



R.Eriksen and D.Ray

122 Karratha Dve,

Sandford 7020

Tasmania

Ph: (03) 62 488 404

Mob: 0429 488 404

Email: dray@aquaticscience.com.au

ABN 12 367 035 320

Update – Long Plains Water Quality Audit to June 2019.

Introduction

Grange Resources are developing mine plans for the extension of the Savage River Mine to include the Long Plains Deposit. The Long Plains Area is 9 km to the South-West of the Savage River Mill. The topography of the area is rugged with steep and deep valleys extending to most watercourses.

Aquatic Science has been contracted to work with Grange Resources to establish the current water quality before mining. This data is to be used to assist with water management and mine planning to enable effective environmental management of future operations.

Initial monitoring of the Long Plains Lease has been undertaken, commencing in November 2012. An overview of the data collected is provided in this update, followed by recommendations for mine planning, water management and future water monitoring.

Currently, the flow monitoring infrastructure at the site requires an upgrade. The collation of collected river level data is required. Once the level data is organised the hydrographic information from the data can be analysed.

The water quality from the lease during low to moderate flows is well understood. The water quality during high flows requires further monitoring as current knowledge is based on one monitoring event that produced limited data due to the associated safety issues that occurred due to the high river flows. Further sampling during high flows is required.

Currently, there are two options for high flow sampling:

- Integrate the sampling with Emergency Response Team (ERT) exercise to take samples during high flow events and incorporate emergency response for remote area assistance under adverse weather conditions.
- The use of 'Low-Powered-Wide-Area-Network (LPWAN) technology to provide both collection of flow data and for the remote triggering of automates sample devices.

Additional work will be undertaken to evaluate these options before the commencement of further sampling.

Track work is required to improve site access. There has been a deterioration in the track condition from a safety perspective over the past year. The trackwork is to be completed once the future sampling strategy has been established.

Long Plains Maps and Sample Sites

Maps of the current sample sites are provided. The maps are provided as separate PDF's to enable them to be printed at the correct scale and format. Please note that the maps include a graticule on their

border with Eastings and Northings (GDA 94). This enables a GPS (Set to UTM UPS) to be used to ascertain position on the map in the field or waypoints to be generated off the map in the field. Thick scrub and inability to use a compass due to interference from the magnetite ore make the use of a good quality GPS essential for navigation.

A laminated version of the maps is recommended for inclusion with the field kit for future sampling. This will improve safety when exploring. The maps are also left with supervisors and emergency staff in the event that samplers require assistance (As required by JSA for remote water sampling at Long Plains)

Map 1: Long Plains All Sample Sites:	Scale 1:20,000
Map 2: Plains Northern Sample Sites	Scale 1:10,000
Map 3: Plains Southern Sample sites	Scale 1:10,000

Sampling was conducted at the following sites (see Map 1, 2 & 3) :

- Bowry Creek, above Bridge and F Creek
- Bowry Creek, lower Flow Station
- F Creek, above Bowry Creek
- Freeman Creek, Flow Station
- Maurice Creek, above Freeman Ck
- NF Creek, above Bowry Creek
- Shadow Creek, above Freeman

It is important to note the number of contours crossed by the tracks, illustrating the steep and difficult terrain to navigate. The sampling is difficult due to the terrain and the associated hazards need to be managed.

Please note that the southern sites also include a track to the South to enable the access or escape during high flow events.

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Insert Map 2 from pdf

Insert Map 3 from pdf

Sampling and equipment

Aquatic Science has assisted Grange staff and provided training on sampling, project specific sampling requirements and flow gauging.

The equipment list used for the sampling:

- pH and conductivity meter
- waders
- waterproof pad to record field results
- Good quality GPS including Maps in Map 1,2,&3 laminated.
- Flow Tracker
- Good quality backpacks
- Handheld radio
- EPIRB or satellite phone
- AST sample bottles 8 Metals Bottles, 8 General Bottles, * metals sample vials and 8 syringes and filters.
- Buffers, pH 7 and 4.
- Conductivity standard 1,413 $\mu\text{S}/\text{cm}$.
- Wet weather gear and first aid kit.
- Torch
- First aid kit
- Sturdy hiking boots

Meters are calibrated prior to sampling.

The parameters measured are consistent between sites and include.

- **Metals (Dissolved and Totals);** Al, As, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Zn.
- **Major Cations;** Ca, Mg, K, Na.
- **Nutrients (Freeman and Lower Bowry);** Ammonia, Nitrate, Nitrite, Nitrogen, Dissolved Phosphorus, Total Phosphorus.
- **Anions;** Sulphate, Chloride, Fluoride.
- **Other Analytes;** Alkalinity- CO_3 , Alkalinity- HCO_3 , Alkalinity Total, DOC (NPOC Dissolved), TSS 0.45 μ , Silica.
- **Flow;** Field measurement via gauging.
- **Field measurements;** pH, Conductivity, Water Temperature and Turbidity

Baseline Water Quality Results

The current water quality results undertaken for the Long Plains Lease are presented. Sampling was conducted quarterly, with a combination of field-based measurements, and laboratory assays. Days sampled were picked randomly to prevent mild weather and associated low flow conditions being sampled. Despite the random sampling, there has been limited sampling during high flow events.

The water quality monitoring strategy for the Long Plains lease has been refined during this sampling period. The sampling strategy has been modified taking into account the water quality results to date, practicalities and safety issues associated with the sampling, and capacity to be integrated into groundwater studies being undertaken on the lease. Grange Staff (Carol Steyn, Roger Hill, Josh Wrigley, Brok Whitaker-Mills and Ben Whitney), Caloundra Environmental (Stephen Kent), Mining One (Alexis Valenza) and Entura (James Butler) have all contributed to the monitoring design.

The reference water quality data for a wide range of parameters for the Main Sites are presented in Table 1 to **Error! Reference source not found.** (median, data range and sample number). Data is provided for the Northern Sites in Table 1 and **Error! Reference source not found.** The data for the

Southern sites are presented in **Error! Reference source not found.** and **Error! Reference source not found.**

Review of the data shows that the levels of metals and sulphate are low, indicating minimal Acid Rock Drainage (ARD) within the catchment.

All data for the project is stored on the Splash-Back Water Quality Database. Further data analyses maybe were undertaken using SplashBack Viewer. Grange Resources is a subscriber to the SplashBack package and data can be distributed to contractor's and staff if required.

