

Bed Material Transport, Cub River, Idaho

I. Goals for learning and discussion:

- A. Practice using models for estimating transport rates and their uncertainty
- B. Practice estimating effective discharge and its uncertainty
- C. Discuss the role of water diversion and sediment supply in channel change

Background

The Cub River is a tributary to the Bear River, draining 590 km² of southeastern Idaho (Fig. 1). Runoff is dominated by snowmelt and has been modified by irrigation and water supply diversions beginning in the 19th century. Grams, Schmidt, and Majerova (2008) conducted a study evaluating the effect of these diversions on the transport regime and on related channel adjustment. In this exercise, we will take advantage of the extensive measurements of flow, sediment transport, and channel geometry to estimate sediment transport rates and explore how diversions might influence the frequency of bed disturbance and sediment transport.

The Cub River study area extends from the confluence of Carter Creek to the mouth of the Cub River canyon, near Franklin, Idaho (Fig. 2). Elevation decreases from 1687 m near the confluence with Carter Creek to 1389 m at the downstream end of the study area. The contributing drainage area increases from 82 km² near the upstream end of the study area to 168 km² at the downstream end. The upstream reaches of the study area include cascade, plane bed, step-pool, and pool-riffle channel patterns. Gradient and grain size decrease downstream, and the dominant channel pattern becomes pool-riffle.

Land use ranges from undeveloped recreation and livestock grazing on forested land within the Caribou-Targhee National Forest to developed recreation and agriculture on private land.

Water withdrawals with 1880-1882 priority dates are made at three locations. The lower two diversions operate during the irrigation season, (typically May through mid-October) and the upper, trans-basin diversion operates during the balance of the year. At the lowest diversion, a fish ladder was installed in 2006 to remove a blockage to upstream fish migration. 2007 observations show that 200 cutthroat trout and 80 whitefish subsequently utilized the fish ladder to migrate upstream.

The diversions are the basis for dividing the study area into 4 segments (Fig. 2). Study sites were established to characterize stream flow and sediment flux in each of the channel segments. Within each segment, a site was selected based on suitability for bed load sampling using bed load traps [Bunte, 2005]. Each study site is located in a reach

with mobile bed material and a relatively wide (~18 m) and shallow channel with minimal cross-channel topographic variation. We will focus on measurements made at the upstream site (Site 1) to use several different approaches to estimate sediment entrainment and transport.

Hydrology

The annual flood on the Cub River is driven by snowmelt and varies in magnitude from year to year (Fig. 3). The 1.5-yr flood is between 518 and 550 ft³/s, based on the Weibull plotting position or the Log-Pearson III distribution, respectively (Fig. 4). The 2-yr flood is between 576 and 635 ft³/s, based on the Weibull plotting position and the Log-Pearson III distribution, respectively. As is characteristic of other streams of the Bear River Range, there is relatively little difference between the magnitude of the 10-yr and 50-yr flood. The largest flood occurred in 1986 and is an outlier in relation to the rest of the distribution of flood flows.

Geomorphology, Hydraulics, and Bed Entrainment at Study Site 1

Study Site 1

Site 1 is located 1.13 km downstream from the confluence of Cub River and Carter Creek (Figure 2). The locations of channel monitoring cross-sections, the bed load sampling cross-section, and the stage plates are shown in Figure 8. Site 1 is within a reach in Segment 1 that has pool-riffle channel morphology with occasional boulder riffles. The upstream end of the site (XS 1F) is about 25 m downstream from a boulder riffle, visible in the background of Figure 9 (a). The bed-load measurement cross-section (XS 1C) is just upstream from a small riffle. A pool forms downstream of this riffle at peak discharges. Repeat cross-section measurements made in 2007 show that the channel was stable during the study period within one median grain diameter (Figure 10). Cross-section 1D was established in 2006, but not repeated in 2007. The 2007 measurements do show changes at and near the left bank of cross-section 1E. This cross-section crosses a large debris pile which accumulated wood during the 2007 runoff season. The presence of the woody debris made it impossible to repeat the cross-section precisely, resulting in the apparent change near the left bank (Figure 10 (e)).

The average slope of the reach encompassing Site 1 is 0.020 at both low and high discharges (Figure 11). The pool shown by the high water surface elevation downstream from XS 1E is also a result of the debris jam (Figure 12). Channel width varies from approximately 19 m at 4 m³/s up to 23 m at 12 m³/s. The width of active bed load transport, defined as the part of the channel composed of mobile bed material, is 16.8 m. The median size of the bed surface at the measurement cross-section is 71 mm (Figure 13). The median size of the gravel bar surface and subsurface is 36 mm and 46 mm, respectively. A gravel bar is located about 25 m downstream from the measurement cross-section (Figure 8).

A total of 218 tracer particles were installed in two lines at Site 1. Of those, 151 particles were recovered, 42 % of which moved from the original line (Figure 14). Because we were able to locate particles on the line and those that moved a short distance, we assume that all particles not recovered moved farther than we could trace them, or were covered by other particles. The results indicate 100% mobilization of particles 16 mm and smaller, with mobilization decreasing to about 40% for 90 mm particles (Figure 15). The stage-discharge relation at Site 1 is shown in Figure 16.

Sediment Transport at Site 1

During the 2006 runoff season, 207 bed-load measurements were made at four study reaches of the Cub River and the diversion canals, and an additional 47 measurements were made in 2007. Samples were collected with both bed-load traps and with hand-held samplers. Each measurement consisted of 3 to 6 individual samples, collected at fixed intervals at each measurement cross-section. All samples were processed for total load and a subset of samples was also processed to determine the grain size distribution. The median size of the transport was computed as the weighted average from the individual samples. Because the trap samplers use a 4-mm mesh and the hand-held samplers have a 0.5 mm mesh, total sample rates computed from the different samplers are not directly comparable. The samples collected using the hand-held samples indicated that the material between 0.5 and 4.0 mm comprised between 10% and 90% of the total sample volume. For the hand-held samples, we calculated transport rates for each sample truncating the sample at 0.5 mm and at 4.0 mm. We computed linear regressions that predict the transport rate for all material larger than 0.5 mm based on the rate for material larger than 4.0 mm. In each case, the regression was fit with intercept forced to zero that resulted in a computed r^2 of 0.97 or greater.

Flow Extractions

Stream flow is extracted from the channel downstream from Site 1. Records obtained from the Cub River Water Master and measurements in canals were used to develop a continuous record of surface water diversions from the system. These data, as well as stage-discharge measurements made at downstream sites, were used to determine the stream flow further along the Cub River. Figure 18 shows the hydrographs for the period between 2007 and 2008 at the USGS gaging station and at Site 3, just upstream from the Lower Diversion. One can see that stream flow in May is greater in downstream parts of the watershed, but diversions reduce the magnitude of the flood in downstream parts of the network by late May.

This exercise focuses on measurements made at the upstream site (Site 1). You can find information on needed input on some of the figures and in CubR_Input.xls .

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Wednesday, 31 July 2024

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*This exercise focuses on measurements made at the upstream site (Site 1). You can find information on needed input on some of the figures and in **CubR_Input.xls**. For efficiency, I have already entered input to the spreadsheets **SRC_Cub.xls** and **MonteCarloCub.xls***

The purpose of the assignment is to compare several different approaches for estimating sediment entrainment and transport.

A. Develop a sediment rating curve using the **Transport** worksheet in **SRC_Cub.xls**. The data presented are from the Bunte samplers, meaning it is for all sizes coarser than 4 mm.

B. At what discharge does sediment transport begin (critical discharge Q_c)? How often is it exceeded (i.e. how frequently is the bed entrained)? Let's evaluate the evidence.

