

**Anvil Range Mine Complex
PRELIMINARY WATER BALANCE AND
CONTAMINANT LOADING STUDY FOR ROSE AND
VANGORDA CREEKS**



**DRAFT REPORT FOR
CLOSURE ALTERNATIVES WORKSHOP**

April 2002

BACKGROUND

No working mass balance models for Rose and Vangorda Creek are available.

These are necessary to identify proportional contaminant loading from various sources on the mine sites as an aid to reclamation planning.

STUDY OBJECTIVES

The objectives of this study are to:

1. Describe water balances for Rose and Vangorda Creeks that allow for calculations of contaminant loadings from various sources on the minesites.
2. Present calculations of current loadings of sulphate and zinc from various sources on the minesites.
3. Provide “models” that can be used to assess the sensitivity of contaminant loadings in the creeks to changes in the source terms.

METHODOLOGY

1. Utilize available information from 1996 ICAP.
2. Assess the streamflow records from three “new” (post 1996) dataloggers.
3. Develop seasonal water balances for the periods of record.
4. Calculate seasonal loadings of sulphate and zinc over the periods of record.
5. Compare the predicted loadings to observed loadings.
6. Determine proportional loading from various sources.

Cachment Areas

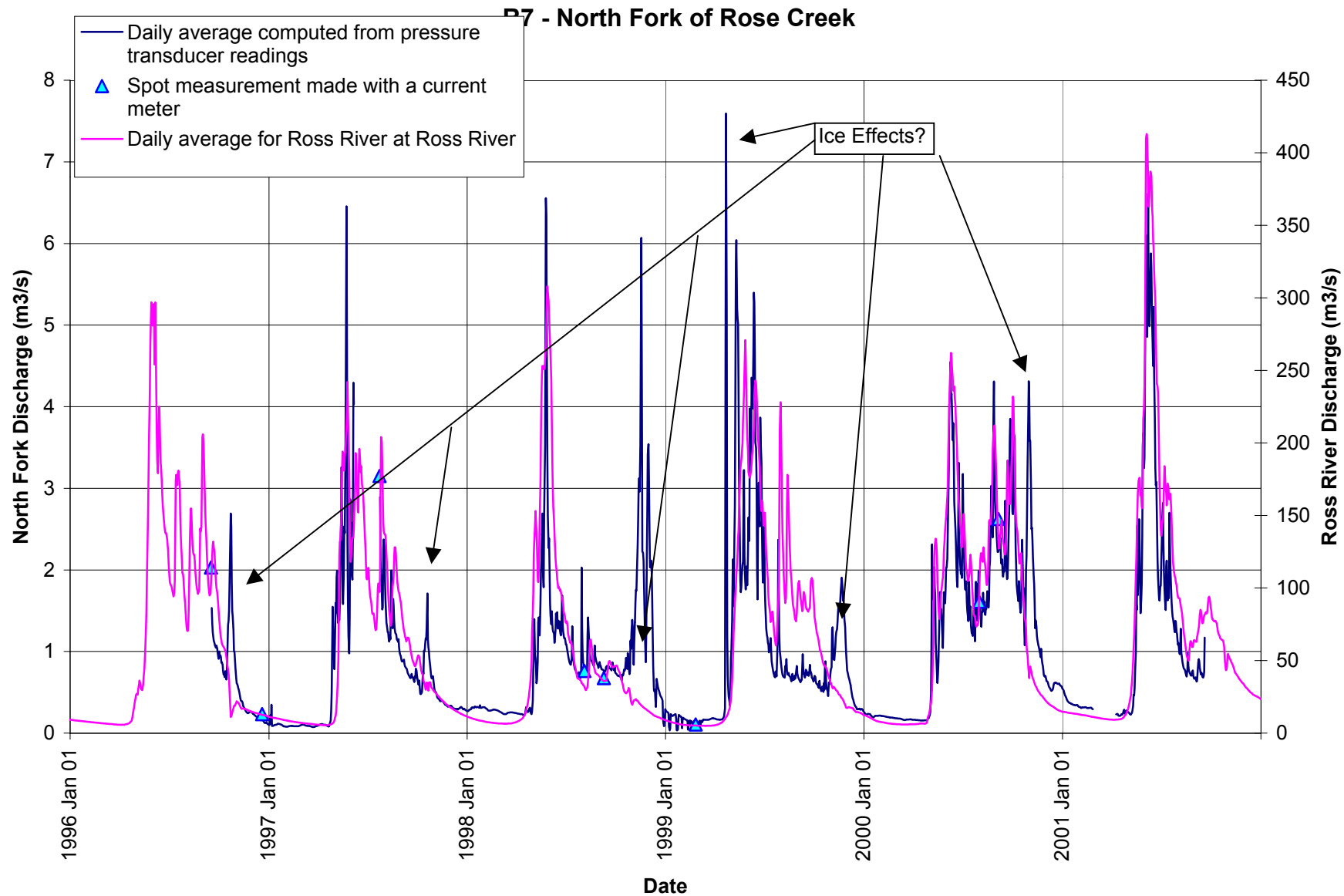
The cachment areas used to describe the water balances are taken from the ICAP. These subcachment areas represent source terms that can be characterized by available flow and water quality monitoring data.

In the ICAP study, regional streamflow records from 1990 to 1995 were used to develop a correlation between median elevation of a cachment area and mean annual runoff. The relationship determined that mean annual runoff increased with increasing elevation.

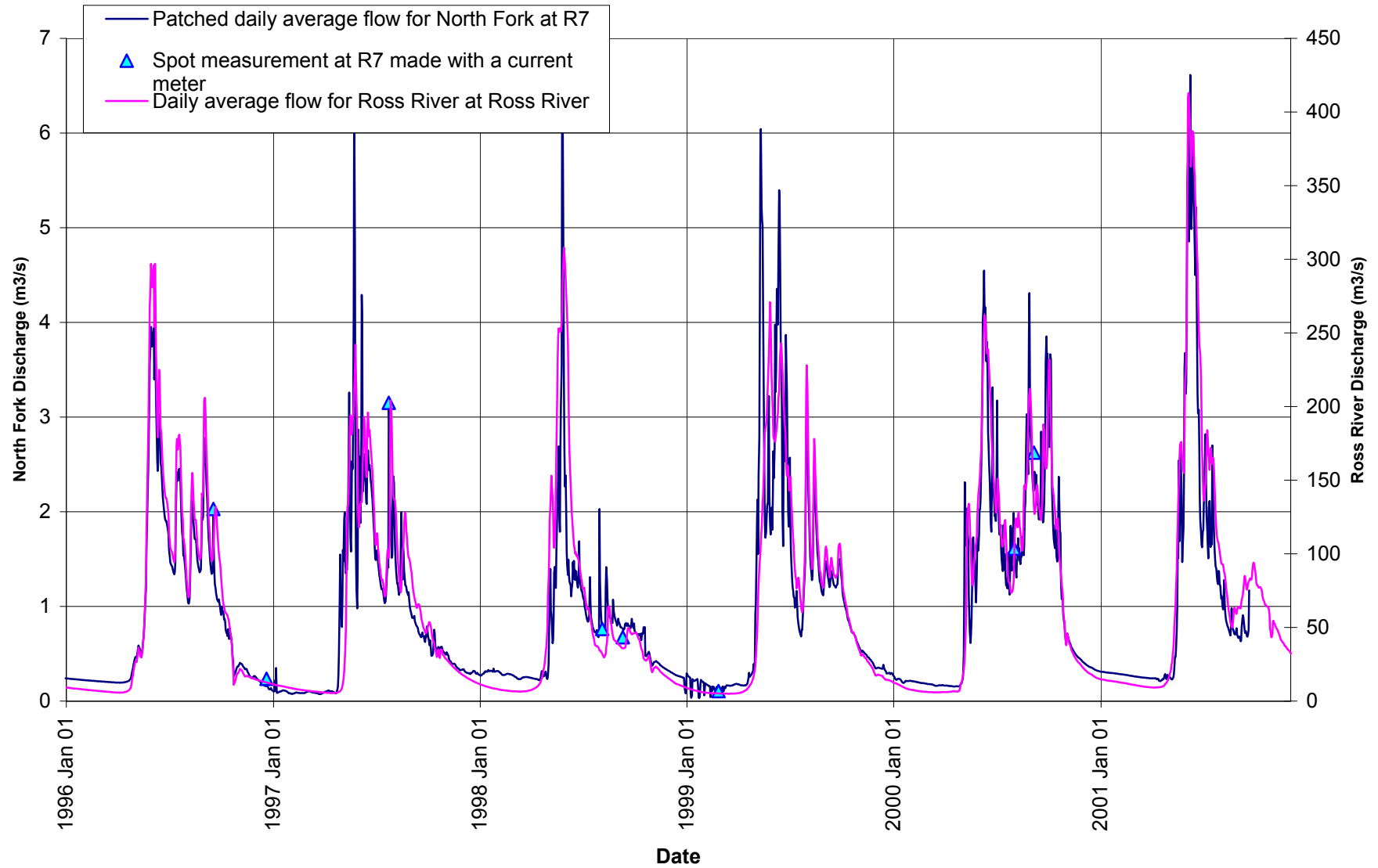
ROSE CREEK WATER BALANCE

STREAMFLOW RECORD: LOCATION R7

1. Continuous record since 1996.
2. Daily average flows compared to regional station to identify and correct anomalous or missing data.
3. The low number of operable monitoring wells prevents a good interpretation of groundwater quality.
4. The contour map of the Intermediate Impoundment shows elevations in the Intermediate impoundment prior to the final raising of the Intermediate Dam in 1991, which are incorrect.



