

Groundwater Fate and Transport Modelling

Leachate Plume – Capped Waste Stockpile
Hydro Aluminium Smelter Kurri Kurri NSW

Prepared for:
Hydro Aluminium Kurri Kurri Pty Ltd

Prepared by:
ENVIRON Australia Pty Ltd

Date:
26 February 2015

Project Number:
AS130335

ENVIRON

Prepared by:			**Authorised by:**		
Name:	Steve Cadman		Name:	Fiona Robinson	
Title:	Senior Environmental Scientist		Title:	Manager - Hunter	
Phone:	+ 61 2 4962 5444		Phone:	+ 61 2 4962 5444	
Email:	scadman@environcorp.com		Email:	frobinson@environcorp.com	
Signature:		Date:26/02/15	Signature:		Date:26/02/15

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VERSION CONTROL RECORD

Document File Name	**Date Issued**	**Version**	**Author**	**Reviewer**
AS130335_modelrep1	10 February 2015	Draft 1	SC	FR
AS130335_modelrep1	26 February 2015	Final	SC	FR

Contents

Executive Summary

The following report presents the hydrogeological review and analytical groundwater contaminant transport modelling conducted by Environ Australia Pty Ltd (ENVIRON). The work was undertaken to assess the fate and transport of shallow, leachate-affected groundwater to the east of the Capped Waste Stockpile. The Capped Waste Stockpile is a aluminium waste repository located on the eastern boundary of the former Kurri Kurri Aluminium Smelter site and is known to discharge leachate.

Data from previous site investigation was reviewed and this information was used to construct a conceptual hydrogeological model of the site and surrounds.

A one-dimensional analytical model (UK EA Remedial Targets Worksheet) was used to simulate the groundwater flow and contaminant transport conditions to predict contaminant (fluoride) concentrations from the source to the nearest down-gradient receptor, (Swamp Creek).

The model was calibrated against observed fluoride concentrations from the existing groundwater monitoring well network to the east and north-east of the capped waste stockpile. The groundwater fluoride concentration at the receptor impact point was then evaluated under the simulated model and compared with the guideline criteria.

The following conclusions were drawn from the results of the modelling:

- Based on the existing hydrogeological conditions and the presence of an ongoing source from the capped waste stockpile, the model estimated a fluoride concentration of 4.3 mg/L at the receptor distance, (1000m), compared to the guideline criteria of 1.5 mg/L;
- This value is considered to be a conservative estimate given the model assumes a continuous source, however, historical, more recent and proposed works are considered to have mitigated the source contribution. Future remedial works are proposed to ultimately remove the source;
- The model demonstrates sensitivity to a number of input parameters including the soil partition coefficient, (Kd). Future studies may include site specific determination of the soil partition coefficient in order to improve model calibration.

1 Introduction

1.1 Background

The following report presents results of a hydrogeological review and groundwater modelling conducted to assess potential impacts from a leachate-plume emanating from an aluminium smelter waste repository (“Capped Waste Stockpile”), on the eastern boundary of the Former Hydro Aluminium Kurri Kurri Smelter at Kurri Kurri, NSW.

Previous investigation has indicated the presence of elevated concentrations of elevated pH, sodium, fluoride and cyanide in shallow groundwater to the east and northeast of the Capped Waste Stockpile. Impacted groundwater at the site is contained within a shallow aquifer derived from alluvial sediments (less than 5m depth), comprised of a series of silty sands and clays, overlying deeper bedrock (weathered siltstone of the Lower Permian-aged Dalwood Group). Shallow groundwater has previously been observed to respond to rainfall events, rising and where intersecting with breaks in topography, ex-filtrating, becoming surface flow

Groundwater generally flows east and north-east towards the topographically lower areas and eventually into Swamp Creek and towards the lower Wentworth Swamp area.

The site is shown in **Figure 1** in the 12 Month Groundwater Monitoring Report**.**

As part of longer term planning for rehabilitation of the Capped Waste Stockpile and the wider area, (including groundwater impacts), the groundwater flow including contaminant transport has been modelled to assess potential existing impacts and future impacts on the wider groundwater environment. The assessment of contaminant flow will focus on the concentrations of fluoride in groundwater.

The modelling was undertaken in conjunction with ongoing monitoring of the network of wells around the Capped Waste Stockpile, and this modelling report will be attached as an appendix to the 12 Month Groundwater Monitoring Report, (for 2013-2014).

The objectives of the groundwater contaminant transport modelling were to:

- assess potential impacts on the down-hydraulic gradient receptors, specifically, Swamp Creek and the Wentworth Swamp.

The following scope of work was undertaken as part of this study:

- Review of existing site data, in particular data relating to site topography geology/hydrogeology (including water level data from the installed groundwater monitoring wells mainly to the east and north-east of the capped waste storage), and groundwater quality analytical data from historical monitoring (Hydro and others), and more recent groundwater monitoring, conducted by ENVIRON;

- Preparation of a conceptual groundwater flow model for the site, based on the geology/hydrogeology information;

- input of the data into a one-dimensional, analytical model based on well understood groundwater flow and contaminant transport principles; and conduct groundwater modelling involving:
  - calibration of the model against measured contaminant concentrations to establish current conditions; and
  - groundwater modelling to predict impacts from fluoride on environmental receptors down hydraulic gradient of the capped waste storage as a result of groundwater flow.

2 Site Background Information

Background information including site geology and hydrogeology is presented in detail in the over-arching annual groundwater monitoring report of which this report forms a part.

