AREA	32.53	A_{bkf} (ft^2)	Bankfull Riffle Mean DEPTH	1.36	d_{bkf} (ft)
Bankfull Riffle WIDTH	24.00	W_{bkf} (ft)	Wetted PERMIMETER ~ $(2 * d_{bkf}) + W_{bkf}$	24.61	W_p (ft)
D_{84} at Riffle	87.11	Dia. (mm)	D_{84} (mm) / 304.8	0.29	D_{84} (ft)
Bankfull SLOPE	0.0319	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	1.32	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R(ft) / D_{84} (ft)	4.62	R / D_{84}
Drainage Area	15.9	DA (mi^2)	Shear Velocity $u^* = (gRS)^{1/2}$	1.164	u* (ft/sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 * \text{Log}\{R / D_{84}\}] u^*$	7.68	ft / sec	249.96	cfs
2. Roughness Coefficient: a) Manning's *n* from Friction Factor / Relative Roughness (Figs. 2-18, 2-19) $u = 1.49*R^{2/3}*S^{1/2}/n$ n = 0.06	5.33	ft / sec	173.39	cfs
2. Roughness Coefficient: b) Manning's *n* from Stream Type (Fig. 2-20) $u = 1.49*R^{2/3}*S^{1/2}/n$ n = 0.06	5.33	ft / sec	173.39	cfs
2. Roughness Coefficient: c) Manning's *n* from Jarrett (USGS): $u = 1.49*R^{2/3}*S^{1/2}/n$; $n = 0.39*S^{0.38}*R^{-0.16}$ n = 0.101 **Note:** This equation is applicable to **steep, step/pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for	3.18	ft / sec	103.32	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) Darcy-Weisbach (Leopold, Wolman and Miller)	7.94	ft / sec	258.34	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) Chezy C	0.00	ft / sec	0.00	cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 0.0 year	0.00	ft / sec	0.00	cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A	0.00	ft / sec	0.00	cfs

Protrusion Height Options for the D_{84} Term in the Relative Roughness Relation (R/D_{84}) – Estimation Method 1

Option 1.	For **sand-bed** channels: Measure 100 **"protrusion heights"** of sand dunes from the downstream side of feature to the top of feature. Substitute the D_{84} sand dune protrusion height in ft for the D_{84} term in method 1.
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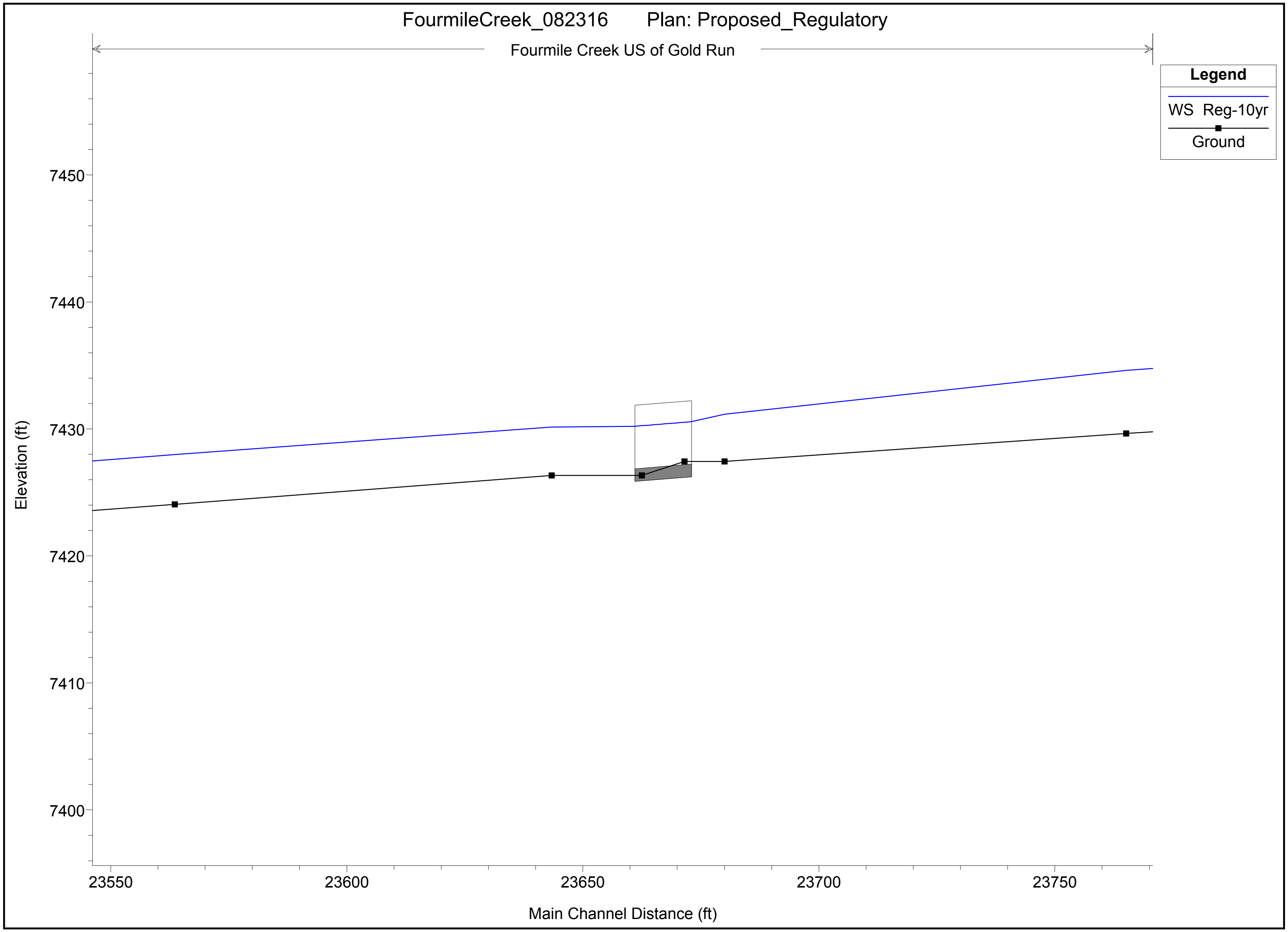
Option 3.	For **bedrock-dominated** channels: Measure 100 **"protrusion heights"** of rock separations, steps, joints or uplifted surfaces above channel bed elevation. Substitute the D_{84} bedrock protrusion height in ft for the D_{84} term in method 1.
Option 4.	For **log-influenced** channels: Measure "**protrustion heights**" proportionate to channel width of log diameters or the height of the log on upstream side if embedded. Substitute the D_{84} protrusion height in ft for the D_{84} term in method 1.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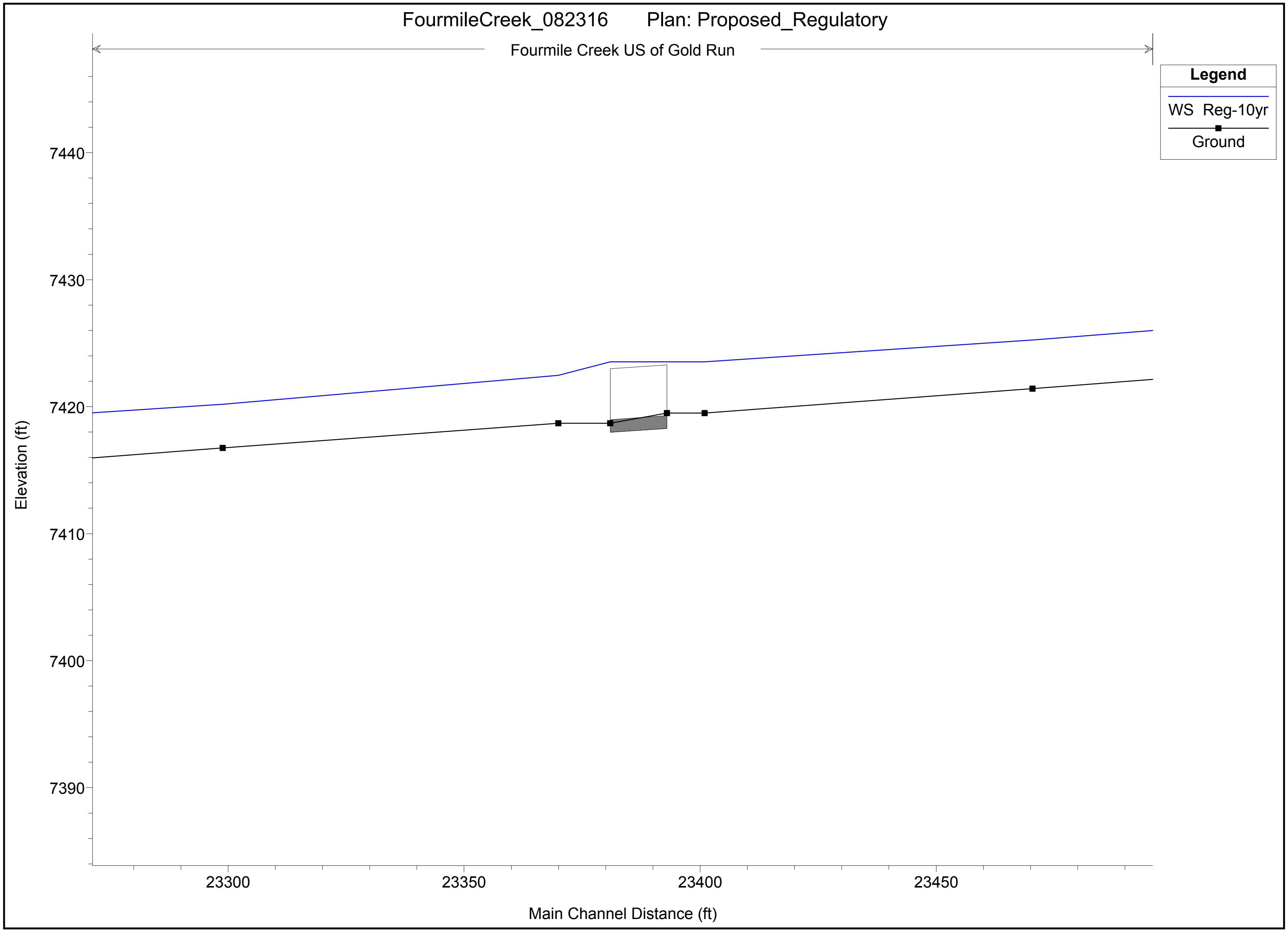
Fourmile Creek US of Gold Run
Legend
WS Reg-10yr
Ground
7450
7440
7430
7420
7410
7400
Elevation (ft)
23550
23600
23650
23700
23750
Main Channel Distance (ft)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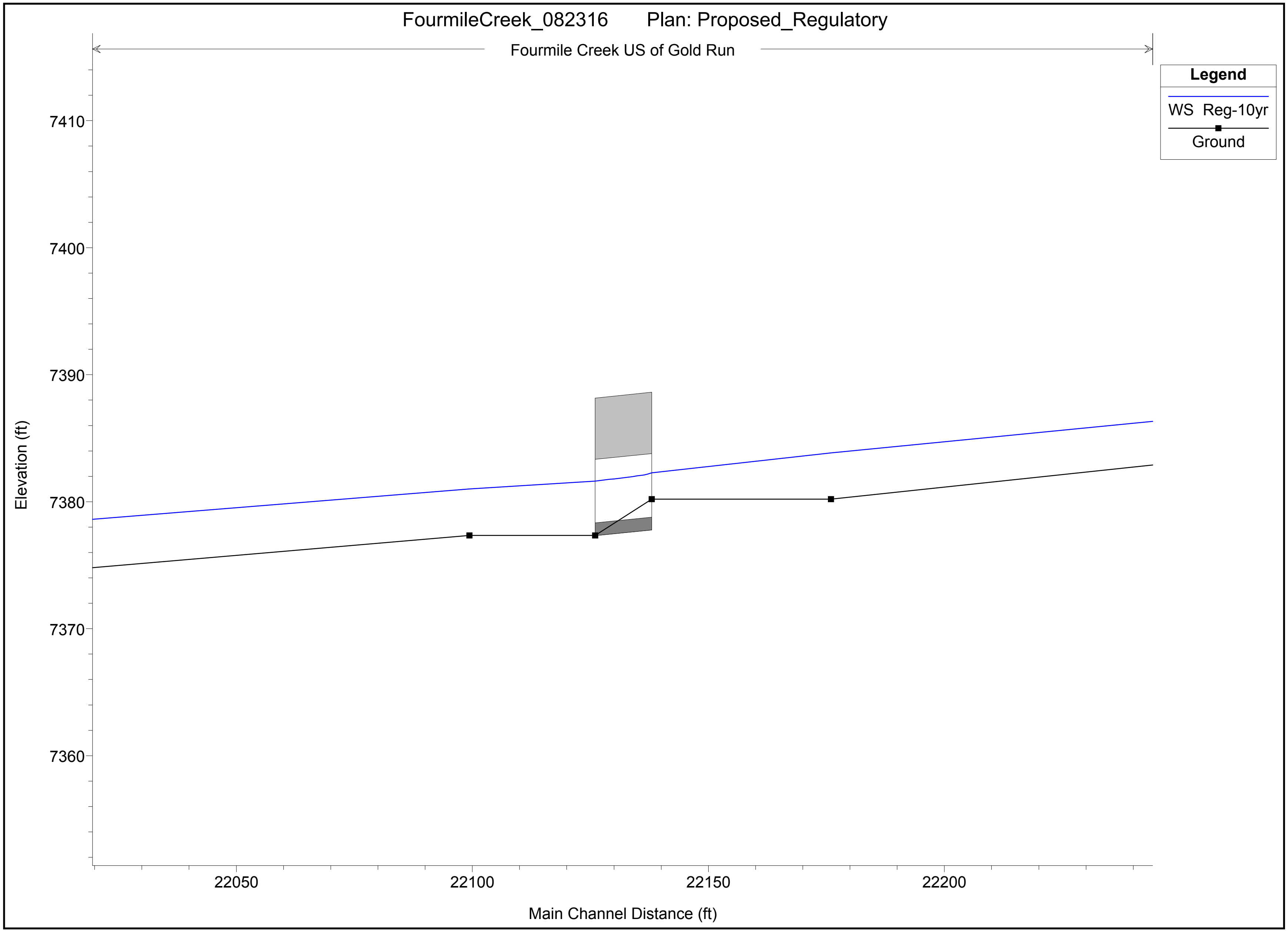
Fourmile Creek US of Gold Run
Legend
WS Reg-10yr
Ground
7440
7430
7420
7410
7400
7390
Elevation (ft)
23300
23350
23400
23450
Main Channel Distance (ft)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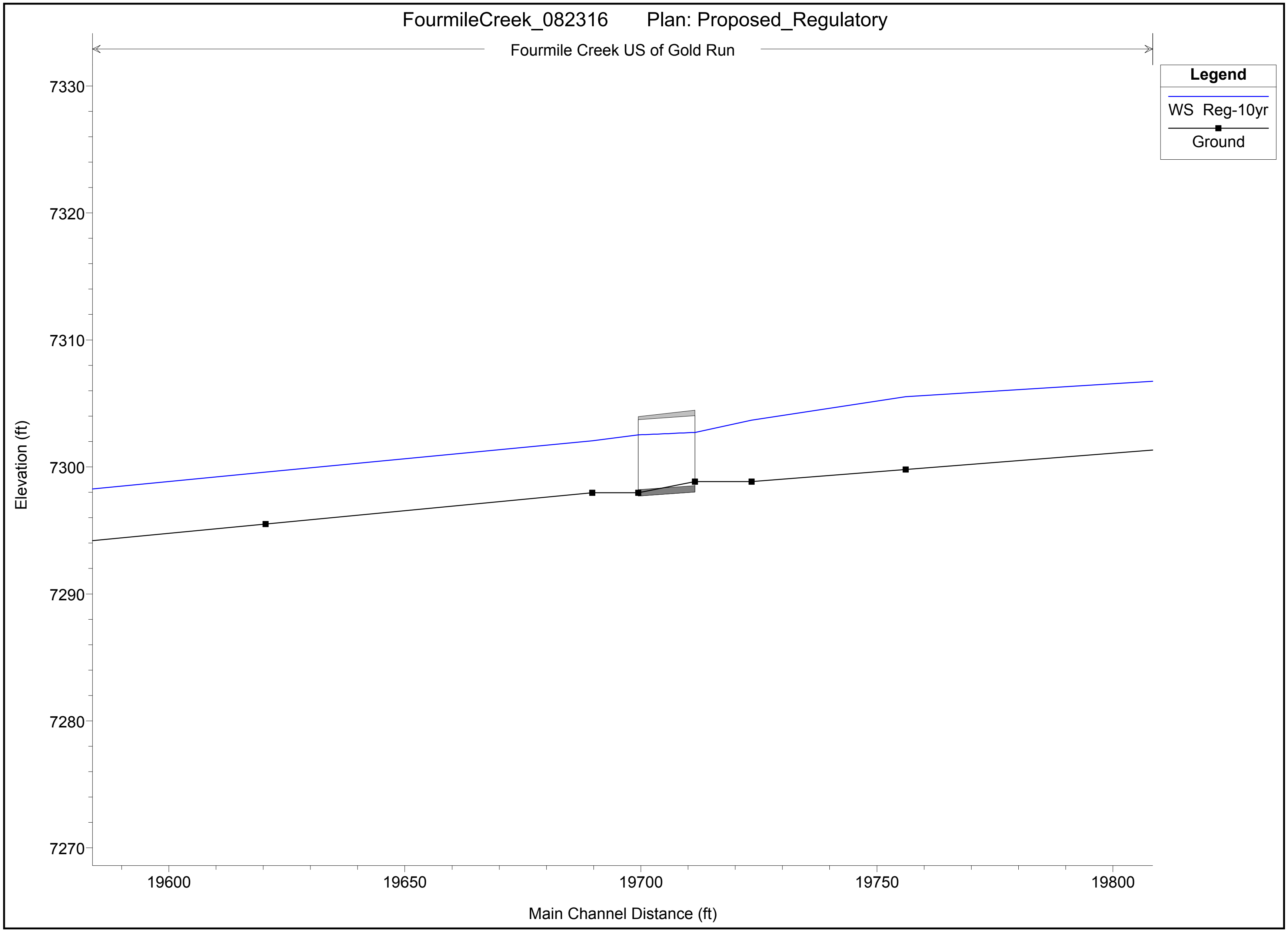
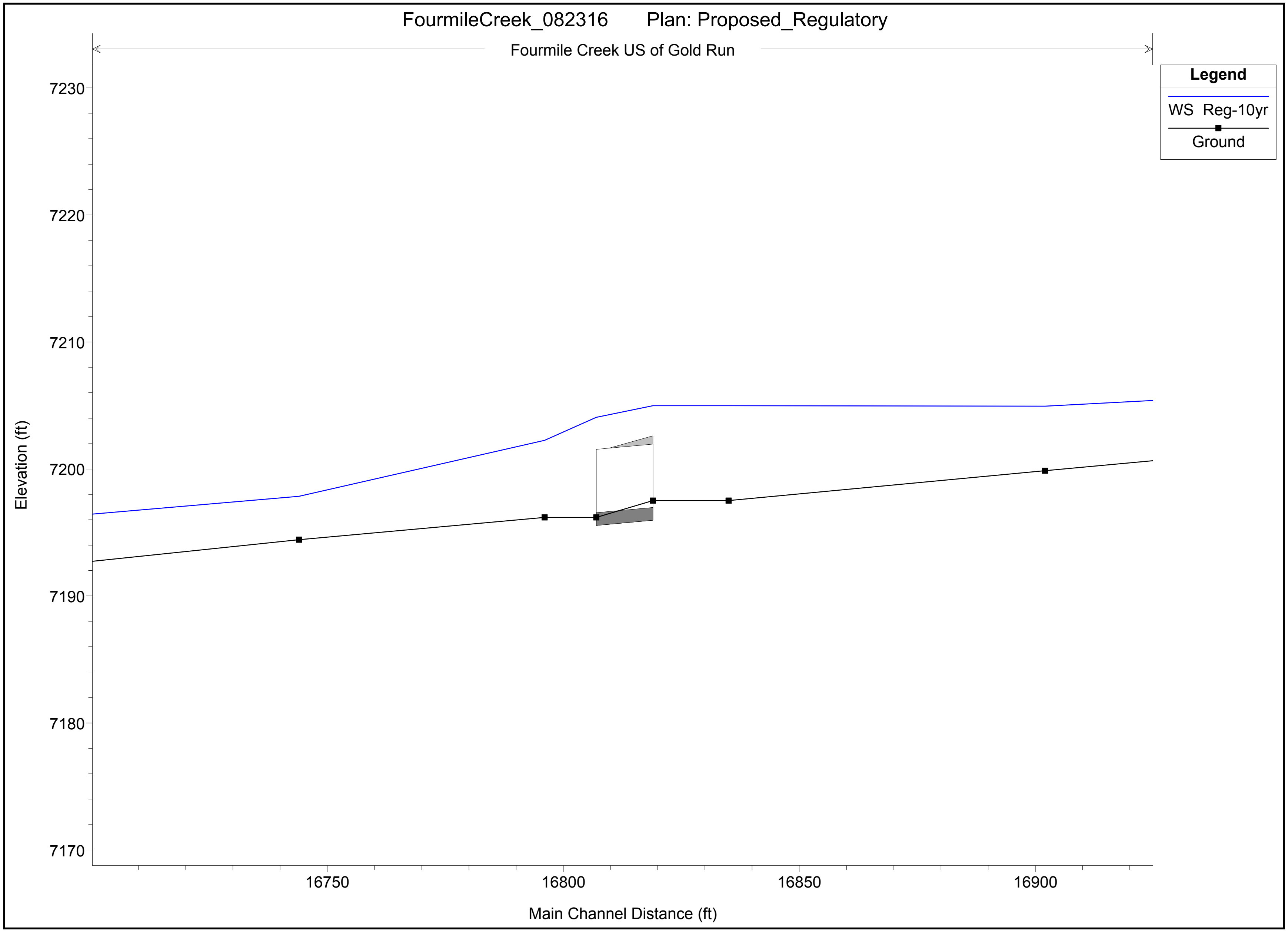
Fourmile Creek US of Gold Run
Legend
WS Reg-10yr
Ground
Elevation (ft)
7410
7400
7390
7380
7370
7360
22050
22100
22150
22200
Main Channel Distance (ft)