R7 - North Fork of Rose Creek



ROSE CREEK WATER BALANCE

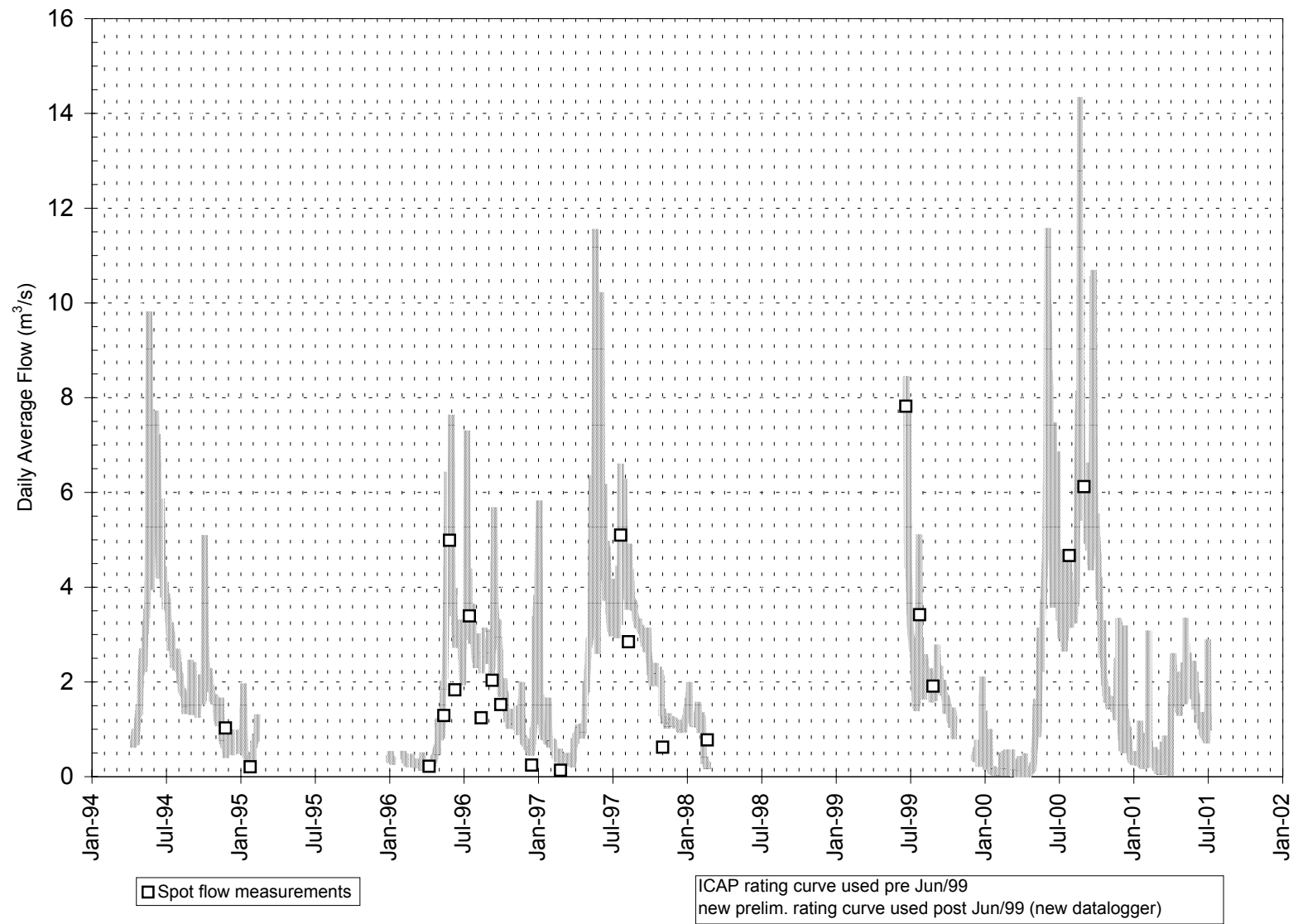
STREAMFLOW RECORD: LOCATION X14

Record intermittent due to malfunctions and vandalism.

New datalogger installed in 1999.

Comparison with regional station not possible due to external controls on flow such as Fresh Water Supply Dam and surface release from Cross Valley Pond.

Daily Average Streamflow Record at Location X14



ROSE CREEK WATER BALANCE

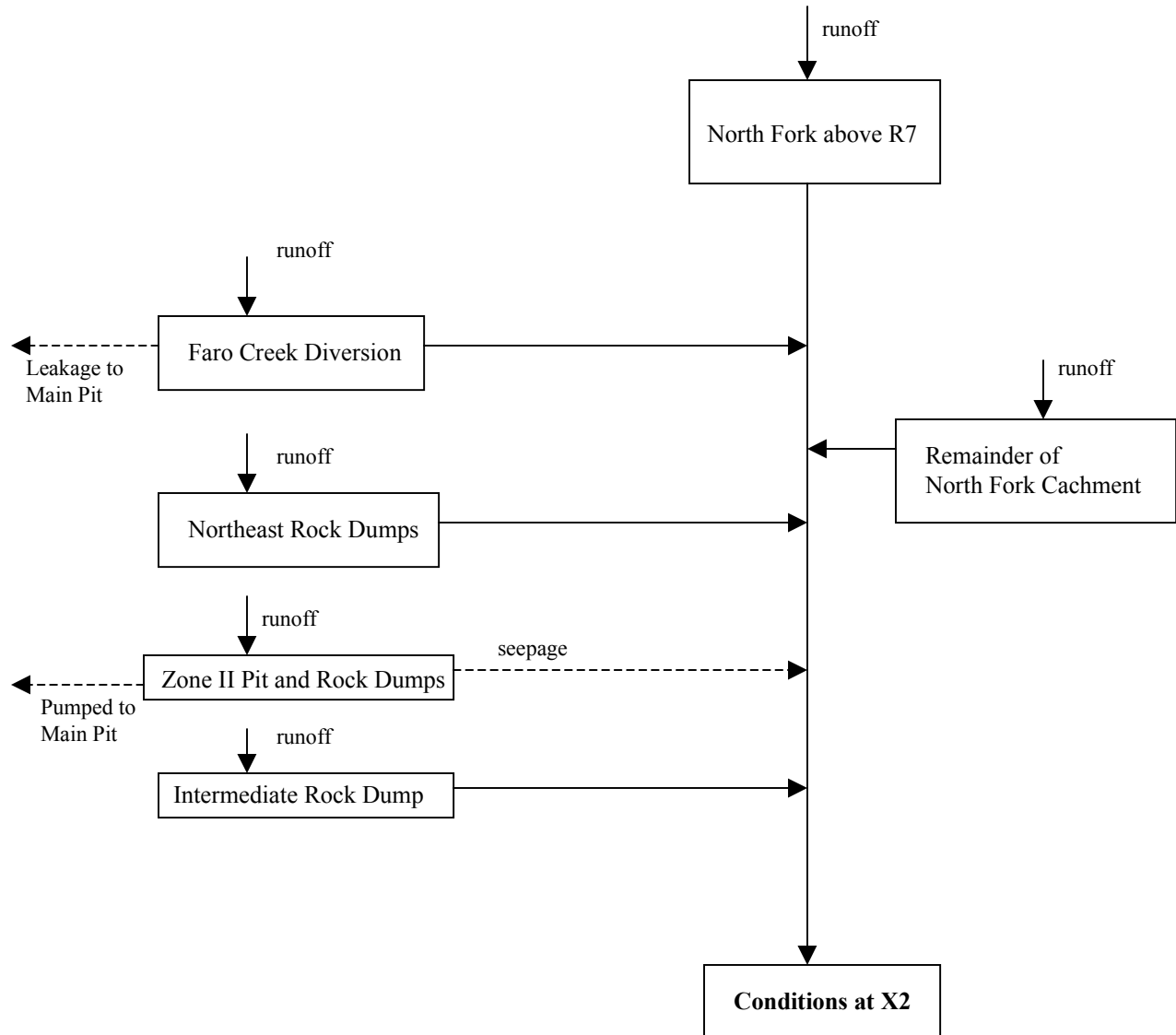
NORTH FORK WATER BALANCE

The water balance was constructed beginning in winter 1995/1996 in order to correspond to the available flow data. Eleven time steps were defined to represent winter and summer seasons to winter 2000/2001.

Flows for ungauged areas were extrapolated from the R7 record in proportion to the catchment areas and mean annual runoffs.

The combined Faro Valley and Faro Creek Diversion Channels was assumed to pass 76% of the flow (extrapolated from the R7 record) into the North Fork of Rose Creek (i.e. leaks 24% into Faro Main Pit).

North Fork Rose Creek Pictorial Water Balance



Water Balance Calculations

FOR X2 (NORTH FORK ROSE CREEK)

		No. days in p	182	184	181	184	181	184	181	184	182	184	181		
Average Discharge for period (m³/s):															
Catchment	Component	Time Step Season From To	1 W Nov-95 Apr-96	2 S May-96 Oct-96	3 W Nov-96 Apr-97	4 S May-97 Oct-97	5 W Nov-97 Apr-98	6 S May-98 Oct-98	7 W Nov-98 Apr-99	8 S May-99 Oct-99	9 W Nov-99 Apr-00	10 S May-00 Oct-00	11 W Nov-00 30-Apr	Average of 11 Periods	Average of First 10 Periods
North Fork above R7	Local runoff (6)		0.245	1.587	0.172	1.454	0.298	1.113	0.224	1.829	0.255	2.010	0.324	0.865	0.919
Faro Creek Diversion	Local runoff (1+2+3)		0.044	0.284	0.031	0.260	0.053	0.199	0.040	0.327	0.046	0.360	0.058	0.155	0.164
	- Groundwater to Main Pit		0.011	0.068	0.007	0.062	0.013	0.048	0.010	0.079	0.011	0.086	0.014	0.037	0.039
	= Discharge to North Fork		0.033	0.216	0.023	0.198	0.041	0.151	0.030	0.249	0.035	0.273	0.044	0.118	0.125
NE Dump	Local runoff (7a)		0.00074	0.00481	0.00052	0.00441	0.00090	0.00337	0.00068	0.00554	0.00077	0.00609	0.00098	0.00262	0.00278
Zone II Pit and Dump	Local runoff (5)		0.00051	0.00333	0.00036	0.00305	0.00063	0.00234	0.00047	0.00384	0.00054	0.00422	0.00068	0.00182	0.00193
	- Estimated seepage to NF		0.00058	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058
	= Pumped to Main Pit (net)		0	0.00268	0	0.00225	0	0.00180	0	0.00315	0	0.00359	0	0.00122	0.00135
Intermediate Dump	Local runoff (7b)		0.0011	0.0071	0.0008	0.0065	0.0013	0.0050	0.0010	0.0082	0.0011	0.0090	0.0015	0.0039	0.0041
Remainder of NF catchment	Local runoff (7c)		0.014	0.092	0.010	0.084	0.017	0.065	0.013	0.106	0.015	0.117	0.019	0.050	0.053
North Fork at X2	Total		0.295	1.908	0.207	1.748	0.358	1.338	0.270	2.199	0.307	2.416	0.389	1.039	1.105

Notes:

- 1) The Faro Ck Diversion controls a total area of 16.2 km². An estimated 24% of the yield from this catchment bypasses the diversion channel and reports to the Main Pit.
- 2) RGC estimated seepage from Zone II Pit to North Fork to be 18,400 m³/y with a water level in pit of 1110 m. No allowance made for overland flow from Zone II Dump to North Fork.
- 3) Some flow bypasses R7 and X2 in the stream alluvium. This flow was assumed to be negligible.
- 4) Local runoff = combination of groundwater, interflow and overland flow.

