How does land use affect sediment loads in Gabilan Creek?

A Capstone Project

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by

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Preface

This is an under-graduate student report. The opinions and conclusions presented do not necessarily reflect the final material to be presented as the outcome of the Salinas Sediment Study (2000-1 contract). Nor do they necessarily reflect the opinions or conclusions of the Central Coast Regional Water Quality Control Board, who funded the work, or any of its staff.

Having said that, I hope you enjoy the report. It is the product of an extra-ordinary level student dedication to the science of bettering the environment of the Central Coast while recognizing the social and economic importance of its agriculture and industry.

Dr. Fred Watson
Project leader.
Student Capstone Advisor

Abstract

The sediment yield of a water body is, in part, determined by the land uses surrounding that water body. However, in small watersheds that have multiple land use types, it is much more difficult to determine which land use practices are having more of an effect. The following study examined the relationship between land use and sediment load in Gabilan Creek.

Four general land use types are found within this 315.9km^2 watershed, natural upland vegetation, grazing, agriculture (crops) and urban. For this study, natural and grazed lands were considered as a single unit. Five winter season storm events were monitored for discharge, total suspended sediment, and bedload at 11 different sites throughout the watershed. Sites were chosen based on their accessibility, safety, and proximity to land use boundaries. Samples were taken at as many bridges as possible and as frequent as possible. Total loads were computed for each event. Analysis of each sample were conducted and totaled for each event. Of the five events monitored only three had samples taken at all eleven sites. These three events were considered to be representative of typical winter storm events for the Gabilan Watershed.

Total area for each of the three general land use types was calculated using the Tarsier Modeling Framework. A simple model predicting sediment load as a function of the coefficients for each upstream land uses was formed. Predictions for total suspended sediment and bedload pre land use type were estimated using the sediment yield coefficients and land use areas.

During the winter of 2000-1, current agricultural practices contributed the majority of both suspended sediment and bedload into Gabilan Creek. Urban areas also contributed a significant TSS load to the system, but had no effect on bedload. Grazing and natural lands contributed to a significant portion of the overall bedload material, but total TSS yields.

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1 Introduction

In 1995, the Environmental Protection Agency (EPA) declared the Salinas River as an impaired water body under the Clean Water Act of 1972, for sediment, nutrient and pesticide concentrations, as well as salinity. In response to this listing, the Central Coast Regional Water Quality Control Board (CCRWQCB) contracted the Watershed Institute at California State University Monterey Bay (CSUMB) to conduct a Total Maximum Daily Load (TMDL) investigation for sediment in the Salinas Valley Watershed (Watson et al., 2000).

The present study is a part of that contractual work. It seeks to evaluate the relationship between sediment load and land use in Gabilan Creek. Research was conducted to further understand the effects of agriculture, urban development, and grazing on sediment loads. Gabilan Creek was monitored during five winter storms to measure actual sediment loads and discharge. The collected data was used to assess or estimate the effects each land use has on sediment load in the creek.

1.1 Human impacts on Gabilan Creek

All streams have a natural carrying capacity for sediment. However, the capacity depends on a number of factors such as slope, bank and bed material, geographic location, and climate (Woodward and Foster, 97). Increases from the natural sediment load or carrying capacity of a stream can have profound affects on the morphology, hydrology, and biology of the stream (Davis, 1976).

Recently, steelhead trout, *Oncorhynchus mykiss*, along the Central Coast of California were listed as a threatened species under the Federal Endangered Species Act of 1972. The National Marine Fishery Service (NMFS) currently considers Gabilan Creek as a steelhead spawning run. At present it is still unknown as to whether or not the species can still use Gabilan Creek as a spawning ground. The Gabilan Cattle Company, owners of the headwaters of Gabilan Creek, are currently working with the U.S. Fish and Wildlife Service and the California Department of Fish and Game on a program that will improve the chance for steelhead runs in Gabilan Creek (Gabilan Cattle Company, 1999).

A large influence on soil erodibility and sediment source is landuse (Woodward and Foster, 1997). Different land uses affect sediment transport at different rates. Over a century of agricultural development, and urban expansion, have significantly changed the flow pattern and biological complexity of the creek. Studies suggest that agriculture, grazing, and urban development, can significantly increase sediment yields into adjacent waterways (Heathwaite et al, 1990). Sedimentation of streams resulting from logging, mining, urban development and agriculture is a primary cause of habitat degradation for *O. mykiss* (NMFS, 1996). Also, excessive turbidity of a stream can affect the number and quality of fish production during spawning periods (NMFS, 1996).

In 1917, the lower portion of the creek (from Moss Landing Harbor to the central portion of the City of Salinas) was channelized into what is now known as The Reclamation Ditch (Schaaf and Wheeler, 1999). With this change came the loss of almost all the riparian vegetation and alteration of the natural flow regime for the lower Gabilan Creek. Coastal riparian habitat was replaced with intense agriculture west of Salinas.

Upstream of Salinas, agriculture, predominantly lettuce and strawberries, has replaced much of the floodplain and riparian vegetation. Here too landowners have removed much of the riparian vegetation as well as shaping the channel with bulldozers on a regular basis in order to protect their lands from erosion and flooding.

Sedimentation of Gabilan Creek affects more than just steelhead habitat. Management of The Reclamation Ditch and Carr Lake (an in-stream lake in the center of Salinas) entails removing sediment buildup in the ditch/lake by means of dredging. Sediment dredging carries a cost for landowners and both city and county agencies.

1.2 Project Aims

The aim of this research was to investigate the relationship between sediment loads and the aforementioned land uses by monitoring winter season storm events.

Currently there is no information on this topic available for Gabilan Creek. With increasing need for habitat restoration, steelhead protection, and erosion control in many of or our local waterways, the presented study should serve as a preliminary documentation of sediment sources along Gabilan Creek. The results presented in this study will aid future restoration projects for Gabilan Creek and The Reclamation Ditch. They will be incorporated into the findings of the Salinas Sediment Study, which will form the basis of the Salinas Sediment TMDL strategy to be adopted by the CCRWQCB in 2002.

2 Study Area

The Gabilan Creek Watershed is approximately 12,000 hectares from the eastern boundary of Salinas to its headwaters (Mulistch, 2000). It is located northeast of the city of Salinas, California. Once reaching Salinas, the creek flows in a northwesterly direction towards Tembladero Slough near the mouth of the Moss Landing Harbor. The entire creek length is approximately 36 kilometers. The upper reaches are perennial until just past the Old Stage Road crossing—(Figure 2.1). Throughout this area the creek flows through steep canyons of oak and maple riparian communities—(Figure 2.2a). Surrounding lands are natural oak and chaparral as well as grazing. Boulders and cobbles of granitic parent material are the dominant bed materials (Hager, 2001). After Old Stage Rd. the creek (still perennial) is slightly incised and begins flowing through a narrow cultivated valley for approximately 4.8-km out into the heavily cultivated Salinas Valley. Along this 4.8-km reach, the stream is lined with heavy to moderate stands of willow-oak communities and bed materials are now coarse sands and small cobbles.

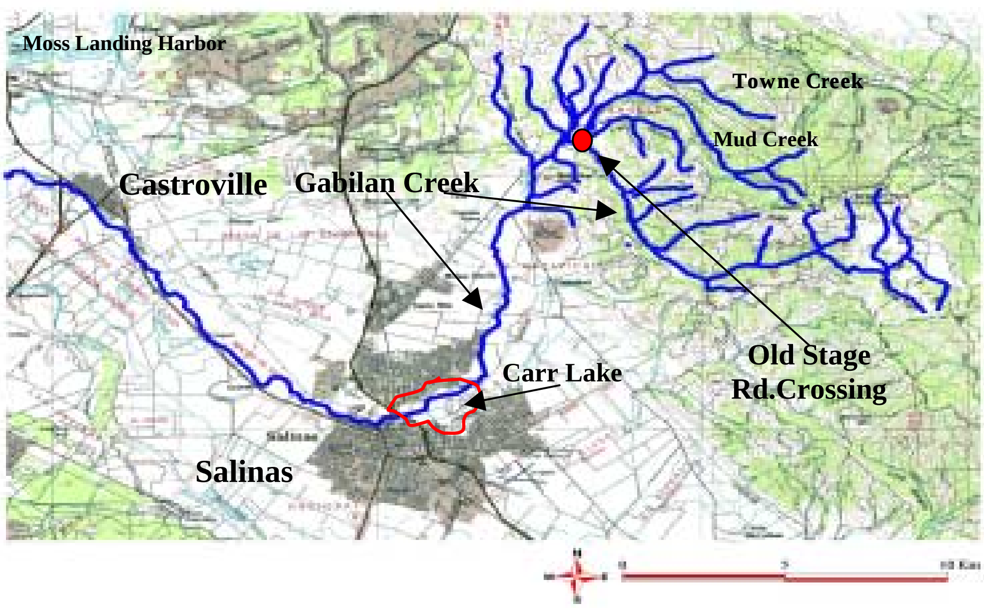

Figure 2.1. The Gabilan Creek Watershed

Once reaching the Salinas Valley (Herbert Rd. crossing), the stream is consistently flat and bordered with cultivated fields for approximately 4.8-km. The channel is incised to depths ranging from one to six meters below the surrounding plains. Very little vegetation, except for various weeds and willow yearlings, is found along the banks at this point—(Figure 2.2b). In this reach the stream only flows after intense rainfall. The bed substrate is made up of coarse sands and fine sediments that allow water to easily percolate into groundwater areas.

Figure 2.2a. Gabilan Creek in the headwaters.

Figure 2.2b. Gabilan Creek at Herbert Rd.

Once reaching the eastern boundary of Salinas, the creek flows through man-made park areas that are lined with willow, cottonwood, and sycamore trees until reaching Veterans Park just upstream from Carr Lake. Gabilan Creek joins with Natividad and Alisal Creeks in Carr Lake located in the center of Salinas. Drainage out of Carr Lake leads into The Reclamation Ditch—(Figure 2.3). Here, adjacent land areas are mostly urban with small amounts of crops. Salinas is home to over 150,000 people (Salinas, 2001).

The Reclamation Ditch runs through the center of Salinas and continues through the coastal artichoke fields to the west until reaching Tembladero Slough. Bed material in The Reclamation Ditch is primarily fine sediment with small portions of sand (Hager, 2001).

Figure 2.3. The Reclamation Ditch west of Salinas

3 Review of Land Systems and Their Relation to Stream Condition

This section discusses how land use practices impact stream conditions on a national scale as well as at Gabilan Creek. It is organized according to land use types found in the Gabilan Creek Watershed.

3.1 Effects of Agriculture on Sediment Load

In the Salinas Valley, the dominant land use is agriculture. In a national study, Woodward and Foster (1997) state that lower elevation catchments, which have been disturbed by either deforestation or intensive cropping, have far greater erosion rates than during pre-disturbed time.

Pollution, including sediment, from agriculture can occur as both non-point source and point-source. Point-source pollution is traceable and generally comes from a man made feature such as drainage pipes, sewage outfalls, and/or industrial discharges. Examples of non-point source pollution are infiltration of pollutants into the groundwater system and hill slope runoff (Woodward and Foster, 97). Figure 3.1 illustrates an example of non point-source pollution. Technically, one might consider this to be point source, as it comes from a pipe. But both the regional board and the Environmental Protection Agency (EPA) consider discharges such as the one seen here in Figure 3.1, to be non point source pollution.

There are many ways to retain as well as detain fluvial sediments. Herbaceous vegetation enhances sediment deposition and containment (Abt, et al. 1994). The detainment of sediment therefore reduces loads passed to downstream areas. However, the establishment of riparian

Figure 3.1. Agricultural drainage pipe feeding into Gabilan Creek. Note the difference in sediment color between just under the pipe (dark mud) and the remainder of the bed material (sands). Also note the lettuce growing in the lower right hand corner of the picture. The adjacent cropland here is a lettuce field.

vegetation can present land managers with significant maintenance burdens, especially in flood prone areas (Darby, 1999). Often, it is easier for landowners to remove the riparian vegetation and bulldoze the channel in order to reduce the flow resistance and the threat of having their land flooded. A broad channel with a high width to depth ratio allows more room for water to flow in the channel, reducing the amount of stress on the banks. Thus, the results of removing riparian vegetation are a decrease in riparian habitat, sediment retention, and aesthetic quality. Also, agricultural lands are too often sparsely vegetated, or bare in the winter, which increases their potential to erode more.

Agricultural lands yield an estimated 40% of stream sediment load in the USA—see Table 3.1 (Brady, 1984). This combined with the 12% from grazing and ranching suggests that more than 50% of stream suspended sediments in the USA are from these two key types of landuse.

Table 3.1. Soil erosion rates on different land uses in the USA and their percentage contribution to stream sediment loads.

Source	**Total Sediment** (10^6Mg/yr)	**Contribution to Stream Sediment load (%)**
Agricultural lands	680	40
Steambank erosion	450	26
Pasture and range lands	210	12
Forest land	130	7
Other Federal Lands	115	6
Urban	73	4
Roads	51	3
Mining	18	1
Other	14	1
Total	1741	100

Source: Woodward and Foster (1997) from Brady (1984).

3.2 Effects of Grazing on Sediment Load

Grazing is another common land use along Gabilan Creek, with most of it occurring in the more mountainous regions of the watershed. There are a few small areas in the lowlands that are also used for grazing.

Like intensive agriculture, excessive grazing and trampling affects riparian-stream habitats by diminishing or eliminating much of the riparian vegetation, altering bank and channel morphology, as well as potentially increasing in sediment transport (Clary and Webster, 1990).

Kauffman and Krueger (1984) state that overgrazing can cause bank slump which leads to false banks, accelerated sedimentation, and silt degradation of spawning habitats.

Mass wasting due to excessive accessibility, in addition to the clearing of riparian vegetation, can result in channel widening. Eventually the bed will begin to aggrade and bank widening slows. It is after the channel widening slows that riparian vegetation will re-establish itself, assuming cattle access is eliminated or limited (Huff and Simon, 1991). Figure 3.2 illustrates some of the effects of grazing on stream channel conditions in Gabilan Creek.

Figure 3.2. Here, Gabilan Creek (main channel outlined in yellow) passes through a small cattle pen. A small wire fence crosses the creek on both sides of the property. Note poor bank conditions and the absence of streamside vegetation.

Presently, there are no legal restrictions on cattle access to streams. Although, many ranches like The Gabilan Cattle Company are working to keep cattle out of the creek during critical times and to protect and enhance the overall habitat of the area.

3.3 Natural Lands

Natural lands can also yield sediment into their waterways. Landslides, gullies, stream scour, and natural fires are examples of possible sediment sources in a natural environment. It is presumed that unless there is a significant landslide or intense fire, sediment yields from natural lands are insignificant. Smith and Stamey (1965) reported that protected woodlands in Ohio yield only 0.01 tons/acre/year. However, natural lands that are managed for fire prevention can pose as a significant sediment source in the event that an intense fire does occur. This is due to an accumulation of debris and thick under-story vegetation. An intense fire can strip an area of all of its vegetation leaving only bare soil and ash. Winter rains can accelerate erosion on these bare areas. After the Kirk Fire in the Arroyo Seco Watershed, overall sediment yields increased 2.9% from normal and up to as much as 12.5% in some of its sub-watersheds (Los Padres National Forest, 1999).

3.4 Effects of Urban Lands on sediment loads

Urban landuse can have an impact on sediment yields especially in areas where new and intense development is occurring. Exposed soil, like at the construction site in Salinas, shown in Figure 3.3 is extremely vulnerable to erosion during heavy precipitation. Table 5.1 shows that urban land use yields 4% of the total suspended sediment in the USA annually (Brady, 1984). The Reclamation Ditch (Rec. Ditch) is the main route for the majority of the storm runoff from Salinas and lands to the east. It is feed by a series of 32 kilometers of drainage pipes, lakes, and canals that collect water from streets and other agricultural ditches within approximately 408 square kilometers of watershed (Schaaf and Wheeler, 1999).

Figure 3.3. A construction site in Salinas near Gabilan Creek.

The majority of water reaching Gabilan Creek and the Reclamation Ditch (Figs 3.4a and 3.4b) from urban landuse is delivered by storm runoff drains from sites like Figure 3.3. However, due to the large expanse of impermeable surfaces, overland runoff from the cities produces high discharges. For example, Schaaf and Wheeler, in their 1999 Operations Study of the Rec Ditch, state that while urban boundaries continue to grow, the capacity of the channel (The Rec Ditch) to support the growing volume of runoff has not. As a result, chronic flooding and erosion occurs in several locations of the ditch.

Figure 3.4a. The Rec Ditch at Victor Way (West Salinas)

Figure 3.4b. The Rec Ditch at San Jon Rd surrounded by lettuce and artichoke fields.

4 Methods

4.1 Sampling Sites and Their Description

Intensive monitoring was conducted on Gabilan Creek during winter storm events. This required taking samples at 11 bridges (Figure 4.2) as often as possible. Sampling sites were decided based on accessibility (bridges), proximity in the watershed based on land use, and safety at night. The sampling sites were named by taking the first three letters of the steam or waterbody followed by the first three letters of the road or bridge that crossed the stream where sampling took place. For example, TOW-OSR is from Towne Creek at the Old Stage Road crossing.

In the northern most portion of the watershed (that was accessible) there were two sites located in the grazing areas of the watershed—TOW-OSR and BOC-OSR. Towne Creek is a small perennial creek with a dense riparian corridor that has a catchment area of 9.7 km^2—(Figure 4.1a).

Figure 4.1a. Dr. Fred Watson taking a TSS sample at Towne Creek (TOW-OSR)

Figure 4.1b. Big Oak Creek (BOC-OSR)

Big Oak Creek (a name given by the present author) is a small perennial tributary of Towne Creek. This creek is located approximately one-quarter of a mile downstream from TOW-OSR. The main difference between the sites is that BOC-OSR has no permanent woody bank vegetation, cattle have direct access to the stream, and its catchment area is only 0.5km^2—(Figure 4.1b).

About three-quarters of a mile downstream from BOC-OSR is the next sampling location, GAB-OSR. This is the first sampling location on Gabilan Creek that was easily

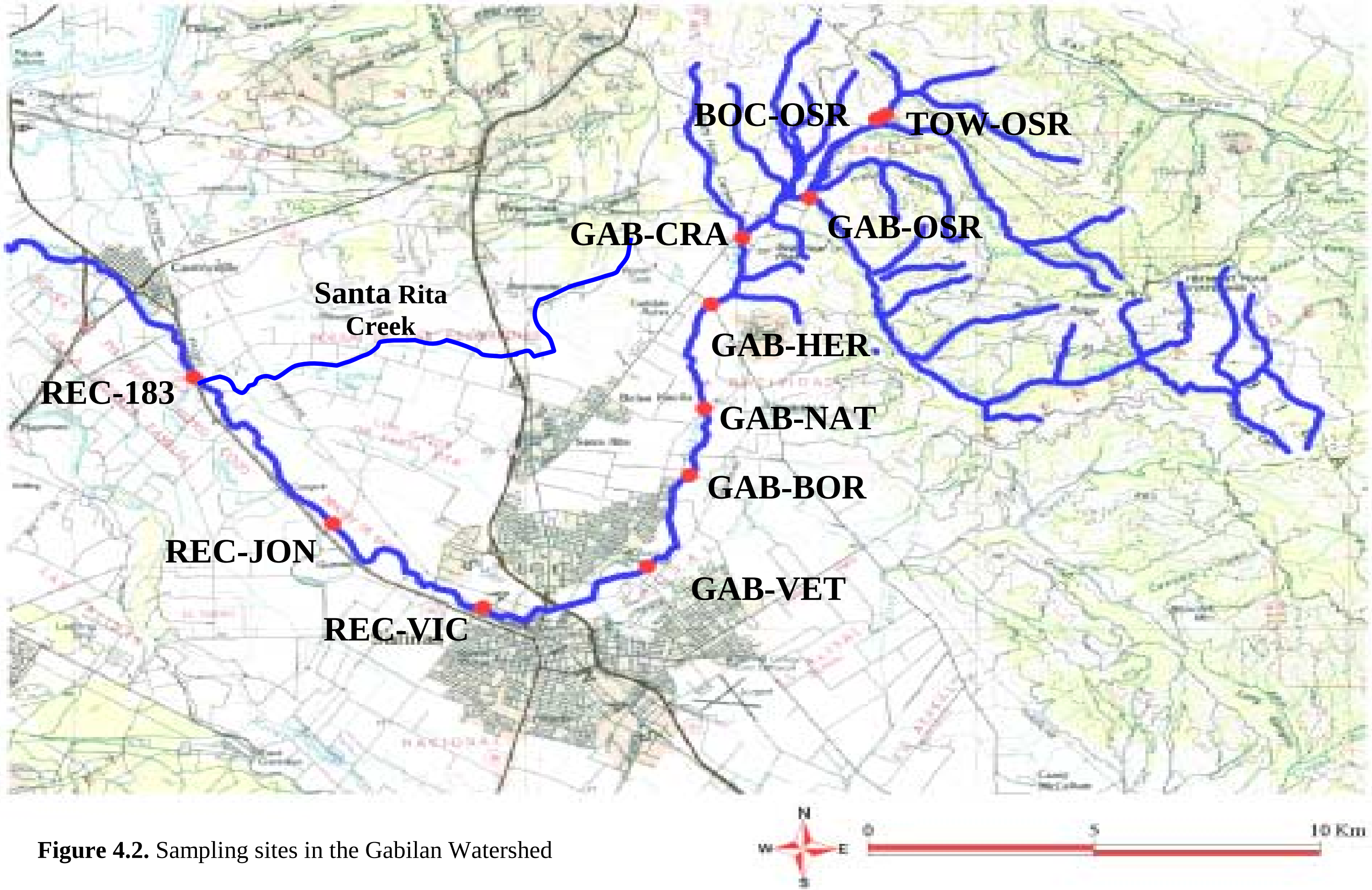

Figure 4.2. Sampling sites in the Gabilan Watershed

accessible to the team—(Figure 4.3a). Drainage (41.4 km^2) from above includes grazing/natural lands in the extreme headwaters of the creek and more closely, a long narrow valley of strawberry fields.

Figure 4.3a. Gabilan Creek at Old Stage Road. (GAB-OSR)

Figure 4.3b. Gabilan Creek at Crazy Horse Canyon Road. (GAB-CRA)

This site is followed by GAB-CRA (Figure 4.3b), which is just below the confluence of three major streams: Towne Creek, Mud Creek (not sampled), and Gabilan Creek. Strawberry fields border GAB-CRA. The total drainage area for GAB-CRA is 90.4 km^2, which includes predominantly inputs from grazing/natural lands as well as strawberry crops.

Once reaching the beginning of the Salinas Valley floor with its deep alluvial sediments and falling groundwater levels, the creek changes from perennial to ephemeral. The change at this point is also attributed to an increase in ground water wells in the local area. Gabilan Creek flows through the Herbert Road USGS station immediately after changing to an ephemeral stream—Figure 3.2b. The Herbert road site has a drainage area of 94.7 km^2. It is here that the strawberry farms decline and vegetable crops, primarily lettuce, begin.

Figure 4.3a. Gabilan Creek at Natividad Road (GAB-NAT)

Figure 4.3b. Gabilan Creek at Boronda Road. (GAB-BOR)

From this point on, Gabilan Creek has had most of its woody riparian vegetation removed except for a small 300-meter section of mature sycamore and willows located near Natividad Road, the next sampling site. Figure 4.3a illustrates this grove at GAB-NAT. GAB-NAT has a drainage area of 98.7 km^2. The next sampling site is located at GAB-BOR—Figure 4.3b. This is the boundary between lettuce growing and urban development. It has a drainage area of 104.3 km^2.

GAB-VET (Figure 4.5) is the first site significantly affected by recent urban development. It is located in Veterans Park, approximately one-quarter mile upstream from Carr Lake. Carr Lake is ephemeral lake used for agriculture when there is no water. GAB-VET has a drainage area of 107.7 km^2.

Sampling sites were abandoned in the central portion of Salinas due to nighttime safety precautions. The first station on The Reclamation Ditch was REC-VIC (See Figure 3.4a), an ideal location for monitoring urban runoff. After REC-VIC, The Reclamation Ditch flows through primarily artichoke fields with some lettuce. REC-JON (former USGS station) was the next sampling site—Figure 3.4b. This site has a cement control structure installed by the USGS for monitoring stream flow. The last sampling site is REC-183, located at the Highway 183 bridge of The Reclamation Ditch—Figure 4.6. REC-183 also receives flow from Santa Rita Creek and from Espinosa Lake.

Figure 4.5. Gabilan Creek at Veterans Park.

Figure 4.6. The Reclamation Ditch at Highway 183.

4.2 Field Data Collection

Samples were taken during a spring event of April 2000 (not included in this study) in order to become familiar with the watershed and to establish some critical sampling locations.

The stream monitoring strategy began by observing the NEXRAD weather radar to monitor the advance of storms from the Pacific. Once a storm was detected, several teams of two or more were assembled and sent to different parts of the stream to monitor the stream's pre-storm flow. Measurements of stage, total suspended sediment (TSS), discharge, and bedload were taken at each bridge where and when applicable. Monitoring continued as long as personnel availability permitted and until the stream returned to its base flow once the storm ceased; usually about five days.

The main objective of storm event monitoring is to visit as many sites as often as possible. Given high personnel availability, more sites and data collection could be accomplished. If personnel availability was low, then the strategy was changed focusing to visit fewer sites with better accuracy and more detailed measurements. Due to the rapid response of Gabilan Creek, the techniques used in this study were different from most published techniques which cover a much lower density of sites and visits.

During the April storm event, several measurements for bedload were taken at the upper most site (TOW-OSR), resulting in no load. At BOC-OSR sampling occurs along a roadside culvert that is bordered with dense groves of blackberry bushes. The narrow nature of the channel and relative inaccessibility of the stream requires that discharge measurements be taken with a pre-marked bucket. During the April store event, discharge measurements at BOC-OSR captured no bedload material. Hence, for the following study, bedload measurements were not taken at these two sites and bedload was assumed to be negligible. This was confirmed visually throughout the study as well.

Techniques for collecting stage, discharge, total suspended sediment (TSS), and bedload were as follows:

Each site, excluding BOC-OSR, GAB-HER and REC-JON, required the installation of a staff plate. The first measurement taken at each site is stage, or a reading of the water level. Depending on the size of the team on site, discharge and TSS measurements were taken at the same time. TSS samples were taken using a DH-48 sampling device when applicable. Otherwise, grab samples were taken (i.e. BOC-OSR). The DH-48 samples were collected in the center of the channel in a vertically integrated manor. However, there were times when the stream flow was dangerously high. A measurement could not be taken from the center of the stream, therefore measurements were taken as close to the center of the stream as possible.

All discharge measurements were taken with an impeller-type flow meter along an extended transect tape. One of the models used for this study was the Global Water Flow Probe. Several other impeller-type models used in the field we made using the Global Probe as a model (Cole, 2001). After a collection of discharges at different stage levels was obtained, stage discharge curves were created for each site. It then became necessary to only collect a discharge measurement for stages that had not been measured before. After taking a discharge measurement, stage was recorded again. If stage level changed significantly between the time that the discharge measurement began and ended then a second TSS sample was collected. The discharge value is represented by the average of the before and after stage levels.

Bedload samples were taken using a Helly-Smith bedload-sampling device. If the stream bottom and bedload movement was visible, then estimates for the "representative widths" were assigned for each sample. Samples were generally taken for two minutes, but this was dependent on stream flow and bedload movement. Measurements were done over a shorter period of time during high load and a longer (more than two minutes) during low loads. If stream bottom and bedload movement was not visible, then several (generally two or three) measurements were taken along a cross-section of the stream each representing the width of water that was moving at a particular velocity.

All precipitation data was retrieved from California Irrigation Management Information Services Stations (CIMIS, 2000-2001).

4.3 Lab Procedure for TSS and Bedload Samples

In the lab, total volume was calculated for each sample taken in the field. Sodium hexametaphosphate was added to keep sediment particles from flocculating. Samples were filtered using a vacuum pump, a 63 μm sand-break filter; Millipore AP40 coarse filters (2.4-6 μm) and Whatman 934-AH fine filters (1.5μm). All filters, except for the sand break, were pre-dried in an oven for 15 minutes at 100°C to ensure that ambient moisture was not a source of systematic error and then weighed to the nearest milligram. After being vacuumed, the samples were dried in an oven for two hours at 100°C. Samples cooled for 15 minutes after drying and then were reweighed for their post filter weights to the nearest milligram (Woodward and Foster, 1997). Total suspended sediment concentrations (mg/L) were the initial data for all sediment samples taken.

Bedload samples were dried in oven bags for 24 hours at 70°C. Samples were cooled for two hours and then weighed for their total mass (g).

4.4 Estimating Event Loads

In order to determine suspended sediment amounts, data from streamflow (and/or velocity) must be included (Starosolszky and Rakoczi, 1981). Stage/discharge curves were constructed for each site in order to estimate discharges for a given stage. Not every stage reading had a TSS sample taken to match. TSS samples (mg/L) where matched with their respective discharge from the stage discharge curves to compute load (g/s). Each load value was given a representative "time slot". Time slots were decided to cover the time from half way between the previous sample and the present one, to half way between the present sample and the next one. Loads estimate for each time slot were summed to create a total load for the event. Final data for TSS load was in tonnes.

Bedload samples were also analyzed for load per time. Width interval loads were calculated by dividing the product of the sample mass and its representative width by the width of the instrument (0.075m). The width interval loads were divided by the number of seconds that the sample was collected to find an estimated load per time (g/s). These values were then given time slots that they represented (same method as TSS) to calculate a load per day. The final data for bedload was tonnes.

4.5 Estimating Inter-Event Loads

In order to estimate seasonal sediment load totals for each site and eventually compare these totals with land use estimates, the loads between storm events were estimated. To do this, a time-series of discharge and sediment was graphed for each site. These curves were analyzed for stream base flow trends along with field observations to estimate what base flow and load was between each pair of events at each site. The product of the number of days and the estimated base flow/load provided an estimate for mean inter-event flow and load. Final data for this estimate were displayed in tonnes. The crudeness of this technique was based on the assumption that inter-event loads are small. If they were large, a more accurate technique would have been developed.

4.6 Land Use Analysis

In order to conduct a land use-based sediment load study for Gabilan Creek, sub-catchment areas for sampling sites had to be calculated. Sub-catchment areas, total watershed drainage area and percentages of land use practice per sub-catchment were calculated using the Tarsier Modeling Framework (Watson, 2001). All other GIS processing was done using Microimages *TNT*mips. The primary data set used was a digital land use/cover type map for Monterey County provided by Association of Monterey Bay Area Governments (AMBAG). The imagery is dated from 1990-93.

Using the catchment areas and seasonal loads, a simple static model of sediment load was constructed to predict which land use practices were producing higher sediment yields in the creek. The model is recursive, in that the load computed for each site depends on the loads computed for the sites above. The following equation and Figure 4.7 illustrate the basics of these models.

Predicted load

$$L_i = \Sigma\,(k_j\ A_{j,i} - \Delta S_i + L_{i-1})$$

Where:

L_i equals the predicted load at the (i) bridge or catchment (i = 1….11) .

k_j equals the sediment load coefficient for the (j) land use practice (j = 1-3).

$A_{j,i}$ equals the area of the (j) land use practice pertaining to bridge (i).

ΔS_i equals the change in storage for the (i) bridge ($+\Delta S_i$ equals net deposition and $-\Delta S_i$ equals net scour for the reach above the (i) bridge).

and

L_{i-1} equals the load at the previous bridge or catchment

Mean Absolute Error (MAE)

The accuracy of the model was assessed using the following function for mean absolute error:

$$\Sigma\,(|Li-Li^*|)/n$$

Where:

Li* equals the observed load for the i bridge. (Based on “three-event totals”—See Results)

n equals the number of bridges.

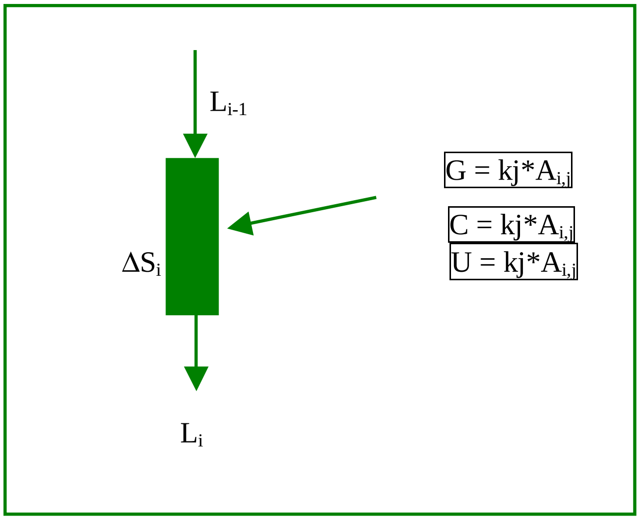

Figure 4.7. An illustration for the static model for the prediction of TSS yields per catchment.

The models are designed to estimate coefficient (k) for total load (both TSS and bedload) of each land use practice as well as instream net scour (k_o). The coefficients, k, were estimated so as to minimize the mean absolute error. The model was assembled as an MS Excel spreadsheet, incorporating an automatic "solver" routine to minimize the error term by adjusting the coefficients k_s (net scour), k_c (crops), k_g (grazing), and k_u (urban). (Frontline Systems, 2001).

The ΔS_i terms were estimated as:

$$\mathbf{\Delta S_i} = \{\mathbf{0};\ \text{steep or hardened reaches}\}$$
$$\text{or } \{\ \mathbf{k_o A_{o,i}}\ ;\ \text{flat and or unlined}\}$$

Where k_o is a scour/deposition coefficient for all scour/depositing reaches and $A_{o,i}$ is the bed area of reach i.

The sediment yield coefficients were used to predict sediment load totals for each land use type by multiplying the coefficients by the area of each land use.

5 Results

5.1 Total Suspended Sediment and Bedload

The following results were collected during five storm events:

- October 25-31, 2000
- January 7-15, 2001
- January 23-26, 2001
- February 9-12, 2001
- February 18-19, 2001

Some storms were covered in greater detail than others due to personnel availability. Typically 10 people were involved over a five-day period.

All sample concentrations were measured within an accuracy of approximately plus or minus eight mg/L. A total of 293 suspended sediment samples were taken in the field along with 405 stage readings.

All sediment load data for each event are summarized in Table 5.1 and inter-event totals are summarized in Table 5.2 by site. Inter-event loads are further discussed in Section 5.2. Seasonal totals for each site are displayed in Table 5.4 and are discussed in further detail in Section 5.3.

For each event, load graphs displaying discharge, TSS load, TSS concentration and bedload were created to illustrate trends and relationships in discharge and stream sediment loads. An example of this is seen in Figure 5.1. See Appendices 10.3-10.7 for all remaining load graphs. The following is a narrative description of results for TSS load, bedload, and discharge for each event.

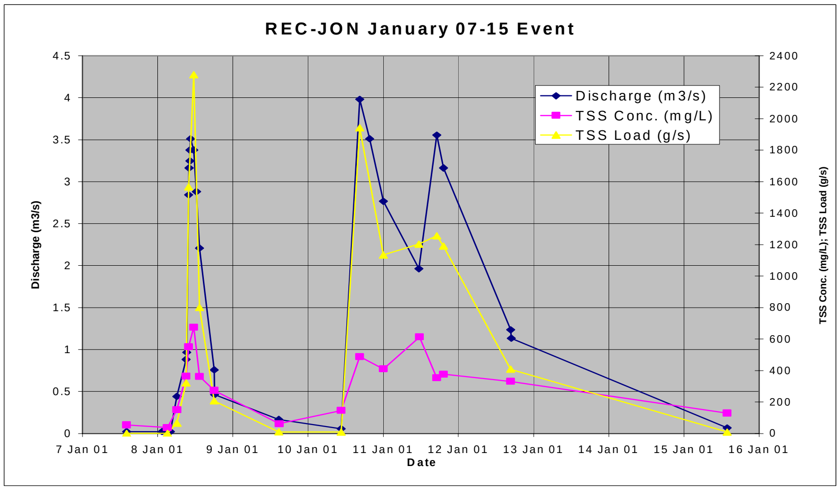

Figure 5.1. Load graph for REC-JON

Table 5.1. Event totals for discharge, total suspended sediment, and bedload.

Sampling Site	Event 1 (October 25-31)			Event 2 (January 7-15)			Event 3 (January 23-26)			Event 4 (February 9-12)			Event 5 (February 18-19)		
	Discharge (m3)	TSS (tonnes)	Bedload (tonnes)	Discharge (m3)	TSS (tonnes)	Bedload (tonnes)	Discharge (m3)	TSS (tonnes)	Bedload (tonnes)	Discharge (m3)	TSS (tonnes)	Bedload (tonnes)	Discharge (m3)	TSS (tonnes)	Bedload (tonnes)
TOW-OSR	*	*	*	6082.6	0.20	*	2900.2	0.9	*	1785.5	0.1	*	835.9	0.1	*
BOC-OSR	*	*	*	685.1	0.17	*	4709.8	8.1	*	1040.4	0.2	*	356.9	0.1	*
GAB-OSR	10957.0	15.2	0.3	16904.5	7.2	1.9	26509.9	29.3	1.8	14604.2	3.5	0.9	11068.0	7.8	14.6
GAB-CRA	61558.7	65.1	46.3	43363.0	7.7	7.2	69542.8	144.7	43.4	64173.6	37.8	18.7	25355.3	41.1	70.1
GAB-HER	21450.3	183.5	0.7	2366.7	2.8	0.0	9680.2	34.5	0.0	42183.2	124.5	0.0	8937.0	35.0	0.0
GAB-NAT	-	-	-	-	-	-	7928.4	53.2	0.6	26956.0	88.8	12.2	5842.2	39.3	11.9
GAB-BOR	-	-	-	-	-	-	-	-	-	10154.5	30.16	0.012	4006.1	23.9	0.0
GAB-VET	*	*	*	10241.0	0.1	0.0	31572.0	3.1	0.0	50833.0	4.96	0.3	20910.6	6.5	0.3
REC-VIC	*	*	*	656598	193.9	0.3	251610	103.8	*	*	*	*	105623	22.5	*
REC-JON	728334	543.5	0.0	616784	251.4	0.0145	364252	245.2	*	*	*	*	225250	58.2	*
REC-183	*	*	*	963093	525.4	0.9	449047	399.2	*	*	*	*	112085	140.9	*

* Site not visited or not sampled for this parameter.
- No samples were taken due to no flow

Table 5.2. Estimated inter-event totals for discharge total suspended sediment, and bedload.

Sampling Site	Oct 31-Jan 7			Jan 16-Jan 22			Jan 27-Feb8			Feb13-17		
	Discharge (m3)	TSS (tonnes)	Bedload (tonnes)	Discharge (m3)	TSS (tonnes)	Bedload (tonnes)	Discharge (m3)	TSS (tonnes)	Bedload (tonnes)	Discharge (m3)	TSS (tonnes)	Bedload (tonnes)
TOW-OSR	41548.4	0.17	0.0	4888.0	0.02	0.0	7943.1	0.03	0.0	5499.1	0.02	0.0
BOC-OSR	927.7	0.01	0.0	109.1	0.002	0.0	177.3	0.003	0.0	122.8	0.00	0.0
GAB-OSR	22913.3	0.34	5.3	9362.5	0.34	0.6	15214.0	0.34	1.01	10532.8	0.34	0.7
GAB-CRA	71251.7	1.13	6.1	25235.6	1.13	0.7	41007.9	1.13	1.2	28390.1	1.13	0.8
GAB-HER	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00	0.0
GAB-NAT	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00	0.0
GAB-BOR	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00	0.0
GAB-VET	318266.0	0.18	0.0	37443.1	0.02	0.0	60845.0	0.04	0.0	42123.4	0.02	0.0
REC-VIC	672798.5	26.59	0.0	79152.8	3.13	0.0	128623.2	5.08	0.0	89046.9	3.52	0.0
REC-JON	128535.1	4.76	0.0	15121.8	0.56	0.0	24572.9	0.91	0.0	17012.0	0.63	0.0
REC-183	137906.8	6.13	0.0	16224.3	0.72	0.0	26364.5	1.17	0.0	18252.4	0.81	0.0

5.1.1 Event 1: October 25-31, 2000

This event was unexpected because it occurred very early in the rain season—(Figure 5.2). October is generally one of the warmest and driest months of the year for Central California.

