Evaluation of Minimum Flow Requirements in the South Fork Flathead River Downstream of Hungry Horse Dam, Montana

September 2000

Evaluation of Minimum Flow Requirements in the South Fork Flathead River Downstream of Hungry Horse Dam, Montana

Montana Wetted Perimeter Method

August and September 2000

Prepared by:

Brian Marotz and Clint Muhlfeld

Montana Fish, Wildlife & Parks
490 North Meridian Road
Kalispell, MT 59901

Prepared for:

Ron Morinaka, EWP

Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208

Contract Number 92 BI 60559
Project Number: 19-19-3
FWP 31002

September 2000

ACKNOWLEDEMENTS

Durae Daniels and Rick Hunt (MFWP) provided technical expertise during field surveys. John Muhlfeld (Land and Water Consulting) provided computer software used during transect profile analysis. Fred Nelson (retired FWP developer of the WETP technique) and Kate Walker (USFWS) provided valuable advice on methodology. Ralph Carter and Kim Fodrea (BOR) assured that discharges remained within the necessary ranges for precise stage measurements during the rapid deployment of the technique. Steve Glutting produced the study area map. The entire project was initiated and completed during late August and early September 2000.

EXECUTIVE SUMMARY

This project was completed by Montana Fish, Wildlife & Parks at the request of the Bonneville Power Administration and U.S. Fish and Wildlife Service to clarify the minimum flow requirement for the South Fork Flathead River downstream of Hungry Horse Dam. The existing minimum flow in this reach is 145 cfs. This volume is less than the turbine flow needed to maintain station service power at the dam (approximately 300 cfs). Prior estimates of the required minimum flow for this river reach were based on the Montana Wetted Perimeter technique in the South Fork Flathead River upstream of Hungry Horse Reservoir and may not be descriptive of the reach downstream of Hungry Horse Dam. Direct measurements in the affected reach were necessary to establish a minimum flow that adequately protects fish species of special concern, including threatened bull trout (*Salvelinus confluentus*).

The U.S. Bureau of Reclamation provided a gradual reduction of Hungry Horse Dam discharges to enable measurements for calibrating the WETP model. Field sampling began on August 22, 2000 and was completed on September 5, 2000. Stage measurements were completed at six transects located across riffles and shallow runs, at five levels of flow. Riffle and shallow run habitats were the focus of the WETP technique because they are most susceptible to dewatering as flows decline, and contain unembedded cobble substrate critical to aquatic insect production. Variation explained by the stage - discharge linear regression models for each transect ranged from R^2= 0.98 to 0.99. Specific estimates of wetted perimeter at each transect and water stage were evaluated separately by habitat type and later pooled to establish the minimum flow for the affected reach. The primary inflection point in the relationship between wetted perimeter and discharge occurred at 900 cfs, and a secondary inflection occurred at 400 cfs.

The minimum flow shall be determined based on the January final volume runoff forecast for Hungry Horse Reservoir for the period of April 1 to August 31. When the April through August forecast is greater than 1,790 KAF, the minimum flow shall be 900 cfs. When the forecast is less than 1,190 thousand acre feet (KAF), the minimum flow may be reduced to 400 cfs. When the forecast is between 1,190 and 1,790 KAF, the minimum flow shall be linearly interpolated between 400 and 900 cfs. These adjustments are necessary to balance the benefits of flow protection for bull trout in the South Fork below the dam with reservoir refill and associated biological benefits in the Flathead and Columbia River systems. Dam discharges must be consistent with the minimum flow requirement of 3,500 cfs at Columbia Falls. The minimum flow in the South Fork can be lowered to the physical limit (145 cfs) when the river reaches flood stage at Columbia Falls (13 ft msl).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

EXECUTIVE SUMMARY

This project was completed by Montana Fish, Wildlife & Parks at the request of the Bonneville Power Administration and U.S. Fish and Wildlife Service to clarify the minimum flow requirement for the South Fork Flathead River downstream of Hungry Horse Dam. The existing minimum flow in this reach is 145 cfs. This volume is less than the turbine flow needed to maintain station service power at the dam (approximately 300 cfs). Prior estimates of the required minimum flow for this river reach were based on the Montana Wetted Perimeter technique in the South Fork Flathead River upstream of Hungry Horse Reservoir and may not be descriptive of the reach downstream of Hungry Horse Dam. Direct measurements in the affected reach were necessary to establish a minimum flow that adequately protects fish species of special concern, including threatened bull trout (*Salvelinus confluentus*).

The U.S. Bureau of Reclamation provided a gradual reduction of Hungry Horse Dam discharges to enable measurements for calibrating the WETP model. Field sampling began on August 22, 2000 and was completed on September 5, 2000. Stage measurements were completed at six transects located across riffles and shallow runs, at five levels of flow. Riffle and shallow run habitats were the focus of the WETP technique because they are most susceptible to dewatering as flows decline, and contain unembedded cobble substrate critical to aquatic insect production. Variation explained by the stage - discharge linear regression models for each transect ranged from R^2= 0.98 to 0.99. Specific estimates of wetted perimeter at each transect and water stage were evaluated separately by habitat type and later pooled to establish the minimum flow for the affected reach. The primary inflection point in the relationship between wetted perimeter and discharge occurred at 900 cfs, and a secondary inflection occurred at 400 cfs.

The minimum flow shall be determined based on the January final volume runoff forecast for Hungry Horse Reservoir for the period of April 1 to August 31. When the April through August forecast is greater than 1,790 KAF, the minimum flow shall be 900 cfs. When the forecast is less than 1,190 thousand acre feet (KAF), the minimum flow may be reduced to 400 cfs. When the forecast is between 1,190 and 1,790 KAF, the minimum flow shall be linearly interpolated between 400 and 900 cfs. These adjustments are necessary to balance the benefits of flow protection for bull trout in the South Fork below the dam with reservoir refill and associated biological benefits in the Flathead and Columbia River systems. Dam discharges must be consistent with the minimum flow requirement of 3,500 cfs at Columbia Falls. The minimum flow in the South Fork can be lowered to the physical limit (145 cfs) when the river reaches flood stage at Columbia Falls (13 ft msl).

INTRODUCTION

This project was completed by Montana Fish, Wildlife & Parks at the request of the Bonneville Power Administration (BPA) and U.S. Fish and Wildlife Service (USFWS) to establish a scientifically based minimum flow requirement for the South Fork Flathead River downstream of Hungry Horse Dam. The USFWS is currently finalizing their Biological Opinion (BiOp) on the operation of the Federal Columbia River Power System. The BiOp, to be completed in 2000, will contain terms and conditions specific to the recovery of threatened bull trout *Salvelinus confluentus*. One such condition will prescribe a minimum flow requirement for the South Fork downstream of Hungry Horse Dam.

Prior estimates of the required minimum flow for the South Fork downstream of the dam (draft USFWS Biological Opinion; MFWP and CSKT 1991) were extrapolated from measurements in the South Fork upstream of Hungry Horse Reservoir (Graham et al. 1982) which were not representative of the downstream reach. The state of Montana holds a water right in the reach from the Powell/Flathead County line, downstream to Hungry Horse Reservoir (SB-76 Murphy Right Law, filing Dec. 2, 1970). The Murphy water right specifies a minimum flow of 700 cfs for the period August 1 through September 30 and 600 cfs for the remainder of the year. Based on this, MFWP and the Confederated Salish and Kootenai Tribes (CSKT) recommended consideration of a minimum flow of 700 cfs for the reach below the dam to be initiated in conjunction with temperature control in the discharge from Hungry Horse Dam (MFWP and CSKT 1991). Although thermal control was achieved by installing a selective water withdrawal device in 1995 (Christenson et al. 1996), this minimum flow recommendation has not been implemented by the federal operating agencies. The existing minimum flow in this reach is 145 cfs. This volume is less than the turbine flow needed to generate station service power at the dam (approximately 300 cfs).

This document reports the results of a study using the wetted perimeter inflection point method (Nelson 1980 and 1984; Leathe and Nelson 1986) applied directly to the South Fork Flathead River downstream of Hungry Horse Dam. Direct measurements reported herein were used to establish a minimum flow requirement that adequately protects fish species of special concern, including threatened bull trout.

STUDY AREA

The affected river reach downstream of Hungry Horse Dam to the Flathead River confluence is 8.4 km long (Figure 1). Average stream gradient is approximately 2.1 percent. Immediately downstream of the dam, the channel enters a confined valley with steep canyon walls. In places, the channel profile is shaped like a key hole, where hydraulic abrasion has incised the bedrock. Pool depths may exceed 24 meters in the canyon. Although channel types vary, approximately 75 percent of the reach is classified as a "B" stream type (Rosgen 1996) due to local confinement that limits the development of a wide flood plain. The remaining 25 percent of the reach is classified a "C" stream

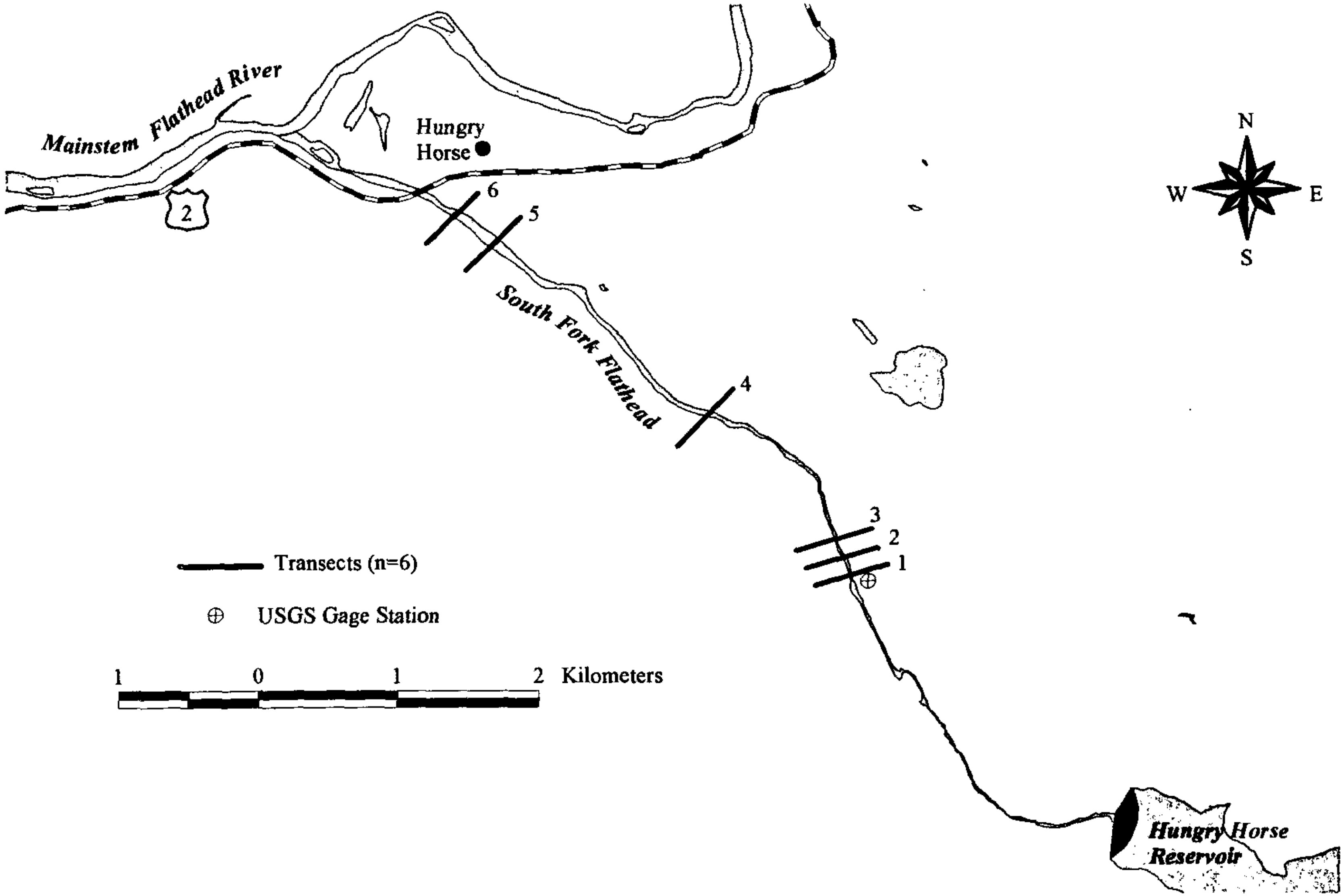


Figure 1. Study area of the minimum fish-flow assessment conducted on the South Fork Flathead River during August and September 2000.

type, characterized by a well developed flood plain (slightly entrenched), and a bedform morphology indicative of a riffle/pool configuration. Only two riffles exist in the entire reach, all located downstream of the USGS gauging station. The main stem Flathead River largely controls water stage in the lowest 5 percent of the channel.

Native salmonids present in the South Fork Flathead River below Hungry Horse Dam include bull trout and westslope cutthroat trout (*Oncorhynchus clarki lewisi*). Westslope cutthroat trout have evolved three life history strategies in the Flathead River system (Shepard et al. 1984; Muhlfeld et al. 2000- In press). Life history forms include: (1) adfluvial stocks that spawn and rear in river tributaries and move downstream to mature and reside in Flathead Lake; (2) fluvial stocks that spawn and rear in river tributaries then move downstream to mature and reside in the Flathead River; and (3) tributary stocks that spend their entire lives in tributary streams (Shepard et al. 1984). Shepard et al. (1984) reported that bull trout adhere to an adfluvial life history form in the Flathead River system. However, recent information suggests that a fluvial form is present in the Flathead River system downstream of Hungry Horse dam (Muhlfeld et al. 2000- In Press). Juvenile bull trout and cutthroat trout remain in tributary streams for 1-3 years before migrating downstream to the river and/or lake. Adfluvial stocks reach the largest size due to improved forage and growth rates in the lake.