ROSE CREEK WATER BALANCE

WATER BALANCE at LOCATION X14

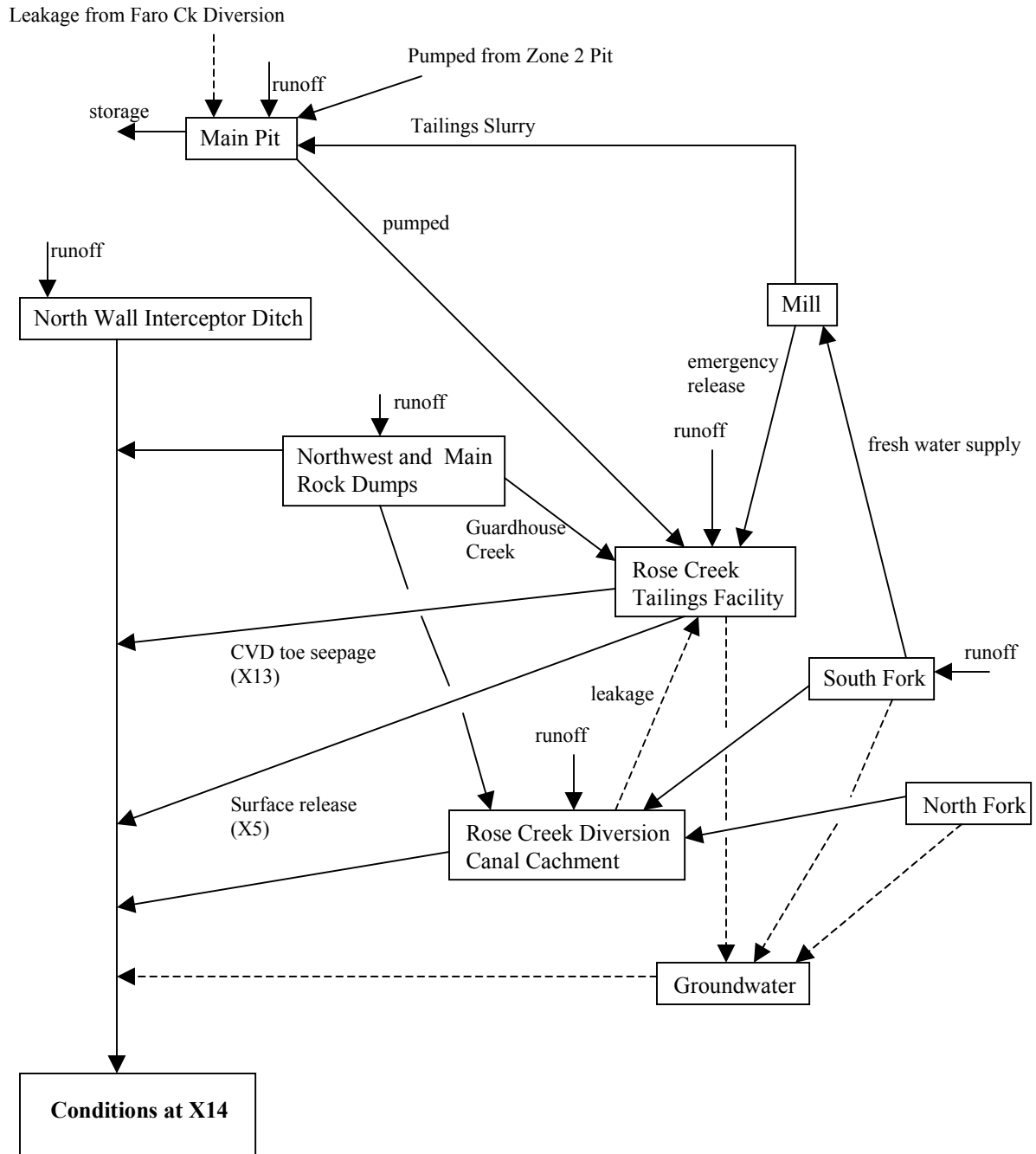
The water balance was constructed beginning in winter 1995/1996 in order to correspond to the available flow data. Eleven time steps were defined to represent winter and summer seasons to winter 2000/2001.

Flows for ungauged areas were extrapolated from the R7 record in proportion to the catchment areas and mean annual runoffs.

Flow from the North Fork of Rose Creek is represented as one source term.

The 2001 Hydrogeological Model and recent Annual Environmental Reports were utilized.

Rose Creek at Location X14 Pictorial Water Balance



Water Balance Calculations
ROSE CREEK BETWEEN X2 AND X14

Measured Flow Stream

Time Step Season From To	1 W Nov-95 Apr-96	2 S May-96 Oct-96	3 W Nov-96 Apr-97	4 S May-97 Oct-97	5 W Nov-97 Apr-98	6 S May-98 Oct-98	7 W Nov-98 Apr-99	8 S May-99 Oct-99	9 W Nov-99 Apr-00	10 S May-00 Oct-00	11 W Nov-00 Apr-01
Dewatering of Main Pit	0	0	0	646	1011	2007	78	982	0	1800	0
Surface release from tailings impoundments (X5)	2319	772	1015	2164	2497	3922	0	1760	400	3000	1000
Measured seepage at toe of Cross Valley Dam (X13)	610	964	737	1256	1031	1273	759	978	700	800	700
Extractions from Pumphouse Reservoir to mill	5401	5198	5145	36	175	0	0	0	0	0	0
Extractions from Pumphouse Wells to Pumphouse Reservoir	1719	0	1565	0	0	0	0	0	0	0	0
No. days in period	182	184	181	184	181	184	181	184	182	184	181

		Average Discharge for period (m³/s):														
Catchment	Component	Time Step Season From To	1 W Nov-95 Apr-96	2 S May-96 Oct-96	3 W Nov-96 Apr-97	4 S May-97 Oct-97	5 W Nov-97 Apr-98	6 S May-98 Oct-98	7 W Nov-98 Apr-99	8 S May-99 Oct-99	9 W Nov-99 Apr-00	10 S May-00 Oct-00	11 W Nov-00 Apr-01	Average of 11 Periods	Average of First 10 Periods	
North Fork above R7	Local runoff (6)		0.245	1.587	0.172	1.454	0.298	1.113	0.224	1.829	0.255	2.010	0.324	0.865	0.919	
Main Pit	Local runoff (4a+4b)		0.004	0.027	0.003	0.025	0.005	0.019	0.004	0.031	0.004	0.034	0.006	0.015	0.016	
	+ Leakage from Faro Ck Diversion		0.011	0.068	0.007	0.062	0.013	0.048	0.010	0.079	0.011	0.086	0.014	0.037	0.039	
	+ Pumped from Zone II Pit (net)		0.0000	0.0027	0.0000	0.0023	0.0000	0.0018	0.0000	0.0031	0.0000	0.0036	0.0000	0.0012	0.0013	
	- Pumped to tailings impoundment		0.000	0.000	0.000	0.041	0.065	0.126	0.005	0.062	0.000	0.113	0.000	0.037	0.041	
	= Change in storage of pit		0.015	0.098	0.010	0.049	-0.047	-0.058	0.008	0.051	0.015	0.011	0.019	0.016	0.015	
NW & Main Dumps	To North Wall Interceptor Ditch (16a)		0.0005	0.0030	0.0003	0.0028	0.0006	0.0021	0.0004	0.0035	0.0005	0.0038	0.0006	0.0016	0.0017	
	To tailings impoundment (11+12+13a)		0.004	0.023	0.002	0.021	0.004	0.016	0.003	0.026	0.004	0.029	0.005	0.012	0.013	
	To Rose Ck Diversion (8a)		0.00019	0.00121	0.00013	0.00111	0.00023	0.00085	0.00017	0.00139	0.00019	0.00153	0.00025	0.00066	0.00070	
	Total runoff (8a+11+12+13a+16a)		0.004	0.027	0.003	0.025	0.005	0.019	0.004	0.031	0.004	0.034	0.005	0.015	0.016	
North Fork above X2	Discharge at X2		0.295	1.908	0.207	1.748	0.358	1.338	0.270	2.199	0.307	2.416	0.389	1.039	1.105	
South Fork	Local runoff (9+10)		0.177	1.149	0.124	1.053	0.216	0.806	0.162	1.324	0.185	1.455	0.234	0.626	0.665	
	- Mill supply from reservoir and wells		0.343	0.327	0.329	0.002	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.092	0.101	
	- Gdw flow to alluvium under tailings (2001)		0.017	0.113	0.012	0.103	0.021	0.079	0.016	0.130	0.018	0.143	0.023	0.061	0.065	
	- Gdw flow to alluvium under tailings (1981)		0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.040	0.040	
	- Change in storage (reservoir + aquifer)		-0.207	0.207	-0.245	0.245	0	0	0	0	0	0	0	0.000	0.000	
	= To Rose Ck Diversion (2001)		0.023	0.503	0.028	0.702	0.183	0.727	0.146	1.194	0.167	1.312	0.211	0.472	0.499	
			0.012	0.078	0.008	0.071	0.015	0.055	0.011	0.090	0.013	0.098	0.016	0.042	0.045	
North Wall Interceptor	Local runoff (15+16b)		0.012	0.078	0.008	0.071	0.015	0.055	0.011	0.090	0.013	0.098	0.016	0.042	0.045	
	+ Runoff from part of NW Dump		0.0005	0.0030	0.0003	0.0028	0.0006	0.0021	0.0004	0.0035	0.0005	0.0038	0.0006	0.0016	0.0017	
	= Total discharge at ditch outlet		0.012	0.081	0.009	0.074	0.015	0.057	0.011	0.093	0.013	0.102	0.016	0.044	0.047	
Rose Ck Diversion	Local runoff (8b+14+17)		0.040	0.260	0.028	0.238	0.049	0.183	0.037	0.300	0.042	0.330	0.053	0.142	0.151	
	+ Runoff from part of Main Dump		0.00019	0.00121	0.00013	0.00111	0.00023	0.00085	0.00017	0.00139	0.00019	0.00153	0.00025	0.00066	0.00070	
	+ North Fork at X2		0.295	1.908	0.207	1.748	0.358	1.338	0.270	2.199	0.307	2.416	0.389	1.039	1.105	
	+ South Fork runoff		0.023	0.503	0.028	0.702	0.183	0.727	0.146	1.194	0.167	1.312	0.211	0.472	0.499	
	- Leakage to tailings impoundments (2001)		0.001	0.004	0.000	0.004	0.001	0.003	0.001	0.006	0.001	0.006	0.001	0.003	0.003	
	- Leakage to tailings impoundments (7%)		0.107	0.107	0.104	0.104	0.100	0.095	0.146	0.146	0.161	0.161	0.123	0.123	0.123	
	Proportion of Leakage from North Fork (X2)		82%	71%	79%	65%	61%	60%	60%	60%	60%	60%	60%			
	Proportion of Leakage from South Fork		7%	19%	11%	26%	31%	32%	32%	32%	32%	32%	32%			
	Proportion of Leakage from Runoff		11%	10%	11%	9%	8%	8%	8%	8%	8%	8%	8%			
	= Total discharge at channel outlet (7%)		0.252	2.566	0.159	2.586	0.491	2.153	0.307	3.548	0.355	3.899	0.531	1.531	1.631	
	Tailings Impoundments (Surface Water)	Local runoff (13b) * 1.5		0.008	0.050	0.005	0.046	0.009	0.035	0.007	0.058	0.008	0.063	0.010	0.027	0.029
		+ Pumped from Main Pit		0.000	0.000	0.000	0.041	0.065	0.126	0.005	0.062	0.000	0.113	0.000	0.037	0.041
+ Runoff from NW & Main Dumps			0.004	0.023	0.002	0.021	0.004	0.016	0.003	0.026	0.004	0.029	0.005	0.012	0.013	
+ Emergency Release from Mill			0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	
+ Mill supply from Pumphouse Reservoir (PB)			0.343	0.327	0.329	0.002	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.092	0.101	
+ Leakage from Rose Ck Diversion (7%)			0.107	0.107	0.104	0.104	0.100	0.095	0.146	0.146	0.161	0.161	0.123	0.123	0.123	
- Surface release at X5			0.147	0.049	0.065	0.136	0.160	0.247	0.000	0.111	0.025	0.189	0.064	0.108	0.113	
- toe seepage (X13) from C-V Pond			0.039	0.061	0.047	0.079	0.066	0.080	0.049	0.062	0.045	0.050	0.045	0.056	0.058	
- Loss to Groundwater (2001)			0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	
= Calc. net storage change (ED)			-0.110	0.029	-0.041	-0.045	-0.088	-0.096	0.072	0.078	0.062	0.086	-0.012	-0.006	-0.005	
Groundwater Discharge		X-V Dam Seepage (X13)		0.039	0.061	0.047	0.079	0.066	0.080	0.049	0.062	0.045	0.050	0.045		
		Aquifer Discharge (2001)		0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012		
	= Total Groundwater Discharge		0.050	0.072	0.059	0.091	0.077	0.092	0.060	0.073	0.056	0.062	0.056	0.068	0.069	
Rose Creek at X14	Total		0.462	2.767	0.291	2.886	0.743	2.548	0.378	3.825	0.449	4.251	0.668	1.752	1.860	
Observed Flow at X14			2.264	0.560	3.008						0.350	4.550	0.890			