FourmileCreek_082316 Plan: Proposed_Regulatory
Fourmile Creek US of Gold Run
Legend
WS Reg-10yr
Ground
Elevation (ft)
7330
7320
7310
7300
7290
7280
7270
19600
19650
19700
19750
19800
Main Channel Distance (ft)



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Fourmile Creek US of Gold Run
Legend
WS Reg-10yr
Ground
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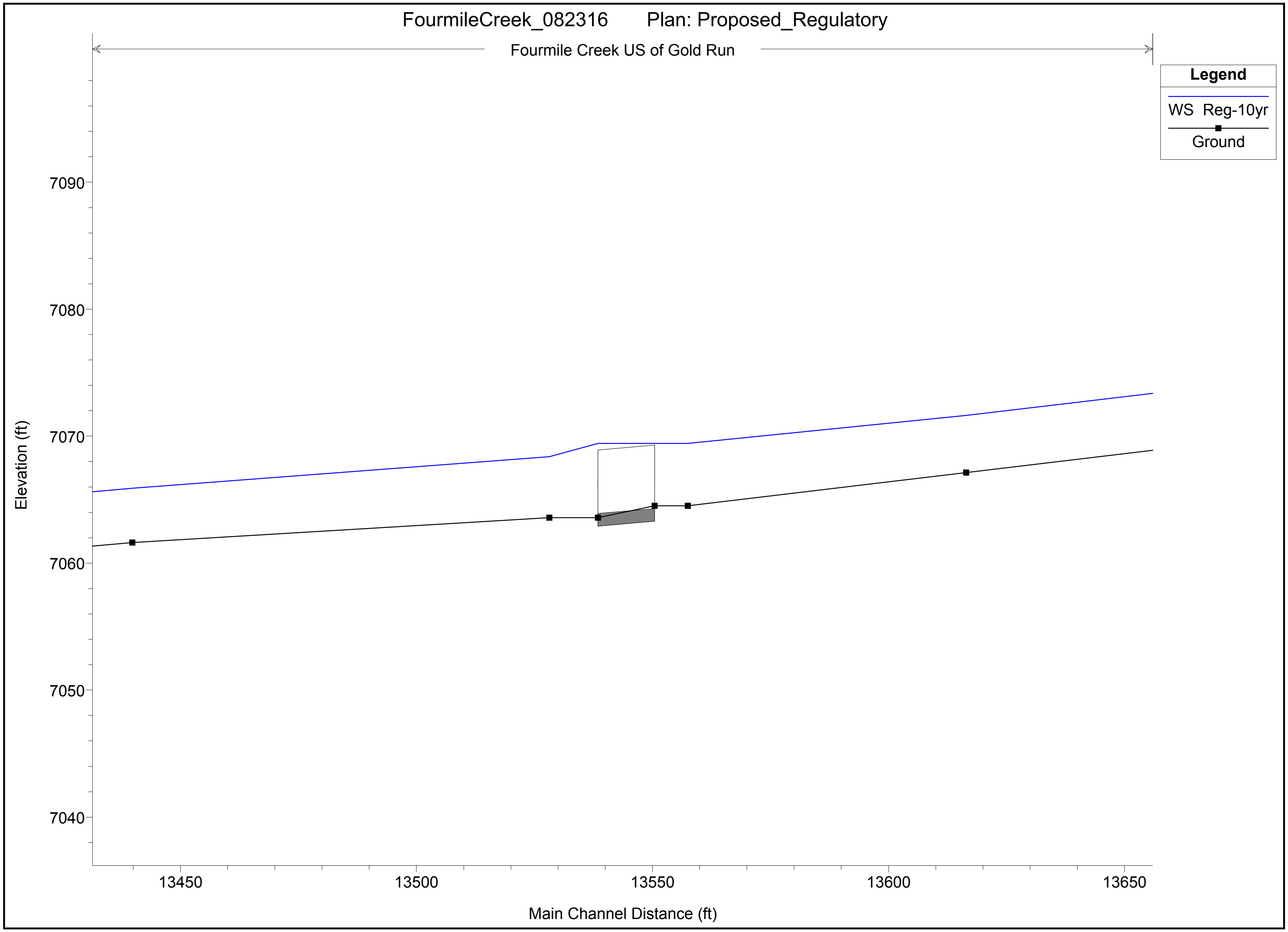
7220
7210
7200
7190
7180
7170
Elevation (ft)
16750
16800
16850
16900
Main Channel Distance (ft)



