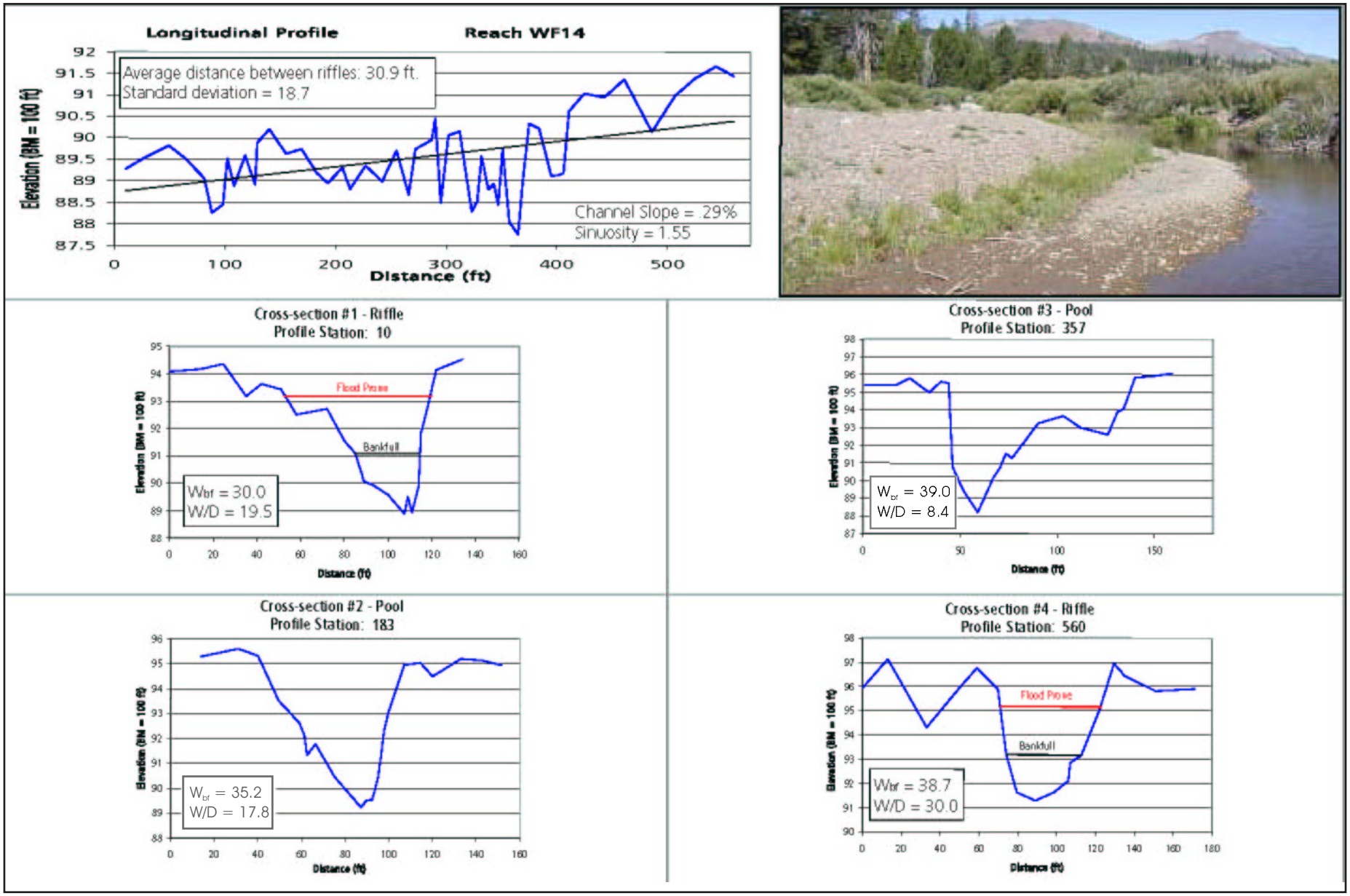

Figure 4.5. Longitudinal profile and cross-section geometry for Reach WF14.