Site	Bowry Creek above Bridge and F Creek				F Creek				NF Creek above Bowry Creek				Bowry Creek lower Flow Station			
	Mean	Max	Std Error	Number	Mean	Max	Std Error	Number	Mean	Max	Std Error	Number	Mean	Max	Std Error	Number
Acidity to pH 8.3 mg/L (CaCO3)	7.3	12	2.6	3	3.5	5	0.5	4	3.0	3	0.0	3	3.0	3	0.0	2
Alkalinity (Total) mg/L	14.1	35	2.4	23	19.0	28	1.6	20	45.1	60	2.1	23	29.7	53	3.4	22
Alkalinity CO3 mg CaCO3/L	2.0	2	0.0	8	2.0	2	0.0	4	2.0	2	0.0	8	2.0	2	0.0	8
Alkalinity HCO3 mg CaCO3/L	11.5	22	2.4	8	18.3	23	2.4	4	43.9	52	2.6	8	27.0	38	4.1	8
Aluminium (Dissolved) as Al ug/L	240.2	510	29.8	23	89.5	479	23.6	20	24.5	55	1.9	23	156.1	371	24.7	22
Aluminium (Total) as Al ug/L	377.0	3040	124.0	23	451.5	4600	233.7	20	109.4	494	19.9	23	188.0	431	25.8	22
Ammonia and Ammonium as N ug/l	39.8	140	8.9	15	25.7	56	6.8	11	26.3	50	5.4	15	26.1	50	4.7	18
Arsenic (Dissolved) as As ug/L	14.6	20	0.8	23	13.1	15	1.0	20	14.2	20	1.0	23	14.8	20	0.8	22
Arsenic (Total) as As ug/L	14.6	20	0.8	23	13.1	15	1.0	20	14.2	20	1.0	23	14.8	20	0.8	22
Barium as Ba mg/L	0.0	0.005	0.0	12	0.0	0.007	0.0	13	0.0	0.008	0.0	13	0.0	0.005	0.0	12
Barium Dissolved as Ba ug/L	4.8	5	0.3	12	4.6	5	0.3	13	4.9	5	0.1	13	4.8	5	0.3	12
Bromide as Br mg/l	0.1	0.1	0.0	12	0.1	0.1	0.0	12	0.1	0.1	0.0	13	0.1	0.1	0.0	13
Cadmium (Dissolved) as Cd ug/L	1.8	2	0.1	23	1.7	2	0.1	20	1.8	2	0.1	23	1.9	2	0.1	22
Cadmium (Total) as Cd ug/L	1.8	2	0.1	23	1.7	2	0.1	20	1.8	2	0.1	23	1.9	2	0.1	22
Calcium (Dissolved) as Ca mg/L	2.5	4.24	0.2	23	3.6	4.84	0.2	20	6.8	9.08	0.3	23	3.7	6.01	0.3	22
Calcium (Total) as Ca mg/L	2.5	4.37	0.2	23	3.7	5.07	0.2	20	6.9	9.59	0.3	23	3.8	5.92	0.3	22
Chloride as Cl mg/L	20.9	25.7	0.5	23	22.7	26.8	0.4	20	24.7	27	0.2	23	22.0	25.9	0.4	22
Chromium (Dissolved) as Cr ug/L	1.9	2	0.1	23	1.8	2	0.1	20	1.9	2	0.1	23	1.9	2	0.1	22
Chromium (Total) as Cr ug/L	2.0	4	0.1	23	2.1	7	0.3	20	1.9	2	0.1	23	1.9	2	0.1	22
Cobalt (Dissolved) as Co ug/L	2.0	3	0.1	23	1.8	2	0.1	20	2.0	3	0.1	23	2.1	3	0.1	22
Cobalt (Total) as Co ug/L	2.3	8	0.3	23	2.3	8	0.4	20	2.0	3	0.1	23	2.1	3	0.1	22
Conductivity Field uS/cm (25 TRef)	110.5	156	5.3	23	119.0	150	4.2	20	185.0	241.3	6.1	23	141.1	203	7.2	22
Copper (Dissolved) as Cu ug/L	1.9	2	0.1	23	2.0	4	0.1	20	1.9	2	0.1	23	1.9	2	0.1	22
Copper (Total) as Cu ug/L	2.1	7	0.2	23	2.5	12	0.5	20	1.9	2	0.1	23	1.9	2	0.1	22
Dissolved Organic Carbon mg/l	13.2	26	1.6	23	3.9	12	0.6	20	1.9	4	0.2	23	9.2	24	1.3	22
Flow (Cumeccs) cumeccs	0.0	0.1221	0.0	22	0.0	0.028	0.0	18	0.0	0.017	0.0	23	0.1	0.1825	0.0	22
Fluoride (Dionex) mg/l	0.1	0.05	0.0	22	0.1	0.05	0.0	19	0.1	0.05	0.0	22	0.1	0.05	0.0	21
Iron (Dissolved) as Fe ug/L	391.3	747	32.6	23	170.9	1060	49.0	20	39.9	108	4.7	23	271.3	578	28.3	22
Iron (Total) as Fe ug/L	651.6	5160	207.0	23	854.1	8380	430.0	20	192.3	815	32.5	23	345.5	663	27.3	22
Lead (Dissolved) as Pb ug/L	9.3	10	0.4	23	8.8	10	0.7	20	9.0	10	0.6	23	9.4	10	0.4	22
Lead (Total) as Pb ug/L	9.3	10	0.4	23	8.8	10	0.7	20	9.0	10	0.6	23	9.4	10	0.4	22
Magnesium (Dissolved) as Mg mg/L	4.2	7.26	0.4	23	4.1	5.3	0.2	20	9.1	11.7	0.4	23	7.2	11.2	0.6	22
Magnesium (Total) as Mg mg/L	4.2	7.27	0.4	23	4.2	5.52	0.2	20	9.2	11.9	0.4	23	7.3	11.1	0.6	22
Manganese (Dissolved) as Mn ug/L	12.1	45	2.1	23	7.2	30	1.3	20	5.2	10	0.2	23	6.9	15	0.6	22
Manganese (Total) as Mn ug/L	17.2	126	5.2	23	41.3	323	19.2	20	11.2	61	2.4	23	10.5	18	0.7	22
Mercury (Dissoved) as Hg ug/L	0.1	0.05	0.0	10	0.1	0.05	0.0	10	0.1	0.05	0.0	10	0.1	0.05	0.0	9
Mercury (Total) as Hg ug/L	0.1	0.05	0.0	11	0.1	0.05	0.0	11	0.1	0.05	0.0	11	0.1	0.05	0.0	10
Molybdenum Dissolved as Mo mg/l	4.786	5	0.2	21	4.5	5	0.3	18	4.6	5	0.3	22	4.79	5.00	0.21	21
Molybdenum Total as Mo mg/l	4.786	5	0.2	21	4.5	5	0.3	18	4.6	5	0.3	22	4.79	5.00	0.21	21

Table 1 - Long Plains Northern Sites-Metals Parameters A to M.

Site	Bowry Creek above Bridge and F Creek				F Creek				NF Creek above Bowry Creek				Bowry Creek lower Flow Station			
	Mean	Max	Std Error	Number	Mean	Max	Std Error	Number	Mean	Max	Std Error	Number	Mean	Max	Std Error	Number
Nickel (Dissolved) as Ni ug/L	9.6	10	0.4	23	9.1	10	0.7	20	9.2	10	0.6	23	9.6	10	0.4	22
Nickel (Total) as Ni ug/L	9.6	10	0.4	23	9.1	10	0.6	20	9.2	10	0.6	23	9.6	10	0.4	22
Nitrate as N ug/l	16.7	34	2.3	15	25.7	46	3.0	11	42.5	60	3.0	15	22.7	44	2.8	18
Nitrite and Nitrate as N ug/L	4.8	26	2.6	13	2.9	26	2.9	9	11.8	58	6.2	13	5.6	33	3.1	13
Nitrite as N ug/l	12.1	20	1.9	15	8.6	20	2.7	11	9.2	20	2.4	15	10.0	20	1.8	18
Nitrogen (Total) as N ug/L	295.3	550	32.8	15	145.5	210	10.0	11	127.3	180	5.2	15	231.7	390	19.2	18
Nitrogen Total Kjeldahl ug-N/L	280.0	530	36.1	14	127.0	190	10.7	10	105.7	150	4.0	14	212.1	380	27.0	14
pH field - sensor TC Units	6.9	8.48	0.2	22	7.3	8.48	0.1	19	7.6	8.24	0.1	22	7.5	8.07	0.1	21
Phosphorus (Dissolved) as P ug/L	14.0	30	3.5	15	13.3	30	4.0	11	14.5	30	3.4	15	12.4	30	3.0	18
Phosphorus (Total) as P ug/L	10.7	20	0.7	15	11.8	30	1.8	11	10.7	20	0.7	15	10.0	10	0.0	18
Potassium (Dissolved) as K mg/L	0.5	0.71	0.0	23	0.6	0.8	0.0	20	0.8	0.86	0.0	23	0.5	0.66	0.0	22
Potassium (Total) as K mg/L	0.5	1.07	0.0	23	0.6	0.95	0.0	20	0.8	0.9	0.0	23	0.5	0.66	0.0	22
Selenium (Dissolved) as Se ug/L	27.9	30	2.1	12	26.2	30	2.6	13	26.2	30	2.6	13	27.9	30	2.1	12
Selenium (Total) as Se ug/L	27.9	30	2.1	12	26.2	30	2.6	13	26.2	30	2.6	13	27.9	30	2.1	12
Silica Molybdate Reactive ug/L	5557.1	7200	513.1	7	8300.0	9500	832.7	3	6785.7	7500	352.2	7	5820.0	7200	380.0	10
Sodium (Dissolved) as Na mg/L	11.3	13.2	0.3	23	12.6	14	0.2	20	13.7	15.6	0.2	23	12.1	13.8	0.2	22
Sodium (Total) as Na mg/L	11.4	13.3	0.3	23	12.6	14	0.2	20	13.9	15.4	0.2	23	12.3	13.6	0.2	22
Sulphate (Dionex) as SO4 mg/l	3.2	5.7	0.2	23	4.3	4.9	0.1	20	8.0	11.4	0.3	23	4.9	7.2	0.3	22
Total suspended solids (0.45um) mg	9.3	158	6.8	23	10.1	141	7.0	20	9.0	134	5.7	23	3.9	32	1.4	22
Turbidity NTU	1.2	2.02	0.1	12	1.9	3.03	0.3	10	2.3	4.77	0.3	12	1.5	2.52	0.1	13
Water Temperature Degrees C	10.1	16.7	0.5	23	9.8	15.5	0.5	20	9.9	13.8	0.4	23	9.9	15.1	0.5	22
Zinc (Dissolved) as Zn ug/L	2.3	4	0.2	23	2.0	4	0.1	20	1.9	2	0.1	23	2.1	3	0.1	22
Zinc (Total) as Zn ug/L	3.5	17	0.8	23	3.3	18	0.9	20	1.9	2	0.1	23	2.2	5	0.2	22
Flux Ca Dissolved kg/day	8.3	18.8	1.0	22	2.3	10.5	0.6	18	3.9	7.5	0.3	23	17.5	38.5	1.7	22
Flux Ca Total kg/day	8.5	19.3	1.0	22	2.3	10.7	0.6	18	3.9	7.5	0.3	23	17.5	33.0	1.5	22
Flux Copper Total kg/day	0.008	0.021	0.001	22	0.001	0.005	0.000	18	0.001	0.003	0.000	23	0.011	0.032	0.002	22
Flux Mg Dissolved kg/day	14.0	33.9	1.6	22	2.7	12.2	0.7	18	5.2	10.5	0.5	23	32.7	58.5	2.5	22
Flux Mg Total kg/day	14.1	34.2	1.6	22	2.7	12.4	0.7	18	5.2	10.6	0.5	23	33.2	60.2	2.6	22

Table 2 - Long Plains Northern Sites-Metals Parameters N to Z including Fluxes.