The following is a summary of that background information.

2.1 Smelter Site Background

The Former Hydro Aluminium Kurri Kurri Smelter is located approximately 30km west of the city of Newcastle and 150km north of Sydney, in New South Wales, Australia. The smelter includes a 60ha plant area surrounded by approximately 2,000ha of buffer zone lands.

The Capped Waste Stockpile is a capped waste repository comprising aluminium smelting wastes. Leachate from the capped waste stockpile is known to have impacted on groundwater resulting in leachate impacted groundwater that is understood to have originated from the north-east corner of the capped waste stockpile and extends approximately 250m north-east.

Leachate from the Capped Waste Stockpile is known to contain high concentrations of fluoride, aluminium and cyanide as well as being highly saline and alkaline.

2.2 Site Geology

The Sydney Basin Geological Sheet indicates that the Smelter Site is underlain by siltstone, marl and minor sandstone from the Permian aged Rutherford Formation (Dalwood Group) in the Sydney Basin. Undifferentiated Quaternary alluvium occurs in the east and northeast of the smelter site including the area around the Capped Waste Stockpile, and is connected to the surrounding surface water bodies. Quaternary sediments which are associated with Swamp Creek (located to the east of the site) and Wentworth Swamps consist of complex interbedded fluvial and marine sands and estuarine muds deposited within an estuarine environment during periods of sea level rise and fall.

The series of investigations conducted in this area of the site has indicated there are several different strata present that are inter-bedded in a complex manner. The strata identified include estuarine mud deposits (high plasticity clays), fluvial channel sands (fine grained sands) and sandy levee deposits (sandy clay/ clayey sand). The depositional environment of the strata at the site is interpreted to be within the upper reaches of an estuary, with the clay deposited as organic rich muds. The muds are interbedded with fluvial sands and sandy levee deposits, flowing into the estuary from upstream during periods of sea level fall.

2.3 Site Hydrogeology

Numerous borehole investigation of the area to the east of the Capped Waste Stockpile, has generally shown the groundwater to be present in a complicated interbedded sequence of granular sediments, which approximately form a south-southwest to north-north-west trending alignment. This area of shallow groundwater occurrence is approximately of 50 to 100m width. Outside this area, further to the east or south, shallow groundwater is not encountered in boreholes.

Groundwater is noted at depths of between 1 and 6 metres below ground surface, (approximately 5 to 11 m AHD) and groundwater flow occurs through two aquifers comprising a shallow sand channel aquifer that is underlain at depth by a separate, and locally confined, deeper aquifer.

Over a number of phases of investigation, limited aquifer testing has been undertaken – chiefly single well tests (falling head, “slug” tests), to determine aquifer parameters. These tests general indicated hydraulic conductivities of $1e^{-5}$ to $1e^{-7}$m/sec.

In 2012, ENVIRON conducted a more comprehensive 12 hour constant pumping rate aquifer test of a well installed into the shallow aquifer sands, adjacent to the north-east corner of the capped waste stockpile. During the test groundwater drawdown and recovery was recorded in selected observation wells. Analysis of the test pumping indicated hydraulic conductivities in the order of $3e^{-5}$ to $7e^{-5}$m/sec, (ENVIRON 2012).

Groundwater within the shallow aquifer is assumed to be isolated from the deeper aquifer. Groundwater flow rates are generally towards the north and north-east, following the former channel and are highly dependent on rainfall events. Daylighting of the shallow aquifer occurs where topography and geology conditions force groundwater to the surface. These daylighting events occur following high rainfall.

Downward vertical groundwater flow is limited by both high plasticity clays and very dense fine-grained sands.

2.4 Site Contaminants of Concern

The following table presents a summary of measured contaminant concentration in the groundwater monitoring network, (2013 to date):

Table 1 Site Contaminants of Concern

Contaminant	Adopted Guideline Concentration (mg/L)	Maximum concentration (mg/L)	Average Concentration (mg/L)	No. Samples exceeding Guideline
Fluoride	1.5	1080	209	68
Aluminium	0.055	415	25	125
Cyanide	0.007	260	38	84

Fluoride was selected as the primary contaminant of concern, appropriate for the groundwater model, as a result of its persistence observed in the groundwater and its concentration range in comparison with the adopted guideline criteria.

Aluminium was not considered due to its ubiquity in aquifer materials and the environment generally. Cyanide was not considered appropriate due its potential for degradation.

2.5 Site Conceptual Model

Leachate generation and mobilisation from the Capped Waste Stockpile is considered to occur by either infiltration through the surface capping layers creating 'new' leachate and causing a discharge through the sandier lenses; or by a rising water table, (as a response to rainfall), causing a flushing of trapped leachate through the sand lens. Historical testing by others has shown that the permeability of the surface capping layer of the capped waste stockpile is low (between $5e^{-9}$m/s to $1e^{-8}$m/s), and therefore infiltration through the surface capping layers is not considered to be the likely mechanism by which leachate mobilises. Based on the data available, the more probable mechanism is from a rising water table, in response to rainfall that causes a flushing of the trapped leachate through the sand lenses.

The leachate-affected groundwater occurs as a shallow aquifer within complex interbedded/braided alluvial sediments associated with Quaternary-aged deposition on the wider Hunter River floodplain. Generally sediments include sands and silty sands with varying degrees of clay content. Information from several stages of investigation has identified limited coarser lenses/layers of coarse sand and fine gravels within the sediments although these are considered to be of limited lateral and vertical extent.

