FINAL REPORT – YEAR 2

Texas Water Development Board contract 2002-483-440

Quantifying sediment transport and delivery on the Lower Trinity River, Texas

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March, 2004

1. Purpose and Methods

The overall objective of this section of the project is to provide detailed information on the current sediment dynamics of the Trinity River between Livingston Dam and Trinity Bay. Ultimately, the question being addressed is how has the sediment transport regime been changed by impoundment of the lower Trinity by the dam? This task involved establishing a new gauging station near the existing USGS gauging station at Romayor (USGS 08066500) that provides the long-term discharge record (Figure 1). Suspended sediment was monitored using a YSI-6000 UPG turbidity probe. This probe is entirely self-contained, and can be installed for 6-month periods irrespective of water levels. The probe was programmed to measure turbidity every 6 hours, adding considerable temporal resolution to the sediment record and allowing for a more accurate assessment of the sediment transport regime. However, an important consideration here is comparability of this data with historic suspended sediment data collected manually with depth-integrating samplers. Several depth-integrated samples were therefore taken at the station, both monthly and during high-flow events, in order to calibrate the automated turbidity record with the historic record. These measurements are ongoing, although preliminary data suggest a strong relationship between turbidity and depth integrated suspended samples (Figure 2). These data were then used to compute a "modern" suspended sediment rating curve which could then be compared graphically and statistically to historic rating curves. Bedload samples were also taken several times during the year using a typical Helley-Smith type sampler. These data should also be considered provisional, as sufficient samples have yet to e taken over the full range of flow conditions.

In addition to sampling at Romayor, suspended and bedload samples have also been collected at two major tributaries downstream of the dam over a range of flow conditions, at Menard Creek (USGS 08066300, drainage area = 152 mi^2) and Long King Creek at Livingston (USGS 08066200, drainage area = 141 mi^2). Both have long-term flow records. Samples were also collected from two additional sites on Long King Creek, at Goodrich on Highway 1988 and at the mouth where it drains into the Trinity at Highway 59. Discharge was measured manually at both locations, although at the mouth measurements could only be taken during low- to medium-sized flows since there is no bridge and channel velocities make sampling hazardous.

2. Results and analysis

The initial task was to determine the degree of variability in suspended sediment concentrations across the channel at Romayor in order to determine both the spatial validity of the single, depth-integrated samples being taken from the channel thalweg as well as the representativeness of the data from the turbidity probe. Overall, the results were very encouraging, as shown in Figure 3, with very little cross-channel variability in turbidity observed.

The complete turbidity record to date is shown in Figure 4. Unfortunately, the probe was stolen in the fall of 2003, and data from May through early September were lost. A new probe was purchased and installed and data for the last three months of the year are included here. The first point of note is that there appears to be a two-stage relationship between turbidity and discharge at Romayor: a steep initial curve between discharges of *c.* 800 cfs and 5000 cfs, and a "collapsed" curve for discharges greater than 5000 cfs. This suggests that, at higher flows, the lower Trinity becomes essentially a "supply-limited" system. One aspect that will be investigated in year 3 of the project is that fines are indeed trapped behind Lake Livingston and that, downstream of the dam, the Trinity becomes a bedload-dominated channel. This will be approached using mineral magnetics as a "fingerprint" to quantify sediment provenance. Another possible explanation is that, even though no general change in flow regimes are associated with the dam, as discussed in the report for year 1, it takes longer for flood waves to make it through the lake than before. What this means is that tributary flows are out of phase with the main channel—that is, the tributaries peak sooner. When they are carrying their maximum sediment loads into the river on the rising limb of the hydrograph, the main channel has not yet risen significantly enough to transport the sand and gravel portion of the load. While the sand and gravel is deposited as deltas (for example, at the mouth of Long King Creek), there is clearly sufficient stream power in the tributary flows to transport the fines. Thus, the fines pass through the system, and beyond Romayor, before the river gets to higher flows (e.g., above 5,000 cfs), and the sandy deltas provide a source of coarse material for transport at high flows. Indeed, analysis of the discharge record for 2002 and 2003 confirmed that Long King Creek is the "flashiest" channel in the lower Trinity basin, peaking, on average, 34.5 hours before the Trinity and Menard Creek. Long King also has the shortest time-of-rise compared to the Trinity and Menard (Figure 5, Table 1).

Table 1: Mean response statistics for the lower Trinity and its two major tributaries.