Notes:

- 1) Net pumpage from Zone II Pit to Main Pit is estimated by water balance analysis. It excludes volume of water that seeps from Main Pit to Zone II Pit.
- 2) Influence of storage in FWR and the Rose Ck alluvium aquifer is treated in a very simplified manner here. Also, some of the mill supply was obtained from North Fork flows diverted into Pumphouse Reservoir. This diversion was not simulated in this water balance.
- 3) Leakage from the Rose Ck Diversion Channel, based on an analysis in the ICAP report, was estimated to be 7% of the flow conveyed by the channel.

VANGORDA CREEK WATER BALANCE

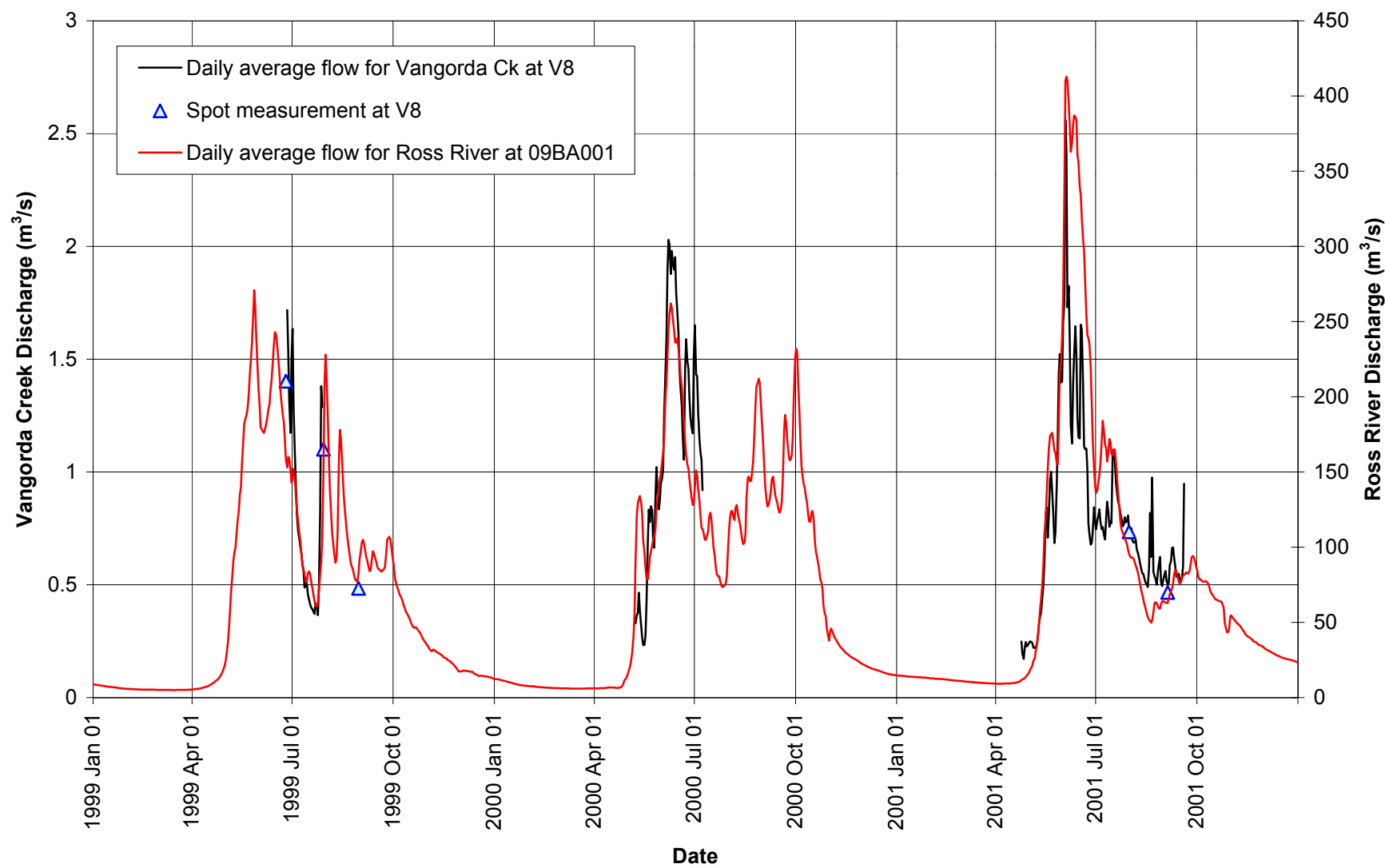
STREAMFLOW RECORD: LOCATION V8

Datalogger installed in 1999.

Record contained some unusable data rendering the flow record intermittent.

Usable data was compared to regional station.

Comparison of Vangorda Creek and Ross River Flows



VANGORDA CREEK WATER BALANCE

The water balance was constructed beginning in winter 1997/1998 to be representative of current conditions post-mine closure.

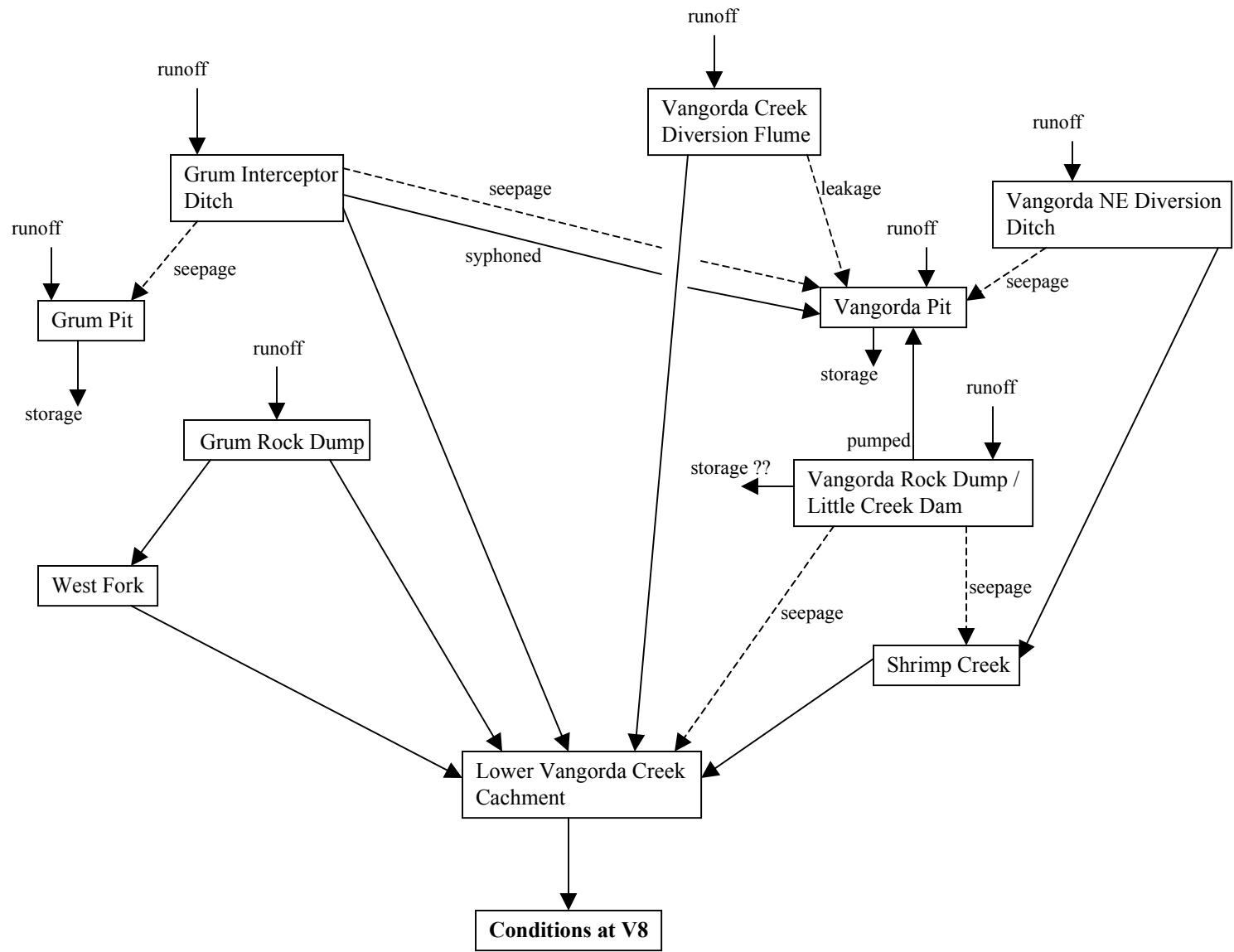
Flows for ungauged areas were extrapolated from the R7 record in proportion to the catchment areas and mean annual runoffs.

Seepage losses from the Vangorda Creek Diversion Flume to the Vangorda Pit are calculated from observed inflows into the pit.

Volumes extracted from the Sheep Pad Pond to the Vangorda pit are taken from the Annual Environmental Reports.

Seepage from Little Creek Dam and the Vangorda Rock Dump to Shrimp and Vangorda Creeks are estimated based on judgement only.

