 

# Technical Memorandum – Tonasket Creek Habitat Enhancement Analysis

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## MEMORANDUM

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Subject: Technical Memorandum - Tonasket Creek Habitat Enhancement

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At the request of the Colville Confederate Tribes (CCT), this Technical Memorandum summarizes a fish habitat enhancement study of Tonasket Creek in Okanogan County. The ultimate goal of the study was to contribute to the science and examine ways to enhance water quality and quantity to improve rearing conditions for anadromous fish. The study includes the following.

- Collection of surface water and groundwater data,
- Hydraulic and hydrologic analyses of the existing conditions with specific emphasis on a “drying reach of the creek”,
- Statistical analyses between surface water and groundwater data, and
- Best estimate of pumping flows needed to provide minimum creek flows during the dry period.

Our analysis is based on limited existing information and measurements collected during the 2010-2011 season. Conclusions could change if water usage (due to either well use or irrigation diversions) adjacent to Tonasket Creek is significantly different or substantially change in future.

## Background

The Tonasket Creek watershed encompasses 35,460 acres of mixed ownership, including private lands (20,000 acres - 56%); Washington Department of Natural Resources managed lands, (5,700 acres--16%); Bureau of Land Management managed lands (960 acres-3%); and the 8,800 acres -25%) managed by the US Forest Service (USFS). Tonasket Creek enters the Okanogan River east of the city of Oroville, Washington, at River Mile (RM) 77.8 of the Okanogan River. The mainstem channel of the creek is approximately14 miles long and there are approximately 75 total miles of stream channel in the Okanogan tributary.

The Tonasket Creek watershed is characterized by high spring runoff due to melting snowpack that accumulates in late fall and the winter months (USFS 1998[1]). Summer and fall runoff is low, fed by the release of stored water from riparian areas in floodplains, seeps, and springs at the headwater tributary streams. The timing of some run-off has been influenced by the road

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[1] USFS,1998. Tonasket Watershed Assessment, US Forest Service, Okanogan National Forest, Tonasket Ranger District, Tonasket, Washington.

network that intercepts ground water and re-routes it overland. Interception reduces the amount of late season flow.

Irrigation withdrawals are in the lower part of the creek. According to MWG et al. (1995[2]), there are 13 permitted surface withdrawals on Tonasket Creek, yielding a potential removal of 0.2 cfs. There are an additional 70 surface water claims for 2.7 cfs. Groundwater withdrawals of 460 gpm (1.1 cfs) are currently permitted, and an additional 84 claims are registered for 1,368 gpm (3.05 cfs). There are likely other water withdrawals from Tonasket Creek and its tributaries in the Nine Mile Ranch subdivision area, as well as Mud Lake Valley and Dry Creek areas. These withdrawals may be for irrigation, stock watering or perhaps domestic use. There may be some domestic use water withdrawals also made from Tonasket Creek. While these figures are somewhat dated and actual withdrawals need to be confirmed, they serve to emphasize that the creek's flow is over-allocated.

Tonasket Creek has the potential to support limited steelhead production in areas accessible by the fish. This is greatly restricted by water quality and water quantity limitations. Anadromous fisheries resources are restricted to the lower 1.9 miles of the Tonasket Creek subwatershed due to steep gradient of the channel in this area that restricts passage and use above this point (Tonasket Falls/Chesaw grade). Steelhead fry have been observed in the confluence area where Tonasket Creek joins the Okanogan River by Ken Williams, Area Fish Biologist Region 2 Washington Department Fish and Wildlife (retired), presumably using the confluence area for rearing, and to evade predators found in the mainstem Okanogan River. Summer steelhead smolt counts totaled 148 from the mouth to the headwaters in 1988 (http://wdfw.wa.gov/webmaps/salmonscape/sasi/full_stock_rpts/1864.pdf). An adult steelhead was caught at approximately RM 1.8 in the late 1970s (D. Buckmiller[3]), and relatively recent redd surveys by the CCT have documented limited spawning by steelhead in the lower creek.

Limiting factors to fish production identified for the Tonasket Creek subwatershed include: sediment from roads (i.e. SR 20 winter maintenance), irrigation de-watering, herbicide and fertilizer application in orchards near the creek, and noxious weeds. While these factors create stressors for the Tonasket system and the fisheries resources that use it, limited and unpredictable flow seems to be the obvious overall limiting factor to salmonid production in the basin. Sufficient water quality is needed year-round to produce out-migrating juvenile fish that are in good enough condition to survive migration to the ocean.

This study focuses on the feasibility of flow augmentation options by conducting surface and subsurface water (hydrologic and hydrogeologic) investigations of the lower Tonasket Creek basin. The restoration of flows to the creek below the Chesaw grade is necessary to facilitate increased fish use and improve fish condition within Tonasket Creek. Evaluation of the feasibility of flow improvements represents a first step in addressing an overall habitat restoration strategy for the creek.

[2] Montgomery Water Group, Inc., Adolfson Associates, Inc., Hong West Associates, Inc, Marshall and Associates, and Washington State Department Of Ecology, 1995.Initial Watershed Assessment, Water Resources Inventory Area 49, Okanogan River Watershed, Open File Report 95-14.

[3] Personal communication – Jeff Fisher with D. Buckmiller

## Objectives

The objectives of this study were to:

- Collect surface water flow and groundwater level data throughout the year at selected locations of Tonasket Creek, and well log information in the vicinity of the creek.
- Analyze collected data and establish relationship between surface flow and groundwater;
- Identify the length of a “dry reach” of Tonasket Creek and duration of a “dry period”;
- Recommend volume of water necessary to replenish losing reach of the creek;
- Recommend mitigation measures

## Methodology

### Step 1: Data Collection

ENVIRON designed and implemented a monitoring program to collect surface water and groundwater data at selected locations of the creek, as shown in Figure 1. This data collection included data collected through continuous and random monitoring programs, and historical data research of flow records on Tonasket Creek.

*Continuous Monitoring* - At locations P1 through P3, Tonasket Creek flows and adjacent groundwater were simultaneously recorded during March 2011 – February 2012 period. These locations were downstream of the Cheesaw waterfalls on Tonasket Creek, but upstream of an observed dry creek reach. Surface flows were obtained utilizing flow discharge-flow depth rating curves obtained from flow depth and velocity data measured with Stingray portable level-velocity loggers (Greyline Instruments, Inc. http://www.greyline.com/specsstingray.htm) in the creek, and several channel cross-section survey at the location of the loggers. Groundwater level was measured utilizing Water Level Logger WL16U (data logger and submersible pressure transducer from Global Water - http://www.globalw.com/products/wl16.html). The flow discharges estimated during the monitoring period are illustrated in Figure 2. The adjacent groundwater levels at P1 through P3 during the same monitoring period are illustrated in Figure 3.

*Random Monitoring* – Along potential dry reach of the creek, creek flows and shallow groundwater levels adjacent to the creek were monitored sporadically in the spring through fall monitoring period. Groundwater level was manually measured using piezometers installed on the creek banks. Creek flow depths were measured in the creek adjacent to each piezometer. Flow discharges were calculated by integrating flow depths and velocities (measured at selected locations using Swoffer or Marsh-McBirney velocity probes) with the “area flow velocity” method. Additional measurements of the groundwater level during the period of 2-3 months was conducted at Gavins well upstream (see Figure 1), and at a private well in the vicinity of the creek near piezometer P8.

*Historical Data Research* – The United States Geological Survey (USGS) maintains continuous flow records at the USGS gage 12439300 (Tonasket Creek at Oroville, operating close to location P5 between 1967 and 1991). The Washington State Department of Ecology (Ecology) conducted manual measurements of the steam stage heights (that are then related to flow discharges via flow rating curve) between 1967 and 1991 at the same location. The USGS daily flow data records indicate consistent drying of the creek (at location P5) during winter time (usually between November and February). However, drying of the creek in summer did not occur until 1987. USGS records show measurable flow in the creek at least through November every year between 1968 and 1986. However, the USGS flow records between 1987 and 1991 indicate consistent drying of the creek starting in late June or early July. Sporadic measurements by Washington State Department of Ecology (Ecology) between 2002 and 2010 indicate flows in the creek have been consistently decreasing to 0.10 cfs in either June or July every year. Ecology has not conducted any flow measurements after July.

**Step 2: Hydrologic/ Hydraulic Model and Water Balance**

*Hydrologic Model* - A general watershed model of Tonasket Creek was developed. Figure 4 outlines major drainages on Tonasket Creek (shown as W), and the locations of monitoring stations and wells (shown as red). The US Army Corps of Engineers (COE) hydrologic HEC-HMS (COE, 2010[4]) model was used. The model was developed utilizing available digital elevation (DEM) data (from Colville Confederate Tribes), soil data (from USDA Soil Conservation Service (SCS)), land-use data (from Google Earth), precipitation-frequency atlas of the United States, and available meteorological data for Oroville, Washington. The following methods were used in the model: The SCS 24-hour Type IA storm with different return periods, Snyder Unit hydrograph method (with basin coefficient Ct=2.0 and peak coefficient Cp=0.6); and the Initial and Constant Loss Method. The hydrologic model was calibrated to the peak flows derived (using PEAKFQ – hydrologic frequency analysis software from USGS) from the daily flow data recorded (between 1968 and 1991) at the former USGS station on Tonasket Creek (USGS 12439300 – Tonasket Creek at Oroville, Washington), as shown in Table 1:

The hydrologic model was calibrated using higher values of infiltration losses (0.35 inches/hour), consistent with more pervious soils (i.e. Type A soils) than the losses expected from more impervious type soils (Type C soils) dominating the site.