- i. Determine the discharge at $\tau = \tau_r$ from the **Transport** worksheet in **SRC_Cub.xls**.
- ii. Estimate Q_c and its variability using **MonteCarloCub.xls**. What are the uncertainty bounds on Q_c ? *The variability in Q_c is more important than the actual value of Q_c .*
- iii. Consider the values estimated in i. and ii. relative to the tracer observations during the 2007 season (Figure 15). The peak discharge during the 2007 runoff season was 12.7 m³/s.
- iv. Using the flood frequency information (Figure 4), estimate the frequency of floods exceeding your estimates of Q_c . Now, what if diversions were to reduce peak flows by, say, 70 cfs? By 160 cfs? How would this change the frequency of bed disturbance?

C. Calculate total and mean annual sediment load (for the data presented; >4mm) using worksheet **Qeffective** in **SRC_Cub.xls**.

D. Calculate the effective discharge using worksheet **Qeffective** in **SRC_Cub.xls**. Does the effective discharge depend on the choice of discharge bin size?

TURN IN*: Short answers to A-D, using screen grabs from the spreadsheets.

Note: To open **MonteCarloCub.xls**, you will have to make sure your macro security settings in Excel are set to medium. If they are set too high, you will not be able to run the VBA program embedded in the spreadsheet.

* Assignments required for those taking the course for credit or for CEU.

