Suspended sediment monitoring in the Motueka catchment: data report to 30 June 2004

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Prepared for

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Jeremy Walsh Ross Woods

Executive Summary

Turbidity sensors and auto-samplers were initially installed at three sites in the Motueka Catchment for the Integrated Catchment Management Programme. These sites are on the Motueka at Woodman's Bend (representing the discharge to the coast), the Motupiko at Christies (representing the 'East Bank' tributaries draining the Moutere Gravels terrain), and the Wangapeka at Walter Peak (representing the 'West Bank' tributaries draining the granitic terrain). Records commenced in mid November 2002, and a continuous record of turbidity has been compiled at each site since then. In April 2004 the Motueka at Gorge site was also added to the programme (representing the steep/mountainous, relatively high rainfall terrain underlain by old sedimentary and ultramafic basement rocks that typify the south-eastern Motueka River headwaters).

Auto-samples collected since December 2002, for the initial three sites, have enabled calibration relationships to be established that relate turbidity to suspended sediment concentration (SSC). Samples collected in the last year have increased the amount of data available for calibration at these sites, and have enabled an initial calibration of the Motueka at Gorge site.

Depth-integrated suspended sediment gaugings during flood runoff events completed up until June 2004 include: one at Motupiko at Christies and two at Wangapeka at Walter Peak. Three additional depth-integrated suspended sediment gaugings were also completed at both of the Motueka River sites in August 2004. At the Motupiko site, the discharge-weighted cross-section average SSC (77.0 mg/l) was a factor of 1.14 larger than the average auto-sampled concentration over the same time period. At the Wangapeka site, the discharge-weighted cross-section average SSCs (320 and 204 mg/l) were 0.85 to 0.89 times the matching auto-sampled concentrations.

1. Background

In the 2002/2003 year, suspended sediment monitoring commenced at three stations in the Motueka Cathment to provide improved information on river suspended loads to the Integrated Catchment Management (ICM) Programme. The sites are on the Motueka mainstem at Woodman's Bend (representing the discharge to the coast), the Motupiko at Christies (representing the 'East Bank' tributaries draining the Moutere Gravels terrain), and the Wangapeka at Walter Peak (representing the 'West Bank' tributaries draining the granitic terrain). In April 2004, the Motueka at Gorge site was also added to the programme (representing the steep/mountainous, relatively high rainfall terrain underlain by old sedimentary and ultramafic basement rocks that typify the south-eastern Motueka River headwaters).

The aim of the data collection is to compile continuous records of suspended sediment concentration (SSC) and to determine the particle size distribution of the suspended load during a representative event for all four sites. The SSC records will be used to compute sediment loads during runoff events and long-term yields.

The measurement strategy has three main components:

- to continuously record back-scatter-type turbidity as a surrogate for SSC
- to collect samples using automatic samplers in order to compile calibration relationships between turbidity and SSC beside the sensors
- to collect a series of depth-integrated samples at multiple verticals so that
    1. the auto-sampled SSC can be related to cross-section concentration, and
    2. the particle size distribution of the suspended load can be sampled.

This report describes the installations, the data that has been collected as far as 30 June 2004, and the turbidity/suspended sediment concentration relationships developed.

2. Instrumentation

At all four sites, the basic instrumentation includes a data-logger, a turbidity sensor, a stage sensor, and an automatic sampler. Site-specific instrumentation is detailed in Appendix 1. The Motueka at Woodman's Bend instrumentation was integrated with Tasman District Council's water level recorder installation, and so can be accessed via their telemetry operation. The installations at the Motupiko, Wangapeka and Motueka at Gorge are stand-alone systems, and turbidity data from these sites are down-loaded from the data-loggers manually during field visits.

The installations are shown on Figures 1.1 to 1.4.

Figure 1.1: Motupiko at Christies. On top photograph, centre box holds auto-sampler battery while white box holds data-logger. On bottom photograph, turbidity sensor is to left of staff gauge, auto-sampler intake pipe is to right.

Figure 1.2: **Wangapeka at Walter Peak. The turbidity sensor and stage sensor are in the white plastic tube. The auto-sampler intake hose runs through the steel pipe several metres downstream.**

Figure 1.3: **Motueka at Woodman's Bend (before installation). The sensors and auto-sampler intake are fixed to the rip-rap; the auto-sampler sits on the bank; the data is cabled to a data-logger housed in a hut to the right of the picture.**

Figure 1.4: Motueka at Gorge. On top photograph, grey box holds battery and data-logger. On bottom photograph, turbidity sensor is hidden within grey plastic tube, while steel pipe is linked to auto-sampler.

The instrumentation package was rigged, programmed, and tested by Dave Johnstone and Hamish Chisholm, NIWA Instrument Services, Christchurch. Installation was carried out by Hamish Chisholm, with assistance from Rob Merrilees and Ralph Dickson from NIWA Nelson.

The stage sensor record is used by the data-logger to provide a running total of water discharge so that the auto-samplers can be activated on a flow-proportional basis once a threshold stage is passed. A simulation program was used with several years of water discharge record from each site to determine appropriate threshold values for the activation stage and discharge volume (Appendix 2).

Turbidity and stage are logged every 15 minutes. The turbidity sensors are of the nephelometric/back-scattering type. They are equipped with a small water pump which regularly squirts a jet of water over the lens to inhibit bio-fouling.

The sites were activated on the following dates:

- Motueka at Woodman's Bend: 23 November 2002
- Motupiko at Christies: 18 November 2002
- Wangapeka at Walter Peak: 19 November 2002
- Motueka at Gorge: 6 April 2004

3. Field procedures, laboratory analyses, and data archiving

Field procedures are detailed in Appendix 2.

A procedure was developed during the year for selecting which auto-samples to analyse for SSC in the laboratory. While it would be ideal to analyse every auto-sample collected, the budget prevents this, and so only a selection of samples are processed. The selection process for each batch of auto-samples involves first inspecting the matching raw turbidity sensor record. If the record appears sensible (i.e., it is not corrupted by fouling and is in phase with the stage record), then usually only a small sub-set of samples are kept for analysis, covering the range of turbidity encountered while the batch was collected. This quasi-regular collection of a few samples allows us to track any drift in the SSC vs turbidity relationship. If, however, the turbidity range extends higher than previously recorded and auto-sampled, then most of the samples from the higher range are processed in order to extend the calibration relationship. If the turbidity record appears to be erroneous, then most of the samples are processed in order to create a SSC record directly from the auto-samples.

For archiving, in brief, the turbidity record is archived in raw form onto a TIDEDA file (Turbidity_raw.mtd), along with a record of stage and discharge. The master stage and discharge record is that from the existing TDC recorders and their current stage-discharge ratings. Raw data are archived under the site numbers given in Table 3.1.

Table 3.1: Archive details for raw Motueka turbidity sites (Turbidity_raw.mtd)

Site	Parameter	Site No.	Item
Motueka at Woodmans Bend	Stage	57015	1
	Discharge	”	2
	Turbidity	5701502	1
	Bottle No.	”	2
Motupiko at Christies	Stage	57036	1
	Discharge	”	2
	Turbidity	5703602	1
	Bottle No.	”	2
Wangapeka at Walter Peak	Stage	57025	1
	Discharge	”	2
	Turbidity	5702502	1
	Bottle No.	”	2
Motueka at Gorge	Stage	57008	1
	Discharge	”	2
	Turbidity	5700802	1
	Bottle No.	”	2

The raw data in Turbidity_raw.mtd is copied to a data processing Tideda file for processing of the turbidity data, and the derivation of the SSC time series for each site. This Tideda file (Turbidity_working.mtd) contains the parameters and site numbers summarised in Table 3.2. The SSC results from the auto-sampler samples are compiled into an Excel table (Sensor calibrations_0304.XLS).

The site numbers for the derived SSC time series, where auto-sample data have been used to fill gaps and ‘tie down’ flood peaks, are 5701511, 5703611, 5702511 and 5700811 for Motueka at Woodmans, Motupiko at Christies, Wangapeka at Walter Peak and Motueka at Gorge, respectively.

Table 3.2: Archive details for the Motueka turbidity sites (Turbidity_working.mtd)

Site	Site No.	Item	Parameter	Processing
Motueka at Woodmans Bend	57015	1	Stage	None
	”	2	Discharge	None
	5701502	1	Turbidity	Spikes, bio-fouling & bad data removed
	”	2	Bottle No.	None
	5701509	1	Turbidity	Data ramped
	5701508	1	SSC	Site 5701509 converted to SSC (See Sect 5.1)
	5701511	1	SSC	Auto-sample data used, where available, to fill gaps & ‘refine’ events
Motupiko at Christies	57036	1	Stage	None
	”	2	Discharge	None
	5703602	1	Turbidity	Spikes, bio-fouling & bad data removed
	”	2	Bottle No.	None
	5703609	1	Turbidity	Data ramped
	5703608	1	SSC	Site 5703609 converted to SSC (See Sect 5.3)
	5703611	1	SSC	Auto-sample data used, where available, to fill gaps & ‘refine’ events
Wangapeka at Walter Peak	57025	1	Stage	None
	”	2	Discharge	None
	5702502	1	Turbidity	Spikes, bio-fouling & bad data removed
	”	2	Bottle No.	None
	5702509	1	Turbidity	Data ramped
	5702508	1	SSC	Site 5702509 converted to SSC (See Sect 5.2)
	5702511	1	SSC	Auto-sample data used, where available, to fill gaps & ‘refine’ events
Motueka at Gorge	57008	1	Stage	None
	”	2	Discharge	None
	5700802	1	Turbidity	Spikes, bio-fouling & bad data removed
	”	2	Bottle No.	None
	5700809	1	Turbidity	Data ramped
	5700808	1	SSC	Site 5700809 converted to SSC (See Sect 5.4)
	5700811	1	SSC	Auto-sample data used, where available, to fill gaps & ‘refine’ events

4. Summary of data collected to 30 June 2004

The recorded turbidity, turbidity auto-samples and depth-integrated suspended sediment gaugings, available up to 30 June 2004, are summarized in Table 4.1.

At Wangapeka, while many auto-samples were triggered during the June 29 – 2 July 2003 event, only one was captured in bottles as a rat had moved into the sampler and chewed through a vital hose. This helps explain the significantly lower number of auto-samples collected at Wangapeka, compared to the other two sites also operating during this event.

Table 4.1: Turbidity data details for Motueka sites

Site	Turbidity time series	Auto-samples	Depth-integrated SS gaugings
Motueka at Woodmans Bend	23-Nov-02 to 30-Jun-04 gap	146 over 11 events	2
Motupiko at Christies	18-Nov-02 to 30-Jun-04	128 over 14+ events	1
Wangapeka at Walter Peak	19-Nov-02 to 30-Jun-04	63 over 16+ events	-
Motueka at Gorge	6-Apr-04 to 30-Jun-04	38 over 5 events	-

5. Derivation of suspended sediment concentration (SSC) time-series data

The water discharge and turbidity time series records up to 30 June 2004 are shown in Sections 5.1 to 5.4 for the four turbidity sites. These sections describe, for each site, the calibration of the sensor and the conversion of the turbidity data into a suspended sediment concentration (SSC) time series by applying calibration relationships.

The water discharge records are from the Tasman District Council. The turbidity data are raw values in NTU. The raw turbidity records contain single-value spikes generated during low flows (usually due to leaf litter around the sensor) and sometimes show drift relating to bio-fouling of the sensor (up to 20 NTU in places). Some sites also seem to have problems with siltation around the time of flood peaks and during the flood recession. This has been observed at times when the concentration of auto-samples, collected during flood events, have peaked and are starting to decrease in concentration while the recorded turbidity is still increasing (or it becomes erratic). This has resulted in some auto-samples with high SSC not being able to be used in the derivation of calibration relationships, as the turbidity data relating to the same time period is unreliable. Gaps have been inserted in the turbidity time series when this occurs.

Where possible, data spikes and drift were removed from the turbidity data before conversion to SSC records using Tideda editing processes. For the derived SSC time series, gaps in the record occurring during flood events (as a result of instrument malfunction, siltation, etc) were filled, where possible, with auto-sample data to provide a continuous time series.

5.1. Motueka at Woodmans Bend

The water discharge and raw turbidity time series from 23 November 2002 to 23 July 2004 are shown in Figure 5.1. This raw turbidity data was edited to remove spikes and drift, likely to have been caused by bio-fouling or silting up of the turbidity sensor. In places, drift of up to 17 NTU occurred. This was particularly noticeable around April to July 2004.

Initially, the auto-sampler was set to collect water samples once a threshold volume of 1.0 million m^3 was reached. In 2003, the trigger volume was increased from 1 to 1.5 million m^3 to reduce the number of samples, after 58 samples were collected for the 29 June to 2 July 2003 event. This led to a total of 146 auto-samples being collected over 11 events between 29 June 2003 and 20 June 2004.

Once laboratory analyses determined the SSC (mg/l) of each auto-sample, the data was compared against the recorded turbidity at the time that the auto-sample was collected. Unfortunately, auto-sample data collected from the 7 to 13 May 2004 appeared to be incorrect since the auto-sample concentrations did not follow the trend of the turbidity or stage/flow data. This data has therefore been excluded from the analyses. The remaining data (137 auto-samples for 10 events) is plotted in Figure 5.2

The *SSC* vs *NTU* relationship (Figure 5.2) was first inspected for signs of drift – i.e., a systematic shift in the relationship with time that might result from instrument drift. While scatter occurred among the data from various events, which we assume was associated with variations in suspended sediment particle size, no systematic drift was detected. Thus a best-fit line was fitted to all of the data to date. The relationship derived was:

$$SSC = 0.000010\,(NTU)^3 + 0.00186\,(NTU)^2 + 1.113\,(NTU)$$

We note that the relationship has some curvature, despite the expected linear response of the Greenspan turbidity sensor. We believe that this reflects the effect of a slight overall fining of sediment particle size as sediment concentration increases at the site (for a given SSC, the sensors indicate a higher NTU value for finer sediment).

This relationship was used to convert the edited turbidity time series (*NTU*) into a suspended sediment concentration (SSC) time series. The resulting suspended sediment concentration time series is shown in Figure 5.3.

Several gaps (81 days in total) occur in the turbidity records over the period:

- 8-19 April 2003. This was due to the data-logger filling its memory. Procedures have been altered to ensure that this does not reoccur. No runoff events occurred over this 11 day period, so the gap is of no consequence.