**Table 1 – Comparison of Calculated and Predicted Flood Peak Values**

| Return Period (years) | Flood Peak (using USGS PEAKFQ) (cfs) | Modeled Flood Peak (cfs) |
|---|---|---|
| 2 | 54 | 60 |
| 10 | 214 | 228 |
| 100 | 673 | 696 |

*Hydraulic Model* – The Corps of Engineers HEC-RAS model (COE 2010[5]) was used to calculate flow velocities and flow depths along Tonasket Creek. The model accuracy is limited to the accuracy (10-meters) of the DEM describing the watershed. Additional transects across the creek at locations P1, P2, P3, P4, P5, P6, P9b and P10 were obtained during the monitoring program. These transects were used to develop the following flow-rating curves at these locations: (a) flow depth-flow discharge; (b) flow velocity-flow discharge, and (c) wetted perimeter – flow discharge rating curve. Each flow rating curve was approximate, as it was defined with only 3 to 5 points. The flow rating curves provide estimate of the low flows (up to the 2-year event recorded during the May 26, 2011 measurements).These rating curves and the measurements were used to define losses of the flows in the creek downstream of stream-

[4] US Army Corps of Engineers (COE) – Hydrologic Modeling System HEC-HMS, User's Manual, Version 3.5, August 2010.

[5] US Army Corps of Engineers (COE) – HEC-RAS River Analysis System, User's Manual, Version 4.1, January 2010.

gages P1 through P3. These losses were utilized to define spatial and temporal extent of drying of the creek and to recalibrate hydrologic model at very low flows.

*Duration and Spatial Extent of the Losing Creek* - The flows estimated at location P5 of Tonasket Creek during the 2011-2012 monitoring period were compared with the USGS streamgage daily flow records (at that location) to determine duration of the losses and the length of the losing creek at different years and today.

*Volume of water to replenish the creek* - Sensitivity analysis of flow losses was conducted to estimate the volume of water necessary to replenish the creek. The losses were calculated assuming homogenous losses through the wetted perimeter of the creek along different reaches. These losses combine regular losses into the soil due to infiltration, infrequent losses due to diversion of water, and potentially indirect losses due to pumping in the surrounding wells.

**Step 3: Groundwater Analysis and Relationship between Surface Flow Data and Groundwater Data**

To investigate the relation between surface water and groundwater along the Tonasket Creek, ENVIRON installed three surface water gauging stations (P1 through P3) along the Tonasket Creek. Adjacent to each gauging station, ENVIRON installed a piezometer that measured groundwater fluctuation in the aquifer (Figure 2). Surface and groundwater fluctuations were recorded for a period of one year, from March 2011 to March 2012. The recording frequency was one record every five (05) minutes then optimized to be one record per ten (10) minutes.

ENVIRON performed spectral and correlation analyses to investigate the causal relationship between surface and groundwater at each station. Correlation and spectral analyses are one form of time series analysis which provides good insight into the studied environmental variable. Correlation and spectral analyses are based on a system approach as they relate inputs to outputs through the use of statistical functions.

The cross-correlation analysis is used to establish the existing link, if any, between the input time series (depth of water in piezometer), and the output time series (river elevation data). If the input time series is random, the cross-correlation function corresponds to the impulse response of the system. In other cases, the cross-correlation function provides information on the causal and non-causal relationships between the input and the output as well as the importance of these relationships. The cross-correlogram will have one of four basic shapes, each relating to the relationship, or lack thereof, between the input and output (see Appendix 1).

The cross correlogram at the up-gradient station (Figure 5) depict a dissymmetric shape, indicating the presence of a causal relationship between groundwater and surface water. We can therefore conclude that the aquifer is losing water to the benefit of surface water at the up-gradient station,.

The intermediate and down-gradient stations (Figures 6 and 7) show a perfectly symmetrical cross-correlation function centered at $k = 0$. This indicates that both the input (groundwater depth) and the output signals (river elevation) react at the same time to a third independent signal, precipitation for example. In this case, the input does not influence the output. We can therefore conclude that there is no hydraulic relation between the creek and the aquifer at the intermediate and down-gradient sections.

**<u>Step 4: Analysis of Mitigation Measures (Restoration Alternative)</u>**

Mitigation measures involving replenishment of water in Tonasket Creek should include utilization of water from a deeper groundwater reservoir. Most of the existing wells in the vicinity of the creek that utilize this groundwater are located upstream of monitoring locations P1-P9 and in the vicinity of Gavins well, upstream of the Chesaw grade. Thus, mitigation measures that include transport of water to the downstream reach of Tonasket Creek, such as pumping of water from a selected deep well and conveying this water to the Tonasket Creek losing reach, should be considered.

## Discussion of Results

*Length of Drying Reach* - The flows calculated from continuous monitoring at stream-gages P1 through P3, and the flows estimated using the flow rating curves at the other locations are illustrated in Figure 8.The highest flow was recorded during the peak of the flood on May 26, 2011, and the flow exceeded 10 cfs at all locations. Likely, the flow could have been even higher at locations downstream of P6, because an overflow from the main creek channel into the floodplain was observed upstream of the monitoring locations, reducing the flow recorded in the main channel. The lowest flow was recorded between August and November. Downstream reach of the creek between piezometers P6 to P10 was continuously dry between August and November (and most probably longer, as no flows was measured between November and March); the reach of the creek between P5 and P10 was also dry between August and October. It is anticipated that the maximum drying could extend from the mouth of the Okanogan River (just downstream of P10) to P4, corresponding to the length close to 5,000 feet.

*Duration of Drying* – As discussed in the historical data research section, the creek has been consistently drying in winter or is under the ice usually between November and February. After 1987, the lower reach of the creek downstream of P5 gets dry as early as June and may continue dry until winter. Figure 9 illustrates the flows recorded at piezometer P3 during the 2010-2011 monitoring period and the average daily flows from the USGS flow records at the same location. According to the USGS gage record, drying occurs in the creek as early as June, or as late as late July/early August. Figure 10 illustrates estimates of creek flow discharges, flow depths and velocities, at monitoring station P5 during the monitoring period, utilizing continuous flow record at P3 and observed and estimated losses between P3 and P5, and flow rating curves at P5. Flow depth at that location was on average about 0.50 feet and reduced to zero (dry creek) in August. Flow velocity was under 1 ft/sec most of the time, except during the April to June snowmelt period. Comparative evaluation of flow discharges, flow depths, and flow velocities at P3, P5, P9, and P10 are presented in Figures 11, 12, and 13, respectively.

*Depth of the groundwater table adjacent to the creek* – At piezometer P1, statistical analysis shows that adjacent groundwater feeds the creek. At Piezometer P2 and P3, no significant relationship between the creek and the groundwater was established, most likely due to more impervious soils in this reach. Correlation analysis of the non-continuous data in the downstream reach (P5 through P10) was not possible; however drying of the creek at every monitoring location was also accompanied by drop in the adjacent groundwater level below the bottom of the monitoring piezometer. This indicates that both groundwater and the creek responded similarly to the lack of water in this reach.

*Withdrawal of adjacent water* – A Comprehensive data base showing utilization of water in Oroville area from the adjacent wells or the creek itself does not exist. Examination of the publicly available data on well logs from Ecology indicates that the majority of the wells in the reach of the creek downstream of piezometer P8 are all shallow wells (between 20 to 40 feet deep). The wells in the creek reach between P8 and P3 utilize both shallow groundwater (20 to 40 feet deep) and intermediate groundwater (over 100 feet deep). The wells in the upstream reach (US1 to US3) utilize also deep groundwater (over 200 feet deep). The only existing artesian wells are also located in the upstream reach. Information on the pumping records and well capacity is only sporadically available; however maximum permitted withdrawals of up to 0.2 cfs from the creek could clearly affect flows in the creek at times where flow is less than 0.20 cfs (that is most of summer), especially during simultaneous maximum pumping from some of the high capacity wells between June and November. It is also possible that unknown and unrecorded diversions could occur directly from the creek.

*Estimate of Water Needs to Replenish Tonasket Creek*

Rearing anadromous fish must have sufficient water quality and quantity throughout entire time they are in the creek to have sustainable production each year. The amount of water in the creek determines the amount and quality of physical habitat available and provides diverse habitat conditions important for food production, refuge from predators and acceptable temperatures that promote growth and survival. Marginal habitat conditions result in increased mortality and poor condition for those fish that survive, which also decreases survival of the young fish migrating to grow during the ocean lifestage before returning to spawn in the creek.

The Tonasket Creek watershed model was specifically calibrated to the low flow estimated during the 2011 summer season. Specifically, measured flows at P3 were reduced by calculating flow lost in the creek due to infiltration through the wetted perimeter in the creek along each consecutive reach downstream (i.e. P3 to P5, P5 to P6, P6 to P8, etc.). The model was used to examine different infiltration rates ranging from the minimum infiltration expected on the site (0.10 inches/hour as an average infiltration rate for Class C soil) to the maximum infiltration required to achieve real losses (due to infiltration and other reasons) observed during summer of 2011 (0.40 inches/hour, consistent with the infiltration through very pervious, i.e. Class A-type soil). Sensitivity analysis was conducted of the minimum required flows in the creek to sustain infiltration losses. If the losses from the creek are close to the minimum infiltration rate of 0.10 inches/hour, the minimum flow of 0.07 cfs will be required at location P3 to sustain flow in the creek to the confluence (Figure 14). If the losses from the creek are close to the maximum infiltration rate of 0.40 inches/hour, the minimum flow of 0.25 cfs will be required at location P3 to sustain flow in the creek to the confluence (Figure 15). If indeed the maximum losses from the creek are close to the permitted withdrawals of 0.20 cfs from the creek, this alternative probably mimics the best all losses in the drying reach of Tonasket Creek. Any mitigation measure including diversion of water to the creek should include bringing (through conveyance piping) the minimum flow of 0.25 cfs to the creek. This minimum flow would need to be more closely examined in terms of the physical habitat conditions that this amount of water would create.

