UraniumSA

Appendix 13

AGT
Groundwater Management Report

Retention Lease Proposal

On

Mineral Claim 4280

for a

Uranium In-situ Recovery Field Trial

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(a wholly owned subsidiary of UraniumSA Limited)

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Groundwater Management for the Mullaquana ISR FT

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Statement of Limitations

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Contents

1 Introduction

1.1 Background

UraniumSA (USA) is working towards development of the Blackbush Deposit using In-Situ Recovery (ISR) methods. USA is currently engaged in the preparation of an application for a Retention Lease to undertake feasibility studies into development of the deposit. The feasibility study entails an ISR Field Trial (ISR-FT).

1.2 Scope

The current document provides a framework for the management of hydrogeological aspects of the proposed ISR-FT. The methodology considers the environmental outcomes that the RLA specifies for management of groundwater at the site during the operation and remediation of the aquifer at trial closure if transition from field trial to mining does not occur.

This document reviews the water balance for the project in order to provide the context for the subsequent sections which discuss all activities expected to impact on groundwater including the wellfield operation, liquid waste disposal operation, and mine closure activities.

The groundwater management plan is designed to be consistent with the Commonwealth Government ISR Uranium Mining Best Practice Guide (Commonwealth Of Australia, 2010) and the conditions specified by the Commonwealth Government in consideration of the USA referral, those being:

The following measures must be taken to avoid significant impacts on the environment (Nuclear actions (sections 21 & 22A)):

- *Disposal of radioactive liquid residues from the project must be in accordance with Australia's In Situ Recovery Uranium Mining Best Practice Guide 2010;*
- *At completion of the project, monitoring must be undertaken to confirm that natural attenuation of residual mining fluid will occur within the boundaries of the Retention Lease; and*
- *If natural attenuation is not occurring at an acceptable rate to achieve the above measure, the affected aquifer will be further remediated as set out in the referral EPBC 2010/5751.*

1.3 Hydrogeological Setting

The hydrogeological setting at the site is described in detail in AGT (2011a). A brief summary is provided here.

1.3.1 Hydrogeological Structure and flow regime

The Mullaquana ISR-FT is located in the Tertiary Pirie Basin. Two primary aquifers have been identified beneath the RL area:

- Quaternary aquifer comprising, thin, marginally permeable fluvial sediments within predominately clayey Quaternary Sediments. This formation is unsaturated to the west where sediments are elevated above the regional water table. To the east sediments are saturated and host saline to hyper saline groundwater. Yields from monitoring wells are consistently below 0.1 L/s indicating that this formation is only marginally permeable at the sites tested.
- Tertiary aquifer comprising the hydraulically connected:
  - Melton Sands 4 to 6 m thick. This aquifer unit contains fine to coarse grained iron rich sands.
  - Kanaka Beds 10 to 40 m thick. This aquifer unit contains medium to coarse grained sands interbedded with clay and lignite.

The Quaternary Sediments are separated from the Tertiary aquifer below by a regionally extensive confining layer of 18 to 22 m thick plastic clays of the Gibbon Beds and, below this, 16 to 20 m of clay and marl of the Melton Limestone stratum.

The Tertiary aquifer system hosts the Mullaquana Orebody and is the target for mining and liquid waste disposal.

The Tertiary aquifer has been characterised as follows:

- The aquifer exhibits a transmissivity of approximately 110 m^2/day and a storage coefficient of 0.0002 at the ISR-FT site.
- The aquifer is laterally continuous to the west, east, north and south for distances exceeding 1 kilometre. I.E the aquifer is not hydraulically bounded in a paleochannel structure.
- The aquifer is vertically confined and capped by the overlying laterally continuous Melton Marl/Gibbon Bed impervious barrier which in aggregate is some 40 m in thickness. Aquifer testing demonstrated that there is no significant hydraulic connection between the Tertiary and Quaternary aquifers at the sites tested.
- Weathered basement rock forms the hydraulic basement at this site. Extended aquifer tests did not induce significant leakage from the underlying rock. Core drilling has intercepted up to 70m thickness of weathered Saprolite beneath the study site.
- There is a low hydraulic gradient west to east, with an indicated very slow movement of groundwater at around 1.5 m per year.
- Recharge to the site is via lateral flow from the west, discharge is via lateral flow to the east.
- Potentiometric pressure (aquifer pressure) at the site is approximately 3 mAHD which equates to a standing water level in wells of approximately 10 to 15m below ground surface.

