DIGBY WELLS
ENVIRONMENTAL

Providing environmental, social and sustainability solutions to the resources sector globally.

Making A Difference
Locally with Global Impact

www.digbywells.com
info@digbywells.com

Influences on Mine Water Quality that are not Related to Acid Mine Drainage

Robel Gebrekristos and Graham Trusler

Digby Wells Environmental

Contaminants in Mine Waters that is not related to AMD

- AMD is well known as a cause of problems with both groundwater and surface water at mine sites
  - There are various guidelines to predict and manage AMD and metal leachability from mine wastes and workings.
  - Mines often conduct proper investigations on the potential threat of AMD and associated metal dissolution
- Our research focused on other lesser known and therefore less proactively managed sources of contamination

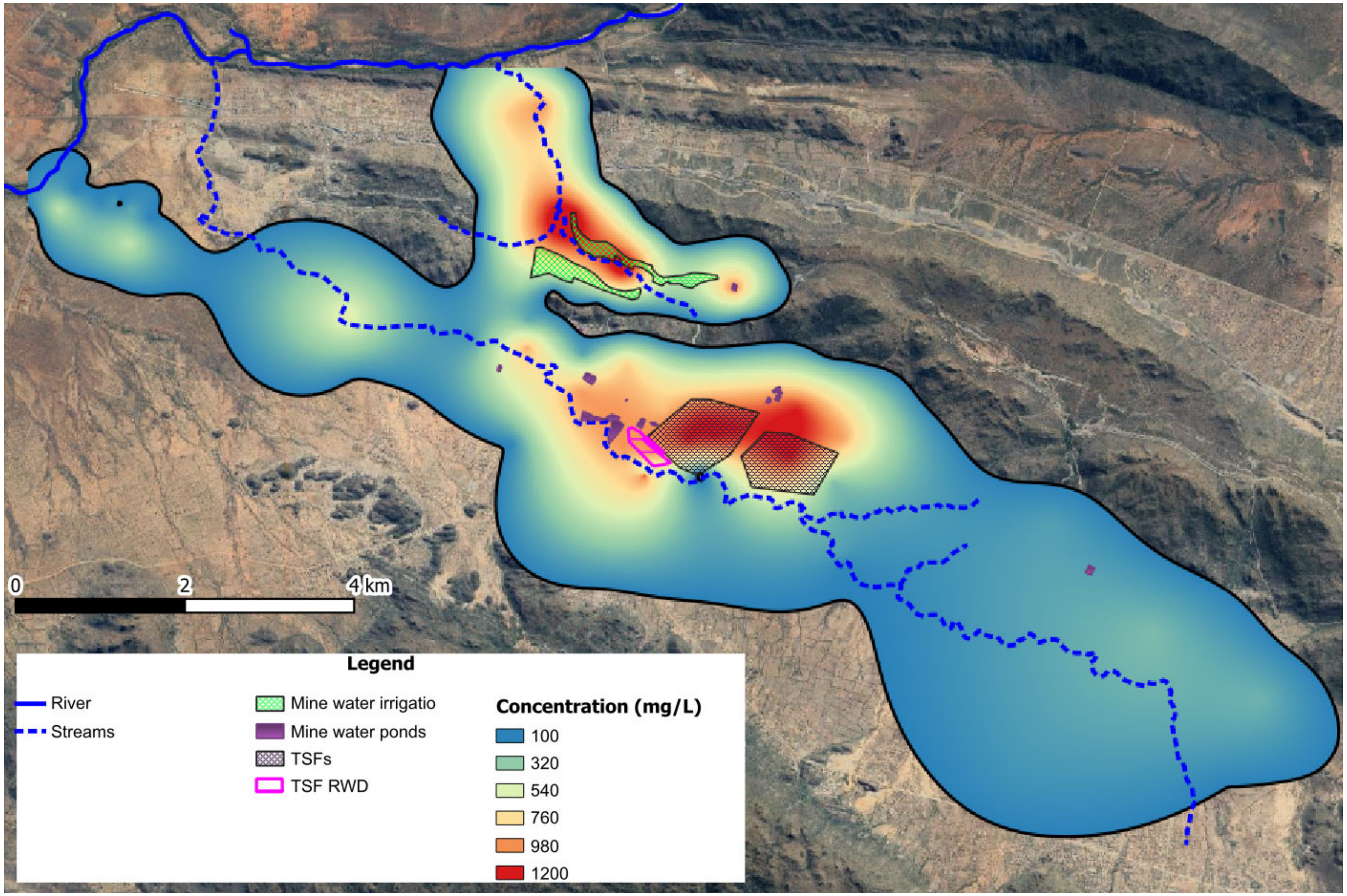
Sources of Water Contamination other than AMD

