Storys Creek Water Quality Monitoring Results – Final Report

1 August 2006

V2

November 2006

A Report to Mineral Resources Tasmania

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Technical Advice on Water

1 Introduction

Mineral Resources Tasmania (MRT) has implemented large-scale remediation works at the historic Storys Creek mine site in eastern central Tasmania, including the removal of the contents of a precipitation dam, closure of adits, removal of some tailings and implementation of an anoxic limestone drain. A 3-year water quality monitoring program was initiated in September 2003 to determine the concentrations and fluxes of pollutants leaving the site and evaluate the efficacy of the remediation works.

This report summarises the results from the eleventh and final water quality-monitoring run completed on August 1, 2006, compares results to previous findings, and summarises the findings of the program. The final monitoring run in August 2006 was completed under conditions of high flow, with ~15 mm of rain falling in the catchment in the previous 24-hours.

2 Sampling details

Water quality and flow monitoring was completed on August 1, 2006 by L. Koehnken of Technical Advice on Water and W Grun of Mineral Resources Tasmania. All sites in Table 1 were visited and at each site pH, conductivity and temperature was measured *in situ* and a water sample was collected for subsequent analysis of metals, sulphate, fluoride and alkalinity. As this was the final monitoring, samples were collected the ALD, Side Cr and Eastern Adit..

At the Storys below Precipitate Dam site, Storys below Side Creek, Storys below Nisbet Creek, Storys at Managers, Storys above Aberfoyle and Aberfoyle above Storys site, the dimensions of the channel were measured (width, depth at various points) and flow measurements were made using a flow-meter at 2 – 5 points across a transect at a depth of 0.6 of the water depth (from the surface). The flow estimates have been used to establish fluxes at each of the sites. The ‘Storys below Precipitation Dam’ site flow measurement was used in the flux calculations for three sites (Storys Creek above mine, Storys below PPT dam, and Storys above Side Creek) because flow varies little between the sites and the site yields the most accurate flow estimate due to the presence of bedrock, resulting in a stable channel with confined flow.

Flow from the ALD was measured using a calibrated bucket and stop watch. At the precipitate dam, flow was visually estimated as the flow is no longer confined to the outflow pipe. Flow from the Eastern Adit was determined using the height of the water in the V-notch weir, and a generalised USGS equation for calculating V-notch flow. This flow measurement should be considered of low reliability due to the sedimentation of iron floc in the portal of the Eastern Adit and downstream of the V-notch.

Conditions during sampling on August 1 were fine. In the 24 hours to 9 am on August 1, no rain was recorded at either Powranna (indicative of the upper catchment) or Fingal. During the previous day, 15.4 mm was recorded at Powranna, and 1.4 mm at Fingal. During the week prior to monitoring, a total of 26.6 mm fell at Powranna and 10.4 mm in Fingal. Based on the observed flow level in the river, it is likely that higher rainfall totals occurred in the upper Storys Creek catchment, as water levels were relatively high. The sampling captured a moderate high flow event following a prolonged dry period.

Table 1. Site number and location of monitoring points.

Site Number	Site Location	Justification
ALD	Anoxic Drain outflow at Storys Creek	Provide indication of alkalinity input to underground workings
2	Storys Cr above mine workings	Provides background water quality and indication of upstream changes
5	Storys Cr below Precipitation Dam	Provide record of changes since dam removal – should continue to change as groundwater 'flushes' through system
7	Storys above Side Creek	Indicate pollutant load from tailings deposit located upstream Side Cr
8	Storys Cr below Side Creek	Significant pollutant load enters via Side Creek
10	Eastern Adit outflow	Adit plugged, monitoring of pH indicates effectiveness of works
13	Storys below Nisbet	Indicates inputs from diffuse sources downstream of Side Creek and dilution from entrance of Nisbet Cr
14	Storys at Managers*	Continue best long-term data collection point; indicates diffuse load entering between Nisbet and Pumphouse
21	Storys Above Aberfoyle	Final measurement of pollutant load in Storys Creek
23	Storys below Aberfoyle	Indicative of water entering South Esk
22	Aberfoyle Creek	Has elevated zinc levels and contributes to loads entering S. Esk
24	South Esk above Storys	'Background' water quality in South Esk River
25	South Esk d/s Storys	Estimate of Storys Creek impact on S. Esk
4	Precip. dam outflow	Historic pollutant source
6	Side Creek	Historic pollutant source

*This site has been referred to as both Storys below Pumphouse and Storys at Manager's. In this and subsequent reports 'Storys at Manager's' will be used.

3 Results and discussion

Water quality results are presented in Table 2 - **Error! Reference source not found.**, and discussed in the following sections.

3.1 Flows

Water flows in August 2006 were relatively high, the forth highest captured during the monitoring program. Importantly, this was the only time during the monitoring program that a flow greater than 400 l/s but less than 1000 l/s was captured (as measured at the Storys at Managers site), thus filling a gap in the monitoring data set. Flows were 350 l/s at the below Precipitate Dam site, 788 l/s at the Managers site, and 935 l/s at the Storys above Aberfoyle Ck site.

Flow from the ALD was low, measured as 0.25 l/s. Similar to the previous few monitoring runs, this water is not directly entering the under ground workings, but is being diverted via surface drains into the Side Creek catchment.

Discharge was estimated at 2 l/s at the Precipitate Dam. The volume of discharge from the dam appeared to be similar to the volume of inflow entering the dam from the upstream catchment. This flow rate was visually estimated as the discharge from the dam is occurring over the dam wall, rather than via the outflow pipe.

Low flow was present in Side Creek (~0.5 l/s) and at Eastern Adit (<0.25 l/s). Although surface flow was low in Side Creek, ground water seepage was evident entering Storys Creek downstream of the creek. Whether this ground water is derived exclusively from the Side Creek catchment, or is affected by seepage from the remaining tailings dam deposits and underground workings is unknown.

Photos 1-5 show flow conditions on the lease site, at the Manager's site, and at the confluence of Storys and Aberfoyle Creeks during monitoring in August 2006. Photos 5 and 6 shows the Managers site during September 2005, which was the monitoring run with the highest flow rate. Comparing Photos 3 and 4, with 5 and 6 shows that water levels in August 2006 were not much lower than in September 2005, although higher water velocities are evident in September 2005. Comparing the photos also shows the deposition of a large log downstream of the photo site at Storys at Managers.

Photo 1. & Photo 2 Storys Creek at mine site. Photo 1 (left) View downstream from Storys below Precipitate Dam monitoring site; Photo 2 (right) View downstream from Storys below Nisbet monitoring site.

Photo 3 & Photo 4. Storys Creek at Managers Residence Photo 1 (left) view upstream, and Photo 2 (right) view downstream.

Photo 5. Confluence of Storys and Aberfoyle Creek. Storys Creek flowing from left to right and Aberfoyle Creek enters from top to bottom of photo.

Photo 5 and 6. Upstream (left) and downstream (right) views from Storys at Managers site during September 2005, showing highest flow rates recorded during monitoring program.

Flow in Storys Creek above Aberfoyle (~935 l/s) was about twice the flow in Aberfoyle Creek (~495 l/s). These flows are consistent with the zinc and sulphate concentrations measured in Storys above Aberfoyle, Aberfoyle Creek and Storys below Aberfoyle, thus providing confidence in the flow estimates.

3.2 Water quality results – concentrations

Water quality concentrations for August 2006 are presented in Table 2, Table 3 and Table 4. Table 2 contains the water quality results for the regular monitoring sites on Storys Creek, Aberfoyle Creek and the South Esk River. Table 3 shows the pH, conductivity and temperature data collected in the field, and an estimate of metal and sulphate fluxes for each of the regular monitoring sites. Table 4 shows field results for the ALD, Side Creek and the Eastern Adit.

3.2.1 Anoxic Limestone Drain (ALD)

Alkalinity concentrations in the ALD and upper Storys Creek for August 2006 are shown in Figure 3.1 along with previous results. In August, the alkalinity concentrations in the ALD were lower than previous results, with the exception of September 2003. It is likely that the late winter conditions of low temperature and high water flow through the system are the reason for reduced alkalinity output during this season. Alkalinity levels in Storys Creek upstream of the mine are similar to previous levels. The flux of alkalinity generated by the drain (Figure 3.2) is low, estimated at ~1 kg/day.

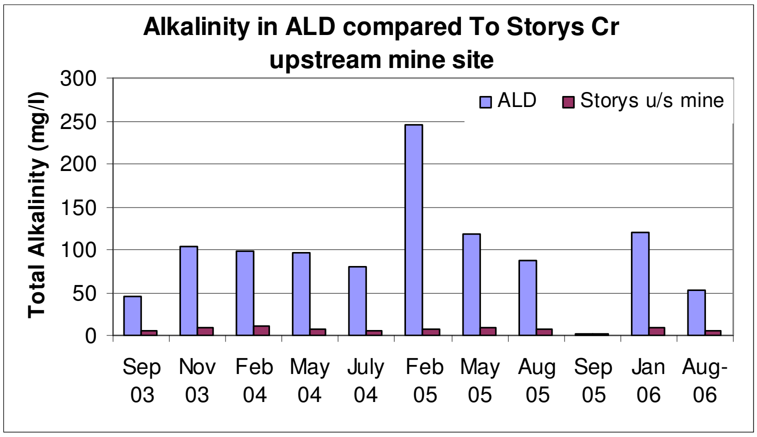


Figure 3.1. Alkalinity levels in water from the ALD compared to alkalinity levels in Storys Creek above the mine site. Laboratory error suspected in ALD result for September 05.