Figure 1 -- Map showing Cub River Basin and USGS stations for this area

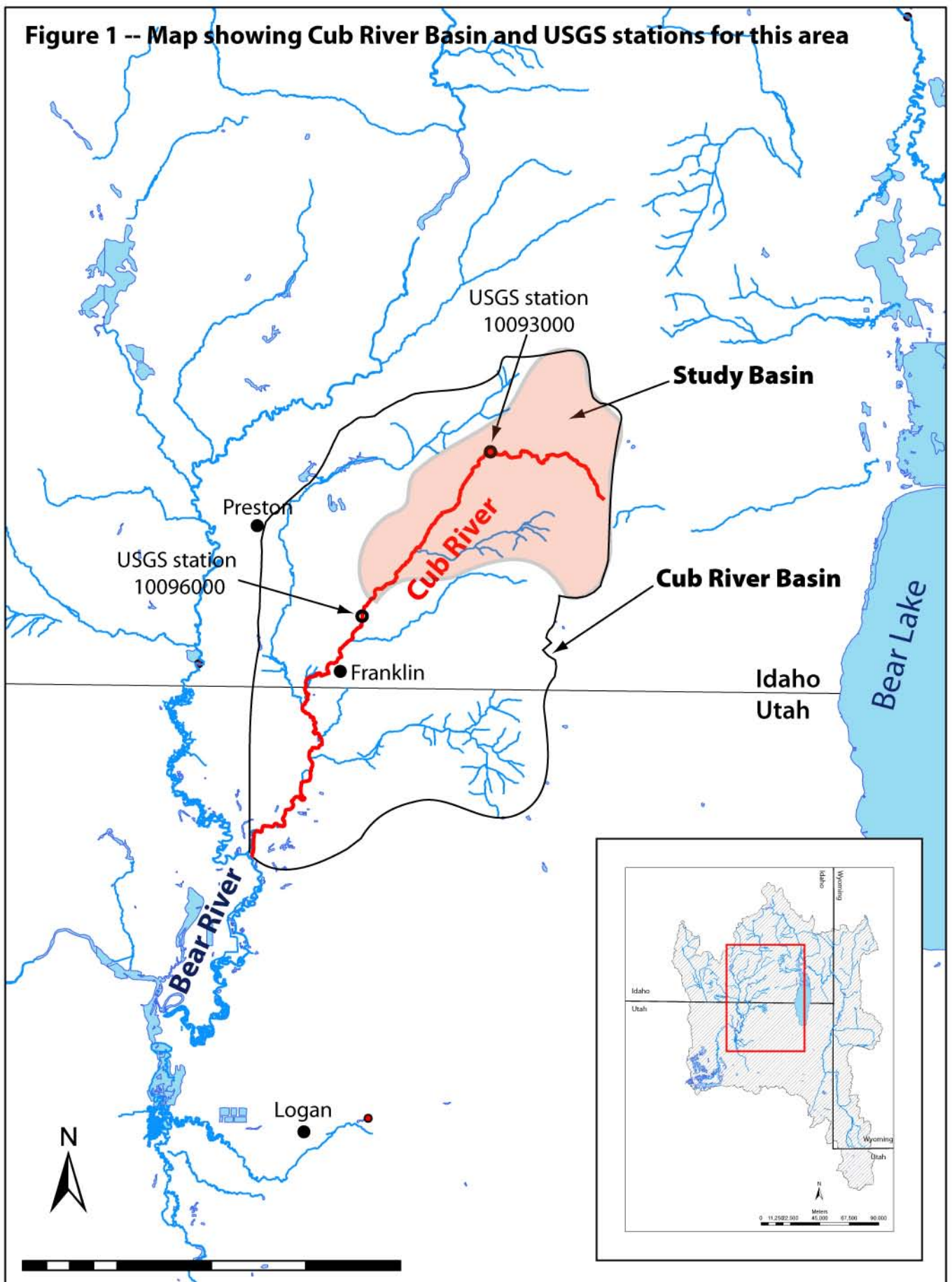


Figure 2 -- Map showing Cub River study area and study reaches

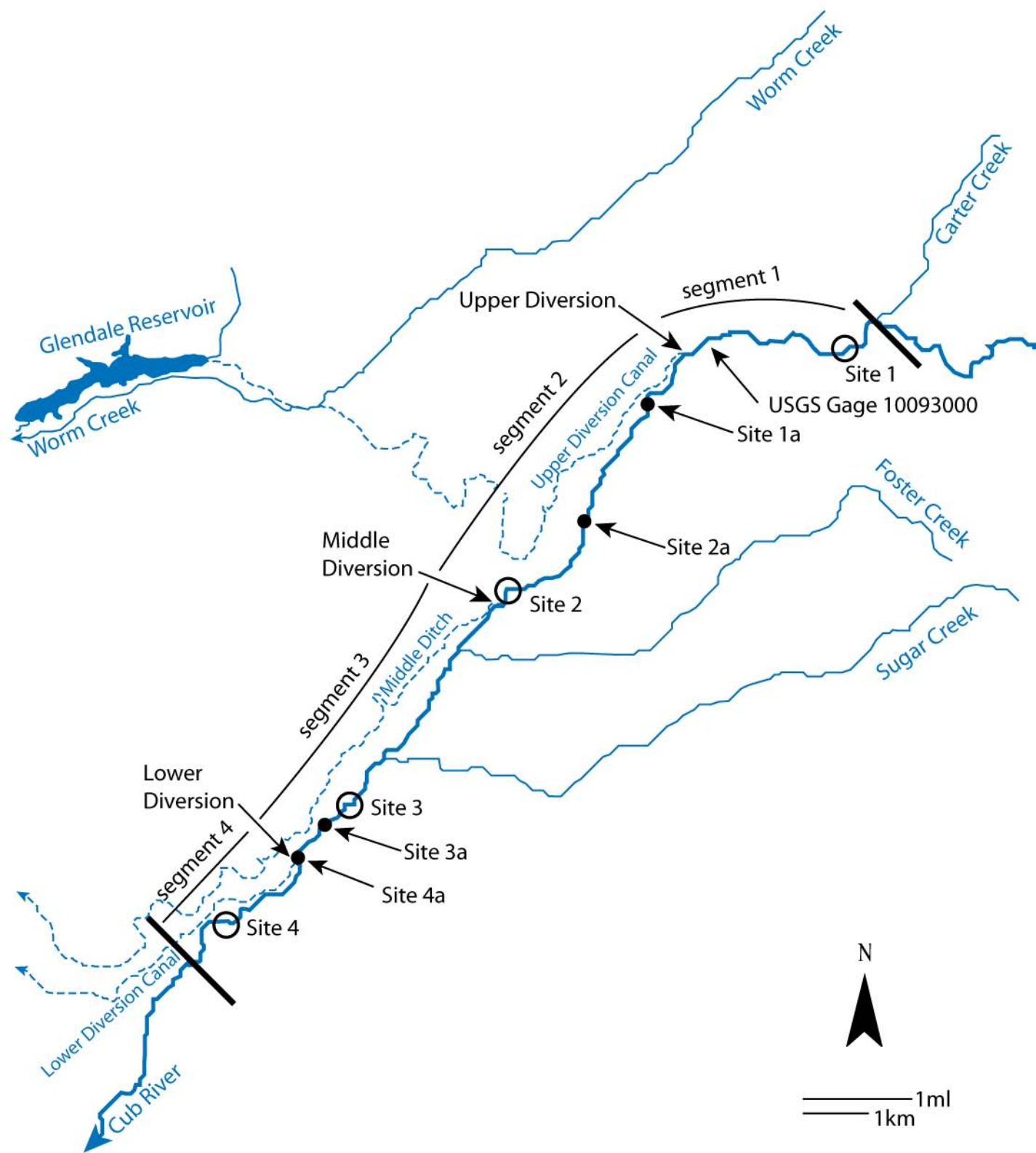


Figure 3. -- Recent Stream Flows of the Cub River near Preston, Idaho
USGS gage 10093000

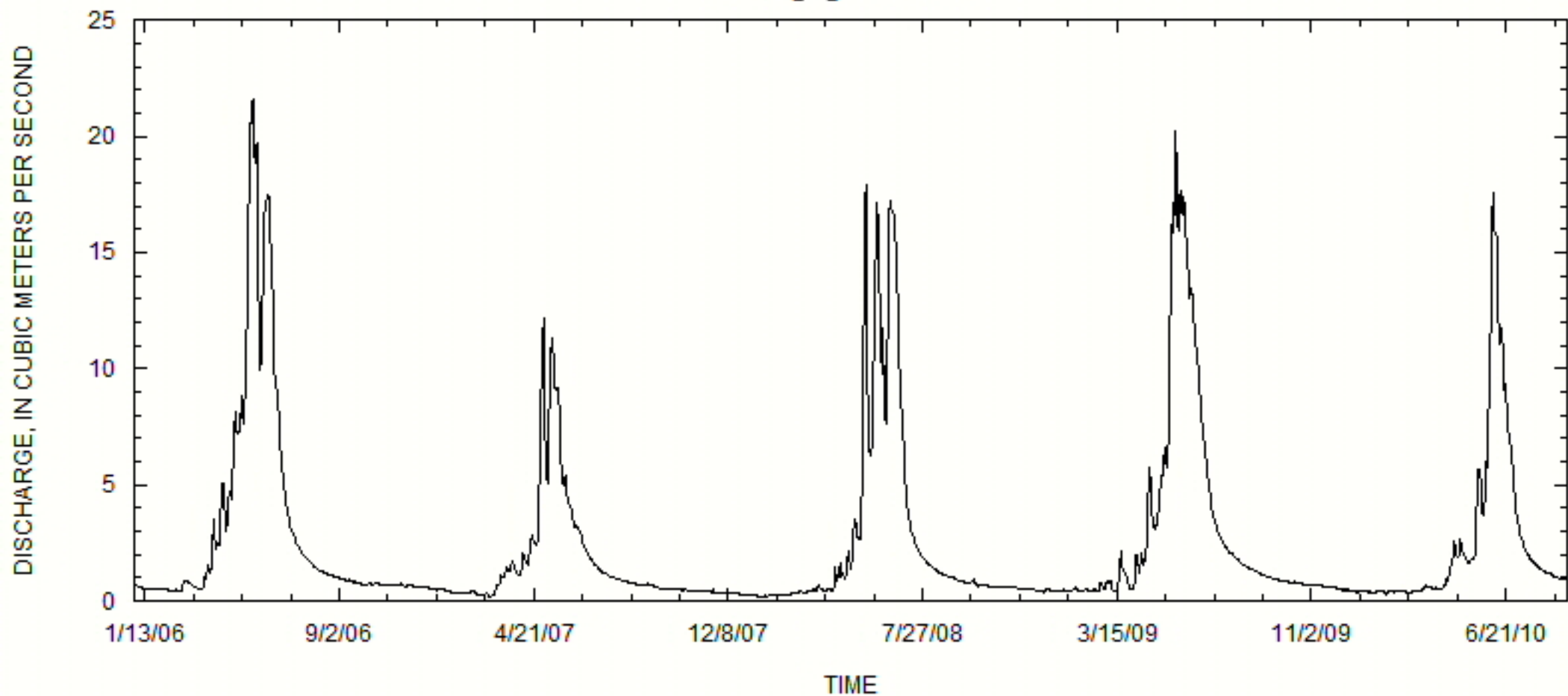
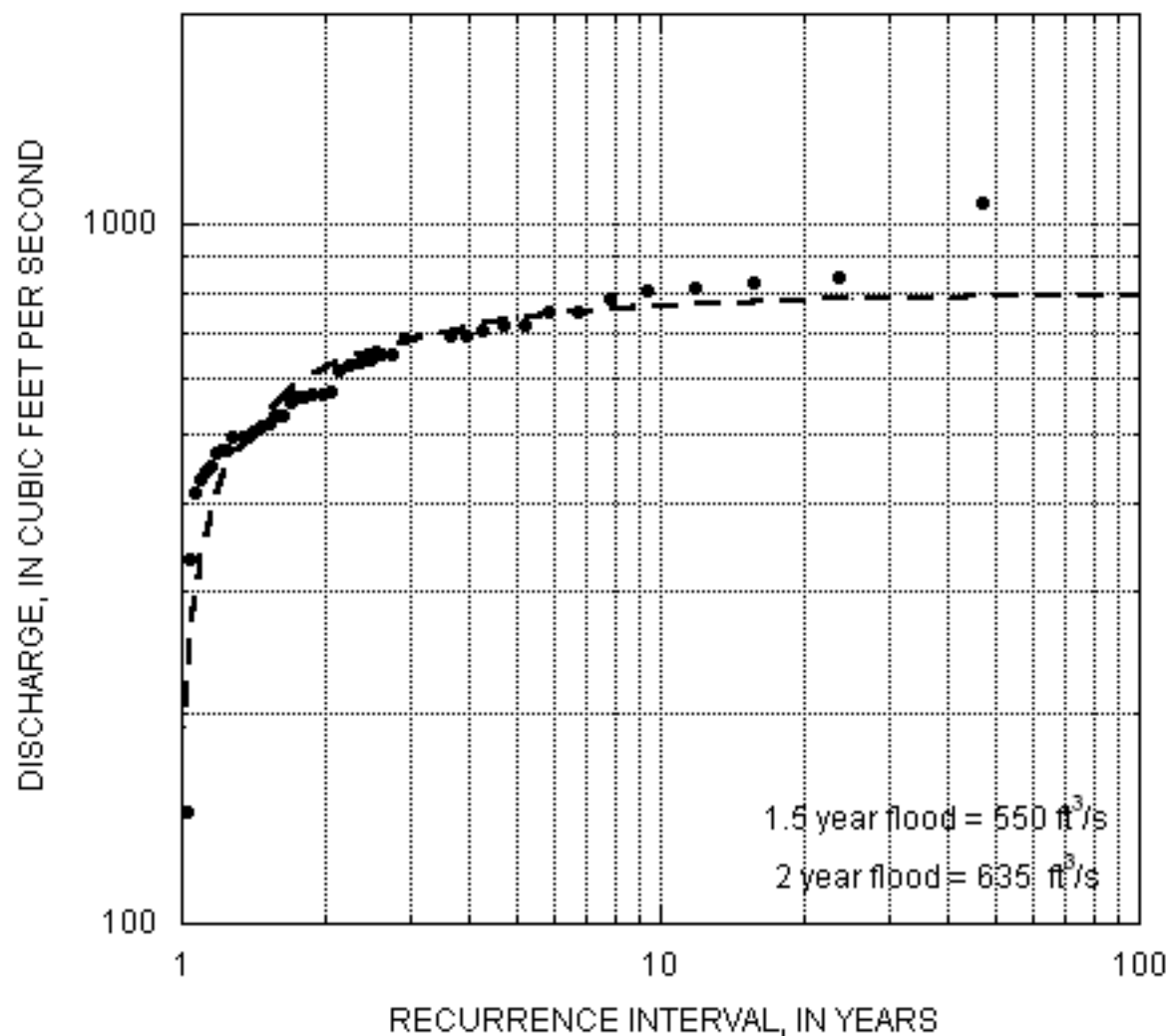