- Chemical reagents used in beneficiation processes
- Hydrocarbon leakage from storage tanks and workshops
- Microorganisms released from pit latrines and septic tanks
- Explosive usage and management
- Sewage treatment plants
- Water treatment chemicals
- Input water from a contaminated source
- Seepage from non-mining waste sites

Case Study 1 – Chloride Contamination

- Location - the site is a platinum mine in South Africa
- Mine life - it has been in operation for nearly 70 years
- Geology - the host rocks and orebody are ultramafic igneous rocks
- AMD - the rocks do not have AMD potential
- Excess water - MAP and MAE are 564 and 1851 mm, but too much groundwater
- Water quality - the background chloride concentration in the groundwater and surface water is <50 mg/L, licence limit is 100 mg/L
- Mine setting - none of the TSFs, RWDs and mine water ponds are lined
  - The TSFs and RWD are on alluvial sediments with K value >1 m/d
  - Nearly 23% of the wastewater seeps to the aquifer and increases the plume size
  - Excess mine water was used for irrigation or discharged

Case Study 1 – Chloride Contamination Plume



Map showing the current chloride plume in the aquifer

- Extends over a distance of ~17 km (10 miles)
- Plume footprint area ~50 km^2
- Maximum Cl concentration is 1200 mg/L (the discharge limit is 100 mg/L)
- Plume joins a major river to the northwest at 500 - 800 mg/L

Chloride Source – Host Rocks and Orebody?

Mineral	Molecular formula	Orebody	Waste Rocks					
			Norite	Gabbro-norite	Pyroxenite	Feldspathic Pyroxenite	Anorthosite	Leuconorite
Plagioclase	$(Na,Ca)(Si,Al)_4O_8$	17	34	58	16	19	85	74
Enstatite	$MgSiO_3$	50.1	-	36	21	27	-	20
Chromite	$FeCr_2O_4$	31.6	-	-	33	-	0.51	-
Smectite	$CaMg_2AlSi_4(OH)_2 \cdot H_2O$		0.45	-	11	15	11	0.95
Quartz	SiO_2		26	2.1	-	0.61	1.2	
Chlorite	$(Mg,Fe)_5Al(AlSi_3O_{10})(OH)$		15	-	5	6.5	1.6	-
Diopside	$CaMgSi_2O_6$		-	-	-	15	-	1.5
Talc	$Mg_3(Si_2O_5)_2(OH)_2$	0.5	-	-	15		0.7	-
Hornblende	$Ca_2(Fe,Mg)_4Al(Si_7Al)O_{22}(OH,F)_2$		15	-	-		-	-
Paragonite	$NaAl_2(AlSi_3)O_{10}(OH)_2$		-		-	12		1.1
Prenhite	$Ca_2Al(AlSi_3O_{10})(OH)_2$		6.1	-	-		-	-
Biotite	$K(Mg,Fe)_3((OH)_2Al Si_3 O_{10})$	0.6	3.5	-	-	-	-	-
Augite	$Ca(Fe,Mg)Si_2O_6$		-	3.3	-		-	-
Actinolite	$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)$		-			2.2		-
Cristobalite	SiO_2		-	-	-	0.95	-	1.2
Rutile	TiO_2		-	-	-	2.1	-	
Magnetite	Fe_3O_4		-	-	-	-	-	0.53
Total % by wt		**100**	**100**	**100**	**100**	**100**	**100**	**100**

- No chloride bearing minerals are detected
- Chloride is therefore not from the natural rocks

Chloride Source – Process Chemicals?