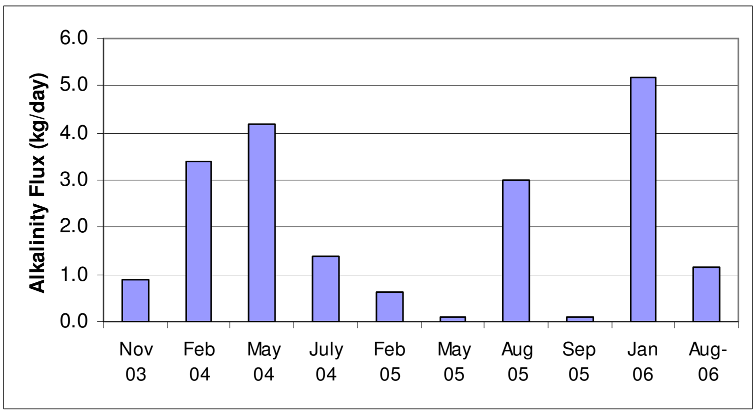


Figure 3.2 Alkalinity flux from ALD at Storys Creek.

Table 2. Water quality results and flow for Storys Creek monitoring, August 1, 2006. All units µg/L except Fluoride, Sulphate and Alkalinity, which are mg/l/. *Flow calculated by adding Storys above Aberfoyle, and Aberfoyle Creek flows

		Storys Ab Mine	Precip Dam Outflow	Storys Bel Precip	Storys Ab Side Cr	Storys Bel Side Cr	Storys Bel Nisbet	Storys at Manage r	Storys Ab Aber	Storys Bel Aber	Aber Ab Storys	S. Esk Ab Storys	S. Esk Bel Storys
Date		1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06
Alkalinity Total	mg/l CaCO3	6	9	6	6	6	7	6	4	7	13	14	13
Fluoride	mg/l	<0.01	0.37	0.02	0.06	0.12	0.1	0.12	0.14	0.23	0.36	0.02	0.03
Sulphate	mg/l	0.4	33.6	1.7	3.3	5.8	6.8	8	7.9	9.9	13.5	2.6	3
Al Dis	µg/l	24	113	49	114	159	124	116	147	85	33	47	74
Al Total	µg/l	97	1350	145	176	326	367	453	400	447	548	344	450
As Dis	µg/l	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
As Total	µg/l	<5	<5	<5	<5	<5	6	<5	<5	<5	<5	<5	6
Cd Dis	µg/l	<1	107	4	14	19	13	18	18	14	6	<1	<1
Cd Total	µg/l	<1	109	5	13	19	14	19	18	15	8	<1	1
Co Dis	µg/l	<1	12	<1	<1	1	1	<1	<1	<1	<1	<1	<1
Co Total	µg/l	<1	12	<1	<1	1	1	<1	<1	<1	<1	<1	<1
Cr Dis	µg/l	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cr Total	µg/l	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cu Dis	µg/l	<1	10	3	32	42	18	29	32	26	16	<1	3
Cu Total	µg/l	<1	19	4	36	51	27	41	38	41	31	3	4
Fe Dis	µg/l	<20	58	31	20	101	181	133	95	116	62	111	124
Fe Total	µg/l	77	627	80	62	213	381	317	261	401	652	433	519
Mn Dis	µg/l	<5	783	25	32	63	73	61	29	42	59	<5	8
Mn Total	µg/l	<5	781	26	33	63	76	62	30	49	80	24	25
Ni Dis	µg/l	<2	15	<2	<2	<2	2	<2	<2	<2	<2	<2	<2
Ni Total	µg/l	<2	16	<2	<2	2	4	2	4	4	5	3	<2
Pb Dis	µg/l	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Pb Total	µg/l	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Zn Dis	µg/l	<1	3250	131	324	461	345	446	439	369	248	<1	27
Zn Total	µg/l	3	3340	141	321	474	369	480	461	416	324	5	35
Flow	l/s	350	2.5	350	350	500	760	788	935	1430	495		

Table 2 (continued)

		ALD	Side Cr	Eastern Adit
Date		**1 Aug 06**	**1 Aug 06**	**1 Aug 06**
Alkalinity Total	mg/l CaCO3	53	<2	11
Fluoride	mg/l	0.02	2.14	1.99
Sulphate	mg/l	0.4	50.8	106
Al Dis	µg/l	<20	2160	68
Al Total	µg/l	433	2320	352
As Dis	µg/l	<5	<5	<5
As Total	µg/l	<5	<5	16
Cd Dis	µg/l	<1	96	20
Cd Total	µg/l	<1	97	22
Co Dis	µg/l	<1	9	30
Co Total	µg/l	2	9	30
Cr Dis	µg/l	<1	<1	1
Cr Total	µg/l	<1	<1	<1
Cu Dis	µg/l	<1	229	<1
Cu Total	µg/l	1	235	<1
Fe Dis	µg/l	548	615	610
Fe Total	µg/l	4520	1190	11500
Mn Dis	µg/l	192	632	2080
Mn Total	µg/l	308	641	1980
Ni Dis	µg/l	<2	19	44
Ni Total	µg/l	<2	19	43
Pb Dis	µg/l	<5	<5	<5
Pb Total	µg/l	<5	<5	<5
Zn Dis	µg/l	<1	2550	1340
Zn Total	µg/l	9	2580	1370
Flow	l/s	0.25	0.5	0.25

Table 3. Flow, pH conductivity and temperature results collected *in situ*, August 1, 2006 and flux calculations based on flows and analytical results.

		Storys Ab Mine*	Precip Dam Outflow	Storys Bel Precip	Storys Ab Side Cr*	Storys Bel Side Cr*	Storys Bel Nisbet	Storys at Manager	Storys Ab Aber	Storys Bel Aber	Aber Ab Storys#	S. Esk Ab Storys	S. Esk Bel Storys
Parameter	Unit	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06
Flow	l/s	350	2.5	350	350	500	760	788	935	1430	495		
pH (field)	pH units	6.89	6.87	7.14	6.93	6.41	6.97	6.96	6.99	7.11	7.24	7.15	7.19
EC	µS/cm	29.5	120.3	28.5	33.0	38.8	45.7	47.3	46.4	57.6	78.2	84.7	83.7
Temp	ºC	5.1	6.4	5.0	5.2	5.3	6.1	6.7	6.6	7.0	7.7	7.4	7.4
Zn tot flux	kg/d	0.09	0.72	4.26	9.71	20.48	24.23	32.68	37.24	51.40	13.86		
Cd tot flux	kg/d	0.02	0.02	0.15	0.39	0.82	0.92	1.29	1.45	1.85	0.34		
Mn tot flux	kg/d	<0.01	0.17	0.79	1.00	2.72	4.99	4.22	2.42	6.05	3.42		
Fe tot flux	kg/d	2.33	0.14	2.42	1.87	9.20	25.02	21.58	21.08	49.54	27.88		
SO_4 flux	kg/d	12.1	7.3	51.4	99.8	250.6	446.5	544.7	638.2	1223.2	577.4		

***Flow estimate from Storys below Precip dam used to estimate fluxes.**
#Calculated based on Storys above Aberfoyle & Aberfoyle above Storys

Table 4. Summary of *in situ* measurements for ALD, Side Creek and Eastern Adit sites on August 1, 2006.

		ALD	Side Ck	Nisbet Cr	Eastern Adit
Date		1 Aug 06	1 Aug 06	1 Aug 06	1 Aug 06
Flow (l/s)		0.25	0.5		0.25
pH (field)	pH units	7.22	3.93	7.0	6.52
Conductivity	µS/cm	152	165.5	36.0	266
Temperature	°C	4.6	6.6	6.4	8.0

3.2.2 Metal concentrations in Storys Creek

The water quality monitoring results from August 2006 are depicted in Figure 3.3 - Figure 3.8. The results show similar trends as previous high-flow monitoring runs:

- Arsenic, chromium, cobalt and lead are present at or below the reporting limit of the laboratory at all the regular monitoring sites;
- The discharge from the Precipitate Dam had the highest concentrations of cadmium, manganese, nickel and zinc of any of the monitoring sites, although is one of the lowest fluxes due to the low flow rate.
- Zinc, cadmium and sulphate concentrations in Storys Creek are lower than recorded during periods of low flow, similar to other high flow monitoring runs;
- The largest increase in metals and sulphate concentrations occurs between the Storys below Precipitate Dam site, and Storys above Side Creek, and between Storys above Side Creek and Storys below Side Creek. This increase is due to ground water entering in this reach of the river, as there was no discharge from the artificial wetland at the mouth of Side Creek. The ground water is derived from the remaining tailings deposit, as evidenced by a strong electrical conductivity gradient across the river, and from ground water in the Side Creek catchment;
- Copper levels show a large increase between the Storys below Precip Dam site, and Storys above Side Creek, with relatively little increase between the Above and Below Side Creek sites. This suggests that the majority of copper is derived from the old tailings deposits on the steep bank of the river upstream of Side Creek;
- The major sources of fluoride to Storys Creek are the Precipitate Dam, the Side Creek area and Aberfoyle Creek in the lower catchment;
- Downstream of the Storys below Side Creek, there is a gradual decrease in metal and sulphate levels due to dilution from downstream inflows;
- Compared to ANZECC trigger values for the protection of aquatic ecosystems, cadmium, copper and zinc are elevated throughout Storys Creek. Inputs from Aberfoyle Creek are lower than in Storys, but also exceed freshwater trigger values.