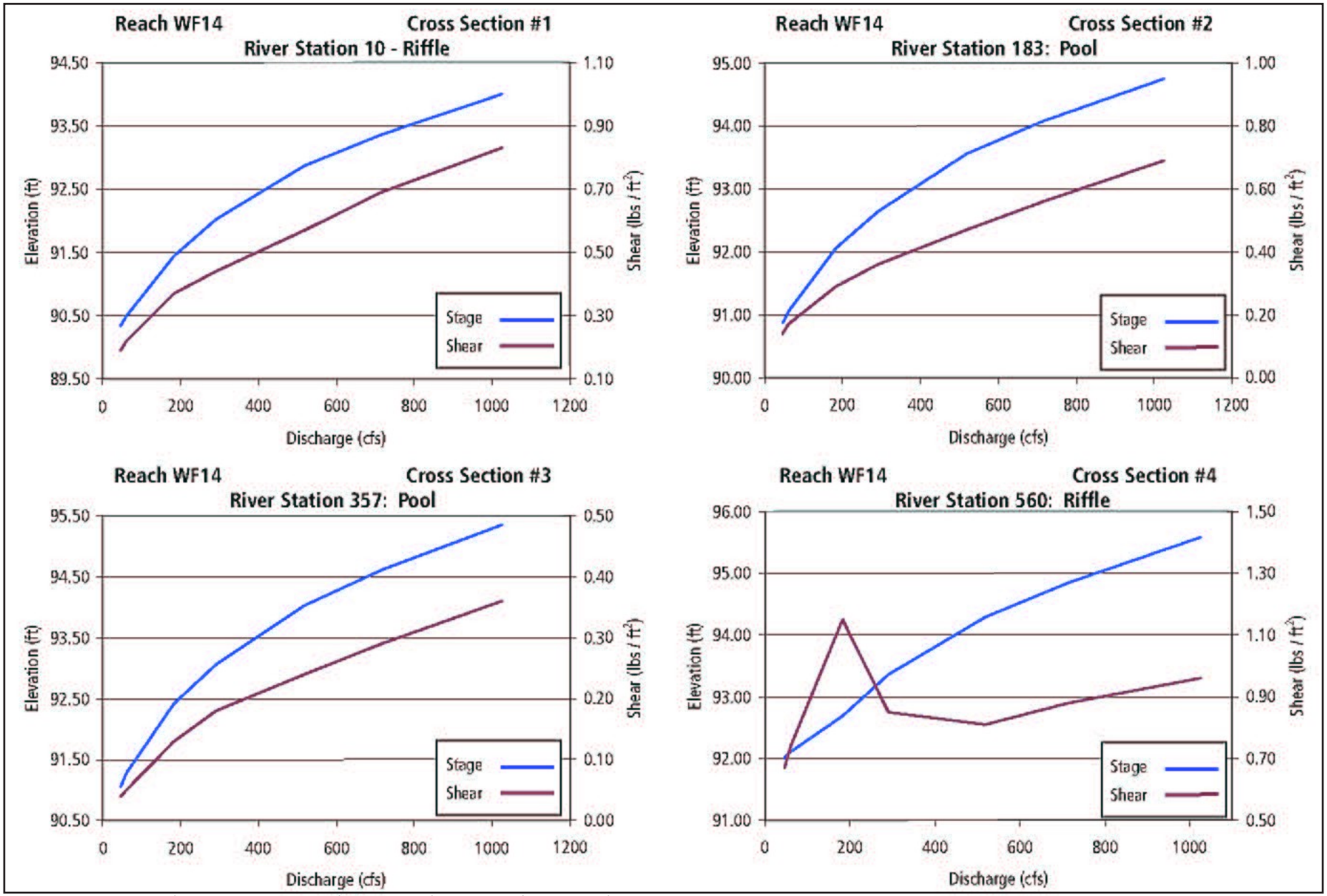

Figure 4.6. Discharge versus shear and stage for Reach WF8.