Figure 4. -- Flood Frequency
Cub River near Preston, Idaho
USGS gage 10093000



**Figure 6. -- Flow Duration Curve for Period of Record,
Cub River near Preston,
gage 10093000
(1940-2008)**

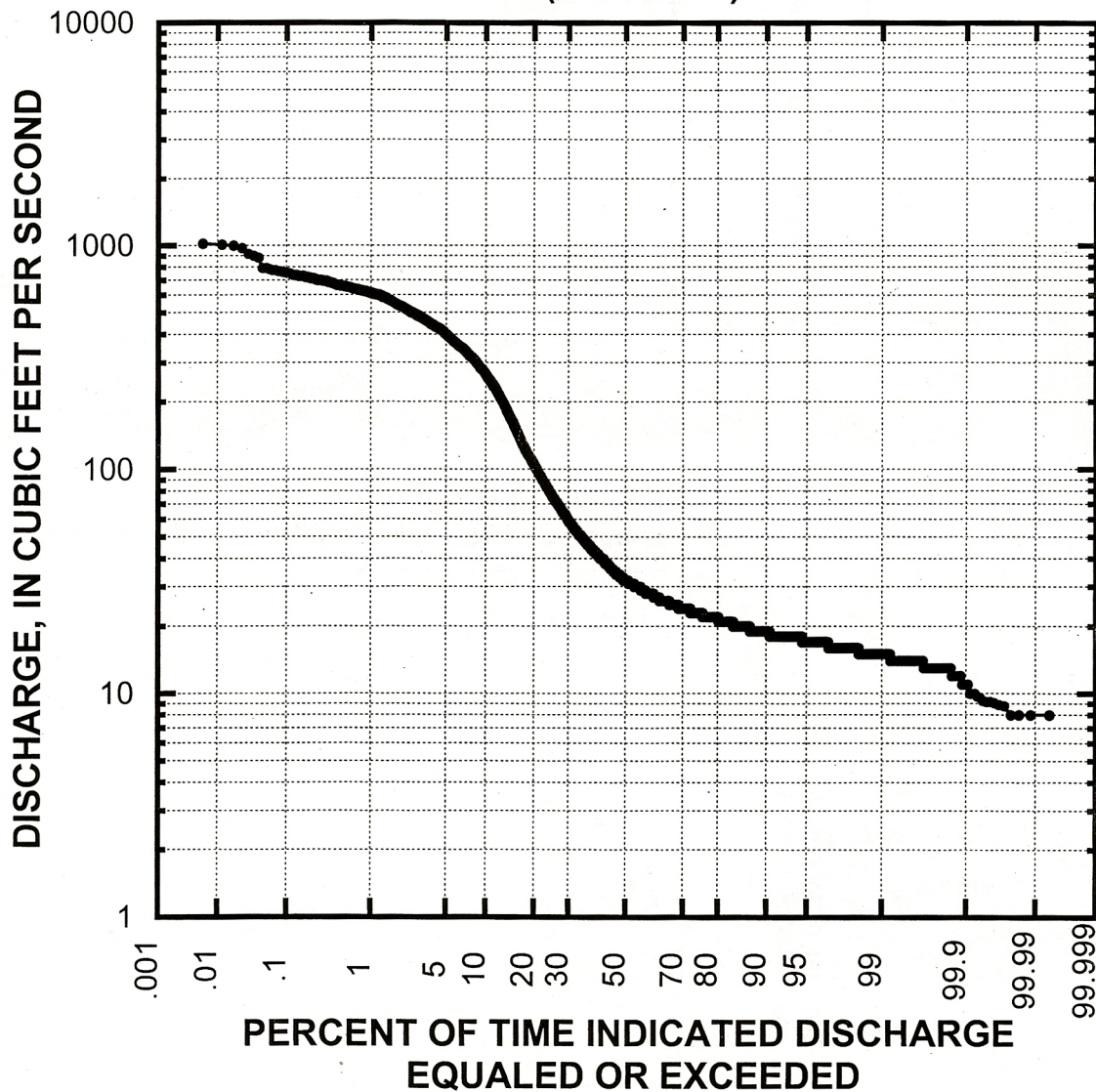
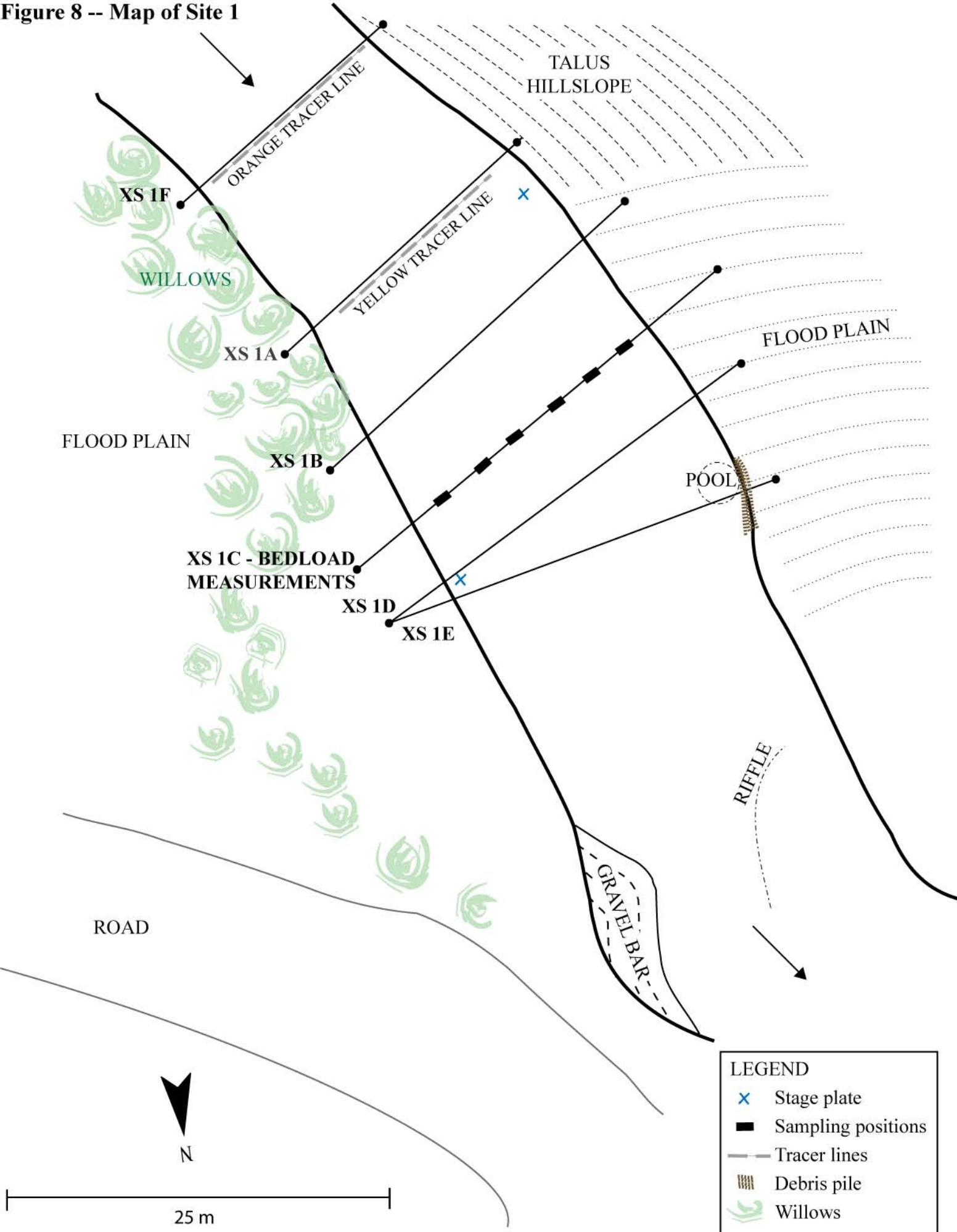