The zinc and cadmium concentrations measured in August 2006 are compared with previous zinc results for the Precipitate Dam, Storys below Side Creek and Storys at the Managers Residence in Figure 3.6 a-c and Figure 3.7 a-c. Levels of zinc and cadmium at all three sites are consistent with previous high flow monitoring periods.

The zinc load from Storys Creek increased zinc concentrations in the South Esk from 5 µg/l to 35 µg/l (Table 2). As shown in Figure 3.8, this increase is similar to previous results, raising zinc levels in the south Esk above ANZECC (2000) freshwater trigger values for the protection of aquatic ecosystems (15 µg/l, 90^{th} percentile protection level).

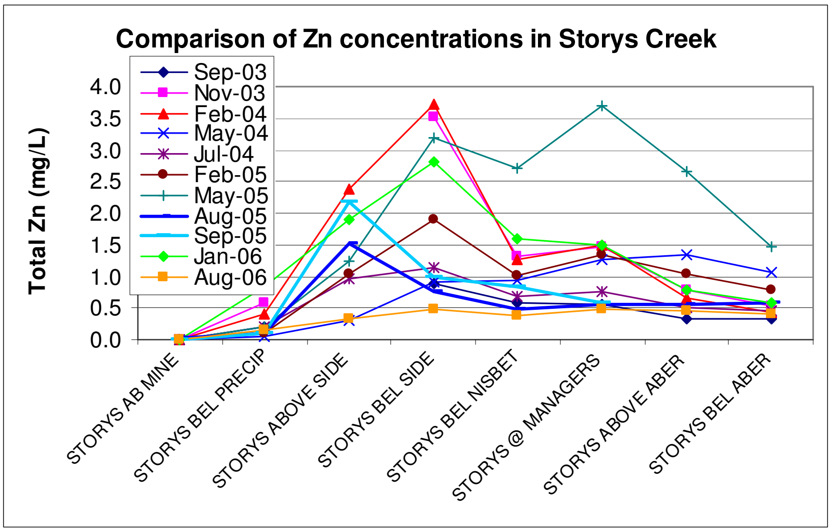


Figure 3.3. Total zinc concentrations at monitoring sites in Storys Creek by date.

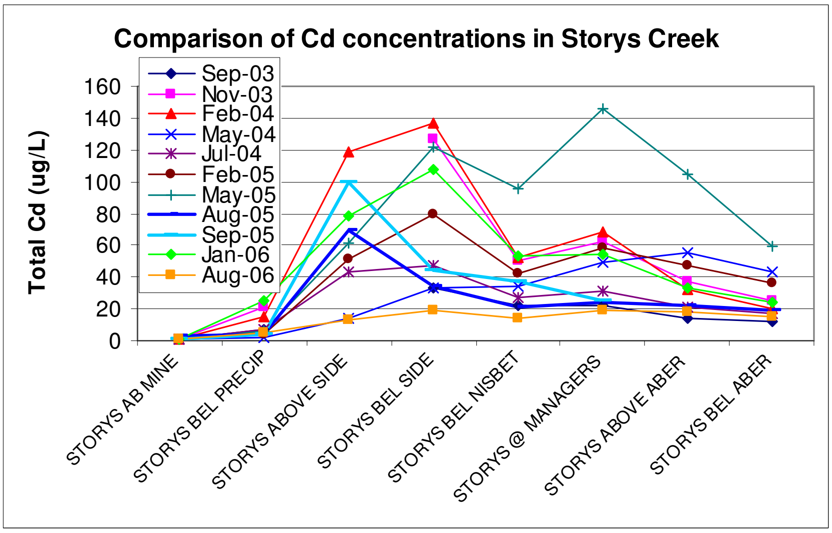


Figure 3.4. Total cadmium concentrations at monitoring sites in Storys Creek by date.

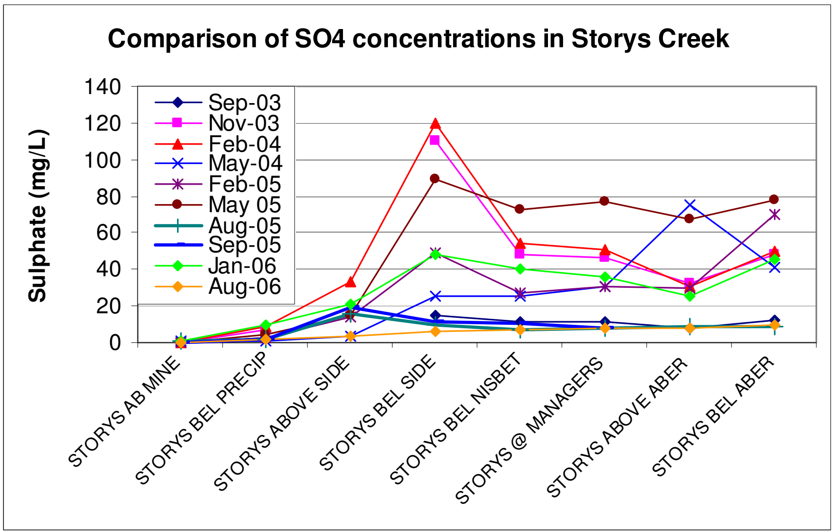


Figure 3.5. Sulphate concentrations at monitoring sites in Storys Creek by date

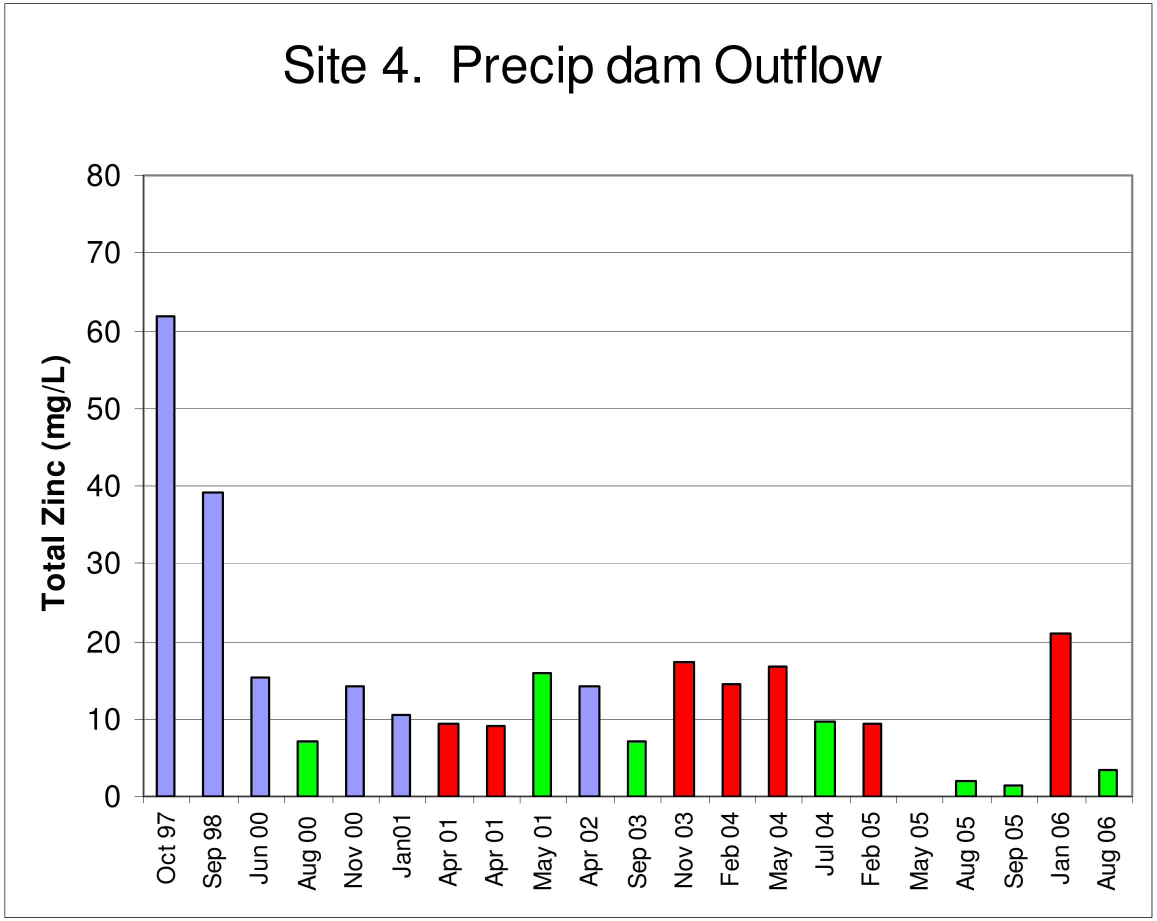


Figure 3.6a . Total zinc graphs comparing the August 2006 results with previous monitoring results. Red bars denote low flow (<250 L/s), blue bars denote medium flows (250 – 350 L/s), and green bars denote high flow (>350 L/s). Note scale is different for the Precipitate dam results.