Willows exhibited a heavy rust infection, perhaps due to drought stress. Fairly recent disturbance was indicated by the large percentage of bare soil present; annual plant species provide the dominant vegetative cover, perhaps due to flooding or heavy recreational use. Impacts of past grazing were shown by the presence of indicator species like yarrow and cinquefoil. The cut off meander may be responsible for the drying of adjacent willow stands.

The USFS Ecology Team conducted plant community sampling within this reach area (comparable plots 96736 through 96738). Ecological status ratings ranged from low to moderate for yarrow and skyline bluegrass dominated community types. The Lemmon's willow/Kentucky bluegrass type was not analyzed. Data developed as part of the present study (Table 4.6) indicates that the area is dominated by mid and early successional status ratings. Vegetation in the area is adjusting to past disturbances (livestock grazing and recreation) and current fluvial processes.

Table 4.6. Reach WF14 successional status data.

Successional Status	Percent Occurrence
Early	36.2
Mid	53.2
High	10.8

***Analysis and Summary*:** Part of the instability of this reach is due to sediment entering the upstream portion of the reach from a tributary to the east. This tributary carried a substantial amount of coarse sediment during the 1997 floods, when it plugged a culvert on the Blue Lakes road. Extensive deposits of coarse material from this flood are found on the meadow downstream of the road crossing. Much of this material also entered the West Fork, and likely contributed to channel dynamics. Sediment produced in the watershed of this tributary appears to be derived primarily from natural sources, as the upper portions of the watershed have extremely steep hill slopes in volcanic rock types.

Though the tributary is influencing the morphology of this reach to some extent, analysis of historical aerial photographs suggests that modifications of the West Fork may be primarily responsible. Sometime between 1963 and 1993, a new channel formed in the lower portion of this reach (see section 5.3.1.4 for a discussion of the aerial photo analysis). The new channel formed is much straighter than the old channel, and may have induced incision upstream, resulting in streambank instability and the production of large quantities of sediment. This incision has resulted in a meander cutoff in the lower portion of Reach WF15. The headcut appears to have advanced to the middle of Reach WF15, where it has been checked by a large beaver dam (see Reach WF15). Large gravel bars are apparent throughout Reach WF14 following the formation of this new channel, though these bars are not apparent in the 1963 photograph prior to channel formation. Straight channels are very uncommon in natural settings, suggesting that the new channel formed after 1963 may have previously been a man-made structure such as an irrigation ditch or road.

Another important aspect of the geomorphology of this reach is the importance of beaver. Beaver dams provide temporary grade control and serve the useful role of storing delivered sediment, increasing flow access to floodplain surfaces, and raising local groundwater elevations (more discussion of this in Reach WF15). However, beaver dams have a limited lifetime. Lack of dam maintenance by beaver can result in a failure that results in head cut propagation upstream and delivery of a wave of sediment downstream. That sediment can cause localized aggradation and increased bank stress.

These effects are especially pronounced in this reach because it is entrenched. If the channel was not so deep, water would flow around beaver dams onto the adjacent meadow during floods and erosive power would be relatively low. In the current incised condition, even larger floods are contained entirely

within the streambanks and large hydraulic drops and high erosive power are concentrated around beaver dams. Thus the risk of failure of dams in the current incised condition is increased.

It should also be noted that the production of sediment within this reach has likely had impacts on downstream reaches. Downstream of Reach WF14, the West Fork enters a confined canyon that has high sediment transport capability. Most of the sediment produced in this reach has therefore probably been delivered directly to the upstream end of Reach WF10, which may partly explain observed dynamism in that reach. This suggests that stabilization efforts in Reach WF14 should have a relatively high priority.

