APPENDIX G

Geomorphology

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Executive Summary

The purpose of this geomorphic assessment was to provide information in support of the Yankee Fork Tributary Assessment that describes (1) the large scale geomorphic processes occurring within the watershed; (2) the basis for delineation of geomorphic reaches within the tributary assessment area; and (3) identifying geomorphic reaches that have the greatest potential for improving geomorphic processes, reconnecting isolated habitats, and improving habitat quantity and quality.

Valley segments and geomorphic reaches were delineated along the Yankee Fork in the middle and lower Yankee Fork subwatersheds; and along lower Jordan Creek in the Jordan Creek subwatershed. The geomorphic reaches were coincident with the valley segments and are located as follows:

- In the middle Yankee Fork subwatershed, three geomorphic reaches were identified (upstream to downstream): (1) Reach YF-6 from RM 16.5 to 13.3; (2) Reach YF-5 from RM 13.3 to 11.7; and (3) Reach YF-4 from RM 11.7 to 9.1.

- In the lower Yankee Fork subwatershed, three geomorphic reaches were identified: (1) Reach YF-3 from RM 9.1 to 6.8; (2) Reach YF-2 from RM 6.8 to 3; and (3) Reach YF-1 from RM 3 to Yankee Fork/Salmon River confluence.

- Two geomorphic reaches were identified in the Jordan Creek subwatershed: (1) Reach JC-2 from RM 4 to 1.4; and (2) Reach JC-1 from RM 1.4 to Yankee Fork/Jordan Creek confluence.

The following are brief summaries of each reach:

- **Yankee Fork Reach YF-6**: Chinook salmon and steelhead use this reach for migration, spawning and rearing. In the late 1800s and early 1900s during the mining boom, timber harvests led to the removal of large wood from the floodplain and valley walls, and may have changed the species assemblage and successional stage (Overton et al. 1999). Other anthropogenic impacts in this reach do not significantly affect geomorphic processes or habitat quantity and quality.

- **Yankee Fork Reach YF-5**: Chinook salmon and steelhead, and other species use this reach primarily as a migratory corridor. The river flows through a V-shaped canyon with a bedrock channel type. There are no anthropogenic impacts that significantly affect geomorphic processes or habitat quantity and quality in this reach.

- **Yankee Fork Reach YF-4**: Chinook salmon and steelhead use this reach for migration, spawning and juvenile rearing. The river flows through a moderately confined valley segment and has a free-formed alluvial channel. Channel/floodplain interactions are occurring in the lower section from RM 10.3 to 9.1. There are localized anthropogenic impacts that are fairly significant to geomorphic processes and habitat quantity and quality that include: (1) small floodplain areas disconnected by a levee and deflection berm, and (2) a bridge crossing near RM 10.9 (General's Bridge) that constricts the channel.

- **Yankee Fork Reach YF-3**: Chinook salmon use this reach for migration, spawning and juvenile rearing, and steelhead use it for migration and juvenile rearing. This reach has been significantly impacted because (1) dredge tailings confine flows to within the Yankee Fork and lower West Fork channels thereby increasing flow velocities to above the 3 ft/s threshold (NOAA Fisheries 2008) which inhibits juvenile upstream fish passage at some biologically significant flows (i.e. spring freshet); (2) dredge tailings disconnect floodplain areas that reduces high water refugia and rearing habitat for juveniles; and (3) imposed channel constraints from dredge tailings have changed the channel structure from an unconfined, meandering-to-island braided alluvial channel to a confined, straight alluvial channel.

- **Yankee Fork Reach YF-2**: Chinook salmon and steelhead use this reach for migration, spawning and juvenile rearing. The most significant anthropogenic impacts are as follows: (1) dredge tailings disconnect perennial tributaries (Jerrys Creek and Silver Creek) from the Yankee Fork mainstem that historically provided juvenile rearing habitat from the Yankee Fork mainstem; and (2) Ramey Creek is connected to the mainstem, but the lower section of the creek has been channelized which may have increased flow velocities to above the 3 ft/s threshold which inhibits juvenile upstream fish passage at some biologically significant flows (i.e. spring freshet). On the Yankee Fork mainstem channel processes and habitat quantity do not appear to have been significantly changed from pre-dredging conditions.

- **Yankee Fork Reach YF-1**: Chinook salmon and steelhead, and other species, use this reach primarily as a migratory corridor. The river flows through a V-shaped canyon with a bedrock channel type. There are anthropogenic impacts from road embankment encroaching on the channel and floodplain, and a bridge crossing that constricts the channel. However, these anthropogenic impacts do not significantly impact geomorphic processes or habitat quantity and quality at the reach-scale.

- **Jordan Creek Reach JC-2**: Chinook salmon use this reach for juvenile rearing, and steelhead use it for spawning and juvenile rearing. The creek flows through a V-shaped bedrock canyon that moderately confines the channel. Anthropogenic impacts include road embankments that encroach on the channel and bridge crossings that constrict the channel, but do not significantly impact geomorphic processes or habitat quantity and quality at the reach-scale.

- **Jordan Creek Reach JC-1**: Chinook salmon and steelhead use this reach primarily for juvenile rearing. The creek flows through a V-shaped alluvial mountain valley that moderately confines the channel. Anthropogenic impacts that affect geomorphic processes and habitat quantity and quality include: (1) mine tailings confining the channel in many locations that impede channel/floodplain interactions; (2) the constructed, confined channel between about RM 0.1 and the Yankee Fork/Jordan Creek confluence may have flow velocities above the 3 ft/s threshold which inhibits juvenile upstream fish passage at some biologically significant flows (i.e. spring freshet); and (3) a grade control structure just upstream of the Jordan Creek Bridge is a juvenile upstream fish passage barrier. The two bridges in this reach do not significantly impact channel processes because they were built in locations where the channel was already constricted by mine tailings near RM 0.9 and RM 0.1.

In conclusion, the geomorphic reaches in order of their potential to improve geomorphic processes and habitat quantity and quality, along with their needs for further assessment are as follows:

1. **Yankee Fork Reach YF-3**: A more detailed reach assessment, potentially involving a more complex hydraulic model, is needed to evaluate current geomorphic and ecologic processes, and to evaluate the overall potential to improve these processes and their benefit and risks to the resource. Large floodplain areas have been disconnected by dredge tailings and the loss of channel/floodplain interactions have reduced available juvenile rearing and high water refugia habitat.

2. **Yankee Fork Reach YF-2**: The Shoshone-Bannock Tribes have worked with consultants and stakeholders on implementing habitat projects in this geomorphic reach. Alternatives should continue to be pursued to reconnect isolated tributaries. In addition, the dredge pond series have the potential to provide additional juvenile rearing habitat that was lost when dredging obliterated the lower sections of some tributaries. Baseline data should be collected prior to any project implementation for monitoring purposes.

3. **Jordan Creek Reach JC-1**: A reach-assessment is not necessary to address the localized anthropogenic impacts in this geomorphic reach. An alternatives analysis could be conducted to address mine tailings that affect channel/floodplain interactions between about RM 1.4 to 0.4, but the feasibility of implementing habitat rehabilitation projects is unlikely while placer mining activities continue. An alternatives analysis should be completed from RM 0.1 to the Yankee

Fork/Jordan Creek confluence to improve juvenile upstream fish passage. Documentation of baseline conditions should be considered as part of all alternatives analysis for monitoring purposes.

4. **Yankee Fork Reach YF-4**: Reach-scale alternatives analysis could be used to address the vegetation structure and assemblage for long-term improvements, and for the short-term address potential modifications to the levee, berm, and bridge crossings, and potential locations for large wood placements. Documentation of baseline conditions should be considered as part of all alternatives analysis for monitoring purposes.

5. **Yankee Fork Reach YF-6**: Active management of timber stands in this reach should be considered to insure proper species assemblage and improve growth rates for long-term recovery. Potential short-term approaches to increase availability of wood to the system could include (1) insuring that wood and sediment inputs from tributaries are not impeded by obstructions (i.e. undersized culverts), and (2) wood loading along the channel and floodplain, with the objective that the anticipated ecologic benefits outweigh the disturbances to the channel or floodplain.

6. **Jordan Creek Reach JC-2**: Reach-scale alternatives analysis could be used to address the road embankments, bridge crossings, and potential locations for large wood placements (or loading). However, there are active mining operations along the creek and a short-term approach using alternatives analysis could be more appropriate.

Yankee Fork Reaches YF-5 and YF-1: These reaches are Chinook salmon and steelhead migratory corridors through confined, bedrock channels. No anthropogenic features negatively impact channel processes at the reach-scale. Therefore, there is no need for further assessment.

1. Introduction

This geomorphic assessment provides scientific information on the geomorphology of the Yankee Fork of the Salmon River watershed in Custer County, Idaho. The Yankee Fork is part of the upper Salmon River basin and flows into the Salmon River near Sunbeam, Idaho, at (Salmon) river mile (RM) 367.1 (USFS 2006; CH2M Hill 2008).

This assessment provides a cursory evaluation of geomorphic processes occurring at the watershed-scale, and it provides a more detailed analysis at the tributary-scale to delineate geomorphic reaches and considers the variability of geomorphic processes that influence channel morphology and habitat structure. The *Tributary Assessment* area covers the Yankee Fork between about RM 3 near Polecamp Flat Campground to RM 16 at the confluence of Eightmile Creek; and Jordan Creek subwatershed, a tributary to the Yankee Fork, from RM 4 to its mouth (Figure 1).

The purpose of this assessment is to provide information on (1) the geomorphic processes occurring within the Yankee Fork River; (2) the delineation of geomorphic reaches within the tributary assessment area; and (3) the relative prioritization of geomorphic reaches based on the potential to improve geomorphic processes. For the purpose of this report, geomorphic process is defined as natural physical action driven largely by flowing water and/or gravity reworking the valley surface by means of a self-regulating balance between erosion and deposition resulting in the formation of distinct landforms, channel forms, and habitat. The information presented in this assessment, in conjunction with other technical analysis conducted for the *Tributary Assessment*, is intended for the use of local stakeholders to develop a comprehensive rehabilitation strategy based on limiting factors to protect and improve survival and steelhead listed under Endangered Species Act (ESA).

The approach used for this geomorphic assessment is predominantly based on the following literature *Process-based Principles for Restoring River Ecosystems* (Beechie et al. 2010), *Hydrogeomorphic Variability and River Restoration* (Montgomery and Bolton 2003), *Channel Processes, Classification, and Response* (Montgomery and Buffington 1998), and the *Monitoring Strategy for the Upper Columbia Basin* (Hillman 2006). Results are presented to capture the spatial and temporal variability of geomorphic processes occurring within the *Tributary Assessment* area.

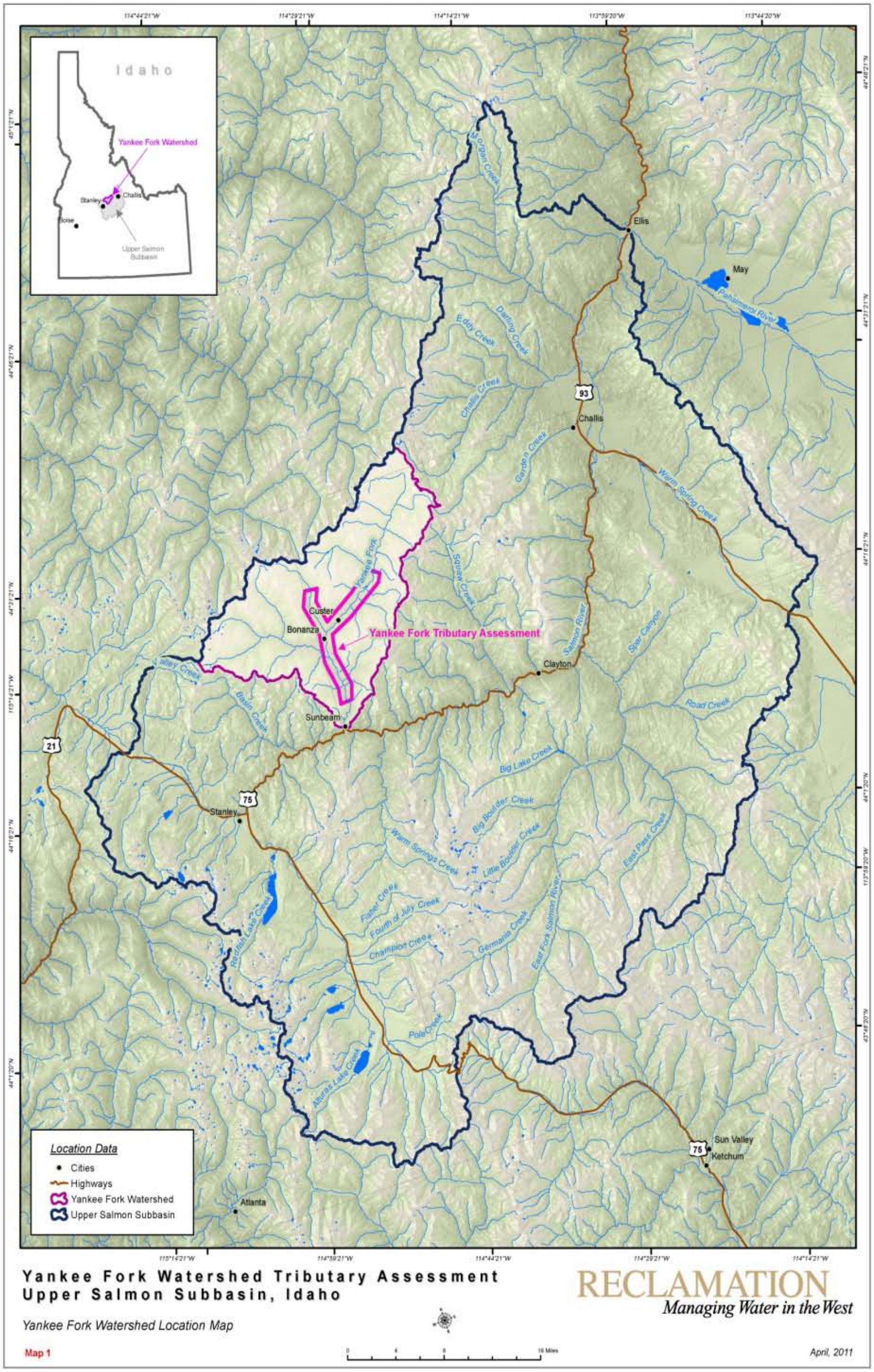

Figure 1. Location of Yankee Fork Tributary Assessment Area in the upper Salmon Subbasin.

2. Assessment Methods

Valley segments were delineated based on the geology, and the classification of valley form (shape), valley type, and valley confinement as follows:

- Bedrock types were broadly classified as igneous, metamorphic or sedimentary; and were further subclassified based on similar rock types and origins that are fault-bounded blocks and markedly different from their adjoining neighbors, generally known as geologic terranes.

- Valley forms were classified based on the cross section of the valley using Naiman et al. (1992) classification system as recommended by Hillman (2006). The valley form is controlled by the geology and geologic history of the valley. Valley shape is influenced by erosion which is largely driven by climatic factors.

- Valley types were classified based on Bisson, Buffington, and Montgomery (2006) classification system. Valley types are colluvial, bedrock, and alluvial depending on valley fill, sediment transport processes, channel transport capacity, and sediment supply.

- Valley confinement was classified based on the ratio between constrained valley width and channel width. Valley floor widths measured from valley wall to valley wall were not used to define valley confinement because the valley walls do not necessarily represent the geomorphic channel constraints for a given reach. The constrained valley width essentially represents the "modern floodplain" and is based on the reach-averaged width between lateral geomorphic controls including erosion-resistant glacial, lake, and alluvial fan deposits, bedrock, and anthropogenic influences (i.e. armored road embankments). Unconfined segments have a ratio greater than 4:1; moderately confined segments were between 4:1 and 2:1; and confined segments had less than 2:1 (Hillman 2006).

Valley segment characteristics influence the overall channel patterns and channel types in a natural system, but in disturbed systems these may change within the valley segment due to anthropogenic disturbances. Channel patterns and channel types were classified and used to detect changes in channel/floodplain interactions caused by disturbances that affect sediment transport capacity and lateral channel migration.

Channel patterns provide a means to interpret the relative rate of lateral channel migration. Beechie et al. (2006) have classified four primary channel pattern types (recognizing there is a continuum between channel patterns) and their implications to lateral channel migration rates. The following is a summary of their channel pattern classifications in order of their increasing lateral channel migration rates:

- Straight – primarily a single thread channel with a sinuosity of less than 1.5
- Meandering – primarily a single thread channel with a sinuosity of greater than 1.5
- Island-braided – multiple channels that are mainly separated by vegetated islands
- Braided – multiple channels that are mainly separated by unvegetated gravel bars

Channel types provide a means of interpreting what channel changes, if any, have occurred overtime due to changes in sediment transport capacity and lateral channel migration. Montgomery and Buffington (1998) have classified four primary channel types, also recognizing there is a continuum between channel types. The following is a summary of their channel type classifications:

- Colluvial channel – channels that typically occupy headwater portions of a channel network and occur where drainage areas are large enough to sustain a channel for the local ground slope
- Bedrock channel – channels with very little alluvial bed material or valley fill, and are generally confined by valley walls and lack floodplains
- Free-formed alluvial channel – alluvial channels that exhibit a wide variety of bed morphologies and roughness configurations that vary with slope and position; channels can be further defined by channel bed-form; cascade, step-pool, plane-bed, pool-riffle, or dune-ripple
- Forced alluvial channel – channels with external flow obstructions, such as large wood, wood complexes and bedrock outcrops, that force local flow convergence, divergence, and sediment impoundment that form pools, bars, and steps

3. Yankee Fork Watershed

3.1 Characteristics

The Yankee Fork watershed is located within the Pacific Northwest Region 1st field hydrologic unit code (HUC) 17, lower Snake subregion (2nd field HUC 1706), Salmon River basin (3rd field HUC 170602), and the upper Salmon subbasin (4th field HUC 17060201). The Yankee Fork watershed (5th field HUC 1706020105) is divided into five 6th field HUC subwatersheds including the upper Yankee Fork, middle Yankee Fork, lower Yankee Fork, Jordan Creek, and West Fork (Figure 2).

The watershed has a dendritic drainage pattern, draining about 190 square miles, and has a drainage density of about 2.71 which is a measure of the amount of stream network necessary to drain the basin. There is an estimated 223.6 miles of perennial stream and

291.3 miles of ephemeral streams within the basin (USFS 2006). Basin relief is about 4,417 feet with a maximum elevation of about 10,329 feet at The General peak and a minimum elevation of about 5,912 feet at the confluence with the Salmon River.

Location of the *Tributary Assessment* area is along the mainstem middle Yankee Fork subwatershed between RM 16.3 and 9.1; most of the mainstem in lower Yankee Fork subwatershed between RM 9.1 and 4.0; and lower Jordan Creek between RM 4.0 and its mouth (Figure 2).

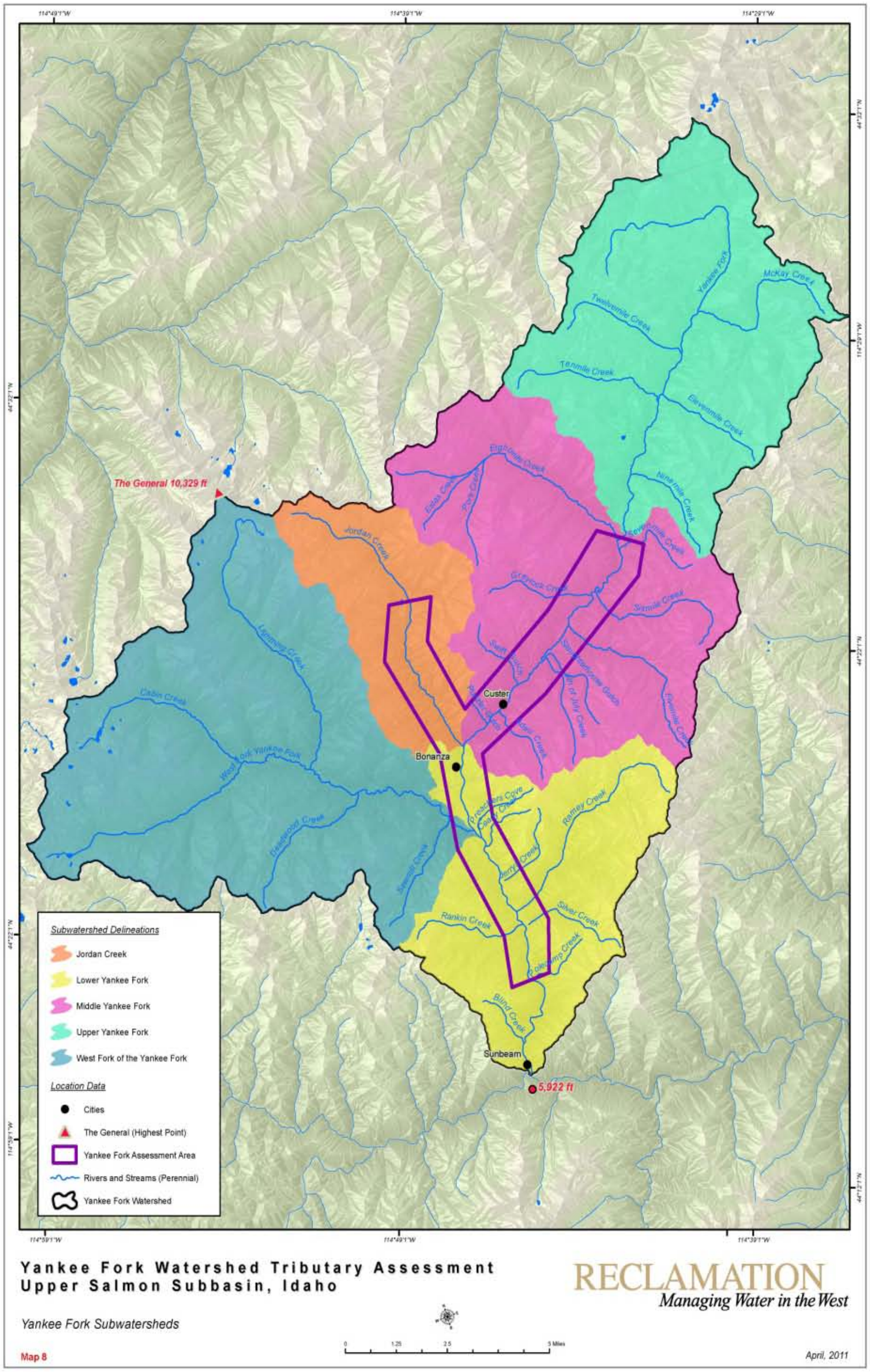

Figure 2. Yankee Fork Hydrologic Unit Code (HUC) 6th field subwatersheds. *The map also shows the location of the tributary assessment area with respect to the watershed and subwatersheds.*

3.2 Bedrock and Glacial Geology

Most of the Yankee Fork watershed (upper Yankee Fork, middle Yankee Fork, Jordan Creek and West Yankee Fork subwatersheds) is within the Challis Volcanics that are comprised predominantly of extrusive lava flows, welded tuffs and volcaniclastic deposits. In the lower Yankee Fork subwatershed there are plutonic rocks of the Idaho batholith, and sedimentary and metasedimentary rocks of Paleozoic and Precambrian formations.

Cutting across the watershed is the Trans-Challis fault zone that trends northeast and, to varying degrees, has displaced all bedrock geologic units. This fault zone had a controlling effect on the location of volcanic features within the watershed that formed during the Challis Volcanics. The location and alignment of some of these volcanic features include the Twin Peaks caldera and Custer graben that influence the drainage pattern and location of the Yankee Fork. The Yankee Fork originates within the Twin Peaks caldera and then flows along the southeast bounding fault of the Custer graben for most of its length.

There has been a minimum of two alpine glaciations in the Yankee Fork watershed during the Pleistocene; the Potholes glaciation about 20 thousand years ago (ka), and the Copper Basin glaciations about 140 ka (Mackin and Schmidt 1956; William 1961; Evenson et al. 1982; Borgert, Lundeen and Thackray 1999). The alpine glaciers have eroded parts of the watershed sculpting U-shaped valleys, and constructing terraces and broad outwash plains. In the broad glacially carved valleys of the Yankee Fork, West Fork Yankee Fork, Jordan Creek, and Eightmile Creek the modern streams are “underfit” in that they do not possess the necessary streampower to completely rework the valley bottoms filled with the Pleistocene-age alluvium.

Analysis of the Yankee Fork longitudinal channel profile (Figure 3) shows the channel slope is steepest in the upper headwater area and then progressively decreases in gradient in the downstream direction. There are three prominent perturbations along the channel slope that are controlled by geologic processes. The slope deviation between about RM 28 and 25 in the upper Yankee Fork is the basal section of a glacial cirque, which was excavated by alpine glaciers. Between about RM 15 and 12 in the middle Yankee Fork the change in slope is the result of a landslide deposit that blocked the river, impounding a lake until the river was able to incise through the deposit. Finally, the steepening of slope between RM 3 and 0 in the lower Yankee Fork is related to river incision most likely associated with the Idaho batholith uplift and base-level change along the mainstem Salmon River creating a V-shaped canyon.

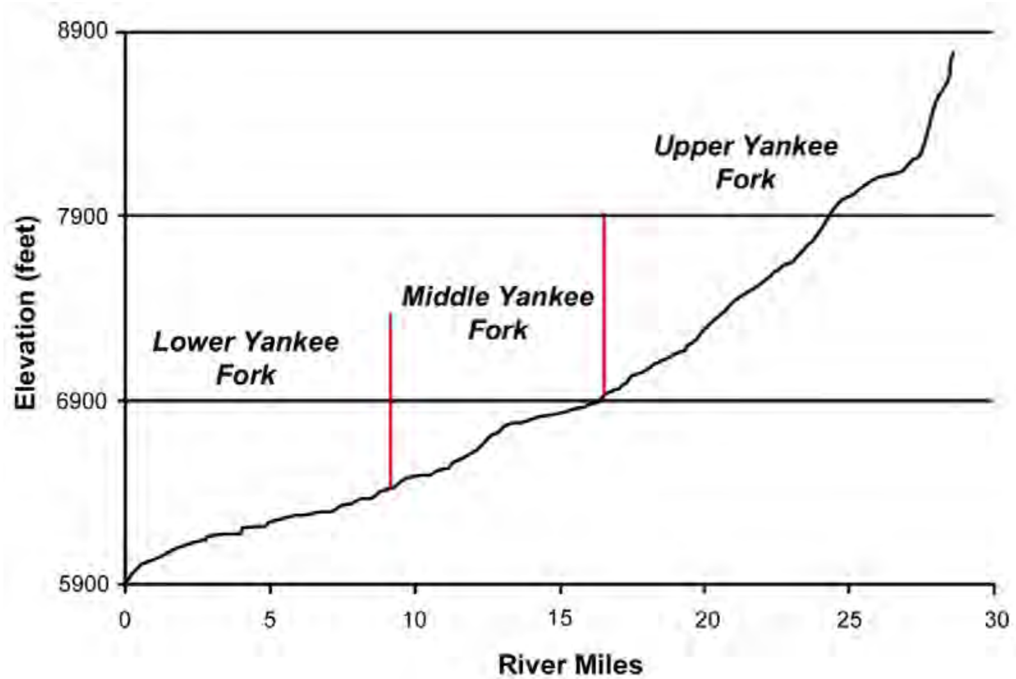

Figure 3. Yankee Fork longitudinal channel profile showing subwatershed location.

