Monitoring Restoration Effectiveness on the Lower Rio Blanco River

J.D. Kurz[1] and D.L. Rosgen[2]

Overview

The Rio Blanco River is located in Southwestern Colorado near Pagosa Springs, Colorado. The watershed encompasses a 170 square mile (mi^2) area that ranges from 13,000 feet at the headwaters along the Continental Divide to 6,400 feet at the confluence with the San Juan River.

Since 1971, the U.S. Bureau of Reclamation has operated a major trans-basin diversion called the San Juan/Chama Project. This diversion transmits approximately 70 percent of the historic annual water yield from the Rio Blanco to the Rio Grande Basin. The diversion not only removes a substantial volume of water from the channel throughout the year, but it also decreases the magnitude and duration, and alters the timing of the channel-maintaining flow (bankfull discharge).

Since the dimension, pattern, and profile of rivers are directly related to the bankfull discharge, a natural decrease in the bankfull discharge should result in a series of adjustments creating a smaller channel, more appropriately sized for the altered flow regime. Unfortunately, the channel below the diversion has not adjusted to the altered flow regime mainly because the magnitude, duration, and timing are insufficient to reshape the channel material, which consists mainly of cobble and large gravel. Sediment supply from unregulated tributaries creates excess sediment deposition into the regulated main stem. The resulting wide and shallow channel has negatively impacted the channel stability, water quality, and aquatic habitat of the lower Rio Blanco.

In November 1999, Wildland Hydrology completed a stream restoration demonstration project on 1.1 miles of river. The goal of the restoration project was to construct a channel to match the altered flow regime in order to restore the physical and biological function of the river. The width/depth ratio was decreased to improve sediment transport capacity and reduce water temperature. Rock vanes were installed to reduce bank erosion and improve aquatic habitat by creating a diversity of bed features.

A monitoring program was initiated following construction to document channel adjustments and restoration effectiveness with respect to the physical objectives. The restored reach was re-surveyed in 2001 following a spring runoff season comparable to the pre-diversion flow regime. In addition, vertical velocity profiles were measured at both restored and un-restored reaches to compare the distribution of energy in the near-bank region.

Hydrology

Pre-Diversion Hydrology

The Rio Blanco has a snowmelt-dominated hydrograph. Snowmelt runoff generally peaks during the first week of June and the flow during the summer commonly drops below 20 cfs. Historically, the major floods have been the result of intense thunderstorm activity in the late summer and fall months.

Analysis of the peak flow records from the USGS stream gaging station number 09343000, which operated upstream of the point of diversion between 1935 and 1971, indicates that the 1.5-year momentary maximum peak discharge was 726 cubic feet per second (cfs) (approximate bankfull discharge) prior to the San Juan/Chama Project

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Post Diversion Hydrology

The San Juan/Chama Project can divert up to 520 cfs from the Rio Blanco River into a series of tunnels that eventually reach the Rio Grand Basin. The U.S. Bureau of Reclamation is required to bypass at least 15 cfs during December through mid-February, 20 cfs mid-February through April, 40 cfs during May, and 20 cfs during June through November. Flow is bypassed during unusually wet years when the New Mexico reservoirs are full or the when tunnel capacity is exceeded. Flow was bypassed during the flood of record, which occurred on August 24, 1992 when thunderstorms produced a peak flow of 3120 cfs.

The USGS operated a gaging station (09343300) downstream of the diversion from 1971 until 1998, at which point Colorado Division of Water Resources began maintaining the gage. Analysis of the peak flow records from this station (1971-1998) indicates that the 1.5-year momentary maximum peak discharge is approximately 463 cfs for the post-diversion flow regime (subtracting 100 cfs from Leche Creek, a 8mi^2 tributary between gage stations 09343000 and 09343300). The diversion removes 263 cfs or 36 percent of the bankfull discharge. The operational hydrology of the Rio Blanco is unlike most regulated rivers in that the bankfull discharge is decreased, but the floods are bypassed.

Consequences

Channel Stability

Decreasing the magnitude and duration of the bankfull discharge has decreased the capacity and competence of the river to move the larger fraction of materials being delivered from the watershed. The decrease in competence and capacity is compounded by insufficient shear stress that is associated with the wide, shallow channel that is remnant of the previous flow regime.

Not only is the magnitude and duration of the bankfull discharge decreased, but the timing is also altered, which leads to in-channel deposition as unregulated, high sediment supply tributaries deliver sediment into the Rio Blanco. Since more energy is required to re-initiate motion of a particle than to keep an entrained particle moving, the sediment delivered from the unregulated tributaries is deposited in the Rio Blanco, which leads to aggradation and lateral migration. During floods, both shear stress and stream power are low and deposited gravel bars re-direct velocity vectors into less resistant streambanks. The net result is an increase in the width/depth ratio as bars grow and banks erode in order to maintain channel capacity.

High width/depth ratio channels have less shear stress and more bed resistance, which increase the flood stage relative to a channel that has the same cross sectional area but a lower width/depth ratio. High width/depth ratio channels are often associated with poor physical water quality and aquatic habitat.

Water Quality

The high width/depth ratio (W/d) channel leads to higher water temperatures and increased evaporation from the large surface width. High water temperature is a major problem when the streamflow drops below 20 cfs during the summer and water temperatures and dissolved oxygen approach the lethal limit of trout populations. At 20 cfs, many sections of the Lower Blanco are 40 feet wide with a mean depth of 0.5 feet (W/d=80). During the winter months limitations for fish occur due to the lack of thermal refugia from the shallow mean depth and absence of deep pools.

Aquatic Habitat

The existing high width/depth ratio channel has a poorly defined thalweg. During low flow the stream lacks the depth necessary to create good instream habitat, which is necessary to support a viable fishery. Natural reproduction is inhibited by the accumulation of fine sediment in spawning gravels during baseflow.

Restoration

History

The enabling legislation for the San Juan/Project required that the Bureau of Reclamation operate the diversion is such a way that the fishery of the Rio Blanco would not be degraded. A U.S. Forest Service Report (Huchinson, 1990) concluded that the altered flow regime has resulted in a wide, shallow stream with inadequate habitat, cover, and water temperatures to support a coldwater fishery.

The Colorado Water Conservation Board, Rio Blanco Homeowner Association, San Juan Water Conservation, and several federal agencies have been working together to obtain funding to improve the stream habitat of the lower Rio Blanco River. Funding was secured for a demonstration project through Section 319 of the EPA Clean Water Act. According to the Colorado Division of Wildlife (WIP, 1998), the water quality issues are increased water temperatures, decreased levels of dissolved oxygen, and the accumulation of fine sediments. During the fall of 1999, Wildland Hydrology and Elk River Construction completed a 1.1-mile restoration project on the lower Rio Blanco.

Objectives

The goal of the restoration project was to construct a channel to match the altered flow regime in order to restore the physical and biological function of the river. More specific objectives were to improve sediment transport and flood capacity, reduce bank erosion, improve the physical water quality by decreasing water temperature and increasing dissolved oxygen, and improve fish habitat and spawning gravel.

Design

The designed channel must maintain a deep, narrow, low flow channel and also be able to accommodate the large floods that bypass the diversion. A small, low width/depth ratio channel meanders within the existing over-wide C3 and F3 stream types. Material excavated from the low flow channel was used to construct floodplains and point bars that extend to the remnant floodplain. The low flow channel was constructed in the shade cast by the alders and willows whenever possible to assist in maintaining low water temperature.

J-Hook Vanes and Cross Vanes were constructed with large boulders that were excavated off-site. The J-Hook Vanes reduce bank erosion and maintain deep pools downstream of each structure. Cross Vanes provide grade control, reduce bank erosion and maintain deep pools below each structure. A Cross Vane was used to protect a bridge within the reach and several other Cross Vanes were used to raise the elevation of the channel bed through a degraded reach in order to re-attach the floodplain as well as to raise the low flow water level for stream-side water pumps. In addition, streamflow is aerated as it cascades over the rock structures into deep pools below.

Monitoring

Channel Stability

Twenty permanent cross sections were installed to monitor channel change and/or to study the effects of the rock vanes on the distribution of channel energy in restored versus unrestored reaches. In addition, a longitudinal profile was surveyed through the entire demonstration reach immediately following completion of the project.

The cross sections and longitudinal profile were resurveyed in September 2001 to document channel change following an above average runoff year in which 1040 cfs was recorded on May 14th. This large flow event (twice bankfull) provided an excellent test of restoration stability and effectiveness. Replicate plots are not included in this paper due to size limitations, but they will be shown during the oral presentation and will be available through the Wildland Hydrology office.

Substantial redistribution of channel material occurred throughout the restored reach during the 2001 spring runoff. Many of the pools below J-Hooks and Cross Vanes scoured to bedrock, allowing these pools to maintain depths of up to 4 feet at low flow. The elevation of the riffles increased slightly or remained unchanged. The width of the low flow channel increased slightly, but a narrow, deep, low flow channel was maintained.

Very little bank erosion occurred throughout the restored reach. The lack of bank erosion can be attributed to the bank protection provided by J-Hooks and Cross Vanes, which redirect velocity vectors away from streambanks. The Cross Vane that was installed upstream of the problematic bridge has reduced the stress against the bridge footers.

Water Quality and Aquatic Habitat

The Colorado Division of Wildlife is monitoring water temperature, dissolved oxygen, siltation, and biological parameters. Five monitoring stations measured temperature during the three years prior to construction and there is currently 2 years of post-construction temperature data. Water quality and fish/macroinvertabrate data is not yet available. The aquatic habitat has improved as holding water and overhead cover have been created.

Summary

Although flow depletion is an unfortunate reality for the lower Rio Blanco River, channel restoration is a viable option to improve channel stability, physical water quality, and aquatic habitat. The demonstration restoration reach performed well during the first high water test. The narrow low flow channel was maintained and deep pools still exist below J-Hooks and Cross Vanes. The restoration has improved the biotic potential of the dewatered stream and has improved the recreational and aesthetic values as well. Children enjoy swimming in the deep pools and one landowner said she loves to be able to hear the river again, even at low flow.

Bibliography

Huchinson, Corey Sue. 1990. Survey of the Rio Blanco Basin, 1990. USDA Forest Service Report, San Juan National Forest, Durango, Colorado.

Water Information Program. 1998. 33 Responses to Questions from the October 5, 1998 Lower Blanco Habitat Restoration Demonstration Project Meeting Pagosa Springs, Colorado. Online. Internet. 31 July 2002. Available: www.waterinfo.org/rio99b.htm.


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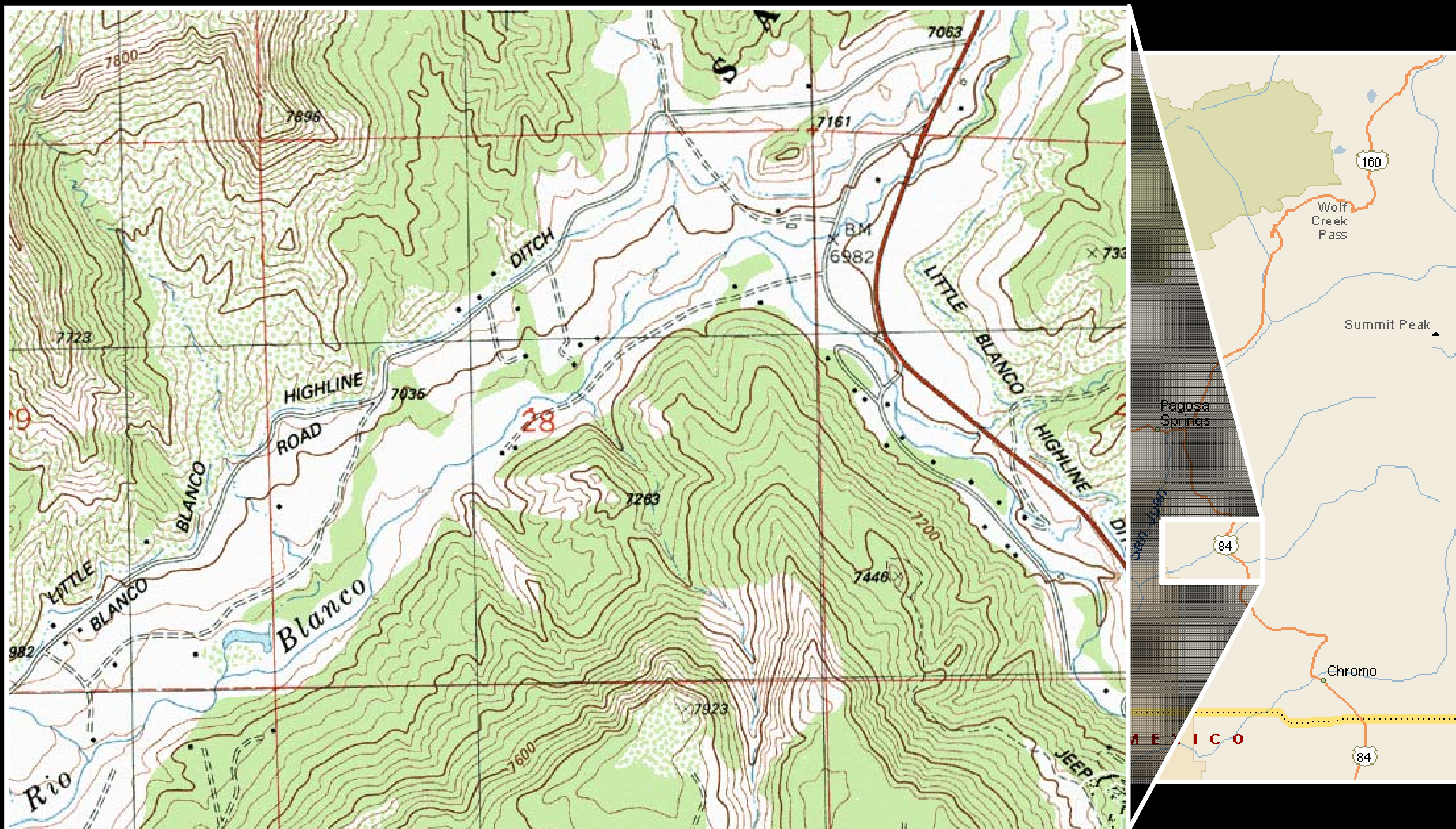
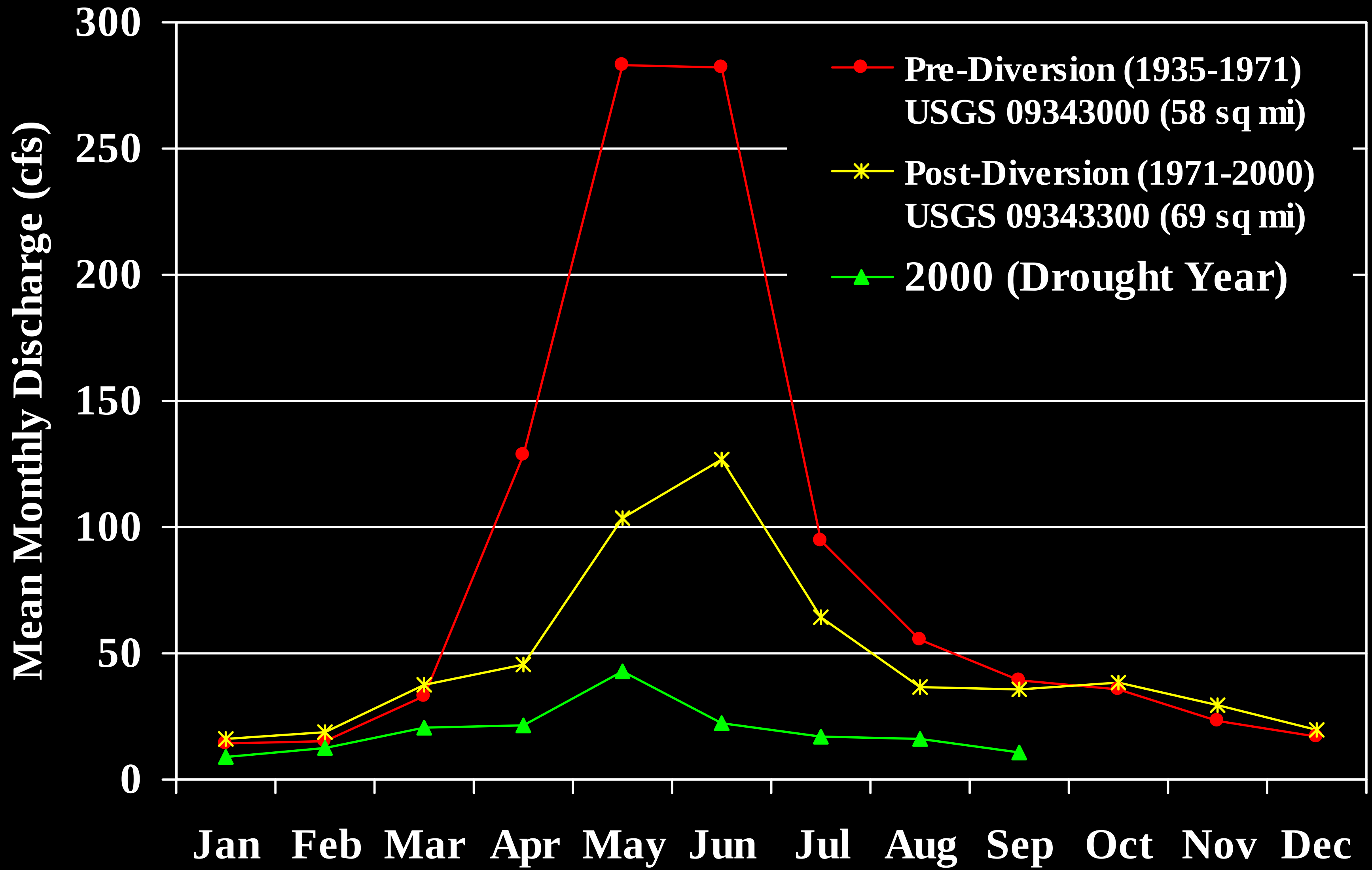
Lower Rio Blanco River near Pagosa Springs, Colorado



Rio Blanco River

- Southwestern Colorado south of Pagosa Springs.
- Drainage Area: 170mi^2.
- Tributary to the San Juan River.
- U.S. Bureau of Reclamation has operated a major trans-basin diversion since 1971.
- Approximately 70 % of annual water yield transmitted to Rio Grande Basin.

Rio Blanco River Hydrograph



Hydrology of the Rio Blanco River

- Diversion has decreased the magnitude and duration and altered the timing of the bankfull discharge.
- Pre-diversion bankfull discharge: 726 cfs (1.5 year flow).
- Post-diversion bankfull discharge: 463 cfs (new 1.5 year flow, a 36% reduction).
- Flood water usually bypassed by diversion – August 24, 1992: 3120 cfs.

Typical photograph showing the wide, shallow channel at low flow prior to restoration

Consequences of Flow Depletion

Channel Stability

- Wide, shallow stream lacking the shear stress necessary route sediment supplied from unregulated tributaries.
- Aggradation and lateral migration.
- Increased flood stage.

Consequences of Flow Depletion

Water Quality

- Higher water temperatures and lower dissolved oxygen during summer low flow.