Restoration and management objectives in this reach should be to increase streambank stability and reverse the effects of channel incision. There are several potential restoration options to meet these objectives. One option, which would likely be controversial, would be to introduce additional beavers with the objective of increasing the number of dams constructed. If beavers remained in the area to maintain the dams, sediment would be stored behind the dams, streambanks would be stabilized, and the streambed would eventually be raised. The introduction of beaver has been successful in meeting similar objectives in other locations (Muller-Schwarze and Sun 2003; Naiman et al. 1988). Although there appears to be ample forage to support beavers in Faith Valley, there is some uncertainty as to whether viable long-term populations can be sustained. If beavers were to abandon the area, it is likely that any dams constructed would eventually fail, resulting in additional erosion. This options therefore has a degree of uncertainty and risk, although the cost would be low.

Another option would be to restore the historic channel in the lower part of the meadow. Our preliminary assessment is that this project is feasible, and would meet the objective of raising the channel bed. However, this is a large-scale construction project, and additional analysis of feasibility and costs would be required to accurately assess risk, costs and benefits.

The final option is to stabilize streambanks using similar biotechnical techniques to those recommended for lower reaches on the West Fork. This option would cost relatively little, and probably provides the highest cost-benefit ratio. Implementation of this alternative should be associated with photo monitoring to evaluate trends in channel condition and the success of revegetation and streambank stabilization.

4.2.4 Reach WF15

Rosgen Channel Type: F4
Valley Form: Meadow

Below Beaver Dam
Bankfull Flow (based on field indicators): 155 cfs (Q5)
Top of Bank Flow: 600 cfs (Q50)
Bed Mobility When Flow is at Top of Bank: 70%
Restoration Objective: bank and grade stabilization

Above Beaver Dam
Bankfull Flow (based on field indicators): 110 cfs (Q2 - Q5)
Top of Bank Flow: 155 cfs (Q5)
Bed Mobility When Flow is at Top of Bank: 70%
Restoration Objective: bank and grade stabilization

Geomorphic Characteristics: Reach WF15 of the West Fork of the Carson River flows through the middle and upper parts of Faith Valley, a broad flat meadow (see Figure 2.2 and maps contained in Section 3.2.1.13 of this report). A longitudinal profile and cross sections of the reach are provided in Figure 4.7, while discharge and sheer data are presented in Figure 4.8.. The prominent feature in this reach is the large, stable beaver dam approximately half way through the detailed survey segment. The beaver dam provides grade control upstream and significantly influences the morphology of the channel and its interactions with the floodplain (Figures 4.7 and 4.8). The streambed is composed primarily of gravel-sized particles both above and below the beaver dam. However, the stream is far more entrenched downstream of the beaver dam (flows seldom access the surrounding valley flat), and has a Rosgen classification of F. Upstream of the beaver dam, the Rosgen classification is C, and even smaller floods can reach the surrounding valley flat.

Channel stability is significantly higher above the beaver dam. Both extensive bank erosion and bar formation are evident downstream of the dam. Upstream of the dam, streambanks are lower and tend to be highly stable. Gravel bars are moderate in size. As in Reach WF14, riparian shrubs are found extensively through this reach, and help to stabilize streambanks. More of the streambed is mobile at relatively low flows than in the lower portions of the West Fork, suggesting that more bedload is in transport in this reach. This is probably due to the proximity of this reach to the upper watershed, where coarse sediment is available from steep hillslopes.

***Aquatic Habitat Characteristics*:** Like Reach WF14, pool frequency and depth are higher in this reach than in downstream areas, and pools are relatively complex, providing instream cover. Riparian shrubs add additional cover on outside bends. The proportion of fine sediment in riffles and bars is relatively low. There are substantial differences in aquatic habitat characteristics above and below the beaver dam. Pools upstream of the beaver dam tend to be larger and deeper. Upstream of the beaver dam the bed of the channel is very close to the elevation of the adjacent meadow surface. The surrounding meadow has a high water table and therefore dense grasses and riparian shrubs, providing cover along streambanks. Downstream of the beaver dam, the adjacent meadow is drier, and streambanks are less densely vegetated.