Jordan Creek's longitudinal channel profile (Figure 4) shows that the channel is steepest in the headwater area and then progressively decreases in gradient in the downstream direction. Perturbations along the channel slope are controlled by geologic processes. The steep channel slope between RM 8 and 6.4 and flatter slope between RM 6.4 and 4 resulted from the erosion of alpine glaciers. Glaciers that formed in the steeper section (RM 8-6.4) eroded a steep-walled recess (cirque) and then flowed down the valley carving a U-shaped trough (RM 6.4-4). The stream has been eroding through the Challis Volcanics creating a V-shaped bedrock canyon from RM 4 to 1.4, and depositing alluvium between about RM 1.4 and the Yankee Fork confluence. "Knick-points" along the channel profile near RM 4 is due to a shallow slide from river right that constricted the channel, and near RM 1.4 is due to a prominent alluvial fan constraining from river left.

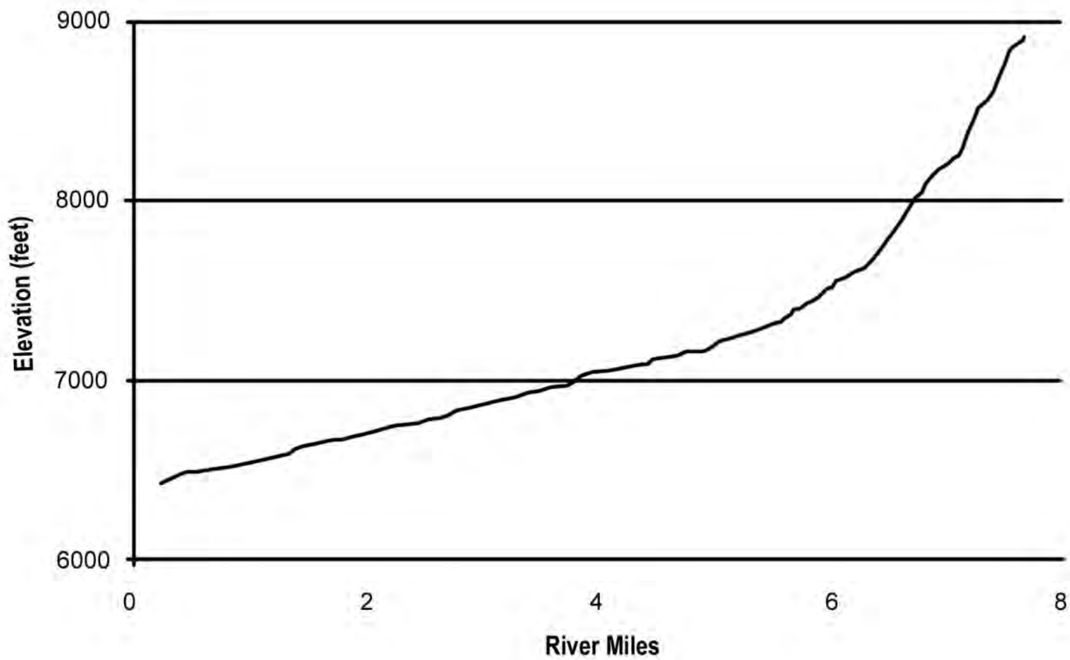

Figure 4. Jordan Creek longitudinal channel profile.

3.3 Surficial Geology

The surficial geology was mapped for this assessment to delineate geologic and anthropogenic valley bottom constraints, and to evaluate sediment sources and delivery mechanisms to the channel network. Valley bottom constraints, both geologic and anthropogenic, were used to determine the degree in which these constraints confine the lateral migration of the stream channel. Sediment sources were delineated to determine the dominant parent material which can be used to infer the durability of the stones and gradation of the material.

3.3.1 Valley Bottom Constraints

Geologic valley bottom constraints were predominantly from alluvial fans, colluvium, bedrock, glacial drift, and lake deposits. Anthropogenic constraints were predominantly from mining activities and embankments (i.e. roads and levees). The anthropogenic constraints were dominant in the lower Yankee Fork subwatershed between RM 9.1 to 3 (i.e. dredge tailings), and in the lower section of the Jordan Creek subwatershed between RM 1.4 to 0 (i.e. mine tailings and road embankments).

3.3.2 Sediment Sources

Sediment sources in the Tributary Assessment area are predominantly from colluvial, alluvial fans, glacial terraces and outwash, and lake deposits. Colluvial deposits, the accumulation of unconsolidated rock debris and soils deposited chiefly by gravity, are the primary source of sediment input in the watershed. These deposits are derived from the Challis Volcanics and contain a wide distribution of particle sizes (boulders-to-fines). Most of the colluvium is stored in depressions (colluvial hollows) along valley walls in the lower order drainages and along the toe of valley walls in the higher order drainages.

Alluvial fans, glacial terraces and outwash, and lake deposits are stored along valley margins and across valley bottoms. Although these deposits are also derived from the Challis Volcanics, they have been mechanically weathered and transported by glaciers and flowing water prior to their deposition. The weathering and transport processes have broken-down the less competent materials to smaller sizes (fines and sand), much of which were transported to the Salmon River by flowing water. The more durable stones that were deposited generally range in size from cobble-to-gravel with lower percentages of boulders.

3.3.3 Sediment Delivery

Sediment delivery is generally through mass wasting processes, reworking of the valley fill, and tributary inputs. Colluvium stored in the lower order drainages are susceptible to mass wasting processes (i.e. debris flows and shallow slides) that are commonly triggered by high intensity thunderstorms, and very infrequently (on the order of several decades) by ground shaking from earthquakes occurring in the region. Debris flows originating within lower order drainages are known to travel long distances and reaching the Yankee Fork; but most debris flows, and generally shallow slides, travel shorter distances and are deposited within the lower order drainages.

Reworking of the valley fill by the Yankee Fork causes localized erosion where the river can migrate laterally and where it comes into contact with alluvial fan, colluvial, glacial and lake deposits, and dredge tailings. As these deposits are eroded by the river they provide predominantly gravel-size materials with cobbles and sand to the channel; and the larger sized materials (large cobbles and boulders) tend to armor the toe of the eroding bank. The gravel and smaller sized materials are then transported downstream in pulses during channel forming flows. In addition, sediment inputs also come from perennial tributaries where similar bank erosion processes occur and the streamflows are competent enough to transport the sediments to the Yankee Fork.

4. Middle Yankee Fork Subwatershed

4.1 Valley Segments

The middle Yankee Fork is located between about RM 16.3 and 9.1 with a drainage area of about 44.3 square miles. Bedrock is the Challis Volcanics that has been off-set by the northeast trending Trans-Challis fault system. The valley has a north-northeast orientation that is structurally controlled by the southern bounding fault of the Custer Graben.

Three valley segments were delineated along the Yankee Fork mainstem (Table 1) that included the following valley cross-sectional forms: (1) U-shaped trough with an alluvial valley type in the upper section; (2) V-shaped bedrock canyon with a bedrock valley type in the middle section; and (3) V-shaped alluvial valley in the lower section.

Table 1. Middle Yankee Fork mainstem valley forms

River Miles	General Valley Location	Valley Form[1]	Side Slope Gradient	Valley Type	Valley Constraints
RM 16.3-13.2	Upper Section	U1: U-shaped trough	WNW 29%: ESE 63%	Alluvial	High terraces comprised of lake and glacial deposits; lake was impounded by downstream landslide; valley was most likely glaciated prior to lake impoundment
RM 13.2-11.6	Middle Section	V3: V-shaped bedrock canyon	NNW 37%: SSE 47%	Bedrock	Deep-seated landslide deposit that included bedrock fragments in excess of 10-feet in diameter; canyon-like corridor with stair-steps due to the very large boulders
RM 11.6-9.1	Lower Section	V4: Alluviated mountain valley	NNW 60%: SSE 63%	Alluvial	Alluvial fans, colluvium, bedrock, and mining activity constrain lateral channel migration; alluvial valley that was probably filled by glacial outwash and/or flood deposits related to breaching of upstream landslide deposit

[1]Classification based on Naiman et al. (1992) as recommended in Hillman (2006)

Valley confinement determinations (Table 2) are as follows: (a) unconfined along the upper section; (b) confined along the middle section; and (c) moderately confined along the lower section.

Table 2. Middle Yankee Fork valley constraints and confinement determinations

River Miles	General Valley Location	Valley Gradient	Valley Floor Width[1]	Constrained Valley Width (CVW)[1]	Channel Width (CW)[1]	Ratio (CW:CVW)	Valley Confinement[2]
RM 16.3-13.2	Upper Section	0.76 percent	911 feet	232 feet	44 feet	1:5.27	Unconfined
RM 13.2-11.6	Middle Section	2.34 percent	824 feet	69 feet	36 feet	1:1.92	Confined
RM 11.6-9.1	Lower Section	1.20 percent	387 feet	153 feet	42 feet	1:3.64	Moderately Confined

[1]Aquatic Inventories Project Methods for Stream Habitat Surveys (ODFW 2010)
[2]Monitoring Strategy for the Upper Columbia Basin (Hillman 2006)

4.2 Geomorphic Reach Delineations

Geomorphic reaches and valley segments were analyzed independently, but in many cases are coincidental where geomorphic channel processes do not significantly change within the valley segment. Along the middle Yankee Fork mainstem three valley segments and coincidental geomorphic reaches were identified based on the geomorphic process and channel morphology (Table 3). Locations of the geomorphic reaches within the subwatershed are provided in Figure 5. The longitudinal channel profile (Figure 6) shows the slope perturbations that are geologically controlled and position of geomorphic reaches within the channel network.

Table 3. Middle Yankee Fork geomorphic reach delineations and associated channel morphology

River Miles	Reach Designation	Reach Area	*Channel Reach Type*[1]	Channel Bed-form Type[1]	Channel Slope	Channel Sinuosity	Dominant Substrate Size Class[2]
RM 16.3-13.2	YF-6	77 acres	*Forced alluvial channel*	Pool-riffle	0.66 percent	1.15	Gravel
RM 13.2-11.6	YF-5	12 acres	*Bedrock channel*	Step-pool	2.24 percent	1.05	Bedrock
RM 11.6-9.1	YF-4	43 acres	*Free-formed alluvial channel*	Plane-bed	1.10 percent	1.08	Gravel

ND – Not determined
[1]Channel type classification based on Montgomery and Buffington (1993)
[2]From Stream Inventory Survey 2010 (Appendix J) and USFS (2006)

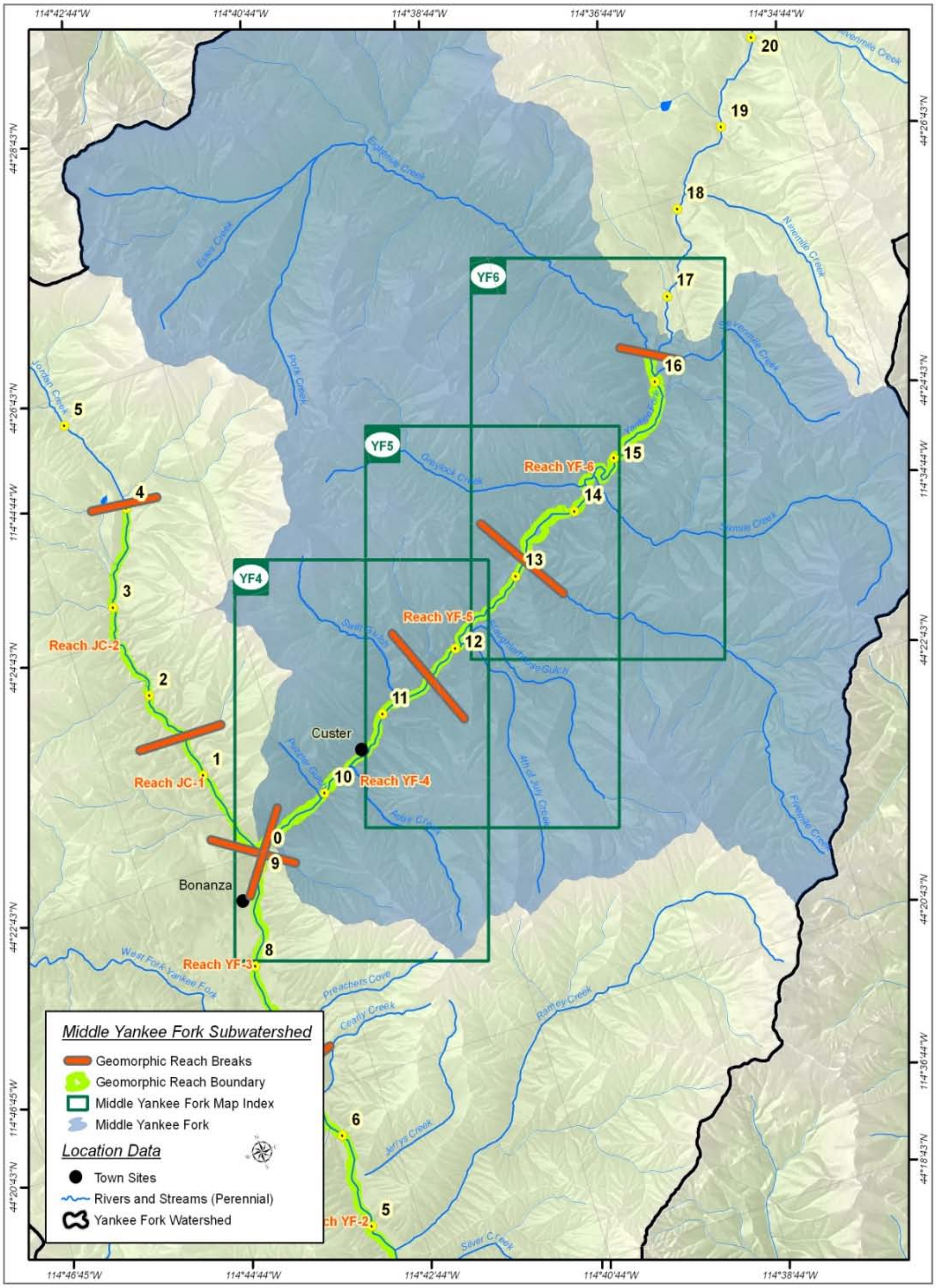

Figure 5. Middle Yankee Fork subwatershed index map with geomorphic reach breaks.

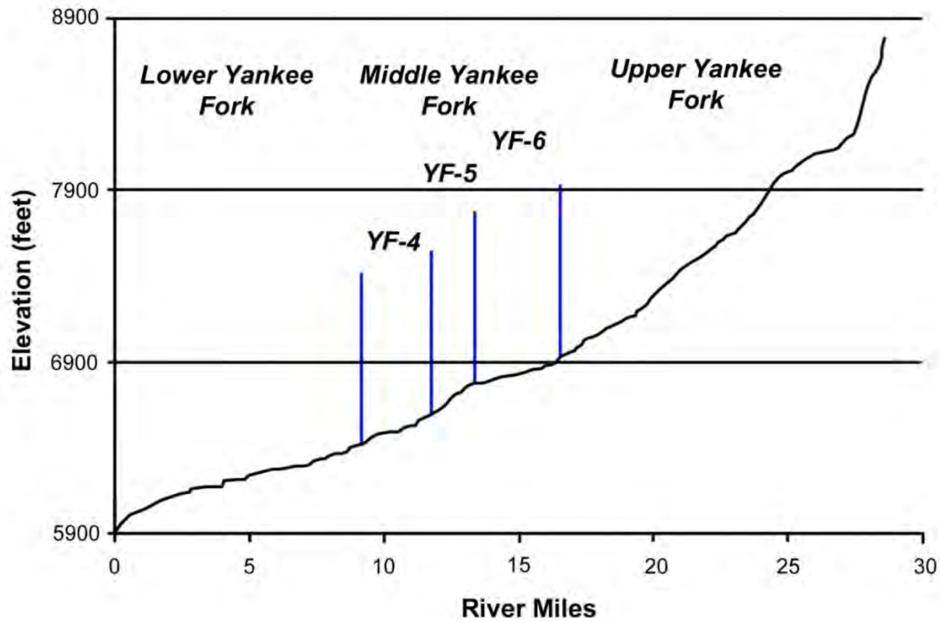

Figure 6. Middle Yankee Fork subwatershed longitudinal channel profile with reach locations.

4.2.2 Reach YF-6

Geomorphic reach YF-6 (Figure 7) is located between about RM 16.5 and 13.3 in an unconfined valley segment. The river has a channel slope of about 0.6 percent that is influenced by a downstream landslide in geomorphic reach YF-5. The landslide impounded the river long enough to create a lake that subsequently filled with sediment and resulted in a relatively flat slope. Channel pattern is predominantly a meandering to island-braided system which indicates that a relatively high rate of lateral channel migration is occurring as compared to other reaches in the assessment area. The channel type is a forced alluvial channel with wood complexes (i.e. logjams) and vegetated islands that provide the external flow obstructions that force local flow convergence, divergence, and sediment impoundments which form a pool-riffle bed-form with gravel as the dominant substrate.

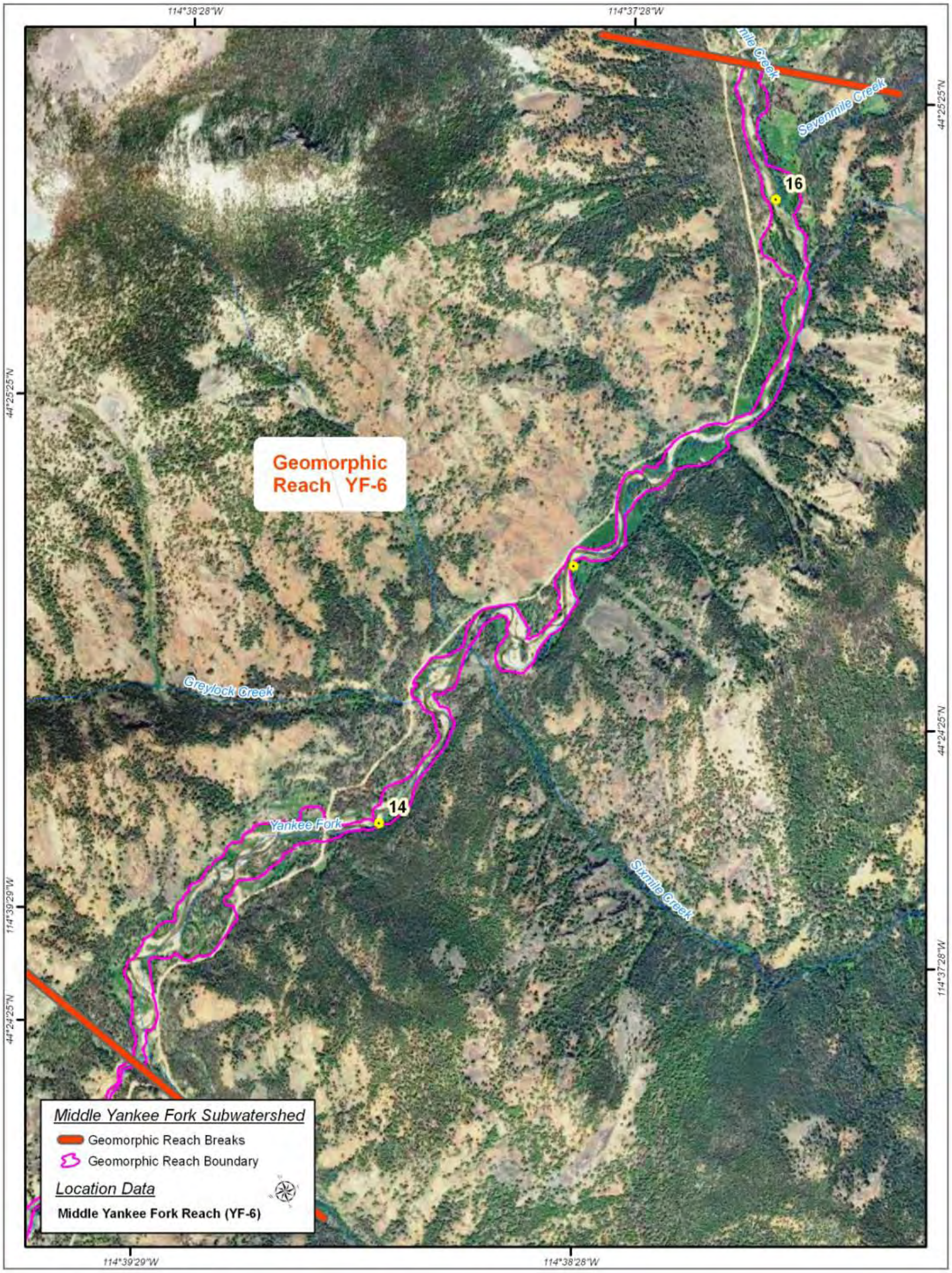

Figure 7. Yankee Fork Reach YF-6 in the middle Yankee Fork subwatershed.

Surficial geologic mapping was conducted to identify valley bottom constraints and evaluate sediment sources (Figure 8). Geologic valley bottom constraints are primarily from high terraces (generally greater than 10-feet in height) constructed along the valley margins as a colluvial and debris flow inputs were deposited in lake. Anthropogenic valley bottom constraints are embankments that primarily encroach on the floodplain and to a lesser degree the channel. The embankments are located predominantly along the floodplain and valley margins, with the exception of the Fivemile Creek Bridge, and do not significantly impact lateral channel migration or channel/floodplain interactions. The Fivemile Creek Bridge causes channel confinement and the approach embankments disconnect a moderately large area of floodplain.

Local coarse sediment inputs are from lateral channel migration and tributaries. The channel is reworking the floodplain deposits through lateral channel migration. Where the channel comes into contact with the lake deposits, erosion is occurring and contributing gravel with sand and fines to the system. There are five perennial tributaries and several ephemeral drainages that are providing sediment inputs. Perennial tributaries are providing sediment pulses during high flow events and as conduits for episodic debris flows. These perennial tributaries include: (a) Eightmile Creek near RM 16.3 on river right; (b) Sevenmile Creek near RM 16 on river left; (c) Sixmile Creek near RM 14.4 on river left; (d) Greylock Creek near RM 14.3 on river right; and (e) Fivemile Creek near RM 13.2 on river left. Greylock and Fivemile Creeks, may also be contributing fine sediment from the erosion of lake deposits near their mouths. Ephemeral tributary sediment inputs are primarily from debris flows associated with high intensity thunderstorms. Ephemeral drainages that show evidence of these debris flows occur near RM 16.3 on river right, RM 16 on river left, RM 15.8 on river left, RM 15.6 on river left, RM 15.4 on river right, and RM14.7 on river left.

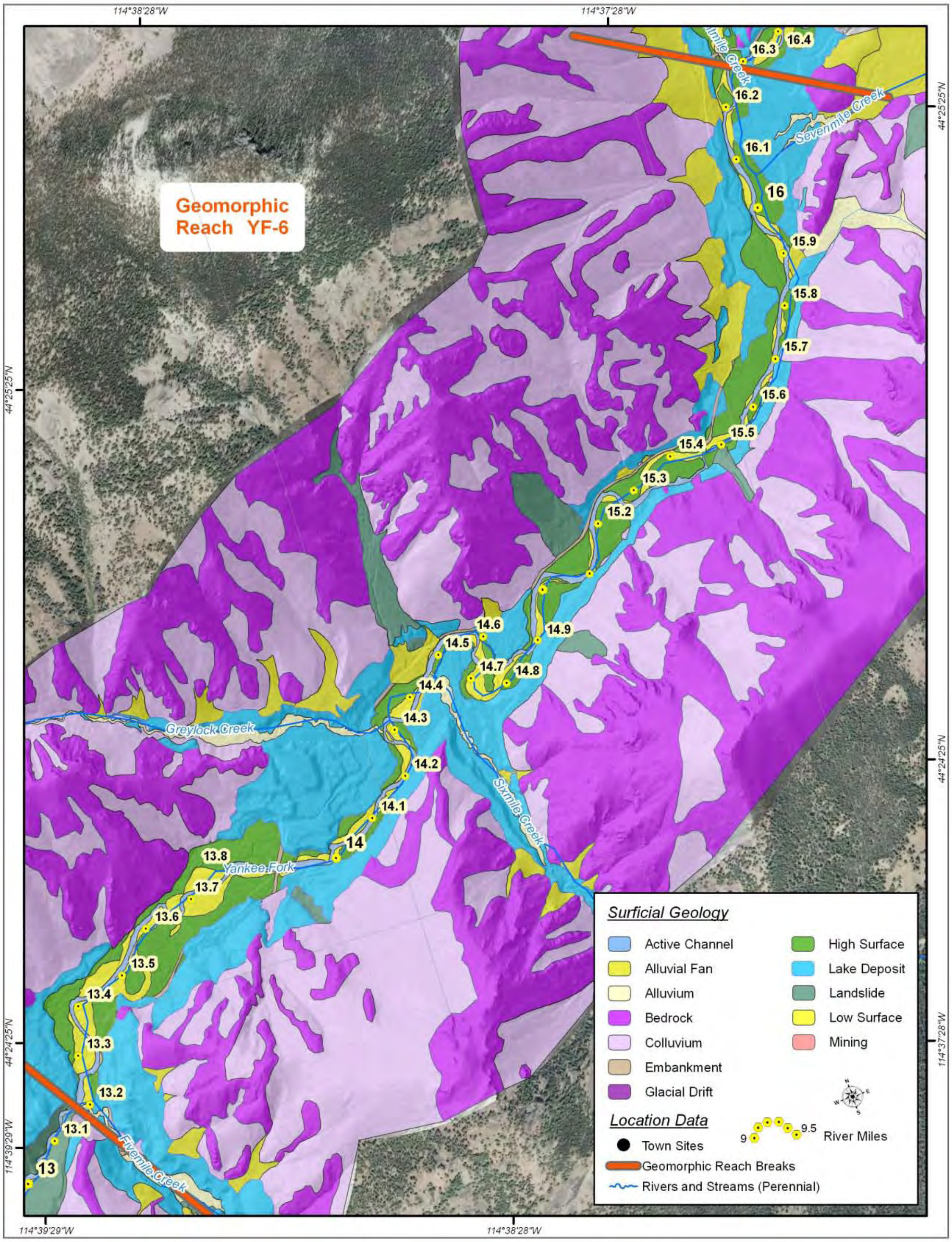

Figure 8. Yankee Fork Reach YF-6 surficial geology map.

Channel alignments were mapped using 1952, 1966, 2004, and 2010 aerial photographs (Figure 9). The 1952 aerial photographs were incomplete and covered the area between about RM 14 and 13.2 of this reach. While the period of record defined by the three aerial photographs sets is relatively short, there is evidence of active channel migration and multiple different channel alignments in the form of old channel scars visible on the LiDAR hillshade elevation model.