Impacts from leachate migrating from the Capped Waste Stockpile are apparent in wells monitoring the shallow aquifer to the immediate east and northeast of the stockpile. Where the deeper aquifer is monitored, all but the wells most proximate to the capped waste stockpile, show little evidence of impacts. Impacts are typified by higher (more alkaline) pH, brown staining and elevated fluoride concentrations and salinities. Cyanide is also elevated in the wells monitoring the shallow aquifer, closer to the source.

Migration of groundwater to the down-gradient groundwater receptor occurs through the connected sand lenses with flow rates being highly rainfall dependent. Perching to surface water occasionally occurs and results in overland flow of leachate impacted water. Vertical migration to the deeper sand aquifer is limited by the presence of clays and dense sands. This barrier to vertical migration is further evidenced by the lower impacts in the deeper aquifer profile, and the preferential upward flowpath for shallow groundwater, suggesting a barrier to downward flow.

3 Groundwater Modelling

3.1 Model Description

To evaluate and predict potential impacts from fluoride in the groundwater on downstream receptors, the "Remedial Targets Worksheet", model was used. Originally developed for the UK environmental regulator, (UK Environment Agency), it is used as a tool to predict the impacts of soil and groundwater contamination.

The model selected is a one-dimensional, analytical model originally to assist with remediation planning. The model is presented as a spreadsheet.

Essentially the model uses a solution to the contaminant flow equation in groundwater using a selection of published solutions Domenico, (time variant or steady state), depending on assessment of vertical horizontal and longitudinal dispersivity.

The model is used to predict groundwater concentrations at a required distance from a source, starting with soil contaminant concentrations and a variety of known or assumed input parameters, and, if required, back-calculate groundwater remediation goals.

In this case, because the source groundwater concentrations are well understood from a large database of monitoring results, the soil components of the spreadsheet model, "Level 1, 2 and 3 Soil" sheets, are not used and inputs are made directly into the groundwater sheet, (Level 3).

The inputs to the model include:

- Geometry of the subject aquifer including depth, saturated thickness, and hydraulic gradient;
- Flow properties of the aquifer including hydraulic conductivity and porosity;
- Properties of the assumed contaminant plume including, plume width, depth, initial contaminant concentration;
- specific contaminant properties including degradation rate (if applicable), partition coefficient, (ie, the propensity for the contaminant to come out of solution and be adsorbed onto the soil particles of the aquifer) and the effects of lateral and vertical dispersion;
- Receptor impact assessment information including guideline criteria concentration, and linear distance to receptor

The above parameters are based on values measured in the field, values derived from literature and assumptions made depending on the site conditions.

A summary of the input parameters for the Hydro model is presented in the following section.

Modelling proceeded using the adopted input parameters as initial settings, and calculating the output which is presented as a curve of concentrations against distance from source. The model was then re-calculated using variable input parameter in order to calibrate the output against known fluoride concentrations within the monitoring well network, to the east and north-east of the capped waste storage, from historical and ongoing monitoring.

Model parameters for the best fit against concentration versus distance were then used to estimate the fluoride concentration at the assumed receptor distance.

A sensitivity analysis, assessing variation in the major parameters, was also undertaken to provide an indication of uncertainty in the model.

3.2 Model Inputs

The following table summarizes inputs to the model, including values and data sources.

Table 2 - Model Input Parameters

Parameter	Unit	Initial Value	Source/Comment
Saturated aquifer thickness	m	5	Obtained from field data during installation of wells across the site
Porosity of aquifer material	d/less	0.3	Based on average value for sandy sediments (Fetter 1988)
Bulk density of aquifer	T/m^3	1.8	Average value for sandy materials.
Hydraulic gradient	d/ess	0.01	Average value of water levels for wells south-west to north-east
Hydraulic conductivity	m/day	4	Based on the 2012 ENVIRON pump test calculated average value of 4.6 e-5 m/sec, (4 m/day).
Distance to receptor	m	1000	This distance is based on the flow path along the former surface water channel, refer to Figure 3 of 12 Month Groundwater Monitoring Report
Contaminant	-	Fluoride	Fluoride has been identified as the principal contaminant of concern from the capped waste stockpile.
Plume thickness	m	4	Set at one metre less than the saturated aquifer thickness to allow for vertical dispersion.
Width of plume at source (perpendicular to flow)	m	50	Set at 50 m based on observed occurrence of leachate in aquifer, (average width is closer to 50m)
Initial Concentration	mg/L	600	An average value for the leachate to account for a steady state source.
Target Concentration	mg/L	1.5	Guideline criteria for fluoride in water (recreational use).
Degradation half life	days	1e99	Assumed no degradation. Conservative.

Table 2 - Model Input Parameters

Parameter	Unit	Initial Value	Source/Comment
Longitudinal Dispersivity	m	10% of pathway	Standard default assumption for model
Transverse Dispersivity	m	1% of pathway	Standard default assumption for model
Vertical Dispersivity	m	0.1 of pathway	Standard default assumption for model
Soil/water partition coefficient	L/kg	0.8	Based on the default value for fluoride in the model help files (minimal adsorption).
Analytical Solution	-	-	Domenico – steady state for constant source (conservative assumption)
Vertical dispersion	m	in one direction	Assumed to be entering at surface of groundwater

Notes:

1. d/less is dimensionless
2. m is metes
3. L/kg litres per kilogram
4. T/m^3 is tonnes per cubic metre
5. m/sec and m/day is metres per second and metres per day

3.3 Model Parameters

The following is an expanded discussion of some major model inputs.