Figure 8 -- Map of Site 1



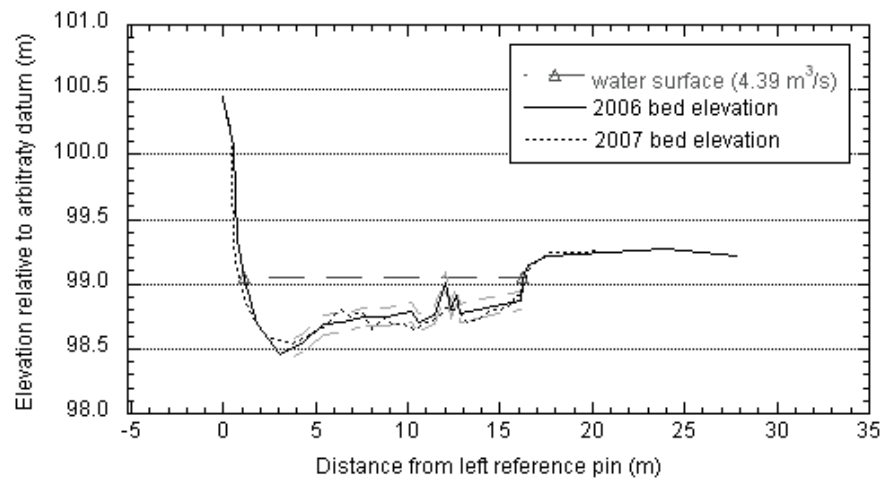


(a)

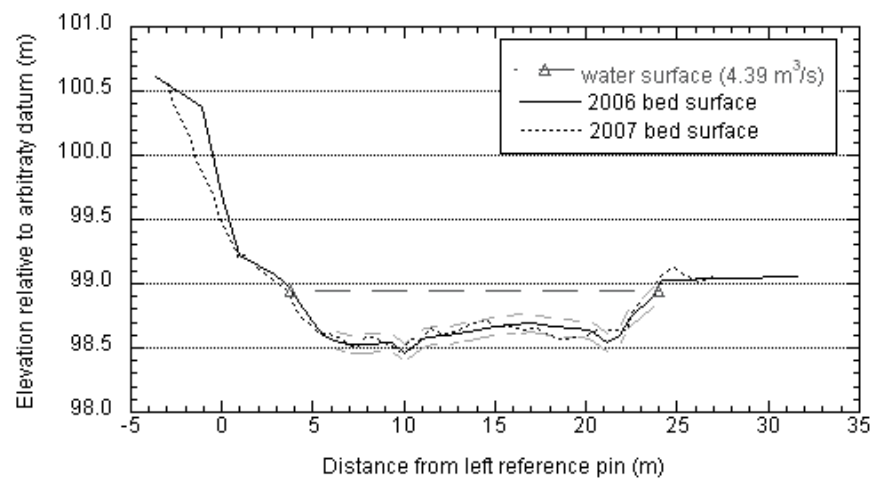


(b)

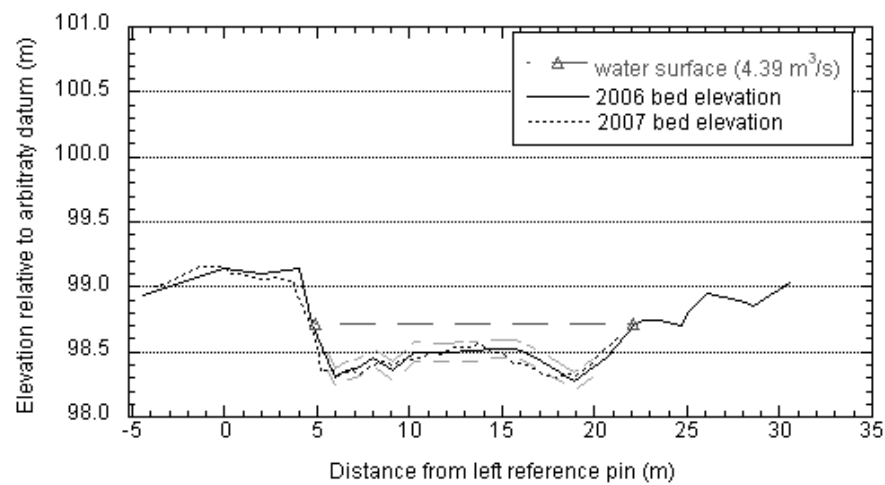
Figure 9 – View looking upstream at Site 1 study area (a), and view looking upstream from XS 1D, showing bed load traps installed on measurement section, XS 1C; flow is from left to right (b), 2006