There are four channel segments where pronounced channel migration has occurred along this reach. These channel segments are described in the following sections:

- Channel segment RM 15.6 to 15.4: Sediment deposition occurred in the 1966 – 2004 main channel near RM 15.6, and the channel avulsed into a side channel along river left sometime between 2004 and 2010. In 2001, 2002 and 2003 there were intense thunderstorms that triggered debris flows and landslides in the upper and middle Yankee Fork subwatersheds. Sediment inputs from the perennial and ephemeral tributaries during these thunderstorms entered the Yankee Fork system creating an influx in the sediment supply. As sediment pulses were transported through this channel segment, the channel bed was most likely raised creating a hydraulic control that allowed flows to access a side channel on along river left. Erosion then increased the cross sectional area, or capacity, of the side channel resulting in the channel avulsion.

- Channel segment RM 15.2 to 14.8: Channel migration has been occurring along the outside bends between about RM 15.2-15 and 14.9-14.8, but this lateral migration is restricted primarily by the valley margins. The Custer Motorway was placed along the valley margins and, therefore, is not considered a restriction. Near RM 14.9 the channel migrated laterally downstream as it eroded into a high terrace (lake deposit) from pre-1966 to at least 2004. By 2004 the meander had evolved to the point in which the river lost its sediment transport capacity, and by 2010 the river avulsed cutting-off the meander.

- Channel segment RM 14.7 to 14.1: Channel migration has been occurring along the outside bends from 1966 to 2010. Vegetation density along the channel and on gravel bars improved from 1966 to 2010 that contributed to narrowing the channel and increasing the amplitude of the meanders. Lateral channel migration and floodplain expansion is restricted between high terraces (lake deposits) on both sides of the river.

- Channel segment RM 14.1 to 13.3: Channel migration has been occurring along the outside bends, and meanders tend to be translating downstream. A meander has been disconnected near RM 13.7 on river left where an embankment was placed at the head of the meander forcing an avulsion and cutting off the meander prior to 1966.

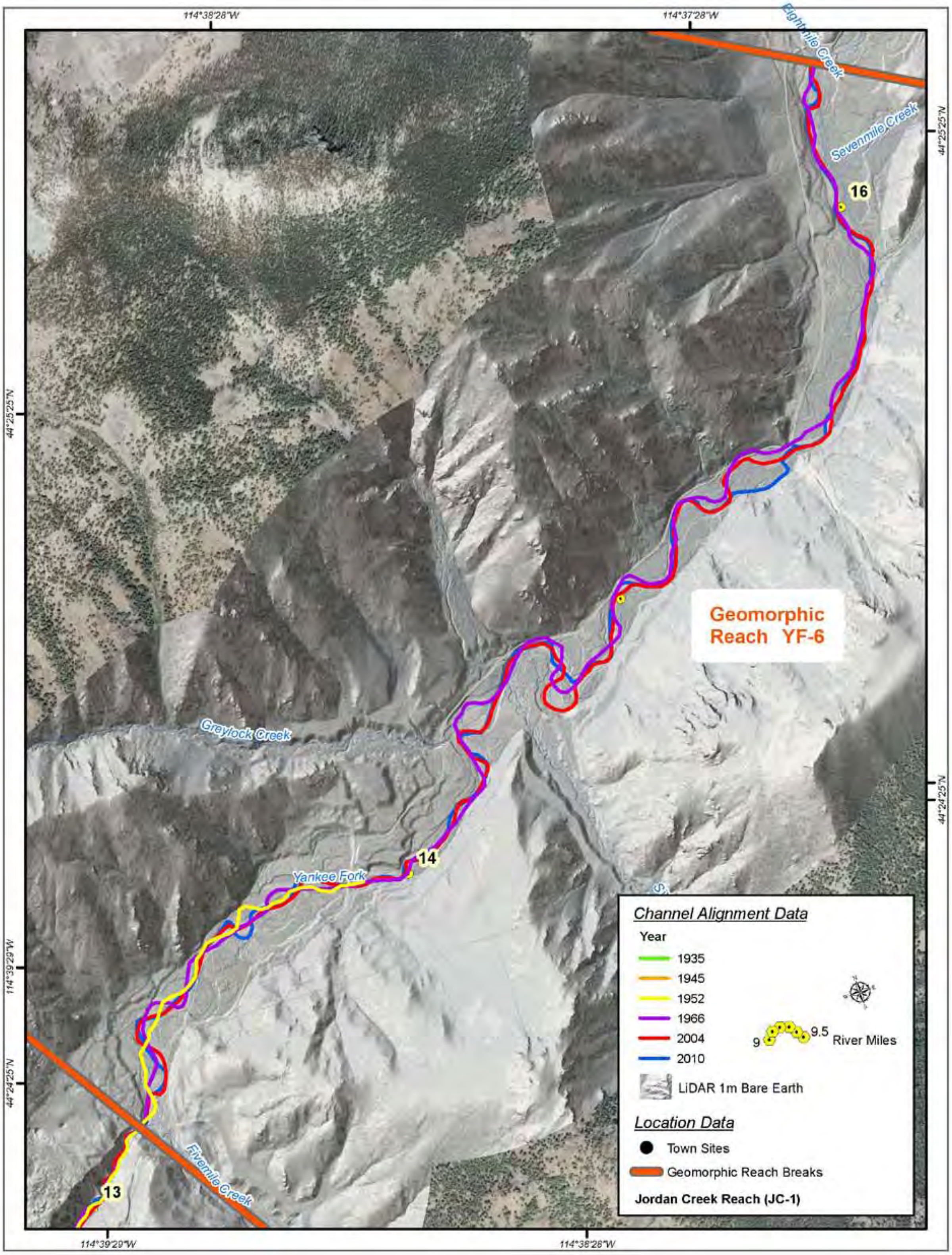

Figure 9. Yankee Fork Reach YF-6: Historical channel alignments.

Channel sinuosity has fluctuated over the period of record (1952-2010) in this reach (Table 4). This variability is most likely correlative to sediment pulses and an increase in vegetation density and wood recruitment potential. Increased vegetation coverage on gravel bars and adjacent floodplains provide improved bank stability as root systems develop and bind the bank material. The improved bank stability tends to narrow and deepen the channel, and generally increases channel sinuosity. In addition, as larger wood becomes available to the channel through lateral channel migration, the instream wood and wood complexes contribute to flow convergence and divergence that can further increase channel sinuosity and side channel evolution (Figure 10).

Table 4. Yankee Fork Reach YF-6: Historic channel alignments and geomorphic chanel metrics

Channel Alignment (Year)	Channel Length	Valley Length	Sinuosity
1952[1]	3,889 feet	3,488 feet	1.11
1966	16,413 feet	14,497 feet	1.13
2004	17,272 feet	14,497 feet	1.19
2010	16,701 feet	14,497 feet	1.15

[1]Based on incomplete set of 1952 aerial photographs covering about RM 14 to 13.2

Figure 10. View to the west near RM 14.9 showing forced alluvial channel variability. *Wood in this reach influences variability in geomorphic channel processes and habitat complexity. Lake deposits (eroded high bank in the background) are common in this reach and provide sediment inputs of fine gravel and sand with fine.* Bureau of Reclamation photograph by Dave Walsh, September 2, 2010.

Summary and Potential Actions

Channel/floodplain interactions and are connected throughout the reach with two exceptions. These exceptions are a bridge and embankment approaches near RM 13.9, and an embankment at the head of a meander near RM 13.7. The bridge and its approaches confine the channel and disconnect a moderately large floodplain area, and the embankment placed at the head of the meander deflects the river and prevents the channel from accessing the meander. Other anthropogenic disturbances (i.e. Custer Motorway) do not significantly impact channel processes.

Vegetation along the active channel and floodplain consist of predominantly riparian shrubs with upland trees. Historically, this reach probably had mature Ponderosa pines and/or Douglas-fir that were available for channel recruitment. During the mining boom in the late 1800s and early 1900s, timber was cleared from the valley bottoms and margins to be used in milling operations and construction. The removal of timber and associated destruction of understory vegetation may have enabled lodgepole pines to become established. This change in the vegetation assemblage is significant in that lodgepole pines never achieve the size of mature Ponderosa pines; and therefore, a sufficient quantity of large trees are no longer available for channel recruitment.

The physical and ecological processes were impacted primarily from past timber harvests along the valley bottoms and margins, and to a lesser degree by embankments. The riverine system appears to be on a recovering trend as the vegetation progresses through varying successional stages. Active management of these stands to insure proper species assemblage and improve growth rates would be an appropriate approach for long-term rehabilitation.

Potential short-term approaches to increase availability of wood to the system to improve channel complexity and aquatic habitat could include (1) insuring that wood and sediment inputs from tributaries are not impeded by obstructions (i.e. undersized culverts), and (2) possible wood loading along the channel and floodplain, with the caveat that the anticipated ecologic benefits outweigh the disturbances to the channel or floodplain.

In addition, an alternatives analysis could be conducted to address the bridge and embankments. A cost-benefit analysis should be considered along with each alternative as these features do not significantly impact channel processes at a reach-scale. Any of these short-term approaches should be assessed as a reach-scale alternatives analysis to determine (a) what the potential actions are, (b) where these actions are appropriate, and (c) how will these actions benefit the resources?

4.2.3 Reach YF-5

Geomorphic Reach YF-5 (Figure 11) is located between about RM 13.2 and 11.7 in a confined valley segment. The river has incised a V-shaped canyon through a landslide deposit that filled the river corridor with slide-blocks and large boulders from RM 13 to 12.5, and smaller materials (boulders to fines) from RM 12.5 to 11.8. Due to the large size of materials, the channel type is bedrock with a straight to slightly meandering channel pattern. The channel slope is about 3.8 percent from RM 13 to 12.5, and then decreases to about 1.7 percent between RM 12.5 and 12 and about 1.2 percent between RM 12 and 11.6. Channel bed-forms are generally cascade to step-pools and there are very little overbank areas.

Figure 11. Yankee Fork Reach YF-5 in the middle Yankee Fork subwatershed.

Geologic valley bottom constraints are from slide-blocks and large boulders that essentially function similar to bedrock (Figure 12). Two waterfalls are located near RM 13 and 12.8 that do not impede fish passage. There are no anthropogenic valley bottom constraints that would affect lateral channel migration. The Custer Bridge crosses the channel near RM 12 and does not appear to artificially confine the channel.

Coarse sediment sources, excluding inputs from upstream, are primarily from debris sloughing from the canyon walls, and contributions from two perennial tributaries and several ephemeral drainages. The perennial tributaries include: Fourth of July Creek and Slaughterhouse Gulch that flow into the mainstem near RM 12.1 on river left. Ephemeral drainages primarily provide sediment input as debris flows. There is evidence of debris flows near RM 12.5 on river right, RM 12.4 on river right, RM 12.1 on river right, RM 11.9 on river right, and RM 11.8 on river left.

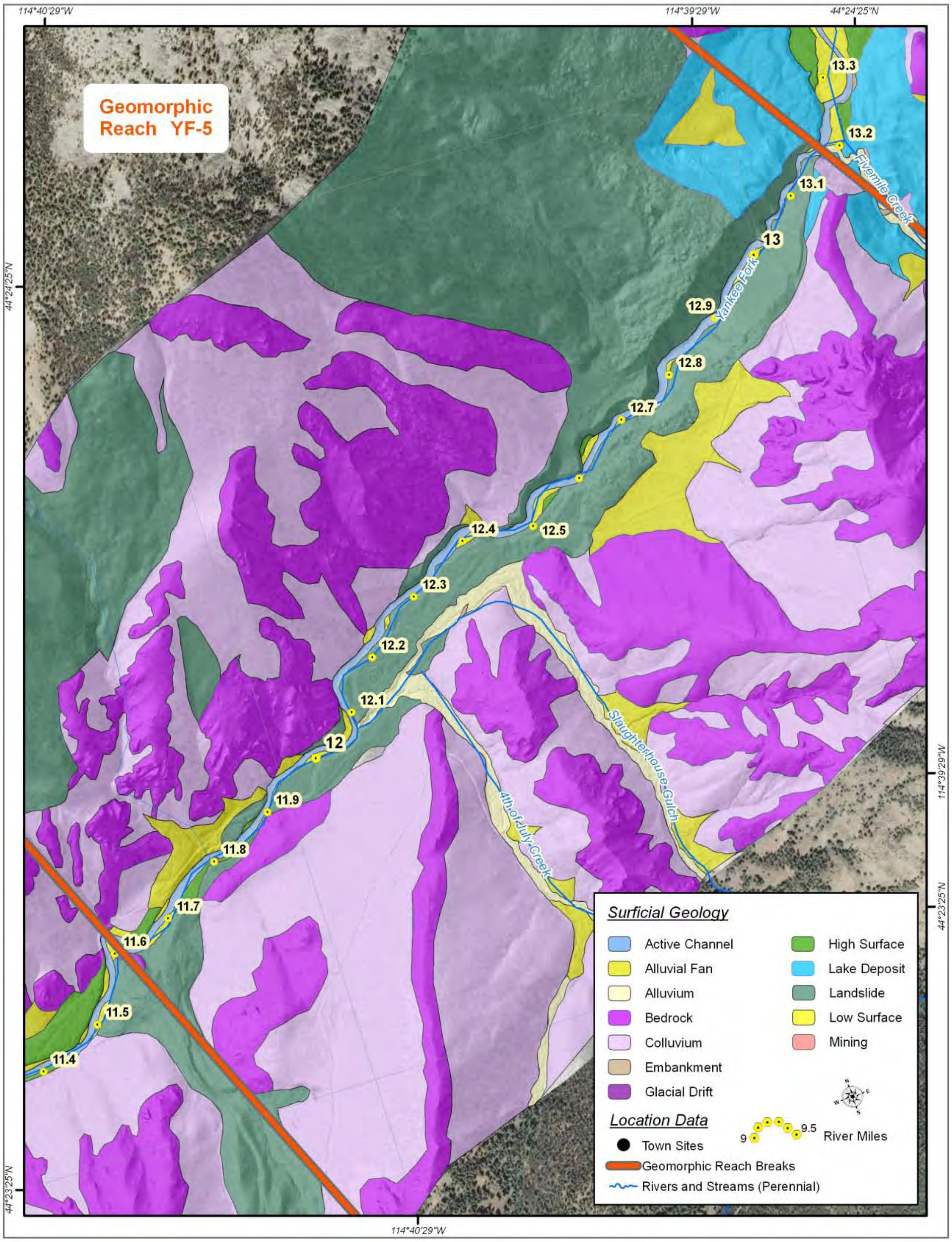

Figure 12. Yankee Fork Reach YF-5 surficial geology map.

Channel alignments were mapped using 1952, 1966, 2004, and 2010 aerial photographs (Figure 13). There are small, localized areas where some lateral channel migration has occurred based on the LiDAR hillshade elevation model. These areas are between about RM 12.9 and 12 where the channel has been able to erode the landslide deposit along the outside of meanders and creating small point-bars on the inside meanders.

Channel sinuosity has slightly increased over the period of record (1952-2010) in this reach (Table 5). The increase in sinuosity is associated with the channel's ability to migrate laterally and erode into the landslide deposit between RM 12.9 and 12.

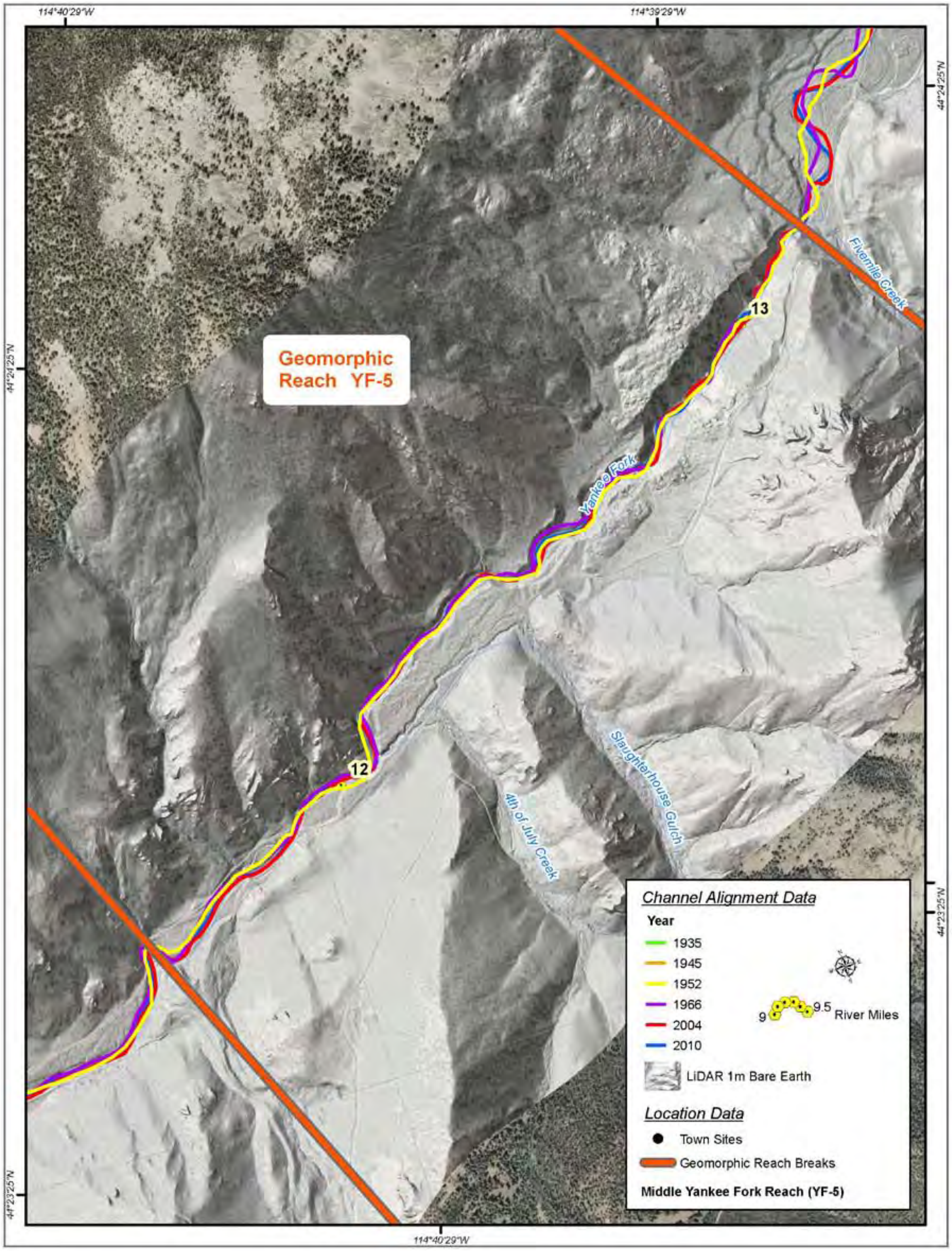

Figure 13. Yankee Fork Reach YF-5: Historical channel alignments.

Table 5. Yankee Fork Reach YF-5: Historic channel alignments and geomorphic channel metrics

Channel Alignment (Year)	Channel Length	Valley Length	Sinuosity
1952	8,281 feet	8,108 feet	1.02
1966	8,474 feet	8,108 feet	1.05
2004	8,447 feet	8,108 feet	1.04
2010	8,484 feet	8,108 feet	1.05

Vegetation along the banks of the active channel is sparse between about RM 13.2 and 12.8, and is comprised primarily of upland trees along the steep slopes (Figure 14). Riparian vegetation becomes more prominent along the banks starting near RM 12.8 to the end of the reach where the channel has been able to erode the landslide deposit. Wood is relatively rare based on examination of the 2010 aerial photographs. The pieces that do remain in the canyon form small jams that are keyed by large boulders. Wood frequency and quantity may seem relatively low, but large quantities of wood would not be expected in confined channel that has high transport capacity.

Figure 14. View to the northwest near RM 12.9 showing bedrock channel. *The channel has been incising through the landslide deposit in what is essentially a bedrock channel reach and has developed a steep step-pool bed-form.* Bureau of Reclamation photograph by Dave Walsh, September 2, 2010.

Summary and Potential Actions

This geomorphic reach is in a confined, V-shaped canyon that has high sediment transport capacity. There are two naturally occurring waterfalls that do not prevent fish passage to the upper drainages. No anthropogenic disturbances directly impact channel processes, but there is a bridge crossing near RM 12.

Vegetation along the banks of the active channel is sparse between about RM 13.2 and 12.8, and is comprised primarily of upland trees along the steep slopes. Riparian vegetation becomes more prominent along the banks starting near RM 12.8 to the end of the reach. Instream wood frequency would be expected to be low in a confined, high transport capacity reach.

This confined geomorphic reach has a bedrock channel with no anthropogenic features impacting channel processes. There are two natural waterfalls within the upper section, but they do not prevent fish passage. Since the fish of interest primarily use this reach as a migratory corridor and there are no fish passage barriers, no further assessments are recommended.

4.2.4 Reach YF-4

Geomorphic Reach YF-4 (Figure 15) is located between about RM 11.6 and 9.1 in a moderately confined valley segment. Average channel slope is about 1.1 percent and the channel pattern is straight-to-meandering which indicates a low-to-moderate rate of lateral channel migration is occurring as compared to other reaches in the assessment area. Channel type is a plane-bed, free-formed alluvial channel with a gravel substrate.

Figure 15. Yankee Fork Reach YF-4 in the middle Yankee Fork subwatershed.

Surficial geologic mapping show that the geologic valley bottom constraints are primarily from alluvial fans, colluvium, and bedrock (Figure 16). There are anthropogenic features that provide some valley bottom constraint in localized areas, but generally influence channel confinement, lateral channel migration, and floodplain connectivity. Table 6 summarizes the anthropogenic features for this geomorphic reach.

Local coarse sediment input is predominantly from lateral channel migration causing bank erosion and to a lesser degree from tributaries. Bank erosion is occurring where the channel is in contact with alluvial fan deposits (RM 11.3 to 11.2 on river right), along the outside of meanders (RM 11 to 10.9 on river right and RM 9.2 to 9.1 on river left), and along unvegetated banks near dispersed campsites (RM 10 on river right). There are three perennial tributaries that provide sediment pulses during high flow events and as conduits for episodic debris flows. These tributaries include Swift Gulch near RM 11.2 on river right; Adair Creek near RM 10.4 on river left; and Jordan Creek near RM 9.1 on river right. Ephemeral drainages that show evidence of debris flows that can potential provide sediment inputs include unnamed drainages near RM 11.3 on river right, and a few between RM 10 and 9.9 on river left.

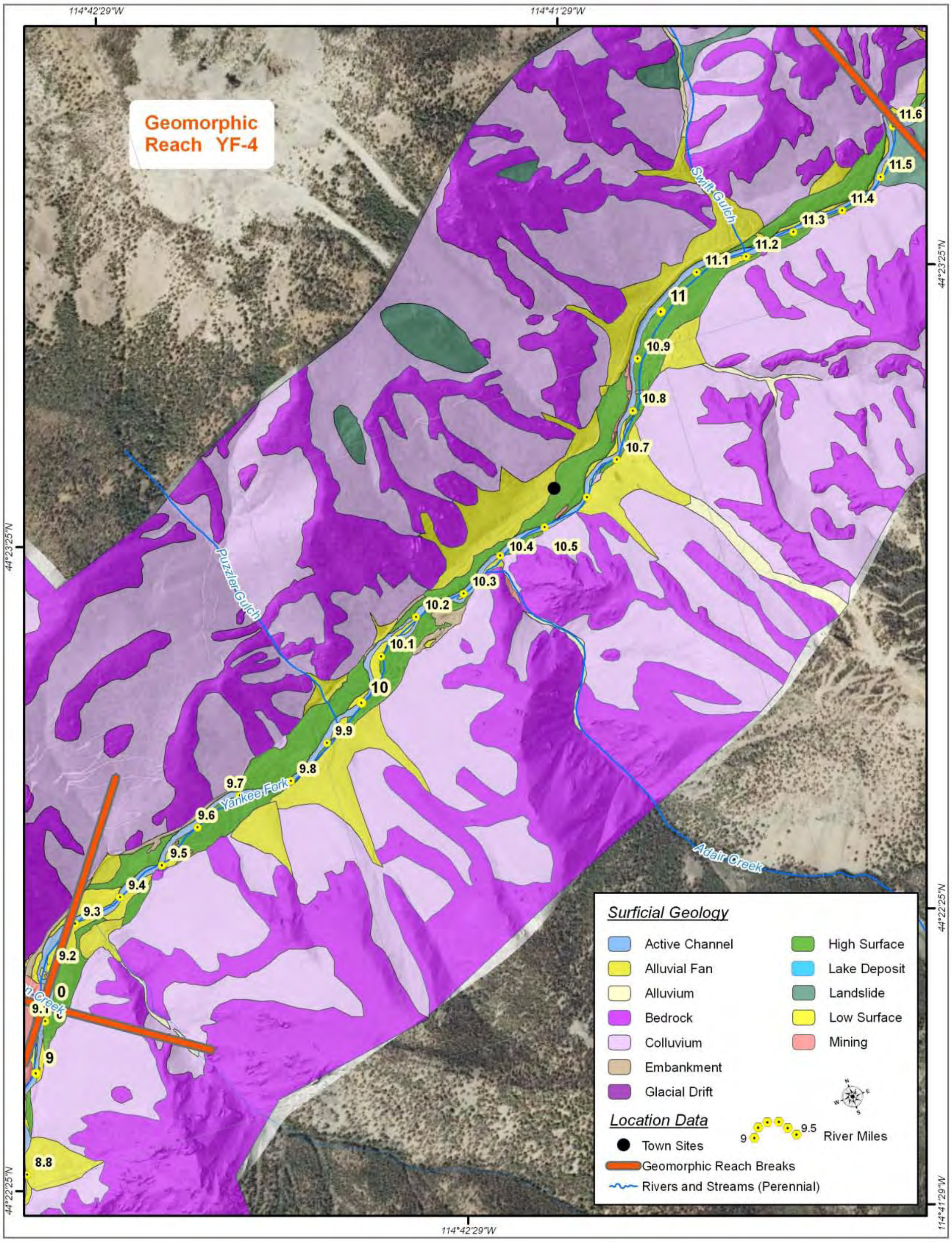

Figure 16. Yankee Fork Reach YF-4 surficial geology map.