METHODS

The wetted perimeter method (WETP) described by Nelson (1980) was used to determine instream flows needed to sustain existing fish populations in the South Fork of the Flathead River downstream of Hungry Horse Dam. Seven permanent transects were established on two riffles and two shallow runs that are representative of the C type channel morphology in the river reach (Rosgen 1996). These hydraulic units are the focus of the WETP technique because they are most susceptible to dewatering as flows decline, and contain unimbedded cobble substrate critical to aquatic insect production.

The U.S. Bureau of Reclamation provided a gradual reduction of Hungry Horse Dam discharges to enable five measurements for calibrating the WETP model. Field sampling began on August 28, 2000 and was completed on September 5, 2000. Discharge (cfs) was measured by the US Geological Survey at the permanent gauging station located immediately upstream of transect 1 (Figure 1). Water stage and channel profile measurements were determined relative to an established bench-mark with a survey theodolite and stadia rod (Nelson 1984). The WETP technique uses a minimum of three stage-discharge measurements for model calibration. We calibrated the model with five stage and discharge measurements at flows of 5071, 3525, 2997, 2312 and 1711 cfs (USGS record). The methodology requires that the water's edge measurements on the right and left banks within each transect must remain within 0.3 ft. as discharge varies. Transect 7 did not meet this requirement and was discarded.

The remaining six transects were used for the duration of the investigation. Channel profile measurements were positioned by line of sight directly between rebar head stakes defining each transect. Where water was too deep to wade, water depth was measured from the measured surface elevation using a metered cable (accurate to 0.1 ft.) and a 34 kg bomb weight deployed from a boat.

Five stage-discharge coordinates were linearly regressed on a logarithmic scale to develop a stage-discharge relationship for each transect. Channel profile measurements combined with predicted water stage elevations at selected river discharges yielded accurate estimates of wetted perimeter using WinXSPRO, Version 2.1 (USFS 1987). Wetted perimeter is that portion of the streambed in contact with water at each discharge. Specific estimates of wetted perimeter at each transect and water stage were evaluated separately and later pooled to establish the minimum flow for the affected reach.

Inflection points identified from a plot of the curvilinear relationship between wetted perimeter and discharge and criteria developed by Nelson (1980) were used to establish the minimum flow requirement. The WETP method for establishing minimum flow requirements has compared favorably this other instream flow methodologies (Leathe and Nelson 1986). We chose this technique for consistency with past investigations in the South Fork watershed, cost-effectiveness, and for rapid implementation.

RESULTS AND DISCUSSION

Channel profiles and stage-discharge relationships were developed for each transect (Appendices 1-6 and 7-12, respectively). Differences in the morphometry of each transect cause the relationship between wetted perimeter and discharge to differ. Hence, a composite of all six transects provides a better description of the affected reach. It would have been desirable to measure a stage-discharge coordinate in the range of 400 to 900 cfs during model calibration. Unfortunately, flows in this range did not occur during this investigation. A minimum discharge of approximately 1,700 cfs from Hungry Horse Dam was required to maintain the established minimum flow of 3,500 cfs in the main stem Flathead River at Columbia Falls. The authors chose to adhere to the Columbia Falls minimum flow requirement, rather than reduce the dam discharge for an additional calibration flow. This was to protect biological productivity downstream in 64 km of the main stem Flathead River during the productive summer months. Montana was experiencing an extended drought (and level IV and V fire restrictions) during the study. Nonetheless, the five calibration flows yielded a predictive capability in the stage-discharge model for each transect ranging from $R^2 =$ 0.98 to 0.99. Error introduced by extrapolating from the observed flows to lower flows of interest was likely offset by rounding the flow recommendation to the nearest 100 cfs. Transect head stakes and associated benchmarks remain intact in the event that additional calibration measurements are required.

The primary inflection point in the relationship between wetted perimeter and discharge occurred at 900 cfs, and a secondary inflection occurred at 400 cfs. Examination of the relationship between wetted perimeter and discharge for transects on riffles (transects 1-3 and 6) and shallow runs (transects 4 and 5) revealed similar inflection points (appendices 13 - 20); hence the data were pooled for the final model (Figure 2). Based on these results, the minimum flow in the South Fork downstream of Hungry Horse Dam should remain at or above 900 cfs. However, the benefits of flow protection in the reach below the dam must be considered in the context of reservoir refill and associated biological benefits elsewhere in the Flathead and Columbia River systems. The minimum flow requirement provides adequate protection for riffle and shallow run habitats in the affected 8.4-km river reach. Conversely, reservoir refill affects biological production in near-shore areas throughout the 42 km long reservoir. Maintaining the 900 cfs minimum flow during dry years at the expense of reservoir refill is a consequence that must be weighed.

A hydraulic model simulation performed by the US Bureau of Reclamation revealed that changing the minimum flow constraint will affect the annual refill of Hungry Horse Reservoir (Flathead Basin Study 2000; Kim Fodrea, USBR, personal communication). The simulation assumed that VARQ flood control was implemented (ACOE 1999) in a 50-year period (1929-1978) of monthly hydro regulations. Results compared the existing minimum flow of 145 cfs to alternative minimum flows at 400 cfs and 1,000 cfs. The hydraulic simulation also assumed that refill operations would continue through the month of July. In the lowest 20-percentile water years, the reservoir failed to refill 50 percent of the time. The worst case scenario was a refill failure of 15 ft at the end of July under the 145 cfs minimum flow, 17 feet with a 400 cfs minimum, and 23 feet when the minimum flow was increased to 1,000 cfs. Four other drought years failed to refill by two to six feet under the 145 cfs minimum flow, but those four years missed refill by three to eight feet with a 400 cfs minimum and by six to thirteen feet with a 1,000 cfs minimum flow requirement. Overall, the three minimum flows resulted in differing reservoir refill elevations in 10 of the 50 years evaluated, with some refill failures in average and wet water years. Five refill failures were simulated in average and wet water years. In those five years, the 145 cfs flow scenario allowed refill, but the 400 cfs minimum flow resulted in three refill failures of 1 foot below full pool. The 1,000 cfs minimum flow resulted in four years that failed to fill by three or four feet, and one year that missed refill by 1 foot. These relatively minor refill failures during average and wet water years are likely caused by volume runoff forecasting error or by an early runoff.

Failure to refill the reservoir is harmful to biological production in the impoundment due to loss of littoral zone area, and results in less water available for flow augmentation downstream (Marotz et al 1999). The established minimum inflow in the main stem Flathead River at Columbia Falls (downstream of the South Fork confluence) is 3,500 cfs. Hungry Horse Dam must augment flows when the combined flows of the unregulated North and Middle Forks of the Flathead River decline below this minimum flow requirement. Flow augmentation for this purpose often exceeds the minimum flow of 900 cfs. When the unregulated river forks exceed 3,500 cfs, the South Fork discharge can decline to the minimum flow.

To protect against reservoir refill failure and to assure adequate flows in the Flathead River downstream, we recommend that the minimum flow requirement in the South Fork downstream of Hungry Horse Dam be reduced during less than average water years. The minimum flow shall be determined based on the January final volume runoff forecast for Hungry Horse Reservoir for the period of April 1 to August 31. Calculation of the minimum flow should be adjusted with the each month's new forecast. When the April through August forecast is greater than 1,790 thousand acre feet (KAF), the minimum flow shall be 900 cfs. When the forecast is less than 1,190 KAF, the minimum flow may be reduced to 400 cfs. When the forecast is between 1,190 and 1,790 KAF, the minimum flow shall be linearly interpolated between 400 and 900 cfs. This adjustment will protect bull trout and other species of special concern in the reservoir and river downstream.

CONCLUSION

The recommended minimum flow downstream of Hungry Horse Dam benefits riffle and shallow run habitats in the affected 8.4-km reach. By comparison, not allowing reservoir refill would affect the entire shoreline of the 42-km long reservoir. Maintaining the 900 cfs minimum flow during dry years at the expense of reservoir refill is a consequence that must be weighed. Hungry Horse Reservoir contains one of the few remaining native species assemblages and one of the strongest metapopulations of bull trout in existence. Reservoir refill failure impacts biological productivity in the pool during the biologically productive summer months. To avoid this impact, we developed a sliding scale for the minimum flow below the dam based on water availability. The minimum flow shall be determined based on the January final volume runoff forecast for Hungry Horse Reservoir for the period of April 1 to August 31. When the April through August forecast is greater than 1,790 KAF, the minimum flow shall be 900 cfs. When the forecast is less than 1,190 KAF, the minimum flow may be reduced to 400 cfs. When the forecast is between 1190 and 1790 KAF, the minimum flow shall be linearly interpolated between 400 and 900 cfs. The 400 cfs minimum flow during dry years is higher than the current minimum (145 cfs) which bull trout have experienced since 1952. Therefore, this low flow, which would occur on average in only 2 out of 10 years, is more beneficial to bull trout than the historic condition. Hungry Horse Dam discharge must maintain the established minimum flow of 3,500 cfs at Columbia Falls. However, in the event of a flood emergency (when river stage at Columbia Falls reaches 13 feet) the minimum flow in the South Fork can be reduced to the physical minimum (approximately 145 cfs).

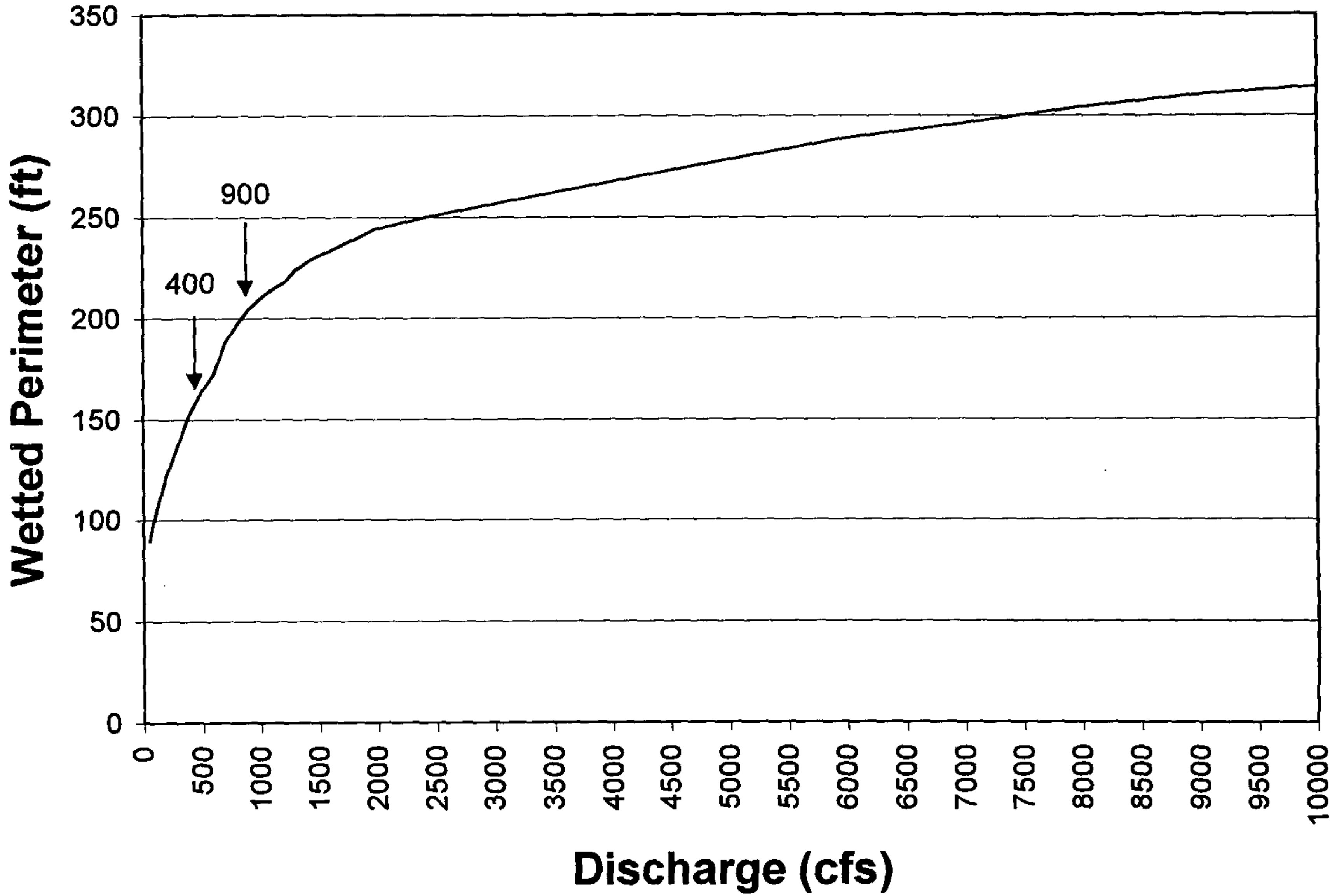


Figure 2. Relationship between wetted perimeter and discharge for six riffle-run transects in the South Fork Flathead River downstream of Hungry Horse Dam.

LITERATURE CITED

ACOE 1999. Work to date on the development of the VARQ flood control operation at Libby Dam and Hungry Horse Dam. U.S. Army Corps of Engineers, Northwestern Division, North Pacific Region, Portland, OR. 83 pp. plus appendices.