	Maurice Creek above Freeman Ck.				Freeman Creek Flow Station				Shadow Creek above Freeman			
	Mean	Max	Std Error	Number	Mean	Max	Std Error	Number	Mean	Max	Std Error	Number
Acidity to pH 8.3 mg/L (CaCO3)	4.8	9	1.4	4	4.0	5	0.6	3	3.0	3	0.0	2
Alkalinity (Total) mg/L	20.2	36	2.1	24	24.0	42	2.7	23	16.9	27	1.6	22
Alkalinity CO3 mg CaCO3/L	2.0	2	0.0	8	2.0	2	0.0	8	2.0	2	0.0	8
Alkalinity HCO3 mg CaCO3/L	19.3	27	2.6	8	23.1	31	3.1	8	16.0	21	2.0	8
Aluminium (Dissolved) as Al ug/L	174.5	433	29.2	24	148.3	434	26.6	23	115.7	281	17.9	22
Aluminium (Total) as Al ug/L	550.0	8100	329.6	24	251.8	1960	81.4	23	194.9	384	22.1	22
Ammonia and Ammonium as N ug/l	31.1	52	5.6	15	21.8	50	4.9	18	25.9	50	5.4	15
Arsenic (Dissolved) as As ug/L	14.0	20	0.9	24	14.6	20	0.8	23	14.8	20	0.8	22
Arsenic (Total) as As ug/L	14.0	20	0.9	24	14.6	20	0.8	23	14.8	20	0.8	22
Barium (Dissolved) as Ba ug/L	5.8	8	0.3	13	4.9	5	0.1	12	4.9	5	0.1	12
Barium (Total) as Ba ug/L	6.5	10	0.5	13	4.9	5	0.1	12	4.9	5	0.1	12
Bromide as Br mg/l	0.1	0.1	0.0	13	0.1	0.1	0.0	13	0.1	0.1	0.0	13
Cadmium (Dissolved) as Cd ug/L	1.8	2	0.1	24	1.8	2	0.1	23	1.9	2	0.1	22
Cadmium (Total) as Cd ug/L	1.8	2	0.1	24	1.8	2	0.1	23	1.9	2	0.1	22
Calcium (Dissolved) as Ca mg/L	5.0	7.98	0.3	24	3.9	6	0.3	23	3.6	5	0.2	22
Calcium (Total) as Ca mg/L	5.2	7.8	0.3	24	3.9	5.97	0.3	23	3.6	5.34	0.2	22
Chloride as Cl mg/L	21.1	27.5	0.5	24	21.2	26.8	0.4	23	20.3	25.7	0.4	22
Chromium (Dissolved) as Cr ug/L	1.8	2	0.1	24	1.9	2	0.1	23	1.9	2	0.1	22
Chromium (Total) as Cr ug/L	2.3	12	0.4	24	2.0	3	0.1	23	1.9	2	0.1	22
Cobalt (Dissolved) as Co ug/L	2.0	4	0.2	24	2.0	3	0.1	23	2.1	3	0.1	22
Cobalt (Total) as Co ug/L	2.7	18	0.7	24	2.2	4	0.1	23	2.1	3	0.1	22
Conductivity Field uS/cm (25 TRef)	121.1	160	4.6	24	128.3	172	5.3	23	110.0	147	3.8	22
Copper (Dissolved) as Cu ug/L	2.0	4	0.1	24	2.0	4	0.1	23	1.9	2	0.1	22
Copper (Total) as Cu ug/L	2.9	21	0.8	24	2.2	5	0.2	23	2.0	3	0.1	22
Dissolved Organic Carbon mg/l	9.4	24	1.3	24	7.8	19	1.2	23	5.1	12	0.7	22
Flow (Cumecs) cumecs	0.1	1	0.0	24	0.1	0.96	0.0	23				0
Fluoride (Dionex) mg/l	0.1	0.05	0.0	23	0.1	0.05	0.0	22	0.1	0.05	0.0	21
Iron (Dissolved) as Fe ug/L	300.9	639	29.4	24	291.1	690	32.2	23	173.1	312	15.1	22
Iron (Total) as Fe ug/L	1026.7	14700	596.0	24	523.7	3680	146.3	23	296.7	509	20.7	22
Lead (Dissolved) as Pb ug/L	9.0	10	0.6	24	9.3	10	0.4	23	9.4	10	0.4	22
Lead (Total) as Pb ug/L	9.0	10	0.6	24	9.3	10	0.4	23	9.4	10	0.4	22
Magnesium (Dissolved) as Mg mg/L	3.7	5.3	0.2	24	5.4	8.09	0.4	23	3.2	4.13	0.2	22
Magnesium (Total) as Mg mg/L	3.9	5.21	0.2	24	5.5	8.1	0.4	23	3.3	4.26	0.2	22
Manganese (Dissolved) as Mn ug/L	16.0	63	2.4	24	7.7	17	0.6	23	6.0	9.0	0.3	22
Manganese (Total) as Mn ug/L	71.1	1040	42.7	24	18.1	156	6.3	23	11.0	24.0	1.2	22
Mercury (Total) as Hg ug/L	0.1	0.05	0.0	10	0.1	0.05	0.0	9	0.1	0.1	0.0	9
Mercury Dissolved as Hg ug/l	0.1	0.05	0.0	11	0.1	0.05	0.0	10	0.1	0.05	0.0	10
Molybdenum Dissolved as Mo ug/l	4.6	5.0	0.3	22	4.8	5.0	0.2	21	4.8	5.0	0.2	21
Molybdenum Total as Mo ug/l	4.6	5.0	0.3	22	4.8	5.0	0.2	21	4.8	5.0	0.2	21

Table 3 - Long Plains Southern Sites-Metals Parameters A to M.

	Maurice Creek above Freeman Ck.				Freeman Creek Flow Station				Shadow Creek above Freeman			
	Mean	Max	Std Error	Number	Mean	Max	Std Error	Number	Mean	Max	Std Error	Number
Nickel (Dissolved) as Ni ug/L	9.2	10	0.5	24	9.6	10	0.4	23	9.6	10	0.4	22
Nickel (Total) as Ni ug/L	9.3	12	0.5	24	9.6	10	0.4	23	9.6	10	0.4	22
Nitrate as N ug/l	18.0	30	2.3	15	30.3	51	3.1	18	20.0	33	2.3	15
Nitrite and Nitrate as N ug/L	4.7	29	2.8	13	7.9	42	4.2	13	5.0	27	2.8	13
Nitrite as N ug/l	10.1	20	2.2	15	9.0	20	1.9	18	9.5	20	2.3	15
Nitrogen (Total) as N ug/L	211.3	400	21.3	15	208.9	400	18.1	18	158.7	200	7.0	15
Nitrogen Total Kjeldahl ug-N/L	196.4	390	25.3	14	183.6	400	26.1	14	140.7	200	8.4	14
pH field - sensor TC Units	7.1	8.35	0.1	22	7.4	7.94	0.1	22	7.2	8.09	0.1	20
Phosphorous (Dissolved) as P ug/L	14.1	30	3.5	15	12.3	30	3.0	18	14.0	30	3.5	15
Phosphorus (Total) as P ug/L	10.0	10	0.0	15	11.1	20	0.8	18	10.0	10	0.0	15
Potassium (Dissolved) as K mg/L	0.6	0.78	0.0	24	0.6	1.22	0.0	23	0.6	0.79	0.0	22
Potassium (Total) as K mg/L	0.6	1.52	0.0	24	0.5	0.74	0.0	23	0.6	0.74	0.0	22
Selenium (Dissolved) as Se ug/L	26.2	30	2.6	13	27.9	30	2.1	12	27.9	30	2.1	12
Selenium (Total) as Se ug/L	26.2	30	2.6	13	27.9	30	2.1	12	27.9	30	2.1	12
Silica Molybdate Reactive ug/L	5100.0	6000	379.2	7	6110.0	7400	384.5	10	6071.4	7600	614.0	7
Sodium (Dissolved) as Na mg/L	11.4	13.8	0.3	24	11.7	13.7	0.2	23	11.3	13	0.2	22
Sodium (Total) as Na mg/L	11.6	14.2	0.3	24	11.8	13.8	0.2	23	11.4	12.9	0.2	22
Sulphate (Dionex) as SO4 mg/l	3.2	4.7	0.1	24	4.1	5.4	0.1	23	2.7	3.5	0.1	22
Total suspended solids (0.45um) mg	30.9	688	28.6	24	6.2	88	3.7	23	4.0	9	0.5	22
Turbidity NTU	1.9	3.35	0.2	13	1.6	3.58	0.2	13	3.3	7.34	0.7	12
Water Temperature Degrees C	8.9	13	0.5	23	9.3	13.9	0.5	23	9.1	13.5	0.5	22
Zinc (Dissolved) as Zn ug/L	2.1	3	0.1	24	2.3	4	0.2	23	2.2	6	0.2	22
Zinc (Total) as Zn ug/L	3.2	29	1.1	24	2.7	10	0.4	23	2.1	4	0.1	22
Flux Ca Dissolved kg/day	13.3	193.5	7.9	24	24.1	172.5	7.0	23				
Flux Ca Total kg/day	22.3	407.8	16.8	24	25.1	192.4	7.8	23				
Flux Copper Total kg/day	0.08	1.81	0.08	24	0.03	0.41	0.02	23				
Flux Mg Dissolved kg/day	10.0	143.4	5.8	24	31.1	187.5	7.4	23				
Flux Mg Total kg/day	16.9	308.4	12.7	24	33.0	223.1	8.9	23				

Table 4 - Long Plains Southern Sites-Metals Parameters N to Z including Fluxes.