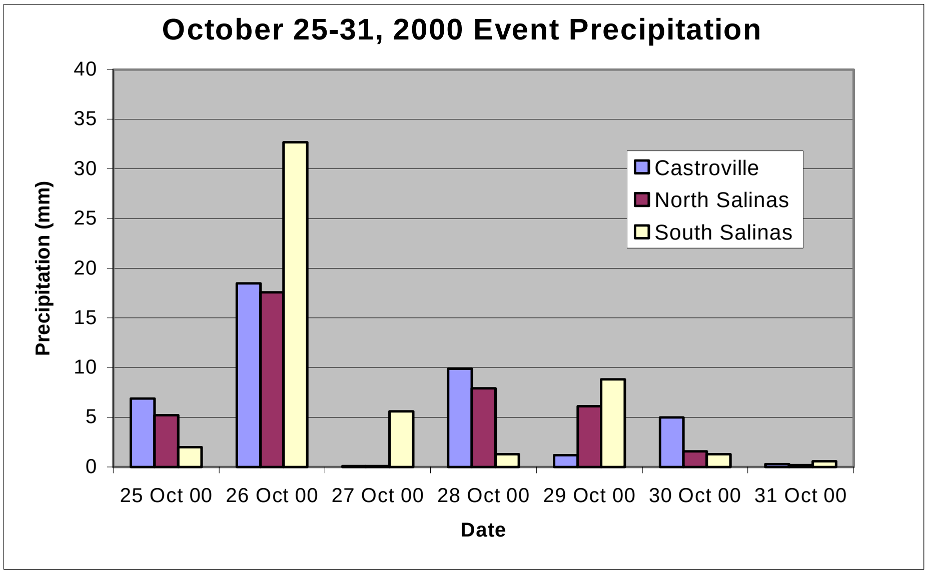

Figure 5.2. Daily precipitation totals for the Salinas and Castroville areas during October 25-31, 2000.

Sampling took place at only four sites. At the time, it was thought that GAB-OSR was in a predominantly grazing landuse setting[1], therefore sampling above this location was not

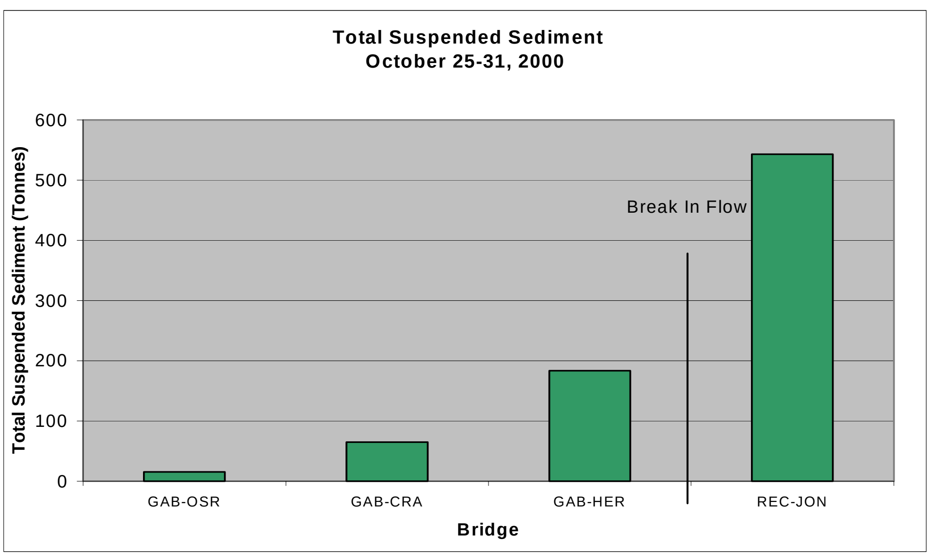

Figure 5.3. Total suspended sediment for each monitoring site during the October 2000 event.

[1] The strawberry fields are hidden from view from public roads.

considered unnecessary. A significant load of TSS came through this location.

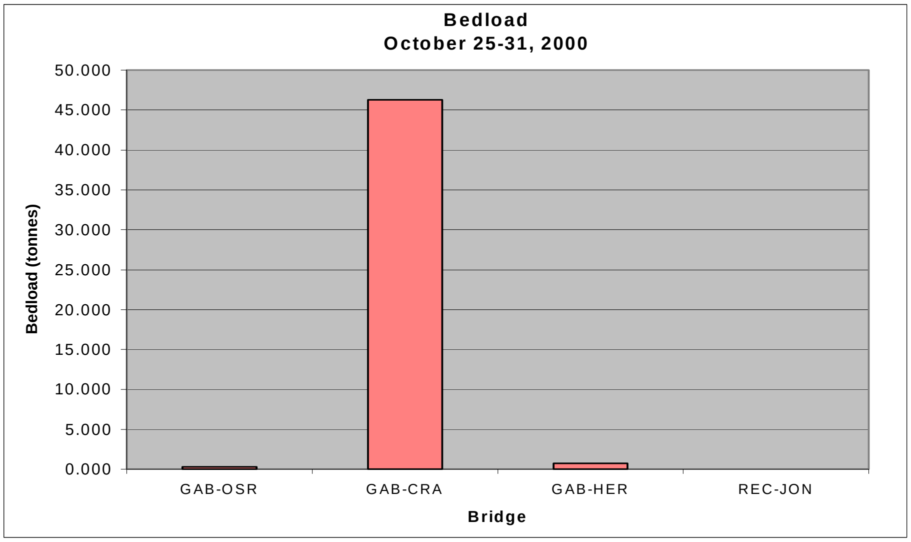

Figure 5.4. Bedload totals for each monitoring site during the October 2000 event.

At GAB-HER, the point of landuse change between strawberries and row crops, the TSS load rose to three times what it was at GAB-CRA. Stream flow did not reach the next sampling sites, GAB-NAT and GAB-BOR.

Monitoring continued at REC-JON. REC-JON was the only established sampling site on The Reclamation Ditch. TSS concentrations were significant, however loads were not substantial. Two bedload samples were taken at REC-JON, each resulting in no load.

5.1.2 Event 2: January 7-15, 2001

This was the first rain since the October Event—(Figure 5.5). For this event all sites were monitored, although stream flow did not reach the GAB-NAT and GAB-BOR stations. The intensity of the event was light to moderate, yet the duration was the longest of the five events.

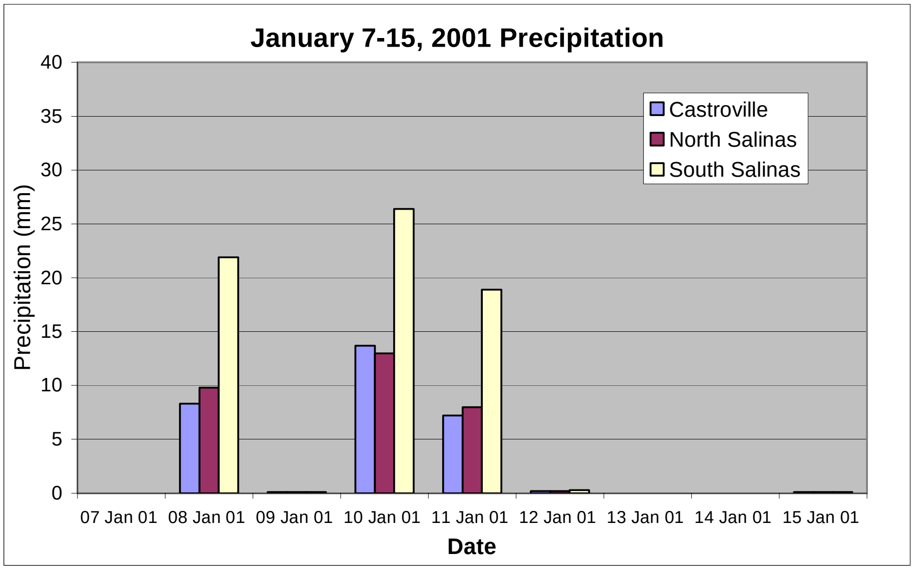

Figure 5.5. Daily precipitation totals for the Salinas and Castroville areas during January 7-15, 2001.

While discharge totals increased from the last event, overall, TSS loads decreased dramatically as well as bedload (except for GAB-OSR, which showed a slight increase in bedload). TSS loads at GAB-HER and GAB-VET were insignificant and no bedload movement was measured—(Figs 5.6 & 5.7).

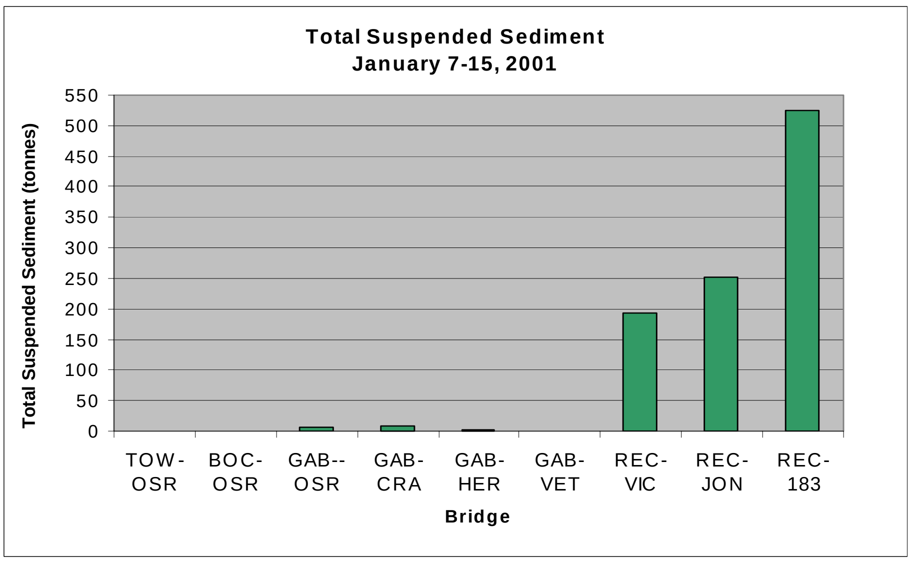

Figure 5.6. Total suspended sediment for each monitoring site during the January 7-15 event.

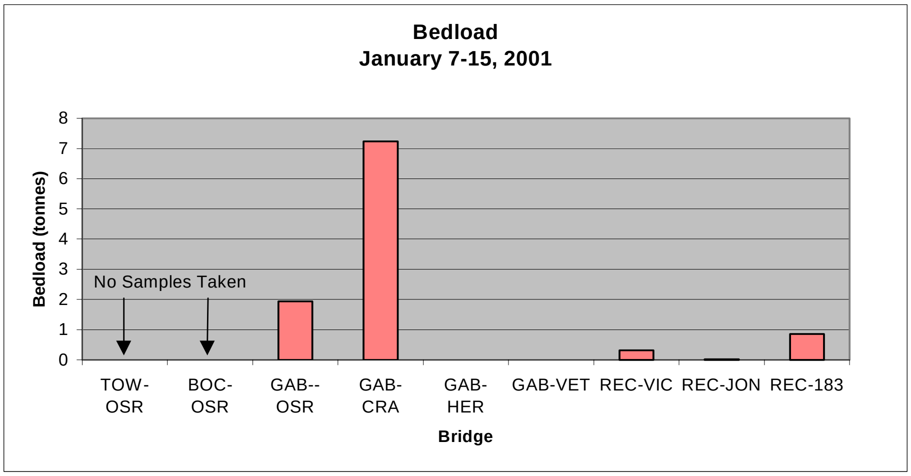

Figure 5.7. Bedload totals for each monitoring site during the January 7-15 event.

Overall, The Reclamation Ditch had a decrease in discharge compared to the last event and both TSS and bedload totals had dropped as well (based on REC-JON comparison). Two new sampling locations were introduced during this event—REC-VIC and REC-183. Discharges were higher at REC-VIC than at REC-JON, yet overall concentration and load were lower. Conversely, REC-183 received more discharge as well as TSS load.

5.1.3 Event 3: January 23-26, 2001

For this event weather forecasts predicted a heavy intensity event with high probability of local flooding. During the first two days of the event, precipitation was intense along the coast—(Figure 5.8). On the 25th, Salinas and Castroville were hit by a well-defined and fast moving front.

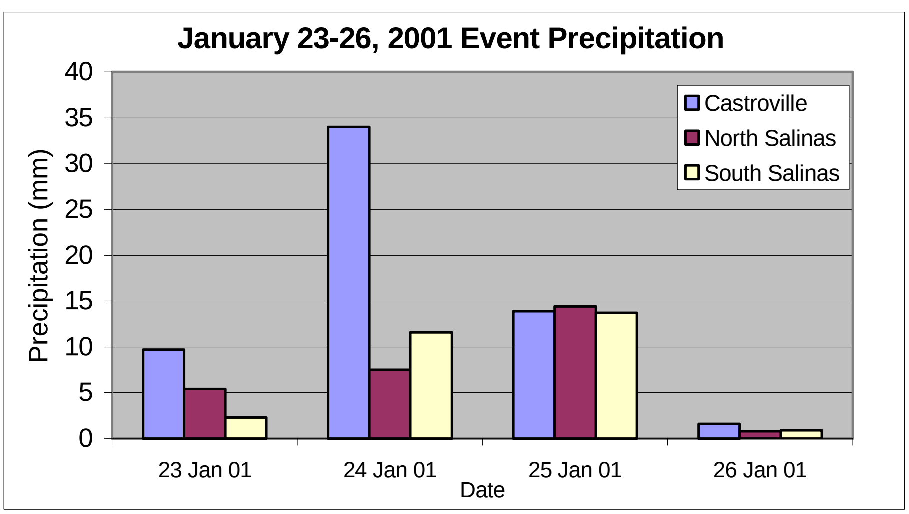

Figure 5.8. Daily precipitation totals for the Salinas and Castroville areas during January 23-26, 2001.

Associated with this intense front were the largest peaks in discharge, TSS loads and bedload (See Graphs in Appendix 10.5).

This pulse in precipitation caused stream loads to respond significantly at all sites. Many bridges reached stage levels that had not been seen before. For the first time during this season, stream flow reached GAB-NAT. However, flows still did not reach GAB-BOR. Data from this

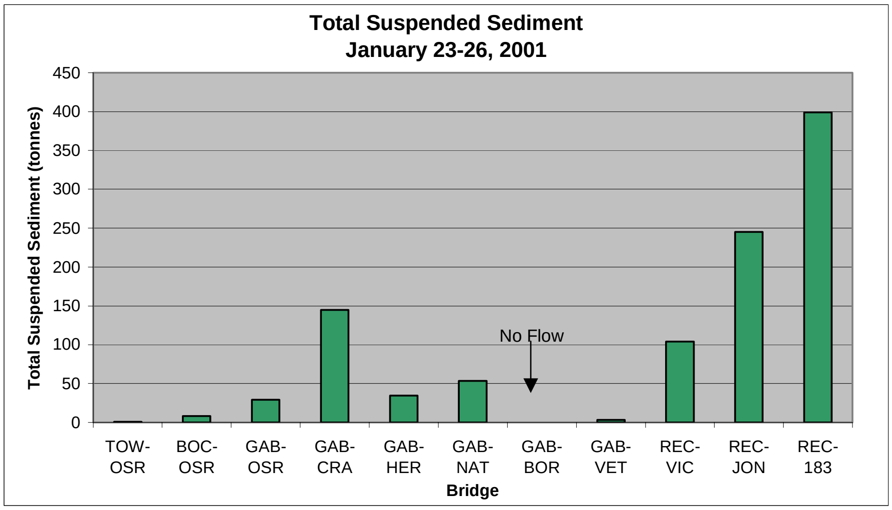

Figure 5.9. Total suspended sediment for each monitoring site during the January 23-26, 2001 event.

event shows high volumes of sediment and water move through The Reclamation Ditch—Figure 5.9 & Table 5.1. Like the previous event, this event had the same trend of increasing loads along The Reclamation Ditch. Bedload was only measured at four monitoring sites. GAB-CRA was the only location that had a significant event load-Figure 5.10.

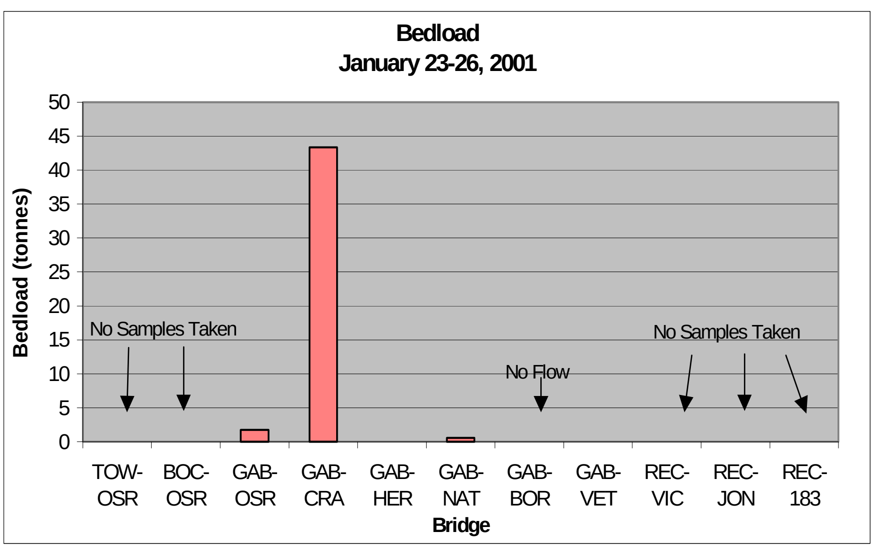

Figure 5.10. Bedload totals for each monitoring site during the January 23-26, 2001 event.

5.1.4 Event 4: February 9-12, 2001

Precipitation for this event was considered moderate to high intensity with day to day consistency—(Figure 5.11). Stream levels again reached levels higher than previously seen during this season. No monitoring was done on The Reclamation Ditch for this event due to personnel availability. This was the first event of the season to see the entire stream connect. Prior to this event, it was thought that stream flow was not connecting the entire stream due to natural phenomenons such as ground infiltration. However, it was during this event that a small,

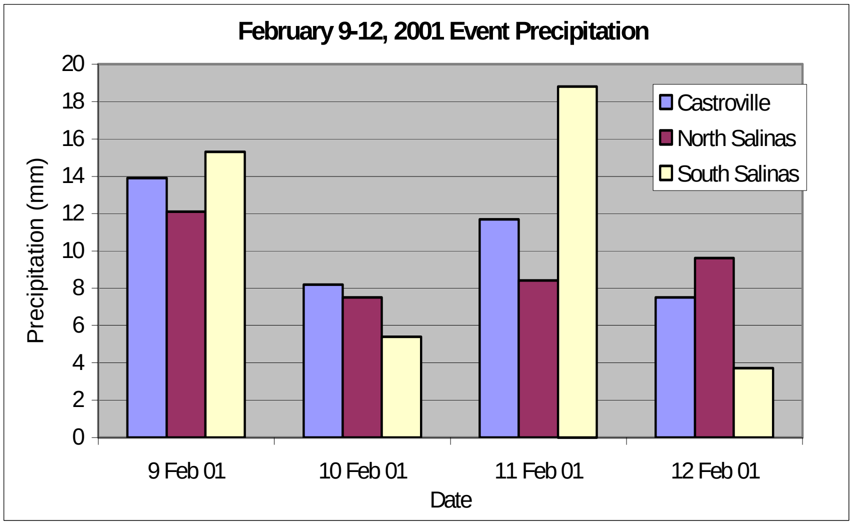

Figure 5.11. Daily precipitation totals for the Salinas and Castroville areas during the February 9-12, 2001 Event.

temporary dam was discovered approximately 1 mile upstream from the eastern boundary of Salinas that was keeping the stream from connecting—Figure 5.12.

Figure 5.12. A small earth dam, minutes after breaching, made of sand above GAB-BOR. It is presumed that this was the reason for no flow at GAB-BOR during previous events.

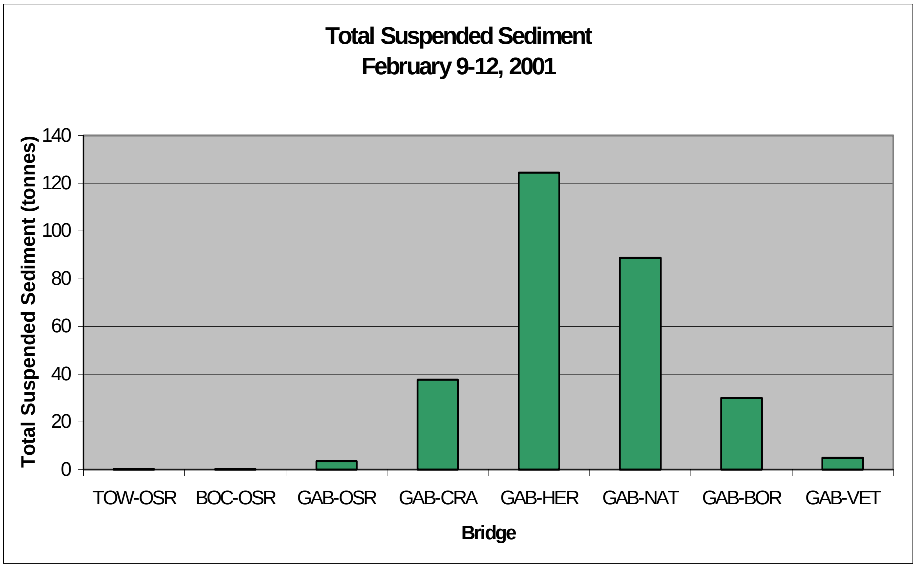

Figure 5.13. Total suspended sediment for each of the monitoring sites during the February 9-12, 2001 event.

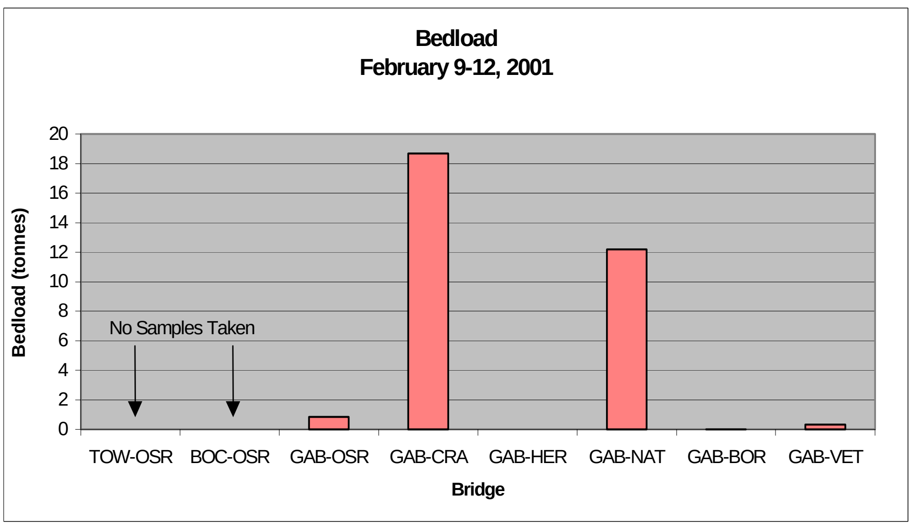

Figure 5.14. Total bedload for each of the monitoring sites during the February 9-12, 2001 event.

The dam breached at approximately 10:30am on the 12th. The first samples were taken at GAB-BOR at 11:10am.

High TSS loads were measured between GAB-CRA and GAB-BOR—(Figure 5.13). Concentrations were extremely high at GAB-BOR—See Load Graph in Appendix 10.6. An increase in TSS load was measured at GAB-VET, possibly as a response to the connection of the upper and lower reaches. Bedload increased significantly at GAB-NAT from the last event and there was a slight increase in bedload at GAB-VET—(Figure 5.14).

5.1.5 Event 5: February 18-19, 2001

The second event of February, and the last for this study, was light to moderate in intensity—(Figure 5.15). In addition, coverage of the event was at a minimum due to personnel availability. Each site was monitored on at least two occasions. The entire stream connected for its second consecutive event. This occurred at approximately 12:00pm on the 19th and remained connected for approximately three to four hours.

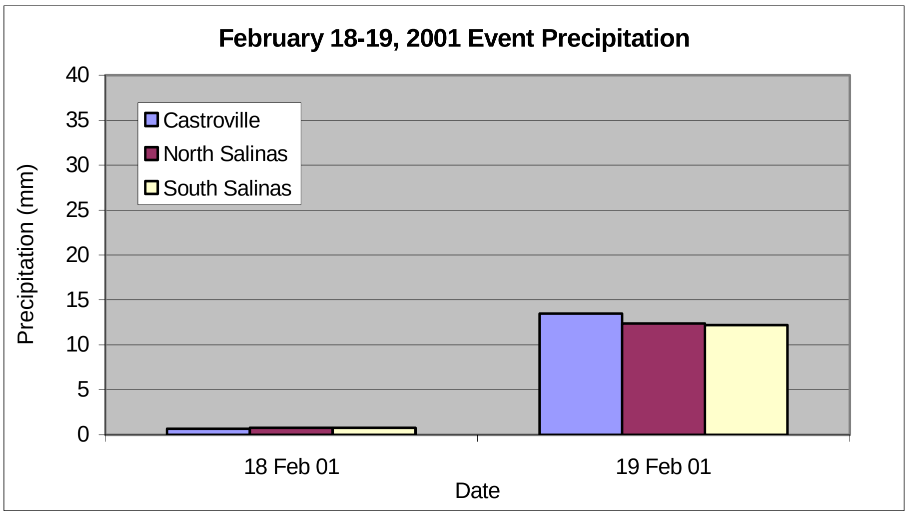

Figure 5.15. Daily precipitation totals for the Salinas/Castroville areas during February 18-19, 2001.

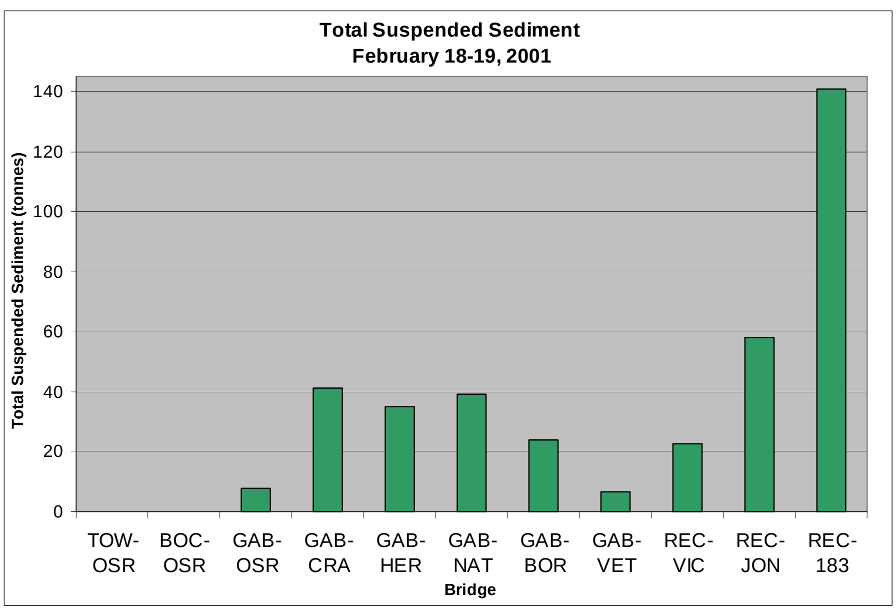

Figure 5.16. Total suspended sediment for each monitoring site during the February 18-19, 2001 event.

Overall, sediment loads and discharges were significantly lower than the previous event, due presumably to the length of the event. The mid-creek section (GAB-HER through GAB-VET) had a significant decrease in TSS loads from the last event. There were minor increases in TSS load at GAB-CRA and GAB-VET. Bedload was substantially higher at GAB-OSR and GAB-CRA from the last event.

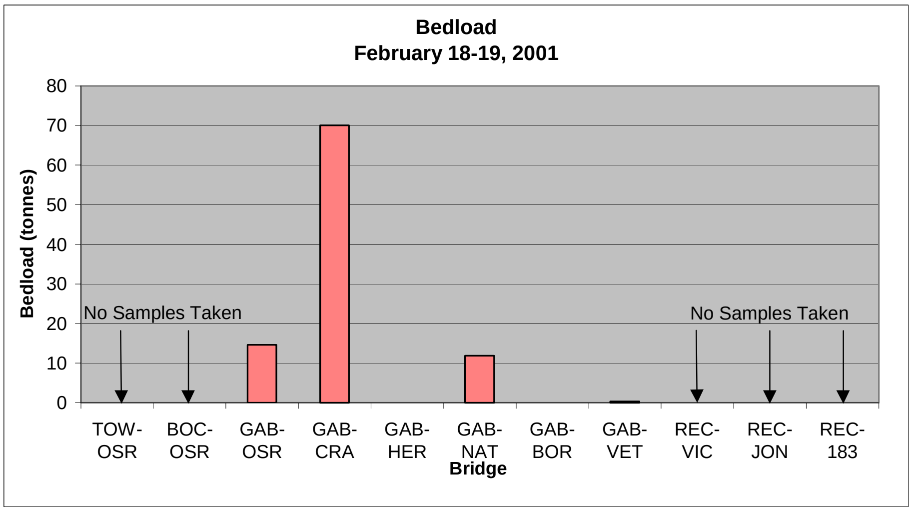

Figure 5.17. Bedload totals for each monitoring site during the February 18-19, 2001 event.

5.2 Inter-Event Estimates of Load

Inter-event load estimates were summarized in Table 5.2. Table 5.3 summarizes the percentages of the seasonal load total for each inter-event load. For both TSS and bedload, the percentages of the season total loads are insignificant. Discharge percentages for inter-event loads are significant, but these flows are low in sediment concentration.

An exception to this trend is Towne Creek, which is estimated to have transported an estimated 33.3 % of its seasonal load during non-event periods. However, an estimated 83.7% of its season total flow occurred during non-event periods.

Table 5.3. Inter-event load percentages of season total load for each monitoring site.

Sampling Site	Oct 31– Jan 7			Jan 16 – Jan 22			Jan 27 – Feb 8			Feb 13 – Feb 17			Totals		
	Discharge (%)	TSS Load (%)	Bedload (%)	Discharge (%)	TSS Load (%)	Bedload (%)	Discharge (%)	TSS Load (%)	Bedload (%)	Discharge (%)	TSS Load (%)	Bedload (%)	Discharge (%)	TSS Load (%)	Bedload (%)
TOW-OSR	58.1	11.2	0	6.8	18.5	0	11.1	2.1	0	7.7	1.5	0	83.7	33.3	0
BOC-OSR	11.9	0.2	0	1.4	0.02	0	2.3	0.03	0	1.6	0.02	0	17.2	0.27	0
GAB-OSR	18	0.5	7.5	7.4	0.5	0.6	12.0	0.5	1.4	8.3	0.5	1.0	45.7	2	10.5
GAB-CRA	16.6	0.4	2.0	5.9	0.4	0.7	9.5	0.4	0.4	6.6	0.4	0.3	38.6	1.6	3.4
GAB-HER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GAB-NAT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GAB-BOR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GAB-VET	55.6	0.1	0	6.5	0.1	0	10.6	0.02	0	7.4	0.2	0	80.1	0.42	0
REC-VIC	33.9	0.9	0	4.0	0.9	0	6.5	1.4	0	4.5	1.0	0	48.9	4.2	0
REC-JON	6.1	0.1	0	0.7	0.1	0	1.2	0.1	0	0.8	0.1	0	8.8	0.4	0
REC-183	8.0	0.1	0	0.9	0.1	0	1.5	0.1	0	1.1	0.1	0	11.9	0.4	0

Table 5.4. Season totals for all sampling sites for discharge, TSS, and bedload.

Sampling Site	# of events monitored	Discharge (m3)	TSS (tonnes)	Bedload (tonnes)	TSS Mean Conc. (tonnes/m3)
TOW-OSR	4	71500	1.3	0.0	$1.8x10^{-5}$
BOC-OSR	4	8100	9	0.0	$1.0x10^{-3}$
GAB-OSR	5	127000	70	27.1	$5.5x10^{-4}$
GAB-CRA	5	368000	305	194.5	$8.2x10^{-4}$
GAB-HER	5	63000	380	0.7	$6.0x10^{-3}$
GAB-NAT	5	41000	181	24.6	$4.4x10^{-3}$
GAB-BOR	5	14000	54	0.012	$3.8x10^{-3}$
GAB-VET	4	572200	15	0.6	$2.5x10^{-5}$
REC-VIC	3	1984000	320	0.3	$1.6x10^{-4}$
REC-JON	4	2120000	1098	0.0145	$5.1x10^{-4}$
REC-183	3	1723000	1066	0.9	$6.1x10^{-4}$

5.3 Seasonal Estimates of Load

All sediment loads, concentrations, and discharge are the result of the sum of the number of events monitored and the estimated inter-event loads. The totals in Table 5.4 should be considered with respect to the fact that some monitoring sites (i.e. REC-VIC, REC-JON, and REC-183 etc.) would, in reality, have larger seasonal loads for all parameters (See "# of events monitored" Table 5.4) if we had sampled for all parameters at all sites.

TSS loads and concentration were significantly larger at BOC-OSR than at TOW-OSR, although TOW-OSR had a significantly larger total discharge—(Table 5.4). There was a large increase in both TSS and bedload between GAB-OSR and GAB-CRA. It is inferred that net bedload was deposited between GAB-CRA and GAB-HER due to the reduction in total flow between these sites.

At GAB-NAT, there is a sharp increase in total bedload yet TSS loads drop considerably. Both TSS and bedload totals decrease substantially at GAB-BOR with a significant decrease in total flow. GAB-VET, which received flow only twice from the above monitoring sites but receives flows perennially from mainly residential runoff, was much cleaner than the above monitoring sites.

Data for the Reclamation Ditch suggests that urban sediment loads are significant. However, the concentration totals reveal that the ditch carries less sediment-laden water throughout the season. It should be noted that the Reclamation Ditch does become dirtier the further you move downstream. Comparing REC-JON and REC-183 totals, with one less event monitored at REC-183, total estimated tonnes for each site remained nearly even.

To better understand the entire system, the following section discusses the three events that covered all sampling sites.

5.4 Three Event Data Totals

Of the five events monitored, only three events had visits to all of the eleven sites. However, not all of the eleven sites received flow during all of these events. Analyzing trends within just these three events serves as a better model for understanding sediment sources along Gabilan Creek in an unbiased manner. Table 5.5 summarizes the three-event totals for discharge, TSS load and EMC, as well as bedload and bedload EMC.

Table 5.5. Three-event totals for each monitoring site.

Sampling Site	3-event Totals (Jan 7-15, Jan 23-26, & Feb 18-19, of 2001)				
	Discharge (m3)	TSS Load (tonnes)	TSS EMC (mg/L)	Bedload (tonnes)	Bedload EMC (mg/L)
TOW-OSR	10000	1.2	121.4	0.0	0.0
BOC-OSR	6000	8.4	1460.3	0.0	0.0
GAB-OSR	54000	44.3	813.7	18.3	336.4
GAB-CRA	139000	193.4	1398.6	120.7	873.0
GAB-HER	21000	72.3	3444.0	0.0	0.0
GAB-NAT	14000	92.6	6722.2	12.4	903.4
GAB-BOR	4000	23.9	5960.0	0.0	0.0
GAB-VET	63000	9.8	155.8	0.3	4.8
REC-VIC	1014000	320.2	315.8	0	0
REC-JON	1206000	554.8	459.9	0	0
REC-183	1524000	1065.6	699.1	0	0

There is a significant increase between TOW-OSR and BOC-OSR in both TSS load and EMC. Even more importantly, the total discharge was much greater at TOW-OSR but loads were eight times as great at BOC-OSR—(Figs 5.18 & 5.19). The TOW-OSR drainage area is roughly 10 times greater than BOC-OSR.

TSS loads were larger at the first site on Gabilan Creek (GAB-OSR) than the other two grazing/natural sites, but the drainage area is four times the area of TOW-OSR and approximately 80 times as big as BOC-OSR catchment. Once reaching the strawberry fields and the convergence of upstream tributaries, both TSS load and bedload increase substantially. At GAB-HER, overall TSS load drops as a result of less water reaching this location. However, the concentration of suspended sediment in waters that did reach this location more than doubled from GAB-CRA. In addition, bedload movement had completely stopped between these two locations.

At GAB-NAT TSS load increased slightly from GAB-HER and TSS EMC nearly doubled again. There was a small resurgence in bedload. Note the high bedload EMC. GAB-BOR only received flow during two events; only one of them is represented in this three-event total. TSS EMC remained high while TSS load and total discharge decreased. No bedload was measured at GAB-BOR.

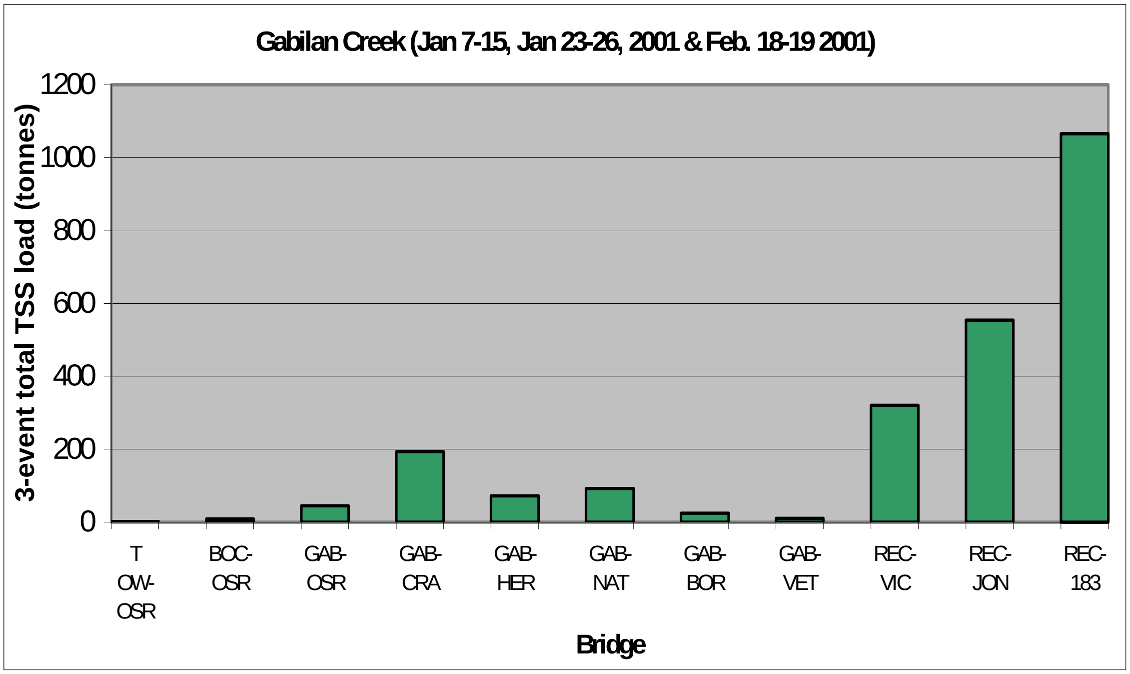

Figure 5.18. Total suspended sediment for three events.