Christenson D.J., R.L. Sund, and B.L. Marotz. 1996. Hungry Horse Dam's successful selective withdrawal system. Hydro Review 15(3):10-15.

Leathe, S. and F. Nelson. 1986. A literature evaluation of Montana's wetted perimeter inflection point method for determining instream flow recommendations. Montana Fish, Wildlife & Parks, Helena, Montana.

Marotz, B., D. Gustafson, C. Althen, and B. Lonon. 1999. Integrated operation rule curves for Montana reservoirs and application for other Columbia River storage projects. Pages 329 - 352 In Ecosystem Approaches for Fisheries Management. Alaska Sea Grant College Program AK-SG-99-01, 1999.

MFWP and CSKT. 1991. Fisheries mitigation plan for losses attributable to the construction and operation of Hungry Horse Dam. Montana Fish, Wildlife & Parks and Confederated Salish and Kootenai Tribes, prepared for the Northwest Power Planning Council. MFWP Kalispell, MT. 71 pp.

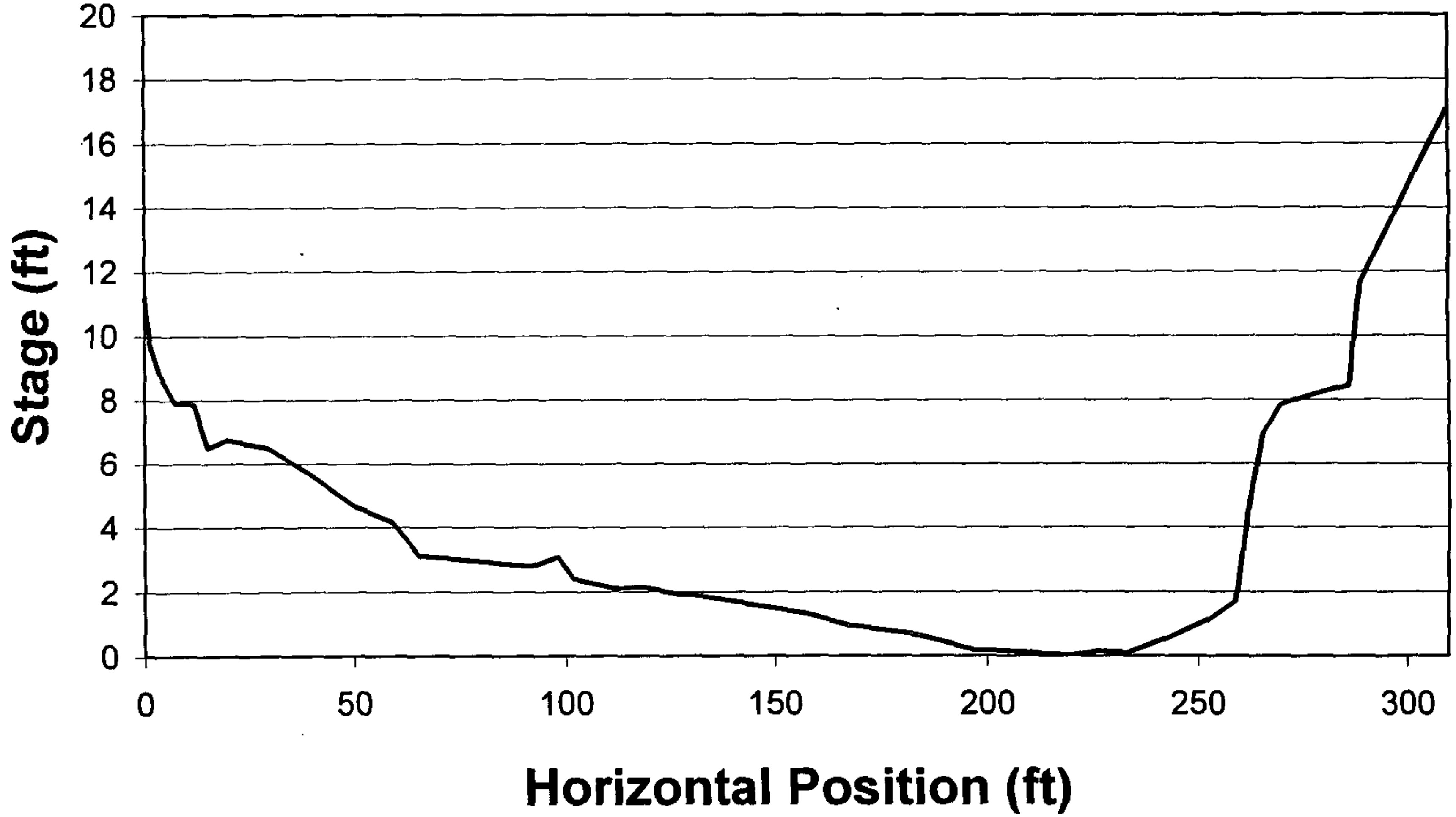
Muhlfeld, C.C., S. Glutting, R. Hunt, and B. Marotz. In press. Seasonal distribution and movements of native and non-native fishes in the upper Flathead River drainage, Montana. Montana Department of Fish, Wildlife and Parks, report to Bonneville Power Administration, Portland, Oregon.

Nelson, F.A. 1980. Evaluation of four instream flow methods applied to four trout rivers in southwest Montana. Montana Fish, Wildlife & Parks report to USFWS. Contract No. 14-16-0006-78-046.

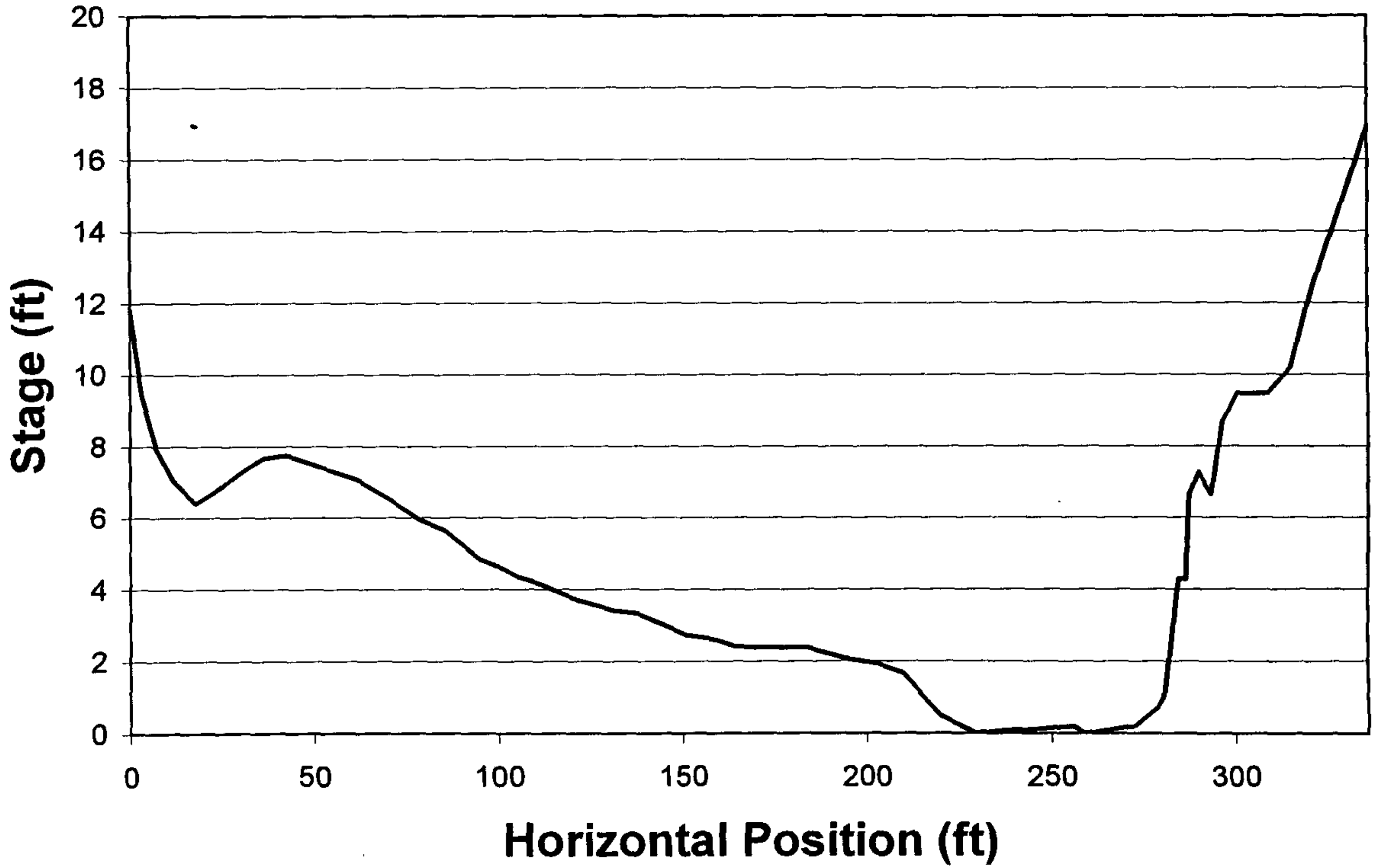
Rosgen, D. 1996. Applied river morphology. Wildlands Hydrology. Pagosa Springs, Colorado. ISBN 0-9653289-0-2.

Shepard, B.B., K.L. Pratt, and P.J. Graham. 1984. Life histories of westslope cutthroat trout and bull trout in the upper Flathead River Basin, Montana. Montana Department of Fish, Wildlife and Parks, Helena.

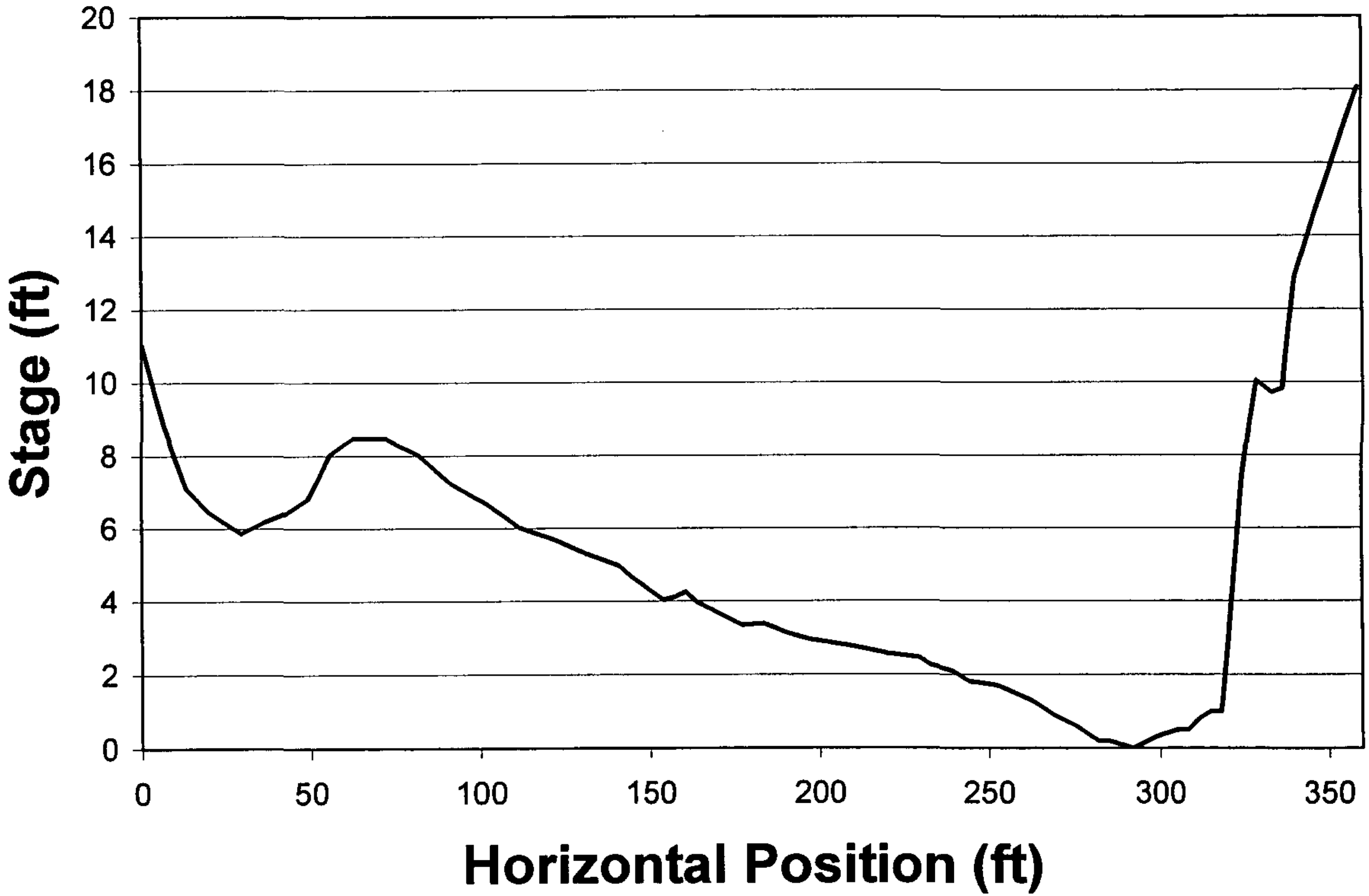
USFS. 1987. WinXSPRO (Version 2.1, July 6, 1998). A channel cross-section analyzer. User's manual. July 1997. WEST Consultants, Inc. San Diego, CA for the USDA Forest Service, Rocky Mountain Experiment Station, Fort Collins, CO. 85 pp (2 diskettes).