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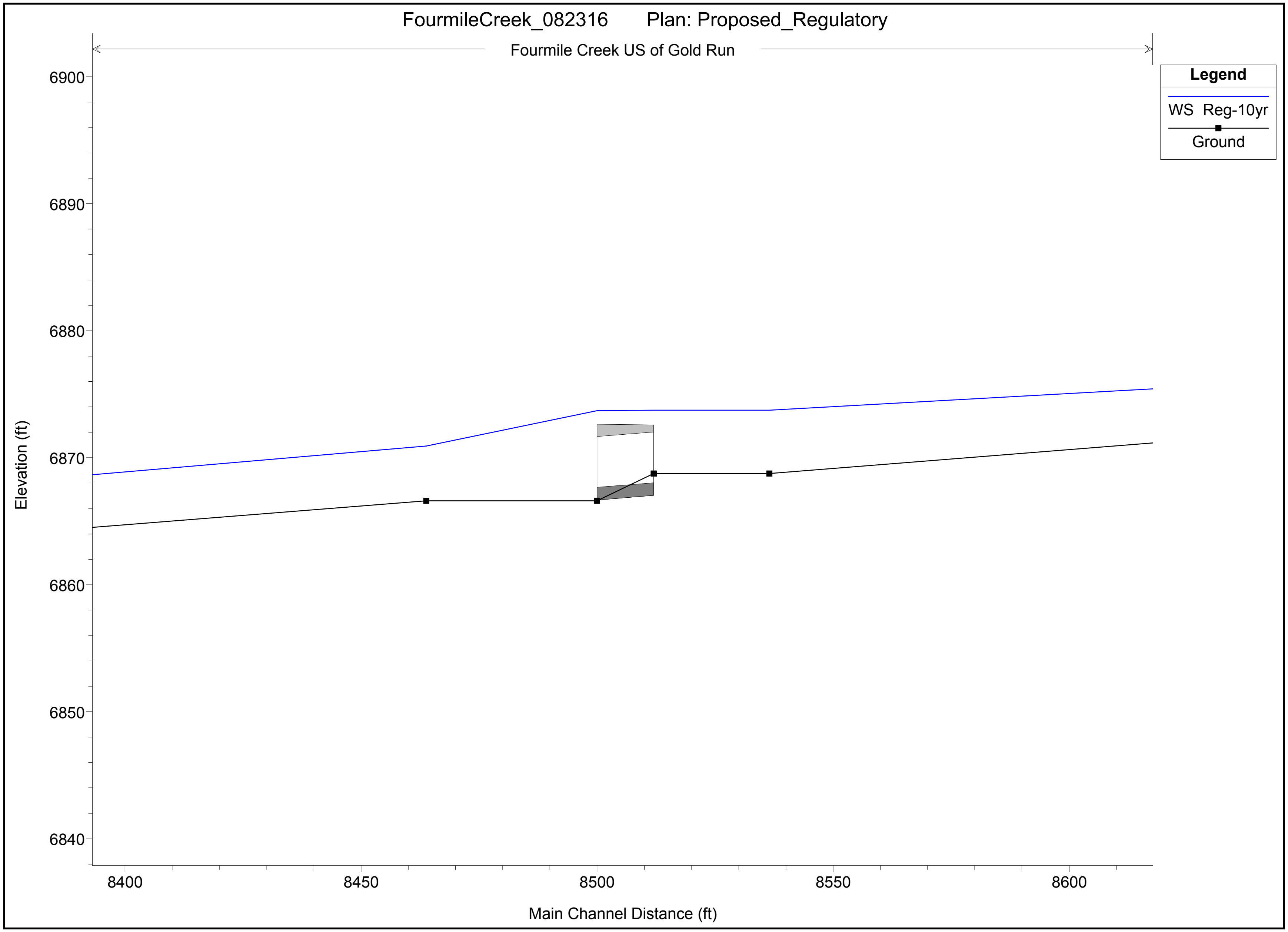
Fourmile Creek US of Gold Run
Legend
WS Reg-10yr
Ground
7090
7080
7070
7060
7050
7040
Elevation (ft)
13450
13500
13550
13600
13650
Main Channel Distance (ft)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Fourmile Creek US of Gold Run
Legend
WS Reg-10yr
Ground
Elevation (ft)
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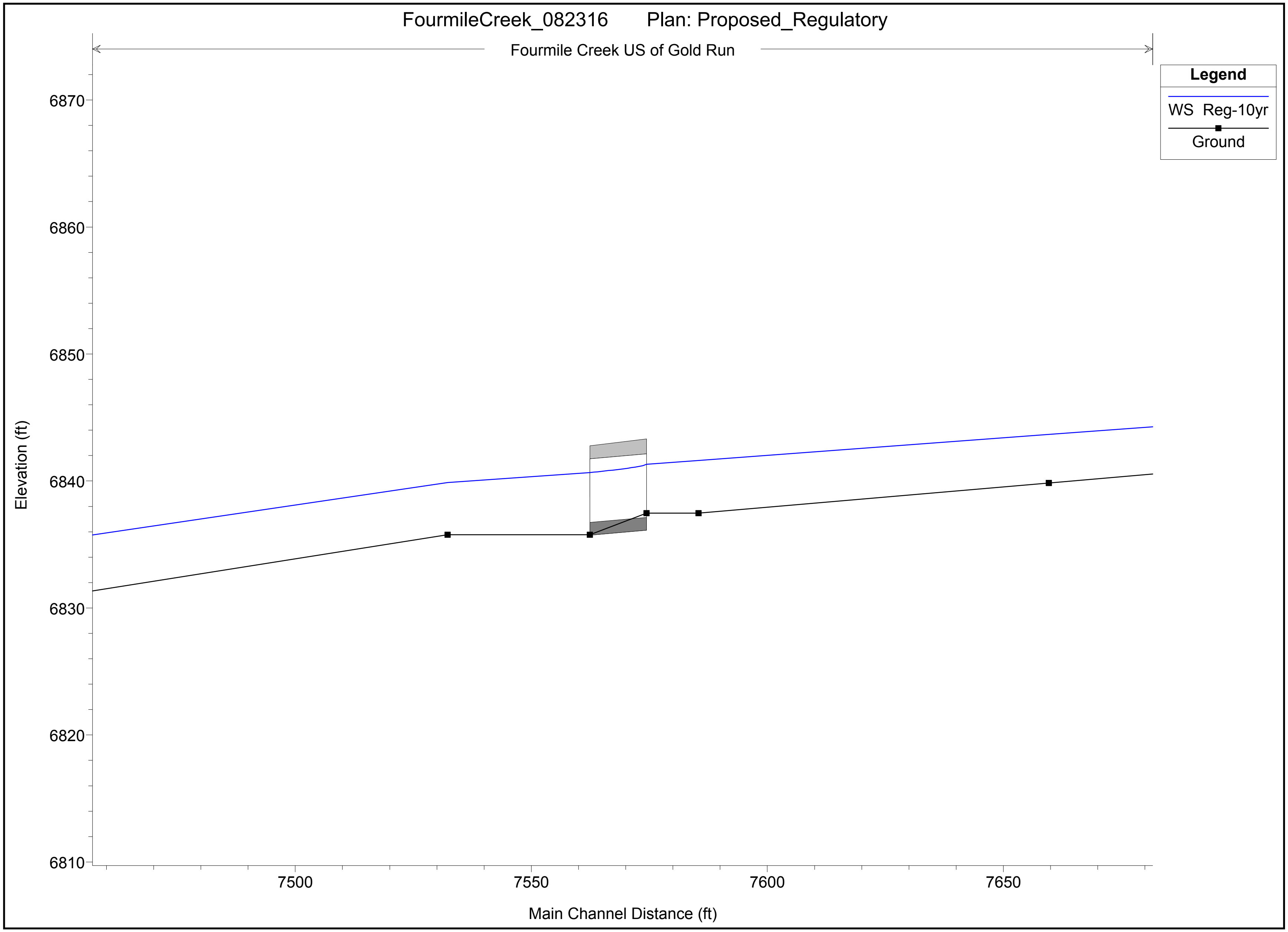
6890
6880
6870
6860
6850
6840
8400
8450
8500
8550
8600
Main Channel Distance (ft)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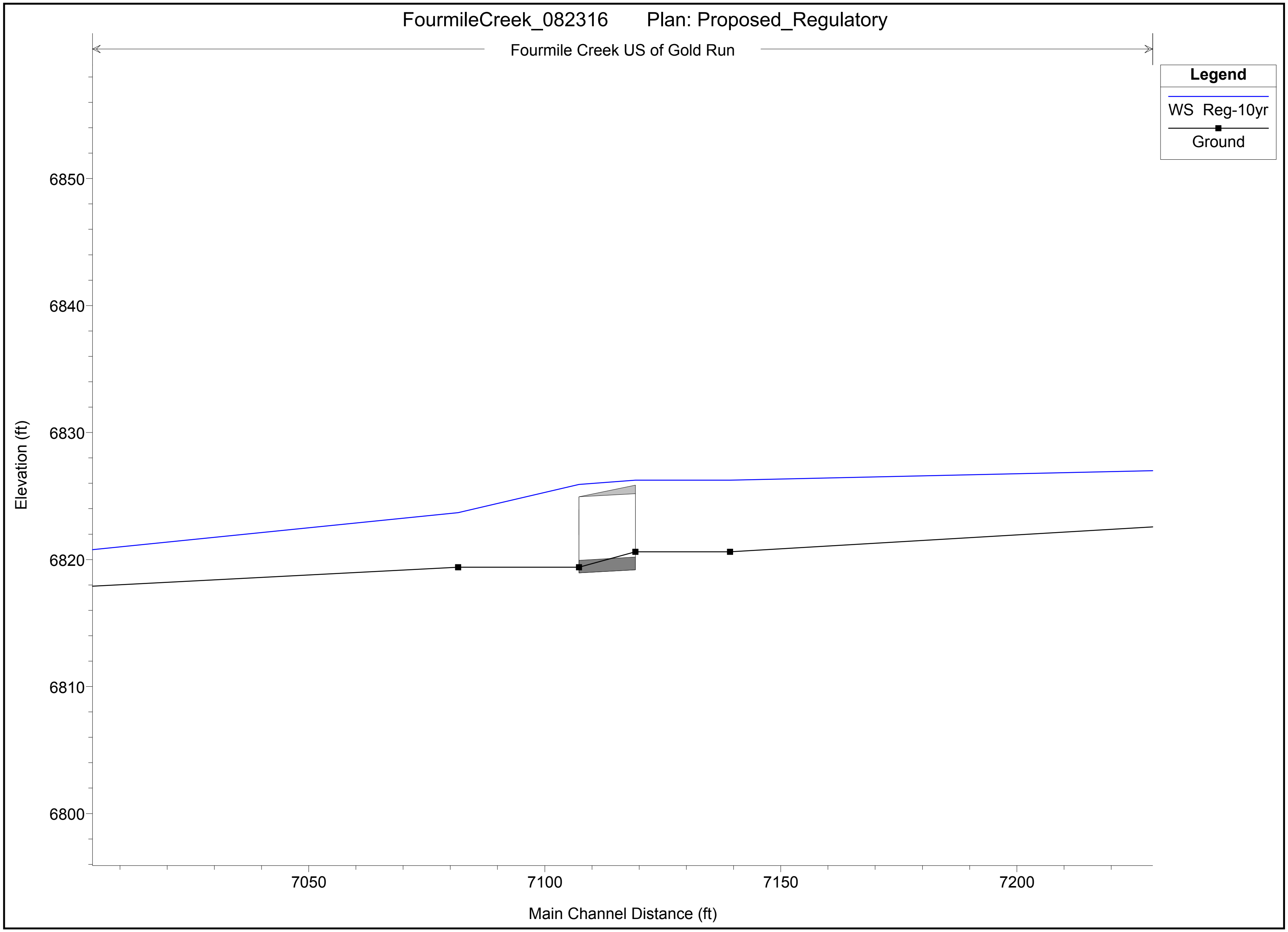
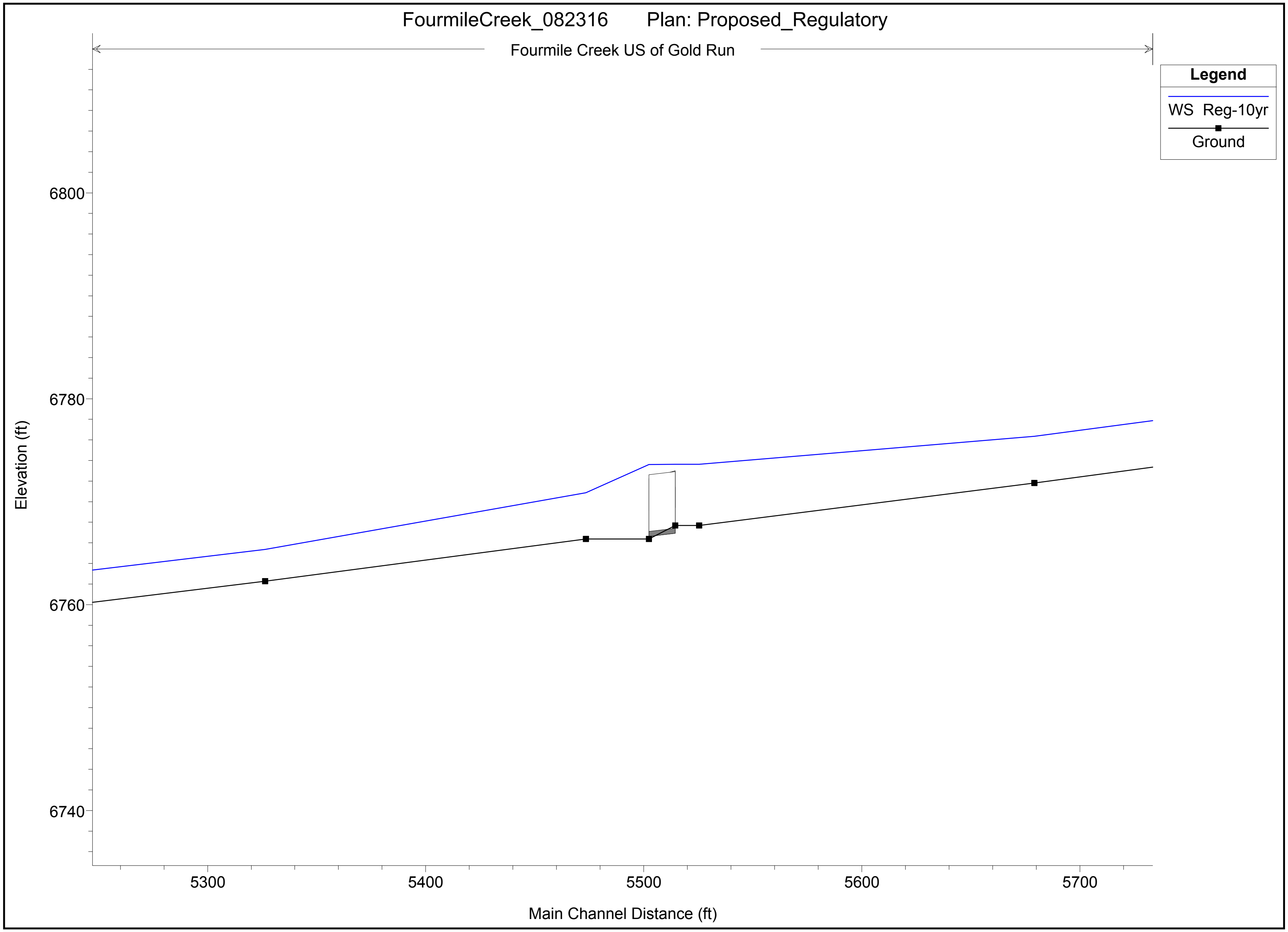
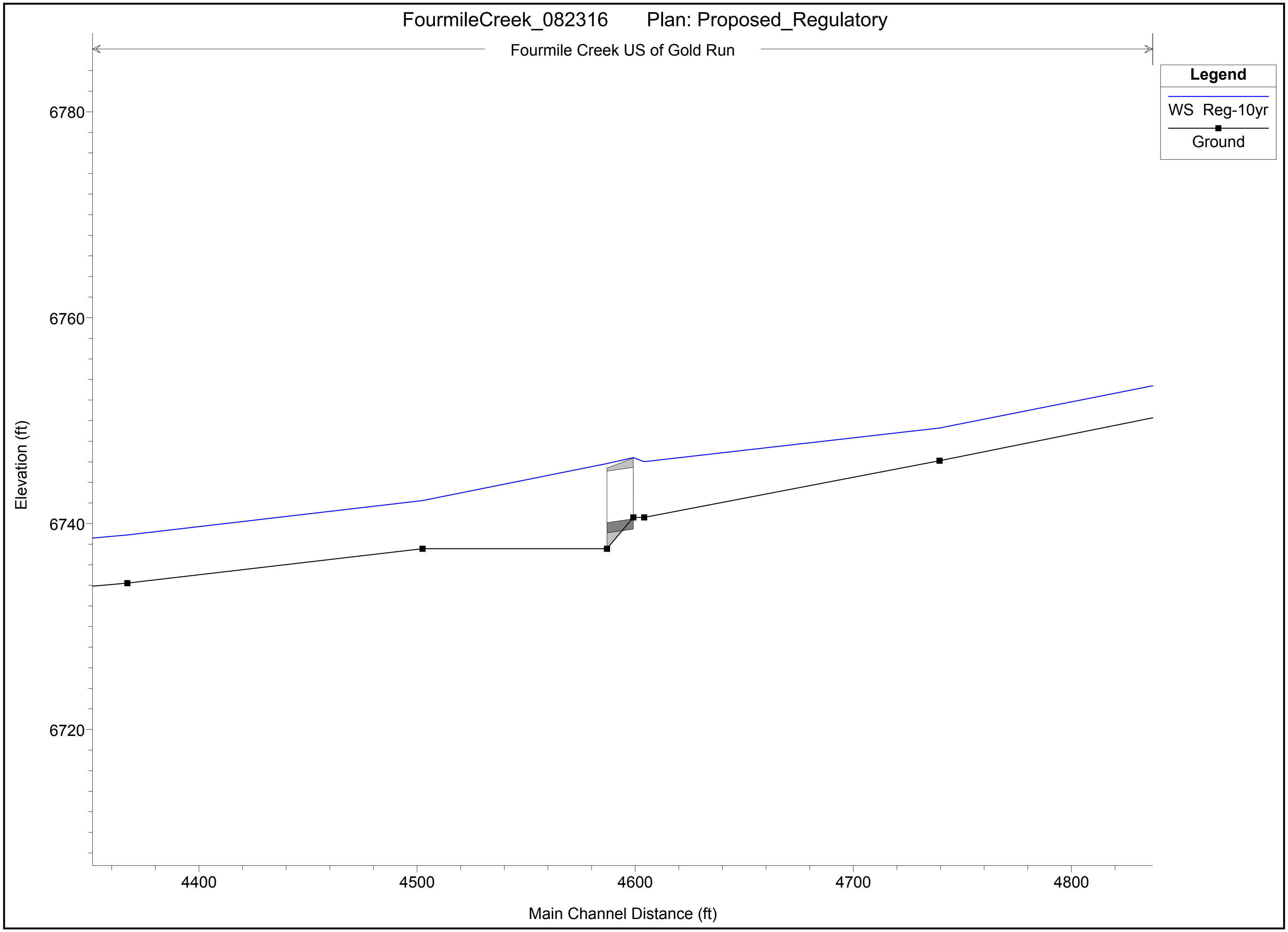
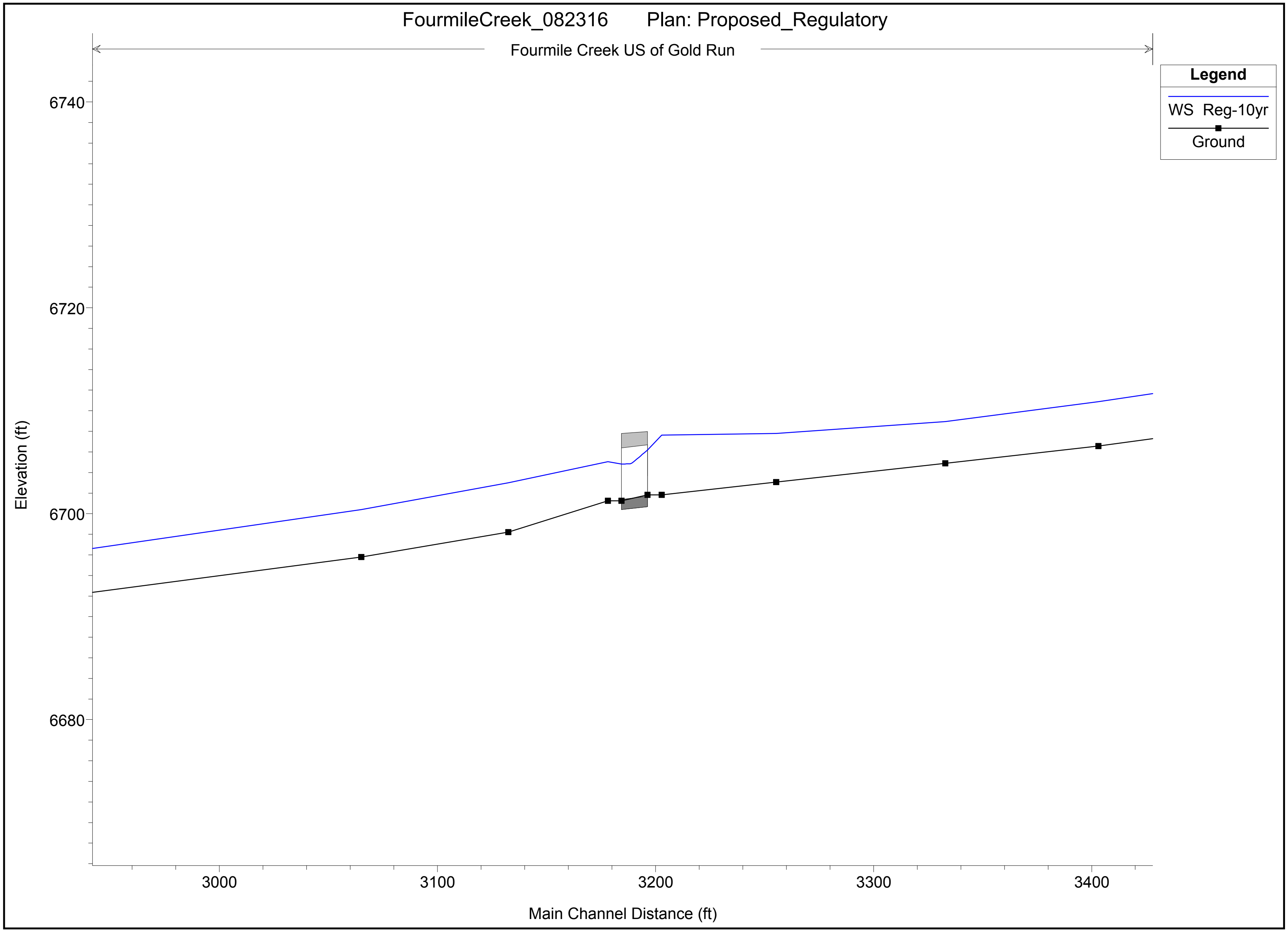
Fourmile Creek US of Gold Run
Legend
WS Reg-10yr
Ground
6870
6860
6850
6840
6830
6820
6810
Elevation (ft)
7500
7550
7600
7650
Main Channel Distance (ft)



FourmileCreek_082316 Plan: Proposed_Regulatory
Fourmile Creek US of Gold Run
Legend
WS Reg-10yr
Ground
Elevation (ft)
6850
6840
6830
6820
6810
6800
7050
7100
7150
7200
Main Channel Distance (ft)


FourmileCreek_082316 Plan: Proposed_Regulatory
Fourmile Creek US of Gold Run
Legend
WS Reg-10yr
Ground
6800
6780
6760
6740
Elevation (ft)
5300
5400
5500
5600
5700
Main Channel Distance (ft)


FourmileCreek_082316 Plan: Proposed_Regulatory
Fourmile Creek US of Gold Run
Legend
WS Reg-10yr
Ground
Elevation (ft)
6780
6760
6740
6720
4400
4500
4600
4700
4800
Main Channel Distance (ft)


FourmileCreek_082316 Plan: Proposed_Regulatory
Fourmile Creek US of Gold Run
Legend
WS Reg-10yr
Ground
Elevation (ft)
6740
6720
6700
6680
3000
3100
3200
3300
3400
Main Channel Distance (ft)