Additional flow diversions to the creek might be necessary to sustain best habitat conditions for steelhead rearing. It is estimated, from a basic examination, that flows of at least 1 cfs may be required in the creek to sustain flow depth and velocities required by the rearing lifestage for steelhead. If adult steelhead migration related to low flow was a potential limiting factor, higher flows could be required. Conveyance of higher flows (1cfs and higher) could be periodically supplied (not continuous) during the adult migration period to provide sufficient time for steelhead to migrate through this reach of Tonasket Creek at least up to the Chesaw grade.

## Recommendations

More information is necessary to understand how pumping from nearby wells and direct diversions from the creek affect water in the creek. This information should at least include collection of the following data:

- Geologic longitudinal profile along the creek and several transects perpendicular to the creek;
- Pump tests from the existing wells adjacent to the creek;
- Slug tests on selected wells to measure change in hydraulic depth at each well (and to estimate hydraulic conductivity and other parameters)
- Information on current pumping from each well in use;
- Information on other direct diversions from the creek;
- Infiltration and other tests necessary to define hydraulic conductivity, porosity, and storage coefficient (these can be obtained by installing transducers measuring groundwater at selected wells);
- Information on the habitat conditions required to ensure successful production of steelhead in the creek in relation to water quantity.

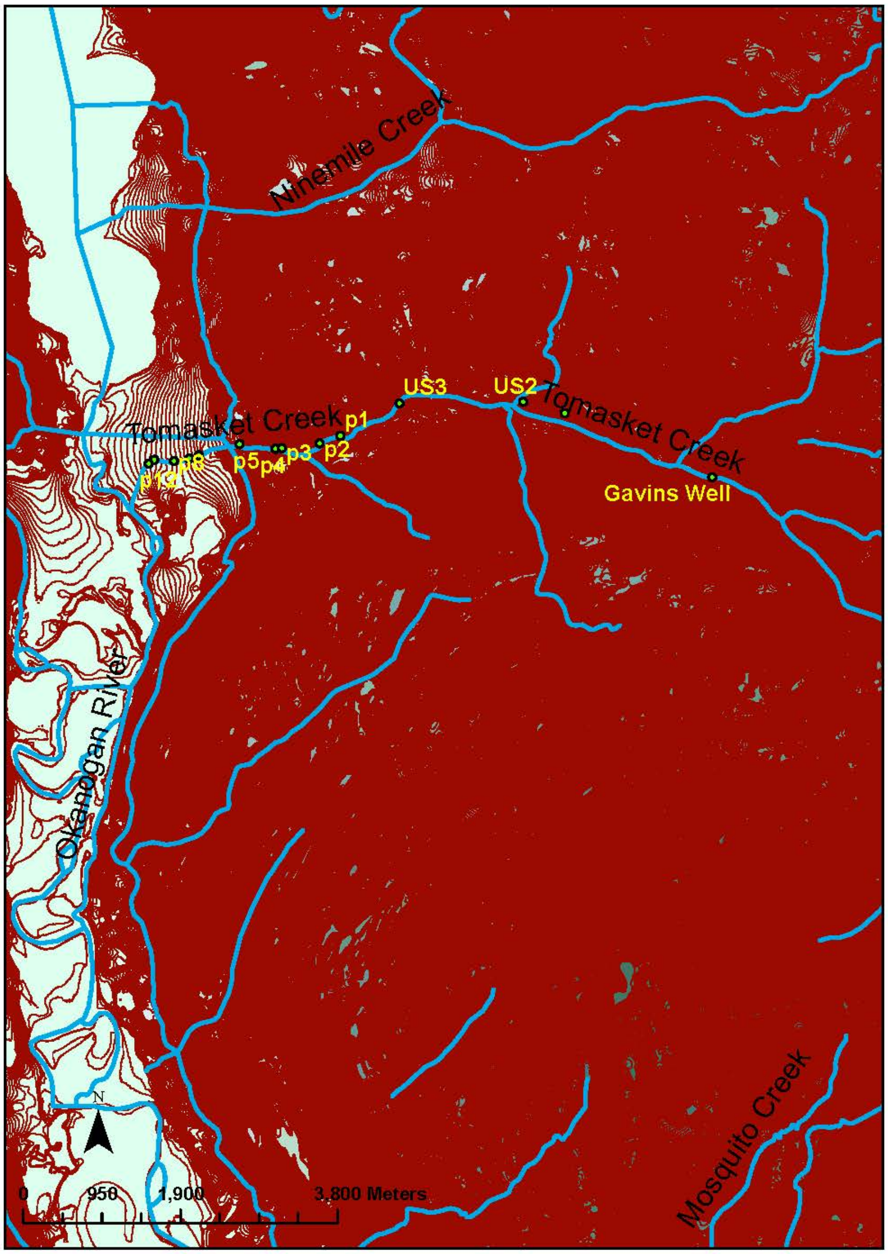
Optimal pumping rate from each well can be established using above information. The above information can be used to develop:

- A numeric groundwater model showing influence on simultaneous pumping from selected wells (i.e. MODFLOW model);
- Optimal pumping rate for extraction of water from a selected deep well upstream of the Chesaw grade necessary for replenishment of water in the downstream reach of the creek;

In summary, our evaluation using 2011-2012 monitoring data indicates that approximately 0.25 cfs of water replenishment is necessary in the lower reach of Tonasket Creek to improve habitat conditions in this part of the creek. However, this replenishment number would be different each year because it is dependent on the watershed hydrology and frequency and magnitude of water use for agricultural and domestic needs.

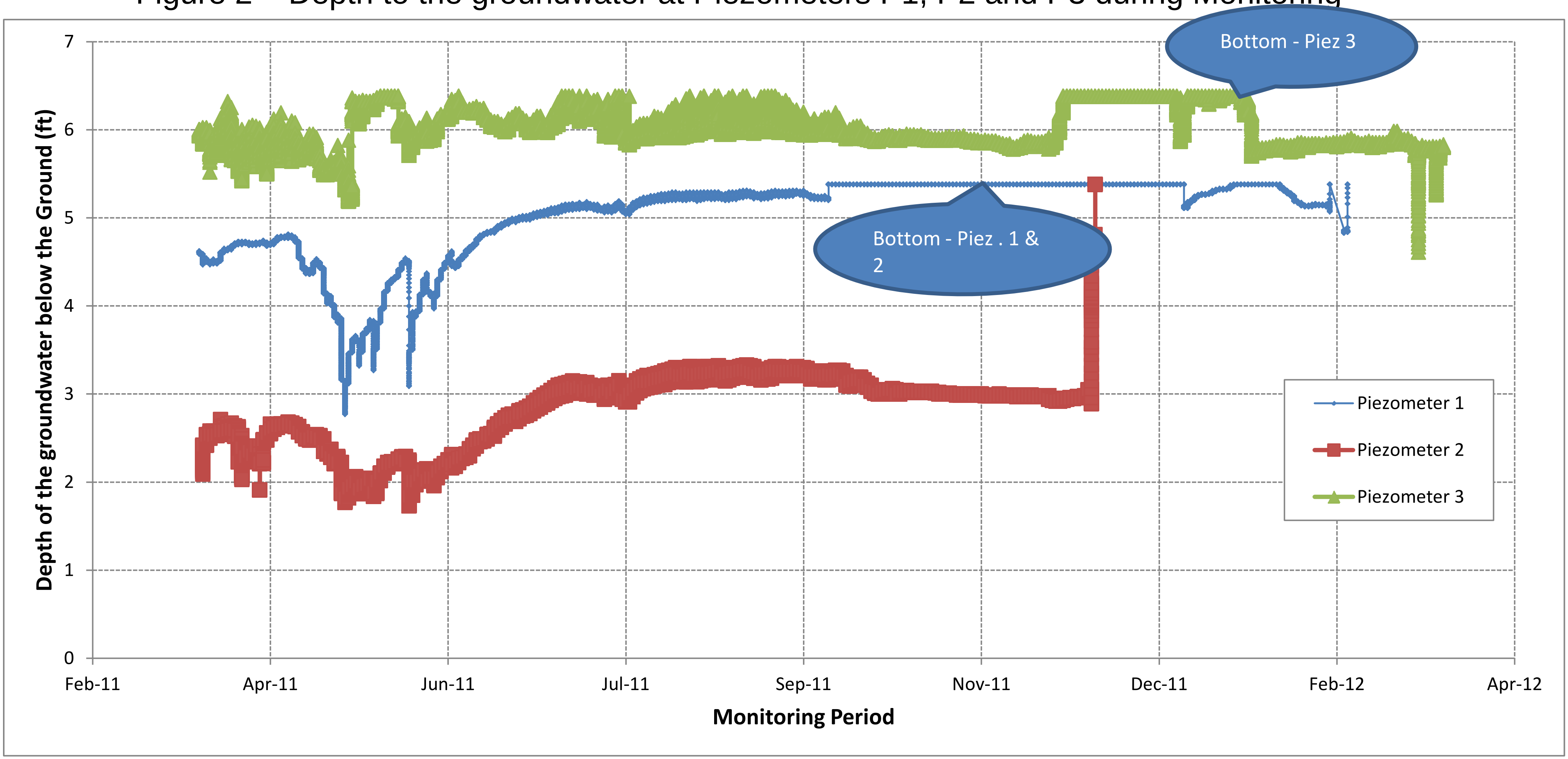
At a minimum, we recommend obtaining geological profiles, step drawdown test and slug test from a selected upstream well to examine the maximum theoretical withdrawal limit that can be pumped and diverted to the lower reach of Tonasket Creek. These tests can also be used to better define times and capacity of periodic pumping (i.e. of 1-2 cfs) that may be necessary to maintain the minimum flows for the steelhead. To support a sustainable population of steelhead, there would need to be a better understanding of water availability on a temporal and spatial basis directly related to the habitat needs of the fish.  Other mitigation related to water storage or channel modification could also be important.