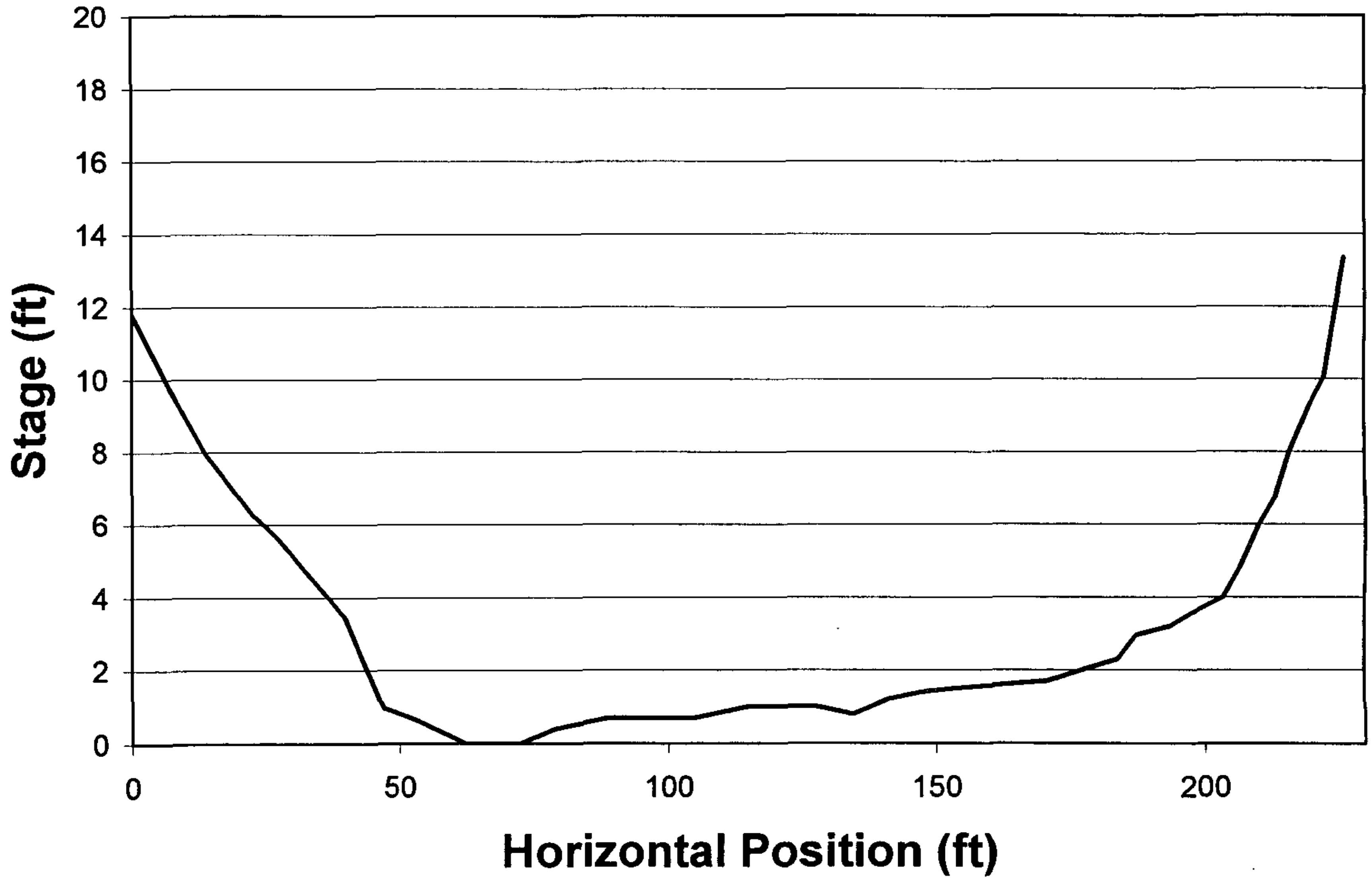
Appendix 1. Cross-section of transect 1 in the South Fork Flathead River downstream of Hungry Horse Dam.



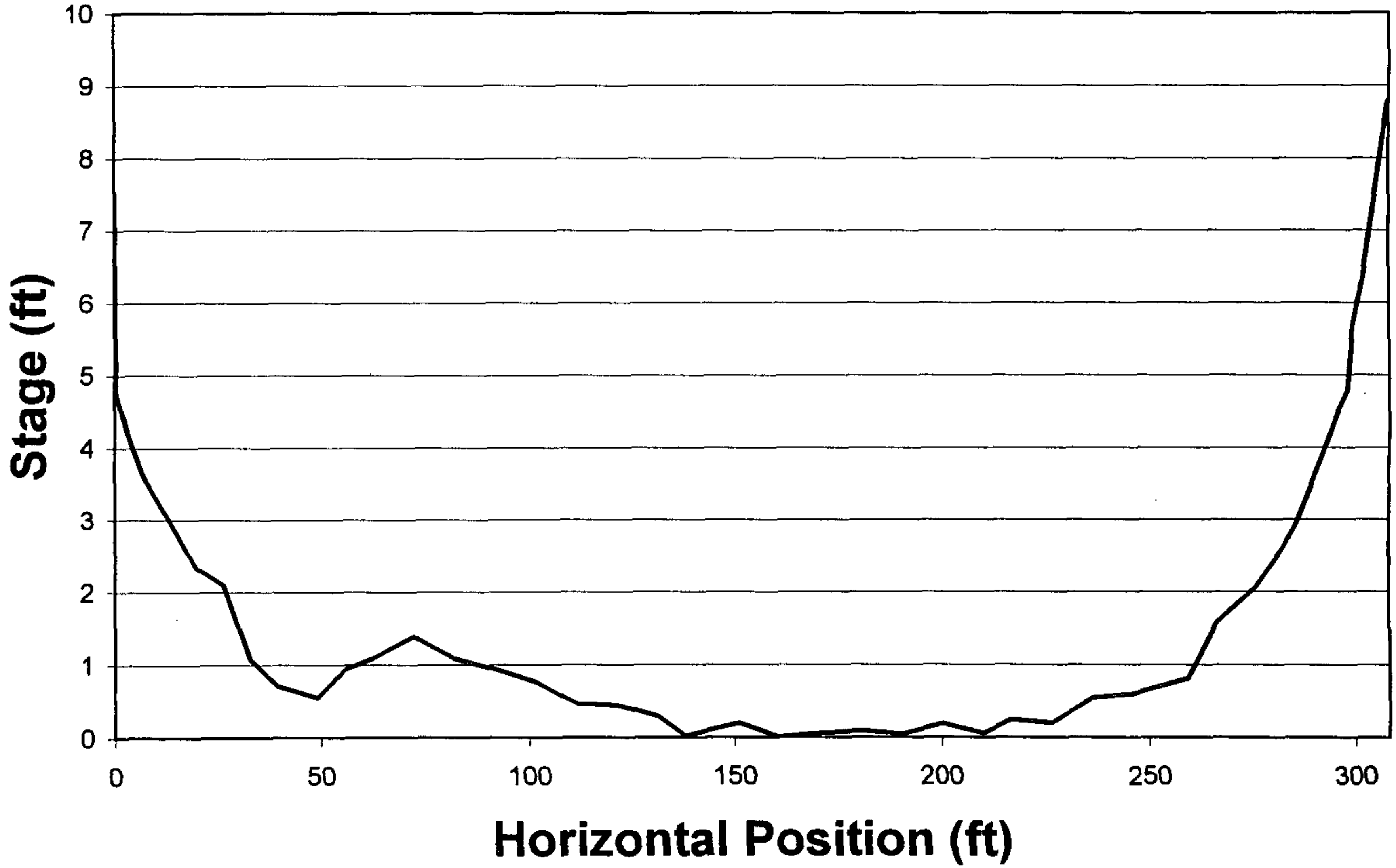
Appendix 2. Cross-section of transect 2 in the South Fork Flathead River downstream of Hungry Horse Dam.



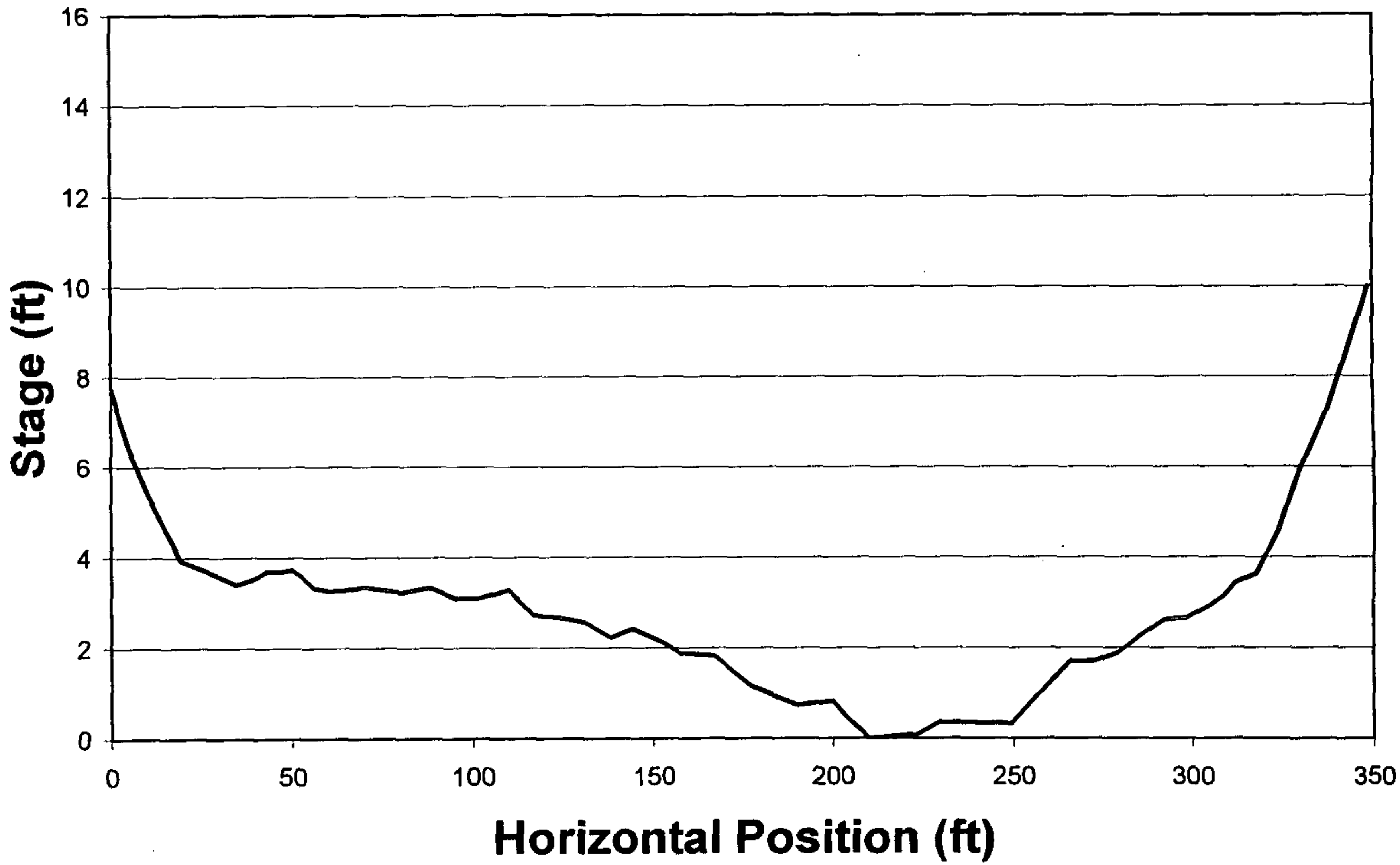
Appendix 3. Cross-section of transect 3 in the South Fork Flathead River downstream of Hungry Horse Dam.