1.3.2 Water Quality and Beneficial Use

All aquifers within the RL and surrounding area contain high salinity water (50,000 to 80,000 mg/L Total Dissolved Solids (TDS) for the Quaternary aquifer and 33,000 to 51,500 mg/L TDS for the Tertiary aquifer), higher than average seawater salinity (35,000 mg/L TDS). Based on TDS levels the water from these aquifers is suitable only for industrial use i.e. mining. Natural concentrations of radionuclides, also preclude potable, irrigation and stock use.

1.3.3 Third party Users

There are no other users of groundwater within at least 20km of the site due to the high natural salinity of groundwater.

There are no Groundwater Dependent Ecosystems (springs, or groundwater fed wetlands) identified within 20km of the site

The aquifers are not a prescribed resource under the *Natural Resources Management Act, 2004.*

2 Water Balance

2.1 Overview

The ISR-FT will entail the operation of nominally four well patterns each comprising a central extraction well and 6 injection wells positioned at 15m radius from the extraction well. Wells will be screened across a selected mineralised interval.

The operation of each ISR-FT pattern will be undertaken in two stages:

Pore Volume Flush (PVF) –Native groundwater containing a high concentration of calcium is displaced by imported water with a low concentration of calcium (either raw sea water, or recycled effluent). PVF at each pattern is undertaken over a period of some 8 days, displacing an estimated 1700 m^3 of water which will be managed through re-injection to the aquifer.

Leaching –The imported water within the pattern is extracted, treated with reagents, and recirculated through the subsurface. Circulation (with ongoing stripping of uranium and addition of reagents) will continue for nominally 130 days pet pattern. During circulation, a liquid waste stream comprising process wastes and bleed-stream[1].

A total of up to 4 patterns will be trialled sequentially. The nominal schedule of operation is four iterations of:

- 8 days: PVF of 1 Pattern
- 130 days: Leaching of 1 pattern

2.2 Source Water

The source of water to the project is expected to be seawater. Raw seawater may be used as the leaching solution, or alternatively recycled effluent sourced from Whyalla Waste Water Treatment plant. All liquid wastes will be disposed of through injection in to the mineralised aquifer. The estimated water requirement is up to 50 m^3/day for the project duration.

Two water sources are under consideration. Details of each source are presented in Table 1.

[1] Bleed-stream is a small volume of water over-extracted from an ISR pattern (typically 0.5 to 2%), in order to maintain a net movement of water towards the pattern.

Table 1: Water Sources

Scenario	Source Water
1	**Recycled Effluent.** Treated Effluent Sourced from Whyalla WWTP
2	**Seawater**. Operate the leaching trial with seawater.

2.3 Calcium Management

The natural groundwater at the site contains high levels of calcium. In addition the aquifer matrix contains calcareous secondary minerals which are expected to dissolve under acidic leaching conditions. High levels of calcium are expected to result in the precipitation of gypsum when sulphate is added to the lixiviant in the form of sulphuric acid.

Calcium management will be achieved through maintenance of a bleed stream where a volume of leaching solution will be removed from the leaching circulate and replaced by low calcium water. The bleed solution will be disposal of through reinjection at the disposal well.

2.4 Liquid Waste Disposal

Liquid waste will be disposed of through re-injection in to the Tertiary aquifer. This methodology is consistent with the Guidelines for Best Practice and aim to minimise the volume of solid waste produced at surface.

2.4.1 Volume

The rates and total volumes of water produced for disposal are presented in Table 2.

Table 2: Water Balance Disposal Rates and Volumes (Per wellfield Pattern)

Pore volume Flush Stage			Leaching Stage			**Total Volume (m^3)**
Rate (m3/day)	Nominal Duration (days)	Volume (m^3)	Rate (m3/day)	Nominal Duration (days)	Volume (m3)	
216	8	1,728	52.8	130	6,864	8,592

2.4.2 Water Quality

The expected average water quality of liquid waste is presented in the Table below. Estimated salinity ranges between 3 to 10 grams per litre if effluent is used as the source water, or 33 to 40 grams per litre if sea water is used as the source water. Salinity estimates are based on the salinity of the source water plus an allowance for addition of reagents and dissolution of minerals from the aquifer. Estimated pH is approximately 2.

Table 3: Expected liquid waste water quality

Source Water	Liquid Waste Water Quality	
	Salinity (g/L TDS)	pH
Recycled Effluent	3 to 10	2
Sea Water	33 to 40	2

2.4.3 Evaporation Ponds

A surge / evaporation pond is being considered as a means to provide some flexibility in the rates and volume of fluids being disposed of via re-injection into the Tertiary aquifer. The maximum pond dimensions will be 80 x 80 m.

The water balance for the scheme is presented graphically in Figure 1.