Vangorda Creek Pictorial Water Balance



Water Balance Calculations
VANGORDA CREEK ABOVE V8

Measured Flow Stream

Average Discharge for period (1000 m ³):							
Time Step Season From To	5 W Nov-97 Apr-98	6 S May-98 Oct-98	7 W Nov-98 Apr-99	8 S May-99 Oct-99	9 W Nov-99 Apr-00	10 S May-00 Oct-00	11 W Nov-00 30-Apr
Flows pumped from Little Creek Dam to Vangorda Pit	0	38	0	44	0	53	0
Flows siphoned from Sheep Pad Pond to Vangorda Pit	0	0	0	20	0	30	0
Approximate total inflow to Vangorda Pit	40	198	40	272	40	860	40
No. days in period	181	184	181	184	182	184	181

		Average Discharge for period (m ³ /s):								Average of 7 Periods	Average of First 6 Periods
Catchment	Component	Time Step Season From To	5 W Nov-97 Apr-98	6 S May-98 Oct-98	7 W Nov-98 Apr-99	8 S May-99 Oct-99	9 W Nov-99 Apr-00	10 S May-00 Oct-00	11 W Nov-00 Apr-01		
North Fork above R7 (Reference)	Local runoff (6)		0.298	1.113	0.224	1.829	0.255	2.010	0.324	0.865	0.955
Vangorda Creek Diversion Channel	Local runoff (21+22)		0.071	0.266	0.054	0.437	0.061	0.480	0.077	0.207	0.228
	- Leakage to Vangorda Pit		0.001	0.004	0.001	0.003	0.001	0.035	0.001	0.007	0.008
	+ Recovered from pit catchment (partial 10)		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	= Flows diverted around Vangorda Pit		0.070	0.262	0.052	0.434	0.060	0.445	0.077	0.200	0.221
Vangorda NE Interceptor Ditch	Local runoff (23)		0.0016	0.0061	0.0012	0.0101	0.0014	0.0111	0.0018	0.0048	0.0053
	- Leakage to Vangorda Pit		0.0000	0.0001	0.0000	0.0001	0.0000	0.0012	0.0000	0.0002	0.0002
	= Flows diverted to Shrimp Creek		0.0016	0.0060	0.0012	0.0100	0.0014	0.0099	0.0018	0.0045	0.0050
Vangorda Pit	Local runoff (24)		0.002	0.006	0.001	0.010	0.001	0.010	0.002	0.0045	0.0050
	+ Seepage from Vangorda Ck Diversion		0.001	0.004	0.001	0.003	0.001	0.035	0.001	0.0066	0.0076
	+ Seepage from Till Dump catchment		0.0001	0.0003	0.0001	0.0002	0.0001	0.0023	0.0001	0.0004	0.0005
	+ Seepage from Vangorda NE Interceptor		0.0000	0.0001	0.0000	0.0001	0.0000	0.0012	0.0000	0.0002	0.0002
	+ Siphoned from Sheep Pad Pond		0.0000	0.0000	0.0000	0.0013	0.0000	0.0019	0.0000	0.0004	0.0005
	+ Pumped from Little Creek Dam		0.0000	0.0024	0.0000	0.0028	0.0000	0.0033	0.0000	0.0012	0.0014
	= Change in storage of pit		0.003	0.012	0.003	0.017	0.003	0.054	0.003	0.0134	0.0152
Vangorda Dump & Little Creek Dam	Local runoff (25+26)		0.001	0.005	0.001	0.008	0.001	0.009	0.001	0.0038	0.0042
	- Pumped to Vangorda Pit		0.0000	0.0024	0.0000	0.0028	0.0000	0.0033	0.0000	0.0012	0.0014
	- Seepage to Vangorda/Shrimp Creeks		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	- Seepage from LCD to Vangorda Ck		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	= Unaccounted loss (storage in voids?)		0.0003	0.0015	0.0000	0.0043	0.0001	0.0045	0.0004	0.0016	0.0018
Grum & Till Dump Interceptor Ditch	Local runoff (27+29)		0.008	0.030	0.006	0.049	0.007	0.054	0.009	0.023	0.026
	- Seepage to Vangorda Pit		0.0001	0.0003	0.0001	0.0002	0.0001	0.0023	0.0001	0.0004	0.0005
	- Siphoned to Vangorda Pit		0.0000	0.0000	0.0000	0.0013	0.0000	0.0019	0.0000	0.0004	0.0005
	- Seepage to Grum Pit		0.0005	0.0018	0.0004	0.0030	0.0004	0.0033	0.0005	0.0014	0.0015
	= Flows diverted to Vangorda Creek		0.007	0.028	0.006	0.045	0.006	0.047	0.008	0.021	0.023
Grum Pit	Local runoff (28)		0.002	0.009	0.002	0.015	0.002	0.017	0.003	0.007	0.008
	+ Seepage from Grum Interceptor Ditch		0.0005	0.0018	0.0004	0.0030	0.0004	0.0033	0.0005	0.0014	0.0015
	= Change in storage of pit		0.003	0.011	0.002	0.018	0.003	0.020	0.003	0.0086	0.0095
Grum Dump	To West Fork Vangorda Ck (34a)		0.0006	0.0023	0.0005	0.0038	0.0005	0.0042	0.0007	0.0018	0.0020
	+ To Vangorda Ck (30+31a+31b)		0.006	0.023	0.005	0.038	0.005	0.042	0.007	0.018	0.020
	= Total yield from Grum Dump		0.007	0.026	0.005	0.042	0.006	0.046	0.007	0.020	0.022
Shrimp Creek	Local runoff (32)		0.023	0.086	0.017	0.141	0.020	0.155	0.025	0.067	0.074
	+ Flows from Vangorda NE Interceptor		0.002	0.006	0.001	0.010	0.001	0.010	0.002	0.005	0.005
	+ Seepage from Vangorda Dump		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	= Flow to Vangorda Creek		0.025	0.092	0.019	0.151	0.022	0.165	0.027	0.072	0.079
West Fork Vangorda Creek	Local runoff (33+34b)		0.066	0.248	0.050	0.408	0.057	0.448	0.072	0.193	0.213
	+ Runoff from a portion of Grum Dump		0.0006	0.0023	0.0005	0.0038	0.0005	0.0042	0.0007	0.0018	0.0020
	= Flow to Vangorda Creek		0.067	0.251	0.050	0.412	0.057	0.452	0.073	0.195	0.215
Lower Vangorda Ck Catchment	Local runoff (31c+35+36)		0.020	0.075	0.015	0.123	0.017	0.135	0.022	0.058	0.064
	+ Runoff from West Fork Vangorda Ck		0.067	0.251	0.050	0.412	0.057	0.452	0.073	0.195	0.215
	+ Runoff from majority of Grum Dump		0.006	0.023	0.005	0.038	0.005	0.042	0.007	0.018	0.020
	+ Outflow from Grum Interceptor Ditch		0.007	0.028	0.006	0.045	0.006	0.047	0.008	0.021	0.023
	+ Outflow from Vangorda Ck Diversion		0.070	0.262	0.052	0.434	0.060	0.445	0.077	0.200	0.221
	+ Seepage from Little Creek Dam		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	+ Outflow from Shrimp Creek		0.025	0.092	0.019	0.151	0.022	0.165	0.027	0.072	0.079
	= Total flow at V8		0.197	0.731	0.148	1.203	0.168	1.287	0.214	0.564	0.622

Observed Flow at V8

Notes:

- Total seepage into Vangorda Pit was estimated by subtracting i) an estimate of local runoff, ii) measured LCD flows and iii) measured Sheep Pad Pond diversions from measured annual accumulation of water in pit.
- Total seepage into Vangorda was apportioned to three sources (Vangorda Creek Diversion, Vangorda NE Interceptor and Till Dump catchment) according to their respective estimated long-term yields.
- Leakages from LCD and Vangorda Dump Collection Ditch are crude estimates not based on data.
- The volume of water pumped from the LCD is significantly less than the estimated yield of the Vangorda Dump catchment.
The difference may be attributed to the filling of void space within the Vangorda Dump and/or the dump results in enhanced evaporation.
- Seepage from Grum Interceptor Ditch assumed to equal 10% of yield from Subcatchment 27.

SULPHATE AND ZINC LOADING

NORTH FORK ROSE CREEK

Concentrations for R7 were applied to all catchment areas unaffected by mine developments.

Concentrations for groundwater wells at the perimeter of the Faro rock dumps were applied to runoff from the dumps.

The model predicts 111% of the observed sulphate loading at location X2.

The model predicts 77% of the observed zinc loading at location X2; however, the model predicts 90% of the observed loading when one poorly correlated time step is excluded.

