COMBINED AQUATICS STUDY PLANS

CAWG-3-FLOW-RELATED PHYSICAL HABITAT IN BYPASS REACHES

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1.0 EXECUTIVE SUMMARY

The main focus of this document is to present the methods and results for flow-related habitat studies conducted on seven streams with seasonal diversions in the Upper Basin (behind Kaiser Pass) during the 2002 field season. In addition, a brief summary of work completed for the CAWG-3 study plan and a list of outstanding items is presented.

Specifically the seven streams for which flow related habitat studies were completed in 2002 are Bolsillo Creek, Camp 62 Creek, Chinquapin Creek, Crater Creek, Hooper Creek, North Slide Creek, South Slide Creek, and Tombstone Creek. (Figure CAWG-3-1). Water is diverted from these streams during the runoff season, typically from April into July. The diversions are not operated during the remainder of the year. These streams were evaluated using the Wetted Perimeter approach, as outlined in CAWG 3 Study Plan (SCE 2001). A description of the methods used is included in Section 4.0, Study Methodology. The information provided in this report will be used in coordination with other instream flow studies to be carried out in 2003, as well as studies of fish, amphibians, riparian zones, geomorphology, recreation and others, to help determine the flow recommendations to be included as part of the new license application for the Big Creek system.

2.0 STUDY OBJECTIVES

3.0 STUDY IMPLEMENTATION

The CAWG-3 study plan identified two primary approaches to evaluate potential project effects on flow-related habitat. One approach focuses on larger streams that may be diverted throughout the year. In these streams, PHABSIM will be used The other approach focuses on smaller streams that are diverted primarily during the run off period. In these streams a wetted perimeter analysis will be used. The potential of diversions to affect fish passage was also identified as a potential issue. Finally, for the PHABSIM analyses, appropriate habitat suitability criteria must be identified. To this end, verification studies are being conducted.

3.1 STUDY ELEMENTS COMPLETED

- All bypass stream segments were divided into study reaches based on the major channel types present (as determined by CAWG-1 Characterize Stream and Reservoir Habitats). These reaches were summarized along with the mesohabitats present in each.
- Recommendations were made to the CAWG as to the reaches and habitat types to be represented and the number of transects to be measured and modeled. These results were presented to the CAWG for approval. These reaches and the number of transects within each reach were approved by the CAWG. The CAWG Transect

Selection Team (CTST) subsequently visited each reach and placed transects to represent the habitat type within that reach.

- Measurements were collected and wetted perimeter and fish passage analyses were completed for seven small streams in the upper basin where transects were selected in Fall 2001.
- Instream flow study sites were reviewed and transects placed in appropriate habitat types within each sub-reach agreed upon by the CAWG Transect Selection Team (CTST) in all remaining streams.
- Existing BiCEP instream flow models were reviewed for applicability and appropriateness for the ALP process. This review was presented to the agencies during the August and September 2002 CAWG meetings. A report dated August 28, 2002 was prepared and submitted to the CAWG members.

  ENTRIX recommended the use of the Mammoth Pool transects developed for the BiCEP project to model habitat in the Mammoth Pool and Stevenson Reaches of the San Joaquin River, pending filed verification. The transects for Mammoth Pool Reach were reviewed in the field by the CTST. While one transect was observed to have changed, the CTST agreed that the BiCEP transects were representative of the habitat in this reach. Additional transects were selected to supplement the BiCEP models. With these additions the CTST agreed that the combined transects (BiCEP and new) were sufficient for modeling this reach.

  In the Stevenson Reach of the San Joaquin River, the CTST found highly complex habitat that was generally unsuitable for modeling. Water flowed under and around large boulders, so that hydraulic regime theory, the underpinning basis for all open-channel hydraulic models, did not apply. The CTST felt that the BiCEP transects (which were the transects developed in the Mammoth Reach) were not appropriate for use and selected new transects where appropriate conditions were found to model this reach. The CTST agreed that the deep pools from the Mammoth Reach would be suitable for use in the Stevenson Reach.

  In Big Creek, the BiCEP transects could not be relocated, and the CTST selected new transects in all habitat types.

- Observations for testing the transferability of existing habitat suitability criteria to the Big Creek system streams were collected in September 2002.

3.2 OUTSTANDING STUDY ELEMENTS

- Field data for completing the instream flow studies on all remaining streams will be collected during 2003.
- Instream flow models will be developed for all remaining models in late 2003 and early 2004.
- BiCEP instream flow models will be recalibrated to reflect current modeling approaches and the models will be adjusted to reflect the habitat composition based on the habitat inventory information collected as part of the ALP process (CAWG 1).

- Field observations collected for testing the transferability of habitat suitability criteria to the Big Creek system will be evaluated and existing suitability criteria will be tested for transferability. Verified criteria will be used to represent target species and lifestages. The results of verification testing will be presented to the CAWG for review prior to habitat modeling. The initial set of criteria to be tested are described in the following reports. The first two reports provide criteria for rainbow and brown trout, while the last provides criteria for native cyprinid and catostomid species.

  Wise, Lawrence M. Jr., Wayne S. Lifton, and Ken A. Voos 1997. Trout habitat suitability criteria for the Response of Fish Populations to Altered Flows Project. Prepared for Pacific Gas and Electric Co. and Southern California Edison Co.

  Smith, Gary and Mike Aceituno. 1987. Habitat preference criteria for brown, brook, and rainbow trout in Eastern Sierra Nevada streams. Final Report. California Department of Fish and Game, Sacramento CA.

  Hardhead, Sacramento suckers and Sacramento pikeminnow by Donald Baltz and Bruce Vondracek. 1985, Appendix 1-D Suitability and microhabitat preference curves in. Pit 3,4,and 5 Project bald eagle and fish study. Prepared by Biosystem and U. C. Davis. Report for Pacific Gas and Electric Company.

- The need for habitat time-series analysis will be reviewed based on initial results of the PHABSIM studies and review of hydrological data. Based on this review, a recommendation will be made to the CAWG with respect to the need for these analyses. This analysis will be undertaken in late 2003 or 2004.
- An alternative approach to evaluating flow related habitat other than wetted perimeter or food transport will be developed for Bolsillo and Rock Creeks. Wetted Perimeter analysis will not work on these streams because of the extremely low amounts of riffle habitat present, and as discussed later in this report, the food transport analysis provided unrealistic results.

4.0 STUDY METHODOLOGY

4.1 AGENCY CONSULTATION

The study design and workplan for this study was developed in consultation with resource agency personnel and other stakeholders at several meetings and field visits. The procedures used are outlined in CAWG-3 (SCE 2001). In the process of developing the CAWG-3 study plan and implementing the ALP relicensing studies, the Licensee worked closely with resource agencies and other stakeholders to develop the objectives and methods for the flow-related habitat assessment. The study plan was approved by the overall ALP Plenary. This group represents a wide variety of stakeholders, resource agencies, and Native American groups (SCE 2001). The resource agencies participating in these consultations included the California Department of Fish and Game (CDFG), California State Water Resources Control Board (SWRCB), US Fish and Wildlife Service (USFWS) and the U.S. Forest Service Sierra National Forest (USFS).

The methods used in this study followed those agreed to in the Big Creek ALP process CAWG-3 Study Plan (SCE 2001a). As part of the CAWG 3 study plan, it was agreed that the wetted perimeter approach would be used to assess habitat for the small streams : Camp 62 Creek, Chinquapin Creek, Crater Creek, Hooper Creek, North Slide Creek, South Slide Creek, and Tombstone Creek.

A meeting was held on September 25, 2001 at the USFS offices in Clovis, CA to review the preliminary study sites and discuss the transect selection approach prior to entering the field for transect selection. Field meetings were held to review study sites, and place transects (for subsequent measurement) in the Project streams between October 9th and 18th, 2001. Additional discussions regarding study design and implementation took place during transect selection field visits. During the October 10, 2001 field visit, the CTST determined that the wetted perimeter method was inappropriate for the Bolsillo Creek reaches. Bolsillo Creek is a stream dominated by step-pool habitat downstream of the diversion. The Wetted Perimeter method focuses on riffle and run habitat. An analysis of step pool habitat using wetted perimeter would not be appropriate. This determination was made by the CTST during transect placement in Fall 2001. Discussions in the field led to the development of a food transport study designed to determine if summer base flows were sufficient to provide sustained invertebrate drift for support of trout populations.

4.2 STUDY SITE AND TRANSECT SELECTION

As outlined in the CAWG-3 Study Plan (SCE 2001), the preliminary Rosgen Level I evaluation (August 2001) and mesohabitat typing conducted in 1999-2001 (Table CAWG-3-1) was used as the basis for selecting the channel segments and habitat units to be represented in the Wetted Perimeter studies (SCE Geomorphology Survey 2003, in prep.).

Prior to field visits by the CAWG Transect Selection Team (CTST), preliminary habitat units were randomly selected within each of the preliminary Rosgen Level I channel types. Five or six habitat units were randomly selected based upon the results of habitat inventory studies (SCE 2002). Riffles are the preferred habitat type for wetted perimeter transect placement because they are very responsive to changes in flow. In some reaches, however, riffles were (a) absent, (b) represented a very small proportion of the total reach length, or (c) were present but contained hydraulic features which could not be accurately modeled. Runs were used in place of riffles, where necessary, because these habitat types are also very responsive to changes in flow and are commonly thought of as “flooded riffles”. The candidate study sites were inspected by an experienced instream flow specialist to screen out any non-representative sites or areas that could not be modeled. The remaining sites were retained for inspection and final transect selection by the CAWG transect selection team.

The CTST included representatives from SCE, CDFG and the USFS. All members of the CAWG were invited to participate in the site review and transect selection process. Some representatives had scheduling conflicts that prevented their direct participation in field transect selection. The CTST toured each of the preliminary study sites to gain an impression of the stream characteristics. During the site review large sections of the stream were examined. The candidate sites were inspected and the group then selected specific habitat units for sampling. For each stream segment one transect was placed within each of the selected habitat units. Transects were placed such that the location was representative of the characteristics of the unit. Transects were not placed in areas where hydraulic models could not be calibrated. The site name, transect designations, and habitat types selected for the wetted perimeter study in each stream are presented in Table CAWG-3-2. The locations of sampling sites used for this study are shown in Figures CAWG-3-2 through CAWG-3-7.

For most streams, transects were located upstream and downstream of the diversions. For three of the streams transects were located only downstream of the diversions because suitable sites for comparison did not exist upstream of their diversions. In Chinquapin Creek, the area upstream of the diversion shares the same Rosgen channel type (Aa+) as the area downstream of the diversion, but no riffle or run habitat types were available upstream of the diversion prior to the point where the channel becomes much steeper and flows over bedrock and rubble which is structurally dissimilar to the reach downstream of the diversion. On North and South Slide creeks, the areas upstream of the diversions descend steep bedrock and rubble slopes . On these creeks there is no defined channel and the areas above the diversion were dissimilar to the areas below the diversion. This was discussed by the CTST during transect selection in Fall 2001.

The transects on Chinquapin Creek downstream of the diversion will use transects above the other project diversions for comparison. In seeking appropriate reference transects, factors such as Rosgen channel type, channel gradient, channel structure and substrate, macrohabitat composition, and stream flow would be considered. If necessary and appropriate, a scalar may be applied to another stream where all characteristics except flow are similar. The diversions on North Slide Creek and South Slide Creek are no longer operational.. The applicant has not decided whether it will seek to put these diversions back into operation at this time.

4.3 TRANSECT INSTALLATION AND DATA COLLECTION

The wetted perimeter method evaluates how wetted perimeter changes with stream flow. Wetted perimeter is the distance along the stream bottom from one water edge to the other along a transect established perpendicular to the flow. Usually this is evaluated in riffles (Lohr 1993). To accomplish this analysis it is necessary to know the bed profile and the location of the left and right water edges at a series of flow levels. To facilitate this analysis, SCE elected to use portions of the PHABSIM programs developed by USFWS to model water surface elevations at different simulated flow levels. Because of this, the field measurement procedures used for the wetted perimeter data collection follow those described for use in PHABSIM studies (Trihey and Wegner 1981).

Each transect selected by the CTST was marked with headpins using rebar driven into the ground or with nails in trees. A staff gage was placed at each transect location to facilitate stage (water surface elevation) measurement at different flows. Headpins and staff gages were installed at the time of selection to facilitate relocation of the transects during spring 2002, when the first set of measurements were to be taken.

The relative elevation of the headpins, staff gage, and bed profile were surveyed using standard surveying techniques (Trihey and Wegner 1981). Elevations were established relative to a temporary benchmark installed for this purpose. Stage measurements were made at two or three flow levels. In addition, mean column velocities and depths were measured at several points along each transect. These data were used to provide information regarding the velocities present at the measurement flows for each transect. This information is provided in Appendix A of this report.

In the performance of this study, several conventions were adopted to facilitate the collection of quality data and timely reduction of those data. These included:

- All survey loops were closed in the field (±0.02 ft).
- All headpins and water surface elevations were referenced to benchmarks allowing relocation of headpins, staff gages, etc.
- More than two water surface elevations were surveyed for transects with rapidly varying flow conditions.
- Water surface elevations were checked before and after transect measurements to identify any change in discharge during the data collection.
- Discharges were computed in the field prior to leaving the site.
- Distance of right headpin was established for each transect and matched in subsequent tape placements to facilitate the collection of point velocity measurements at different calibration flows.

After head pin elevations had been established, transects were surveyed to provide bed profiles for input into the IFG-4a stage-discharge model. While surveying the bed profile, we also surveyed the water surface elevation, water surface slope, and stage of zero flow. The stage of zero flow is defined as “the water surface elevation at a cross section when the flow reaches zero. This is either the lowest point of the bed or the pool water surface when no flow occurs” (Hardy 2002).

Measurements were taken at various times during the natural runoff period with the objective of collecting measurements over a range of flows wider than could be obtained through operation of Project facilities alone. The flow measurements taken were used to develop stage-discharge models. Project operations were modified, as necessary, during the study to provide the flows needed to develop reliable stage-discharge relationship.

Discharge was measured within each study site at each of three calibration flows. Flow measurements were taken within each study site, where transects were closely clustered, or near each transect where the transects were more distant from each other. Flow measurements were collected at locations with the best characteristics for a good flow measurement. These were typically not located on the wetted perimeter analysis transects selected by the CAWG. Locations with uniform depth and velocity profiles, preferably runs or pool tails, were selected for calibration discharge measurements. Three stage-discharge measurements were collected for all but five of the flow-related habitat transects. We were unable to obtain a discharge measurement at the lowest calibration flow at transects C and E on Crater Creek below the diversion. These transects were completely dry during the July sampling event, although the diversion was not in operation. Water released from the diversion was lost to subsurface flow and evaporation. Discharge was measured only twice at Bolsillo Creek transects T1, T2, and T3 as these transects could not be located during the initial field measurement event in April 2002.

Another area where we were unable to collect data as described in the study plan was on Crater Creek above the diversion. In this location the point velocity measurements could not be collected during the middle flow data collection as inclement weather moved in and the crew had to be evacuated by helicopter immediately. However, the crew was able to complete the stage discharge measurements prior to being evacuated. The dates the various diversions were turned out in 2002 are provided in Table CAWG-3-3. The point velocity data for one transect on Chinquipin Creek above the diversion (Transect C2) was lost after collection and could not be recovered. This data was for the high flow.

For each discharge measurement, standard USGS protocols were followed: depths were measured to the nearest 0.1 ft and velocity to the nearest 0.01-ft per second (fps). The velocity correction angle also was noted at each vertical. The spacing and number of verticals per transect depended on the cross-section profile and complexity of the velocity distribution along each of the transects. An attempt was made to collect measurements at a minimum of 15 to 20 verticals for each measurement, but because of the small size of the channels, this was not always possible. In these cases, we placed as many verticals as possible at 0.2 ft spacing.

4.4 MODELING AND ANALYSIS

The data collected at the study transects were used to develop stage-discharge models which were used for the wetted perimeter and fish passage analyses. Stage-discharge predictions were developed using either the IFG4a regression model or the MANSQ model of the PHABSIM program. If the mean error of the IFG4a model exceeded acceptable limits or produced unrealistic stage changes, the MANSQ model was used. For 27 of the 31 transects, we used the IFG-4a Regression Model. This model regresses the logarithm of discharge against the logarithm of water surface elevation minus the stage at zero flow.

Two transects on Crater Creek, one transect on the North Slide Creek, and one transect on Tombstone Creek could not be calibrated using this method. For these transects Stage-Discharge models were developed using the MANSQ model. The MANSQ model uses Manning's Equation to develop a stage-discharge relationship based on the bed profile and two or more water surface elevation measurements. The stage-discharge models were used to predict water surface elevations at a series of unmeasured discharges. On rare occasions, in order to complete our analyses, it was necessary to model discharges either higher or lower than the range of calibration flows that were measured in the field. These instances are noted in the results section of this report and the relevant limitations of the model, if any, are discussed.

WETTED PERIMETER ANALYSIS

The wetted perimeter inflection point method is usually based on stream riffles (Lohr 1993), which are affected more by flow changes than other areas of streams. Riffles are important sites for production of invertebrate fish-food organisms (Hynes 1970). Leathe and Nelson (1986) found that the carrying capacity of the stream for fish is proportional to fish-food producing areas and that riffle wetted-perimeter is a reliable index of food producing areas. Because the physical characteristics of riffles are more sensitive to changes in flow than most other habitat types, maintenance of acceptable flows in riffles preserves other stream habitats for fish and macroinvertebrates, as well.

From zero flow, wetted perimeter increases rapidly with small increases in flow until water reaches the sides of the channel. At the point, where the instantaneous rate of change in wetted perimeter with increasing discharge decreases, an inflection point occurs on a plot of wetted perimeter versus flow. A typical wetted perimeter versus discharge curve has either one or two prominent inflection points. Flow recommendations are made at stream flows equal to or greater than the stream flow at the inflection point since flows are judged sufficient to maintain existing aquatic communities. When two inflection points occur in the wetted perimeter curve, the upper inflection point is assumed to represent flows providing optimal stream conditions (Nelson 1989). Ultimate selection of a flow recommendation is based on professional judgment relative to the biological potential of the specific stream.

The stage-discharge model for each transect was used in conjunction with the bed profile to develop a wetted perimeter versus flow relationship for each transect. This relationship was plotted, along with the instantaneous rate of change in the wetted perimeter vs. flow relationship to assist in determining the inflection points. In this analysis, emphasis was placed on the instantaneous rate of change curve, as this is most representative of the flow at which the inflection point in the curve is located. The flows at which these inflection points occur serve as the basis for identifying the recommended flow levels in this analysis.

The wetted perimeter analysis for the study streams covers a broad range of flows. Wetted perimeter was simulated for flows approaching and sometimes exceeding bank-full flow. By doing this, the inflection points associated with the channel in non-flood conditions were captured. The wetted perimeter method is intended to assess the flow levels that provide adequate habitat conditions under baseflow conditions. It is not intended to assess habitat conditions under flood conditions. For example, in Hooper Creek, a second inflection point is present at 10.36 cfs. However, this flow is only observed during the wet season and is not an appropriate flow level for maintaining habitat during the summer months, as such flows do not occur naturally during that season.

PASSAGE ANALYSIS

SCE used the channel geometry and the stage-discharge model to evaluate the flows needed for fish passage. The passage flows were determined using Thompson's (1972) criteria for the passage of adult trout. These criteria call for a minimum depth of 0.4 ft occurring over a minimum of 25 percent of the channel width. At least a contiguous 10 percent of the channel width must meet the depth criterion for a transect to be considered passable. Thompson's criteria also requires that maximum water velocity be less than 4 feet per second (fps) to be passable. This analysis was completed for each transect, and then, as described in Thompson's method, the average of the resulting flows was calculated to determine the recommended flow for that sub-reach of the stream. This recommended passage flow is intended to describe the flows required for passage in the stream through the shallower habitats present, in the absence of other structural barriers to passage (i.e., drops, dams, weirs, or substantial debris jams). These structural barriers were assessed during the habitat inventory and are included in the fish passage section of the SCE Big Creek Habitat Inventory Report (SCE 2003).

FOOD TRANSPORT ANALYSIS

The wetted perimeter method of prescribing instream flows focuses on riffles because it is recognized that this habitat type is most responsive to changes in flow. On Bolsillo Creek, riffle habitat was very scarce and comprised between 0 and 1.2 percent of the habitat types present in the three Rosgen Channel types observed. Given the lack of riffle habitat on Bolsillo Creek, the CAWG found that the wetted perimeter method was an inappropriate tool to analyze flow-related fish habitat. Through subsequent discussions and correspondence, the CAWG developed a food transport study for this stream as an alternative methodology for assessing instream flows.

Invertebrate drift is a significant component of the diet of stream feeding salmonids (Studley *et. al.* 1995). This type of foraging behavior is generally related to a number of factors including stream velocity and depth. Pool habitat was abundant on Bolsillo Creek, comprising between 24.5 and 61.5 percent of the habitat types observed in the three Rosgen Channel types. Observed conditions on Bolsillo Creek during the October 2001 field visit led to concern that velocities might be insufficient for the feeding requirements of trout even during the time period in which the stream was not diverted.

The ability of different streamflow levels to transport organic matter and aquatic insects in the Project Area was evaluated using a procedure similar to the calculation of weighted usable area. Water velocity is the chief hydraulic determinant of invertebrate drift rates.

Velocity criteria were developed to identify the minimum stream velocity necessary for sustained transport of organic particles and passive drifting insects. The American

Society of Civil Engineers (ASCE) and American Water Resources Association (AWRA) criteria for settling organic solids indicate the mean column velocities in the range of 0.3 to 0.5 fps are reasonable estimates for the sustained transport of organic material or dead aquatic insects. The results of a controlled flow study on the West Fork San Gabriel River, California, indicate that when mean column velocities were less than 0.3 fps the transport of fine sediment and organic matter was minimal. When mean column velocities exceed 0.5 fps fine sediment and organic matter transport was sufficiently high to indicate that aquatic insects would also be transported (Trihey 1988). Smith and Li (1983) found a positive relationship between mean column velocity and relative insect drift. Their observations indicated that little drift occurs at velocities less than 0.3 fps. Smith and Li (1983) also examined the focal velocities at feeding stations occupied by juvenile steelhead trout on Uvas Creek. They found that trout most frequently occupied stations where the velocity equaled 0.8 fps. The relationship between velocity and relative insect drift was roughly linear demonstrating that more invertebrates drifted at higher velocities. The number of observed trout did not increase with increasing focal velocities implying that despite the greater abundance of drifting invertebrates, the energetic costs associated with swimming at higher velocities outweighed the increased food availability.

Based on the review of these studies it was concluded that 0.3 fps is sufficient to initiate invertebrate drift and that the optimal foraging velocity of 0.8 fps observed on Uvas Creek implies the presence of sustained invertebrate drift (Smith and Li 1983). We assume that the mean column velocity that will generate sustained invertebrate drift is somewhere between 0.3 and 0.8 fps. For the purposes of this study we will refer to the velocity of 0.3 fps as the drift initiation threshold and 0.8 fps will be referred to as the sustained drift velocity. Based on consultations with the USFS, an additional criteria that at least one third of the total width of the channel must satisfy the depth and velocity criteria in order for a transect to have “suitable” food transport capacity was applied.

Depth was considered to have little influence on food transport with the exception that the water must be deep enough for adult trout to access the areas. This is not totally correct because changes in depth (as well as stream width) cause secondary velocity currents which can be quite important to the transport of organic particles and insects. Total depth can also affect the trajectory of small suspended particles in turbulent flow. But such effects of flow depth on transport mechanics are considered small in comparison to the influence of stream velocity. Thus, with the exception of shallow water preventing adult trout from feeding, depth is considered to have little influence on the food transport model. Based on the criteria presented in Trihey 1988, we assumed that depths of 0.5 ft. and greater provided suitable depths for adult trout to intercept drift, while depths less than 0.5 ft were too shallow for adult trout to access.

During the first data collection trip to Bolsillo Creek in April 2002 (the middle flow data collection), the field team was unable to locate transects T1, T2 and T3 below the diversion. Because of this, no measurements were taken at this flow. These transects were located during the second data collection trip in May 2002 and measurements were taken in this and subsequent data collection trips. Because the middle flow velocity and depth measurements were not collected, these values were modeled using the PHABSIM programs and the results of these models are provided in Appendix A with the measured depths and velocities for other flows and other transects.

4.5 RESULTS

4.5.1 MODEL CALIBRATION RESULTS

Field measurements at stream transect locations were collected during April, May June, and July of 2002. Stream channel cross-section profiles and measured water surface elevations at the transect locations are provided in Appendix B. Middle flow measurements were collected during April, high flow measurements were collected during May, and low flow measurements were collected during June or July. Flows at the individual streams varied with watershed size, geographic orientation, and snow melt pattern. The range of calibration flows observed at North and South Slide Creek ranged between 0.04 and 2.26 cfs and was very limited when compared to other streams (Table CAWG-3-4). Low flows for all streams excluding Hooper Creek were less than 1.0 cfs. Middle flows for streams other than North and South Slide Creek ranged between 1.4 and 12.9 cfs. High flows typically ranged from about 2.5 cfs on Tombstone Creek to about 32 cfs on Hooper Creek above the diversion.

The IFG-4a stage-discharge regression method was the preferred method and was used for 27 of the 31 transects. In order to develop a stage-discharge relationship using the regression model it is necessary to have three calibration discharge measurements while only two measurements are required for the use of MANSQ. For various reasons it was necessary to use the MANSQ method for the remaining transects. Two of the remaining four transects were located on Crater Creek below the diversion. Transects C and E were completely dry during the low flow measurement even though the diversion was turned out. Consequently, we were able to measure only two discharges at these transects. On Tombstone Creek above the diversion, Transect Run-1, a change in the channel configuration occurred between the first and second data collection effort. Thus, only the high and low flow measurements had the same channel configuration which prevented use of the regression method. On North Slide Creek below the diversion, Transect SRN-2, the Stage Discharge regression method provided unreasonable results and so MANSQ was employed. Using this method, an excellent fit of the observed stage at each of the three calibration flows was obtained.

Modeling of the stage discharge relationships was highly successful and acceptable water surface simulations were obtained for all transects through this method. For the transects where the IFG-4a regression method was used, the highest mean error was 7.4 percent, and 16 transects had mean errors of less than 5 percent. The Instream Flow Group (Milhaus et al., 1989) describes a stage discharge relationship with a mean error of less than 10 percent as “good”, and one with a mean error of less than 5 percent as “excellent”. The MANSQ method does not provide a similar statistic, but the simulated water surface elevations provided the same level of variation from the measured values as did the IFG-4a method. For all but three transects, simulated water surface elevations from the model were within 0.03 feet of the measured water surface elevations at the measured flow (Appendix C). At the remaining three transects the largest observed error was 0.06 feet

On Tombstone Creek above the diversion at Transect SRN2, a side channel became active at the middle calibration flow. At this flow, there was less than 0.05 feet of depth in the side channel. The elevation of the side channel was lower than that of the main channel with flow through the side channel being controlled upstream of the transect. Because the PHABSIM model allows the use of only one water surface elevation for each flow level, the model predicted water depths in the side channel that were much greater than those observed in the field. This limitation of the PHABSIM model resulted in unrealistic predictions of depth and velocity and, therefore, for wetted perimeter inflection points and fish passage flows. To correct for this, we leveled the water surface elevations between the two channels and raised the bed beneath the side channel and on the right bank by a commensurate amount to preserve the observed depths. In addition, a second low point in the bed profile that was not inundated at any of the observed flows was eliminated so that the model did not use this dry area in its calculations. The analysis was then performed on this modified channel.

4.5.2 WETTED PERIMETER VERSUS FLOW RELATIONSHIPS ON SEASONALLY DIVERTED STREAMS

Wetted perimeter versus flow relationships were developed for 31 transects on Project streams. Ten of these transects were located above diversions while 21 transects were located below. Plots of wetted perimeter versus flow and the rate of change in wetted perimeter with flow are provided in Appendix D.

The flow at the inflection point in the seven streams ranged from 0.4 cfs on North Slide Creek to 1.5 cfs for Tombstone Creek above the diversion (Table CAWG-3-5). There was generally close agreement between the flow at the inflection point above and below the diversion on streams where data were collected in both areas. This result reflects similar channel morphology above and below the diversions. Since, as previously discussed, no transects were placed above the diversions on Chinquapin, North Slide and South Slide creeks alternate reference sites were selected from other Project streams. The most appropriate comparison site for Chinquapin Creek below the diversion is Camp 62 Creek above the diversion, as Chinquapin Creek is tributary to Camp 62 Creek. The flow at the inflection point above the diversion on Camp 62 Creek is similar to that for Chinquapin Creek below the diversion. No suitable reference exists for North and South Slide Creeks. Tombstone Creek above the diversion is probably the best available comparison, although it has a somewhat larger channel. Because of Tombstone's larger channel, the flow at the inflection point on Tombstone Creek above the diversion is considerably higher than that on North and South Slide Creeks below their diversions.