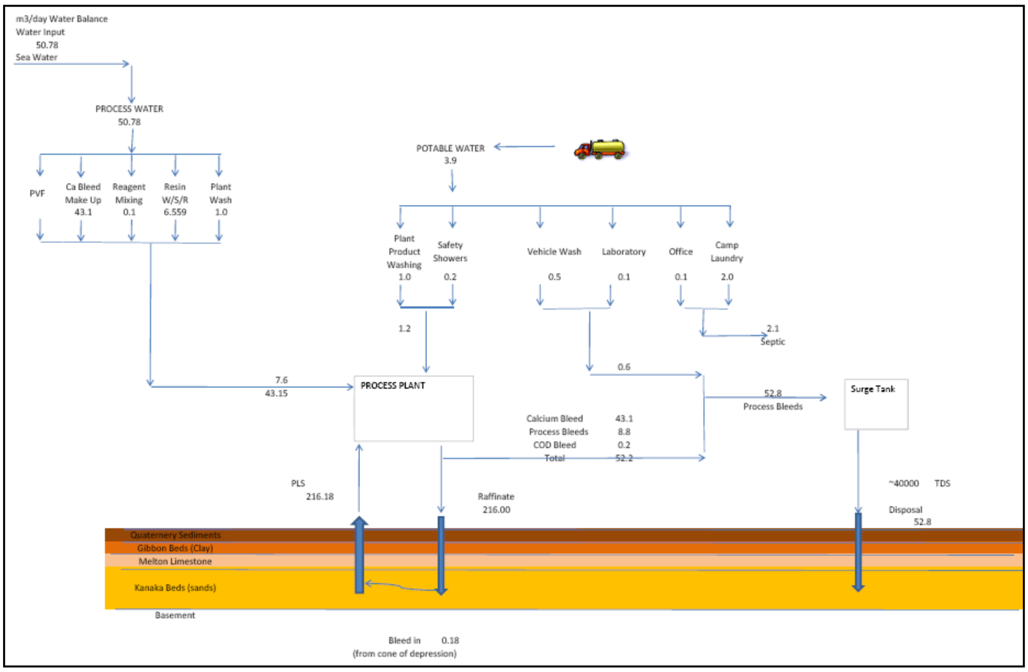

Figure 1: Scenario 1 and 2 Water Balance

3 Wellfield

3.1 Operation

The wellfield will be constructed and operated to ensure that mining solution does not move into non-target aquifers including the overlying Quaternary aquifers and laterally adjacent Tertiary aquifer outside the mining zone during the operation of the wellfield.

3.1.1 Well construction

All injection, extraction and monitoring wells will be grouted and cased with materials that are resistant to the leach solution and will be constructed to be strong enough to withstand any injection pressures. Wells will be integrity tested after construction to ensure that they are structurally sound. Wells that fail integrity test will be cemented and abandoned. Exploration holes will be cement grouted.

3.1.2 Water Balance

A bleed stream will be used to ensure that the volume of solution extracted is maintained at a slightly higher level than the solution injected to ensure a net migration of groundwater towards the ISR-FT target aquifer rather than away.

3.2 Monitoring

A groundwater monitoring program will be implemented to ensure that mining fluid does not move into non-target aquifers undetected.

Further monitoring will be undertaken to assess movement and natural attenuation of mining fluid close to the active wellfield. This is described in Section 5 Mine Closure.

3.2.1 Monitoring Network

The requirements of the monitoring network are to provide data to demonstrate that:

- mining solutions are contained within the mining zone
- mining solutions are contained within the target (Tertiary) aquifer

Two categories of Mining Zone Perimeter monitoring wells will be employed (Figure 2):

- Overlying Monitoring Wells – Wells completed in the overlying Quaternary aquifer (where saturated).
- Lateral Monitoring Wells - Wells laterally adjacent to the mining and disposal zone completed in the Tertiary aquifer at a distance that places them outside the active mining zone.