Time-series graphs in Figure 1 to Figure 8 show the water quality data during the period of November 2012 to May/2019.

In Figure 1 the flow data over time is presented. In Figure 2 the same data is presented with flow on a log scale, to present the lower flow values with more intelligibility. The high flow event on the 2nd of July 2013 had a major effect on the other parameters presented in later figures with increased concentrations of metals and decreasing sulphate and magnesium concentrations.

The total copper values over time for the different sites is presented in Figure 3. The levels remain low for the samples collected over the past year. The highest levels of copper are associated with the July 2013 high flow event, although the dissolved copper levels remained low (See maximum values listed in Table 1 and Table 3). The copper increase in higher flows is most probably associated with sediment mobilised.

In Figure 4, the sulphate levels are presented over time. The levels are considered low, and a comparison with the flow data suggests levels are diluted in higher flow events. Levels remain low for this year's sampling events. There is a slight increase in sulphate over time in NF Creek potentially due to ground disturbance with exploration, but levels are low.

Total manganese concentrations over time presented in Figure 5, have high levels occurring during high flows suggesting sediment mobilisation during high flows. Manganese data presented in Table 1 and Table 3 suggest that Maurice Creek has the highest manganese levels in the area. Upper Bowry Creek also has relatively high manganese concentrations.

In Figure 6 total aluminium and in Figure 7 total iron is plotted over time on a log scale. Levels are considered low except during the high flow event.

The magnesium concentrations over time data presented in Figure 8. In Figure 9 the mass loads of magnesium are presented for the Bowry Creek catchment are presented. The data would suggest the following (referencing):

- Based on the concentration time-series in Figure 8, NF Creek catchment has high levels of magnesium.
- The difference between mass loads from upper and Lower Bowry Creek sites and the mass load from NF Creek in Figure 9 the Bowry Creek catchment between Upper Bowry Creek and the junction with NF Creek suggests a substantive source of Magnesium.
- The low concentrations of magnesium in Maurice Creek and the moderately high levels in Freeman Creek downstream of the Maurice Creek confluence suggest that Freeman Creek has sources of magnesium above the confluence with Maurice Creek (see Figure 8).
- Upper Bowry Creek, Maurice Creek and Shadow Creek catchments all have relatively low concentrations of magnesium, shown in Figure 8.

The DOC concentrations in NF Creek and F Creek are low compared with the other sites, as presented in Figure 10. This is evident when sampling as there is less brown colour in the water. The variation in values evident in Figure 10 is due to an annual pattern with higher DOC concentration occurring in Autumn and Winter as seen in Figure 11. DOC can reduce the toxicity of metals as it forms complexes that reduce the uptake into aquatic organisms.

In Figure 12 total aluminium is plotted against the total iron concentrations on log scales. The data suggest that the mobilisation of the iron and aluminium is occurring together, most probably due to sediment transport.

Figure 13 suggests that there are different origin, or mechanism of release for manganese and sulphate. The concentrations are also reasonably low. Acid rock drainage within the catchment would produce sulphate and is likely to produce manganese. Acid Rock Drainage is not a prevalent form of pollutant generation in this area.

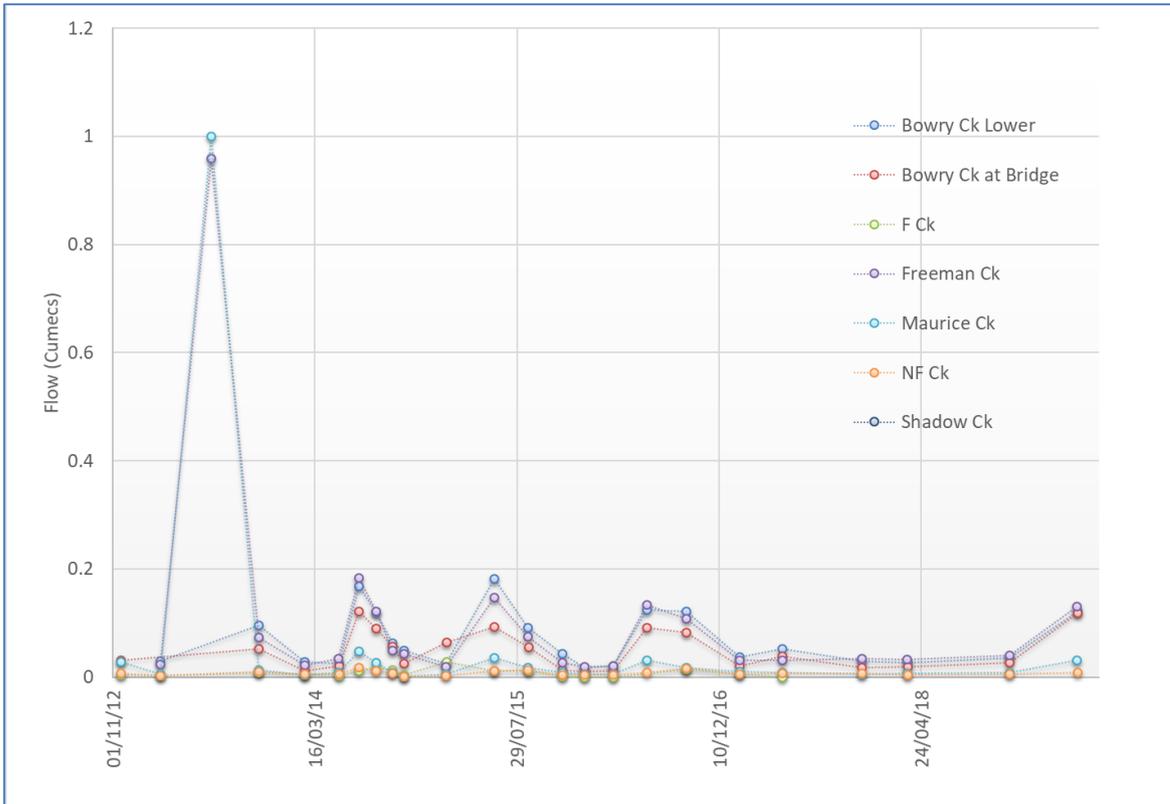


Figure 1 – Flow over time at different Long Plains sites.

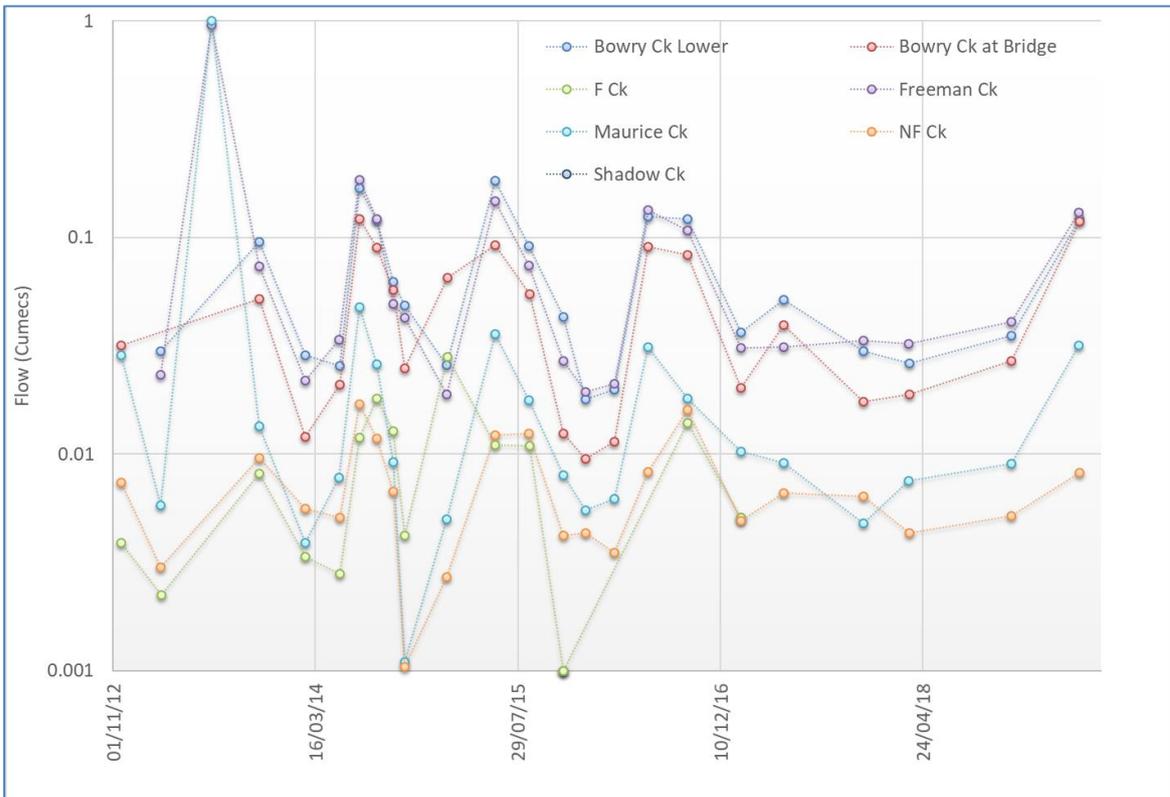


Figure 2 – Flow (Log Scale) over time at different Long Plains sites.