3.3.1 Monitoring Well Network

The 12 Month Groundwater Monitoring Report, (Figure 6), presents the location of wells comprising the current monitoring well network for the eastern plant area monitoring the groundwater down-gradient from the capped waste stockpile.

3.3.2 Flow Path Length

The length of the groundwater flow path from the assumed contamination source (the capped waste stockpile), has been set at 1000m which is the approximate flow path length along the infilled drainage channel. Figure 3 of the 12 Month Groundwater Monitoring Report shows the flow path, which is more realistically 1,100m to 1,500m to the nearest receptor, (Wentworth wetlands).

3.3.3 Aquifer Parameters

In 2000, a single well tests, ("slug" tests), indicated hydraulic conductivities between 0.012 to 6.92 m/day or between 1.4 e^{-7} and 1 e^{-5} m/sec.

The hydraulic conductivity of the shallow aquifer was assessed in a pump test undertaken in 2012 using observations of drawdown and recovery in the pumped well and nearby observation wells. This testing indicated average hydraulic conductivity of approximately 4 m/day, or 4.6 e^{-5} m/sec.

3.3.4 Contaminant Source

The source of the fluoride concentrations in the groundwater is assumed to be the unlined capped waste stockpile**.**

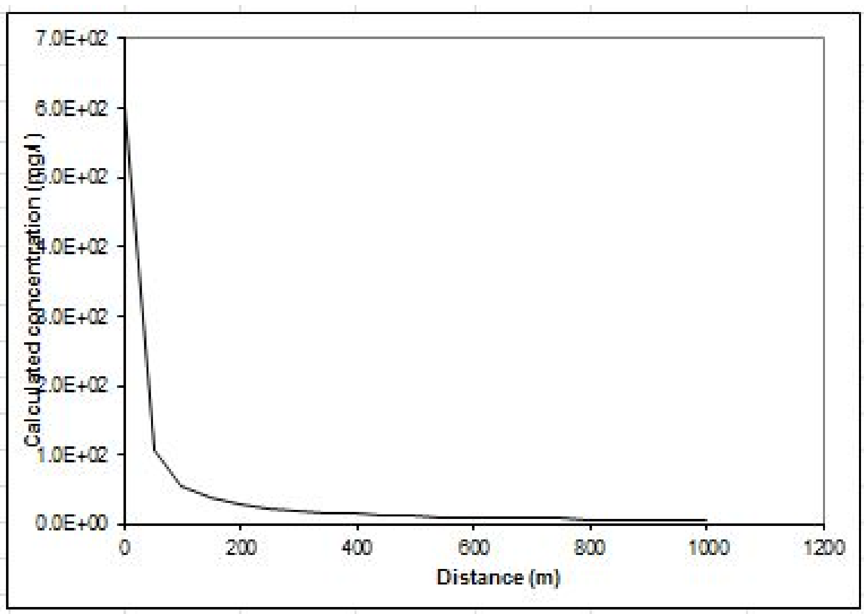
In the model, the initial settings have assumed a constant source concentration. This is considered to be a conservative case given:

- the length of time since cessation of placement of new wastes into the stockpile;
- the partial mitigation of leachate production by the capping works completed in the 1995; and
- the ongoing and planned future works to restrict and, ultimately, remove the source materials, including the operation of the current groundwater interception trench and the longer-term overall site remediation strategy in which leachate contributions from the capped waste stockpile are to be removed.

3.4 Modelling Results

3.4.1 Initial Results

Based on the initial parameters listed in **Table 2,** above, the model projects the following fluoride concentrations for the assumed impact point, as presented in **Figure 1**.



Calculated concentrations for distance-concentration graph

Domenico - Steady state
From calculation sheet

Distance	Concentration
	mg/l
0	6.0E+02
50.0	1.06E+02
100.0	5.66E+01
150.0	3.86E+01
200.0	2.92E+01
250.0	2.35E+01
300.0	1.97E+01
350.0	1.69E+01
400.0	1.49E+01
450.0	1.32E+01
500.0	1.19E+01
550.0	1.09E+01
600.0	9.96E+00
650.0	9.20E+00
700.0	8.55E+00
750.0	7.98E+00
800.0	7.49E+00
850.0	7.05E+00
900.0	6.66E+00
950.0	6.31E+00
1000.0	6.00E+00

Figure 1 Initial Modelling Results

The result indicates a fluoride concentration of **6 mg/L** at the assumed receptor point, at 1000m from the source.

This is a value at assumed steady state, with the conservative assumption of a continuous source.

However, in order to validate the model and modelled concentrations at the adopted boundary/receptor impact distance, calibration of the model is required.

Calibration involves a comparison between the modelled results and observed results (fluoride concentrations in groundwater), from historical and recent/ongoing monitoring.

Figure 2, presents a summary of fluoride concentrations in groundwater on the basis of distance from the source, (assumed as the mid-eastern point of the Capped Waste Stockpile), versus concentration. Only wells from the shallow, leachate-impacted aquifer have been included. Maximum fluoride concentrations were determined for wells in the plume by reviewing all monitored data results, and these maximum values were plotted against distance.

Figure 3, presents the steady state model results against the observed concentration-distance graph. Also included are a time series for the time-variant Domenico solution, for 50 years for the same initial parameters.