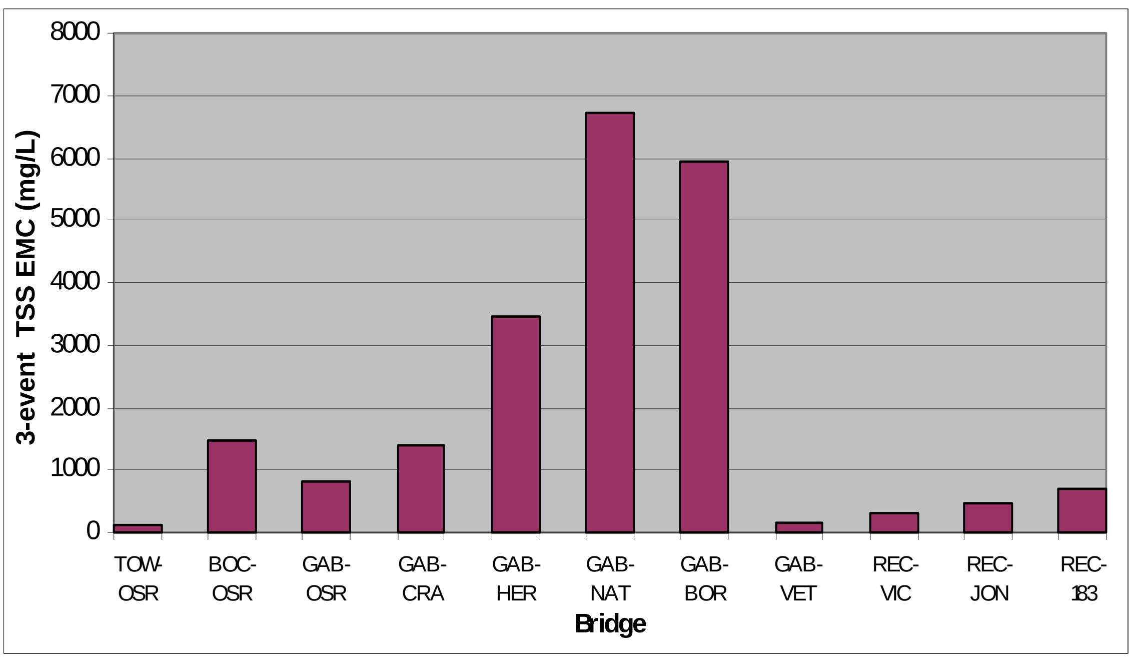

Figure 5.19. Event mean concentration (EMC) for total suspended sediment for three events.

An increase in residential runoff produced much lower sediment concentrations and loads at GAB-VET. It appears that very little of the sediment movement in the upstream sites makes it into Carr Lake during events of the size measured during this study. If this was not the case, sediment loads and concentrations would be much higher at GAB-VET (located just upstream from Carr Lake).

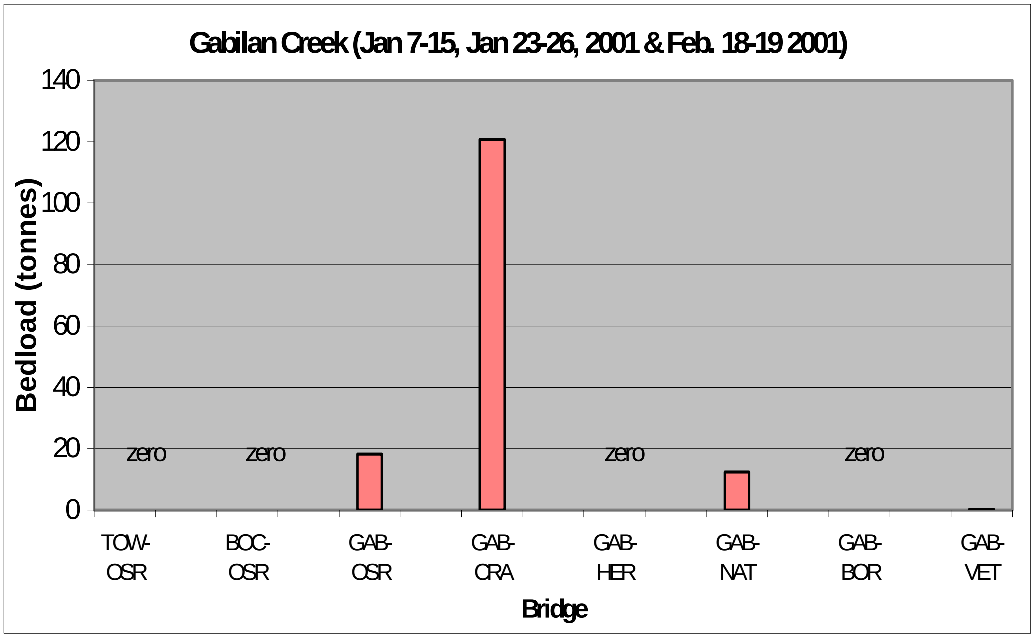

Figure 5.20. Bedload totals for three events.

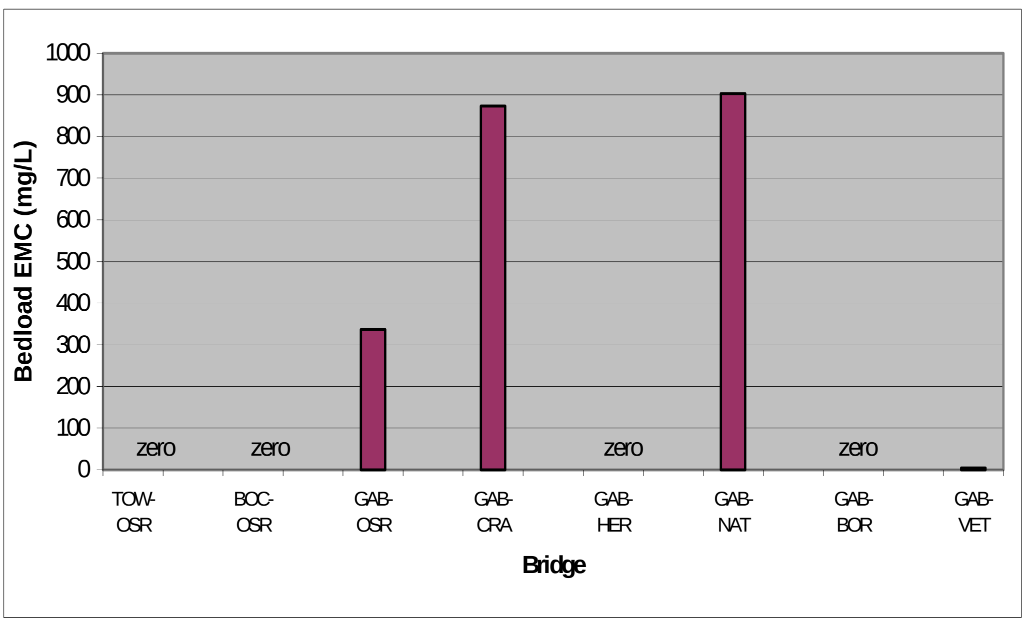

Figure 5.21. Bedload event mean concentration for three events.

Data for the three event totals along The Reclamation Ditch provides another good model of its own with sediment loads and EMC increasing further downstream. Concentrations in the

Reclamation Ditch were lower than monitoring sites above GAB-VET. In addition, total discharge was significantly higher in the Rec Ditch than all other sites on Gabilan Creek. No bedload was measured in the Rec Ditch.

5.5 Landuse Analysis

The results of the landuse analysis are summarized in Tables 5.6 and 5.7. This section is separated into two different sections. The first is total area for each sub-catchment defined by the monitoring sites. The second is the percentage of landuse type found within that sub-catchment. Each downstream catchment is the sum of the previous catchments. Thus, all lands that drain into the Gabilan Creek and Reclamation Ditch system (i.e. from Fremont Peak to REC-183) define the total drainage area.

5.5.1 Sub-Catchment Areas

Total area for each sub-catchment was calculated using the Tarsier Modeling Framework. Table 5.6 summarizes the total area for each sub-catchment based on the monitoring site as well as the total drainage area for each site. Figure 5.21 is a map of the sub-catchments.

Table 5.6. Sub-Catchment and total drainage area for each monitoring site.

Sampling Site	Sub-Catchment Area km2	Drainage Area km2
TOW-OSR	9.7	9.7
BOC-OSR	0.5	0.50
GAB-OSR	41.5	41.5
GAB-CRA	38.7	90.4
GAB-HER	4.3	94.7
GAB-NAT	4.1	98.7
GAB-BOR	5.4	104.3
GAB-VET	3.4	107.7
REC-VIC	155.7	263.3
REC-JON	12.5	275.9
REC-183	40.0	315.9

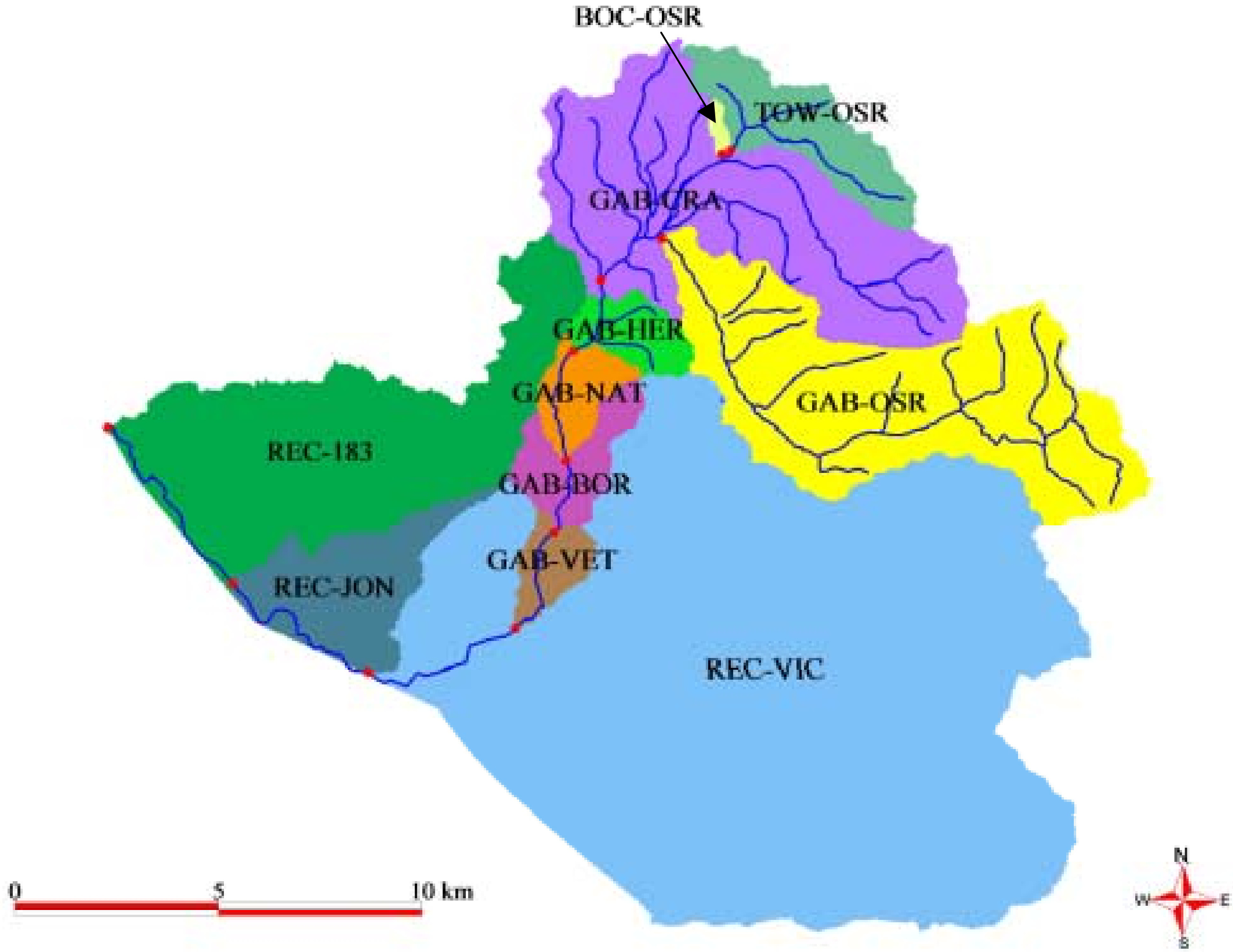

Figure 5.21. Sub-catchments of the Gabilan Watershed

5.5.2 Landuse Practice Percentages

The AMBAG land use classification shows 10 different land uses/ cover types in the Gabilan Watershed. These include grass, oak woodland/woody vegetation, shrub, artichoke, row crops, orchard/nursery, strawberries, greenhouses, golf courses, and urban. For basis of this study, *grazing/natural* is the sum of the grass and oak woodland/woody vegetation covers. *Crops* is the sum of the artichoke, greenhouse, orchard/nursery, row crops, strawberries, and fallow covers. *Urban* areas consisted of urban and golf course uses. Table 5.7 shows land use areas and percentages for each specific catchment (i.e. not including the catchments above).

Table 5.7. Land use areas and their percentages for each sub-catchment

Sub-Catchment	Land Use							
	Grazing/ Natural		Crops		Urban		Total	
	Km^2	%	Km^2	%	Km^2	%	Km^2	%
TOW-OSR	9.7	100	0	0	0	0	9.7	100
BOC-OSR	0.5	100	0	0	0	0	0.5	100
GAB-OSR	41.5	100	0	0	0	0	41.5	100
GAB-CRA	38.2	98.6	0.55	1.4	0	0	38.7	100
GAB-HER	3.3	77.7	0.92	22.3	0	0	4.3	100
GAB-NAT	1.2	31	2.7	66.5	0.12	3	4.1	100
GAB-BOR	1.4	24.5	4.0	75.5	0	0	5.4	100
GAB-VET	1.2	35	1.0	29	1.2	35.6	3.4	100
REC-VIC	85.7	55	49.8	32	20.2	13	155.7	100
REC-JON	0.2	2	7.5	61	4.7	38	12.5	100
REC-183	5.1	13	31.9	80	2.9	7	40.0	100

The entire sub-catchments for TOW-OSR, BOC-OSR, and GAB-OSR[2] are 100% grazing/natural lands—(Tables 5.7 & 5.8). GAB-CRA consists of mainly grazing/natural land cover (98.6%) and a small amount, 1.4%, of crop cover (strawberries)[3]. The GAB-HER sub-catchment is 78% grazing/natural lands with an additional 22.3% crop lands. At GAB-NAT there is a change from grazing/natural lands (31%), as the dominant land use, to crop cover (66.5%) as well as the first urban cover (3%). GAB-BOR has a larger expanse of crop cover (75.5%) as compared to grazing/natural

[2] The AMBAG data is from 1990-93. However, the Salinas Sediment Study has created an unpublished data layer (based on 1999 satellite data) that estimates the GAB-OSR sub-catchment to be 14.1% (5.38km^2) crop cover. Field observations indicate that there are large strawberry fields immediately upstream from the sampling site in this sub-catchment, but there is skepticism about the accuracy for the total area of these strawberries. Thus, it was decided that the area is approximately 2 km^2.
[3] The GAB-CRA sub-catchment for the SSS data layer is 14.5% (4.71km^2) crops compared to the 0% for the AMBAG data

(24.5%). GAB-VET has relatively even distribution of the three dominant land use types: grazing/natural (35%), crops (29%), and urban (35.6%).

The drainage area specific to REC-VIC consists of 55% grazing/natural, 32% crops and 13% urban cover. By far, it is the largest of the sub-catchments (152.6 km^2). It includes the foothills of the Gabilan Range, a large proportion of the city of Salinas, as well as some of the artichoke fields immediately west of Salinas.

Table 5.8. Land use areas and their percentages specific to the whole watershed.

Sub-Catchment	Land Use							
	Grazing/ Natural		Crops		Urban		Total	
	Km^2	%	Km^2	%	Km^2	%	Km^2	%
TOW-OSR	9.7	100	0	0	0	0	9.7	100
BOC-OSR	0.5	100	0	0	0	0	0.50	100
GAB-OSR	41.4	100	0	0	0	0	41.5	100
GAB-CRA	89.9	99.4	0.55	0.6	0	0	90.4	100
GAB-HER	93.3	98.5	1.5	1.5	0	0	94.7	100
GAB-NAT	94.5	95.6	4.2	4.2	0.12	0.1	98.7	100
GAB-BOR	95.9	92.0	8.2	7.9	0.12	0.1	104.3	100
GAB-VET	97.1	90.2	9.2	8.6	1.4	1.3	107.7	100
REC-VIC	182.7	69.4	59	22.4	21.5	8.2	263.3	100
REC-JON	182.9	66.3	66.6	24.1	26.3	9.5	275.9	100
REC-183	188.1	59.5	98.6	31.2	29.2	9.3	315.9	100

The REC-JON sub-catchment, much smaller than REC-VIC, has a significant increase in the total area covered by crops (60.5%). It also includes the western portion of urbanized Salinas (37.5%) as well as a small portion of grazing/natural lands (2%). REC-183 consists of nearly 80% crop cover along with 13% grazing/natural and 7.5% urban.

Throughout the watershed, grazing/natural areas decreases moving downstream, while the amount of row crops and urban lands increase—Table 5.8. At the beginning of the Reclamation Ditch (REC-VIC) there is a sharp increase in the percentage of both crop and urban land use drainage. The total drainage area from the headwaters to the REC-183 Bridge, is approximately 316km^2. Of the 316 km^2, 188 km^2 (59.5%) of it is considered grazing/natural lands, 98.6 km^2 (31.2%) is considered crops and 29.2 km^2 (9.3%) is considered to be urban lands.

Figs 5.21a &5.21b illustrate the total TSS and bedload per drainage area for each sampling location.

BOC-OSR (grazing without a vegetative buffer) and the post-urban sites in the Reclamation Ditch had substantial TSS yields per drainage area, especially BOC-OSR. Net bedload movement was large in the foothill sites (GAB-OSR and GAB-CRA).

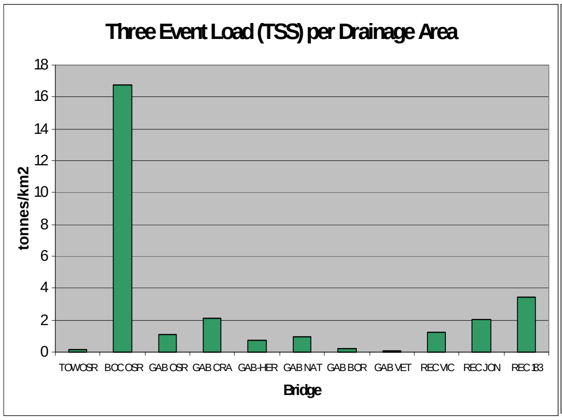

Figure 7.22a. Three-event TSS load per drainage area.

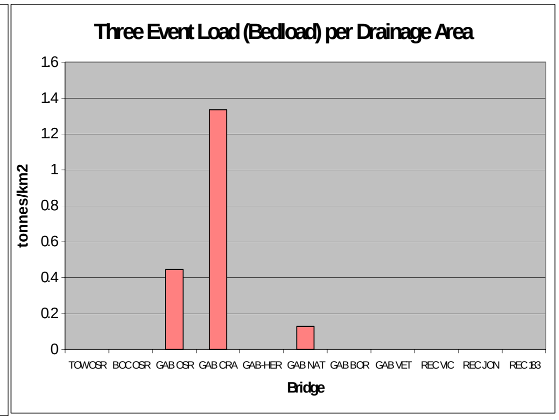

Figure 7.22b. Three-event bedload totals per drainage area.

5.5.3 Land use practices and sediment loads in Gabilan Creek

Based on field monitoring observations and data analysis, each reach was given a "yes" or "no" value for scouring/depositing. A yes value means that the reach does have a net scour or net deposition (ΔS). Reaches that received a "no" for scouring/depositing value had no net ΔS. A positive value means that scouring occurs in this reach and a negative value means that there was net deposition. Table 5.9 summarizes which sites had a ΔS. The yes or no designation was set according to our knowledge of depositional areas gained through an estimated 100 person days of field observations.

Table 5.9. Inputs for whether or not each specific reach had a net ΔS.

Bridge	TSS (ΔS)	Bedload (ΔS)
TOW-OSR	No	No
BOC-OSR	No	No
GAB-OSR	No	No
GAB-CRA	No	No
GAB-HER	Yes	Yes
GAB-NAT	Yes	No
GAB-BOR	Yes	Yes
GAB-VET	Yes	Yes
REC-VIC	No	Yes
REC-JON	No	Yes
REC-183	No	Yes

The values for ΔS shown in Table 5.10, are the estimated tonnes per square kilometer that were deposited in each reach. However, not all reaches used this value. The mean absolute error for the TSS static model was 37% and for bedload it was 14%.

Table 5.10. Output k coefficients for both the TSS and Bedload static models.

K coefficients	TSS k-values (tonnes/km2)	Bedload k-values (tonnes/km2)
Grazing/Natural (k_1)	0.12	0.24
Crops (k_2)	8.38	4.50
Urban (k_3)	3.50	0
Scour/Deposite (k_0)	-7891	-30000
Mean Absolute Error	**%**	**%**
MAE	37	14

The results of the static model are summarized in Table 5.10. For both TSS and bedload the estimated k for the crop areas is significantly higher than both grazing and urban. The bedload k-value for urban was set to be 0 and k_0 was set to –30,000 tonnes/km^2. This ensured that all bedload is deposited in designated areas. A small value of 0.24 tonnes/km^2 was estimated for grazing/natural bedload k-values.

The k coefficients were then used to predict total TSS load and bedload per land use type. Table 5.11 summarizes the predicted load totals for each land use practice during three typical events.

Table 5.11. Predicted loads for TSS and bedload for each land use practice.

Land Use Practice	TSS (tonnes)	TSS (% of total)	Bedload (tonnes)	Bedload (% of total
Grazing/Natural	23.1	2.4%	44.4	9.1%
Crop	826.3	86.8%	444	90.9%
Urban	102.2	10.8%	0	0%
Total	951.6	100%	488.4	100%

6 Discussion

6.1 Effectiveness of the Methods used

The data used in this study was collected during a single winter season. A better understanding of the system would require reproducing this study over several winter seasons. The static models used to predict sediment yield coefficients (k) for each land use practice reasonably predict loads for the Gabilan Creek Watershed with respect to the four parameters used in the equation. However, a more accurate prediction could have been made with a dynamic model that would have taken more account of temporal processes. The short time frame for this study did not allow for a more in depth (dynamic) approach to the system. In addition, more access to privately owned land would have increased the accuracy of the land use percentages, which most likely would have assisted in the accuracy of the static model predictions as well as data collection.

At this stage it is hard to precisely determine whether or not the suspended sediment that is measured came from adjacent lands or from instream storage. Woodward and Foster (1990) confirm this by stating that data collection at a gauging station downstream provides information on the material that is actually leaving that particular catchment but fails to detect the amount and spatial pattern of the primary erosion, deposition (storage) or reworking.

6.2 Land use and Sediment Load

Data from this study suggest that agricultural lands delivered significant sediment to Gabilan Creek, based on three typical winter events. Both TSS and bedload totals increased significantly in areas where crop coverage increased significantly. The sediment yield coefficient estimate for croplands was 8.4 tonnes/km^2, which is 8 times that estimated for urban areas and 37 times estimated for grazing/natural areas—(Table 5.10). Heathwaite (1990) concluded that agricultural land use is one of the major controls on the source and magnitude of sediment transfer to streams.

Bulldozing of the channel by land managers affected the natural transport of bedload material. Preliminary measurements of bedload were done at GAB-HER during April of 2000 that totaled 73 tonnes for that event. In August of that same year adjacent landowners bulldozed the reach from GAB-HER upstream close to the GAB-CRA site—(Figure 6.1). No bedload was recorded at GAB-HER in the 2000-01 winter, implying that the bulldozed area induced deposition of all bedload above GAB-HER. Bedload yield coefficients predict that crop areas have a 10:1 ratio for bedload when compared with grazing/natural areas.

Figure 6.1. Bulldozing of the channel between GAB-HER and GAB-CRA in August of 2000.

Urban lands also appear to be a source for TSS loads in Gabilan Creek, although not to the extent seen in the agricultural areas. However, urban lands appear to not have any effect on bedload or larger particle sizes presumably because of the nature of the Carr Lake/Reclamation Ditch System design.

Pure grazing/natural sites appeared not to deliver any significant bedload-sized material during the events monitored (based on data collected at TOW-OSR and BOC-OSR). TSS appeared to not be impacted except for areas where there is no vegetative buffer, i.e. BOC-OSR. Figs 5.22a & 5.22b illustrate the difference between the two differently managed grazing monitoring sites (TOW-OSR and BOC-OSR). Kauffman and Krueger (1984; from Winegar, 1977) concluded that sediment loads were reduced 48-79% in a 3.5 mile reach that was protected from grazing. Clary and Webster (1990) stated that stream bank morphology and woody vegetation are extremely susceptible to long-term damage by improper grazing practices and Heathwaite et al (1990) suggest that heavily grazed lands result in high-suspended sediment production during winter storm events.

While the ratio for crop to grazing/natural areas for TSS is 37:1, grazing areas do make-up 60% of the total watershed area. When compared to the entire Salinas Valley, which is estimated at nearly 75% grazing/natural lands, it is clear that total sediment load from grazing/natural land use practices is in fact significant on a larger watershed scale.

7 Conclusions

Data from winter storm event monitoring suggests that agriculture and urban land use practices contribute significant proportions of the total suspended sediment in Gabilan Creek. It is presumed that the use of sediment detention basins and or riparian corridors will help retain sediment loss from streamside agricultural areas. Basins are already widely used, but there still remain many fields that do not have them. Currently, most agricultural landowners along Gabilan drain their lands via pipes and or ditches directly into the creek. During storm and irrigation events, all surface runoff and its contaminants have access to the creek channel and become available for transport.

According to the bedload coefficient estimates, agricultural reaches transported the most bedload during the season that was monitored. Further work should confirm if this material did originate from agricultural lands or if it was stored in the streambed from previous erosion further upstream. There is evidence to suggest that high bedload values at GAB-OSR and GAB-CRA are associated with the strawberry fields upstream from each site. Again, no bedload was recorded in the pure grazing/natural areas (TOW-OSR and BOC-OSR).

There are already plans for the restoration of the Reclamation Ditch and Carr Lake. Ideally, the use of settling ponds for both established and developing urban area runoff before entering into the Reclamation Ditch would help prevent the loss of fine sediments. Urban land use does provide a significant load to the creek, primarily in the Reclamation Ditch. Perhaps a wider channel that allows for a riparian corridor along with the termination of input drainage pipes from artichoke fields would help reduce the sediment loads in the Reclamation Ditch.

Unbuffered grazing areas also contribute considerable amounts of suspended sediment compared to areas that have riparian buffers. It is recommended that landowners and managers continue to adopt a management plan that incorporates the use of riparian corridors on riparian grazing areas. In addition, eliminating late season (late fall and winter) grazing access when banks are well saturated would help reduce the chance of increased bank failure and suspended sediment load.

Suspended sediment concentrations measured during this winter season were above the tolerable range for steelhead migration and spawning. Bell (1973) states that steelhead migration is adversely affected by suspended sediment concentrations higher than 4000 mg/L. At peak flow TSS concentrations were commonly measured above 5000mg/L in the mid-stream sampling sites (GAB-CRA to GAB-BOR). Still, further studies are needed to confirm if steelhead could, or do, use Gabilan Creek as a spawning run.

7.1 Future Studies

Examination of the effects of riparian vegetation loss along much of Gabilan Creek and its tributaries would complement this study. It is suspected that an increase in riparian vegetation would help reduce suspended sediment yield from adjacent lands as well as bank erosion by enhancing bank protection and in-stream deposition.

A study that closely examines the effect of strawberry versus row crop (lettuce) production on stream suspended sediment will help to better understand how these two land use practices differ.

Also, the use of a dynamic model to more accurately predict and estimate loads would further improve our understanding of sediment sources along Gabilan Creek and its tributaries.

Finally, data collection in future winter seasons would add to the accuracy of both the methodologies used, as well as the detection of sediment sources within the Gabilan Creek Watershed.

8 Acknowledgments

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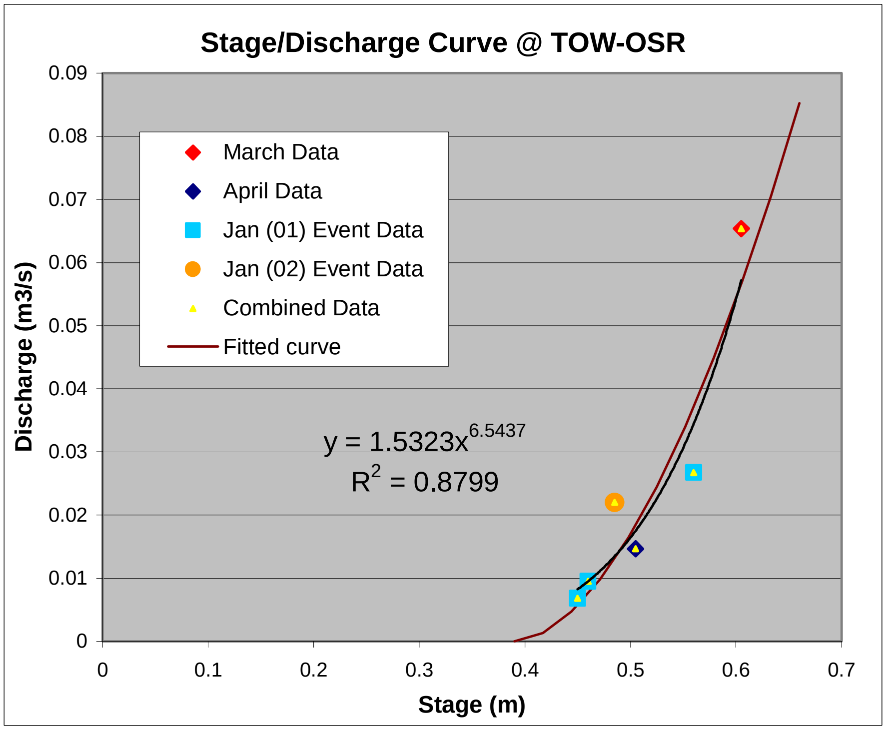
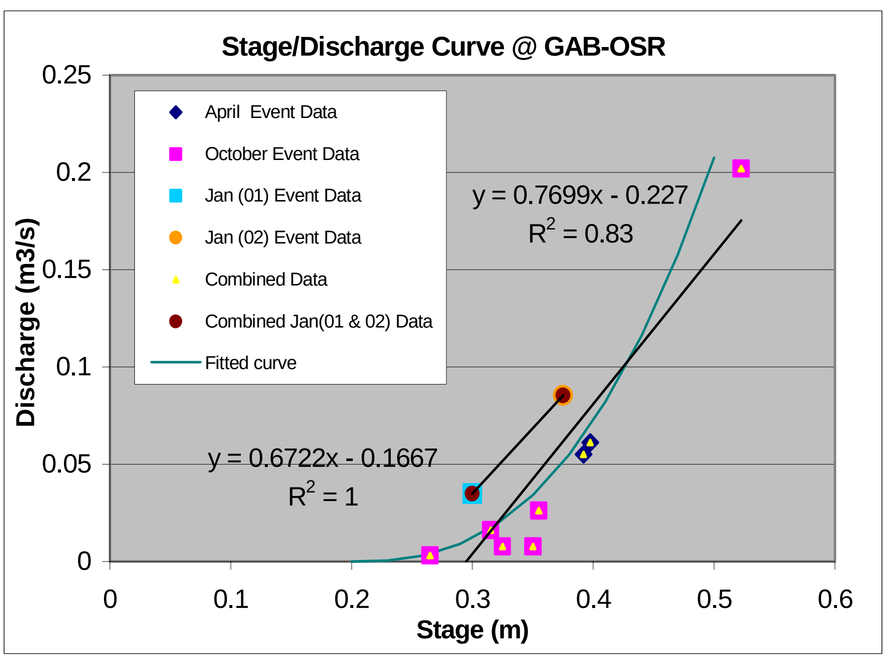
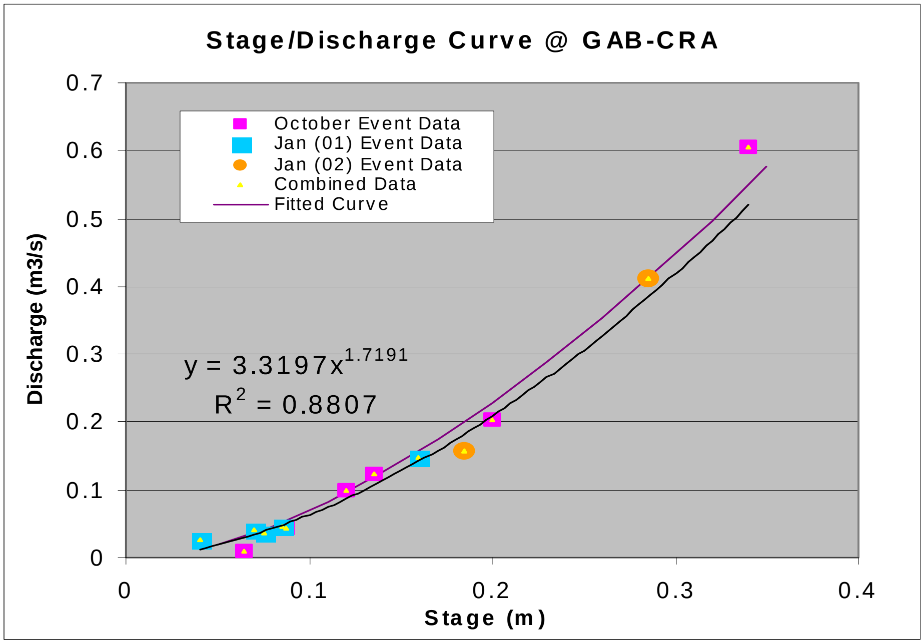
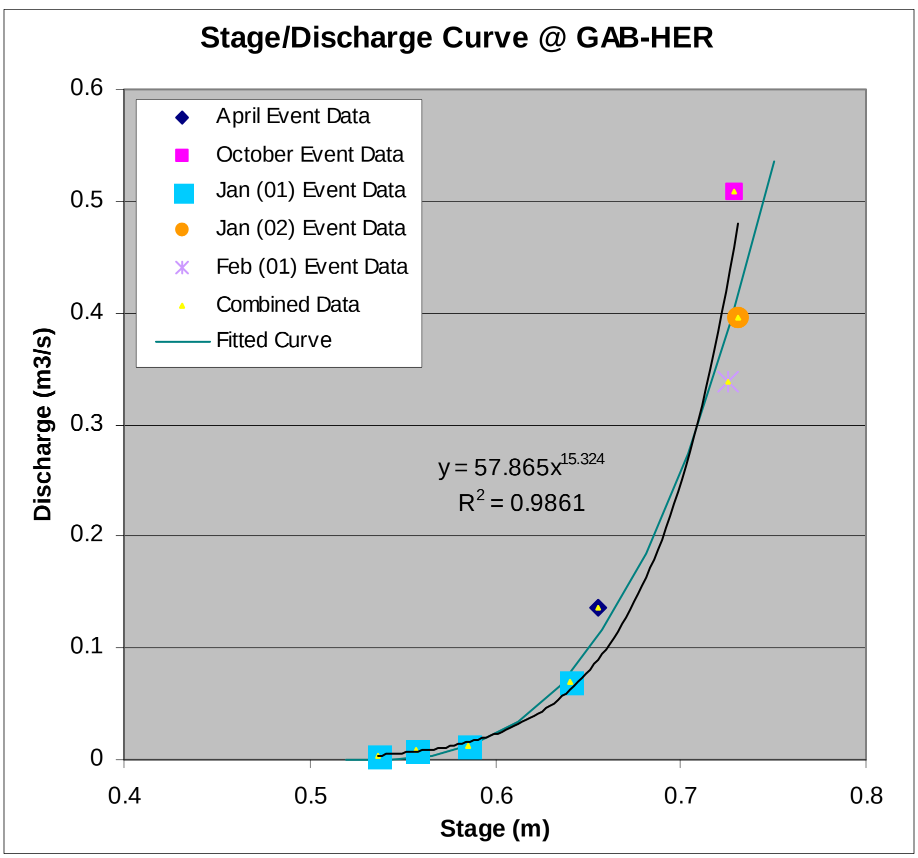
Appendix 10.1

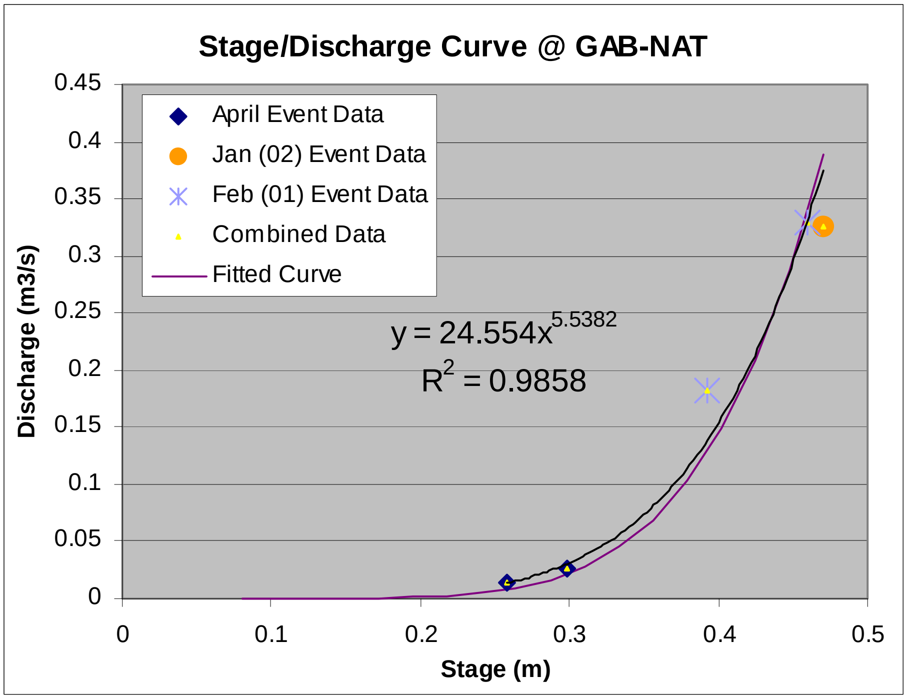
Site Stage Discharge Curves For All Events Monitored