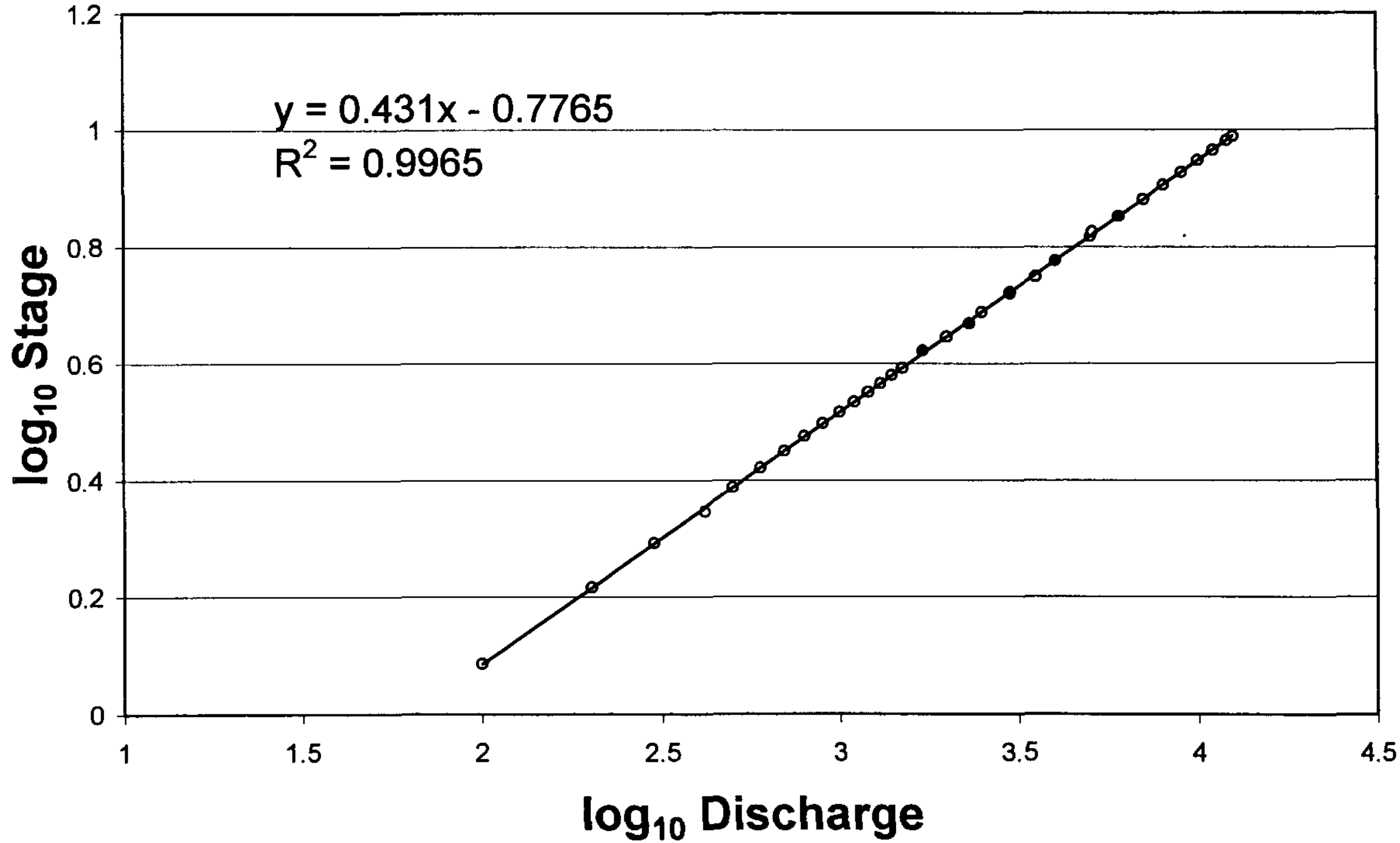
Appendix 4. Cross-section of transect 4 in the South Fork Flathead River downstream of Hungry Horse Dam.



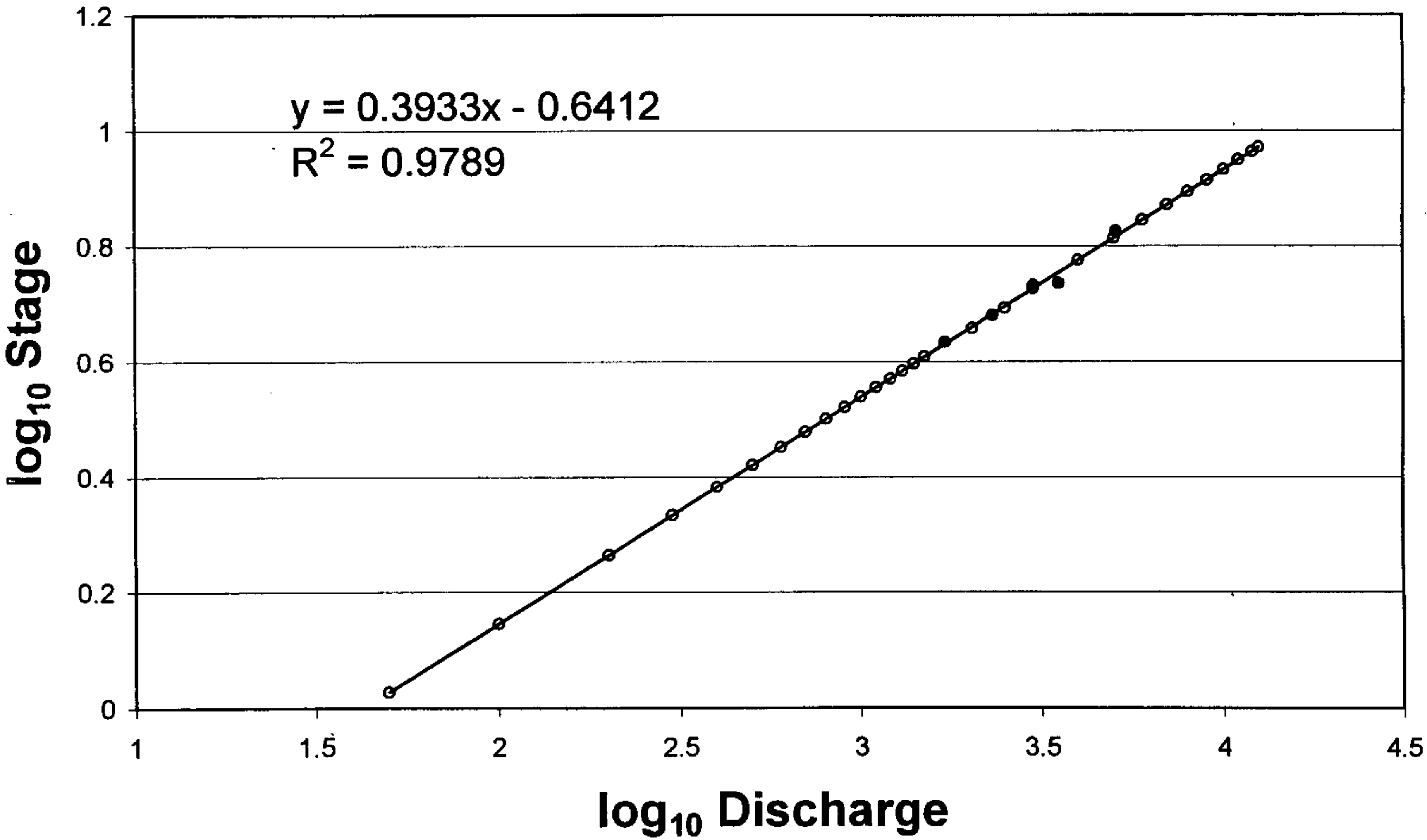
Appendix 5. Cross-section of transect 5 in the South Fork Flathead River downstream of Hungry Horse Dam.



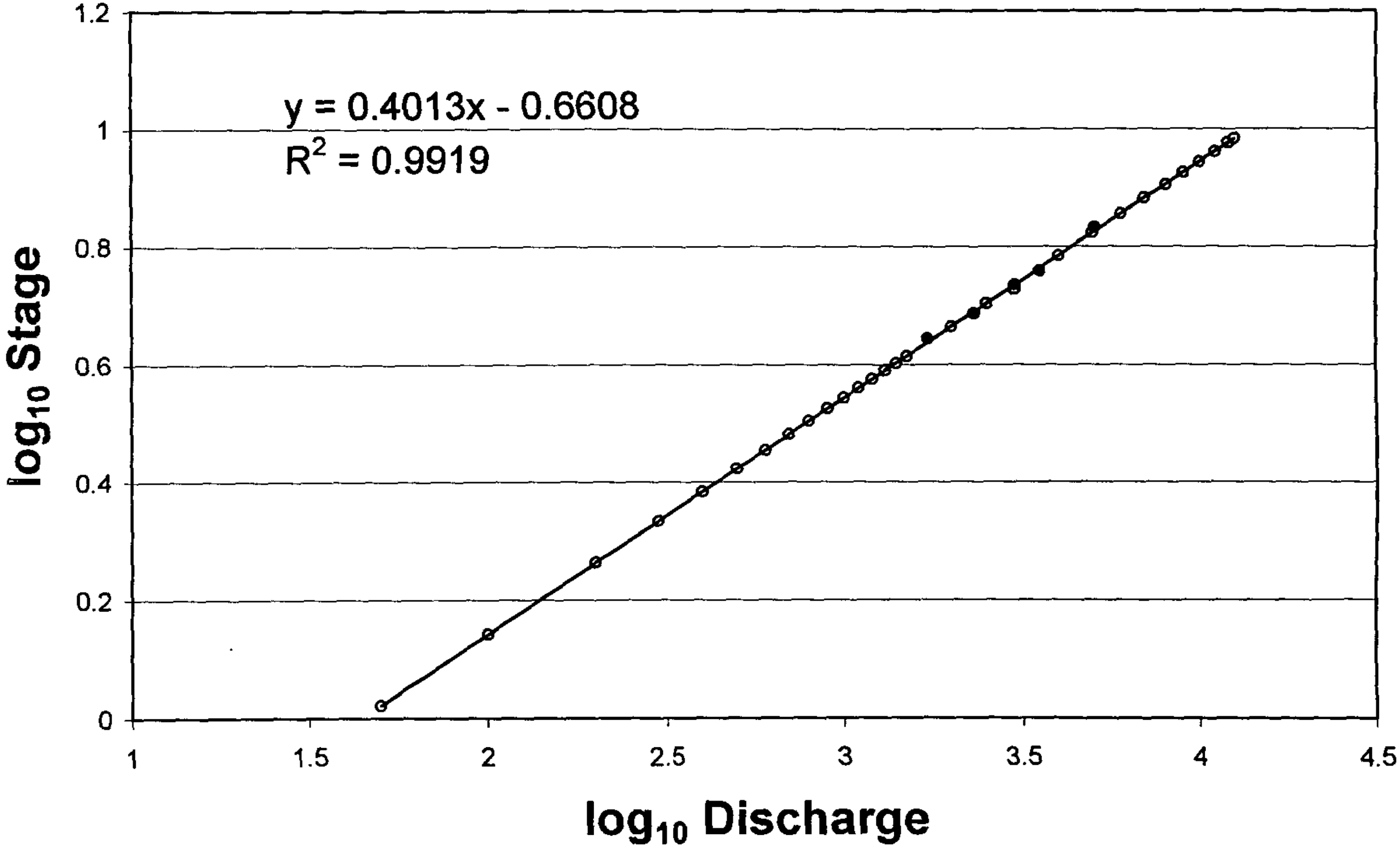
Appendix 6. Cross-section of transect 6 in the South Fork Flathead River downstream of Hungry Horse Dam.



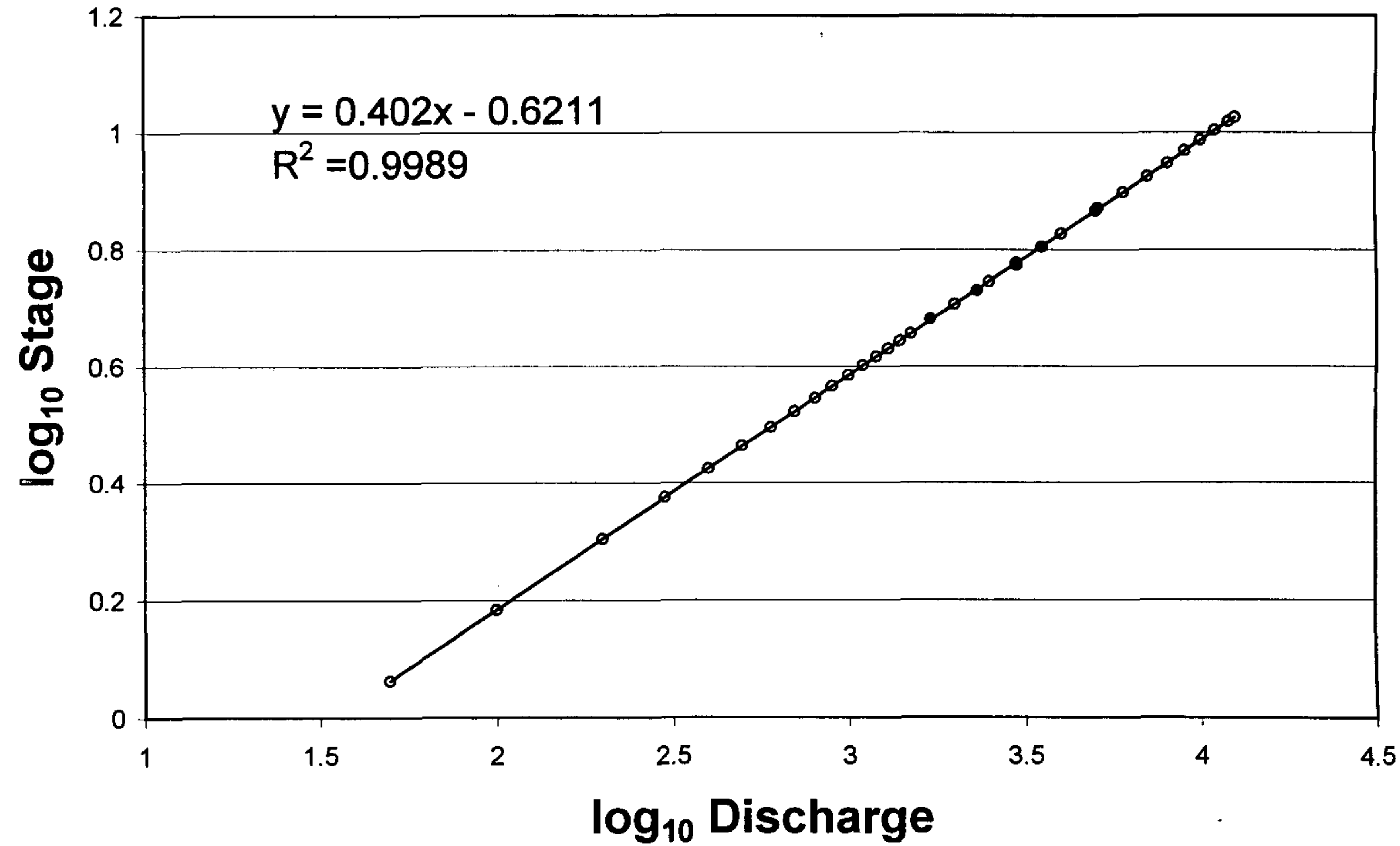
Appendix 7. Relationship between stage (log_{10}) and discharge (log_{10}) for transect 1 in the South Fork Flathead River downstream of Hungry Horse Dam. Note: observed values are black and expected values are white.