SULPHATE AND ZINC LOADING

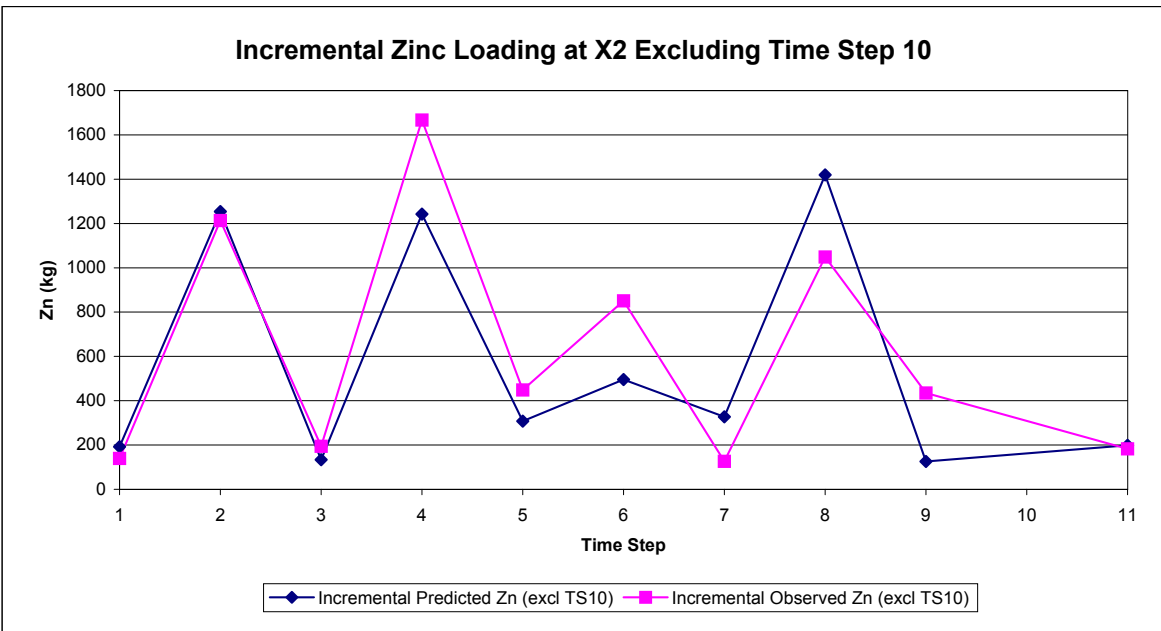
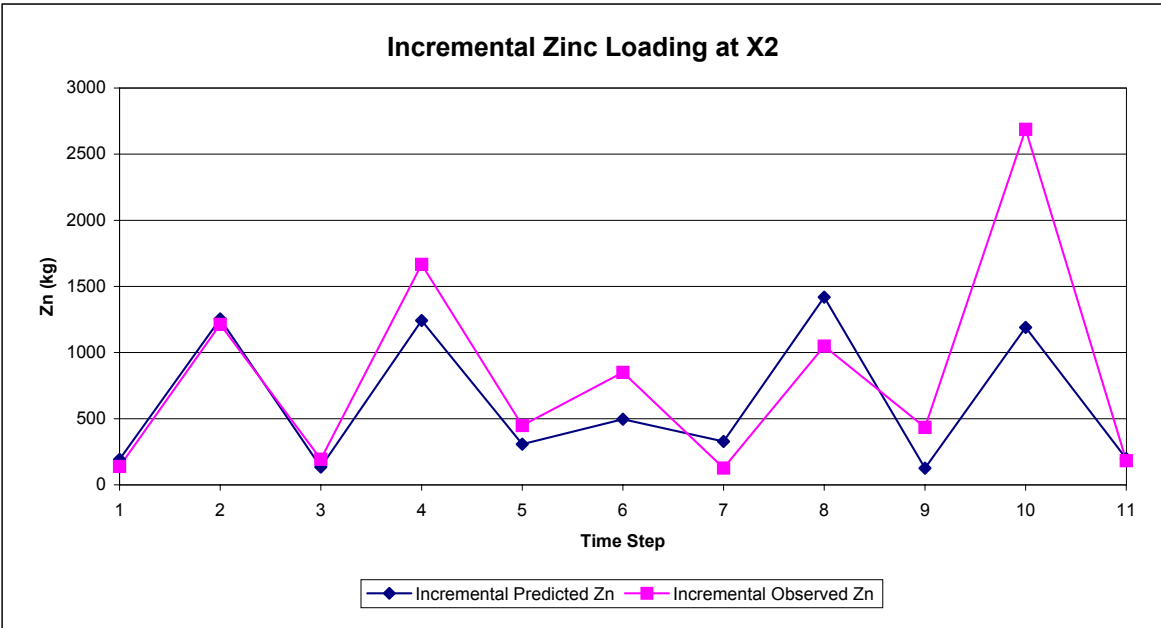
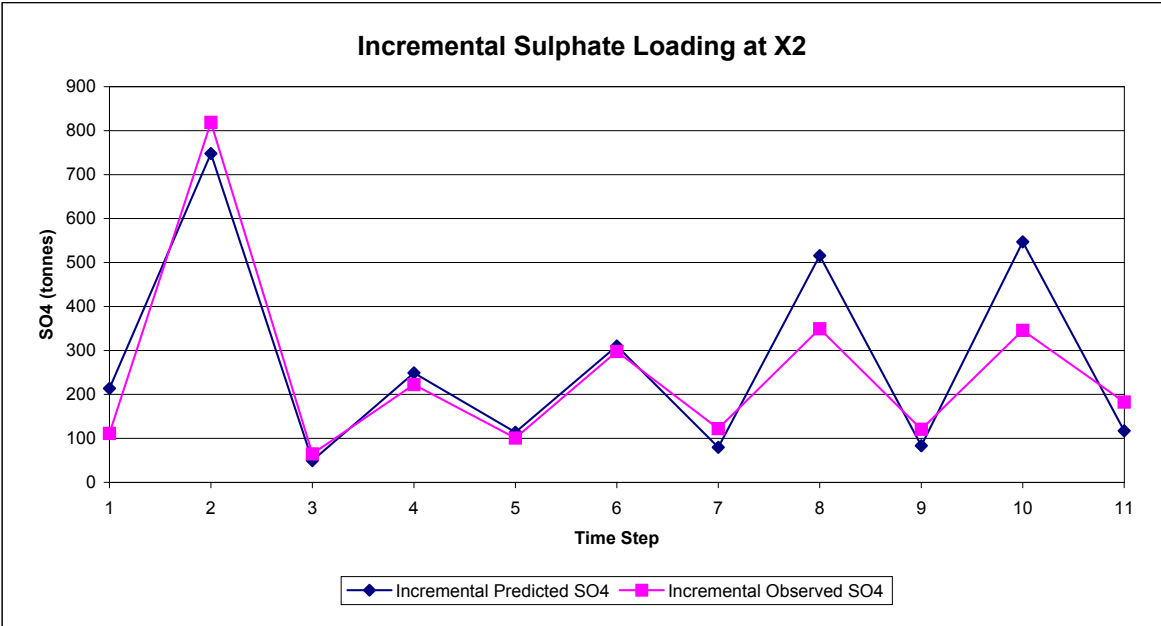
NORTH FORK ROSE CREEK

The largest source sulphate loading (over the entire period of study) was natural runoff upstream of location R7 (43% of total) followed by the Faro Creek Diversion and the Intermediate Rock Dump (23% and 22%).

The largest source of zinc loading (over the entire period of study) was natural runoff upstream of location R7 (52% of total) followed by the Faro Creek Diversion (31%).

Load Balance Calculations for Station X2

Time Step Season From To	1 W Nov-95 Apr-96	2 S May-96 Oct-96	3 W Nov-96 Apr-97	4 S May-97 Oct-97	5 W Nov-97 Apr-98	6 S May-98 Oct-98	7 W Nov-98 Apr-99	8 S May-99 Oct-99	9 W Nov-99 Apr-00	10 S May-00 Oct-00	11 W Nov-00 Apr-01	Sum	
Flow Volume (1000 m³)													
North Fork above R7	3851	25237	2684	23116	4657	17694	3505	29081	4012	31955	5060	150850	
Faro Creek Diversion (to NF)	524	3433	365	3145	633	2407	477	3956	546	4347	688	20522	
NE Dump	12	76	8	70	14	54	11	88	12	97	15	457	
Zone II Pit and Dump (seepage)	9	9	9	9	9	9	9	9	9	9	9	101	
Intermediate Dump	17	114	12	104	21	80	16	131	18	144	23	679	
Remainder of NF catchment	223	1464	156	1341	270	1026	203	1687	233	1853	293	8749	
Total: North Fork at X2	4636	30333	3234	27784	5604	21270	4220	34952	4830	38406	6089	181359	
Average Sulphate Concentration (mg/L)													
North Fork above R7	15	6	11	7	11	9	13	9	11	9	11		
Faro Creek Diversion (to NF)	239	131	7	4	54	7	34	4	6	3	1		
NE Dump	600	601	600	236	635	597	700	655	744	520	1102		
Zone II Pit and Dump (seepage)	150	429	90	276	87	136	276	329	151	204	305		
Intermediate Dump	1083	775	831	442	750	1151	342	1240	1264	1235	1666		
Remainder of NF catchment	15	6	11	7	11	9	13	9	11	9	11		
X2	24	27	20	8	18	14	29	10	25	9	30		
Sulphate Load (tonnes)													
North Fork above R7	58	151	30	162	51	159	46	262	44	288	56	1306	43%
Faro Creek Diversion (to NF)	125	450	3	13	34	17	16	16	3	13	1	690	23%
NE Dump	7	46	5	17	9	32	7	58	9	50	17	257	8%
Zone II Pit and Dump (seepage)	1	4	1	3	1	1	3	3	1	2	3	22	1%
Intermediate Dump	19	88	10	46	16	92	5	162	23	178	38	676	22%
Remainder of NF catchment	3	9	2	9	3	9	3	15	3	17	3	76	3%
Incremental Predicted SO4	213	748	50	249	114	310	80	516	83	547	117	3027	100%
Incremental Observed SO4	111	819	65	222	101	298	122	350	121	346	183	2737	
Incremental % of Observed SO4	192%	91%	77%	112%	113%	104%	65%	148%	69%	158%	64%	111%	
Cumulative Predicted SO4	213	961	1011	1260	1374	1684	1764	2279	2363	2910	3027		
Cumulative Observed SO4	111	930	995	1217	1318	1616	1738	2088	2209	2554	2737		
Cumulative % of Observed SO4	192%	103%	102%	103%	104%	104%	101%	109%	107%	114%	111%		
Average Zinc Concentration (mg/L)													
North Fork above R7	0.01	0.01	0.02	0.04	0.04	0.02	0.03	0.03	0.02	0.02	0.01		
Faro Creek Diversion (to NF)	0.25	0.25	0.15	0.05	0.16	0.03	0.10	0.09	0.01	0.08	0.03		
NE Dump	0.01	0.03	0.04	0.07	0.07	0.01	0.10	0.08	0.46	0.02	0.15		
Zone II Pit and Dump (seepage)	1.77	9.99	0.59	6.00	1.21	1.91	18.14	9.85	2.94	9.52	10.36		
Intermediate Dump	0.09	0.17	1.37	0.32	0.12	0.26	0.11	0.32	0.15	0.53	1.21		
Remainder of NF catchment	0.02	0.02	0.02	0.05	0.02	0.03	0.03	0.03	0.02	0.02	0.01		
X2	0.03	0.04	0.06	0.06	0.08	0.04	0.03	0.03	0.09	0.07	0.03		
Zinc Load (kg)													
North Fork above R7	39	252	54	925	186	354	105	872	80	639	51	3557	52%
Faro Creek Diversion (to NF)	131	858	55	157	101	72	48	356	5	348	21	2152	31%
NE Dump	0	2	0	5	1	1	1	7	6	2	2	27	0%
Zone II Pit and Dump (seepage)	16	93	5	56	11	18	166	91	27	88	95	665	10%
Intermediate Dump	2	19	17	33	3	21	2	42	3	76	28	244	4%
Remainder of NF catchment	4	29	3	67	5	31	6	51	5	37	3	241	4%
Incremental Predicted Zn	192	1254	134	1243	308	496	327	1419	126	1190	199	6887	100%
Incremental Observed Zn	139	1213	194	1667	448	851	127	1049	435	2688	183	8994	
Incremental % of Observed	138%	103%	69%	75%	69%	58%	258%	135%	29%	44%	109%	77%	
Cumulative Predicted Zn	192	1446	1580	2823	3130	3626	3953	5373	5498	6689	6887		
Cumulative Observed Zn	139	1352	1546	3213	3662	4513	4639	5688	6123	8811	8994		
Cumulative % of Observed	138%	107%	102%	88%	85%	80%	85%	94%	90%	76%	77%		
Excluding Time Step 10													
Incremental Predicted Zn (excl TS10)	192	1254	134	1243	308	496	327	1419	126		199	5697	
Incremental Observed Zn (excl TS10)	139	1213	194	1667	448	851	127	1049	435		183	6305	
Incremental % of Observed	138%	103%	69%	75%	69%	58%	258%	135%	29%		109%	90%	
Cumulative Predicted Zn	192	1446	1580	2823	3130	3626	3953	5373	5498		5697		
Cumulative Observed Zn	139	1352	1546	3213	3662	4513	4639	5688	6123		6305		
Cumulative % of Observed	138%	107%	102%	88%	85%	80%	85%	94%	90%		90%		



SULPHATE AND ZINC LOADING

ROSE CREEK at LOCAITON X14

Flow from the North Fork of Rose Creek was treated as a single source using the measured concentrations at location X2.