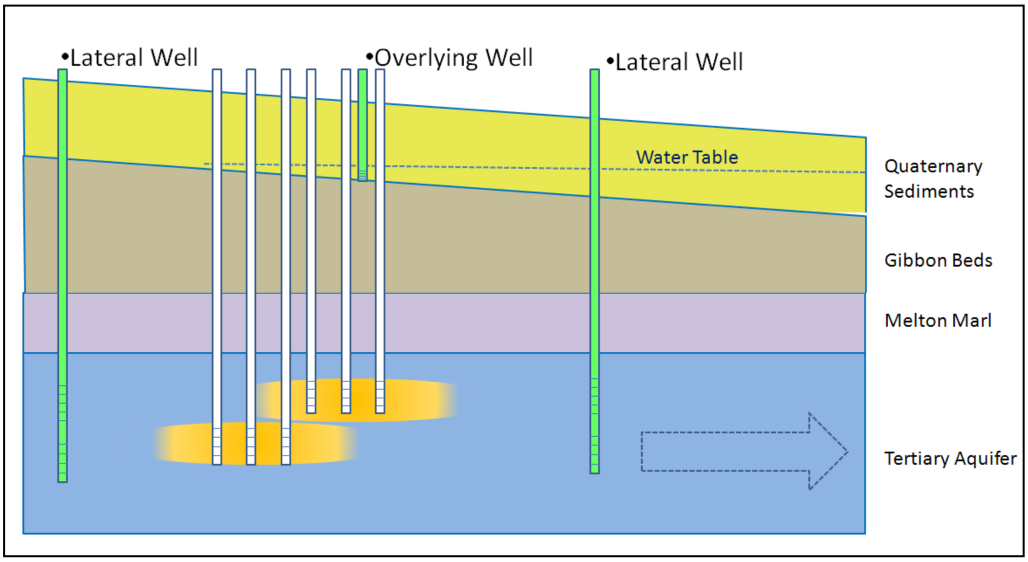

Figure 2: Monitoring Network Conceptual Cross Section

3.2.2 Overlying wells

Overlying wells will be placed to meet the criteria that no production or disposal well be located more than 250m from an overlying monitoring well in area where the overlying Quaternary aquifers are saturated.

Wells will be screened at the base of the Quaternary sediments.

3.2.3 Lateral wells

Wells will be located no more than 150m from the trial wellfield. Monitoring wells spaced 150m from the wellfield allow sufficient area to operate the mining zone whilst providing confidence that unplanned fluid movement will be detected long before it reaches the RLA boundary.

Well spacing will be based on a risk management approach. Where the risk of unplanned fluid movement is greatest, i.e down-gradient. Well spacing will be reduced. Where the risk of unplanned fluid movement is least, i.e up-gradient, well spacing will be increased. Maximum well spacing will be:

- Down gradient : 100m
- Lateral to flow: 200m
- Up gradient : 300m

Wells will be screened across the Tertiary aquifer units laterally adjacent to the mining zone.

3.2.4 Sampling

3.2.4.1 Parameters

Groundwater levels will be measured as depth to standing water level. Groundwater level trends will be assessed to provide a leading indicator of:

- Operational water balance (for lateral monitoring wells).
- Integrity of the hydraulic separation between the mining zone and the Quaternary aquifer (for overlying wells).

Wells will be sampled and analysed for Excursion Control Parameters (ECPs). ECPs are agreed concentrations of selected water quality parameters that are the best indicators of the influence of mining or disposal solution on natural groundwater. ECP limits will be developed in general accordance with NUREG guidelines (NUREG 2003). NUREG states that ideal ECPs are elevated or significantly different in mining and disposal solutions compared with natural groundwater and are easily measured to provide timely feedback. The likely ECPs are:

- pH;
- sulphate; and
- uranium.

The actual ECP limits will be determined following the installation of the monitoring network, and analysis of baseline chemical data collected from monitoring wells. An excursion will be deemed to have occurred if any two excursion indicators in any monitor well exceeded their respective ECP or a single indicator exceeds its ECP by 20% or more.

3.2.4.2 Frequency

Wells will be sampled monthly during ISR-FT operation. Monitoring frequency will be reviewed at the completion of the trial.

3.3 Contingency

In the event that an excursion is detected the following will be undertaken:

- Excursion at an overlying well
    - Stop wellfield operation
    - Resample to confirm results
    - Re-Integrity test all wells
    - Pump contaminated groundwater to surface for treatment and disposal until ECP levels of pumped water return to baseline.
- Excursion at a lateral well
    - Resample to confirm results.
    - Increase sampling frequency to weekly
    - Increase bleed stream to draw water back to the active mining zone until ECP levels at the monitoring well return to baseline.

4 Liquid Waste Disposal

4.1 Operation

Liquid waste will be disposed of through re-injection into the Tertiary aquifer in accordance with the Commonwealth Government ISR Uranium Mining Best Practice Guide (Commonwealth Of Australia, 2010).

The volumes and composition of liquid waste will vary depending on the operation of the wellfield and the stage of Field Trial operation. Relatively small volumes will be generated during active leach whilst proportionally larger volumes will be generated during pore volume flushing.

Liquid waste will comprise the following components:

- Plant Process wastes
- Wellfield Bleed stream.

A description of the water balance and water quality is provided in Section 2.2.

The location of liquid waste disposal is not yet identified. The site will be selected with the intention that wastes will not be injected where they may impact on the economic ore zone.