Aquatic Habitat

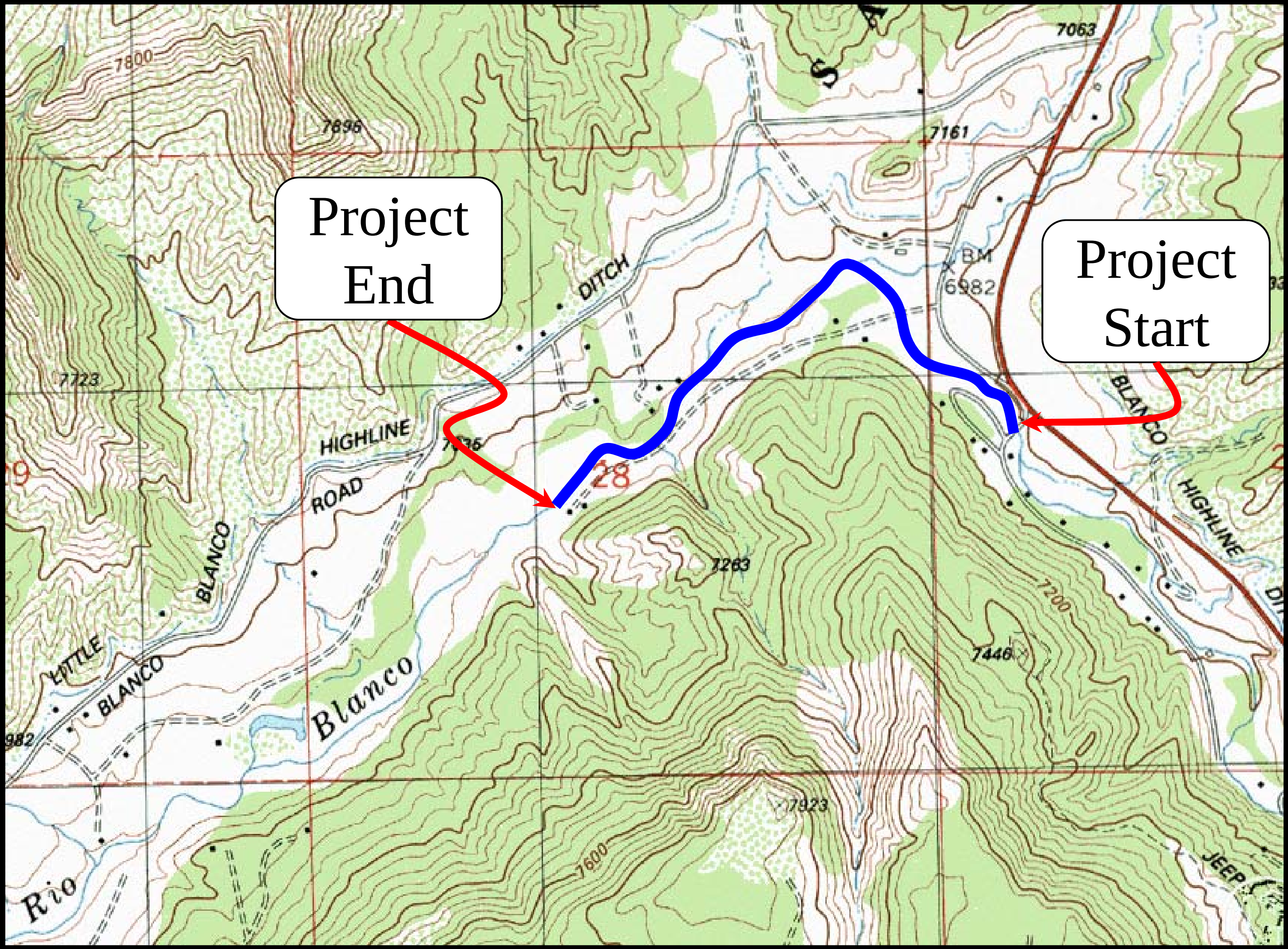
- Poorly defined thalweg lacking the depth necessary to create good instream habitat for trout.

- Accumulation of fine sediment in spawning gravels during low flow.

Restoration

- A collective effort by Rio Blanco Homeowners Association, Colorado Water Conservation Board, and several federal agencies.
- Section 319 of the Clean Water Act (EPA) provided partial funding (Hydrologic Modification is recognized as non-point source pollution in CO).
- A 1.1 mile demonstration reach was restored in the fall of 1999.

Location of the Demonstration Reach



Restoration Objectives

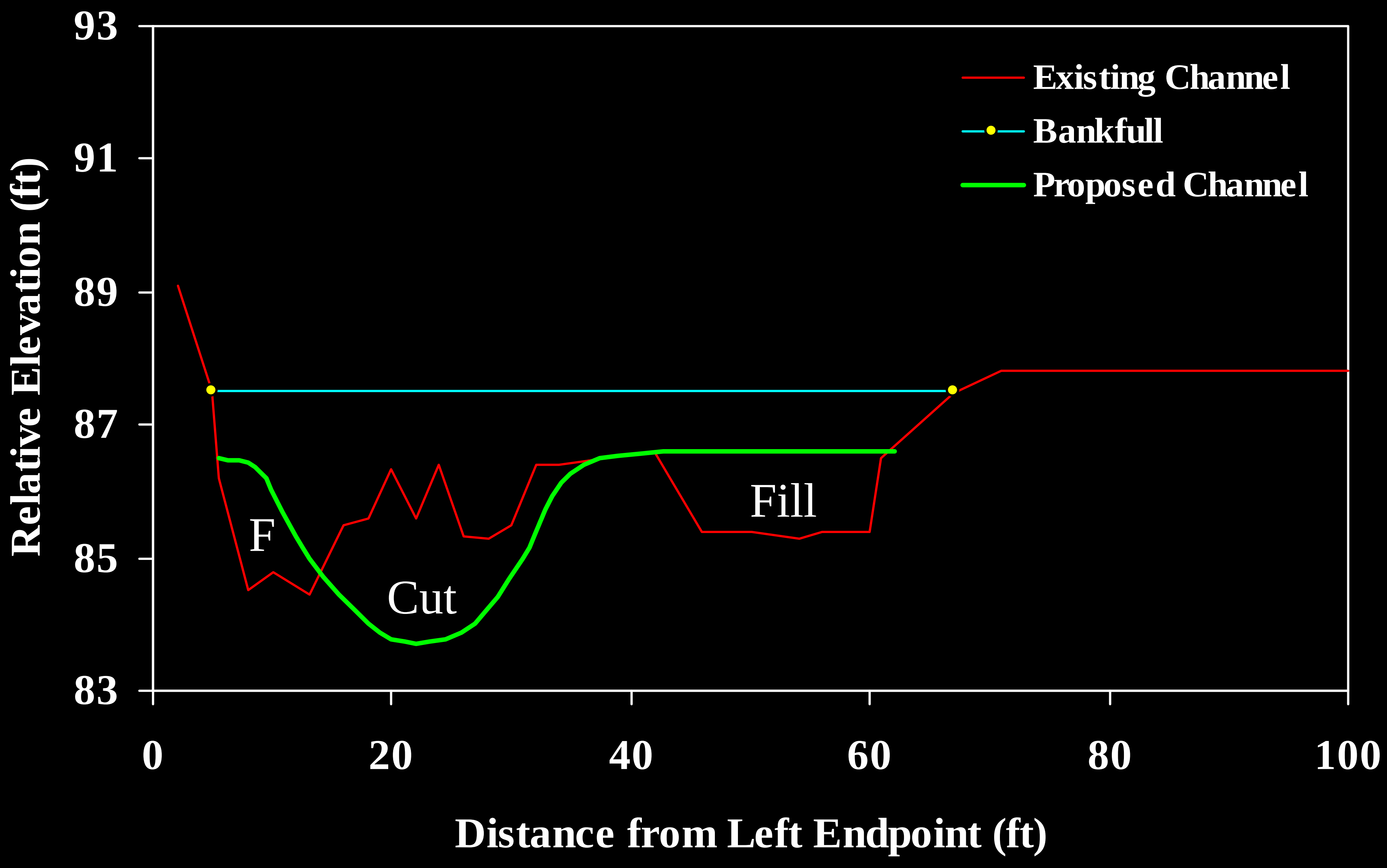
Construct a channel to match the altered flow regime in order to restore the physical and biological function of the river.

- Improve sediment transport and flood capacity.
- Reduce bank erosion.
- Raise water table during low flow.
- Decrease water temperature.
- Increase dissolved oxygen.
- Improve fish habitat.
- Improve spawning gravel.
- Improve aesthetics.

Restoration Design

- Create a small, low width/depth ratio channel within the over-wide C3 and F3 stream types.
- Use material excavated from the low flow channel to construct floodplains and point bars.
- Use large boulders to construct J-Hook Vanes and Cross Vanes.

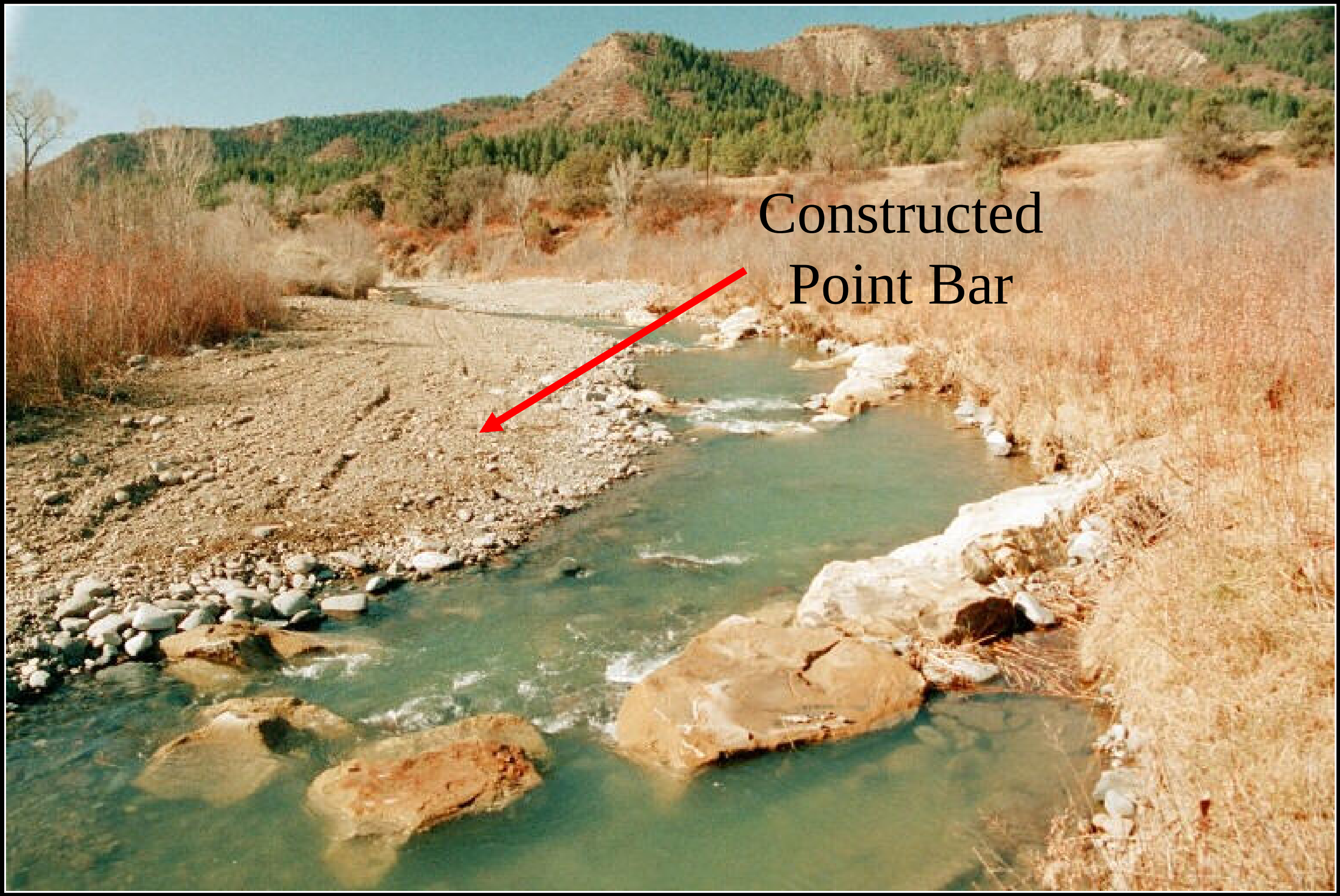
Restoration Design – Typical Cross Section



Channel Construction

J-Hook Vanes

Reduce bank erosion and maintain deep pools downstream of each structure.



Cross Vanes

Provide grade control, reduce bank erosion, and maintain deep pools downstream of each structure.

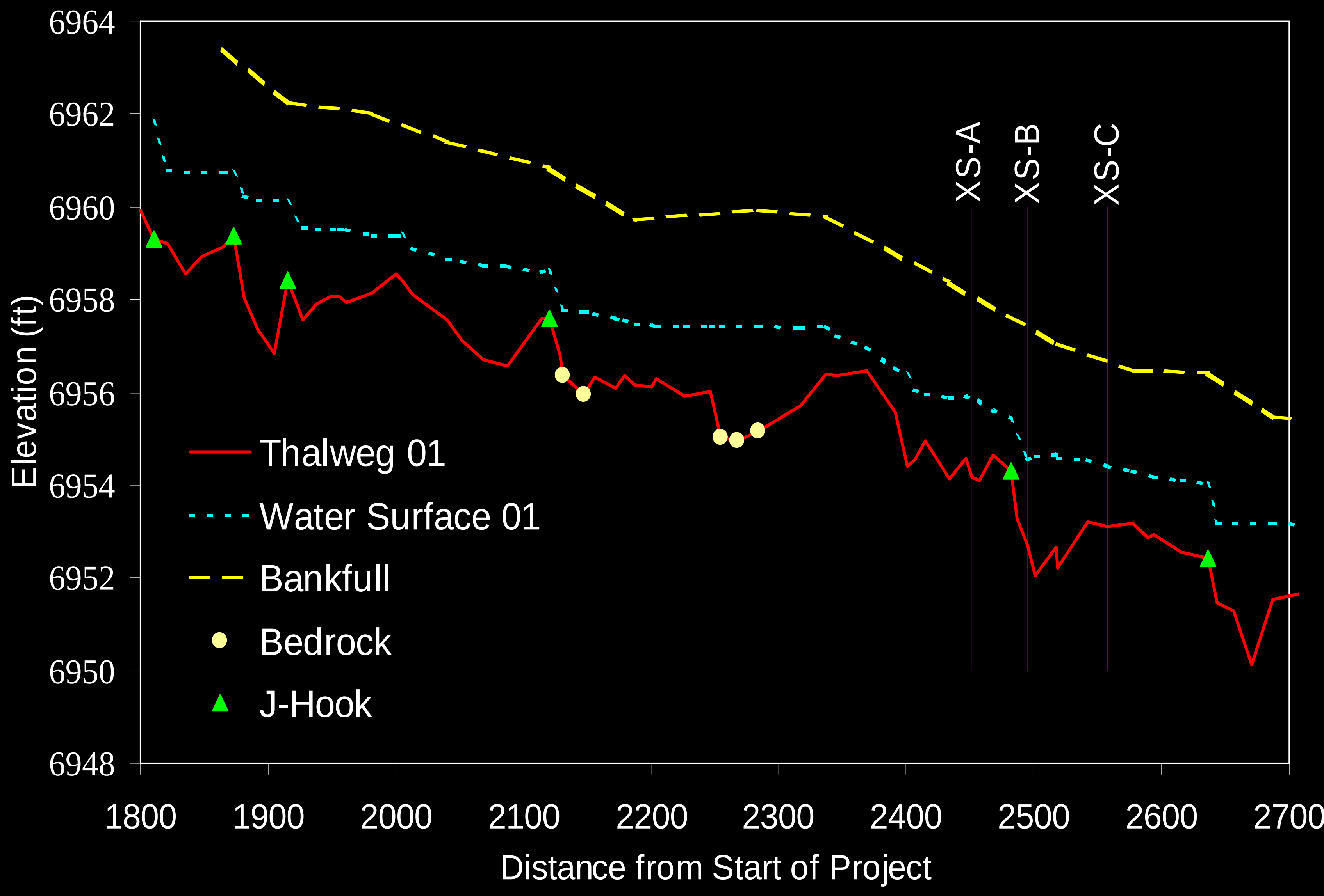
Cross Vanes

Provide bridge protection.

Monitoring Restoration Effectiveness

- Permanent cross sections were installed following construction to monitor channel change.
- A longitudinal profile was surveyed through the entire project length.
- Resurveyed following the 2001 spring runoff , which provided excellent test of the restoration stability (1040 cfs).

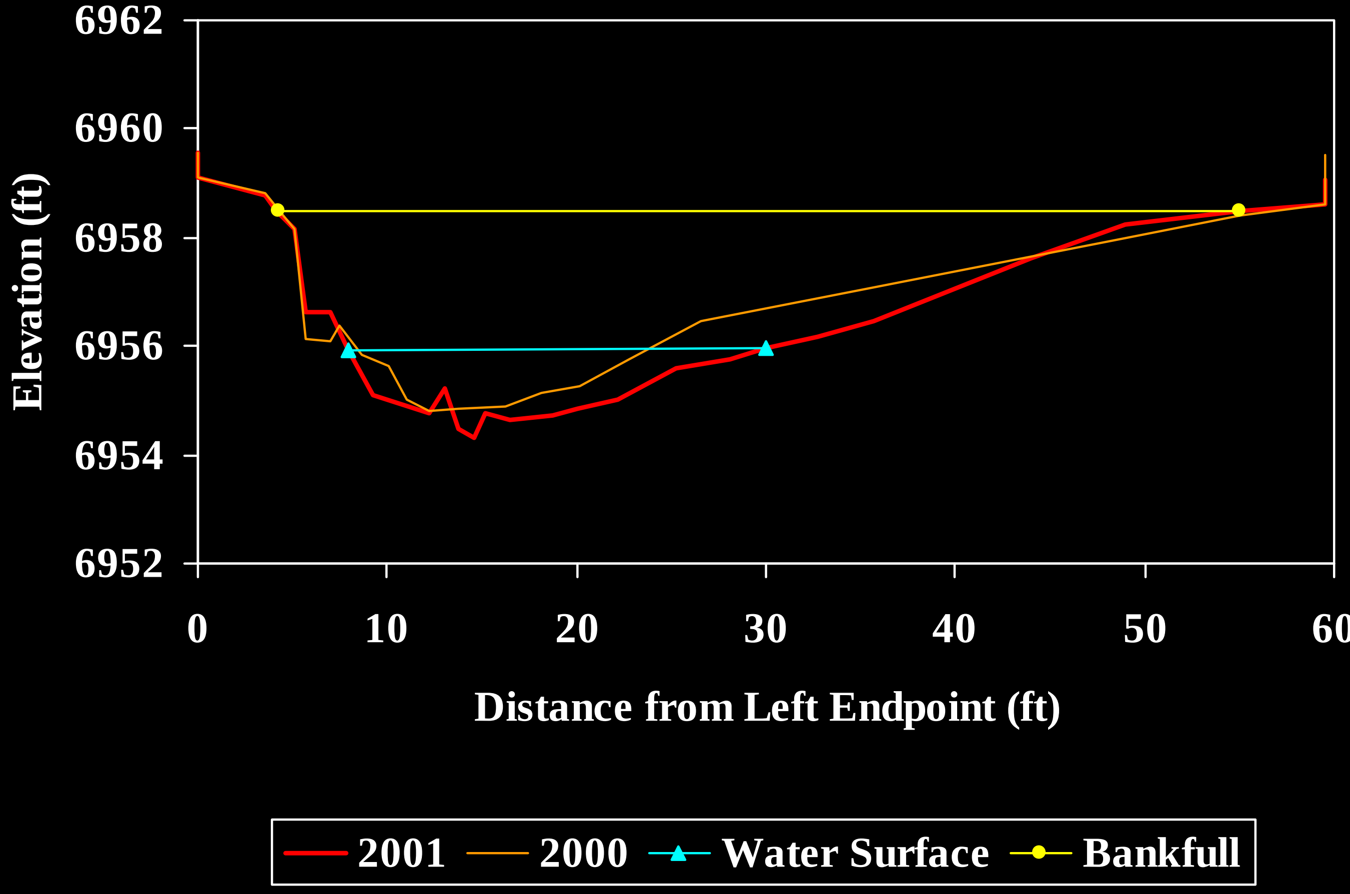
Longitudinal Profile through Cross Sections A, B, and C