CHANNEL	MEAN TIME-OF-RISE (HOURS)	TIME-TO-PEAK (POST-TRINITY)
Long King Creek at Livingston	12.2	-
Menard Creek	28.4	34.8
Trinity River	52.9	34.6

There is also clear evidence of strong positive (i.e., clockwise) hysteresis in the turbidity-discharge relationship at the Romayor site (Figure 6). For example, the events of 19 Oct – 3 Nov, and the proceeding period 3 Nov – 27 Nov, both show open turbidity-discharge loops, indicating significantly higher concentrations on the rising limbs of the hydrographs, with concomitant sediment exhaustion on the falling limbs. This is a very typical response in fluvial systems where sediment is sourced from either near-channel locations (e.g., remobilization of sediment stored along the channel bed) or where surface runoff flushes sediment into the system. Both these loops also show a classic "collapse" in the relation at higher discharges, confirming the suggestion made earlier that the Trinity is indeed a supply-limited system at high discharges. The event of 28 Sep – 5 Dec 2003, however, does not show this collapse, with concentrations elevated throughout the duration of the rising limb.

Depth-integrated suspended sediment measurements at Romayor, Long King Creek at both Livingston and Goodrich, and Menard Creek are shown in Figure 7. Note that these data are from samples taken in the thalweg of the channels off the bridges at each site. The relationship at Romayor is $y = 0.0011x^{1.578}$ with an r-squared value of 0.846. One outlier does weaken the relationship, though this occurred during a large event on June 14, 2003 during an extended low-flow period with significant flushing and concentrations consistently in excess of 1,000 mg/l. Interestingly, the sediment discharge relations for Long King Creek show higher concentrations and flux at Livingston on Highway 190, which is several miles upstream of the site at Goodrich. In either case, sediment discharge from Long King Creek is generally an order-of-magnitude higher than sediment discharge in the Trinity <u>at similar flow levels</u>, indicating its significance as a source of sediment within the delivery system. Similarly, Menard Creek shows elevated suspended sediment discharge when compared to the Trinity at Romayor, though generally lower than Long King Creek.

The complete suspended sediment-discharge curve for Romayor, as computed from the turbidity-depth integrated calibration, is shown in Figure 8, along with the USGS record at Romayor from 1969-1972. Overall, there appears to have been no change in the sediment transport regime at this site since closure of the dam, and the contemporary measurements overlie the historical USGS rating curve closely. The "tail" in the sediment-discharge curve below *c.* 5,000 cfs is again confirmed, though we are exploring the possibility that many of these data may be spurious as the turbidity probe may have been stranded above the water level during these low flow conditions.

Figure 9 shows the Romayor data derived from the turbidity probe plotted alongside the depth-integrated samples, and the strong correlation between the two is confirmed. We have included in this plot bedload samples from Long King Creek at Goodrich (orange triangles). Whilst we recognize that we only have seven bedload samples at this site, and that a single sample taken in the thalweg of the channel may not capture the spatial variability of transport across the entire reach, the data nonetheless give us a first indication of the nature of bedload transport along this important tributary. Interestingly, at the lowest discharges, bedload is far more significant than suspended sediment transport. Even during high discharge conditions, bedload remains a significant component of the overall load, approximating 40% in some instances (see circle, Figure 9). This casts serious doubt on the often-quoted "conventional wisdom" that, in low-energy, coastal plain rivers such as the Trinity, bedload is relatively unimportant and often constitutes less than 10% of the total sediment flux.

3. Concluding thoughts

Year 2 has shed further light on the nature of sediment transport in the lower Trinity. The suspended sediment record has, we feel, enough resolution at this point to indicate no significant change in sediment transport and delivery since closure of the dam. The tributaries are an important source of sediment to the main channel and, at similar discharges, transport sediment at concentrations at least an order of magnitude higher than the Trinity itself. Bedload in Long King Creek is a substantial component of the overall load, approximating 40% at higher flows.