4.1.1 Disposal Rates and Injection volumes

The maximum (assuming no evaporation) rate of disposal injection during the trial is shown in Table 4.

Table 4: Disposal Injection Rates (m^3/day)

Pore volume Flush Stage			Leaching Stage			Total Volume Per Pattern (m^3)	Total Volume Four Patterns (m^3)
Rate (m3/day)	Nominal Duration (days)	Volume (m^3)	Rate (m3/day)	Nominal Duration (days)	Volume (m3)		
216	8	1,728	52.8	130	6,864	8,592	34,368

4.2 Aquifer Assessment

4.2.1 Pressure increase

The hydraulic capacity of the aquifer to accept the planned fluid injection has been assessed. Pressure impacts were assessed using the Theis equation (Theis, 1935). Aquifer properties determined through aquifer testing (AGT 2010) were employed in this assessment:

- Transmissivity = 110 m2/day
- Storativity = 0.0002

Maximum pressure increase at the wells screen is approximately 3.5 m head.

The fracture pressure[2] of this aquifer is approximately 44m head measured at the ground surface. The standing water level is approximately 15m below ground level. A pressure increase of 59 m would be required to risk fracturing of this aquifer.

The predicted maximum pressure increase of 3.5 m resulting from injection of liquid waste is within the fracture pressure limit for this aquifer.

4.2.2 Plume Extent

The extent of the plume of liquid waste can be calculated geometrically since, in this hydrogeological setting where natural groundwater movement is very slow, movement of the liquid waste plume will be approximately radial and primarily driven by injection of the fluid. For a plume thickness of 6m and a rock porosity of 0.3, a radial extent of 80m is predicted. The predicted extent of the liquid waste plume for a nominal re-injection location is presented in Figure 3.

This prediction is the position of a “sharp front” of liquid waste. In practice, dilution at the margin of the plume is expected through dispersion. This will result in a dilute halo which extends some distance beyond the predicted 80 m extent. Further the shape of the plume may be influenced by spatial variations in hydraulic conductivity of the aquifer sediments.

4.3 Monitoring

A groundwater monitoring program will be implemented to ensure that disposal fluid does not move into the non-target (overlying) aquifer undetected.

Further monitoring will be undertaken to assess movement and natural attenuation of disposal fluid. This is described further in Section 5: Mine Closure.

4.3.1 Monitoring Network

An overlying monitoring well will be installed into the Quaternary sediments immediately adjacent to the disposal well.

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[2] Fracture pressure is the aquifer pressure required to cause buoyancy and failure of the overlying confining layers. This estimate assumes a bulk density of overlying sediments of 1.8 and is conservative in that it does not consider the structural strength of the overlying sediments, only the mass.