Cross Section A

2001 Low Flow Dimensions

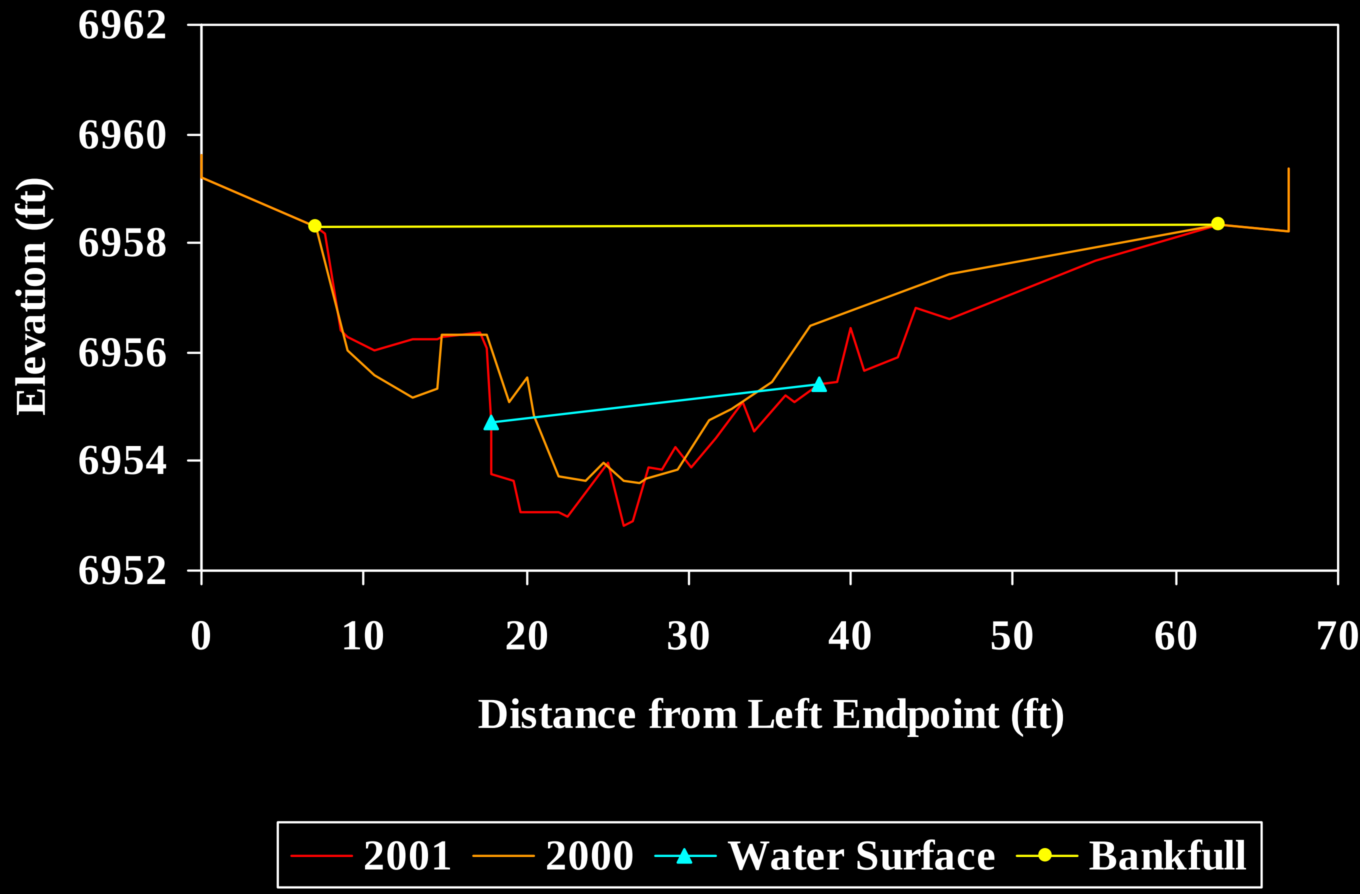
Discharge	Width	Mean Depth	Width/Depth Ratio	Max Depth
18 cfs	22.0 ft	0.81 ft	27.1	1.6 ft



Cross Section B

2001 Low Flow Dimensions

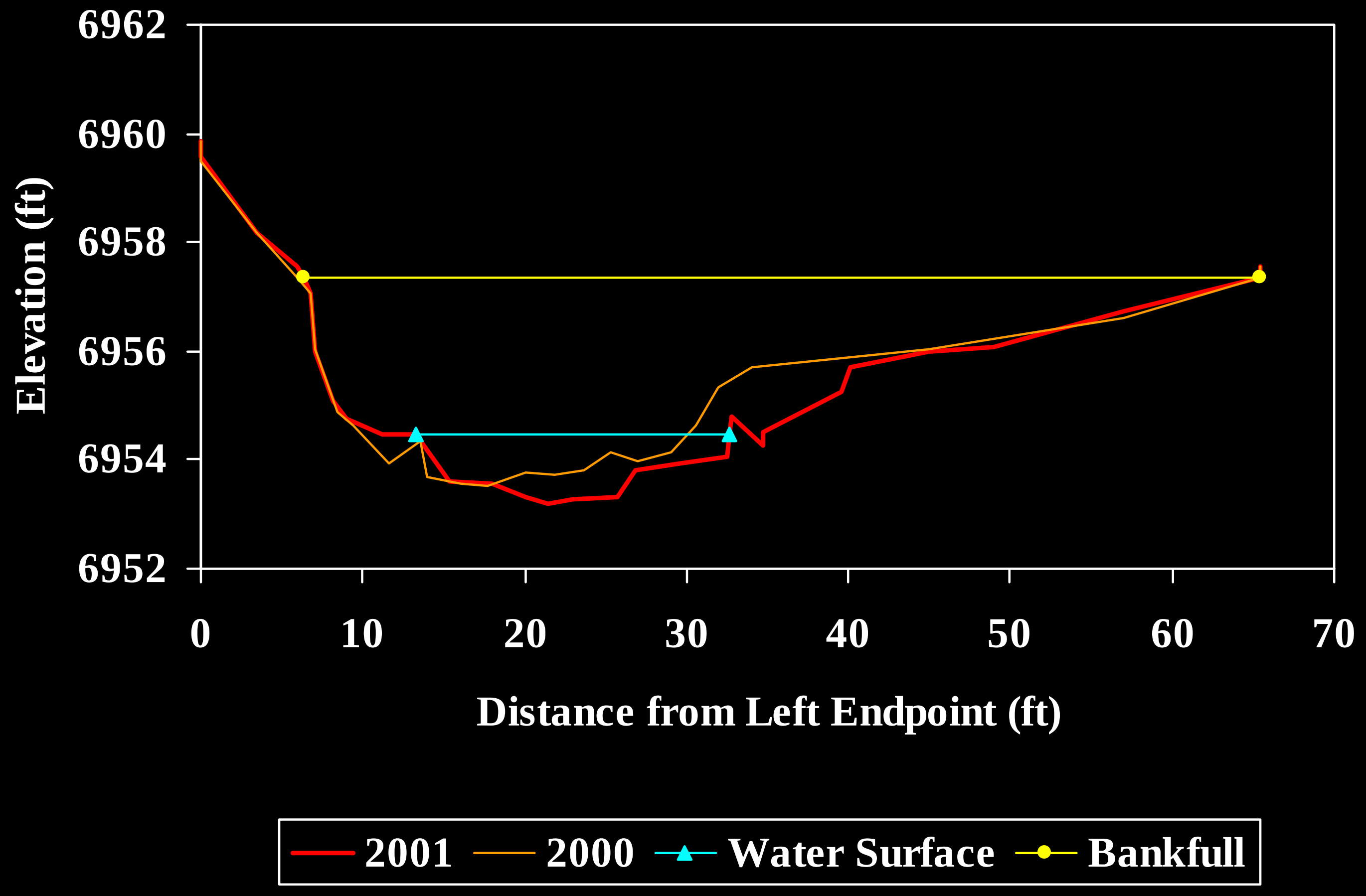
Discharge	Width	Mean Depth	Width/Depth Ratio	Max Depth
18 cfs	20.3 ft	0.81 ft	25.2	1.9 ft



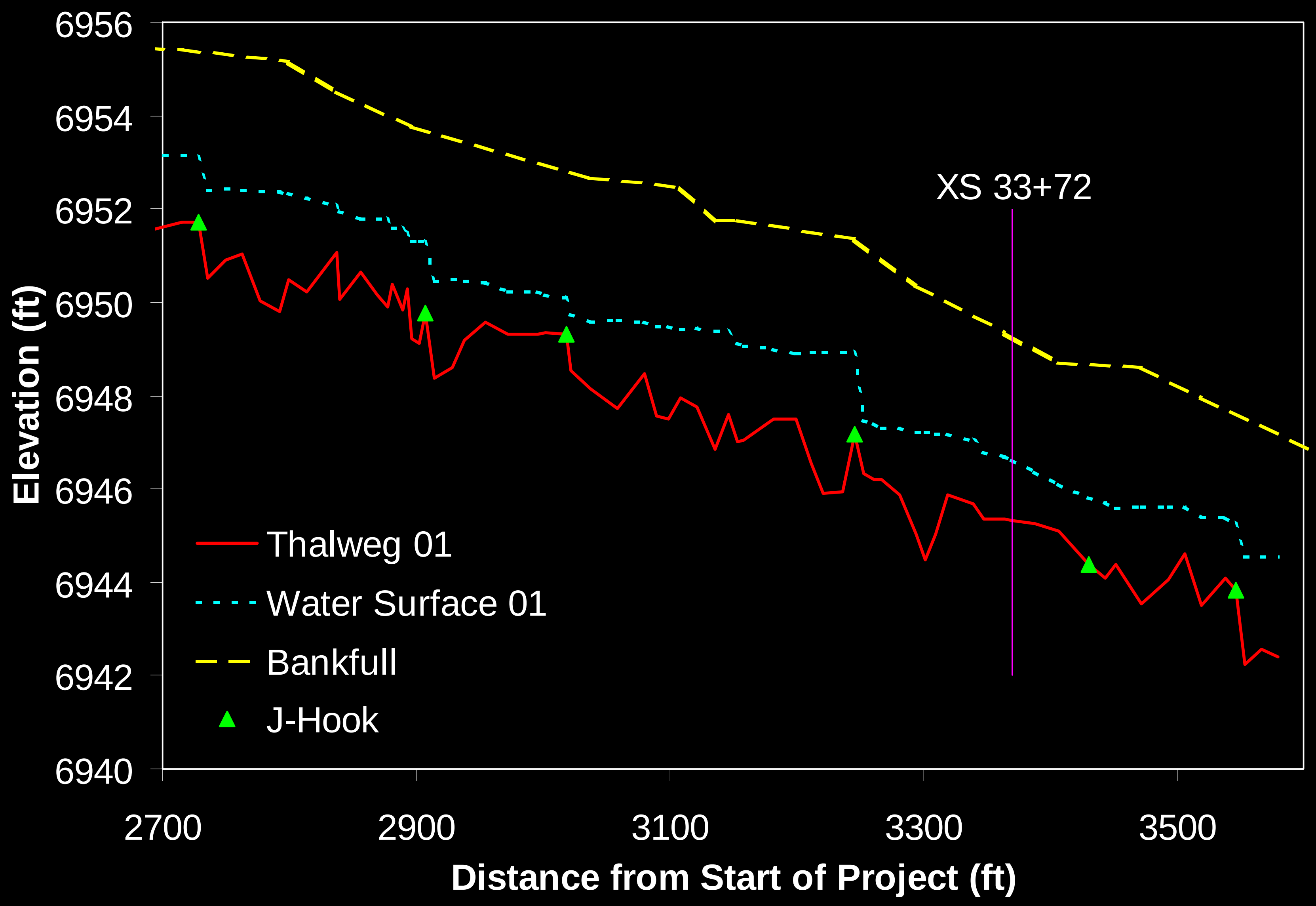
Cross Section C

2001 Low Flow Dimensions

Discharge	Width	Mean Depth	Width/Depth Ratio	Max Depth
18 cfs	19.4 ft	0.83 ft	23.4	1.3 ft



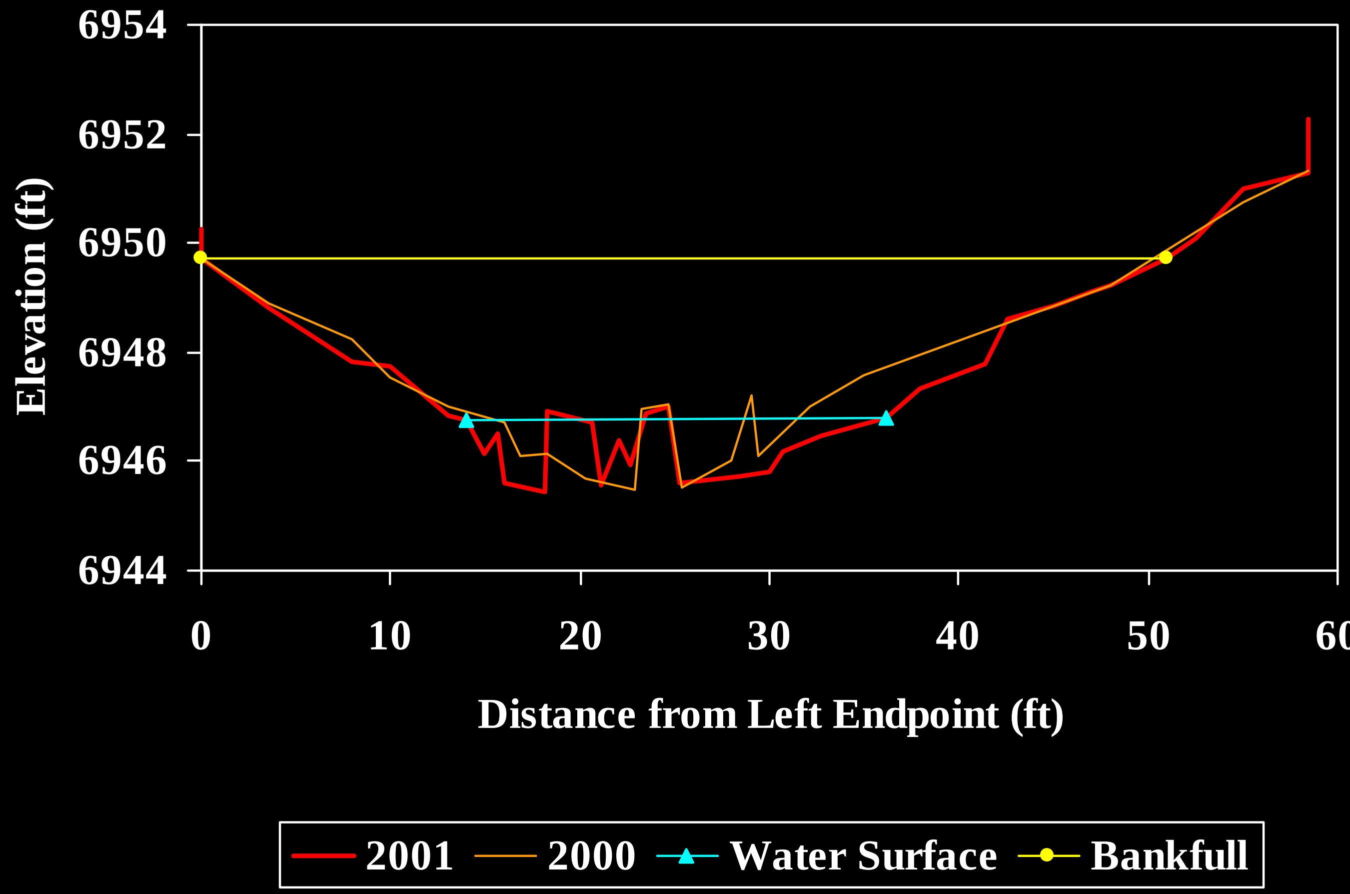
Longitudinal Profile through Cross Section 33+72



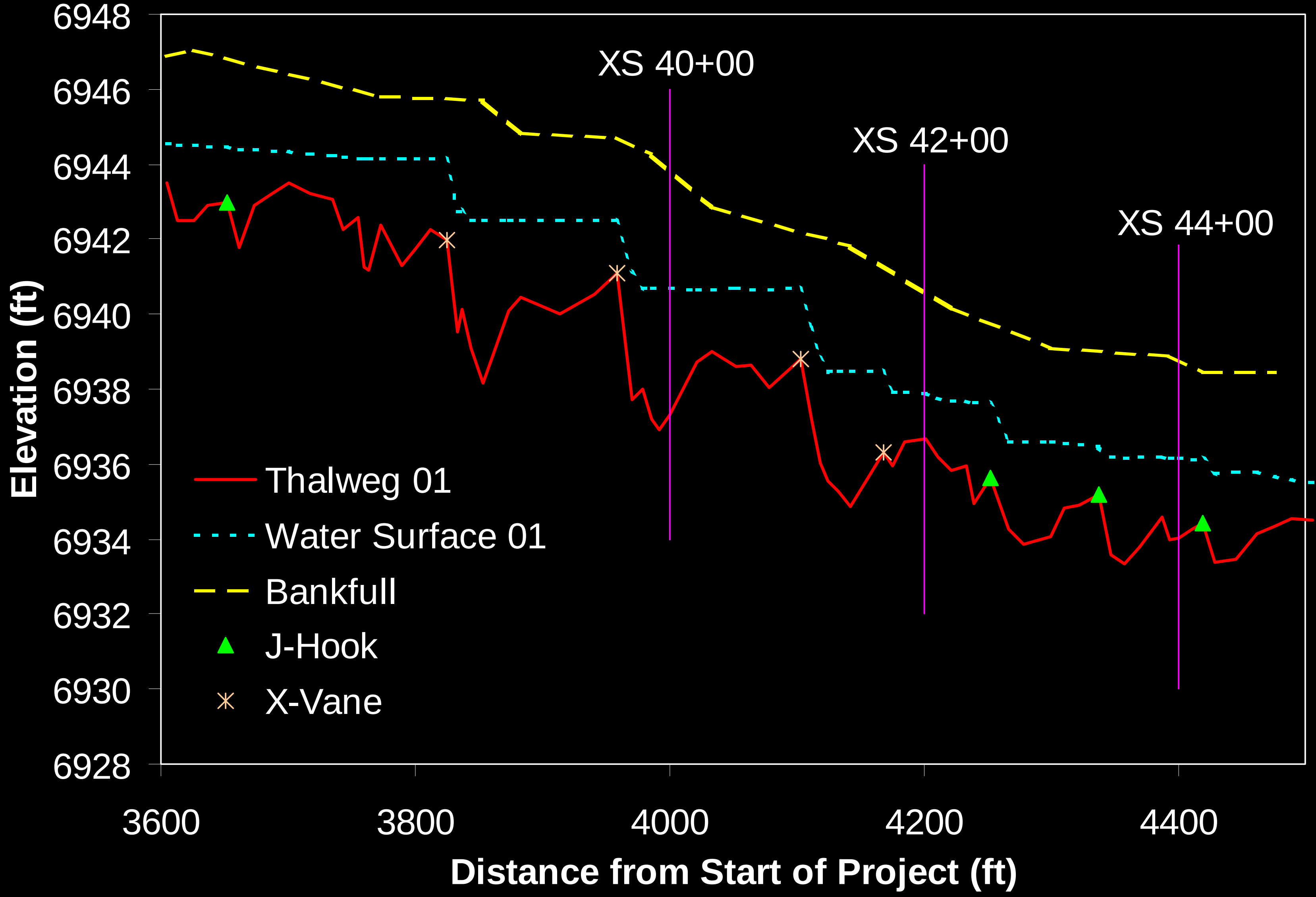
Cross Section 33+72

2001 Low Flow Dimensions

Discharge	Width	Mean Depth	Width/Depth Ratio	Max Depth
18 cfs	18.6 ft	0.68 ft	27.5	1.3 ft