Confidence in the results of the wetted perimeter analysis is increased by the fact that for most streams, the inflection points are within the range of observed flows. Thus these results are derived from interpolation of measured water surface elevations. Interpolated water surface elevations are extremely reliable, as the observed and simulated water surface elevations at the calibration flows match closely (Appendix C). At some sites (Crater Creek below the diversion at Transects C and E, Hooper Creek above and below the diversion, and North Slide Creek below the diversion), the inflection points occur at flows within the acceptable extrapolation range of the model, but beyond the measured flows. For North Slide Creek and Hooper Creek below the diversion, the inflection points are considered to be reliable, as they fall within the extrapolation range considered to provide the most reliable results (0.4 times the minimum observed flow to 2.5 times the maximum observed flow (Milhaus et al. 1989)). For Crater Creek below the diversion and Hooper Creek above the diversion, the inflection points fall below the lowest flow in the recommended range of extrapolation. At these transects, the flows for the inflection point provided in Table CAWG-3-6 are less reliable than at the previously described transects. These values represent the best available estimate, and are likely close to the actual inflection point flow, especially at the three transects where the inflection point is only slightly beyond the lower limit of extrapolation. (Crater Creek BD Transects C and E, Hooper Creek AD, Transect C. For these transects a comparison of the flow at the inflection point, the lower limit of extrapolation, and the lowest observed flow are provided in Table CAWG-3-6.

4.5.3 FISH PASSAGE

The purpose of this analysis is to estimate the flow needed to provide passage upstream through the representative wide, shallow habitats – typically riffles – where transects were placed for the wetted perimeter analysis. The flow necessary for fish passage was evaluated based on the channel cross-sections and the water surface elevation predictions at simulated flows. The depths across the transects were evaluated based upon the passage criteria of Thompson (1972) for adult trout as described in Section 5.0, Study Results and Analysis, of this report.

A review of measurements taken at the transects indicated that the depth and width criteria were almost always satisfied at flows much lower than those required to generate velocities of 4 fps, the velocity that impairs passage. In the remainder of this section, velocities are not discussed except at those few transects where they approach levels that might impair passage.

The flows required for passage ranged from 0.2 cfs for Hooper Creek above the diversion to 3.6 cfs for South Slide Creek below the diversion. Most reaches had passage flows between 0.6 and 1.9 cfs (Table CAWG-3-7). There was considerable overlap in the results from the individual transects above and below the diversions. Typically, the minimum passage flow above the diversion was lower than that for the same stream downstream of the diversion. This does not appear to be the result a function of channel type, habitat type, or active channel width, as these are similar above and below the diversions. It may be the result of the higher gradient that typically occurs above the diversions.

For most streams in the study area, the flow needed for passage fell within the range of flows measured during field data collection, lending confidence to these results. For Hooper Creek above the diversion modeled passage flows were much lower than the lowest calibration discharge measurement. For North Slide Creek, modeled passage values greatly exceeded the largest discharge calibration measurement.

On Hooper Creek, high velocities were observed at both transects above the diversion (see Appendix A) at the middle and high flows. These velocities may begin to impair passage in some cells, but adequate areas to provide passage were available even at 32 cfs, the highest observed flow. On Hooper Creek below the diversion, velocities that approached or exceeded 4.0 fps were observed at two of the transects. However, portions of these transects were passable at flows exceeding 10 cfs.

On South Slide Creek below the diversion the passage flow at the three transects studied ranged between 0.9 and 7.5 cfs. It was determined that 7.5 cfs was required to provide fish passage at transect C. This value is considerably higher than that of the other two transects and is also higher than that found in some of the other, larger streams, such as Hooper and Tombstone. This unusually high value is caused by a wide bar on the left side of the channel. This bar was inundated at all flows. An examination of the channel cross section indicates that width and depth are sufficient for trout migration near station 11 on the transect at flows of 0.5 cfs. When using 0.5 cfs as the passage value for this transect, the recommended passage flow for the reach would be 1.2 cfs.

At Transect E, on Tombstone Creek below the diversion, the Thompson criterion for 10 percent continuous depth is met at a flow of 2.7 cfs, but the 25 percent of the total width criterion is not met until flows reach approximately 3.5 cfs. Fish would likely be able to pass upstream at a flow of 2.7 cfs. Taking this into account the recommended passage flow would reasonably be 1.5 cfs.

4.5.4 FOOD TRANSPORT

On Bolsillo Creek, food transport was evaluated using the criteria described in Section 5.0, Study Results and Analysis. Through this process, velocities and depths across each transect were analyzed to determine if conditions at a specific flow were sufficient to initiate and sustain food transport. The measured depths and velocities at the three calibration flows are located in Appendix E and the analytical results are summarized below.

BOLSILLO CREEK ABOVE THE DIVERSION

The food transport capacity of Bolsillo Creek above the diversion was evaluated at stream flows of 0.24, 2.34, and 7.16 cfs. Three transects, consisting of three pools (LP, SP, and RUN) were installed-upstream of the diversion.

For the observed streamflow of 0.24 cfs food transport was limited. Only one cell at one transect (Transect LP, Station 14) had a velocity of 0.3 fps, the velocity needed to initiate food transport (Table CAWG-3-8). At this cell, depth was less than the 0.5 ft required to allow adult trout to utilize that cell for feeding and thus even this cell would be considered unsuitable according to the criteria. Velocities at all other stations on the three transects were lower than the minimum threshold for drift initiation (0.3 fps). Many of the transect stations at the two pools satisfied the depth criteria but none of the stations satisfied depth criteria at the run.

At a streamflow of 2.34 cfs, we observed velocities sufficient for drift initiation at all three transects. For transect RUN, the drift initiation velocity and depth criteria were satisfied for approximately 30% of the total wetted width, just less than the criterion (Table CAWG-3-7). The sustained food transport criteria were met at the LP transect, for approximately 52% of the wetted width. At the SP transect, measured velocities at two stations were only slightly lower than the sustained drift threshold. The criteria would be met at this transect at flows only slightly higher than the measured flow.

For the measured streamflow of 7.16 cfs, both the drift initiation and sustained drift criteria were satisfied at transect RUN. At transect LP, several stations satisfied the velocity and depth criteria for both drift initiation and sustained drift. The wetted width criteria, however, was not satisfied at this transect for either initiation or sustained food transport, although both were satisfied at a flow of 2.3 cfs. This resulted from a side channel that became active at the highest observed discharge. Roughly 13% of the channel totaling 2.0 ft. satisfied the sustained drift criteria. Despite the low overall percentage, feeding lanes are likely of sufficient size to support feeding trout. Velocity and depth measurements for SP at 7.16 cfs were unavailable, but both initiation and sustained food transport criteria would likely have been met as they were just slightly lower than required values at the 2.3 cfs measurement.

BOLSILLO CREEK BELOW THE DIVERSION

We examined the food transport capacity of Bolsillo Creek below the diversion, for stream flows equaling 0.18, 2.23, and 5.89 cfs. Five pool transects (B, PR, T1, T2, and T3) were evaluated.

At a stream flow of 0.18 cfs, the lowest flow level observed, none of the measured velocities at the five transects were sufficient to either initiate or sustain invertebrate drift (Table CAWG-3-7).

At streamflow of 2.23 cfs, food transport initiation criteria were met at three of the five transects, and were nearly met at a fourth (PR) where 31 percent of the width of the transect met criteria. At the remaining transect (T1), food transport initiation criteria were met for one cell, encompassing 19 percent of the wetted width of the transect. Sustained food transport criteria were met at two transects. At the other three transects, the width criterion was not met for sustained food transport. At Transect PR, this width was 31 percent, slightly lower than the width criterion. At the two remaining transects, areas supporting sustained food transport were present in 16 and 19 percent of the width of the stream.

All transects met the criteria for food transport initiation at the highest flow measured, with the percentage of suitable width ranging from 50 to 100 percent. Sustained food transport criteria were met at three of the five transects, but failed to meet the width criteria at Transects T1 and T2. At these transects, 18 and 14 percent, respectively, of the channel width, provided sustained food transport.

The results of the food transport analysis indicate that the flow levels required to sustain food transport for Bolsillo Creek would be 15 to 20 times the natural base flow for this stream. Given the healthy populations of trout in this stream (SCE 2003 CAWG-7 Report), this result is clearly inappropriate. This result is also clearly well outside the range of results reported using the wetted perimeter method for other streams of similar size in the same area. This leads to the conclusion that the food transport model, as configured, is inappropriate for use in these small streams, and that another technique should be used to assess habitat versus flow relationships where wetted perimeter cannot be used. The determination of an alternative assessment method is being added to the “outstanding element table” and will be included in the results and discussion in the 2004 report to the CAWG.

5.0 STUDY RESULTS AND ANALYSIS

This report provides the results of flow-related habitat analysis for seasonally diverted streams tributary to the South Fork San Joaquin River. Specifically these streams included: Bolsillo Creek, Camp 62 Creek, Chinquapin Creek, Crater Creek, Hooper Creek, North Slide Creek, South Slide Creek, and Tombstone Creek. Transects for evaluating flow related habitat on these streams were selected by the CTST in fall 2001. These transects represent a subset of the transects that will be addressed in the overall relicensing of the Big Creek Hydroelectric System.

Wetted perimeter or food transport analyses were conducted for these streams, as were fish passage analyses. The food transport analysis provided results that were unrealistic and a consideration of alternative approaches for Bolsillo and Rock creeks has been undertaken. These considerations will be presented to the CAWG and the results of the alternative approach will be provided in next year’s report.

The results of these studies will be used in conjunction with an assessment of the management goals and the results of other studies for these streams, to develop flow recommendations for the FERC license application. Management considerations include those for the individual streams, the basin as a whole, and the Big Creek Hydroelectric system. Among the other study results to be considered are those from other instream flow studies (to be carried out in 2003), as well as studies of fish, amphibians, riparian zones, geomorphology, recreation and others.

Many elements of the CAWG-3 study plan were addressed in 2002 and this aspect of the ALP studies is currently on schedule. Data was collected and analyzed to support flow related habitat studies in seasonally diverted upper basin streams where transects were selected in Fall 2001. Existing PHABSIM models for some project reaches were reviewed and recommendations made and agreed to regarding their use in the ALP process. Transects were selected in all remaining stream reaches. Data collection at these transects will be conducted in 2003. Habitat suitability criteria observations were collected. This information will be reduced and preliminary analyses will be presented to the CAWG in March 2003.

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TABLES

Table CAWG-3-1. Rosgen Level 1 Channel Types for Upper Basin Small Streams

Stream	Reach	Preliminary Rosgen Typing 2000-2001	Geomorphology Rosgen Typing 2000-2001
Bolsillo	AD		
	BD		
Camp 62	AD	Aa+	Aa+
	BD	A	Aa+
Chinquapin	BD	A	Aa+
Crater	AD	Aa+	Aa+
	BD	A/C	Aa+/C
Hooper	AD	Aa+	Aa+
	BD	A	Aa+
North Slide	BD	Aa+	Aa+
South Slide	BD	Aa+	Aa+
Tombstone	AD	Aa+	Aa+
	BD	Aa+/C	Aa+/E

Table CAWG-3-2. Site Names and Transect Designations for Wetted Perimeter Study

Site Name	Transect Designation	Habitat Type1
Bolsillo Creek Above Diversion	LP	SPO
	SP	SPO
	RUN	SPO
Bolsillo Creek Below Diversion	B	SPO
	PR	SPO
	T1	SPO
	T2	SPO
	T3	SPO
Camp 62 Creek Above Diversion	A	HGR
	B	HGR
Camp 62 Creek Below Diversion	A	HGR
	B	HGR
	C	HGR
Chinquapin Creek Below Diversion	C1	LGR
	C2	LGR
	C3	LGR
Crater Creek Above Diversion	DS_RIF	SRN
	PL	SPO
	US_RIF	SRN
Crater Creek Below Diversion	A	HGR
	C	HGR
	E	HGR
Hooper Creek Above Diversion	A	HGR
	C	HGR
Hooper Creek Below Diversion	A	HGR
	B	LGR
	D	HGR
North Slide Creek Below Diversion	SRN-1	SRN
	SRN-2	SRN
	HGR-1	HGR
South Slide Creek Below Diversion	A	SRN
	B	SRN
	C	HGR
Tombstone Creek Above Diversion	RUN1	RUN
	RUN2	RUN
	HGR	HGR
Tombstone Creek Below Diversion	C	HGR
	D	HGR
	E	HGR

[1] SPO – Step Pool, HGR – High Gradient Riffle, LGR – Low Gradient Riffle, SRN – Step Run

Table CAWG-3-3. Flows Measured During Data Collection at Upper Basin Wetted Perimeter Transects

Stream and Site	Transect	Low	Middle	High
Bolsillo Creek Above Diversion	All	0.25	2.34	7.07
Bolsillo Creek Below Diversion	All	0.18	2.23	5.89
Camp 62 Creek Above Diversion	All	0.65	3.81	12.93
Camp 62 Creek Below Diversion	A,B	0.23	3.72	8.77
	C	0.39	6.49	16.77
Chinquapin Creek Below Diversion	All	0.15	2.64	5.66
Crater Creek Above Diversion	All	0.68	7.86	18.64
Crater Creek Below Diversion	A	0.01	2.14	13.98
	C	DRY	2.14	13.98
	E	DRY	2.14	13.98
Hooper Creek Above Diversion	A	6.20	12.94	33.89
	C (below trib.)	6.14	10.49	32.02
Hooper Creek Below Diversion	A (above split)	2.26	8.94	24.40
	B	1.01	5.79	10.36
	D	1.01	5.79	10.36
North Slide Creek Below Diversion	All	0.04	0.09	0.18
South Slide Creek Below Diversion	All	0.08	0.64	2.26
Tombstone Creek Above Diversion	All	0.47	1.47	2.54
Tombstone Creek Below Diversion	All	0.50	1.83	2.99

Table CAWG-3-4. Flow at the Inflection Point of the Wetted Perimeter vs. Discharge Relationship for the Big Creek ALP Relicensing Project

	Above Diversion		Below Diversion	
Stream	**Transect Designation**	**Flow**	**Transect Designation**	**Flow**
Camp 62	A	0.7	A	0.7
	B	0.7	B	0.7
			C	1.1
	Average:	**0.7**	**Average:**	**0.8**
Chinquapin	None		C1	0.9
			C2	0.9
			C3	0.7
			Average:	**0.8**
Crater	DS - RIF	0.9	A	0.9
	PL	0.9	C	0.9
	US - RIF	0.9	E	0.7
	Average:	**0.9**	**Average:**	**0.8**
Hooper	A	0.9	A	0.7, 3.0 = 1.85
	C	2.1	B	1.2
			D	0.7
	Average:	**1.5**	**Average:**	**1.3**
North Slide	None		1 - SRN	0.3
			2 - SRN	0.4
			1 - HGR	0.4
			Average:	**0.4**
South Slide	None		A	0.8
			B	0.7
			C	0.7
			Average:	**0.7**
Tombstone	Run1	1.2	C	0.5
	Run2	0.7	D	0.9
	HGR	1.5	E	1.2
	Average:	**1.1**	**Average:**	**0.9**

Table CAWG-3-5. Inflection Point, Lowest Extrapolation Flow, and Lowest Observed Flow for Selected Transects

Stream	Transect	Inflection Point	Lower Limit of Extrapolation	Lowest Observed Flow
Crater Creek Below Diversion	C	0.9	0.98	2.45
	E	0.7	0.85	2.13
Hooper Creek Above Diversion	A	0.9	2.48	6.2
	C	2.1	2.45	6.14

Table CAWG-3-6. Minimum Passage Flows Upper Basin Wetted Perimeter Transects

	Above Diversion				Below Diversion			
Stream	**Transect Designation**	**Flow**	**Percent of Total Width**	**Percent of Width Contiguous**	**Transect Designation**	**Flow**	**Percent of Total Width**	**Percent of Width Contiguous**
Camp 62	A	1.5	25.5	19.4	A	1.2	38.3	15.9
	B	0.1	24.4	24.4	B	4.5	27	21.7
					C	0.1	25	17.6
	Average:	**0.8**			**Average:**	**1.9**		
Chinquapin	None				C1	0.9	34.2	20.9
					C2	1.2	36.6	24.4
					C3	1.8	37.9	20.9
					Average:	**1.3**		
Crater	DS - RIF	0.3	34	34	A	0.3	47.6	21.8
	PL	Inappropriate analysis for this transect			C	0.3	29.5	29.5
	US - RIF	0.9	26	14.4	E	1.5	33	28.7
	Average:	**0.6**			**Average:**	**0.7**		
Hooper	A	0.3	32.7	32.7	A	0.5	28.1	28.1
	C	0.1	44.1	44.1	B	3.5	32.3	15.7
					D	3.5	27.7	17
	Average:	**0.2**			**Average:**	**2.5**		
North Slide	None				1 - SRN	0.4	38.1	23.8
					2 - SRN	0.5	27.8	27.8
					1 - HGR	0.5	100	100
					Average:	**0.5**		
South Slide	None				A	0.9	25.5	25.5
					B	2.3	34.1	34.1
					C	7.5	28.9	17.6
					Average:	**3.6**		
Tombstone	Run1	0.3	48.7	47.4	C	1.2	29.9	23.1
	Run2	1.5	30.5	20.5	D	0.5	27.8	27.8
	HGR	0.9	45.5	45.5	E	3.5	31.5	29.3
	Average:	**0.9**			**Average:**	**1.7**		

Table CAWG-3-7. Suitability of Bolsillo Creek Transects for Food Transport at Three Flow Levels

	Transect SP			Transect LP			Transect RUN		
Flow	0.24	2.34	7.16	0.24	2.34	7.16	0.24	2.34	7.16
Wetted Width	6.7	7.2	7.7	10.6	12.6	15	8.9	9.1	9.6
Initiate Food Transport									
Suitable Width (0.3 fps)	0	3.8	NA	0	7.5	3	0	2.8	5.6
% Suitable Width (0.3 fps)	0	53	NA	0	60	20	0	30	58
Sustain Food Transport									
Suitable Width (0.8 fps)	0	0	NA	0	6.5	2	0	2.8	5.6
% Suitable Width (0.8 fps)	0	0	NA	0	52	13	0	30	58

	Transect B			Transect PR			Transect T1			Transect T2			Transect T3		
Flow	0.18	2.23	5.89	0.18	2.23	5.89	0.18	2.23	5.89	0.18	2.23	5.89	0.18	2.23	5.89
Wetted Width	5.1	6.6	6.5	5.7	6.8	7.2	8.3	10.3	11.1	5	6.3	7.3	1.8	3.3	3.9
Initiate Food Transport															
Suitable Width (0.3 fps)	0	5.9	6.5	0	2.1	7.2	0	2	7.1	0	2.7	3.7	0	2.7	3.9
% Suitable Width (0.3 fps)	0	89	100	0	31	100	0	19	64	0	42	50	0	82	100
Sustain Food Transport															
Suitable Width (0.8 fps)	0	2.3	5	0	2.1	7.2	0	2	2	0	1	1	0	1.5	2.8
% Suitable Width (0.8 fps)	0	34	77	0	31	100	0	19	18	0	16	14	0	44	72

FIGURES

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APPENDIX A

Measured Velocities and Depths at Wetted Perimeter Transects

CAWG-3 Appendix A Table A-1. Measured Depths and Velocities for Bolsillo Creek

		Discharge (cfs)				Velocity (fps)			Depth (feet)		
Site	**Transect**	**Hi Q**	**Mid Q**	**Low Q**	**Station**	**Hi Q**	**Mid Q**	**Low Q**	**Hi Q**	**Mid Q**	**Low Q**
Bolsillo Creek Above Diversion	AD-PL small	7.16	2.34	0.24	6.0	1.96	0.70	-0.03	1.00	0.70	0.45
					7.0	2.06	0.78	-0.03	1.20	1.00	0.75
					8.0	1.29	0.31	0.03	1.40	1.15	0.90
					9.0	0.23	0.18	0.04	1.30	1.10	1.10
					10.0	-0.25	0.09	0.07	1.00	0.75	1.10
	AD-PL large	7.16	2.34	0.24	13.0	0.18	0.04	0.01	1.20	0.85	0.40
					14.0	1.15	0.50	0.30	1.00	0.90	0.30
					15.0	1.62	-0.19	0.05	2.70	2.40	2.00
					16.0	0.55	-0.08	-0.04	2.40	2.15	1.00
					17.0	-0.06	1.07	-0.04	1.60	1.40	1.20
	AD-RUN	7.16	2.34	0.24	3.5	-0.07	-0.11	0.00	0.80	0.55	0.30
					5.0	2.28	1.55	*	0.60	0.45	*
					6.0	1.78	-0.12	*	0.50	0.25	*
					7.5	1.90	1.34	*	0.40	0.25	*
					10.0	1.77	0.88	0.12	0.65	0.70	0.35

**No measurement taken
cfs = cubic feet per second
fps = feet per second

CAWG-3 Appendix A Table A-1. Measured Depths and Velocities for Bolsillo Creek

		Discharge (cfs)				Velocity (fps)			Depth (feet)		
Site	Transect	Hi Q	Mid Q	Low Q	Station	Hi Q	Mid Q	Low Q	Hi Q	Mid Q	Low Q
Bolsillo Creek Below Diversion	B - SPO	5.89	2.23	0.18	5.20	0.47	0.43	*	0.60	0.50	*
					6	1.29	1.16	0.13	0.50	0.40	0.25
					6.7	1.71	1.01	0.17	0.65	0.50	0.50
					7.6	1.86	0.96	0.14	0.90	0.65	0.50
					8	1.87	0.94	0.13	1.00	0.70	0.45
					9.2	1.38	0.54	0.03	0.80	0.50	0.20
	PR - SPO	5.89	2.23	0.18	4	1.56	1.27	*	0.6	0.4	*
					5.0	2.68	1.33	*	0.5	0.35	*
					6.0	2.44	1.64	*	0.5	0.25	*
					7.0	2.41	1.58	*	0.5	0.2	*
					8.0	2.31	1.61	*	0.75	0.6	*
					9.0	2.18	**	*	1.1	**	*
	T1 - SPO	5.89	2.23	0.18	5.0	0.47	**	*	1.00	**	**
					7.0	1.74	**	0.17	1.25	**	0.30
					9.0	0.26	**	0.00	1.50	**	0.50
					11.0	0.04	**	0.00	1.60	**	0.50
					13.0	0.44	**	0.00	1.90	**	0.70
	T2 - SPO	5.89	2.23	0.18	4.5	0.21	**	0.00	1.60	**	0.10
					5.5	0.15	**	0.00	1.80	**	0.20
					6.5	1.38	**	0.03	1.90	**	0.40
					7.5	0.47	**	0.15	2.00	**	0.50
					8.5	0.42	**	0.00	2.00	**	0.60
					9.6	0.46	**	*	2.10	**	*
					9.7	0.33	**	*	0.30	**	*
	T3 - SPO	5.89	2.23	0.18	7.0	0.40	**	*	1.10	**	*
					8.0	0.85	**	0.25	1.50	**	0.20
					8.5	1.01	**	0.28	1.90	**	0.60
					9.0	1.50	**	0.11	2.00	**	0.70
					9.5	1.53	**	0.03	2.00	**	0.60

*Insufficient depth for measurement
**No measurement taken
cfs = cubic feet per second
fps = feet per second

CAWG-3 Appendix A Table A-2. Measured Depths and Velocities for Camp 62 Creek

		Discharge (cfs)				Velocity (fps)			Depth (feet)		
Site	Transect	Hi Q	Mid Q	Low Q	Station	Hi Q	Mid Q	Low Q	Hi Q	Mid Q	Low Q
Camp 62 Creek Above Diversion	A - HGR	12.93	3.81	0.65	18.2	2.95	1.87	*	0.70	0.50	*
					21.4	2.43	1.48	*	0.70	0.40	*
					24.4	0.30	0.41	0.07	0.60	0.40	0.35
					28.4	1.92	1.05	0.06	0.60	0.50	0.20
					30.2	1.08	0.47	*	0.40	0.30	*
	B - HGR	12.93	3.81	0.65	15.4	-0.32	0.83	*	1.00	0.80	*
					17.0	-0.27	2.19	0.04	1.30	1.20	0.50
					18.6	4.00	1.17	*	1.70	1.30	*
					20.4	0.45	0.06	*	1.10	1.00	*
					22.8	-0.42	0.20	*	0.40	0.30	*
Camp 62 Creek Below Diversion	A - HGR	8.77	3.72	0.23	8.2	2.47	1.27	*	0.60	0.50	*
					9.2	2.07	1.27	0.21	1.00	0.80	0.20
					10.6	2.35	0.92	0.37	0.90	0.80	0.20
					11.3	0.93	0.81	*	0.70	0.60	*
					12.0	2.52	0.44	0.49	0.80	0.60	0.20
	B - HGR	8.77	3.72	0.23	17.3	0.37	2.30	*	0.60	0.40	*
					18.9	2.70	1.52	*	0.60	0.50	*
					20.3	0.35	0.29	*	0.40	0.30	*
	C - HGR* Below Confluence of Chinquipin Creek	16.77	6.49	0.39	12.8	0.64	0.32	*	0.30	0.20	*
					14.4	1.31	1.41	0.20	0.50	0.30	0.30
					15.8	0.39	1.05	0.36	1.50	0.40	0.40
					17.5	0.82	1.30	*	1.60	1.00	*
					19.2	0.61	0.75	0.26	1.30	0.90	0.30

*Insufficient depth for measurement
cfs = cubic feet per second
fps = feet per second

CAWG-3 Appendix A Table A-3. Measured Depths and Velocities for Chinquapin Creek

Site	Transect	Discharge (cfs)			Station	Velocity (fps)			Depth (feet)		
		Hi Q	Mid Q	Low Q		Hi Q	Mid Q	Low Q	Hi Q	Mid Q	Low Q
Chinquapin Creek Above Diversion	C1 - LGR	5.66	2.64	0.15	8.0	1.69	0.99	*	0.70	0.60	*
					10.0	1.21	0.69	*	0.60	0.60	*
					12.0	1.02	0.86	0.61	0.60	0.70	0.20
					14.0	1.86	1.16	*	0.40	0.30	*
					16.0	0.98	1.40	*	0.35	0.30	*
	C2 - LGR	5.66	2.64	0.15	9.0	***	0.56	0.45	***	0.50	0.20
					11.0	***	1.98	*	***	0.30	*
					12.6	***	1.34	*	***	0.30	*
					13.6	***	0.88	*	***	0.40	*
					14.6	***	0.55	*	***	0.20	*
	C3 - LGR	5.66	2.64	0.15	11.0	***	0.59	*	***	0.30	*
					12.0	2.92	1.98	*	0.70	0.60	*
					13.6	2.43	1.43	*	0.80	0.80	*
					14.7	2.33	1.25	0.00	0.60	0.40	0.20
					17.0	0.36	0.58	*	0.50	0.40	*

**No measurement taken
***Data Sheet lost
cfs = cubic feet per second
fps = feet per second

CAWG-3 Appendix A Table A-4. Measured Depths and Velocities for Crater Creek

		Discharge (cfs)				Velocity (fps)			Depth (feet)		
Site	**Transect**	**Hi Q**	**Mid Q**	**Low Q**	**Station**	**Hi Q**	**Mid Q**	**Low Q**	**Hi Q**	**Mid Q**	**Low Q**
Crater Creek Above Diverson	US_RIF - SRN	18.64	7.86	0.68	22.6	1.57	**	-0.02	1.15	**	0.30
					24.6	3.21	**	*	0.60	**	*
					25.3	3.81	**	1.06	1.10	**	0.20
					26.6	3.41	**	0.19	1.20	**	0.20
					29.7	2.25	**	0.46	1.40	**	0.20
	PL - SPO	18.64	7.86	0.68	21.3	1.72	**	0.14	3.50	**	2.35
					22.1	0.97	**	0.16	3.40	**	2.25
					24.0	1.30	**	0.03	2.90	**	1.65
					25.6	-0.52	**	-0.01	2.50	**	1.15
					28.7	0.61	**	0.00	1.40	**	0.50
	DS_RIF - SRN	18.64	7.86	0.68	7.9	0.80	**	*	0.60	**	*
					12.8	0.65	**	*	0.90	**	*
					15.1	1.69	**	*	0.80	**	*
					17.1	1.77	**	0.49	1.60	**	0.50
					18.4	2.48	**	*	1.40	**	*
Crater Creek Below Diverson	A - HGR	13.98	2.14	0.01	6.0	2.03	1.06	*	1.10	0.40	*
					8.0	0.68	0.65	*	1.20	0.70	*
					9.0	0.04	0.36	*	1.20	0.65	*
	C - HGR	13.98	2.14	Dry	10.8	1.82	0.73	*	0.60	0.20	*
					12.6	2.49	1.05	*	1.40	0.20	*
					13.3	2.02	1.15	*	1.50	1.10	*
					14.0	1.02	0.59	*	1.50	1.15	*
					15.0	2.68	0.76	*	1.20	0.70	*
	E - HGR	13.98	2.14	Dry	9.7	0.03	0.16	*	1.40	0.60	*
					10.0	0.85	1.69	*	1.50	0.50	*
					12.5	1.43	-0.18	*	1.10	0.60	*
					13.0	1.63	0.33	*	1.60	0.55	*
					15.0	0.86	1.01	*	1.50	0.40	*