It is apparent from **Figure 3** that the model is underestimating the fluoride concentrations as observed, over the first 300m. It also indicates that the steady-state curve is approximately equal to the 50 year time series curve which corresponds to the approximate age of the capped waste storage.

The following section describes the calibration of the model to a best fit to the observed concentration values.

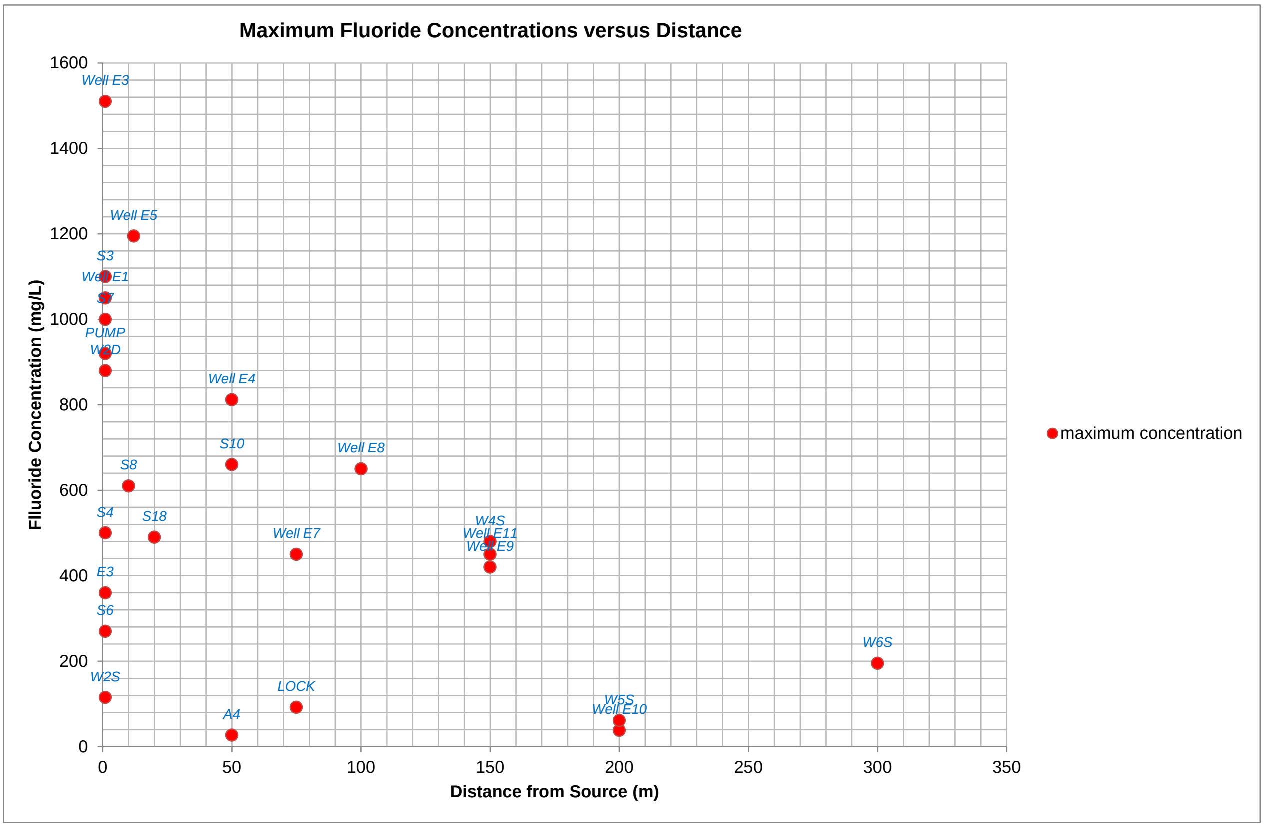


Figure 2 Maximum Observed Fluoride Concentrations Versus Distance from Source

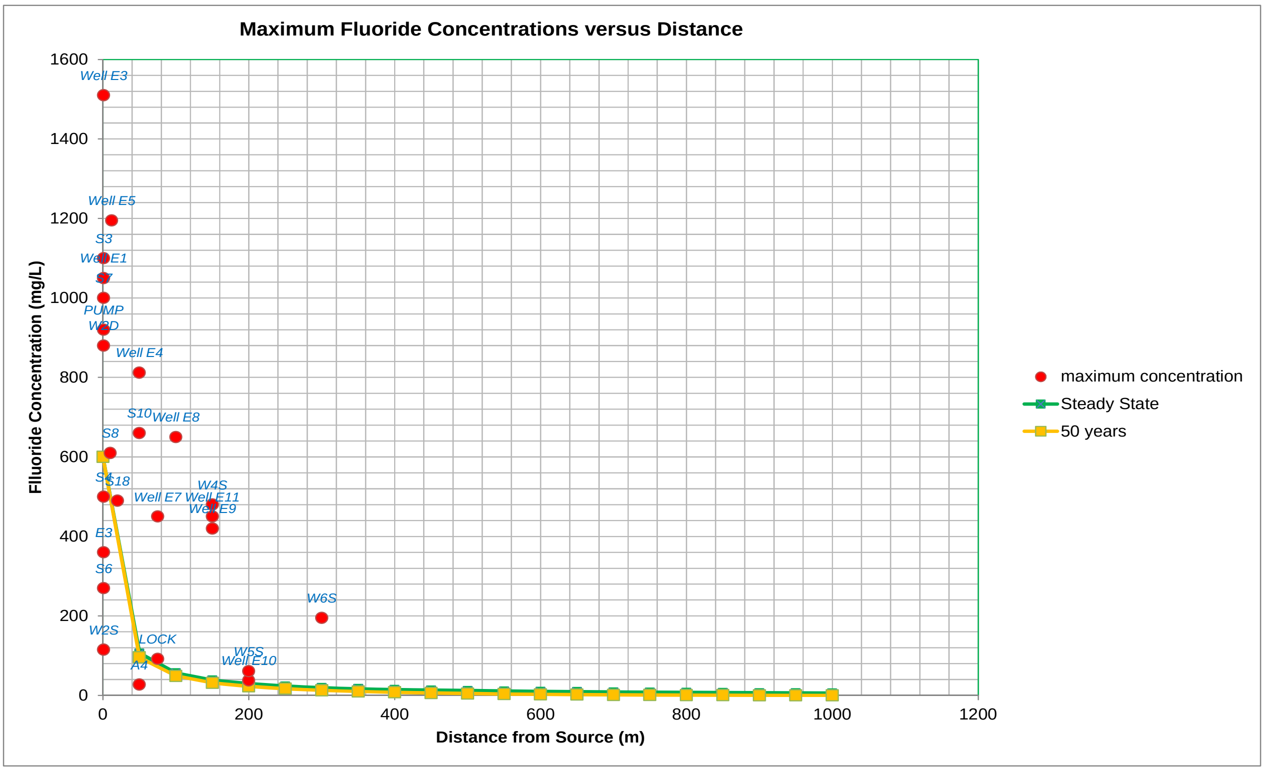


Figure 3 Modelled Steady State and Time Variation Plot for Fluoride Against Observed

3.5 Model Calibration

The objective of model calibration is to adjust model parameters until the model provides a close approximation of the monitored system.

The model was calibrated to the fluoride concentrations measured as part of ongoing monitoring of the site.

The parameters modified to achieve model calibration were hydraulic conductivity and dispersivity (transverse and vertical), initial concentration and partition coefficient.

The model was run in the Domenico time variant solution, set at 50 years, as variations in hydraulic conductivity are not able to be reflected in the steady state model.

Accepted criteria to ensure a representative model calibration were adopted as follows.

- The best fit to the monitored data based on visual curve matching; and
- Test of reasonableness. The final chosen model parameters must be considered reasonable when compared to field and literature data.

Figure 4 presents results from the model where only hydraulic conductivity has been varied from 4 m/day up to 50 m/day, which is considered to be a reasonable upper limit for hydraulic conductivity in sands at the Hydro site. The results indicate that increasing hydraulic conductivity does not significantly change the concentration curve and the curve still underestimates the observed results. A hydraulic conductivity of 12m/day was therefore adopted as a reasonable value for the site.

Calibration was then achieved by varying transverse and vertical dispersivity, initial concentration, and partition coefficient until a fit with observed data was achieved. **Figure 5** presents the results where the best fit options where achieved using for a transverse dispersivity of 1m, (0.1m vertical), with initial concentrations, (C_0), varied of 1000mg/L and partition coefficient, (Kd), of 2. Using these parameters, the fluoride concentration at the adopted target point was **4.3 mg/L.**