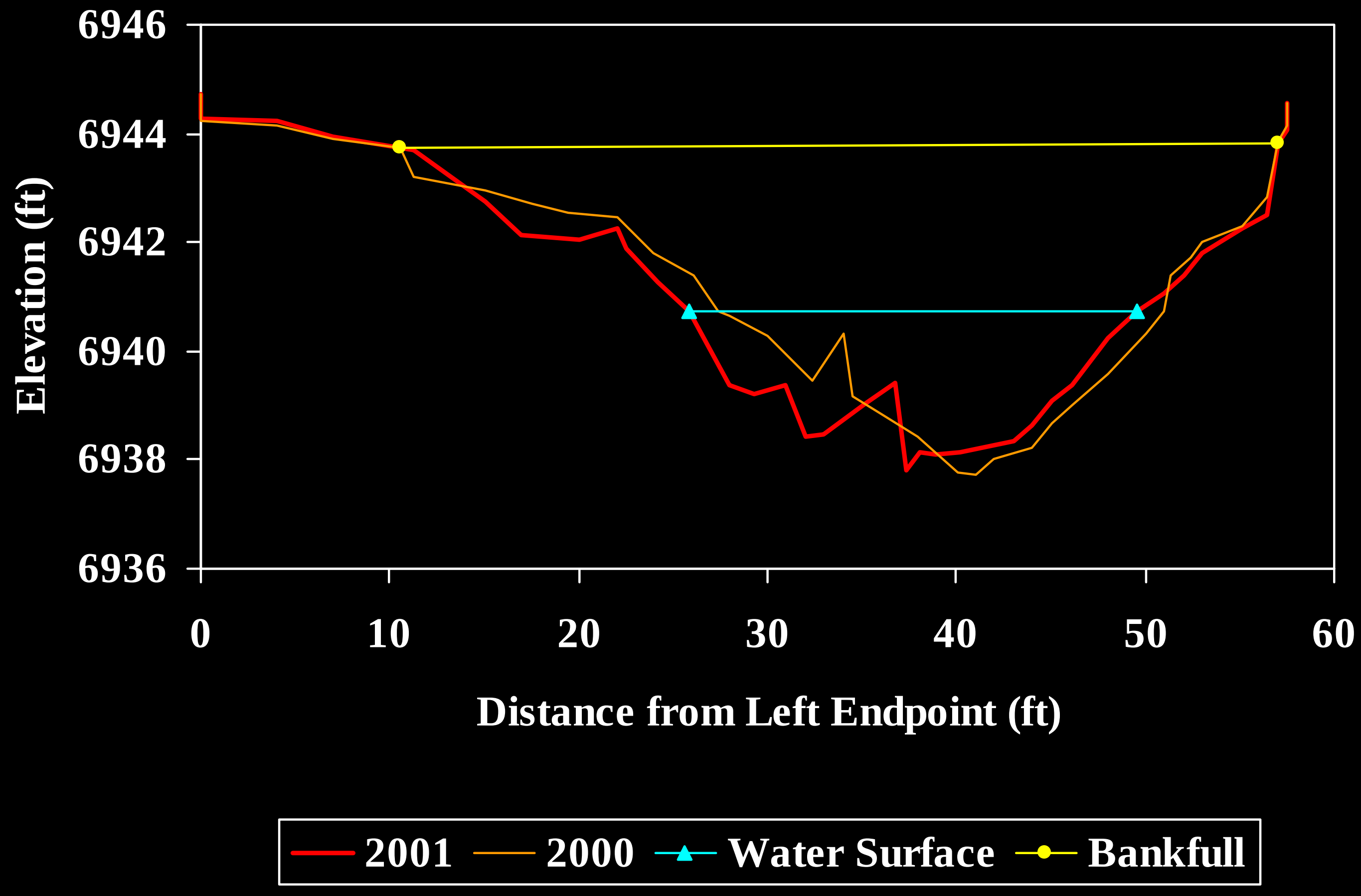
Longitudinal Profile through Cross Sections 40+00, 42+00, and 44+00



Cross Section 40+00

2001 Low Flow Dimensions

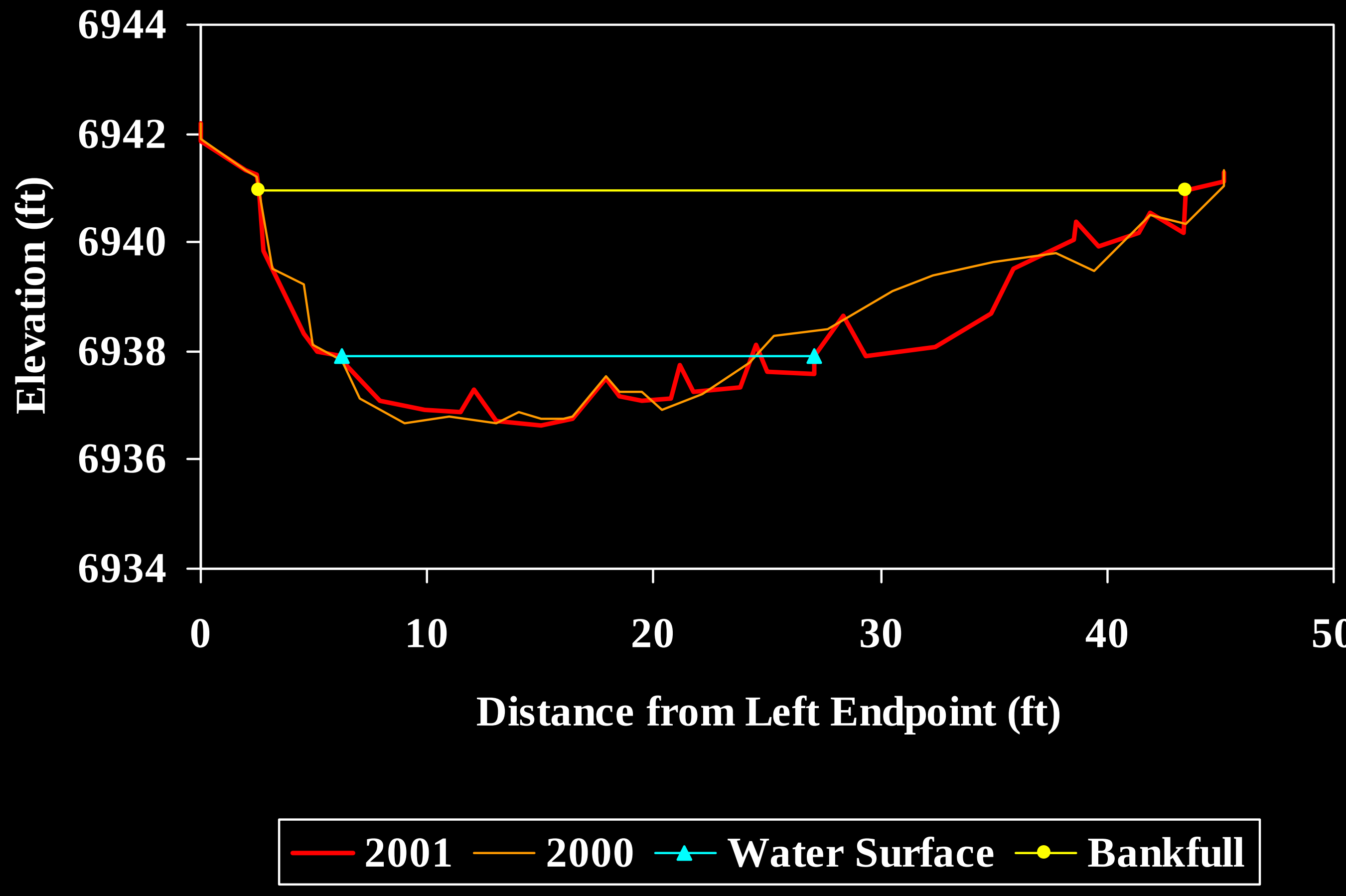
Discharge	Width	Mean Depth	Width/Depth Ratio	Max Depth
18 cfs	23.7 ft	1.68 ft	14.0	2.9 ft



Cross Section 42+00

2001 Low Flow Dimensions

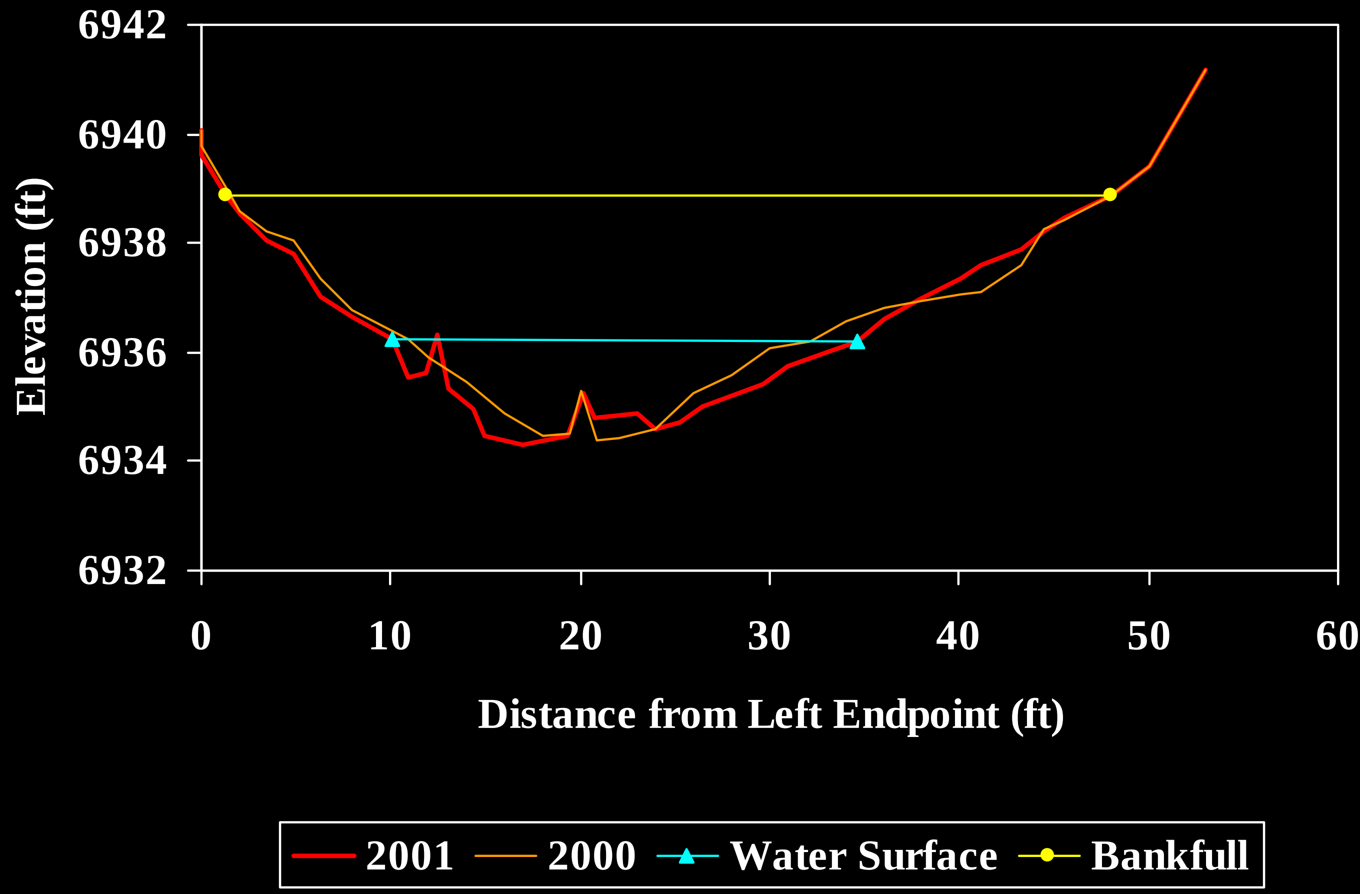
Discharge	Width	Mean Depth	Width/Depth Ratio	Max Depth
18 cfs	20.9 ft	0.72 ft	29.1	1.3 ft



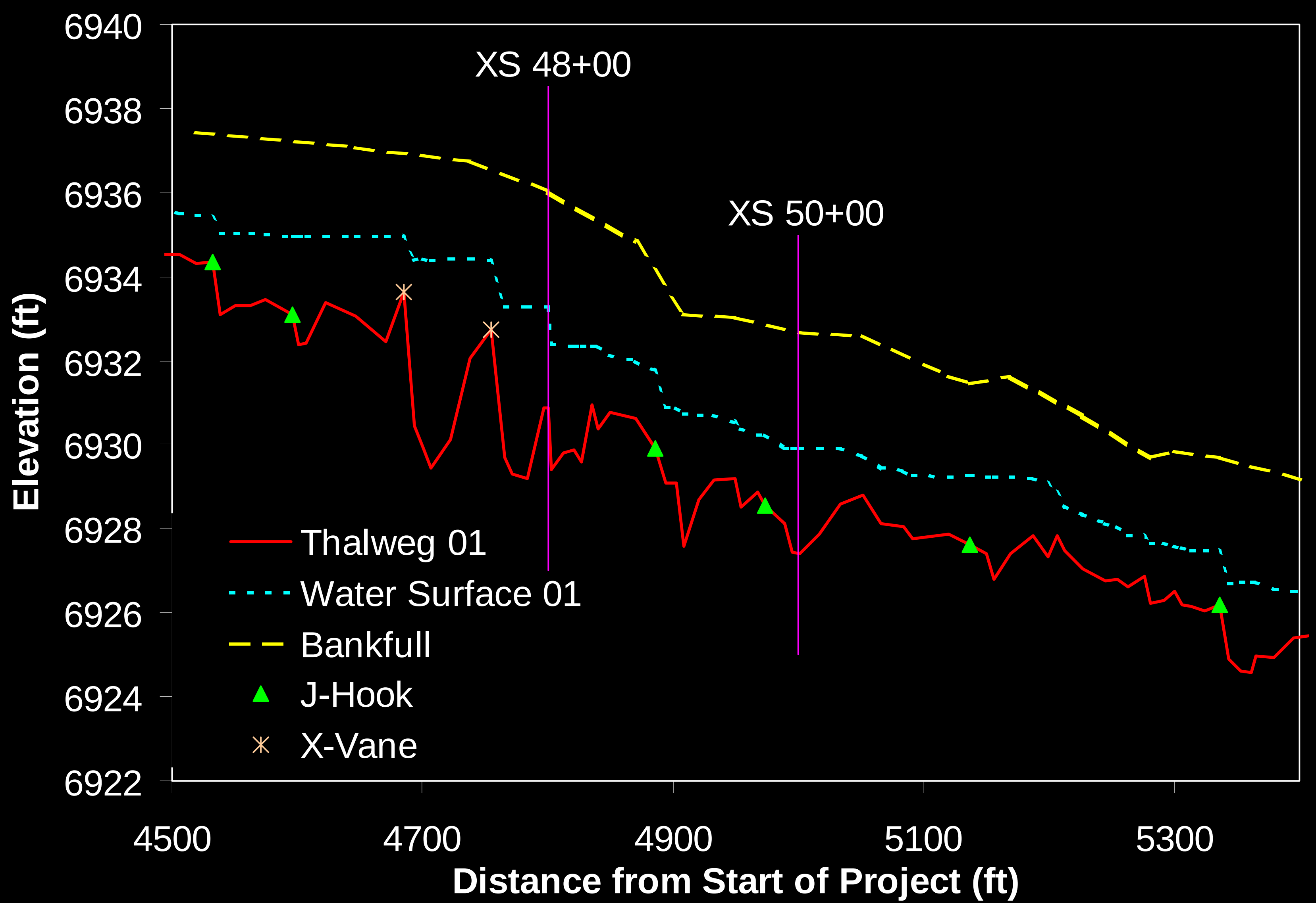
Cross Section 44+00

2001 Low Flow Dimensions

Discharge	Width	Mean Depth	Width/Depth Ratio	Max Depth
18 cfs	24.5 ft	1.09 ft	22.5	1.9 ft



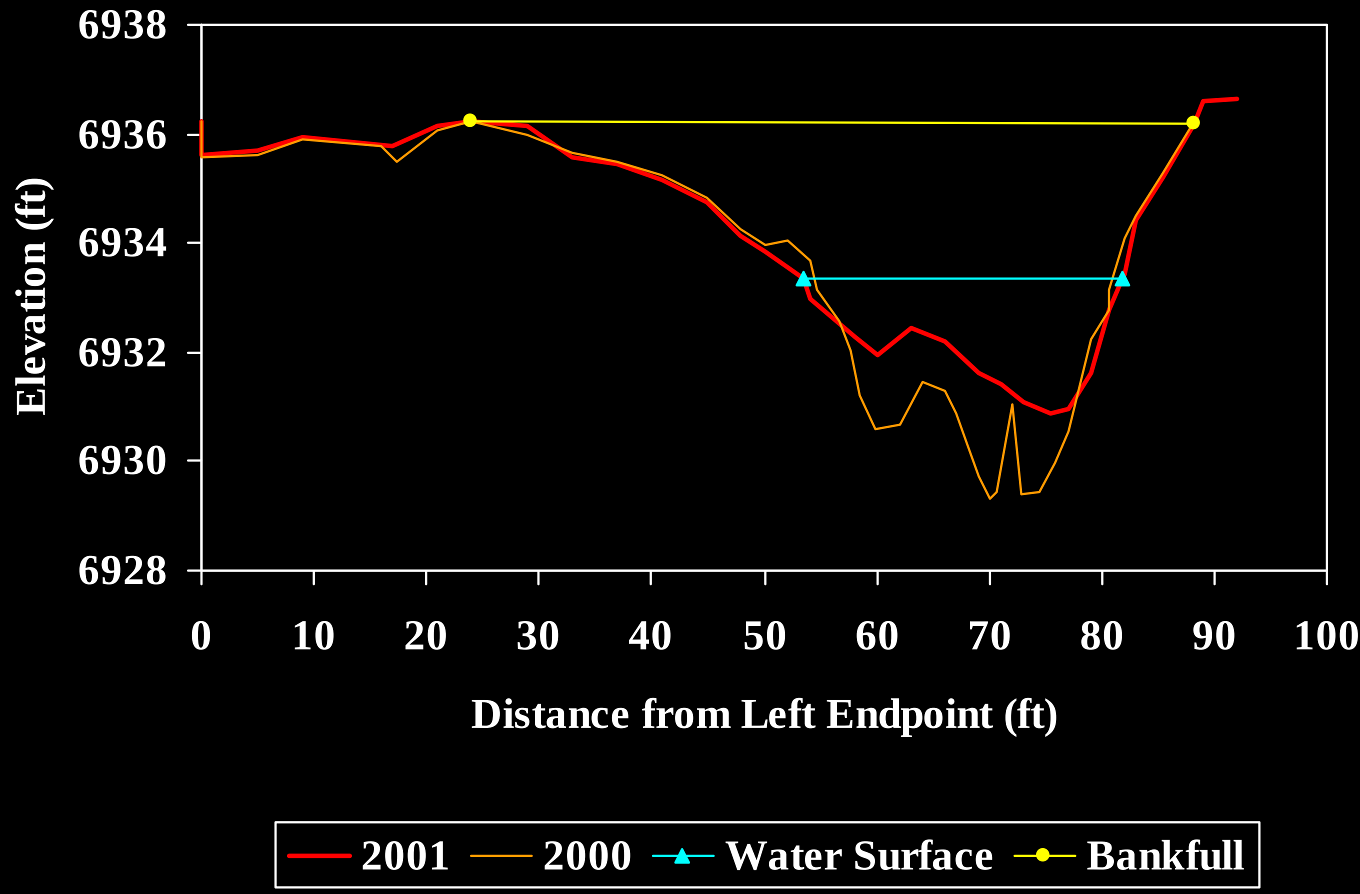
Longitudinal Profile through Cross Sections 48+00 and 50+00