*Insufficient depth for measurement
**No measurement taken
cfs = cubic feet per second
fps = feet per second

CAWG-3 Appendix A Table A-5. Measured Depths and Velocities for Hooper Creek

		Discharge (cfs)				Velocity (fps)			Depth (feet)		
Site	**Transect**	**Hi Q**	**Mid Q**	**Low Q**	**Station**	**Hi Q**	**Mid Q**	**Low Q**	**Hi Q**	**Mid Q**	**Low Q**
Hooper Creek Above Diversion	A - HGR Below Tributary	33.89	12.94	6.20	9.9	2.44	0.80	0.63	0.80	0.40	0.20
					14.0	1.45	-0.13	0.15	1.00	0.70	0.50
					15.7	2.00	2.08	0.44	1.00	0.80	0.80
					18.0	1.46	4.20	0.43	1.20	0.35	0.20
					19.0	6.57	4.70	2.03	1.20	0.70	0.90
	C - HGR Above Tributary	32.02	10.49	6.14	25.0	2.13	0.65	2.45	1.00	0.60	0.20
					28.0	1.95	0.57	0.55	1.00	0.70	0.70
					30.0	6.41	0.60	0.83	0.70	0.70	0.70
					30.5	8.55	4.44	0.11	1.30	0.50	0.90
					33.5	0.89	-0.38	0.25	1.80	1.60	1.10
Hooper Creek Below Diversion	A - HGR Above Split	24.40	8.94	2.26	9.5	1.23	2.11	1.42	1.60	0.70	0.80
					11.0	4.95	3.16	3.04	1.30	1.10	0.50
					12.0	2.38	2.01	*	1.40	1.00	*
					13.4	3.82	2.86	0.90	1.00	0.50	0.20
					14.0	3.18	2.01	1.27	0.70	0.40	0.20
	B - HGR Below Split	10.36	5.79	1.01	15.8	3.26	0.63	0.58	0.50	0.60	0.20
					17.5	1.91	1.04	1.45	0.60	0.50	0.20
					20.2	0.42	0.26	*	0.40	0.30	*
	D - HGR Below Split	10.36	5.79	1.01	10.4	3.77	3.75	*	0.60	0.40	*
					11.0	3.24	4.01	2.39	0.60	0.50	0.20
					12.0	3.62	3.79	*	0.50	0.40	*
					12.6	3.70	2.87	0.51	0.60	0.40	0.20
					13.4	3.19	3.57	0.11	0.60	0.50	0.20

*Insufficient depth for measurement
cfs = cubic feet per second
fps = feet per second

CAWG-3 Appendix A Table A-6. Measured Depths and Velocities for North Slide Creek

Site	Transect	Discharge (cfs)			Station	Velocity (fps)			Depth (feet)		
		Hi Q	Mid Q	Low Q		Hi Q	Mid Q	Low Q	Hi Q	Mid Q	Low Q
North Slide Below Diversion	1 - SRN	0.18	0.09	0.03	*	*	*	*	*	*	*
					*	*	*	*	*	*	*
					*	*	*	*	*	*	*
					*	*	*	*	*	*	*
					*	*	*	*	*	*	*
	2 - SRN	0.18	0.09	0.03	6.3	0.05	0.36	0.05	0.30	0.3	0.20
					6.7	0.00	0.35	0.06	0.30	0.2	0.20
					6.9	0.26	0.57	-0.03	0.20	0.2	0.20
					7.1	0.34	0.27	0.03	0.20	0.2	0.15
					7.3	0.42	0.14	*	0.20	0.15	*
	1 - HGR	0.18	0.09	0.03	*	*	*	*	*	*	*
					*	*	*	*	*	*	*
					*	*	*	*	*	*	*
					*	*	*	*	*	*	*
					*	*	*	*	*	*	*

cfs = cubic feet per second
fps = feet per second

CAWG-3 Appendix A Table A-7. Measured Depths and Velocities for South Slide Creek

		Discharge (cfs)				Velocity (fps)			Depth (feet)		
Site	Transect	Hi Q	Mid Q	Low Q	Station	Hi Q	Mid Q	Low Q	Hi Q	Mid Q	Low Q
South Slide Below Diversion	A - SRN	2.26	0.64	0.08	10.0	2.04	1.17	*	0.40	0.20	*
					10.5	2.81	1.85	*	0.60	0.20	*
					10.8	2.34	1.78	*	0.60	0.15	*
					11.4	2.70	1.90	*	0.50	0.30	*
					11.1	2.59	2.74	*	0.50	0.20	*
	B - SRN	2.26	0.64	0.08	9.3	2.85	1.53	*	0.30	0.20	*
					9.7	2.54	1.24	*	0.30	0.20	*
					10.5	3.24	1.70	0.00	0.50	0.25	0.15
					10.7	3.85	1.00	*	0.40	0.25	*
					11.5	3.15	0.54	*	0.20	0.20	*
	C - HGR	2.26	0.53	0.08	8.5	1.17	1.30	*	0.40	0.20	*
					9.0	0.50	0.23	*	0.40	0.25	*
					9.4	0.97	-0.27	*	0.40	0.30	*
					10.0	2.02	-0.30	*	0.20	0.20	*
					11.0	2.01	0.44	*	0.20	0.20	*

cfs = cubic feet per second
fps = feet per second

CAWG-3 Appendix A Table A-8. Measured Depths and Velocities for Tombstone Creek

		Discharge (cfs)				Velocity (fps)			Depth (feet)		
Site	Transect	Hi Q	Mid Q	Low Q	Station	Hi Q	Mid Q	Low Q	Hi Q	Mid Q	Low Q
Tombstone Creek Above Diversion	AD-RUN2	2.67	1.67	0.47	4.5	0.62	1.55	0.34	0.40	0.30	0.20
					6.2	1.09	0.25	0.06	0.50	0.30	0.15
					6.7	1.79	1.56	0.63	0.40	0.20	0.15
					7.7	2.01	0.44	0.65	0.35	0.35	0.20
					8.6	1.05	0.87	0.28	0.40	0.30	0.20
	AD-RUN1	2.67	1.67	0.47	8.6	0.18	0.15	0.16	0.60	0.30	0.30
					9.3	1.06	0.81	0.74	0.60	0.15	0.15
					10.0	1.34	0.80	0.60	0.90	0.35	0.45
					10.9	1.31	0.00	0.66	0.80	0.40	0.40
	AD-HGR	2.67	1.67	0.47	7.2	0.54	0.69	*	0.40	0.30	*
					7.4	1.93	1.56	*	0.40	0.40	*
					9.5	-0.49	0.23	*	0.30	0.20	*
					10.4	0.50	-0.10	*	0.30	0.20	*
					10.6	-0.05	0.19	*	0.20	0.15	*
Tombstone Creek Below Diversion	BD-C	2.99	1.83	0.50	14.1	3.47	3.53	*	0.50	0.40	*
					14.7	2.46	2.04	2.52	0.50	0.40	0.30
					15.3	3.58	2.53	2.02	0.40	0.40	0.20
					15.7	1.18	1.40	*	0.50	0.20	*
					16.3	0.49	0.00	0.00	0.50	0.30	0.20
	BD-D	2.99	1.83	0.50	5.6	0.26	0.31	*	0.6	0.5	*
					6.2	3.64	1.23	0.2	0.6	0.5	0.20
					6.7	**	1.46	**	**	0.3	**
					7.0	2.42	3.31	0.2	0.7	0.6	0.20
	BD-E	2.99	1.83	0.50	5.2	0.32	0.00	*	0.50	0.40	*
					5.8	1.58	1.15	2.36	0.50	0.30	0.20
					6.4	3.27	2.84	2.78	0.70	0.50	0.20
					7.0	1.67	0.90	*	0.50	0.30	*
					7.6	1.20	0.50	*	0.50	0.30	*
					8.5	0.96	0.92	*	0.30	0.20	*

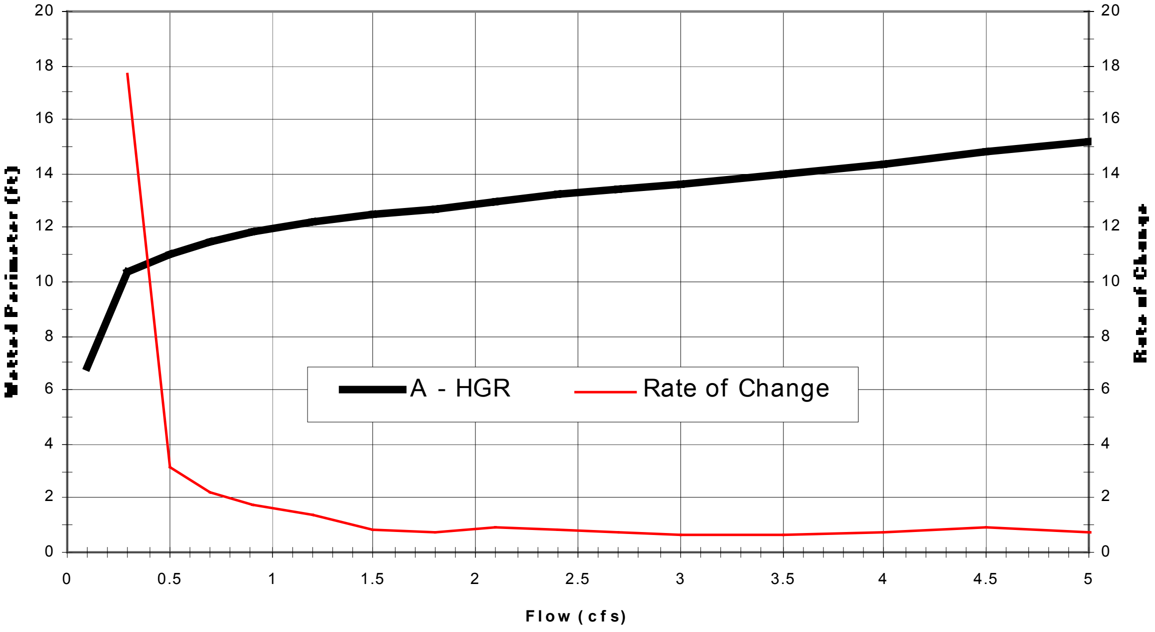
*Insufficient depth for measurement
**No measurement taken
cfs = cubic feet per second
fps = feet per second

APPENDIX B

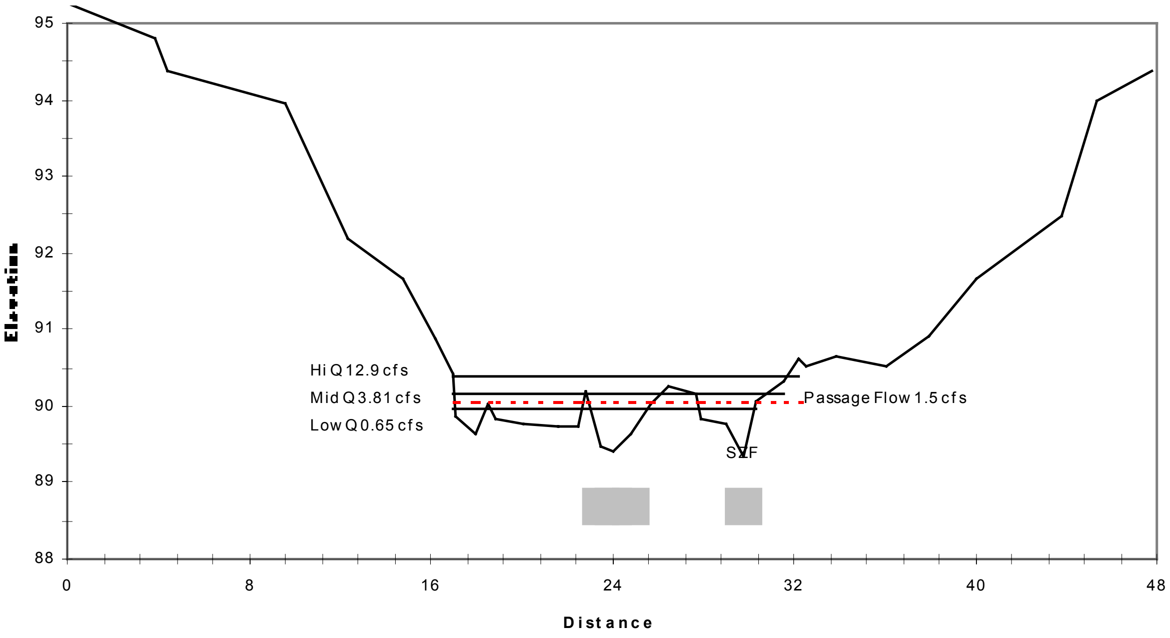
Wetted Perimeter vs. Flow Plots
and
Transect Profiles and Measured Water Surface Elevations

The figures in this appendix are presented one page per transect. The figure at the top of each page presents the wetted perimeter vs. flow relationship for the transect and the instantaneous rate of change in the wetted perimeter vs. flow relationship. The figure at the bottom of each page shows the channel profile, the measured water surface elevations during data collection and the water surface elevation at the flow providing passage for adult trout. The shaded bar underneath the cross section profile indicates the approximate area where passage would be possible.

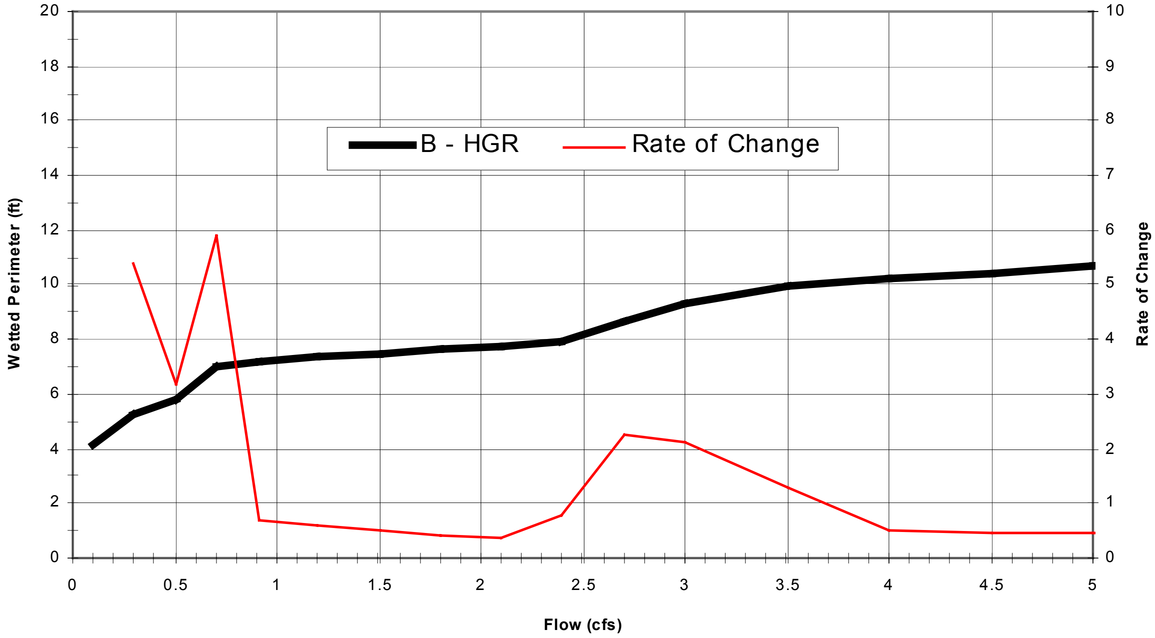
Camp 62 Creek Above Diversion A - HGR Wetted Perimeter vs Flow



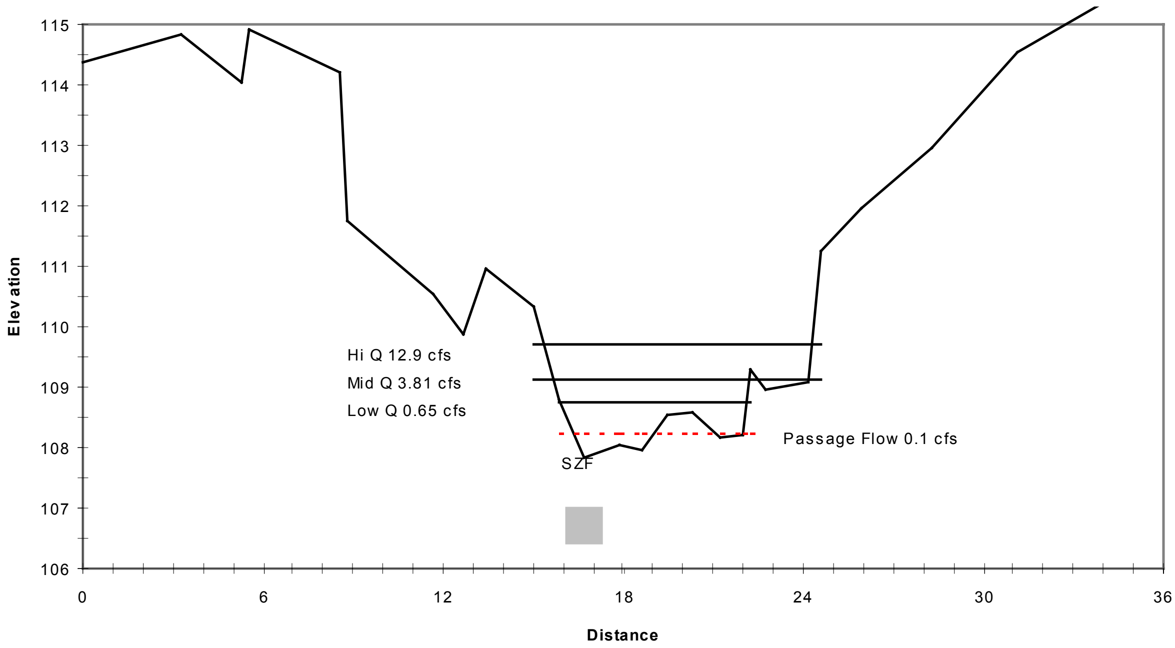
Camp 62 Creek Above Diversion A - HGR Channel Cross Section

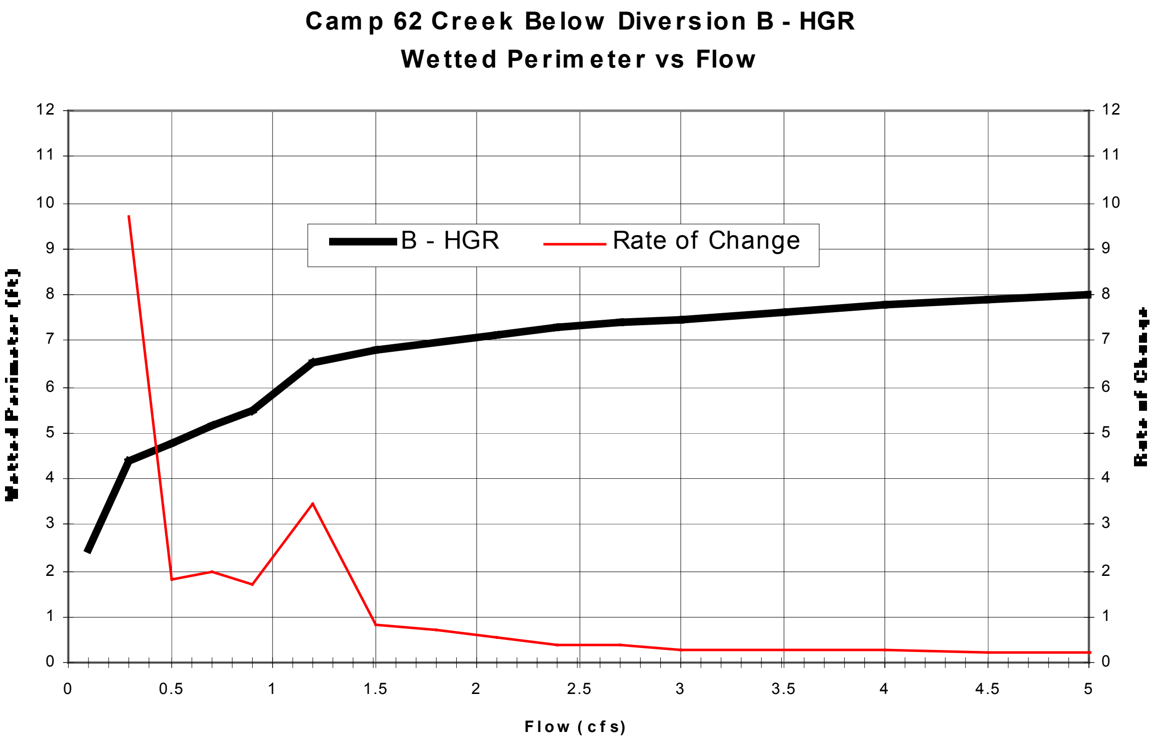


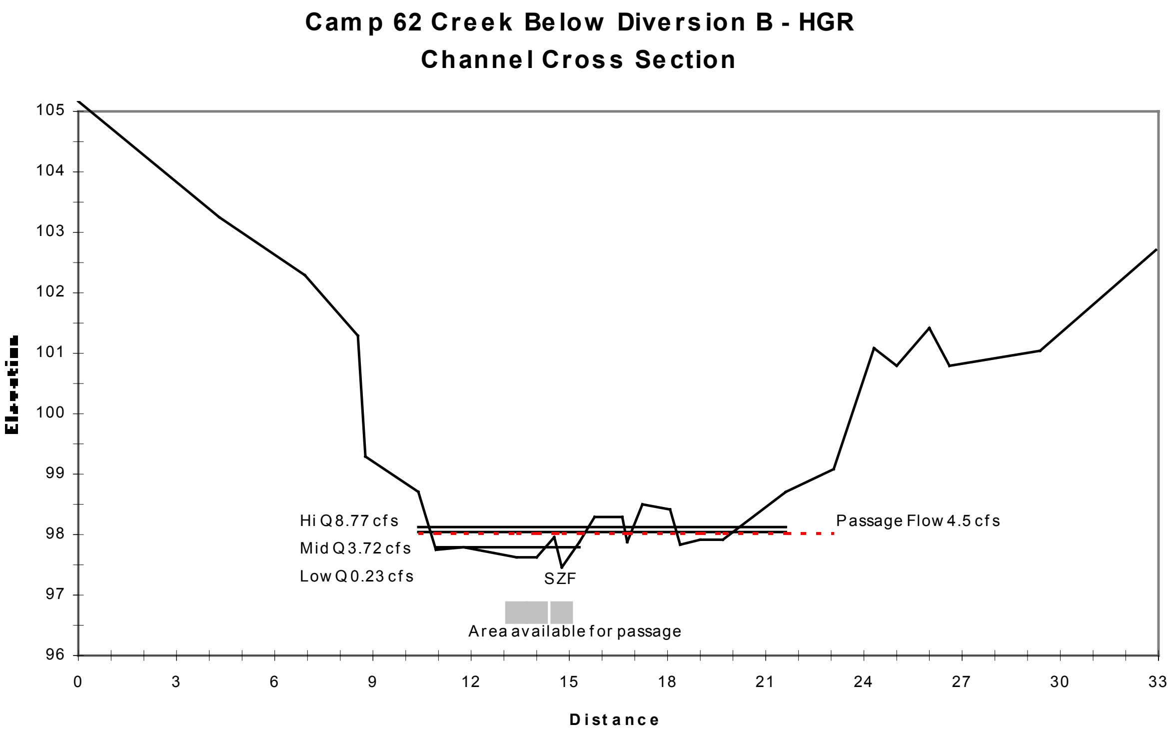
Camp 62 Creek Above Diversion B - HGR
Wetted Perimeter vs Flow

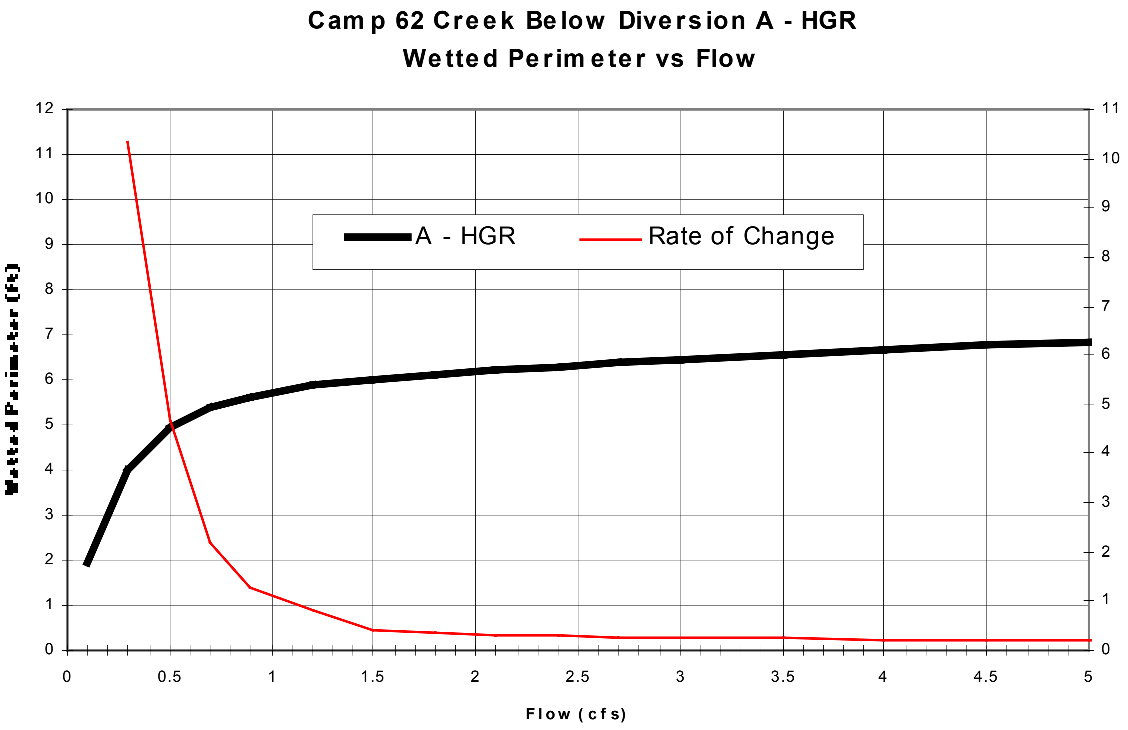


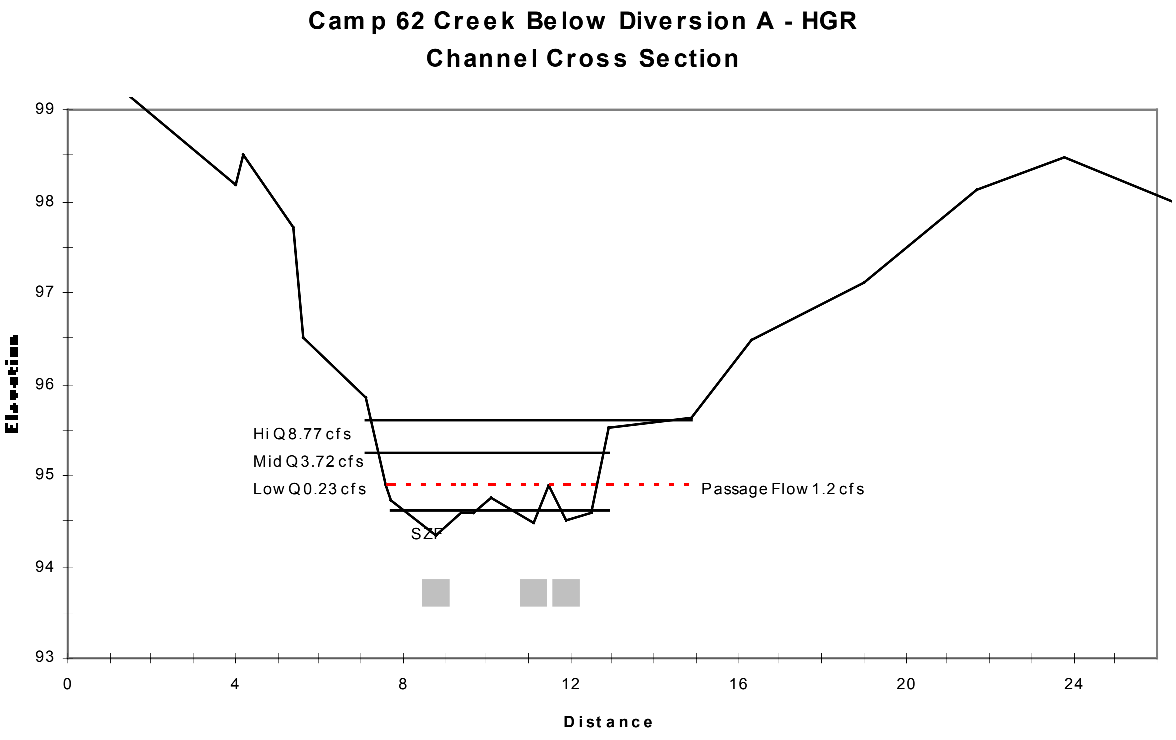
Camp 62 Creek Above Diversion B - HGR
Channel Cross Section