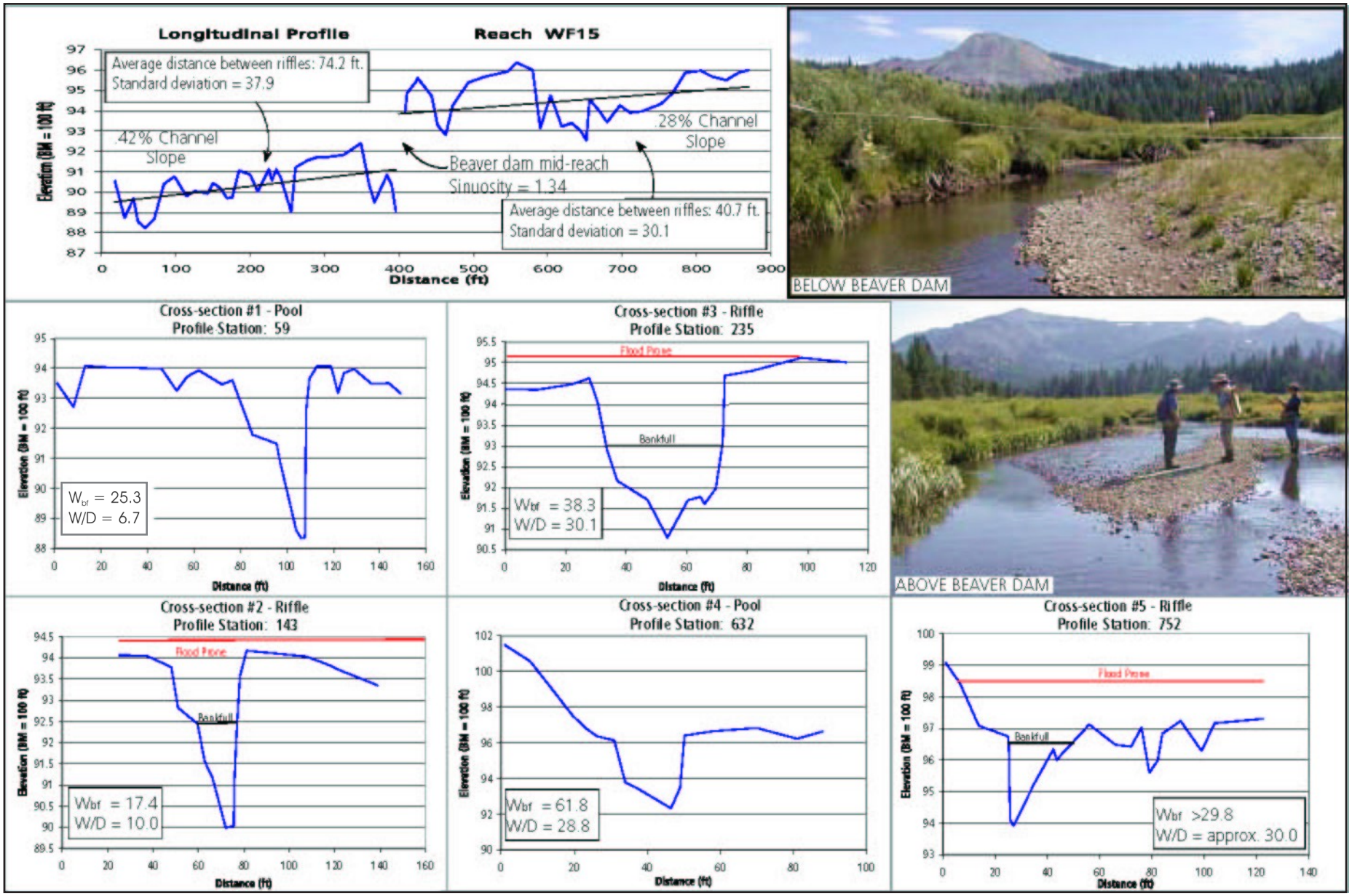

Figure 4.7. Longitudinal profile and cross-section geometry for Reach WF15.