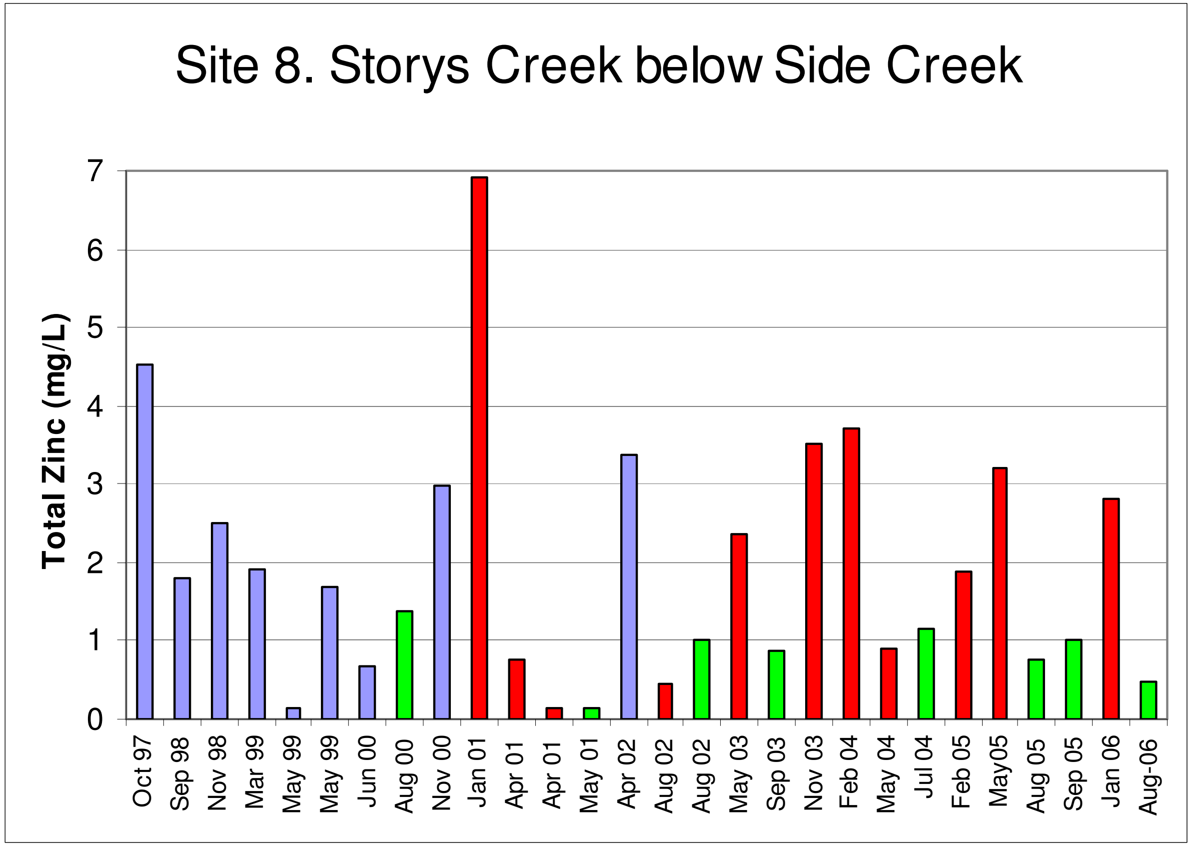
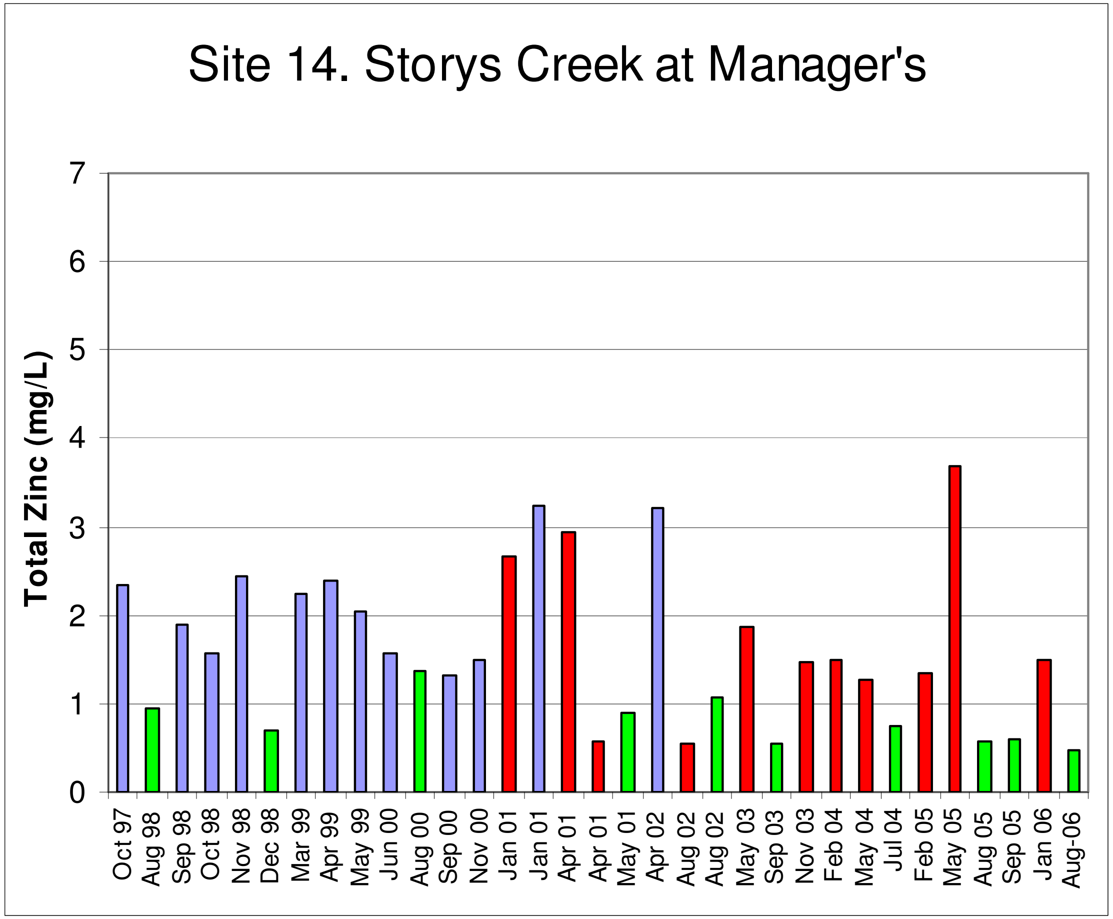


Figure 3.6b. Total zinc graphs comparing the August 2006 results with previous monitoring results. Red bars denote low flow (<250 L/s), blue bars denote medium flows (250 – 350 L/s), and green bars denote high flow (>350 L/s).



Total zinc graphs comparing the August 2006 results with previous monitoring results. Red bars denote low flow (<250 L/s), blue bars denote medium flows (250 – 350 L/s), and green bars denote high flow (>350 L/s).