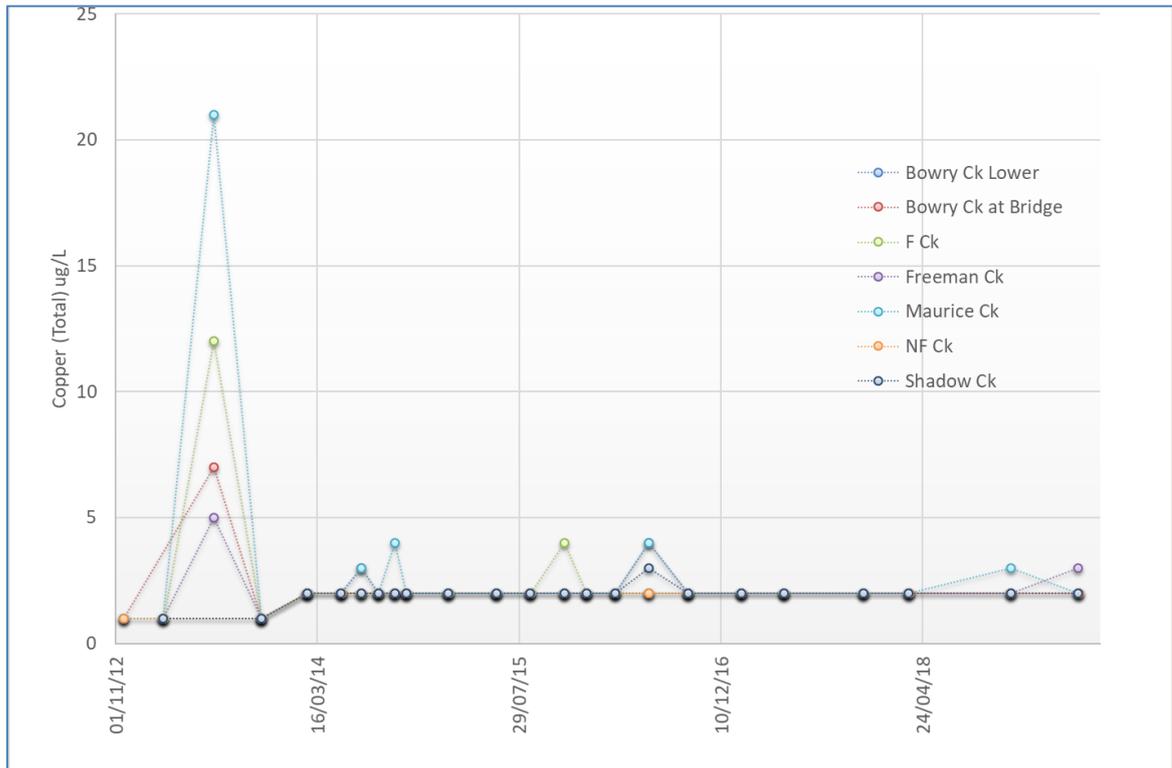


Figure 3 - Total Copper over time at different Long Plains sites*.

* Note that all total copper levels are at or near detection limit except for the high flow event on the 2nd of July 2013. Dissolved copper levels all less than 4ug/L.

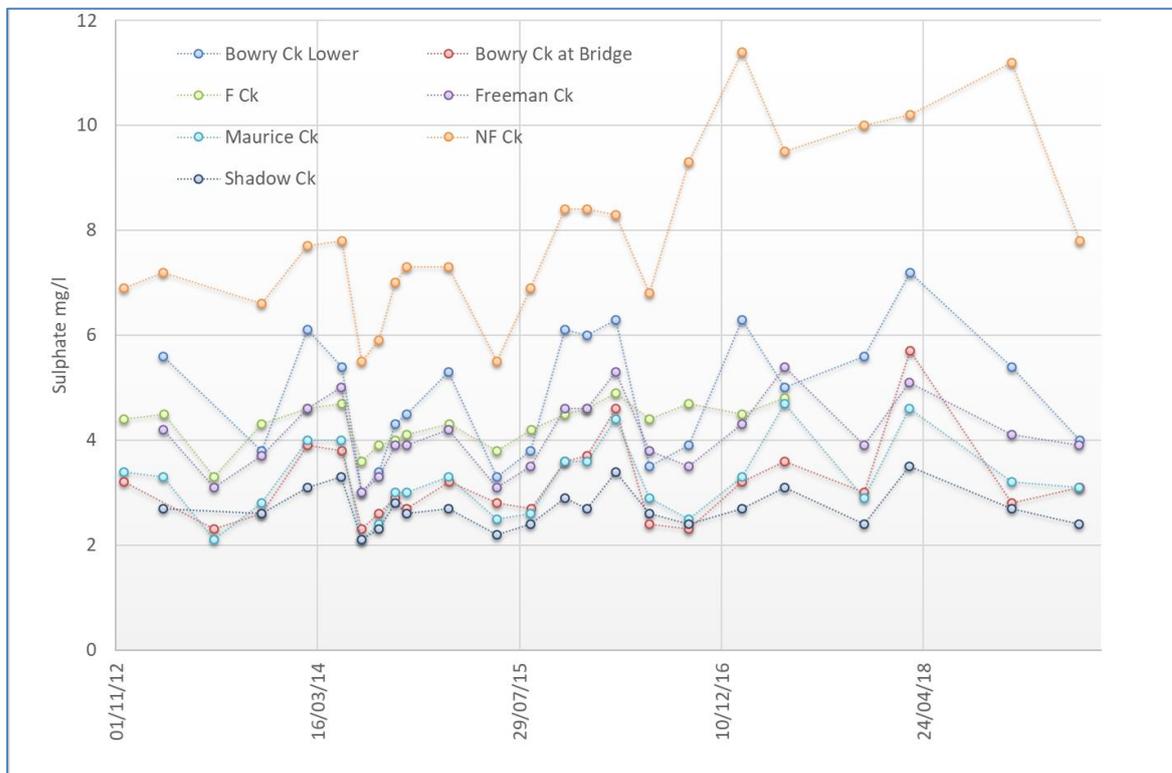


Figure 4 – Sulphate over time at different Long Plains sites*.

* Levels considered low and indicate low rates of acid rock drainage in catchment

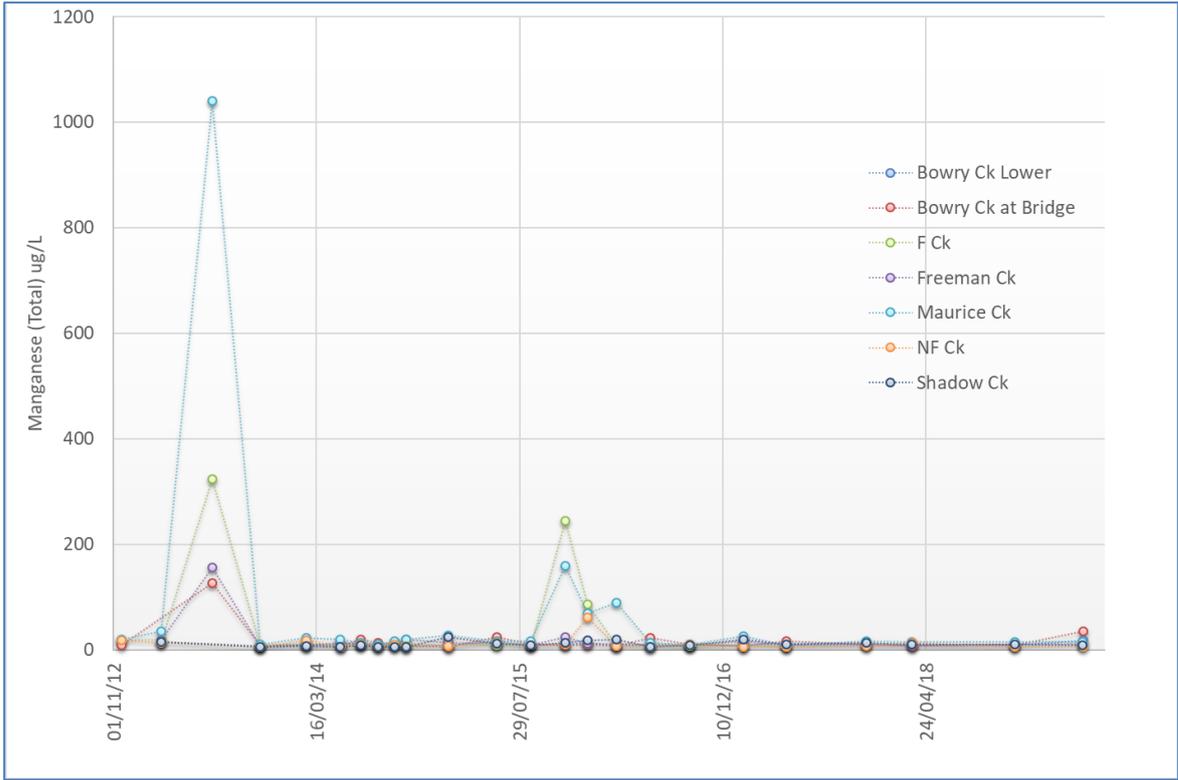


Figure 5 – Manganese over time at different Long Plains sites.