Concentrations for R7 were applied to runoff areas unaffected by mine contaminants.

Groundwater concentrations from the 2001 Hydrogeological Investigation were applied groundwater discharge to surface between the Cross Valley Dam and location X14.

The model predicts 60% of the observed sulphate loading and 69% of the observed zinc loading at location X14.

SULPHATE AND ZINC LOADING

ROSE CREEK at LOCAITON X14

If the calculated loadings associated with surface release from the Cross Valley Pond (X5) are increased by a factor of 2, then the model predicts 91% of the observed zinc loading at location X14.

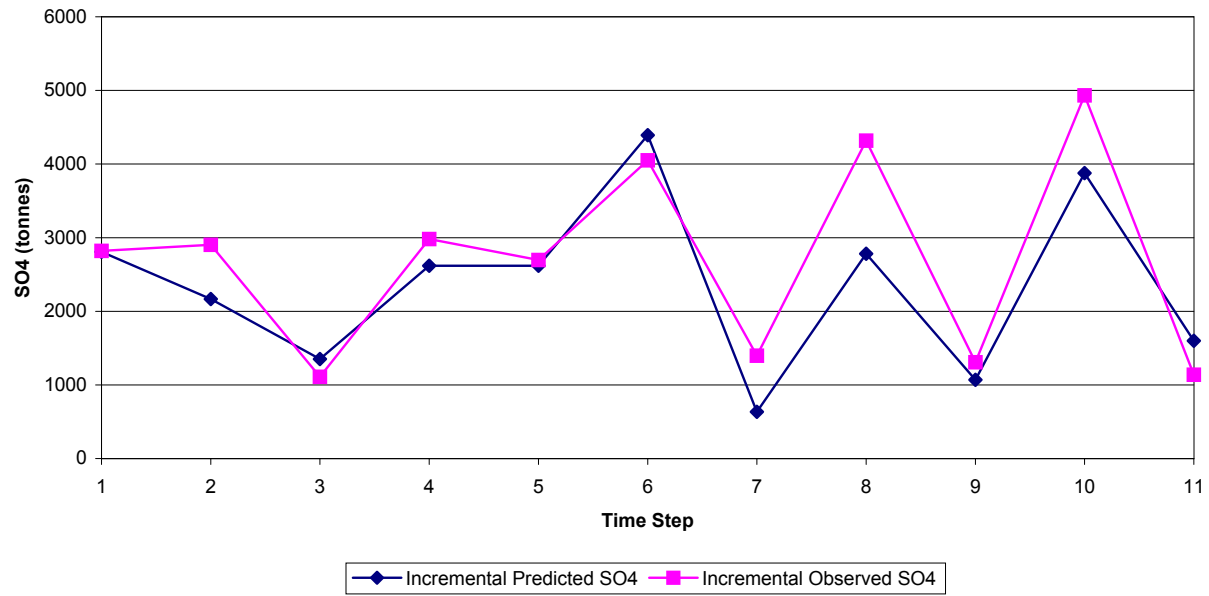
Given the above adjustment, the largest source of sulphate loading (over the entire period of study) was surface release from the Cross Valley Pond (64%) followed by seepage from the Cross Valley Dam (20%).

Given the above adjustment, the largest source of zinc loading (over the entire period of study) was surface release from the Cross Valley Pond (48%) followed by the North Fork of Rose Creek (38%).

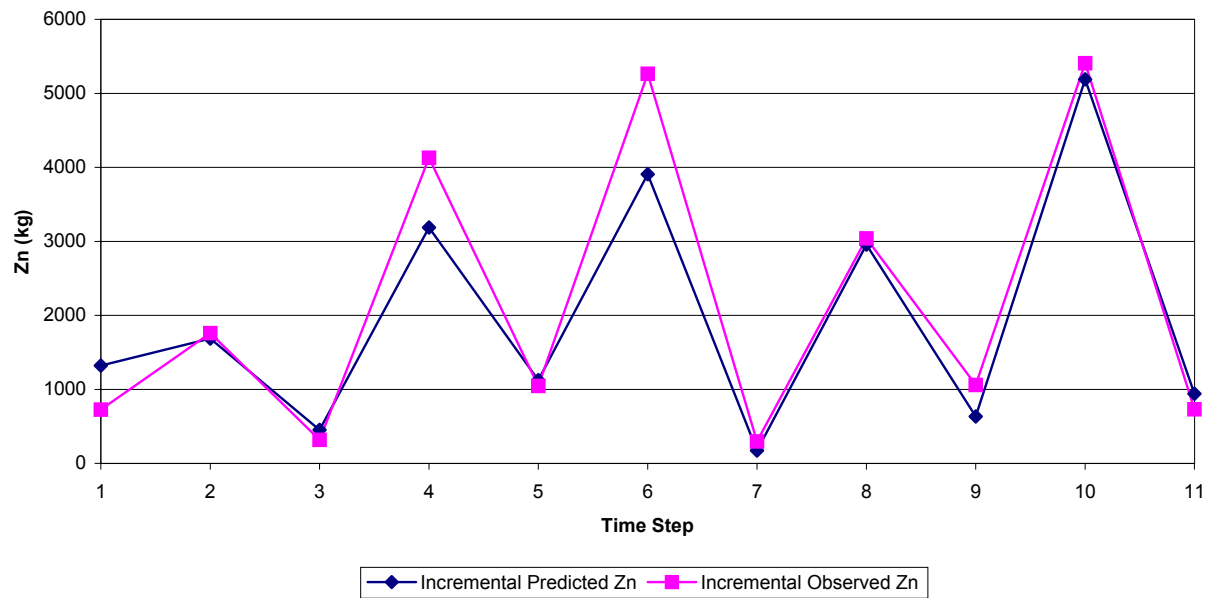
Load Balance Calculations for Station X14

Time Step Season From To	1 W Nov-95 Apr-96	2 S May-96 Oct-96	3 W Nov-96 Apr-97	4 S May-97 Oct-97	5 W Nov-97 Apr-98	6 S May-98 Oct-98	7 W Nov-98 Apr-99	8 S May-99 Oct-99	9 W Nov-99 Apr-00	10 S May-00 Oct-00	11 W Nov-00 Apr-01	Sum	Multiplier
Flow Volume (1000 m³)													
North Fork Rose Creek (X2)	3258	29124	1953	26709	4657	20370	2859	33570	3324	36884	4943	167650	
South Fork Rose Creek	259	7670	263	10733	2381	11064	1550	18236	1803	20037	2682	76678	
Rose Creek Diversion Canal Runoff	368	3477	213	3189	543	2431	320	4008	374	4404	574	19902	
Main Rock Dump	3	19	2	18	4	13	3	22	3	24	4	115	
North Wall Interceptor Ditch	196	1285	137	1177	237	901	178	1480	204	1627	258	7678	
X-V Dam Surface Release (X5)	2319	772	1015	2164	2497	3922	0	1760	400	3000	1000	18849	
X-V Dam Seepage (X13)	610	964	737	1256	1031	1273	759	978	700	800	700	9808	
Groundwater Discharge	181	183	180	183	180	183	180	183	181	183	180	1995	
Runoff Below X-V Dam (Est.)	76	497	53	455	92	348	69	572	79	629	100	2969	
Total: Rose Creek at X14	7269	43990	4552	45884	11621	40505	5918	60810	7068	67587	10440	305644	
Average Sulphate Concentration (mg/L)													
North Fork Rose Creek (X2)	24	27	20	8	18	14	29	10	25	9	30		
South Fork Rose Creek	15	6	11	7	11	9	13	9	11	9	11		
Rose Creek Diversion Canal Runoff	15	6	11	7	11	9	13	9	11	9	11		
Main Rock Dump	15	6	11	7	11	9	13	9	11	9	11		
North Wall Interceptor Ditch	15	6	11	7	11	9	13	9	11	9	11		
X-V Dam Surface Release (X5)	499	461	443	383	390	401	558	443	566	471	484		
X-V Dam Seepage (X13)	533	533	449	446	461	590	591	603	613	502	526		
Groundwater Discharge	422	422	422	422	422	422	422	422	422	422	422		
Runoff Below X-V Dam (Est.)	15	6	11	7	11	9	13	9	11	9	11		
X14	388	66	244	65	232	100	236	71	185	73	109		
Sulphate Load (tonnes)													
North Fork Rose Creek (X2)	78	786	39	214	84	285	83	336	83	332	148	2468	10%
South Fork Rose Creek	4	46	3	75	26	100	20	164	20	180	30	668	3%
Rose Creek Diversion Canal Runoff	6	21	2	22	6	22	4	36	4	40	6	169	1%
Main Rock Dump	0	0	0	0	0	0	0	0	0	0	0	1	0%
North Wall Interceptor Ditch	3	8	2	8	3	8	2	13	2	15	3	66	0%
X-V Dam Surface Release (X5)	2314	712	899	1658	1948	3145	0	1559	453	2826	968	16482	64%
X-V Dam Seepage (X13)	325	514	331	560	475	751	449	590	429	402	368	5194	20%
Groundwater Discharge	76	77	76	77	76	77	76	77	76	77	76	842	3%
Runoff Below X-V Dam (Est.)	1	3	1	3	1	3	1	5	1	6	1	26	0%
Incremental Predicted SO4	2808	2167	1352	2618	2618	4392	635	2781	1068	3877	1600	25916	100%
Incremental Observed SO4	2821	2903	1111	2982	2696	4050	1397	4317	1308	4934	1138	29657	
Incremental % of Observed SO4	100%	75%	122%	88%	97%	108%	45%	64%	82%	79%	141%	87%	
Cumulative Predicted SO4	2808	4974	6327	8944	11563	15955	16589	19370	20439	24316	25916		
Cumulative Observed SO4	2821	5724	6835	9817	12513	16564	17960	22278	23585	28519	29657		
Cumulative % of Observed SO4	100%	87%	93%	91%	92%	96%	92%	87%	87%	85%	87%		
Average Zinc Concentration (mg/L)													
North Fork Rose Creek (X2)	0.03	0.04	0.06	0.06	0.08	0.04	0.03	0.03	0.09	0.07	0.03		
South Fork Rose Creek	0.01	0.01	0.02	0.04	0.04	0.02	0.03	0.03	0.02	0.02	0.01		
Rose Creek Diversion Canal Runoff	0.01	0.01	0.02	0.04	0.04	0.02	0.03	0.03	0.02	0.02	0.01		
Main Rock Dump	0.01	0.01	0.02	0.04	0.04	0.02	0.03	0.03	0.02	0.02	0.01		
North Wall Interceptor Ditch	0.01	0.01	0.02	0.04	0.04	0.02	0.03	0.03	0.02	0.02	0.01		
X-V Dam Surface Release (X5)	0.26	0.24	0.15	0.21	0.12	0.35	0.31	0.34	0.32	0.34	0.37		
X-V Dam Seepage (X13)	0.01	0.02	0.02	0.04	0.02	0.04	0.03	0.02	0.04	0.04	0.02		
Groundwater Discharge	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01		
Runoff Below X-V Dam (Est.)	0.01	0.01	0.02	0.04	0.04	0.02	0.03	0.03	0.02	0.02	0.01		
X14	0.10	0.04	0.07	0.09	0.09	0.13	0.05	0.05	0.15	0.08	0.07		
Zinc Load (kg)													
North Fork Rose Creek (X2)	98	1165	117	1603	373	815	86	1007	299	2582	148	8292	38%
South Fork Rose Creek	3	77	5	429	95	221	47	547	36	401	27	1888	9%
Rose Creek Diversion Canal Runoff	4	35	4	128	22	49	10	120	7	88	6	472	2%
Main Rock Dump	0	0	0	1	0	0	0	1	0	0	0	3	0%
North Wall Interceptor Ditch	2	13	3	47	9	18	5	44	4	33	3	181	1%
X-V Dam Surface Release (X5)	1206	371	305	909	599	2745	0	1197	256	2040	740	10367	48%
X-V Dam Seepage (X13)	6	19	15	50	21	51	23	20	28	32	14	278	1%
Groundwater Discharge	2	2	2	2	2	2	2	2	2	2	2	20	0%
Runoff Below X-V Dam (Est.)	1	5	1	18	4	7	2	17	2	13	1	70	0%
Incremental Predicted Zn	1321	1686	452	3186	1124	3908	174	2955	634	5190	940	21571	100%
Incremental Observed Zn	727	1760	319	4130	1046	5266	296	3040	1060	5407	731	23781	
Incremental % of Observed	182%	96%	142%	77%	108%	74%	59%	97%	60%	96%	129%	91%	
Cumulative Predicted Zn	1321	3007	3458	6645	7769	11677	11851	14806	15440	20630	21571		
Cumulative Observed Zn	727	2487	2805	6935	7981	13246	13542	16583	17643	23050	23781		
Cumulative % of Observed	182%	121%	123%	96%	97%	88%	88%	89%	88%	90%	91%		