Table 6. Anthropogenic features location, description, and effects

River Mile	Anthropogenic Feature	Description	Effects
RM 10.3 – 10.1; RM 9.7 – 9.5; RM 9.4 – 9.2	Custer Motorway	Road embankment along valley wall adjacent to channel and floodplain on river right	The road was placed along the valley wall and does encroach on the channel and floodplain, thereby effecting channel processes. Although the impacts to channel processes do not appear to be significant
RM 10.9	General's Bridge	Bridge crossing and elevated embankment (approach along river left)	Channel confinement and small floodplain area disconnected along river left
RM 10.9 -10.8	Levee	Levee along channel on river right and road embankment near RM 10.9 along river left are used to confine the channel near General's Bridge	Levee disconnects a relatively large floodplain area and flows are confined to within the channel.
RM 10.6	Levee	Levee along floodplain terrace on river right	Small levee along floodplain terrace reduces floodplain connectivity, but not significantly
RM 10.3	Embankment (Mine Tailings)	Embankment made from mine tailings used to protect mining operation on river left from floods and lateral channel migration	Tailings embankment confines the channel, deflects flood flows toward river right, and disconnects a small floodplain area.
RM 9.6	Embankment (Mine Tailings)	Embankment made from mine tailings used to protect mining operation on river left	Tailings embankment disconnects small floodplain area and constrains lateral channel migration
RM 9.1	Dredge Tailings	Dredge tailing mounds at Jordan Creek confluence on river right	Dredge tailing mounds confine the channel and restricts lateral channel migration

Channel alignments were mapped using 1945, 1952, 1966, 2004, and 2010 aerial photographs (Figure 17). The 1945 aerial photographs were incomplete and covered the area between about RM 8.4 and 6.8 of this reach. The period of record defined by the five aerial photograph sets cover the time period prior to dredging operations conducted downstream of the reach in the 1940s and early 1950s, following completion of the dredging operations and after channel reconstruction in the early 1950s. There is evidence of active channel migration and multiple different channel alignments in the form of old channel scars visible on the LiDAR hillshade elevation model between about RM 10.3 and 10.1 along river left, RM 9.7 to 9.5 on river left, and RM 9.3 to 9.2 on river left.

Little channel migration has occurred from about RM 11.7 to 10.3 and RM 10 to 9.6. Areas where active channel migration has been occurring in this reach over the period of record are as follows:

- Channel segment RM 10.3 to 10: Channel migration has been occurring downstream of a tailings embankment near RM 10.3 where the channel is constricted between the tailings embankment and the Custer Motorway road embankment. Sediment deposition has occurred downstream of the constriction causing the channel to actively adjust in response as sediment pulses are transported through the system.

- Channel segment RM 9.6 to 9.2: Some channel migration has occurred downstream of a tailings embankment near RM 9.6 where channel/floodplain interactions have been disconnected along river left. The embankment appears may have been placed (or replaced) after 1966 because the 1952 and 1966 channel alignments show the channel position in the area of the embankment. There has been little channel migration since the embankment was placed based on the 2004 and 2010 aerial photographs.

- Channel segment RM 9.2 to 9.1: The 1945 channel had been filled with dredge tailings and the valley bottom near Yankee Fork/Jordan Creek confluence was completely filled with dredge tailings in the 1952 aerial photograph. The channel was reconstructed around the dredge tailing mounds and along a high terrace southeast of the old 1945 alignment sometime between 1952 and 1966. A moderate rate of channel migration has occurred after the channel realignment upstream of the dredge tailing mounds. The channel constriction between the dredge tailings and high terrace causes a backwater affect at channel forming flows and results in sediment deposition directly upstream of the constriction.

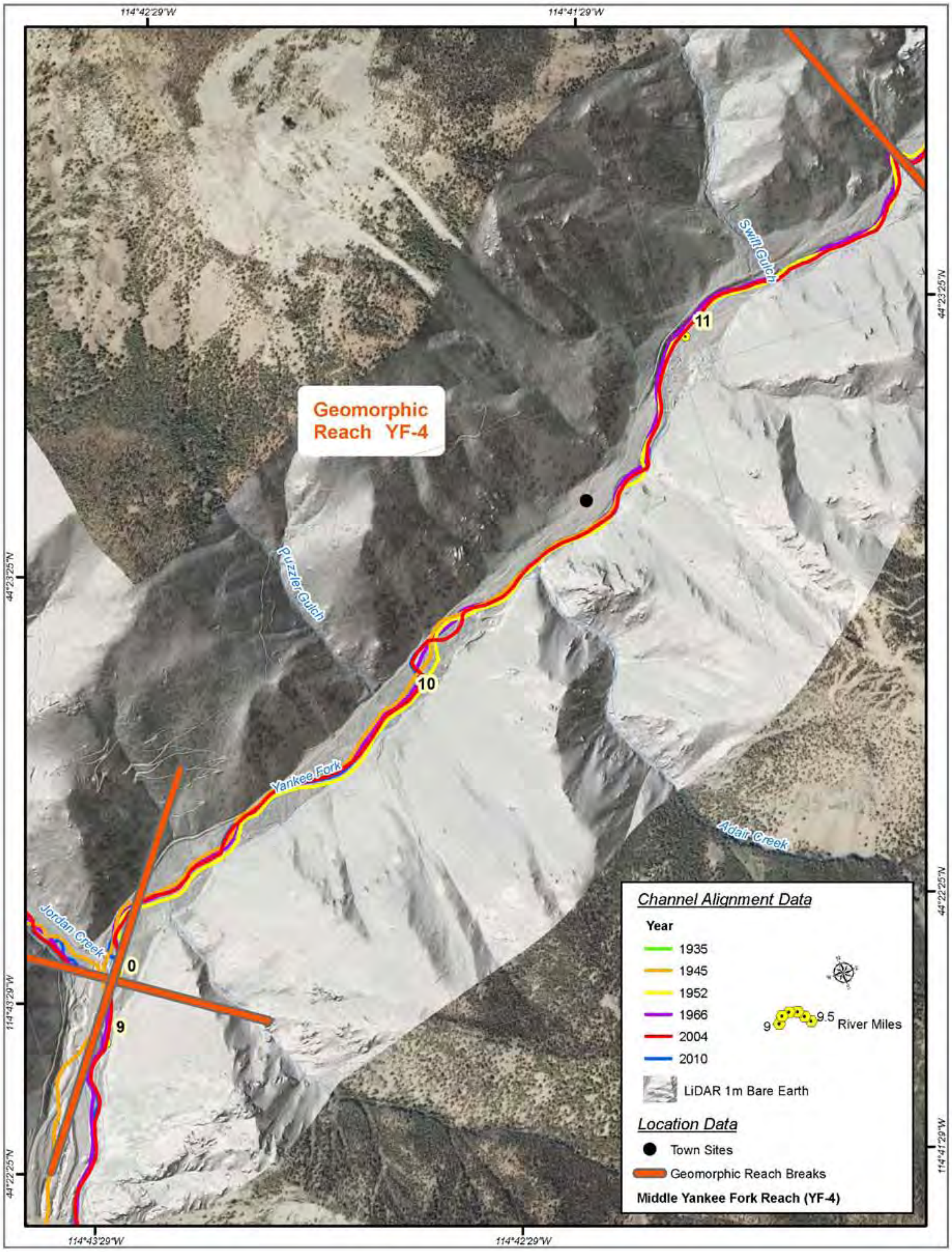

Figure 17. Yankee Fork Reach YF-4: Historical channel alignments.

Channel sinuosity (Table 7) has essentially remained constant with little variability (note the 1945 channel alignment was only mapped between RM 10.6 and 9.1). Vegetation coverage and land use has not significantly changed over the period of record (1945 to 2010). The exceptions are as follows: vegetation clearing for a mining operation near RM 10.3 on river left between 1952 and 2004; residential development near RM 10.9 on river right (Figure 18); and an increase in vegetation coverage between RM 9.4 and 9.2 upstream of the Yankee Fork/Jordan Creek confluence.

Table 7. Yankee Fork Reach YF-4: Historic channel alignments and geomorphic channel metrics

Channel Alignment (Year)	Channel Length	Valley Length	Sinuosity
1945[1]	8,100 feet	7,684 feet	1.05
1952	13,428 feet	12,541 feet	1.07
1966	13,386 feet	12,541 feet	1.07
2004	13,557 feet	12,541 feet	1.08
2010	13,580 feet	12,541 feet	1.08

[1]Based on incomplete set of 1945 aerial photographs covering about RM 10.6 to 9.1

Figure 18. View to the southwest near RM 10.8 showing floodplain clearing associated with development. *Mining activities have been occurring along river left (left foreground in photo); residential development protected by a push-up levee has been occurring along river right (center of photo); and the Generals Bridge provides access to the mining site constricts the river near RM 10.9.* Bureau of Reclamation photograph by Dave Walsh, September 2, 2010.

Summary and Potential Actions

This geomorphic reach is in a moderately confined valley and the channel pattern is straight-to-meandering which indicates a low-to-moderate rate of lateral channel migration is occurring as compared to other reaches in the assessment area. The channel type is a plane-bed, free-formed alluvial channel with an average channel slope of about 1.1 percent and gravel is the dominant substrate.

Anthropogenic features along the active channel and floodplain have locally impacted channel processes. These impacts include channel confinement, restricted lateral channel migration, and disconnected floodplain areas. The following are the locations and impacts from anthropogenic features:

- Channel segment RM 10.3 to 10: Tailings embankment near RM 10.3 constricts channel between embankment and Custer Motorway road embankment.

- Channel segment RM 9.6 to 9.2: Tailings embankment near RM 9.6 disconnects channel/floodplain interactions.

- Channel segment RM 9.2 to 9.1: Dredge tailing mounds and a high terrace constrict the reconstructed channel which causes a backwater effect upstream and increases streampower at the constriction near the mouth of Jordan Creek.

Channel sinuosity has essentially remained constant through the reach with little variability. The vegetation coverage and land use has not significantly changed over the period of record (1945 to 2010) with the following exceptions: vegetation clearing for a mining operation near RM 10.3 on river left; residential development near RM 10.9 on river right; and an increase in vegetation coverage between RM 9.4 and 9.2 upstream of the Yankee Fork/Jordan Creek confluence.

A reach-assessment is not necessary to address the localized anthropogenic impacts in this geomorphic reach. An alternatives analysis could be conducted to address the anthropogenic features that are affecting channel/floodplain interactions and channel processes depending on feasibility of project implementation. Documentation of baseline conditions should be considered as part of the alternatives analysis for monitoring purposes, and how the potential actions would benefit the resources and their potential risks.

5. Lower Yankee Fork Subwatershed

5.1 Valley Segment

The lower Yankee Fork is located between about RM 9.1 and the Yankee Fork/Salmon River confluence near the town of Sunbeam. The lower Yankee Fork drainage area is about 29 square miles and the drainage density is about 1.45. Bedrock geology consists predominantly of Challis Volcanics except between RM 3 and the Yankee Fork/Salmon River confluence where the Idaho batholith crops out. The valley has a north-south orientation except for the lower section where it trends north-northwest through the Idaho batholiths downstream of a fault that separates the two geologic rock types.

Three valley segments were delineated along the Yankee Fork mainstem (Table 8) that included the following cross-sectional valley forms: (1) U-shaped trough with an alluvial valley type in the upper section; (2) U-shaped trough with an alluvial valley type in the middle section; and (3) V-shaped bedrock canyon with a bedrock valley type in the lower section. Although the upper and middle sections have the same valley form, geologically they are significantly different and there is a change in channel slope near RM 6.9, and the change from Challis Volcanics to the Idaho batholith bedrock types near RM 3 shows a steepening in channel slope.

Table 8. Lower Yankee Fork mainstem valley forms

River Miles	General Valley Location	Valley Form[1]	Side Slope Gradient	Current Channel Constraints and Valley Geology
RM 9.1-6.8	Upper Section	U1: U-shaped trough	WSW 5%: ENE 40%	Glacial terraces, alluvial fans, and dredge tailings; broad glaciated valley that may have been a zone of accumulation during Pioneer and/or Copper Basin glaciations
RM 6.8-3.0	Middle Section	U1: U-shaped trough	W 60%: E 62%	Glacial terraces, alluvial fans, dredge tailings, and bedrock; glaciated valley within the Challis Volcanics; from about RM 3 upstream, the Yankee Fork watershed is within the Challis Volcanics
RM 3.0-0	Lower Section	V1: V-shaped moderate gradient bottom	NW 62%: SE 52%	Bedrock and colluvium; channel developed through granitic rocks due to uplift of the Idaho batholith lowering of base-level along Salmon River

[1]Classification based on Naiman et al. (1992) as recommended in Hillman (2006)

Valley confinement determinations (Table 9) are as follows: (1) moderately confined along the upper section; (2) confined along the middle section; and (3) confined along the lower section.

Table 9. Lower Yankee Fork valley constraints and confinement determinations

River Miles	General Valley Location	Valley Gradient	Valley Floor Width[1]	Constrained Valley Width (CVW)[1]	Channel Width (CW)[1]	Ratio (CW:CVW)	Channel Confinement[2]
RM 9.1-6.8	Upper Section	1.05 percent	1,140 feet	123 feet	50 feet	1:2.46	Moderately Confined
RM 6.8-3.0	Middle Section	0.68 percent	631 feet	129 feet	66 feet	1:1.95	Confined
RM 3.0-0	Lower Section	1.17 percent	141 feet	97 feet	58 feet	1:1.67	Confined

[1]Aquatic Inventories Project Methods for Stream Habitat Surveys (ODFW 2010)
[2]Monitoring Strategy for the Upper Columbia Basin (Hillman 2006)

5.2 Geomorphic Reach Delineations

Along the lower Yankee Fork mainstem, three geomorphic reaches were identified based on geomorphic processes and channel morphology (Table 10). The middle reach could have been divided into two reaches at the bedrock constriction near RM 8.3, but there were no significant changes to the overall geomorphic character upstream or downstream of this constriction. Locations of the geomorphic reaches within the subwatershed are provided in Figure 19. The longitudinal channel profile (Figure 20) shows the geomorphic reaches within the channel network. There is a prevalent slope increase in Reach YF-1 that is a geologically fault-controlled change from the Challis Volcanics to the Idaho batholith.

Table 10. Lower Yankee Fork geomorphic reach delineations and associated channel morphology

River Miles	Reach Designation	Reach Area	Channel Reach Type[1]	Channel Bed-form Type[1]	Channel Slope	Channel Sinuosity	Dominant Substrate Size Class[2]
RM 9.1-6.9	YF-3	29 acres	*Free-formed alluvial channel*	Plane-bed	1.00 percent	1.05	Cobble
RM 6.9-3	YF-2	60 acres	*Free-formed alluvial channel*	Plane-bed	0.64 percent	1.07	Cobble
RM 3-0	YF-1	ND	*Bedrock channel*	Step-pool	1.13 percent	1.04	ND

ND – Not determined
[1]Channel type classification based on Montgomery and Buffington (1993)
[2]From Stream Inventory Survey 2010 (Tributary Assessment report Appendix A) and USFS (2006)

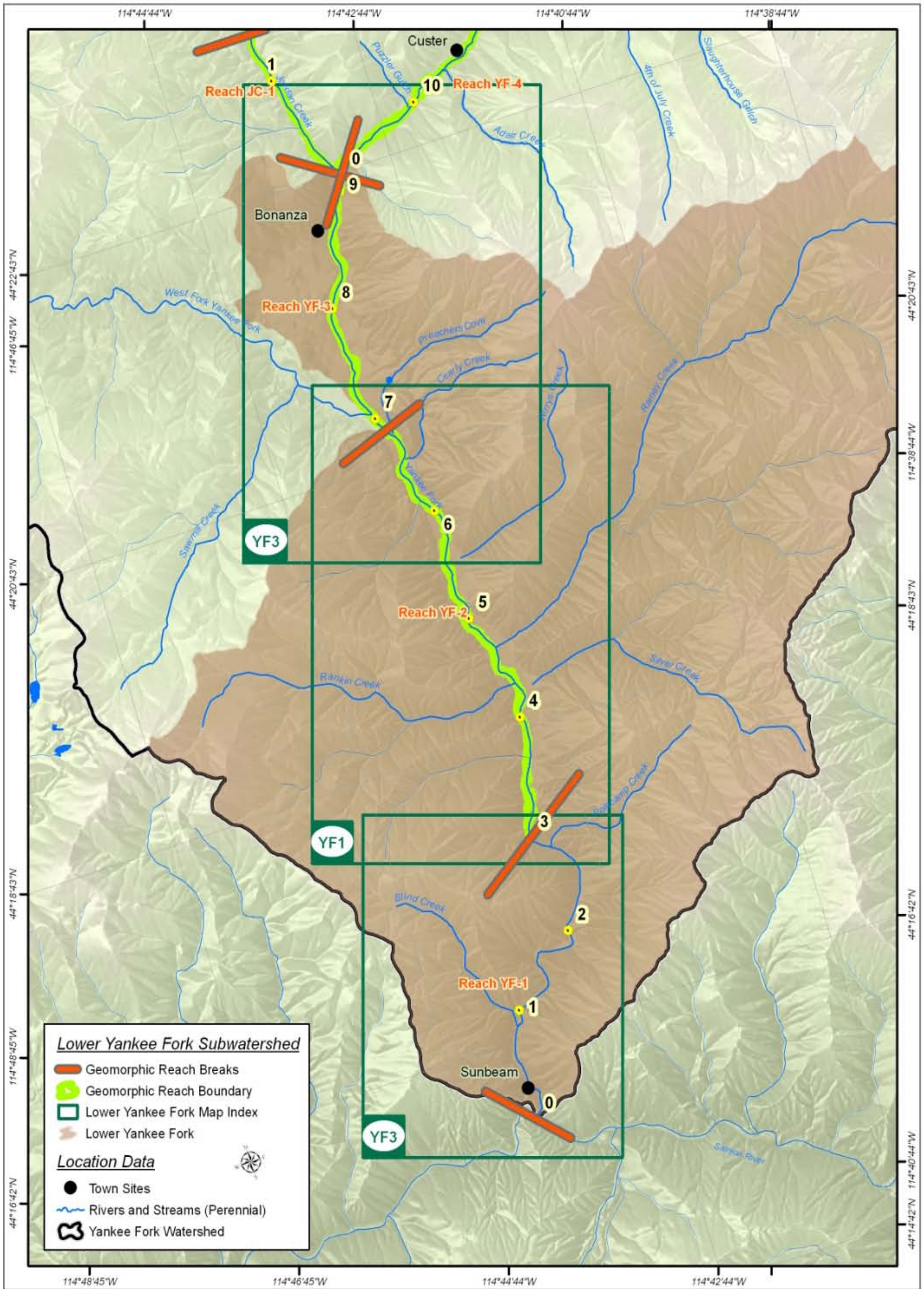

Figure 19. Lower Yankee Fork subwatershed index map with geomorphic reach breaks.

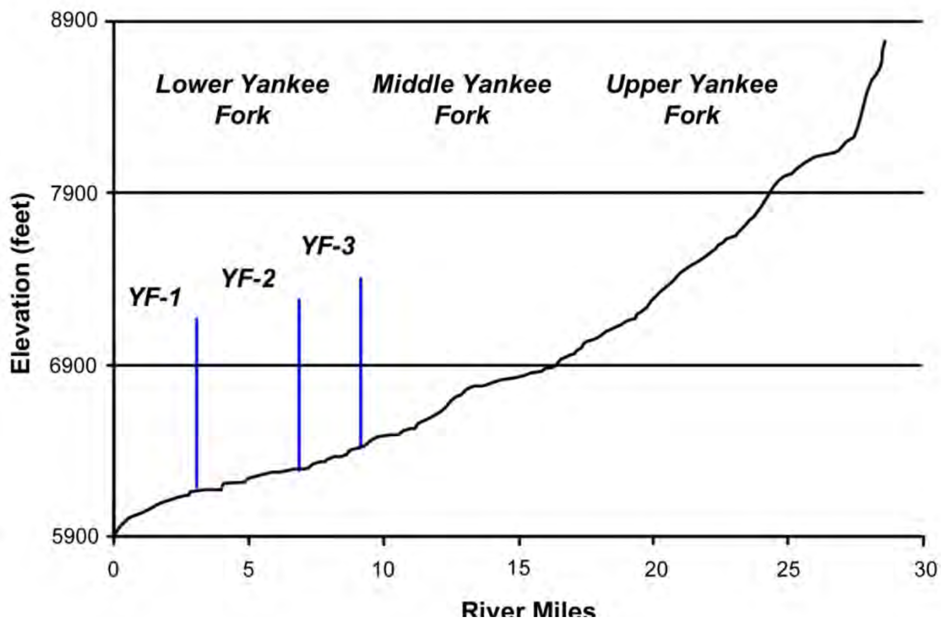

Figure 20. Lower Yankee Fork subwatershed longitudinal channel profile with reach locations.

5.2.2 Reach YF-3

Geomorphic Reach YF-3 (Figure 21) is located between about RM 9.1 and 6.9 in a moderately confined valley segment that is constrained by dredge tailings throughout most of the reach. The channel type is a free-formed alluvial channel with a plane-bed and a straight-to-meandering channel pattern. Channel slope is about 1 percent with a cobble dominated substrate.

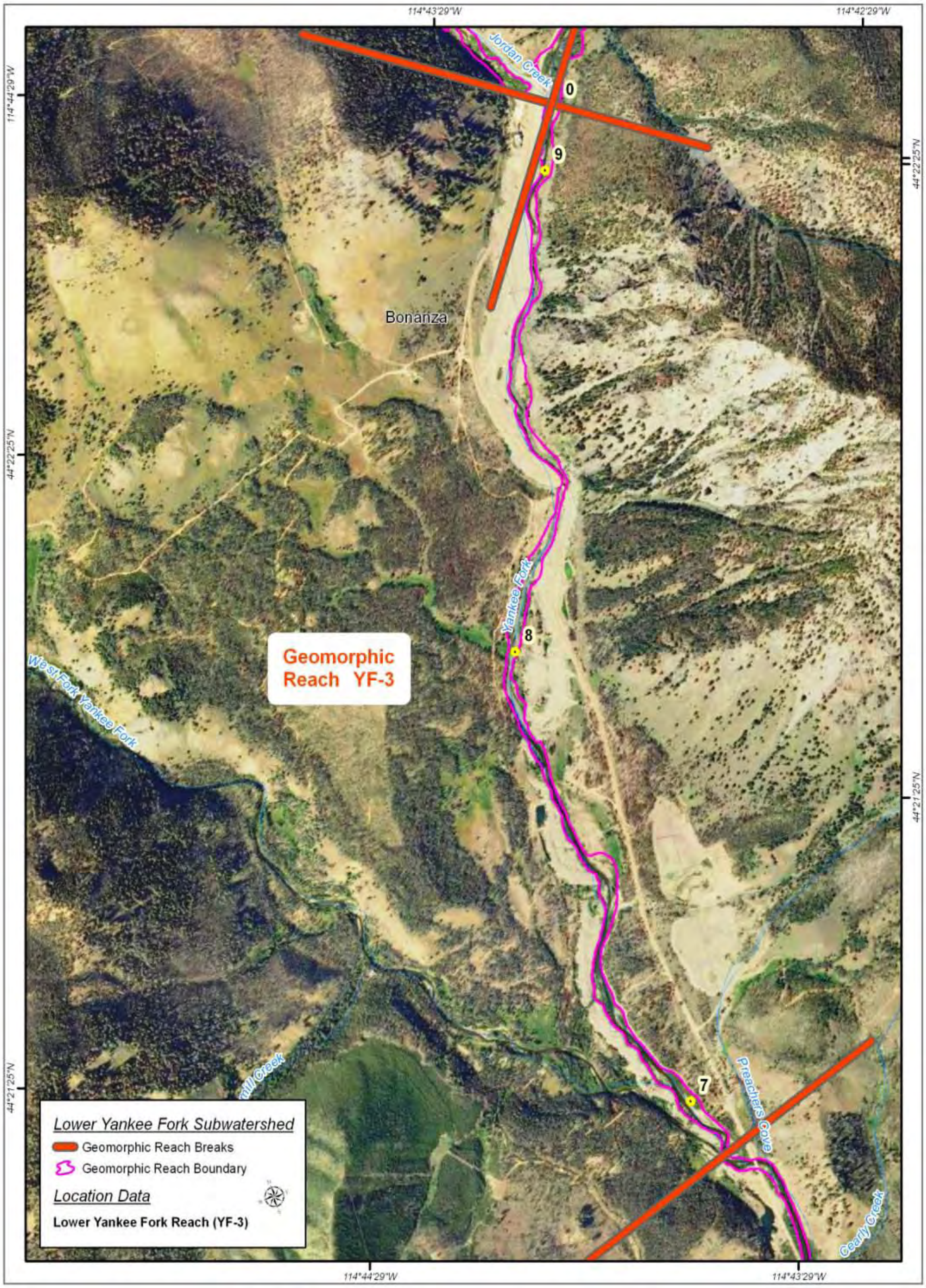

Figure 21. Yankee Fork Reach YF-3 in the lower Yankee Fork subwatershed.

Surficial geologic mapping (Figure 22) was conducted to identify present valley bottom constraints and to assist in interpreting pre-dredging, or natural, valley bottom constraints. The valley type is a U-shaped glacial trough and the present valley bottom constraints are from dredge tailings, alluvial fans, and bedrock that have moderately confined the channel. There are anthropogenic features that provide valley bottom constraints throughout most of the reach. The primary features include the constructed channel and dredge tailing mounds that constraint the channel. Table 11 summarizes the anthropogenic features for this geomorphic reach.

Local coarse sediment inputs are primarily from two perennial tributaries and an ephemeral drainage. The perennial tributaries are Jordan Creek near RM 9.1 on river right and Preachers Cove near RM 7.4 on river left, which are providing sediment pulses during high flow events. An ephemeral drainage that is unnamed near RM 8.3 on river left is providing sediment primarily as debris flows. Other sediment sources include bank erosion occurring along river right near RM 7.9 where the river flows against a glacial terrace, and near RM 7.4 on river left where the river flows against an alluvial fan and right near where it flows against dredge tailings.

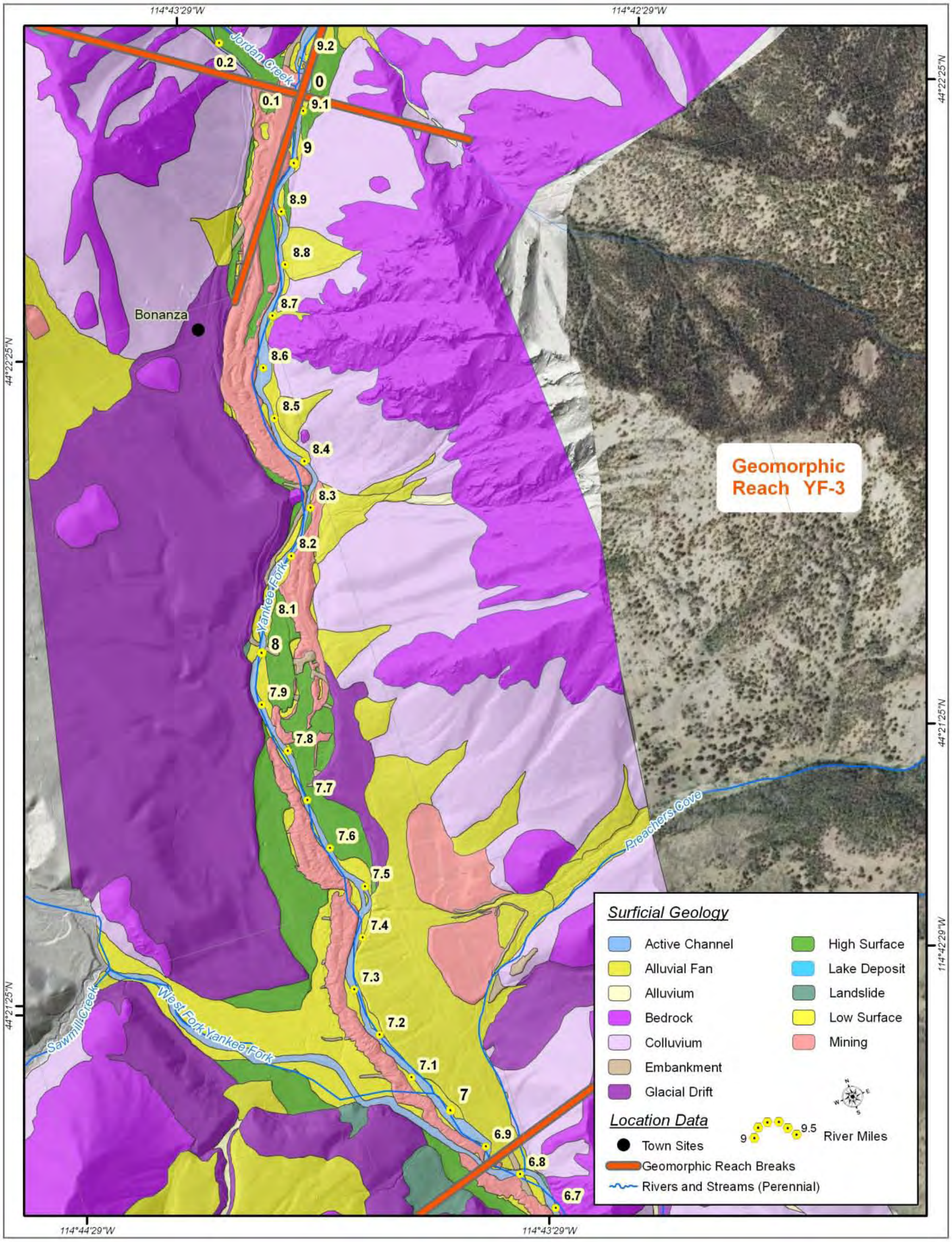

Figure 22. Yankee Fork Reach YF-3 surficial geology map.