Proposed Crossings Output

Reach	River Sta	Profile	E.G. US.	W.S. US.	E.G. IC	E.G. OC	Min El Weir Flow	Q Culv Group	Q Weir	Delta WS	Culv Vel US	Culv Vel DS
			(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(ft)	(ft/s)	(ft/s)
US of Gold Run	23702 X-5 6X24	Reg-10yr	7432.27	7431.15	7432.27	7432.19	7432.48	670		0.99	8.95	8.96
US of Gold Run	23420.65 Xing-6 24x5	Reg-10yr	7424.26	7423.52	7424.01	7424.26	7423.2	518	152	1.06	7.41	7.38
US of Gold Run	22164.3 FP Culverts	Reg-10yr	7383.66	7383.84	7383.65	7383.15	7388.64	34.63		2.84	6.85	8.01
US of Gold Run	22164.3 Xing-7 24x6	Reg-10yr	7383.66	7383.84	7383.65	7383.66	7388.64	635.37		2.84	9.4	9.97
US of Gold Run	19739.3 Xing-8 24x6	Reg-10yr	7304.07	7303.69	7304.07	7303.89	7304.48	790		1.64	8.52	8.34
US of Gold Run	16848.68 Xing-10 24x6	Reg-10yr	7205.21	7204.98	7202.45	7205.21	7202.62	240.74	549.26	2.71	2.54	2.54
US of Gold Run	13580.7 FP Right	Reg-10yr	7070.44	7069.43	7070.44	7069.82	7069.31	93.63	8.76	1.06	8.31	6.64
US of Gold Run	13580.7 Xing-11 24x6	Reg-10yr	7070.44	7069.43	7069.87	7070.44	7069.31	817.62	8.76	1.06	9.12	8.98
US of Gold Run	8536.1 Xing-12 24x5	Reg-10yr	6874.02	6873.75	6873.88	6874.02	6873.31	712.09	207.91	2.83	10.27	11
US of Gold Run	7593.3 FP Culverts	Reg-10yr	6842.99	6841.61	6842.99	6842.56	6843.48	180.65		1.73	8.17	9.43
US of Gold Run	7593.3 Xing-13 24x6	Reg-10yr	6842.99	6841.61	6842.68	6843	6843.48	809.35		1.73	10.18	11.19
US of Gold Run	7141.522 FP Culverts	Reg-10yr	6826.31	6826.24	6827.79	6826.27	6825.86	117.76	30.37	2.55	9.37	9.37
US of Gold Run	7141.522 Xing-14 24x6	Reg-10yr	6826.31	6826.24	6825.9	6826.32	6825.86	841.87	30.37	2.55	9.77	10.3
US of Gold Run	5532.5 FP Culverts	Reg-10yr	6773.72	6773.64	6774.12	6772.94	6773.59	51.97	22.12	2.77	8.27	12.57
US of Gold Run	5532.5 Xing-15 24x6	Reg-10yr	6773.72	6773.64	6773.42	6773.7	6773.59	915.91	22.12	2.77	10.15	10.74
US of Gold Run	4615.2 FP Culverts	Reg-10yr	6746.59	6746	6746.59	6745.67	6746.41	135.55	1.61	3.77	6.9	12.09
US of Gold Run	4615.2 Xing-16 24x6	Reg-10yr	6746.59	6746	6746.21	6746.58	6746.41	852.84	1.61	3.77	10.34	11.5
US of Gold Run	3230 FP Culverts	Reg-10yr	6707.85	6707.64	6707.86	6706.91	6707.99	137.3		2.58	6.99	11.94
US of Gold Run	3230 Xing-17 24x6	Reg-10yr	6707.85	6707.64	6707.45	6707.84	6707.99	852.7		2.58	10	10.63

Sediment Transport Modeling Results

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Fourmile Creek**			Stream Type:	**C 4b**
Location:	**Reach 1**			Valley Type:	**XIII**
Observers:	**Sean Abel, Daniel Aragon**			Date:	**07/24/2015**
Enter Required Information for Existing Condition					
52.3	D_{50}	Median particle size of riffle bed material (mm)			
0.0	$\hat{D}_{50}$	Median particle size of bar or sub-pavement sample (mm)			
0.666	D_{max}	Largest particle from bar sample (ft)	**203**	**(mm)**	304.8 mm/ft
0.03490	S	Existing bankfull water surface slope (ft/ft)			
1.22	d	Existing bankfull mean depth (ft)			
1.65	$\gamma_s - \gamma / \gamma$	Immersed specific gravity of sediment			
Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress					
0.00	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834 \left(D_{50}/\hat{D}_{50} \right)^{-0.872}$		
3.88	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384 \left(D_{max}/D_{50} \right)^{-0.887}$		
	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:		**N/A**
Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample					
	d	Required bankfull mean depth (ft)	$d = \frac{\tau^* (\gamma_s - 1) D_{max}}{S}$		(use D_{max} in ft)
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample					
	S	Required bankfull water surface slope (ft/ft)	$S = \frac{\tau^* (\gamma_s - 1) D_{max}}{d}$		(use D_{max} in ft)
		Check: ☐ Stable ☐ Aggrading ☑ Degrading			

Sediment Competence Using Dimensional Shear Stress		
2.657		Bankfull shear stress $\tau = \gamma d S$ (lbs/ft²) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope
Shields **215.8**	CO **311.9**	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**
Shields **2.505**	CO **1.482**	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**
Shields **1.15**	CO **0.68**	Predicted mean depth required to initiate movement of measured D_{max} (mm) $d = \frac{\tau}{\gamma S}$ τ = predicted shear stress, γ = 62.4, S = existing slope
Shields **0.0329**	CO **0.0195**	Predicted slope required to initiate movement of measured D_{max} (mm) $S = \frac{\tau}{\gamma d}$ τ = predicted shear stress, γ = 62.4, d = existing depth
		Check: ☐ Stable ☐ Aggrading ☑ Degrading

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Fourmile Creek**		Stream Type: **B 4**		
Location:	**Reach 2**		Valley Type: **XIII**		
Observers:	**Sean Abel, Daniel Aragon**		Date: **07/24/2015**		
Enter Required Information for Existing Condition					
8.4	D_{50}	Median particle size of riffle bed material (mm)			
0.0	$\hat{D}_{50}$	Median particle size of bar or sub-pavement sample (mm)			
0.666	D_{max}	Largest particle from bar sample (ft)	**203**	**(mm)**	304.8 mm/ft
0.03900	S	Existing bankfull water surface slope (ft/ft)			
1.29	d	Existing bankfull mean depth (ft)			
1.65	$\gamma_s - \gamma / \gamma$	Immersed specific gravity of sediment			
Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress					
0.00	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834\,(D_{50}/\hat{D}_{50})^{-0.872}$		
24.31	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$		
	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:		**N/A**
Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample					
	d	Required bankfull mean depth (ft) $d = \frac{\tau^*(\gamma_s - 1)D_{max}}{S}$ (use D_{max} in ft)			
Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample					
	S	Required bankfull water surface slope (ft/ft) $S = \frac{\tau^*(\gamma_s - 1)D_{max}}{d}$ (use D_{max} in ft)			
		Check: ☐ Stable ☐ Aggrading ☑ Degrading			

Sediment Competence Using Dimensional Shear Stress		
3.139		Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope
Shields **256.8**	CO **352.6**	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**
Shields **2.505**	CO **1.482**	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**
Shields **1.03**	CO **0.61**	Predicted mean depth required to initiate movement of measured D_{max} (mm) $d = \frac{\tau}{\gamma S}$ τ = predicted shear stress, γ = 62.4, S = existing slope
Shields **0.0311**	CO **0.0184**	Predicted slope required to initiate movement of measured D_{max} (mm) $S = \frac{\tau}{\gamma d}$ τ = predicted shear stress, γ = 62.4, d = existing depth
		Check: ☐ Stable ☐ Aggrading ☑ Degrading

Worksheet 3-14. Sediment competence calculation form to assess bed stability.

Stream:	**Fourmile Creek**		Stream Type:	
Location:	**Reach 3**		Valley Type:	**XIII**
Observers:			Date:	**01/27/2016**

Enter Required Information for Existing Condition

25.4	D_{50}	Median particle size of riffle bed material (mm)			
0.0	$\hat{D}_{50}$	Median particle size of bar or sub-pavement sample (mm)			
0.666	D_{max}	Largest particle from bar sample (ft)	**203**	**(mm)**	304.8 mm/ft
0.03450	S	Existing bankfull water surface slope (ft/ft)			
1.36	d	Existing bankfull mean depth (ft)			
1.65	$\gamma_s - \gamma / \gamma$	Immersed specific gravity of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

0.00	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\ (D_{50}/\hat{D}_{50})^{-0.872}$
7.99	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\ (D_{max}/D_{50})^{-0.887}$
	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	**N/A**

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

	d	Required bankfull mean depth (ft)	$d = \frac{\tau^* (\gamma_s - 1) D_{max}}{S}$	(use D_{max} in ft)

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

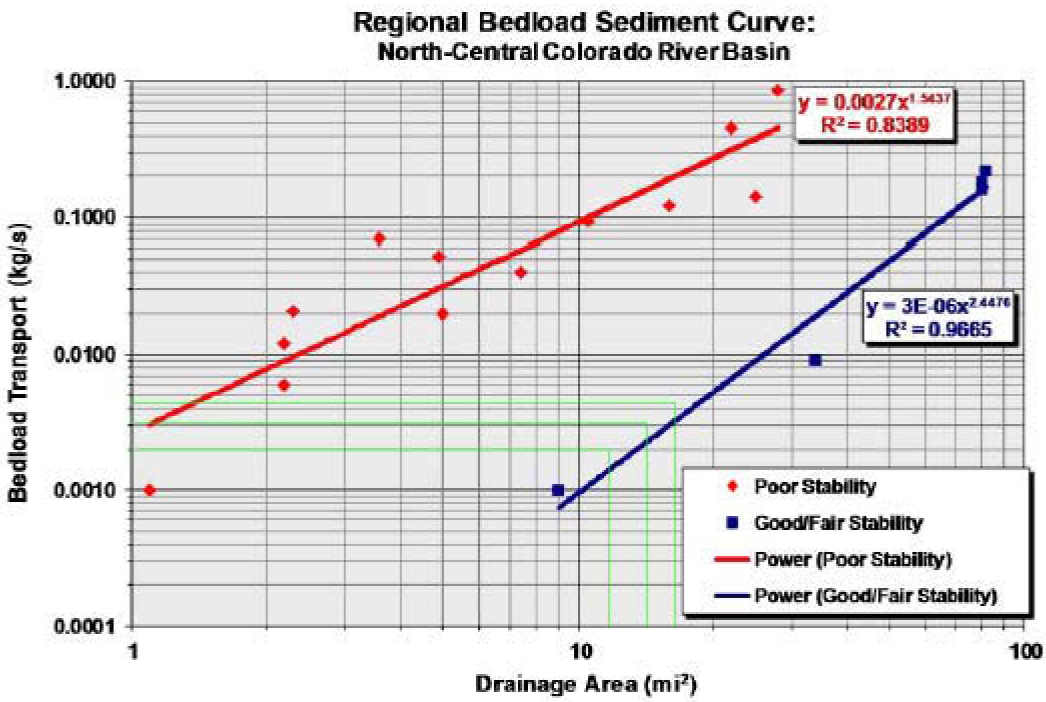
	S	Required bankfull water surface slope (ft/ft)	$S = \frac{\tau^* (\gamma_s - 1) D_{max}}{d}$	(use D_{max} in ft)

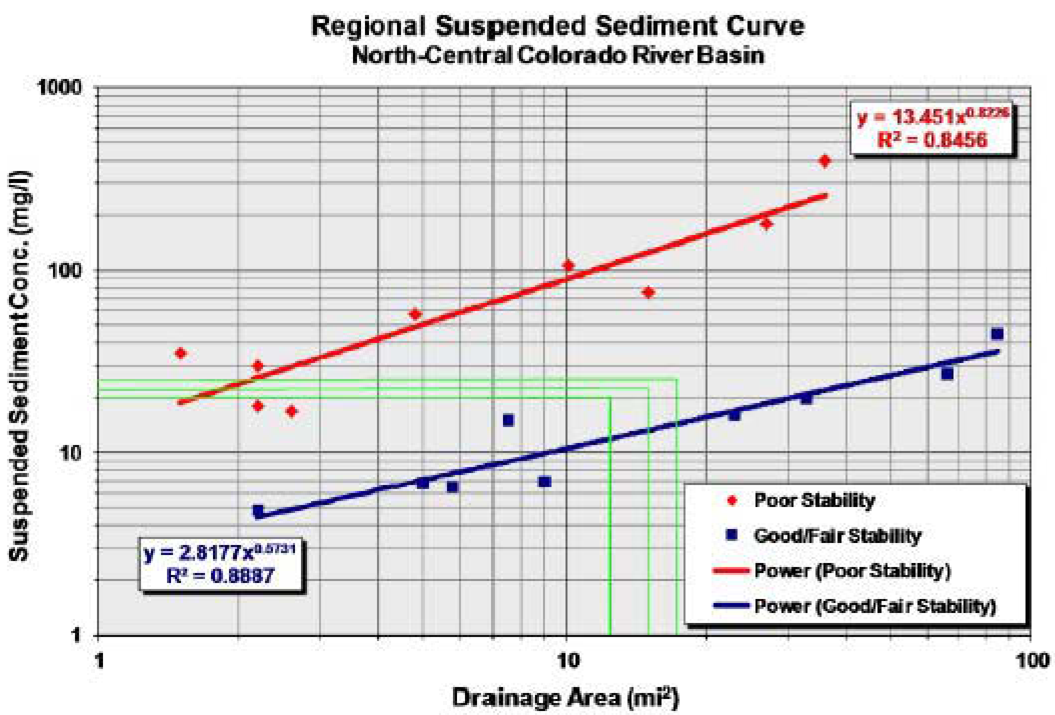
Check: ☐ Stable ☐ Aggrading ☑ Degrading

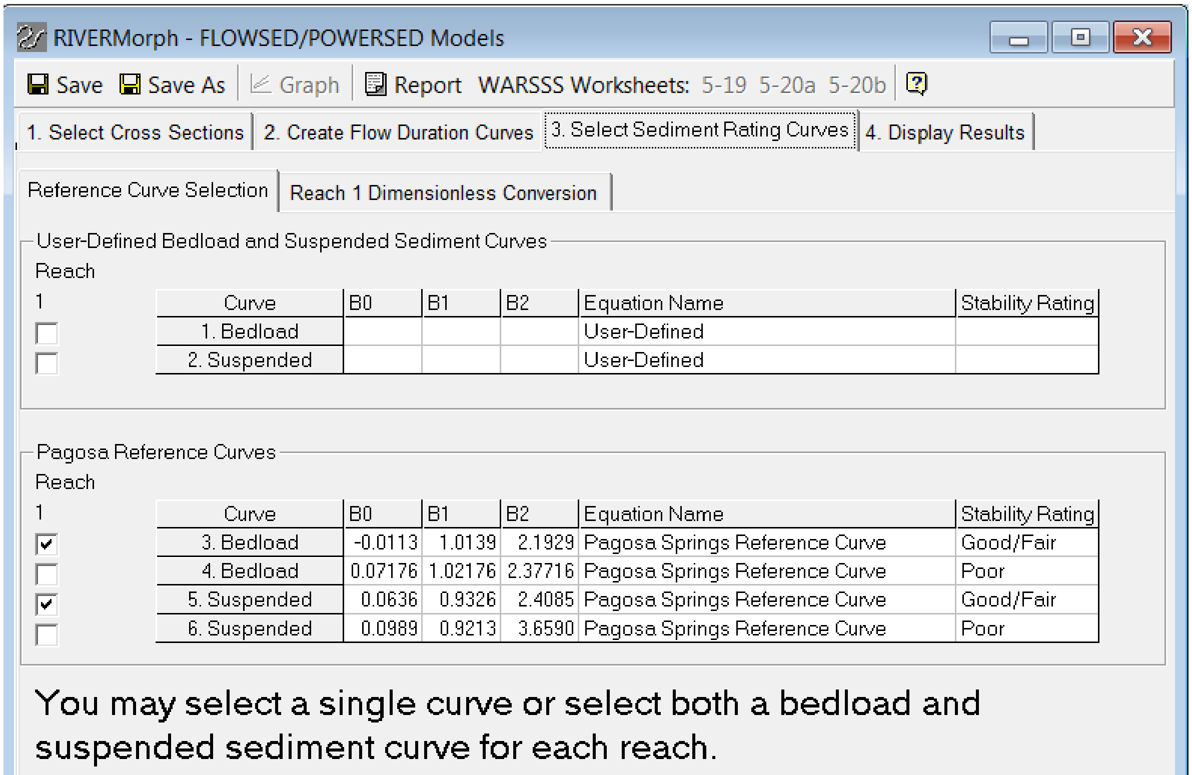
Sediment Competence Using Dimensional Shear Stress

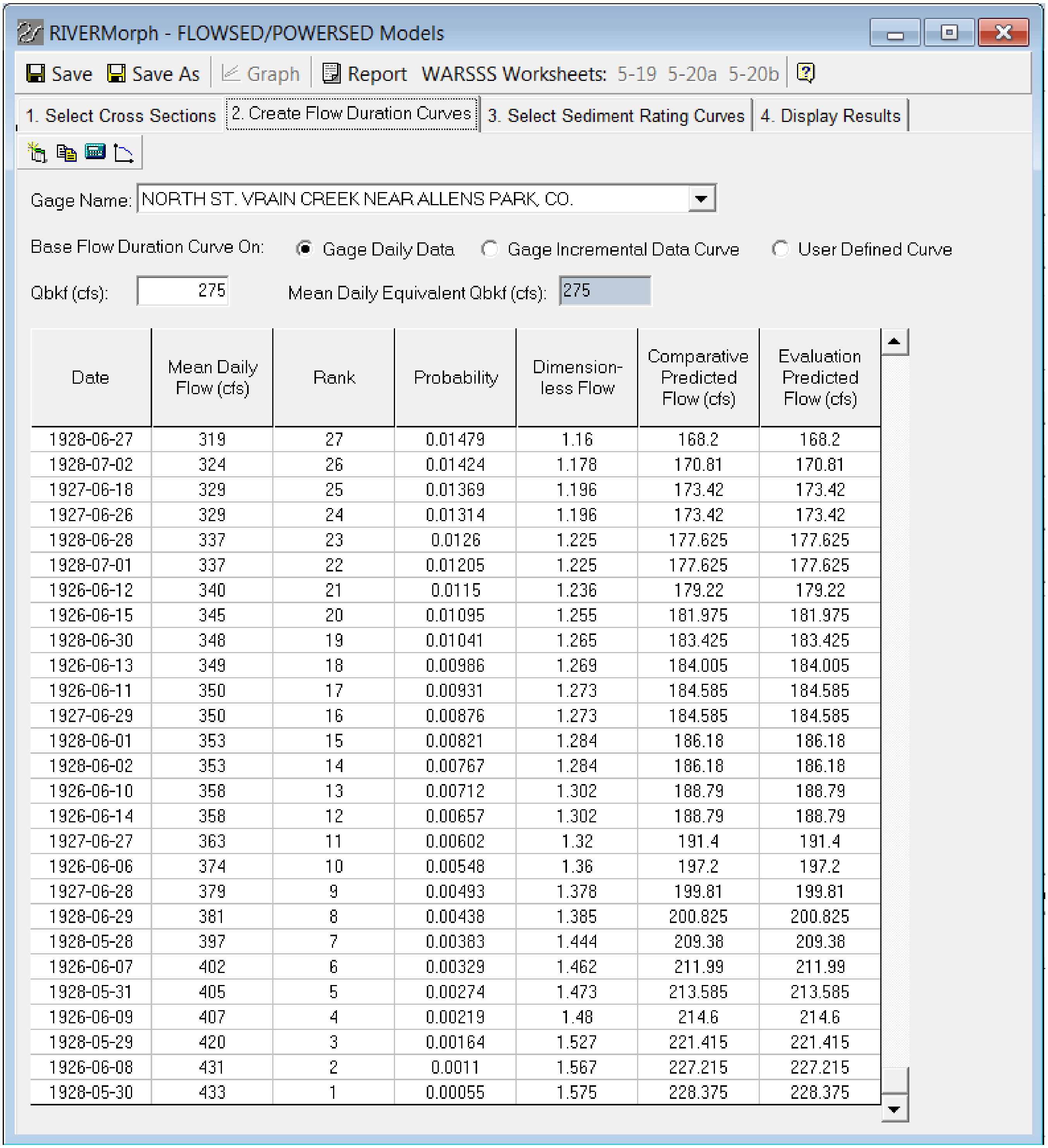
2.928		Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope	
Shields **238.8**	CO **335**	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**	
Shields **2.505**	CO **1.482**	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**	
Shields **1.16**	CO **0.69**	Predicted mean depth required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, S = existing slope	$d = \frac{\tau}{\gamma S}$
Shields **0.0295**	CO **0.0175**	Predicted slope required to initiate movement of measured D_{max} (mm) τ = predicted shear stress, γ = 62.4, d = existing depth	$S = \frac{\tau}{\gamma d}$