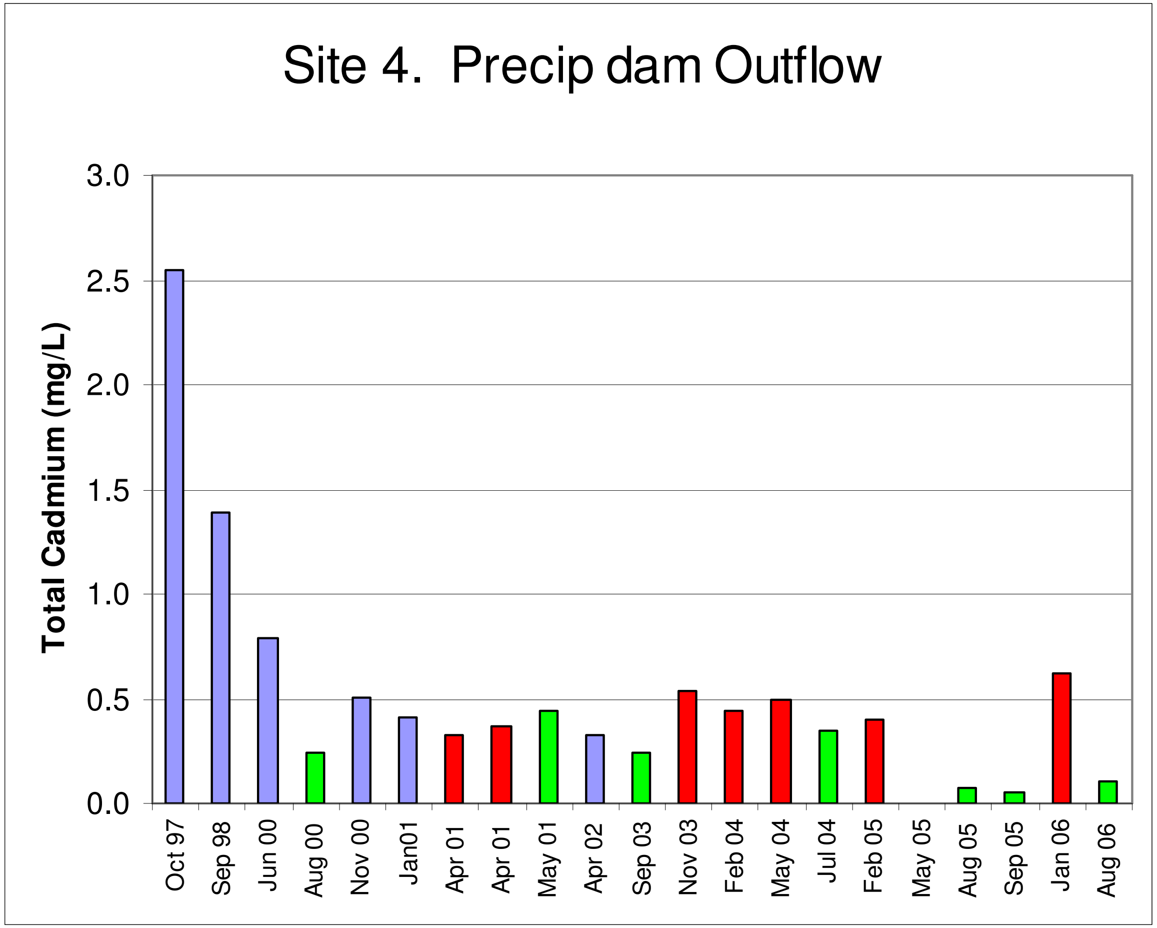


Figure 3.7a. Total cadmium graphs comparing the August 2006 results with previous monitoring results. Red bars denote low flow in storys Creek (<250 L/s), blue bars denote medium flows (250 – 350 L/s), and green bars denote high flow (>350 L/s). Note different scale for the Precipitate dam results.

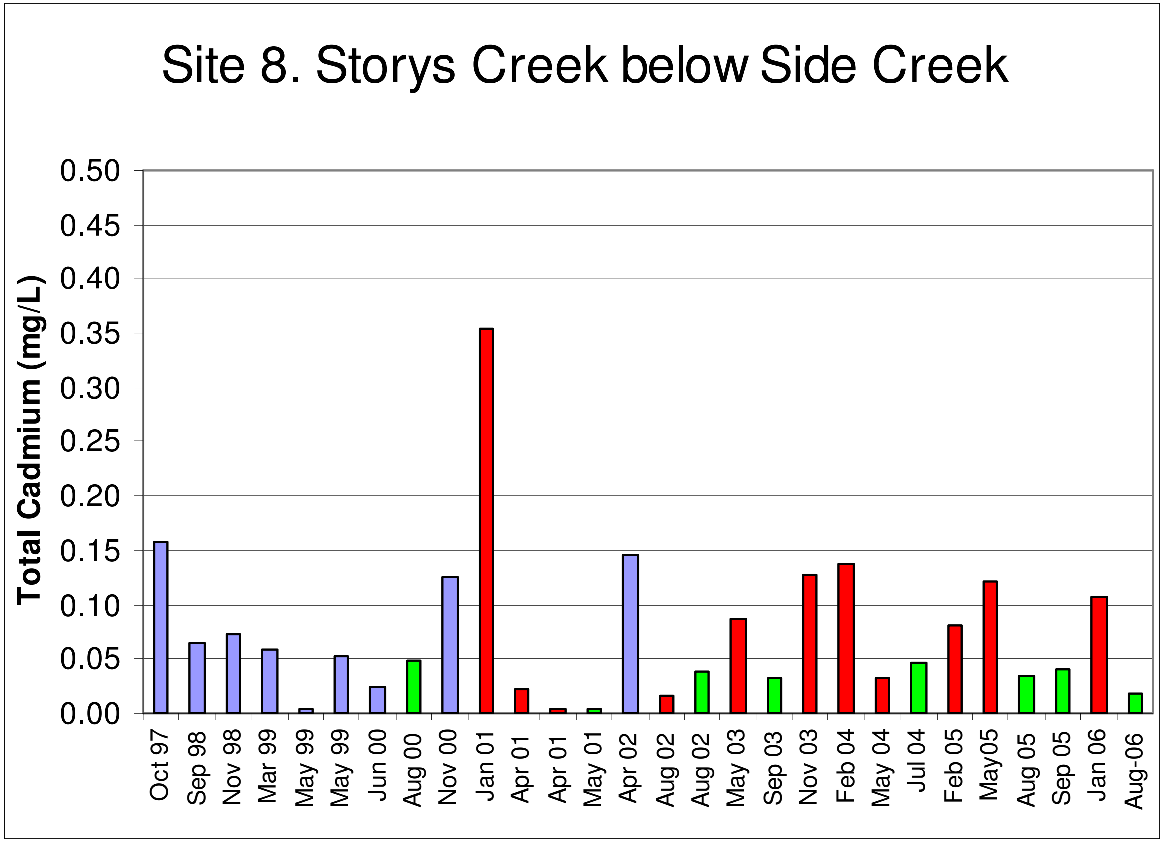


Figure 3.7b. Total cadmium graphs comparing the August 2006 results with previous monitoring results. Red bars denote low flow in storys Creek (<250 L/s), blue bars denote medium flows (250 – 350 L/s), and green bars denote high flow (>350 L/s).

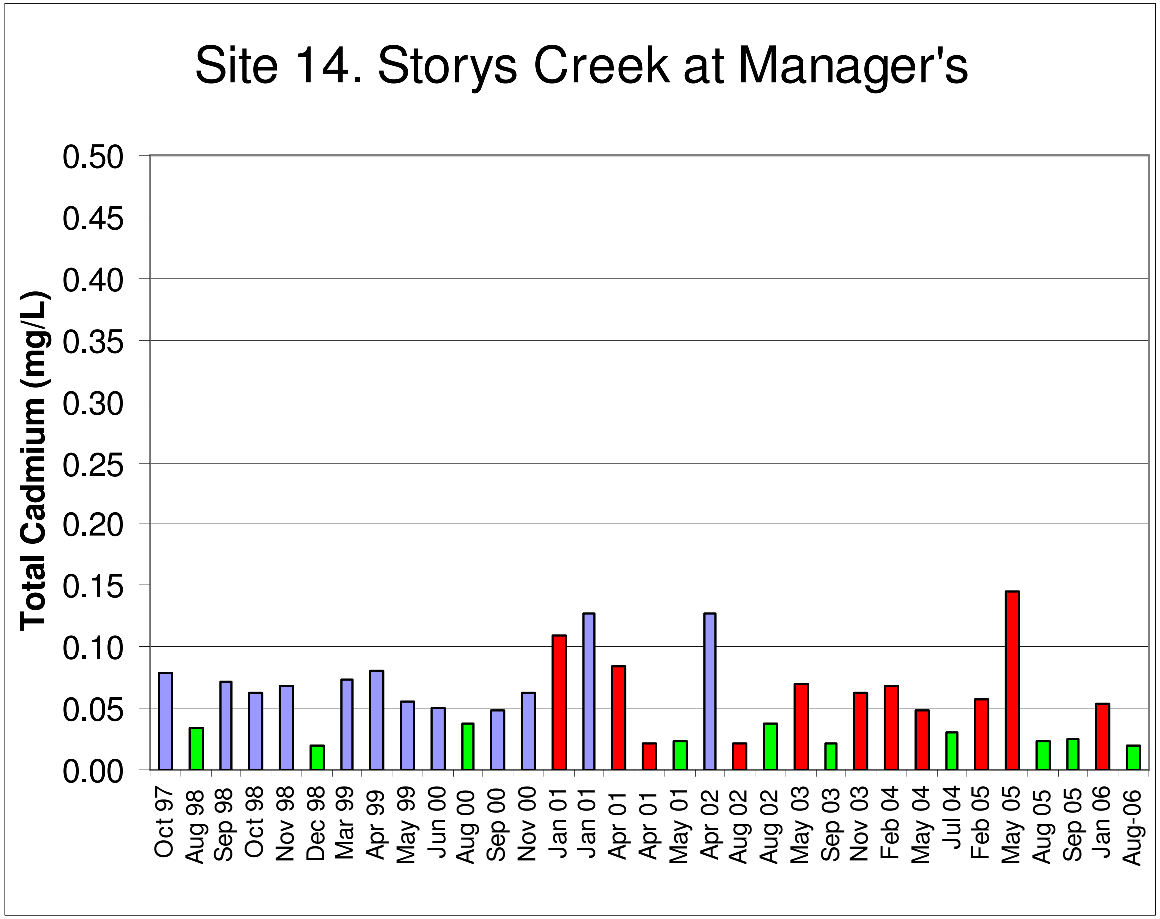


Figure 3.7c. Total cadmium graphs comparing the August 2006 results with previous monitoring results. Red bars denote low flow in storys Creek (<250 L/s), blue bars denote medium flows (250 – 350 L/s), and green bars denote high flow (>350 L/s).