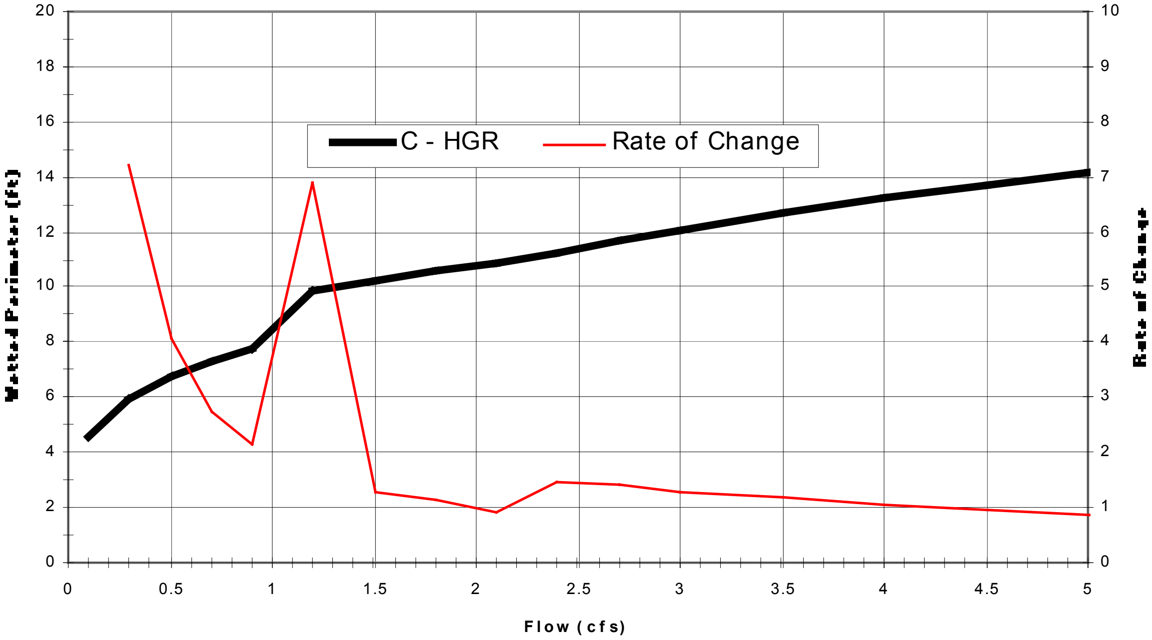

Camp 62 Creek Below Diversion B - HGR
Wetted Perimeter vs Flow
B - HGR
Rate of Change
Wetted Perimeter (ft)
Rate of Change
Flow (cfs)
0
1
2
3
4
5
6
7
8
9
10
11
12
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Camp 62 Creek Below Diversion B - HGR
Channel Cross Section
Hi Q 8.77 cfs
Mid Q 3.72 cfs
Low Q 0.23 cfs
Passage Flow 4.5 cfs
SZF
Area available for passage
Elevation
Distance
96
97
98
99
100
101
102
103
104
105
0
3
6
9
12
15
18
21
24
27
30
33

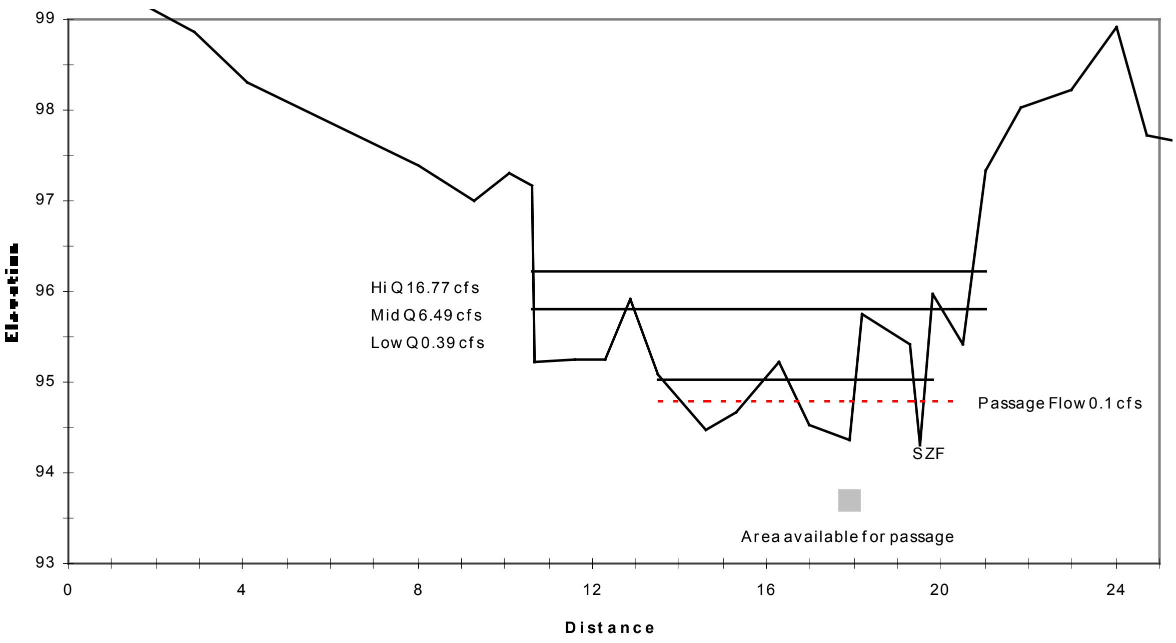

Camp 62 Creek Below Diversion A - HGR
Wetted Perimeter vs Flow
A - HGR
Rate of Change
Wetted Perimeter (ft)
Rate of Change
Flow (cfs)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
1
2
3
4
5
6
7
8
9
10
11
12


Camp 62 Creek Below Diversion A - HGR
Channel Cross Section
Hi Q 8.77 cfs
Mid Q 3.72 cfs
Low Q 0.23 cfs
Passage Flow 1.2 cfs
SZF
Elevation
Distance
93
94
95
96
97
98
99
0
4
8
12
16
20
24

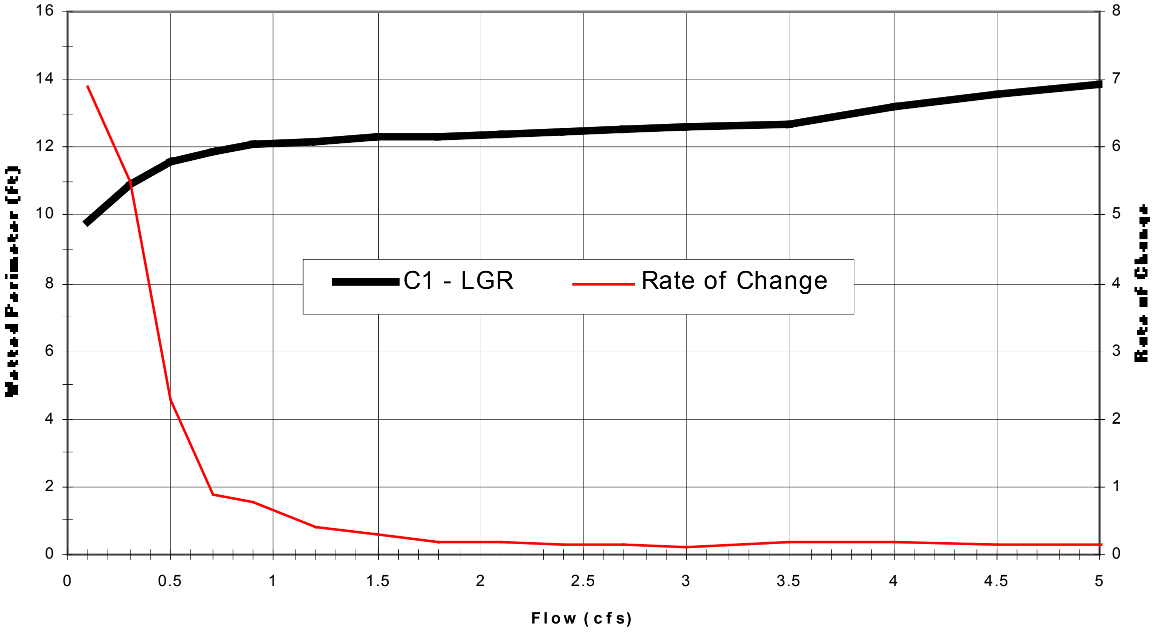
Camp 62 Creek Below Diversion C - HGR
Wetted Perimeter vs Flow



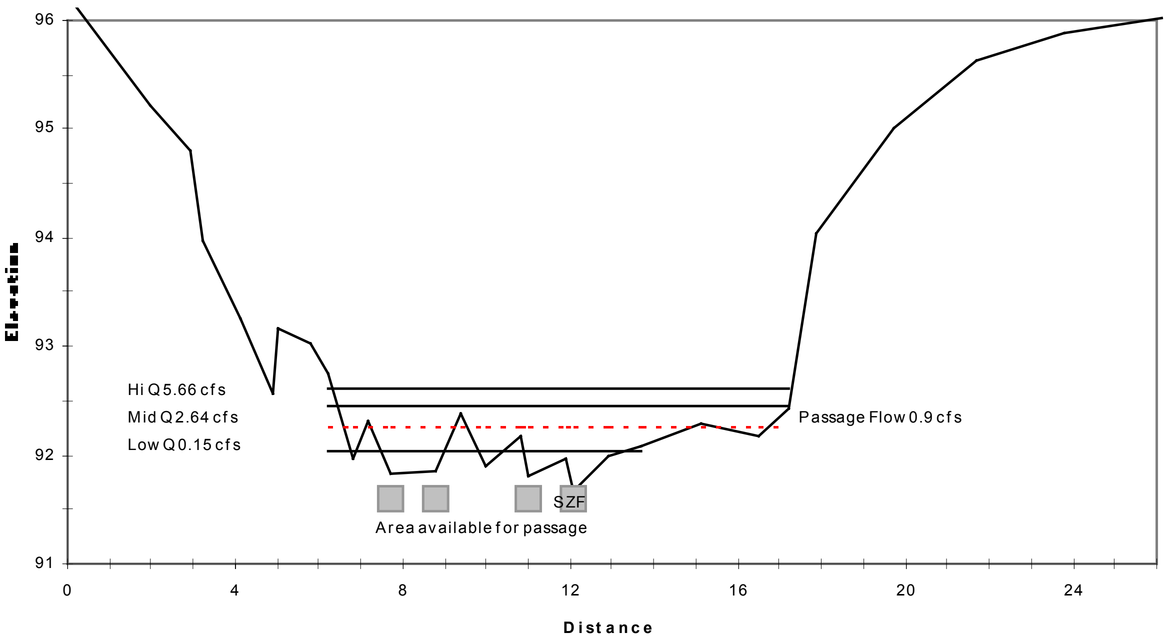
Camp 62 Creek Below Diversion C - HGR
Channel Cross Section



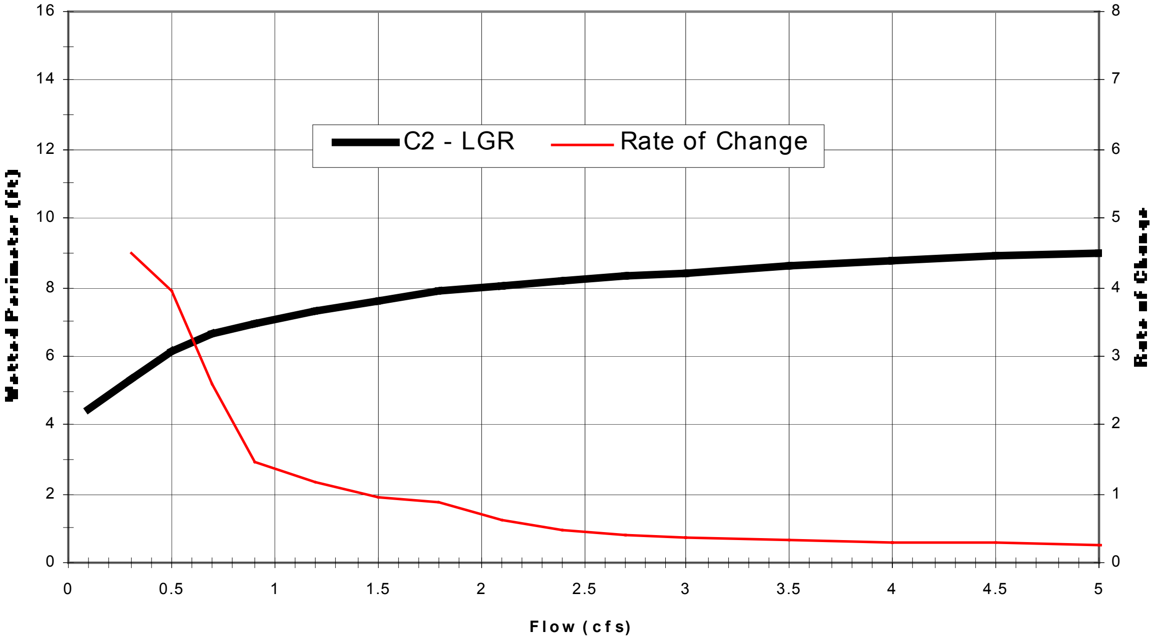
Chinquapin Creek Below Diversion C1 - LGR
Wetted Perimeter vs Flow



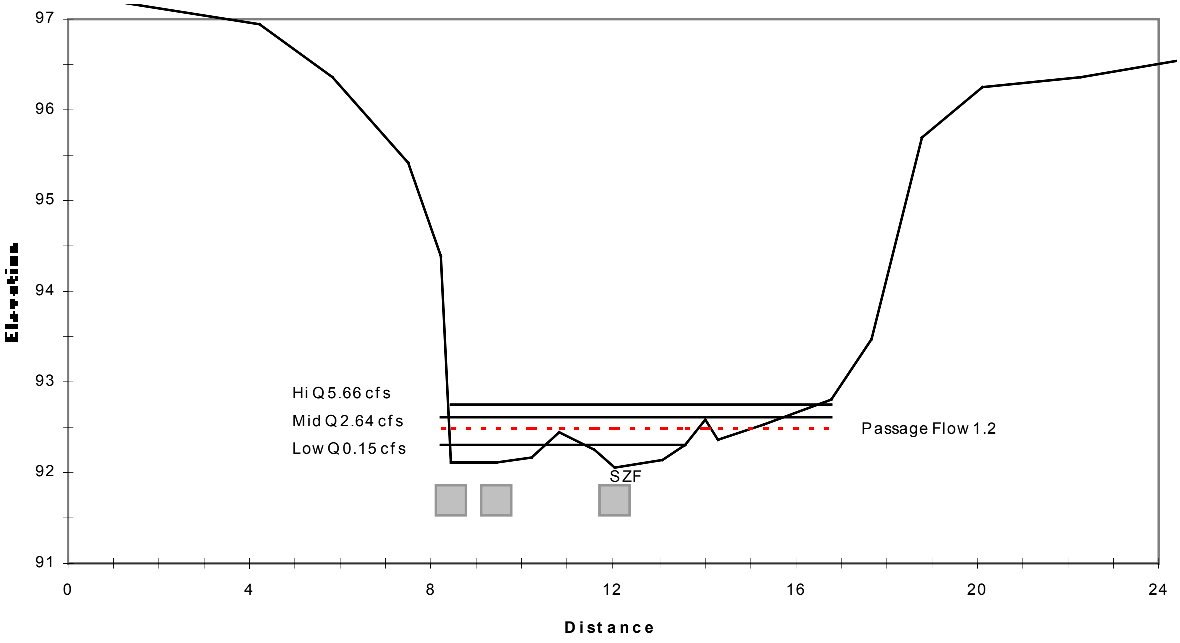
Chinquapin Creek Below Diversion C1 - LGR
Channel Cross Section



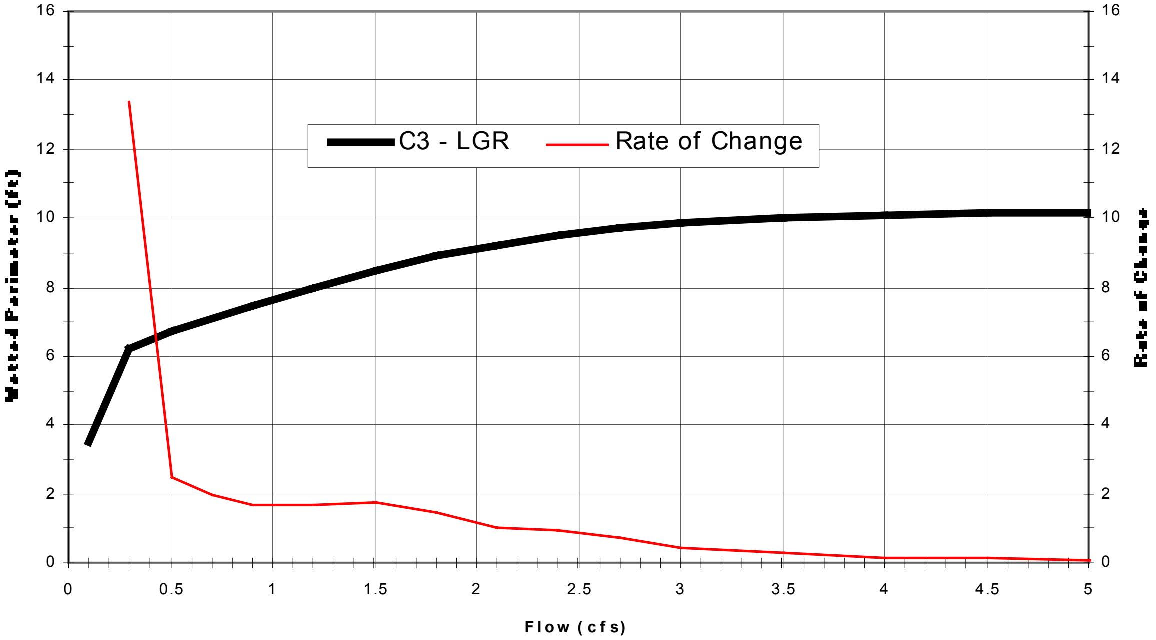
Chinquapin Creek Below Diversion C2 - LGR
Wetted Perimeter vs Flow



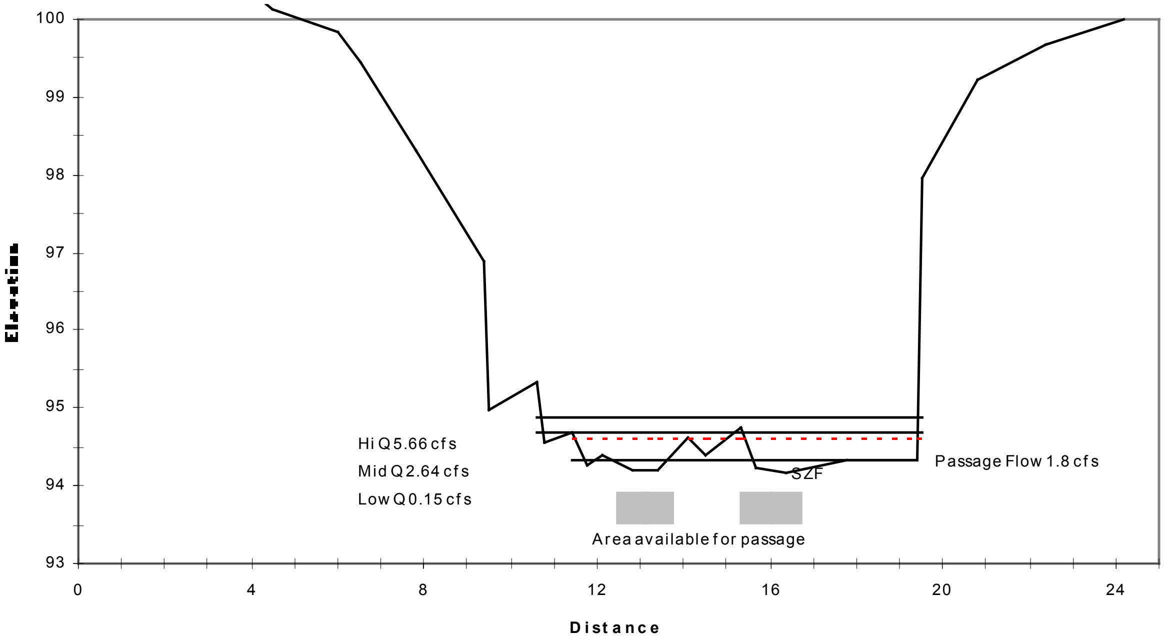
Chinquapin Creek Below Diversion C2 - LGR
Channel Cross Section



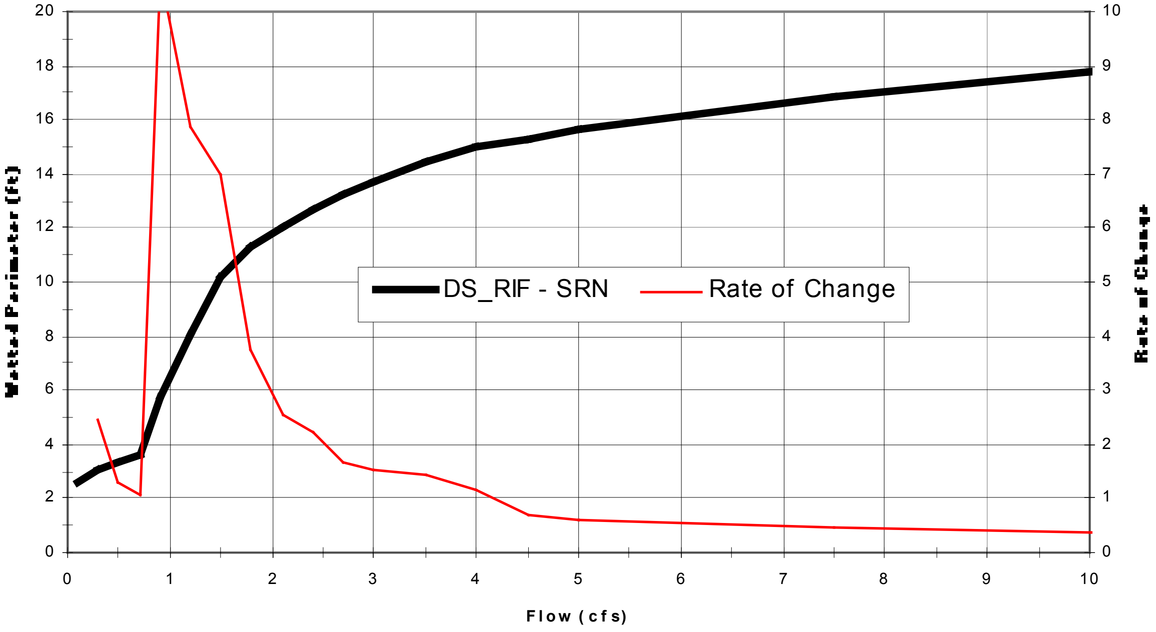
Chinquapin Creek Below Diversion C3 - LGR
Wetted Perimeter vs Flow



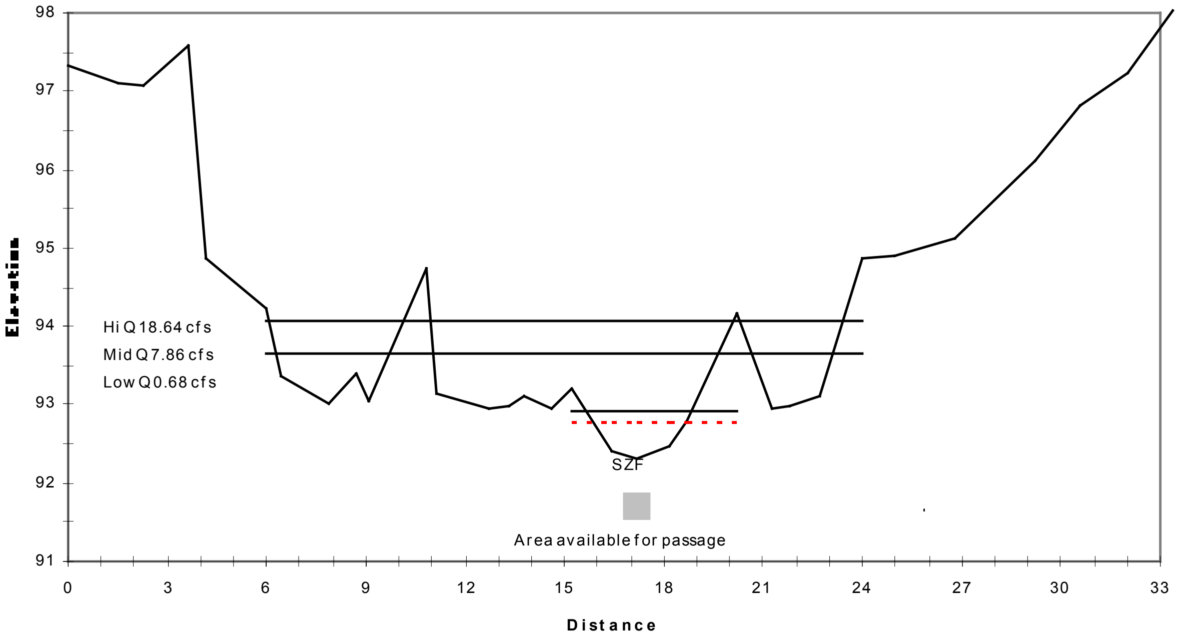
Chinquapin Creek Below Diversion C3 - LGR
Channel Cross Section



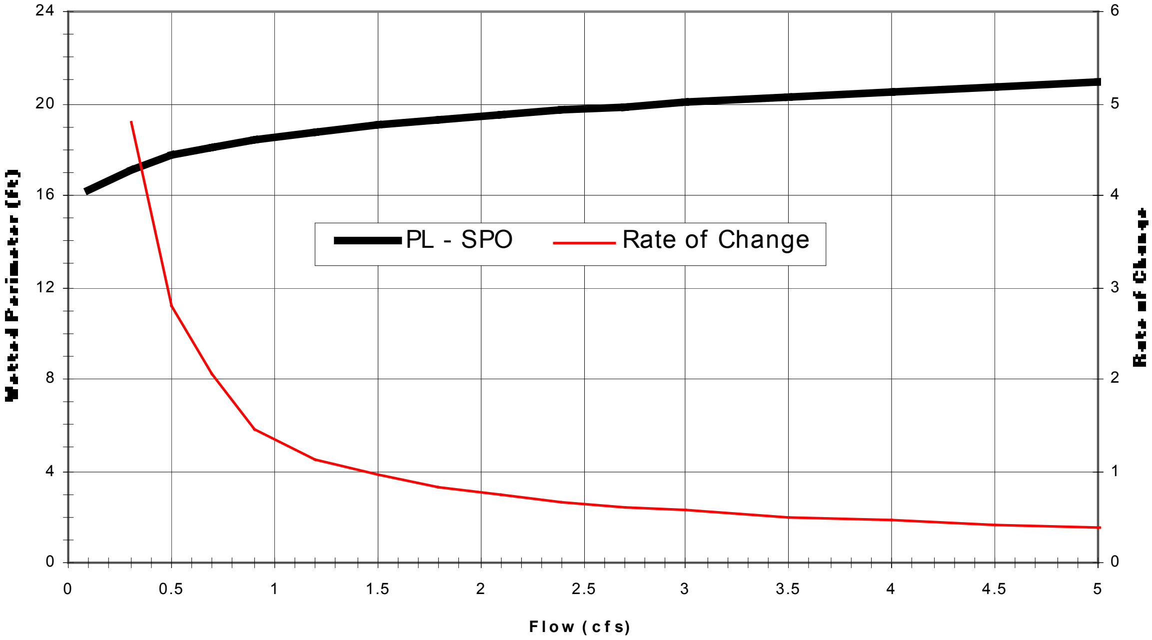
Crater Creek Above Diversion DS_RIF - SRN
Wetted Perimeter vs Flow