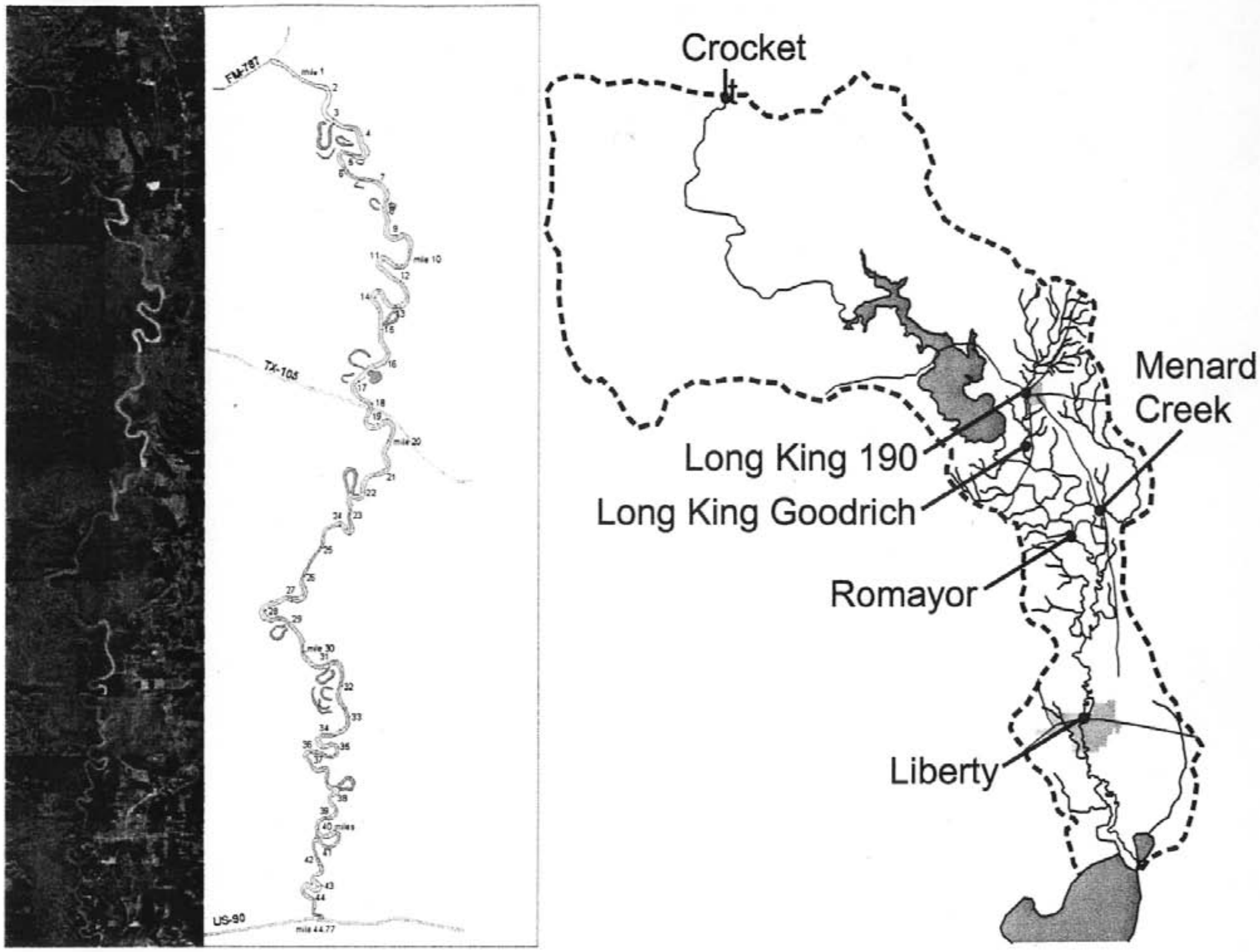

Figure 1: The lower reach of the Trinity River between Romayor and Liberty (left) and a general map of the study area showing major sampling stations (right).