Check: ☐ Stable ☐ Aggrading ☑ Degrading

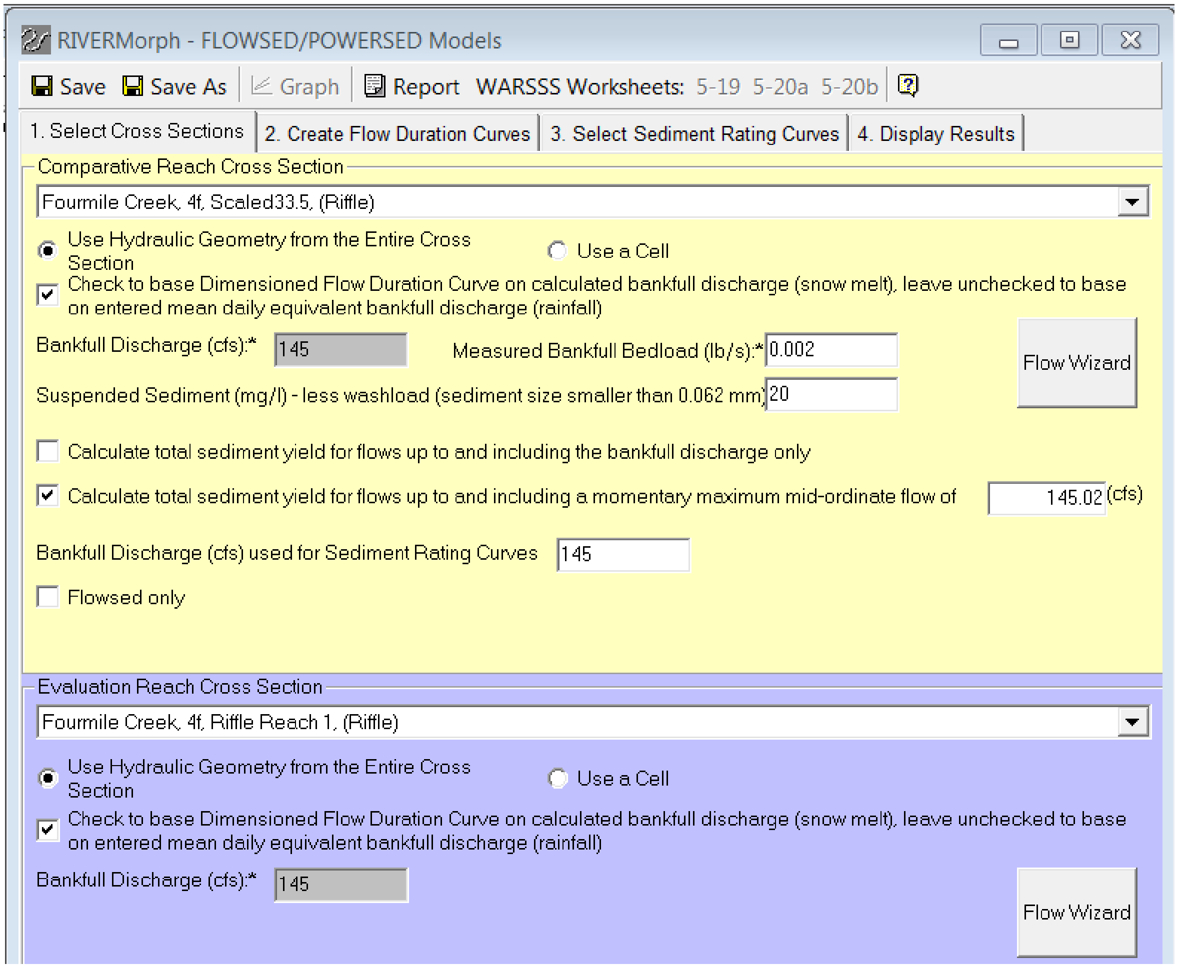

Regional Bedload Sediment Curve:
North-Central Colorado River Basin
Bedload Transport (kg/s)
1.0000
0.1000
0.0100
0.0010
0.0001
1
10
100
Drainage Area (mi²)
y = 0.0027x^1.5437
R² = 0.8389
y = 3E-06x^2.4476
R² = 0.9665
Poor Stability
Good/Fair Stability
Power (Poor Stability)
Power (Good/Fair Stability)


Regional Suspended Sediment Curve
North-Central Colorado River Basin
Suspended Sediment Conc. (mg/l)
1000
100
10
1
1
10
100
Drainage Area (mi²)
y = 13.451x^0.8226
R² = 0.8456
y = 2.8177x^0.5731
R² = 0.8887
Poor Stability
Good/Fair Stability
Power (Poor Stability)
Power (Good/Fair Stability)

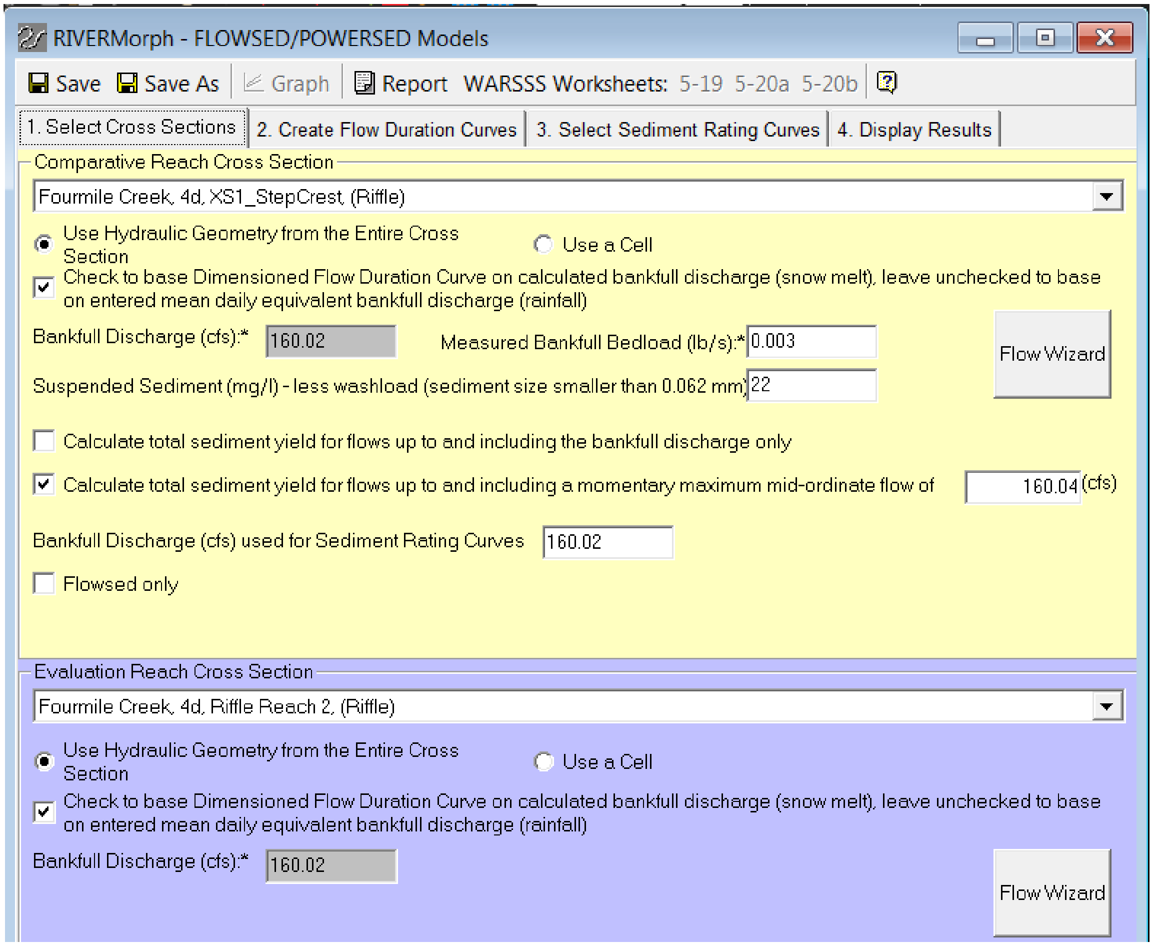

RIVERMorph - FLOWSED/POWERSED Models
Save
Save As
Graph
Report
WARSSS Worksheets: 5-19 5-20a 5-20b
1. Select Cross Sections
2. Create Flow Duration Curves
3. Select Sediment Rating Curves
4. Display Results
Reference Curve Selection
Reach 1 Dimensionless Conversion
User-Defined Bedload and Suspended Sediment Curves
Reach
1
Curve | B0 | B1 | B2 | Equation Name | Stability Rating
1. Bedload | | | | User-Defined |
2. Suspended | | | | User-Defined |
Pagosa Reference Curves
Reach
1
Curve | B0 | B1 | B2 | Equation Name | Stability Rating
3. Bedload | -0.0113 | 1.0139 | 2.1929 | Pagosa Springs Reference Curve | Good/Fair
4. Bedload | 0.07176 | 1.02176 | 2.37716 | Pagosa Springs Reference Curve | Poor
5. Suspended | 0.0636 | 0.9326 | 2.4085 | Pagosa Springs Reference Curve | Good/Fair
6. Suspended | 0.0989 | 0.9213 | 3.6590 | Pagosa Springs Reference Curve | Poor
You may select a single curve or select both a bedload and suspended sediment curve for each reach.

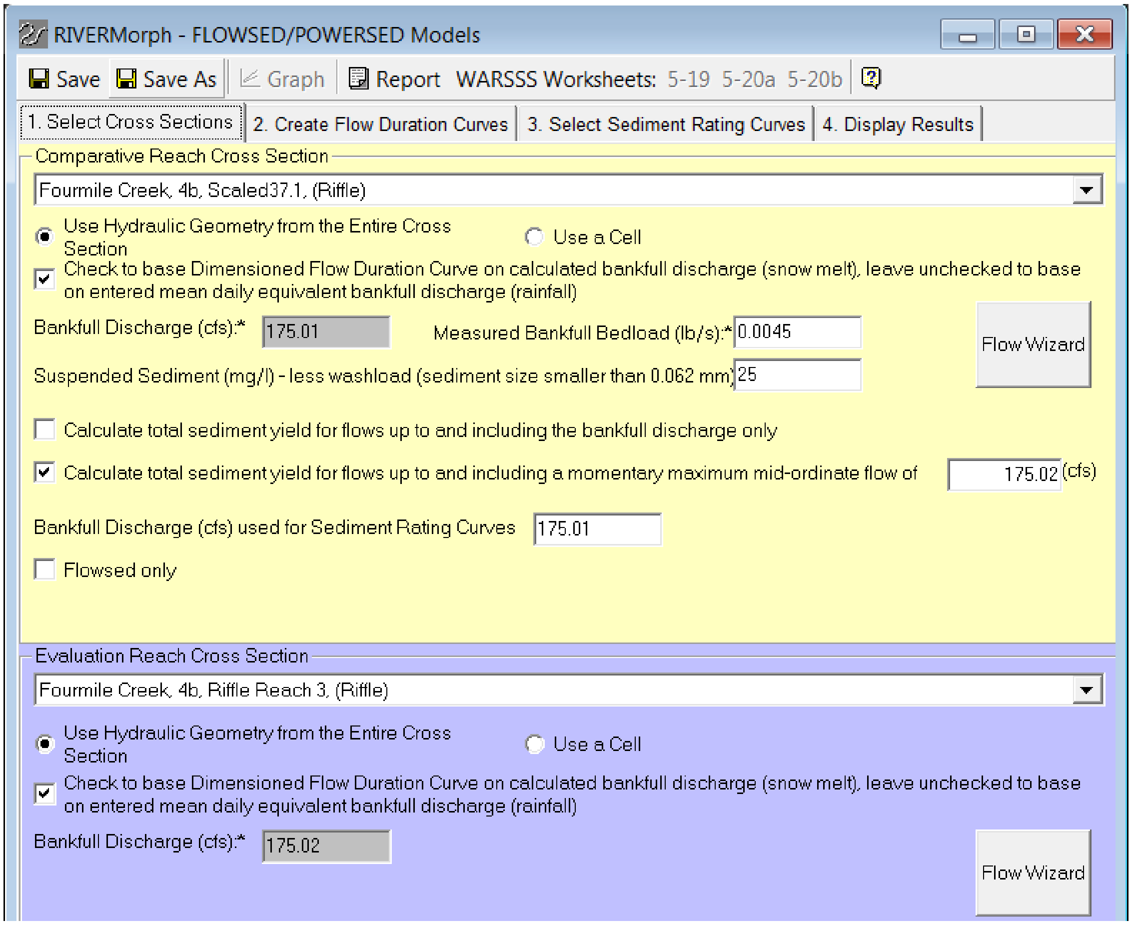


Date	Mean Daily Flow (cfs)	Rank	Probability	Dimension-less Flow	Comparative Predicted Flow (cfs)	Evaluation Predicted Flow (cfs)
1928-06-27	319	27	0.01479	1.16	168.2	168.2
1928-07-02	324	26	0.01424	1.178	170.81	170.81
1927-06-18	329	25	0.01369	1.196	173.42	173.42
1927-06-26	329	24	0.01314	1.196	173.42	173.42
1928-06-28	337	23	0.0126	1.225	177.625	177.625
1928-07-01	337	22	0.01205	1.225	177.625	177.625
1926-06-12	340	21	0.0115	1.236	179.22	179.22
1926-06-15	345	20	0.01095	1.255	181.975	181.975
1928-06-30	348	19	0.01041	1.265	183.425	183.425
1926-06-13	349	18	0.00986	1.269	184.005	184.005
1926-06-11	350	17	0.00931	1.273	184.585	184.585
1927-06-29	350	16	0.00876	1.273	184.585	184.585
1928-06-01	353	15	0.00821	1.284	186.18	186.18
1928-06-02	353	14	0.00767	1.284	186.18	186.18
1926-06-10	358	13	0.00712	1.302	188.79	188.79
1926-06-14	358	12	0.00657	1.302	188.79	188.79
1927-06-27	363	11	0.00602	1.32	191.4	191.4
1926-06-06	374	10	0.00548	1.36	197.2	197.2
1927-06-28	379	9	0.00493	1.378	199.81	199.81
1928-06-29	381	8	0.00438	1.385	200.825	200.825
1928-05-28	397	7	0.00383	1.444	209.38	209.38
1926-06-07	402	6	0.00329	1.462	211.99	211.99
1928-05-31	405	5	0.00274	1.473	213.585	213.585
1926-06-09	407	4	0.00219	1.48	214.6	214.6
1928-05-29	420	3	0.00164	1.527	221.415	221.415
1926-06-08	431	2	0.0011	1.567	227.215	227.215
1928-05-30	433	1	0.00055	1.575	228.375	228.375



RIVERMorph - FLOWSED/POWERSED Models
Save
Save As
Graph
Report
WARSSS Worksheets: 5-19 5-20a 5-20b
1. Select Cross Sections
2. Create Flow Duration Curves
3. Select Sediment Rating Curves
4. Display Results
Comparative Reach Cross Section
Fourmile Creek, 4f, Scaled33.5, (Riffle)
Use Hydraulic Geometry from the Entire Cross Section
Use a Cell
Check to base Dimensioned Flow Duration Curve on calculated bankfull discharge (snow melt), leave unchecked to base on entered mean daily equivalent bankfull discharge (rainfall)
Bankfull Discharge (cfs):* 145
Measured Bankfull Bedload (lb/s):* 0.002
Flow Wizard
Suspended Sediment (mg/l) - less washload (sediment size smaller than 0.062 mm) 20
Calculate total sediment yield for flows up to and including the bankfull discharge only
Calculate total sediment yield for flows up to and including a momentary maximum mid-ordinate flow of 145.02 (cfs)
Bankfull Discharge (cfs) used for Sediment Rating Curves 145
Flowsed only
Evaluation Reach Cross Section
Fourmile Creek, 4f, Riffle Reach 1, (Riffle)
Use Hydraulic Geometry from the Entire Cross Section
Use a Cell
Check to base Dimensioned Flow Duration Curve on calculated bankfull discharge (snow melt), leave unchecked to base on entered mean daily equivalent bankfull discharge (rainfall)
Bankfull Discharge (cfs):* 145
Flow Wizard