Cross Section 48+00

2001 Low Flow Dimensions

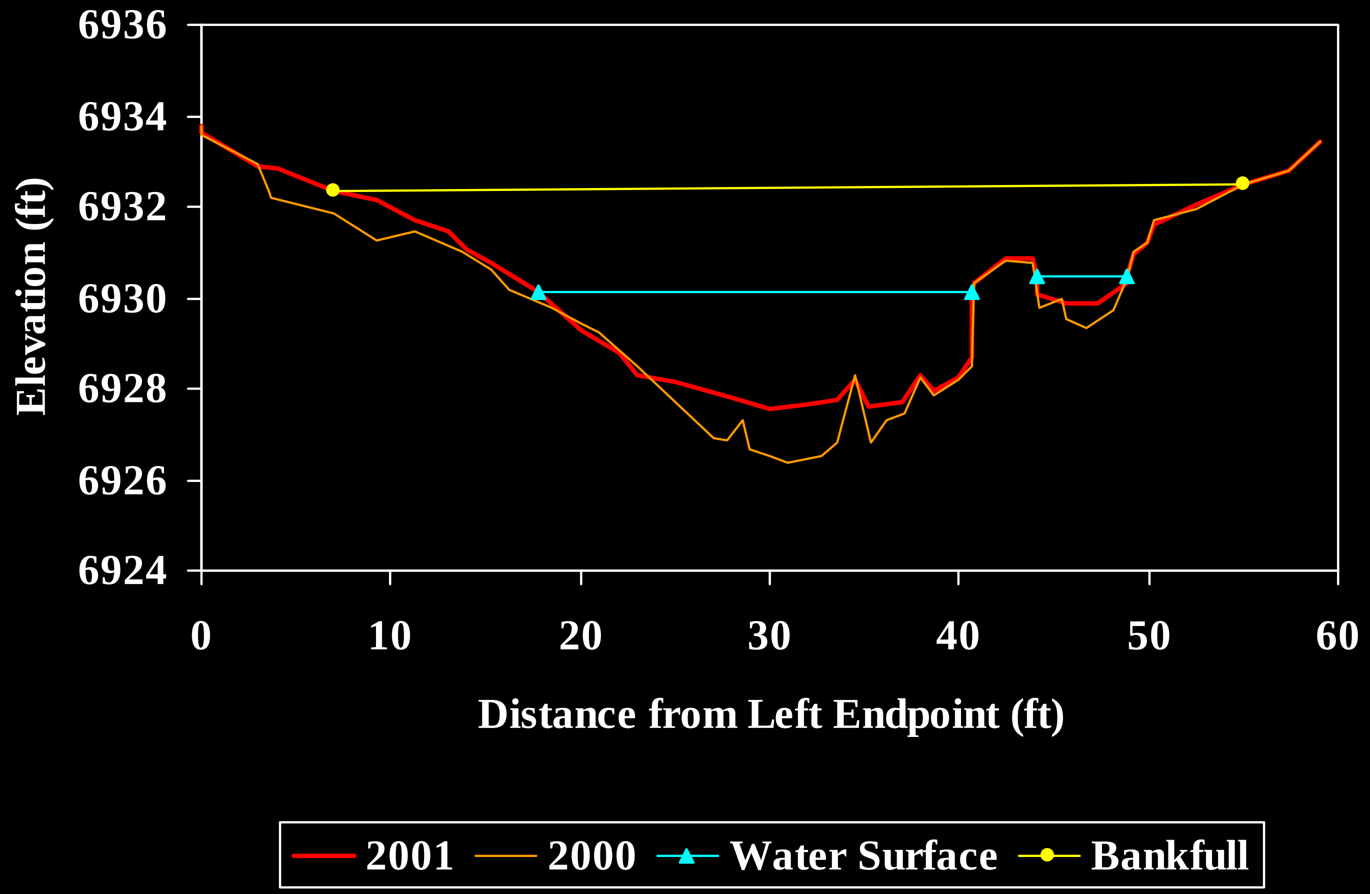
Discharge	Width	Mean Depth	Width/Depth Ratio	Max Depth
22 cfs	28.3 ft	1.4 ft	20.2	2.5 ft



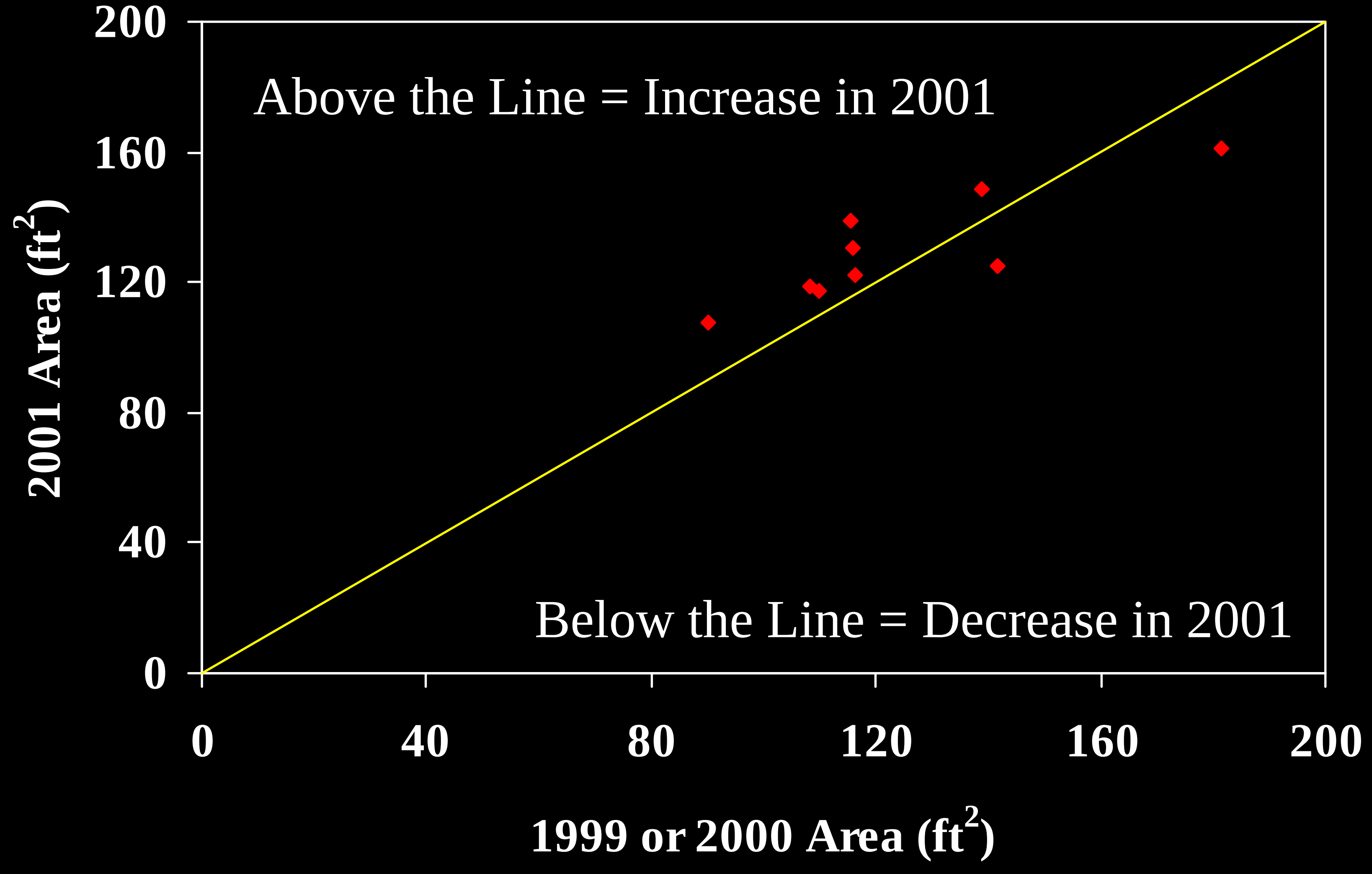
Cross Section 50+00

2001 Low Flow Dimensions

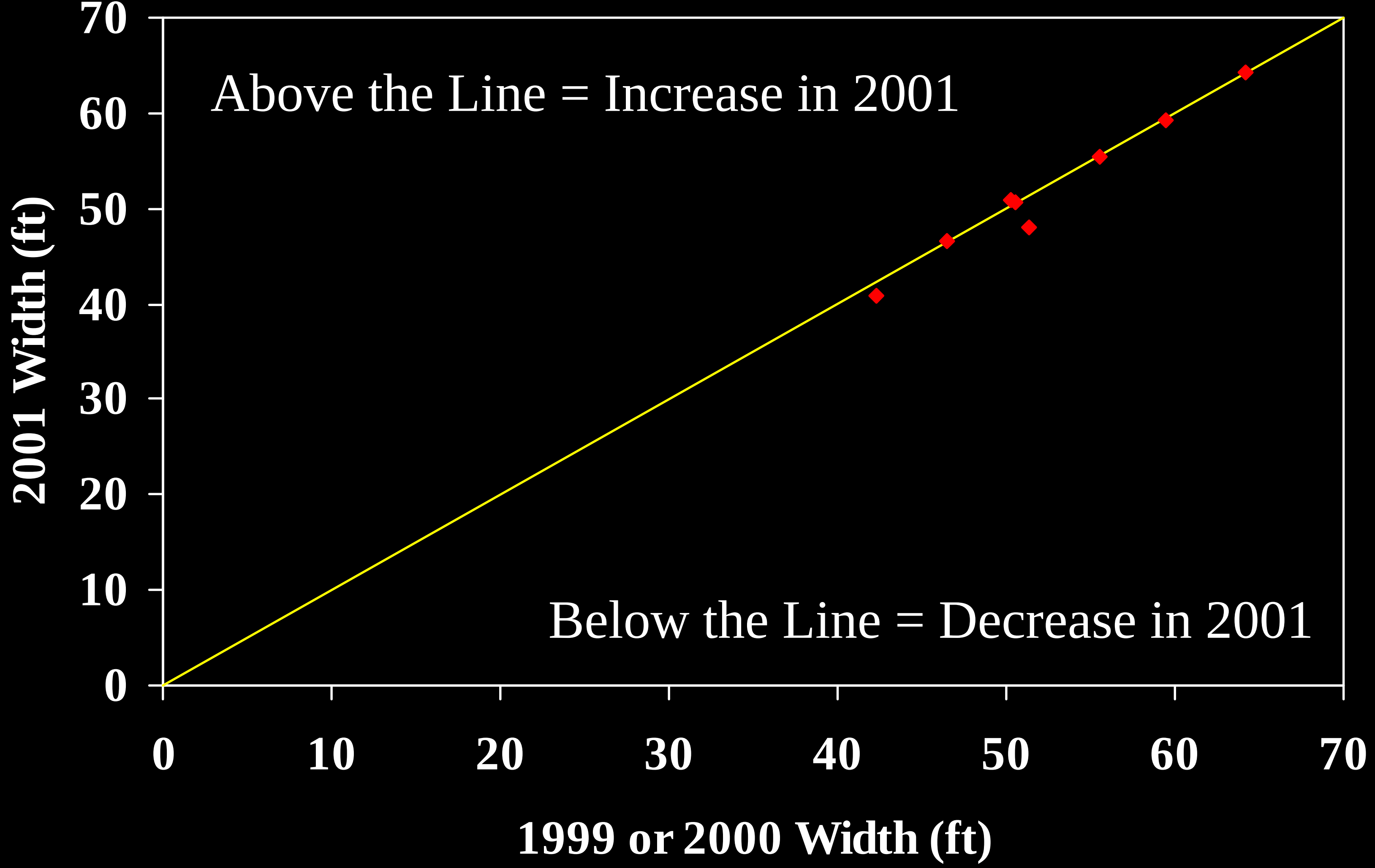
Discharge	Width	Mean Depth	Width/Depth Ratio	Max Depth
22 cfs	27.7 ft	1.67 ft	16.6	2.6 ft



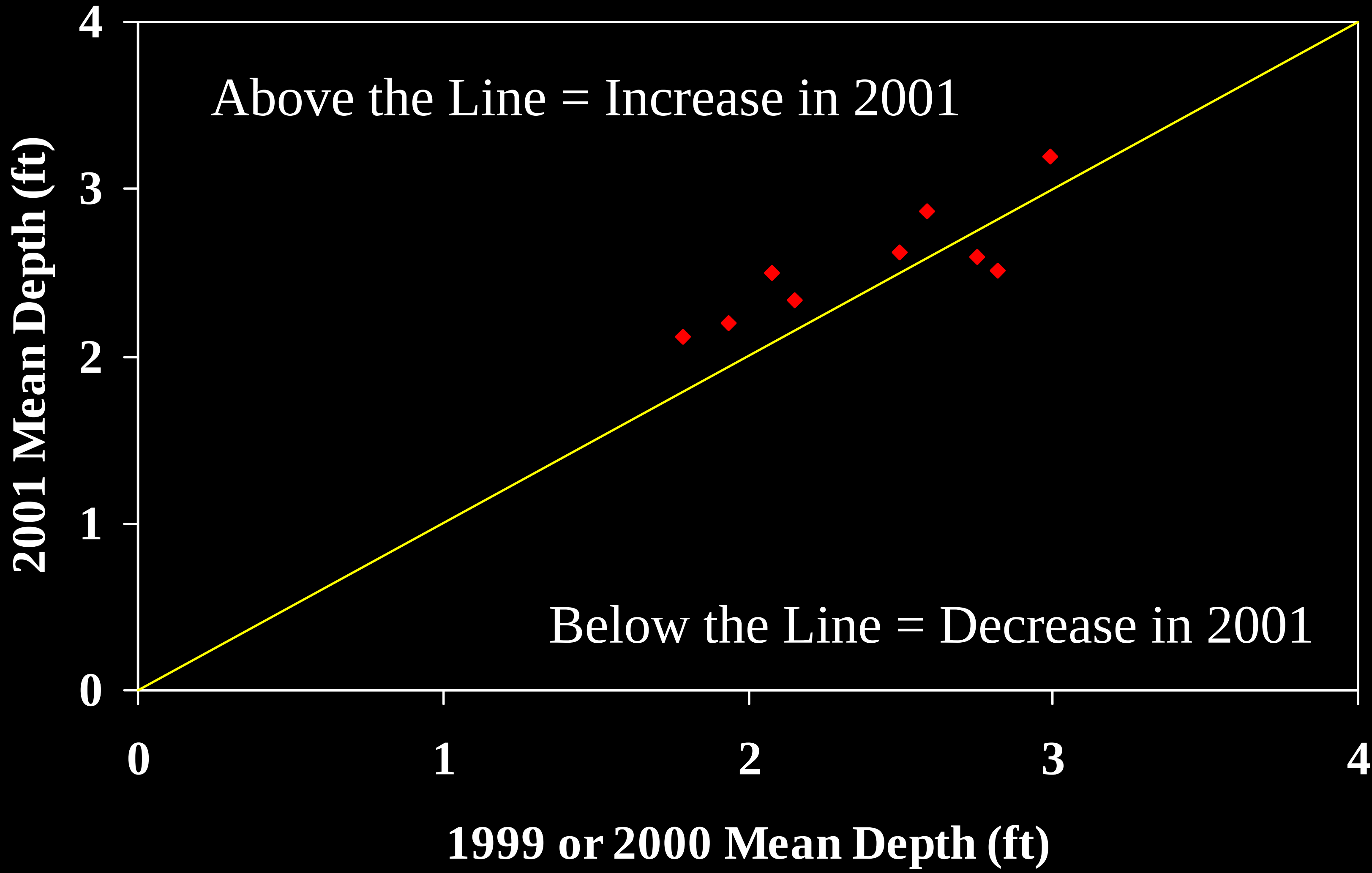
Summary of Changes in Bankfull Area of 9 Cross Sections



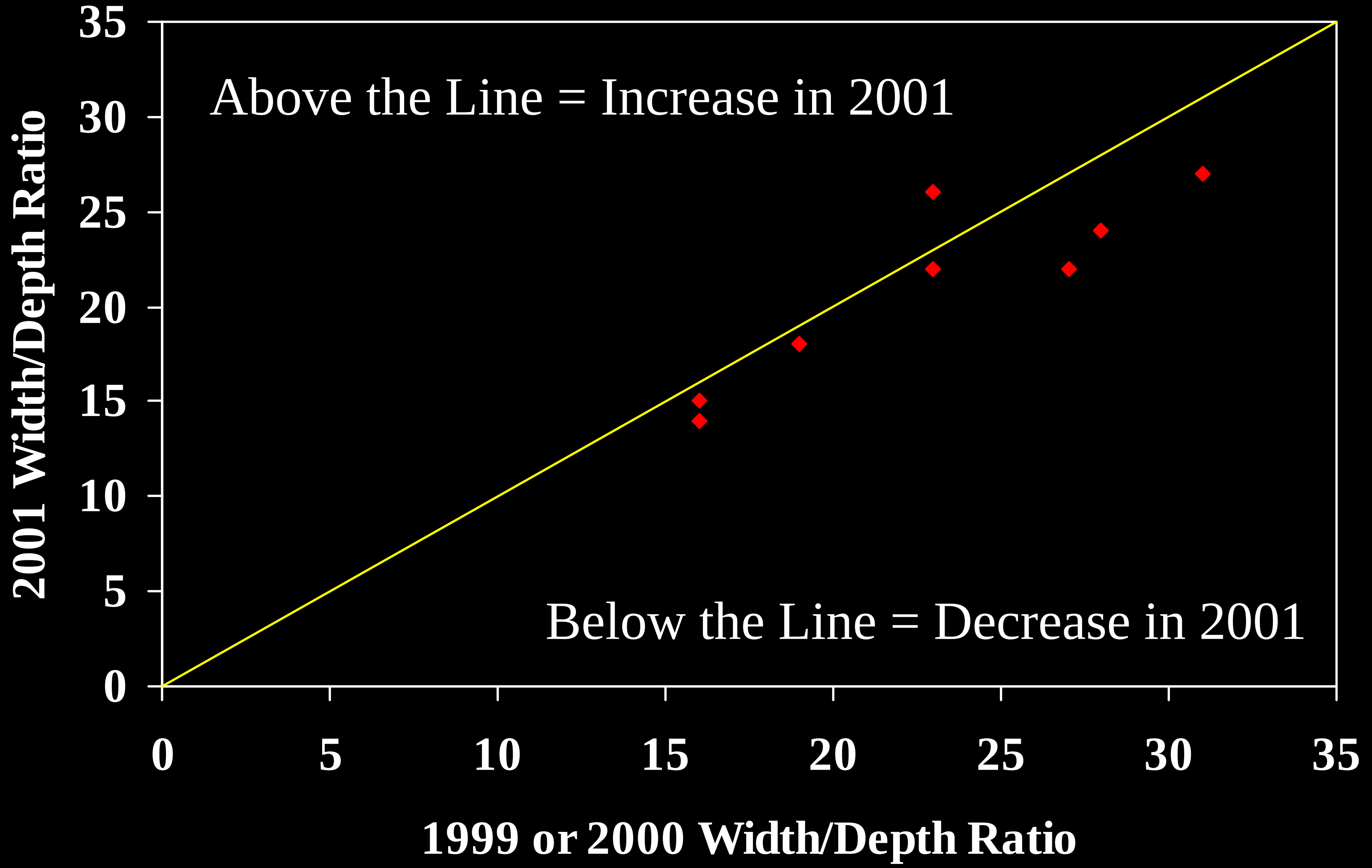
Summary of Changes in Bankfull Width of 9 Cross Sections