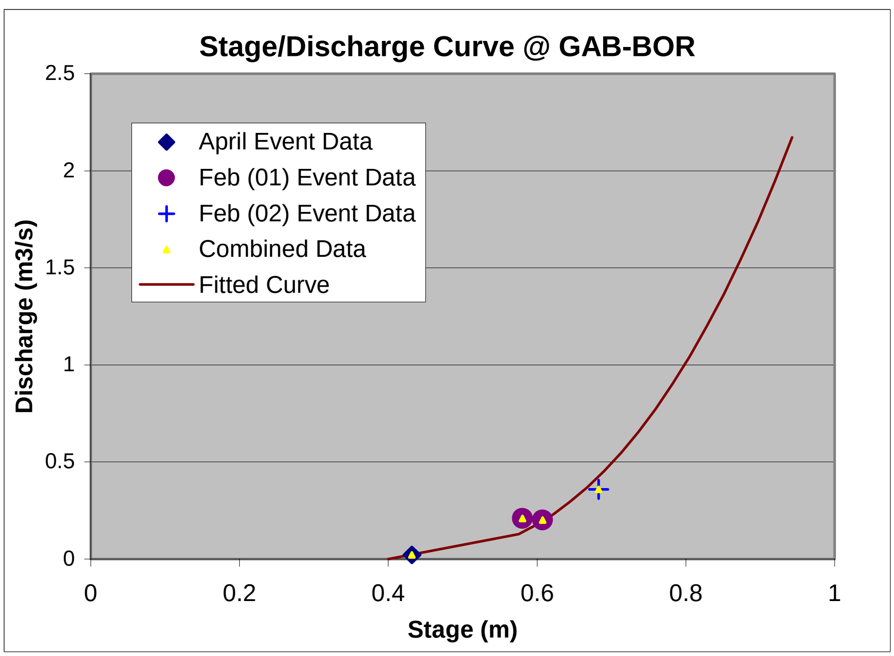


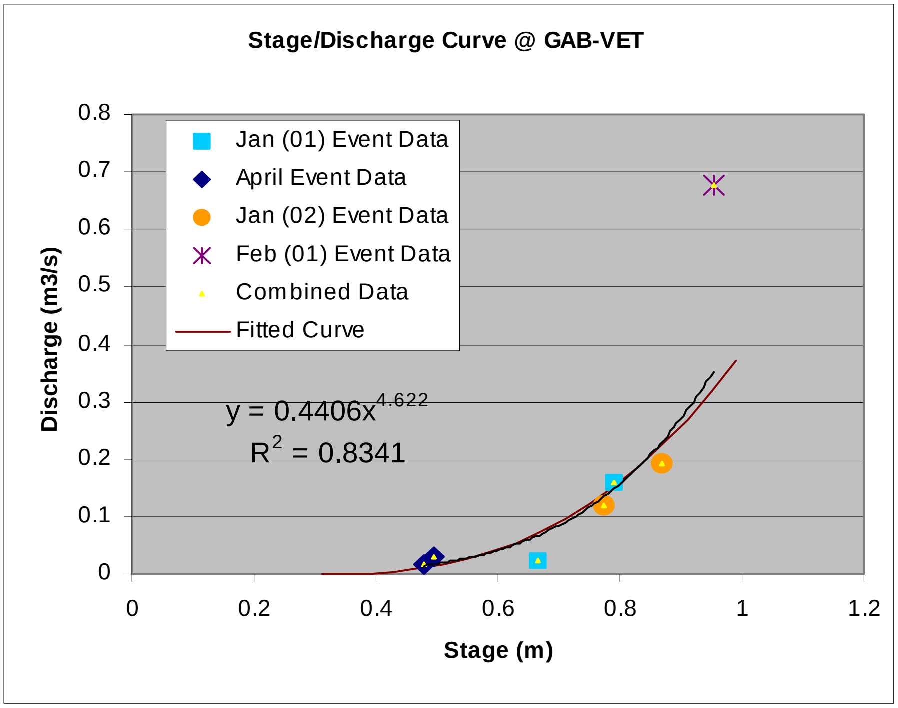



Stage/Discharge Curve @ GAB-CRA
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Discharge (m3/s)
October Event Data
Jan (01) Event Data
Jan (02) Event Data
Combined Data
Fitted Curve
y = 3.3197x^1.7191
R^2 = 0.8807
0
0.1
0.2
0.3
0.4
Stage (m)

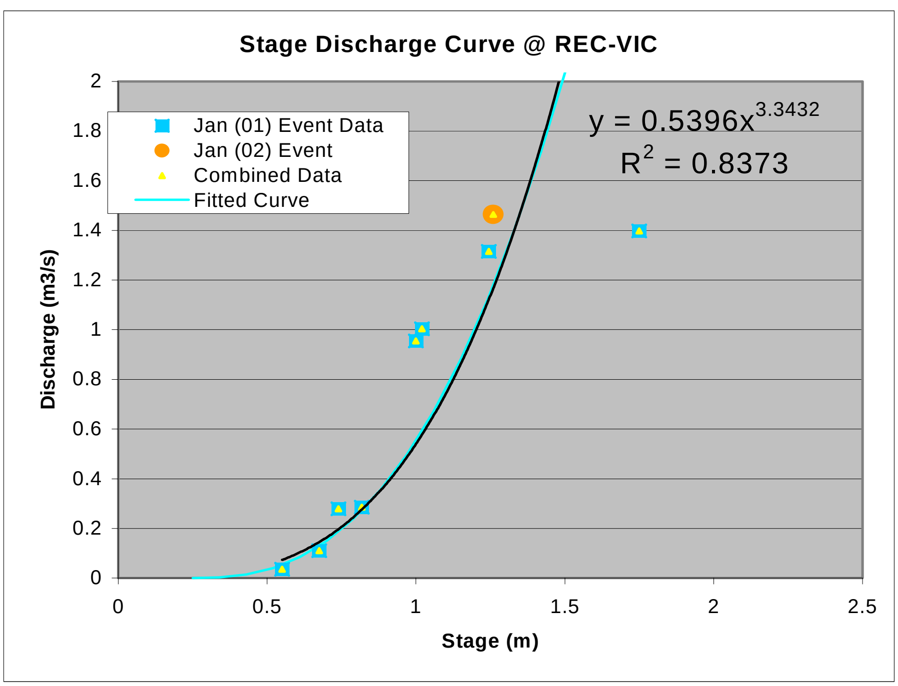

Stage/Discharge Curve @ GAB-HER
0.6
0.5
0.4
0.3
0.2
0.1
0
Discharge (m3/s)
April Event Data
October Event Data
Jan (01) Event Data
Jan (02) Event Data
Feb (01) Event Data
Combined Data
Fitted Curve
y = 57.865x^15.324
R^2 = 0.9861
0.4
0.5
0.6
0.7
0.8
Stage (m)


Stage/Discharge Curve @ GAB-NAT
April Event Data
Jan (02) Event Data
Feb (01) Event Data
Combined Data
Fitted Curve
y = 24.554x^5.5382
R^2 = 0.9858
Discharge (m3/s)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.1
0.2
0.3
0.4
0.5
Stage (m)

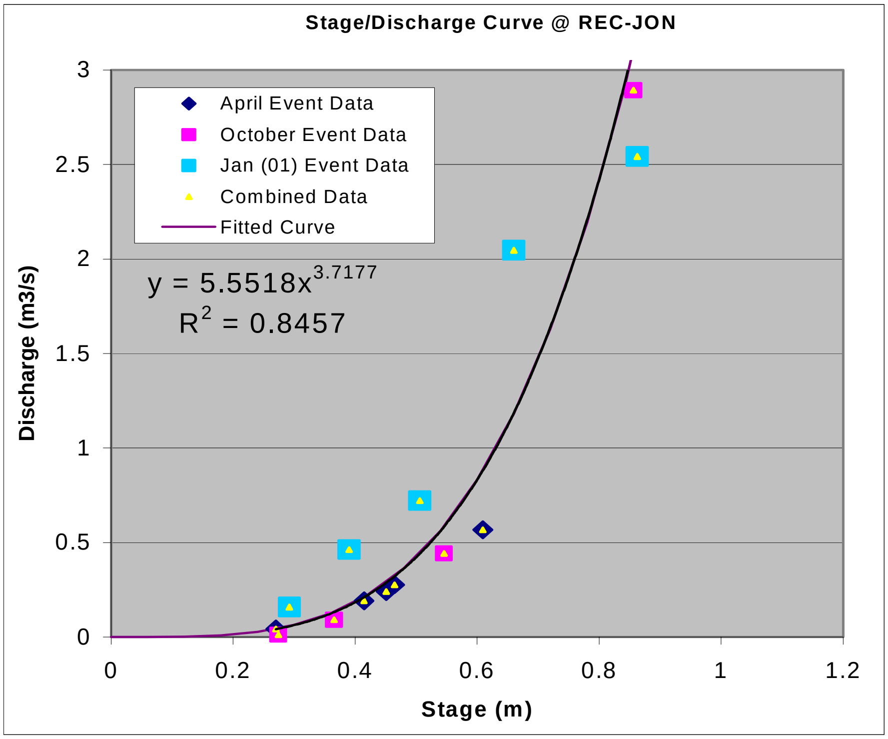

Stage/Discharge Curve @ GAB-BOR
April Event Data
Feb (01) Event Data
Feb (02) Event Data
Combined Data
Fitted Curve
Discharge (m3/s)
2.5
2
1.5
1
0.5
0
0
0.2
0.4
0.6
0.8
1
Stage (m)



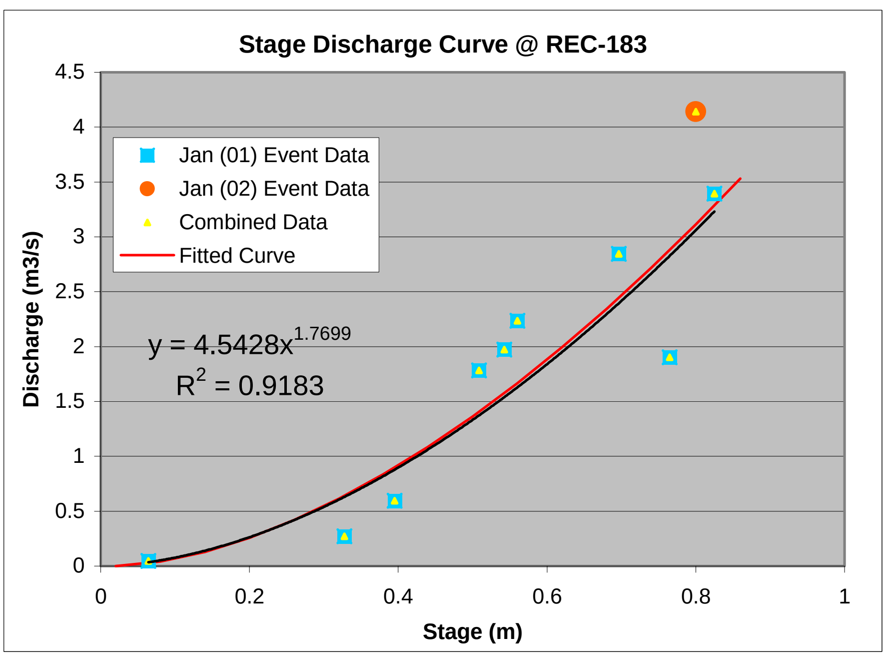
Stage/Discharge Curve @ GAB-VET
Jan (01) Event Data
April Event Data
Jan (02) Event Data
Feb (01) Event Data
Combined Data
Fitted Curve
y = 0.4406x^4.622
R^2 = 0.8341
Discharge (m3/s)
Stage (m)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
0.2
0.4
0.6
0.8
1
1.2



Stage Discharge Curve @ REC-VIC
Jan (01) Event Data
Jan (02) Event
Combined Data
Fitted Curve
y = 0.5396x^3.3432
R^2 = 0.8373
Discharge (m3/s)
Stage (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
0.5
1
1.5
2
2.5



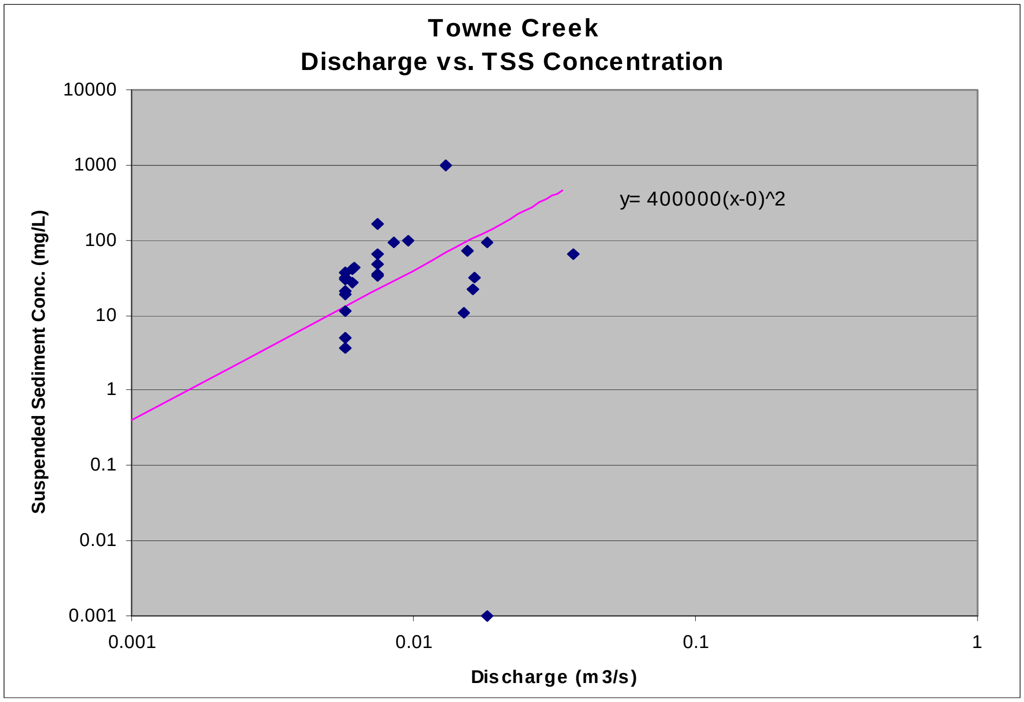
Stage/Discharge Curve @ REC-JON
April Event Data
October Event Data
Jan (01) Event Data
Combined Data
Fitted Curve
y = 5.5518x^3.7177
R^2 = 0.8457
Discharge (m3/s)
Stage (m)
0
0.5
1
1.5
2
2.5
3
0
0.2
0.4
0.6
0.8
1
1.2

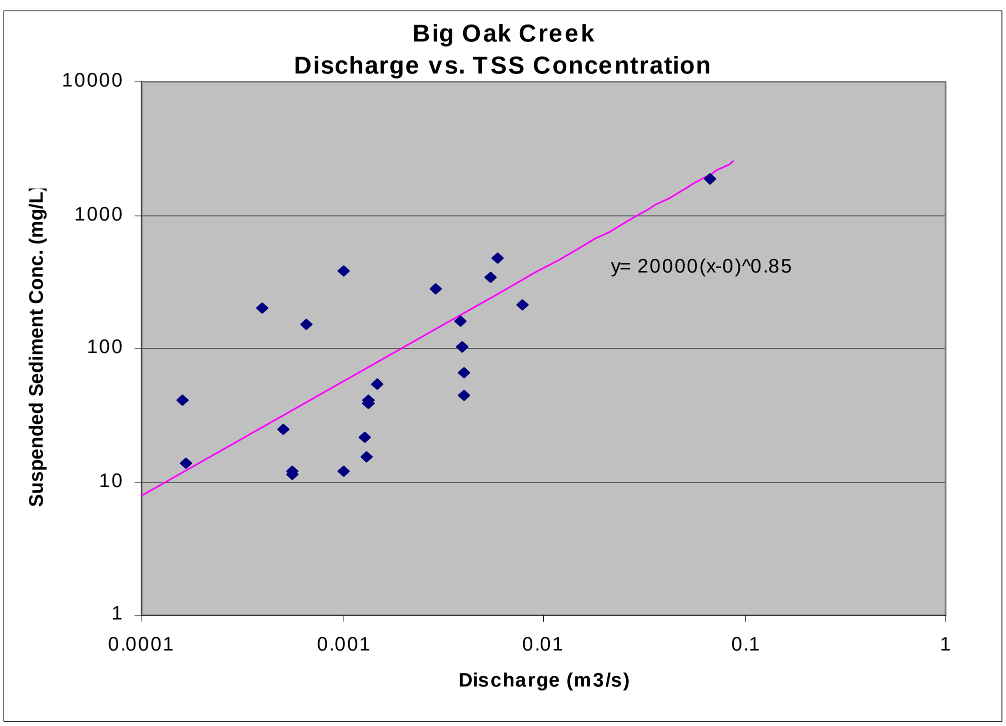


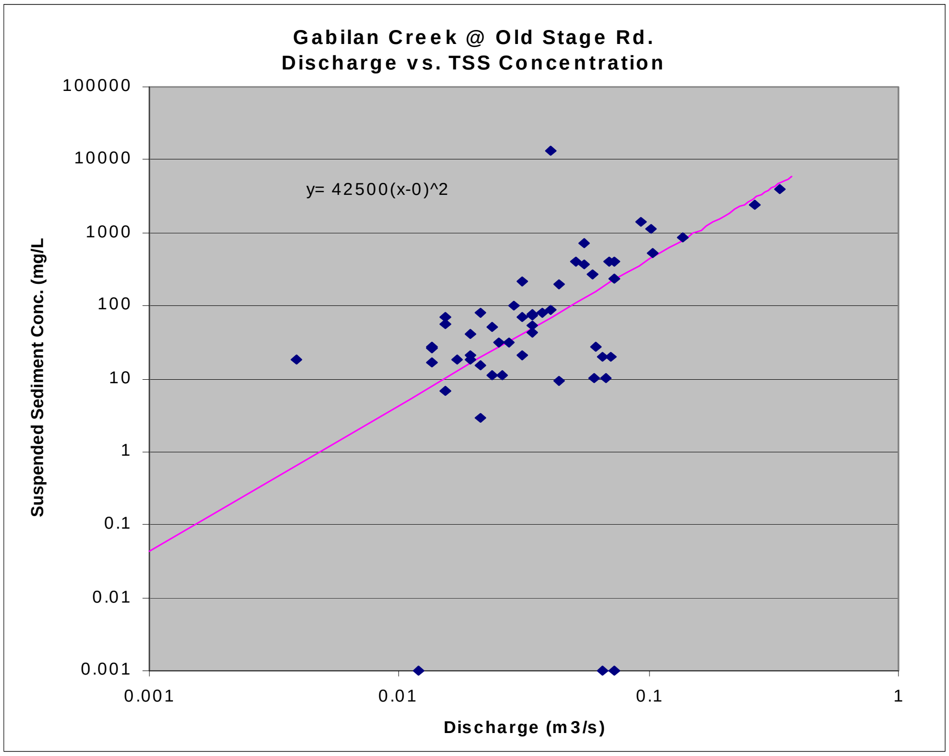
Stage Discharge Curve @ REC-183
Jan (01) Event Data
Jan (02) Event Data
Combined Data
Fitted Curve
y = 4.5428x^1.7699
R^2 = 0.9183
Discharge (m3/s)
Stage (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
0.2
0.4
0.6
0.8
1

Appendix 10.2

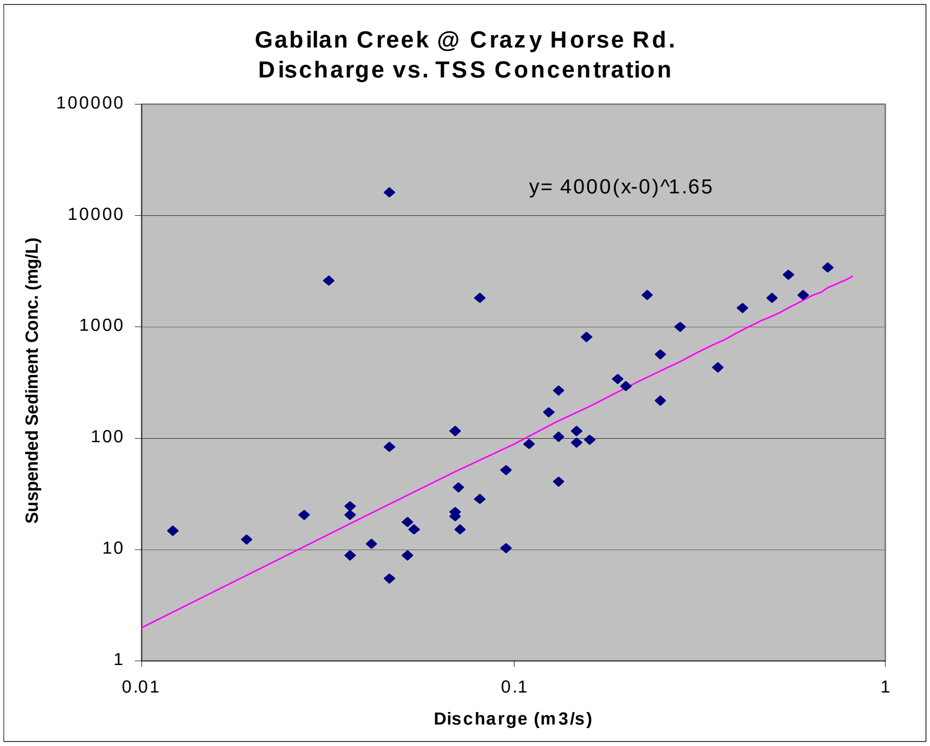
Discharge vs. TSS Concentration for All Sampling Locations



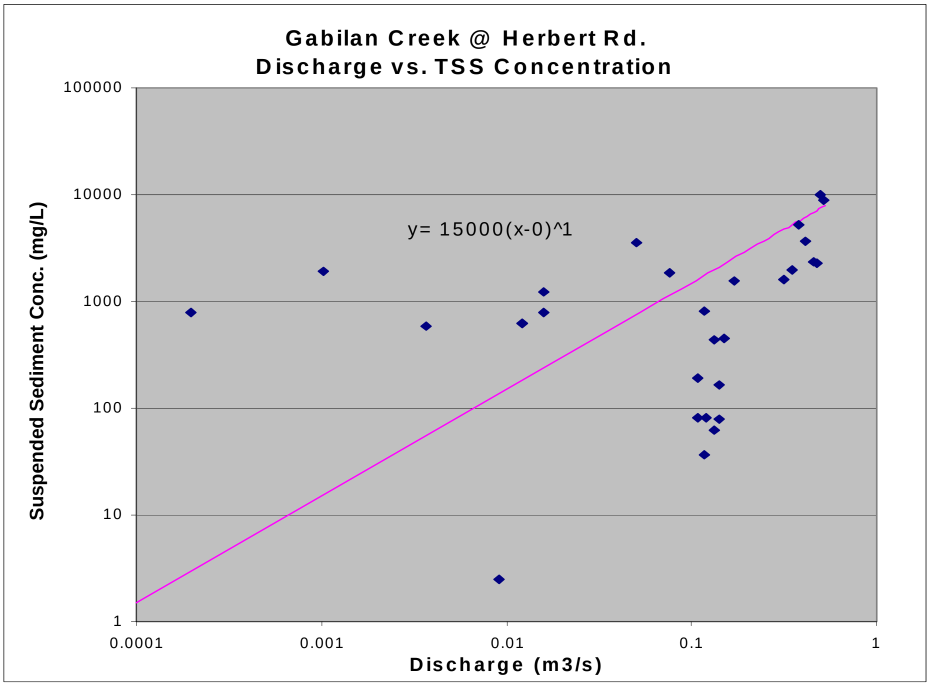




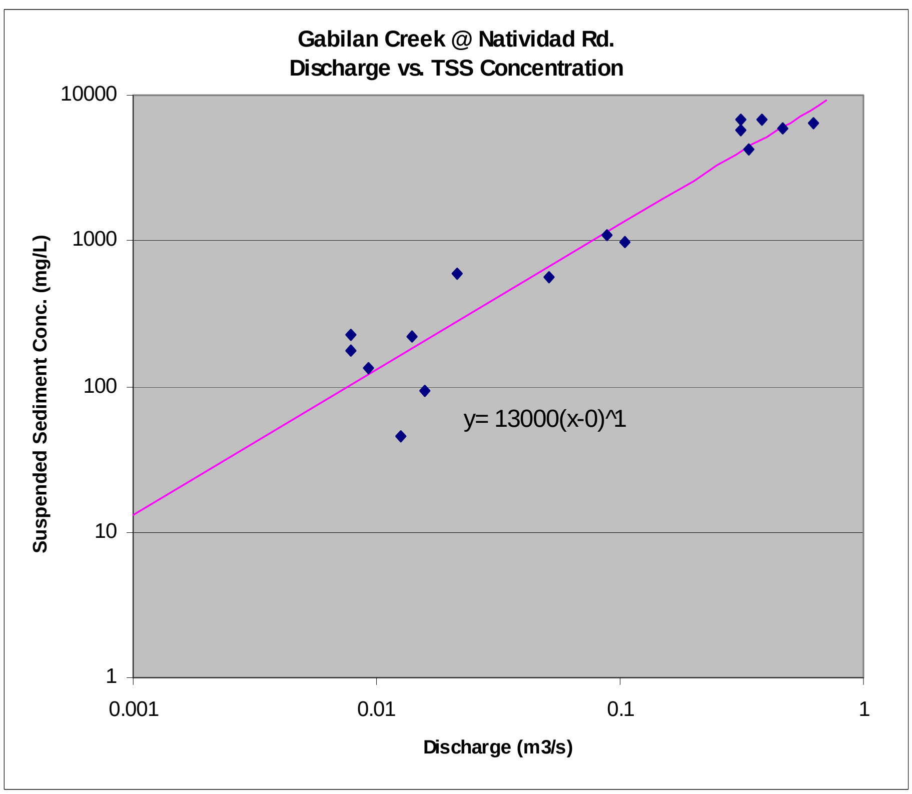
Gabilan Creek @ Old Stage Rd.
Discharge vs. TSS Concentration
y= 42500(x-0)^2
Suspended Sediment Conc. (mg/L
Discharge (m3/s)
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.001
0.01
0.1
1



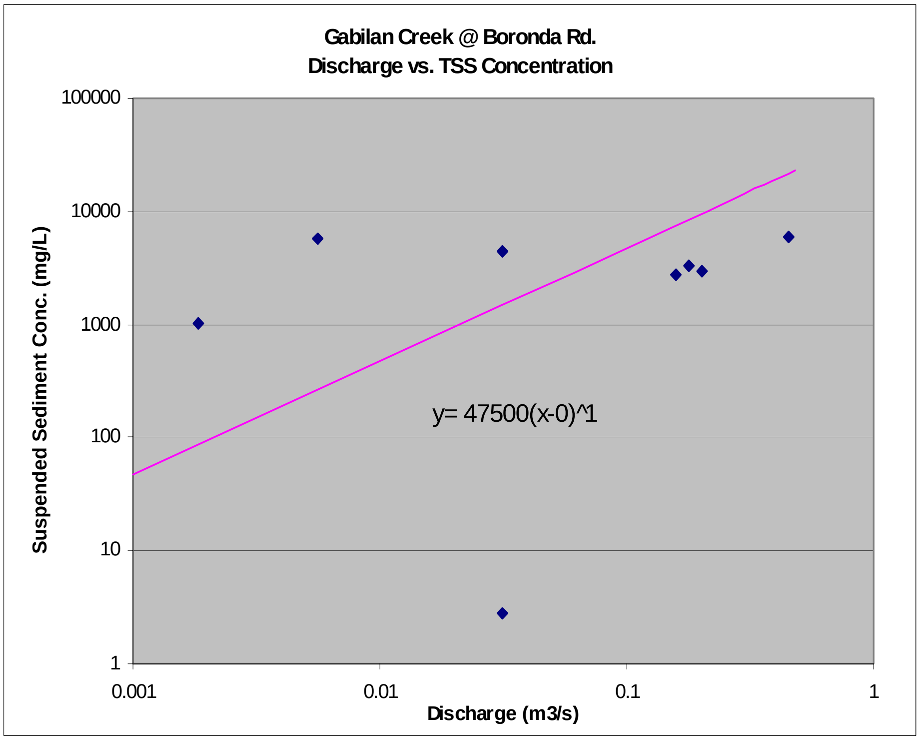
Gabilan Creek @ Crazy Horse Rd.
Discharge vs. TSS Concentration
y= 4000(x-0)^1.65
Suspended Sediment Conc. (mg/L)
Discharge (m3/s)
100000
10000
1000
100
10
1
0.01
0.1
1



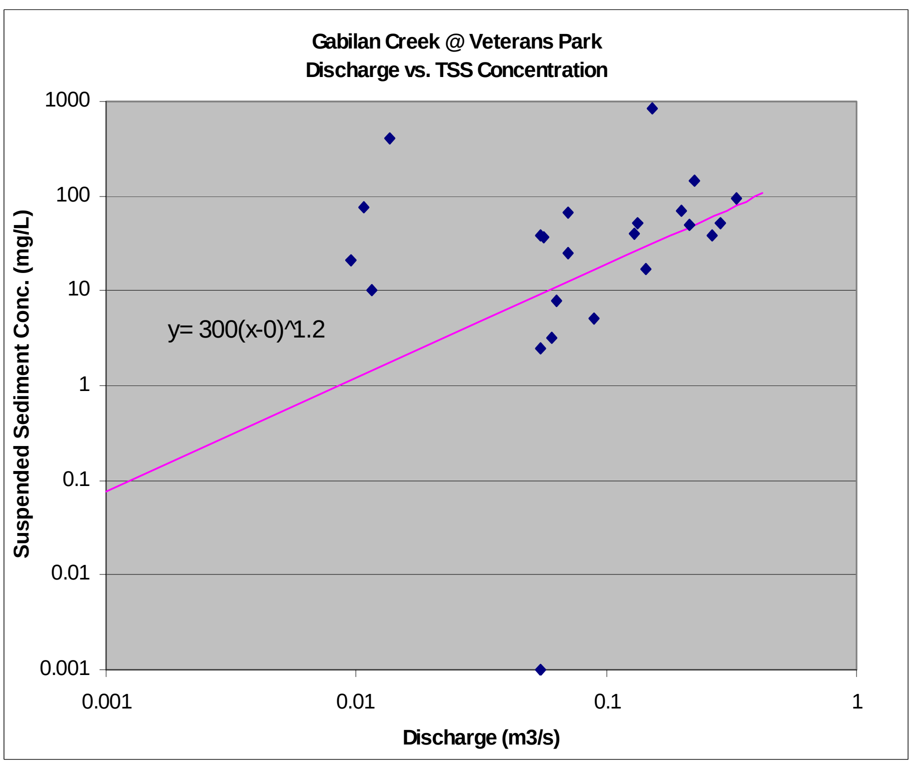
Gabilan Creek @ Herbert Rd.
Discharge vs. TSS Concentration
Suspended Sediment Conc. (mg/L)
100000
10000
1000
100
10
1
y= 15000(x-0)^1
0.0001
0.001
0.01
0.1
1
Discharge (m3/s)



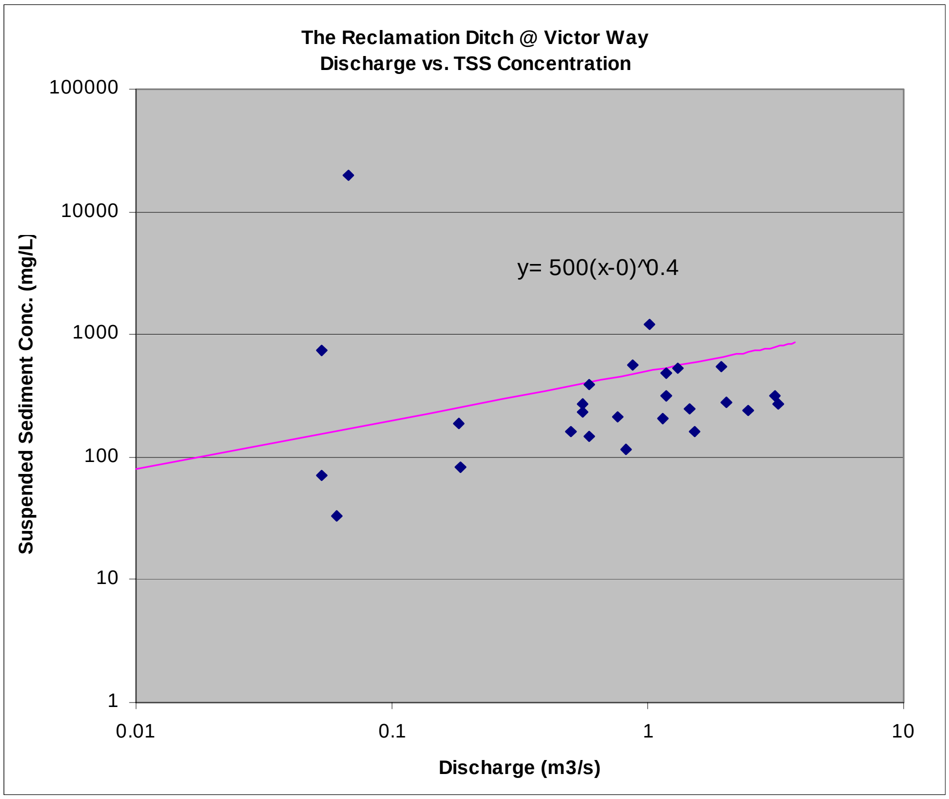
Gabilan Creek @ Natividad Rd.
Discharge vs. TSS Concentration
Suspended Sediment Conc. (mg/L)
10000
1000
100
10
1
y= 13000(x-0)^1
0.001
0.01
0.1
1
Discharge (m3/s)

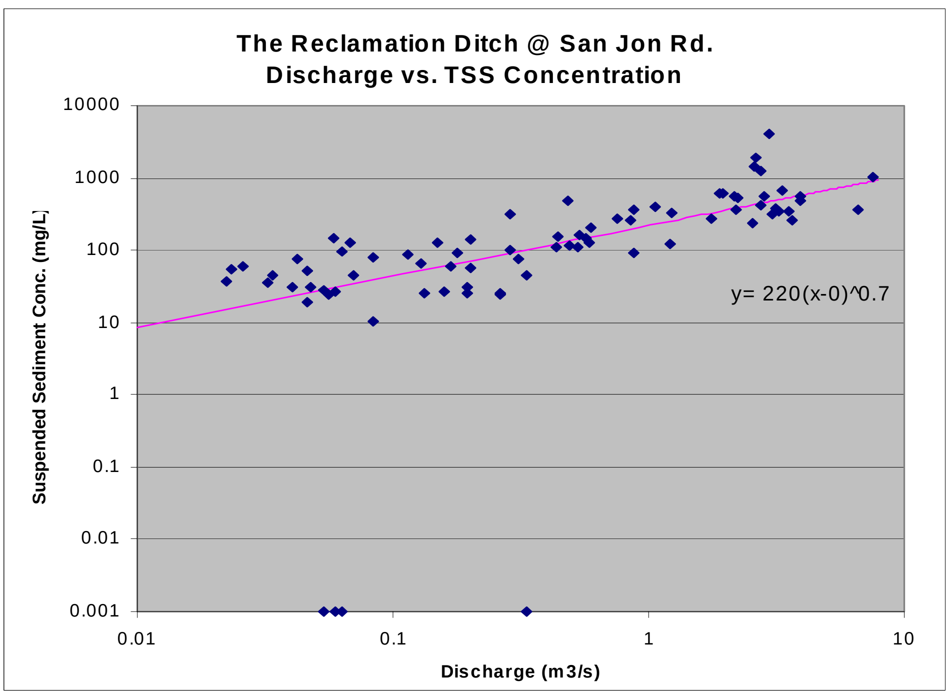


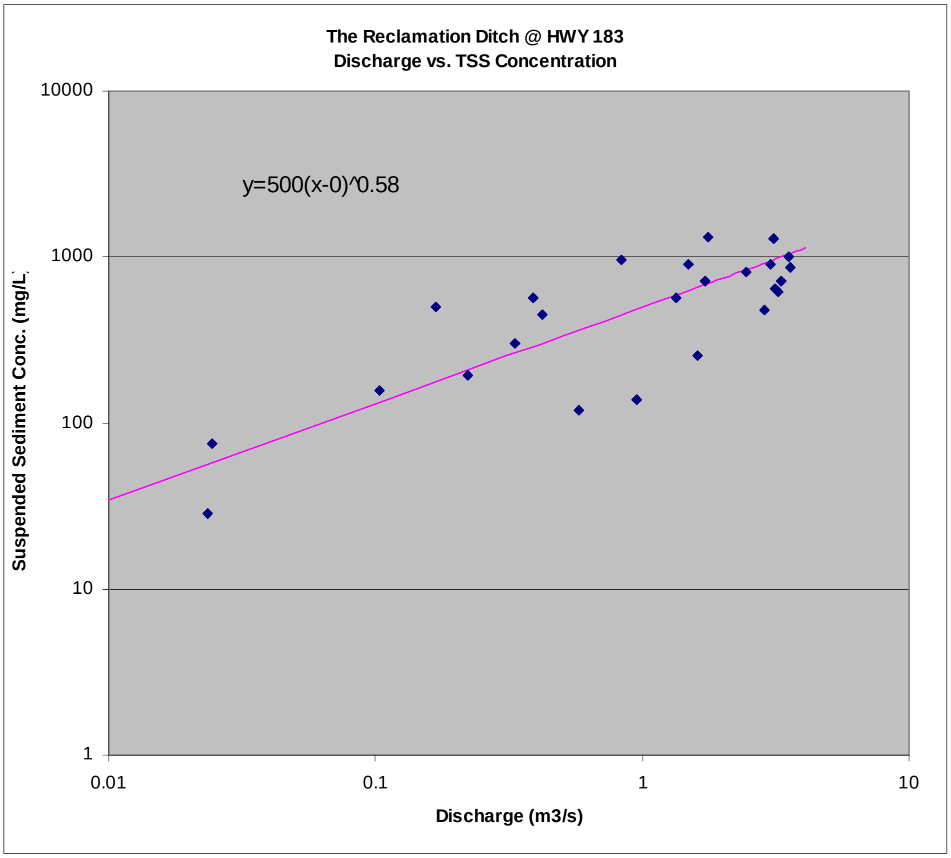
Gabilan Creek @ Boronda Rd.
Discharge vs. TSS Concentration
Suspended Sediment Conc. (mg/L)
100000
10000
1000
100
10
1
y= 47500(x-0)^1
0.001
0.01
0.1
1
Discharge (m3/s)



Gabilan Creek @ Veterans Park
Discharge vs. TSS Concentration
Suspended Sediment Conc. (mg/L)
1000
100
10
1
0.1
0.01
0.001
y= 300(x-0)^1.2
0.001
0.01
0.1
1
Discharge (m3/s)


The Reclamation Ditch @ Victor Way
Discharge vs. TSS Concentration
100000
10000
1000
100
10
1
0.01
0.1
1
10
y= 500(x-0)^0.4
Suspended Sediment Conc. (mg/L)
Discharge (m3/s)