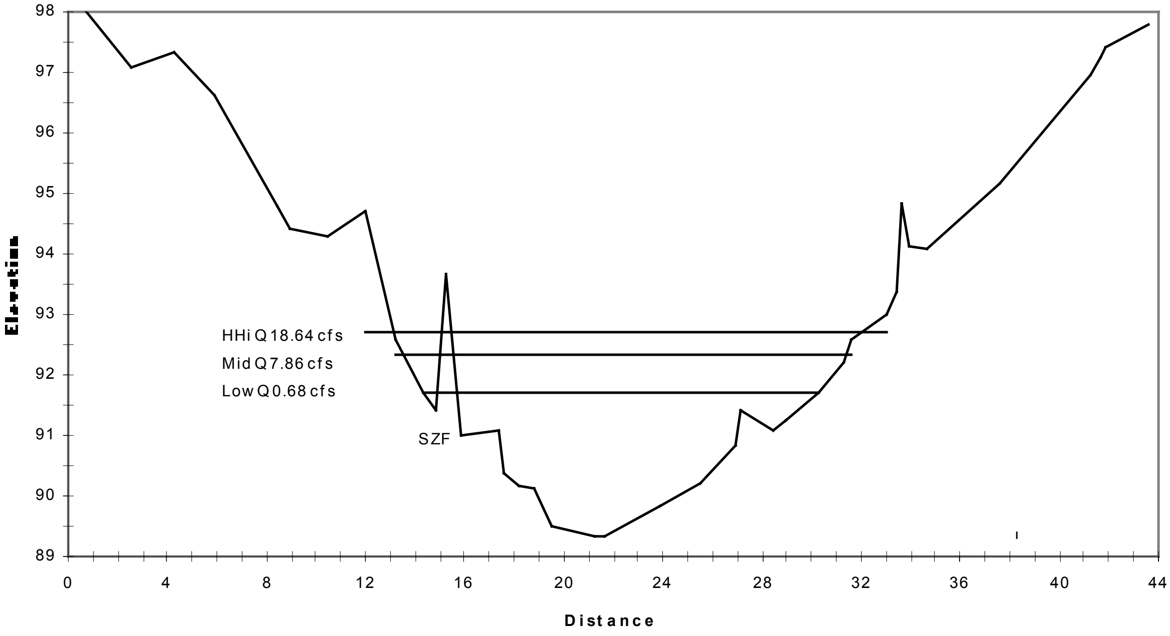
Crater Creek Above Diversion DS_RIF - SRN
Channel Cross Section

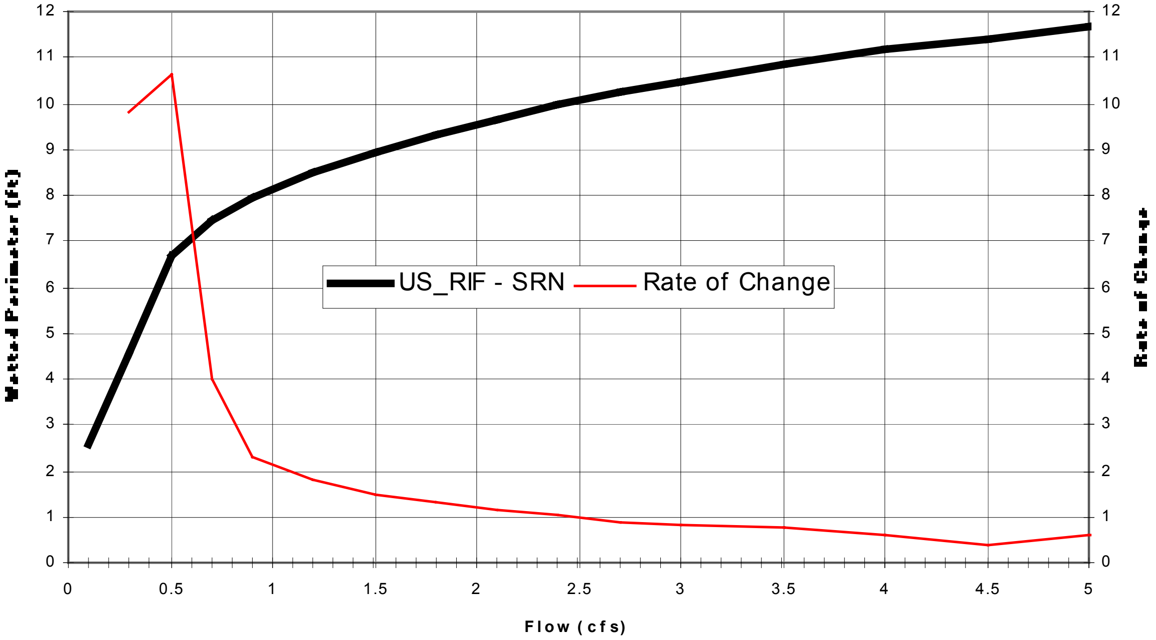


Crater Creek Above Diversion PL - SPO
Wetted Perimeter vs Flow

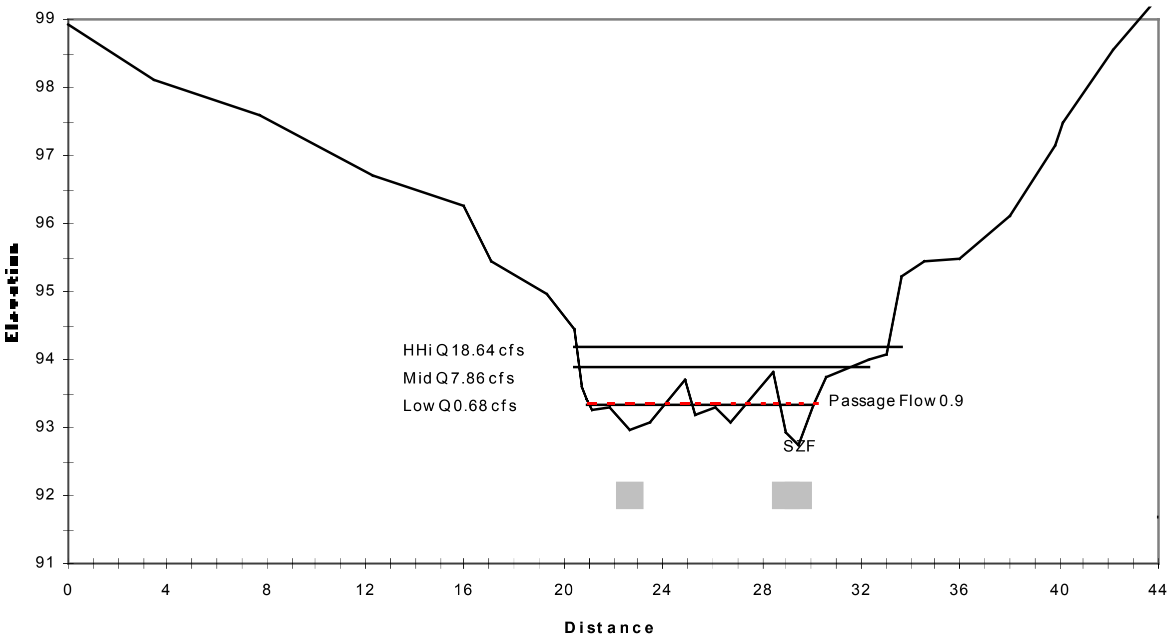


Crater Creek Above Diversion PL - SPO
Channel Cross Section



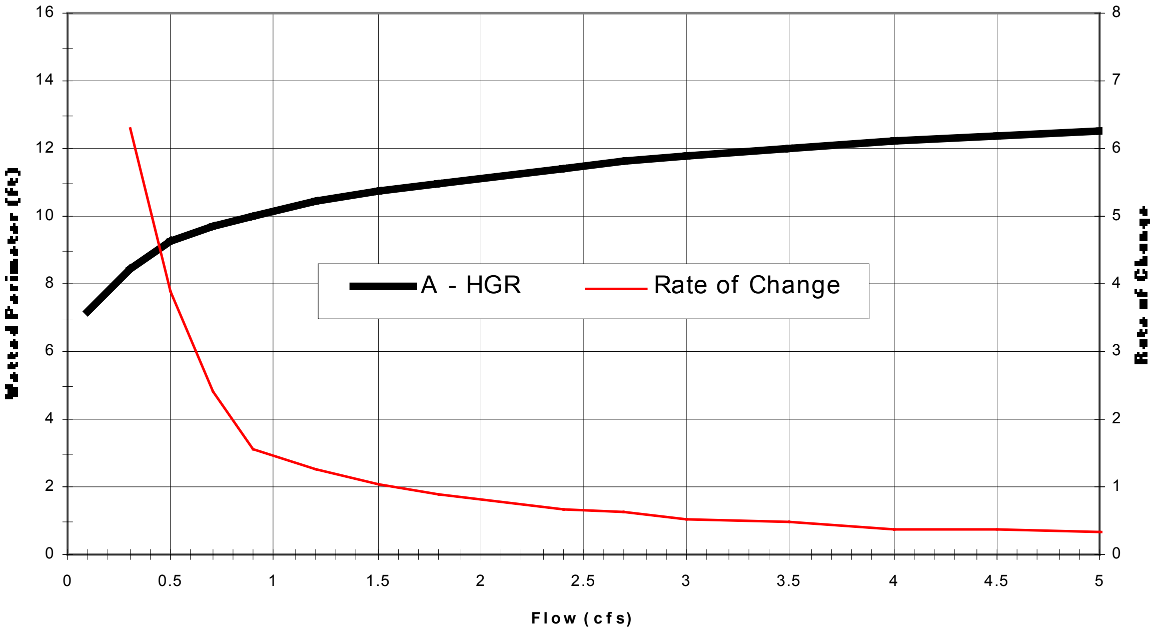


Crater Creek Above Diversion US_RIF - SRN
Wetted Perimeter vs Flow

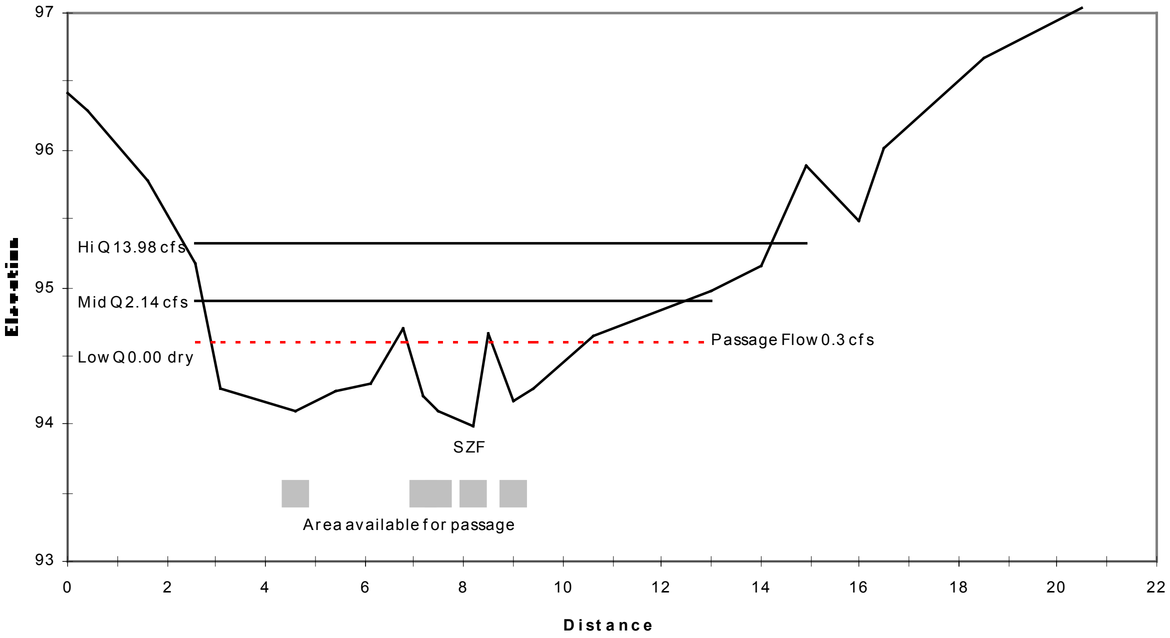


Crater Creek Above Diversion US_RIF - SRN
Channel Cross Section

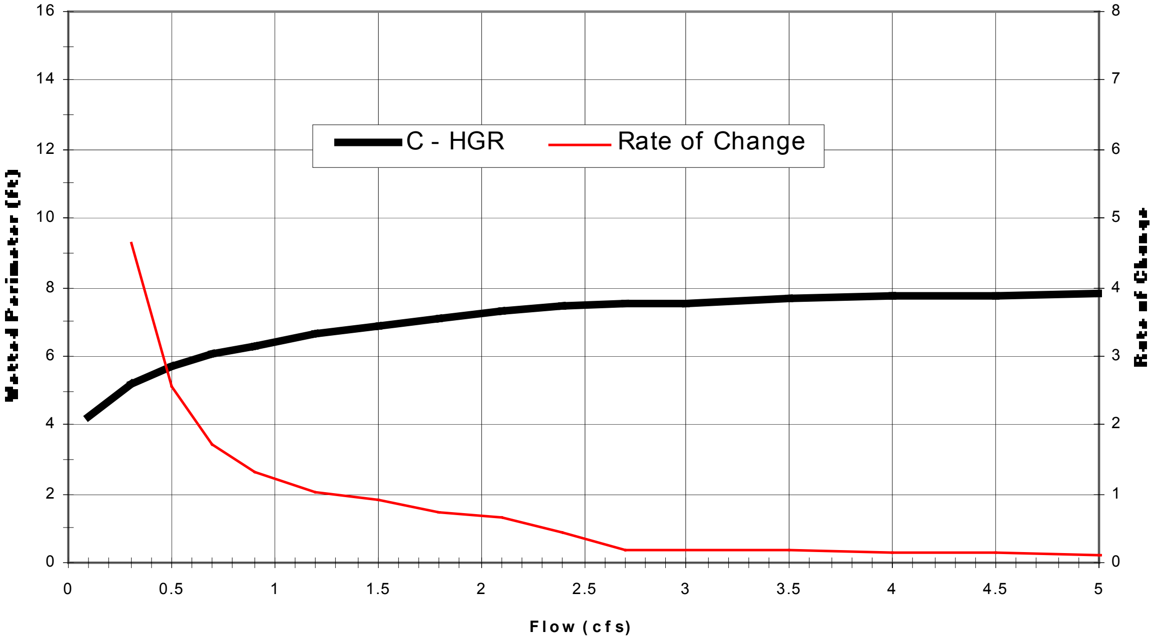
Crater Creek Below Diversion A - HGR
Wetted Perimeter vs Flow



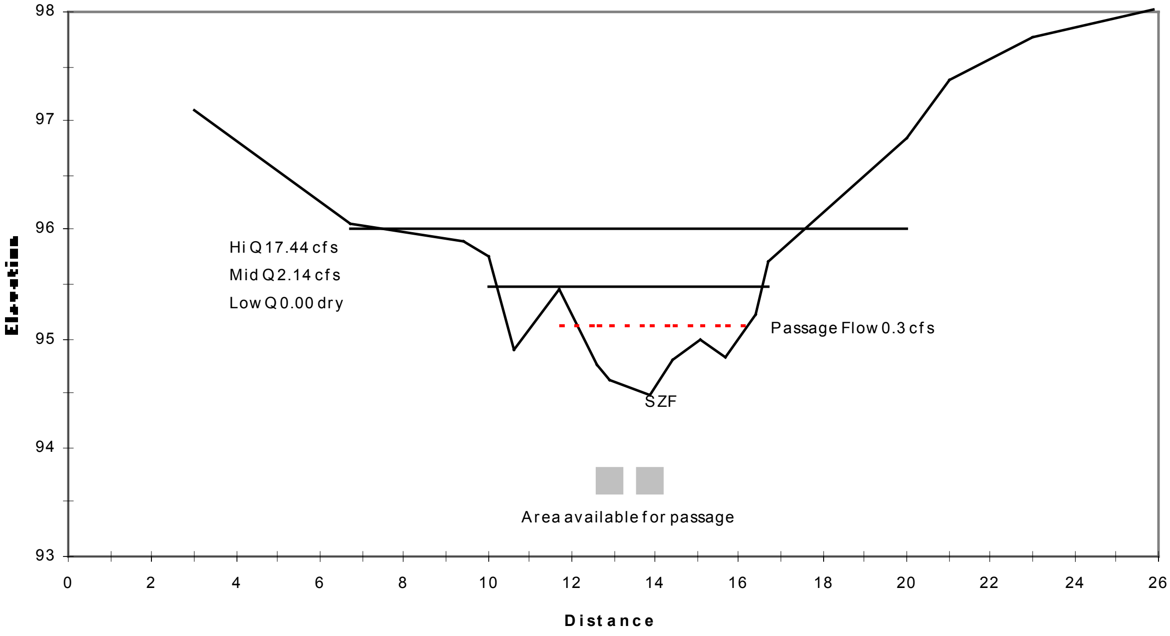
Crater Creek Below Diversion A - HGR
Channel Cross Section



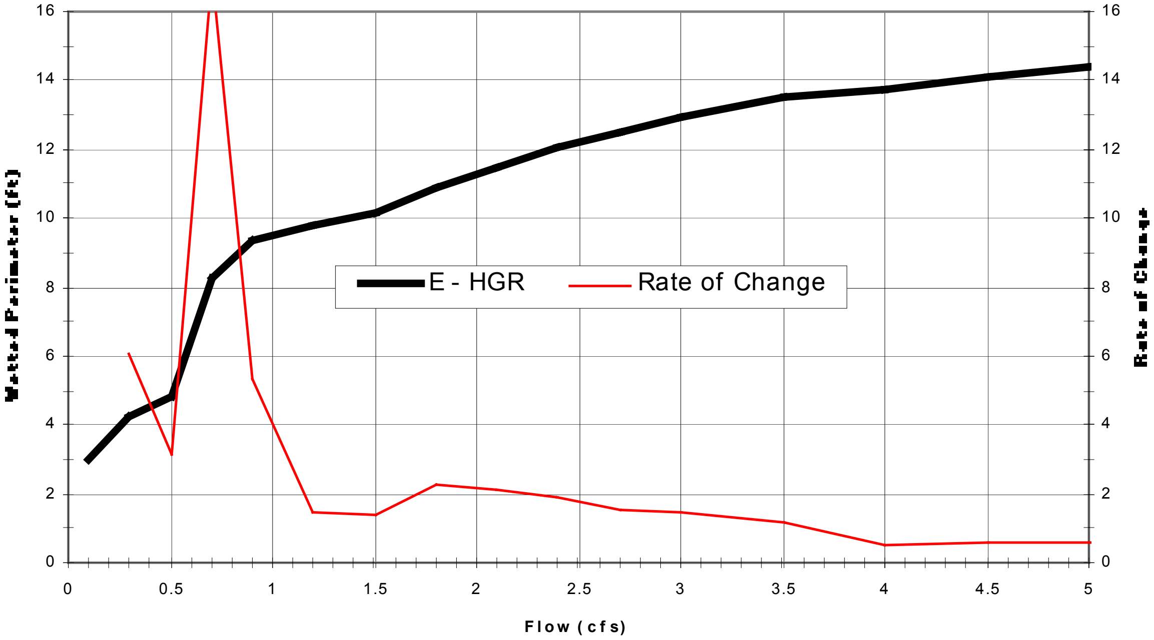
Crater Creek Below Diversion C - HGR
Wetted Perimeter vs Flow



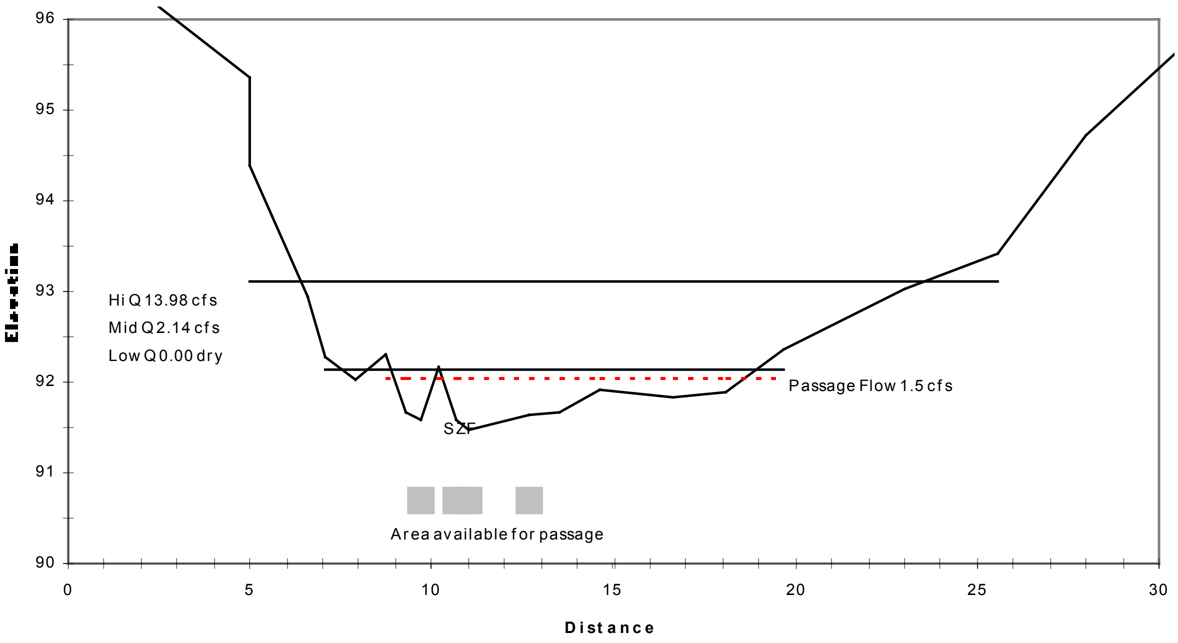
Crater Creek Below Diversion C - HGR
Channel Cross Section

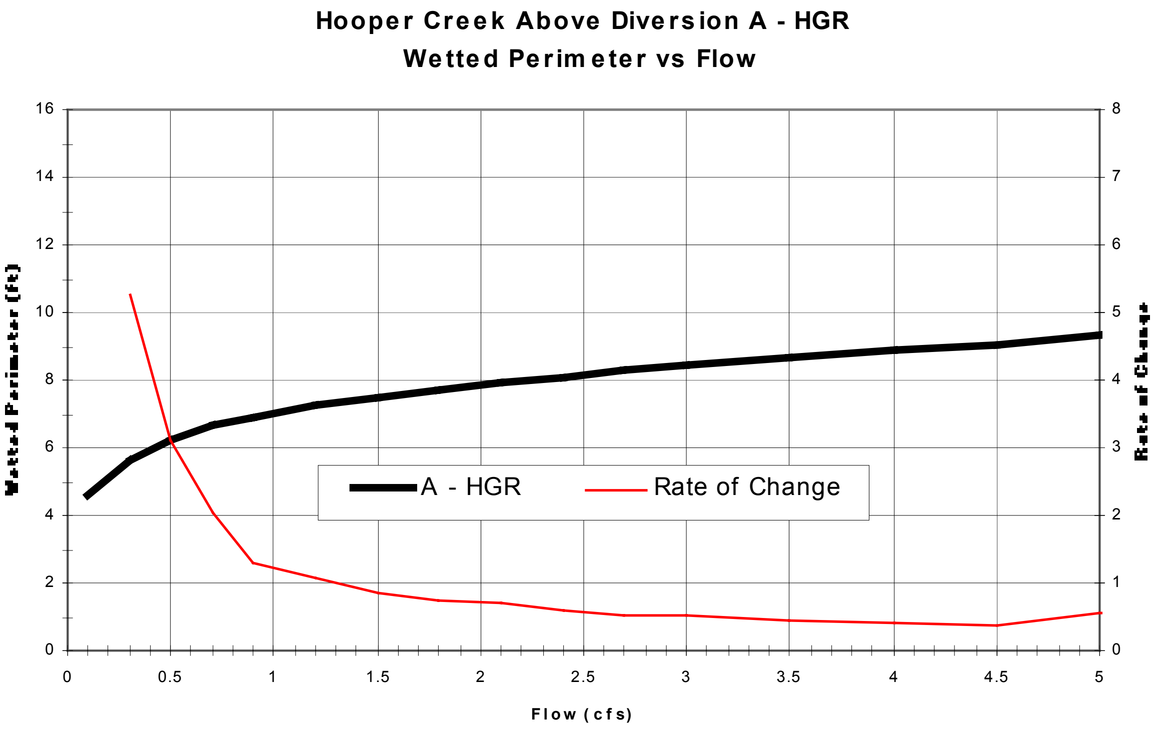


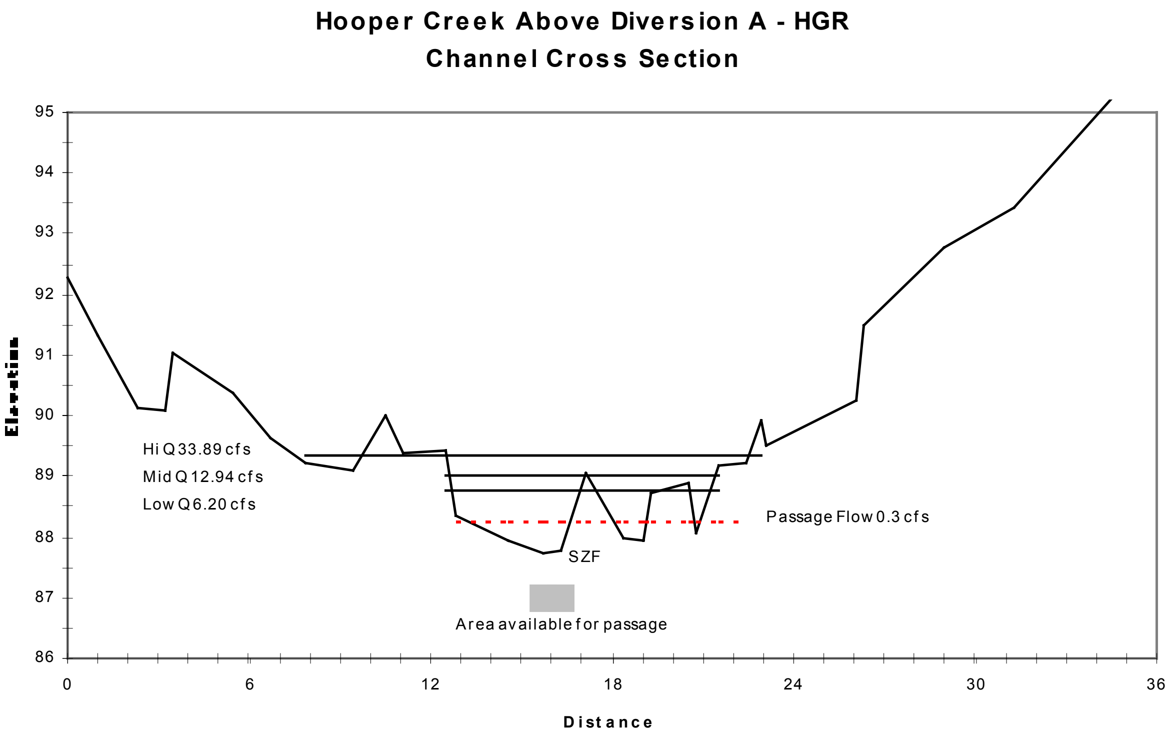
Crater Creek Below Diversion E - HGR
Wetted Perimeter vs Flow