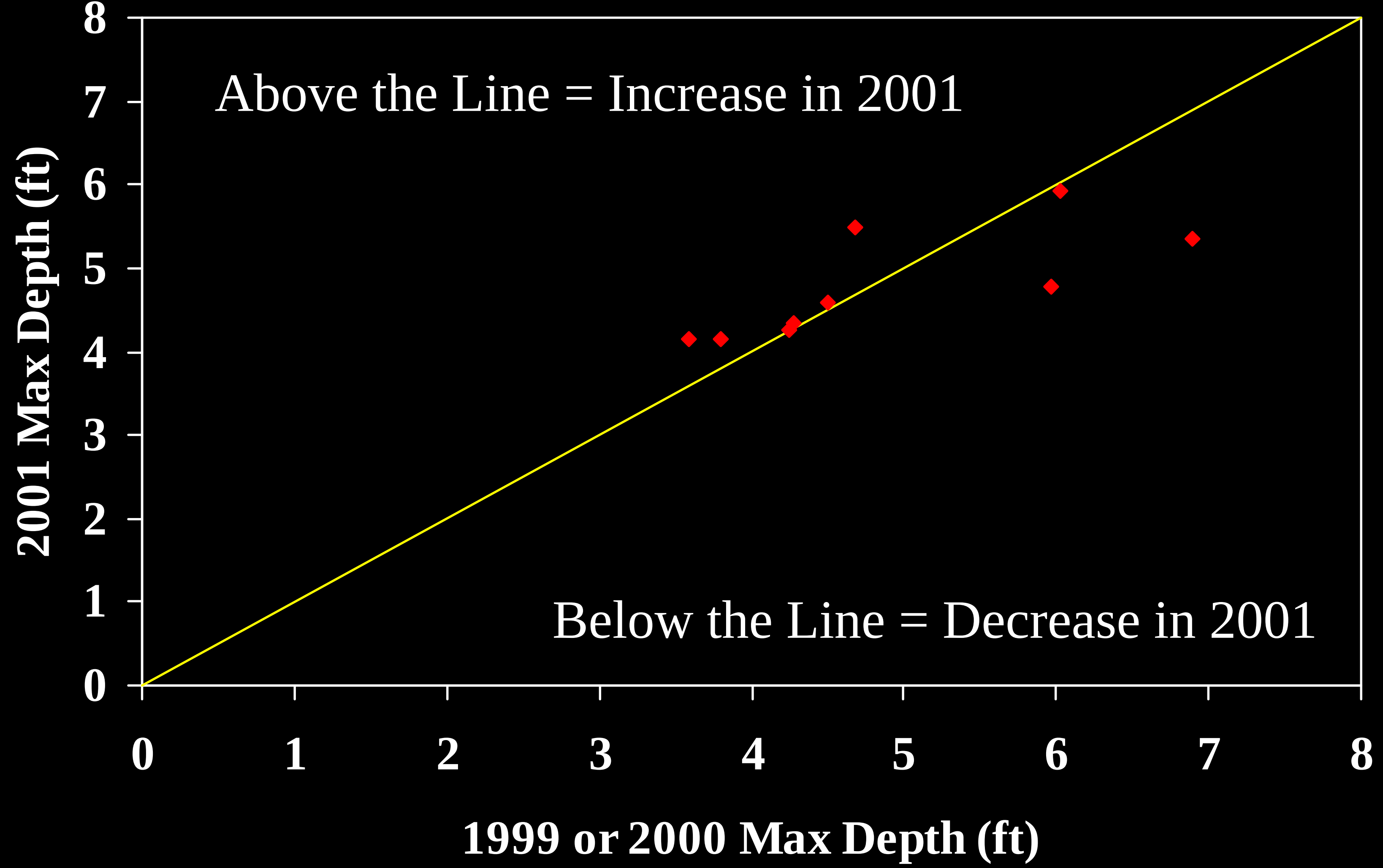
Summary of Changes in Bankfull Mean Depth of 9 Cross Sections



Summary of Changes in Bankfull Width/Depth Ratio of 9 Cross Sections

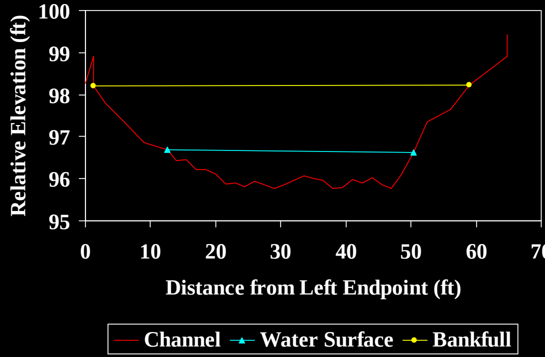


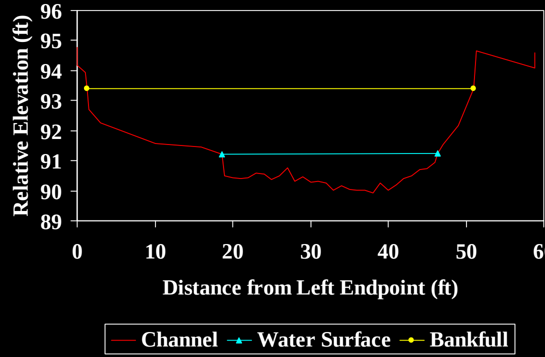
Summary of Changes in Bankfull
Bankfull Max Depth of 9 Cross Sections

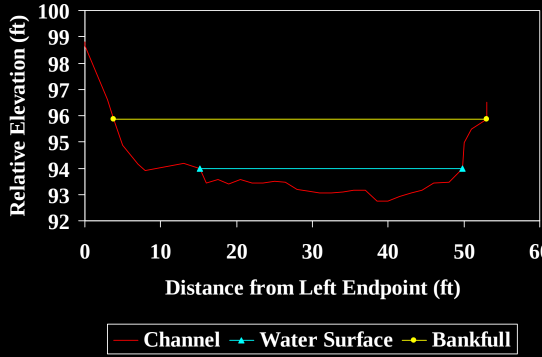


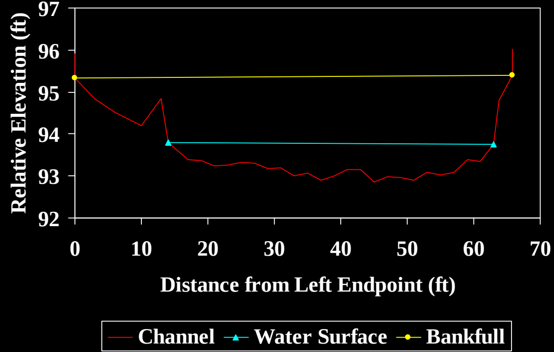
Division of Wildlife Cross Sections

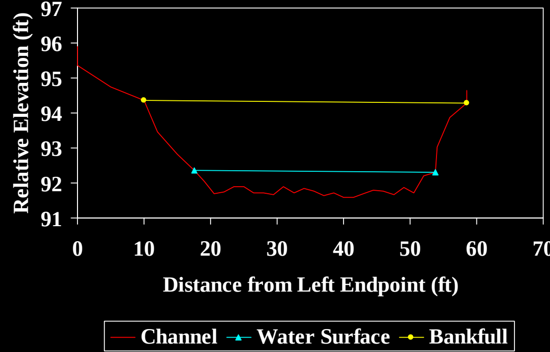
(Surveyed Prior to Construction)







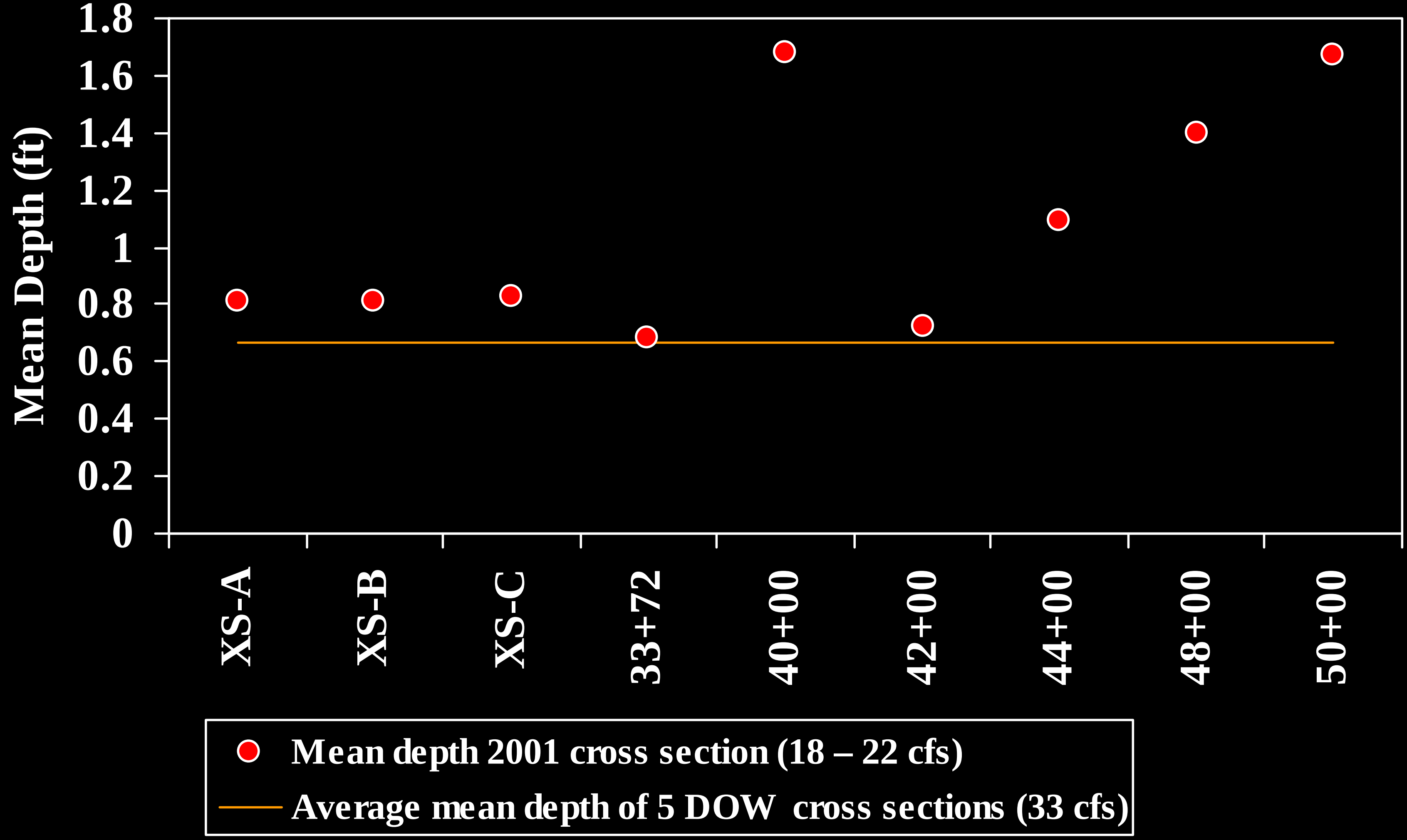




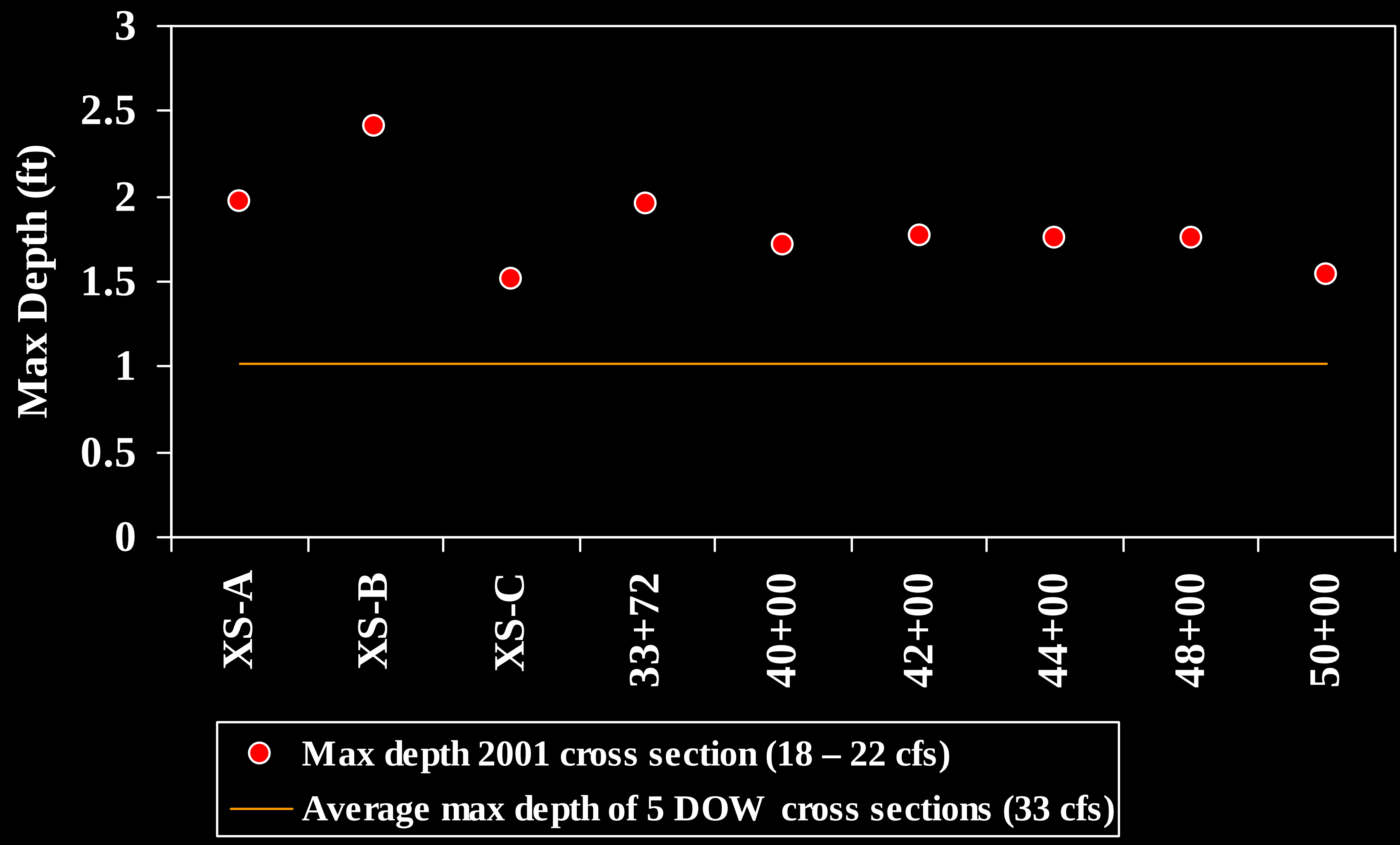
Discharge	Width*	Mean Depth*	Width/Depth Ratio*	Max Depth*
33 cfs	37.1 ft	0.67 ft	57.9	1.0ft

*Average values from 5 cross sections at 33 cfs

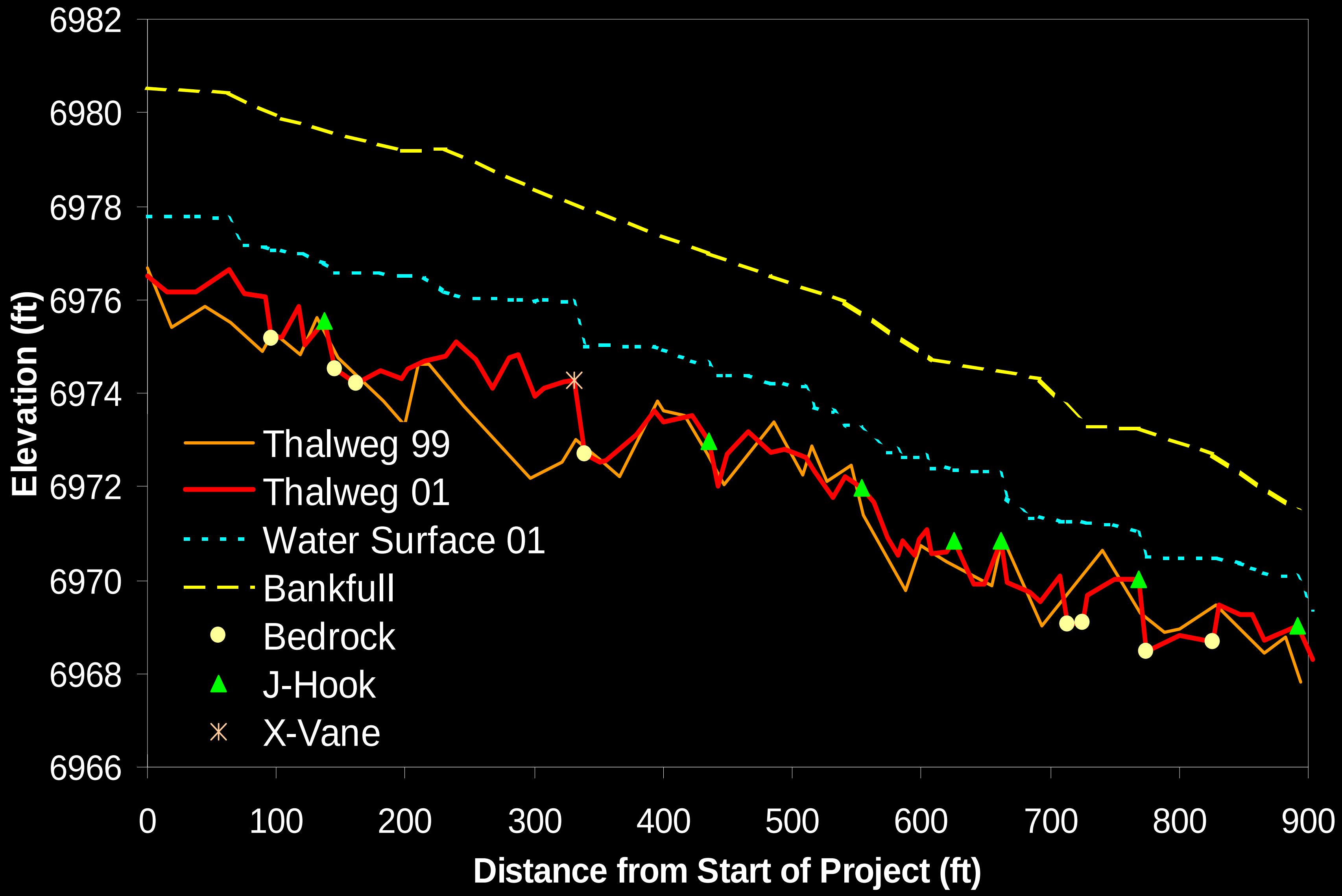
Even with 33 percent less flow, the mean depths of the 2001 cross sections are greater than the average mean depth of 5 Division of Wildlife pre-restoration cross sections.