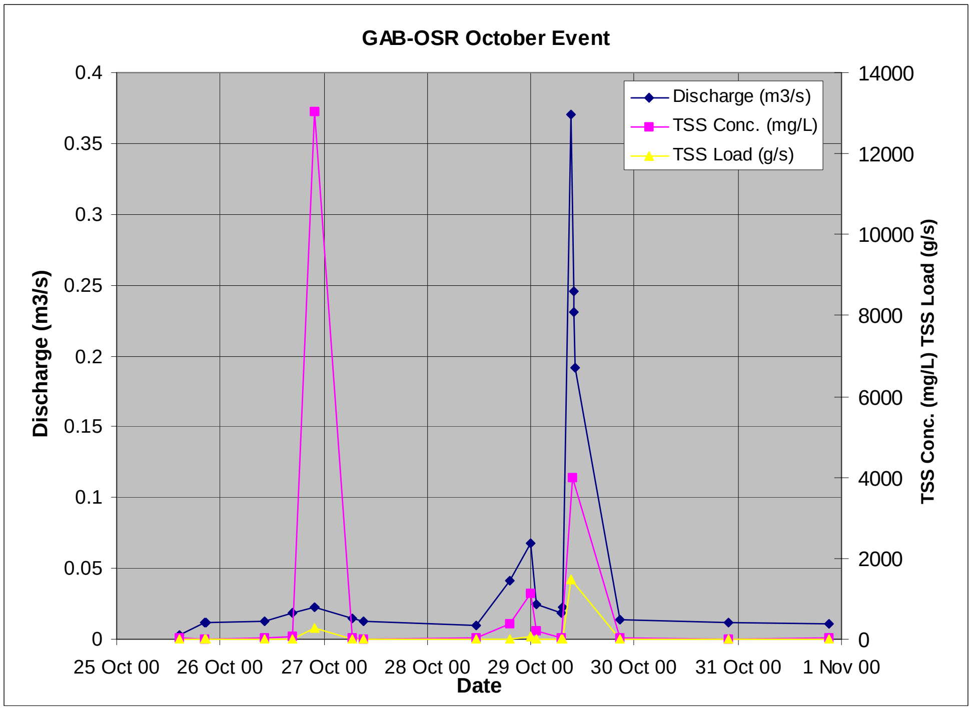

The Reclamation Ditch @ San Jon Rd.
Discharge vs. TSS Concentration
10000
1000
100
10
1
0.1
0.01
0.001
0.01
0.1
1
10
y= 220(x-0)^0.7
Suspended Sediment Conc. (mg/L)
Discharge (m3/s)

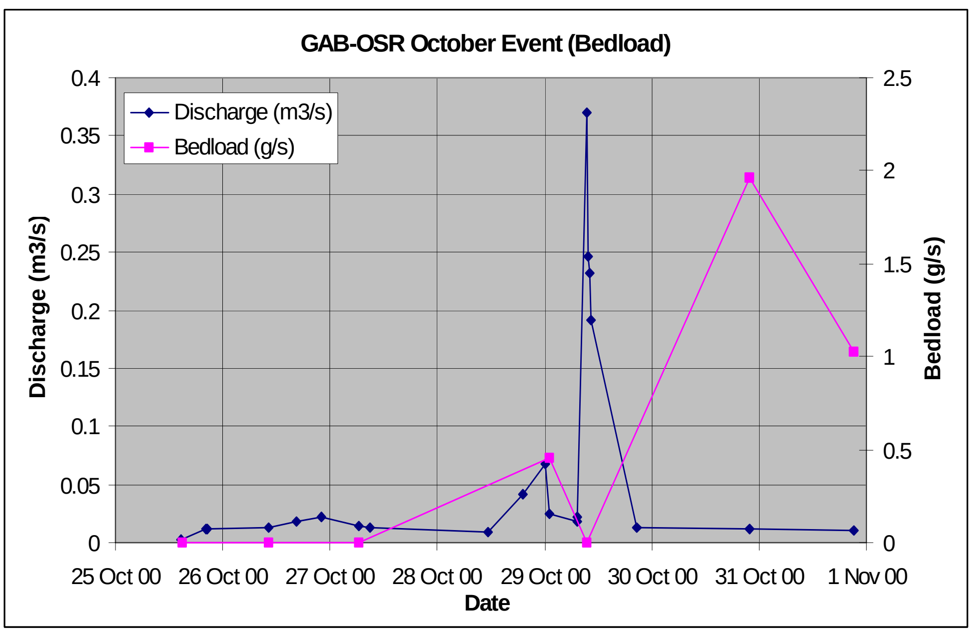


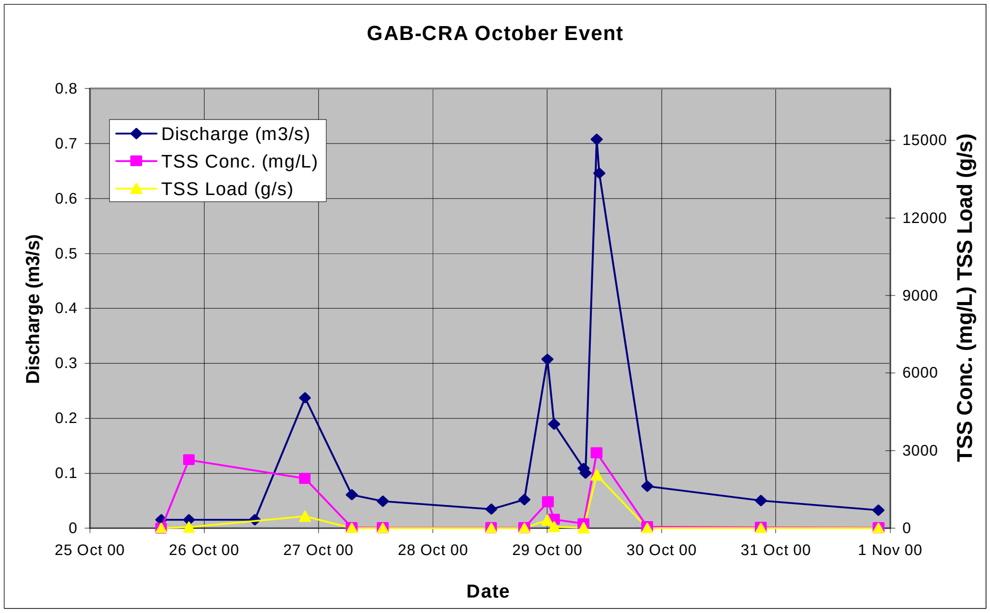
The Reclamation Ditch @ HWY 183
Discharge vs. TSS Concentration
10000
1000
100
10
1
y=500(x-0)^0.58
Suspended Sediment Conc. (mg/L)
0.01
0.1
1
10
Discharge (m3/s)

Appendix 10.3

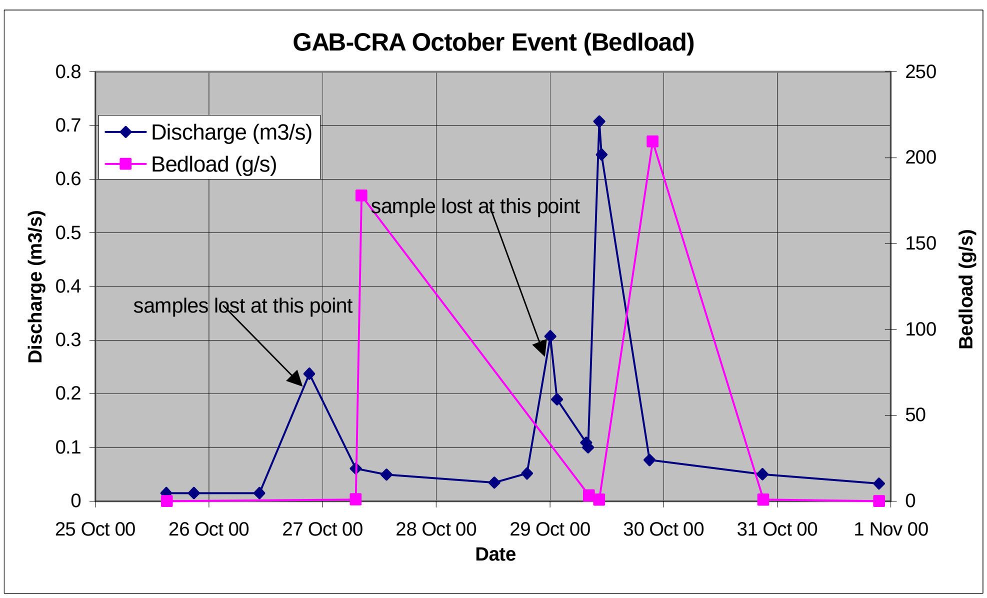
October Event Load Graphs



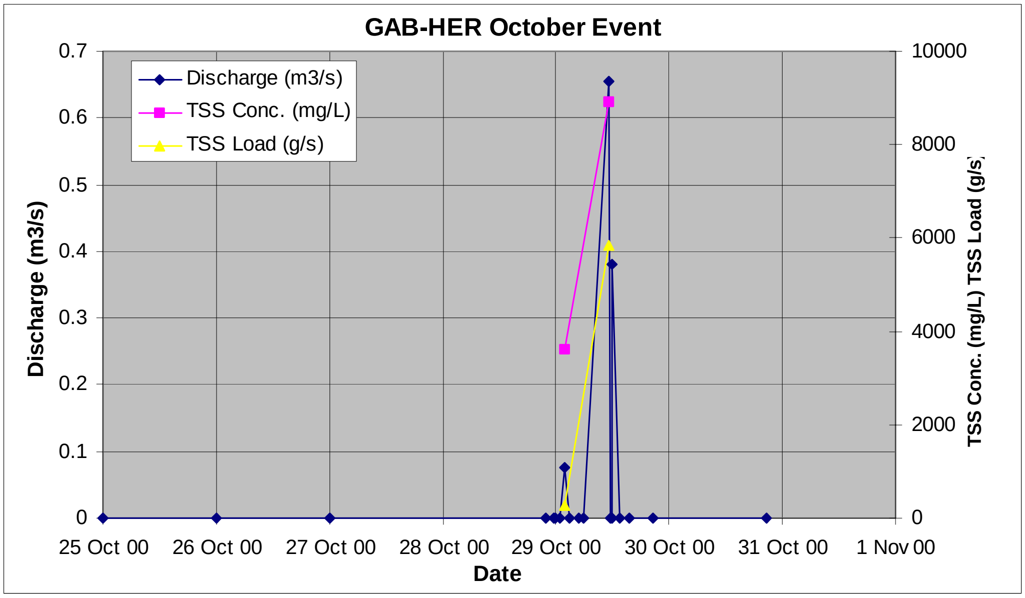


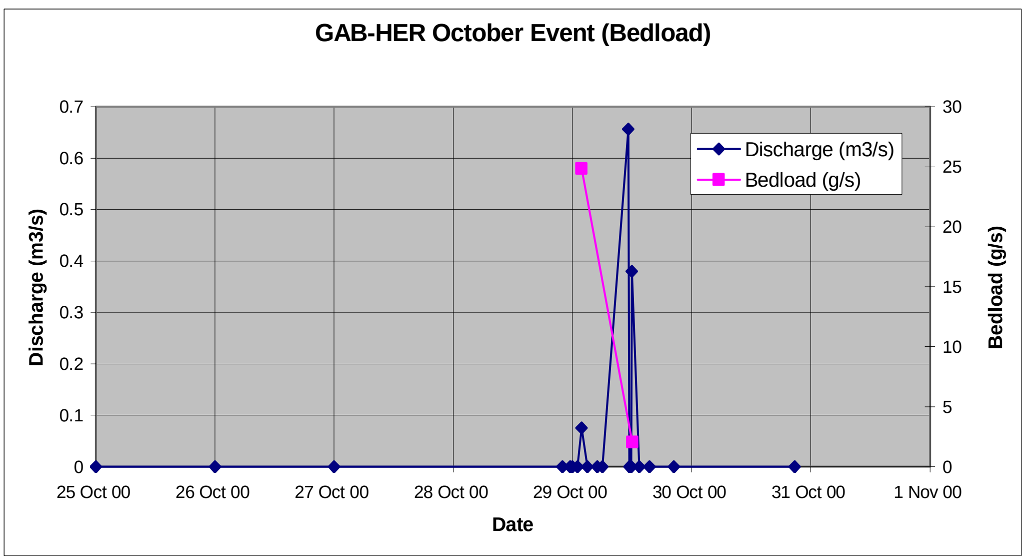


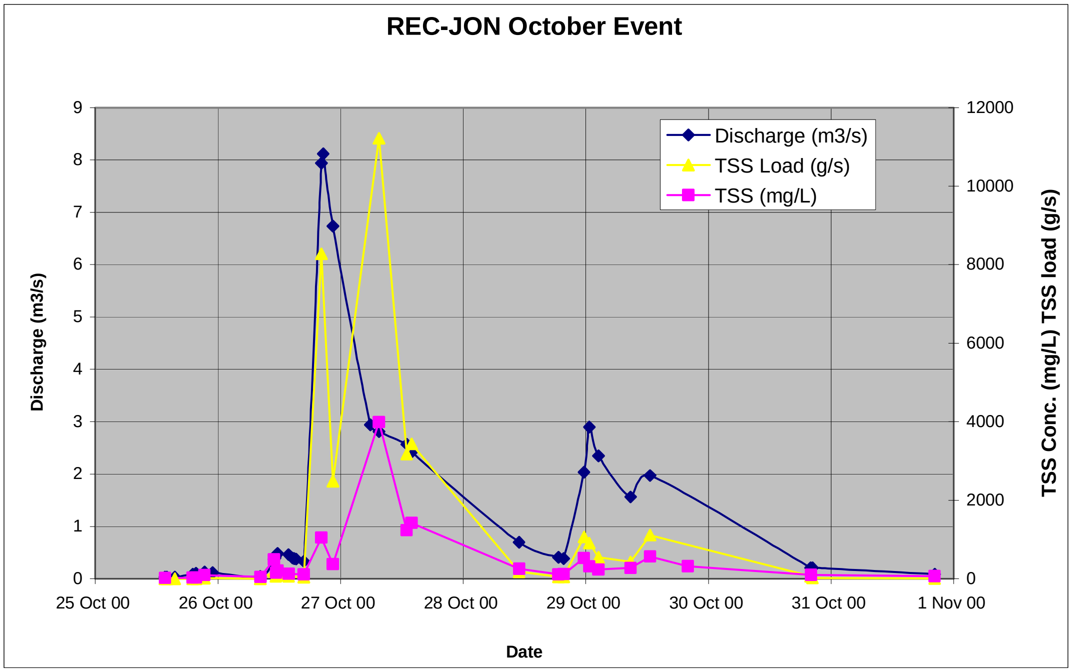
GAB-CRA October Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Discharge (m3/s)
TSS Conc. (mg/L) TSS Load (g/s)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
3000
6000
9000
12000
15000
25 Oct 00
26 Oct 00
27 Oct 00
28 Oct 00
29 Oct 00
30 Oct 00
31 Oct 00
1 Nov 00
Date



GAB-CRA October Event (Bedload)
Discharge (m3/s)
Bedload (g/s)
sample lost at this point
samples lost at this point
Discharge (m3/s)
Bedload (g/s)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
50
100
150
200
250
25 Oct 00
26 Oct 00
27 Oct 00
28 Oct 00
29 Oct 00
30 Oct 00
31 Oct 00
1 Nov 00
Date


GAB-HER October Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10000
8000
6000
4000
2000
0
TSS Conc. (mg/L) TSS Load (g/s)
25 Oct 00
26 Oct 00
27 Oct 00
28 Oct 00
29 Oct 00
30 Oct 00
31 Oct 00
1 Nov 00
Date

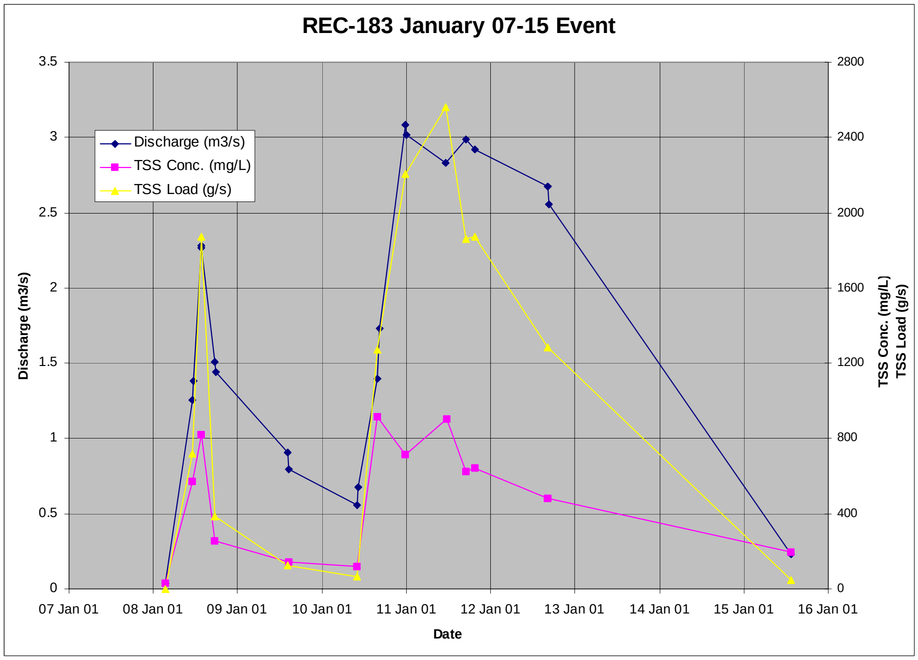

GAB-HER October Event (Bedload)
Discharge (m3/s)
Bedload (g/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30
25
20
15
10
5
0
25 Oct 00
26 Oct 00
27 Oct 00
28 Oct 00
29 Oct 00
30 Oct 00
31 Oct 00
1 Nov 00
Date

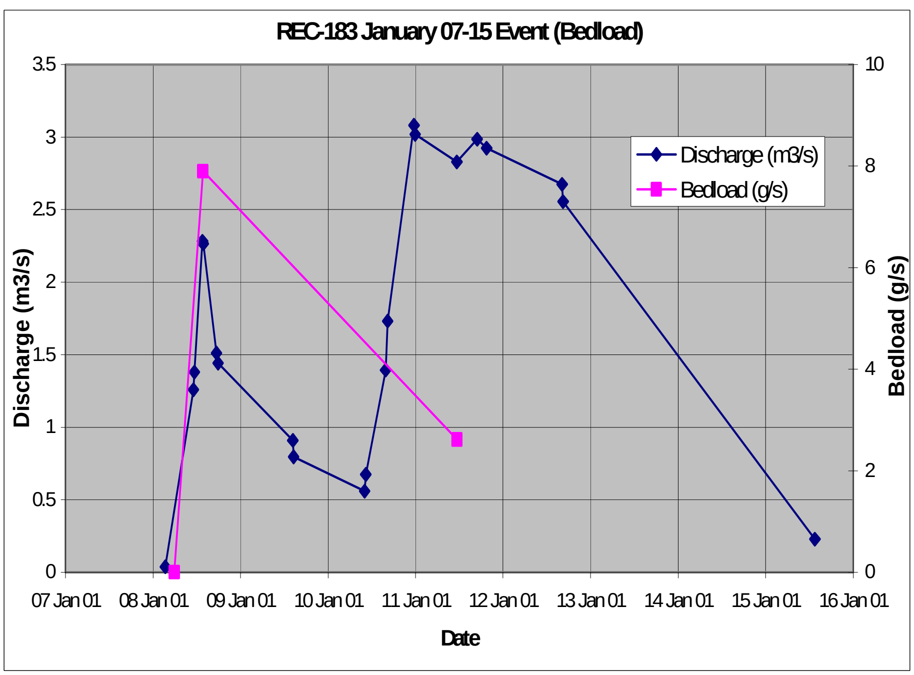


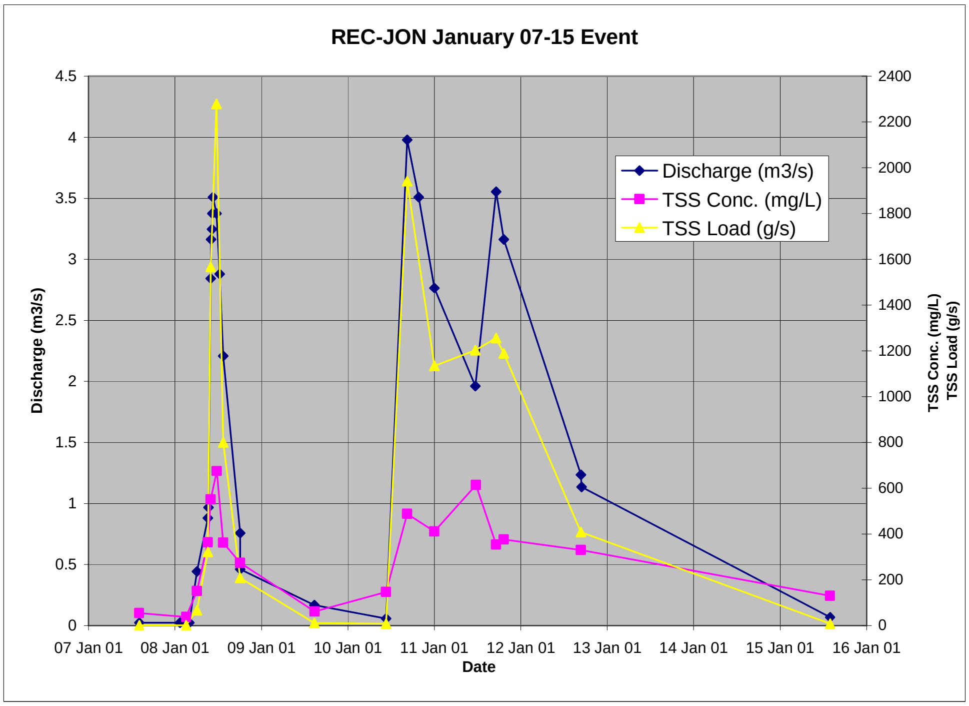
REC-JON October Event
Discharge (m3/s)
TSS Load (g/s)
TSS (mg/L)
9
8
7
6
5
4
3
2
1
0
12000
10000
8000
6000
4000
2000
0
Discharge (m3/s)
TSS Conc. (mg/L) TSS load (g/s)
25 Oct 00
26 Oct 00
27 Oct 00
28 Oct 00
29 Oct 00
30 Oct 00
31 Oct 00
1 Nov 00
Date

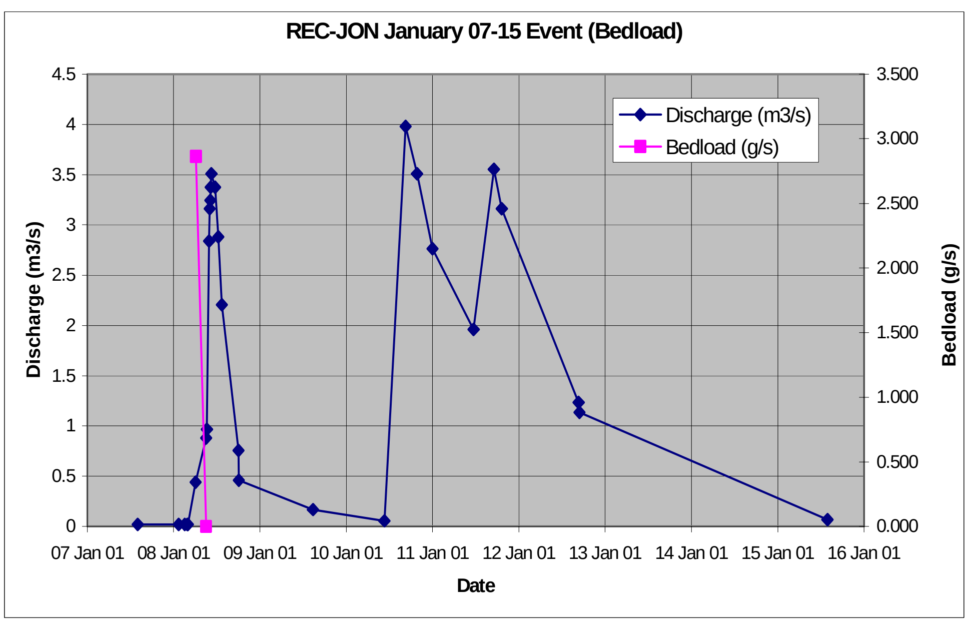
Appendix 10.4

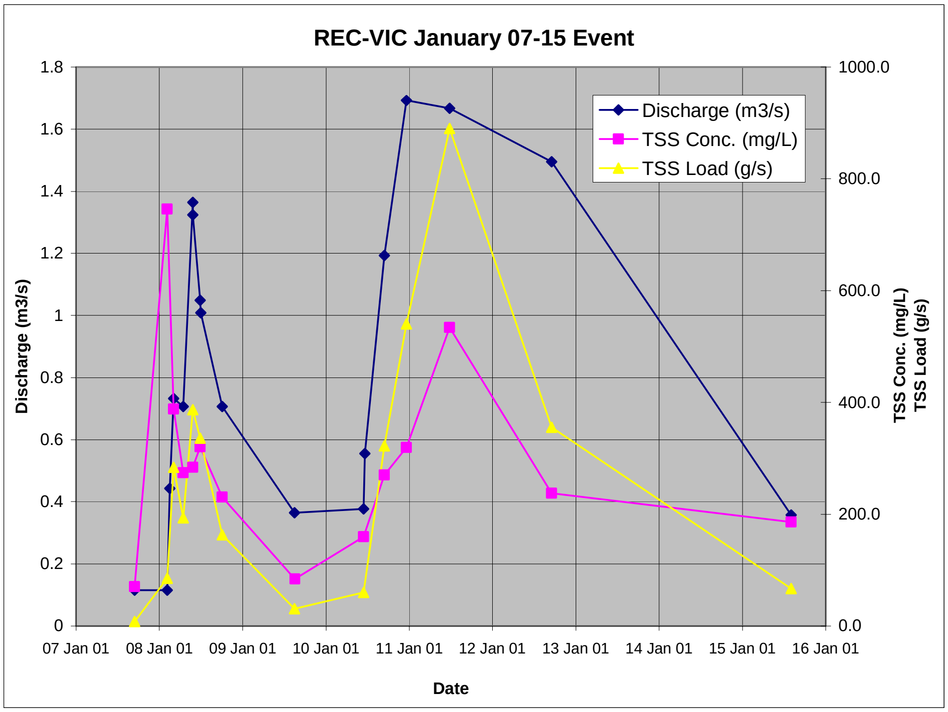
January 07-15, 2001 Event Load Graphs



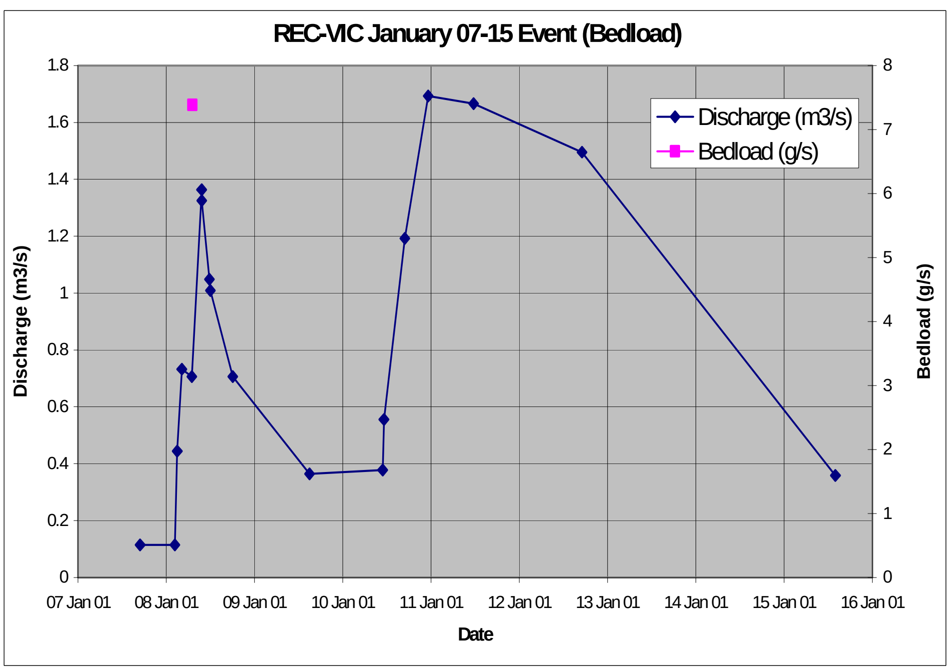



REC-JON January 07-15 Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Date
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
07 Jan 01
08 Jan 01
09 Jan 01
10 Jan 01
11 Jan 01
12 Jan 01
13 Jan 01
14 Jan 01
15 Jan 01
16 Jan 01

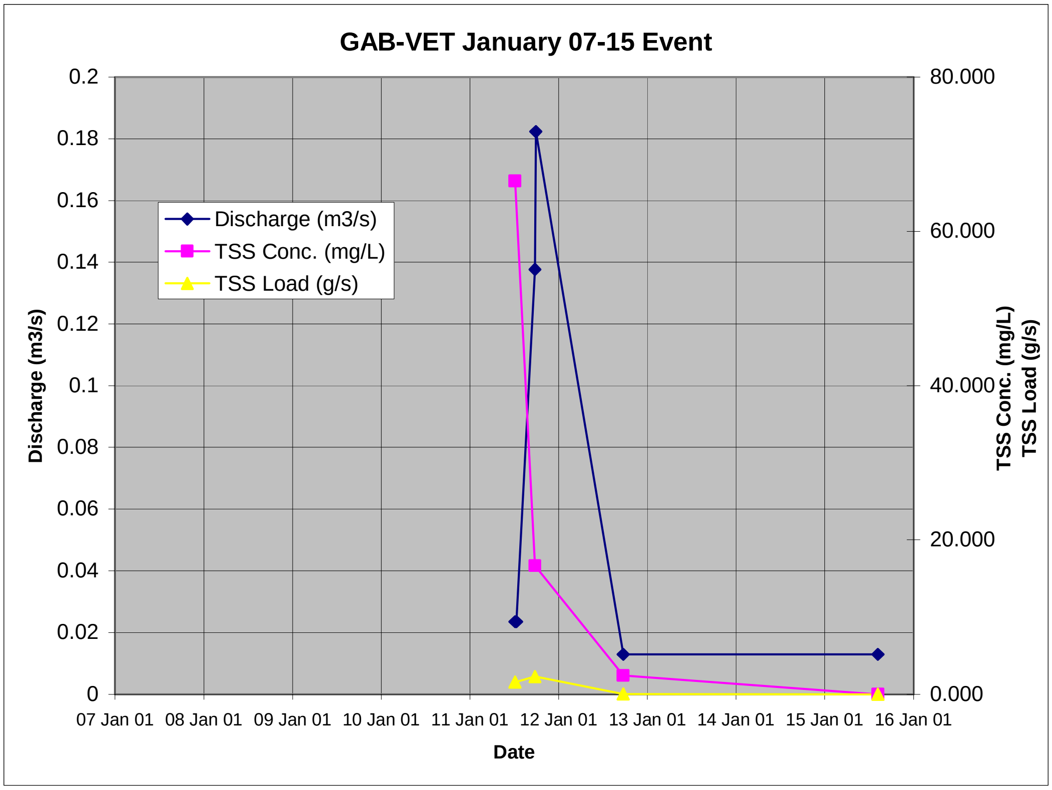

REC-JON January 07-15 Event (Bedload)
Discharge (m3/s)
Bedload (g/s)
Discharge (m3/s)
Bedload (g/s)
Date
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
07 Jan 01
08 Jan 01
09 Jan 01
10 Jan 01
11 Jan 01
12 Jan 01
13 Jan 01
14 Jan 01
15 Jan 01
16 Jan 01

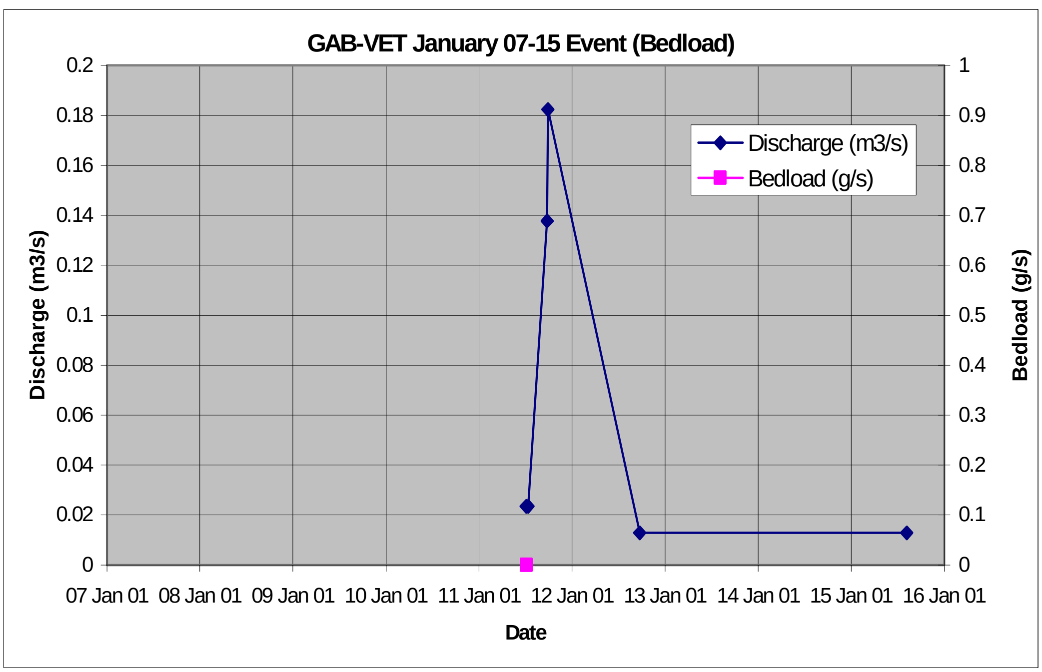


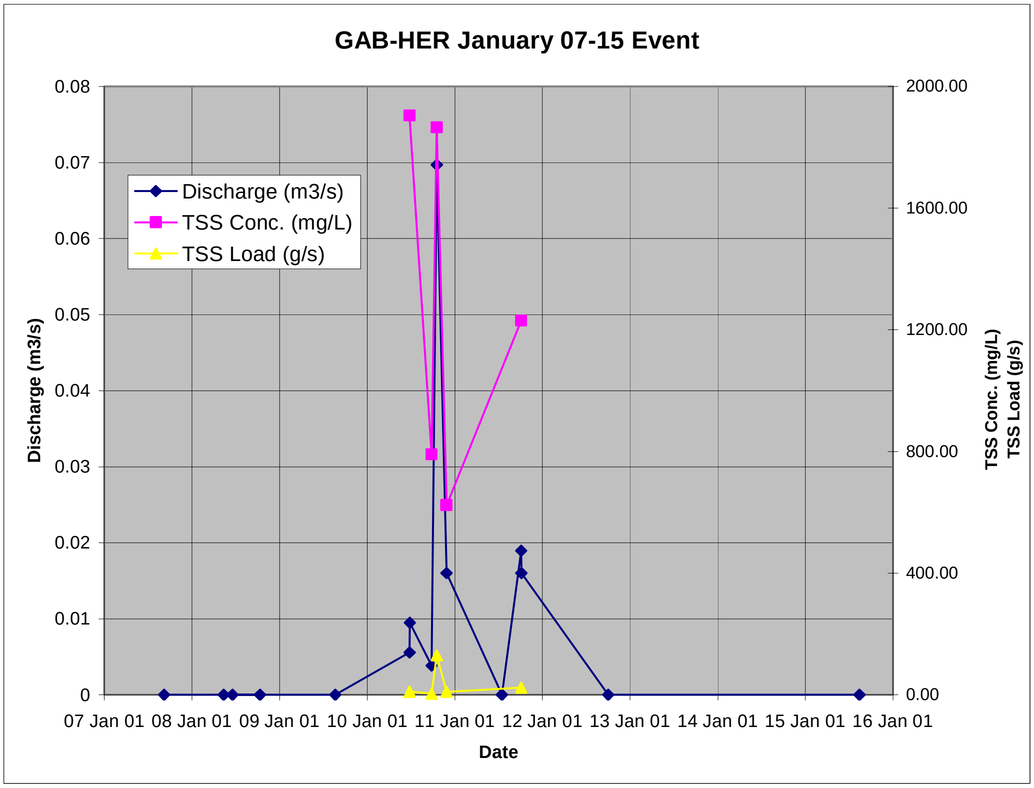
REC-VIC January 07-15 Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Date
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0.0
200.0
400.0
600.0
800.0
1000.0
07 Jan 01
08 Jan 01
09 Jan 01
10 Jan 01
11 Jan 01
12 Jan 01
13 Jan 01
14 Jan 01
15 Jan 01
16 Jan 01



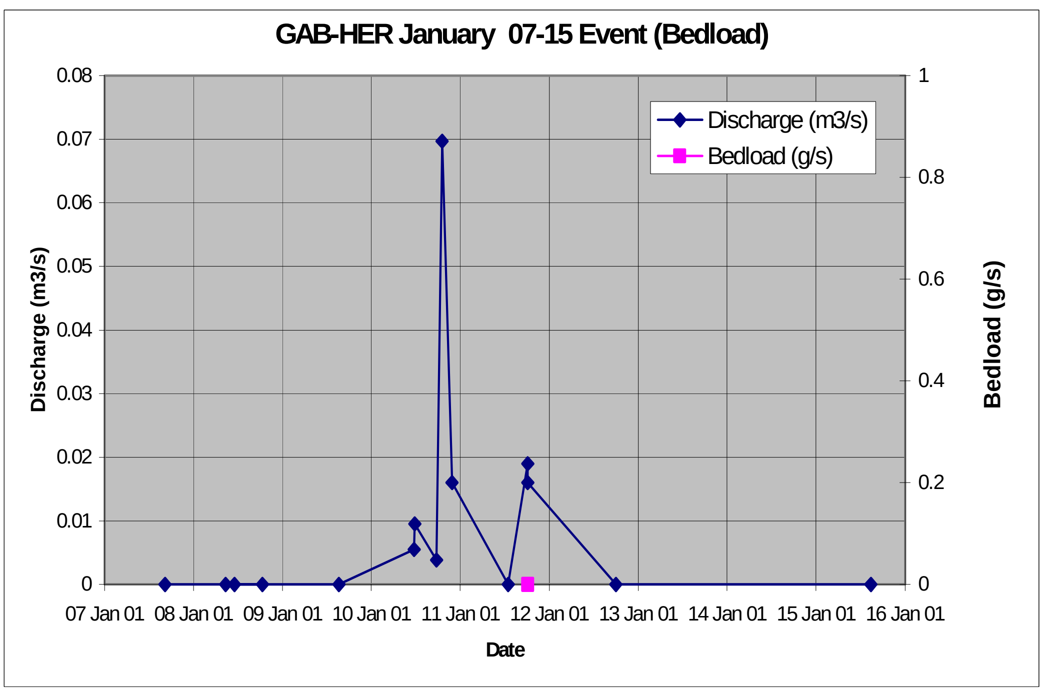
REC-VIC January 07-15 Event (Bedload)
Discharge (m3/s)
Bedload (g/s)
Discharge (m3/s)
Bedload (g/s)
Date
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0
1
2
3
4
5
6
7
8
07 Jan 01
08 Jan 01
09 Jan 01
10 Jan 01
11 Jan 01
12 Jan 01
13 Jan 01
14 Jan 01
15 Jan 01
16 Jan 01


GAB-VET January 07-15 Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
80.000
60.000
40.000
20.000
0.000
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
07 Jan 01
08 Jan 01
09 Jan 01
10 Jan 01
11 Jan 01
12 Jan 01
13 Jan 01
14 Jan 01
15 Jan 01
16 Jan 01
Date