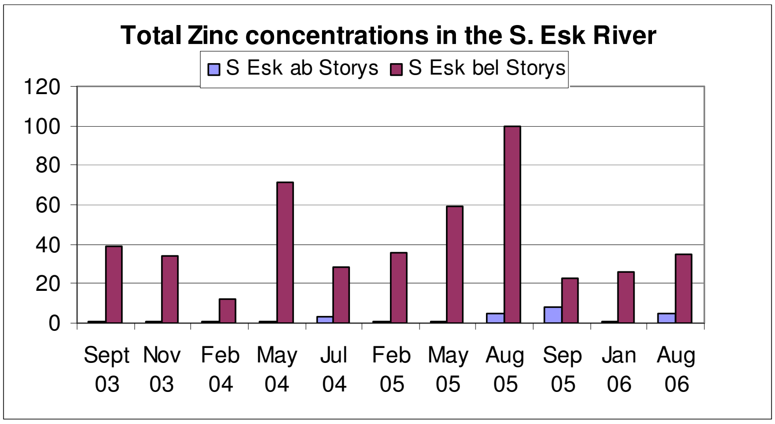


Figure 3.8. Comparison of total zinc concentrations in the South Esk River upstream and downstream of the confluence with Storys Creek.

3.2.3 Water quality – fluxes

Using the flow estimates and water quality results, fluxes for zinc, cadmium, iron, manganese and sulphate were determined, and are presented in Table 3. Figure 3.9, Figure 3.10 and Figure 3.11 show zinc, cadmium and sulphate fluxes at each of the monitoring sites in Storys Creek compared to previous results since September 2003. Figure 3.12 a-c compares all flux calculations between 1997 and the present.

Overall, fluxes in August 2006 were intermediate compared to previous results, being higher than the low – flow fluxes, but lower than fluxes associated with higher flow events such as August and September 2005. Figure 3.9 and Table 3 show that similar to previous results, the majority of the zinc flux entered between the Precipitate Dam and Storys above Side Creek, and between Storys above and below Side Creek.

Downstream of Side Creek, fluxes continued to increase through the Storys at Manager's monitoring site. These results are consistent with major metal sources located on the mine site between the Precipitate Dam and Side Creek, but also show that some zinc is continuing to enter below Side Creek, presumably due to the large volumes of tailings in the river. A similar pattern exists for the cadmium flux.

Iron, manganese and sulphate fluxes show the largest increases between the Above and Below Side Creek sites, consistent with the low pH, high metal water known to persist in this area.

In the lower river, Storys Creek contributed about 70% of the zinc load and 80% of the cadmium load entering the South Esk, with Aberfoyle Creek contributing the remainder. The contribution of sulphate to the lower river was more evenly distributed between the two rivers, with Storys contributing ~53%.

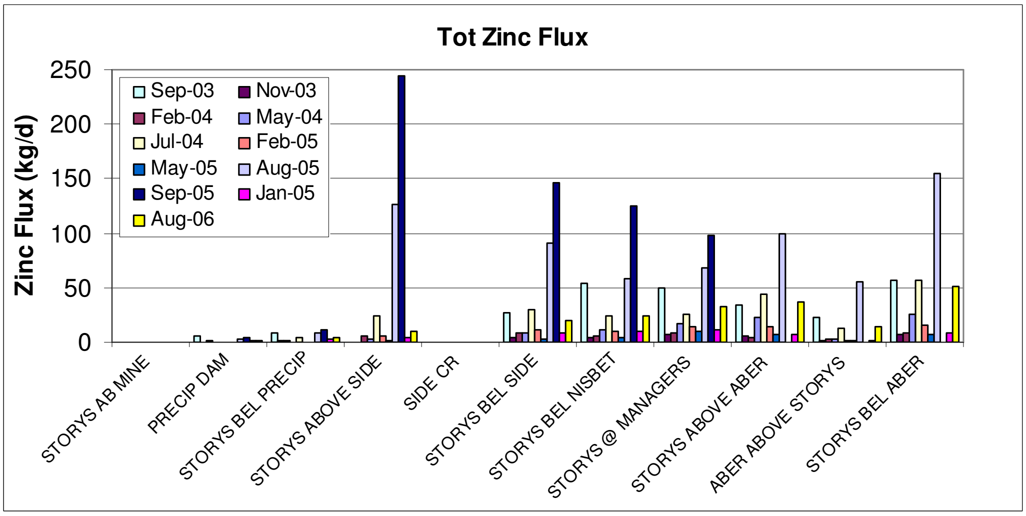


Figure 3.9. Total zinc fluxes for sites in Storys Creek for all sampling runs since September 2003. Note, Storys above Side Creek was not monitored in September 2003.

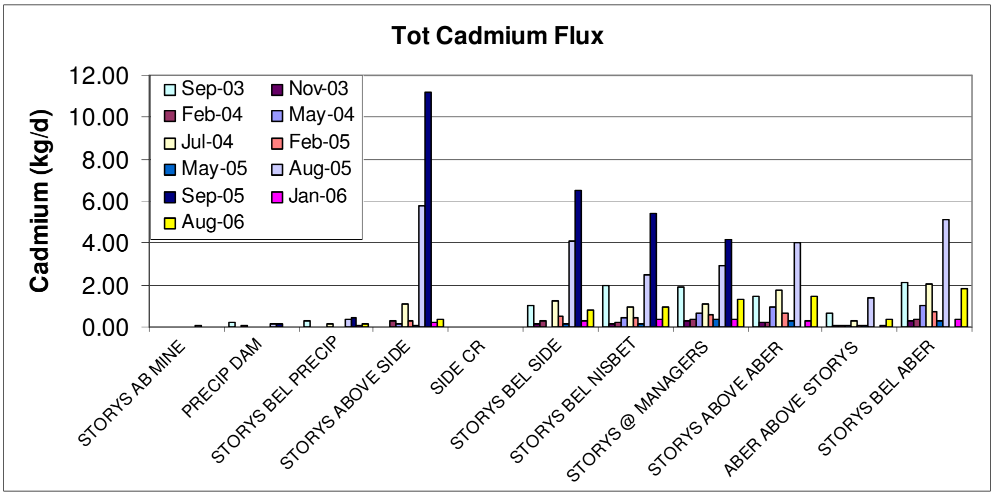


Figure 3.10. Total cadmium fluxes in Storys Creek since September 2003.

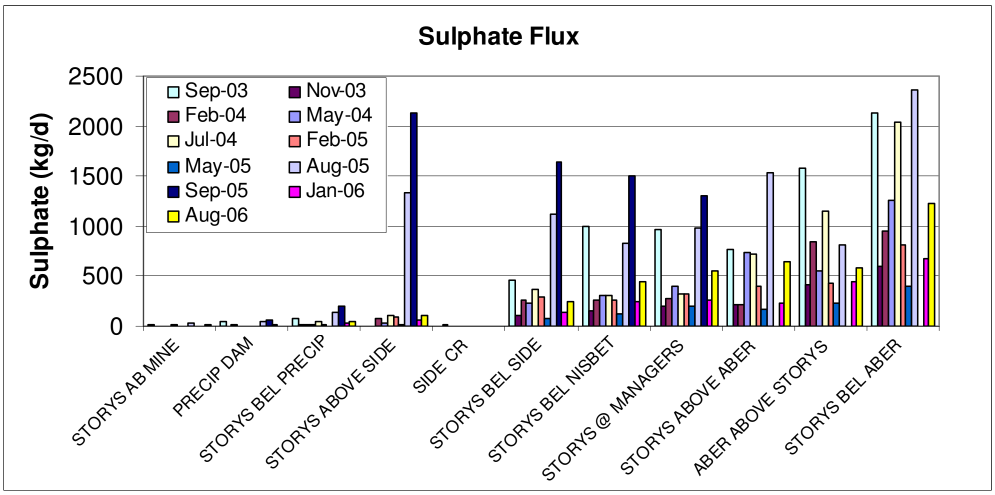


Figure 3.11. Sulphate fluxes in Storys Creek since September 2003. Storys above Side Cr was not monitored in September 2003.