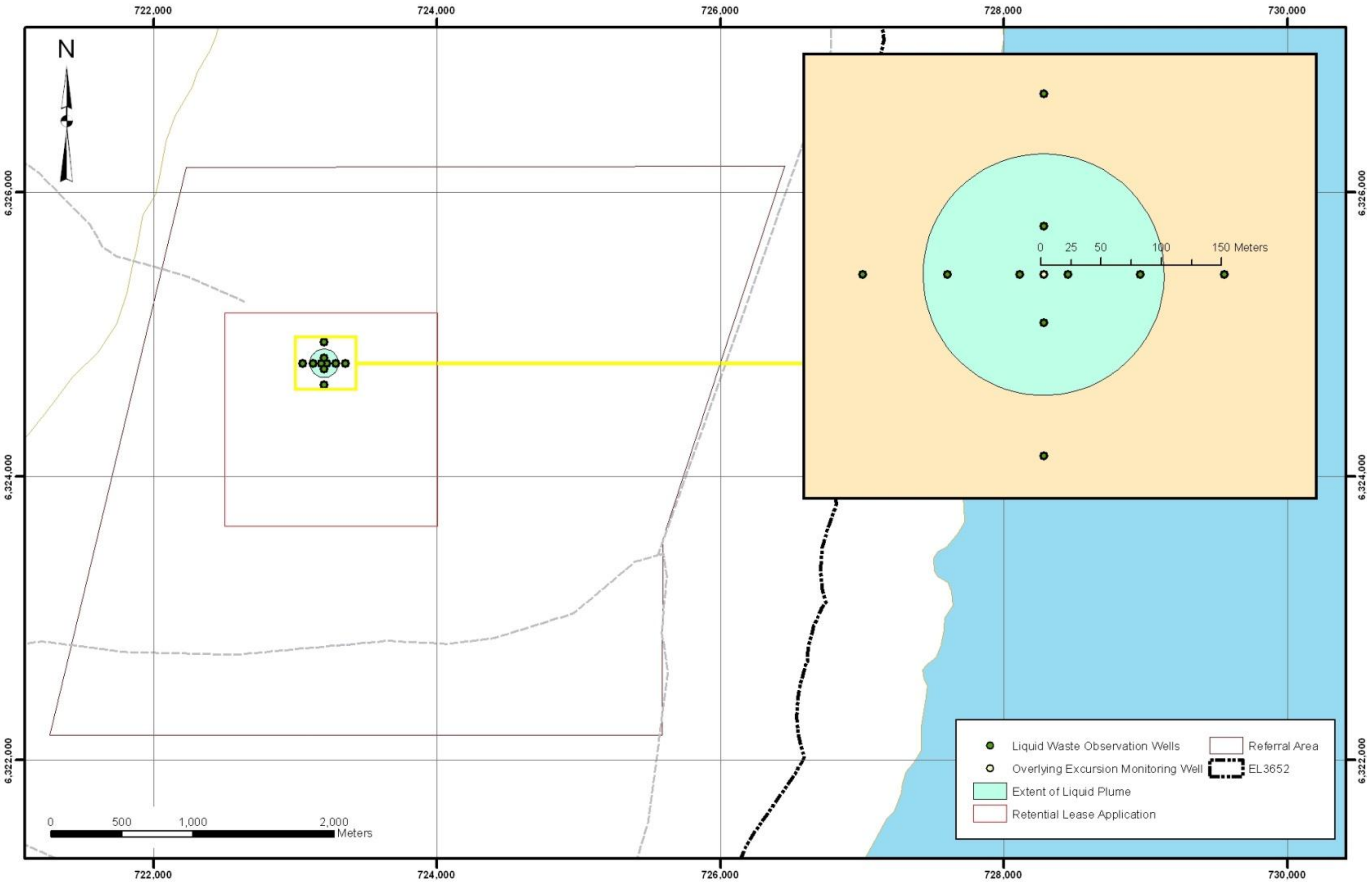

Figure 3: Extent of liquid waste plume (Assuming sharp front, and nominal re-injection location).

4.3.2 Sampling

The well will be sampled monthly for ECP parameters pH, SO4, U.

5 ISR-FT Closure

5.1 Context

In the event that the ISR-FT does not progress to a mining operation, rehabilitation of the trial will be undertaken.

Aquifer rehabilitation must be considered in the context of the project Mine Closure Outcomes i.e.

- No compromise to the existing use category of the Target (Tertiary) aquifer outside the RLA in accordance with the Commonwealth Government ISR Uranium Mining Best Practice Guide (Commonwealth Of Australia, 2010) and the conditions specified by the Commonwealth Government in consideration of the USA referral

The use category of the Tertiary aquifer within and down gradient of the RLA is industrial due to elevated natural salinity and natural radioactivity. Operation of the ISR FT will not change this use category.

The Commonwealth Government ISR Uranium Mining Best Practice Guide (Commonwealth Of Australia, 2010) state that:

> Where the natural groundwater throughout the mineralised aquifer are established to be of poor quality such that they have no pre-mining or potential use other than industrial, liquid residues should not require treatment, provided it can be demonstrated that the affected aquifer waters are confined and will stabilise, such that the site will be fit for agreed future land use.

In this context no further remediation of liquid residues should be required once injected into the Tertiary aquifer.

UraniumSA will implement an aquifer remediation strategy which uses the lowest possible impact methodology to ensure that liquid residues remaining in the aquifer are stabilised.

5.2 Methodology

UraniumSA will employ Monitored Natural Attenuation (MNA) in the first instance to achieve aquifer remediation. This method minimizes energy and resource use and does not produce solid wastes at the surface.

In the event that MNA will not achieve the required outcome, higher impact contingency methods will be used.

5.3 Natural Attenuation

The process where groundwater, which has been altered through the addition of leach solution, reverts through reaction to its surrounding aquifer matrix and pre-existing groundwater over a period of time to or towards its pre-contaminated state, without additional attenuating treatment is termed natural attenuation (CSIRO,2004).

The Tertiary aquifer at the Mullaquana Project exhibits a very slow migration of groundwater towards the east at around 1.5 m/year. At the completion of the ISR-FT, residual mining fluid left in the pore spaces of the rock can be expected to move with the natural groundwater migration.

Along this flow-path, natural attenuation of mining fluid is expected to occur as the mining fluid contacts and reacts with ‘fresh” un-altered aquifer material. Attenuation occurs through two mechanisms:

- chemical processes including reaction with pore fluids, reaction with rock minerals, and sorption to clay minerals, and
- physical dilution of water along a flow path through dispersion.