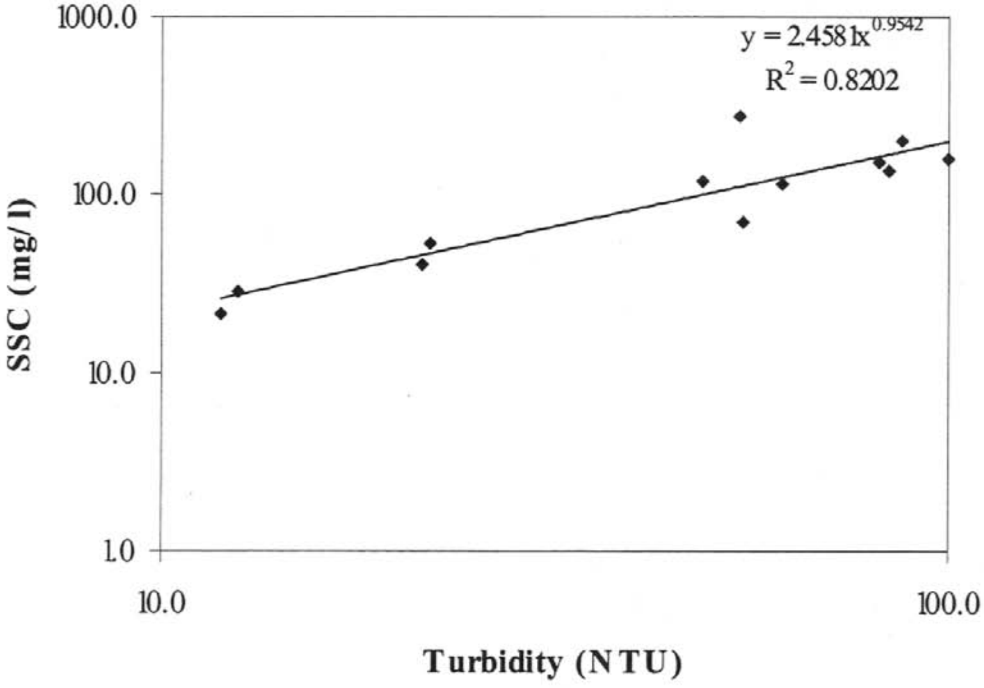

Figure 2: Relationship between turbidity and suspended sediment at the Romayor site.

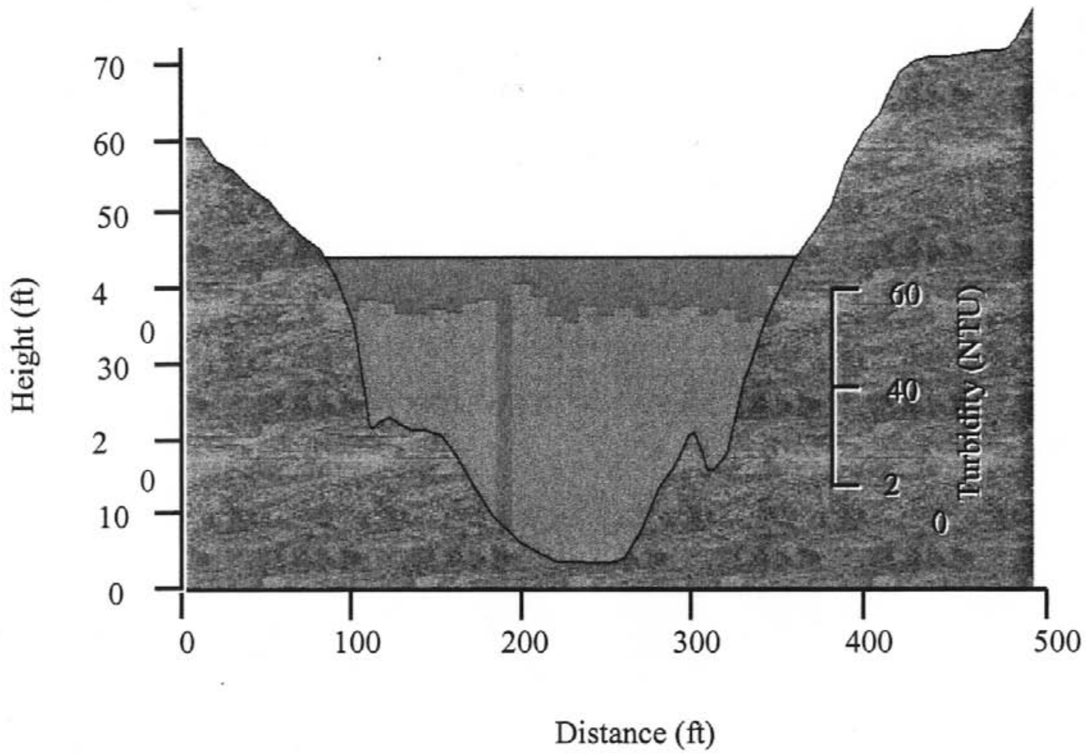

Figure 3: Channel cross section at Romayor showing depth-integrated turbidity measurements.