RIVERMorph - FLOWSED/POWERSED Models
Save
Save As
Graph
Report
WARSSS Worksheets: 5-19 5-20a 5-20b
1. Select Cross Sections
2. Create Flow Duration Curves
3. Select Sediment Rating Curves
4. Display Results
Comparative Reach Cross Section
Fourmile Creek, 4d, XS1_StepCrest, (Riffle)
Use Hydraulic Geometry from the Entire Cross Section
Use a Cell
Check to base Dimensioned Flow Duration Curve on calculated bankfull discharge (snow melt), leave unchecked to base on entered mean daily equivalent bankfull discharge (rainfall)
Bankfull Discharge (cfs):* 160.02
Measured Bankfull Bedload (lb/s):* 0.003
Flow Wizard
Suspended Sediment (mg/l) - less washload (sediment size smaller than 0.062 mm) 22
Calculate total sediment yield for flows up to and including the bankfull discharge only
Calculate total sediment yield for flows up to and including a momentary maximum mid-ordinate flow of 160.04 (cfs)
Bankfull Discharge (cfs) used for Sediment Rating Curves 160.02
Flowsed only
Evaluation Reach Cross Section
Fourmile Creek, 4d, Riffle Reach 2, (Riffle)
Use Hydraulic Geometry from the Entire Cross Section
Use a Cell
Check to base Dimensioned Flow Duration Curve on calculated bankfull discharge (snow melt), leave unchecked to base on entered mean daily equivalent bankfull discharge (rainfall)
Bankfull Discharge (cfs):* 160.02
Flow Wizard


RIVERMorph - FLOWSED/POWERSED Models
Save
Save As
Graph
Report
WARSSS Worksheets: 5-19 5-20a 5-20b
1. Select Cross Sections
2. Create Flow Duration Curves
3. Select Sediment Rating Curves
4. Display Results
Comparative Reach Cross Section
Fourmile Creek, 4b, Scaled37.1, (Riffle)
Use Hydraulic Geometry from the Entire Cross Section
Use a Cell
Check to base Dimensioned Flow Duration Curve on calculated bankfull discharge (snow melt), leave unchecked to base on entered mean daily equivalent bankfull discharge (rainfall)
Bankfull Discharge (cfs):* 175.01
Measured Bankfull Bedload (lb/s):* 0.0045
Flow Wizard
Suspended Sediment (mg/l) - less washload (sediment size smaller than 0.062 mm) 25
Calculate total sediment yield for flows up to and including the bankfull discharge only
Calculate total sediment yield for flows up to and including a momentary maximum mid-ordinate flow of 175.02 (cfs)
Bankfull Discharge (cfs) used for Sediment Rating Curves 175.01
Flowsed only
Evaluation Reach Cross Section
Fourmile Creek, 4b, Riffle Reach 3, (Riffle)
Use Hydraulic Geometry from the Entire Cross Section
Use a Cell
Check to base Dimensioned Flow Duration Curve on calculated bankfull discharge (snow melt), leave unchecked to base on entered mean daily equivalent bankfull discharge (rainfall)
Bankfull Discharge (cfs):* 175.02
Flow Wizard

Worksheet 5-19. FLOWSED calculation of total annual sediment yield.

Stream: **Fourmile Creek** Location: **4f** Date: **07/24/2015**

Observers: **Sean Abel, Daniel Aragon** Gage Station #: **06721500** Stream Type: **C 4b** Valley Type: **XIII**

Equation type	Intercept	Coefficient	Exponent	Form (e.g., linear, non-linear, etc.)	Equation name
1. Bedload (dimensionless)	-0.0113	1.0139	2.1929	Non-Linear	Pagosa Springs Reference Curve
2. Suspended sediment (dimensionless)	0.0636	0.9326	2.4085	Non-Linear	Pagosa Springs Reference Curve
3. User-defined relations (bedload)					
4. User-defined relations (suspended sediment)					

Bankfull discharge (cfs)	Bankfull bedload (kg/s)	Bankfull suspended (mg/l)
145	0.0009	20

Notes:

From dimensioned flow-duration curve							From sediment rating curves				Calculate	Calculate sediment yield		
(1) Flow exceedence	(2) Daily mean discharge	(3) Mid-ordinate	(4) Time increment (percent)	(5) Time increment (days)	(6) Mid-ordinate streamflow	(7) Dimension-less streamflow	(8) Dimension-less suspended sediment discharge	(9) Suspended sediment discharge	(10) Dimension-less bedload discharge	(11) Bedload	(12) Time adjusted streamflow	(13) Suspended sediment [(5)×(9)]	(14) Bedload sediment [(5)×(11)]	(15) Suspended + bedload [(13)+(14)]
(%)	(cfs)	(%)	(%)	(days)	(cfs)	(Q/Q_{bkf})	(S/S_{bkf})	(tons/day)	(b_s/b_{bkf})	(tons/day)	(cfs)	(tons)	(tons)	(tons)
100.000	2.2													
90.000	3.3	95.00	10.00	36.50	2.8	0.02	0.0637	0.0	0.0000	0.00	27.50	0.36	0.00	0.36
80.000	4.2	85.00	10.00	36.50	3.8	0.03	0.0637	0.0	0.0000	0.00	37.70	0.36	0.00	0.36
70.000	4.8	75.00	10.00	36.50	4.5	0.03	0.0638	0.0	0.0000	0.00	45.00	0.73	0.00	0.73
60.000	6.4	65.00	10.00	36.50	5.6	0.04	0.0640	0.0	0.0000	0.00	55.80	0.73	0.00	0.73
50.000	10.6	55.00	10.00	36.50	8.5	0.06	0.0646	0.0	0.0000	0.00	84.80	1.09	0.00	1.09
40.000	16.8	45.00	10.00	36.50	13.7	0.09	0.0668	0.1	0.0000	0.00	137.10	1.83	0.00	1.83
30.000	31.6	35.00	10.00	36.50	24.2	0.17	0.0761	0.1	0.0087	0.00	242.10	3.65	0.00	3.65
20.000	61.6	25.00	10.00	36.50	46.6	0.32	0.1242	0.3	0.0729	0.00	466.20	11.31	0.00	11.31
10.000	106.2	15.00	10.00	36.50	83.9	0.58	0.3135	1.4	0.2944	0.04	839.30	51.83	1.46	53.29
5.000	131.2	7.50	5.00	18.25	118.7	0.82	0.6397	4.1	0.6427	0.04	593.60	74.82	0.73	75.55
4.000	140.2	4.50	1.00	3.65	135.7	0.94	0.8589	6.3	0.8657	0.09	135.72	22.99	0.33	23.32
3.000	149.8	3.50			145.0	1.00	0.9962		1.0026		0.00	0.00	0.00	0.00
2.000	158.7	2.50			154.2	1.06	1.1456		1.1495		0.00	0.00	0.00	0.00
1.500	167.2	1.75			162.9	1.12	1.2987		1.2981		0.00	0.00	0.00	0.00
1.000	183.9	1.25			175.5	1.21	1.5412		1.5303		0.00	0.00	0.00	0.00
0.900	184.6	0.95			184.2	1.27	1.7238		1.7028		0.00	0.00	0.00	0.00
0.800	186.2	0.85			185.4	1.28	1.7489		1.7264		0.00	0.00	0.00	0.00
0.700	188.8	0.75			187.5	1.29	1.7954		1.7700		0.00	0.00	0.00	0.00
0.600	191.6	0.65			190.2	1.31	1.8563		1.8270		0.00	0.00	0.00	0.00
0.500	199.5	0.55			195.6	1.35	1.9802		1.9423		0.00	0.00	0.00	0.00
0.250	214.0	0.38			206.8	1.43	2.2554		2.1961		0.00	0.00	0.00	0.00
0.100	227.4	0.18			220.7	1.52	2.6294		2.5366		0.00	0.00	0.00	0.00
0.050	228.4	0.08			227.9	1.57	2.8351		2.7219		0.00	0.00	0.00	0.00
0.010	228.4	0.03			228.4	1.58	2.8489		2.7343		0.00	0.00	0.00	0.00
0.005	228.4	0.01			228.4	1.58	2.8489		2.7343		0.00	0.00	0.00	0.00
0.001	228.4	0.00			228.4	1.58	2.8489		2.7343		0.00	0.00	0.00	0.00
											Annual totals:	169.7 (tons/yr)	2.5 (tons/yr)	172.2 (tons/yr)

Worksheet 5-19. FLOWSED calculation of total annual sediment yield.

Stream: **Fourmile Creek** Location: **4d** Date: **07/24/2015**

Observers: **Sean Abel, Daniel Aragon** Gage Station #: **06721500** Stream Type: **B 4** Valley Type: **XIII**

Equation type	Intercept	Coefficient	Exponent	Form (e.g., linear, non-linear, etc.)	Equation name
1. Bedload (dimensionless)	-0.0113	1.0139	2.1929	Non-Linear	Pagosa Springs Reference Curve
2. Suspended sediment (dimensionless)	0.0636	0.9326	2.4085	Non-Linear	Pagosa Springs Reference Curve
3. User-defined relations (bedload)					
4. User-defined relations (suspended sediment)					

Bankfull discharge (cfs)	Bankfull bedload (kg/s)	Bankfull suspended (mg/l)
160.02	0.0014	22

Notes:

From dimensioned flow-duration curve							From sediment rating curves				Calculate	Calculate sediment yield		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Flow exceedence	Daily mean discharge	Mid-ordinate	Time increment (percent)	Time increment (days)	Mid-ordinate streamflow	Dimension-less streamflow	Dimension-less suspended sediment discharge	Suspended sediment discharge	Dimension-less bedload discharge	Bedload	Time adjusted streamflow	Suspended sediment [(5)×(9)]	Bedload sediment [(5)×(11)]	Suspended + bedload [(13)+(14)]
(%)	(cfs)	(%)	(%)	(days)	(cfs)	(Q/Q_{bkf})	(S/S_{bkf})	(tons/day)	(b_s/b_{bkf})	(tons/day)	(cfs)	(tons)	(tons)	(tons)
100.000	2.4													
90.000	3.7	95.00	10.00	36.50	3.0	0.02	0.0637	0.0	0.0000	0.00	30.40	0.36	0.00	0.36
80.000	4.6	85.00	10.00	36.50	4.2	0.03	0.0637	0.0	0.0000	0.00	41.60	0.73	0.00	0.73
70.000	5.3	75.00	10.00	36.50	5.0	0.03	0.0638	0.0	0.0000	0.00	49.60	0.73	0.00	0.73
60.000	7.0	65.00	10.00	36.50	6.2	0.04	0.0640	0.0	0.0000	0.00	61.60	0.73	0.00	0.73
50.000	11.7	55.00	10.00	36.50	9.4	0.06	0.0646	0.0	0.0000	0.00	93.60	1.46	0.00	1.46
40.000	18.6	45.00	10.00	36.50	15.1	0.09	0.0668	0.1	0.0000	0.00	151.20	2.19	0.00	2.19
30.000	34.9	35.00	10.00	36.50	26.7	0.17	0.0761	0.1	0.0087	0.00	267.20	4.38	0.00	4.38
20.000	68.0	25.00	10.00	36.50	51.5	0.32	0.1242	0.4	0.0729	0.00	514.50	13.87	0.00	13.87
10.000	117.2	15.00	10.00	36.50	92.6	0.58	0.3135	1.7	0.2944	0.04	926.20	63.14	1.46	64.60
5.000	144.8	7.50	5.00	18.25	131.0	0.82	0.6399	5.0	0.6428	0.09	655.15	90.89	1.64	92.53
4.000	154.7	4.50	1.00	3.65	149.8	0.94	0.8589	7.6	0.8657	0.13	149.78	27.89	0.47	28.36
3.000	165.3	3.50	1.00	3.65	160.0	1.00	0.9962	9.5	1.0026	0.13	160.02	34.57	0.47	35.04
2.000	175.1	2.50			170.2	1.06	1.1457		1.1496		0.00	0.00	0.00	0.00
1.500	184.5	1.75			179.8	1.12	1.2986		1.2980		0.00	0.00	0.00	0.00
1.000	202.9	1.25			193.7	1.21	1.5410		1.5301		0.00	0.00	0.00	0.00
0.900	203.7	0.95			203.3	1.27	1.7237		1.7027		0.00	0.00	0.00	0.00
0.800	205.5	0.85			204.6	1.28	1.7490		1.7265		0.00	0.00	0.00	0.00
0.700	208.4	0.75			206.9	1.29	1.7954		1.7700		0.00	0.00	0.00	0.00
0.600	211.5	0.65			209.9	1.31	1.8565		1.8271		0.00	0.00	0.00	0.00
0.500	220.1	0.55			215.8	1.35	1.9801		1.9422		0.00	0.00	0.00	0.00
0.250	236.2	0.38			228.2	1.43	2.2554		2.1961		0.00	0.00	0.00	0.00
0.100	251.0	0.18			243.6	1.52	2.6293		2.5365		0.00	0.00	0.00	0.00
0.050	252.0	0.08			251.5	1.57	2.8346		2.7215		0.00	0.00	0.00	0.00
0.010	252.0	0.03			252.0	1.57	2.8487		2.7341		0.00	0.00	0.00	0.00
0.005	252.0	0.01			252.0	1.57	2.8487		2.7341		0.00	0.00	0.00	0.00
0.001	252.0	0.00			252.0	1.57	2.8487		2.7341		0.00	0.00	0.00	0.00
										Annual totals:		240.9 (tons/yr)	4.0 (tons/yr)	244.9 (tons/yr)

Worksheet 5-19. FLOWSED calculation of total annual sediment yield.

Stream: **Fourmile Creek**	Location: **4b**	Date: **01/27/2016**
Observers:	Gage Station #: **06721500**	Stream Type:
		Valley Type: **XIII**

Equation type	Intercept	Coefficient	Exponent	Form (e.g., linear, non-linear, etc.)	Equation name	Bankfull discharge (cfs)	Bankfull bedload (kg/s)	Bankfull suspended (mg/l)
1. Bedload (dimensionless)	-0.0113	1.0139	2.1929	Non-Linear	Pagosa Springs Reference Curve	175.01	0.002	25
2. Suspended sediment (dimensionless)	0.0636	0.9326	2.4085	Non-Linear	Pagosa Springs Reference Curve			
3. User-defined relations (bedload)						Notes:		
4. User-defined relations (suspended sediment)								

From dimensioned flow-duration curve							From sediment rating curves				Calculate	Calculate sediment yield		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Flow exceedence	Daily mean discharge	Mid-ordinate	Time increment (percent)	Time increment (days)	Mid-ordinate streamflow	Dimension-less streamflow	Dimension-less suspended sediment discharge	Suspended sediment discharge	Dimension-less bedload discharge	Bedload	Time adjusted streamflow	Suspended sediment [(5)×(9)]	Bedload sediment [(5)×(11)]	Suspended + bedload [(13)+(14)]
(%)	(cfs)	(%)	(%)	(days)	(cfs)	(Q/Q_{bkf})	(S/S_{bkf})	(tons/day)	(b_s/b_{bkf})	(tons/day)	(cfs)	(tons)	(tons)	(tons)
100.000	2.6													
90.000	4.0	95.00	10.00	36.50	3.3	0.02	0.0637	0.0	0.0000	0.00	33.30	0.36	0.00	0.36
80.000	5.1	85.00	10.00	36.50	4.6	0.03	0.0637	0.0	0.0000	0.00	45.50	0.73	0.00	0.73
70.000	5.8	75.00	10.00	36.50	5.4	0.03	0.0638	0.0	0.0000	0.00	54.30	0.73	0.00	0.73
60.000	7.7	65.00	10.00	36.50	6.7	0.04	0.0640	0.0	0.0000	0.00	67.40	1.09	0.00	1.09
50.000	12.8	55.00	10.00	36.50	10.2	0.06	0.0646	0.0	0.0000	0.00	102.40	1.46	0.00	1.46
40.000	20.3	45.00	10.00	36.50	16.5	0.09	0.0668	0.1	0.0000	0.00	165.40	2.56	0.00	2.56
30.000	38.2	35.00	10.00	36.50	29.2	0.17	0.0761	0.2	0.0087	0.00	292.30	5.47	0.00	5.47
20.000	74.4	25.00	10.00	36.50	56.3	0.32	0.1242	0.5	0.0729	0.00	562.70	17.15	0.00	17.15
10.000	128.2	15.00	10.00	36.50	101.3	0.58	0.3135	2.1	0.2944	0.04	1013.00	78.11	1.46	79.57
5.000	158.4	7.50	5.00	18.25	143.3	0.82	0.6398	6.2	0.6428	0.13	716.50	112.97	2.37	115.34
4.000	169.2	4.50	1.00	3.65	163.8	0.94	0.8589	9.5	0.8657	0.17	163.81	34.67	0.62	35.29
3.000	180.8	3.50	1.00	3.65	175.0	1.00	0.9962	11.8	1.0026	0.22	175.01	42.96	0.80	43.76
2.000	191.5	2.50			186.2	1.06	1.1458		1.1497		0.00	0.00	0.00	0.00
1.500	201.8	1.75			196.7	1.12	1.2987		1.2981		0.00	0.00	0.00	0.00
1.000	221.9	1.25			211.9	1.21	1.5411		1.5302		0.00	0.00	0.00	0.00
0.900	222.8	0.95			222.4	1.27	1.7236		1.7027		0.00	0.00	0.00	0.00
0.800	224.7	0.85			223.8	1.28	1.7489		1.7264		0.00	0.00	0.00	0.00
0.700	227.9	0.75			226.3	1.29	1.7954		1.7700		0.00	0.00	0.00	0.00
0.600	231.3	0.65			229.6	1.31	1.8563		1.8269		0.00	0.00	0.00	0.00
0.500	240.8	0.55			236.0	1.35	1.9800		1.9421		0.00	0.00	0.00	0.00
0.250	258.3	0.38			249.5	1.43	2.2553		2.1961		0.00	0.00	0.00	0.00
0.100	274.5	0.18			266.4	1.52	2.6294		2.5365		0.00	0.00	0.00	0.00
0.050	275.6	0.08			275.1	1.57	2.8349		2.7217		0.00	0.00	0.00	0.00
0.010	275.6	0.03			275.6	1.57	2.8487		2.7341		0.00	0.00	0.00	0.00
0.005	275.6	0.01			275.6	1.57	2.8487		2.7341		0.00	0.00	0.00	0.00
0.001	275.6	0.00			275.6	1.57	2.8487		2.7341		0.00	0.00	0.00	0.00
											Annual totals:	**298.3** (tons/yr)	**5.3** (tons/yr)	**303.6** (tons/yr)

Worksheet 5-20a. Bedload and suspended sand bed-material load transport prediction for the upstream reach, using the POWERSED model.