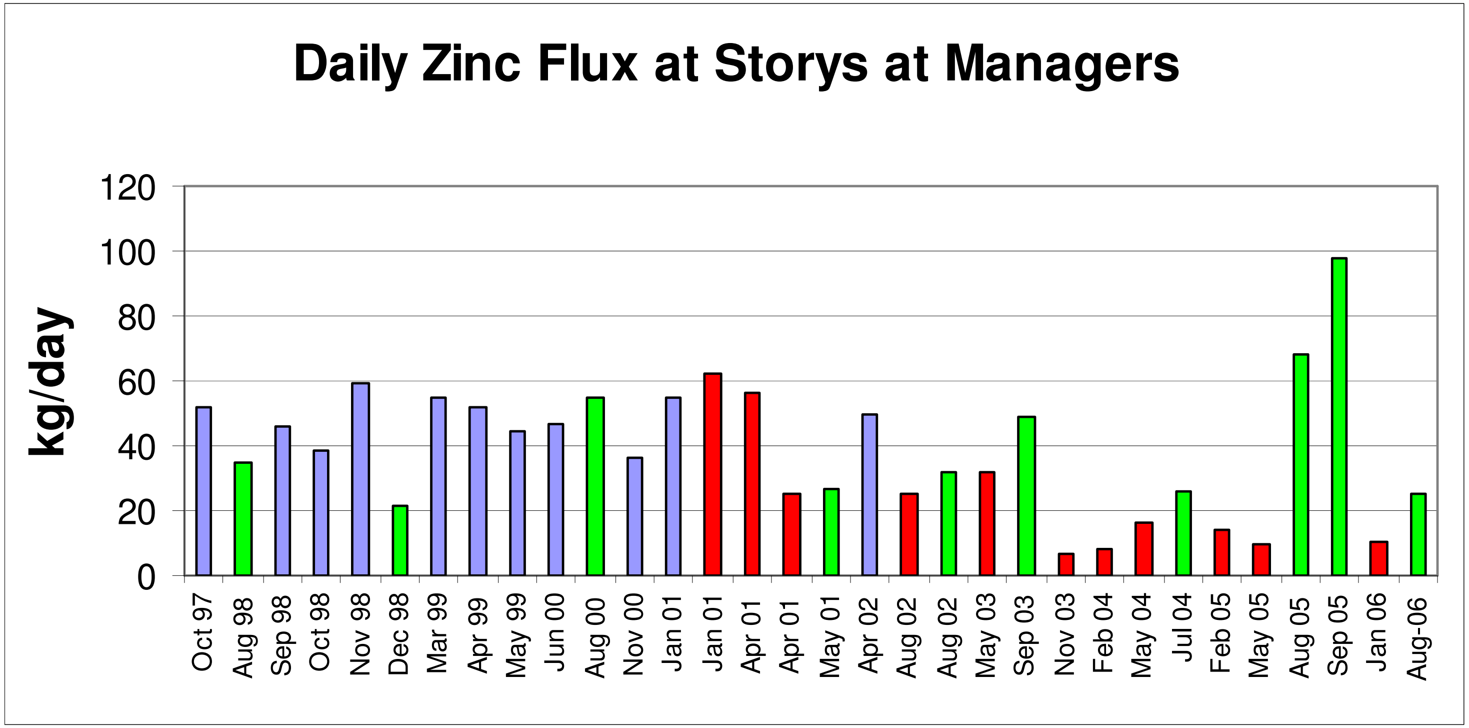


Figure 3.12a Daily total zinc fluxes at Managers Site. Red denotes low flow (<250 l/s); blue denotes moderate flow (250 -350 l/s) and green denotes high flow (>350 l/s)

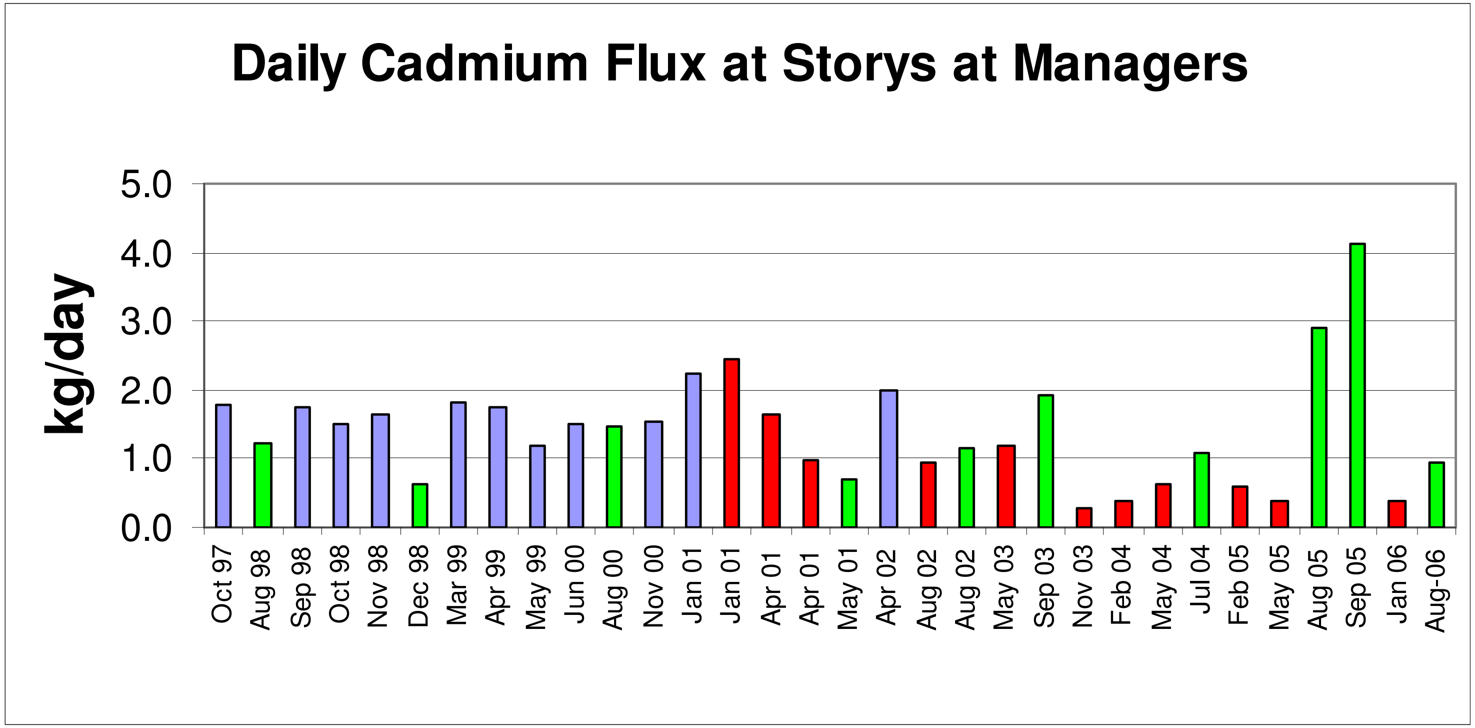


Figure 3.12b. Daily total cadmium fluxes at Managers Site. Red denotes low flow (<250 l/s); blue denotes moderate flow (250 -350 l/s) and green denotes high flow (>350 l/s)

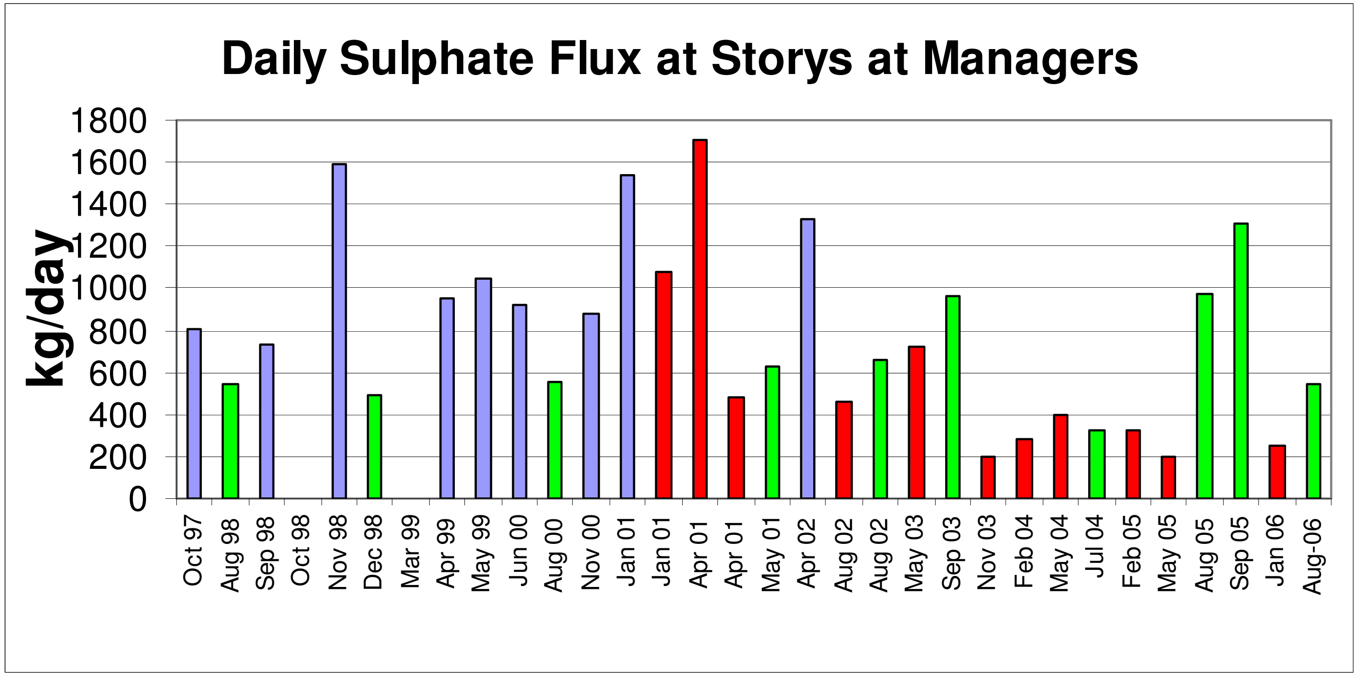


Figure 3.12c. Daily total sulphate fluxes at Managers Site. Red denotes low flow (<250 l/s); blue denotes moderate flow (250 -350 l/s) and green denotes high flow (>350 l/s)