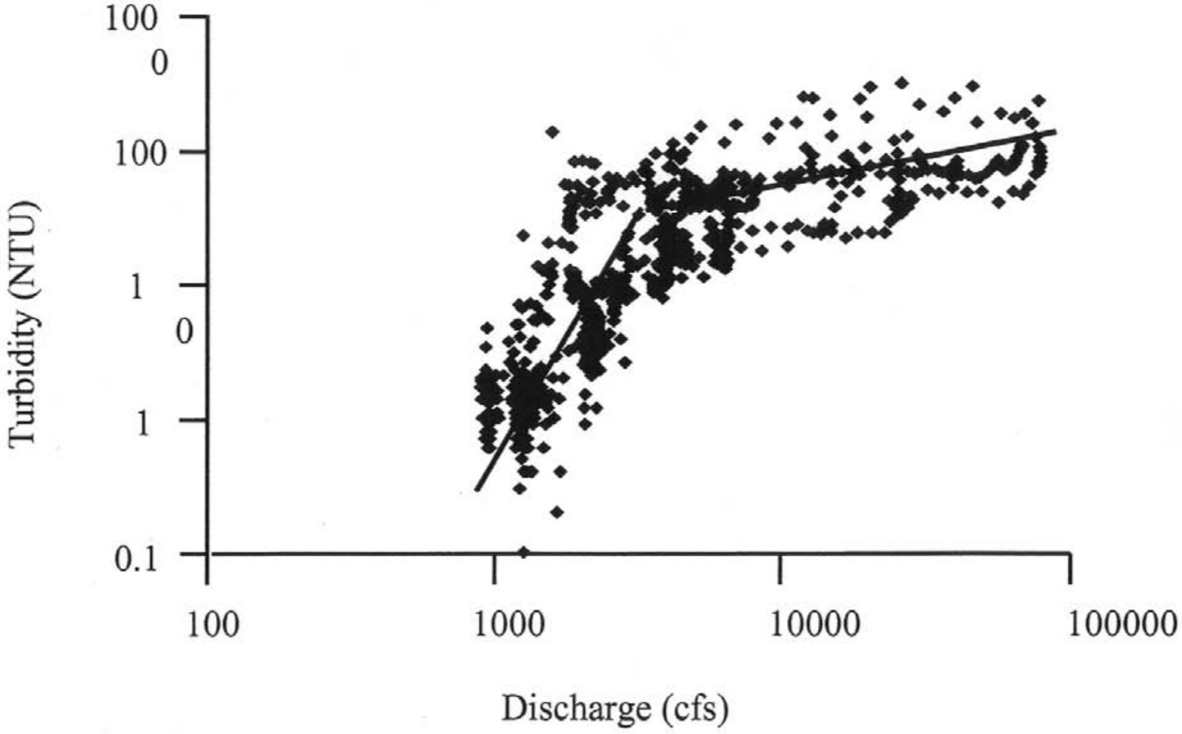

Figure 4: Turbidity record for Romayor showing two-stage relationship.