Figure 1- Tonasket Creek and Monitoring Locations




Note: P1, P2, P3 = continuous monitoring: March 2011 – March 2012

Figure 2 – Depth to the groundwater at Piezometers P1, P2 and P3 during Monitoring



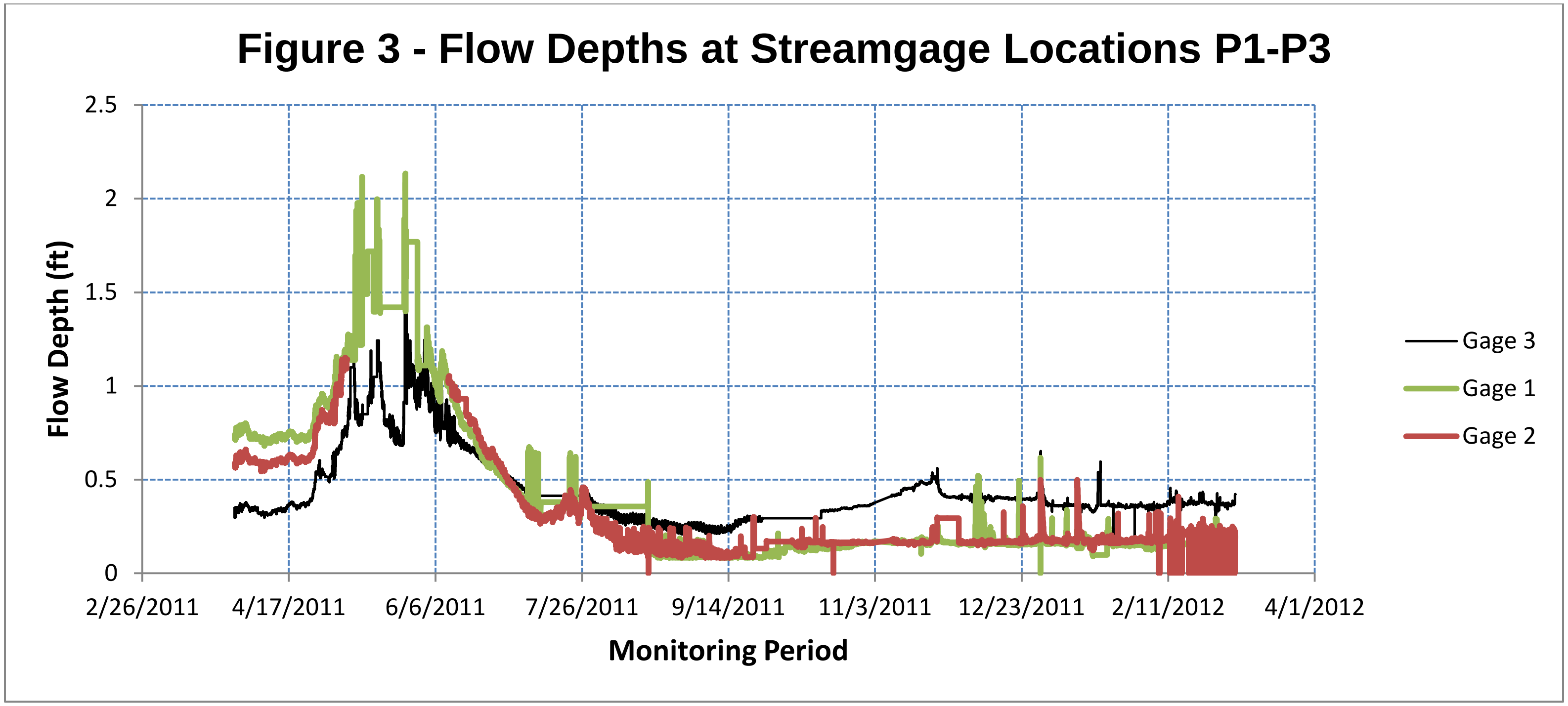


Figure 3 - Flow Depths at Streamgage Locations P1-P3
Flow Depth (ft)
2.5
2
1.5
1
0.5
0
2/26/2011
4/17/2011
6/6/2011
7/26/2011
9/14/2011
11/3/2011
12/23/2011
2/11/2012
4/1/2012
Monitoring Period
Gage 3
Gage 1
Gage 2

# Figure 4 – Tonasket Creek Watershed

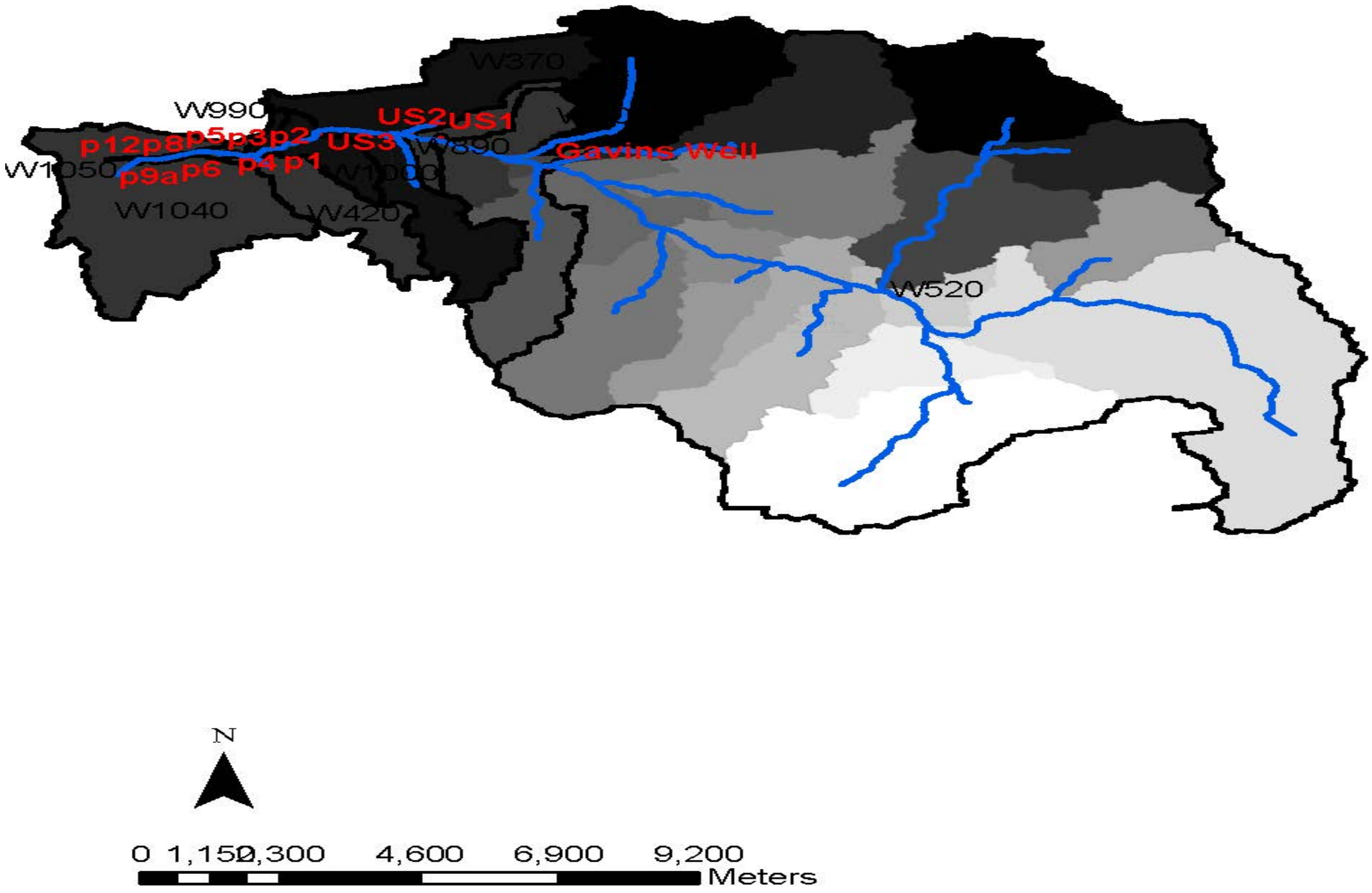


**Figure 5. Cross-Correlogram: Depth to water in piezometer P1 as input and river elevations as output (Up-gradient section)**

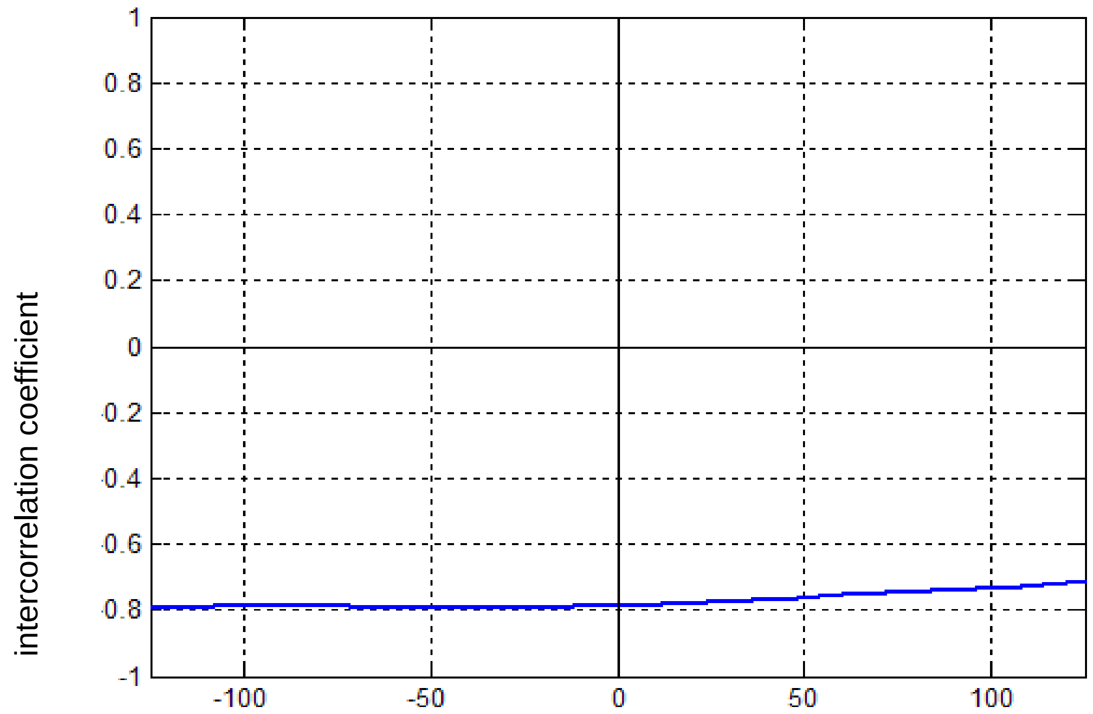


**Figure 6. Cross-Correlogram: Depth to water in piezometer P2 as input and river elevations as output (Intermediate section)**