Table 11. Anthropogenic features location, description, and effects

River Mile	Anthropogenic Feature	Description	Effects
RM 9.1 – 8.3	Dredge tailing mounds	Channel reconstructed along left valley wall adjacent to the dredge tailing mounds	Constructed channel confined between dredge tailing mounds and left valley wall with small patches of accessible floodplain area
RM 8	Road embankment	Road embankment transects floodplain where a bridge was once present	Road embankments confine the channel and disconnect a small floodplain area on river right
RM 7.8	Dredge tailing mounds	Dredge tailing mounds on both sides of channel	Dredge tailing mounds comprised predominantly of cobbles confine the channel and restrict lateral channel migration
RM 7.8 – 7.5	Dredge tailing mounds	Dredge tailing mounds along river right	Constructed channel confined between dredge tailing mounds and high terrace adjacent to the 1945 channel alignment
RM 7.4 – 6.9	Dredge tailing mounds	Dredge tailing mounds along river right	Constructed channel confined between dredge tailing mounds and alluvial fan; historic channel alignment and floodplain areas present in 1945 have been disconnected; Yankee Fork/West Fork confluence relocated from about RM 7.1 downstream to about RM 6.8

Historically (pre-dredging), the valley bottom constraints were from higher surfaces (comprised predominantly of glacial outwash), alluvial fans and bedrock. From about RM 7.5 to 6.9 the channel was unconfined and the river had developed a broad floodplain and channel/floodplain interactions were connected (Figure 23). The river had a meandering-to-island braided channel pattern that indicates a moderate rate of lateral channel migration was occurring. Channel type was a free-formed to forced alluvial channel with vegetated islands and wood complexes creating flow convergence and divergence that formed a pool-riffle bed-form. In addition, the floodplain contained riparian shrub and upland tree species that stabilized streambanks and provided floodplain roughness.

Figure 23. View is to the north looking upstream from Preachers cove alluvial fan near RM 6.8 on river right towards West Fork confluence (Smith 1911). *Photograph taken by Maven Sawyer, winter of 1910.*

Channel alignments were mapped using 1945, 1952, 1966, 2004, and 2010 aerial photographs (Figure 24). The 1952 aerial photographs were complete, but the channel was only visible between about RM 8.4 and 6.8 because the channel had been obliterated and dredge tailings covered the valley bottom from about RM 9.2 to 8.4.

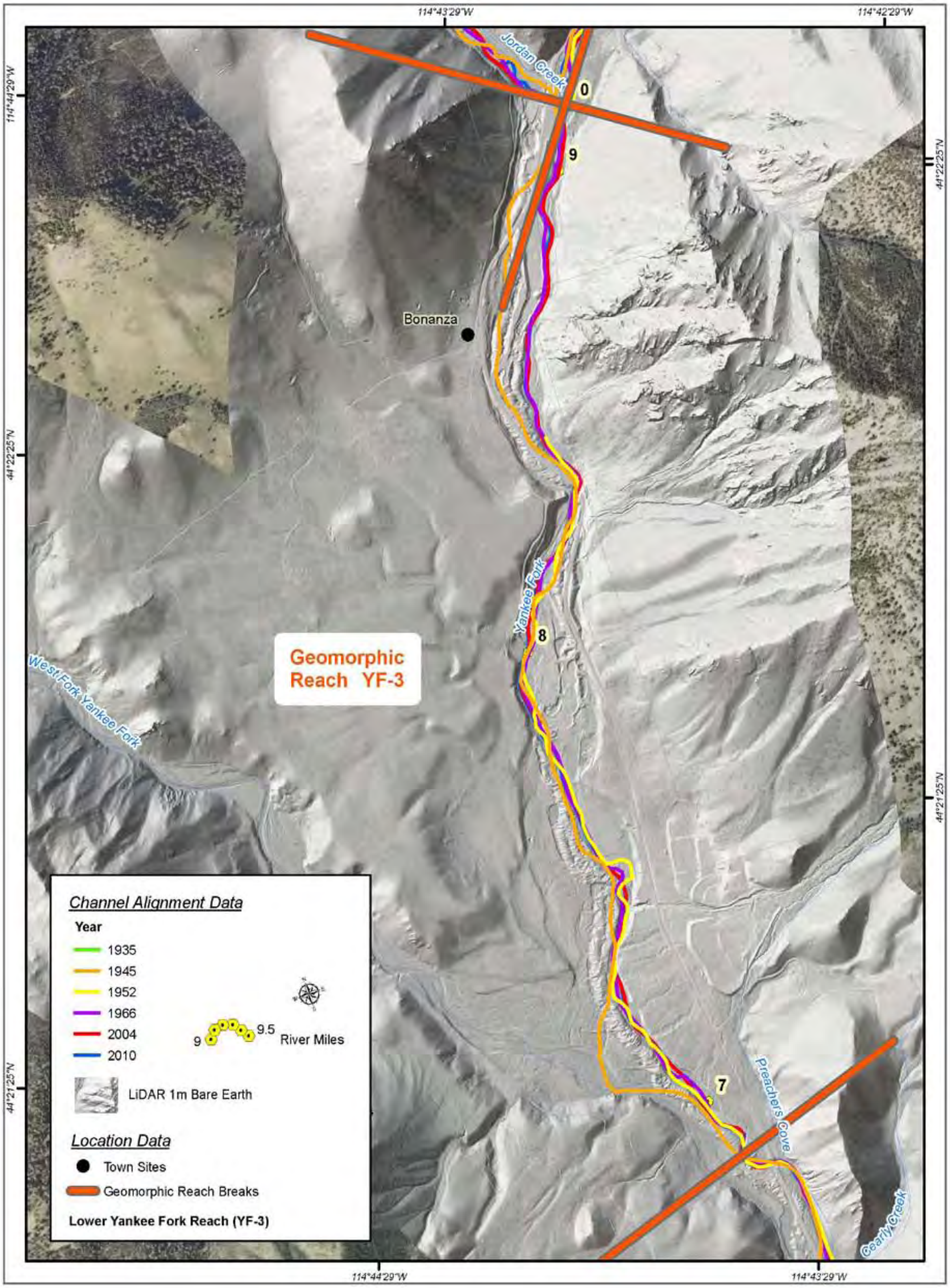

Figure 24. Yankee Fork Reach YF-3: Historical channel alignments.

The river was manipulated in order to maintain the dredging operations by rerouting and/or impounding flows to support the floating dredge. In the 1945 aerial photographs the channel flowed along the right valley wall between RM 9.1 and 8.4, and a new channel was constructed through the dredge tailings along the left valley wall by the 1966 aerial photographs. Between about RM 8.3 and 7.5, the channel has essentially remained in the same location based on the 1945-2010 aerial photographic record; however, in order for the dredge to have operated in this location the channel had to be at least temporarily impounded or otherwise manipulated to support the floating dredge. From RM 7.3 to 6.8 the channel was rerouted away from the West Fork confluence and disconnected from floodplain areas (Figure 25 and Figure 26) by dredge tailings sometime between 1945 and 1952.

Figure 25. 1945 aerial photgraph of West Fork and Yankee Fork confluence.

Figure 26. 2010 aerial photograph of West Fork and Yankee Fork confluence.

Little to no channel migration has occurred within this reach since the channel was constructed through the dredge tailings between 1945 and 1952. The constructed channel alignment, assumed to be similar to the 1952 alignment, had a little more sinuosity than the present, 2010, channel alignment (Table 12). Channel confinement between the dredge tailings (comprised predominantly of cobbles), and the lack of channel/floodplain interactions constrain the flows to within the channel (Figure 27); thereby translating streampower downstream, and increasing sediment transport capacity. Over the last 58 year time period the channel has adjusted by slightly straightening to pass discharges and sediment more efficiently.

Table 12. Yankee Fork Reach YF-3: Historic channel alignments and geomorphic channel metrics

Channel Alignment (Year)	Channel Length	Valley Length	Sinuosity
1945	12,638 feet	11,451 feet	1.10
1952[1]	8,743 feet	8,028 feet	1.09
1966	12,019 feet	11,451 feet	1.05
2004	11,928 feet	11,451 feet	1.04
2010	11,968 feet	11,451 feet	1.05

[1]Based on 1952 aerial photographs covering about RM 8.4 to 6.8; note dredge disconnect channel near RM 8.4

Figure 27. View to the south near RM 7.8 showing dredge tailings constraining channel against valley wall. Bureau of Reclamation photograph by Dave Walsh, September 2, 2010.

Summary and Potential Actions

This geomorphic reach is in a moderately confined valley and the channel pattern is straight-to-meandering which indicates a low-to-moderate rate of lateral channel migration is occurring as compared to other reaches in the assessment area. The channel type is a plane-bed, free-formed alluvial channel with an average channel slope of about 1 percent and the dominant substrate is cobble.

Anthropogenic features provide valley bottom constraints throughout most of the reach. Primary features are the constructed channel through dredge tailing mounds that constrain the channel. The following are locations and effects of these features:

- Channel segment RM 9.1 to 8.3: Channel constructed along left valley wall adjacent to dredge tailings. The constructed channel is confined between the dredge tailings and left valley wall with small patches of accessible floodplain.

- Channel segment RM 7.8 to 7.5: Channel constructed near center of valley bottom. Channel is constrained between dredge tailings (river right) and a high terrace (river left) adjacent to the 1945 (pre-dredge) channel alignment.

- Channel segment RM 7.4 to 6.9: Channel constructed along left valley wall. Channel is constrained between dredge tailings (river right) and alluvial fan (river left). Historic channel alignment and floodplain areas present in 1945 have been disconnected by dredge tailings. The Yankee Fork/West Fork confluence was relocated from about RM 7.1 downstream to about RM 6.8.

Other anthropogenic features that locally confine the channel and/or disconnect floodplains include the following: (a) elevated road embankments (historic bridge approaches) near RM 8 confine the channel and disconnect small floodplain areas along both sides of the channel; and (b) dredge tailings near RM 7.8 confine the channel creating a "pinch-point".

Historically (pre-dredging), the valley bottom constraints were from higher surfaces (comprised predominantly of glacial outwash), alluvial fans and bedrock. From about RM 7.5 to 6.9 the channel was unconfined and the river had developed a broad floodplain and channel/floodplain interactions were connected. The river had a meandering-to-island braided channel pattern that indicates a moderate rate of lateral channel migration was occurring (refer to Figure 25and Figure 26). Channel type was a free-formed to forced alluvial channel with vegetated islands and wood complexes creating flow convergence and divergence that formed a pool-riffle bed-form. In addition, riparian vegetation was present in the floodplain with some upland tree species that stabilized streambanks, and provided channel boundary and floodplain roughness.

There has been little to no lateral channel migration since the channel was constructed in the early 1950s through the dredge tailings. Channel confinement between dredge tailings comprised of cobbles, and the lack of channel/floodplain interactions constrain flows to within the channel; thereby translating streampower downstream. Over the last 58 year time period the channel has adjusted by slightly straightening to more efficiently pass discharges and sediment.

Qualitatively, this reach would have provided high water refugia and rearing habitats for juveniles, and spawning and holding pool habitats for adults based on physical and ecological processes that occurred prior to dredging. The main concern is that there is a pre-mature out-migration of juveniles presently occurring because of high flow velocities, and the lack of accessibility to high water refugia and rearing habitats (Richards and Cernera 1989).

A reach-assessment is recommended to further refine, and quantify, present conditions versus historic (pre-dredge) conditions, changes to physical and ecologic processes, and the habitat potential for this reach. At a minimum, a more thorough analysis is needed to determine the following: (a) if during channel forming flows (especially during the spring-freshet) velocities exceed 3 ft/s (NOAA Fisheries 2008) preventing upstream juvenile fish passage in the Yankee Fork and into the West Fork subwatershed, (b) if the Yankee Fork/West Fork confluence and channel/floodplain interactions were rehabilitated to pre-dredging conditions, what would be the benefits, and risks, to the physical and ecological processes and to the resource, and (c) conceptually, what are some viable alternatives, and their limitations, for reconnecting historic channel/floodplain interactions throughout the reach?

5.2.3 Reach YF-2

Geomorphic Reach YF-2 (Figure 28) is located between about RM 6.9 and 3 in a confined valley segment that is constrained by dredge tailings throughout most of the reach. The channel type is a free-formed alluvial channel with a plane-bed and a straight-to-meandering channel pattern. Channel slope is about 0.6 percent with a cobble dominated substrate.

Figure 28. Yankee Fork Reach YF-2 in the lower Yankee Fork subwatershed.

Surficial geologic mapping (Figure 29) was conducted to identify present valley bottom constraints and to assist in interpreting pre-dredging, or natural, valley bottom constraints. The valley type is a U-shaped glacial trough and the present valley bottom constraints are from dredge tailings, glacial outwash, alluvial fans, and bedrock that have confined the channel. There are anthropogenic features that provide valley bottom constraints throughout most of the reach. The primary features include the constructed channel and dredge tailings that constrain the channel. Table 13 summarizes the anthropogenic features for this geomorphic reach.

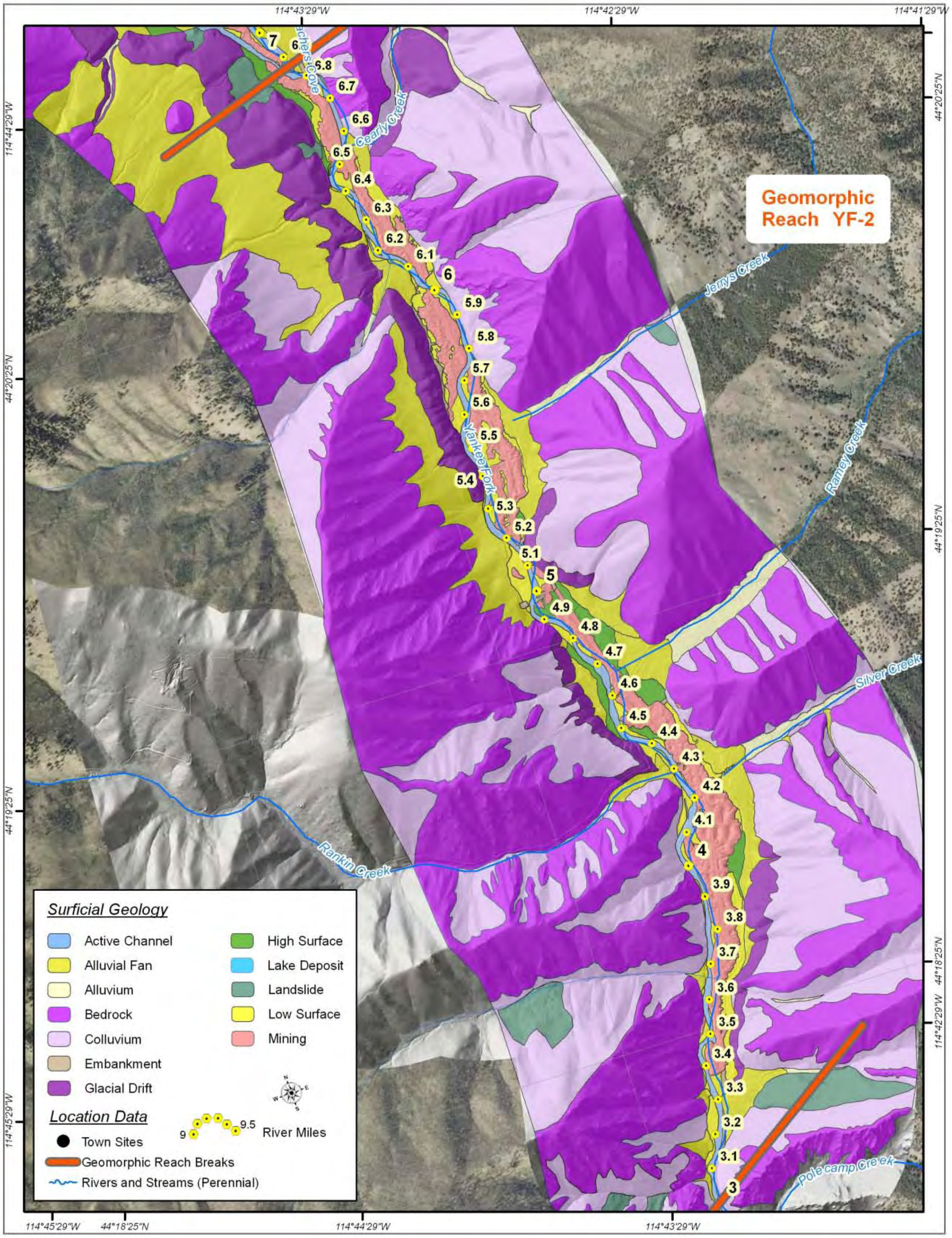

Figure 29. Yankee Fork Reach YF-2 surficial geology map.

Table 13. Anthropogenic features location, description, and effects

River Mile	Anthropogenic Feature	Description	Effects
RM 6.8	Bridge crossing	Bridge crossing with embankment approaches and riprap bank protection	Bridge crossing confines the channel; right embankment approach constructed with dredge tailings disconnects a small floodplain area; riprap restricts lateral channel migration
RM 6.7 – 6.5	Dredge tailings	Dredge tailing mounds along river right	Constructed channel confined between dredge tailing mounds on river right and the valley wall on river left; channel is located about on 1945 pre-dredge channel alignment
RM 6.5	Bridge crossing	Channel constructed through dredge tailing mounds; bridge constructed across apex of mounds; riprap bank protection	Channel is confined between dredge tailing mounds; left bridge abutment has riprap bank protection that causes bed scour
RM 6.5 - 6	Dredge tailings	Channel constructed adjacent to dredge tailing mounds and along right valley wall	Channel relocated to right valley wall where in 1945 it flowed against the left valley wall; channel is moderately confined between dredge tailing mounds along river left and glacial outwash terrace and alluvial fans along river right
RM 6	Bridge crossing	Channel constructed through dredge tailing mounds; bridge constructed across apex of mounds; riprap bank protection	Channel is confined between dredge tailing mounds; right bridge abutment has riprap bank protection that causes bed scour
RM 5.7	Bridge crossing	Channel constructed through dredge tailing mounds; bridge constructed across apex of mounds; riprap bank protection	Channel is confined between dredge tailing mounds; left bridge abutment has riprap bank protection that causes bed scour
RM 5.7 – 5.4	Dredge tailings	Channel constructed through and adjacent to dredge tailing mounds	Channel is moderately confined between dredge tailing mounds and glacial outwash terrace
RM 5.4 – 5.1	Dredge tailing	Channel constructed adjacent to dredge tailing mounds	Channel is confined between dredge tailing mounds, and glacial outwash terrace and alluvial fans
RM 5.1	Road embankment	Custer Motorway road embankment adjacent to channel	Road embankment is comprised of dredge tailings along the left valley wall; affects on channel are minimal
RM 5	Road embankment	Road embankment transects floodplain where a bridge was once present	Road embankments constructed from tailings confine the channel and disconnect small floodplain areas on river both sides of the channel

River Mile	Anthropogenic Feature	Description	Effects
RM 4.9 - 4	Dredge tailings	Channel constructed adjacent to dredge tailing mounds	Channel is moderately confined between dredge tailing mounds along river left, and glacial outwash terraces, alluvial fans and bedrock along river right
RM 4 – 3.3	Dredge tailings	Channel constructed adjacent to dredge tailing mounds	Channel is confined between dredge tailing mounds along river left, and glacial outwash terraces, alluvial fans and bedrock along river right
RM 3.2	Road embankment	Custer Motorway road embankment adjacent to channel	Road embankment disconnects small floodplain area on river left

Local coarse sediment inputs are primarily from bank erosion along outside meanders and are described in Table 14. Other sources include three perennial tributaries and seven ephemeral drainages. The perennial tributaries are West Fork near RM 6.8 along river right; Ramey Creek near RM 4.6 along river left; and Rankin Creek near RM 4.3 along river right. Unnamed ephemeral drainages along river right that provide sediment inputs primarily as debris flows are located near RM 6.3; RM 6.1; RM 5.1; RM 3.6; RM 3.3; RM 3.1; and RM 3.

Two perennial tributaries along river left are presently disconnected from the Yankee Fork by dredge tailings and no longer supply sediment to the mainstem. These tributaries include Jerrys Creek near RM 5.5, and Silver Creek near RM 4.2. Cearley Creek near RM 6.5 is connected to a series of dredge ponds that are adjacent to and connected to the Yankee Fork, but the sediment is deposited in the ponds and does not reach the Yankee Fork mainstem.

Table 14. Summary of sediment inputs from bank erosion

River Mile (Approx.)	Description
RM 6.7	Bank erosion along outside meander on river left eroding colluvial deposit
RM 6.4	Bank erosion along outside meander on river right eroding glacial terrace
RM 6.3	Bank erosion along outside meander on river left eroding dredge tailings
RM 6.3 to 6.2	Bank erosion along a straight channel segment along river right eroding alluvial fan deposit
RM 6.1	Bank erosion along outside meander along river left eroding dredge tailings
RM 5.6	Bank erosion along outside meander along river left eroding dredge tailings
RM 5.4	Bank erosion along outside meander along river left eroding dredge tailings

River Mile (Approx.)	Description
RM 5.3 to 5.2	Bank erosion along outside meander along river left eroding dredge tailings
RM 5	Bank erosion along outside meander along rive left eroding dredge tailings
RM 4.9	Bank erosion along outside meander along river right eroding alluvial fan and colluvial deposits
RM 4.8	Bank erosion along outside meander along river left eroding dredge tailings
RM 4.8 to 4.7	Bank erosion along outside meander along river right eroding glacial outwash
RM 4.7 to 4.6	Bank erosion along outside meander along river left eroding dredge tailings
RM 4.6 to 4.5	Bank erosion along a straight channel segment along river right eroding glacial outwash
RM 4.4	Bank erosion along outside meander along river left eroding dredge tailings
RM 4.2 to 4.1	Bank erosion along outside meander along river left eroding dredge tailings
RM 4.1 to 4	Bank erosion along outside meander along river right eroding glacial outwash
RM 3.9 to 3.8	Bank erosion along outside meander along river left eroding dredge tailings
RM 3.8	Bank erosion along a straight channel segment along river right eroding glacial outwash
RM 3.7 to 3.6	Debris flow from unnamed tributary on river right is eroding on the upstream end and forces the river to the left bank where it is eroding dredge tailings
RM 3.5 to 3.4	Bank erosion along the outside meander along river left and the flows are forced to river right by large dredge tailing mound and is eroding a colluvial deposit that overlies bedrock
RM 3.1	Debris flow from unnamed tributary on river right is eroding on the upstream end and forces the channel toward river left; debris flow deposit constricts the channel and has created a backwater affect upstream

Historically (pre-dredging), the channel was moderately confined to confined based on valley bottom constraints from glacial terraces and outwash, alluvial fans and bedrock (Figure 30). The river had a straight-to-meandering channel pattern that indicates a low rate of lateral channel migration was occurring. Channel type was a plane-bed (USDC 1934), free-formed alluvial channel with a cobble dominated substrate. There were small-to-moderate sized floodplain areas accessible to the river during high flows, but these floodplain areas were not extensive (Figure 31), and qualitatively appear similar to their present (2010) extent. In addition, three perennial tributaries were connected to the Yankee Fork that included Cearley Creek, Jerrys Creek, and Silver Creek.

Figure 30. View is to the north looking upstream from glacial terrace near RM 5.2 on river left at Jerrys Creek alluvial fan (Smith 1911).

Figure 31. 1945 aerial photograph of Yankee Fork near Jerrys Creek. *Note the floating dredge in the lower center of the photograph and the dredge tailings deposited across the valley floor.*

Channel alignments were mapped using 1935 Iowa Group Placer Mining Claim plat map between about RM 4.7 and 3.1; and 1945, 1952, 1966, 2004, and 2010 aerial photographs (Figure 32). The 1945 channel alignment covers from about RM 6.8 to 5.2 where the valley bottom had not been dredged. The period of record defined by the 1935 plat map and five aerial photograph sets cover the time period prior to dredging operations between about RM 6.8 and 5.2 (1945) and RM 4.7 and 3.2 (1935), and after dredging and channel construction was completed (1952-2010).

Little channel migration has occurred from about RM 6.8 and 6.5, RM 6.1 and 5.7, and RM 5.3 and 5. Areas where active channel migration has been occurring in this reach over the period of record are as follows:

- Channel segment RM 6.5 to 6.1: Channel has adjusted by straightening based on the 1952 channel alignment which is assumed to be similar to the constructed channel.

- Channel segment RM 5.7 to 5.3: Channel migration has been occurring downstream of a bridge constriction near RM 5.7 where the channel flows against the right valley wall. The channel is moderately confined between the valley wall on river right and dredge tailings on river left.

- Channel segment RM 5 to 3: There has been some channel migration in sections where the channel is moderately confined between the valley wall and dredge tailings. Little to no channel migration has occurred in the sections where the channel is confined.