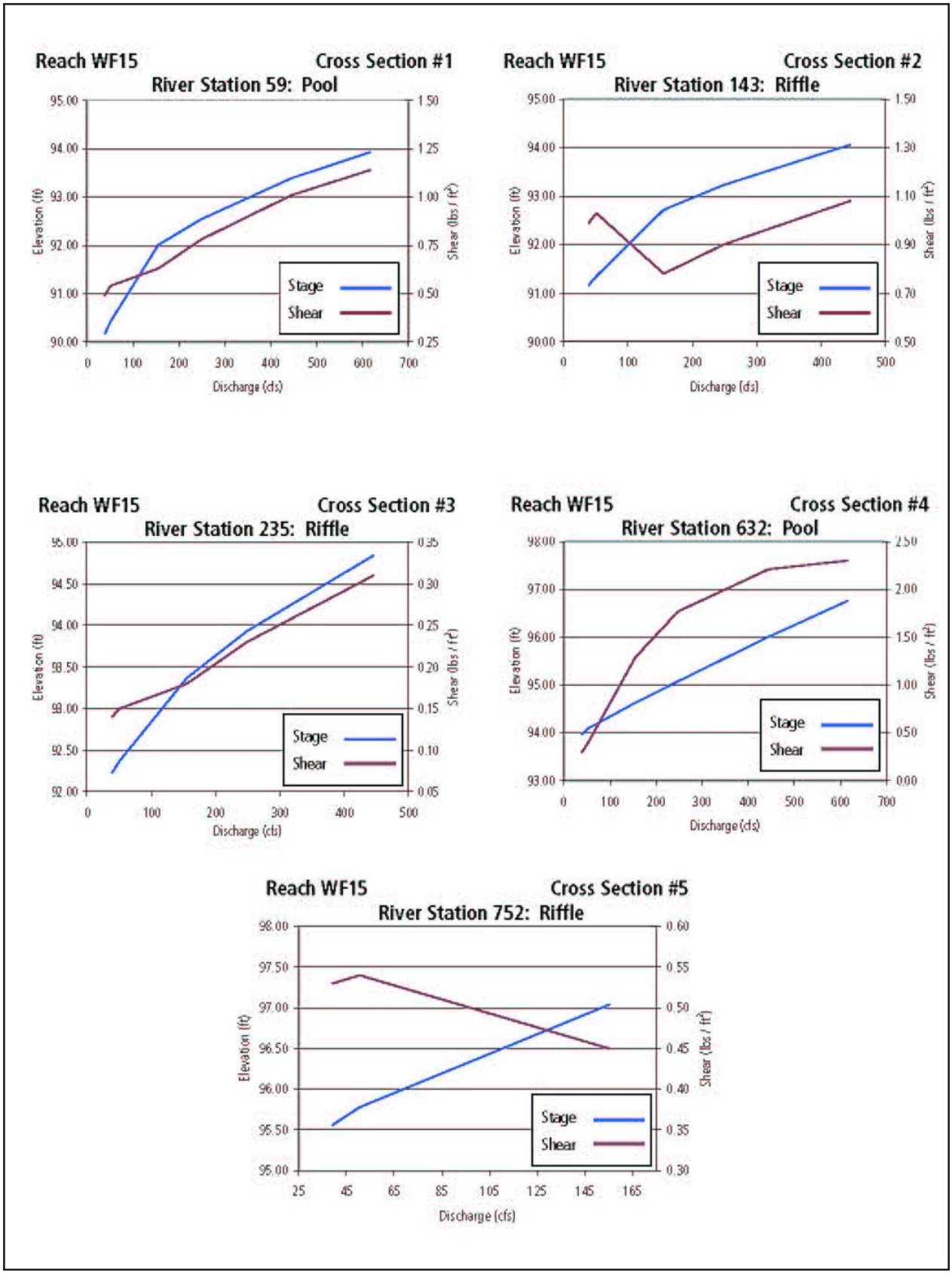

Figure 5.8. Discharge versus shear and stage for Reach WF15.