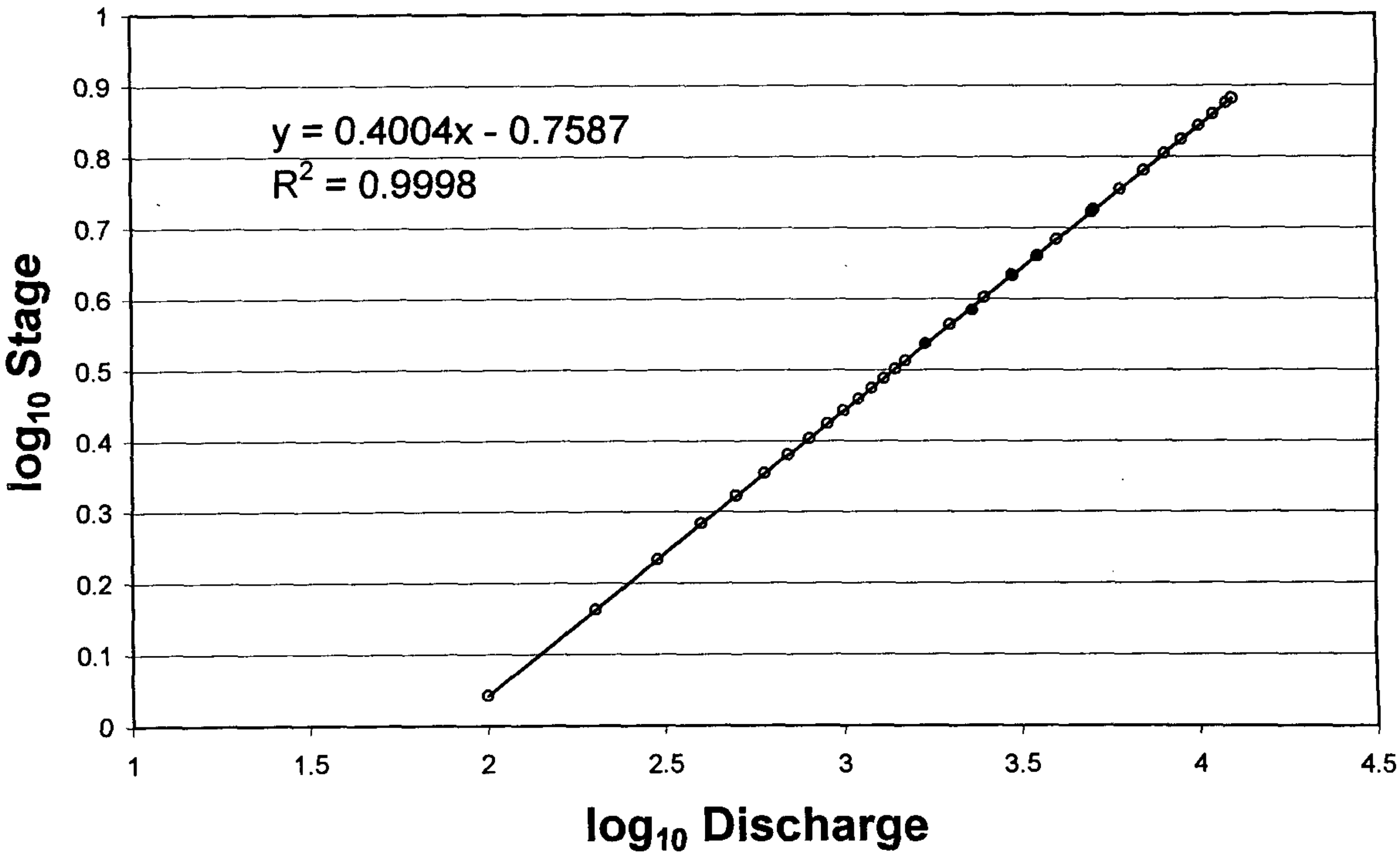
Appendix 8. Relationship between stage ($\log_{10}$) and discharge ($\log_{10}$) for transect 2 in the South Fork Flathead River downstream of Hungry Horse Dam. Note: observed values are black and expected values are white.



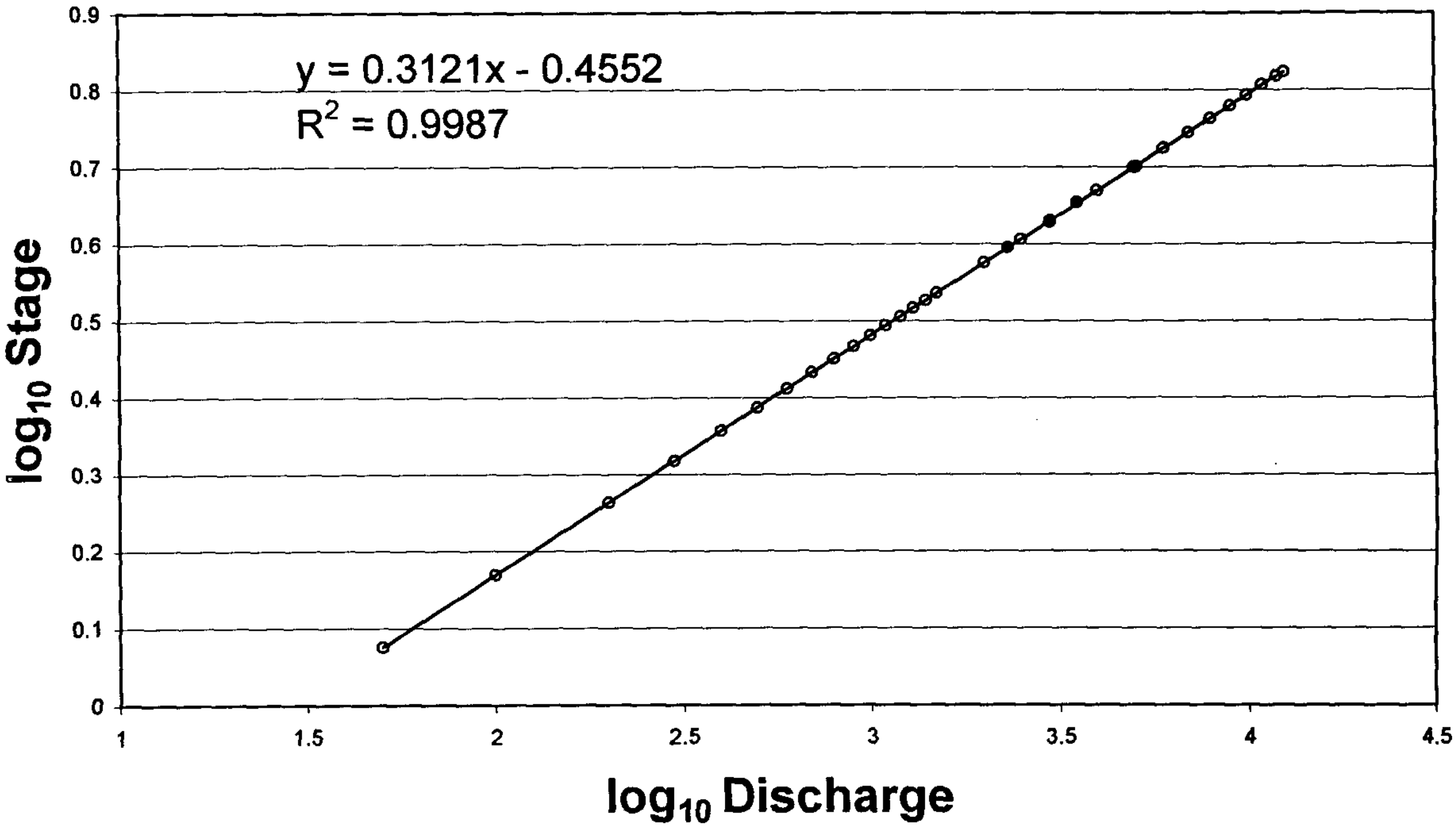
Appendix 9. Relationship between stage ($\log_{10}$) and discharge ($\log_{10}$) for transect 3 in the South Fork Flathead River downstream of Hungry Horse Dam. Note: observed values are black and expected values are white.



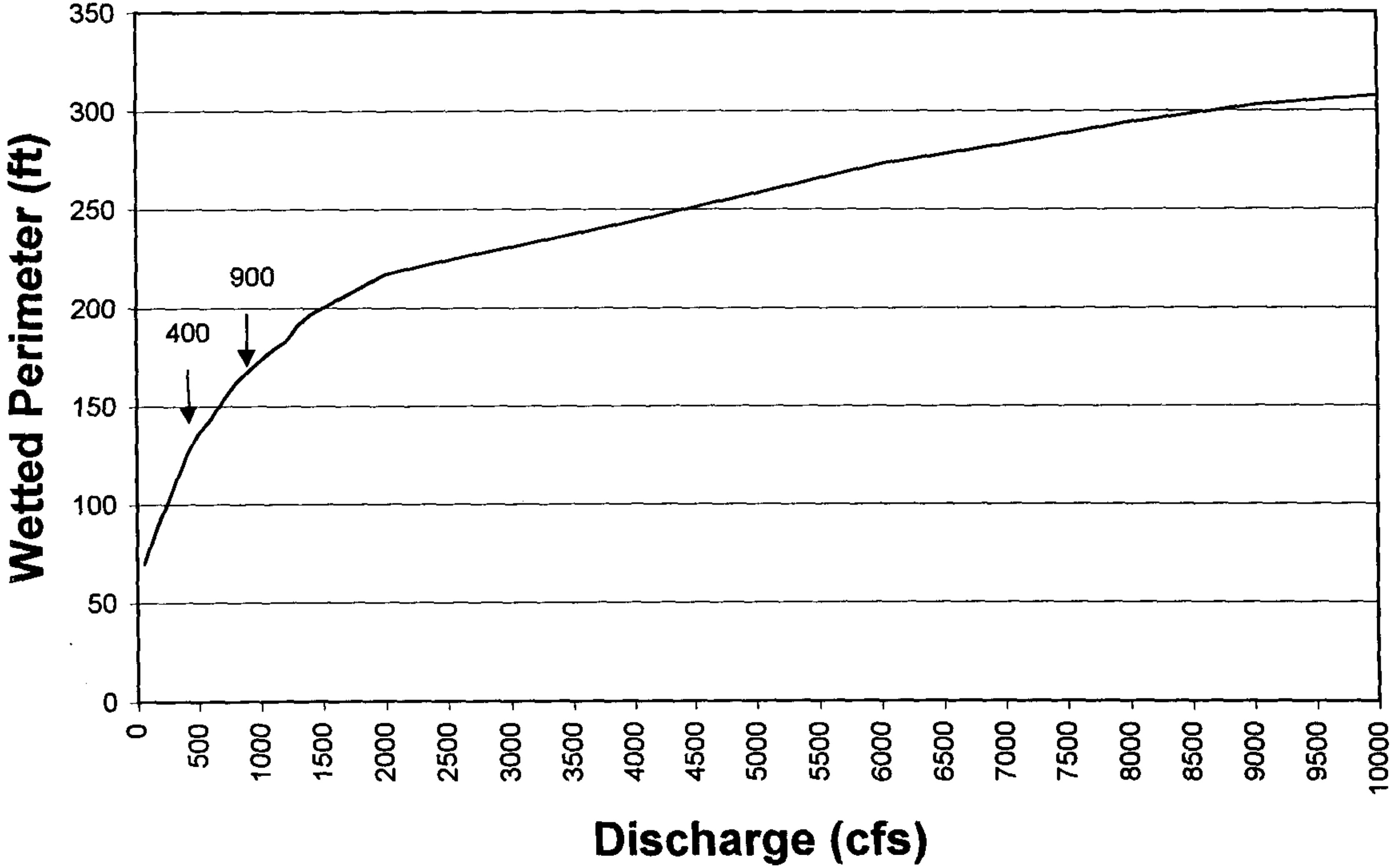
Appendix 10. Relationship between stage (log_{10}) and discharge (log_{10}) for transect 4 in the South Fork Flathead River downstream of Hungry Horse Dam. Note: observed values are black and expected values are white.