- Four types of chemical reagents are used for the mineral beneficiation process which is a Flotation concentration operation.
  - Depressant
  - Frother
  - Flocculant
  - Collector (flotation)
- Each reagent was analysed for chloride content during this study
- The reagents were diluted 1:1000 using distilled water as they were too concentrated for normal laboratory equipment

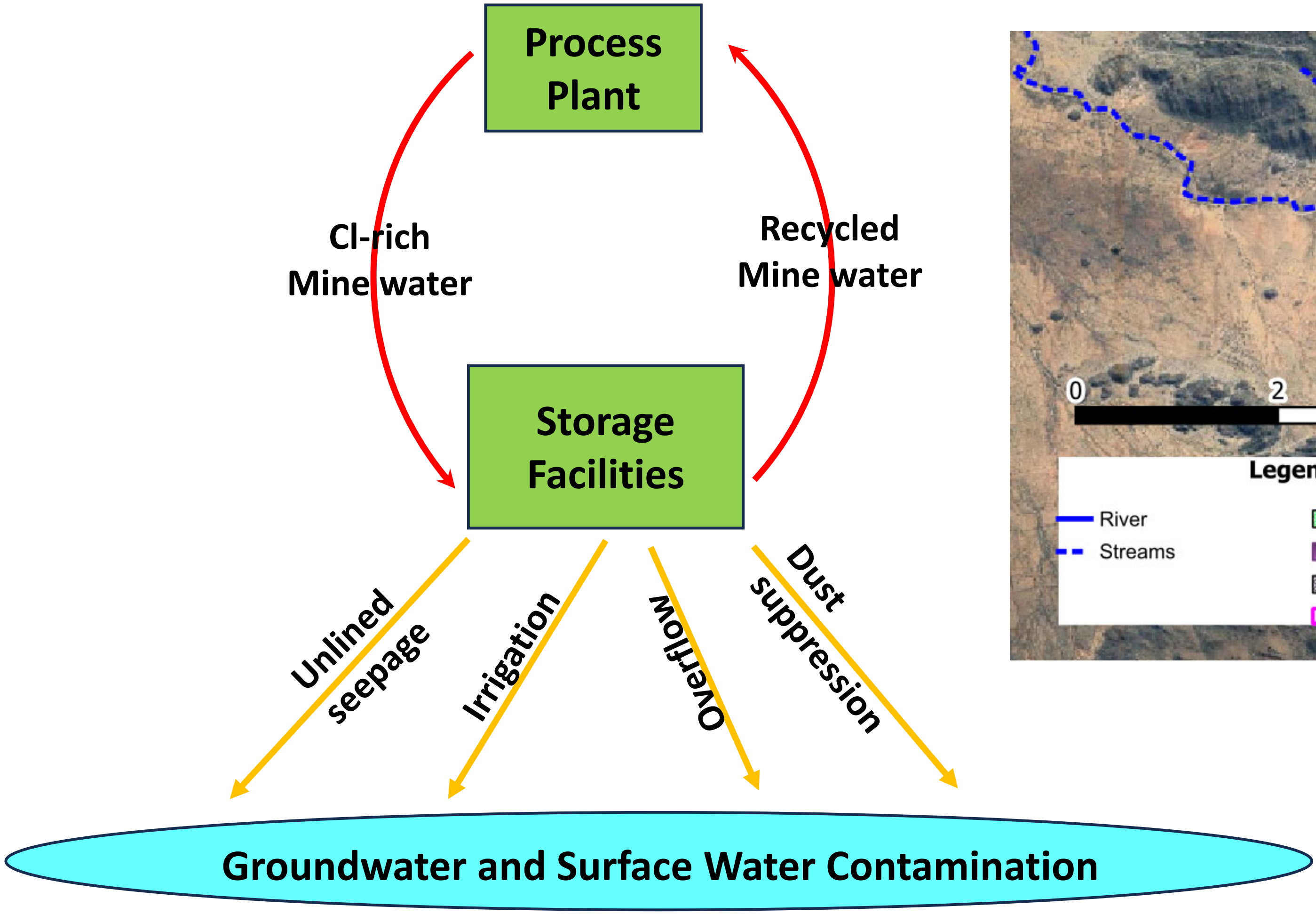
Chloride Source – Process Chemicals?