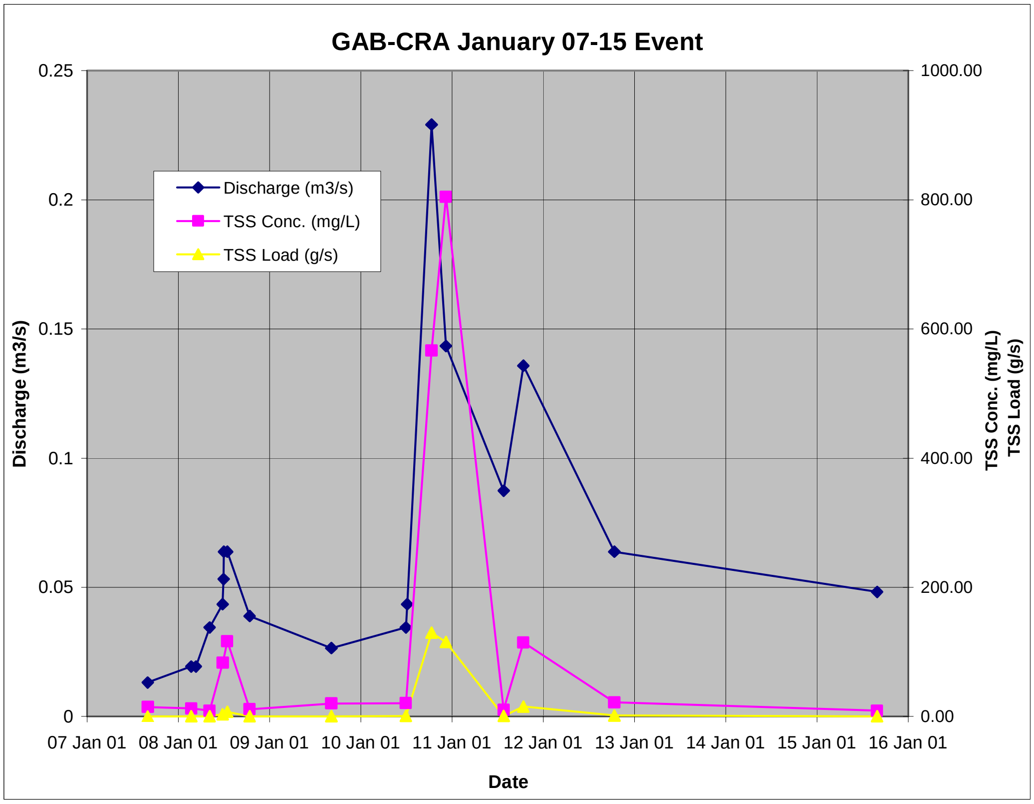

GAB-VET January 07-15 Event (Bedload)
Discharge (m3/s)
Bedload (g/s)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Discharge (m3/s)
Bedload (g/s)
07 Jan 01
08 Jan 01
09 Jan 01
10 Jan 01
11 Jan 01
12 Jan 01
13 Jan 01
14 Jan 01
15 Jan 01
16 Jan 01
Date

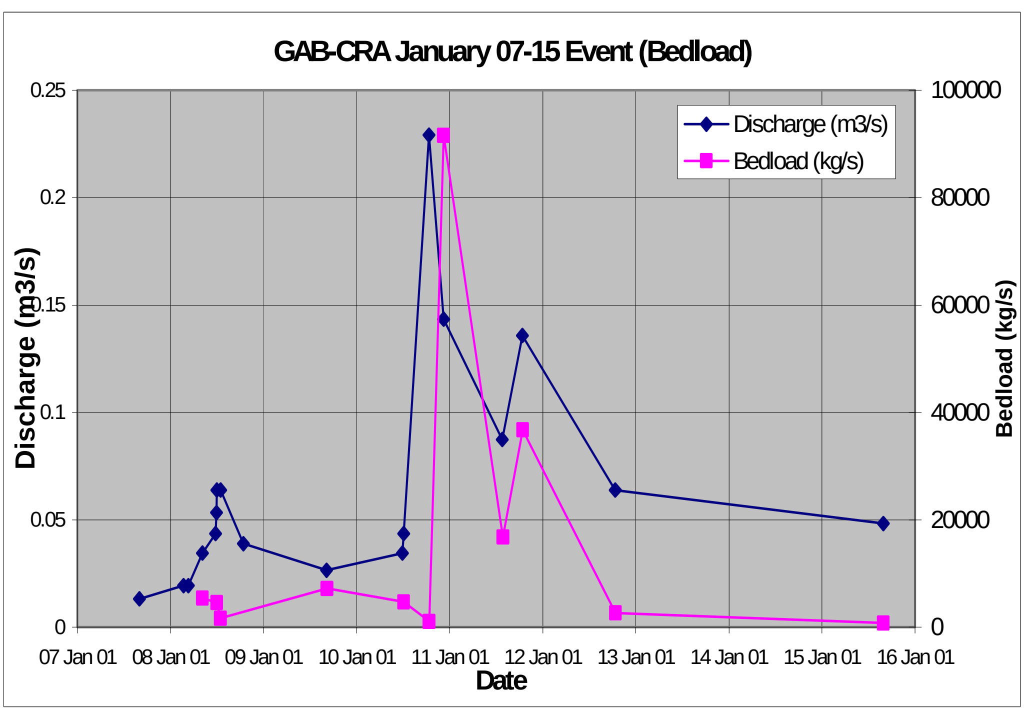


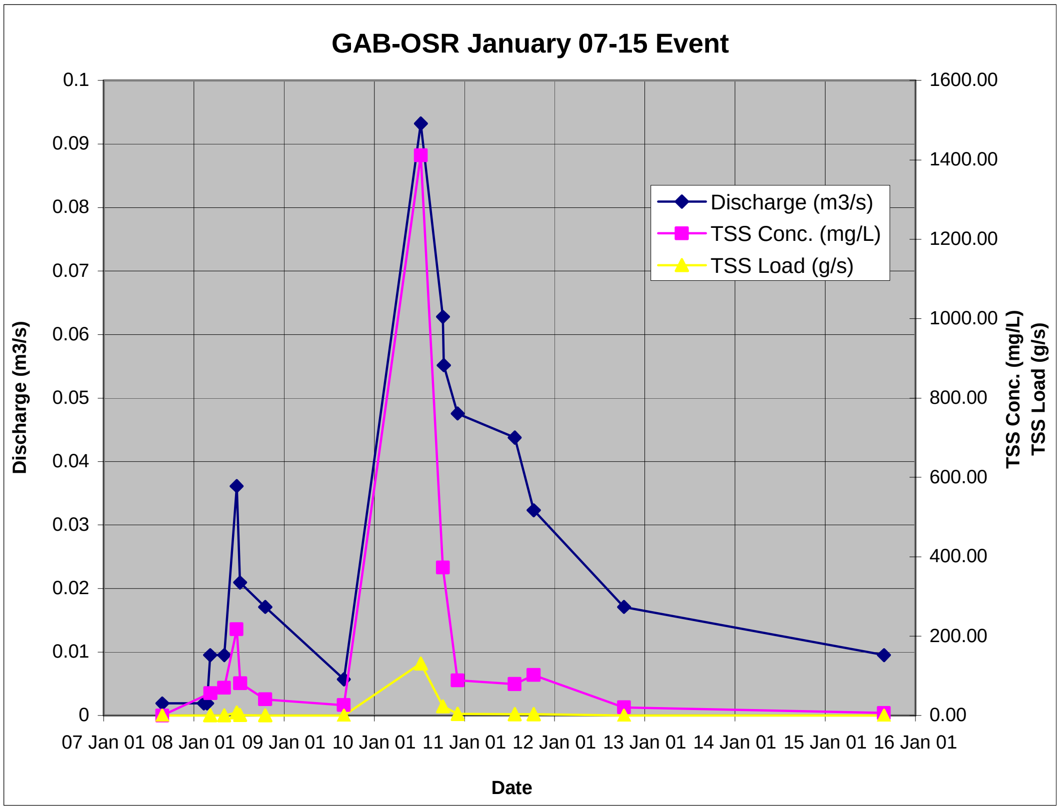
GAB-HER January 07-15 Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
2000.00
1600.00
1200.00
800.00
400.00
0.00
07 Jan 01
08 Jan 01
09 Jan 01
10 Jan 01
11 Jan 01
12 Jan 01
13 Jan 01
14 Jan 01
15 Jan 01
16 Jan 01
Date
TSS Conc. (mg/L)
TSS Load (g/s)

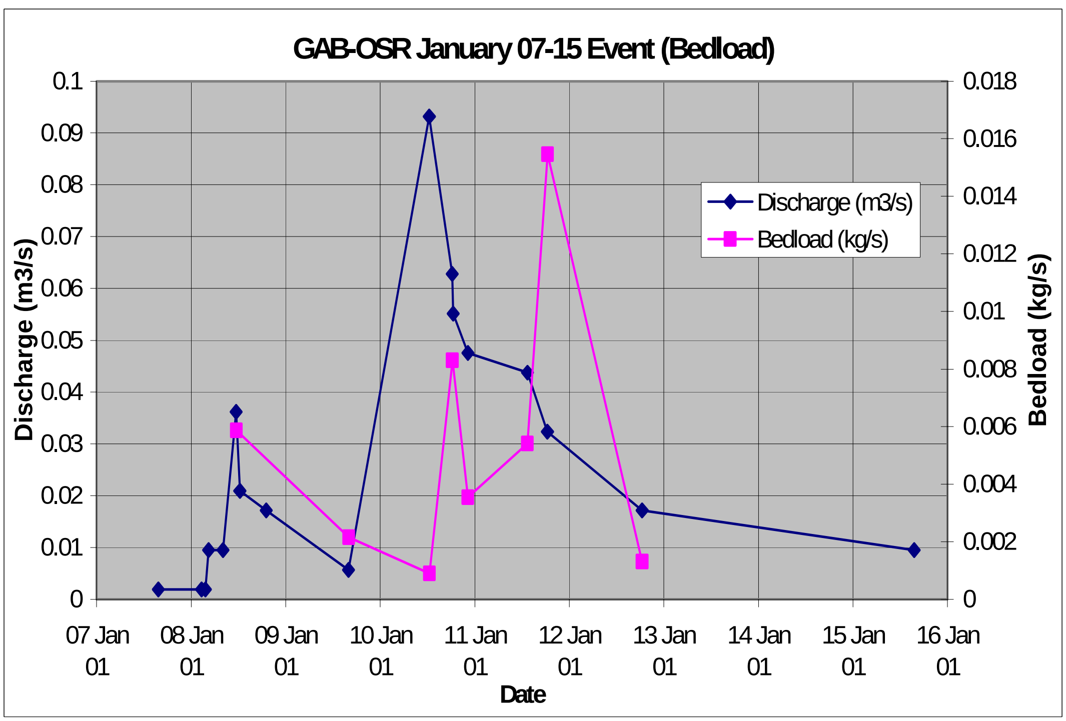


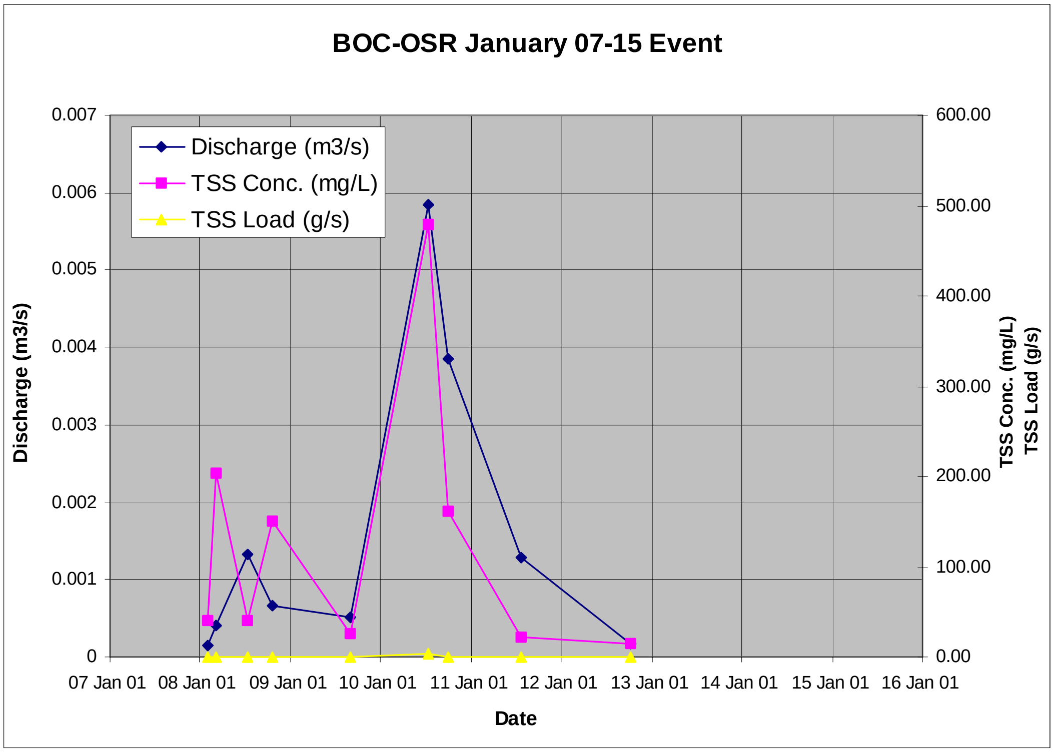
GAB-HER January 07-15 Event (Bedload)
Discharge (m3/s)
Bedload (g/s)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1
0.8
0.6
0.4
0.2
0
07 Jan 01
08 Jan 01
09 Jan 01
10 Jan 01
11 Jan 01
12 Jan 01
13 Jan 01
14 Jan 01
15 Jan 01
16 Jan 01
Date

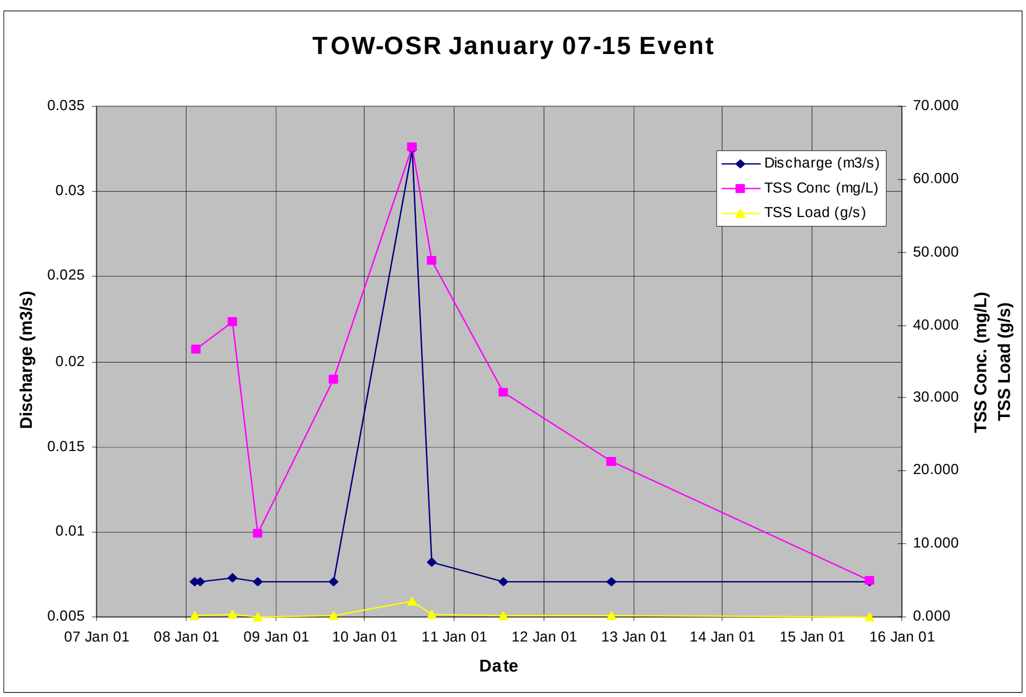

GAB-CRA January 07-15 Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.25
0.2
0.15
0.1
0.05
0
1000.00
800.00
600.00
400.00
200.00
0.00
07 Jan 01
08 Jan 01
09 Jan 01
10 Jan 01
11 Jan 01
12 Jan 01
13 Jan 01
14 Jan 01
15 Jan 01
16 Jan 01
Date


GAB-CRA January 07-15 Event (Bedload)
Discharge (m3/s)
Bedload (kg/s)
Discharge (m3/s)
Bedload (kg/s)
0.25
0.2
0.15
0.1
0.05
0
100000
80000
60000
40000
20000
0
07 Jan 01
08 Jan 01
09 Jan 01
10 Jan 01
11 Jan 01
12 Jan 01
13 Jan 01
14 Jan 01
15 Jan 01
16 Jan 01
Date

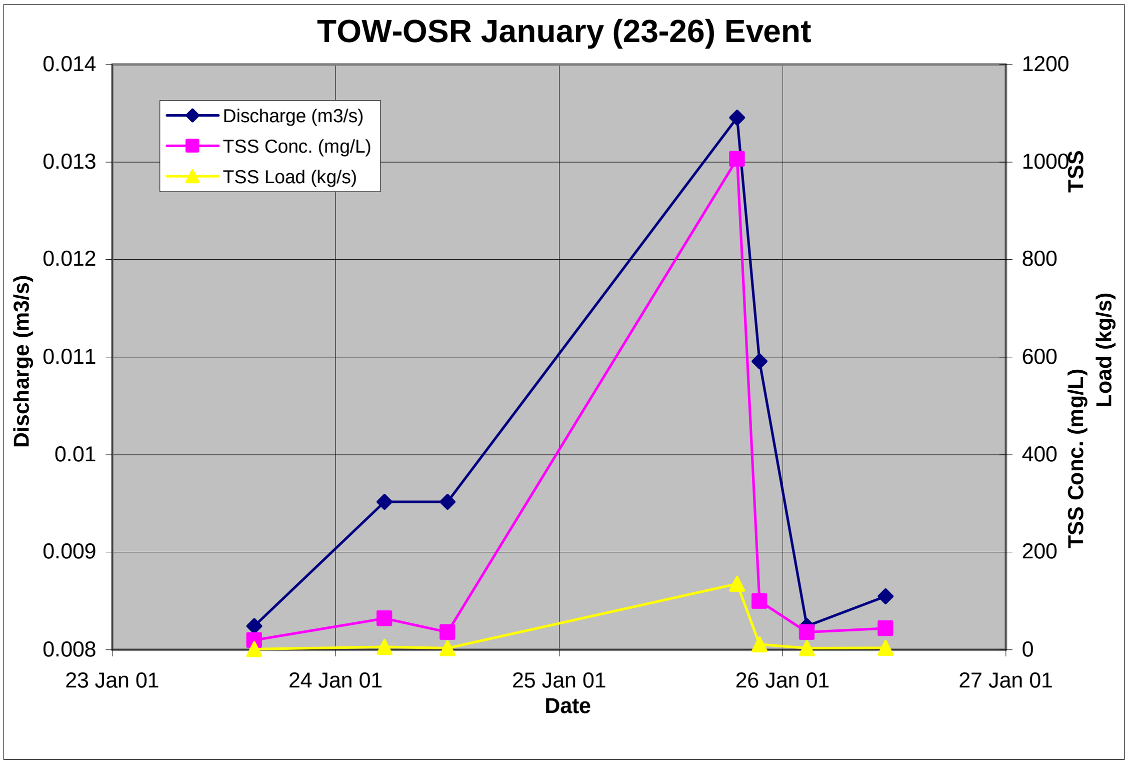

GAB-OSR January 07-15 Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Date
07 Jan 01 08 Jan 01 09 Jan 01 10 Jan 01 11 Jan 01 12 Jan 01 13 Jan 01 14 Jan 01 15 Jan 01 16 Jan 01

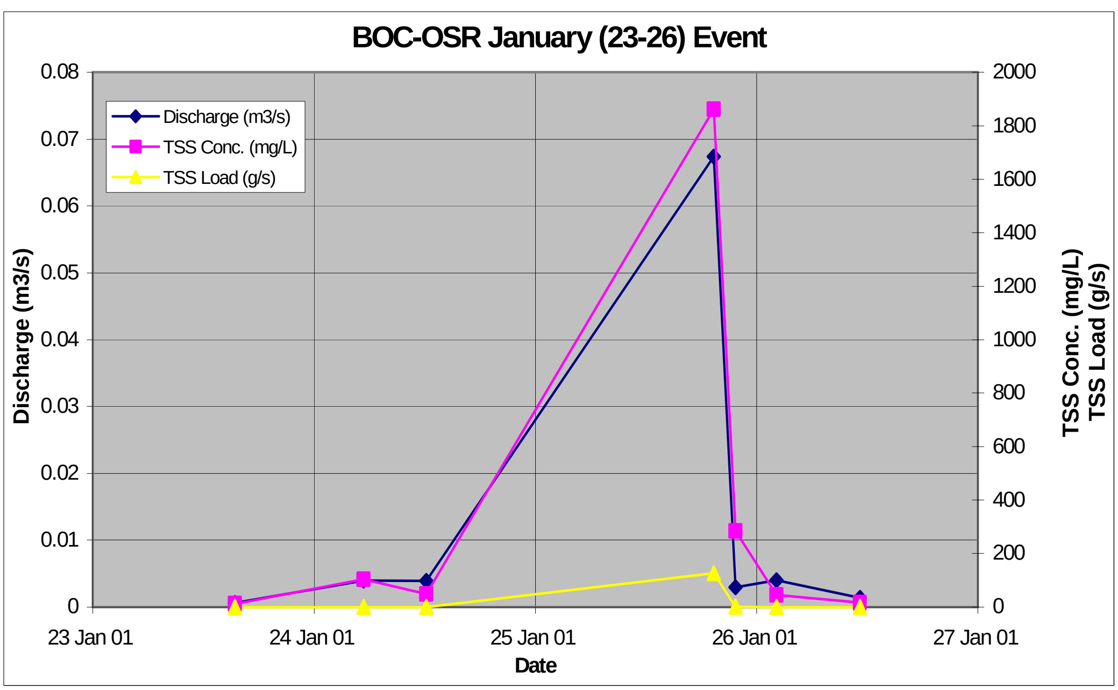

GAB-OSR January 07-15 Event (Bedload)
Discharge (m3/s)
Bedload (kg/s)
Discharge (m3/s)
Bedload (kg/s)
Date
07 Jan 01 08 Jan 01 09 Jan 01 10 Jan 01 11 Jan 01 12 Jan 01 13 Jan 01 14 Jan 01 15 Jan 01 16 Jan 01

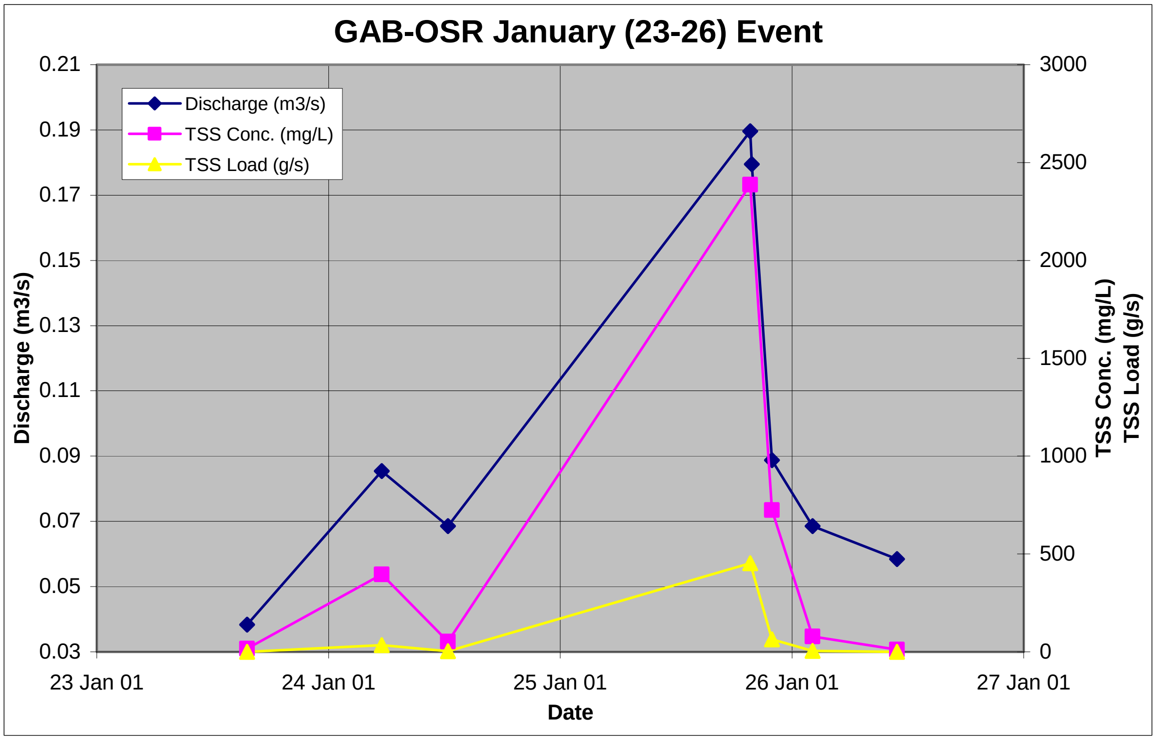

BOC-OSR January 07-15 Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
600.00
500.00
400.00
300.00
200.00
100.00
0.00
07 Jan 01
08 Jan 01
09 Jan 01
10 Jan 01
11 Jan 01
12 Jan 01
13 Jan 01
14 Jan 01
15 Jan 01
16 Jan 01
Date
TSS Conc. (mg/L)
TSS Load (g/s)

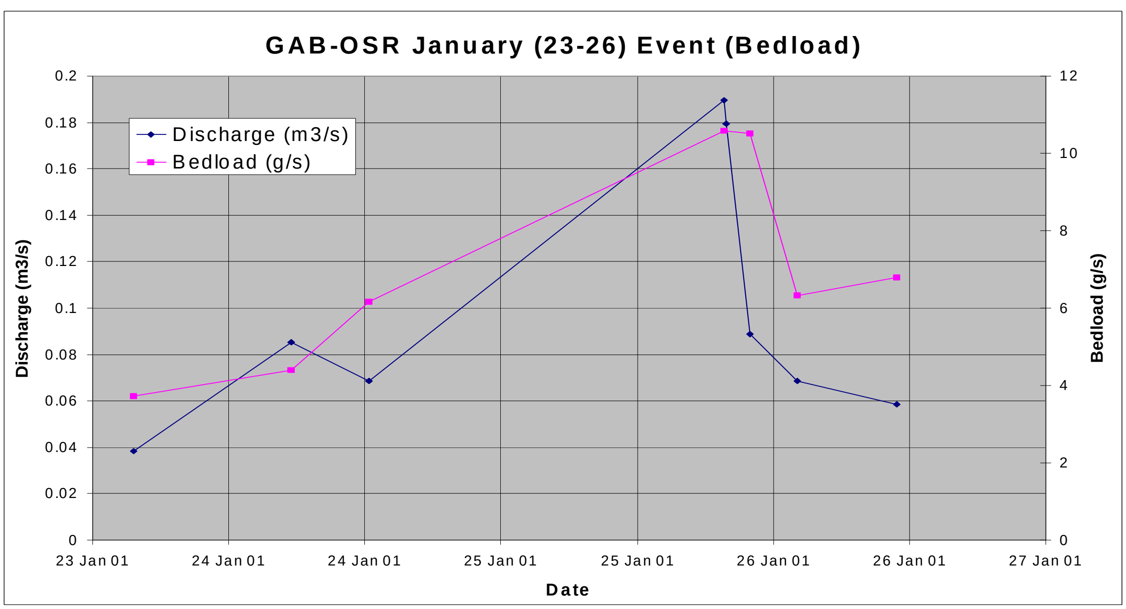

TOW-OSR January 07-15 Event
Discharge (m3/s)
TSS Conc (mg/L)
TSS Load (g/s)
0.035
0.03
0.025
0.02
0.015
0.01
0.005
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.000
07 Jan 01
08 Jan 01
09 Jan 01
10 Jan 01
11 Jan 01
12 Jan 01
13 Jan 01
14 Jan 01
15 Jan 01
16 Jan 01
Date
TSS Conc. (mg/L)
TSS Load (g/s)

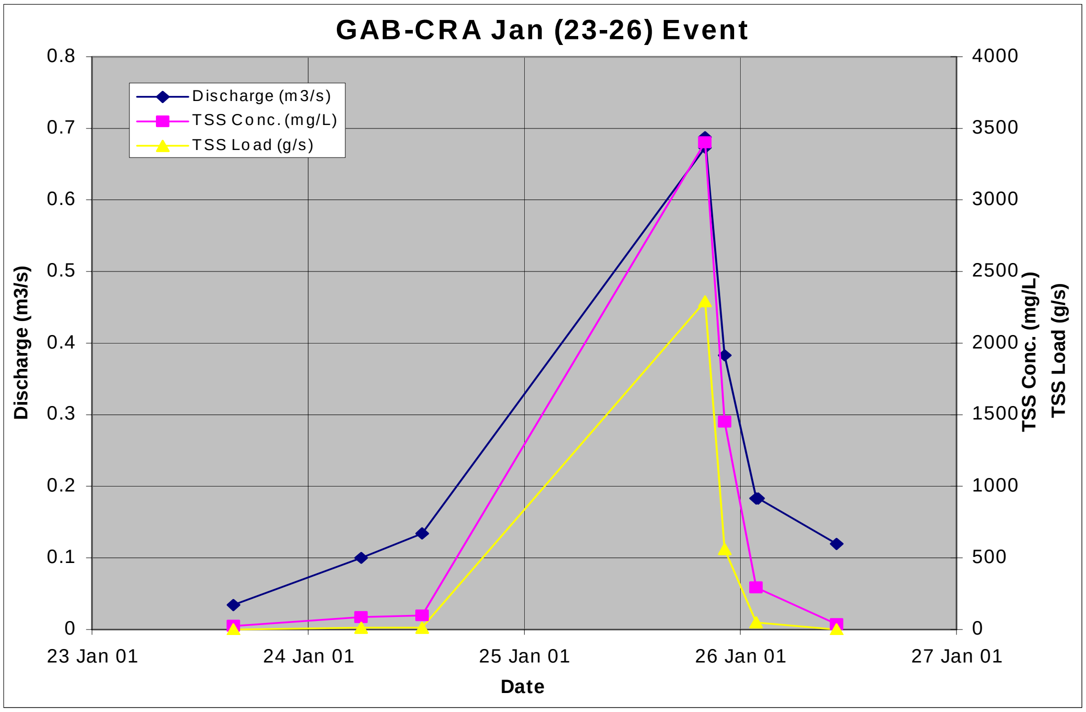
Appendix 10.5 January 23-26, 2001 Load Graphs



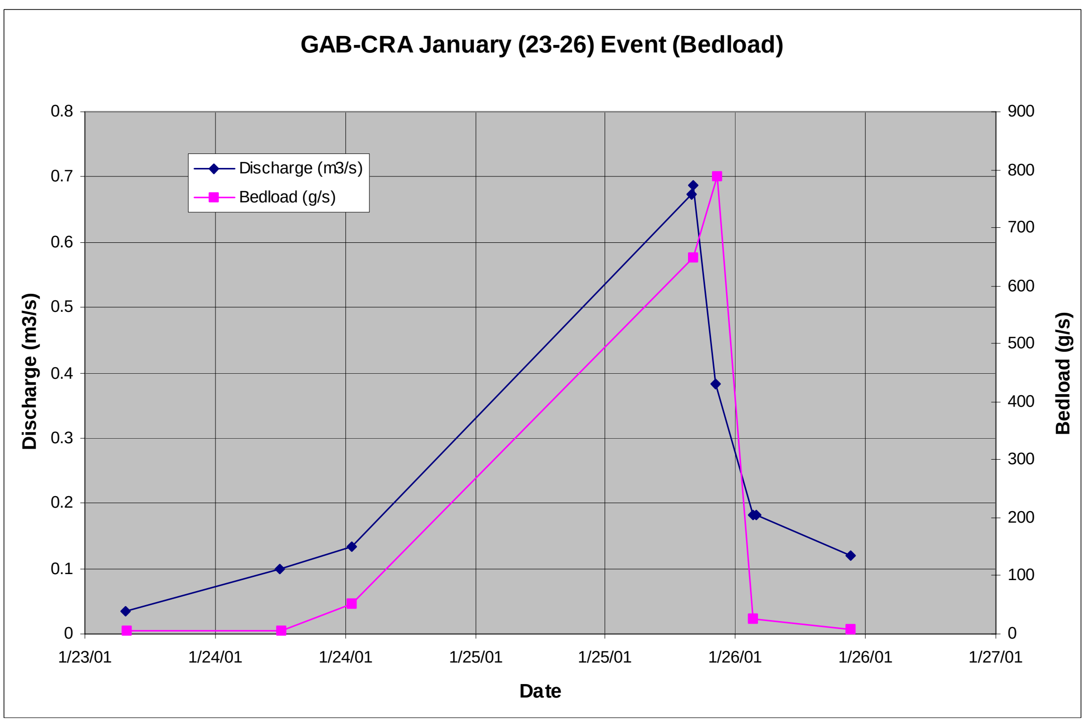



GAB-OSR January (23-26) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.21
0.19
0.17
0.15
0.13
0.11
0.09
0.07
0.05
0.03
3000
2500
2000
1500
1000
500
0
23 Jan 01
24 Jan 01
25 Jan 01
26 Jan 01
27 Jan 01
Date

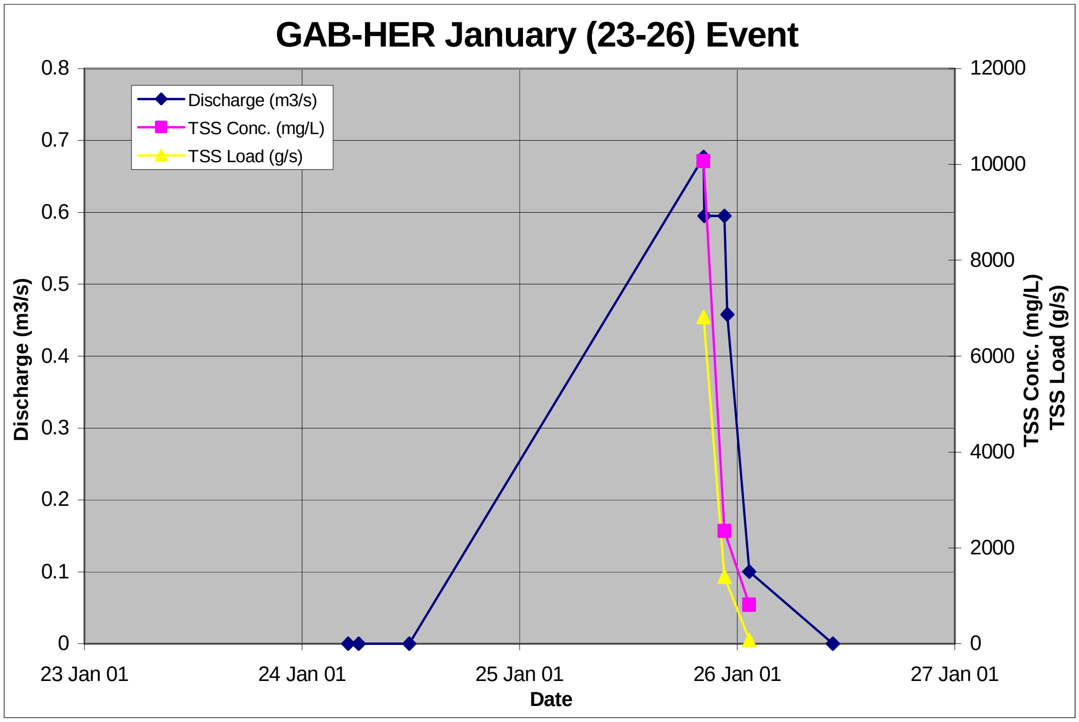

GAB-OSR January (23-26) Event (Bedload)
Discharge (m3/s)
Bedload (g/s)
Discharge (m3/s)
Bedload (g/s)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
12
10
8
6
4
2
0
23 Jan 01
24 Jan 01
24 Jan 01
25 Jan 01
25 Jan 01
26 Jan 01
26 Jan 01
27 Jan 01
Date



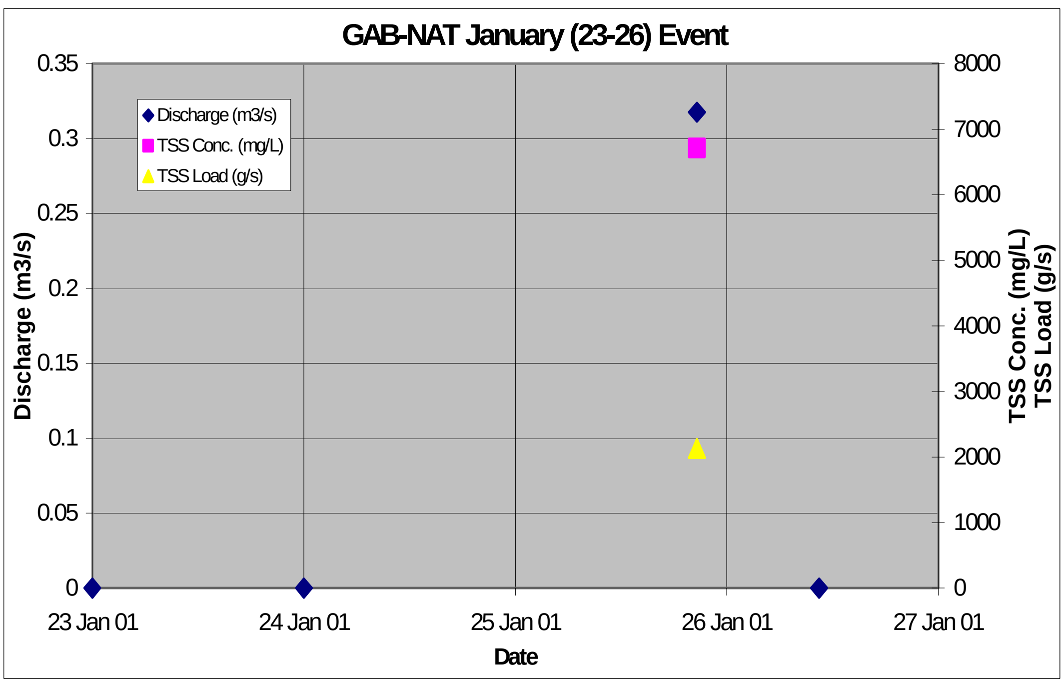
GAB-CRA Jan (23-26) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Date
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
500
1000
1500
2000
2500
3000
3500
4000
23 Jan 01
24 Jan 01
25 Jan 01
26 Jan 01
27 Jan 01