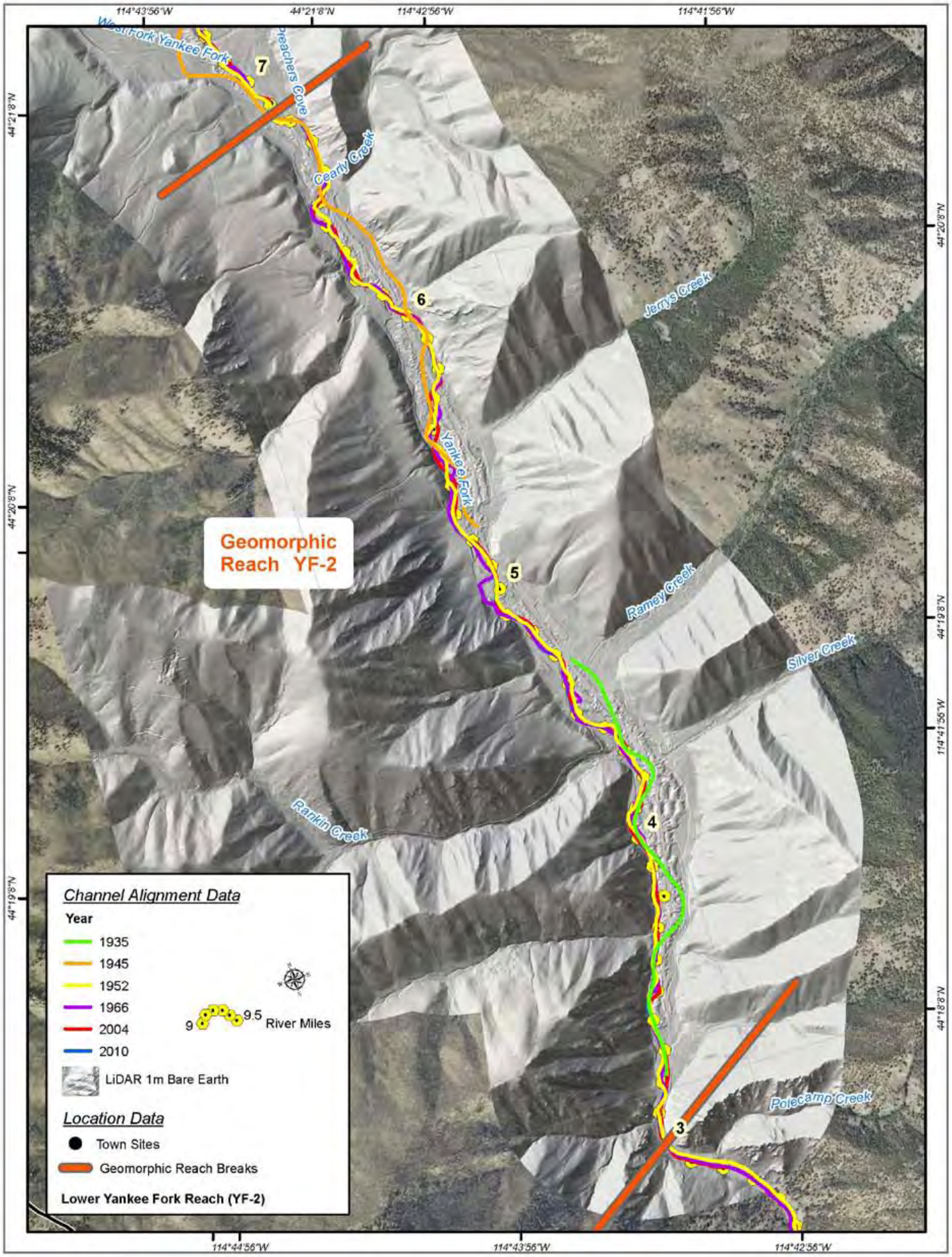

Figure 32. Yankee Fork Reach YF-2: Historical channel alignments.

Present channel sinuosity is similar to pre-dredging channel sinuosity (Table 15). Note the channel sinuosity for 1935 covered from about RM 4.7 to 3.1, and for 1945 covered from 6.8 to 5.2. A thin riparian corridor has re-established adjacent to the channel along the dredge tailings that provides some bank stability and channel boundary roughness. The land use has not significantly changed adjacent to the river since the valley bottom was dredged leaving an expanse of dredge tailings. An exception is the construction and new alignment of the Custer Motorway that is located near the center of the valley floor and built on mostly along the dredge tailings.

Table 15. Yankee Fork Reach YF-2: Historic channel alignments and geomorphic channel metrics

Channel Alignment (Year)	Channel Length	Valley Length	Sinuosity
1935[1]	7,822 feet	7,370 feet	1.06
1945[2]	8,251 feet	7,649 feet	1.08
1952	20,421 feet	19,024 feet	1.07
1966	20,881 feet	19,024 feet	1.10
2010	20,430 feet	19,024 feet	1.07

[1]Based on 1935 surveyed plat map from about RM 4.7 to RM 3.1
[2]Based on incomplete set of 1945 aerial photographs covering about RM 6.8 to 5.2

Summary and Potential Actions

The channel in this geomorphic reach is presently confined and the channel pattern is straight-to-meandering which indicates a low-to-moderate rate of lateral channel migration is occurring as compared to other reaches in the assessment area. The channel type is a plane-bed, free-formed alluvial channel with an average channel slope of about 0.6 percent and the dominant substrate is cobble.

Anthropogenic features provide valley bottom constraints throughout most of the reach. Primary features are the constructed channel through dredge tailing mounds that constrain the channel. The following are locations and effects of these features:

- Channel segment RM 6.7 to 6.5: Channel constructed along left valley wall and adjacent to dredge tailings. The constructed channel is confined between dredge tailings on river right and the valley wall on river left with small sized patches of accessible floodplain.

- Channel segment RM 6.5 to 6: Channel constructed along right valley wall and adjacent to dredge tailings. The constructed channel is moderately confined between dredge tailings (river left) and, glacial terrace and alluvial fan deposits (river right) with a moderately sized patches of accessible floodplain.

- Channel segment RM 5.7 to 5.4: Channel constructed through dredge tailings. Channel is moderately confined by dredge tailings with moderately sized patches of accessible floodplain.

- Channel segment RM 5.4 to 5.1: Channel constructed along right valley wall adjacent to dredge tailings. Channel is confined between dredge tailings (river left) and, glacial terrace and alluvial fan deposits (river right) with small sized patches of accessible floodplain.

- Channel segment RM 4.9 to 4: Channel constructed along right valley wall adjacent to dredge tailings. Channel is moderately confined between dredge tailings (river left) and, glacial terrace, alluvial fans, and bedrock (river right) with small-to-moderately sized patches of accessible floodplain.

- Channel segment RM 4 to 3.3: Channel constructed along right valley wall adjacent to dredge tailings. Channel is confined between dredge tailings (river left) and, glacial terrace, alluvial fans and bedrock (river right) with small sized patches of accessible floodplain.

Other anthropogenic features that locally confine the channel and/or disconnect floodplains include the following: (a) bridge crossings near RM 6.8, RM 6.5, RM 6, and RM 5.7, (b) Custer Motorway road embankment along valley wall that encroaches on the channel near RM 5.1, (c) road embankment (historic bridge location) transects valley bottom confining the channel and disconnecting small floodplain areas near RM 5, and (d) Custer Motorway road embankment disconnects small floodplain area near RM 3.2. In addition, two perennial tributaries (Jerrys Creek and Silver Creek) have been disconnected from the Yankee Fork by dredge tailings.

Historically (pre-dredging), the channel was moderately confined to confined based on valley bottom constraints from glacial terraces and outwash, alluvial fans and bedrock. The river had a straight-to-meandering channel pattern that indicates a low rate of lateral channel migration was occurring. Channel type was a plane-bed, free-formed alluvial channel with a cobble dominated substrate. There were small-to-moderate sized floodplain areas accessible to the river during high flows, but these floodplain areas were not extensive. Similar conditions are currently present with the exception that the channel may be slightly more confined in some locations.

Since the channel was constructed in the late 1940s or early 1950s, there has been some lateral channel migration in areas where the channel is moderately confined by the dredge tailings. Relatively small floodplain areas have developed through lateral channel migration that have good channel/floodplain interactions and provide some high water refugia and rearing habitat. Where the channel is confined due to dredge tailings, there has been almost no lateral channel migration.

A reach-assessment is not necessary to address the localized anthropogenic impacts in this geomorphic reach. There are similar channel processes and available habitats currently present that were occurring historically (pre-dredge). The exceptions are the disconnected tributaries that once provided juvenile rearing habitat, but were separated from the Yankee Fork mainstem by dredge tailings. There are four series of ponds adjacent to the mainstem that could be utilized to reconnect some tributaries and/or to increase juvenile rearing habitat. An alternatives analysis could be conducted to address the reconnection of the tributaries to provide additional habitat, and anthropogenic features affecting channel/floodplain interactions. Documentation of baseline conditions should be considered as part of the alternatives analysis for monitoring purposes, and how the potential actions are anticipated to benefit the resources and their potential risks.

5.2.4 Reach YF-1

Geomorphic Reach YF-1 (Figure 33) is located between about RM 3 to the Yankee Fork/Salmon River confluence in a V-shaped canyon confined by bedrock and talus. The river has a bedrock channel with a step-pool bed-form and a slope of about 1.1 percent. Two perennial tributaries contribute flows to the Yankee Fork. These tributaries include Polecamp Creek near RM 2.8 on river left; and Blind Creek near RM 0.9 on river right. There are minimal overbank areas and most are accessible to the channel. The road embankment does encroach on the channel in some locations and there is one bridge crossing, Flat Rock Bridge, near RM 1.9. The bridge and road embankments do not have significant impacts on channel processes in this reach.

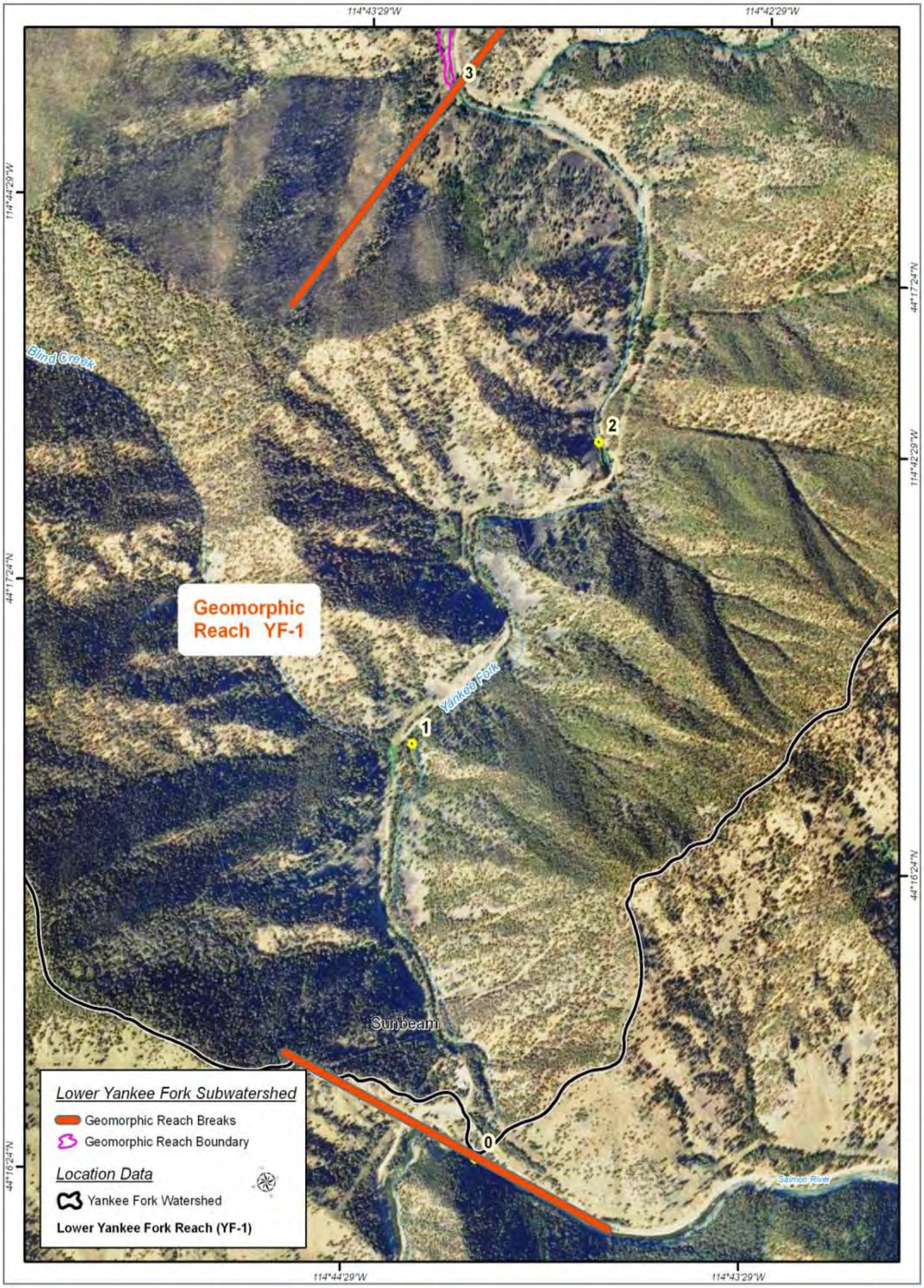

Figure 33. Yankee Fork Reach YF-1 in the lower Yankee Fork subwatershed.

Lateral channel migration was evaluated using 1952, 1966, and 2004 aerial photographs (Figure 34). The period of record defined by the aerial photograph sets cover a 52 year time period. Little lateral channel migration has occurred in the last 52 years. There has been a small amount of lateral channel migration where the valley bottom slightly increases in width and the outside edge of meanders where bank erosion has occurred.

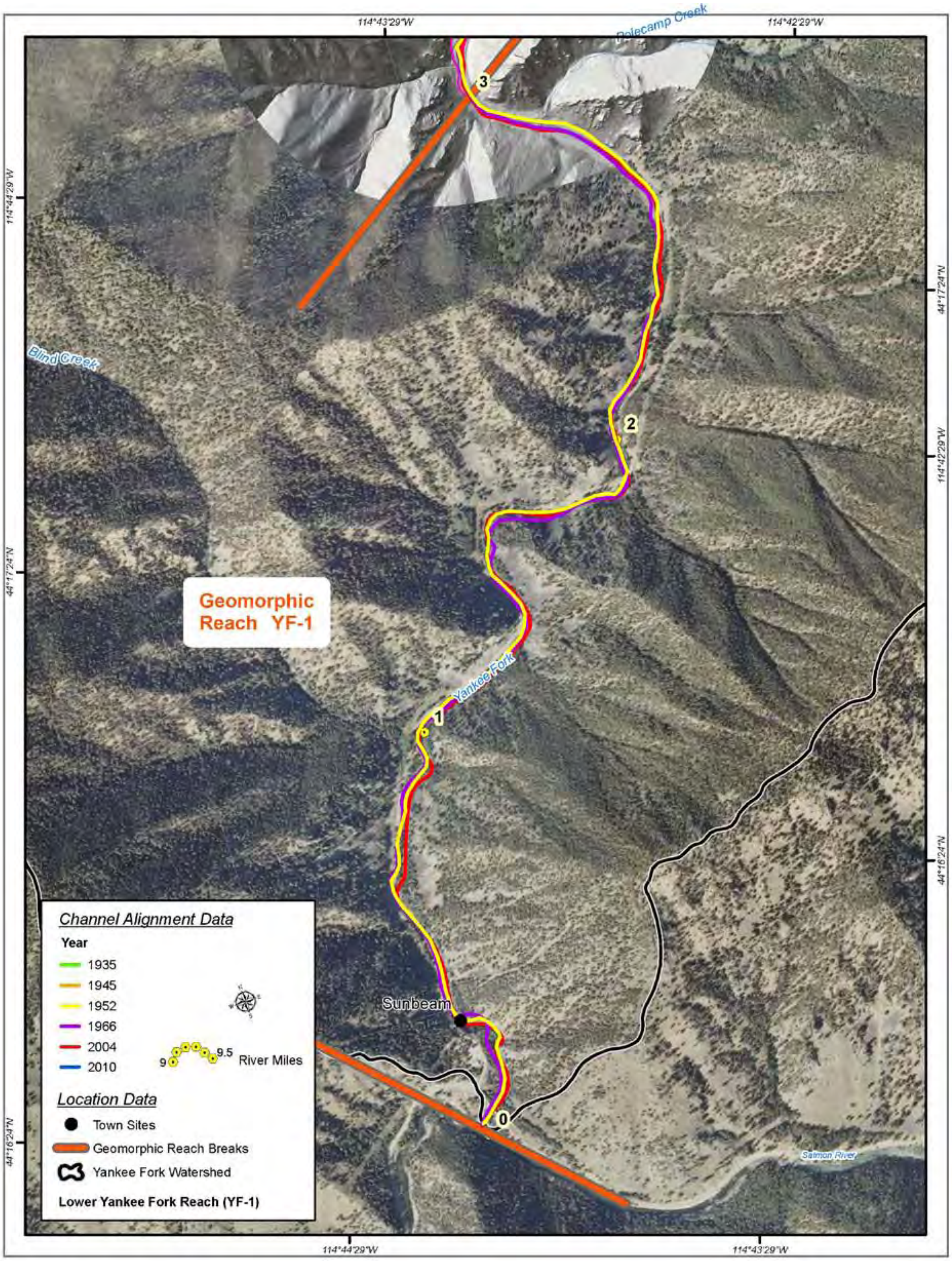

Figure 34. Yankee Fork Reach YF-1: Historical channel alignments.

Channel sinuosity has slightly increased over the period of record (1952-2010) in this reach (Table 16). The increase in sinuosity is associated with the channel's ability to erode some colluvial deposits along the outside edge of meanders from about RM 1.9 to 1.8, RM 0.9 to 0.8, and 0.3 to 0.2.

Table 16. Yankee Fork Reach YF-1: Historic channel alignments and geomorphic channel metrics

Channel Alignment (Year)	Channel Length	Valley Length	Sinuosity
1952	15,679 feet	15,433 feet	1.02
1966	15,579 feet	15,433 feet	1.01
2004	15,991 feet	15,433 feet	1.04

There are small overbank areas in the reach that appear to be connected to the channel. Road embankments do encroach on the channel, but do not significantly impact channel processes. Vegetation along the active channel banks is comprised predominantly of upland trees along the steep, valley side-slopes. Few pieces of large wood were observed which would be expected for this high energy transport reach (Figure 35).

Figure 35. View to the southeast looking downstream at reach YF-1 near RM 3. Bureau of Reclamaiton photograph by Dave Walsh, September 2, 1010.

Summary and Potential Actions

This geomorphic reach is in a confined, V-shaped canyon that has high sediment transport capacity. No anthropogenic disturbances significantly impact channel processes. The reach is utilized by Chinook salmon, steelhead and bull trout as a migratory corridor, and provides very little, if any, juvenile rearing habitat. No fish passage barriers or habitat deficiencies have been identified for this reach.

Since the bedrock canyon is primarily a migratory corridor with no fish passage barriers and no real potential to change or develop additional habitat, there is no need for further assessment. Maintaining fish passage should be the priority for this geomorphic reach.

6. Jordan Creek Subwatershed

6.1 Valley Segments

Jordan Creek subwatershed enters the Yankee Fork near RM 9.1. The valley has a predominantly north-northwest orientation with a drainage area of about 16.4 square miles and a drainage density of about 1.51. Bedrock geology is the Challis Volcanics transected by the northeast trending trans-Challis fault zone. Movement along the trans-Challis fault has created a broad shear zone through this drainage where mineralization of precious metals has occurred along fractures, shears, and faults. Several hard-rock and placer mines have operated adjacent to the stream and along adjacent valley walls.

Two valley segments in the *Tributary Assessment* area were delineated along Jordan Creek (Table 17) that included the following cross-sectional valley forms: (1) an upper section V-shaped bedrock canyon between RM 4 and 1.4; and (2) a lower section V-shaped alluvial canyon between RM 1.4 and the Yankee Fork/Jordan Creek confluence.

Table 17. Jordan Creek valley forms

River Miles	General Valley Location	Valley Form[1]	Side Slope Gradient	Current Channel Constraints and Valley Geology
RM 4.0-1.4	Upper Section	V3: V-shaped bedrock canyon	SW 53%: NE 50%	Bedrock with colluvial, glacial, alluvial fan and landslide deposits that further constrain the channel; road embankments encroach on channel in some locations: valley geology is Challis Volcanics
RM 1.4-0	Lower Section	V4: V-shaped alluvial canyon	W 30%: E 38%	Mine tailings and mining spoils, glacial and colluvial deposits; road embankments provide some localized constraints: valley geology is Challis Volcanics mantled with primarily glacial outwash

[1]Classification based on Naiman et al. (1992) as recommended in Hillman (2006)

The valley was determined to be moderately confined along both the upper and lower sections (Table 18).

Table 18. Jordan Creek valley constraints and confinement determinations

River Miles	Valley Gradient	Valley Floor Width[1]	Constrained Valley Width (CVW)[1]	Channel Width (CW)[1]	Ratio (CVW:CW)	Channel Confinement[2]
RM 4.0-1.4	3.30 percent	228 feet	61 feet	19 feet	1:3.21	Moderately Confined
RM 1.4-0	2.62 percent	245 feet	72 feet	19 feet	1:3.79	Moderately Confined

[1]Aquatic Inventories Project Methods for Stream Habitat Surveys (ODFW 2010)
[2]Monitoring Strategy for the Upper Columbia Basin (Hillman 2006)

6.2 Geomorphic Reach Delineations

Two geomorphic reaches were identified along Jordan Creek in the Tributary Assessment area based on geomorphic processes and channel morphology (Table 19). Locations of the geomorphic reaches are provided Figure 36. The longitudinal channel profile (Figure 37) shows the geomorphic reaches within the channel network. Details associated with each geomorphic reach are discussed in the following sections.

Table 19. Jordan Creek geomorphic reach delineations and associated channel morphology

River Miles	Reach Designation	Reach Area	Channel Confinement	Channel Type[1]	Channel Slope	Channel Sinuosity	Dominant Substrate Size Class[2]
RM 4-0.4	JC-2	16 acres	Moderately Confined	Plane-bed to Pool-riffle	2.90 percent	1.06	Cobble/Gravel
RM 1.4-0	JC-1	9 acres	Moderately Confined	Plane-bed to Pool-riffle	2.50 percent	1.05	Cobble/Gravel

ND – Not determined
[1]Channel type classification based on Montgomery and Buffington (1993)
[2]From Stream Inventory Survey 2010 (Tributary Assessment report Appendix A) and USFS (2006)

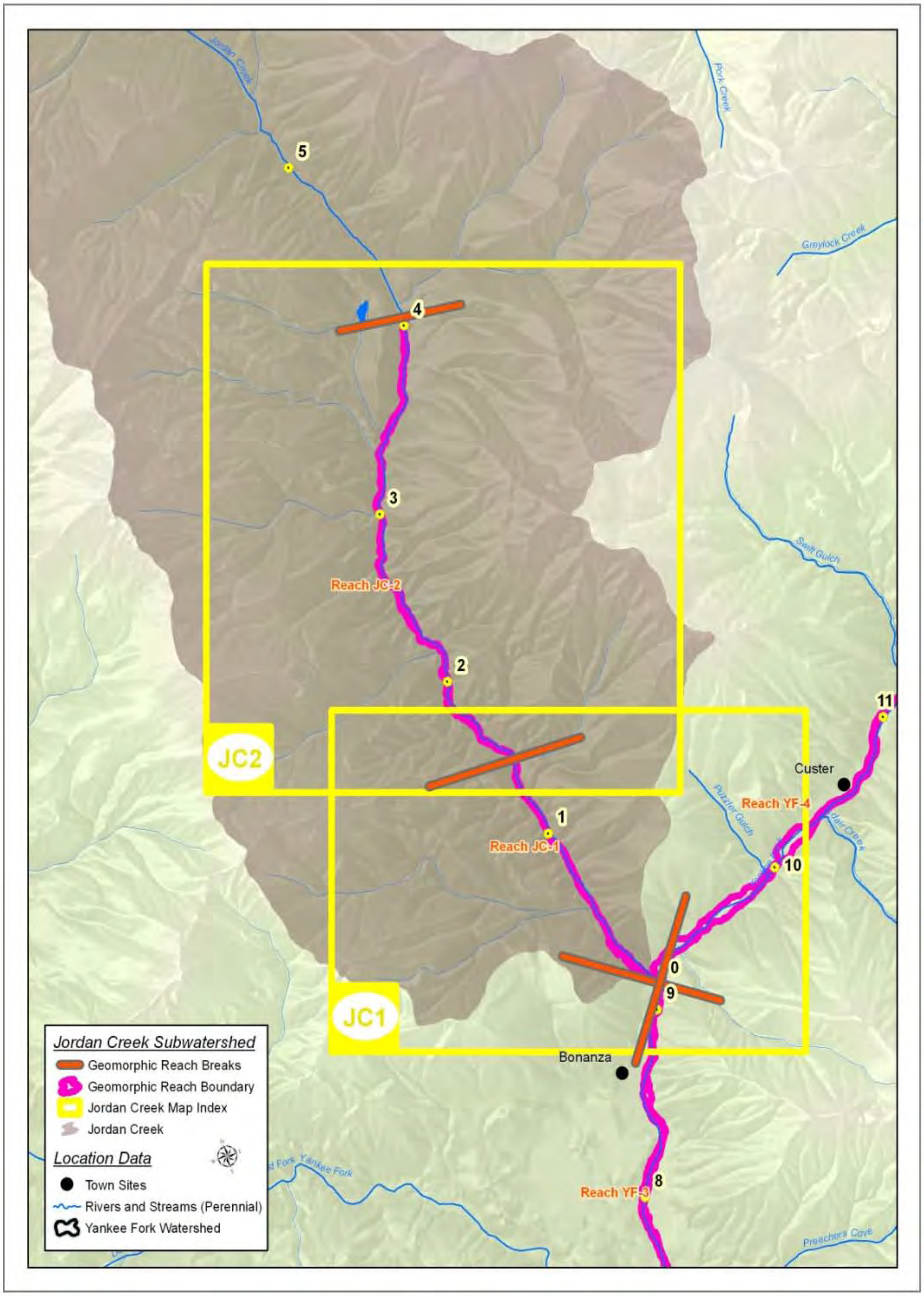

Figure 36. Jordan Creek subwatershed index map with geomorphic reach breaks.