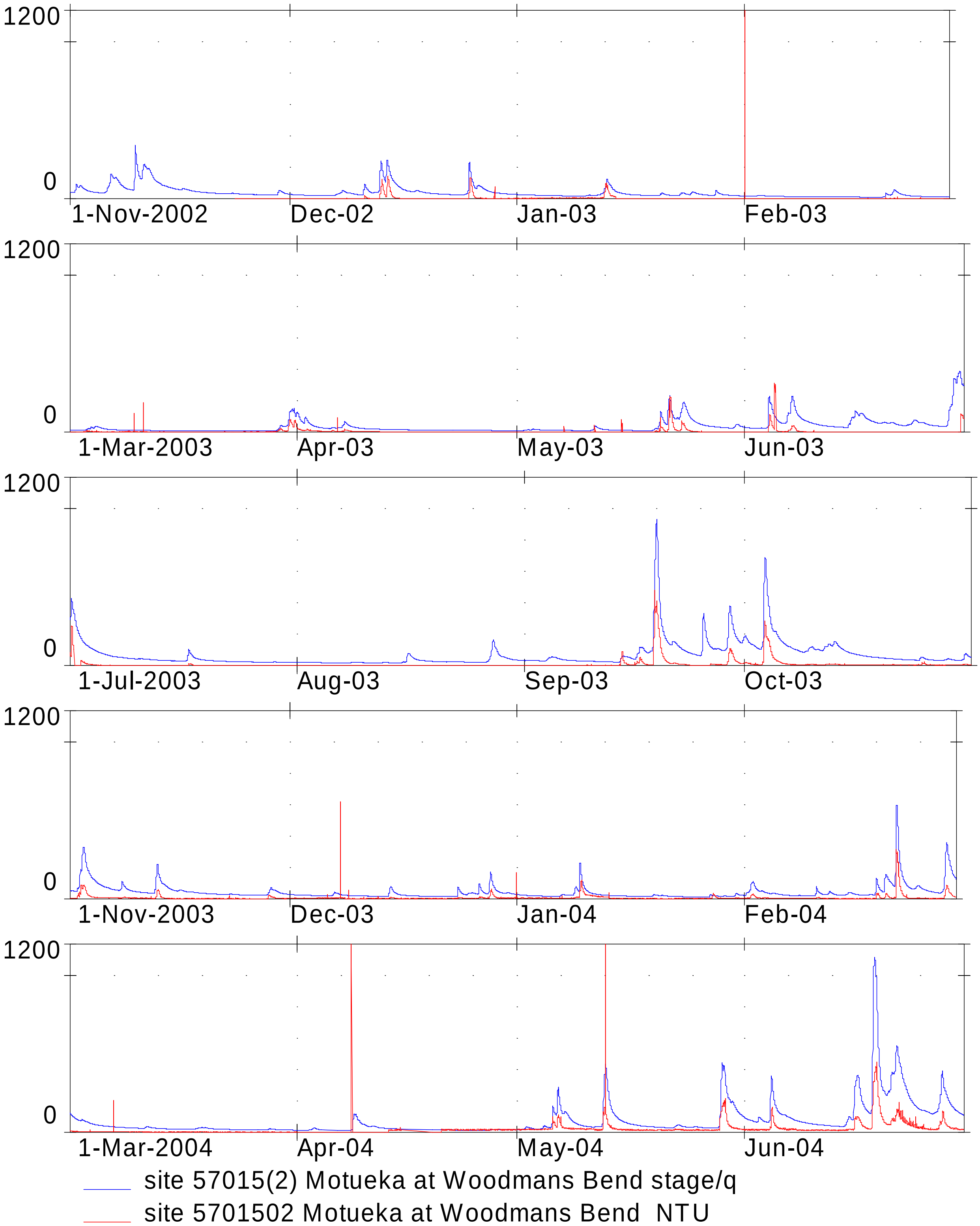
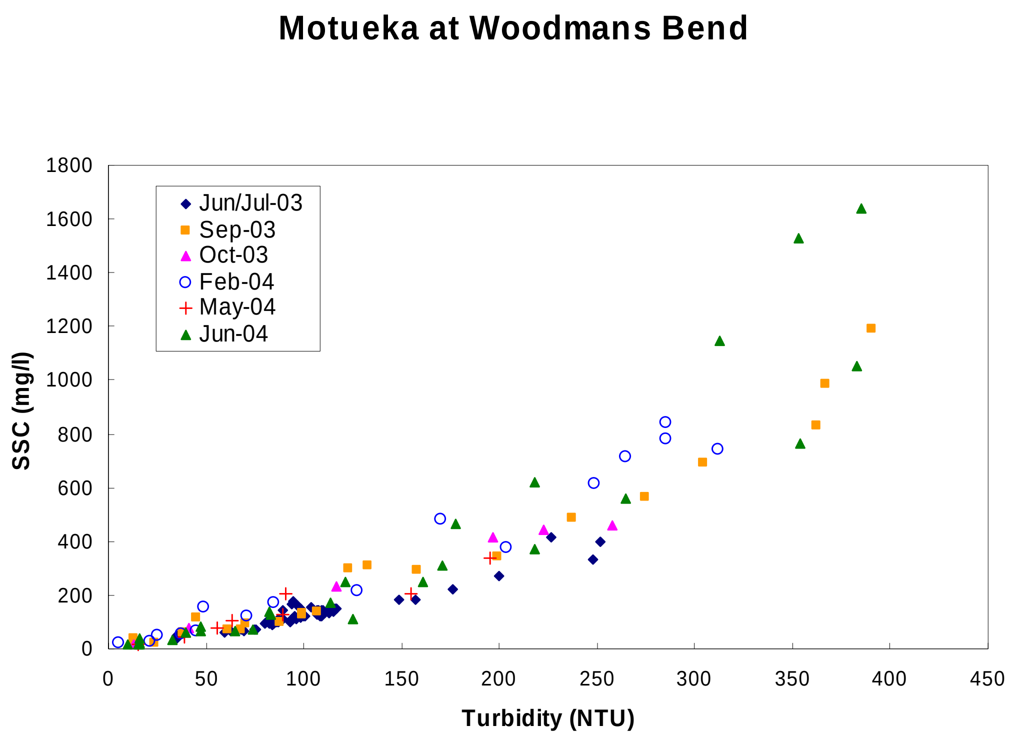


Figure 5.1: Water discharge (blue, in m^3/s) and raw turbidity (red, in NTU) records to 30 June 2004 at Motueka at Woodman's Bend.



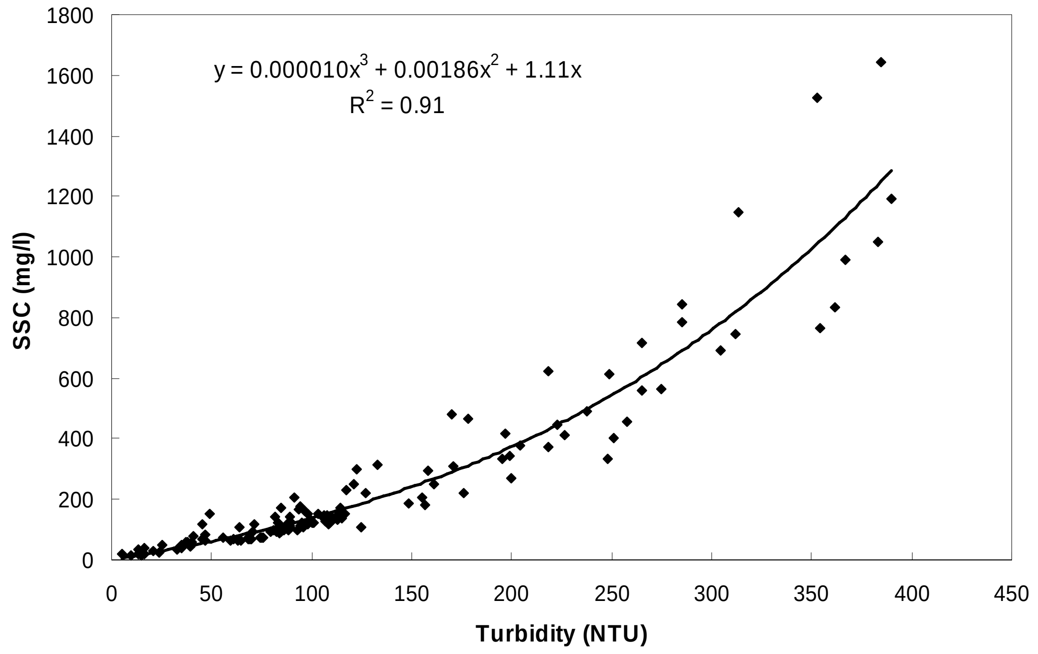


Figure 5.2: **Measured auto-sample SSC versus recorded turbidity for Motueka at Woodman's Bend (bottom figure shows derived relationship between turbidity and SSC).**

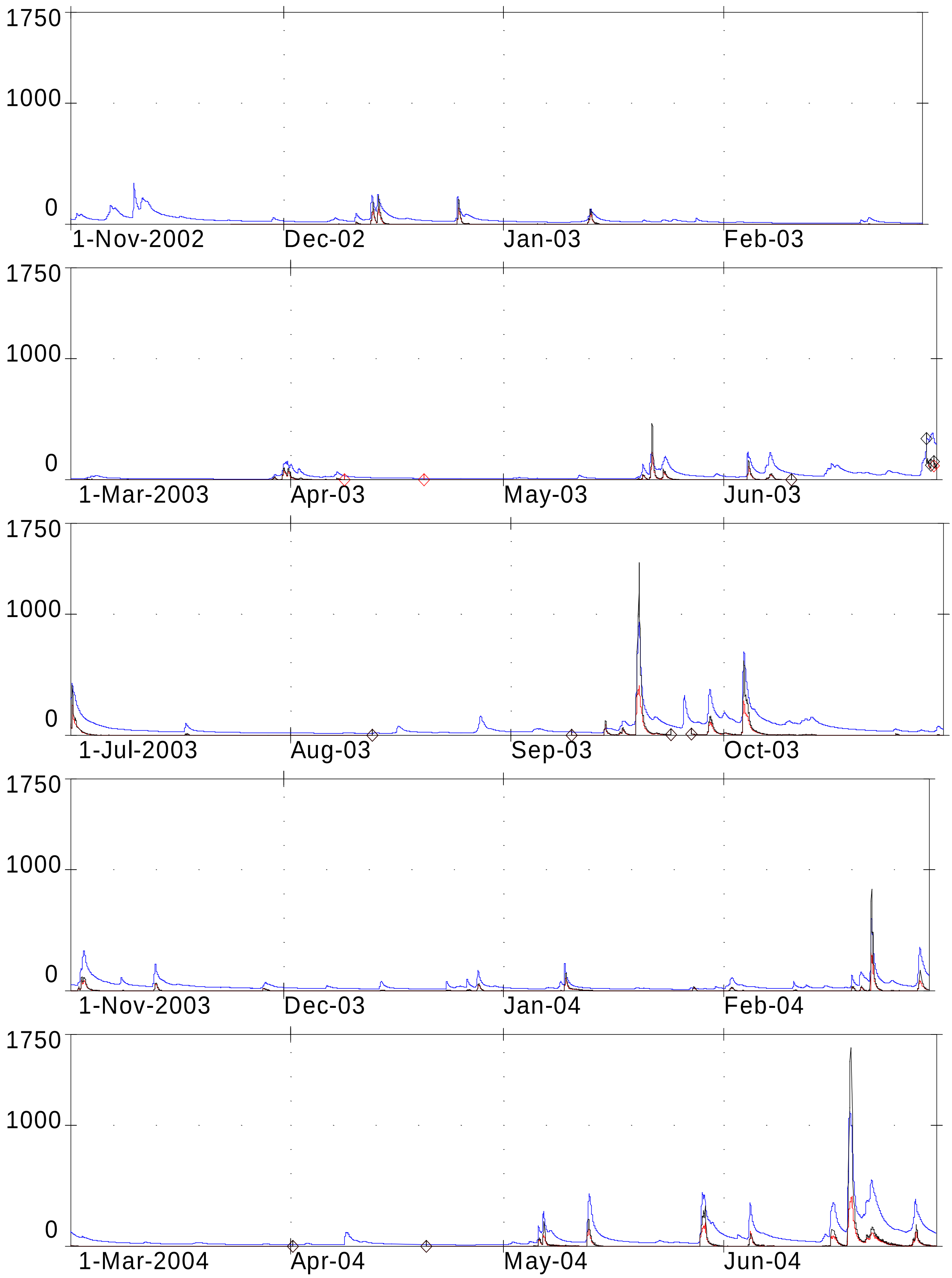


Figure 5.3: **Comparison of derived SSC (black, mg/l), edited turbidity (red, NTU) and raw water discharge (blue, m^3/s) for Motueka at Woodmans Bend**

- 10-30 June 2003. Instrument recording ‘0’ or erratic turbidity values.

- 12 August - 9 September 2003. Instrument recorded ‘-500’ NTU values[1].

- 23-26 September 2003. Instrument recorded ‘-500’ NTU values

- 1-20 April 2004. A spike, ‘0s’ and erratic data.

Of these gaps, only the 8-19 April 2003 gap can be safely removed for the SSC time series on the basis of no events. A small part of the 10-30 June 2003 gap was removed by adding in auto-sample data. The derived SSC time series is shown in Figure 5.3, together with the edited turbidity data and flow data for the site. There are 69 days of data gaps in the SSC time series up to the end of June 2004.

To determine some of the characteristics of the sediment passing the Motueka at Woodmans Bend site, the derived SSC time series was plotted against flow (Figure 5.4). Looking at this data in detail, it was possible to determine that, for the two largest events, the rising limb of the flood event had a lower SSC than the falling limb, immediately after the peak. Figure 5.5 shows the SSC-flow relationship and SSC time series for the largest event, occurring on 18-19 June 2004. The higher SSC after the flood peak tends to suggest that the main sediment source is further upstream, rather than in the immediate vicinity of the site.

As Figure 5.4 demonstrates a reasonable SSC vs flow rating relationship, we suggest that this be used to develop synthetic SSC records to fill the gaps discussed above.

5.2. Wangapeka at Walter Peak

The water discharge and raw turbidity time series from 19 November 2002 to 19 July 2004 are shown in Figure 5.6. This raw turbidity data was edited to remove spikes and drift, likely to have been caused by bio-fouling or silting up of the turbidity sensor. In places, drift of up to 7 NTU occurred. This was particularly noticeable around late January-early February 2003.