4 Synthesis of results from monitoring program

- Flow levels in Storys Creek are a major factor controlling downstream water quality. During periods of low flow, metal and sulphate concentrations in the river are elevated, although flux levels are low. In contrast, during high flow events, concentrations are lower, although still above ANZECC (2000) trigger values, but fluxes are high.
- Sediment transport and deposition also affects water quality in Storys Creek. Sediment supply to the river has been far greater than 'natural' due to the disposal of mining wastes, and the river is slowly transporting this material through the catchment. Because much of the sediment is metal rich, the disturbance, transport and deposition of the material contributes to metal loads through the catchment. Fine grained sediments, deposited on banks and bars following large flow events, contain very high levels of zinc, cadmium and other metals, and are readily dispersed by wind and subsequent high water flows. During high flow events, zinc fluxes increase below the mine site, which was in sharp contrast to the low-flow events where there is little change downstream of the mine site. It is hypothesized that this additional zinc source is from the flushing of exposed in the river channel. This process will continue for a very long time.
- Metal input from the sediments and tailings deposited in Storys Creek is very low compared to inputs from the historic mine site. Specifically, the area bounded by the monitoring sites Storys below Precipitation Dam and Storys below Side Creek contributes the largest metal and sulphate loads to the river under low or high flow conditions. This area contains the remaining tailings deposit, which are exposed on the steep valley wall of the river, the underground mine workings, and the Side Creek catchment, a source of seepage from the underground workings Almost all of the contaminants entering this area of the river are associated with ground water inputs, with Side Creek flows recorded as ≤2 l/s on all sampling runs.
- The ground water inputs can be attributed to sources based on the pH of the input. During periods of very low flow, the pH of the river in this region decreases, and iron, sulphate and metal concentrations increase. It is likely that most of this low-flow input is derived from ground water associated with the underground workings, and is the result of sulphide oxidation. During periods of high flow, the pH of the river does not decrease as much, and zinc and copper increases proportionately greater than iron. This groundwater input is derived from the flushing of metals from the exposed tailings deposit.

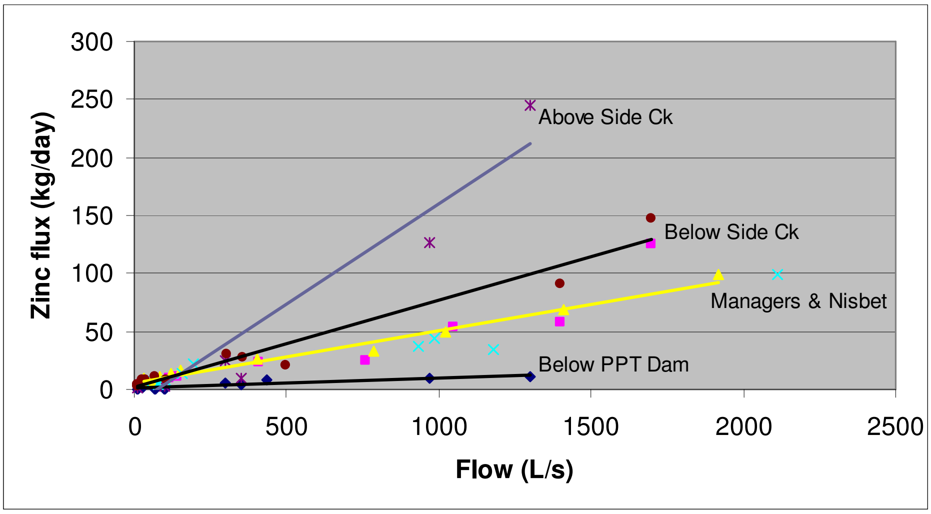


Figure 4.1. Graph of zinc fluxes from Storys Creek between September 2003 and August 2006.

- Zinc fluxes at the monitoring sites show distinct trends (Figure 4.1). At the Below the Precipitate Dam site, zinc fluxes are low, and increase uniformly with flow (black trend line). At the Storys above Side Creek site, zinc fluxes are undetectable when flow is very low, but increase rapidly and uniformly during high flow. This is indicative of zinc being flushed from the tailings deposits during high flows. The Below Side Creek trend shows that at very low flow, zinc fluxes are higher than the Above Side Creek site, but that at higher flows, zinc fluxes are relatively lower at the downstream site. This is due to the inflow of additional water between the sites, and possibly the loss of zinc to the sediments between the sites. The, final trend line (yellow) is fitted to the Storys at Managers and Storys below Nisbet zinc fluxes. The results show that no additional zinc sources are entering the river between these sites, and that the fluxes can be accounted for by the inputs from the mine.

- The fluxes determined at the Storys above Side Creek site are the highest in the catchment (Figure 3.9), and decrease downstream. This is unusual (fluxes should not decrease), and is possibly due to the water quality gradient present across the river at this monitoring site. The western side of the river, near the tailings deposits, has higher concentrations of metals and sulphate as compared to the eastern bank. Although monitoring attempted to collect a representative sample, the high flux values may indicate that the results at this site over represent the metal-rich inputs. An alternative interpretation is that much of this flux is lost to the bed of the river through precipitation and sedimentation of metal hydroxides, and / or through the loss of surface flow into the sub-surface. The results, which show a strong and uniform trend in flux v flow (Figure 4.1, R^2 for Storys above Side = 0.93) for this site supports the second interpretation.

- Fluxes increase in a linear manner over the range of flows monitored. This demonstrates that the mine site is transport limited with respect to zinc. That is, the rate of zinc release from the sediments is higher than the rate of transport by water away from the sediments.

- The flux and concentration results are consistent with a scenario in which metal rich-ground water is continuously entering Storys Creek in the vicinity of Side Creek, with episodic inputs of high metal fluxes associated with high rainfall events.

- The concentration of metals in the discharge from the Precipitate Dam is higher during periods of low flow, suggesting ground water flows through the system are probably the source of the metals. The zinc and cadmium flux from the dam is sufficient to increase metal concentrations in Storys Creek from at or below levels of detection, to above the ANZECC (2000) water quality guidelines for the protection of aquatic ecosystems.
- Zinc, cadmium and copper concentrations at the Above Side Creek site and all downstream sites exceed the ANZECC (2000) trigger values for protection of aquatic ecosystems for all monitoring runs.
- Eastern Adit has low flow, but elevated zinc, manganese and fluoride levels. The discharge from the adit does not reach Storys Creek as a surface flow, so is another (relatively small) ground water contribution.
- Aberfoyle Creek contributes 30 -50% of the total zinc load entering the South Esk River. Aberfoyle Creek also contributes substantial although varying quantities of cadmium, copper, fluoride and sulphate.
- The impact on the South Esk River due to Storys Creek (including Aberfoyle Creek) is to increase zinc concentrations by ~30 µg/l, which results in zinc concentrations in the South Esk exceeding the ANZECC (2000) trigger values for the protection of aquatic ecosystems. An exception occurs when the headwaters of Storys Creek receive high rainfall, but the remaining South Esk catchment does not. Under these conditions, the impact of Storys on the South Esk is much greater, with zinc concentrations increasing by 70 – 100 µg/l.
- Establishing the effects of the remediation works on water quality is difficult as flow levels associated with monitoring completed prior to remediation are visual estimates, and of poor reliability. If it is assumed that flow rates have remained constant, then comparing concentrations provides an indication of long-term water quality trends. A comparison of average zinc, cadmium and sulphate concentrations at the Precipitate Dam and at Storys at Managers site is contained in Table 5. The removal and remediation of the Precipitation Dam has resulted in a large decrease in the concentration (and flux) of cadmium and zinc entering Storys Creek. At the Storys at Manager site, concentrations have decreased by 20 – 30% for the three parameters. This is likely under estimating the impact of the remediation works, as many of the post-works monitoring runs were completed during periods of very low flow, when concentrations are high (see **Error! Reference source not found.** and **Error! Reference source not found.**)

Table 5. Average concentrations of total zinc, total cadmium and sulphate before remediation efforts (pre-August 2002), and following remediation works (Sept 03 - present).

Average Concentration	Precipitate Dam		Storys at Managers	
	Pre-works	Post-works	Pre-works	Post-works
Zinc (tot) mg/l	19.7	9.3	1.8	1.3
Cadmium (tot) µg/l	0.74	0.30	0.06	0.05
Sulphate	232	91	38	29

5 Recommendations

- To retain and enhance the present benefits of the existing remediation works, some infrastructure maintenance is required:
    - Fix the ALD so the outflow enters the under ground workings;
    - Reconstruct the overflow of the Precipitate Dam so the outflow does not erode the dam wall;
- In the future, channel disturbance should be minimized. The movement of disturbed material through the river is contributing to the zinc loads, although this is a small portion of the total;
- Additional improvements in water quality will only be achieved through addressing the ground water emanating from the Side Creek area, and / or the storm water flushing the exposed tailings deposits. Focusing future remediation efforts on the tailings deposits would be a logical step as they are a large source of metals and readily accessible.
- A re-assessment of sources in Aberfoyle Creek should be completed, as this waterway contributes 30-50% of the metals entering the South Esk.

6 Related References

ANZECC/ARMCANZ, 2000, Australian Water Quality Guidelines for Fresh and Marine Waters.

John Miedecke & Partners, 1998, Storys Creek / Rossarden Acid Drainage Remediation Study, Preliminary Report December 1997. Report to MRT.

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