***Vegetation Characteristics*:** Within this reach, most of the right side vegetation was a mesic, sedge dominated meadow that was saturated even in September. In contrast, the left side was vegetated almost continually with a willow band buffering the surrounding uplands. Eight community types were identified within this reach.

Point bars exhibited a sparse cover of sprout and sapling willows. Mature willows on the right side of the channel were relegated to a narrow band and are younger than those on the left side. Those on left were in larger stands and located on mounds as described for WF14. Some willow sprouts were observed at lower elevations adjacent to old willow clumps. Some willows present on right on upper cross sections were located on elevated clumps within the sedge stand. Many dead willow stems were present, indicating drowning of willow as water impoundment changed hydrology. This may also indicate the lateral migration of the channel to its present location.

Downstream of the beaver dam, bank "calving" was common, and occurred adjacent to the multiple channels present throughout the willow stands, particularly on the right side. These channels were head cutting where entering the river. Rust infestation on willows was noted in this area, effecting overall vigor of willow. Willows exhibited smaller stature, fewer stems and diminished leafing. Along upper cross sections (located upstream of the beaver dam), willows were not affected by rust and were more vigorous. Sedge sod on upper cross sections provided for bank stabilization.

USFS Ecology Team conducted plant community sampling within this reach area (comparable plots 96732 and 96733). They assigned ecological status ratings ranging from low to moderate, respectively, for Lemmon's willow/inflated sedge and Kentucky bluegrass dominated community types. Data developed as part of the present study (Table 4.7) indicate that the area is dominated by mid successional status ratings. Vegetation in the area is adjusting to past disturbances and current fluvial processes.

Table 4.7. Reach WF15 successional state data.

Successional Status	Percent Occurrence
Early	5.0
Mid	77.8
High	17.2

Analysis and Summary: The beaver dam appears to be the current upstream terminus of recent head cutting through this reach that most likely propagated through the entire extent of Faith Valley. The downstream segment of this reach is morphologically similar to what was observed in Reach 14, with Reach 14 being at an earlier stage of development and recovery. Since the beaver dam is potentially the upstream terminus of a headcut, failure of the beaver dam would result in rapid upstream propagation of the headcut. A large pulse of coarse sediment would likely move downstream, exacerbating downstream bank erosion and channel widening.

The upstream portion of this reach may represent channel characteristics in the absence of land use impacts. The beaver dam has been in place long enough that the stream has adjusted to the beaver dam and the surrounding valley flats. Upstream of the dam, this adjustment has resulted in a channel that is stable, relatively small, and floods the surrounding meadow at about a 2-year recurrence interval. The bankfull width-to-depth ratio is moderate, probably due to a fairly high supply of coarse sediment from the steep slopes in the surrounding upper watershed.

The smaller channel size and higher frequency of flooding found in this reach are desired conditions for the West Fork in meadow reaches throughout the watershed. However, it should be noted

that there are important differences between this reach and lower reaches, especially Hope Valley. Our substrate analysis suggests that bedload transport is more important as a geomorphic process in this reach, likely due to its location high in the watershed. Higher rates of bedload transport generally result in higher width-to-depth ratios and lower sinuosity, so this reach likely would differ in these characteristics from the Hope Valley reaches even in the absence of land use impacts. Also, the higher rates of bedload transport also suggest that the channel was probably somewhat more dynamic and erosive historically in this reach than in lower reaches. This dynamism probably explains the high density of riparian shrubs in Reach WF15, which are adapted to colonization of disturbed areas, such as gravel bars, following floods. Because the Hope Valley channel is less inherently dynamic, it is unlikely that riparian shrubs were ever as widespread as in Faith Valley.