Together with the recorded data, the auto-sampler collects water samples once a trigger threshold volume of 0.4 million m^3 is reached. This led to a total of 63 auto-samples being collected over 16+ events/time durations between 14 December 2002 and 19 June 2004.

[1] The data-logger is programmed to return a nonsense value such as –500 when the sensor over-ranges, such as due to leaf clutter.

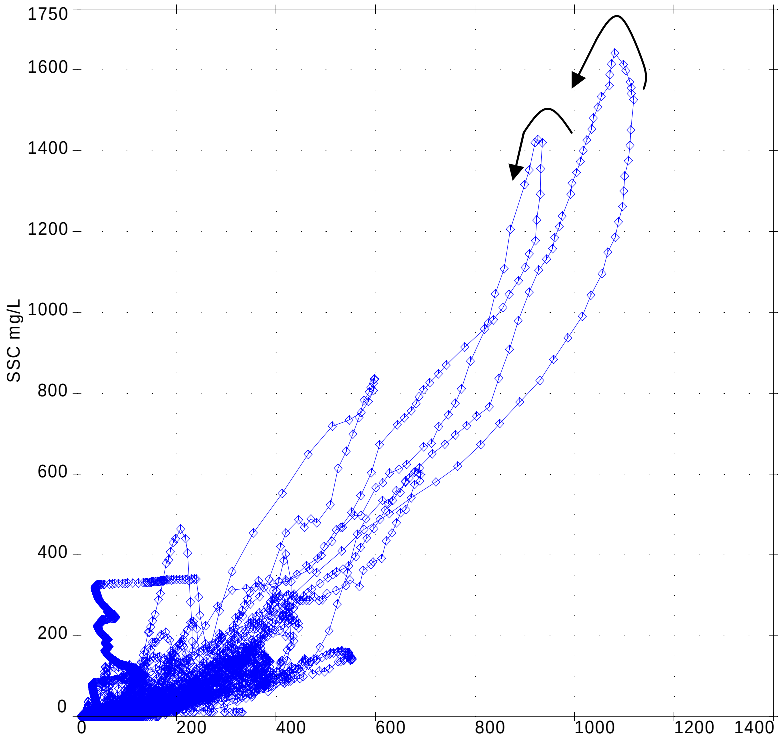


Figure 5.4: SSC versus flow (m^3/s) for Motueka at Woodmans Bend for 23 November 2002 to 30 June 2004.

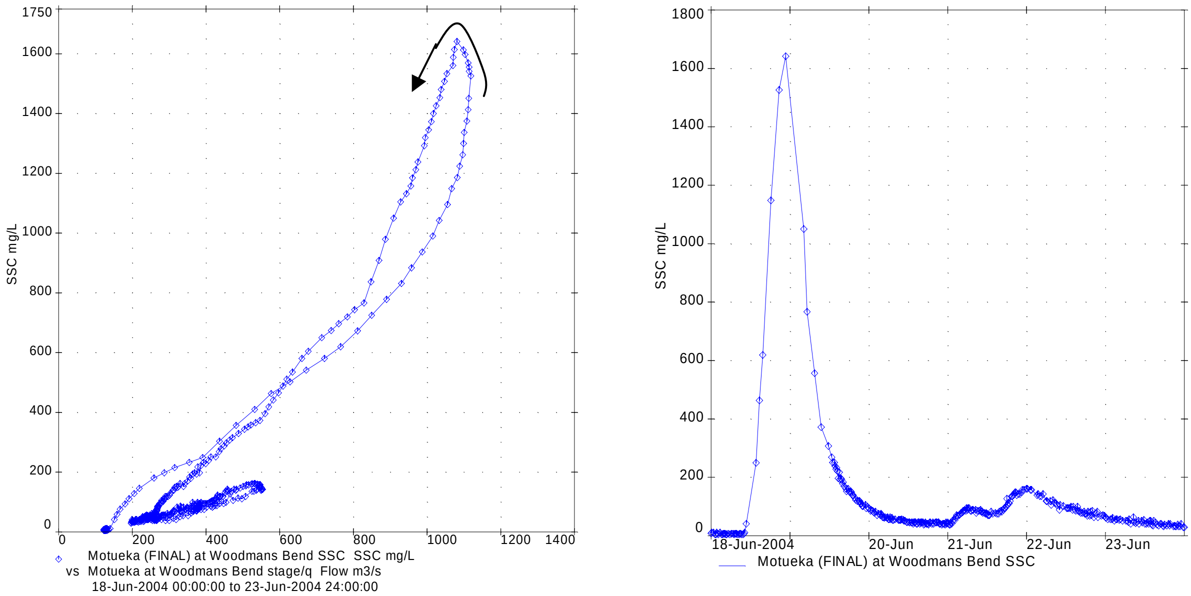


Figure 5.5: Left: SSC versus flow for Motueka at Woodmans Bend for 18 - 25 June 2004. Right: SSC time series for 18-25 June 2004.

Once laboratory analyses determined the SSC (mg/l) of each auto-sample the data was compared against the recorded turbidity at the time that sample was collected. Unfortunately some auto-sample data collected in December 2002, June 2003, September 2003, February 2004 and May 2004 could not be used in the calibration relating SSC to turbidity. This was generally where the auto-sample suspended sediment concentration (SSC) or turbidity record did not follow the trend of the stage/flow data. In this situation the data is excluded from the analyses. The remaining data is plotted in Figure 5.7

Again, the *SSC* vs *NTU* relationship (Figure 5.7) was first inspected for signs of drift. None was detected, and a best-fit line was fitted to all of the data to date. The relationship derived was:

$$SSC = 0.00476\left(NTU\right)^2 + 4.720\left(NTU\right)$$

We note that this relationship also has some curvature, which we believe reflects the effect of a slight overall fining of sediment particle size as sediment concentration increases at the site.

This relationship was used to convert the edited turbidity time series (*NTU*) into a suspended sediment concentration (SSC) time series. The resulting suspended sediment concentration time series is shown in Figure 5.8.

Only one gap of 10.25 hours was inserted in the turbidity, and resulting SSC, time series. This occurred during a small event on 26-27 January 2004, when the turbidity was considered high relative to the flow/stage.

To determine some of the characteristics of the sediment passing the Wangapeka at Walter Peak site, the derived SSC time series was plotted against flow (Figure 5.9). Looking at this data in detail, it was possible to determine that, for the two largest events, the rising limb of the flood event had a higher SSC than the falling limb. Figure 5.10 shows the SSC-flow relationship and SSC time series for the largest event, occurring on 18-19 September 2003. The lower SSC after the flood peak suggests that the main sediment source is in the immediate vicinity of the site.

As Figure 5.9 demonstrates a reasonable SSC versus flow rating relationship, we suggest that this be used to develop synthetic SSC record to fill the small gap discussed above.

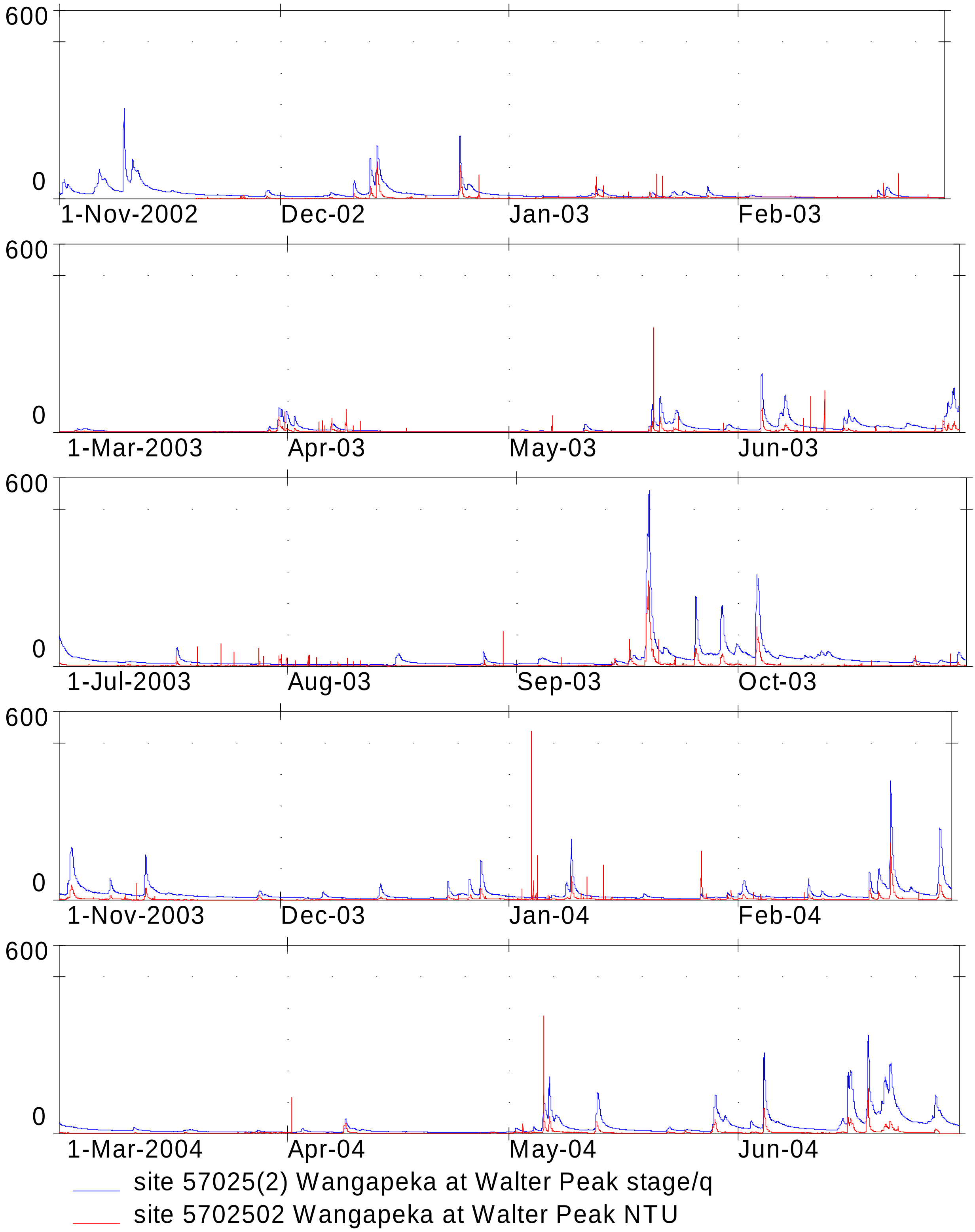
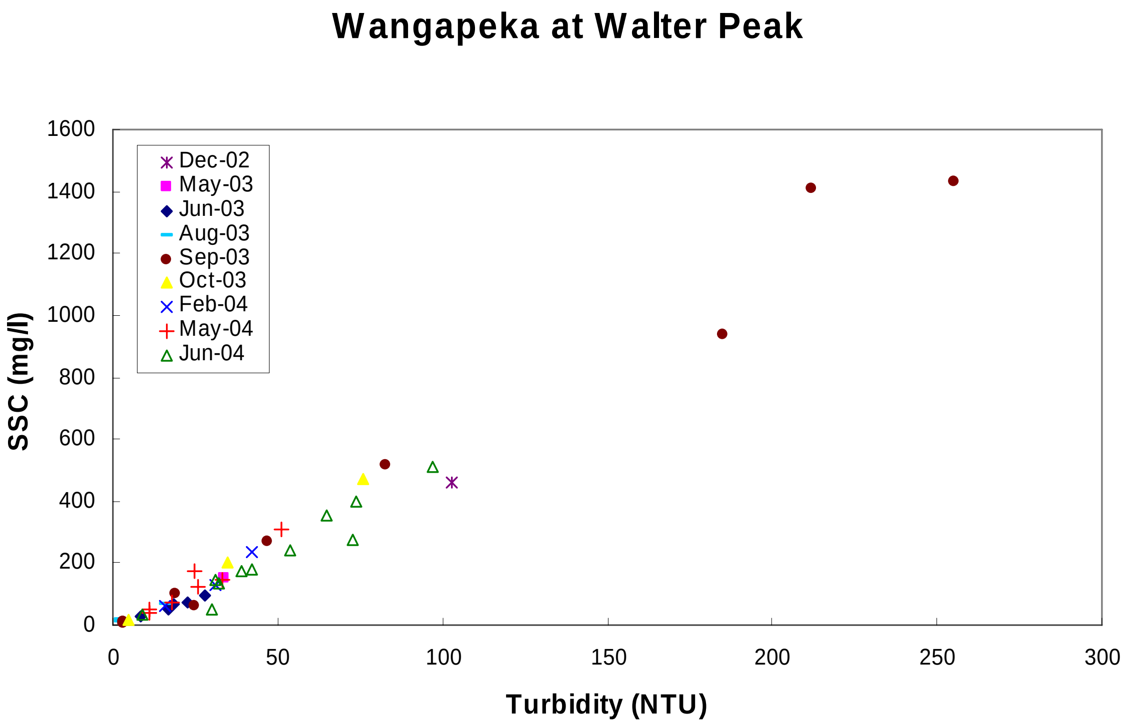


Figure 5.6: **Raw water discharge (blue, in m^3/s) and turbidity (red, in NTU) records to 30 June 2004 at Wangapeka at Walter Peak.**



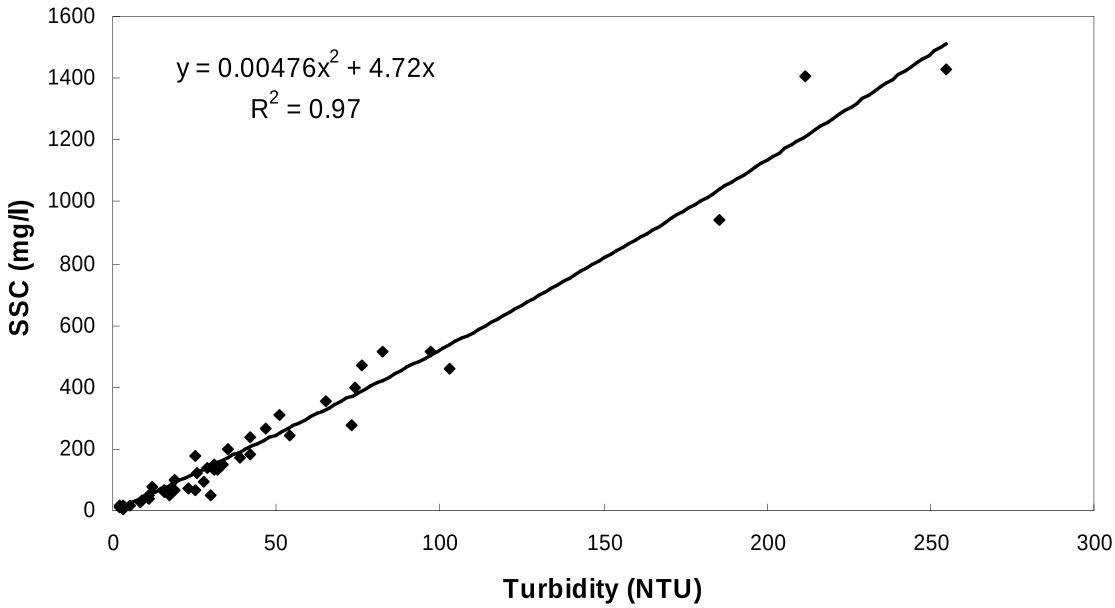


Figure 5.7: Measured auto-sample SSC versus recorded turbidity for Wangapeka at Walter Peak (bottom figure shows derived relationship between turbidity and SSC).