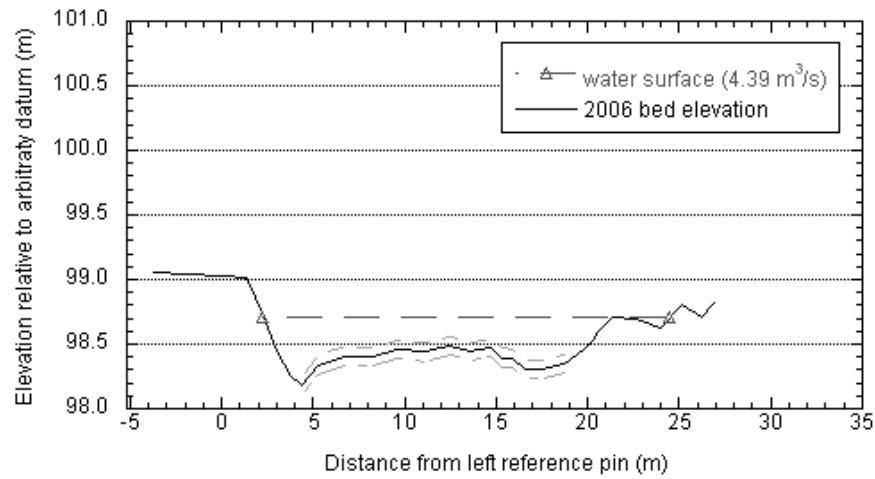
(a) Cross-section 1A



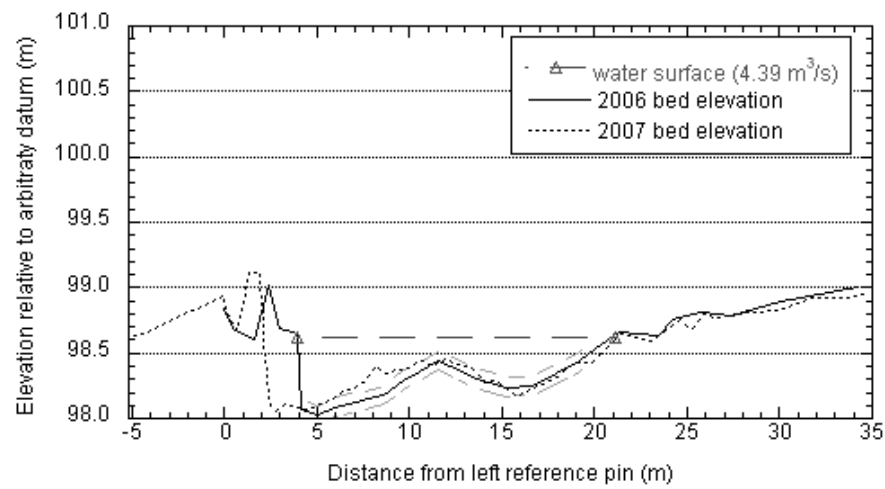
(b) Cross-section 1B



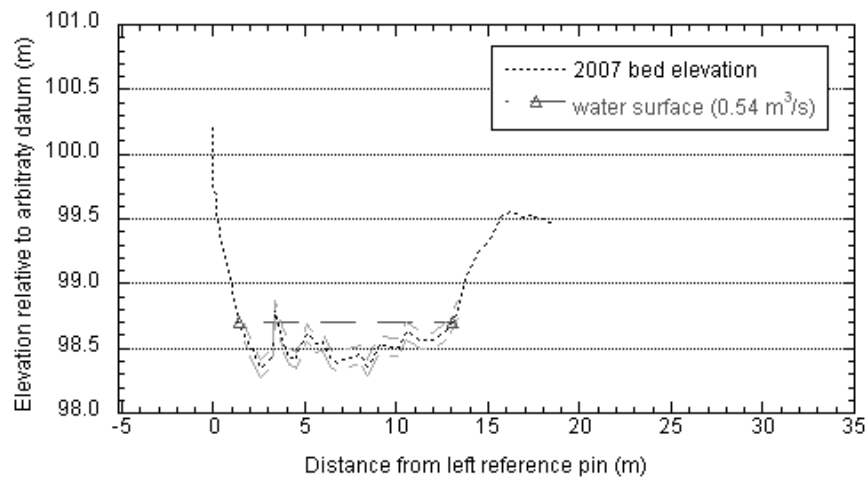
(c) Cross-section 1C



(d) Cross-section 1D

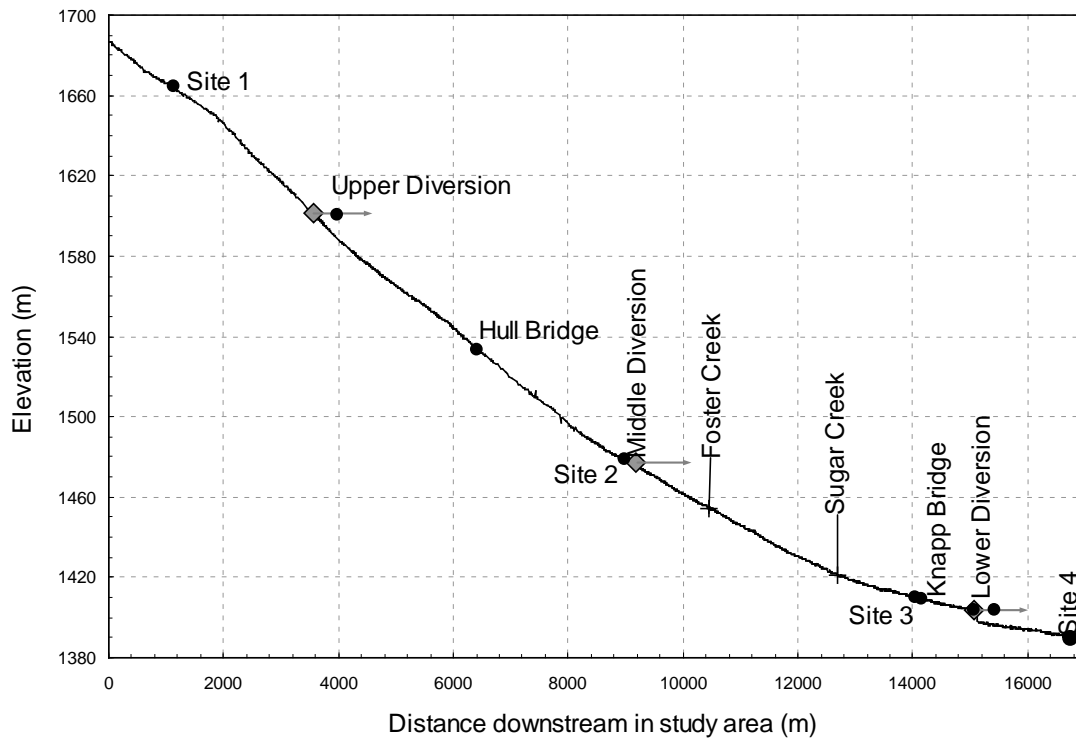


(e) Cross-section 1E

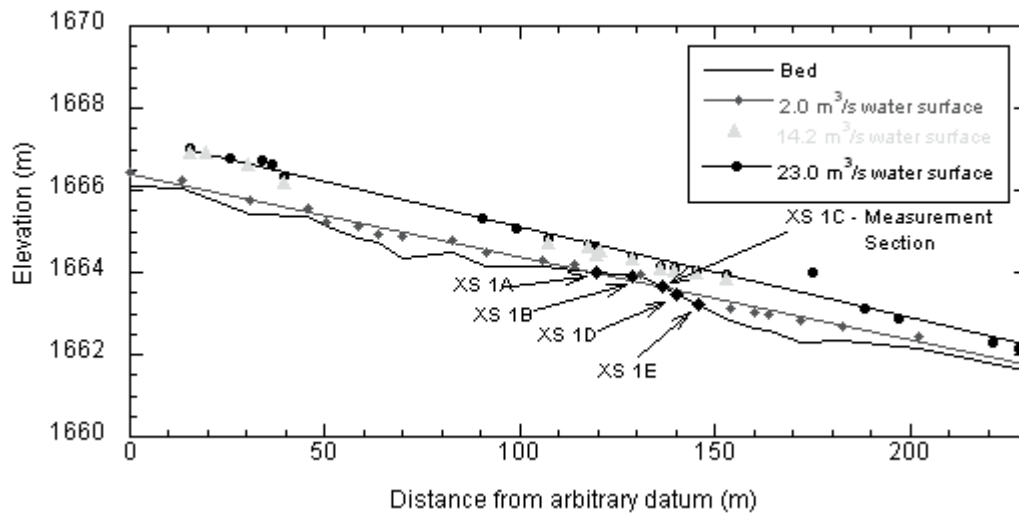


(f) Cross-section 1F

Figure 10 – Plots showing cross-sections at Site 1 in 2006 and 2007. Cross-sections 1A, 1B and 1C were stable during the study period. Cross-section 1E changed near the left bank as a result of woody material accumulation in a debris jam. Cross-section 1F was added in 2007.



(a)



(b)

Figure 11 – Longitudinal profile of Cub River study area (a) and longitudinal profile of Site 1, showing location of cross-sections, measurement section and surveyed water surface elevations for the indicated discharges (b). The lines were fitted to the 2.0 and 23.00 m³/s water surface surveys by least-squared regression and each has slope of 0.02 with $r^2 = 0.99$ or greater.



Figure 12 – Photograph showing debris jam on the left bank at Site 1.