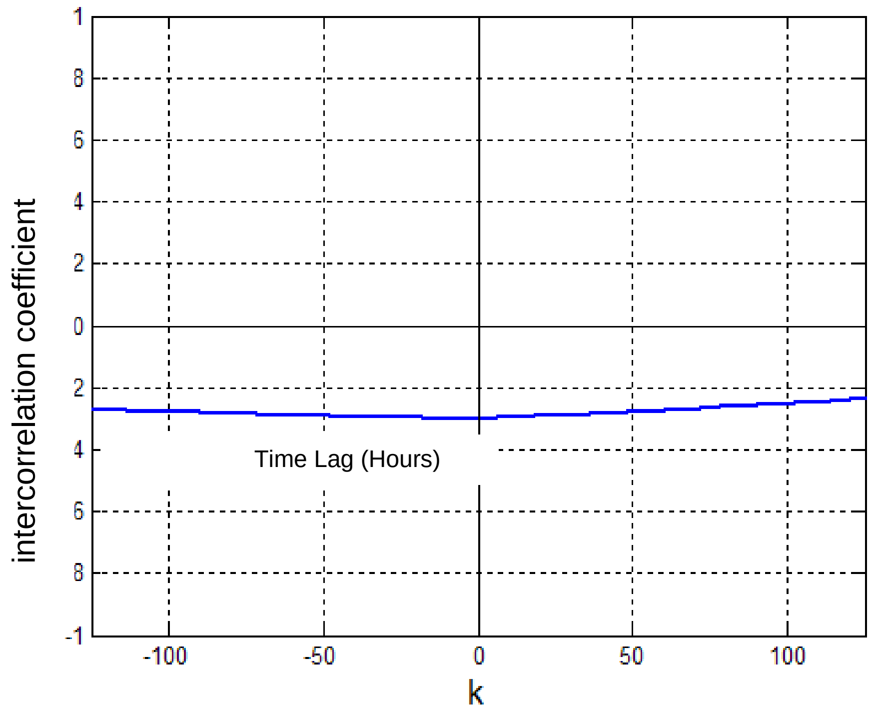
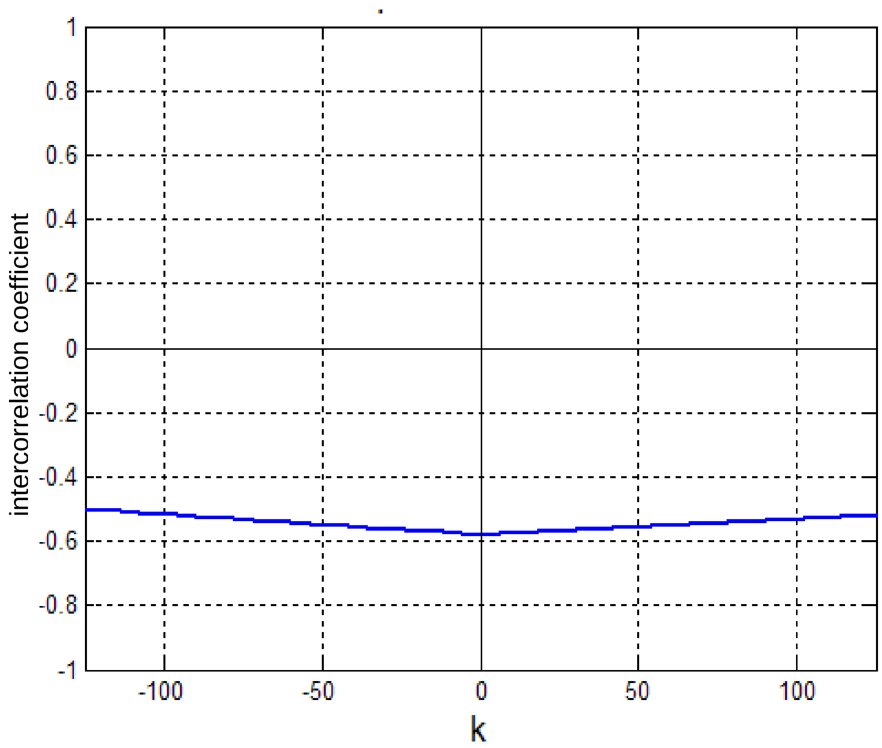


**Figure 7. Cross-Correlogram: Depth to water in piezometer P3 as input and river elevations as output (down-gradient section)**



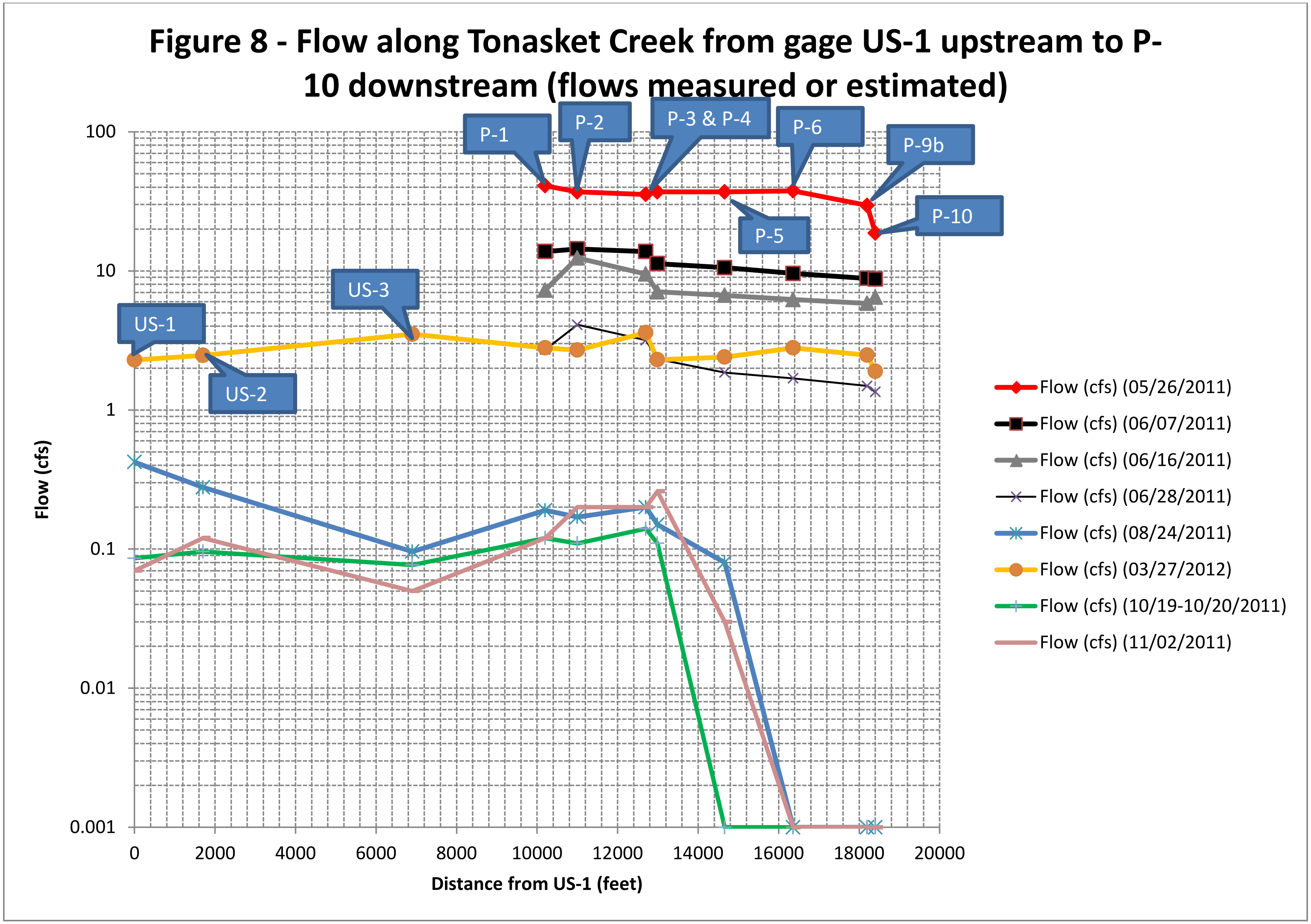


Figure 8 - Flow along Tonasket Creek from gage US-1 upstream to P-10 downstream (flows measured or estimated)
Flow (cfs)
Distance from US-1 (feet)
100
10
1
0.1
0.01
0.001
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
US-1
US-2
US-3
P-1
P-2
P-3 & P-4
P-5
P-6
P-9b
P-10
Flow (cfs) (05/26/2011)
Flow (cfs) (06/07/2011)
Flow (cfs) (06/16/2011)
Flow (cfs) (06/28/2011)
Flow (cfs) (08/24/2011)
Flow (cfs) (03/27/2012)
Flow (cfs) (10/19-10/20/2011)
Flow (cfs) (11/02/2011)