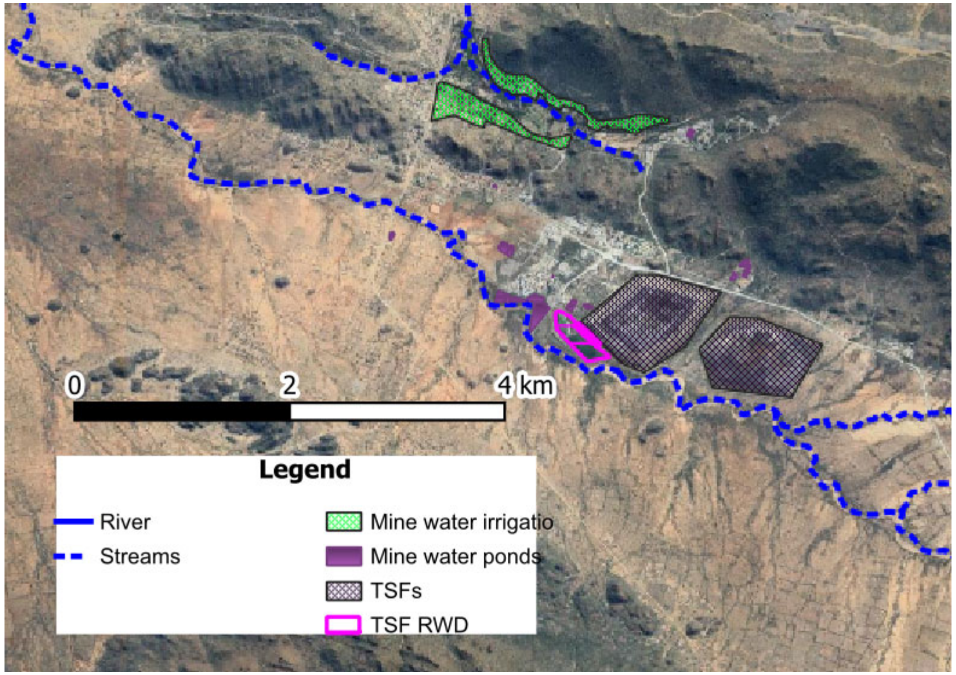
Sample ID	Flocculant	Frother	Depressant	Collector
pH	6.40	6.20	6.50	9.40
Total Dissolved Solids (mg/L)	<10	<10	<10	326
Total Alkalinity as $CaCO_3$ (mg/L)	<5	<5	<5	44
Chloride as Cl (mg/L)	<2	<2	**6**	**158**
Sulphate as SO_4 (mg/L)	<2	<2	<2	90
Sodium as Na (mg/L)	<1	<1	2	80
Potassium as K (mg/L)	<0.5	<0.5	<0.5	<0.5
Calcium as Ca (mg/L)	<1	1	<1	<1
Magnesium as Mg (mg/L)	<1	<1	<1	<1
Aluminium as Al (mg/L)	<0.100	<0.100	<0.100	<0.100
Manganese as Mn (mg/L)	<0.025	<0.025	<0.025	<0.025

- ~48% of the Collector is chloride by weight
- And ~80% of the Depressant is chloride
- The process reagents are therefore chloride sources

Even though reagent addition is at very low rates, there is an accumulation and concentration increase over 70 years

Are the reagents solely responsible for the current impact?





- If the wastewater was contained, there would have been no environmental impact even if there is chloride source.