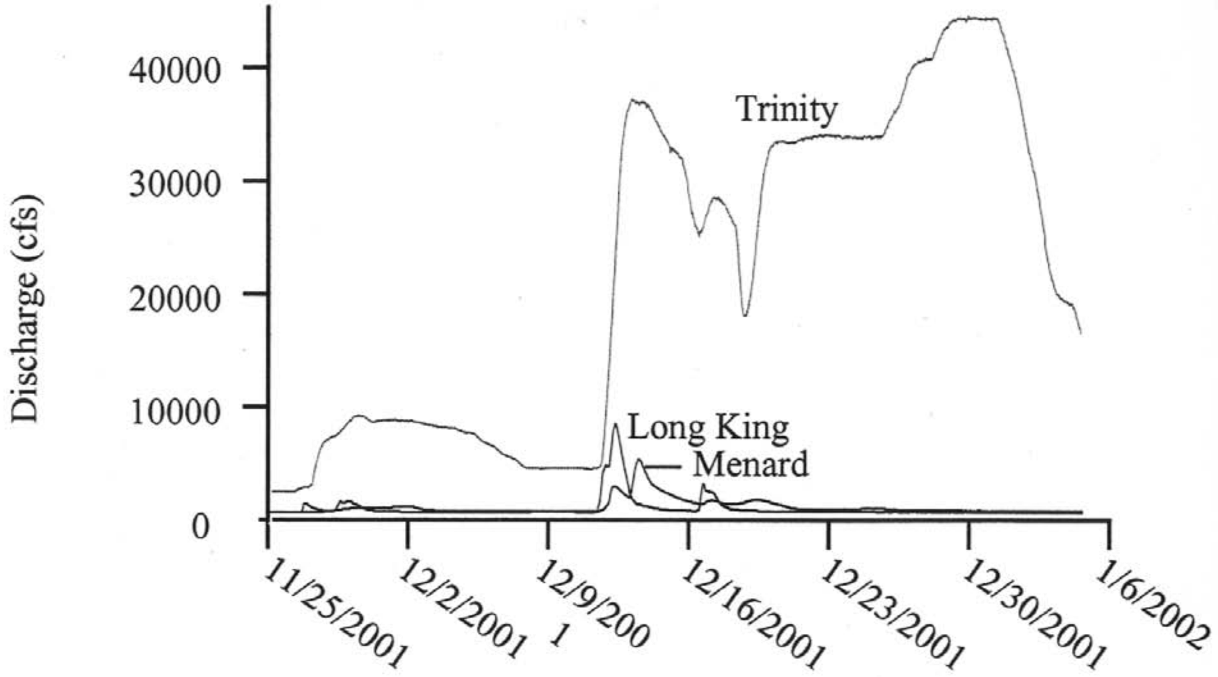

Figure 5: Flow record for the lower Trinity, Long King Creek at Livingston and Menard Creek showing out of phase discharge between Long King and the main channel.

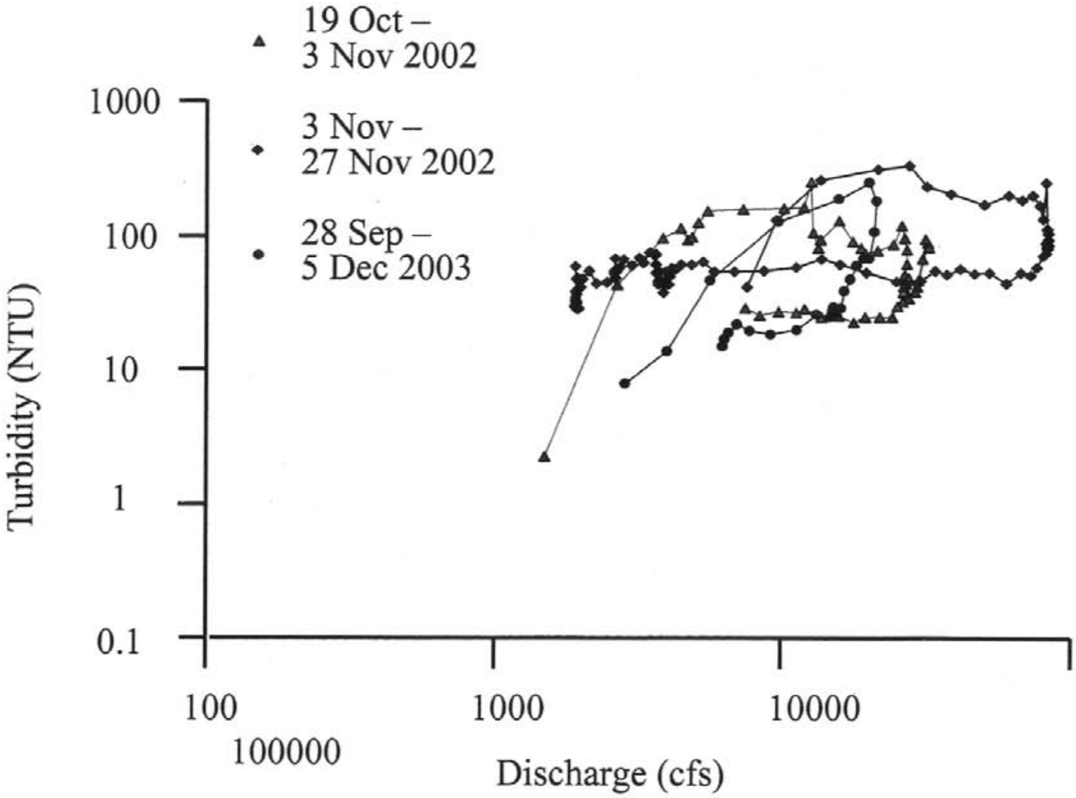

Figure 6: Turbidity record during three storm events at Romayor showing strong positive hysteresis.