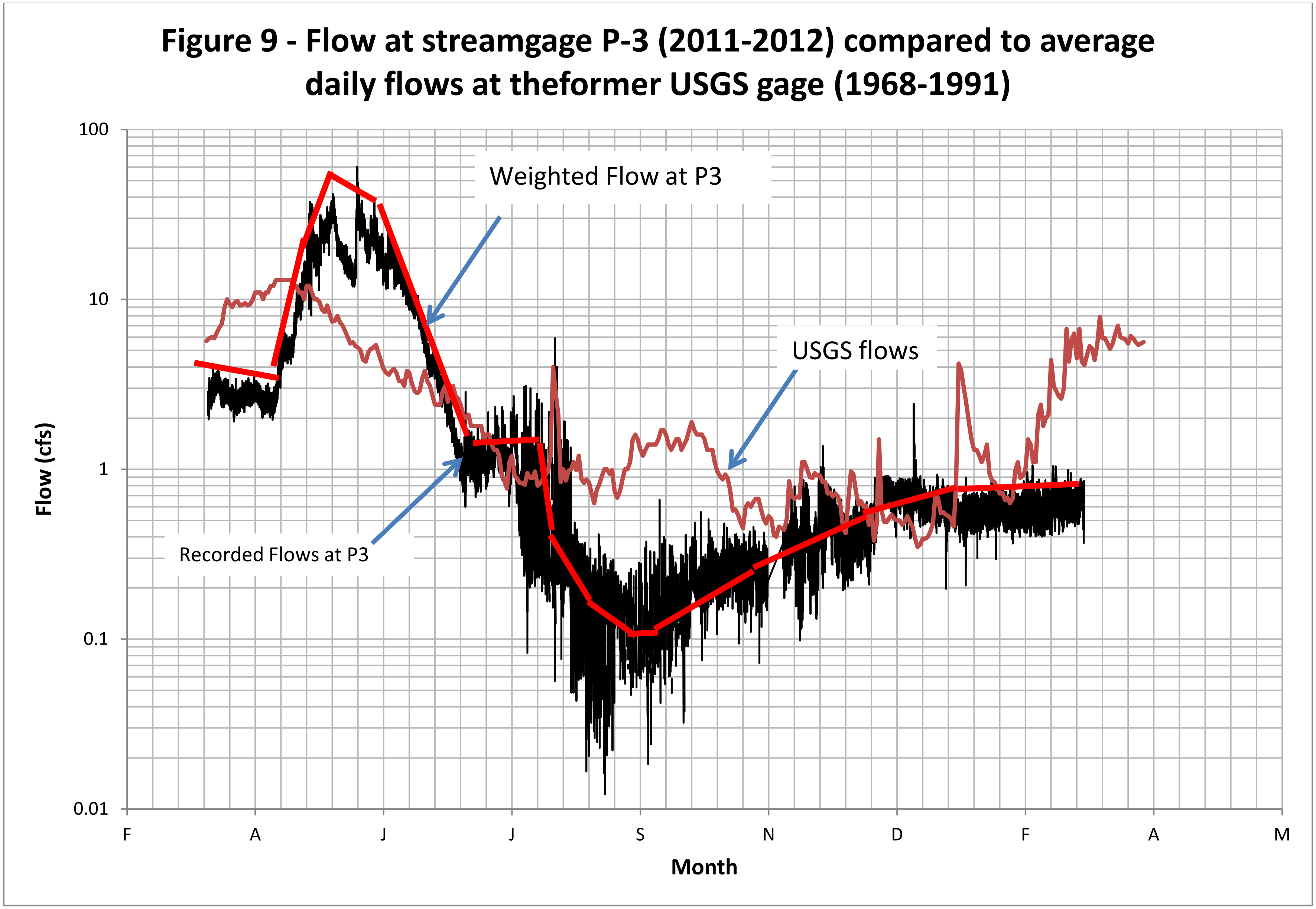


Figure 9 - Flow at streamgage P-3 (2011-2012) compared to average daily flows at theformer USGS gage (1968-1991)
Weighted Flow at P3
USGS flows
Recorded Flows at P3
Flow (cfs)
100
10
1
0.1
0.01
F
A
J
J
S
N
D
F
A
M
Month

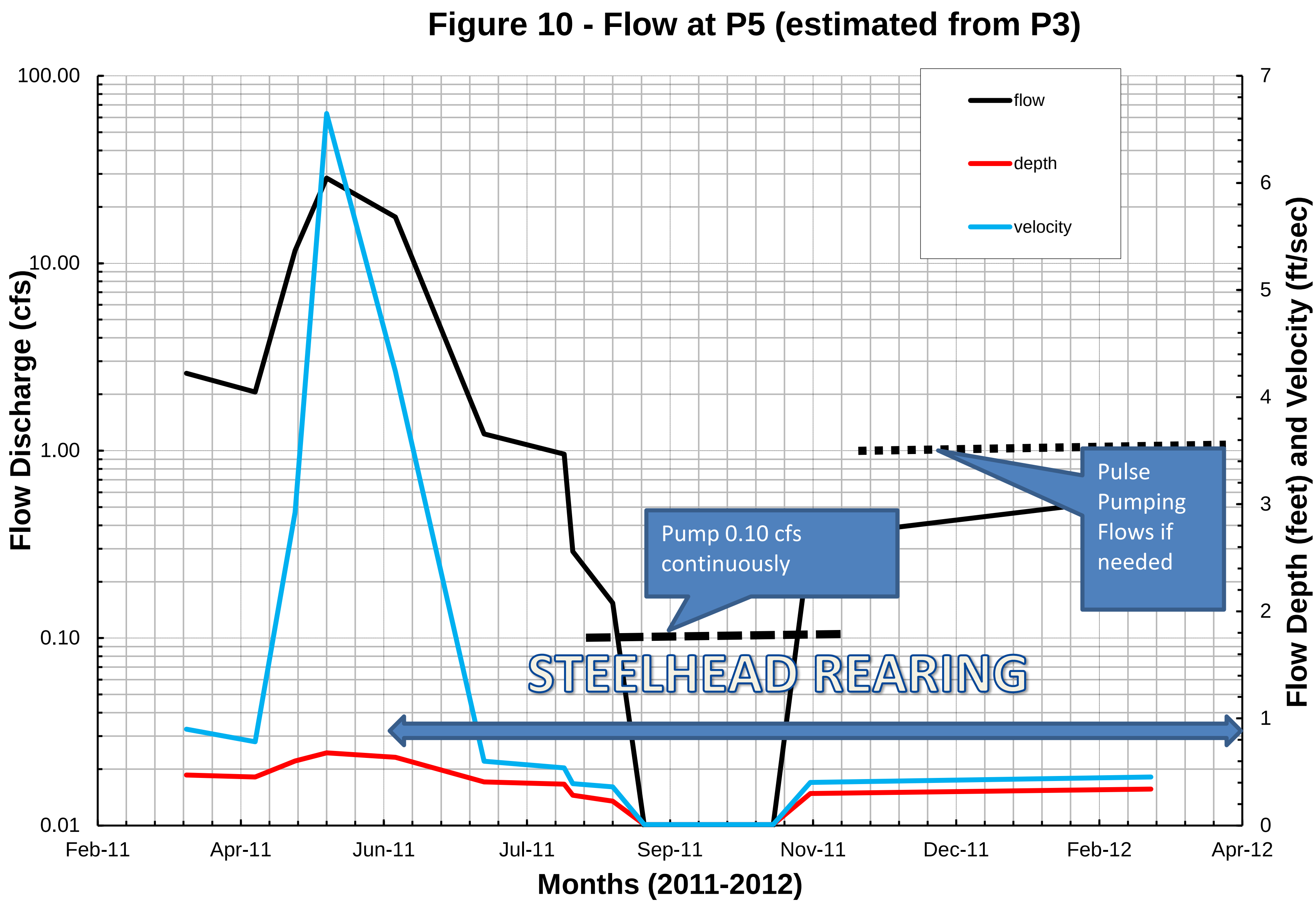


Figure 10 - Flow at P5 (estimated from P3)
Flow Discharge (cfs)
100.00
10.00
1.00
0.10
0.01
Flow Depth (feet) and Velocity (ft/sec)
7
6
5
4
3
2
1
0
flow
depth
velocity
Pump 0.10 cfs continuously
Pulse Pumping Flows if needed
STEELHEAD REARING
Feb-11
Apr-11
Jun-11
Jul-11
Sep-11
Nov-11
Dec-11
Feb-12
Apr-12
Months (2011-2012)