5.3.1 Chemical Attenuation

The distance that mining and disposal solution will move before complete natural attenuation of acidic mining fluids is achieved has been estimated from acid consumption data measured through laboratory testing of aquifer material. Detail is provided in AGT (2011).

5.3.1.1 Wellfield

The data indicate that the Kanaka beds have the chemical capacity to attenuate residual acid in a ISR-FT well pattern within approximately 7 m of natural groundwater flow, based on measured acid consumption of 23kg acid per m^3 of aquifer matrix, and a residual acid concentration of approximately 1.5 kg/m^3 at each wellfield pattern.

The acid consumption is expected to be acceptable for mining, where acid is continually added to the mining solution and circulated through the orebody. However, once mining ceases and no more acid is added to the system, the residual acid will be consumed within a very short distance as it moves laterally and contacts fresh unaltered rock.

At the cessation of mining it will take approximately 38 years for all residual mining fluids to move from the wellfield pattern down gradient and pass through the attenuation zone to encounter fresh rock (Figure 4). These calculations assume a homogeneous flow rate of 1.5m per year, a sharp front of fluid movement, and complete reaction with available minerals. In reality fluid movement will be dispersed resulting in dilution down-gradient and complete reaction with all available minerals may not occur. Field data regarding the efficiency of natural attenuation will be obtained immediately upon cessation of mining by positioning monitoring wells in close proximity to the mining zone at 10m and 20m distance. Natural Attenuation Monitoring is discussed in detail below.

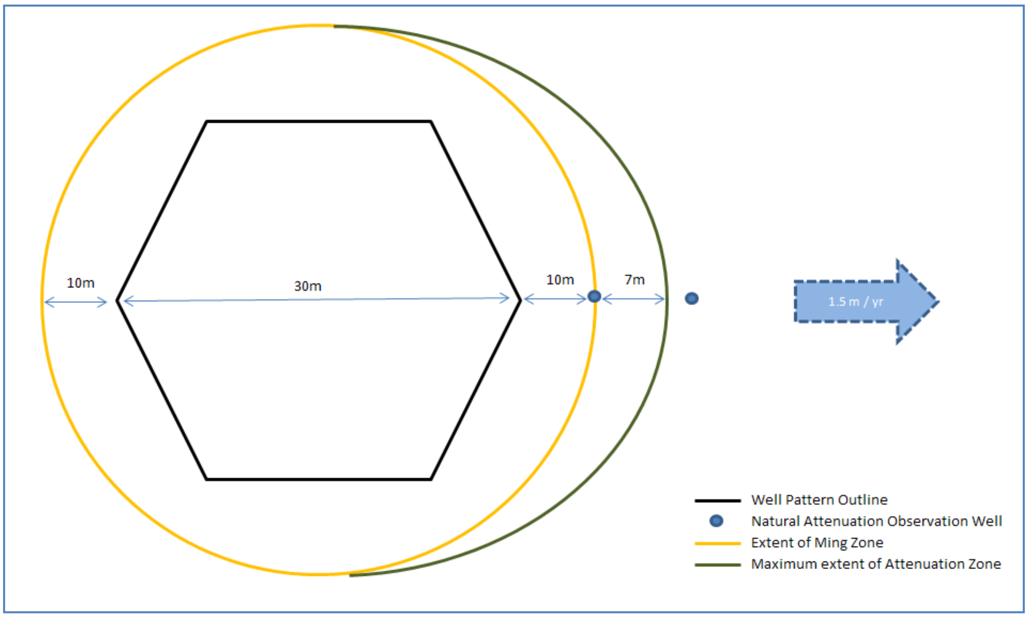

Figure 4: Extent of Estimated attenuation zone for wellfield patterns

The very high acid consumption of the overlying Melton Sand and Melton Limestone provides a chemical "cap" or seal to the ISR-FT zone.

5.3.1.2 Liquid Waste

Residual acid contained in liquid wastes will not exceed 1.5kg/m^3 (for a solution with pH 1.7). For a porosity of 0.3, this equates to 0.45 kg residual acid per m^3 of aquifer.

The aquifer has an acid buffering potential of 23 kg acid per cubic metre of aquifer. This means that the aquifer matrix can buffer 51 times the volume of acid contained in the pore space if all pores are filled with liquid waste.

The high acid consumption of the aquifer matrix means that all acid contained in liquid waste is expected to be consumed within the extent of the injection plume during injection and any residual fluids are expected to be completely neutralised before any natural down-gradient movement occurs.