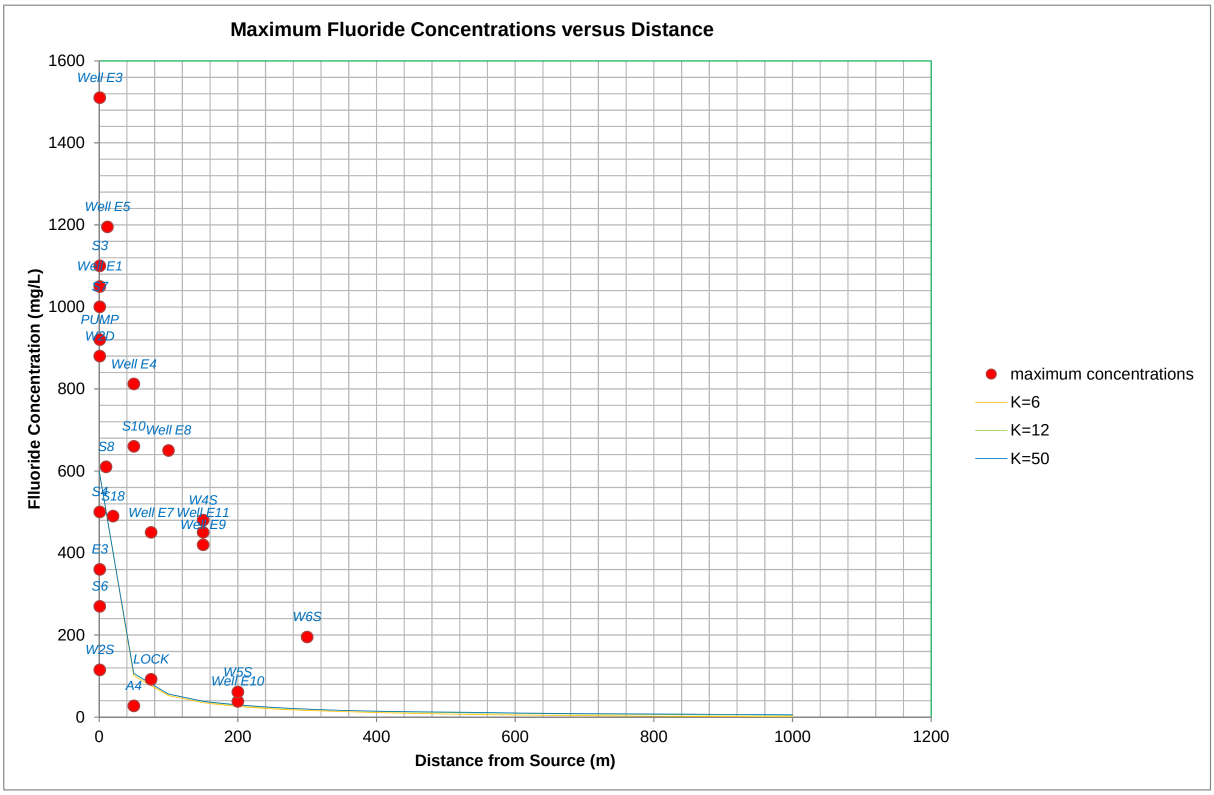


Figure 4 Model Results for Changing Hydraulic Conductivity against Observed

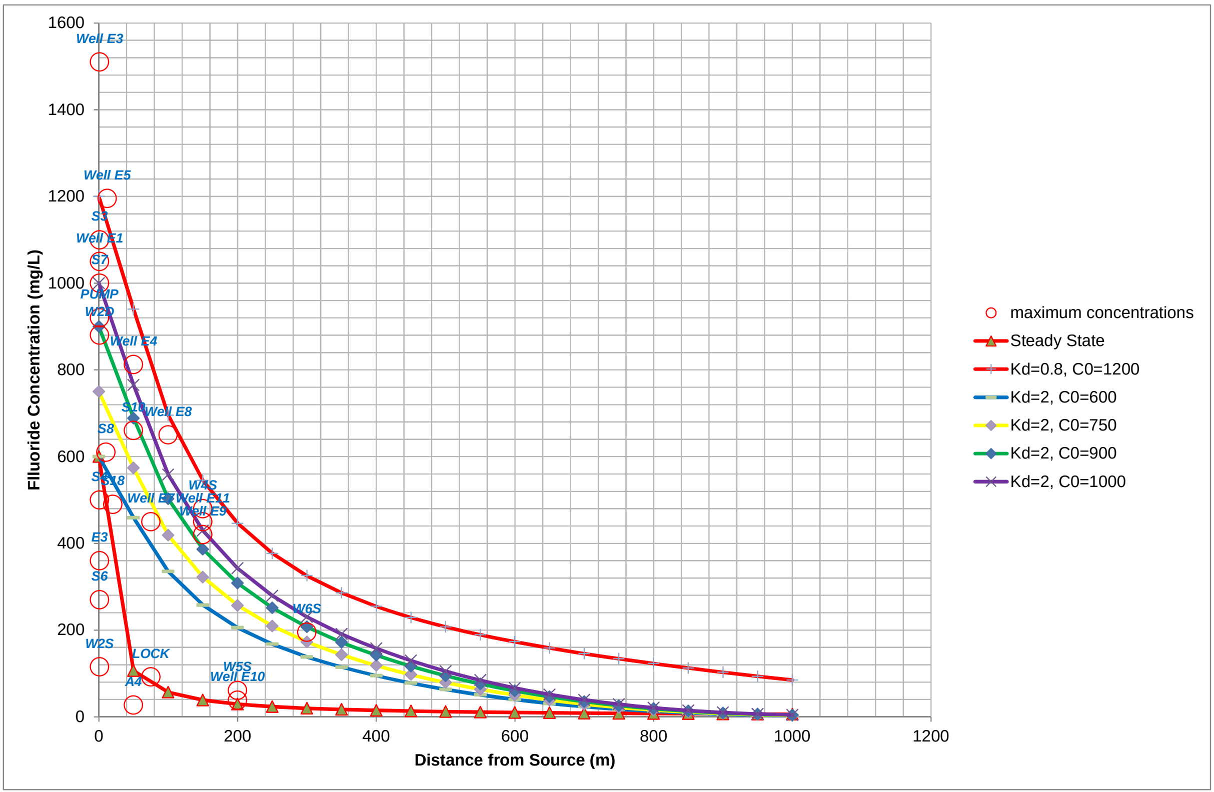


Figure 5 Model Results for Changing Dispersivity, Kd and C_0 against Observed

In summary, the final adopted input parameters, (where different to the initial parameters), were:

Table 3 Model Result Summary	
Model analytical solution	Domenico Time Variant set at 18,250 days (50 years)
Hydraulic conductivity	12 m/day (1.4 e^{-4} m/sec);
Transverse dispersivity	1m
Vertical dispersivity	0.1m
Partition coefficient	2
Initial concentration	1000 mg/L
Fluoride concentration at 1000 m down-gradient	4.3 mg/L (guideline criteria 1.5 mg/L)

This combination of hydraulic conductivity and dispersivity is considered plausible for the project site and surrounds although is not likely to be a unique solution. It is possible that other combinations of are available that can provide a similar approximation.

3.6 Sensitivity Analysis

Additional simulations were undertaken to assess the sensitivity of the model to the principal input parameters.