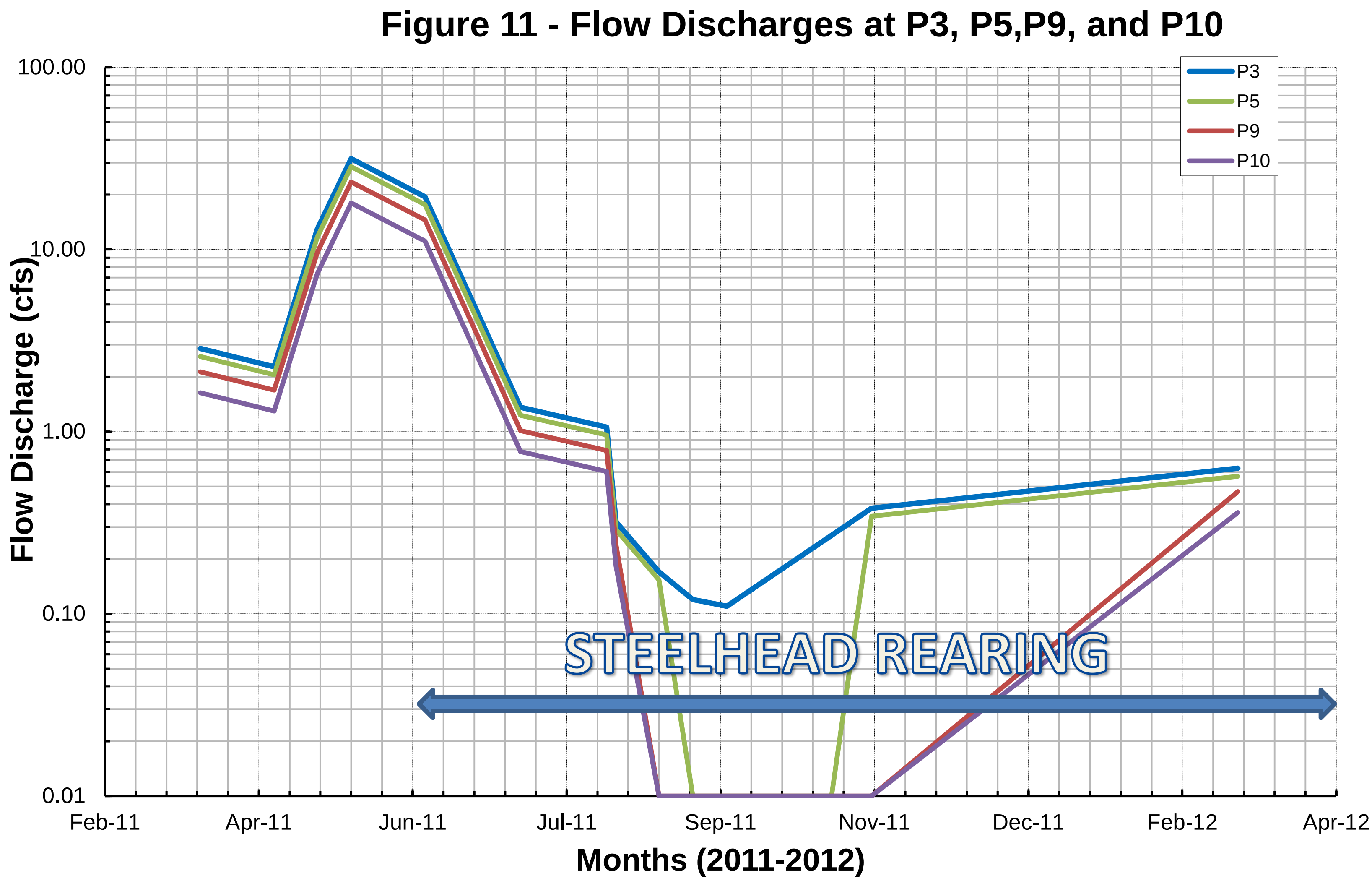


Figure 11 - Flow Discharges at P3, P5,P9, and P10
P3
P5
P9
P10
100.00
10.00
1.00
0.10
0.01
Flow Discharge (cfs)
STEELHEAD REARING
Feb-11
Apr-11
Jun-11
Jul-11
Sep-11
Nov-11
Dec-11
Feb-12
Apr-12
Months (2011-2012)

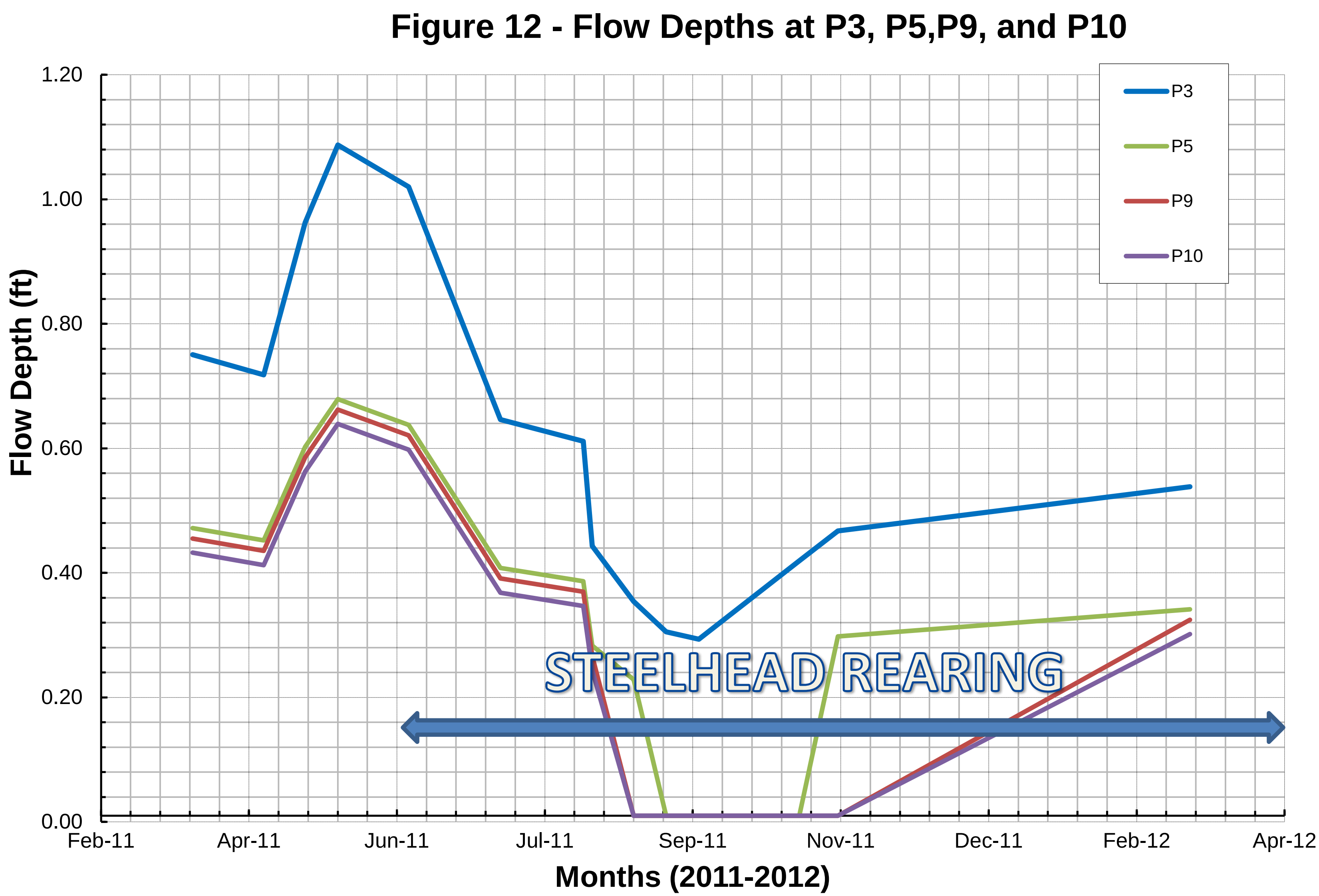


Figure 12 - Flow Depths at P3, P5,P9, and P10
P3
P5
P9
P10
STEELHEAD REARING
Flow Depth (ft)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Feb-11
Apr-11
Jun-11
Jul-11
Sep-11
Nov-11
Dec-11
Feb-12
Apr-12
Months (2011-2012)

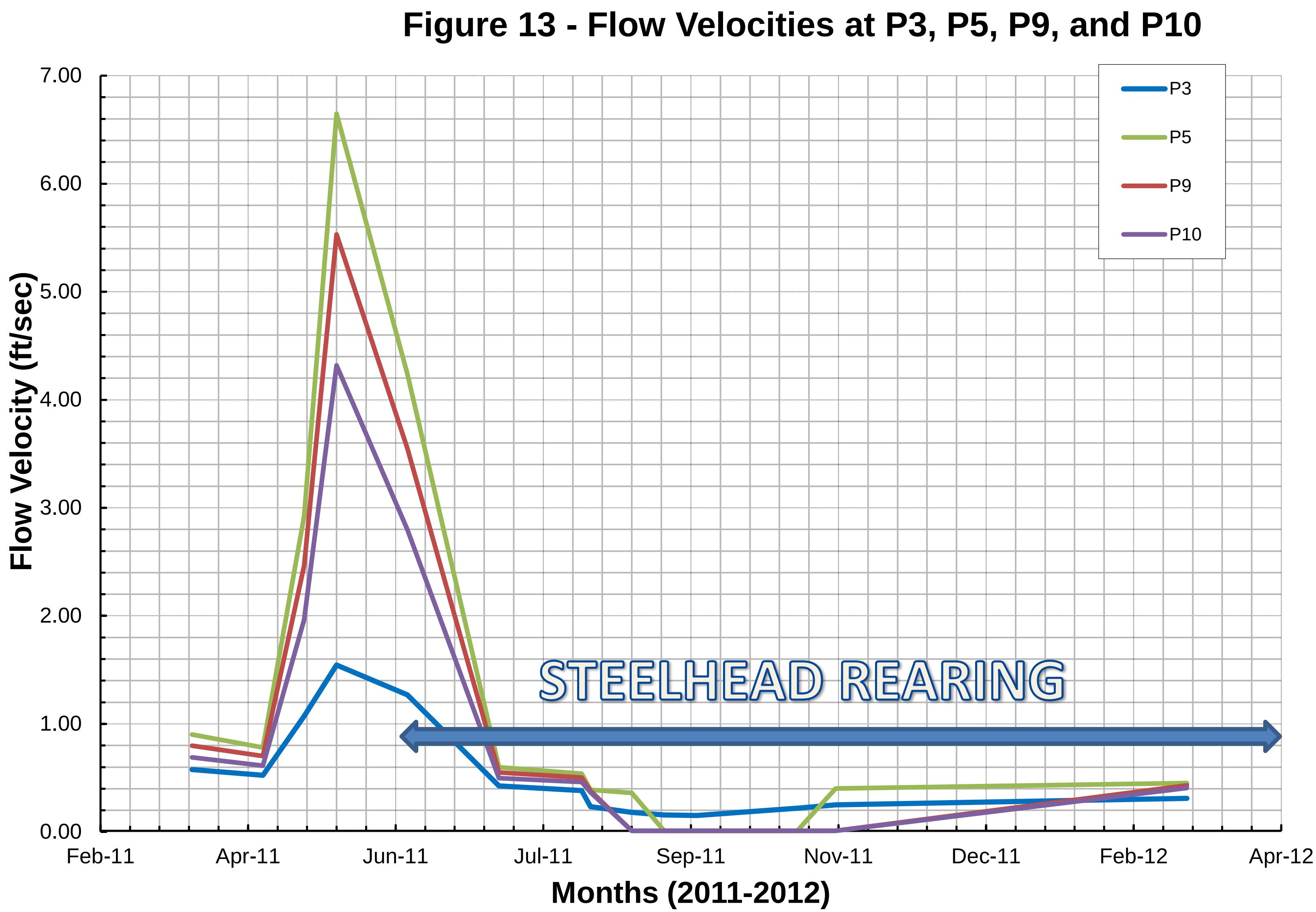


Figure 13 - Flow Velocities at P3, P5, P9, and P10
P3
P5
P9
P10
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Flow Velocity (ft/sec)
STEELHEAD REARING
Feb-11
Apr-11
Jun-11
Jul-11
Sep-11
Nov-11
Dec-11
Feb-12
Apr-12
Months (2011-2012)