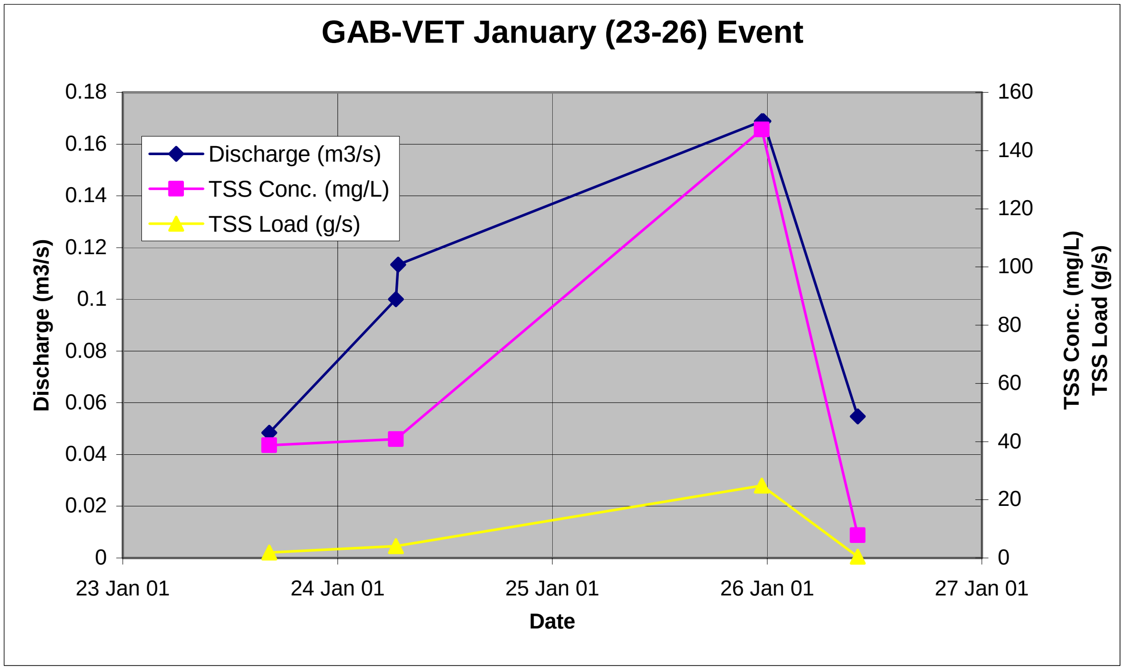
GAB-CRA January (23-26) Event (Bedload)
Discharge (m3/s)
Bedload (g/s)
Discharge (m3/s)
Bedload (g/s)
Date
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
100
200
300
400
500
600
700
800
900
1/23/01
1/24/01
1/24/01
1/25/01
1/25/01
1/26/01
1/26/01
1/27/01

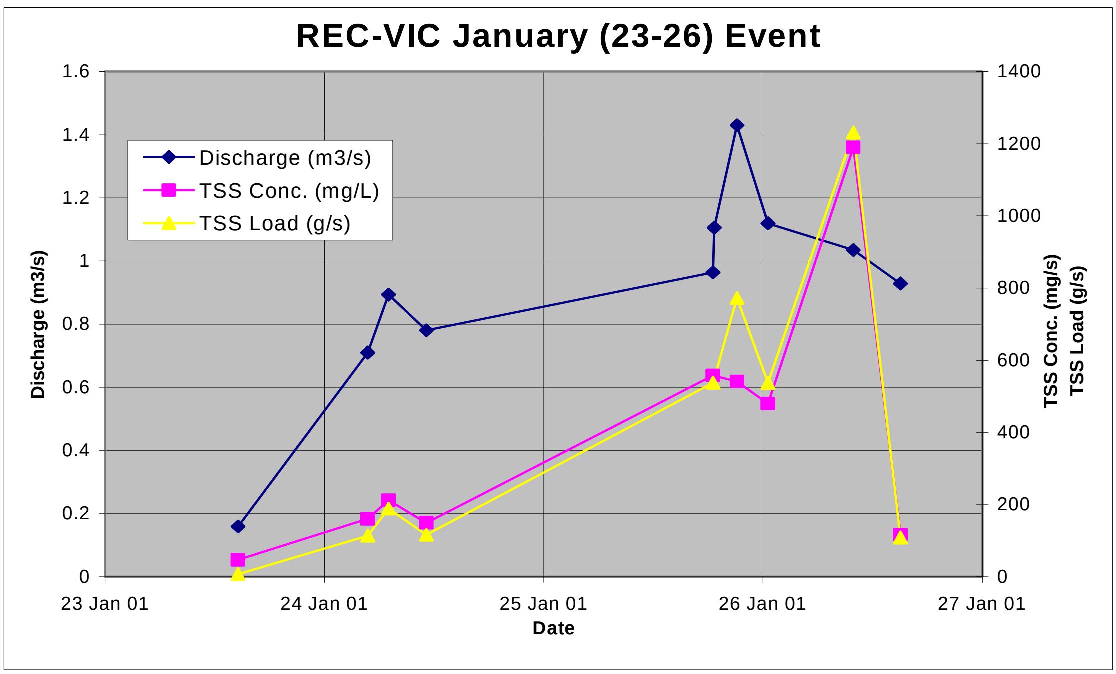


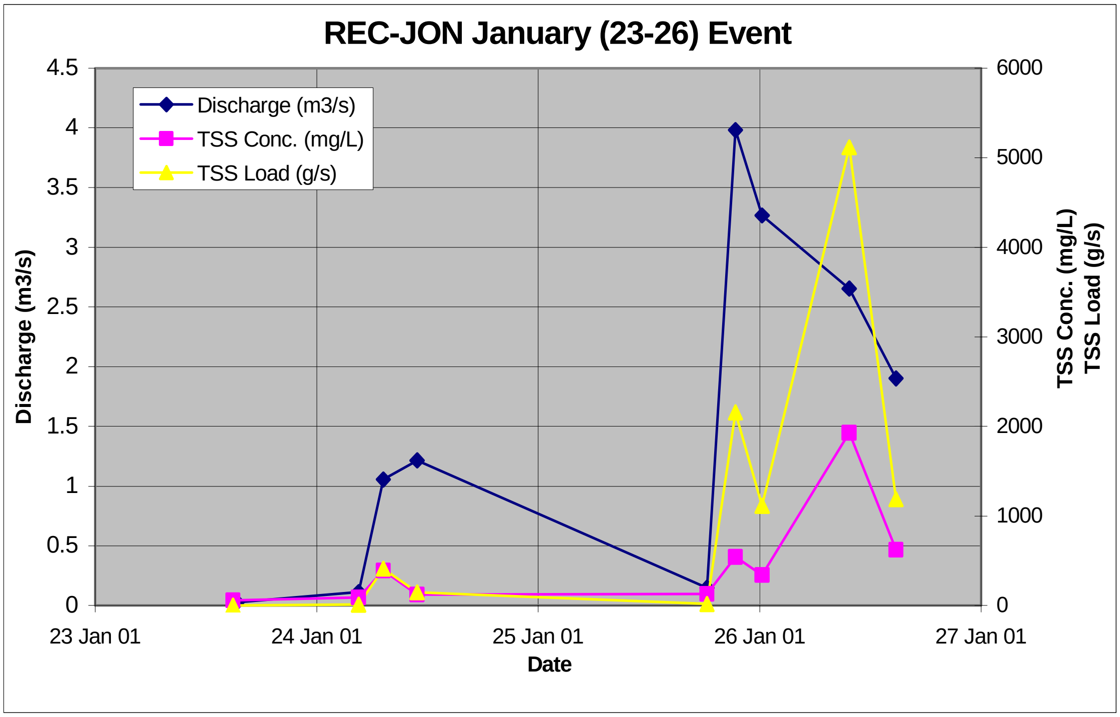
GAB-HER January (23-26) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Discharge (m3/s)
12000
10000
8000
6000
4000
2000
0
TSS Conc. (mg/L)
TSS Load (g/s)
23 Jan 01
24 Jan 01
25 Jan 01
26 Jan 01
27 Jan 01
Date



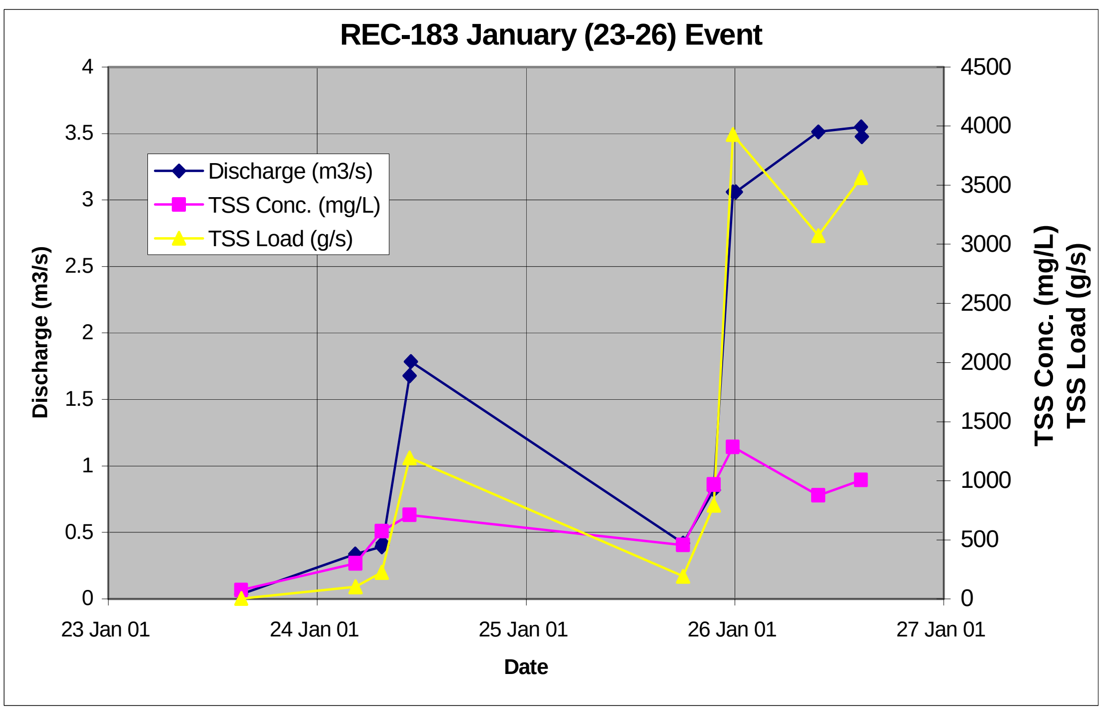
GAB-NAT January (23-26) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Discharge (m3/s)
8000
7000
6000
5000
4000
3000
2000
1000
0
TSS Conc. (mg/L)
TSS Load (g/s)
23 Jan 01
24 Jan 01
25 Jan 01
26 Jan 01
27 Jan 01
Date


GAB-VET January (23-26) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
160
140
120
100
80
60
40
20
0
TSS Conc. (mg/L)
TSS Load (g/s)
23 Jan 01
24 Jan 01
25 Jan 01
26 Jan 01
27 Jan 01
Date


REC-VIC January (23-26) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1400
1200
1000
800
600
400
200
0
TSS Conc. (mg/s)
TSS Load (g/s)
23 Jan 01
24 Jan 01
25 Jan 01
26 Jan 01
27 Jan 01
Date



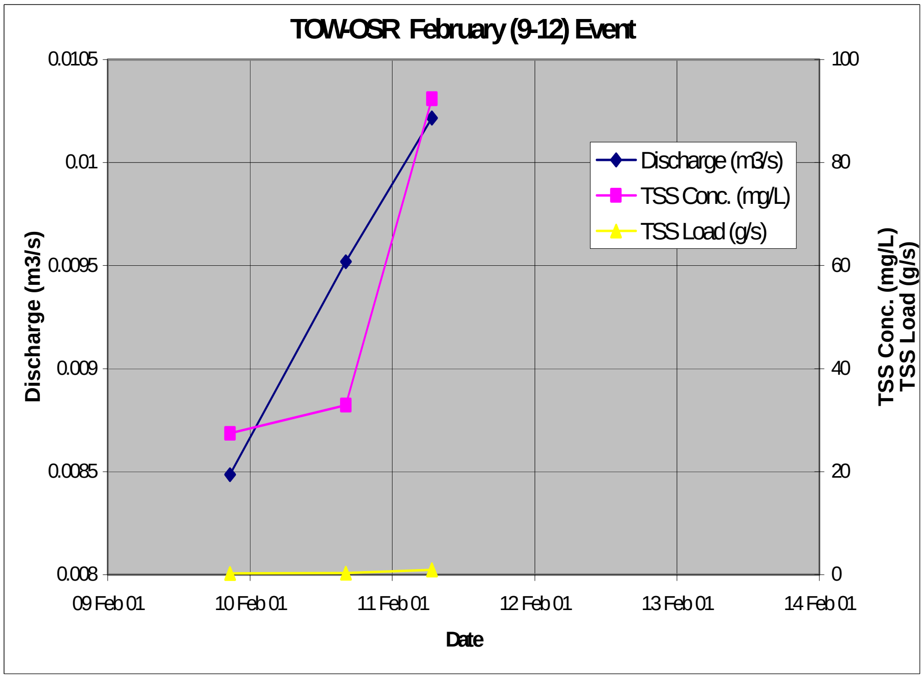
REC-JON January (23-26) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
6000
5000
4000
3000
2000
1000
0
23 Jan 01
24 Jan 01
25 Jan 01
26 Jan 01
27 Jan 01
Date
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)

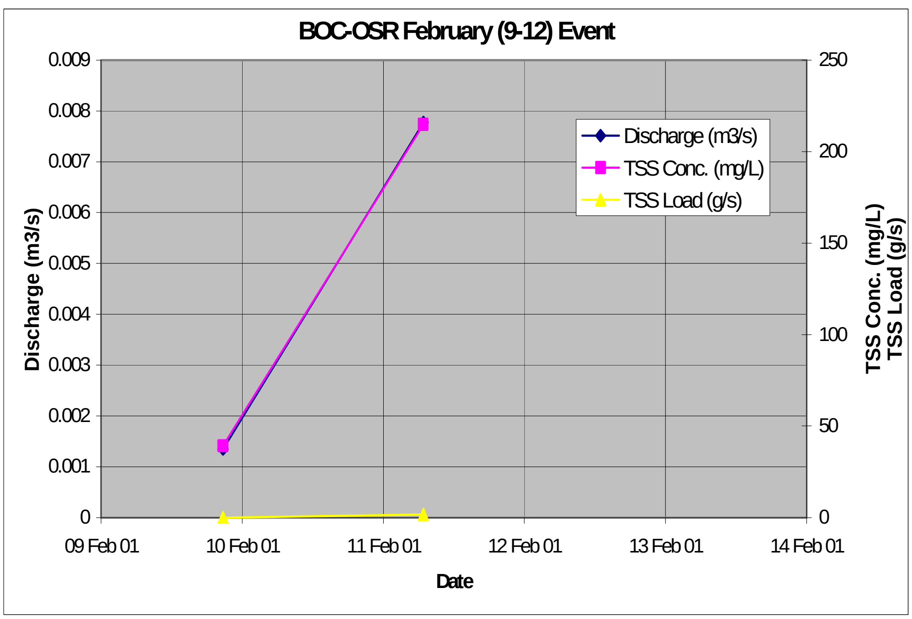


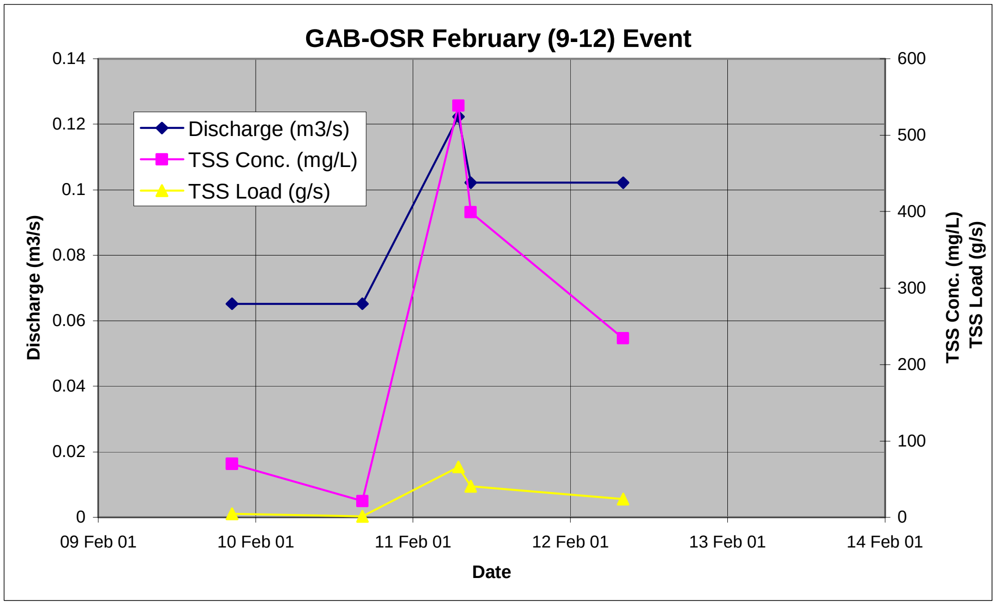
REC-183 January (23-26) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
4
3.5
3
2.5
2
1.5
1
0.5
0
4500
4000
3500
3000
2500
2000
1500
1000
500
0
23 Jan 01
24 Jan 01
25 Jan 01
26 Jan 01
27 Jan 01
Date
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)

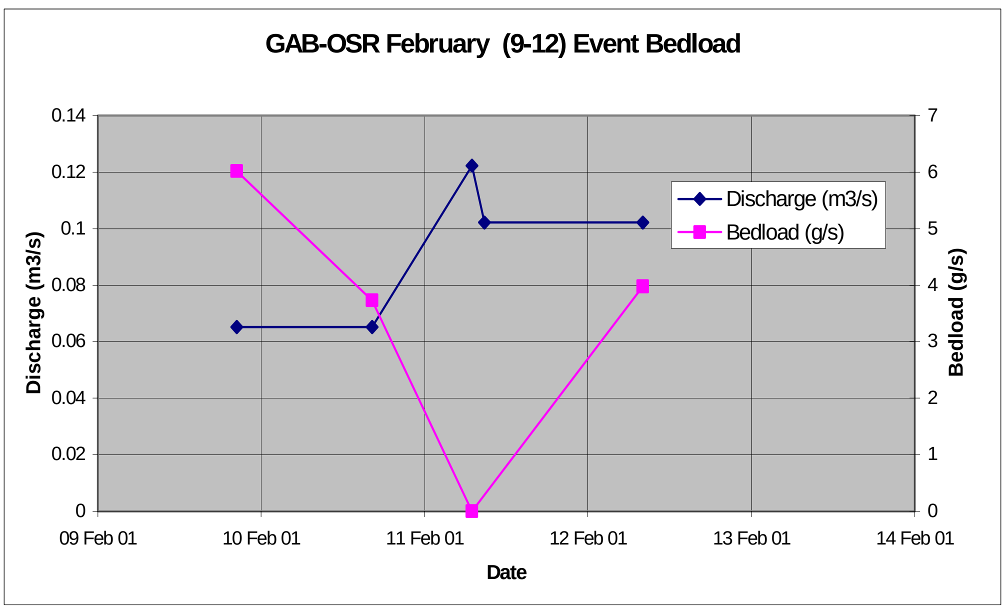
Appendix 10.6

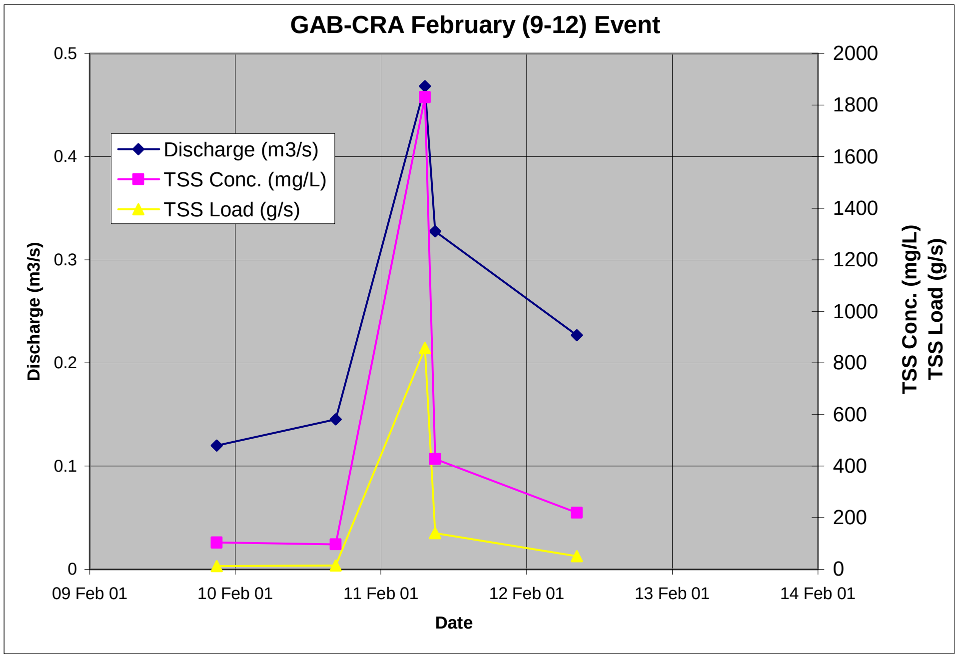
February 9-12, 2001 Load Graphs

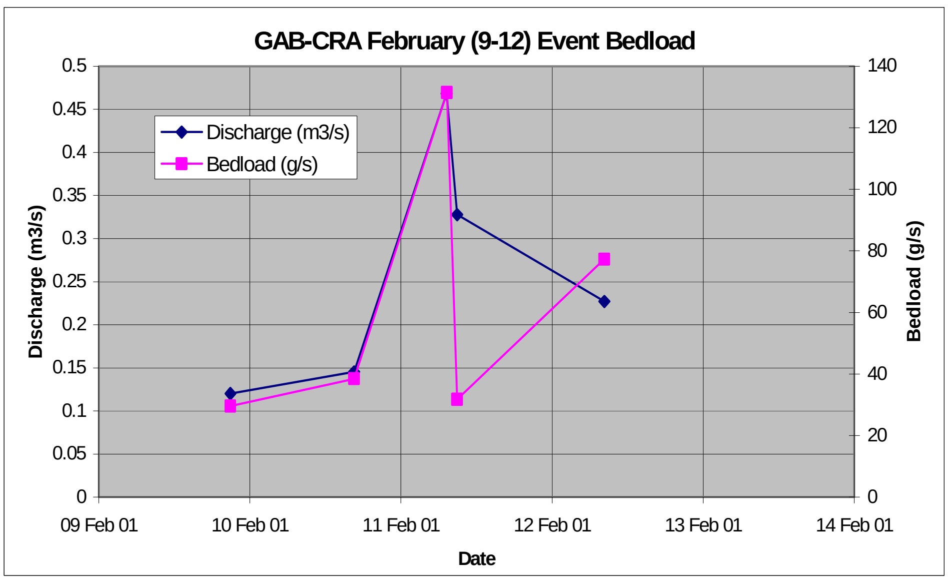


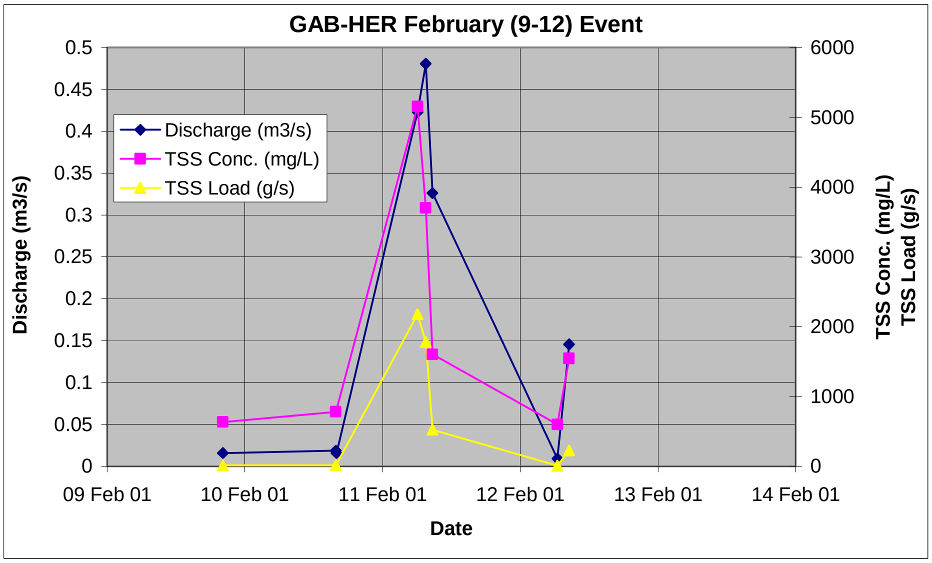



GAB-OSR February (9-12) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Date
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
600
500
400
300
200
100
0
09 Feb 01
10 Feb 01
11 Feb 01
12 Feb 01
13 Feb 01
14 Feb 01

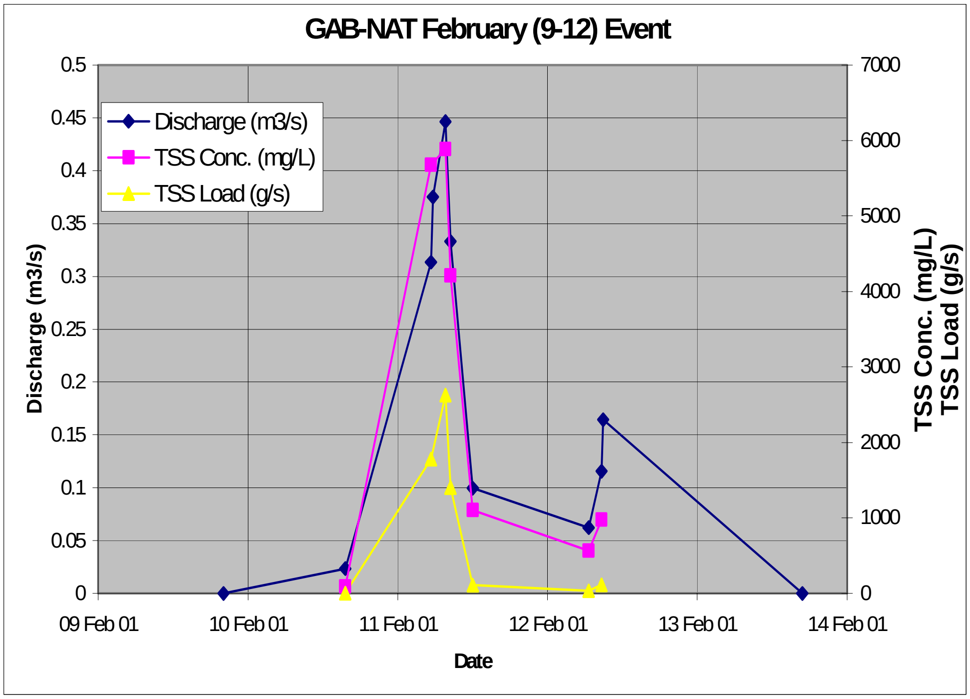

GAB-OSR February (9-12) Event Bedload
Discharge (m3/s)
Bedload (g/s)
Discharge (m3/s)
Bedload (g/s)
Date
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
7
6
5
4
3
2
1
0
09 Feb 01
10 Feb 01
11 Feb 01
12 Feb 01
13 Feb 01
14 Feb 01

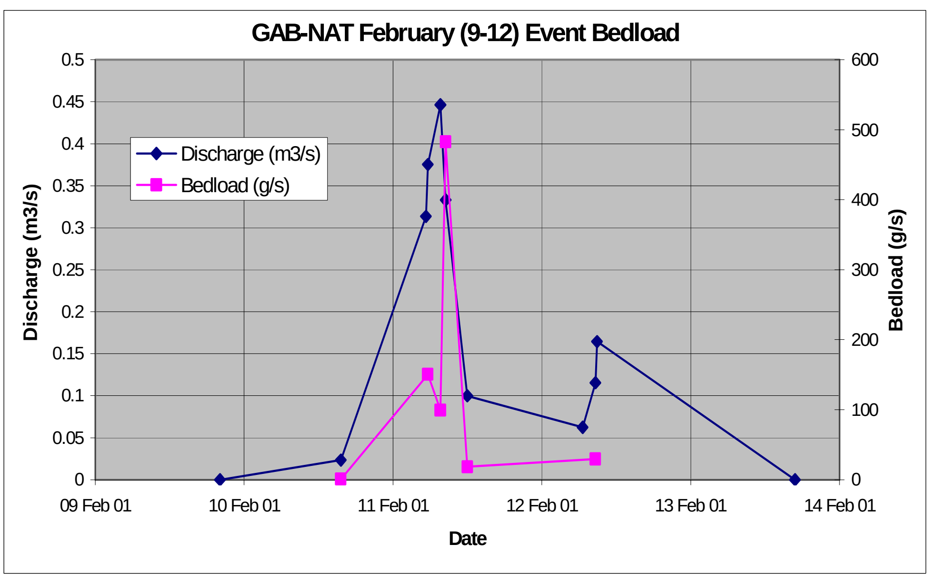

GAB-CRA February (9-12) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.5
0.4
0.3
0.2
0.1
0
2000
1800
1600
1400
1200
1000
800
600
400
200
0
09 Feb 01
10 Feb 01
11 Feb 01
12 Feb 01
13 Feb 01
14 Feb 01
Date
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)

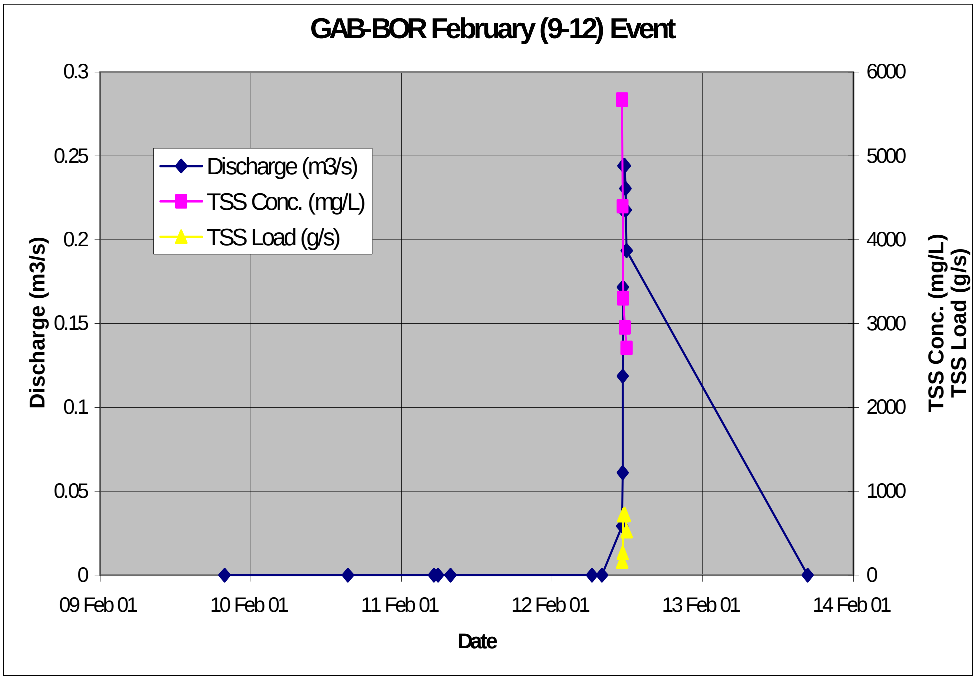

GAB-CRA February (9-12) Event Bedload
Discharge (m3/s)
Bedload (g/s)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
140
120
100
80
60
40
20
0
09 Feb 01
10 Feb 01
11 Feb 01
12 Feb 01
13 Feb 01
14 Feb 01
Date
Discharge (m3/s)
Bedload (g/s)

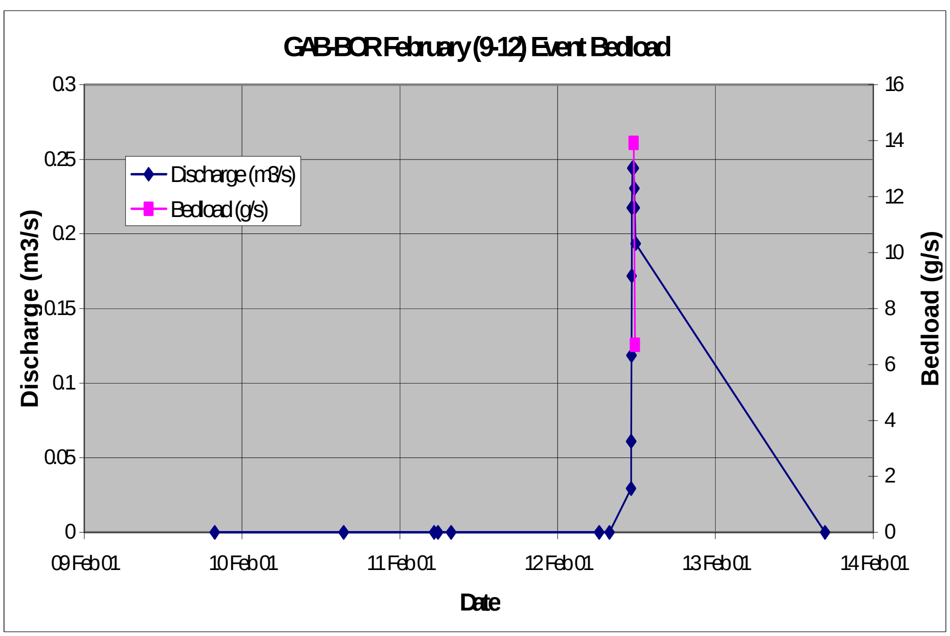


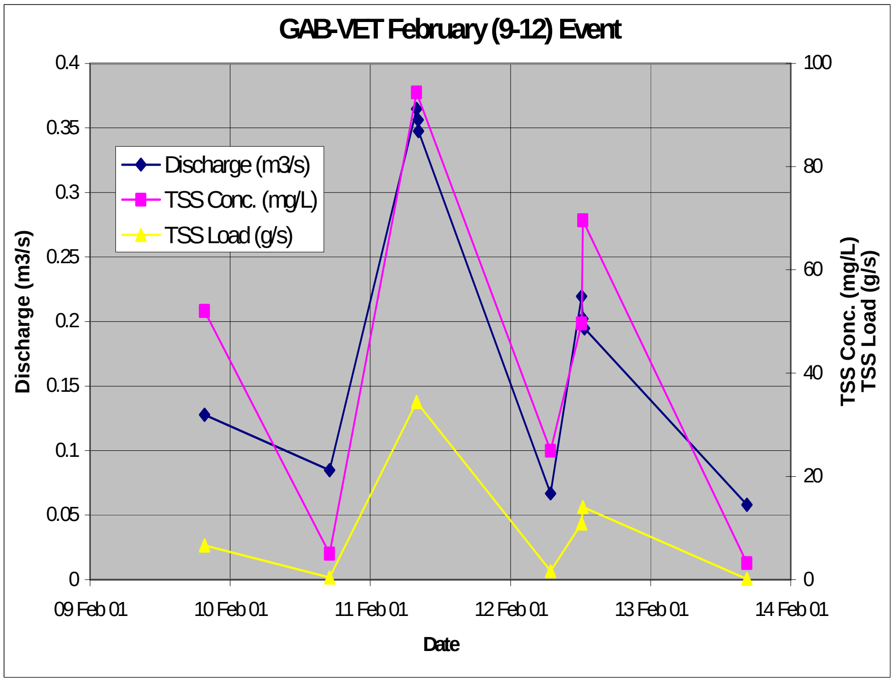
GAB-HER February (9-12) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
6000
5000
4000
3000
2000
1000
0
09 Feb 01
10 Feb 01
11 Feb 01
12 Feb 01
13 Feb 01
14 Feb 01
Date
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)

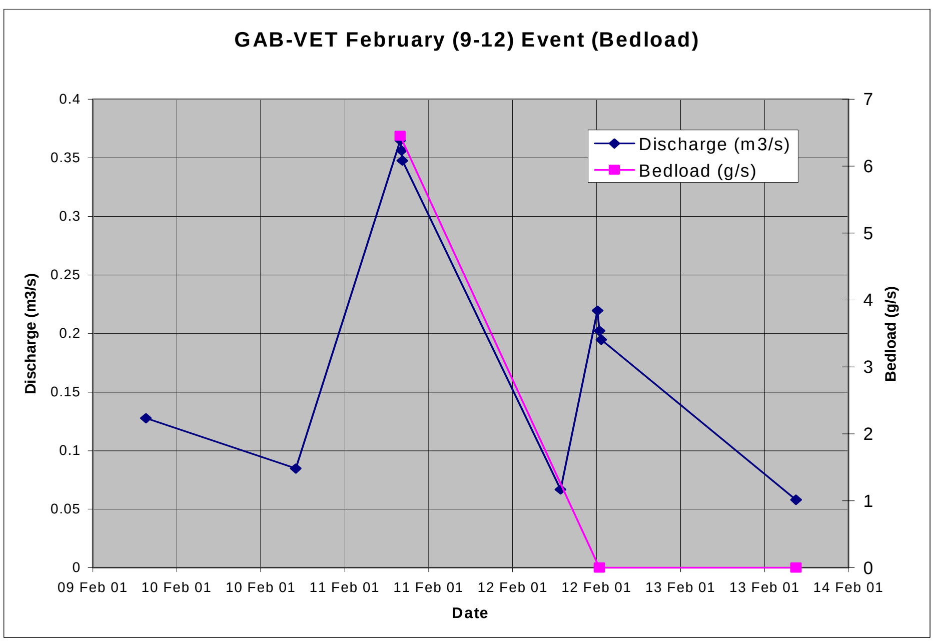

GAB-NAT February (9-12) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Date
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7000
6000
5000
4000
3000
2000
1000
0
09 Feb 01
10 Feb 01
11 Feb 01
12 Feb 01
13 Feb 01
14 Feb 01


GAB-NAT February (9-12) Event Bedload
Discharge (m3/s)
Bedload (g/s)
Discharge (m3/s)
Bedload (g/s)
Date
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
600
500
400
300
200
100
0
09 Feb 01
10 Feb 01
11 Feb 01
12 Feb 01
13 Feb 01
14 Feb 01


GAB-BOR February (9-12) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Date
0.3
0.25
0.2
0.15
0.1
0.05
0
6000
5000
4000
3000
2000
1000
0
09 Feb 01
10 Feb 01
11 Feb 01
12 Feb 01
13 Feb 01
14 Feb 01

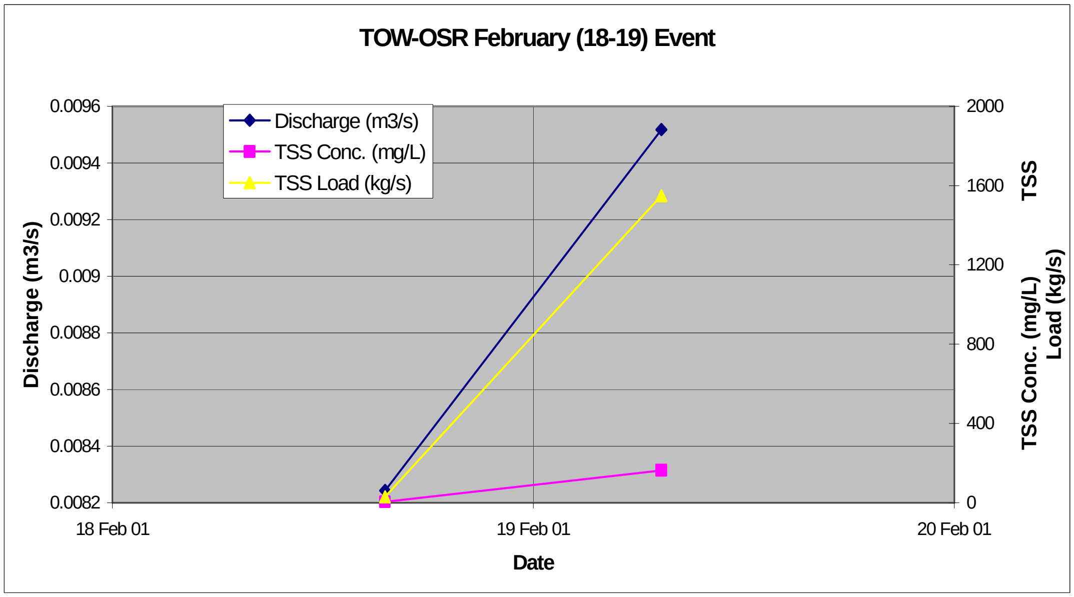

GAB-BOR February (9-12) Event Bedload
Discharge (m3/s)
Bedload (g/s)
Discharge (m3/s)
Bedload (g/s)
Date
0.3
0.25
0.2
0.15
0.1
0.05
0
16
14
12
10
8
6
4
2
0
09 Feb 01
10 Feb 01
11 Feb 01
12 Feb 01
13 Feb 01
14 Feb 01