The following table presents the results of the sensitivity analysis:

Table 4 Model Sensitivity Analysis

Parameter	Value used in Model	Sensitivity Analysis Value	Percentage Change from Original Receptor Concentration	Comment
Initial Concentration	1000	1500	50% increase	1000 mg/L is already considered to be a conservative estimate based on average measured concentrations.
Plume Width	50	100	83% increase	Considered unlikely to be wider due to delineation evaluation completed and confinement with infilled channel.
Plume thickness	4	5	25% increase	Limited by the saturated aquifer thickness – observed as 5m maximum
Aquifer thickness	5	8	No change	
Bulk Density	1.8	2.5	No change	
Porosity	0.3	0.45	No change	
Hydraulic Gradient	0.01	0.05	No change	Increase in gradient resulted in no change however a reduction resulted in 18% reduction
Hydraulic conductivity	12	150	No change	Increase in conductivity resulted in no change however lowering the conductivity resulted in a significant reduction in concentration.
Distance to Receptor	1000	600	Tenfold increase	The distance to the receptor is considered to be conservative
Soil Partition	2	0.5	Tenfold increase	Decrease in partition coefficient resulted in significant increase in

Table 4 Model Sensitivity Analysis

Parameter	Value used in Model	Sensitivity Analysis Value	Percentage Change from Original Receptor Concentration	Comment
Coefficient				concentration,

The evaluation indicates the most sensitive parameters were: partition coefficient, initial concentration (C_0), plume width, distance to receptor, which, when more conservative values were modelled, all showed a significant increase in receptor fluoride concentrations.

- Initial concentration is based on an average fluoride concentration in the leachate in groundwater at the source. Although higher concentrations can be encountered, it is considered unlikely, based on observations from monitoring, that a continuous source at a concentration over the observed average, would be present in the groundwater.
- Plume width is based on the observed occurrence of shallow groundwater (leachate impacted) to the east and north-east of the capped waste storage. An average width of 50m was estimated. The value of 100m width, used in the sensitivity analysis, has not been encountered, and, based on the geological conceptual model, the aquifer, (and hence the plume), width is constrained by the surrounding fine grained, low permeability sediments.
- The distance to the receptor is a conservative estimate, as discussed in **Section 3.2.2**.
- Soil partition coefficient is a sensitive parameter which is site specific and can be calculated from empirical testing using aquifer materials and site groundwater. The value of 2 is considered reasonable given the default value of 0.8, (from the model notes). However if additional site studies are planned, determination for Kd may be considered to further refine the model.

4 Conclusions

ENVIRON has undertaken preliminary groundwater modelling of the shallow groundwater to the north east and east of the existing capped waste storage on the eastern boundary of the Hydro plant site.

An analytical, one-dimensional, groundwater model of the site was constructed, based on a conceptual model of site geology and hydrogeology, derived from previous and ongoing investigations at the site, and an ongoing groundwater monitoring programme. The model was used to evaluate a predicted groundwater concentration of fluoride at a distance from the source where it may impact on the nearest surface water receptor, (Swamp Creek).

The model comprised a spreadsheet solution for contaminant transport flow, inputting parameters estimated for aquifer characteristics, aquifer geometry and contaminant characteristics. All parameters were based, where possible, on field measurements or relevant literature values.

These values were used to derive a preliminary result as a plot of concentration versus distance, extending to the predicted receptor impact distance.

The model was then calibrated against observed fluoride concentrations derived from monitored averages and maximums, and model input properties were then adjusted to give the best fit, whilst still reflecting reasonable and realistic values.

The model was then re-evaluated for fluoride concentrations at the receptor impact distance.

The following conclusions were drawn from the results of the modelling:

- Based on the existing hydrogeological conditions and the presence of an ongoing source from the capped waste stockpile, the model estimated a fluoride concentration of 4.3 mg/L at the receptor distance (1000m), compared to the guideline criteria of 1.5 mg/L;
- This value is considered to be a conservative estimate given the model assumes a continuous source, however, historical, more recent and proposed works are considered to have mitigated the source contribution. Future remedial works are proposed to ultimately remove the source.
- The model demonstrates sensitivity to a number of input parameters including the soil partition coefficient, (Kd). Future studies may include site specific determination of the soil partition coefficient in order to improve model calibration.

5 References

1) UK Environment Agency, “Remedial Targets Worksheet, version 3.2a”,” ref National Groundwater and Contaminated Land Report NC/99/11, 2006.

2) CW Fetter, “Applied Hydrogeology”, Merrell Publishing 1988

3) ENVIRON, Environmental Site Assessment, Alcan Mound, Kurri Kurri Aluminium Smelter, December 2012 (ENVIRON 2012).

6 Limitations

ENVIRON Australia prepared this report in accordance with the scope of work as outlined in our proposal to Hydro Aluminium Kurri Kurri Ltd dated April 2013 and in accordance with our understanding and interpretation of current regulatory standards.

Site conditions may change over time. This report is based on conditions encountered by others at the site at the time of the report and ENVIRON disclaims responsibility for any changes that may have occurred after this time.

The conclusions presented in this report represent ENVIRON's professional judgment based on information made available during the course of this assignment and are true and correct to the best of ENVIRON's knowledge as at the date of the assessment.

ENVIRON did not independently verify all of the written or oral information provided to ENVIRON during the course of this investigation. While ENVIRON has no reason to doubt the accuracy of the information provided to it, the report is complete and accurate only to the extent that the information provided to ENVIRON was itself complete and accurate.

This report does not purport to give legal advice. This advice can only be given by qualified legal advisors.

6.1 User Reliance

This report has been prepared exclusively for Hydro Aluminium Kurri Kurri Ltd and may not be relied upon by any other person or entity without ENVIRON's express written permission.