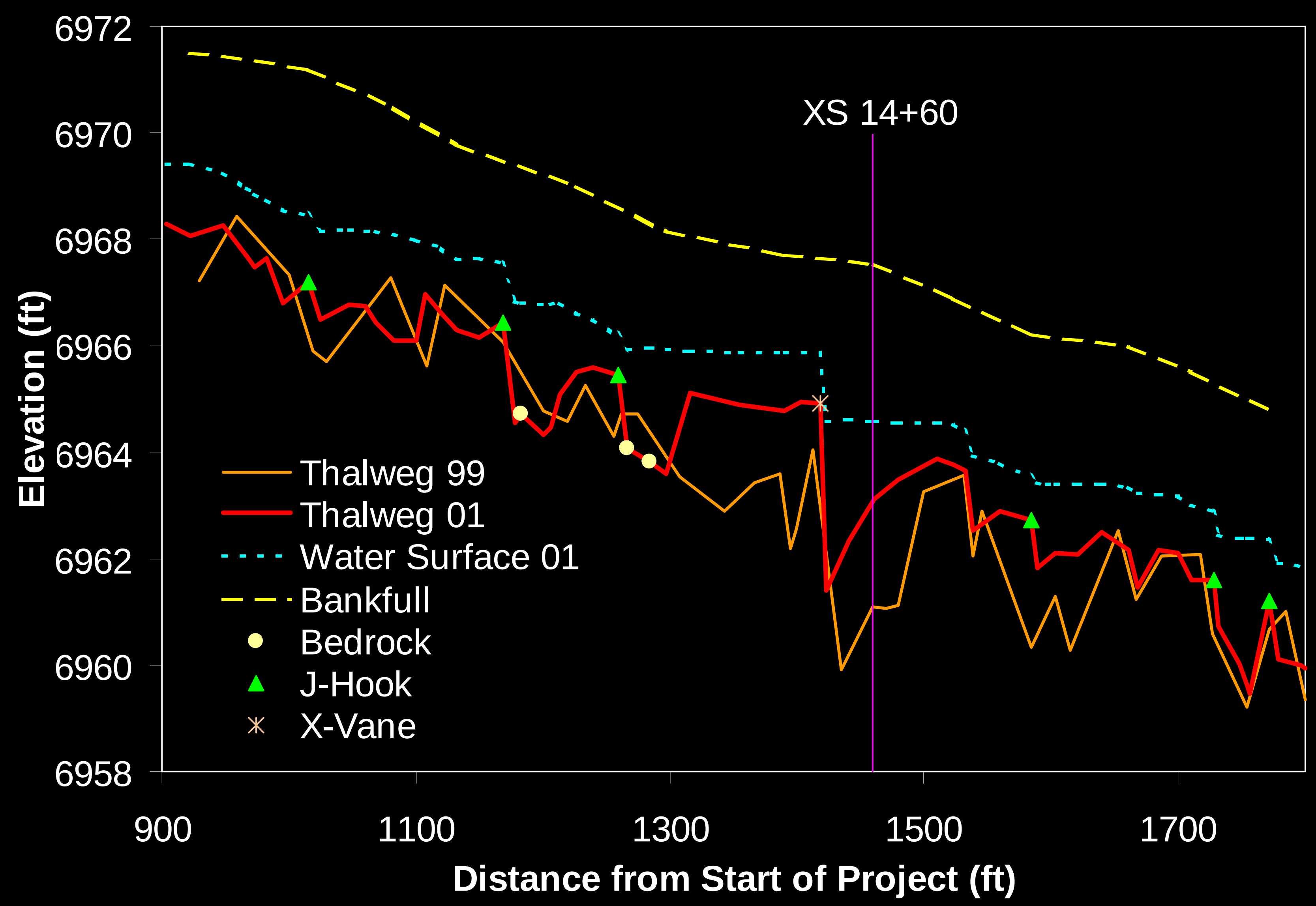
Even with 33 percent less flow, the max depths of the 2001 cross sections are greater than the average max of 5 Division of Wildlife pre-restoration cross sections.