Case Study 1 – Mitigation Plans

- The mine is installing a water treatment plant, and no wastewater will be discharged or used for irrigation without treatment
- All RWDs and mine ponds are in the process of being lined
- Further actions to be done include:
    - Manage TSF pool size to minimise the current seepage
    - Reduce TSF infiltration through revegetation, capping and covering them with less permeable clayey soil
    - Reduce freshwater requirements and wastewater generation by reusing more process water
    - Change flotation chemical reagents

Case Study 1 – Mitigation Plans

- Develop a wholistic water balance that includes not only the floatation test work but also salt loads that are released to the receiving environment.
- Consider mine dewatering from boreholes upgradient of the mine, rather than from the mine void which is already contaminated. This water is clean and can be discharged without treatment
- Conduct active aquifer remediation via pump and treat or other techniques.
- Lesson learned:
  - Include the management of process chemicals in advance of mine development rather than getting restricted on AMD and metal leachability characterisation.
  - Ensure environmental problems are adequately discussed with production personnel to make it a joint problem to solve.

Case Study 2: Nitrate Issue

- The mine site is in Tanzania with positive water balance
  - More water is captured from groundwater and rainfall than can be locked up in the system or evaporated
- The mine did not discharge water for many years (by design) and kept water in ponds and on the TSF pool
- AMD was generated from some Waste Rock Dumps (WRDs) and pumped on to the TSF without treatment
- The excess water is consisted of sewage, process and mine dewatering water
- The water volumes built up to dangerous levels. TSF design capacity is 800 000 m^3 but stored up to 7 000 000 m^3 of water
- A large load of nitrate (up to 40 mg/L NO_3-N) was contained in these waters while the discharge limit is only was 20 mg/L

Case Study 2: Nitrate Issue

- Before the water can be discharged, treatment was necessary to meet the discharge standards for nitrate, TDS, chloride and sulphate
- Large RO plants were installed
- The brine was recirculated back to the TSF pool and thus the nitrate continued to build up without limit
- The TSF is neutral and was used to neutralise the AMD from the WRDs. The salt load in the TSF pool originated from the AMD, sewage and process water.
- A comprehensive water and salt balance was drawn up showing that Cl would be a limitation salt for discharge and would build up.

Case 2: Management Measures Implemented

- Changing attitudes by getting personal to buy into the idea that water discharge had to happen and should be done in a controlled manner, meet regulated discharge limits and that PCDs should normally be kept empty
- Reducing water ingress by reducing water capture (runoff from WRDs and covers over the dumps)
- Sewage water stopped being added to the TSF and was discharged to a passive treatment system using eucalyptus trees and wetlands
- The sewage treatment plant was improved
- Explosive manufactures and blasting systems were changed to optimise rock fragmentation and minimise nitrate wastage into the water systems
- Discharge of water was encouraged, and nitrate levels were maximised in the discharge waters but kept just below the discharge limit
- A high recovery water treatment plant was built to treat the RO plant brine utilising high pressure RO and lime addition to control calcium and magnesium salt build up.

Case 2: Management Measures Implemented

- Biological sampling was instituted to monitor the influence of discharges, and chemical sampling was systematised for the same reasons
- The highly concentrated brine was stored in double lined ponds for evaporation, further treatment, and blending to reduce volumes
- The mine is now operating in a controlled and safe manner with respect to water storage, provision and discharge
- The water in the TSF pool is now at 50 000 m^3, which is below its design capacity of 800 000 m^3 and way below the 7 000 000 m^3 it used to store 3 years earlier.

TSF before (left) and after (right) pool reduction

Thank You

3 DECADES

Established in **1995** with a global focus on the resources industry

Multidisciplinary in-house Specialist Team

Environmental and Social Solutions Partner

NOTABLE **GLOBAL** footprint

Local presence and project experience spanning 77 countries

6 Regional Operating Hubs across **EUROPE & AFRICA**

Projects undertaken to in-country specific requirements and international guidelines

DIGBY WELLS
ENVIRONMENTAL

www.digbywells.com
info@digbywells.com