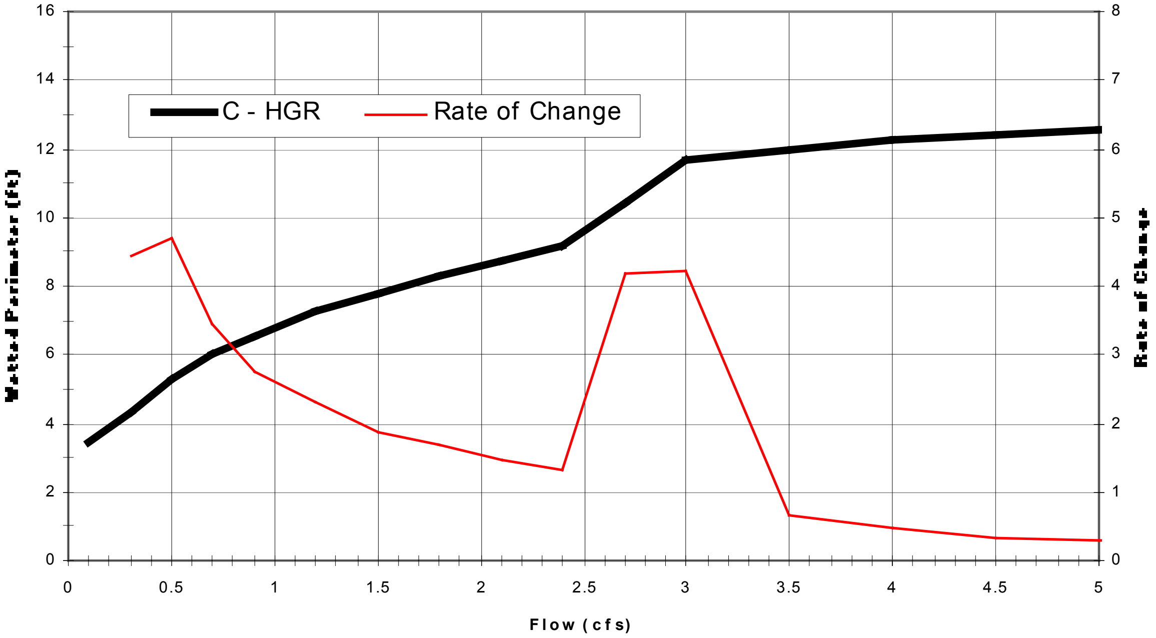


Crater Creek Below Diversion E - HGR
Channel Cross Section

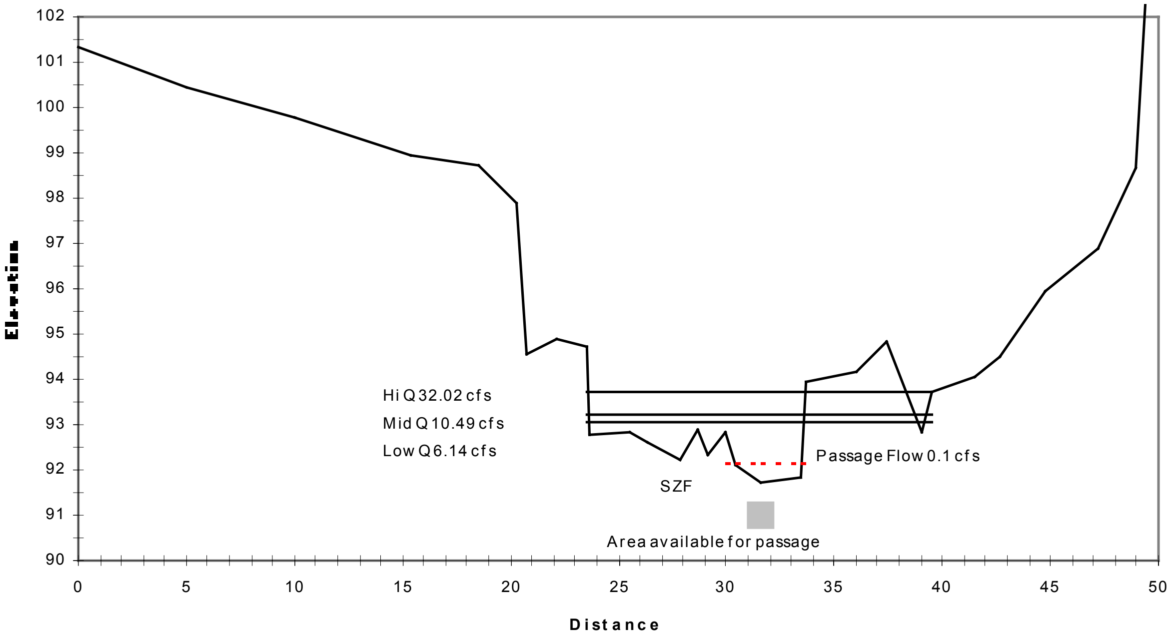



Hooper Creek Above Diversion A - HGR
Wetted Perimeter vs Flow
Wetted Perimeter (ft)
Rate of Change
Flow (cfs)
0
2
4
6
8
10
12
14
16
0
1
2
3
4
5
6
7
8
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
A - HGR
Rate of Change


Hooper Creek Above Diversion A - HGR
Channel Cross Section
Elevation
Distance
86
87
88
89
90
91
92
93
94
95
0
6
12
18
24
30
36
Hi Q 33.89 cfs
Mid Q 12.94 cfs
Low Q 6.20 cfs
Passage Flow 0.3 cfs
SZF
Area available for passage

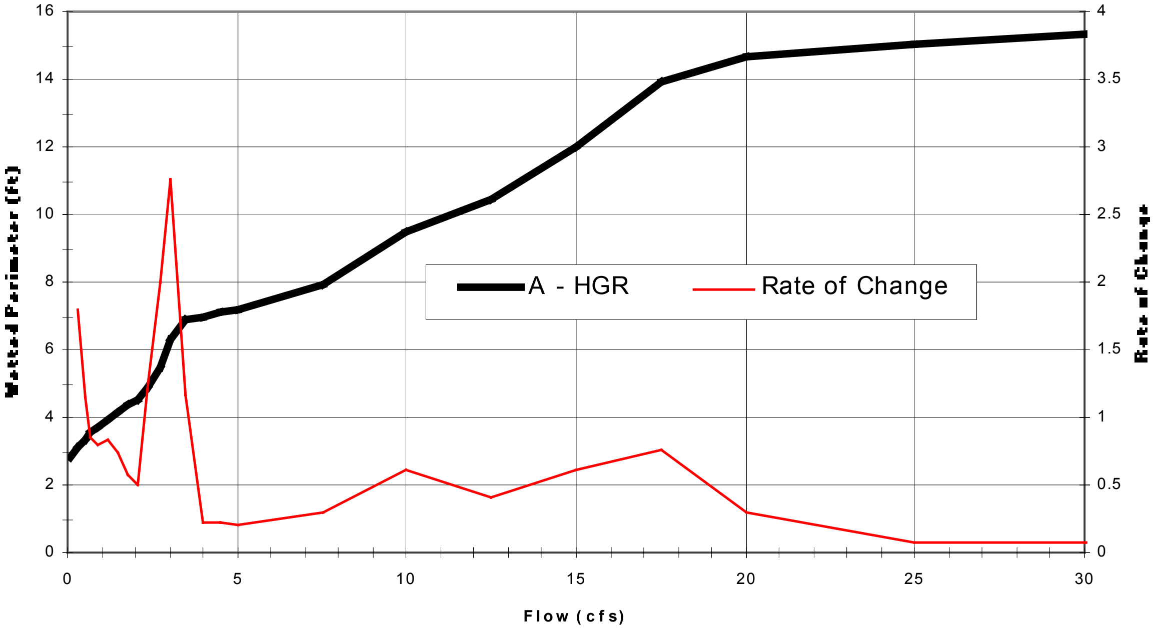


Hooper Creek Above Diversion C - HGR
Wetted Perimeter vs Flow

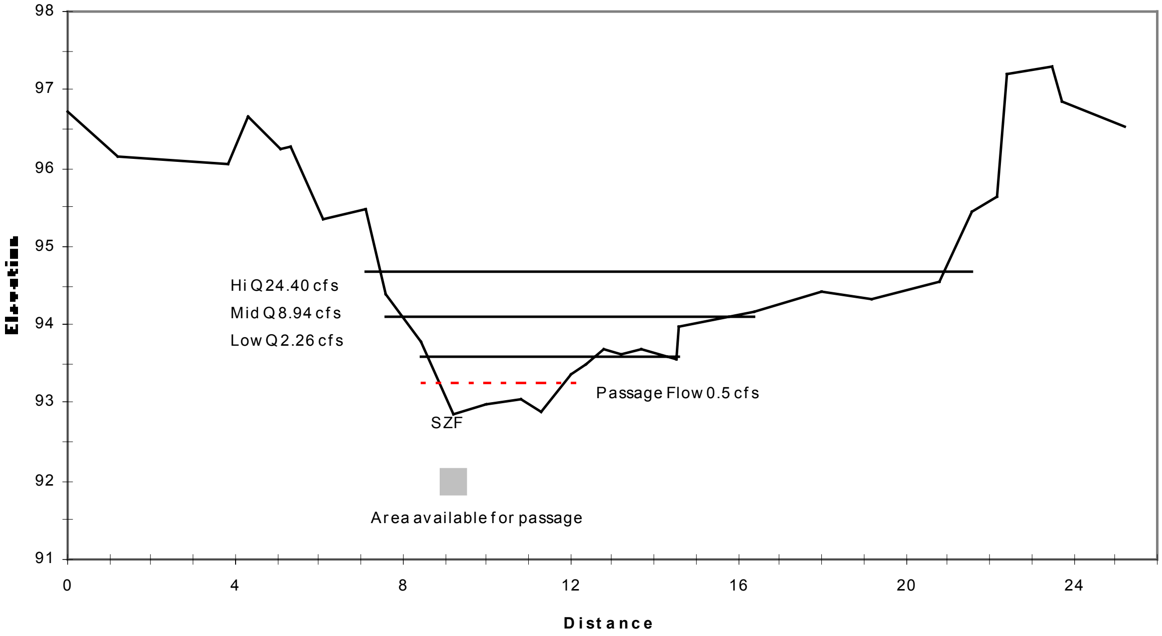


Hooper Creek Above Diversion C - HGR
Channel Cross Section

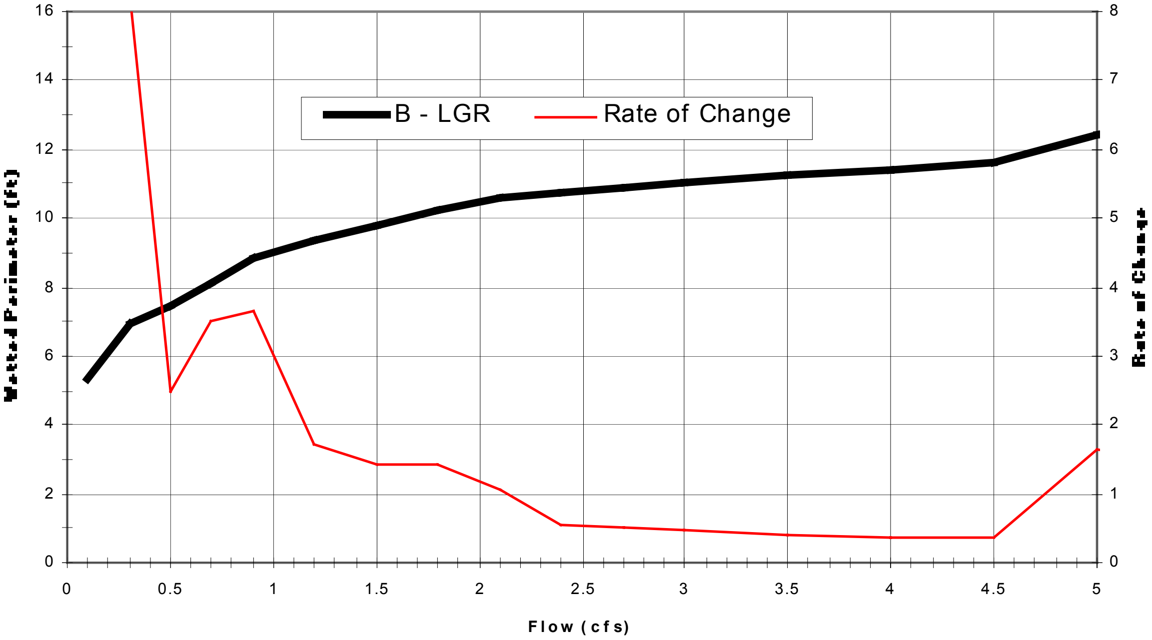
Hooper Creek Below Diversion A - HGR
Wetted Perimeter vs Flow



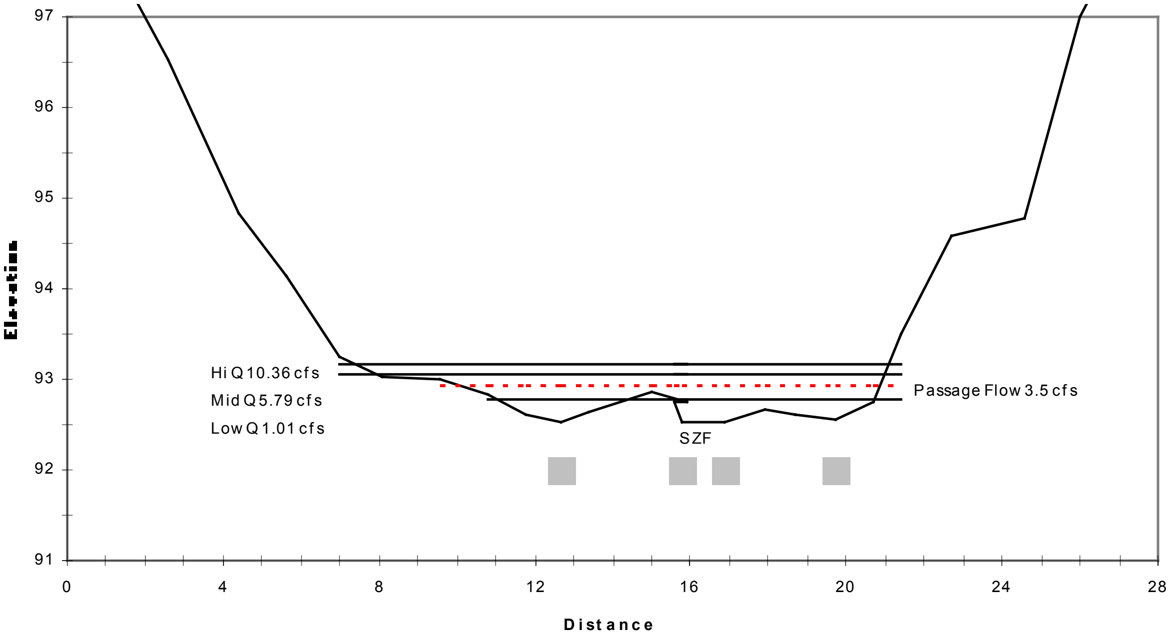
Hooper Creek Below Diversion A - HGR
Channel Cross Section



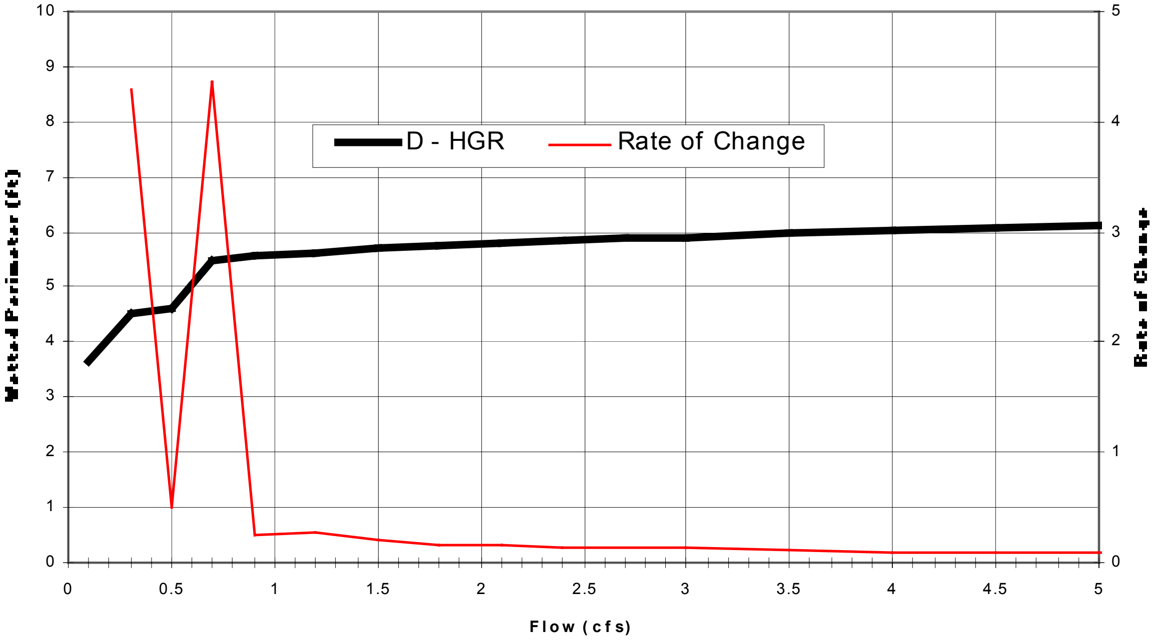
Hooper Creek Below Diversion B - LGR
Wetted Perimeter vs Flow



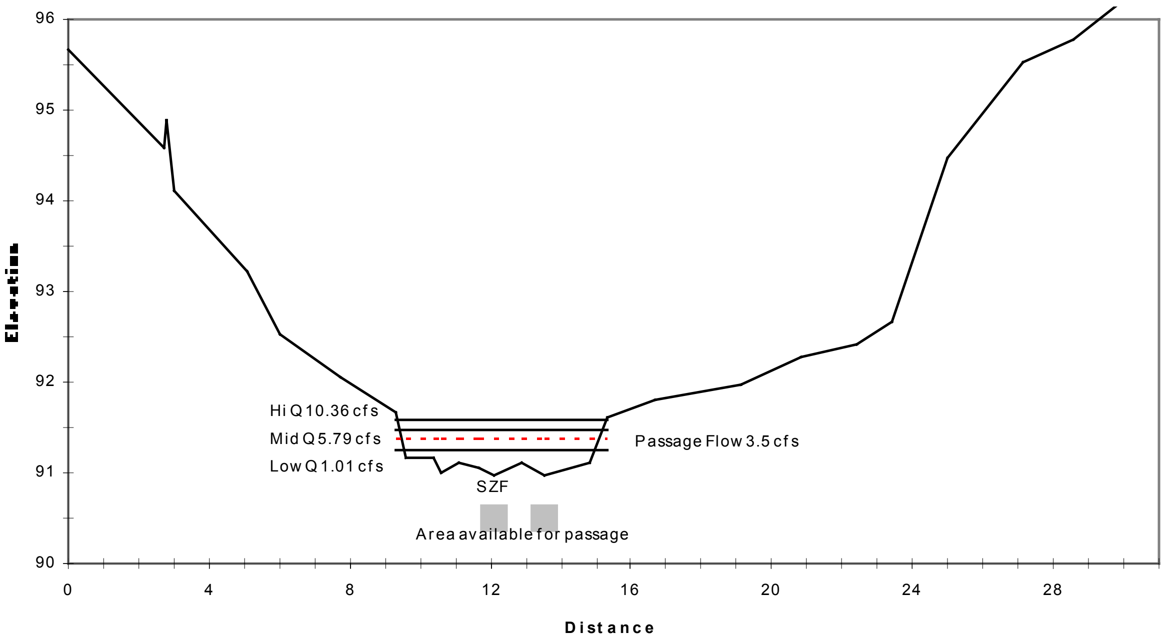
Hooper Creek Below Diversion B - LGR
Channel Cross Section



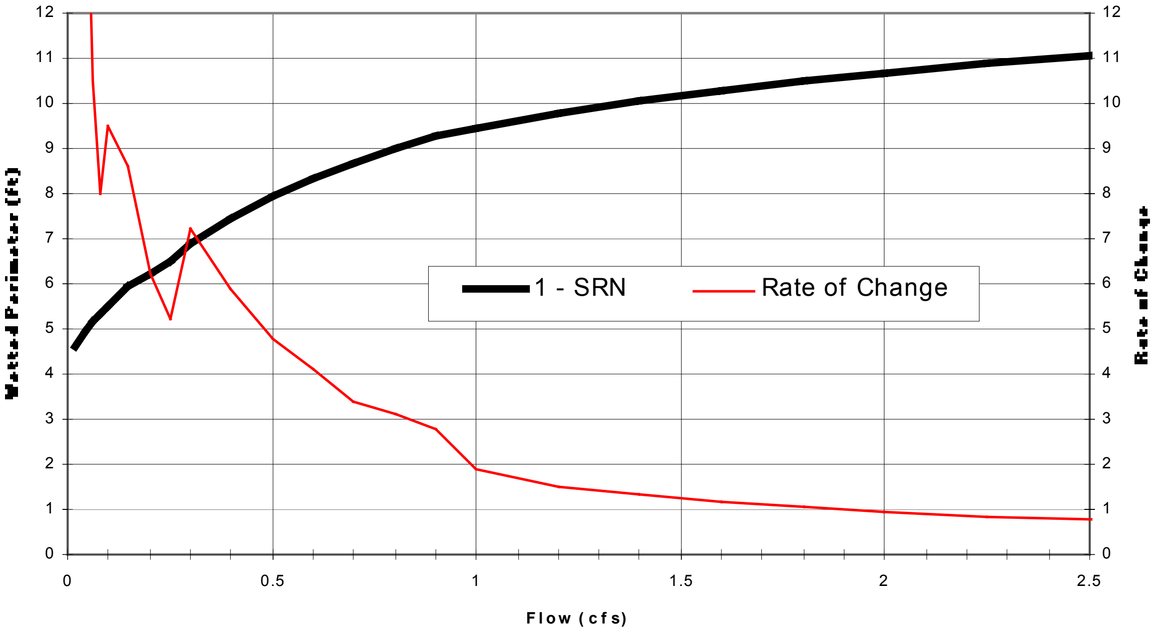
Hooper Creek Below Diversion D - HGR
Wetted Perimeter vs Flow



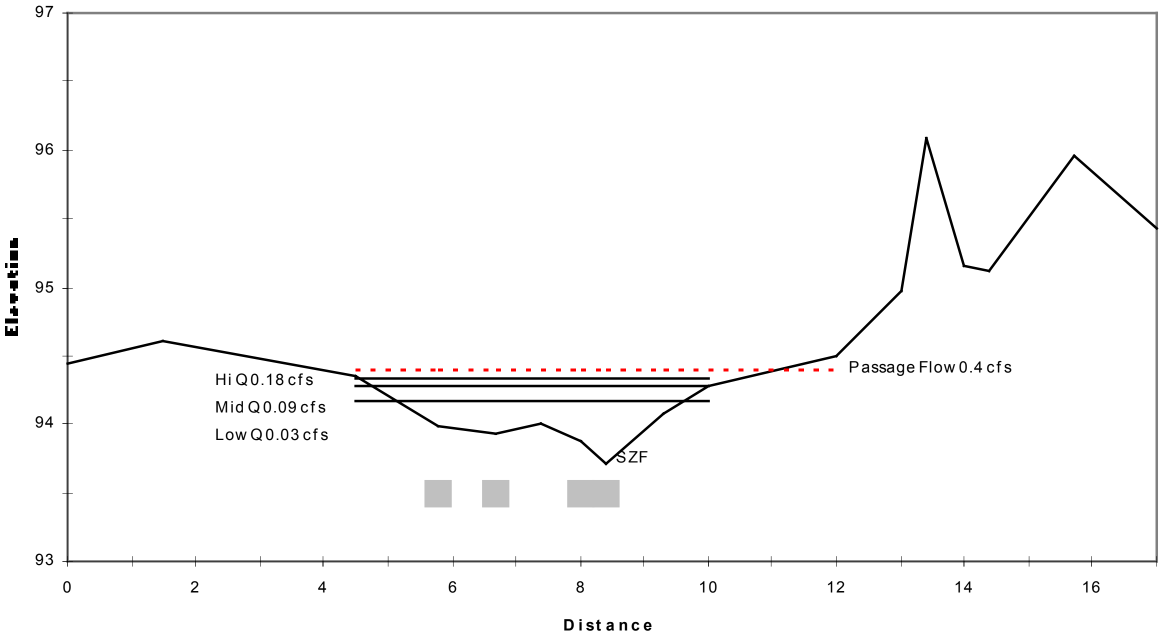
Hooper Creek Below Diversion D - HGR
Channel Cross Section



North Slide Creek Below Diversion 1 - SRN
Wetted Perimeter vs Flow

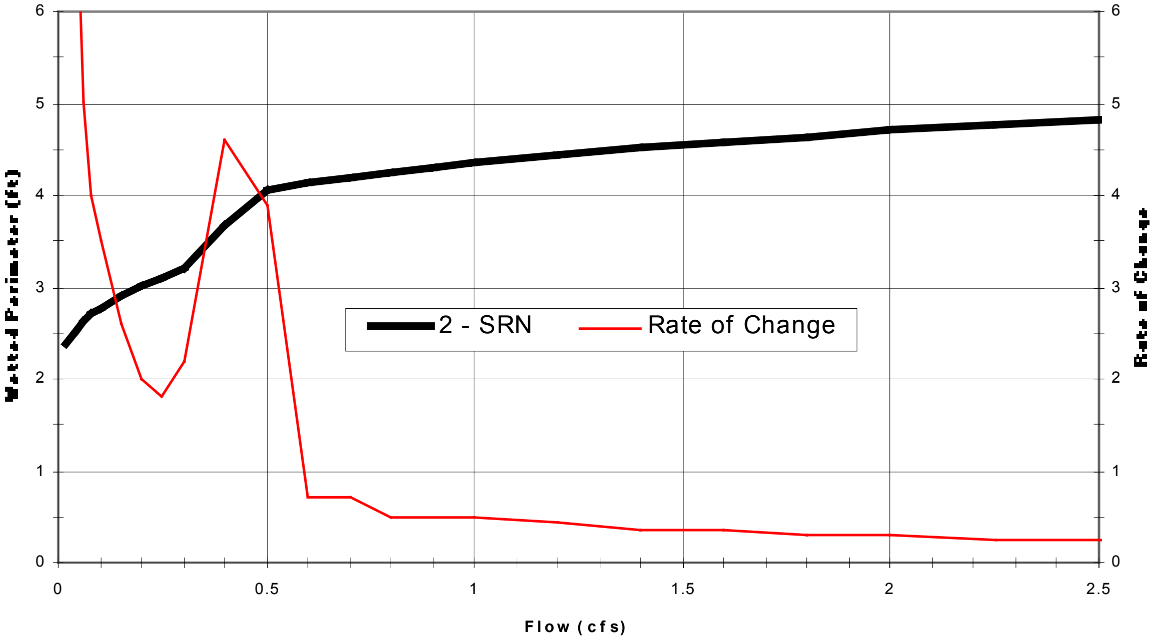


North Slide Creek Below Diversion 1 - SRN
Channel Cross Section

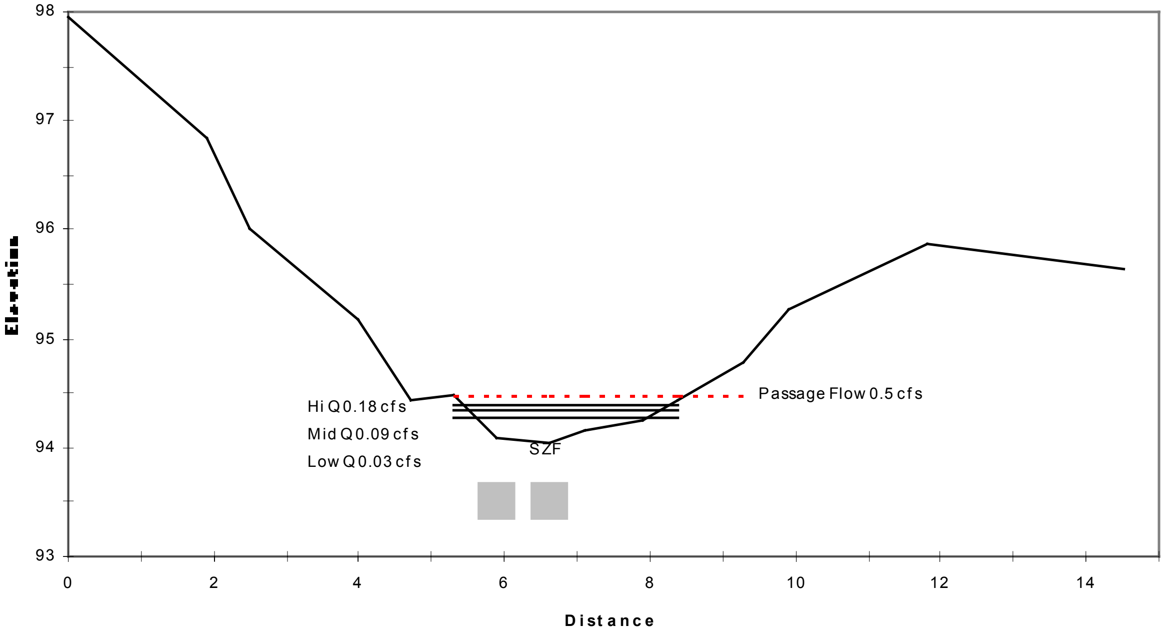


September 2003

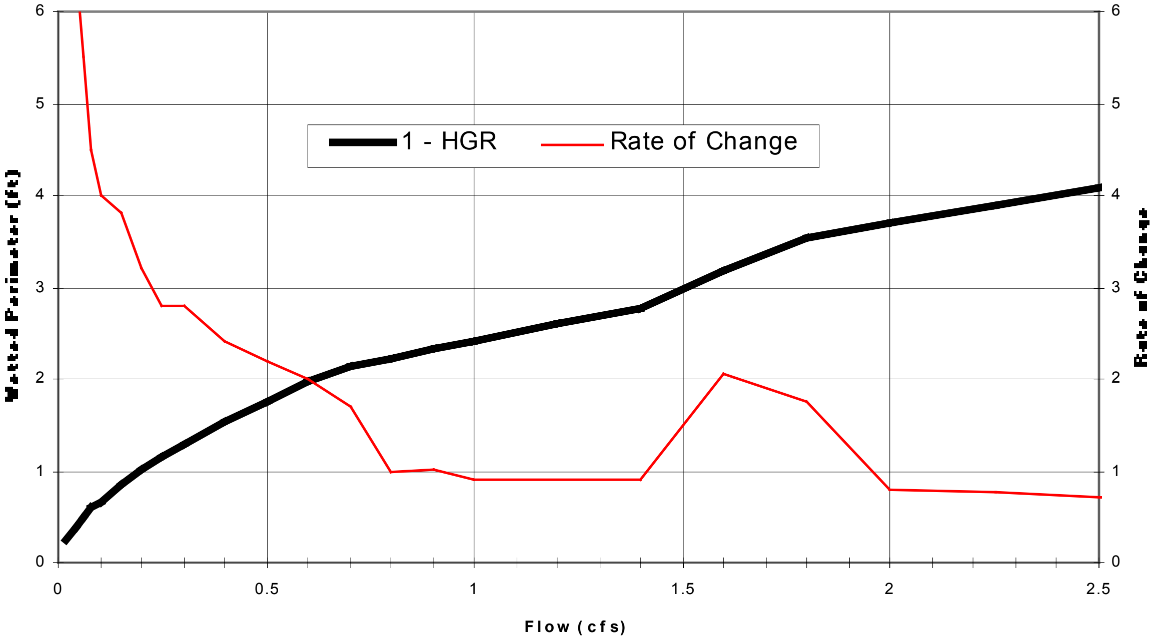
North Slide Creek Below Diversion 2 - SRN
Wetted Perimeter vs Flow