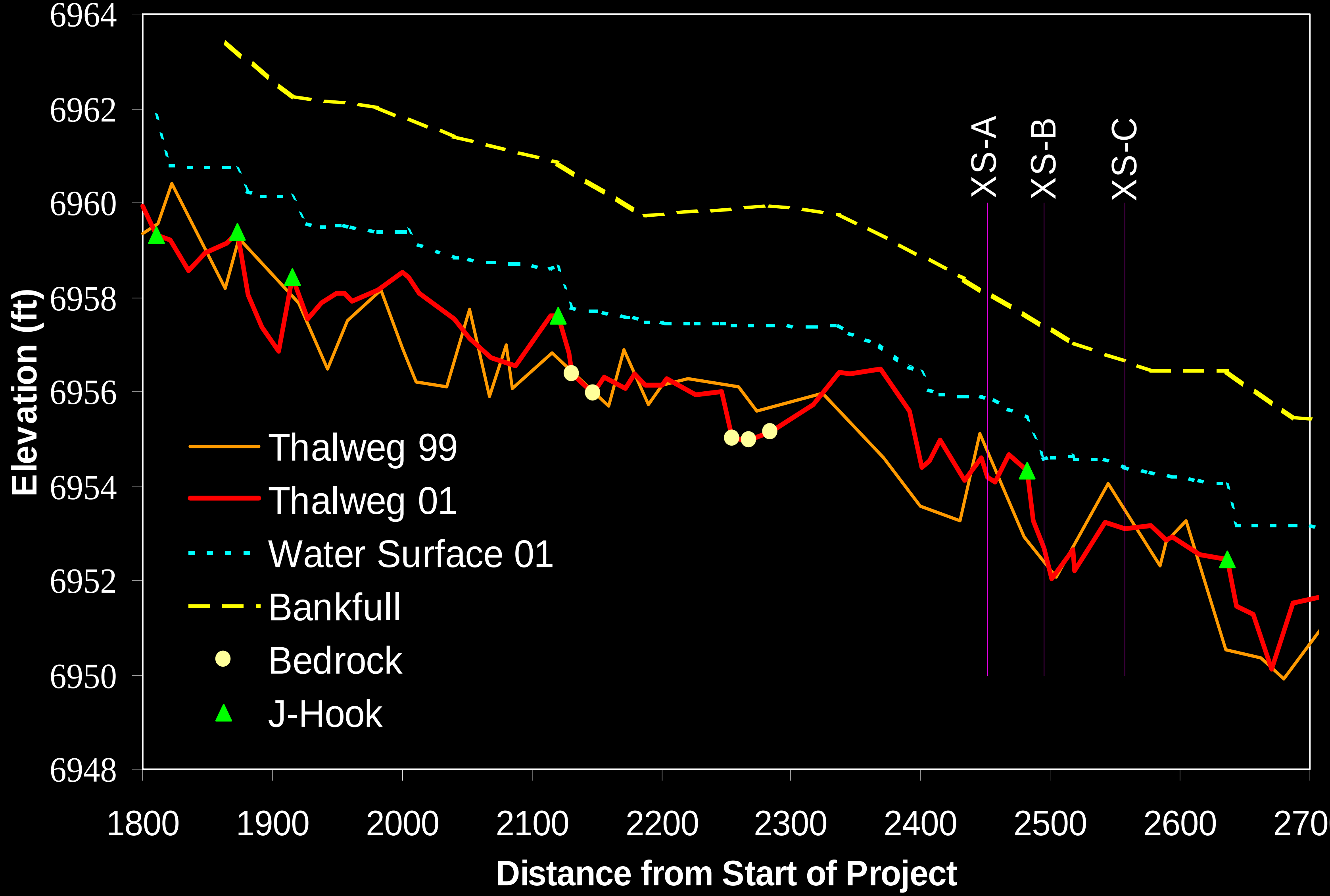
Longitudinal Profile 0+00 – 9+00



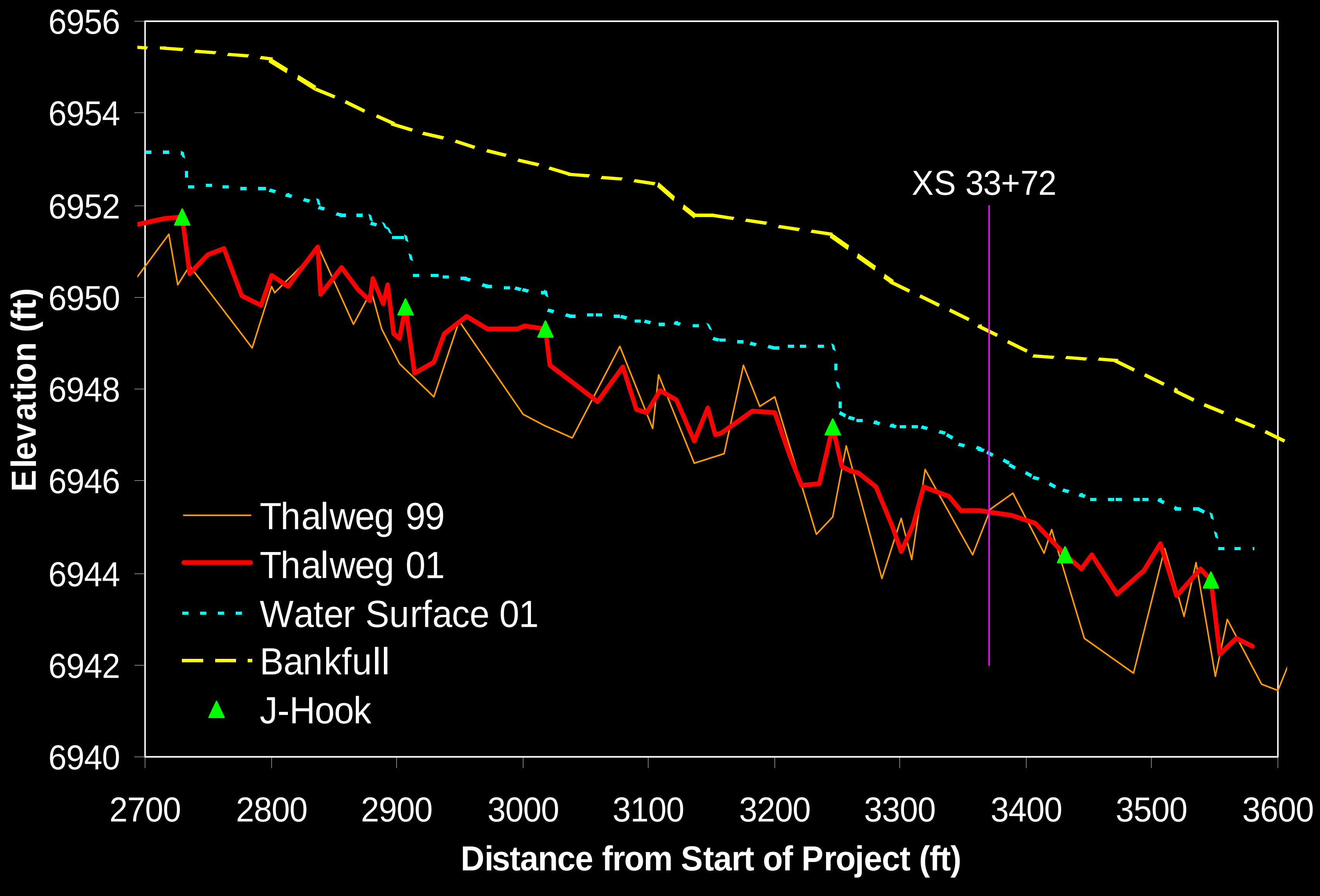
Longitudinal Profile 9+00 – 18+00



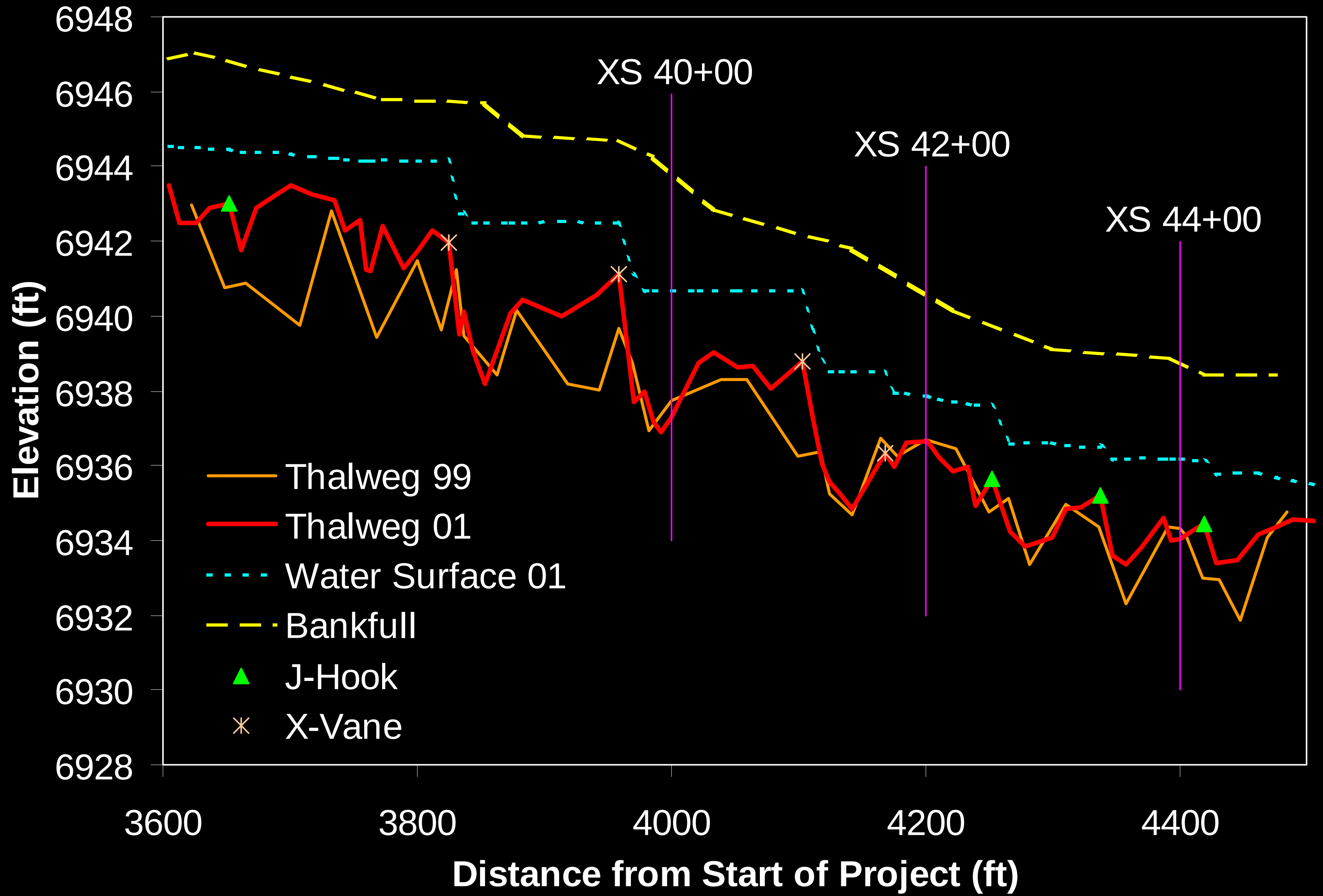
Longitudinal Profile 18+00 – 27+00



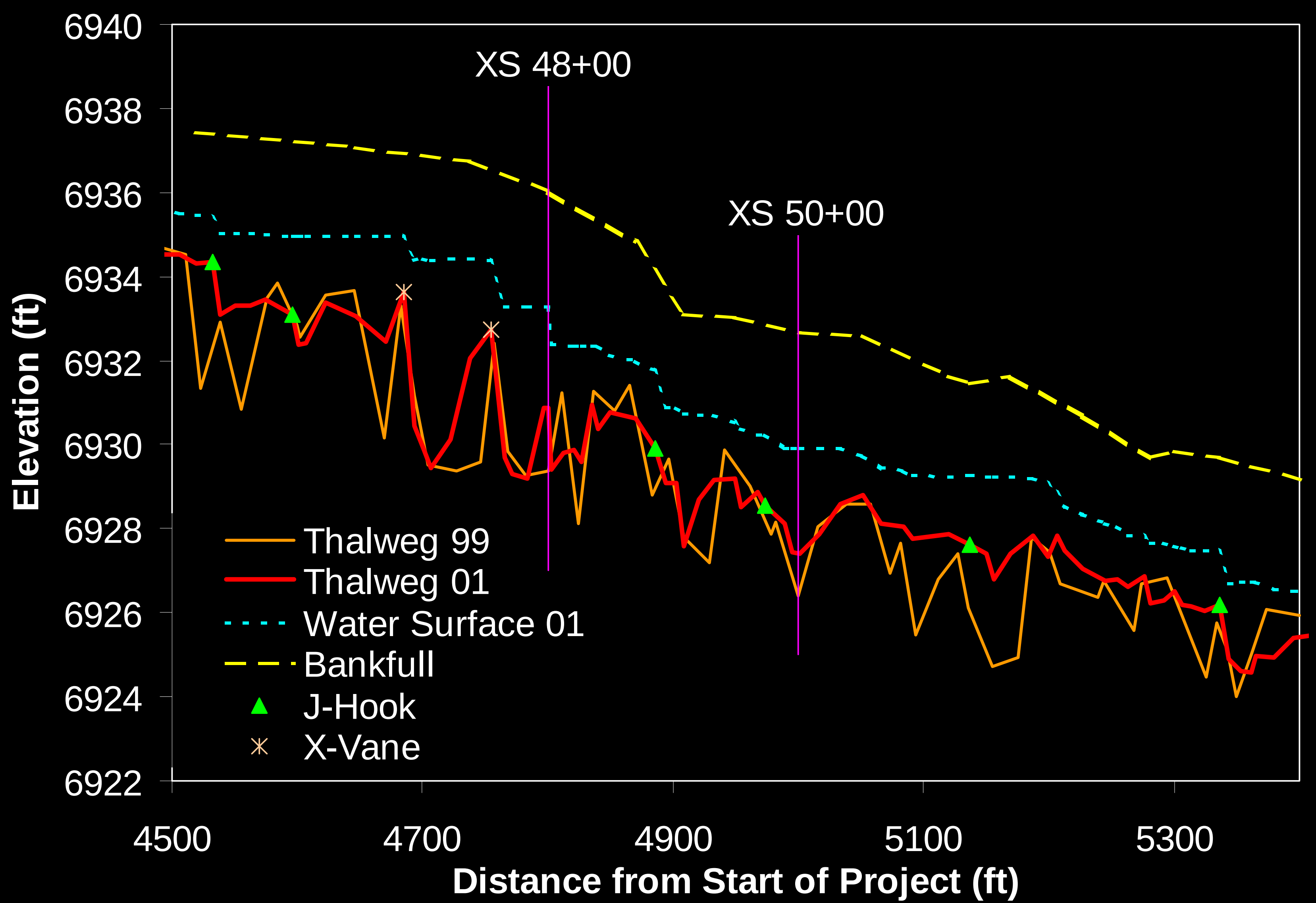
Longitudinal Profile 27+00 – 36+00



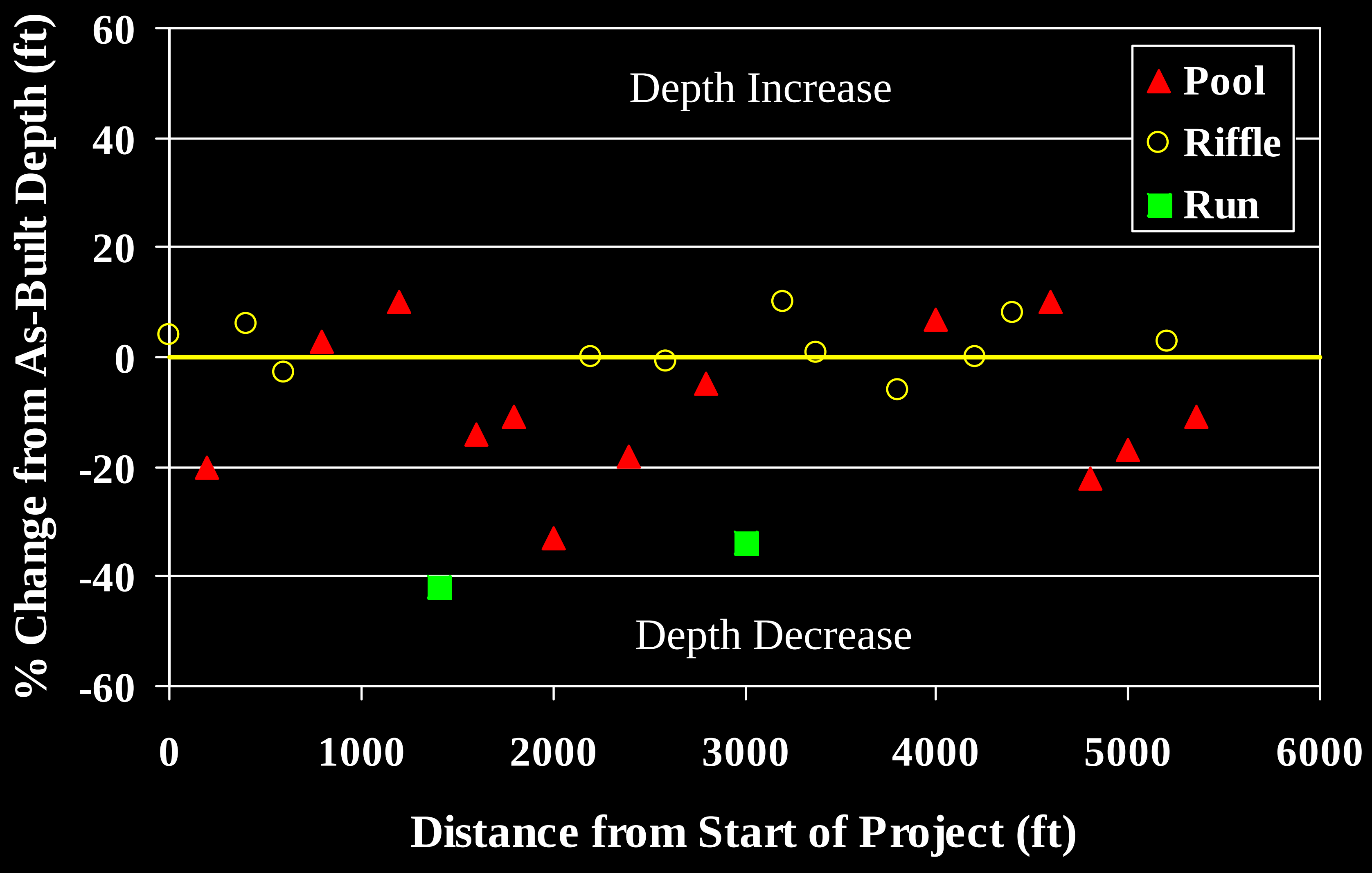
Longitudinal Profile 36+00 – 45+00



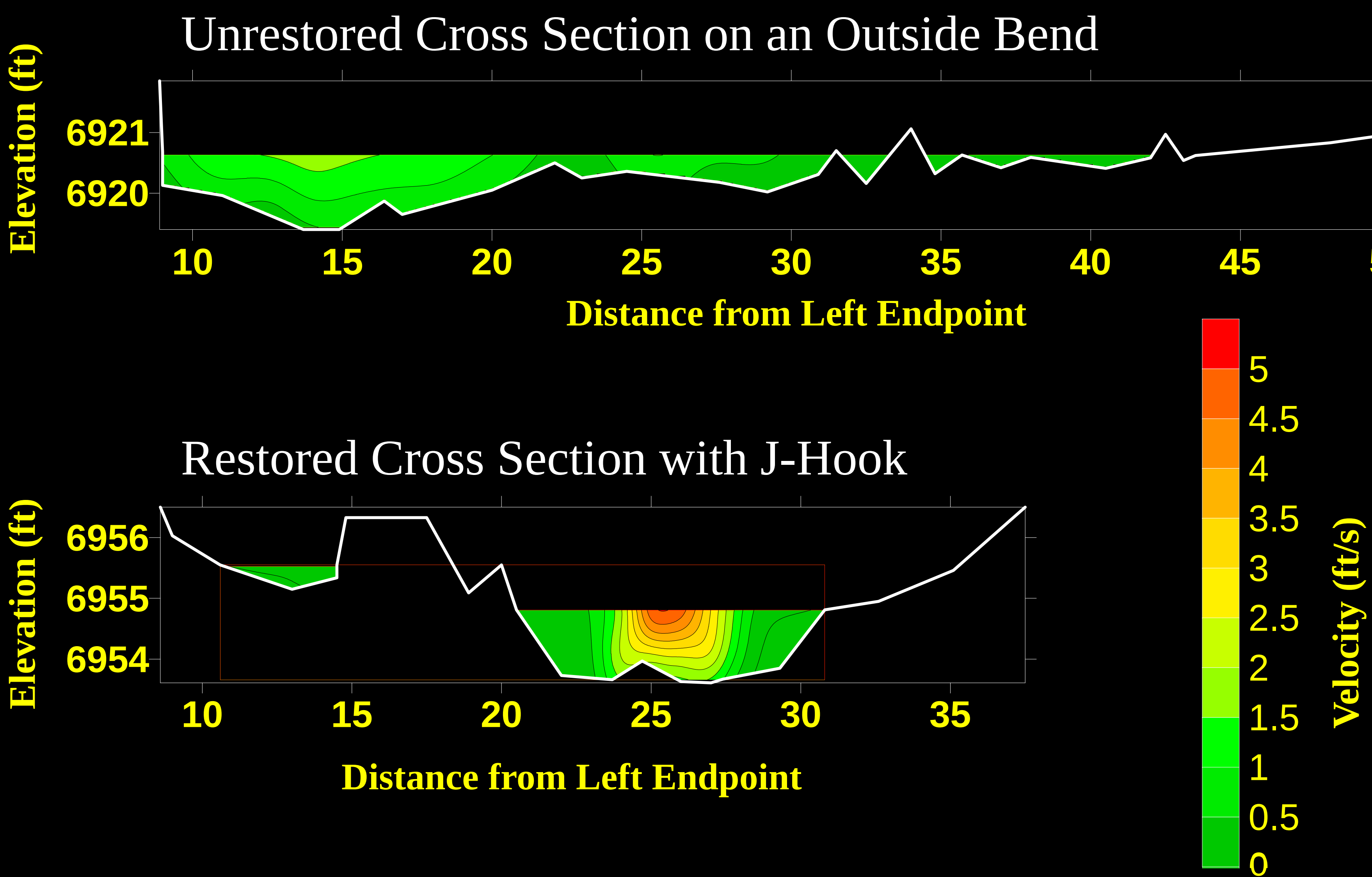
Longitudinal Profile 45+00 – 54+00



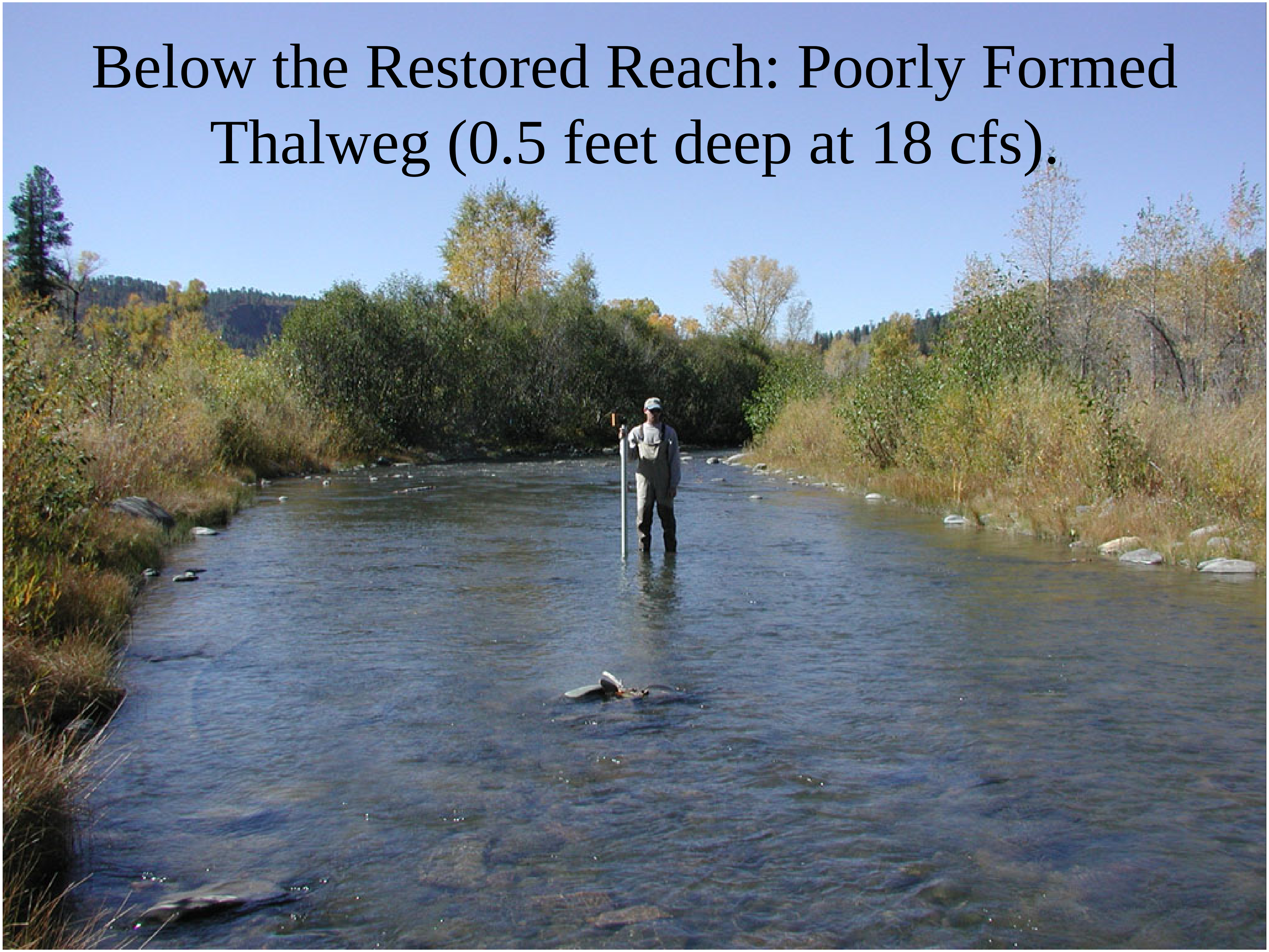
Longitudinal Profile Permanent Stationing Points (Every 200 feet)

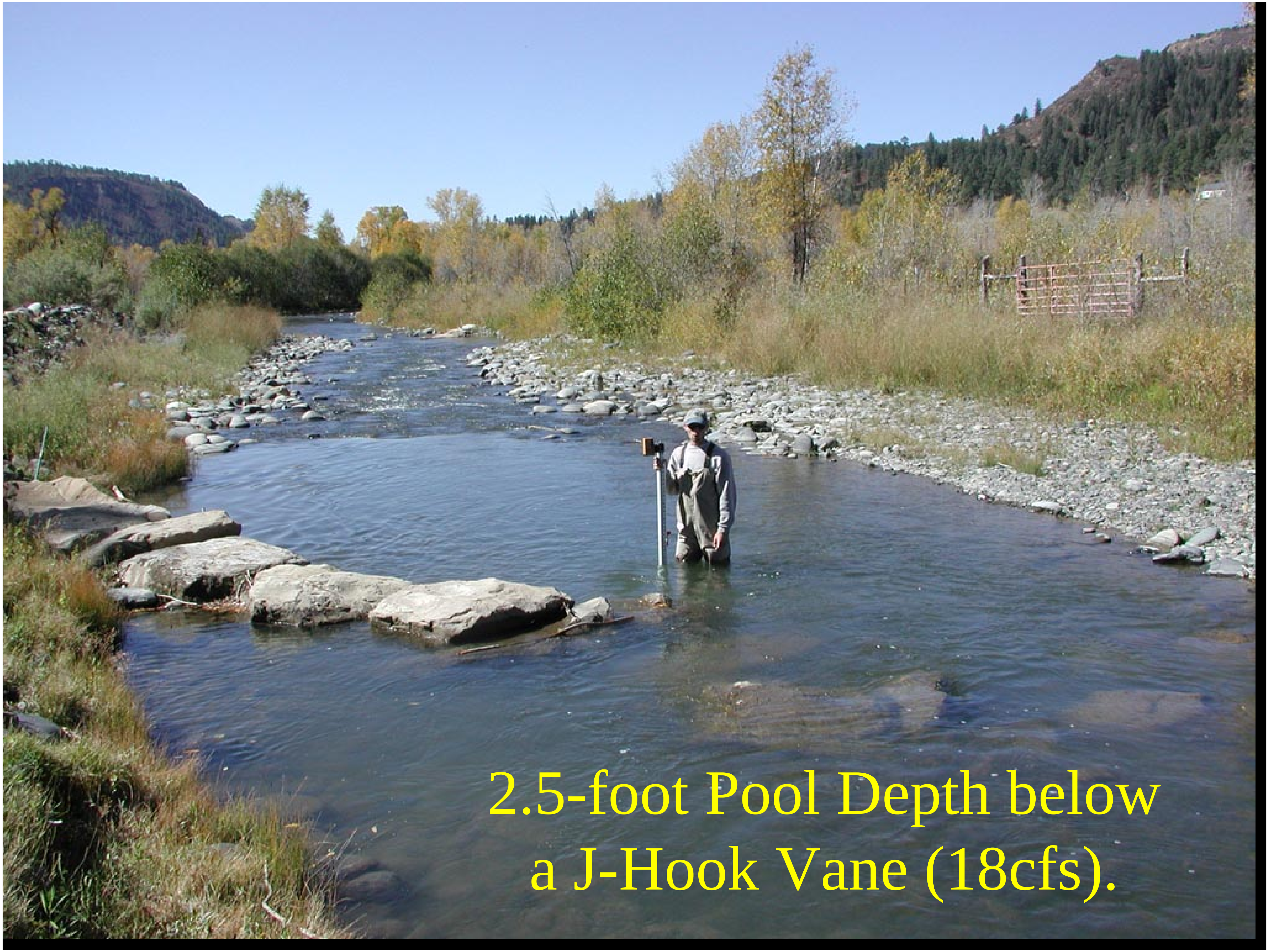


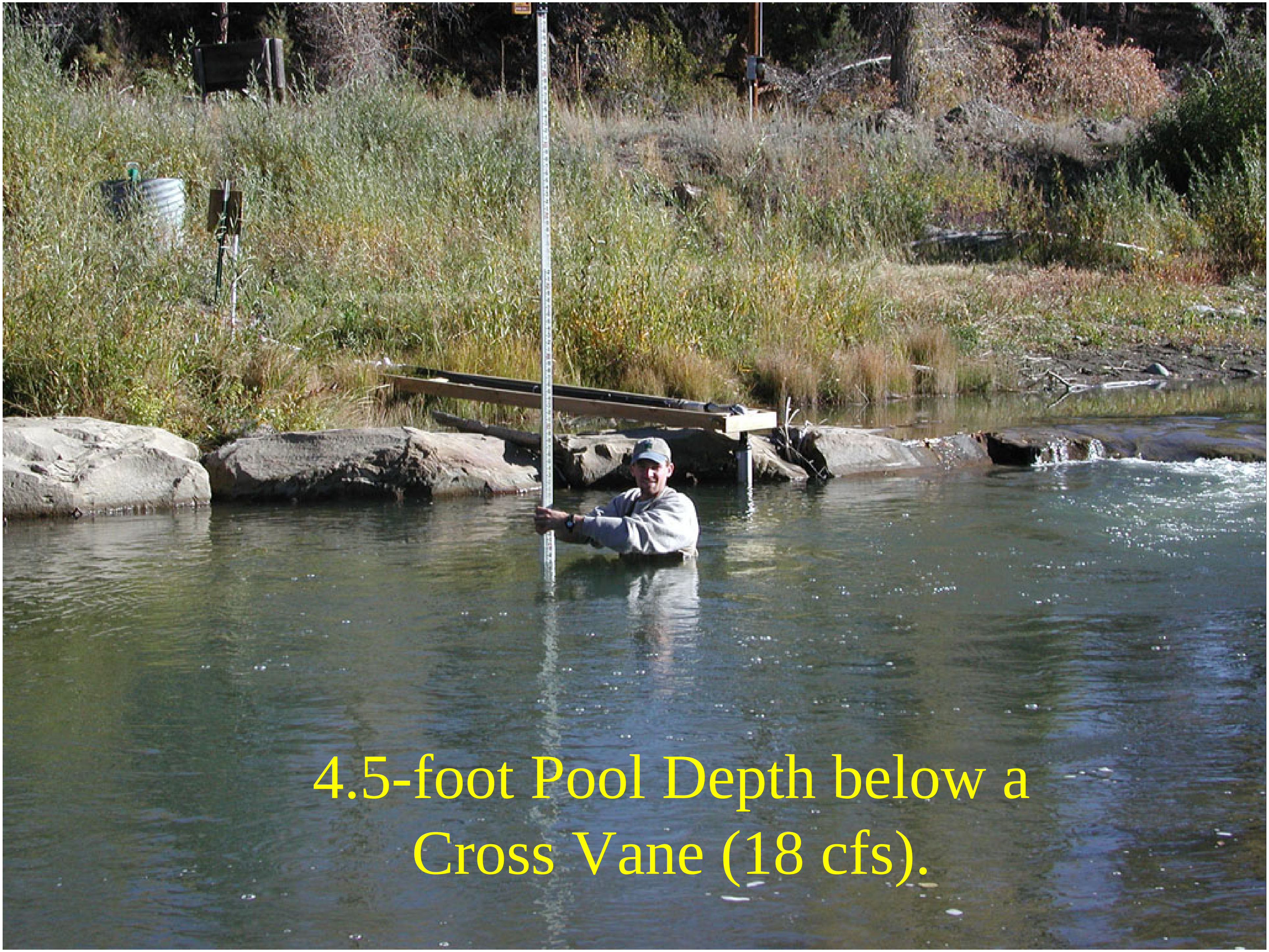
Comparing Velocity Distribution at 2 Cross Sections



Below the Restored Reach: Poorly Formed Thalweg (0.5 feet deep at 18 cfs).




2.5-foot Pool Depth below
a J-Hook Vane (18cfs).



4.5-foot Pool Depth below a
Cross Vane (18 cfs).