Restoration opportunities for this reach are the same as described for Reach WF14. The restoration of the historic channel in the lower portion of the valley would have benefits in the lower portion of this reach as well, by raising the channel bed. No matter which of these options is chosen, the beaver dam in this reach should be stabilized. This dam is currently holding back a great deal of sediment, and is raising groundwater levels in the adjacent meadow. Failure of the dam is likely to cause erosion in the stream channel and drying of the surrounding meadow. Stabilization may require some grade control (perhaps rock structures in the stream), and should also incorporate biotechnical methods of streambank stabilization.

4.2.5 Red Lake Creek – Reference Meadow

Rosgen Channel Type: E4
Valley Form: Meadow
Bankfull Flow (based on field indicators): 60 cfs (Q2)
Top of Bank Flow: 130 cfs (Q2 – Q5)
Bed Mobility When Flow is at Top of Bank: 35%
Restoration Objective: Not Applicable

Geomorphic Characteristics: Although grazing has occurred in this area in the past, the Red Lake Creek Meadow was selected as a reference reach for meadow channels (see Figure 2.2 and maps contained in Section 3.2.2.1 of this report). This was because its streambanks are relatively stable, and it has a low width to depth ratio, high sinuosity, and floodplain access during the annual snowmelt. These geomorphic characteristics are often strongly affected by land use practices, but are indicative of an intact, functional meadow stream in this reach of Red Lake Creek. A longitudinal profile and cross sections of the reach are provided in Figure 4.9, while discharge and sheer data are presented in Figure 4.10.

While this meadow is fairly broad and flat, it is relatively steep. At most cross sections, the stream has a high Rosgen entrenchment ratio. However bankfull indicators were found well below the top of the banks. The flow at these indicators was about a 2-year recurrence interval flood, while the top of the streambanks was between a 2- and 5-ear recurrence flood. Thus while relatively small floods access the surrounding floodplain, there is some evidence that the stream is slightly entrenched.

Channel stability is moderate to high. There are very few eroding streambanks. Point bars are the dominant form of instream bar, and they are of modest size. Interestingly, our bed mobility analysis suggests that a relatively high proportion of the streambed material is moving at the bankfull flood. This material does not appear to be derived from streambanks, and is transported to this reach from upstream sources. However, these sources must be fairly close to this reach, as a dam upstream stores the coarse sediment provided by the upper portion of the watershed.

***Aquatic Habitat Characteristics*:** Pool frequency and depth are both high in this reach. Pools are complex, providing instream cover. Most of the streambanks are dense meadow sod, consisting of long grasses which overhang the banks and provide some cover. In addition, the stable streambanks are often undercut, which also provides good instream cover. The proportion of fine sediment in riffles and bars is relatively low.

***Vegetation Characteristics*:** Four vegetation community types were documented. A sedge dominated meadow provides continuous vegetative cover along this creek. Contiguous cover of a woody riparian community type was not present, although occasional willows were observed. Abandoned meanders also exhibited a mesic forb component within the dominant sedges. One dry meadow community type exhibited 30 percent total vegetative cover and 60 percent bare soil. Ground squirrel activity was evidenced here by the presence of numerous burrows.

A few willow saplings were noted on point bars and within the floodplain along with wooly sedge and tufted hairgrass. At one location, six more mature, multiple stemmed willow clumps (approximately two feet tall) were observed at the top of bank.

This reach appears fairly stable. Sedge sod provides consistent cover along the creek/bank interface. Within the dry meadow community type, increaser species included aster and yarrow. Cinquefoil and dandelion were observed, indicating a response to past land uses.