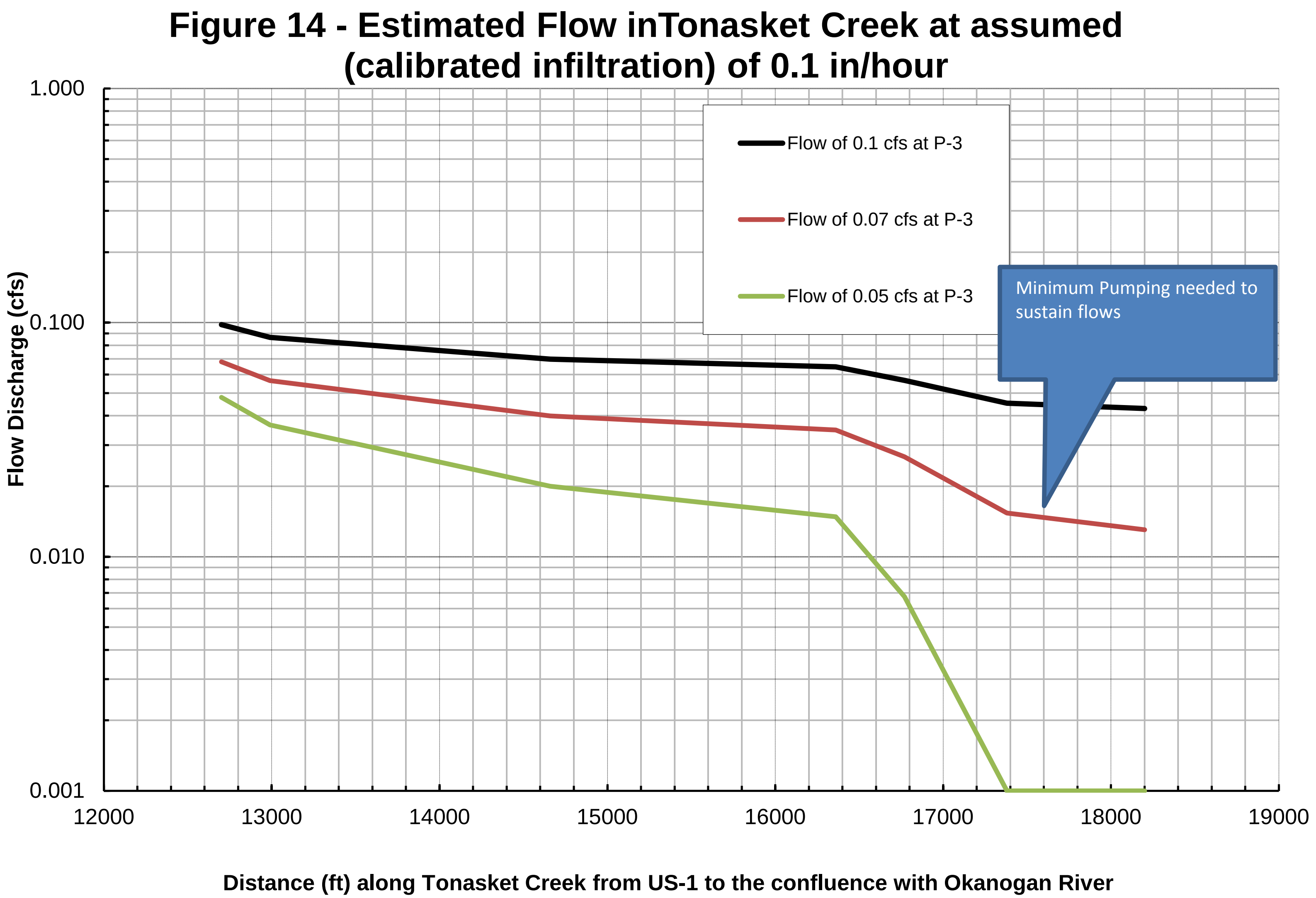


Figure 14 - Estimated Flow inTonasket Creek at assumed (calibrated infiltration) of 0.1 in/hour
Flow Discharge (cfs)
1.000
0.100
0.010
0.001
12000
13000
14000
15000
16000
17000
18000
19000
Flow of 0.1 cfs at P-3
Flow of 0.07 cfs at P-3
Flow of 0.05 cfs at P-3
Minimum Pumping needed to sustain flows
Distance (ft) along Tonasket Creek from US-1 to the confluence with Okanogan River

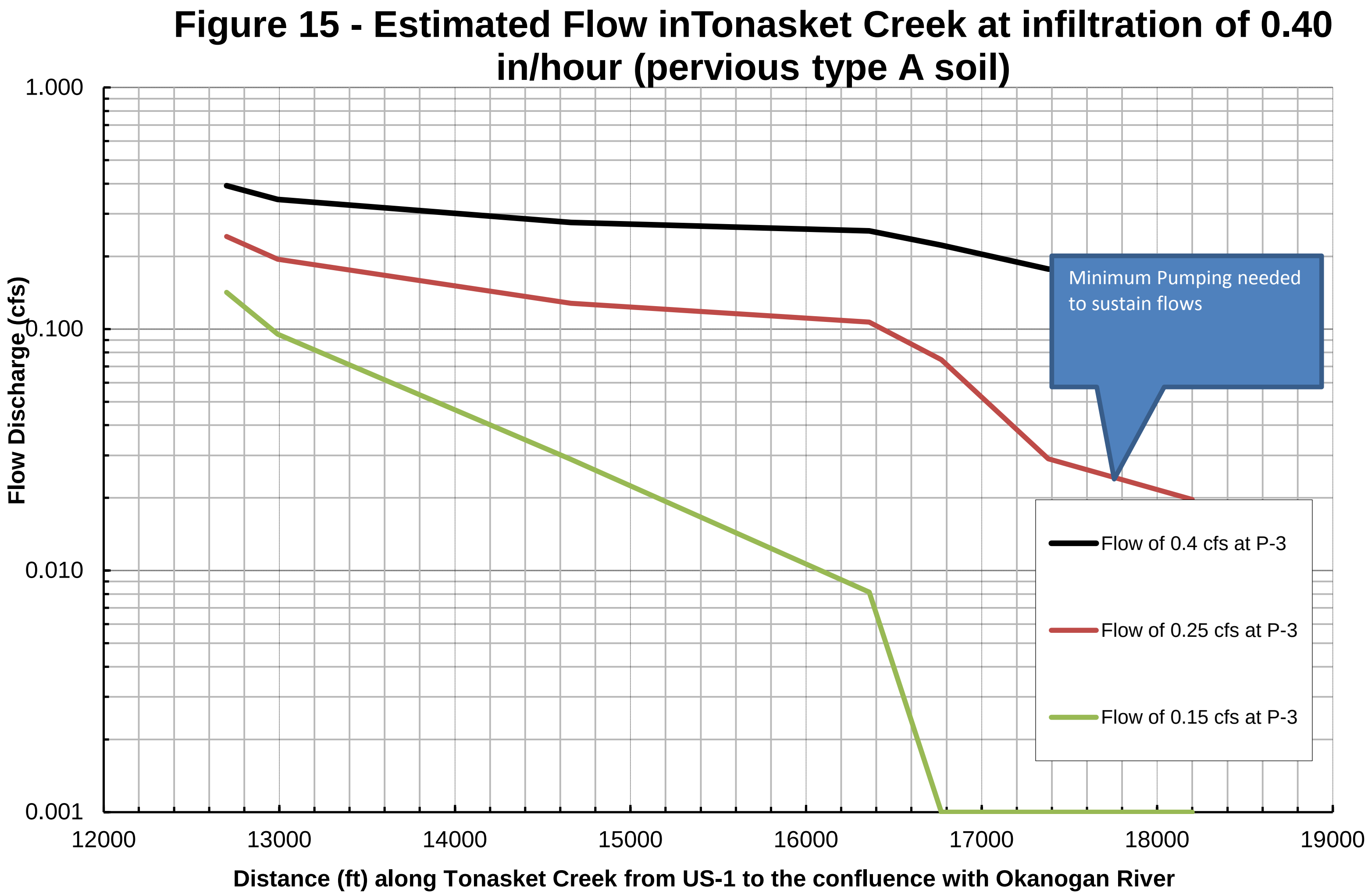


Figure 15 - Estimated Flow inTonasket Creek at infiltration of 0.40 in/hour (pervious type A soil)
Flow Discharge (cfs)
1.000
0.100
0.010
0.001
12000
13000
14000
15000
16000
17000
18000
19000
Distance (ft) along Tonasket Creek from US-1 to the confluence with Okanogan River
Minimum Pumping needed to sustain flows
Flow of 0.4 cfs at P-3
Flow of 0.25 cfs at P-3
Flow of 0.15 cfs at P-3