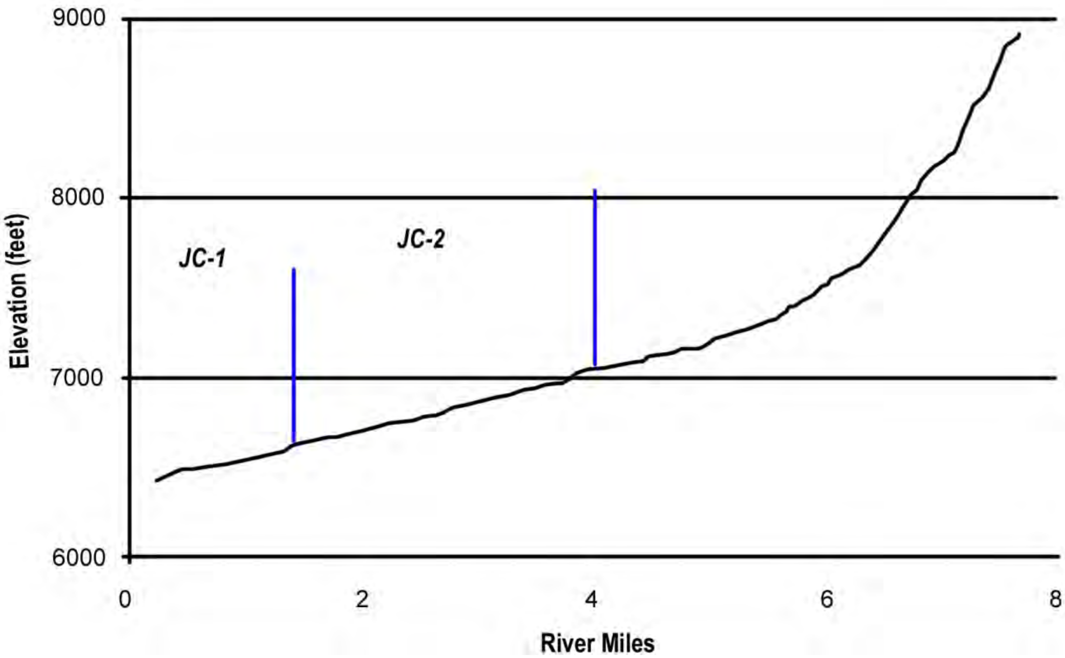

Figure 37. Jordan Creek subwatershed longitudinal channel profile with reach locations.

6.2.2 Reach JC-2

Geomorphic Reach JC-2 (Figure 38) is located between about RM 4 and 1.4 in a moderately confined valley segment that is constrained by bedrock with colluvial, glacial, alluvial fan, and landslide deposits that further constrain the channel. The channel type is predominantly a bedrock channel with alternating plane-bed and pool-riffle bed-forms and a straight channel pattern. Channel slope is about 2.9 percent with a cobble dominated substrate with boulders and bedrock common.

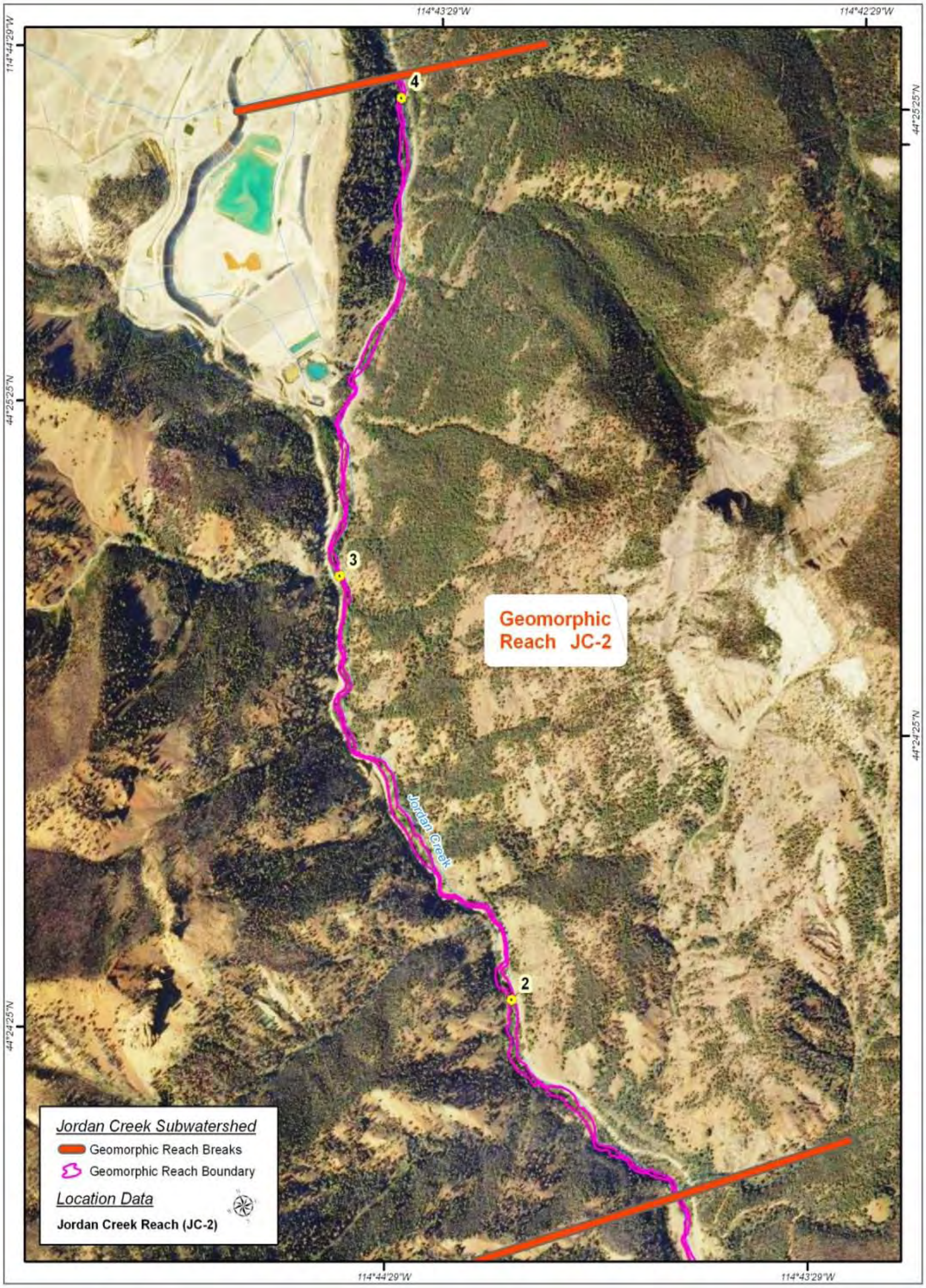

Figure 38. Jordan Creek Reach JC-2 in the Jordan Creek subwatersheds.

Surficial geologic mapping (Figure 39) was conducted to identify present valley bottom constraints and to assist in interpreting natural valley bottom constraints. The valley type is predominantly a V-shaped bedrock canyon that is further constrained by Quaternary-age sedimentary deposits. Road embankments are the primary anthropogenic features that provide valley bottom constraints. Table 20 summarizes the anthropogenic features for this geomorphic reach.

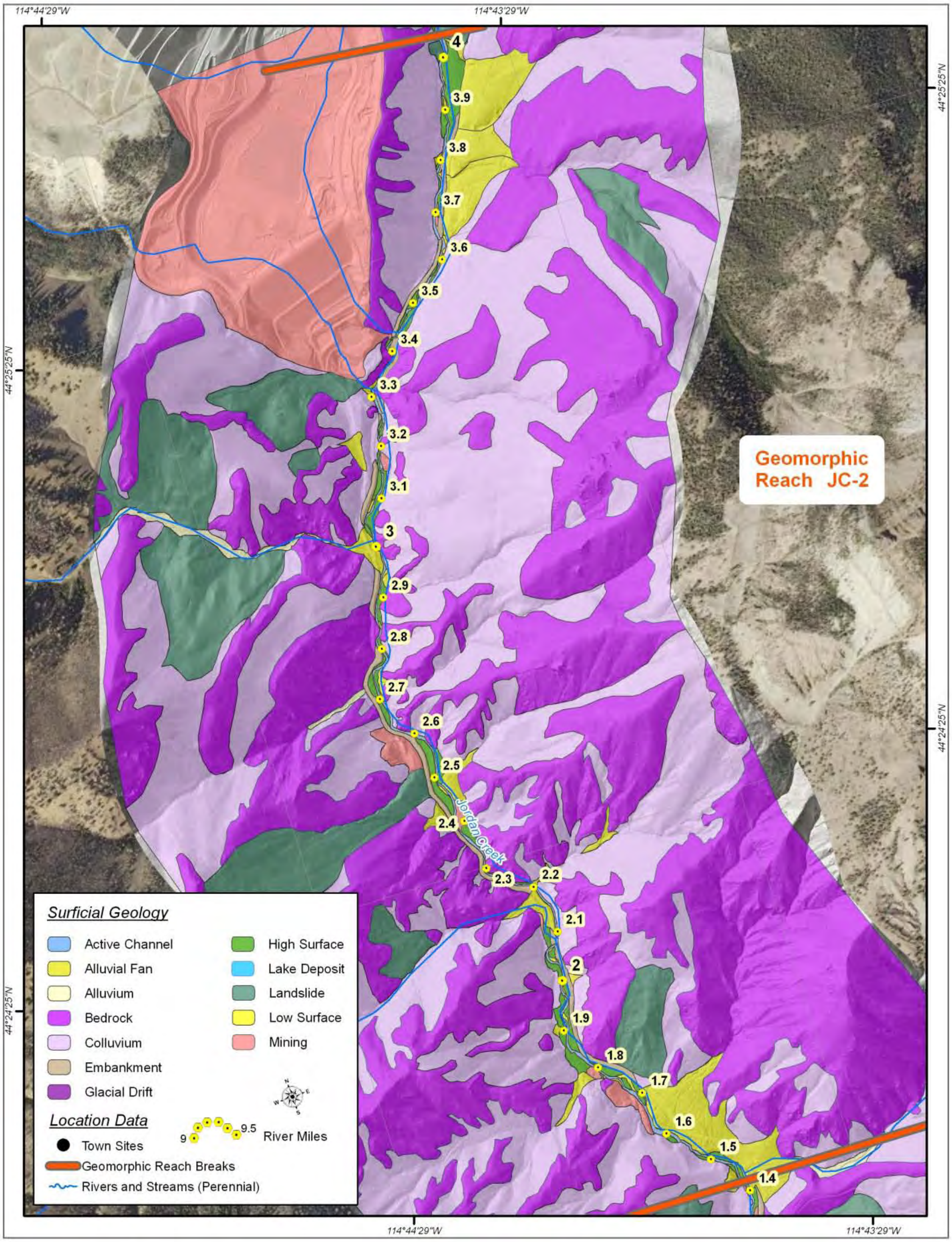

Figure 39. Jordan Creek Reach JC-2 surficial geology map.

Table 20. Anthropogenic features location, description, and effects

River Mile	Anthropogenic Feature	Description	Effects
RM 4	Road embankment	Loon Creek Road embankment adjacent to channel	Road embankment encroaches on the channel along river left and constricts the channel between the embankment and landslide deposit; affects on channel are minimal
RM 3.8 – 3.6	Road embankment	Loon Creek Road embankment adjacent to channel	Road embankment encroaches on the channel along river left and constricts the channel between the embankment and colluvial deposit; affects on channel are minimal
RM 3.7 – 3.6	Mining spoils	Mining spoils adjacent to channel	Mound of mining spoils along river left impede channel/floodplain interactions
RM 3.6	Bridge crossing	Bridge crossing with embankment approaches and riprap bank protection	Bridge crossing confines and re-directs the channel; riprap restricts lateral channel migration
RM 3.6 – 3.4	Road embankment	Loon Creek Road embankment adjacent to channel and floodplain	Road embankment encroaches on the channel and floodplain along river right; affects on channel are minimal
RM 3.2	Bridge crossing	Bridge crossing with embankment approaches and riprap bank protection	Bridge crossing confines the channel; riprap restricts lateral channel migration; affects on channel are minimal due to bedrock controls
RM 3.1	Mining spoils	Mining spoils adjacent to floodplain	Mining spoils from active placer mine encroach on floodplain along river left
RM 3.1 - 3	Road embankment	Loon Creek Road embankment adjacent to floodplain	Road embankment encroaches on the floodplain along river right; affects are minimal because there are accessible floodplain areas along river left
RM 3 – 2.9	Road embankment	Loon Creek Road embankment adjacent to channel	Road embankment encroaches on the channel along river right; affects are minimal as the road is along the valley wall and there are bedrock controls
RM 2.8 – 2.2	Road embankment	Loon Creek Road embankment adjacent to channel and floodplain	Road embankment encroaches on the channel and floodplain along river right; affects are not significant as the road is along the valley wall and there are bedrock controls

River Mile	Anthropogenic Feature	Description	Effects
RM 2.4	Mining spoils	Mining spoils adjacent to channel and floodplain	Mining spoils impede channel/floodplain interactions on river left; some spoil mounds are higher than floodplain elevation; affects are minimal
RM 2.1	Bridge crossing	Bridge crossing with embankment approaches and riprap bank protection	Bridge crossing confines the channel; riprap restricts lateral channel migration; affects on channel are minimal due to alluvial fan and colluvium constraints on the channel
RM 2.1 – 1.7	Road embankment	Loon Creek Road embankment adjacent to channel and floodplain	Road embankment encroaches on the channel and floodplain along river left; affects are not significant as the road is along the valley wall
RM 1.8	Mining spoils	Mining spoils adjacent to channel and floodplain	Mining spoils impede channel/floodplain interactions on river right; some spoil mounds are higher than floodplain elevation; affects are minimal
RM 1.7 – 1.6	Mine tailings and mining spoils	Mine tailings (i.e. Doodle-bug) and mining spoils adjacent to channel and floodplain	Tailing and spoil mounds encroach on the channel along river right; affects are not significant as they are located at an alluvial fan constrictions

Local coarse sediment inputs are primarily from bank erosion along outside meanders and are described in Table 21. Other sources are episodic debris flows from ephemeral drainages that are in contact or connected by culverts with the active channel.

Table 21. Summary of sediment inputs from erosion

River Mile (Approx.)	Description
RM 3.9	Bank erosion along outside meander on river right eroding colluvial deposit
RM 3.7 – 3.6	Bank erosion along outside meander on river right eroding colluvial deposit
RM 3.4	Bank erosion along outside meander on river right eroding colluvial deposit overlying bedrock
RM 3.3	Grouse Creek Mine drainage outlet causing gully erosion on river right
RM 2.9	Bank erosion along outside meander on river left eroding colluvial deposit overlying bedrock

River Mile (Approx.)	Description
RM 2.8	Bank erosion along outside meander on river right eroding road embankment
RM 2.1 - 2	Bank erosion along outside meander along river right eroding colluvial overlying bedrock
RM 2 – 1.9	Channel reworking alluvial deposit
RM 1.7 – 1.6	Bank erosion along straight channel segment eroding mine tailings on river right
RM 1.4	Bank erosion on both sides of the channel eroding opposing alluvial fan deposits

Channel alignments were mapped using 1966, 2004, and 2010 aerial photographs (Figure 40). The period of record defined by the three aerial photograph sets is about 44 years. Little to no lateral channel migration has occurred from about RM 4 to 2.9, RM 2.3 to 2.1 and RM 1.6 to 1.4. Areas where active channel migration has been occurring in this reach over the period of record are as follows:

- Channel segment RM 2.9 to 2.3: There has been a little lateral channel migration where erosion is occurring along the outside edge of meanders.
- Channel segment RM 2.1 to 1.6: There has been a moderate amount of lateral channel migration (one to two channel widths) where erosion is occurring along the outside edge of meanders.

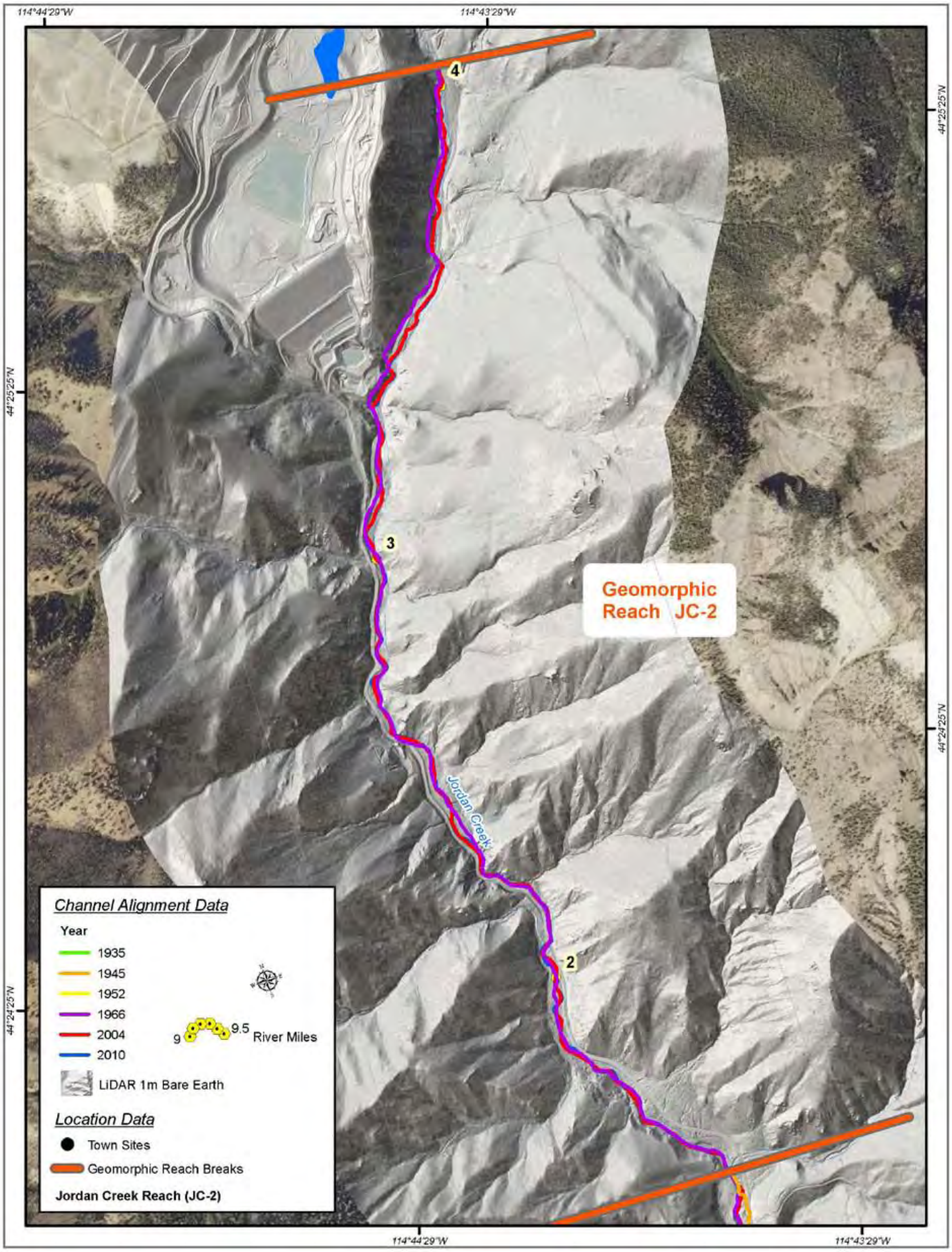

Figure 40. Jordan Creek Reach JC-2: Historical channel alignments.

Channel sinuosity has slightly increased over the period of record (Table 22). Improving riparian vegetation density along the riparian corridor and local sediment inputs from bank erosion could have influenced the rate of channel migration over the last 44 years of record. There is a fairly well established riparian corridor with varying widths adjacent to the channel between RM 4 and 2.3, and RM 2.2 to 1.4 that provides bank stability and channel boundary roughness. Along the more confined channel segments there are larger upland tree species accessible to the channel for recruitment. And there is only a small channel segment that is devoid of vegetation between RM 2.3 and 2.2 along river right due to riprap along the Loon Creek Road.

Table 22. Jordan Creek Reach JC-2: Historic channel alignments and geomorphic channel metrics

Channel Alignment (Year)	Channel Length	Valley Length	Sinuosity
1966	13,997 feet	13,713 feet	1.02
2004	14,237 feet	13,713 feet	1.04
2010	14,499 feet	13,713 feet	1.06

Summary and Potential Actions

This geomorphic reach is in a V-shaped bedrock canyon that moderately confines the channel. The channel type is predominantly a bedrock channel with alternating plane-bed and pool-riffle bed-forms and a straight channel pattern indicating a low rate of lateral channel migration. Substrate is cobble dominated with boulders and bedrock and the channel slope is about 2.9 percent.

Anthropogenic features that constrain the valley bottom are primarily the Loon Creek Road embankment, mine tailings and mining spoils. There are three bridge crossings that constrict the channel near RM 3.6, 3.2, and 2.1. However, none of these anthropogenic features have a significant impact on reach-scale channel processes.

A reach-assessment is not necessary to address the localized anthropogenic impacts in this geomorphic reach. An alternatives analysis could be conducted to address anthropogenic features affecting channel/floodplain interactions. Documentation of baseline conditions should be considered as part of the alternatives analysis for monitoring purposes, and how the potential actions are anticipated to benefit the resources and their potential risks.

6.2.3 Reach JC-1

Geomorphic Reach JC-1 (Figure 41) is located between about RM 1.4 and the Yankee Fork/Jordan Creek confluence in a moderately confined valley segment that is constrained by mine tailings and mining spoils, and by glacial and colluvial deposits. Channel slope is variable and is about 5.5 percent between RM 1.4 and 1.3; about 2.4 percent between RM 1.3 to 0.4; and about 1.8 percent between RM 0.4 and the mouth. Channel type is a plane-bed to pool-riffle, free-formed alluvial channel that has a straight-to-meandering channel pattern indicating a low to moderate rate of lateral channel migration. Dominant substrate is gravel- to cobble-size material with boulders.

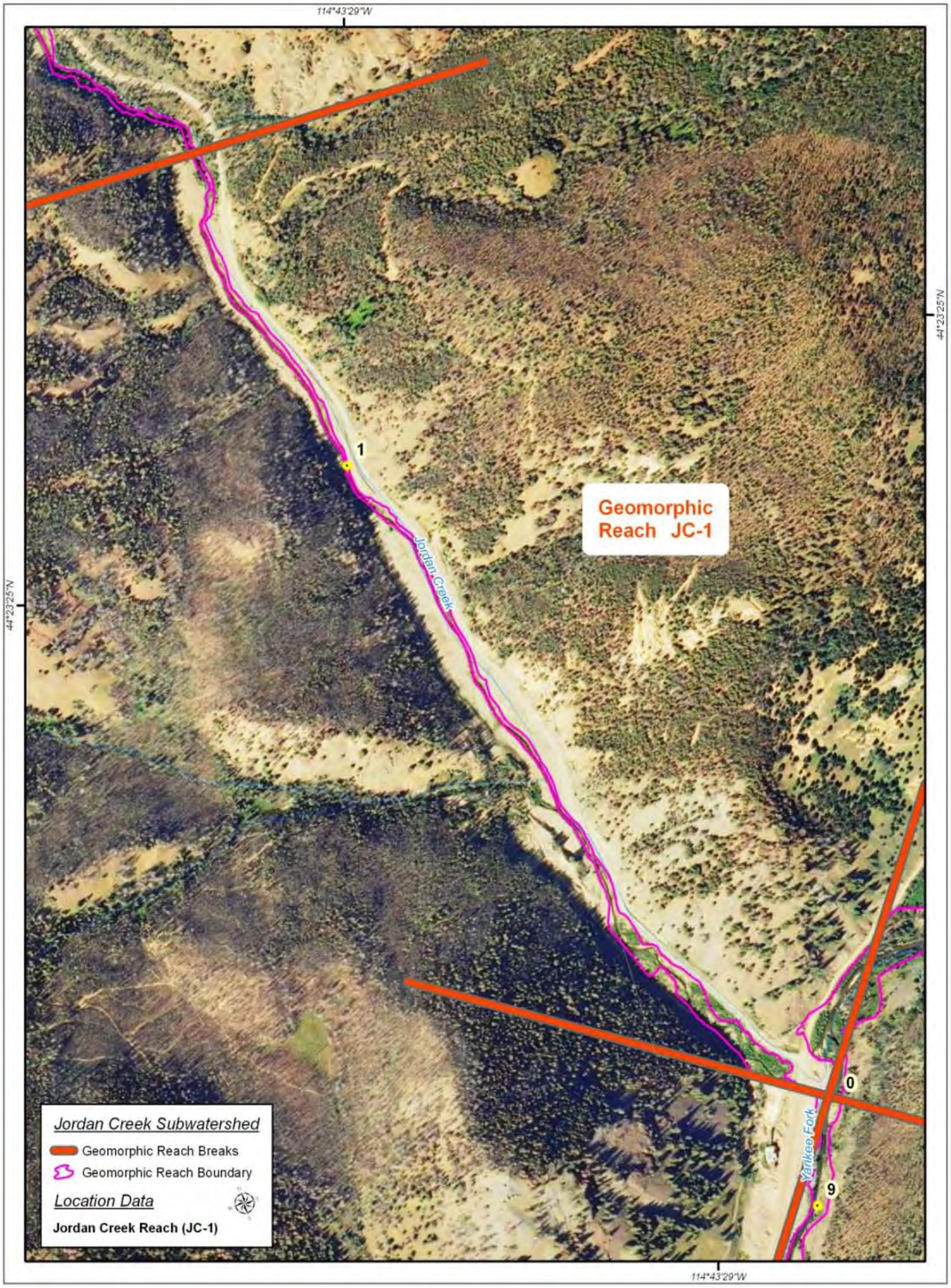

Figure 41. Jordan Creek Reach JC-1 in the Jordan Creek subwatershed.

Surficial geologic mapping (Figure 42) was conducted to identify present valley bottom constraints and to assist in interpreting natural valley bottom constraints. The valley type is predominantly a V-shaped alluvial canyon that is constrained by glacial and colluvial deposits, and bedrock. The primary anthropogenic features the constructed channel and valley bottom constraints from mine tailings and mining spoils. Table 23 summarizes the anthropogenic features for this geomorphic reach.

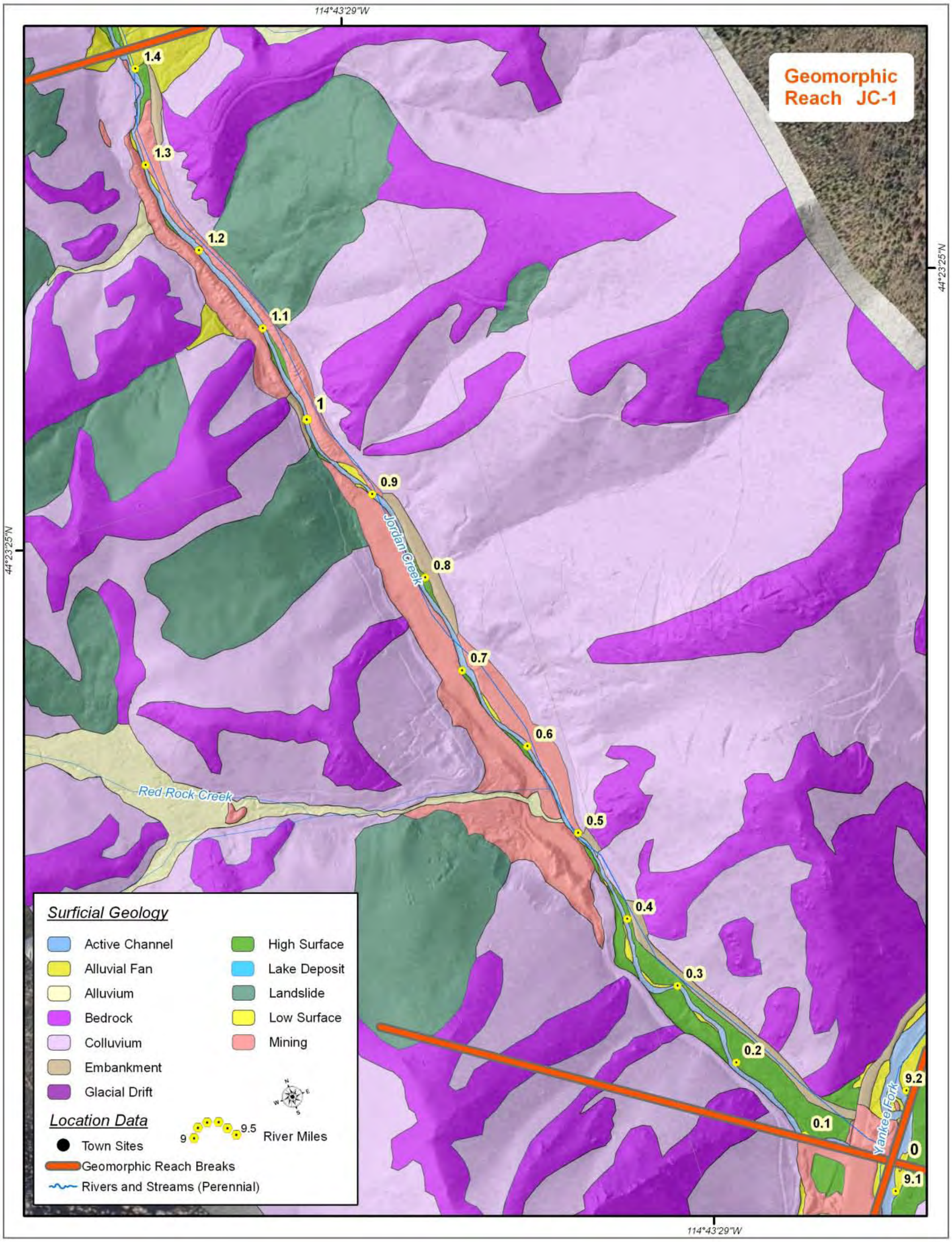

Figure 42. Jordan Creek Reach JC-1 surficial geology map.