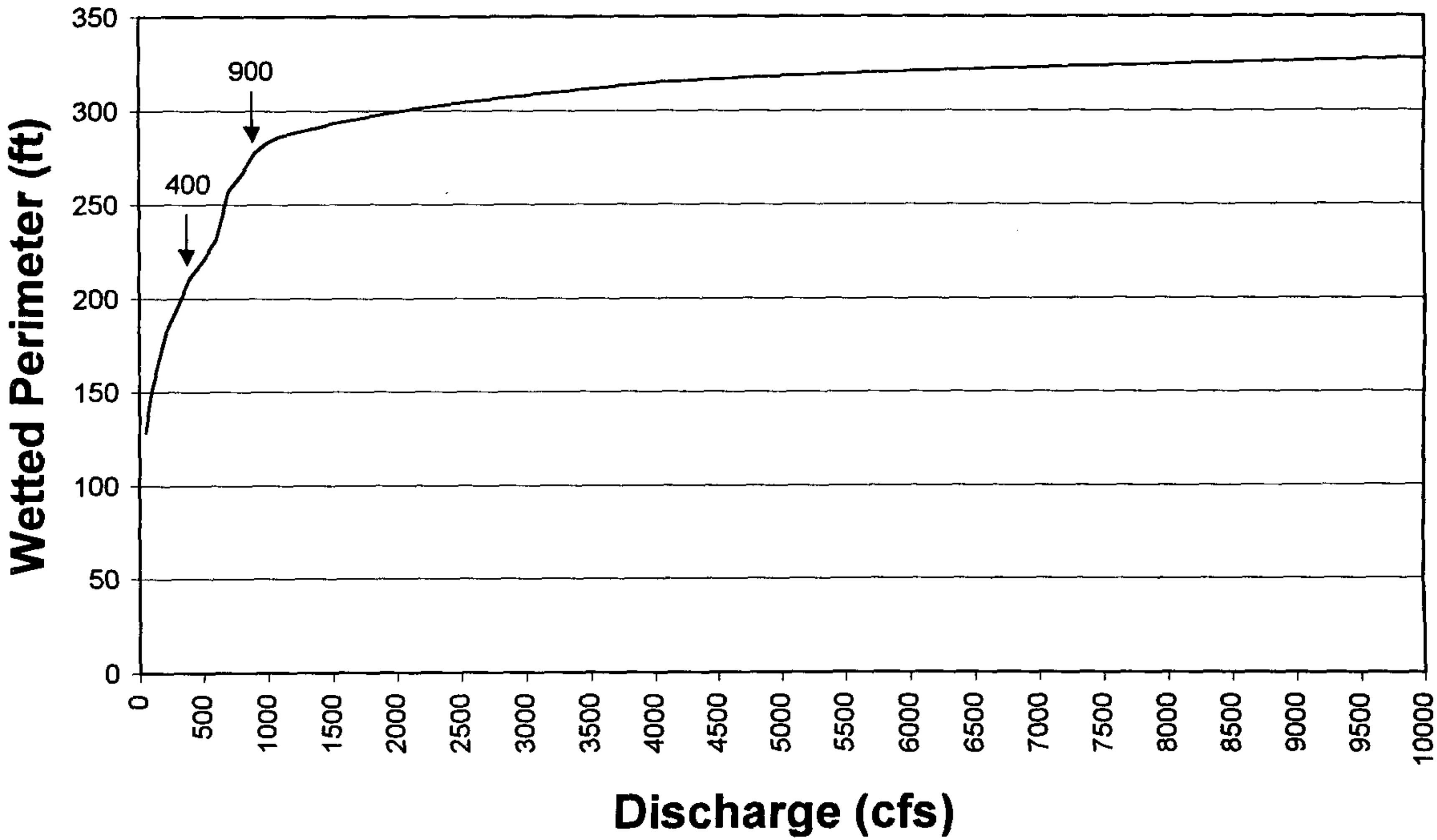
Appendix 11. Relationship between stage (log_{10}) and discharge (log_{10}) for transect 5 in the South Fork Flathead River downstream of Hungry Horse Dam. Note: observed values are black and expected values are white.



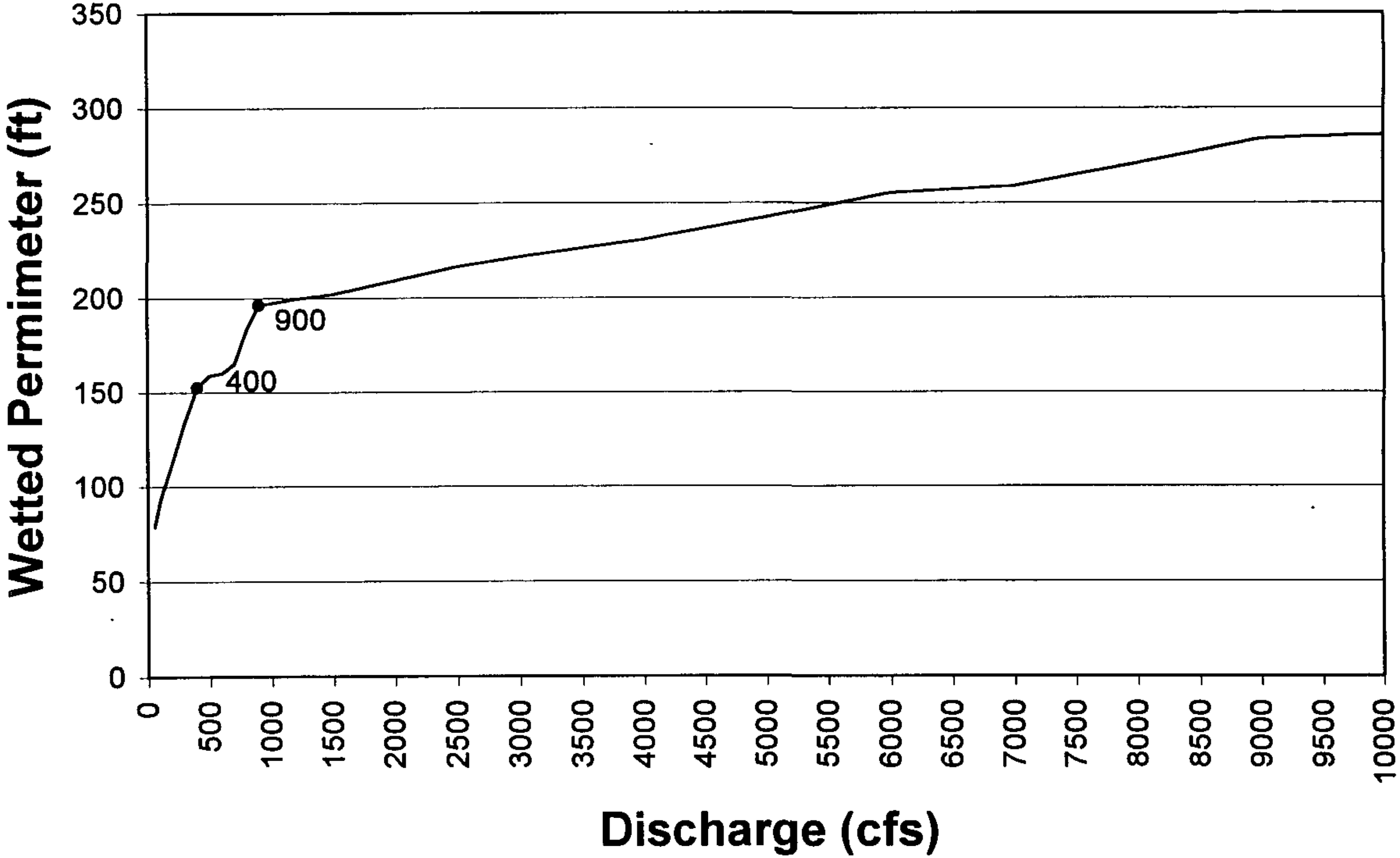
Appendix 12. Relationship between stage (log_{10}) and discharge (log_{10}) for transect 6 in the South Fork Flathead River downstream of Hungry Horse Dam. Note: observed values are black and expected values are white.



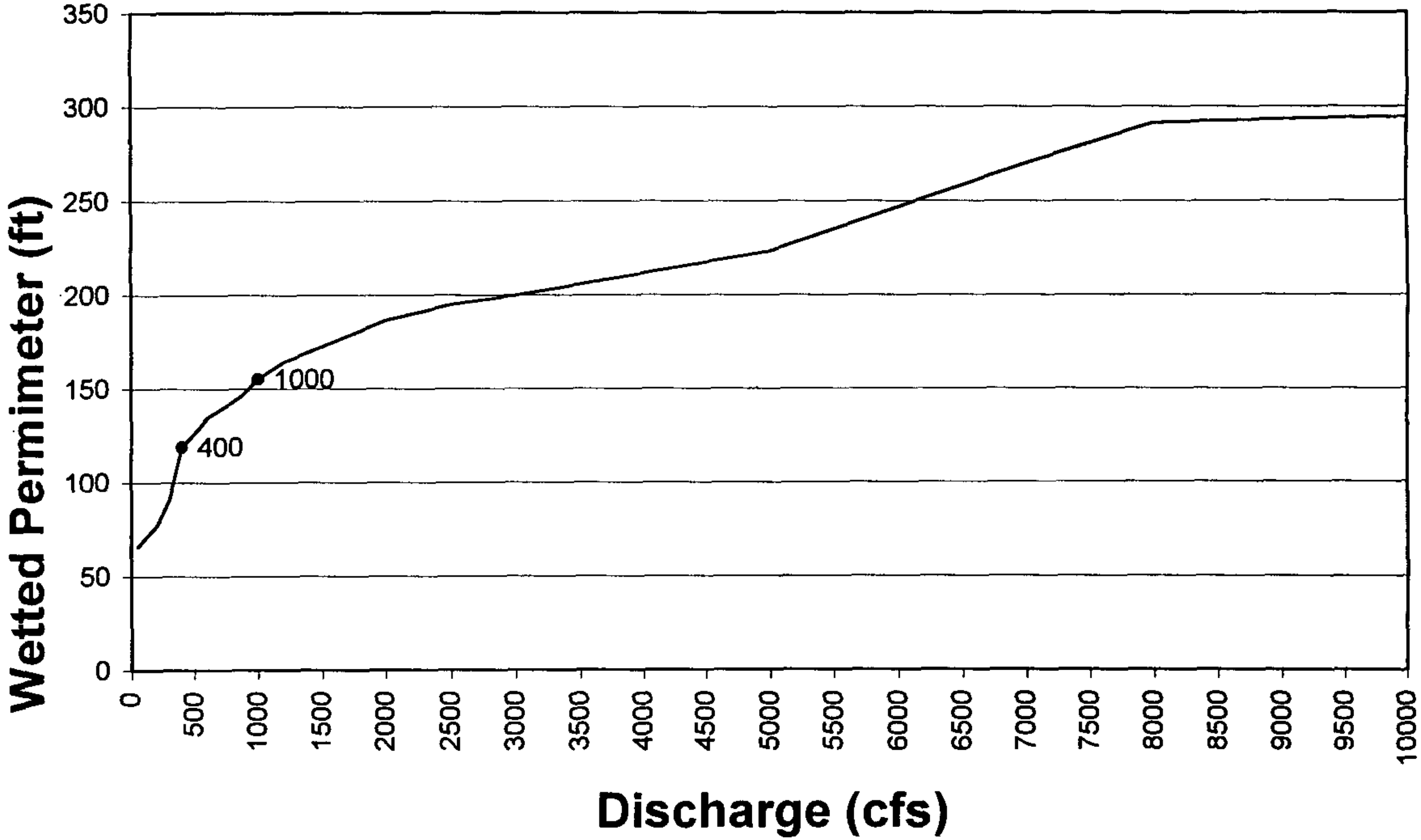
Appendix 13. Relationship between wetted perimeter and discharge for four riffle transects (1-3, and 6) in the South Fork Flathead River downstream of Hungry Horse Dam.



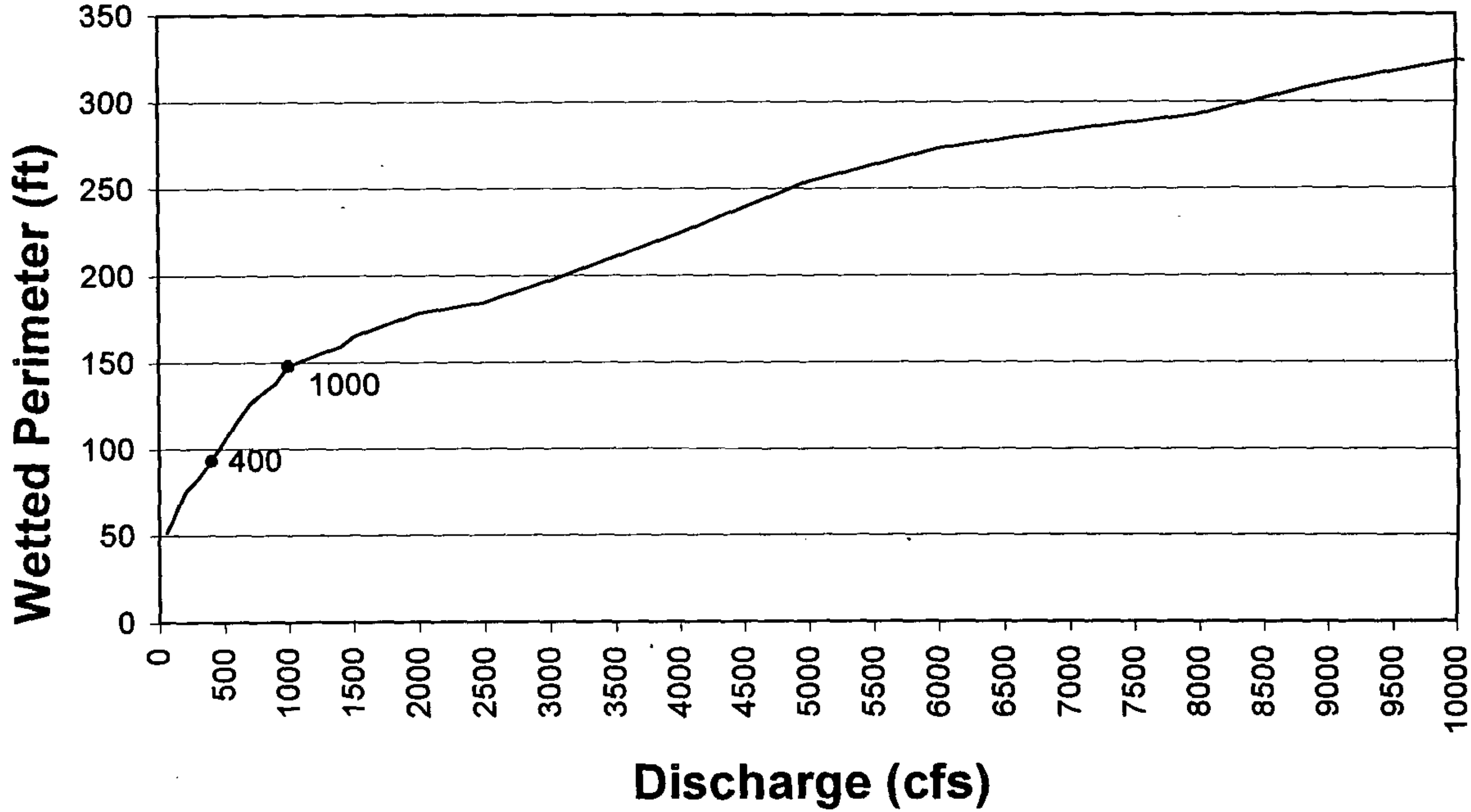
Appendix 14. Relationship between wetted perimeter and discharge for two run transects (4 and 5) in the South Fork Flathead River downstream of Hungry Horse Dam.