Stream:	**Fourmile Creek, 4f, Scaled33.5, (Riffle)**	Location:	Date: **07/24/15**
Observers:	**Sean Abel, Daniel Aragon**	Stream Type: **C 4b**	Valley Type: **XIII** Gage Station #: **06721500**

Flow-duration curve		Calculate	Hydraulic geometry				Measure	Calculate									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Percentage of time	Daily mean discharge	Mid-ordinate stream-flow	Area	Width	Depth	Velocity	Slope	Shear stress	Stream power	Unit power	Time increment	Time increment	Daily mean bedload transport	Daily mean suspended sand transport	Time adjusted bedload transport **[(13)×(14)]**	Time adjusted suspended sand transport **[(13)×(15)]**	Time adjusted total transport **[(16)+(17)]**
(%)	(cfs)	(cfs)	(ft^2)	(ft)	(ft)	(ft/s)	(ft/ft)	(lb/ft^2)	(lb/s)	(lb/ft/s)	(%)	(days)	(tons/day)	(tons/day)	(tons)	(tons)	(tons)
100.000	**2.17**									**0.00**					**0.00**	**0.00**	**0.00**
90.000	**3.33**	**2.75**	**1.74**	**6.45**	**0.27**	**1.58**	**0.0240**	**0.40**	**4.12**	**0.64**	**10.000**	**36.50**	**0.00**	**0.01**	**0.00**	**0.36**	**0.36**
80.000	**4.21**	**3.77**	**2.22**	**7.41**	**0.30**	**1.69**	**0.0240**	**0.44**	**5.65**	**0.76**	**10.000**	**36.50**	**0.00**	**0.01**	**0.00**	**0.36**	**0.36**
70.000	**4.79**	**4.50**	**2.55**	**8.04**	**0.32**	**1.76**	**0.0240**	**0.47**	**6.74**	**0.84**	**10.000**	**36.50**	**0.00**	**0.02**	**0.00**	**0.73**	**0.73**
60.000	**6.38**	**5.58**	**3.01**	**8.81**	**0.34**	**1.85**	**0.0240**	**0.50**	**8.36**	**0.95**	**10.000**	**36.50**	**0.00**	**0.02**	**0.00**	**0.73**	**0.73**
50.000	**10.59**	**8.48**	**4.02**	**9.72**	**0.41**	**2.10**	**0.0240**	**0.61**	**12.70**	**1.31**	**10.000**	**36.50**	**0.00**	**0.03**	**0.00**	**1.09**	**1.09**
40.000	**16.82**	**13.71**	**5.53**	**10.46**	**0.53**	**2.47**	**0.0240**	**0.77**	**20.53**	**1.96**	**10.000**	**36.50**	**0.00**	**0.05**	**0.00**	**1.83**	**1.83**
30.000	**31.61**	**24.21**	**8.09**	**11.41**	**0.71**	**2.99**	**0.0240**	**1.03**	**36.26**	**3.18**	**10.000**	**36.50**	**0.00**	**0.10**	**0.00**	**3.65**	**3.65**
20.000	**61.63**	**46.62**	**12.39**	**12.05**	**1.03**	**3.76**	**0.0240**	**1.45**	**69.82**	**5.79**	**10.000**	**36.50**	**0.00**	**0.31**	**0.00**	**11.31**	**11.31**
10.000	**106.23**	**83.93**	**19.38**	**15.26**	**1.27**	**4.33**	**0.0240**	**1.80**	**125.69**	**8.24**	**10.000**	**36.50**	**0.04**	**0.77**	**1.46**	**28.11**	**29.57**
5.000	**131.22**	**118.72**	**27.34**	**21.74**	**1.26**	**4.34**	**0.0240**	**1.80**	**177.80**	**8.18**	**5.000**	**18.25**	**0.04**	**1.98**	**0.73**	**36.13**	**36.86**
4.000	**140.22**	**135.72**	**31.57**	**25.63**	**1.23**	**4.30**	**0.0240**	**1.78**	**203.25**	**7.93**	**1.000**	**3.65**	**0.04**	**2.12**	**0.15**	**7.74**	**7.89**
3.000	**149.78**	**145.00**					**0.0240**			**0.00**	**1.000**	**3.65**	**0.00**	**0**	**0.00**	**0.00**	**0.00**
2.000	**158.68**	**154.23**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
1.500	**167.19**	**162.94**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
1.000	**183.86**	**175.53**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.900	**184.59**	**184.23**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.800	**186.18**	**185.38**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.700	**188.79**	**187.49**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.600	**191.61**	**190.20**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.500	**199.48**	**195.55**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.250	**214.03**	**206.75**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.100	**227.43**	**220.73**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.050	**228.38**	**227.91**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.010	**228.38**	**228.38**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.005	**228.38**	**228.38**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.001	**228.38**	**228.38**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
										Total annual sediment yield (bedload and suspended sand bed-material load) (tons/yr):					**2.3**	**91.9**	**94.4**

Worksheet 5-20a. Bedloaded and suspended sand bed-material load transport prediction for the upstream reach, using the POWERSED model.

Stream:	Fourmile Creek, 4d, XS1_StepCrest, (Riffle)							Location:								Date:	07/24/15
Observers:	Sean Abel, Daniel Aragon					Stream Type:	B 4			Valley Type:	XIII		Gage Station #:	06721500			
Flow-duration curve		**Calculate**	**Hydraulic geometry**				**Measure**	**Calculate**									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Percentage of time	Daily mean discharge	Mid-ordinate stream-flow	Area	Width	Depth	Velocity	Slope	Shear stress	Stream power	Unit power	Time increment	Time increment	Daily mean bedload transport	Daily mean suspended sand transport	Time adjusted bedload transport **[(13)×(14)]**	Time adjusted suspended sand transport **[(13)×(15)]**	Time adjusted total transport **[(16)+(17)]**
(%)	(cfs)	(cfs)	(ft^2)	(ft)	(ft)	(ft/s)	(ft/ft)	(lb/ft^2)	(lb/s)	(lb/ft/s)	(%)	(days)	(tons/day)	(tons/day)	(tons)	(tons)	(tons)
100.000	2.40									0.00					0.00	0.00	0.00
90.000	3.68	3.04	1.69	5.99	0.28	1.80	0.0240	0.36	4.55	0.76	10.000	36.50	0.00	0.01	0.00	0.36	0.36
80.000	4.64	4.16	2.12	6.69	0.32	1.95	0.0240	0.41	6.23	0.93	10.000	36.50	0.00	0.02	0.00	0.73	0.73
70.000	5.28	4.96	2.45	7.37	0.33	2.02	0.0240	0.43	7.43	1.01	10.000	36.50	0.00	0.02	0.00	0.73	0.73
60.000	7.04	6.16	2.99	8.93	0.33	2.06	0.0240	0.44	9.23	1.03	10.000	36.50	0.00	0.02	0.00	0.73	0.73
50.000	11.68	9.36	4.04	10.18	0.40	2.31	0.0240	0.53	14.02	1.38	10.000	36.50	0.00	0.04	0.00	1.46	1.46
40.000	18.56	15.12	5.63	11.50	0.49	2.67	0.0240	0.65	22.64	1.97	10.000	36.50	0.00	0.06	0.00	2.19	2.19
30.000	34.88	26.72	8.06	11.82	0.68	3.31	0.0240	0.90	40.02	3.39	10.000	36.50	0.00	0.12	0.00	4.38	4.38
20.000	68.01	51.45	12.26	12.35	0.99	4.19	0.0240	1.28	77.05	6.24	10.000	36.50	0.00	0.38	0.00	13.87	13.87
10.000	117.23	92.62	18.51	14.24	1.30	5.00	0.0240	1.67	138.71	9.74	10.000	36.50	0.04	1.73	1.46	63.14	64.60
5.000	144.82	131.03	25.06	18.61	1.35	5.23	0.0240	1.78	196.23	10.54	5.000	18.25	0.09	4.98	1.64	90.89	92.53
4.000	154.74	149.78	28.26	20.76	1.36	5.30	0.0240	1.82	224.31	10.80	1.000	3.65	0.13	6.64	0.47	24.24	24.71
3.000	165.30	160.02	30.74	23.47	1.31	5.21	0.0240	1.77	239.65	10.21	1.000	3.65	0.09	4.8	0.33	17.52	17.85
2.000	175.12	170.21					0.0240			0.00					0.00	0.00	0.00
1.500	184.50	179.81					0.0240			0.00					0.00	0.00	0.00
1.000	202.90	193.70					0.0240			0.00					0.00	0.00	0.00
0.900	203.71	203.31					0.0240			0.00					0.00	0.00	0.00
0.800	205.47	204.59					0.0240			0.00					0.00	0.00	0.00
0.700	208.35	206.91					0.0240			0.00					0.00	0.00	0.00
0.600	211.46	209.91					0.0240			0.00					0.00	0.00	0.00
0.500	220.14	215.80					0.0240			0.00					0.00	0.00	0.00
0.250	236.20	228.17					0.0240			0.00					0.00	0.00	0.00
0.100	250.98	243.59					0.0240			0.00					0.00	0.00	0.00
0.050	252.03	251.50					0.0240			0.00					0.00	0.00	0.00
0.010	252.03	252.03					0.0240			0.00					0.00	0.00	0.00
0.005	252.03	252.03					0.0240			0.00					0.00	0.00	0.00
0.001	252.03	252.03					0.0240			0.00					0.00	0.00	0.00
										Total annual sediment yield (bedload and suspended sand bed-material load) (tons/yr):					3.9	220.2	224.2

Worksheet 5-20a. Bedload and suspended sand bed-material load transport prediction for the upstream reach, using the POWERSED model.

Stream: **Fourmile Creek, 4b, Scaled37.1, (Riffle)**	Location:	Date: **01/27/16**
Observers:	Stream Type:	Valley Type: **XIII** Gage Station #: **06721500**

Flow-duration curve		Calculate	Hydraulic geometry				Measure	Calculate									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Percentage of time	Daily mean discharge	Mid-ordinate stream-flow	Area	Width	Depth	Velocity	Slope	Shear stress	Stream power	Unit power	Time increment	Time increment	Daily mean bedload transport	Daily mean suspended sand transport	Time adjusted bedload transport **[(13)×(14)]**	Time adjusted suspended sand transport **[(13)×(15)]**	Time adjusted total transport **[(16)+(17)]**
(%)	(cfs)	(cfs)	(ft^2)	(ft)	(ft)	(ft/s)	(ft/ft)	(lb/ft^2)	(lb/s)	(lb/ft/s)	(%)	(days)	(tons/day)	(tons/day)	(tons)	(tons)	(tons)
100.000	**2.63**									**0.00**					**0.00**	**0.00**	**0.00**
90.000	**4.03**	**3.33**	**1.92**	**6.70**	**0.29**	**1.72**	**0.0240**	**0.42**	**4.99**	**0.74**	**10.000**	**36.50**	**0.00**	**0.01**	**0.00**	**0.36**	**0.36**
80.000	**5.08**	**4.55**	**2.46**	**7.77**	**0.32**	**1.85**	**0.0240**	**0.47**	**6.81**	**0.88**	**10.000**	**36.50**	**0.00**	**0.02**	**0.00**	**0.73**	**0.73**
70.000	**5.78**	**5.43**	**2.81**	**8.36**	**0.34**	**1.92**	**0.0240**	**0.50**	**8.13**	**0.97**	**10.000**	**36.50**	**0.00**	**0.02**	**0.00**	**0.73**	**0.73**
60.000	**7.70**	**6.74**	**3.32**	**9.17**	**0.36**	**2.03**	**0.0240**	**0.53**	**10.09**	**1.10**	**10.000**	**36.50**	**0.00**	**0.03**	**0.00**	**1.09**	**1.09**
50.000	**12.78**	**10.24**	**4.45**	**10.24**	**0.43**	**2.29**	**0.0240**	**0.64**	**15.34**	**1.50**	**10.000**	**36.50**	**0.00**	**0.04**	**0.00**	**1.46**	**1.46**
40.000	**20.30**	**16.54**	**6.13**	**10.99**	**0.56**	**2.69**	**0.0240**	**0.82**	**24.77**	**2.25**	**10.000**	**36.50**	**0.00**	**0.07**	**0.00**	**2.56**	**2.56**
30.000	**38.15**	**29.23**	**8.97**	**12.04**	**0.75**	**3.25**	**0.0240**	**1.08**	**43.77**	**3.64**	**10.000**	**36.50**	**0.00**	**0.15**	**0.00**	**5.47**	**5.47**
20.000	**74.38**	**56.27**	**13.72**	**12.68**	**1.08**	**4.10**	**0.0240**	**1.53**	**84.27**	**6.65**	**10.000**	**36.50**	**0.00**	**0.47**	**0.00**	**17.15**	**17.15**
10.000	**128.21**	**101.30**	**21.50**	**16.13**	**1.33**	**4.71**	**0.0240**	**1.89**	**151.71**	**9.41**	**10.000**	**36.50**	**0.13**	**1.15**	**4.75**	**41.97**	**46.72**
5.000	**158.38**	**143.30**	**30.25**	**22.81**	**1.33**	**4.74**	**0.0240**	**1.90**	**214.61**	**9.41**	**5.000**	**18.25**	**0.13**	**1.63**	**2.37**	**29.75**	**32.12**
4.000	**169.24**	**163.81**	**34.97**	**26.98**	**1.30**	**4.68**	**0.0240**	**1.87**	**245.32**	**9.09**	**1.000**	**3.65**	**0.04**	**3.22**	**0.15**	**11.75**	**11.90**
3.000	**180.78**	**175.01**	**37.35**	**28.86**	**1.29**	**4.69**	**0.0240**	**1.87**	**262.10**	**9.08**	**1.000**	**3.65**	**0.04**	**3.44**	**0.15**	**12.56**	**12.71**
2.000	**191.53**	**186.16**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
1.500	**201.79**	**196.66**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
1.000	**221.91**	**211.85**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.900	**222.79**	**222.35**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.800	**224.71**	**223.75**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.700	**227.86**	**226.29**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.600	**231.27**	**229.56**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.500	**240.76**	**236.01**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.250	**258.32**	**249.54**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.100	**274.50**	**266.41**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.050	**275.64**	**275.07**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.010	**275.64**	**275.64**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.005	**275.64**	**275.64**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
0.001	**275.64**	**275.64**					**0.0240**			**0.00**					**0.00**	**0.00**	**0.00**
										Total annual sediment yield (bedload and suspended sand bed-material load) (tons/yr):					**7.4**	**125.8**	**133.0**

Worksheet 5-20b. Bedload and suspended sand bed-material load transport prediction for the potentially impaired reach, using the POWERSED model.