Table 23. Anthropogenic features location, description, and effects

River Mile	Anthropogenic Feature	Description	Effects
RM 1.4 – 1.3	Road embankment	Loon Creek Road embankment adjacent to floodplain	Road embankment encroaches on the floodplain on river left; affects on channel/floodplain interactions are minimal
RM 1.3 – 0.5	Mine tailings	Mine tailings adjacent to channel	Channel confined between dredge tailing mounds almost continuously along both banks; affects on channel are significant
RM 1.0	Road embankment	Unimproved road embankment adjacent to channel	Road embankment constructed for mine access encroaches on the channel on river right and constricts the channel between the embankment and mine tailings; affects on channel are minimal
RM 0.9	Bridge crossing	Bridge crossing with embankment approaches	Bridge crossing confines the channel; affects on channel are minimal due to mine tailings constraints on the channel
RM 0.9 – 0.7	Road embankment	Loon Creek Road embankment adjacent to channel and floodplain	Road embankment encroaches on the channel and floodplain on river left; affects on channel/floodplain interactions are minimal
RM 0.5	Road embankment	Loon Creek Road embankment adjacent to channel	Road embankment encroaches on the channel on river left; affects on channel are minimal due to bedrock control
RM 0.4 – 0.1	Road embankment	Loon Creek Road embankment adjacent to floodplain	Road embankment encroaches on the floodplain on river left; affects on channel are minimal due to bedrock controls
RM 0.4 – 0.1	Habitat rehabilitation project	Rehabilitation project involving channel and floodplain	Hecla Grouse Creek Mining Project Wetland Mitigation Site; project to restore about 6.4 acres of mine tailings along the lower reach of Jordan Creek was completed in 1993; mine tailings were spread out along the floodplain an grass seed was applied; channel/floodplain interactions were re-established; grade control structure near RM 0.1 is a juvenile upstream fish passage barrier during high flows
RM 0.1	Bridge crossing	Custer Motorway bridge crossing near mouth	Bridge crossing over constructed channel between mine tailings; affects on channel are minimal due to mine tailings constraints on the channel
RM 0.1 - 0	Mine tailings	Mine tailings adjacent to channel	Constructed channel confined between mine tailing mounds near mouth; affects on channel are significant

Local coarse sediment inputs are almost entirely from bank erosion along mine tailings and are described in Table 24. One perennial tributary, Red Rock Creek near RM 0.5 on river right, contributes flows to Jordan Creek but does not appear to be a significant source of sediment input. Most ephemeral drainages are disconnected from the channel due to mine tailings.

Table 24. Summary of sediment inputs from erosion

River Mile (Approx.)	Description
RM 1.4 – 1.3	Bank erosion on river right eroding mine tailings; active channel area is widening
RM 1.3 – 1.2	Bank erosion along straight channel on river right eroding mine tailings
RM 1.0	Bank erosion on river right eroding mine tailings/access road embankment that encroaches on channel
RM 0.9	Bank erosion on river right eroding mine tailings upstream of bridge constriction
RM 0.9 – 0.7	Bank erosion along straight channel on river right; active channel area is widening
RM 0.4	Bank erosion on river right eroding mine tailings; active channel area is widening
RM 0.2	Bank erosion along outside meander on river right eroding colluvium overlying bedrock

Channel alignments were mapped using 1945, 1966, 2004, and 2010 aerial photographs (Figure 43). The period of record defined by the three aerial photograph sets is about 66 years. The 1945 channel alignment represents the pre-dredging and pre-channel construction alignment. Post-dredging and constructed channel alignments are represented by the 1966, 2004, and 2010 channel alignments.

Little to no lateral channel migration has occurred along the constructed channel from about RM 1.4 to 0.9, and RM 0.1 to 0. Areas where active channel migration has been occurring along the constructed channel in this reach are as follows:

- Channel segment RM 0.9 to 0.1: 1966 channel relocated and/or modified due to Loon Creek Road embankment placements and rehabilitation project.
- Channel segment RM 0.9 to 0.5: There has been a little lateral channel migration where erosion is occurring and the channel is widening.
- Channel segment RM 0.4 to 0.1: There has been moderate amount of lateral channel migration and avulsions in the wetland mitigation project area.

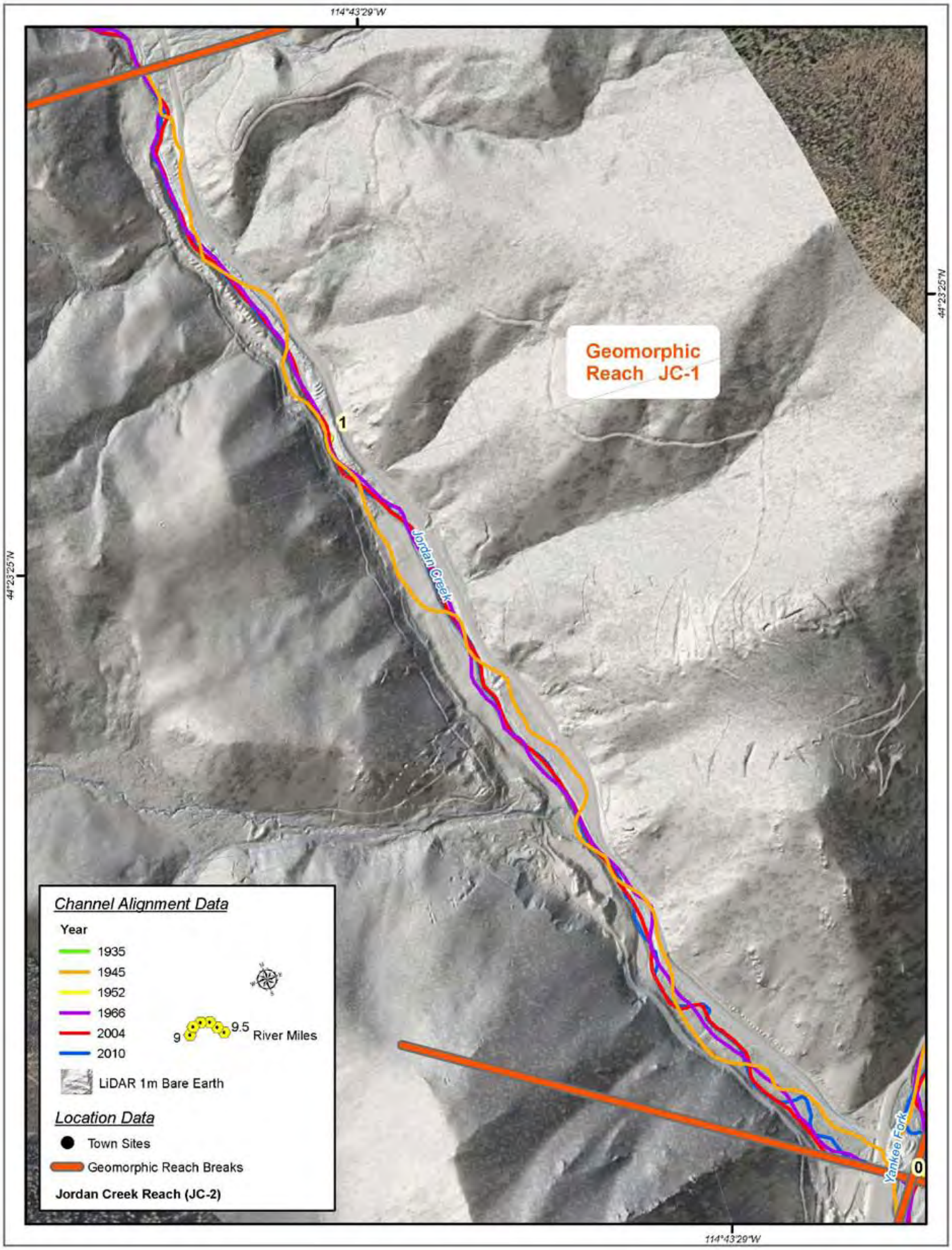

Figure 43. Jordan Creek Reach JC-1: Historical channel alignments.

Channel sinuosity has slight variability over the period of record (Table 25). Changes in channel sinuosity from 1945 to 2004 are predominantly from channel construction following dredging operations (1945 versus1966 alignments), Loon Creek Road improvements (1966 versus 2004 alignments), and wetland mitigation project (1966 versus 2004 alignments).

There is a thin riparian buffer zone (about 10 meters or less) from about RM 1.4 and 0.4 where the channel is confined by mine tailings that somewhat improve bank stability and channel boundary roughness (Figure 44). Between RM 0.4 and 0.1 riparian vegetation density has significantly improved following the completion of the Grouse Creek Mine Wetland Mitigation Project in 1993. The project included leveling the mine tailings, seeding the area, and addition of wood to improve channel complexity which re-established channel/floodplain interactions, improved bank stability and channel/floodplain roughness, and the added wood contributes to forcing channel adjustments (i.e. scour, avulsion, and lateral channel migration). From about RM 0.1, just above the Custer Motorway bridge, to the Yankee Fork/Jordan Creek confluence Jordan Creek is channelized and the riparian vegetation is sparse, providing very little bank stability.

Table 25. Jordan Creek Reach JC-1: Historic channel alignments and geomorphic channel metrics

Channel Alignment (Year)	Channel Length	Valley Length	Sinuosity
1945	7,606 feet	7,240 feet	1.05
1966	7,431 feet	7,240 feet	1.03
2004	7,505 feet	7,240 feet	1.04
2010	7,606 feet	7,240 feet	1.05

Figure 44. View to the north-northwest looking upstream near RM 0.3. *The rehabilitated area is in the foreground; and mine tailings and mining activity is visible in the background. Grouse Creek Mine can be seen in the distance as the barren ground below hilltop.* Bureau of Reclamation photograph by Dave Walsh, September 2, 2010.

Summary and Potential Actions

This geomorphic reach is in a V-shaped alluvial valley that moderately confines the channel. Channel type is a plane-bed to pool-riffle, free-formed alluvial channel that has a straight-to-meandering channel pattern indicating a low to moderate rate of lateral channel migration. Dominant substrate is cobble-to-gravel size material with boulders. Channel slope is variable and is about 5.5 percent between RM 1.4 and 1.3; about 2.4 percent between RM 1.3 to 0.4; and about 1.8 percent between RM 0.4 and the mouth.

Anthropogenic features that constrain the valley bottom are primarily mine tailings, mining spoils, and road embankments. There are two bridge crossings that do not significantly impact channel processes because they were built in locations where the channel was already constricted by mine tailings near RM 0.9 and RM 0.1. The mine tailings significantly impact geomorphic processes by confining the channel in many locations and providing an essentially continuous sediment source. Along the lower section of the reach, between about RM 0.1 to the Yankee Fork/Jordan Creek confluence, the constructed channel is straight and confined between mine tailings. Flow velocities during the spring freshet may be a juvenile upstream fish passage velocity barrier. In addition, the grade control structure just upstream of the Jordan Creek Bridge may also be a juvenile upstream fish passage barrier.

A reach-assessment is not necessary to address the localized anthropogenic impacts in this geomorphic reach. An alternatives analysis could be conducted to address mine tailings that affect channel/floodplain interactions between about RM 1.4 to 0.4, but the feasibility of any habitat rehabilitation projects is unlikely while placer mining activities continue. An alternatives analysis could be completed from RM 0.1 to the Yankee Fork/Jordan Creek confluence to improve juvenile upstream fish passage. Documentation of baseline conditions should be considered as part of all alternatives analysis for monitoring purposes, and how the potential actions are anticipated to benefit the resources and their potential risks.

7. Summary and Conclusions

The purpose of this assessment was to provide information that describes (1) the large scale geomorphic processes occurring within the watershed; (2) the basis for delineation of geomorphic reaches within the tributary assessment area; and (3) identifying geomorphic reaches that have the greatest potential for improving geomorphic processes, reconnecting isolated habitats, and improving habitat quantity and quality.

Valley segments and geomorphic reaches were delineated along the Yankee Fork in the middle and lower Yankee Fork subwatersheds; and along lower Jordan Creek in the Jordan Creek subwatershed. The geomorphic reaches were coincident with the valley segments and are located as follows:

- In the middle Yankee Fork subwatershed three geomorphic reaches were identified (upstream to downstream): (1) Reach YF-6 from RM 16.5 to 13.3; (2) Reach YF-5 from RM 13.3 to 11.7; and (3) Reach YF-4 from RM 11.7 to 9.1.

- In the lower Yankee Fork subwatershed three geomorphic reaches were identified: (1) Reach YF-3 from RM 9.1 to 6.8; (2) Reach YF-2 from RM 6.8 to 3; and (3) Reach YF-1 from RM 3 to Yankee Fork/Salmon River confluence.

- Two geomorphic reaches were identified in the Jordan Creek subwatershed: (1) Reach JC-2 from RM 4 to 1.4; and (2) Reach JC-1 from RM 1.4 to Yankee Fork/Jordan Creek confluence.

The following are brief summaries of each reach:

- **Yankee Fork Reach YF-6**: Chinook salmon and steelhead use this reach for migration, spawning and rearing. In the late 1800s and early 1900s during the mining boom, timber harvests led to the removal of large wood from the floodplain and valley walls, and have changed the species assemblage and successional stage (Overton et al. 1999). Other anthropogenic impacts in this reach do not significantly affect geomorphic processes or habitat quantity and quality.

- **Yankee Fork Reach YF-5**: Chinook salmon and steelhead, and other species use this reach primarily as a migratory corridor. The river flows through a V-shaped canyon with a bedrock channel type. There are no anthropogenic impacts that significantly affect geomorphic processes or habitat quantity and quality in this reach.

- **Yankee Fork Reach YF-4**: Chinook salmon and steelhead use this reach for migration, spawning and juvenile rearing. The river flows through a moderately confined valley segment and has a free-formed alluvial channel. Channel/floodplain interactions are occurring in the lower section from RM 10.3 to 9.1. There are localized anthropogenic impacts that are fairly significant to geomorphic processes and habitat quantity and quality that include: (1) small floodplain areas disconnected by a levee and deflection berm, and (2) a bride crossing near RM 10.9 (General's Bridge) that constricts the channel.

- **Yankee Fork Reach YF-3**: Chinook salmon use this reach for migration, spawning and juvenile rearing, and steelhead use it for migration and juvenile rearing. This reach has been significantly impacted because (1) dredge tailings confine flows to within the Yankee Fork and lower West Fork channels thereby increasing flow velocities to above the 3 ft/s threshold which inhibits juvenile upstream fish passage at some biologically significant flows (i.e. spring freshet); (2) dredge tailings disconnect floodplain areas that significantly reduces high water refugia and rearing habitat for juveniles; and (3) imposed channel constraints from dredge tailings have changed the channel structure from an unconfined, meandering-to-island braided alluvial channel to a confined, straight alluvial channel.

- **Yankee Fork Reach YF-2**: Chinook salmon and steelhead use this reach for migration, spawning and juvenile rearing. The most significant anthropogenic impacts are as follows: (1) dredge tailings disconnect perennial tributaries (Jerrys Creek and Silver Creek) from the Yankee Fork mainstem that historically provided juvenile rearing habitat from the Yankee Fork mainstem; and (2) Ramey Creek is connected to the Yankee Fork mainstem, but the lower section of the creek has been channelized which may have increased flow velocities to above the 3 ft/s threshold which inhibits juvenile upstream fish passage at some biologically significant flows (i.e. spring freshet). On the Yankee Fork mainstem channel processes and habitat quantity do not appear to have been significantly changed from pre-dredging conditions.

- **Yankee Fork Reach YF-1**: Chinook salmon and steelhead, and other species, use this reach primarily as a migratory corridor. The river flows through a V-shaped canyon with a bedrock channel type. There are anthropogenic impacts from road embankment encroaching on the channel and floodplain, and a bridge crossing that constricts the channel. However, these anthropogenic impacts do not significantly impact geomorphic processes or habitat quantity and quality at the reach-scale.

- **Jordan Creek Reach JC-2**: Chinook salmon use this reach for juvenile rearing, and steelhead use it for spawning and juvenile rearing. The creek flows through a V-shaped bedrock canyon that moderately confines the channel. Anthropogenic impacts include road embankments that encroach on the channel and bridge crossings that constrict the channel, but do not significantly impact geomorphic processes or habitat quantity and quality at the reach-scale.

- **Jordan Creek Reach JC-1**: Chinook salmon and steelhead use this reach primarily for juvenile rearing. The creek flows through a V-shaped alluvial mountain valley that moderately confines the channel. There has been some significant anthropogenic impacts that affect geomorphic processes and habitat quantity and quality that include: (1) mine tailings confining the channel in many locations that impede channel/floodplain interactions; (2) the constructed channel between about RM 0.1 and the mouth probably has increased flow velocities to above the 3 ft/s threshold which inhibits juvenile upstream fish passage at some biologically significant flows (i.e. spring freshet); and (3) a grade control structure just upstream of the Jordan Creek Bridge is also be a juvenile upstream fish passage barrier. The two bridges in this reach do not significantly impact channel processes because they were built in locations where the channel was already constricted by mine tailings near RM 0.9 and RM 0.1.

In conclusion, the geomorphic reaches in order of their potential to improve geomorphic processes and habitat quantity and quality, along with their needs for further assessment are as follows:

1. **Yankee Fork Reach YF-3**: A more detailed reach assessment, potentially involving a more complex hydraulic model, is needed to evaluate current geomorphic and ecologic processes, and to evaluate the overall potential to improve these processes and their benefit and risks to the resource. Large floodplain areas have been disconnected by dredge tailings and the loss of channel/floodplain interactions have reduced available juvenile rearing and high water refugia habitat.

2. **Yankee Fork Reach YF-2**: The Shoshone-Bannock Tribes have worked with consultants and stakeholders on implementing habitat projects in this geomorphic reach. Alternatives should continue to be pursued to reconnect isolated tributaries. In addition, the dredge pond series have the potential to provide additional juvenile rearing habitat that was lost when dredging obliterated the lower sections of some tributaries. Baseline data should be collected prior to any project implementation for monitoring purposes. This documentation could be incorporated as part of the alternatives analysis to illustrate pre-project conditions, the proposed or anticipated conditions for each alternative, and the documentation on how successful the implemented project would be in achieving the desired goals.

3. **Jordan Creek Reach JC-1**: A reach-assessment is not necessary to address the localized anthropogenic impacts in this geomorphic reach. An alternatives analysis could be conducted to address mine tailings that affect channel/floodplain interactions between about RM 1.4 to 0.4, but the feasibility of implementing habitat rehabilitation projects is unlikely while there placer mining activities continue. An alternatives analysis should be completed from RM 0.1 to the Yankee Fork/Jordan Creek confluence to improve juvenile upstream fish passage. Documentation of baseline conditions should be considered as part of all alternatives analysis for monitoring purposes, and how the potential actions are anticipated to benefit the resources and their potential risks.

4. **Yankee Fork Reach YF-4**: Reach-scale alternatives analysis could be used to address the vegetation structure and assemblage for long-term improvements, and for the short-term address potential modifications to the levee, berm and bridge crossings, and potential locations for large wood placements. Documentation of baseline conditions should be considered as part of all alternatives analysis for monitoring purposes.

5. **Yankee Fork Reach YF-6**: Active management of timber stands in this reach should be considered to insure proper species assemblage and improve growth rates for long-term recovery. Potential short-term approaches to increase availability of wood to the system could include (1) insuring that wood and sediment inputs from tributaries are not impeded by obstructions (i.e. undersized culverts), and (2) wood loading along the channel and floodplain, with the objective that the anticipated ecologic benefits outweigh the disturbances to the channel or floodplain.

6. **Jordan Creek Reach JC-2**: Reach-scale alternatives analysis could be used to address the road embankments, bridge crossings, and potential locations for large wood placements (or loading). However, there are active mining operations along the creek and a short-term approach using alternatives analysis could be more appropriate.

7. **Yankee Fork Reaches YF-5 and YF-1**: These reaches are Chinook salmon and steelhead migratory corridors through confined, bedrock channels. No anthropogenic features negatively impact channel processes at the reach-scale. Therefore, there is no need for further assessment.

8. List of Preparers

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Edward W. Lyon, Jr., L.G.	Bureau of Reclamation Pacific Northwest Regional Office Boise, Idaho	Principal Author River Systems Analysis Group Geomorphologist
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9. Literature Cited

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10. Glossary

Some terms in the glossary appear in this geomorphic appendix.

TERM	DEFINITION
action	Proposed protection and/or rehabilitation strategy to improve selected physical and ecological processes that may be limiting the productivity, abundance, spatial structure or diversity of the focal species. Examples include removing or modifying passage barriers to reconnect isolated habitat (i.e. tributaries), planting appropriate vegetation to reestablish or improve the riparian corridor along a stream that reconnects channel/floodplain processes, placement of large wood to improve habitat complexity, cover and increase biomass that reconnects isolated habitat units.
alluvial fan	An outspread, gently sloping mass of alluvium deposited by a stream, esp. in an arid or semiarid region where a stream issues from a narrow canyon onto a plain or valley floor. Viewed from above, it has the shape of an open fan, the apex being at the valley mouth.
alluvium	A general term for detrital deposits made by streams on river beds, floodplains, and alluvial fans; esp. a deposit of silt or silty clay laid down during time of flood. The term applies to stream deposits of recent time. It does not include subaqueous sediments of seas and lakes.
anthropogenic	Caused by human activities.
bedrock	The solid rock that underlies gravel, soil or other superficial material and is generally resistant to fluvial erosion over a span of several decades, but may erode over longer time periods.
channel forming flow	Sometimes referred to as the effective flow or ordinary high water flow and often as the bankfull flow or discharge. For most streams, the channel forming flow is the flow that has a recurrence internal of approximately 1.5 years in the annual flood series. Most channel forming discharges range between 1.0 and 1.8. In some areas it could be lower or higher than this range. It is the flow that transports the most sediment for the least amount of energy, mobilizes and redistributes the annually transient bedload, and maintains long-term channel form.
channel morphology	The physical dimension, shape, form, pattern, profile, and structure of a stream channel.
channel planform	The two-dimensional longitudinal pattern of a river channel as viewed on the ground surface.
control	A natural or human feature that restrains a streams ability to move laterally and/or vertically.
diversity	Genetic and phenotypic (life history traits, behavior, and morphology) variation within a population. Also refers to the relative abundance and connectivity of different types of physical conditions or habitat.

TERM	DEFINITION
ecosystem	An ecologic system composed of organisms and their environment. It is the result of interaction between biological, geochemical, and geophysical systems.
floodplain	that portion of a river valley, adjacent to the channel, which is built of sediments deposited during the present regime of the stream and is covered with water when the river overflows its banks at flood stages.
fluvial	Fish that migrate within or between rivers and streams.
fluvial process	A process related to the movement of flowing water that shape the surface of the earth through the erosion, transport, and deposition of sediment, soil particles, and organic debris.
geomorphic reach	An area containing the active channel and its floodplain bounded by vertical and/or lateral geologic controls, such as alluvial fans or bedrock outcrops, and frequently separated from other reaches by changes in channel slope and valley confinement. Within a geomorphic reach, similar fluvial processes govern channel planform and geometry affecting streamflow and sediment transport.
geomorphology	The science that treats the general configuraion of the earth's surface; specif. the study of the classification, description, nature, origin and development of landforms and their relationships to underlying structures, and the history of geologic changes as recorded by these surface changes.
limiting factor	Any factor in the environment that limits a population from achieving complete viability with respect to any Viable Salmonid Population parameter.
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
river mile (RM)	Miles measured in the upstream direction beginning from the mouth of a river or its confluence with the next downstream river.
side channel	A distinct channel with its own defined banks that is not part of the main channel, but appears to convey water perennially or seasonally/ephemerally. May also be referred to as a secondary channel.
spawning and rearing habitat	Stream reaches and the associated watershed areas that provide habitat components necessary for adult spawning and juvenile rearing for a local salmonid population. Spawning and rearing habitat generally supports multiple year classes of juveniles of resident and migratory fish, and may also support subadults and adults from local populations.
subbasin	A subbasin represents the drainage area upslope of any point along a channel network (Montgomery and Bolton 2003). Downstream boundaries of subbasins are typically defined in this assessment at the location of a confluence between a tributary and mainstem channel.
terrace	A relatively level bench or steplike surface breaking the continuity of a slope. The term is applied to both the lower or front slope (the riser) and the flat surface (the tread).
tributary	Any stream that contributes water to another stream.

TERM	DEFINITION
valley segment	An area of river within a watershed sometimes referred to as a subwatershed that is comprised of smaller geomorphic reaches. Within a valley segment, multiple floodplain types exist and may range between wide, highly complex floodplains with frequently accessed side channels to narrow and minimally complex floodplains with no side channels. Typical scales of a valley segment are on the order of a few to tens of miles in longitudinal length.
viable salmonid population	An independent population of Pacific salmon or steelhead trout that has a negligible risk of extinction over a 100-year time frame. Viability at the independent population scale is evaluated based on the parameters of abundance, productivity, spatial structure, and diversity (ICBTRT 2007).
watershed	The area of land from which rainfall and/or snow melt drains into a stream or other water body. Watersheds are also sometimes referred to as drainage basins. Ridges of higher ground form the boundaries between watersheds. At these boundaries, rain falling on one side flows toward the low point of one watershed, while rain falling on the other side of the boundary flows toward the low point of a different watershed.