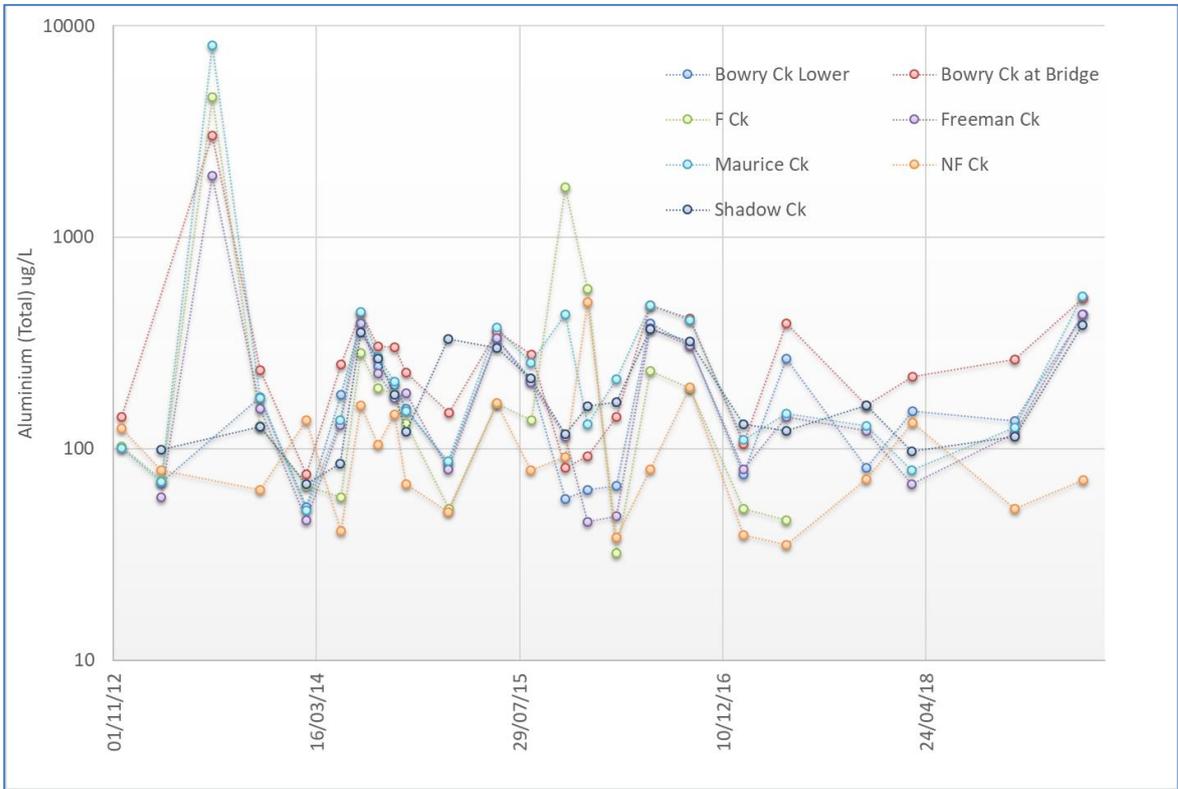


Figure 6 – Total Aluminium over time at different Long Plains sites (Log scale)*

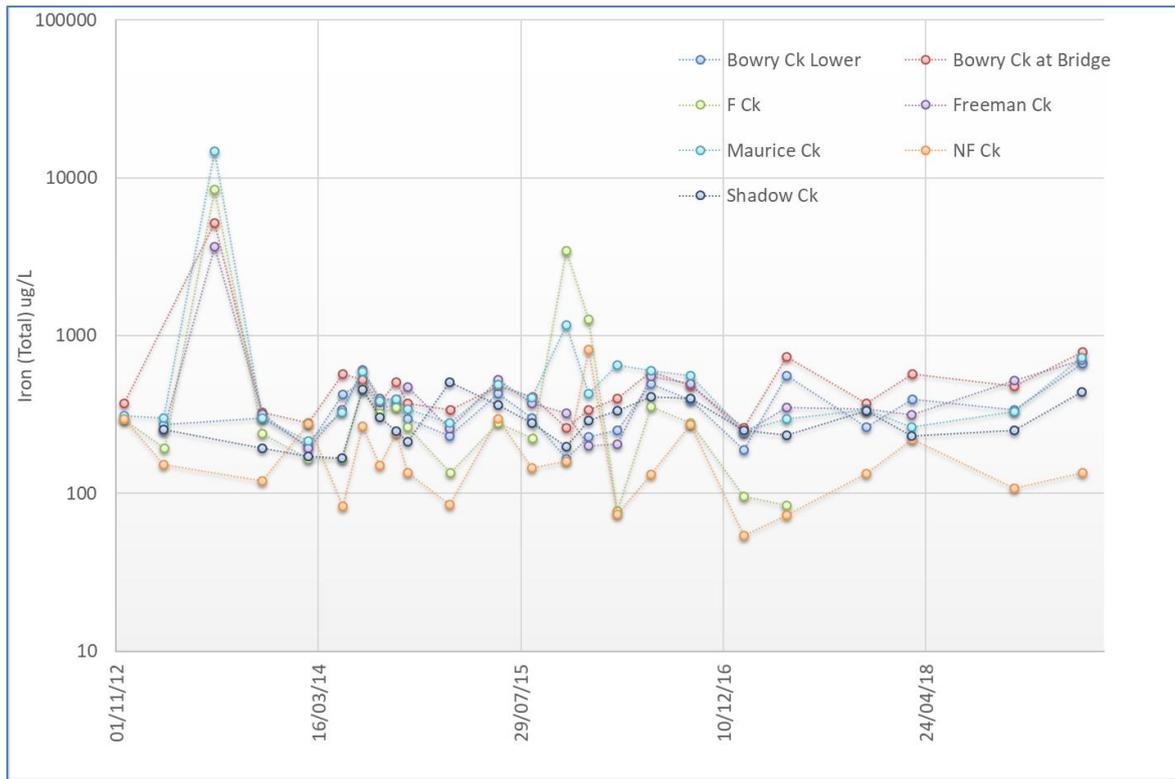


Figure 7 – Total Iron over time at different Long Plains sites (Log scale)*

* Levels considered low except during high flow event

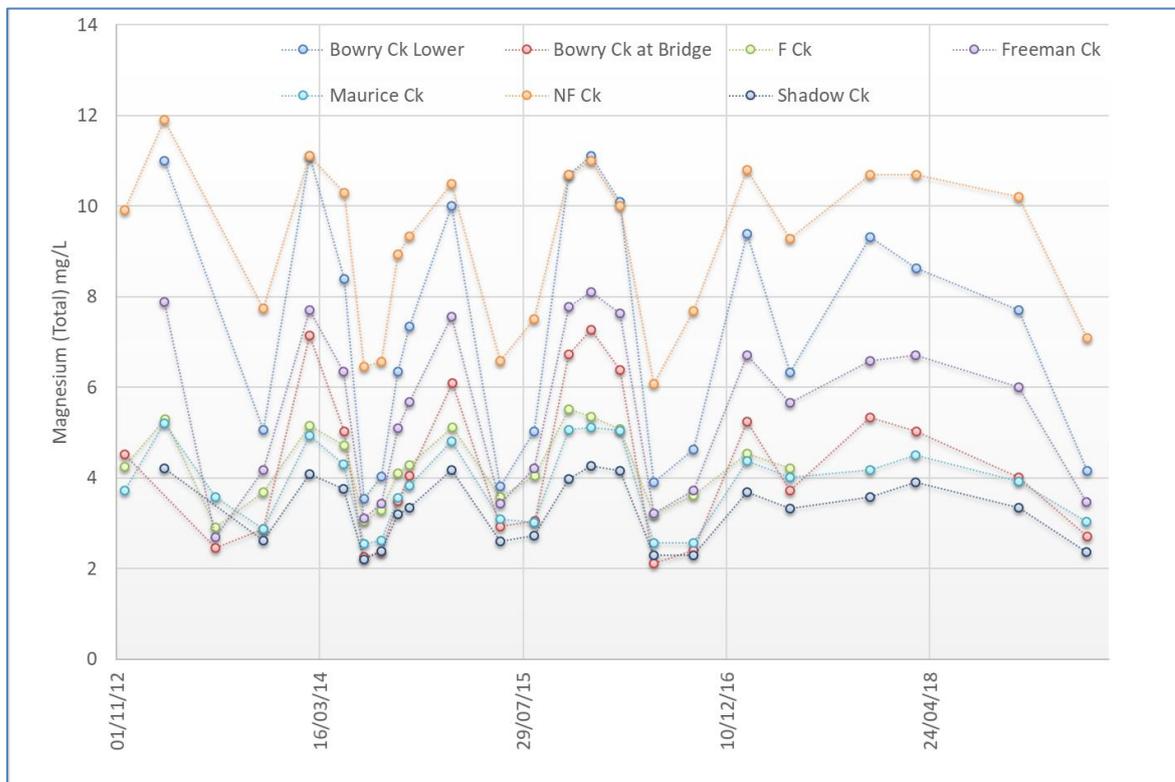


Figure 8 – Total magnesium over time at different Long Plains sites*

*The dissolved magnesium levels very similar to total values.