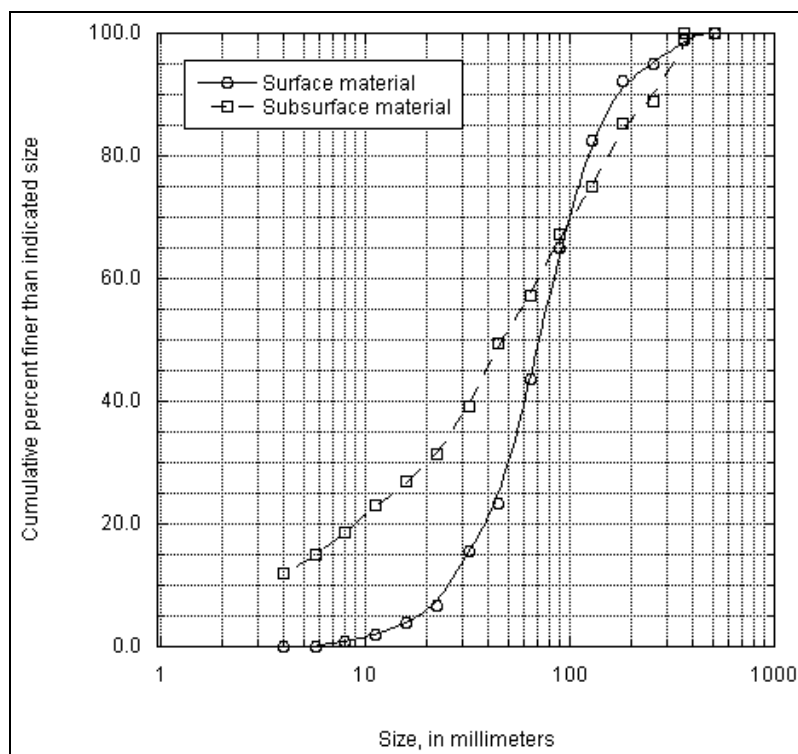


Figure 13 – Size distribution of bed surface at the measurement cross-section and subsurface of gravel bar located about 25 m downstream from cross-section for Site 1.

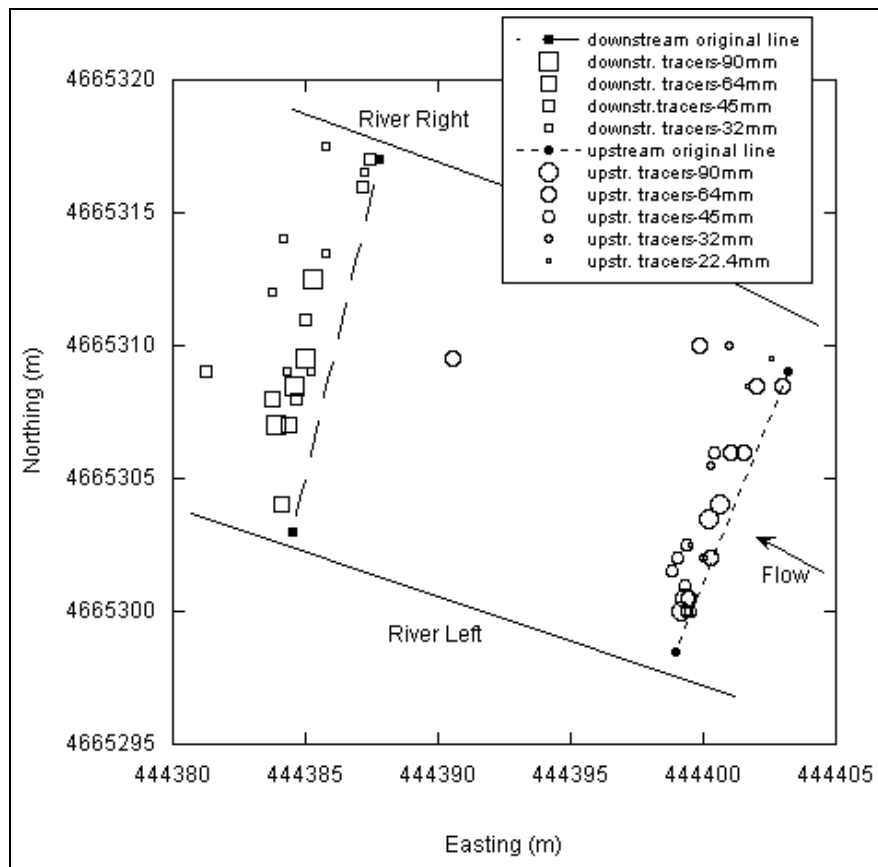


Figure 14 – Movement of tracer particles at Site 1.

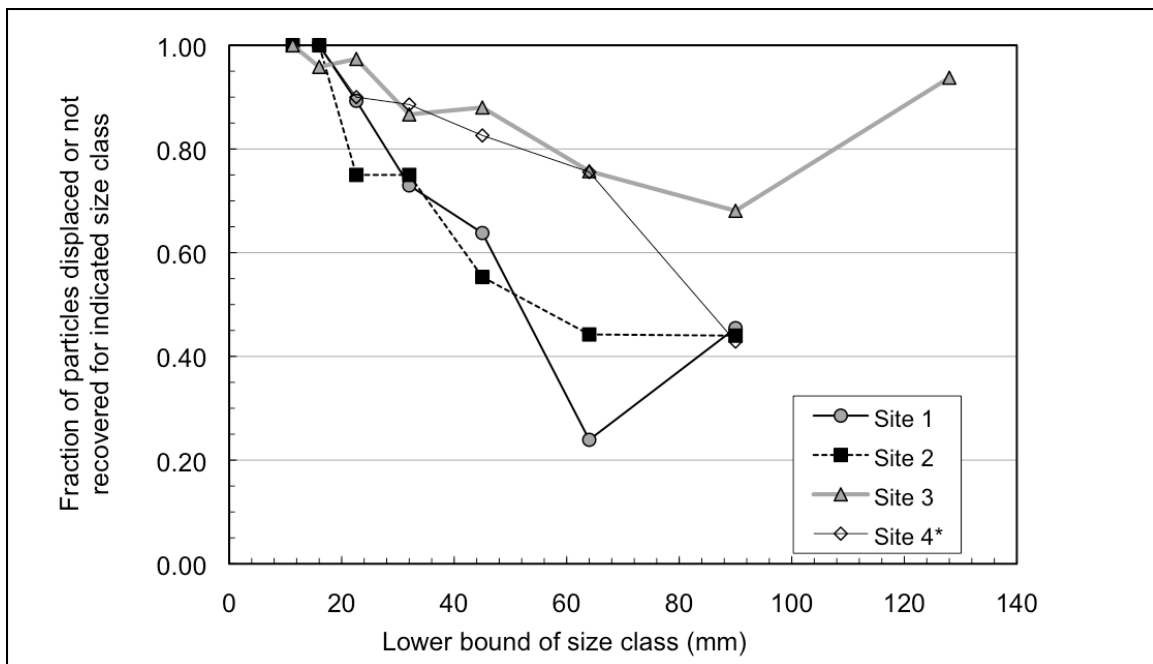


Figure 15 – Plot showing the proportion of tracer particles in each size class that moved at each site in 2007. All particles not recovered are assumed to have moved at Site 1, Site 2, and Site 3. * For Site 4, only the proportion of recovered particles that moved is shown.