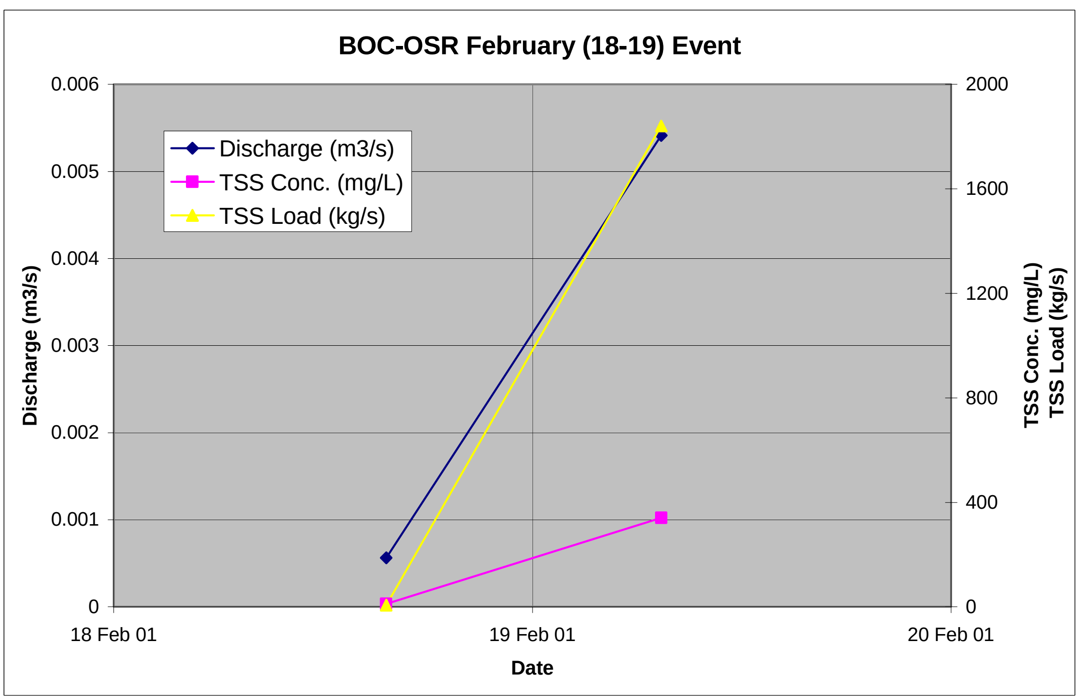

GAB-VET February (9-12) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
100
80
60
40
20
0
09 Feb 01
10 Feb 01
11 Feb 01
12 Feb 01
13 Feb 01
14 Feb 01
Date
TSS Conc. (mg/L)
TSS Load (g/s)

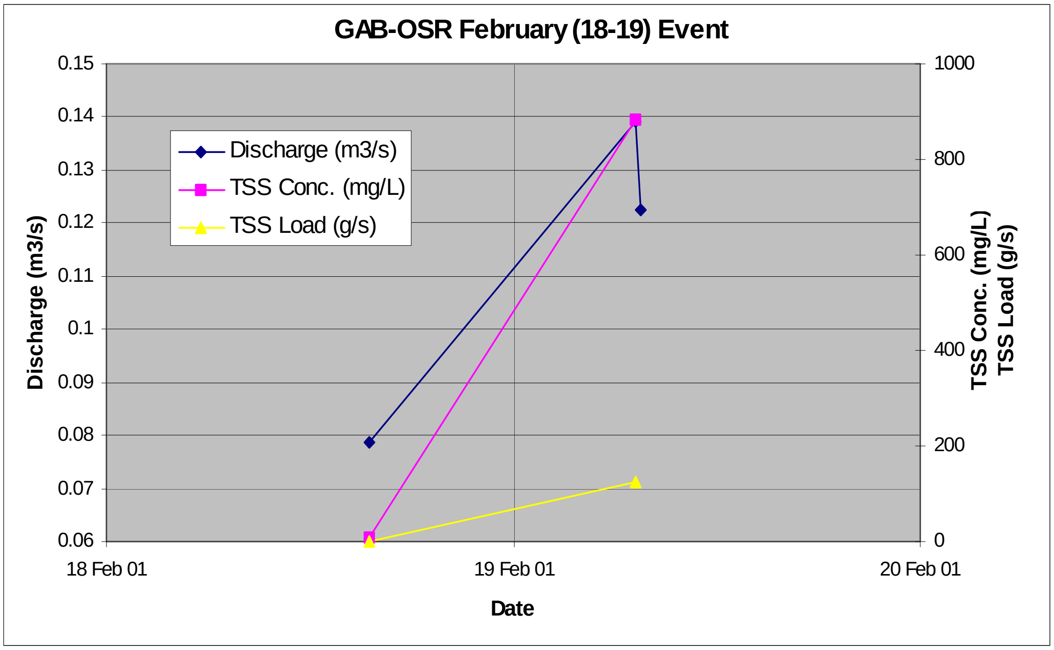

GAB-VET February (9-12) Event (Bedload)
Discharge (m3/s)
Bedload (g/s)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
6
5
4
3
2
1
0
09 Feb 01
10 Feb 01
10 Feb 01
11 Feb 01
11 Feb 01
12 Feb 01
12 Feb 01
13 Feb 01
13 Feb 01
14 Feb 01
Date

Appendix 10.7

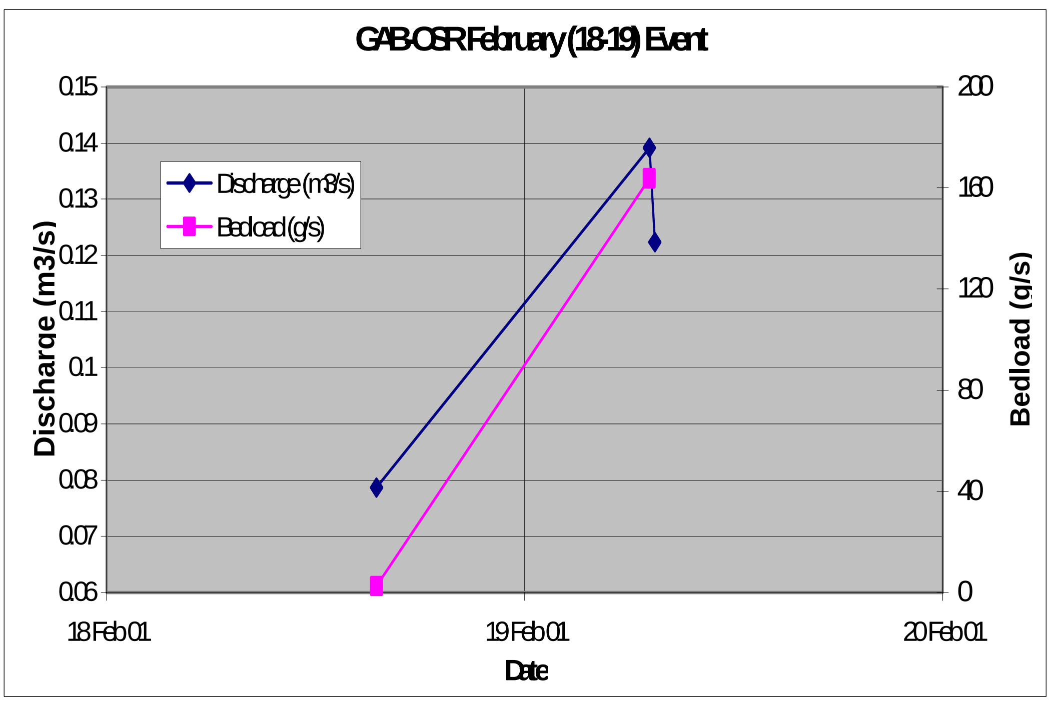
February 18-19, 2001 Load Graphs



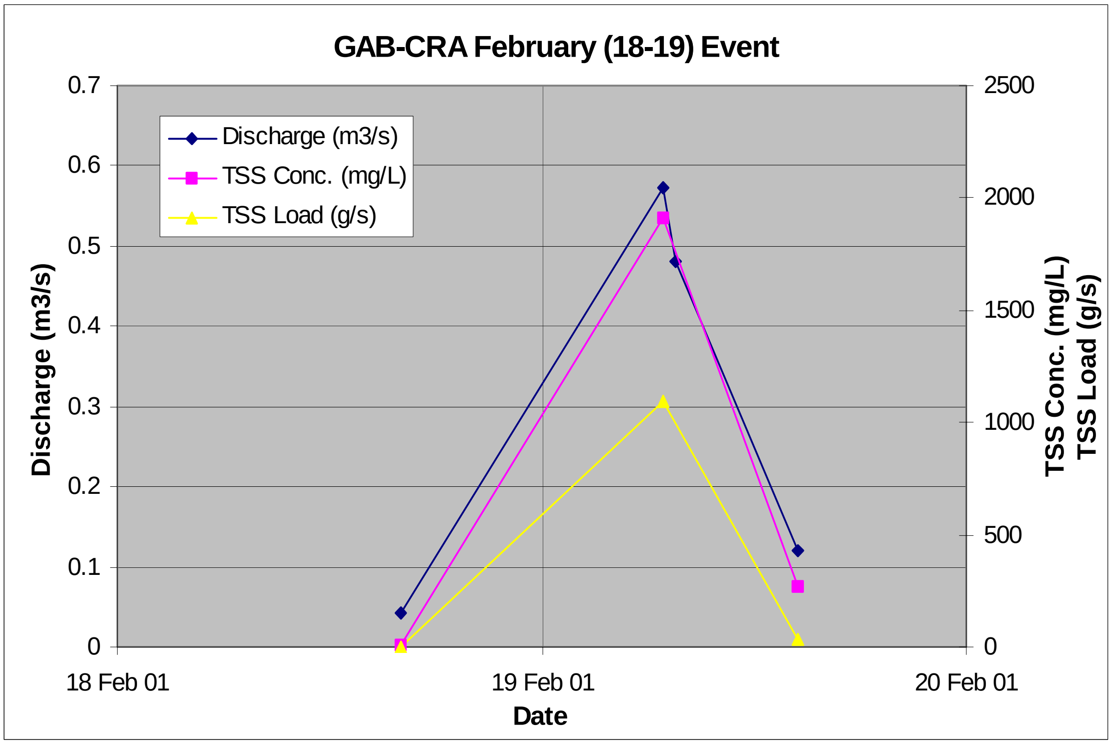


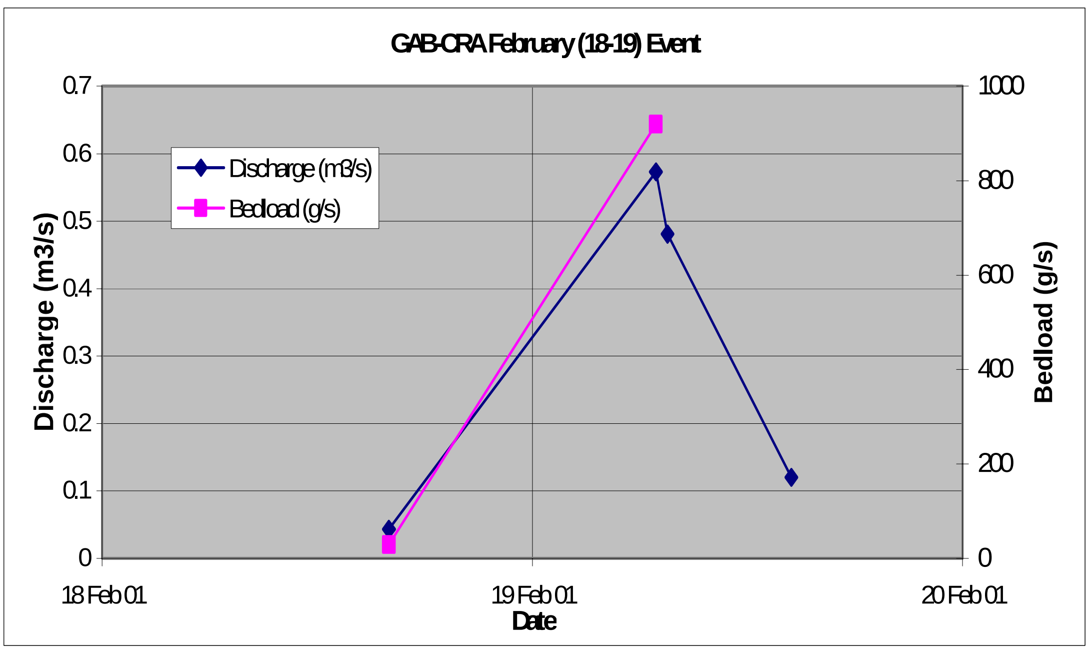


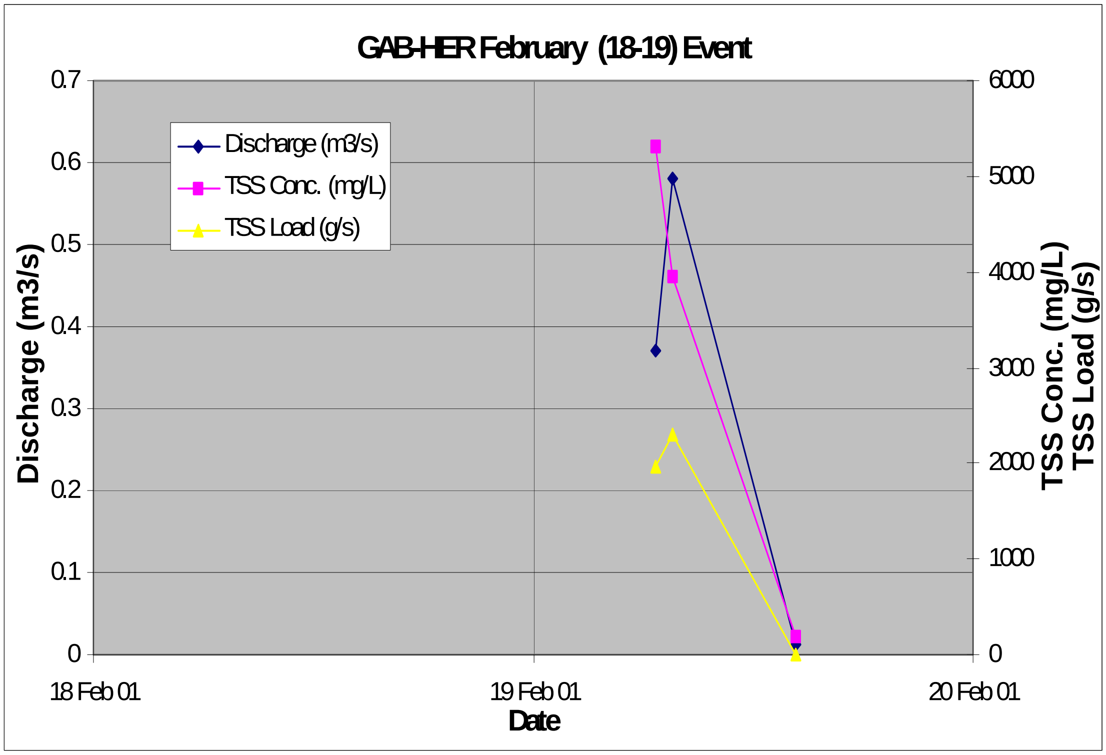
GAB-OSR February (18-19) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
1000
800
600
400
200
0
18 Feb 01
19 Feb 01
20 Feb 01
Date
TSS Conc. (mg/L)
TSS Load (g/s)



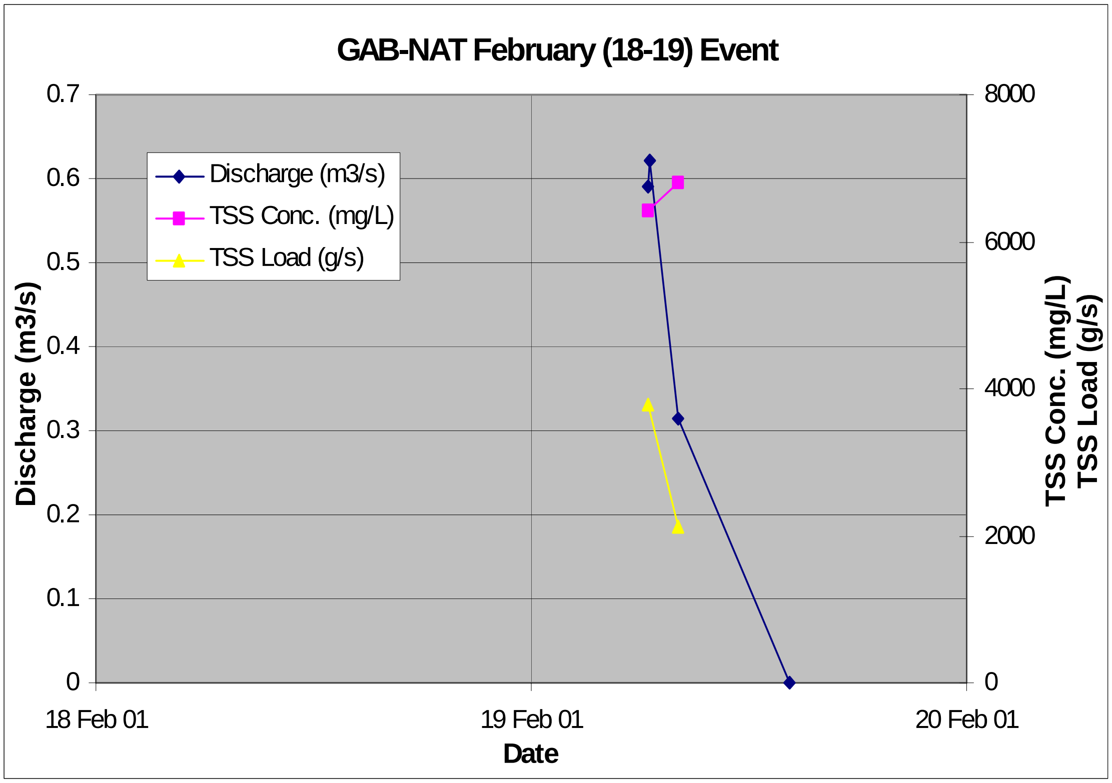
GAB-OSR February (18-19) Event
Discharge (m3/s)
Bedload (g/s)
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
200
160
120
80
40
0
18 Feb 01
19 Feb 01
20 Feb 01
Date


GAB-CRA February (18-19) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2500
2000
1500
1000
500
0
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
18 Feb 01
19 Feb 01
20 Feb 01
Date

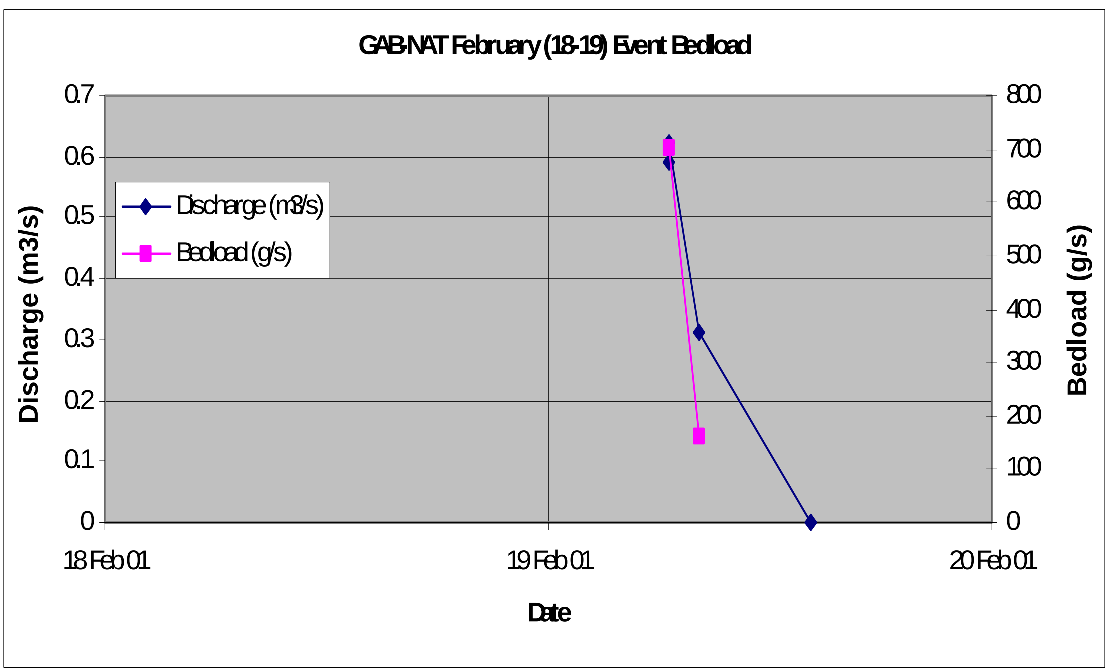

GAB-CRA February (18-19) Event
Discharge (m3/s)
Bedload (g/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1000
800
600
400
200
0
Discharge (m3/s)
Bedload (g/s)
18 Feb 01
19 Feb 01
20 Feb 01
Date



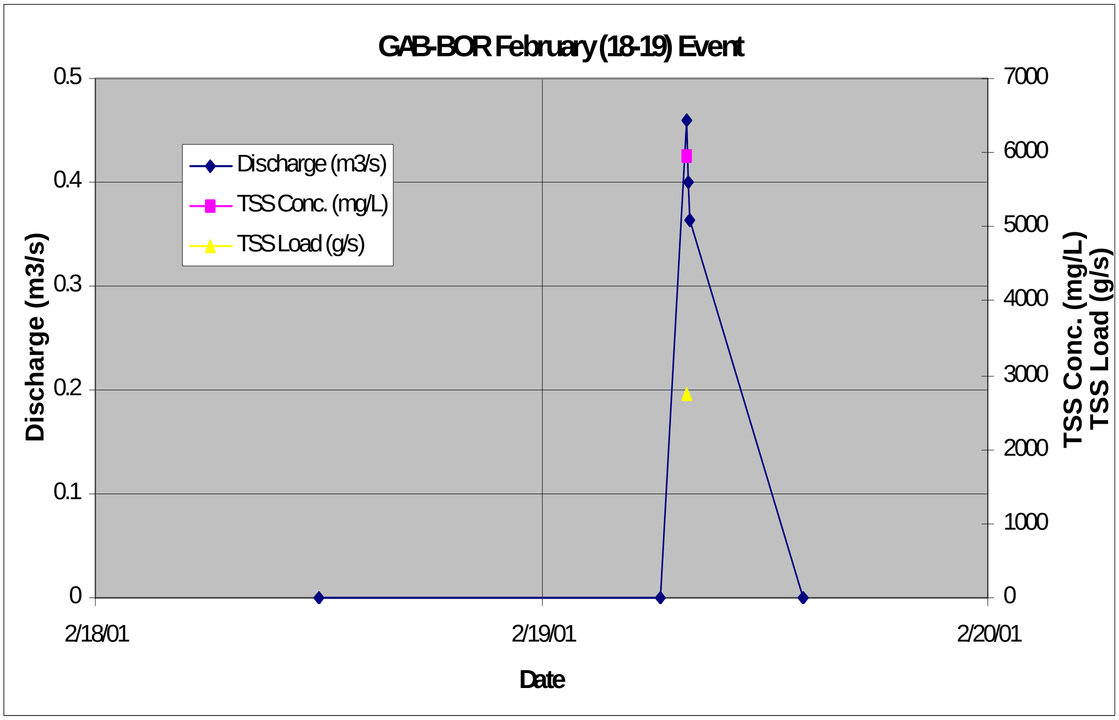
GAB-HER February (18-19) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
6000
5000
4000
3000
2000
1000
0
18 Feb 01
19 Feb 01
20 Feb 01
Date
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)



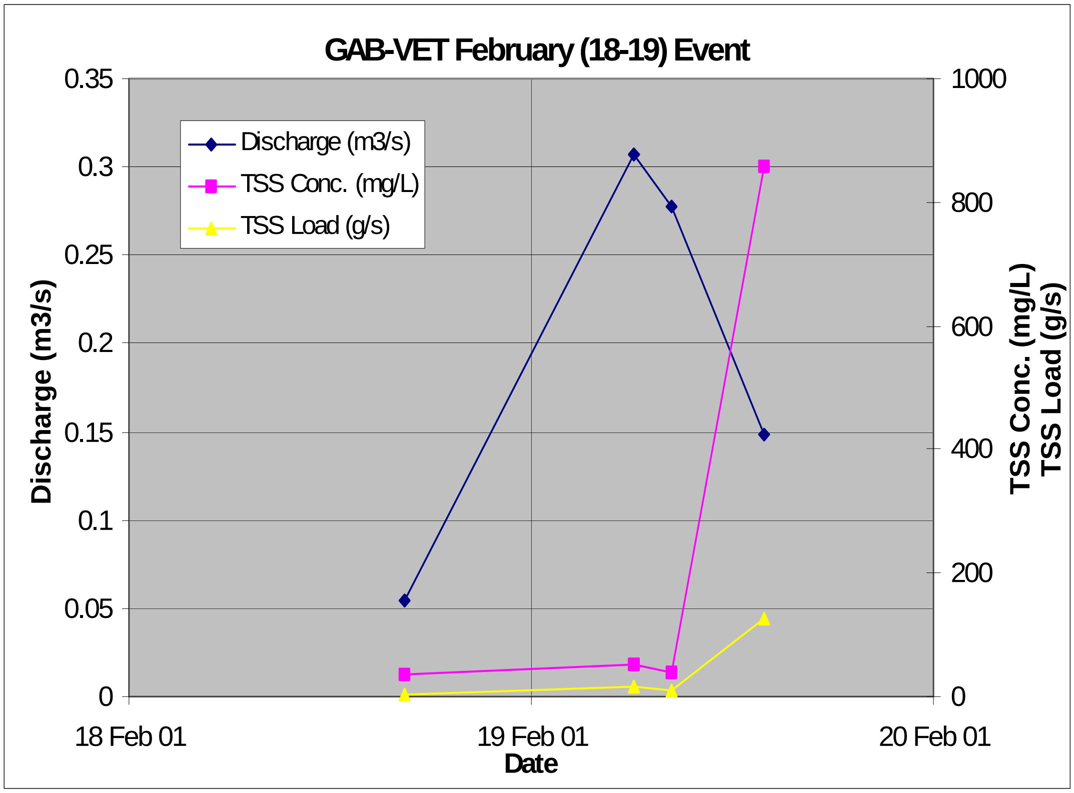
GAB-NAT February (18-19) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
8000
6000
4000
2000
0
18 Feb 01
19 Feb 01
20 Feb 01
Date
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)



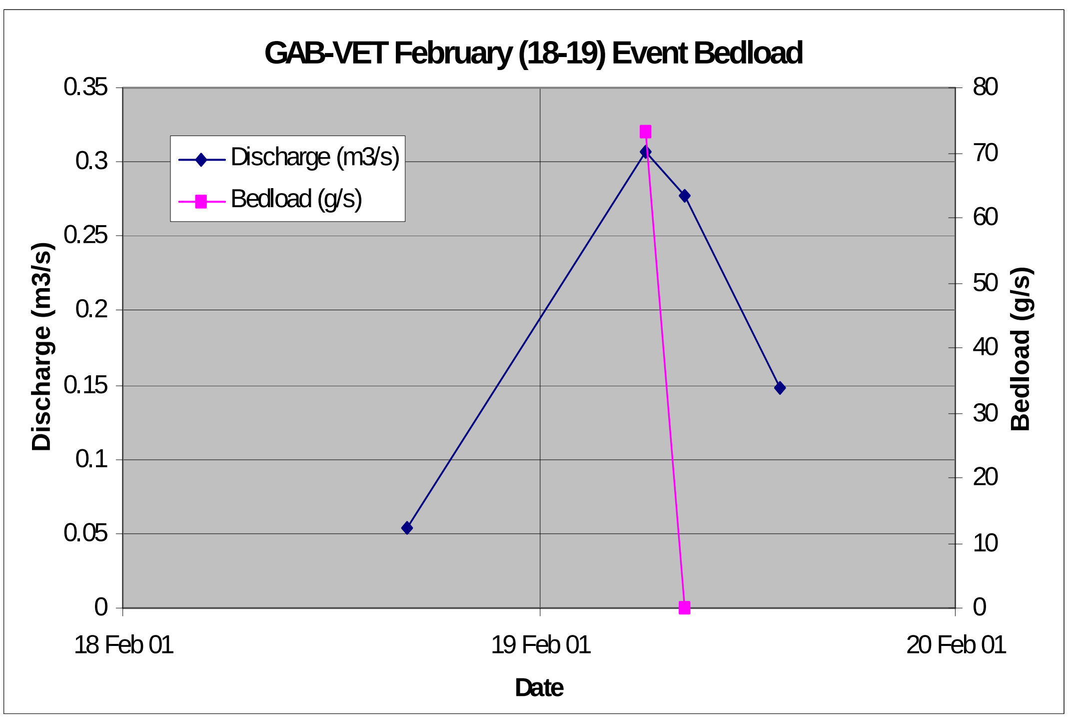
GAB-NAT February (18-19) Event Bedload
Discharge (m3/s)
Bedload (g/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
800
700
600
500
400
300
200
100
0
18 Feb 01
19 Feb 01
20 Feb 01
Date
Discharge (m3/s)
Bedload (g/s)



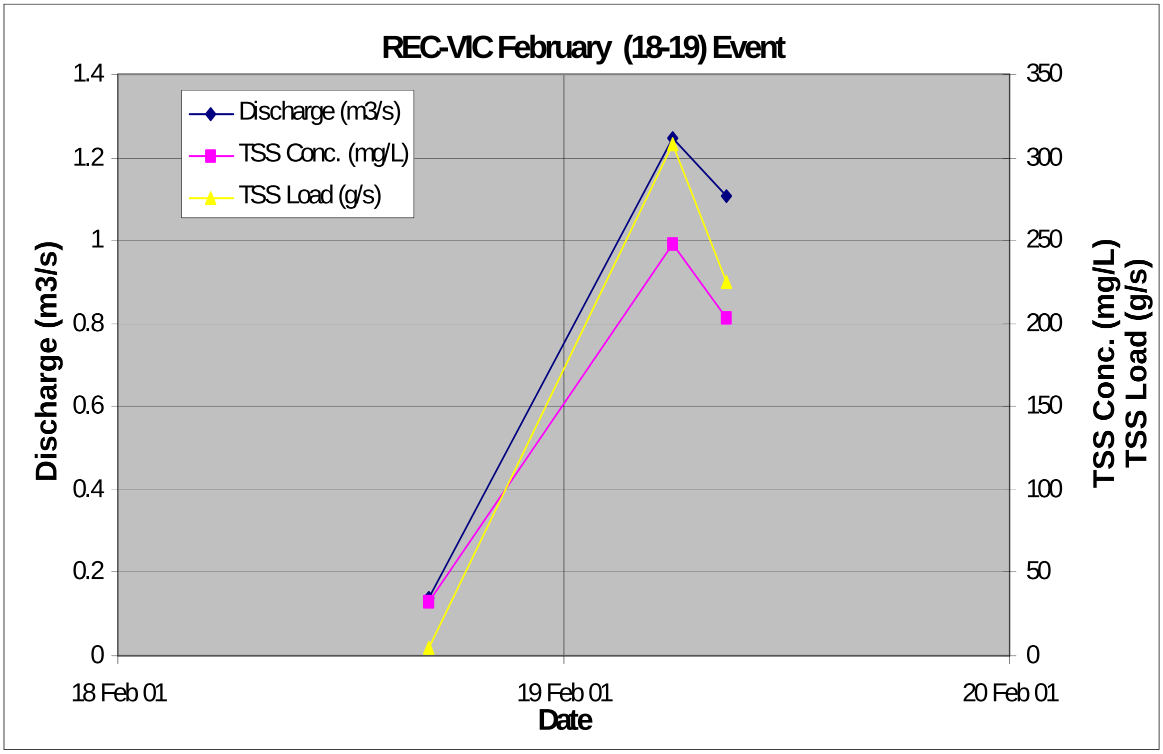
GAB-BOR February (18-19) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.5
0.4
0.3
0.2
0.1
0
7000
6000
5000
4000
3000
2000
1000
0
TSS Conc. (mg/L)
TSS Load (g/s)
2/18/01
2/19/01
2/20/01
Date

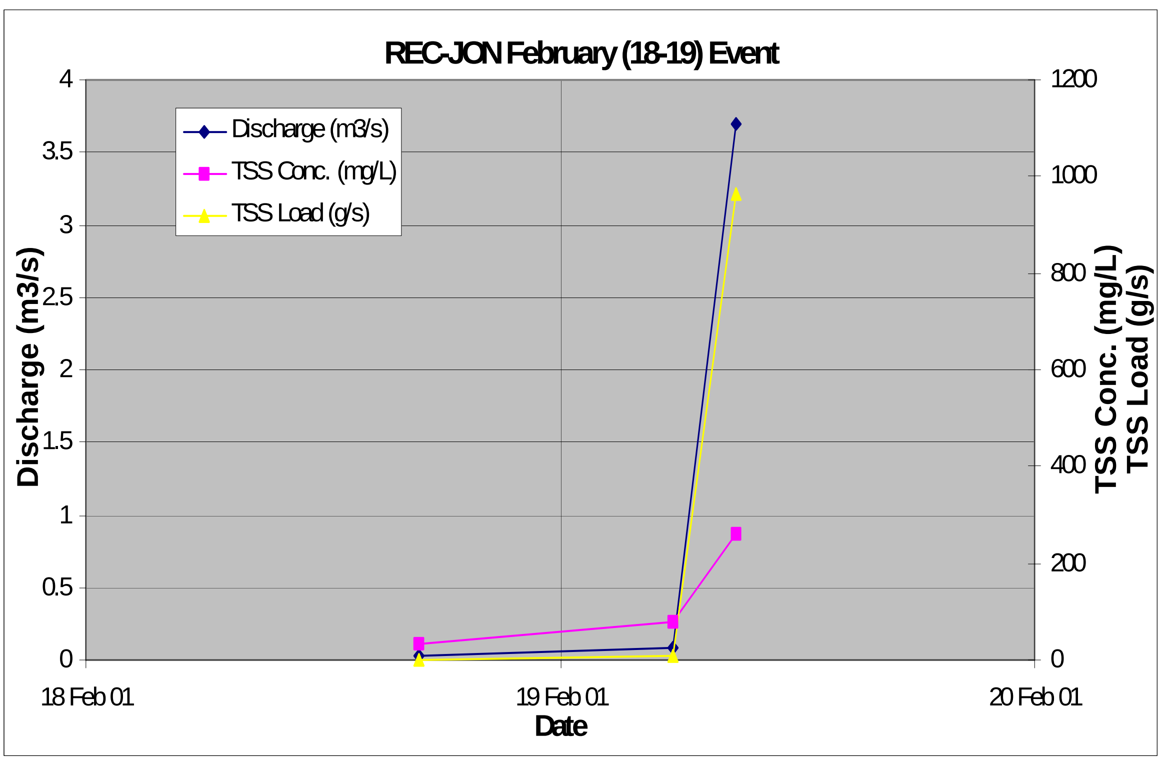


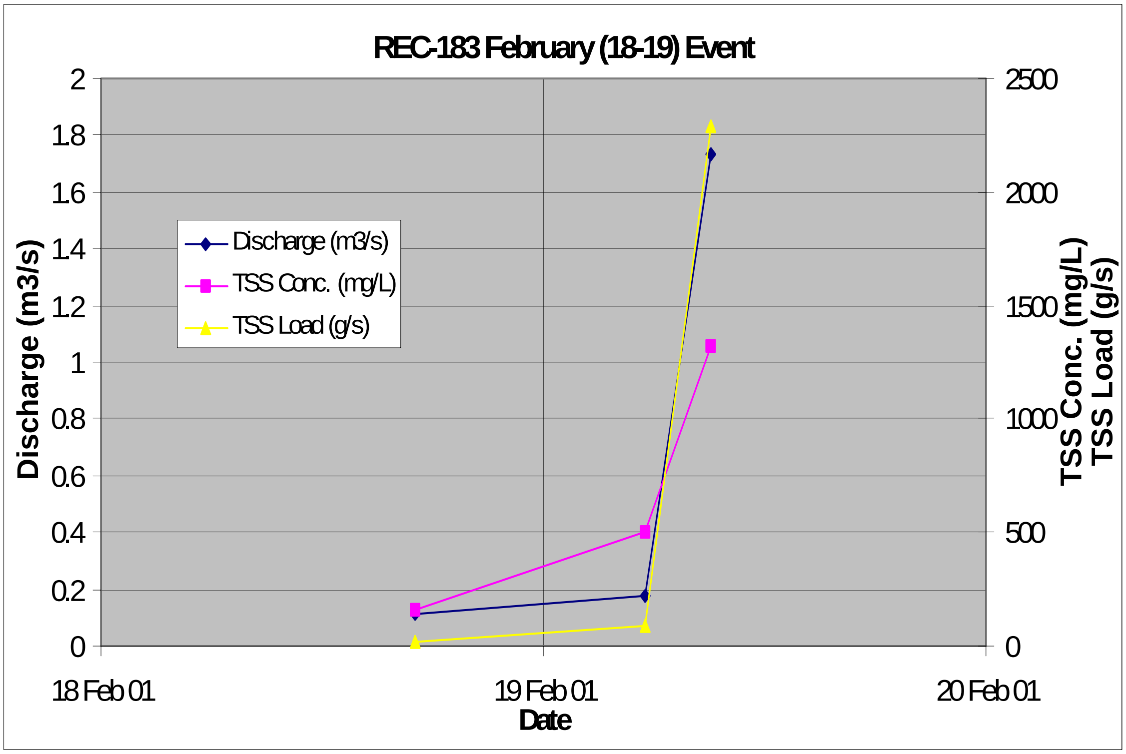
GAB-VET February (18-19) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1000
800
600
400
200
0
18 Feb 01
19 Feb 01
20 Feb 01
Date



GAB-VET February (18-19) Event Bedload
Discharge (m3/s)
Bedload (g/s)
Discharge (m3/s)
Bedload (g/s)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
80
70
60
50
40
30
20
10
0
18 Feb 01
19 Feb 01
20 Feb 01
Date


REC-VIC February (18-19) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
350
300
250
200
150
100
50
0
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
18 Feb 01
19 Feb 01
20 Feb 01
Date


REC-JON February (18-19) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
4
3.5
3
2.5
2
1.5
1
0.5
0
1200
1000
800
600
400
200
0
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
18 Feb 01
19 Feb 01
20 Feb 01
Date


REC-183 February (18-19) Event
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)
Date
18 Feb 01
19 Feb 01
20 Feb 01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
500
1000
1500
2000
2500
Discharge (m3/s)
TSS Conc. (mg/L)
TSS Load (g/s)