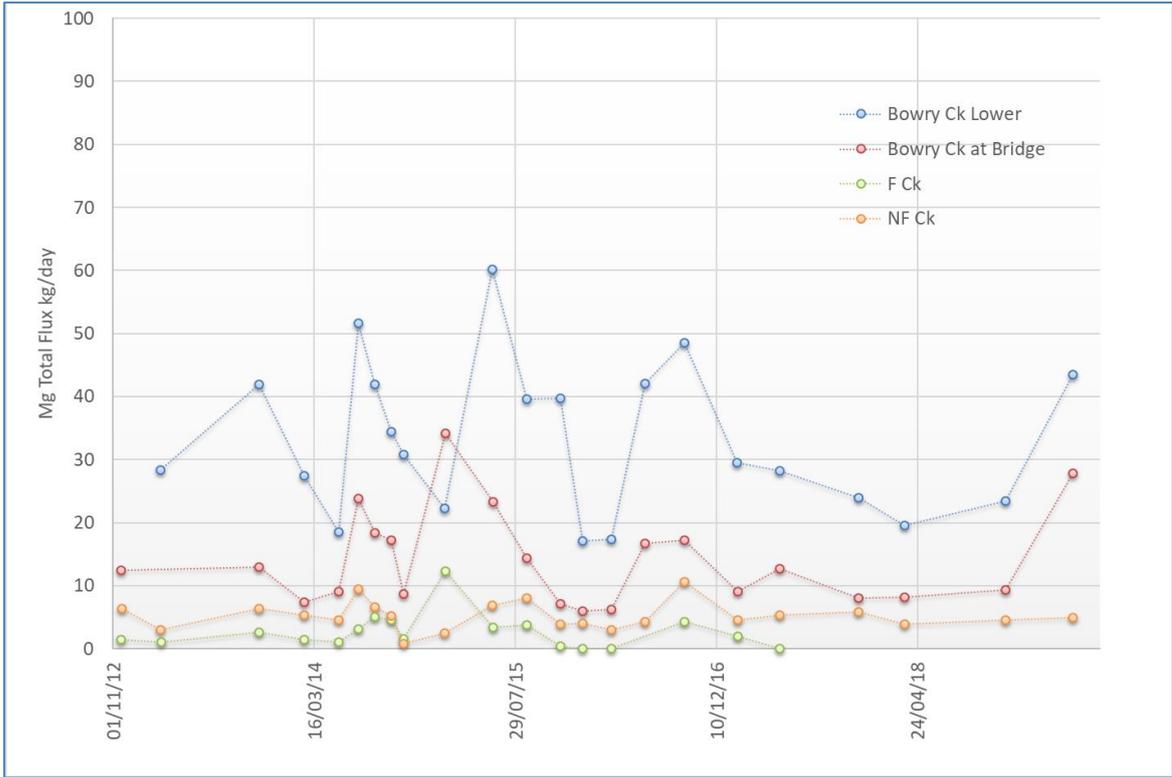


Figure 9 – Magnesium load over time at Bowry Creek catchment sites.

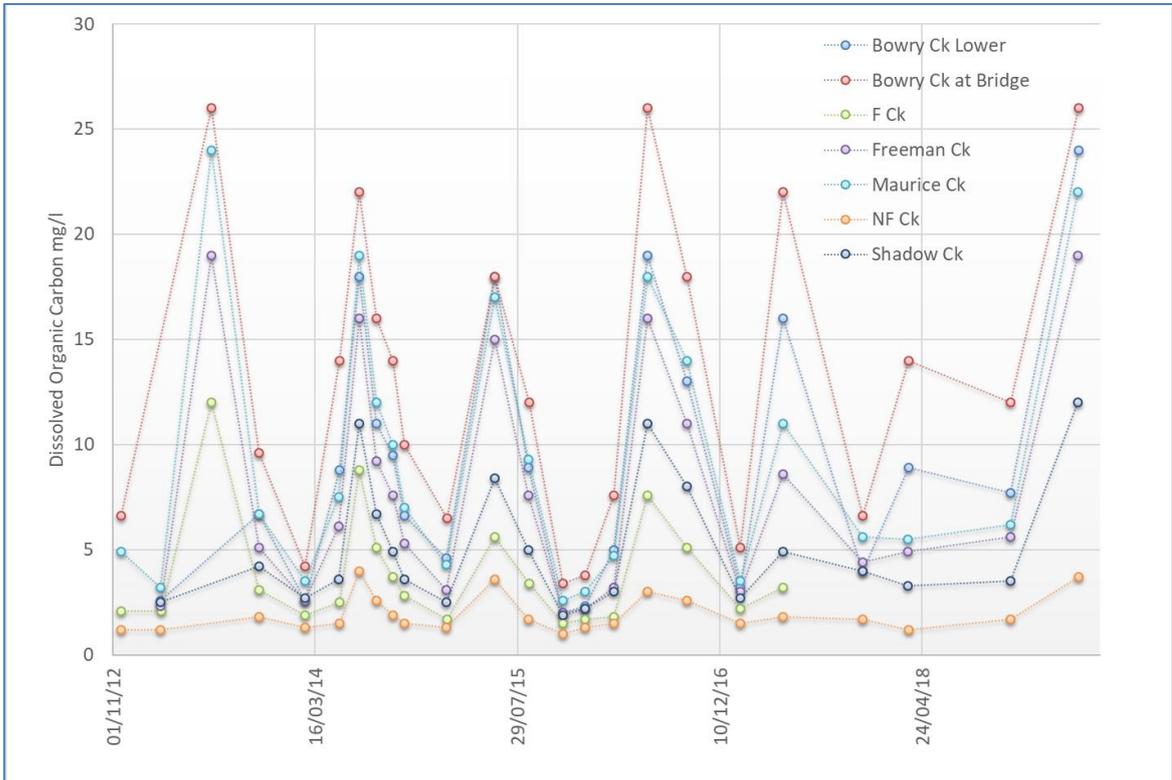


Figure 10 – Dissolved organic carbon over time at different Long Plains sites

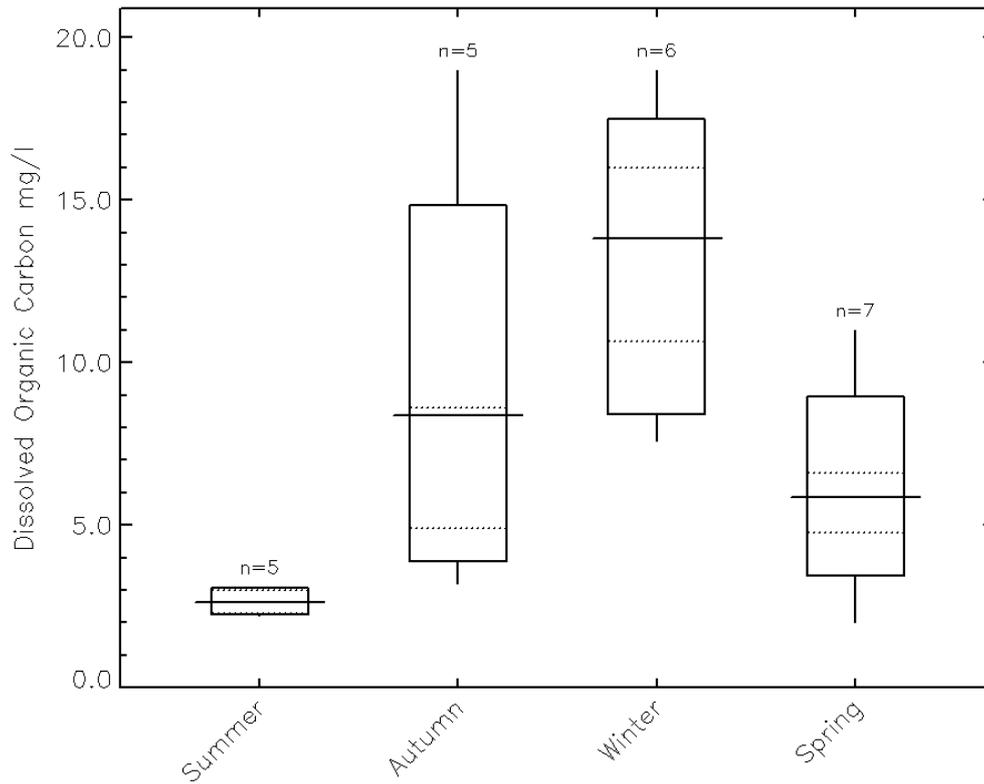


Figure 11 – Dissolved organic carbon during different seasons at Freeman Creek Flow station