Stream: **Fourmile Creek, 4f, Riffle Reach 1, (Riffle)** Location: Date: **07/24/15**

Observers: **Sean Abel, Daniel Aragon** Stream Type: **C 4b** Valley Type: **XIII** Gage Station #: **06721500**

Flow-duration curve		Calculate	Hydraulic geometry				Measure	Calculate									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Percentage of time	Daily mean discharge	Mid-ordinate stream-flow	Area	Width	Depth	Velocity	Slope	Shear stress	Stream power	Unit power	Time increment	Time increment	Daily mean bedload transport	Daily mean suspended sand transport	Time adjusted bedload transport **[(13)×(14)]**	Time adjusted suspended sand transport **[(13)×(15)]**	Time adjusted total transport **[(16)+(17)]**
(%)	(cfs)	(cfs)	(ft^2)	(ft)	(ft)	(ft/s)	(ft/ft)	(lb/ft^2)	(lb/s)	(lb/ft/s)	(%)	(days)	(tons/day)	(tons/day)	(tons)	(tons)	(tons)
100.000	**2.17**								**0.00**						**0.00**	**0.00**	**0.00**
90.000	**3.33**	**2.75**	**1.64**	**7.73**	**0.21**	**1.65**	**0.0344**	**0.45**	**5.90**	**0.76**	**10.000**	**36.50**	**0.00**	**0.01**	**0.00**	**0.36**	**0.36**
80.000	**4.21**	**3.77**	**2.01**	**8.04**	**0.25**	**1.84**	**0.0344**	**0.53**	**8.09**	**1.01**	**10.000**	**36.50**	**0.00**	**0.01**	**0.00**	**0.36**	**0.36**
70.000	**4.79**	**4.50**	**2.27**	**8.25**	**0.28**	**1.95**	**0.0344**	**0.59**	**9.66**	**1.17**	**10.000**	**36.50**	**0.00**	**0.02**	**0.00**	**0.73**	**0.73**
60.000	**6.38**	**5.58**	**2.63**	**8.54**	**0.31**	**2.12**	**0.0344**	**0.65**	**11.98**	**1.40**	**10.000**	**36.50**	**0.00**	**0.02**	**0.00**	**0.73**	**0.73**
50.000	**10.59**	**8.48**	**3.49**	**9.19**	**0.38**	**2.43**	**0.0344**	**0.81**	**18.20**	**1.98**	**10.000**	**36.50**	**0.00**	**0.03**	**0.00**	**1.09**	**1.09**
40.000	**16.82**	**13.71**	**4.83**	**10.11**	**0.48**	**2.82**	**0.0344**	**1.01**	**29.43**	**2.91**	**10.000**	**36.50**	**0.00**	**0.05**	**0.00**	**1.83**	**1.83**
30.000	**31.61**	**24.21**	**8.14**	**15.90**	**0.51**	**2.97**	**0.0344**	**1.08**	**51.97**	**3.27**	**10.000**	**36.50**	**0.00**	**0.10**	**0.00**	**3.65**	**3.65**
20.000	**61.63**	**46.62**	**12.59**	**17.63**	**0.71**	**3.70**	**0.0344**	**1.51**	**100.07**	**5.68**	**10.000**	**36.50**	**0.00**	**0.31**	**0.00**	**11.31**	**11.31**
10.000	**106.23**	**83.93**	**18.80**	**19.81**	**0.95**	**4.46**	**0.0344**	**2.00**	**180.16**	**9.09**	**10.000**	**36.50**	**0.09**	**0.84**	**3.28**	**30.66**	**33.94**
5.000	**131.22**	**118.72**	**23.90**	**21.42**	**1.12**	**4.96**	**0.0344**	**2.34**	**254.84**	**11.90**	**5.000**	**18.25**	**0.26**	**1.52**	**4.75**	**27.74**	**32.49**
4.000	**140.22**	**135.72**	**26.25**	**22.13**	**1.19**	**5.17**	**0.0344**	**2.49**	**291.33**	**13.16**	**1.000**	**3.65**	**0.35**	**1.90**	**1.28**	**6.93**	**8.21**
3.000	**149.78**	**145.00**	**27.50**	**22.50**	**1.22**	**5.27**	**0.0344**	**2.57**	**311.25**	**13.83**	**1.000**	**3.65**	**0.43**	**2.13**	**1.57**	**7.77**	**9.34**
2.000	**158.68**	**154.23**					**0.0344**		**0.00**						**0.00**	**0.00**	**0.00**
1.500	**167.19**	**162.94**					**0.0344**		**0.00**						**0.00**	**0.00**	**0.00**
1.000	**183.86**	**175.53**					**0.0344**		**0.00**						**0.00**	**0.00**	**0.00**
0.900	**184.59**	**184.23**					**0.0344**		**0.00**						**0.00**	**0.00**	**0.00**
0.800	**186.18**	**185.38**					**0.0344**		**0.00**						**0.00**	**0.00**	**0.00**
0.700	**188.79**	**187.49**					**0.0344**		**0.00**						**0.00**	**0.00**	**0.00**
0.600	**191.61**	**190.20**					**0.0344**		**0.00**						**0.00**	**0.00**	**0.00**
0.500	**199.48**	**195.55**					**0.0344**		**0.00**						**0.00**	**0.00**	**0.00**
0.250	**214.03**	**206.75**					**0.0344**		**0.00**						**0.00**	**0.00**	**0.00**
0.100	**227.43**	**220.73**					**0.0344**		**0.00**						**0.00**	**0.00**	**0.00**
0.050	**228.38**	**227.91**					**0.0344**		**0.00**						**0.00**	**0.00**	**0.00**
0.010	**228.38**	**228.38**					**0.0344**		**0.00**						**0.00**	**0.00**	**0.00**
0.005	**228.38**	**228.38**					**0.0344**		**0.00**						**0.00**	**0.00**	**0.00**
0.001	**228.38**	**228.38**					**0.0344**		**0.00**						**0.00**	**0.00**	**0.00**

Notes:

	(16)	(17)	(18)
Total annual sediment yield (bedload and suspended sand bed-material load) (tons/yr):	**11.0**	**93.1**	**103.9**
Upstream total annual sediment comparative reach (tons/yr) (**WS 5-20a**):	**2.3**	**92.0**	**94.3**
Difference in sediment transport capacity (tons/yr) (+ or -):	**8.7**	**1.1**	**9.6**
Stability evaluation: Aggradation, Degradation or Stable:			

Worksheet 5-20b. Bedload and suspended sand bed-material load transport prediction for the potentially impaired reach, using the POWERSED model.

Stream: **Fourmile Creek, 4d, Riffle Reach 2, (Riffle)** Location: Date: **07/24/15**

Observers: **Sean Abel, Daniel Aragon** Stream Type: **B 4** Valley Type: **XIII** Gage Station #: **06721500**

Flow-duration curve		Calculate	Hydraulic geometry				Measure	Calculate									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Percentage of time	Daily mean discharge	Mid-ordinate stream-flow	Area	Width	Depth	Velocity	Slope	Shear stress	Stream power	Unit power	Time increment	Time increment	Daily mean bedload transport	Daily mean suspended sand transport	Time adjusted bedload transport **[(13)×(14)]**	Time adjusted suspended sand transport **[(13)×(15)]**	Time adjusted total transport **[(16)+(17)]**
(%)	(cfs)	(cfs)	(ft^2)	(ft)	(ft)	(ft/s)	(ft/ft)	(lb/ft^2)	(lb/s)	(lb/ft/s)	(%)	(days)	(tons/day)	(tons/day)	(tons)	(tons)	(tons)
100.000	**2.40**								**0.00**						**0.00**	**0.00**	**0.00**
90.000	**3.68**	**3.04**	**1.75**	**7.83**	**0.22**	**1.73**	**0.0390**	**0.54**	**7.40**	**0.95**	**10.000**	**36.50**	**0.00**	**0.01**	**0.00**	**0.36**	**0.36**
80.000	**4.64**	**4.16**	**2.13**	**8.14**	**0.26**	**1.91**	**0.0390**	**0.63**	**10.12**	**1.24**	**10.000**	**36.50**	**0.00**	**0.02**	**0.00**	**0.73**	**0.73**
70.000	**5.28**	**4.96**	**2.41**	**8.36**	**0.29**	**2.04**	**0.0390**	**0.69**	**12.07**	**1.44**	**10.000**	**36.50**	**0.00**	**0.02**	**0.00**	**0.73**	**0.73**
60.000	**7.04**	**6.16**	**2.78**	**8.66**	**0.32**	**2.20**	**0.0390**	**0.77**	**14.99**	**1.73**	**10.000**	**36.50**	**0.00**	**0.02**	**0.00**	**0.73**	**0.73**
50.000	**11.68**	**9.36**	**3.69**	**9.33**	**0.40**	**2.52**	**0.0390**	**0.95**	**22.78**	**2.44**	**10.000**	**36.50**	**0.00**	**0.04**	**0.00**	**1.46**	**1.46**
40.000	**18.57**	**15.13**	**5.13**	**10.31**	**0.50**	**2.94**	**0.0390**	**1.19**	**36.82**	**3.57**	**10.000**	**36.50**	**0.00**	**0.07**	**0.00**	**2.56**	**2.56**
30.000	**34.89**	**26.73**	**8.49**	**15.48**	**0.55**	**3.14**	**0.0390**	**1.32**	**65.05**	**4.20**	**10.000**	**36.50**	**0.00**	**0.14**	**0.00**	**5.11**	**5.11**
20.000	**68.02**	**51.45**	**13.19**	**17.34**	**0.76**	**3.90**	**0.0390**	**1.82**	**125.21**	**7.22**	**10.000**	**36.50**	**0.00**	**0.54**	**0.00**	**19.71**	**19.71**
10.000	**117.25**	**92.63**	**19.76**	**19.64**	**1.01**	**4.68**	**0.0390**	**2.40**	**225.42**	**11.48**	**10.000**	**36.50**	**0.17**	**2.24**	**6.21**	**81.76**	**87.97**
5.000	**144.84**	**131.05**	**25.18**	**21.37**	**1.18**	**5.20**	**0.0390**	**2.80**	**318.92**	**14.92**	**5.000**	**18.25**	**0.52**	**4.62**	**9.49**	**84.31**	**93.80**
4.000	**154.76**	**149.80**	**27.67**	**22.11**	**1.25**	**5.41**	**0.0390**	**2.97**	**364.55**	**16.49**	**1.000**	**3.65**	**0.78**	**6.04**	**2.85**	**22.05**	**24.90**
3.000	**165.32**	**160.04**	**29.00**	**22.50**	**1.29**	**5.52**	**0.0390**	**3.06**	**389.47**	**17.31**	**1.000**	**3.65**	**0.91**	**6.88**	**3.32**	**25.11**	**28.43**
2.000	**175.14**	**170.23**					**0.0390**		**0.00**						**0.00**	**0.00**	**0.00**
1.500	**184.53**	**179.83**					**0.0390**		**0.00**						**0.00**	**0.00**	**0.00**
1.000	**202.93**	**193.73**					**0.0390**		**0.00**						**0.00**	**0.00**	**0.00**
0.900	**203.73**	**203.33**					**0.0390**		**0.00**						**0.00**	**0.00**	**0.00**
0.800	**205.49**	**204.61**					**0.0390**		**0.00**						**0.00**	**0.00**	**0.00**
0.700	**208.37**	**206.93**					**0.0390**		**0.00**						**0.00**	**0.00**	**0.00**
0.600	**211.49**	**209.93**					**0.0390**		**0.00**						**0.00**	**0.00**	**0.00**
0.500	**220.17**	**215.83**					**0.0390**		**0.00**						**0.00**	**0.00**	**0.00**
0.250	**236.23**	**228.20**					**0.0390**		**0.00**						**0.00**	**0.00**	**0.00**
0.100	**251.02**	**243.63**					**0.0390**		**0.00**						**0.00**	**0.00**	**0.00**
0.050	**252.06**	**251.54**					**0.0390**		**0.00**						**0.00**	**0.00**	**0.00**
0.010	**252.06**	**252.06**					**0.0390**		**0.00**						**0.00**	**0.00**	**0.00**
0.005	**252.06**	**252.06**					**0.0390**		**0.00**						**0.00**	**0.00**	**0.00**
0.001	**252.06**	**252.06**					**0.0390**		**0.00**						**0.00**	**0.00**	**0.00**

Notes:

	(16)	(17)	(18)
Total annual sediment yield (bedload and suspended sand bed-material load) (tons/yr):	**21.9**	**244.7**	**266.5**
Upstream total annual sediment comparative reach (tons/yr) (**WS 5-20a**):	**3.9**	**220.2**	**224.1**
Difference in sediment transport capacity (tons/yr) (+ or -):	**18.0**	**24.5**	**42.4**
Stability evaluation: Aggradation, Degradation or Stable:			

Worksheet 5-20b. Bedload and suspended sand bed-material load transport prediction for the potentially impaired reach, using the POWERSED model.

Stream: **Fourmile Creek, 4b, Riffle Reach 3, (Riffle)** Location: Date: **01/27/16**

Observers: Stream Type: Valley Type: **XIII** Gage Station #: **06721500**

Flow-duration curve		Calculate	Hydraulic geometry				Measure	Calculate									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Percentage of time	Daily mean discharge	Mid-ordinate stream-flow	Area	Width	Depth	Velocity	Slope	Shear stress	Stream power	Unit power	Time increment	Time increment	Daily mean bedload transport	Daily mean suspended sand transport	Time adjusted bedload transport **[(13)×(14)]**	Time adjusted suspended sand transport **[(13)×(15)]**	Time adjusted total transport **[(16)+(17)]**
(%)	(cfs)	(cfs)	(ft^2)	(ft)	(ft)	(ft/s)	(ft/ft)	(lb/ft^2)	(lb/s)	(lb/ft/s)	(%)	(days)	(tons/day)	(tons/day)	(tons)	(tons)	(tons)
100.000	**2.63**								**0.00**						**0.00**	**0.00**	**0.00**
90.000	**4.03**	**3.33**	**1.99**	**8.65**	**0.23**	**1.67**	**0.0319**	**0.45**	**6.63**	**0.77**	**10.000**	**36.50**	**0.00**	**0.01**	**0.00**	**0.36**	**0.36**
80.000	**5.08**	**4.55**	**2.42**	**8.92**	**0.27**	**1.85**	**0.0319**	**0.54**	**9.06**	**1.02**	**10.000**	**36.50**	**0.00**	**0.02**	**0.00**	**0.73**	**0.73**
70.000	**5.78**	**5.43**	**2.72**	**9.11**	**0.30**	**1.98**	**0.0319**	**0.59**	**10.81**	**1.19**	**10.000**	**36.50**	**0.00**	**0.02**	**0.00**	**0.73**	**0.73**
60.000	**7.70**	**6.74**	**3.14**	**9.37**	**0.34**	**2.13**	**0.0319**	**0.66**	**13.42**	**1.43**	**10.000**	**36.50**	**0.00**	**0.03**	**0.00**	**1.09**	**1.09**
50.000	**12.78**	**10.24**	**4.14**	**9.96**	**0.42**	**2.46**	**0.0319**	**0.82**	**20.38**	**2.05**	**10.000**	**36.50**	**0.00**	**0.05**	**0.00**	**1.83**	**1.83**
40.000	**20.30**	**16.54**	**5.73**	**10.83**	**0.53**	**2.88**	**0.0319**	**1.03**	**32.92**	**3.04**	**10.000**	**36.50**	**0.00**	**0.08**	**0.00**	**2.92**	**2.92**
30.000	**38.15**	**29.23**	**9.56**	**16.65**	**0.57**	**3.05**	**0.0319**	**1.12**	**58.18**	**3.49**	**10.000**	**36.50**	**0.00**	**0.15**	**0.00**	**5.47**	**5.47**
20.000	**74.38**	**56.27**	**14.82**	**18.59**	**0.80**	**3.79**	**0.0319**	**1.56**	**112.01**	**6.03**	**10.000**	**36.50**	**0.00**	**0.43**	**0.00**	**15.70**	**15.70**
10.000	**128.22**	**101.30**	**22.18**	**21.01**	**1.06**	**4.56**	**0.0319**	**2.06**	**201.64**	**9.60**	**10.000**	**36.50**	**0.17**	**1.18**	**6.21**	**43.07**	**49.28**
5.000	**158.39**	**143.31**	**28.26**	**22.81**	**1.24**	**5.07**	**0.0319**	**2.41**	**285.27**	**12.51**	**5.000**	**18.25**	**0.39**	**2.12**	**7.12**	**38.69**	**45.81**
4.000	**169.24**	**163.81**	**31.04**	**23.59**	**1.32**	**5.27**	**0.0319**	**2.56**	**326.07**	**13.82**	**1.000**	**3.65**	**0.56**	**2.65**	**2.04**	**9.67**	**11.71**
3.000	**180.80**	**175.02**	**35.50**	**30.00**	**1.18**	**4.93**	**0.0319**	**2.31**	**348.39**	**11.61**	**1.000**	**3.65**	**0.30**	**2.41**	**1.09**	**8.80**	**9.89**
2.000	**191.54**	**186.17**					**0.0319**		**0.00**						**0.00**	**0.00**	**0.00**
1.500	**201.80**	**196.67**					**0.0319**		**0.00**						**0.00**	**0.00**	**0.00**
1.000	**221.92**	**211.86**					**0.0319**		**0.00**						**0.00**	**0.00**	**0.00**
0.900	**222.80**	**222.36**					**0.0319**		**0.00**						**0.00**	**0.00**	**0.00**
0.800	**224.73**	**223.76**					**0.0319**		**0.00**						**0.00**	**0.00**	**0.00**
0.700	**227.88**	**226.31**					**0.0319**		**0.00**						**0.00**	**0.00**	**0.00**
0.600	**231.29**	**229.58**					**0.0319**		**0.00**						**0.00**	**0.00**	**0.00**
0.500	**240.78**	**236.03**					**0.0319**		**0.00**						**0.00**	**0.00**	**0.00**
0.250	**258.34**	**249.56**					**0.0319**		**0.00**						**0.00**	**0.00**	**0.00**
0.100	**274.51**	**266.42**					**0.0319**		**0.00**						**0.00**	**0.00**	**0.00**
0.050	**275.66**	**275.09**					**0.0319**		**0.00**						**0.00**	**0.00**	**0.00**
0.010	**275.66**	**275.66**					**0.0319**		**0.00**						**0.00**	**0.00**	**0.00**
0.005	**275.66**	**275.66**					**0.0319**		**0.00**						**0.00**	**0.00**	**0.00**
0.001	**275.66**	**275.66**					**0.0319**		**0.00**						**0.00**	**0.00**	**0.00**

Notes:

	(16)	(17)	(18)
Total annual sediment yield (bedload and suspended sand bed-material load) (tons/yr):	**16.4**	**129.1**	**145.5**
Upstream total annual sediment comparative reach (tons/yr) (**WS 5-20a**):	**7.4**	**125.6**	**133.0**
Difference in sediment transport capacity (tons/yr) (+ or -):	**9.0**	**3.5**	**12.5**
Stability evaluation: Aggradation, Degradation or Stable:			