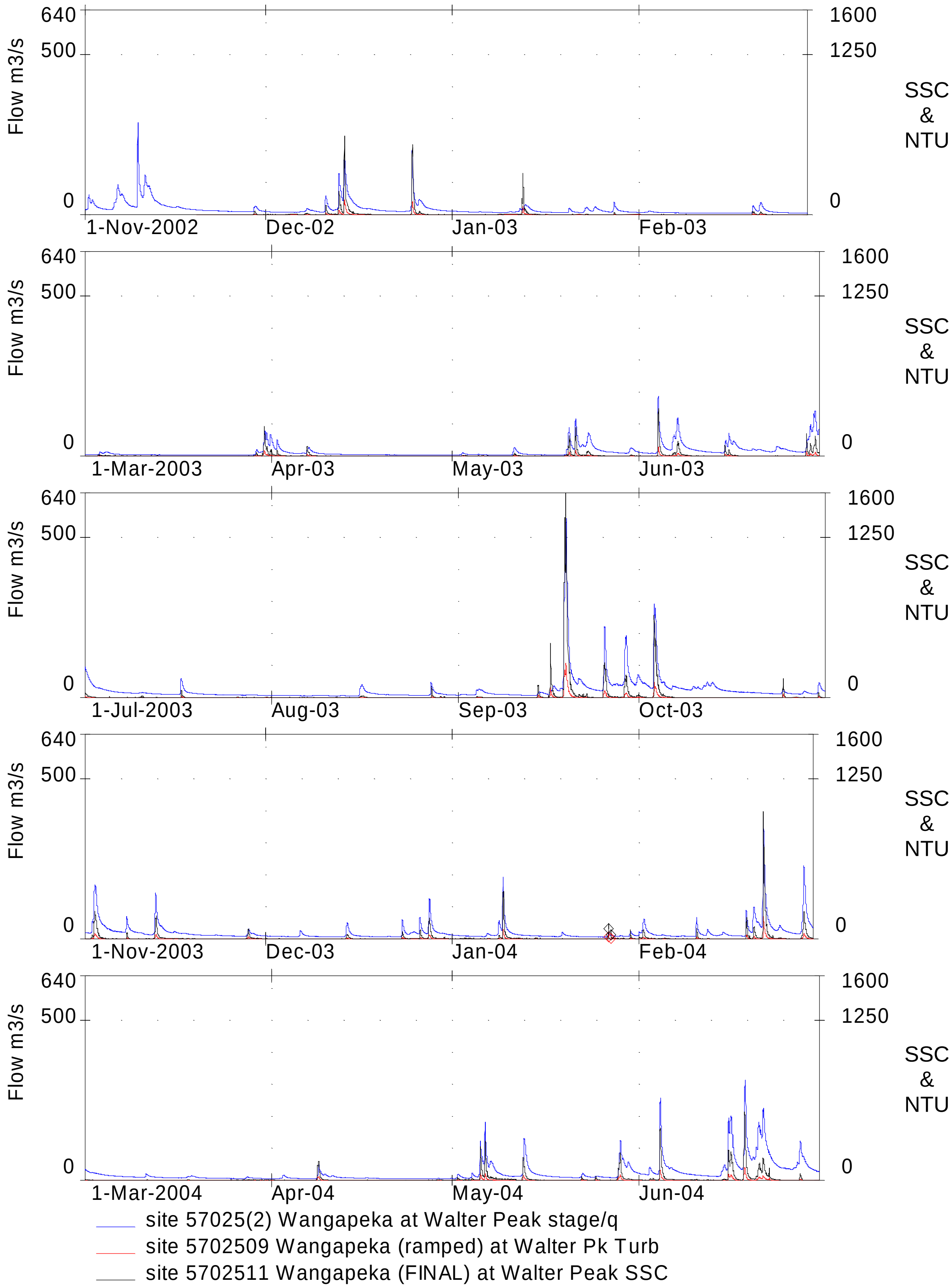


Figure 5.8: Comparison of derived SSC (black, mg/l), edited turbidity (red, NTU) and raw water discharge (blue, m^3/s) for Wangapeka at Walter Peak

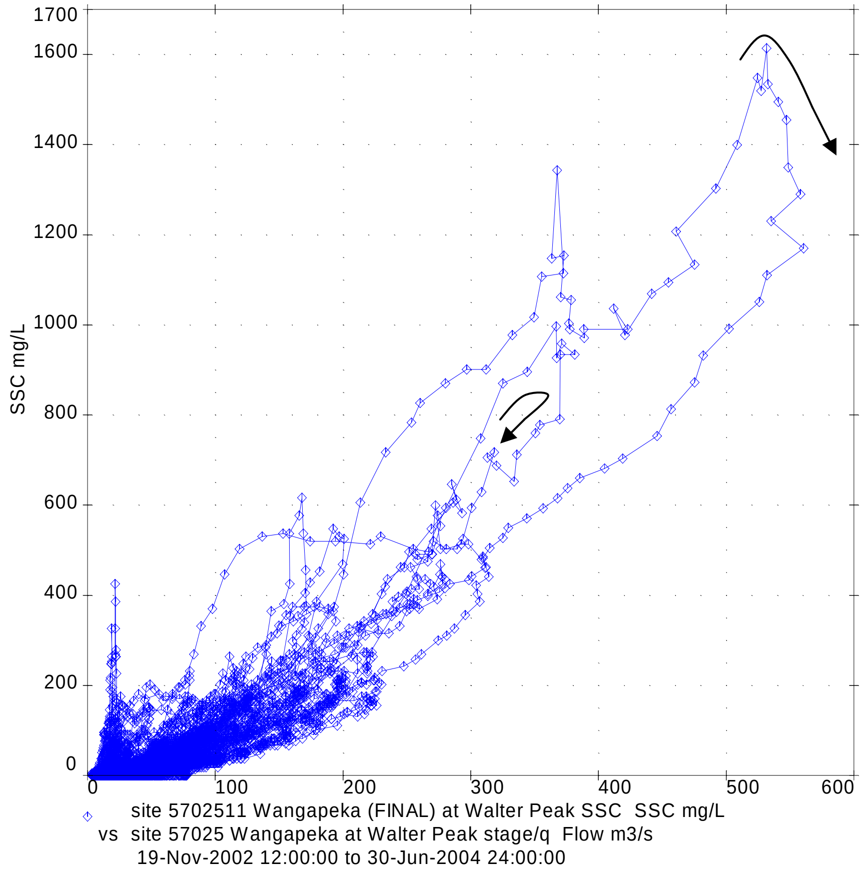


Figure 5.9: **SSC versus flow for Wangapeka at Walter Peak for 19 November 2002 to 30 June 2004.**

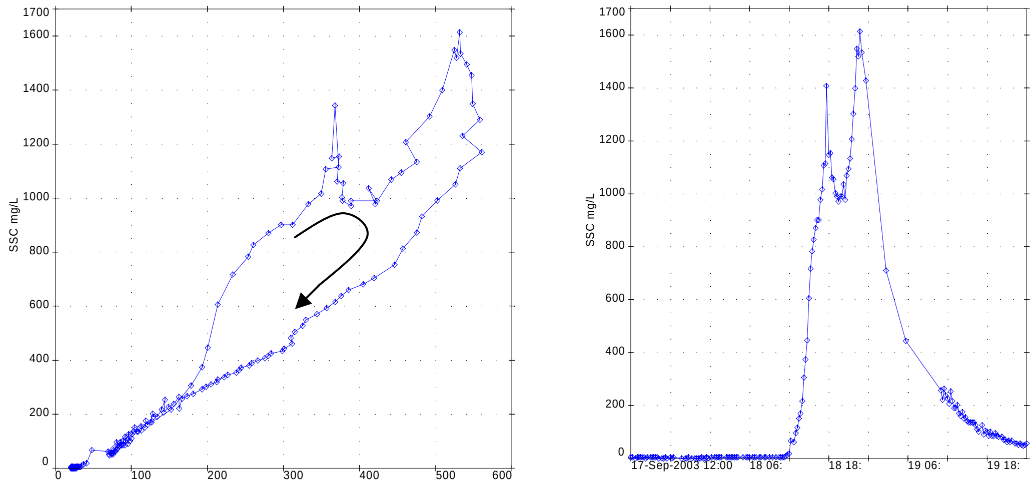


Figure 5.10: **Left: SSC versus flow for Wangapeka at Walter Peak for 17 - 19 September 2003. Right: SSC time series for 17 - 19 September 2003.**

5.3. Motupiko at Christies Bridge

The water discharge and raw turbidity time series from 18 November 2002 to 18 July 2004 are shown in Figure 5.11. This raw turbidity data was edited to remove spikes and drift, likely to have been caused by bio-fouling or silting up of the turbidity sensor. This turbidity record has some particularly bad data indicating high turbidity at times when there is no increase in stage or flow (e.g. late October 2003), and immediately after flood events (e.g. after the early October 2003 flood event). Some of these discrepancies may be due to channel works upstream of the site, occurring between 22 December 2003 and 30 March 2004 (excluding Christmas holidays), but the increase in turbidity immediately after flood events is likely to be because of siltation. Where there is any doubt as to the reason for increases in turbidity, the data has been removed.

Once laboratory analyses determined the SSC (mg/l) of each auto-sample the data was compared against the recorded turbidity at the time that sample was collected. A major ‘downside’ to siltation during flood events is that any auto-samples collected during a period of siltation will not be able to be used in the sensor calibration. This is because there is no recorded turbidity data to match to the suspended sediment concentration (SSC, mg/l) of the auto-samples. The auto-sampler collects water samples once a trigger threshold volume of 0.07 million m^3 is reached (representative of a flood flow). A total of 128 auto-samples were collected over 14 events between 13 December 2002 and 19 June 2004. Of these 128 auto-samples, 104 representing 13+ events could be used in the sensor calibration.

Unfortunately auto-sample data collected between 21-24 February 2003 and for part of May 2003, October 2003 and June 2004 appears to have turbidity values affected by siltation (i.e. turbidity levels remain unrealistically high and erratic after the peak auto-sample SSC passes). This data has therefore been excluded from the analyses, but will be incorporated in the final SSC series. The remaining data is plotted in Figure 5.12

Again, the *SSC* vs *NTU* relationship (Figure 5.12) was inspected for signs of drift. None was detected, and a best-fit line was fitted to all of the data to date. The relationship derived was:

$$SSC = 0.0114\left(NTU\right)^2 + 2.120\left(NTU\right)$$

This relationship also has some slight curvature, which, again, we believe reflects the effect of a slight overall fining of sediment particle size as sediment concentration increases at the site.