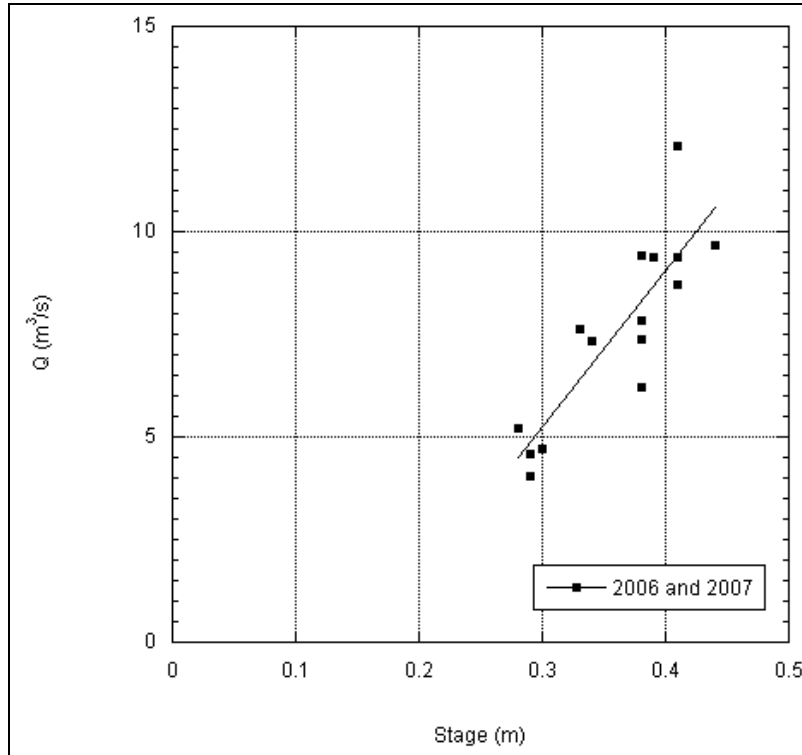


Figure 16 – Stage – discharge relation for Site 1 for 2006 and 2007.

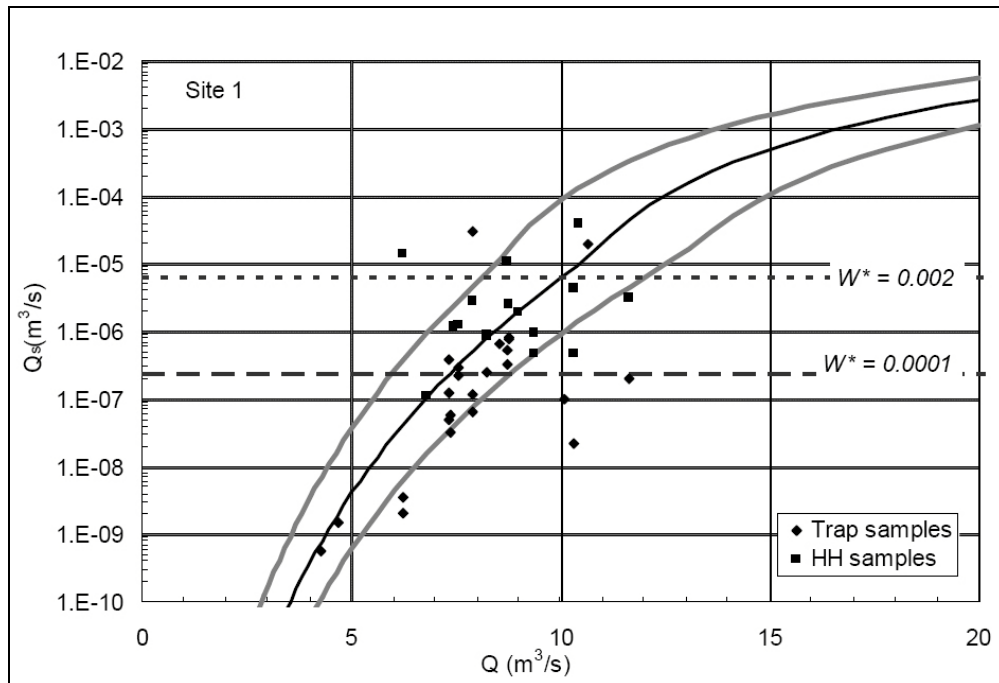


Figure 17 – Plot showing measured bedload transport and measured discharge. The calibrated transport functions (black line) were fitted to the observations considering only measurements with a transport rate greater than the dimensionless rate of $W^* = 0.0001$. The error envelopes are defined such that at least 75% of the observations fall within the upper and lower error bounds for each site.

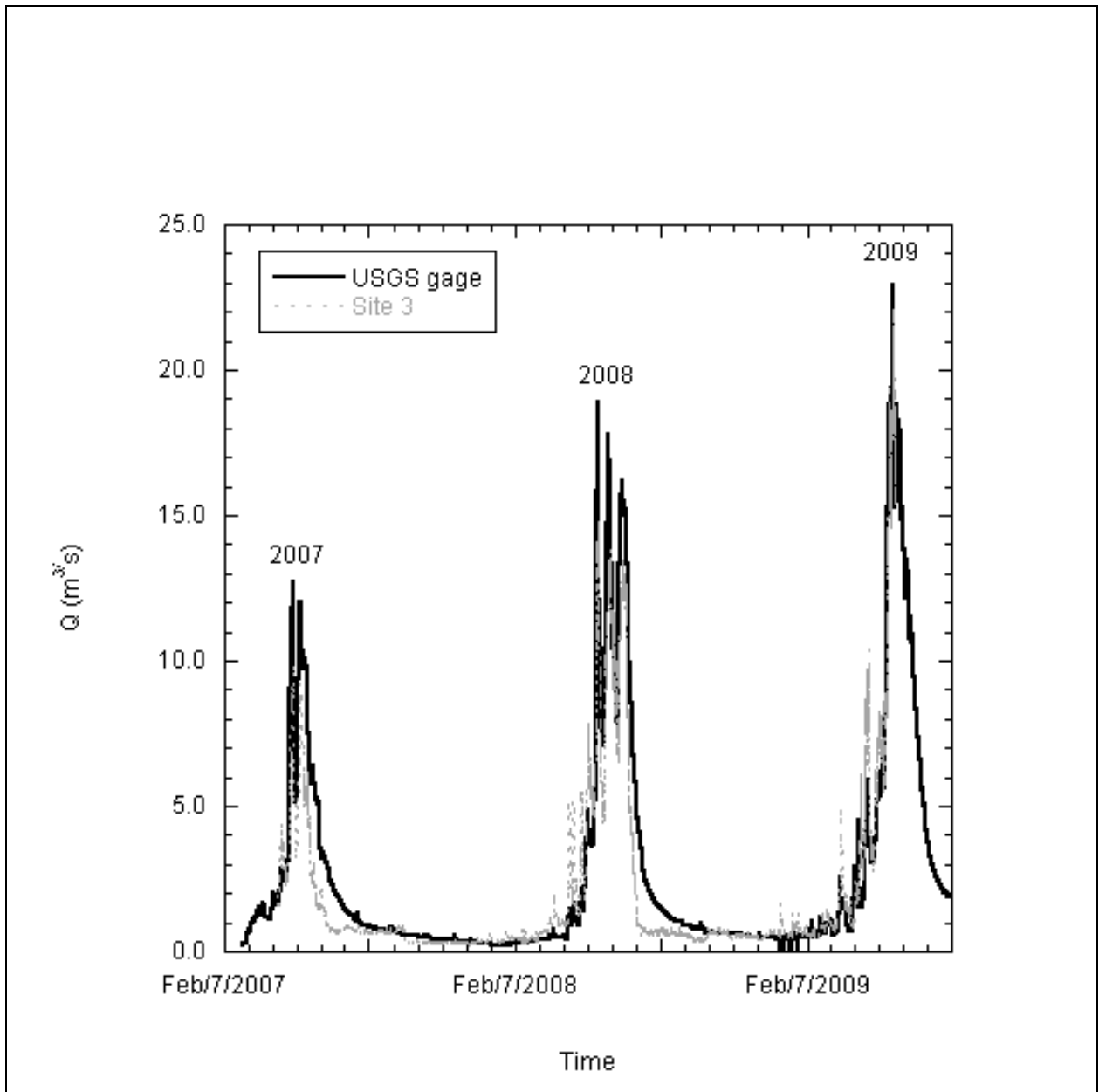


Figure 18 – Hydrograph showing discharge for USGS gage and Site 3 for years 2006 – 2008.