Incremental Sulphate Loading at X14



Incremental Zinc Loading at X14



SULPHATE AND ZINC LOADING

VANGORDA CREEK

Concentrations for location V1 were applied to runoff areas unaffected by mine contaminants.

The model predicts 111% of the observed sulphate loading at location V8.

The model predicts 113% of the observed zinc loading at location V8.

The largest source of sulphate loading (over the entire period of study) was the West Fork of Vangorda Creek (58%) followed by the Grum Rock Dump via Grum Creek (18%).

SULPHATE AND ZINC LOADING

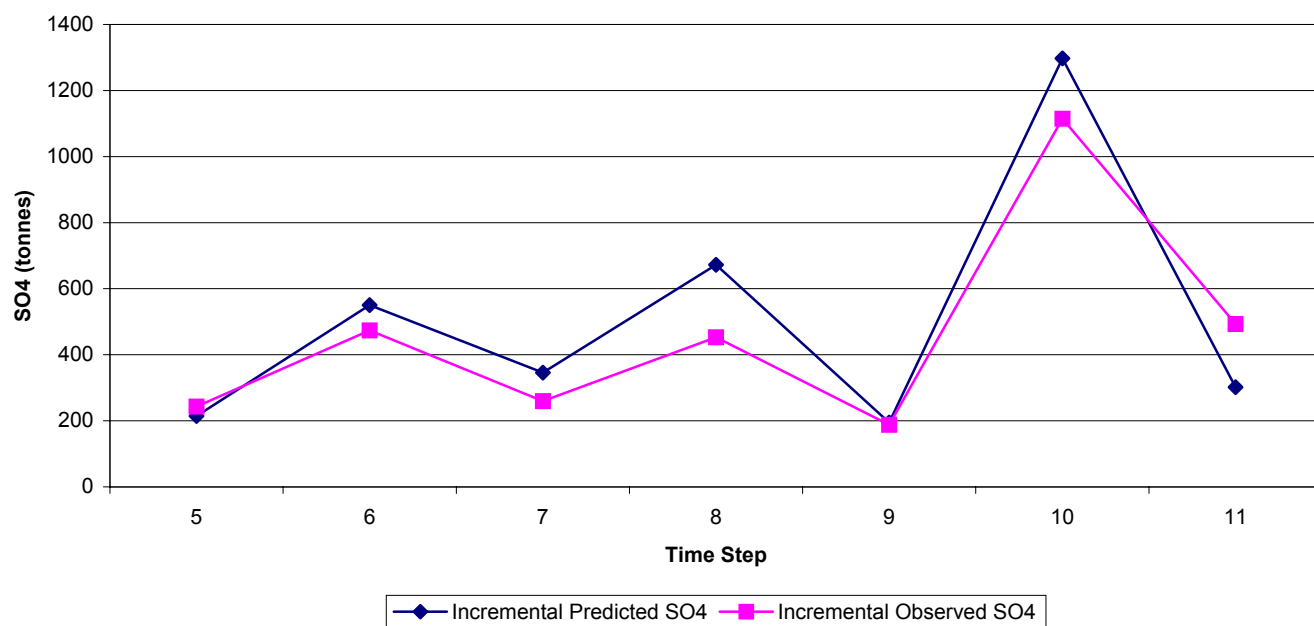
VANGORDA CREEK

The largest sources of zinc loading (over the entire period of study) were the West Fork of Vangorda Creek (25%) and the Grum Rock Dump via Grum Creek (23%) followed by the Vangorda Creek Diversion Channel (19%).

Load Balance Calculations for Station V8

Time Step Season From To	5 W Nov-97 Apr-98	6 S May-98 Oct-98	7 W Nov-98 Apr-99	8 S May-99 Oct-99	9 W Nov-99 Apr-00	10 S May-00 Oct-00	11 W Nov-00 Apr-01	Sum	
Flow Volume (1000 m³)									
Vangorda Creek Diversion Channel (V1)	1099	4167	818	6899	942	7081	1197	22202	
Grum Interceptor Ditch (V25BSP)	117	445	88	715	101	744	128	2337	
Grum Rock Dump (Grum Creek) (V2)	98	372	74	611	84	671	106	2015	
Seepage from Little Creek Dam	8	8	8	8	8	8	8	55	
Seepage from Vangorda Rock Dump	8	8	8	8	8	8	8	55	
Shrimp Creek (V4)	384	1458	288	2397	330	2618	417	7893	
Runoff from Lower Vangorda Creek Catchment (31c + 35 + 36)	312	1185	235	1948	269	2141	339	6430	
Discharge from West Fork Vangorda Creek (V5)	1048	3983	789	6546	903	7193	1139	21601	
Total: Vangorda Creek at V8	2025	7643	1518	12586	1742	13272	2202	40987	
Average Sulphate Concentration (mg/L)									
Vangorda Creek Diversion Channel	10	17	13	5	10	7	16		
Grum Interceptor Ditch	437	153	66	106	132	57	96		
Grum Rock Dump (Grum Creek)	72	158	178	180	165	605	462		
Seepage from Little Creek Dam	100	100	100	100	100	100	100		
Seepage from Vangorda Rock Dump	100	100	100	100	100	100	100		
Shrimp Creek	61	33	134	42	86	38	60		
Runoff from Lower Vangorda Creek Catchment (31c + 35 + 36)	10	17	13	5	10	7	16		
Discharge from West Fork Vangorda Creek	112	71	346	52	139	95	166		
V8	120	62	171	36	108	84	224		
Sulphate Load (tonnes)									
Vangorda Creek Diversion Channel	11	71	11	34	9	50	19	205	6%
Grum Interceptor Ditch	51	68	6	76	13	42	12	269	8%
Grum Rock Dump (Grum Creek)	7	59	13	110	14	406	49	658	18%
Seepage from Little Creek Dam	1	1	1	1	1	1	1	6	0%
Seepage from Vangorda Rock Dump	1	1	1	1	1	1	1	6	0%
Shrimp Creek	23	48	39	101	28	99	25	364	10%
Runoff from Lower Vangorda Creek Catchment (31c + 35 + 36)	3	20	3	10	3	15	5	59	2%
Discharge from West Fork Vangorda Creek	117	283	273	340	126	683	189	2011	56%
Incremental Predicted SO4	215	550	346	673	195	1297	302	3577	100%
Incremental Observed SO4	243	474	260	453	188	1115	493	3226	
Incremental % of Observed SO4	88%	116%	133%	148%	104%	116%	61%	111%	
Cumulative Predicted SO4	215	765	1111	1783	1978	3276	3577		
Cumulative Observed SO4	243	717	976	1430	1618	2732	3226		
Cumulative % of Observed SO4	88%	107%	114%	125%	122%	120%	111%		
Average Zinc Concentration (mg/L)									
Vangorda Creek Diversion Channel	0.01	0.02	0.05	0.00	0.01	0.04	0.02	0.03	
Grum Interceptor Ditch	0.21	0.12	0.15	0.24	0.31	0.13	0.10	0.09	
Grum Rock Dump (Grum Creek)	0.02	0.05	0.06	0.12	0.03	0.64	0.32	0.09	
Seepage from Little Creek Dam	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.09	
Seepage from Vangorda Rock Dump	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.08	
Shrimp Creek	0.03	0.04	0.05	0.04	0.01	0.02	0.02	9.85	
Runoff from Lower Vangorda Creek Catchment (31c + 35 + 36)	0.01	0.02	0.05	0.00	0.01	0.04	0.02	0.32	
Discharge from West Fork Vangorda Creek	0.07	0.03	0.04	0.02	0.03	0.03	0.02	0.03	
V8	0.06	0.04	0.04	0.04	0.02	0.08	0.03	0.03	
Zinc Load (kg)									
Vangorda Creek Diversion Channel	11	83	41	14	9	283	24	466	19%
Grum Interceptor Ditch	25	53	13	172	31	97	13	403	17%
Grum Rock Dump (Grum Creek)	2	19	4	73	3	429	34	564	23%
Seepage from Little Creek Dam	0	0	0	0	0	0	0	1	0%
Seepage from Vangorda Rock Dump	0	0	0	0	0	0	0	1	0%
Shrimp Creek	12	58	14	96	3	52	8	244	10%
Runoff from Lower Vangorda Creek Catchment (31c + 35 + 36)	3	24	12	4	3	86	7	138	6%
Discharge from West Fork Vangorda Creek	73	119	32	131	27	216	23	621	25%
Incremental Predicted Zn	126	357	116	489	76	1163	109	2437	100%
Incremental Observed Zn	121	306	61	503	35	1062	66	2154	
Incremental % of Observed	103%	117%	192%	97%	219%	110%	165%	113%	
Cumulative Predicted Zn	126	483	599	1089	1165	2328	2437		
Cumulative Observed Zn	121	427	488	991	1026	2088	2154		
Cumulative % of Observed	103%	113%	123%	110%	114%	112%	113%		

Incremental Sulphate Loading at V8



Incremental Zinc Loading at V8