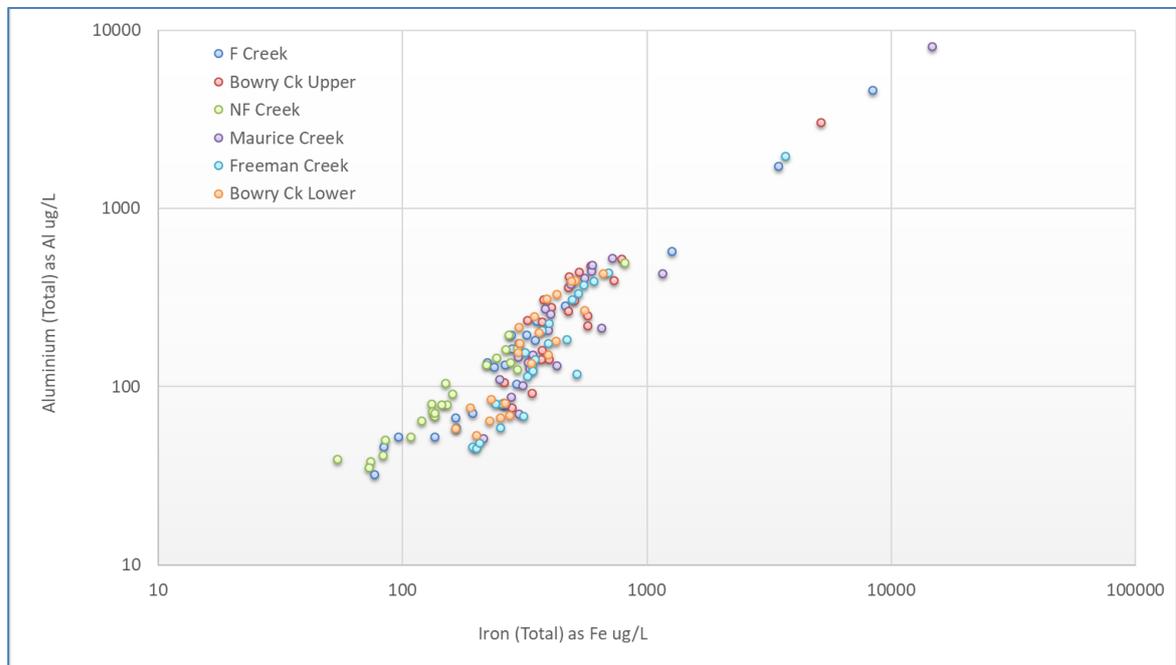


Figure 12 – Total iron versus total aluminium at different Long Plains sites (Log scales)

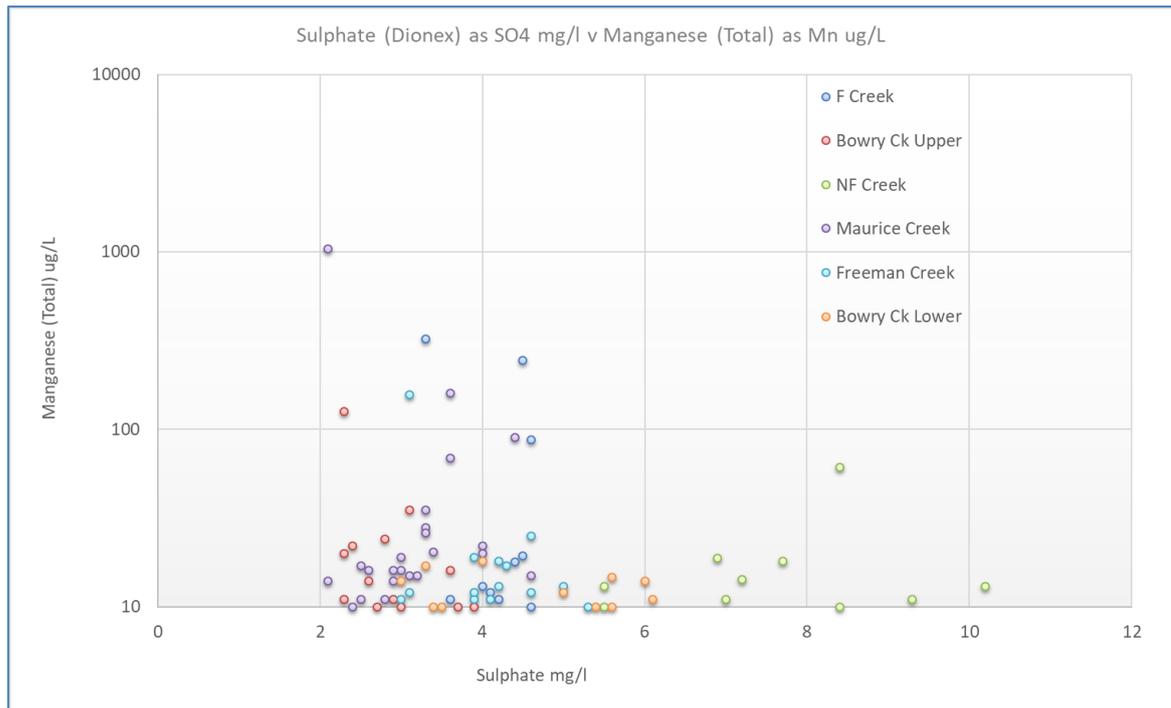


Figure 13 – Sulphate versus dissolve manganese at different Long Plains sites

Water quality review and recommendations

The water quality within the Long Plains lease for low to moderate flow events is of good quality. There is little evidence of Acid Rock Drainage from past mining disturbance. The last years' data is consistent with previous data.

The flood event on the 2nd of July 2013 shows that there is a deterioration under high flows. The deterioration is particularly evident with increase copper, manganese, iron and aluminium levels as seen in Figure 3, Figure 5, Figure 6 and Figure 7, respectively.

The July 2013 event was poorly monitored due to safety concerns at the time. Sites were not sampled, such as Lower Bowry and NF Creek. Flows could not be measured safely for any of the Bowry Creek sites. The Freeman Creek and Maurice Creek sites were gauged quickly as the flows were rising quickly as samplers would have been trapped by floodwaters if more time was taken.

Once mining begins in the catchment it will be difficult and very expensive, to separate the pollutant loads that occur from the background catchment compared with the operations themselves. It is more cost-effective to gain an understanding of the background levels prior to mining. If the background conditions are not known prior to mining, it can be problematic to take them into account when creating the permit conditions for the operations at the lease.

As the water chemistry under low to moderate flow conditions is well understood, future sampling efforts need to improve the understanding of water quality under high flow conditions as a priority. This will include the understanding of the water chemistry at the different flow percentiles. Chemistry may also change with the rising water level differently to falling water levels.

The flow measurement infrastructure at the site is deteriorating and flow records are being lost.

Future Water Monitoring Recommendations

As this report recommends a change in approach, different people will be required to provide expertise. It is imperative to include people that have experience with the Long Plains tracks to accompany new contractors and staff that will be required to visit the sites.

Level and flow data

It is a priority to formalise what is known from the river level information that has been collected so far. Entura should be contacted to decipher jumbled level information that has been collected. This data can then be combined with all previous data into a cohesive dataset.

After the level data has been collated a hydrographer should be engaged to aid with converting flows and levels from the gauging information collected so far and to generate flow information. The gauging information is stored on Grange's Splashback sample data repository.

Track upgrades

The tracks that access the sample sites require an upgrade. The tracks are becoming more slippery and hazardous due to both time and wear from use. Ropes are also due for replacement. There is also the possibility of upgrading the access from the South to the Freeman Creek sample site that does not require a river crossing (Marked in Map 1 and Map 3).

Water quality at high flows

The development of a plan to monitor high flows is required. There are two strategies currently being considered by Grange Resources, manual sample collection, and Low Power Wide Area Network (LPWAN).

Manual sample collection will require staff and contractors to work in adverse weather conditions. The current plan being considered is to combine the sampling with Emergency Response Team (ERT) training. This will have value due to the relatively steep terrain and the experience gained. Exercises such as injured person recovery could be conducted. This would be a worthwhile exercise as industry geologists are exposed to conditions like those encountered in this project.

The LPWAN option will enable the continual monitoring of flow that will be transmitted and could be viewed within Grange Offices and within mine control if required. The technology would also permit auto-samplers to be triggered and samples could be collected after the storm event. LPWAN is required as there is no cell phone coverage. LPWAN technology such as Symphony Link (commonly used in Northern America) allows for the use of repeaters. This will enable signals to be passed back to Savage River.

The lower power consumption of LPWAN is also an advantage solar energy is very limited in the steep valleys where the water monitoring sites are located.

The above recommendation is likely to be expensive to implement. If required the quarterly monitoring could be stopped. More intensive monthly monitoring should be initiated a minimum of 12 months prior to environmental approval documents (e.g. DPEMP) being drafted for the project.