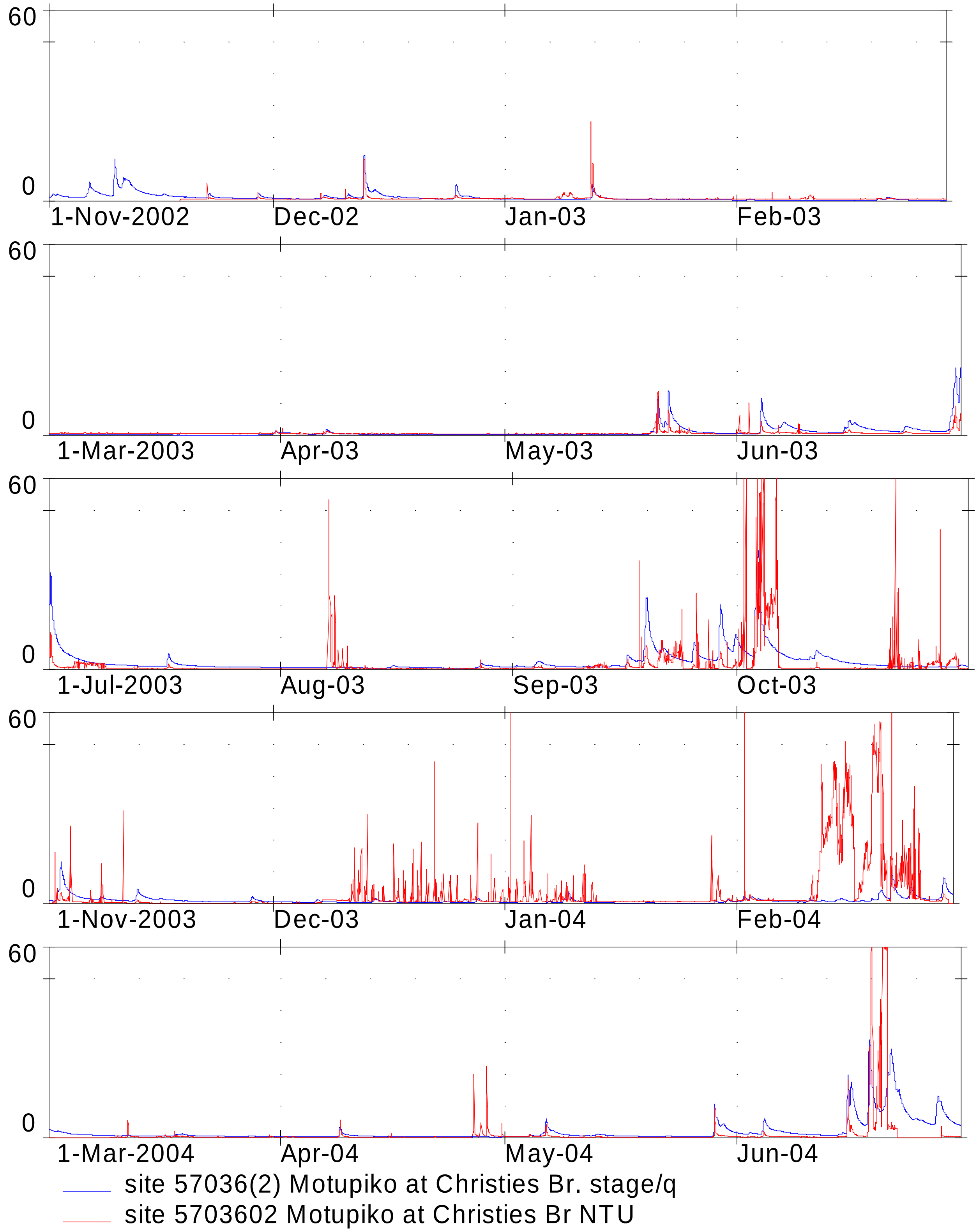
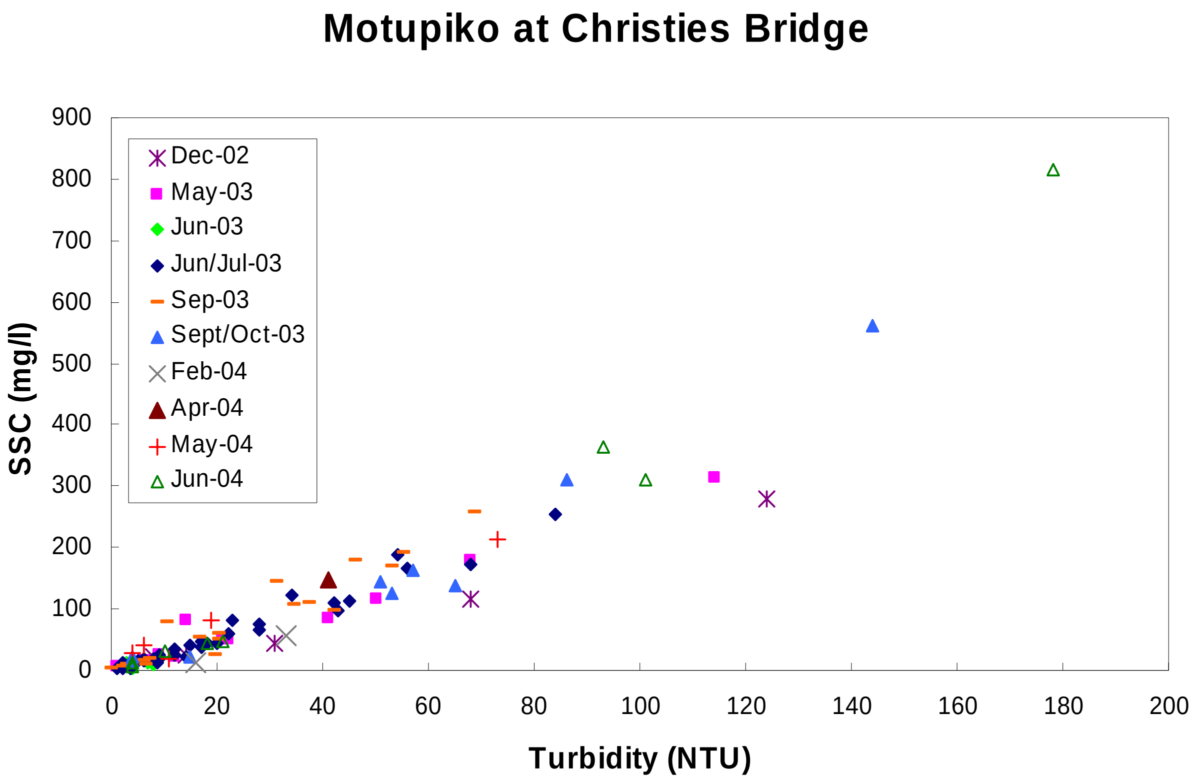


Figure 5.11: **Raw water discharge (blue, in m^3/s) and turbidity (red, in 0.1*NTU so that plot ranges from 0-600 NTU) records to 30 June 2004 at Motupiko at Christies Bridge.**



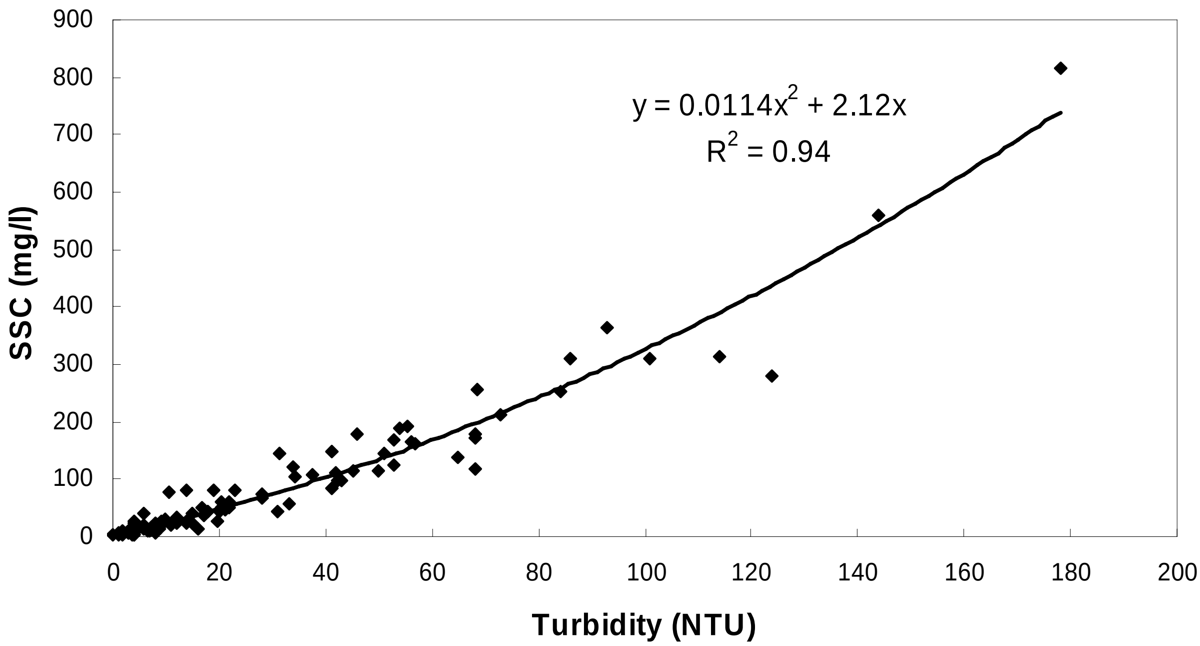


Figure 5.12: Measured auto-sample SSC versus recorded turbidity for Motupiko at Christies Bridge (bottom figure shows derived relationship between turbidity and SSC).

This relationship was used to convert the edited turbidity time series (*NTU*) into a suspended sediment concentration (SSC) time series. The resulting suspended sediment concentration time series is shown in Figure 5.13.

Editing of the turbidity time series resulted in 10 gaps between 8 hours and 82 days in length being inserted into the record. The gaps are tabulated in Table 5.1.

Table 5.1: **Summary of gaps in turbidity record for Motupiko at Christies**

Start Date	Finish Date	Length of gap (days)
12 January 2003	14 January 2003	2.0
20 September 2003	25 September 2003	4.5
1 October 2003	2 October 2003	1.3
3 October 2003	3 October 2003	0.3
3 October 2003	6 October 2003	3.1
3 November 2003	12 November 2003	9.6
28 November 2003	29 November 2003	1.2
7 December 2003	28 February 2004	82.8
26 April 2004	1 May 2004	5.1
18 June 2004	28 June 2004	9.7

Some of these gaps have be removed or reduced in length in the derived SSC time series by inserting auto-sample data and by extending 0 mg/l concentrations forward and backward in time between flood events. All other gaps (approximately 81 days) remain in the SSC time series.

The derived SSC time series is shown in Figure 5.13 together with the edited turbidity data and flow data for the site.

To determine some of the characteristics of the sediment passing the Motupiko at Christies site, the derived SSC time series was plotted against flow (Figure 5.15). The larger events in 2004 and 2003 are shown in more detail in Figure 5.15. The three 2004 events (left graph) and the two largest 2003 events (right graph) have the rising limb of each flood event with a higher SSC than the falling limb. The higher SSC prior to the flood peak suggests that the main sediment source is in the vicinity of the site. Also of interest are the smaller 2003 events, on 23 May and 30 June, that do not have a definite distinction between SSC before and after the flood peak. As these events occur soon after a larger event, it is likely that a large portion of the source sediment has already been ‘flushed’ from the area by the previous event.

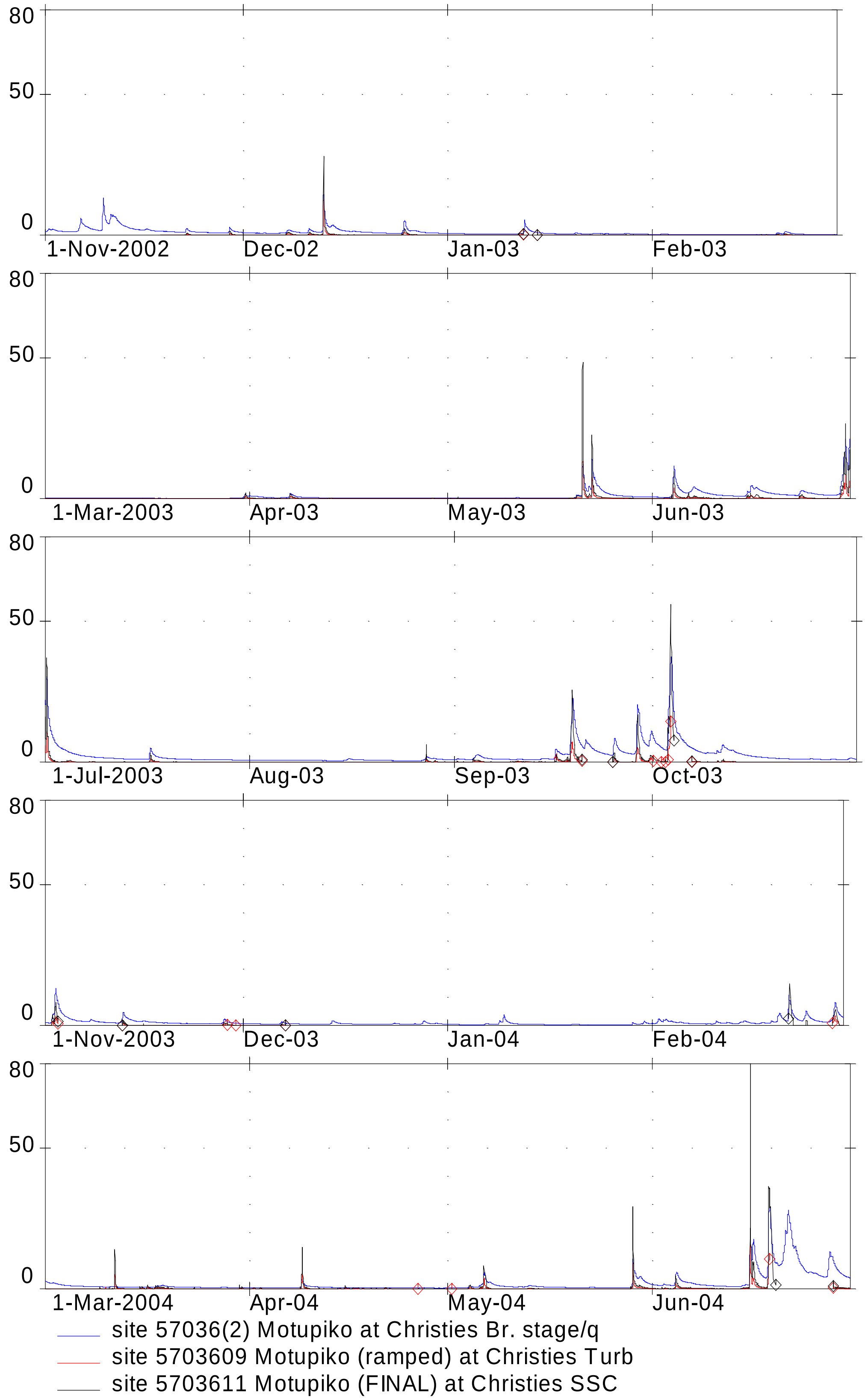


Figure 5.13: Comparison of derived SSC (black, 0.1*mg/l), edited turbidity (red, 0.1*NTU) and raw water discharge (blue, m³/s) for Motupiko at Christies Bridge

As Figure 5.14 demonstrates a more complex, time-varying SSC vs flow rating relationship, we suggest that the best approach for generating synthetic SSC records to fill the gaps discussed above would be with 'on-the-fly' rating relationships developed for short time intervals.

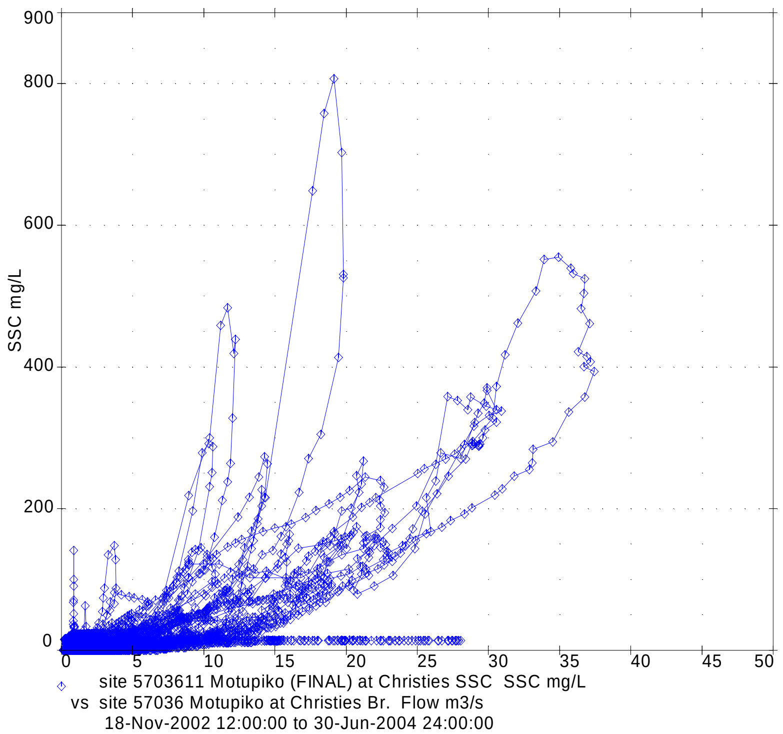


Figure 5.14: Suspended sediment concentration, SSC, versus flow for Motupiko at Christies Bridge for 18 November 2002 to 30 June 2004.