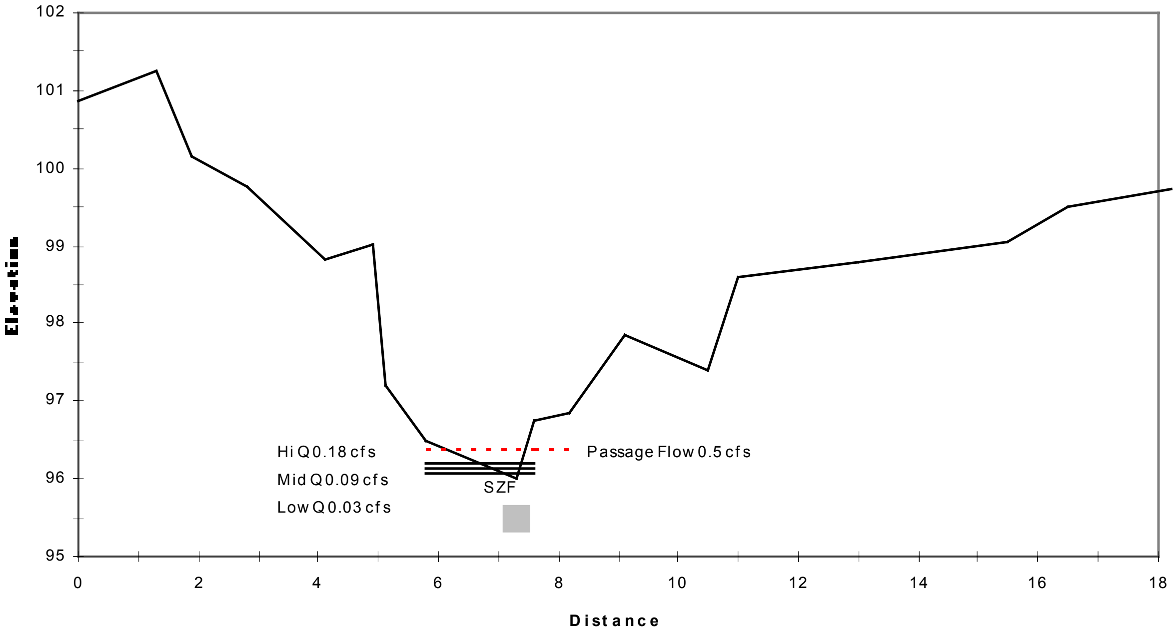
North Slide Creek Below Diversion 2 - SRN
Channel Cross Section



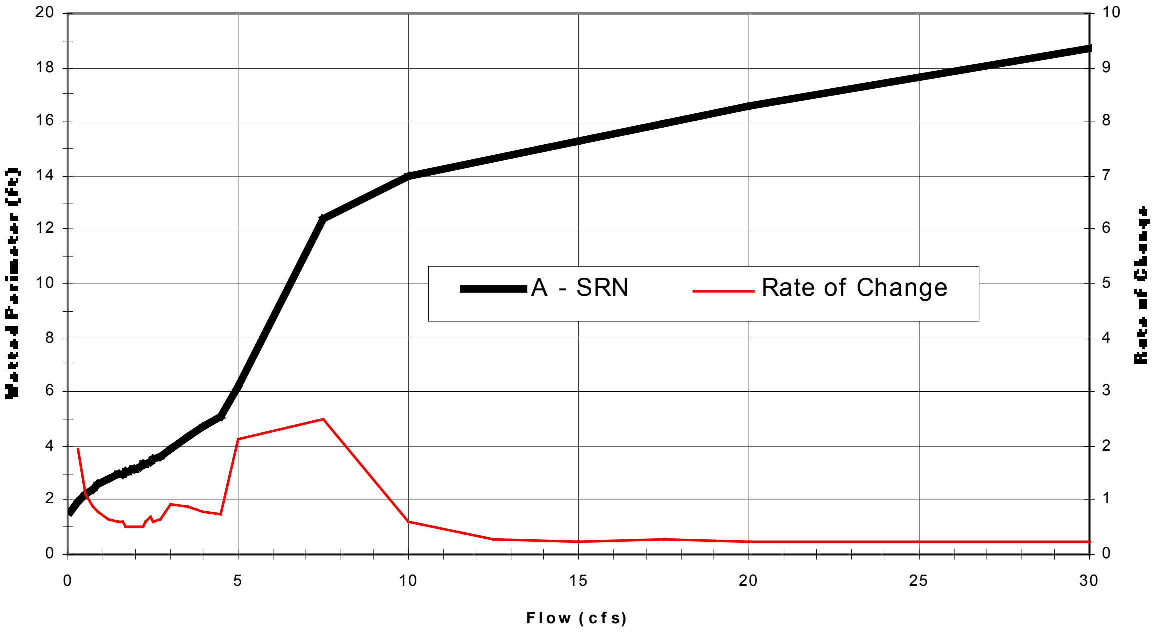
North Slide Creek Below Diversion 1 - HGR
Wetted Perimeter vs Flow



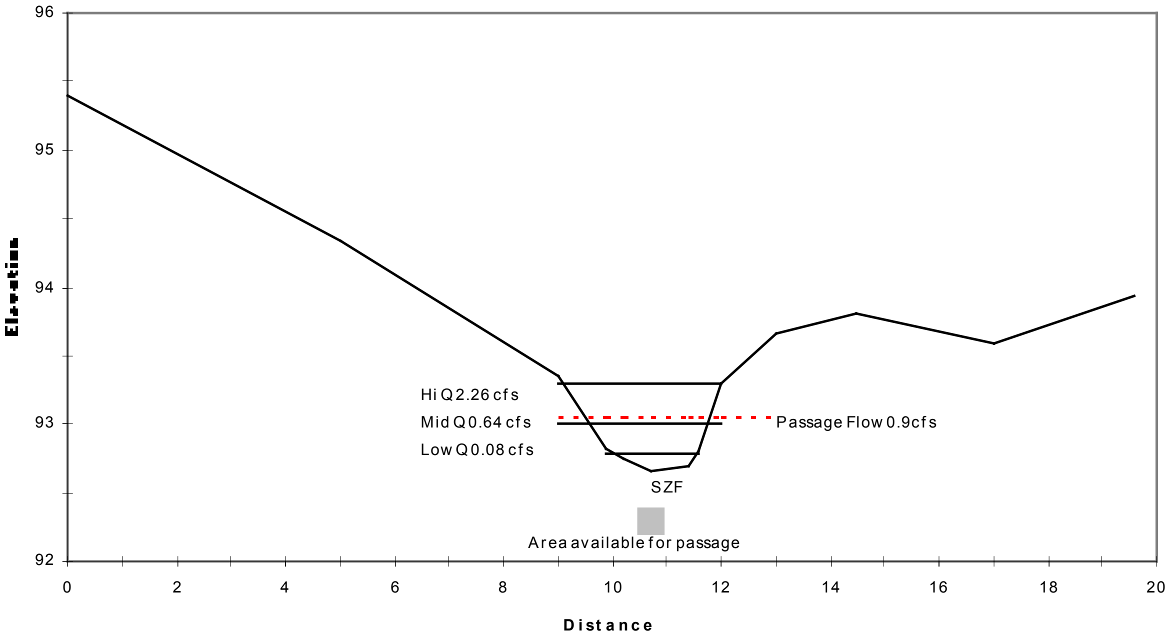
North Slide Creek Below Diversion 1 - HGR
Channel Cross Section



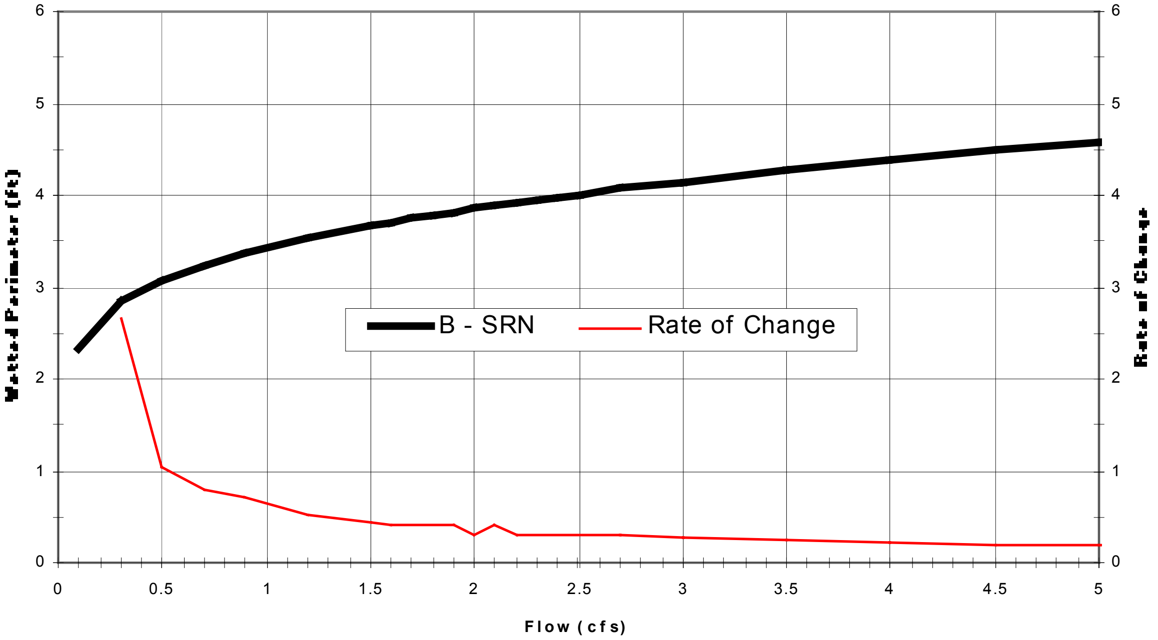
South Slide Creek Below Diversion A - SRN
Wetted Perimeter vs Flow



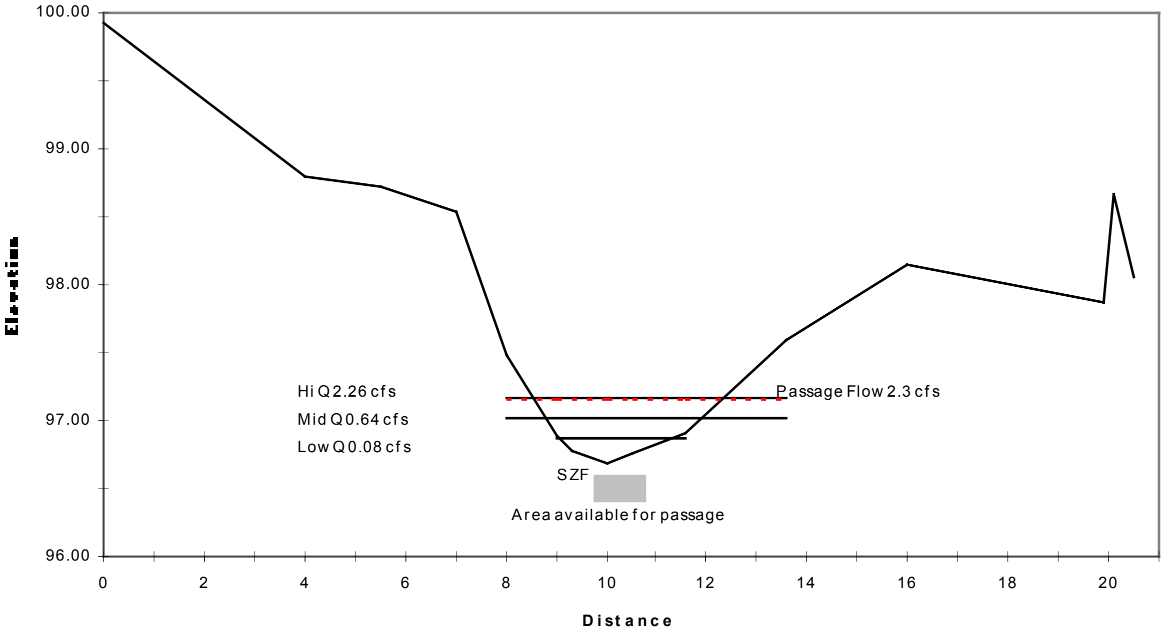
South Slide Creek Below Diversion A - SRN
Channel Cross Section

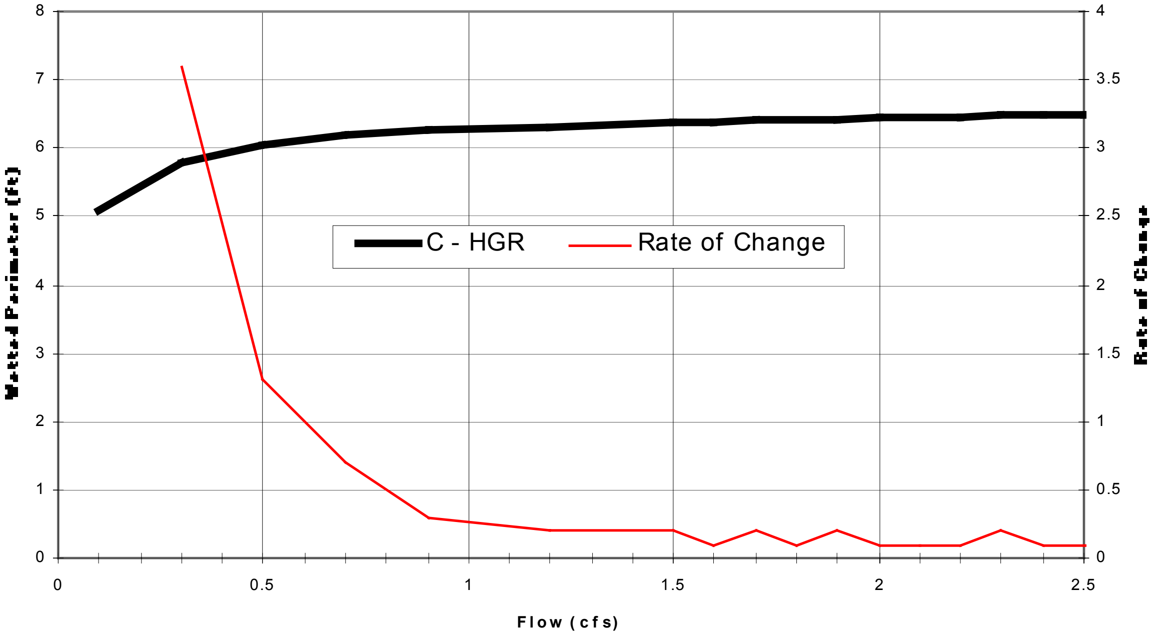


South Slide Creek Below Diversion B - SRN
Wetted Perimeter vs Flow

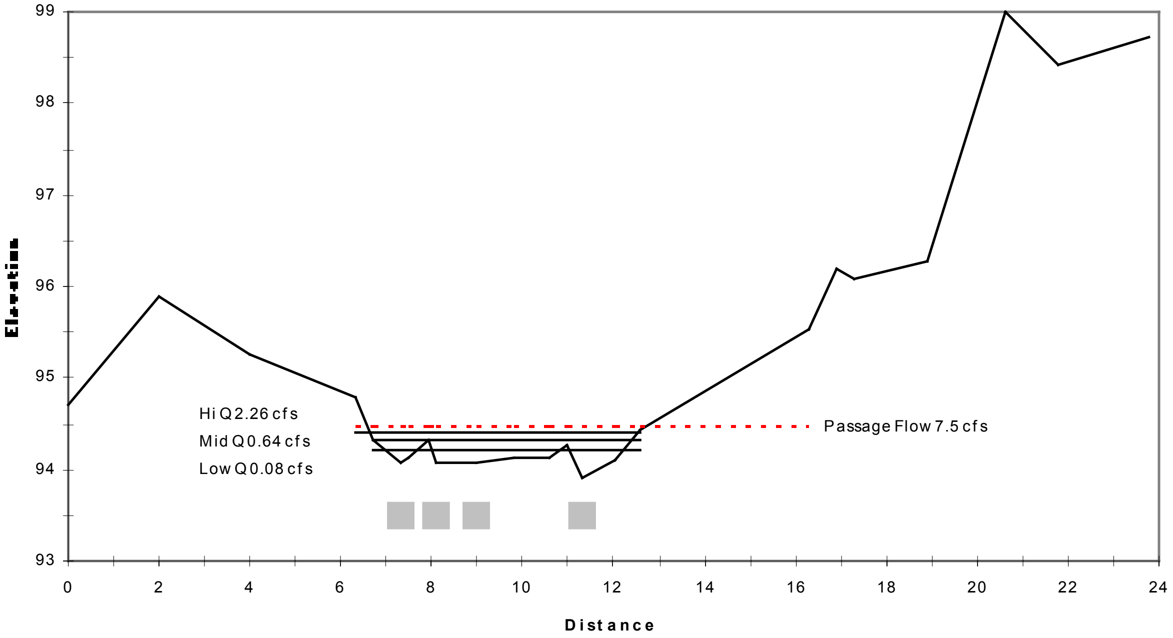


South Slide Creek Below Diversion B - SRN
Channel Cross Section



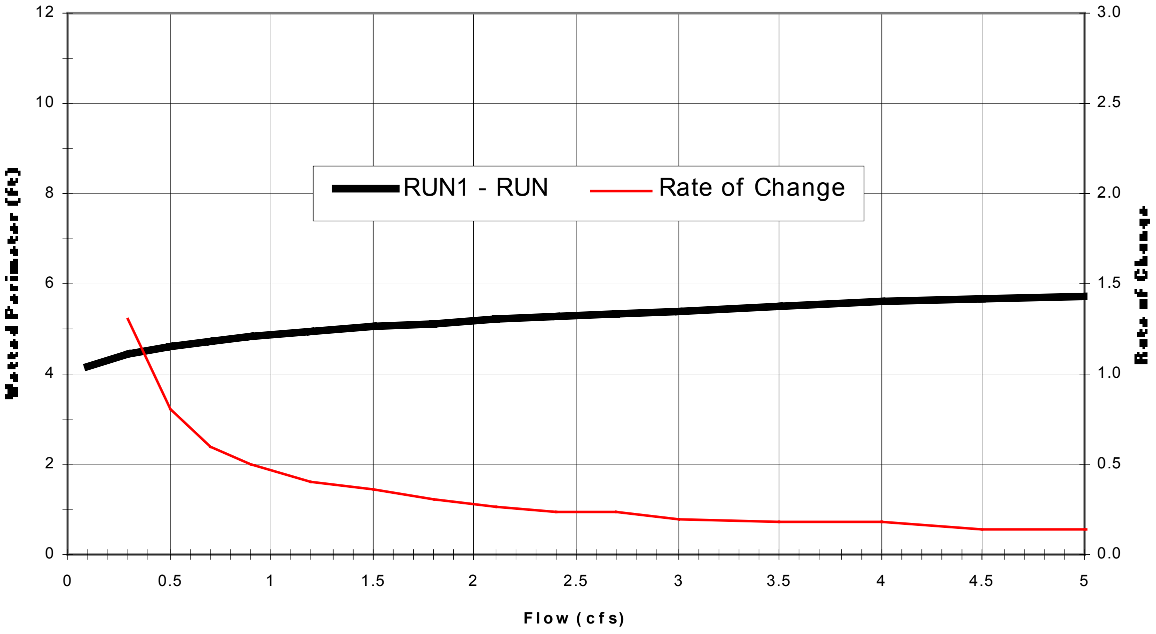


South Slide Creek Below Diversion C - HGR
Wetted Perimeter vs Flow

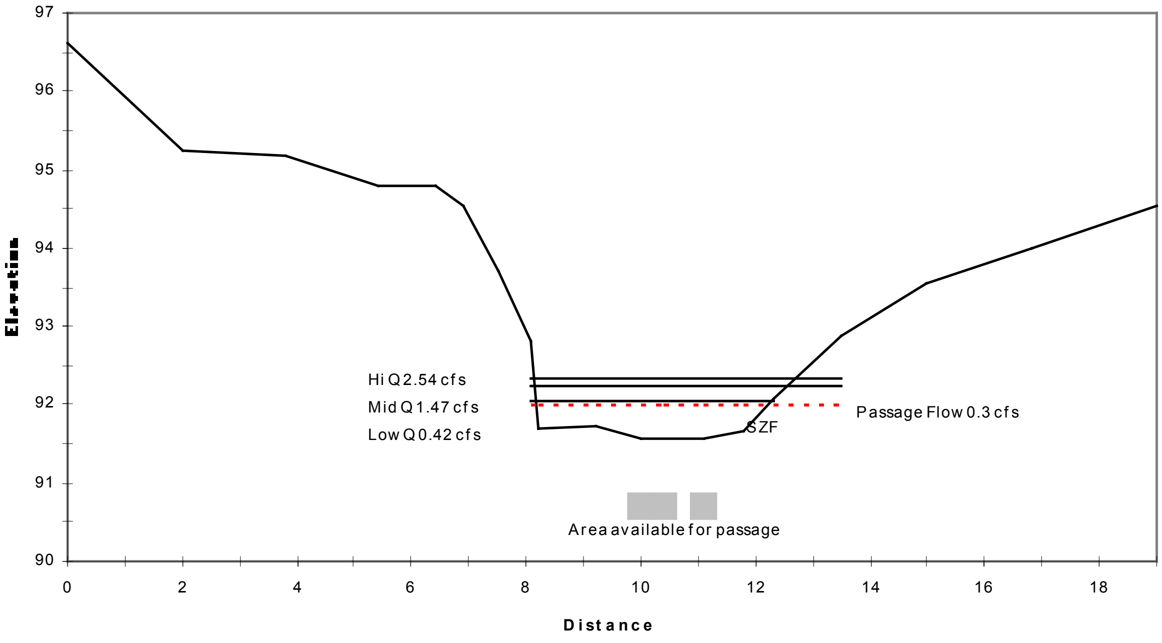


South Slide Creek Below Diversion C - HGR
Channel Cross Section

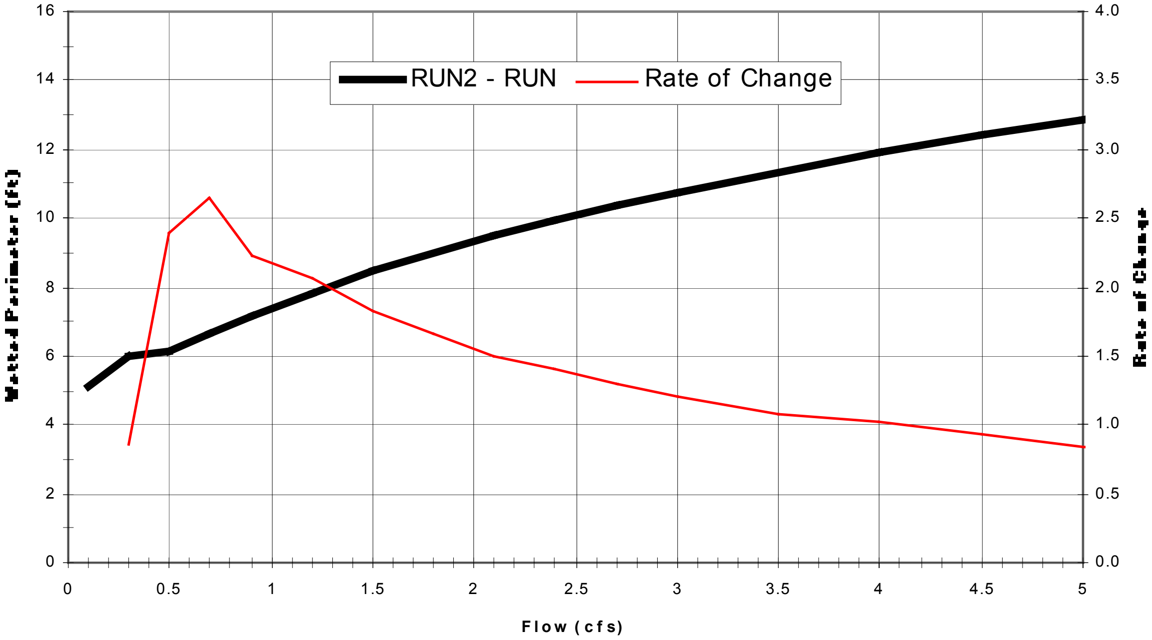
Tombstone Creek Above Diversion RUN1 - RUN
Wetted Perimeter vs Flow



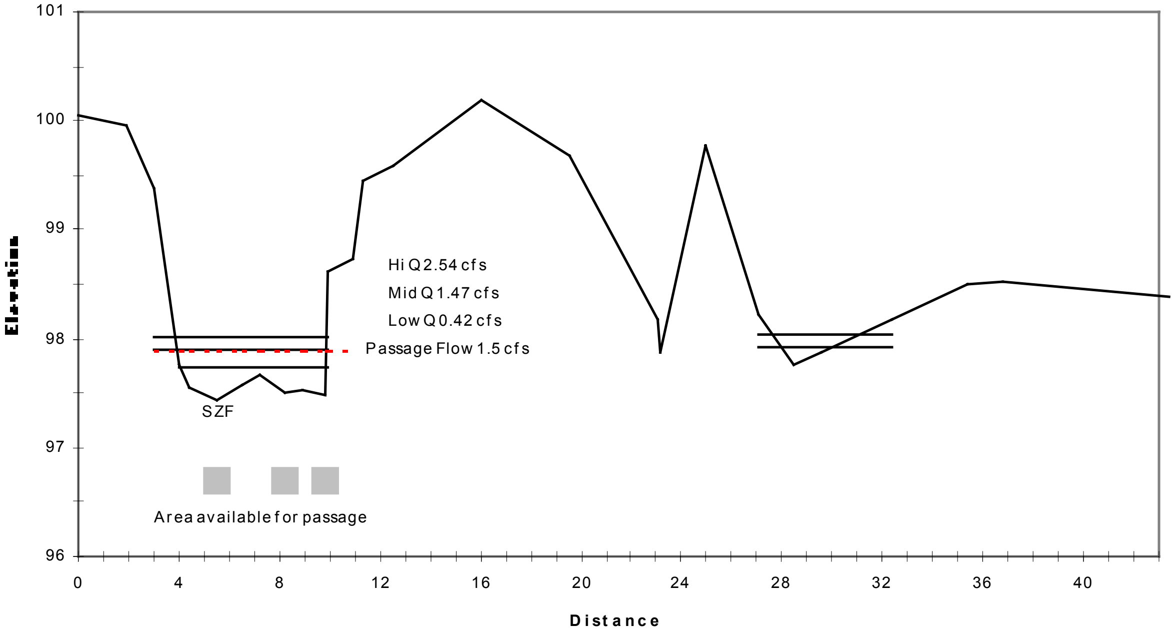
Tombstone Creek Above Diversion RUN1 - RUN
Channel Cross Section