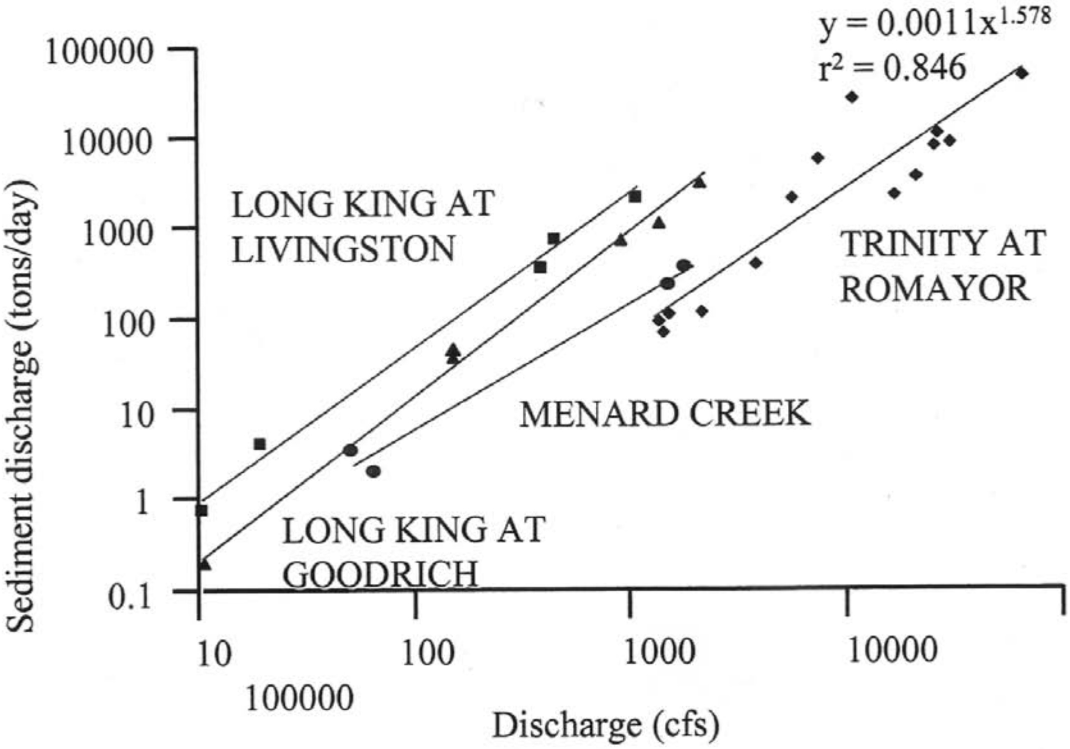

Figure 7: Depth-integrated suspended sediment at Romayor with suspended sediment samples taken at Long King Creek at Livingston (dark green squares) and at Goodrich (blue triangles) and Menard Creek (green circles).