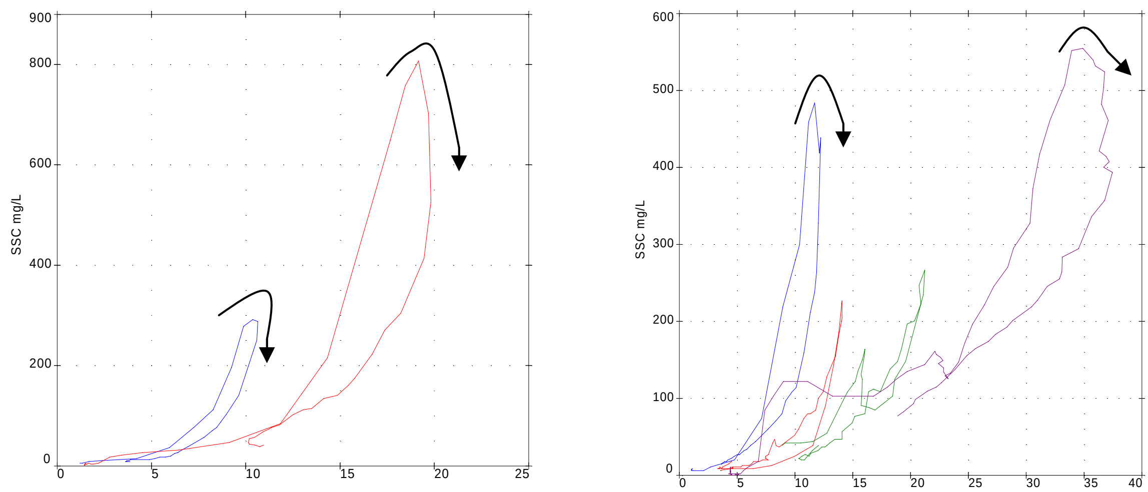


Figure 5.15: Suspended sediment concentration, SSC, versus flow for Motupiko at Christies Bridge. Left: 2004 events on 29 May (blue) and 15/16 June (red. Right: 2003 events on 21 May (blue), 23 May (red), 30 June (green) and 4 October (purple).

5.4. Motueka at Gorge

The water discharge and raw turbidity time series from 6 April 2004 to 6 July 2004 are shown in Figure 5.16. This raw turbidity data was edited to remove spikes and drift, likely to have been caused by bio-fouling or silting up of the turbidity sensor.

Together with the recorded data, the auto-sampler collects water samples once a trigger threshold volume of 200,000 m^3 is reached. This led to a total of 38 auto-samples being collected over 5 events between 4 May and 19 June 2004.

Once laboratory analyses determined the SSC (mg/l) of each auto-sample the data was compared against the recorded turbidity at the time that sample was collected. Three auto-samples collected on 29 May 2004 appeared to be incorrect since the auto-sample concentrations show a peak concentration coinciding with the peak flow, while the turbidity peaks slightly later with a higher than expected turbidity. This is most likely to be due to siltation occurring so this data has been excluded from the analyses. The remaining data is plotted in Figure 5.17.

The *SSC* vs *NTU* relationship (Figure 5.17) was inspected for signs of drift. None was detected, and a best-fit line was fitted to all of the data to date. The relationship derived was:

$$SSC = 0.0088\left(NTU\right)^2 + 2.329\left(NTU\right)$$

As at the other sites, this relationship has some slight curvature, which, again, we believe reflects the effect of a slight overall fining of sediment particle size as sediment concentration increases at the site.

This relationship was used to convert the edited turbidity time series (*NTU*) into a suspended sediment concentration (SSC) time series. The resulting suspended sediment concentration time series is shown in Figure 5.18.

Only one gap of 1.75 hours occurs in the turbidity record to 30 June 2004 after data editing. This gap was placed in the record around the peak of the event that occurred on 29 May 2004. The removed data is believed to have been affected by siltation for reasons, as described above. Fortunately the auto-sample data can be used to fill this gap in the SSC series, so there are no gaps in the SSC time series. The derived SSC time series is shown in Figure 5.18 together with the edited turbidity data and flow data for the site.

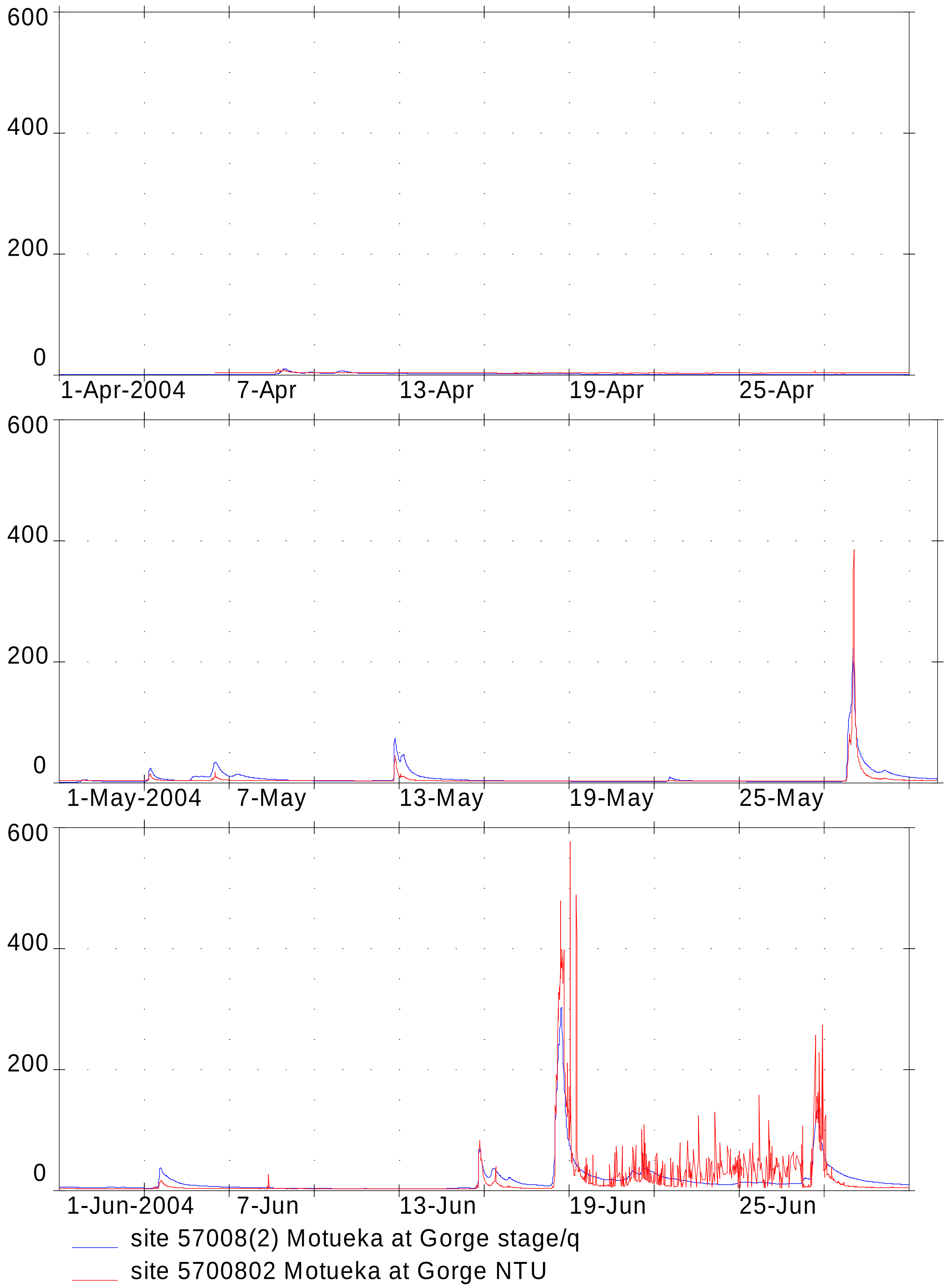
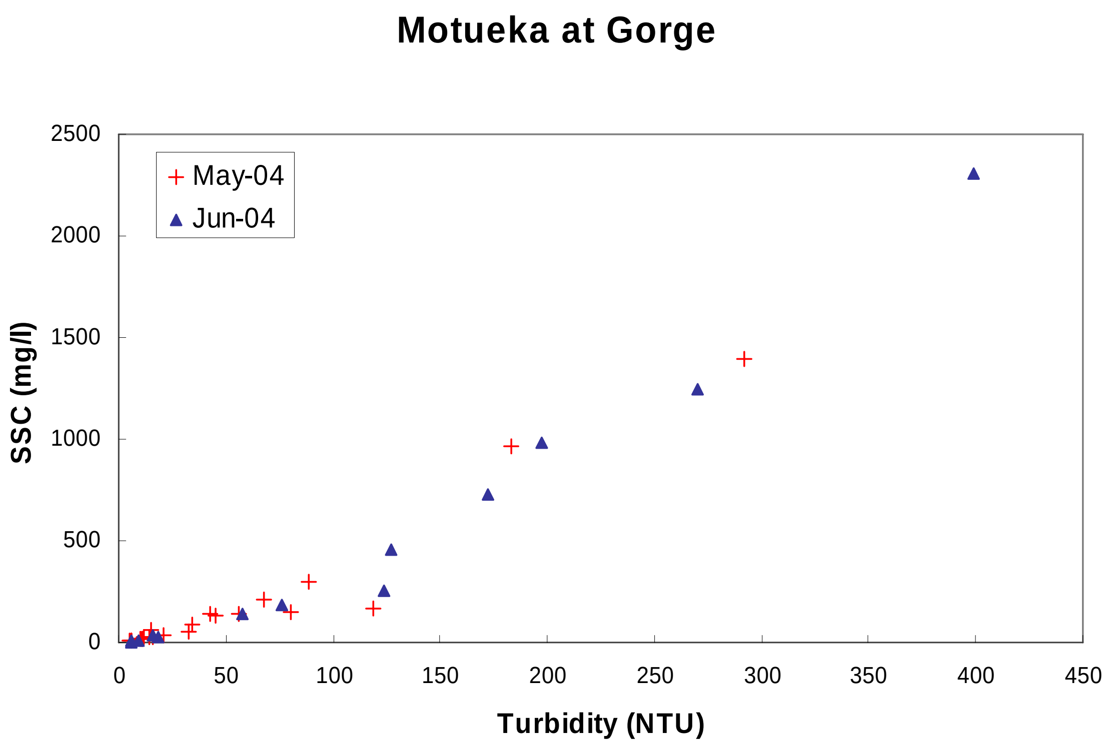


Figure 5.16: Raw water discharge (blue, in m^3/s) and turbidity (red, in NTU) records to 30 June 2004 at Motueka at Gorge.



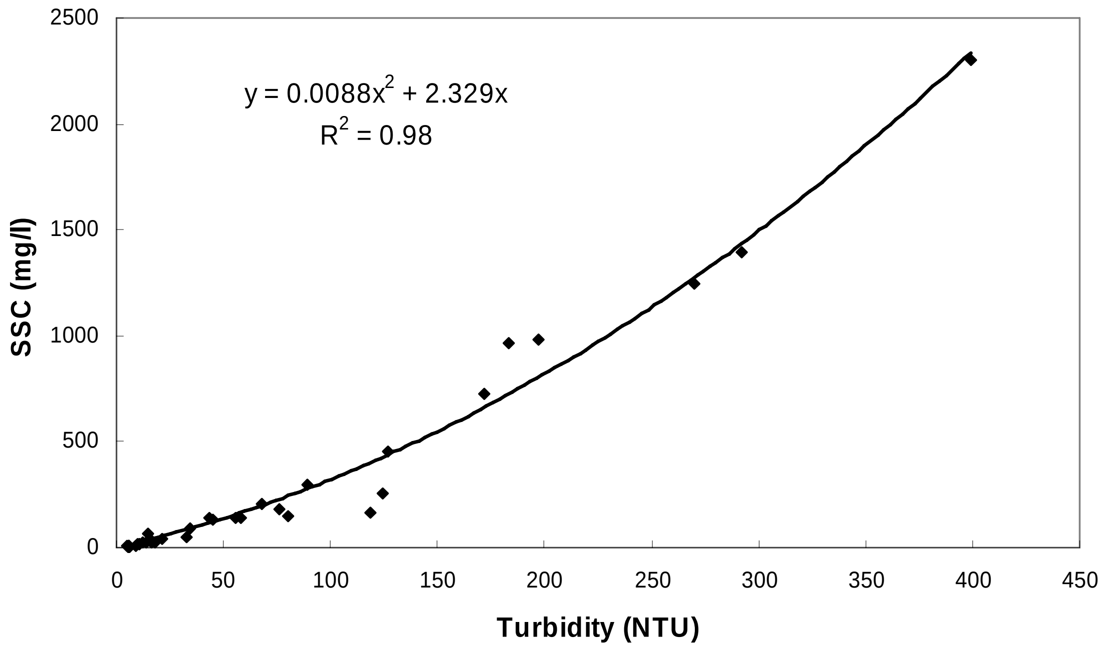


Figure 5.17: Measured auto-sample SSC versus recorded turbidity for Motueka at Gorge (bottom figure shows derived relationship between turbidity and SSC).