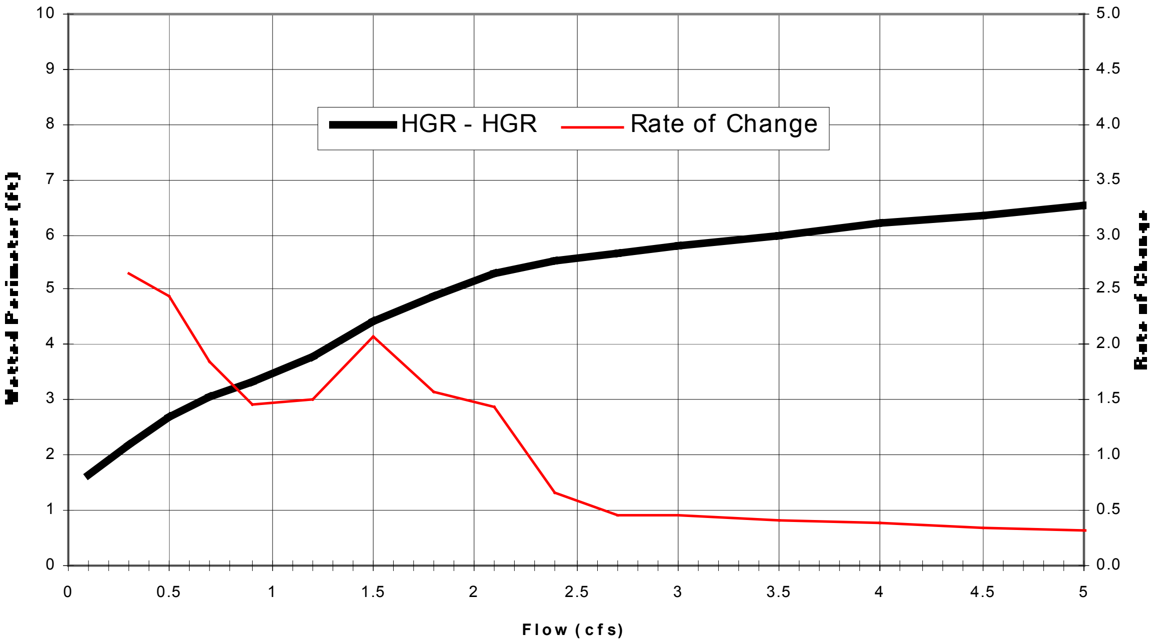
Tombstone Creek Above Diversion RUN2 - RUN
Wetted Perimeter vs Flow



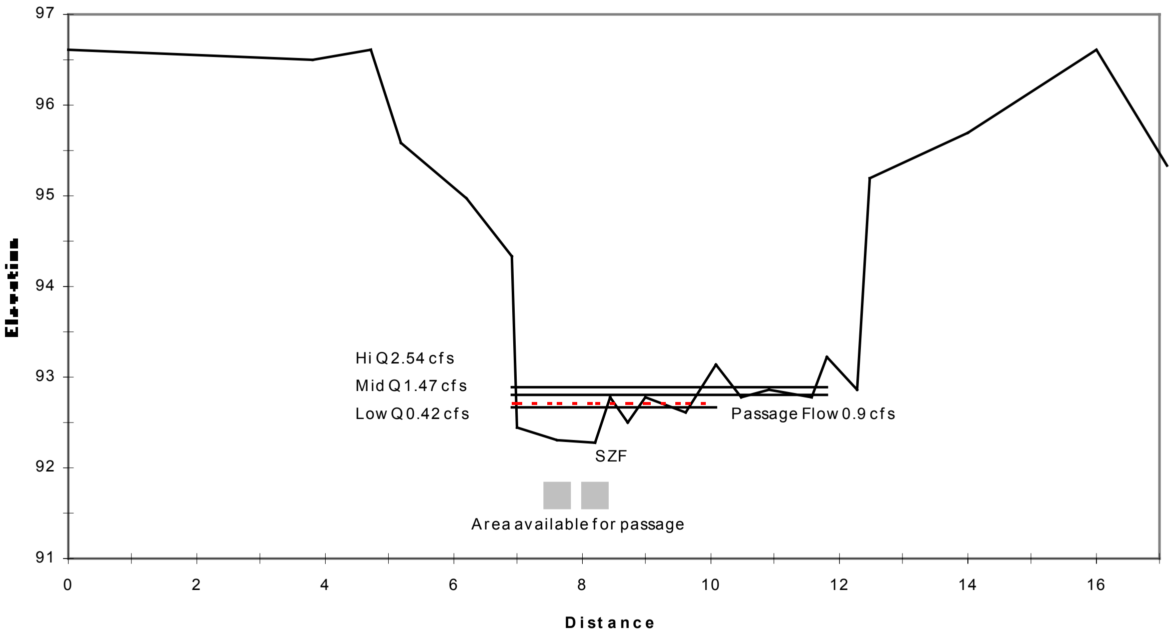
Tombstone Creek Above Diversion RUN2 - RUN
Channel Cross Section

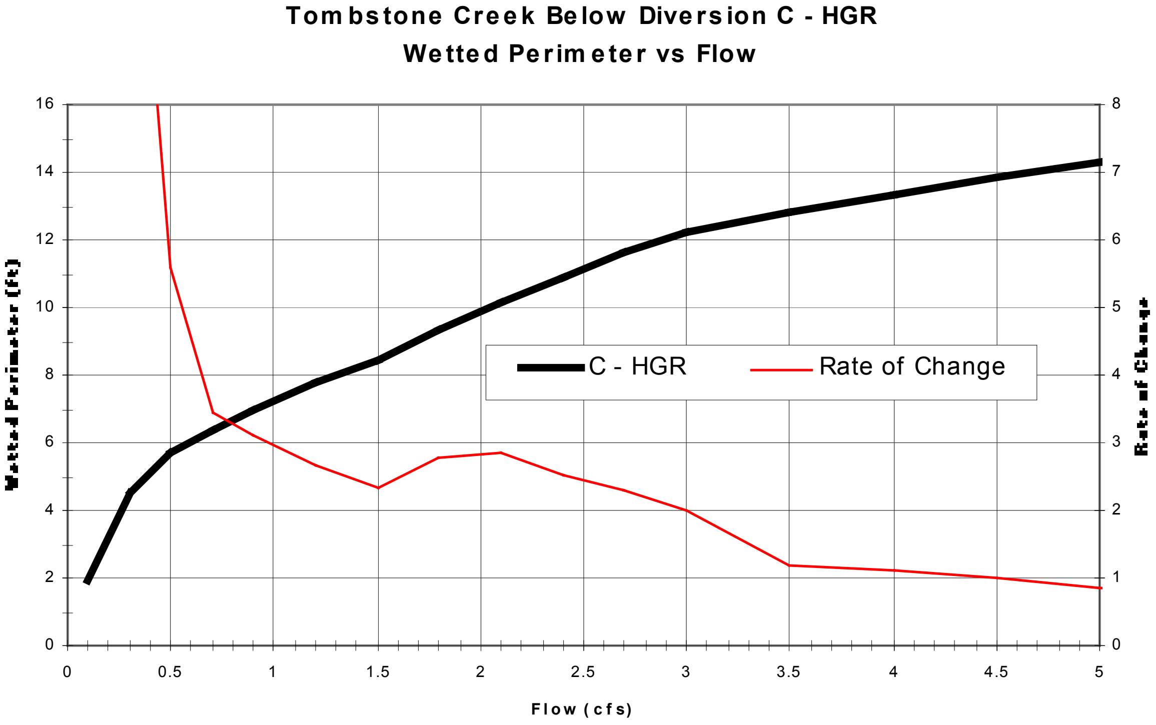


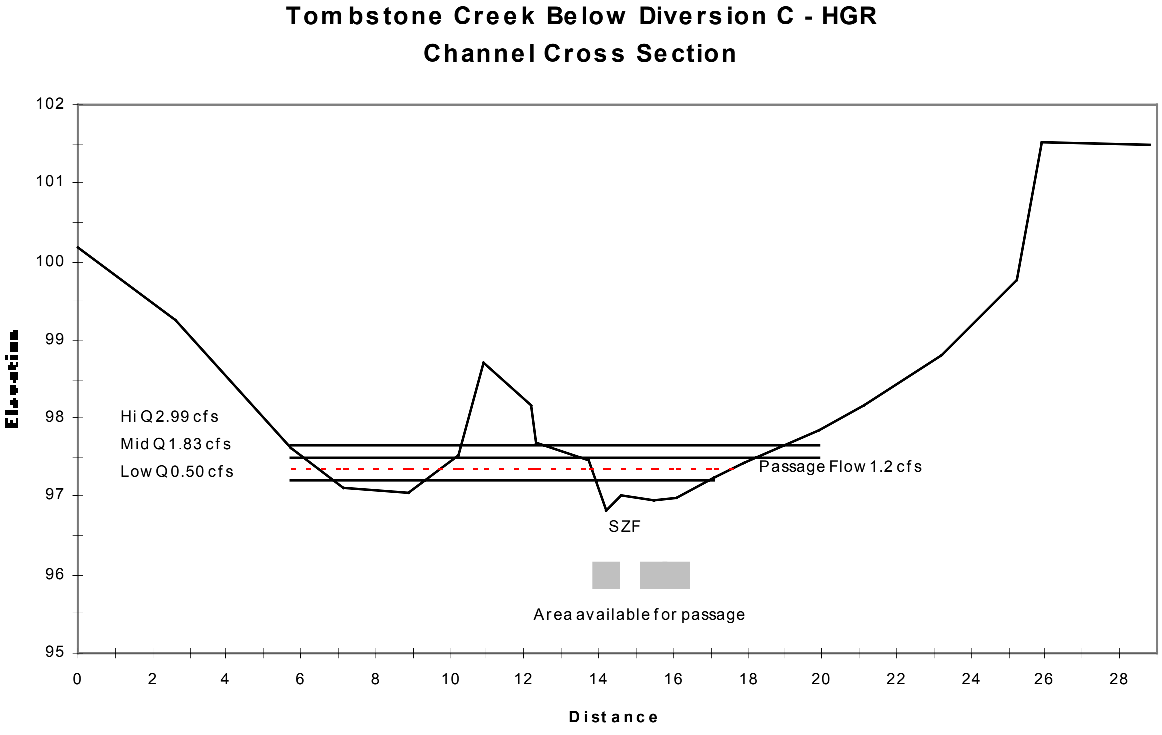
Tombstone Creek Above Diversion HGR - HGR
Wetted Perimeter vs Flow

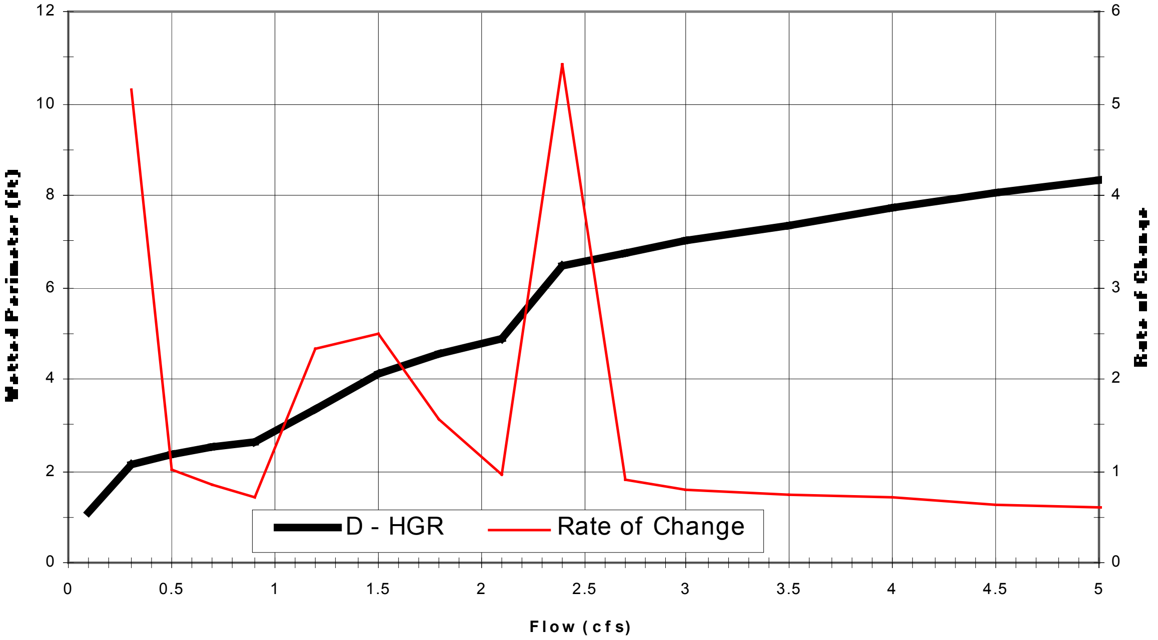


Tombstone Creek Above Diversion HGR - HGR
Channel Cross Section

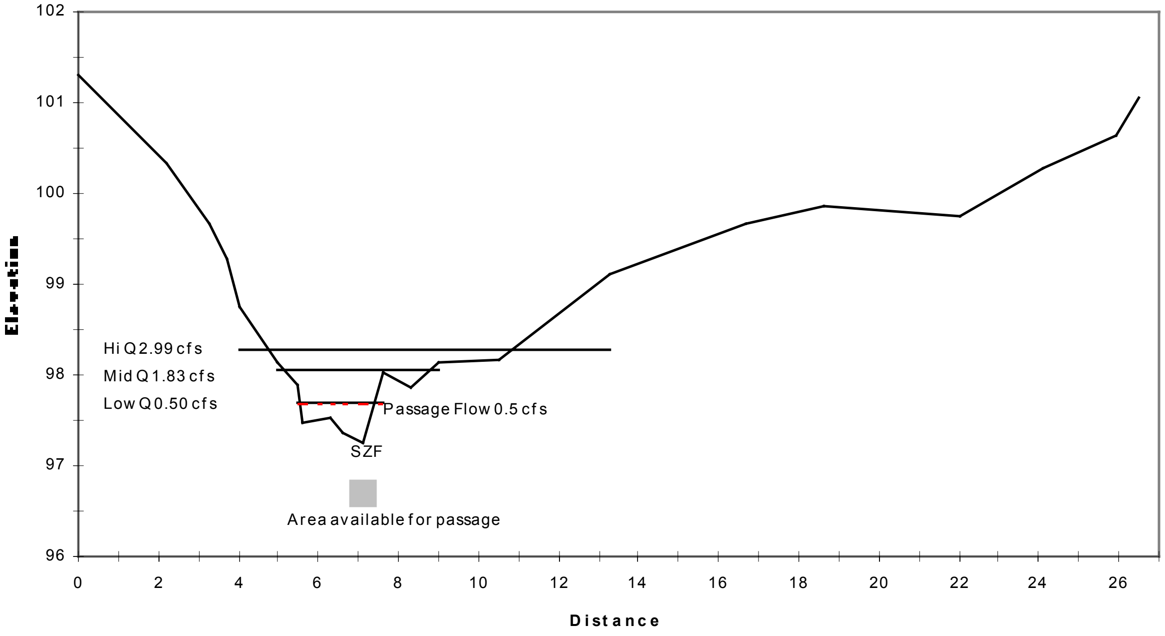



Tombstone Creek Below Diversion C - HGR
Wetted Perimeter vs Flow
Wetted Perimeter (ft)
Rate of Change
Flow (cfs)
C - HGR
Rate of Change
0
2
4
6
8
10
12
14
16
0
1
2
3
4
5
6
7
8
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Tombstone Creek Below Diversion C - HGR
Channel Cross Section
Elevation
Distance
Hi Q 2.99 cfs
Mid Q 1.83 cfs
Low Q 0.50 cfs
Passage Flow 1.2 cfs
SZF
Area available for passage
95
96
97
98
99
100
101
102
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28

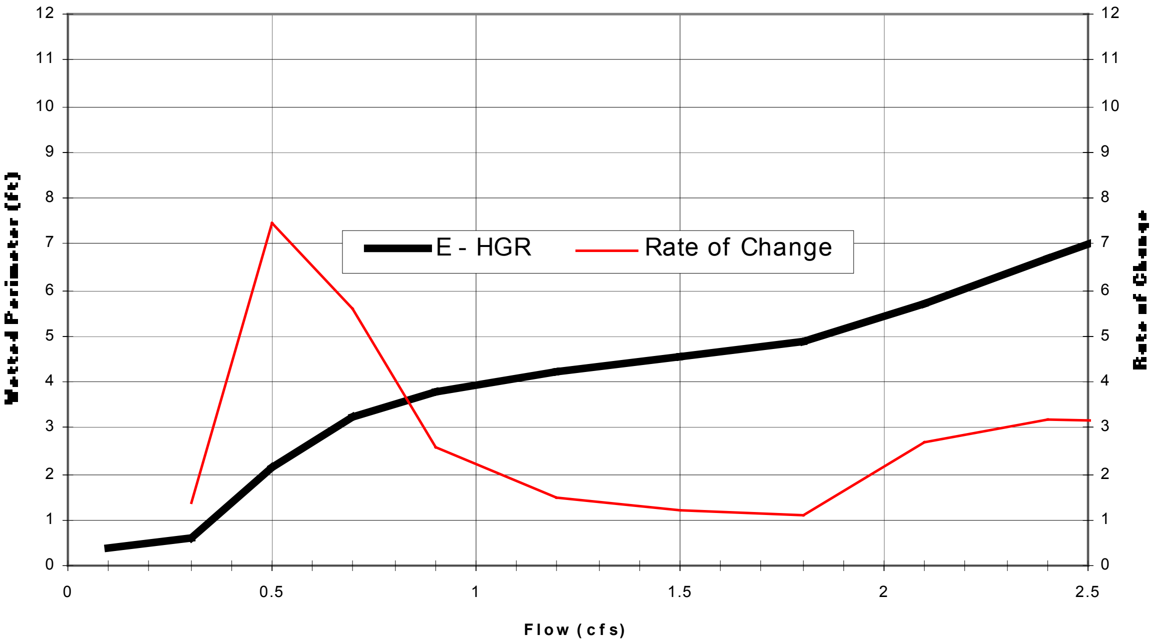


Tombstone Creek Below Diversion D - HGR
Wetted Perimeter vs Flow

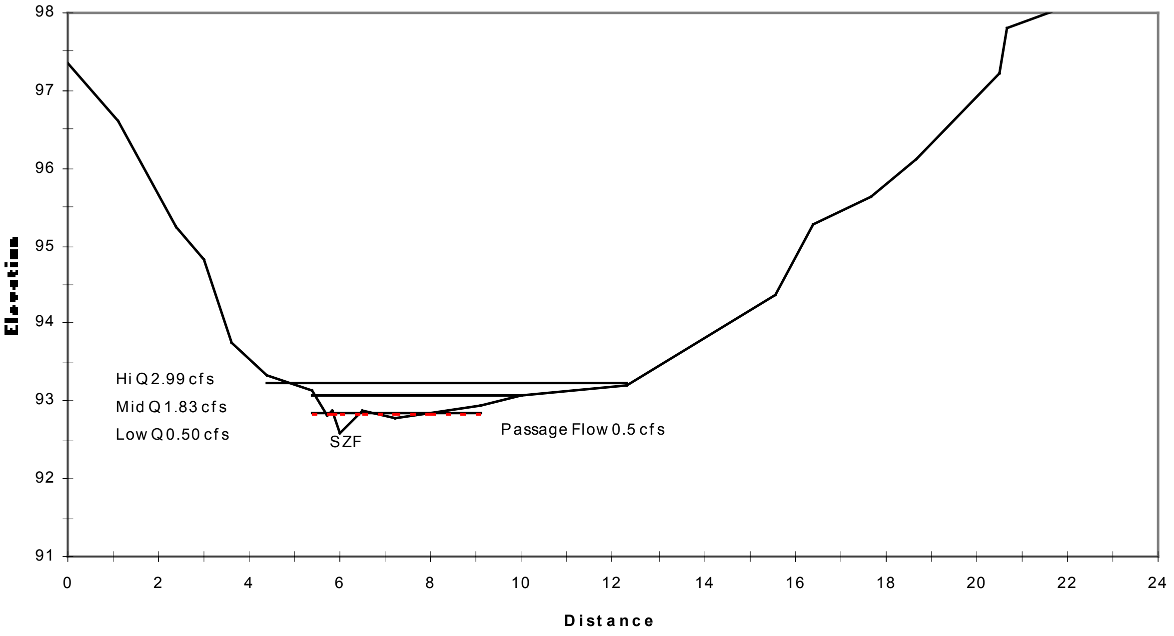


Tombstone Creek Below Diversion D - HGR
Channel Cross Section

Tombstone Creek Below Diversion E - HGR
Wetted Perimeter vs Flow



Tombstone Creek Below Diversion E - HGR
Channel Cross Section



APPENDIX C

Model Calibration Results

CAWG-3 Appendix C Table C-1. Stage Discharge Method and Model Calibration for Upper Basin Wetted Perime

Stream and Site	Transect Designation	Habitat Type[1]	Stage-Discharge Method	Flow (cfs)	Measured WSE	Predicted WSE	Stage at Zero Flow	Mean Error
Camp 62 Creek Above Diversion	A	HGR	IFG-4a	0.65	89.95	89.95	89.33	3.3
				3.81	90.18	90.19		
				12.93	90.38	90.37		
	B	HGR	IFG-4a	0.65	108.58	108.59	107.83	4.7
				3.81	109.16	109.13		
				12.93	109.70	109.73		
Camp 62 Creek Below Diversion	A	HGR	IFG-4a	0.23	94.66	94.66	94.34	2.9
				3.72	95.25	95.23		
				8.77	95.59	95.61		
	B	HGR	IFG-4a	0.23	97.80	97.80	97.44	1.2
				3.72	98.03	98.03		
				8.77	98.13	98.13		
	C	HGR	IFG-4a	0.39	95.02	95.02	94.31	6.8
				6.49	95.84	95.80		
				16.77	96.18	96.22		

[1] HGR - High Gradient Riffle
cfs = cubic feet per second

CAWG-3 Appendix C Table C-2. Stage Discharge Method and Model Calibration for Upper Basin Wetted Perime

Stream and Site	Transect Designation	Habitat Type[1]	Stage-Discharge Method	Flow (cfs)	Measured WSE	Predicted WSE	Stage at Zero Flow	Mean Error
Chinquapin Creek Below Diversion	C1	LGR	IFG-4a	0.15	92.05	92.05	91.66	2.5
				2.64	92.46	92.45		
				5.66	92.61	92.62		
	C2	LGR	IFG-4a	0.15	92.31	92.31	92.05	2.9
				2.64	92.63	92.62		
				5.66	92.75	92.76		
	C3	LGR	IFG-4a	0.15	94.34	94.34	94.16	5.9
				2.64	94.71	94.69		
				5.66	94.85	94.87		

[1] LGR - Low Gradient Riffle
cfs = cubic feet per second

CAWG-3 Appendix C Table C-3. Stage Discharge Method and Model Calibration for Upper Basin Wetted Perime

Stream and Site	Transect Designation	Habitat Type[1]	Stage-Discharge Method	Flow (cfs)	Measured WSE	Predicted WSE	Stage at Zero Flow	Mean Error
Crater Creek Above Diversion	DS_RIF	SRN	IFG-4a	0.68	92.94	92.93	92.34	7.4
				7.86	93.60	93.65		
				18.64	94.11	94.07		
	PL	SPO	IFG-4a	0.68	91.70	91.70	91.04	1.9
				7.86	92.35	92.34		
				18.64	92.68	92.69		
	US_RIF	SRN	IFG-4a	0.68	93.34	93.34	92.73	3.1
				7.86	93.87	93.88		
				18.64	94.19	94.18		
Crater Creek Below Diversion	A	HGR	IFG-4a	0.01	94.30	94.30	93.98	5.6
				2.14	94.89	94.91		
				13.98	95.34	95.32		
	C	HGR	MANSQ	2.14	95.48	95.48	94.48	NA
				13.98	96.02	96.02		
	E	HGR	MANSQ	2.14	92.14	92.14	91.47	NA
				13.98	93.13	93.12		

[1] SRN - Step Run, SPO - Step Pool, HGR - High Gradient Riffle
cfs = cubic feet per second

CAWG-3 Appendix C Table C-4. Stage Discharge Method and Model Calibration for Upper Basin Wetted Perime

Stream and Site	Transect Designation	Habitat Type[1]	Stage-Discharge Method	Flow (cfs)	Measured WSE	Predicted WSE	Stage at Zero Flow	Mean Error
Hooper Creek Above Diversion	A	HGR	IFG-4a	6.20	88.80	88.79	87.89	4.2
				12.94	88.98	89.00		
				33.89	89.36	89.35		
	C	HGR	IFG-4a	6.14	93.02	93.04	91.73	5.1
				10.49	93.26	93.23		
				32.02	93.72	93.74		
Hooper Creek Below Diversion	A	HGR	IFG-4a	2.26	93.58	93.58	92.85	0.8
				8.94	94.10	94.10		
				24.40	94.68	94.69		
	B	LGR	IFG-4a	1.01	92.79	92.79	92.52	0.3
				5.79	93.03	93.03		
				10.36	93.18	93.18		
	D	HGR	IFG-4a	1.01	91.24	91.24	90.97	0.8
				5.79	91.47	91.47		
				10.36	91.59	91.59		

[1] HGR - High Gradient Riffle, LGR - Low Gradient Riffle
cfs = cubic feet per second

CAWG-3 Appendix C Table C-5. Stage Discharge Method and Model Calibration for Upper Basin Wetted Perime

Stream and Site	Transect Designation	Habitat Type[1]	Stage-Discharge Method	Flow (cfs)	Measured WSE	Predicted WSE	Stage at Zero Flow	Mean Error
North Slide Creek Below Diversion	1	SRN	IFG-4a	0.04	94.21	94.21	93.72	6.1
				0.09	94.28	94.27		
				0.18	94.33	94.34		
	2	SRN	MANSQ	0.04	94.29	94.29	94.26	NA
				0.09	94.34	94.34		
				0.18	94.39	94.39		
	1	HGR	IFG-4a	0.04	96.08	96.08	95.99	2.2
				0.09	96.14	96.14		
				0.18	96.21	96.21		

[1] SRN - Step Run, HGR - High Gradient Riffle
cfs = cubic feet per second

CAWG-3 Appendix C Table C-6. Stage Discharge Method and Model Calibration for Upper Basin Wetted Perime

Stream and Site	Transect Designation	Habitat Type[1]	Stage-Discharge Method	Flow (cfs)	Measured WSE	Predicted WSE	Stage at Zero Flow	Mean Error
South Slide Creek Below Diversion	A	SRN	IFG-4a	0.08	92.78	92.78	92.66	6.8
				0.64	92.98	93.00		
				2.26	93.32	93.30		
	B	SRN	IFG-4a	0.08	96.86	96.86	96.69	6.4
				0.64	97.02	97.01		
				2.26	97.15	97.16		
	C	HGR	IFG-4a	0.08	94.20	94.20	93.90	1.6
				0.64	94.31	94.31		
				2.26	94.40	94.40		

[1] SRN - Step Run, HGR - High Gradient Riffle
cfs = cubic feet per second

CAWG-3 Appendix C Table C-7. Stage Discharge Method and Model Calibration for Upper Basin Wetted Perime

Stream and Site	Transect Designation	Habitat Type[1]	Stage-Discharge Method	Flow (cfs)	Measured WSE	Predicted WSE	Stage at Zero Flow	Mean Error
Tombstone Creek Above Diversion	RUN1	RUN	MANSQ	0.47	92.06	92.06	91.78	NA
				2.67	92.34	92.34		
	RUN2	RUN	IFG-4a	0.47	97.74	97.74	97.44	3.2
				1.47	97.91	97.92		
				2.67	98.01	98.01		
	HGR	HGR	IFG-4a	0.47	92.66	92.66	92.28	0.5
				1.47	92.80	92.80		
				2.67	92.89	92.89		
Tombstone Creek Below Diversion	C	HGR	IFG-4a	0.50	97.20	97.20	96.82	5.4
				1.87	97.51	97.48		
				2.98	97.62	97.65		
	D	HGR	IFG-4a	0.50	97.70	97.70	97.26	3.1
				1.83	98.08	98.06		
				2.99	98.25	98.27		
	E	HGR	IFG-4a	0.50	92.84	92.84	92.58	1.7
				1.83	93.09	93.08		
				2.99	93.22	93.23		

[1] RUN - Run, HGR - High Gradient Riffle

[2] Debris accumulation changed water surface elevation

cfs = cubic feet per second

APPENDIX D