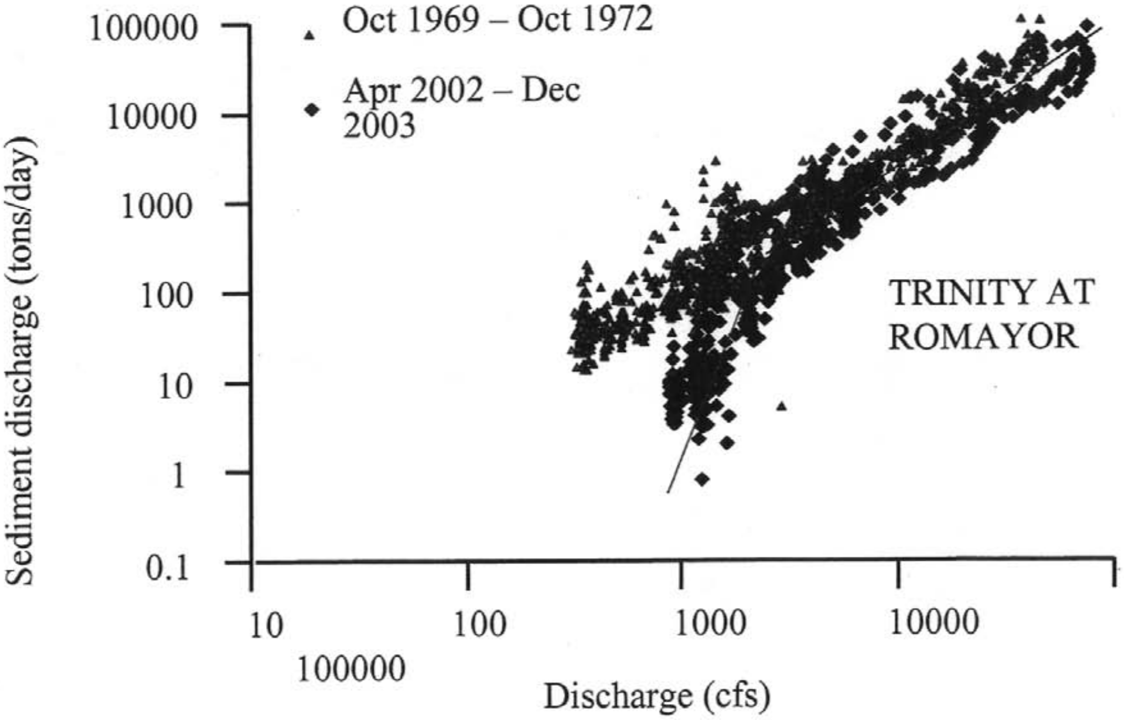

Figure 8: Sediment discharge curve at Romayor computed from the turbidity-depth integrated calibration (purple diamonds) and USGS data from 1969-1972.

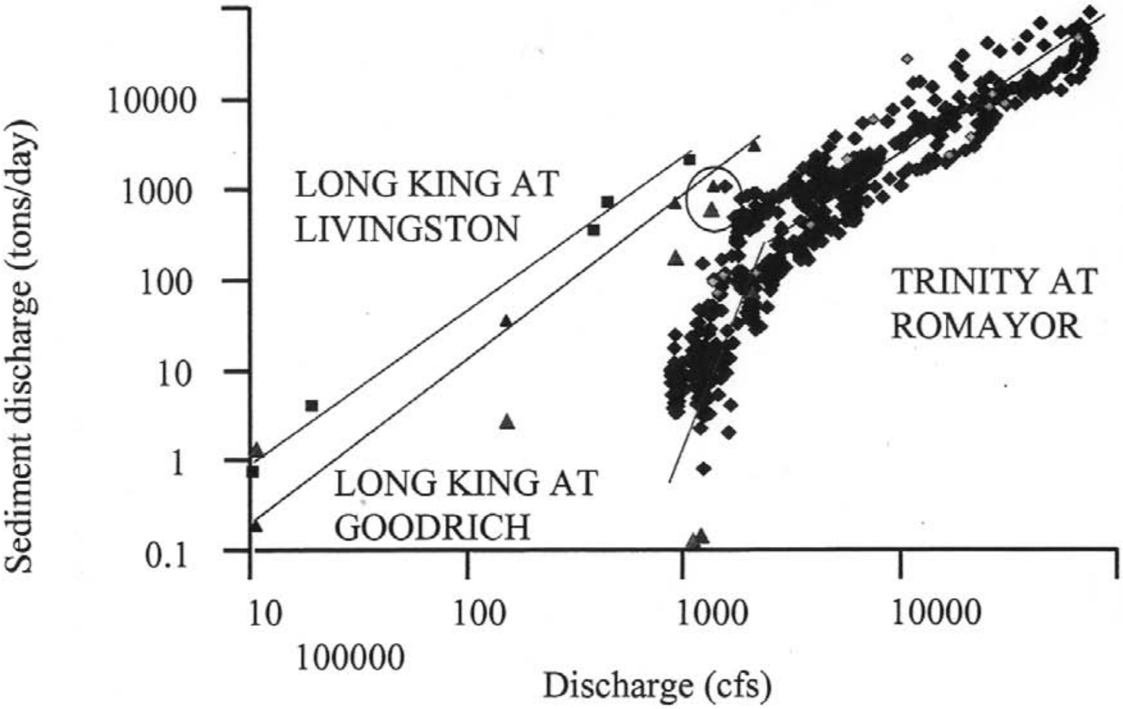

Figure 9: Sediment discharge curve at Romayor computed from the turbidity-depth integrated calibration (purple diamonds). The depth-integrated samples are shown with green diamonds. Bedload measurements taken at Long King Creek at Goodrich are also shown (orange triangles).