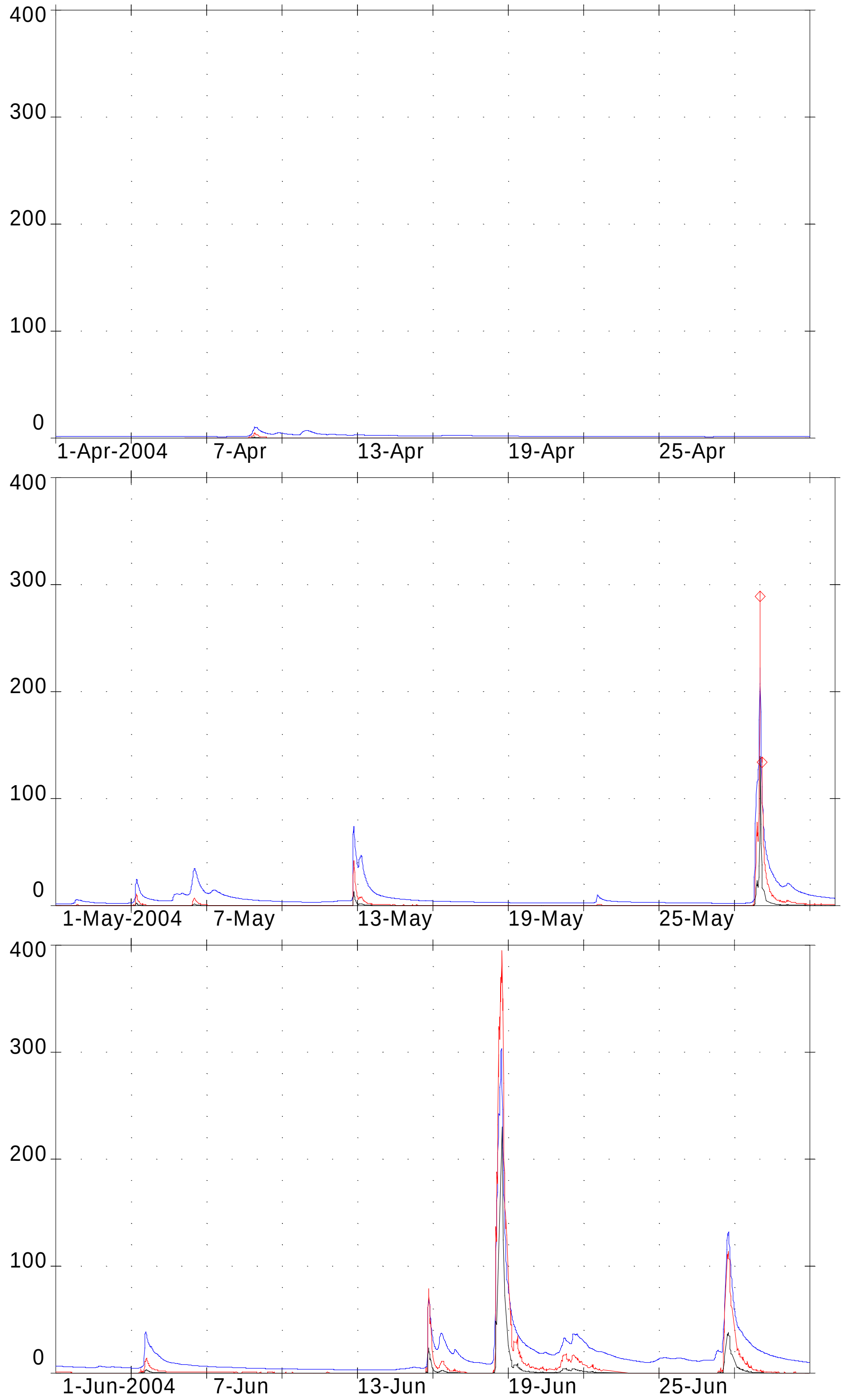


Figure 5.18: Comparison of derived SSC (black, 0.1*mg/l so that the plot ranges from 0-4000 mg/l), edited turbidity (red, NTU) and raw water discharge (blue, m^3/s) for Motueka at Gorge

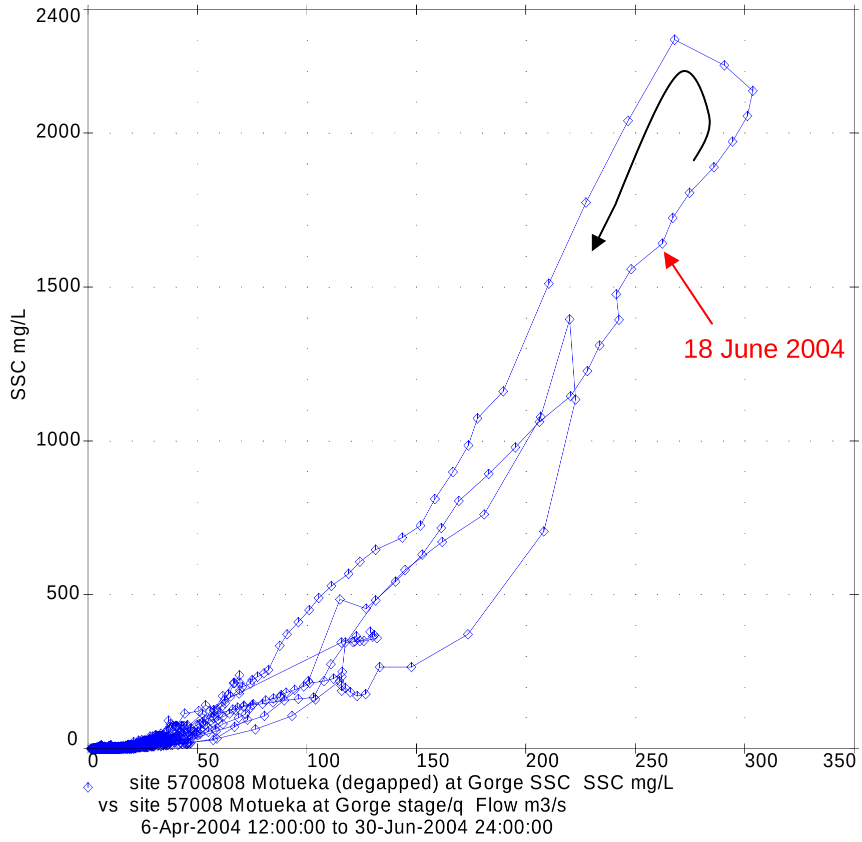


Figure 5.19: Suspended sediment concentration, SSC, versus flow for Motueka at Gorge for 6 April 2004 to 30 June 2004.

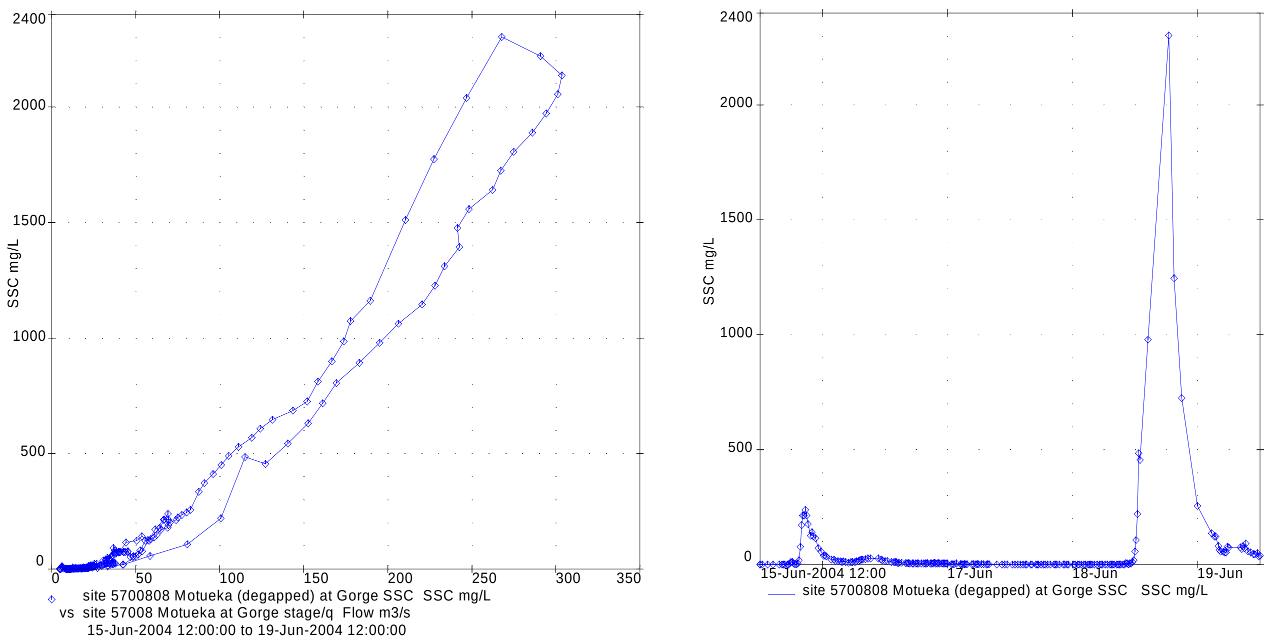


Figure 5.20: Suspended sediment concentration, SSC, versus flow for Motueka at Gorge for 15 - 19 June 2004.

To determine some of the characteristics of the sediment passing the Motueka at Gorge site, the derived SSC time series was plotted against flow (Figure 5.19). Looking at this data in detail, it was possible to determine that, for the two largest events, the rising limb of the flood event had a lower SSC than the falling limb. Figure 5.20 shows the SSC-flow relationship and SSC time series for the largest event, occurring on 18 June 2004. The higher SSC after the flood peak tends to suggest that the main sediment source is further upstream, rather than in the immediate vicinity of the site.

6. Sensor calibrations

The calibration relations to hand between sensor turbidity and auto-sampled SSC are summarized in Figure 6.1. Figure 6.2 shows the fit between the measured and predicted SSC values, using the calibration relationships shown in Figure 6.1. From Figures 6.1 and 6.2 it appears that the calibrations are quite reasonable, although there is obviously a need for more data in the higher NTU ranges (i.e. >100 NTU for all sites except the Motueka at Woodmans Bend site) to further calibrate the sensors.

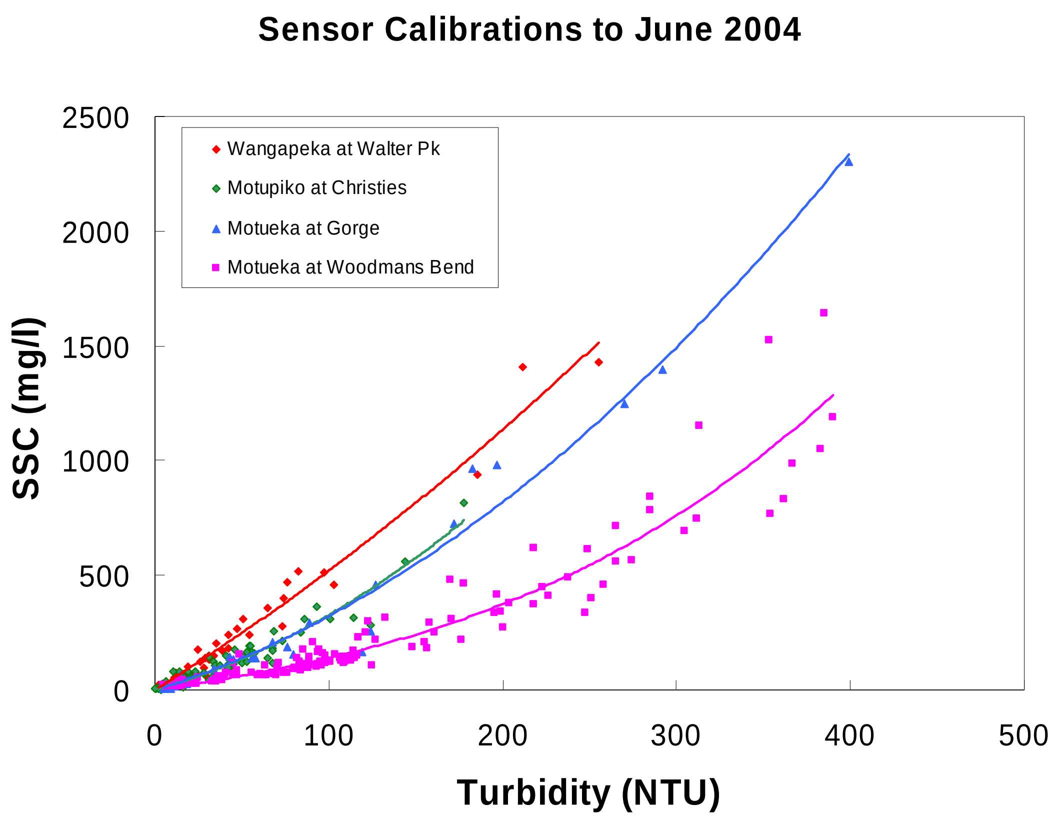


Figure 6.1: Relations between auto-sampled SSC and turbidity for the four sites.