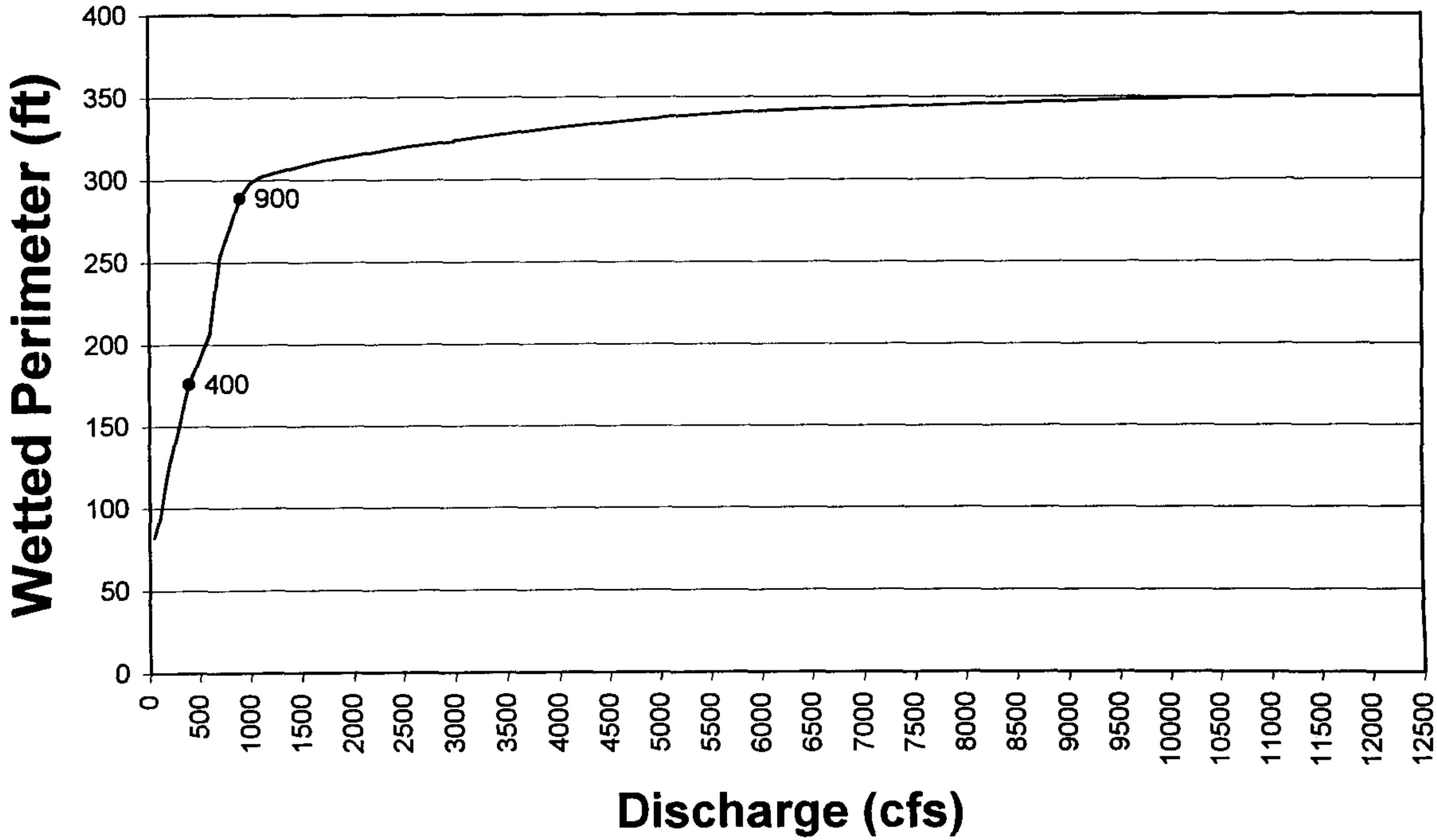
Appendix 15. Relationship between wetted perimeter and discharge for transect 1 in the South Fork Flathead River downstream of Hungry Horse Dam.



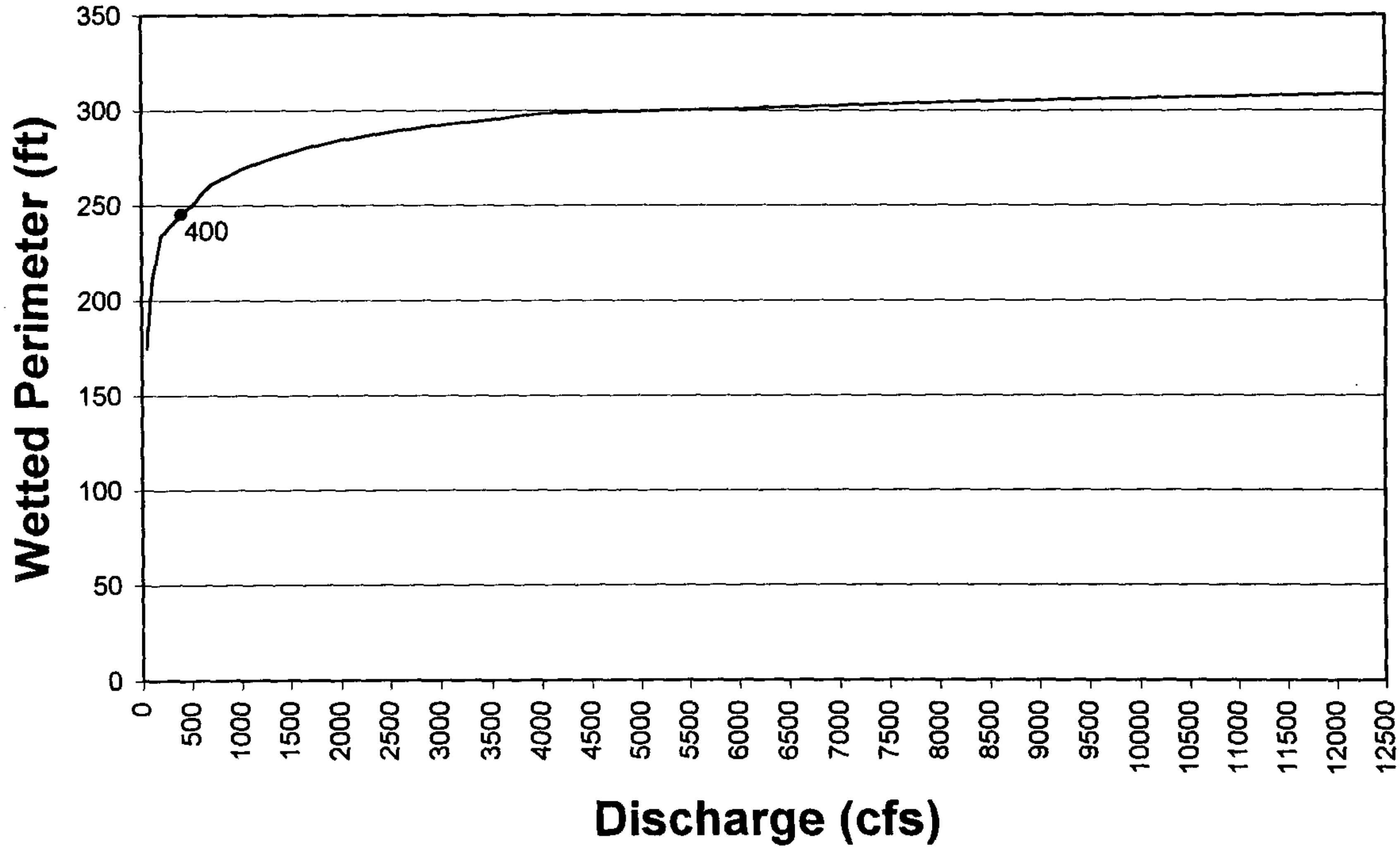
Appendix 16. Relationship between wetted perimeter and discharge for transect 2 in the South Fork Flathead River downstream of Hungry Horse Dam.



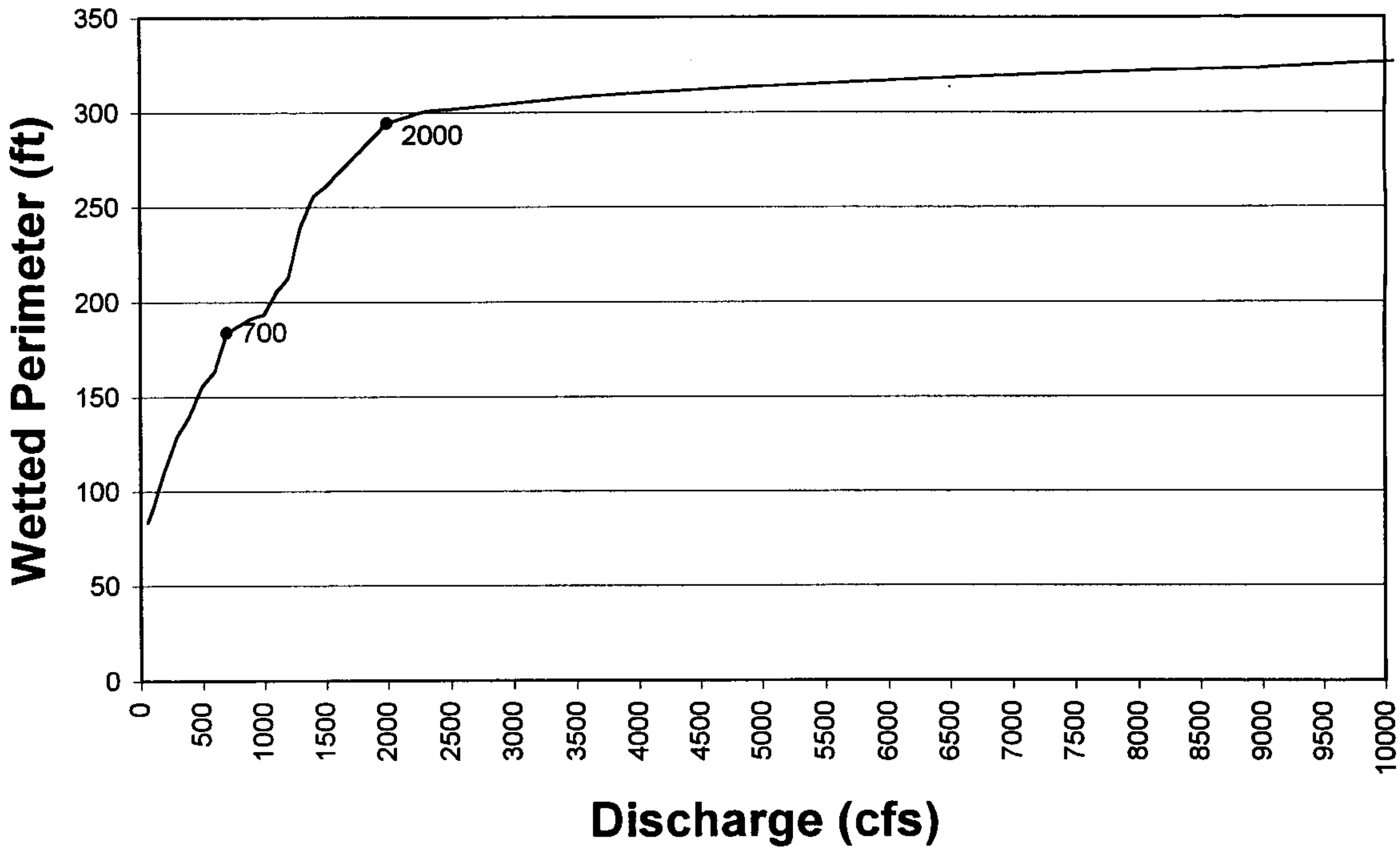
Appendix 17. Relationship between wetted perimeter and discharge for transect 3 in the South Fork Flathead River downstream of Hungry Horse Dam.



Appendix 18. Relationship between wetted perimeter and discharge for transect 4 in the South Fork Flathead River downstream of Hungry Horse Dam.



Appendix 19. Relationship between wetted perimeter and discharge for transect 5 in the South Fork Flathead River downstream of Hungry Horse Dam.



Appendix 20. Relationship between wetted perimeter and discharge for transect 6 in the South Fork Flathead River downstream of Hungry Horse Dam.