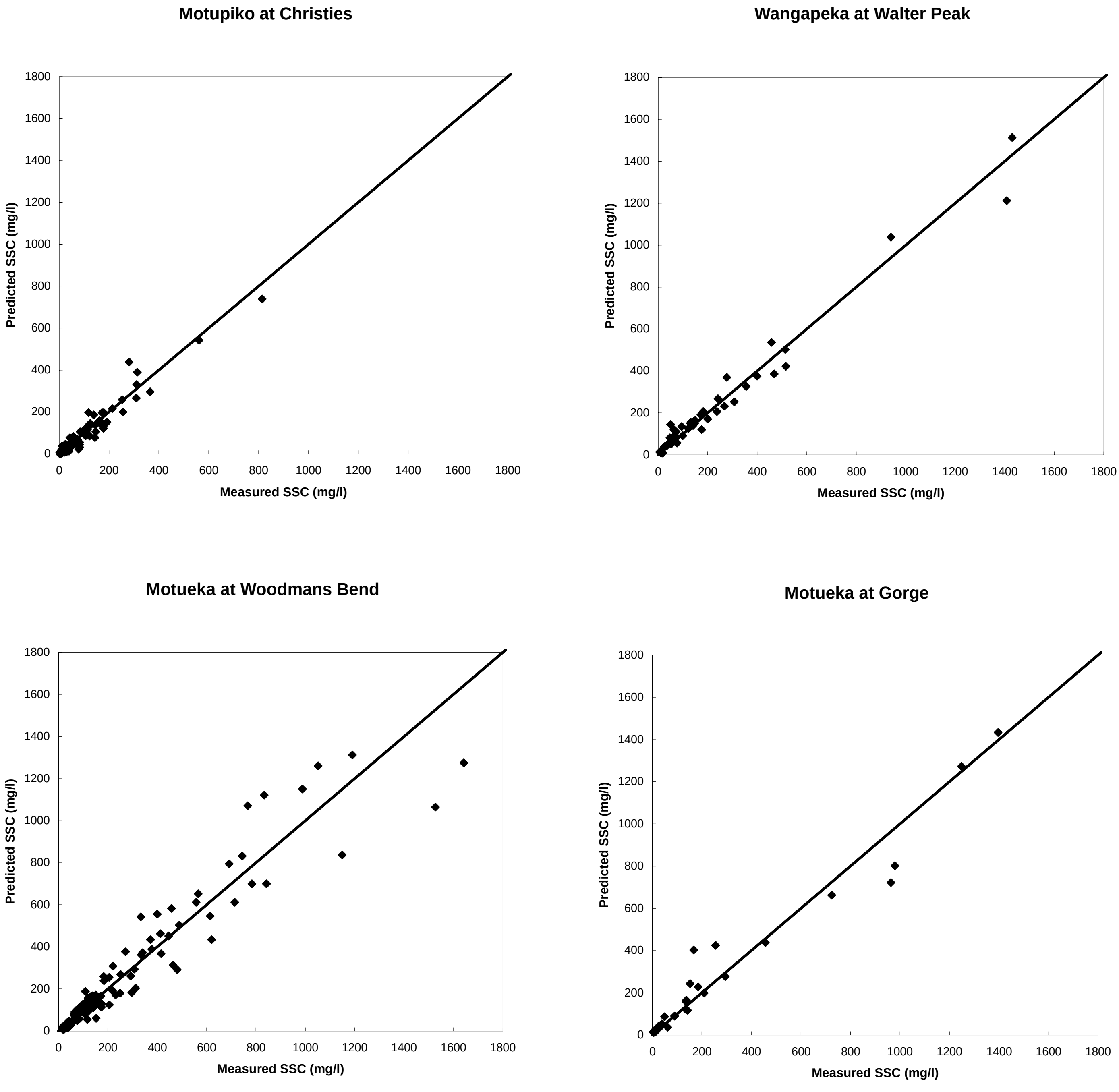


Figure 6.2: Relations between measured and predicted SSC values for the four sites.

The different relations among the four sites are most likely a result of variations in suspended sediment particle size. Specific turbidity (NTU/mgl^{-1}) tends to be lower for coarser particles. The steepest relation (lowest specific turbidity) occurs at the Wangapeka, where we expect the suspended load to be coarser, with a higher sand component, due to the granitic source terrain. Note, from Figure 6.1, the SSC versus turbidity relationship for Wangapeka also exhibits less curvature than the other sites for the same reason.

Table 6.1 summarises the minimum and maximum turbidity, flows and SSC measured to date. For the three sites with records since November 2002, it is interesting to note that all sites had their lowest flows around 27/28 March 2003. By contrast, the maximum flows for each of these sites occurred during different events.

Table 6.1: Summary of parameters for each site

	Motueka at Woodmans Bend	Motupiko at Christies Br.	Wangapeka at Walter Peak	Motueka at Gorge
Start of record	23/11/02	18/11/02	19/11/02	6/04/04
End of record	30/06/04	30/06/04	30/06/04	30/06/04
Min. Flow (m^3/s)	9.4 (28/3/03)	0.2 (27/3/03)	3.8 (28/3/03)	1.5 (27/4/04)
Max. Flow (m^3/s)	1119.5 (18/6/04)	37.5 (3/10/03)	561.0 (19/9/03)	303.8 (18/6/04)
Mean Flow (m^3/s)	53.6	1.6	19.6	9.6
Min Turbidity (NTU)	0	0	0	0
Max Turbidity (NTU)	417 (19/6/04)	181 (15/6/04)	269 (18/9/03)	395 (18/6/04)
Sensor Range (NTU)	0-2000	0-1000	0-1000	0-500
Min SSC (mg/l)	0	0	0	0
Max SSC (mg/l)	1642 (18/6/04)	814 (15/6/04)	1614 (18/9/03)	2303 (18/6/04)
Number of gaps in derived SSC record	5	6	1	0
Total length of gaps (days)	69.0	103.7	0.4	0

7. Manual, depth-integrated sediment gaugings

Depth-integrated sediment gaugings allow the auto-sampled SSC (and therefore SSC time series derived in Section 5) to be related to the average cross-section concentration.

One full depth-integrated suspended sediment gauging (7 verticals) was completed at Motupiko at Christies on 1 July 2003. The discharge-weighted cross-section average SSC was 77.0 mg/l, which was a factor of 1.14 larger than the average auto-sampled concentration over the same time period. The gauged water discharge was 17,025 l/s.

Two full depth-integrated suspended sediment gaugings (each with 10 verticals) were completed at the Wangapeka at Walter Peak site on 28 February 2004. Unfortunately when the water samples were collected, water velocities were not measured. The average cross-section SSC was therefore calculated by dividing the total mass of suspended sediment in the samples (collected for the 10 verticals) by the total volume of the samples. The matching water discharge was taken from the stage record at the mid-time of the sediment gauging. The suspended sediment data collected on 28 February 2004, on the falling limb after the flood peak, is summarised in Table 7.1. It appears that the discharge-weighted cross-section average SSCs (320 and 204 mg/l) were 0.85 to 0.89 times the matching auto-sampled concentrations.

The river peaked at 11:45 at 230,250 l/s. By 12:45 and 15:30 the flow had decreased to 214,400 l/s and 180,700 l/s, respectively. Duplicates of the bulked depth-integrated samples are currently with NIWA Hamilton awaiting particle size analysis on the GALAI laser size analyser.

Table 7.1: Summary of suspended sediment concentration (SSC) data collected at the Wangapeka at Walter Peak site on 28 February 2004

Time	Auto-sample SSC (mg/l)	DI gauging SSC (mg/l)	Discharge (l/s)
12:50 – 13:42		319.7	214,700
13:55	377.1		
14:46 – 15:28	229.1 (estimate)	204.2	182,300
15:50	140.7		
19:02	68.1		
21:36	76.3		

Appendix 1: Instrumentation inventory for Motueka sediment sampling stations.

Station	Equipment/Parameter	Make	Model	S/N	Range	Signal	Owner
Motueka @ Woodmans Bend (02) 623419	logger	Campbell	CR10X	X5933			Landcare
	SC32A	Campbell		9702			NIWA
	logger housing						TDC
	stage	Sutron	Accubar		0 - 15m	SDI-12	TDC
	turbidity	Greenspan	TS100	18080	0 - 2000NTU	4 - 20mA	Landcare
	pump controller	Greenspan		11395			Landcare
	relay driver						NIWA
	AWS	Isco	3700	202E01000			Landcare
	AWS battery						NIWA
	logger battery						TDC
Wangapeka @ Walter Peak	logger	Unidata	Starlogger				TDC
	logger housing						TDC
	stage	Greenspan	PS210	PS2745	0 - 5m	0 - 2.5V	NIWA
	turbidity	Greenspan	TS300	16758	0 - 1000NTU	RS232	Landcare
	pump controller	Greenspan		11390			Landcare
	AWS	Isco	3700	200B00865			Landcare
	AWS battery						NIWA
	logger battery						NIWA

Station	Equipment/Parameter	Make	Model	S/N	Range	Signal	Owner
Motupiko @ Christies Bridge	logger	Campbell	CR10X	X1650			Landcare
	logger housing						Landcare
	stage	Greenspan	PS210	9228	0 - 5m	4 - 20mA	NIWA
	turbidity	Greenspan	TS300	18079	0 - 1000NTU	RS232	Landcare
	pump controller	Greenspan		11394			Landcare
	relay driver						NIWA
	AWS	Isco					Landcare
	AWS battery						NIWA
	logger battery						NIWA
Motueka @ Gorge	logger	Unidata	Starlogger				Landcare
	logger housing						NIWA
	stage	Kainga encoder					TDC
	turbidity	Greenspan	TS1200		0 - 1000NTU		Landcare
	pump controller	Greenspan					Landcare
	AWS	Isco	3700				Landcare
	AWS battery						NIWA
	logger battery						NIWA

Appendix 2:

Monitoring strategy and instructions for Motueka Basin suspended sediment sites, 2003-4:
Motupiko at Christies Bridge
Wangapeka at Walter Peak
Motueka at Woodmans Bend
Motueka at Gorge

General aims and monitoring strategy
The aim at all four sites is to compile a continuous record of suspended sediment concentration (SSC) and to determine the particle size distribution of the suspended load during a representative event. The SSC records will be used to compute sediment loads during runoff events and long-term yields.

The strategy is to "sense" the SSC by the bank using the Greenspan turbidity sensors, and to convert this to cross-section mean sediment concentration by collecting calibration samples. There are two stages to this calibration: (i) turbidity signal vs. point concentration near the sensor, (ii) point concentration vs. section mean concentration. We will generally use automatic pumping samplers (coordinated with the turbidity sensor) to establish the first calibration, and manual depth-integrated sampling at several verticals for the latter.

Maintaining turbidity sensors and records
The Greenspan sensors at Motupiko, Wangapeka, and Motueka Gorge should be inspected and downloaded at least 3-monthly, more often and ideally monthly if you are in the area. The Motueka at Woodman's Bend record should be retrievable from the telemetry, but the sensor should be inspected at least 3-monthly and/or when auto-samples are retrieved.

The turbidity and stage series data should be extracted from the data-logger and/or smart-sensor and archived on TIDEDA files. Plot and inspect the series data as soon as it is downloaded, checking for problems such as fouling, drift, or missing record. It's worth doing this in the field if you have a laptop. A copy of the Tideda files should be forwarded to Murray Hicks every 3 months.

About every 6 months, the calibration of the Greenspan sensors should be field-checked. This will involve extracting the sensor from its housing and immersing it in a stock solution of formazin. Report the results back by e-mail to Michelle Wild at NIWA Christchurch.

Auto-sampler operation, maintenance, sample and data processing
The auto-samplers are there to collect calibration samples and to provide a back-up in case the turbidity record croaks. They are scheduled to sample on a flow-proportional basis, only during runoff events when the stage exceeds a given threshold. Sampling parameters have been adjusted, according to whether more or less samples are required. As of 6 July 2004 the parameters used are:

Site	*Threshold stage (mm) / Discharge (m^3/s)*	*Trigger Volume* (m^3)
Motupiko at Christies	1715 / 3	99,000
Wangapeka at Walter Pk	2400 / 97	800,000
Motueka at Woodmans Bend	2254 / 250	2,000,000
Motueka at Gorge	1100 / 25	400,000

You can keep track of whether the samplers should have activated by checking the TDC web-site, or better still, from the Woodmans Bend telemetry. Visit the site and recover the samples when it looks like the bottle magazine should be getting near full, and at least every 3 months.

All auto-samples should be analysed for SSC by the filtration method.
Report results in an Excel table as …
Date Time Stage SSC(auto) Turbidity (off the logger at the matching time)

Dates, times, and stage can be extracted from the logger files by matching-up bottle numbers.
Add to this table with every batch of samples, and send a copy of the table to Murray Hicks every 6 months or when there is a significant new batch of data. It is a good idea to maintain an Excel plot of Turbidity vs auto-sampled SSC, (a) to see how the calibration is coming along and (b) to pick up any problems such as might be indicated by an apparent jump or drift in calibration.

Manual sampling during events
This year (2003-2004), we are funded to do manual sampling at Motupiko and Wangapeka. The aim for the year is to collect at both sites through one event 6-8 series of DI samples along with concurrent manually-triggered auto-samples. Each series will consist of a multi-vertical, EDI-type SS gauging, with a duplicate set of samples collected for particle-size analysis. DI samples from multiple verticals can be bulked before lab analysis. The DI samples will need to be collected from the nearest bridge. The auto-samples should be triggered either at the mid-time of the DI sampling, or else auto-samples should be triggered both at the start and end of the DI sampling. Keep careful notes of the time and bottle number with each manually-triggered auto-sample, so these are not confused with auto-triggered samples.

It may be possible to work both Motupiko and Wangapeka during the same event, but it is not essential that all sites be sampled concurrently. An ideal event would be something of the scale of an annual average or larger event. Note that one of the aims is to compute the yield of that event from the manual samples, so (ideally) there should be enough samples collected to define the variation in SSC, the samples should be reasonably uniformly spaced in time, and the first sample should be collected as early as possible during the event. Another aim is to collect matching DI and auto-samples over as wide arrange of discharge as possible (so catch the event peak if possible).

It will be up to the NIWA field team to be on the look-out and mobilize for such an event, and to make judgment calls about when to collect samples.

One set of depth-integrated samples should be analysed for SS concentration and the other set for particle size. The particle size information through the sampled event will give an indication of how the turbidity vs. SSC is affected by particle size, and it will also enable calculation of the event suspended sediment yield by size fraction, which can then by used to estimate a size distribution of the event yield. This will be assumed indicative of the size distribution of the long-term yield.

All samples (auto-sampler, depth-integrated samples) should be analysed for SSC by the Nelson NIWA office using the filtration approach. The bulked DI samples for PS analysis should be forwarded to Ron Ovenden at NIWA Hamilton for analysis on the GALAI. When dispatching, request that these are to be analysed before ultra-sonic dispersion and then again after ultra-sonic dispersion, that the whole GALAI analysis file should be kept, and that samples should be kept until the results have been inspected by Murray Hicks. Ideally, advise Murray Hicks first so he can warn Ron Ovenden they are coming. The GALAI results files should be sent to Murray Hicks with a copy to Nelson NIWA to keep for backup.

It is not necessary that a flow gauging be done with each SS gauging, but the stage and time at the start and end of each SS gauging should be noted and the discharge extracted from the curent rating. Some homework may be required to estimate the EDI vertical locations; otherwise I'll accept your experienced on-site assessment.

Results of the auto-samples can be reported in an excel table under the following headings

Date Time Stage Discharge DI Conc Auto-sampled conc (average of before and after if necessary).

These should be included in a very short, informal, e-mailed data report to Murray Hicks, basically saying what was collected, when, what the results were, and any comments (e.g. problems, suggestions for next time around, etc)

Questions/comments
Any questions, contact
Murray Hicks
Ph 03 343 7872 wk
03 351 7192 (after hours)
e-mail: m.hicks@niwa.co.nz

Murray Hicks