5.4 Natural Attenuation Monitoring

The Monitored Natural Attenuation methodology proposed for aquifer remediation requires a monitoring program which is designed to provide timely data to determine the progress and efficacy of Natural Attenuation.

Monitoring will continue for the following timeframes:

- Three consecutive years (minimum) of post-closure water quality from overlying aquifer (if present)
- Target Aquifer: Five consecutive years (minimum) of post-closure groundwater quality monitoring

5.4.1 Analytical suite

Wells will be sampled and analysed monthly for a full suite of chemical parameters detailed in Table 5.

Table 5: Natural Attenuation Observation Analytical Suite.

Physico-chemical parameters	Major and minor anions
pH Value	Hydroxide Alkalinity as CaCO3
Total Dissolved Solids @180°C	Carbonate Alkalinity as CaCO3
Suspended Solids (SS)	Bicarbonate Alkalinity as CaCO3
Chemical Oxygen Demand	Total Alkalinity as CaCO3
Redox Potnetial	
Dissolved Metals	Sulfate as SO4 2-
Arsenic	Sulfide as S2-
Barium	Chloride
Beryllium	Fluoride
Boron	
Cadmium	**Major and minor cations**
Cobalt	Calcium
Chromium	Magnesium
Copper	Sodium
Iron (ferrous)	Potassium
Manganese	Strontium
Mercury	
Nickel	
Lead	
Vanadium	
Zinc	
Aluminium	
Bismuth	
Lithium	
Silver	
Thorium	
Tin	
Uranium	
Radium -226	

The data obtained from NAOW will be used to assess the rate and efficacy of MNA as fluids flow through the aquifer. In the event that MNA is not considered likely to achieve the outcomes for closure then contingency aquifer remediation methods may be employed.

5.4.2 Wellfield

A wellfield monitoring network comprising Natural Attenuation Observation Wells (NAOW) will be established. A well will be located 10, 20, 40, 80 and 150m down gradient of the wellfield. Wells will be screened in the Tertiary aquifer. Screened intervals will be consistent with the mining zone.

This well spacing is designed such that residual fluids will be observed in the first year of operation at the 10 and 20m distant wells and subsequently at more distant wells.

A conceptual cross section for wellfield NAOW is shown in Figure 5.

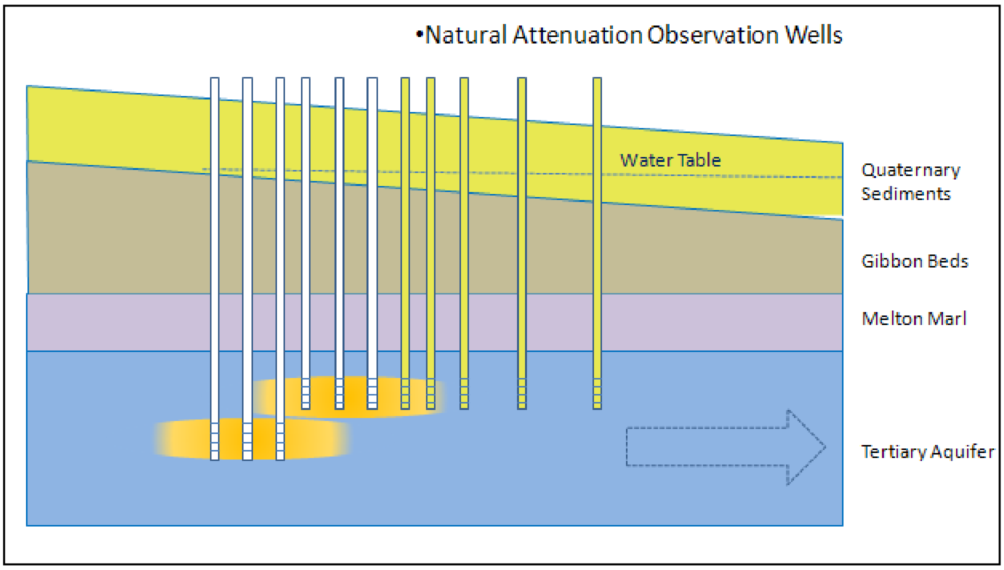

Figure 5: Wellfield natural attenuation monitoring wells conceptual section.

5.4.3 Liquid Waste

A monitoring network will be established with the aim of measuring the movement and attenuation of disposal fluids injected into the aquifer. Wells will be installed at 20, 40, 80 m and possibly 150 m from the disposal well. At a radial distance of 20, 40 and 80 m, 2 wells will be installed at 90 degree offsets at each distance. At 150m 4 wells will be installed. This layout is presented conceptually in Figure 7.

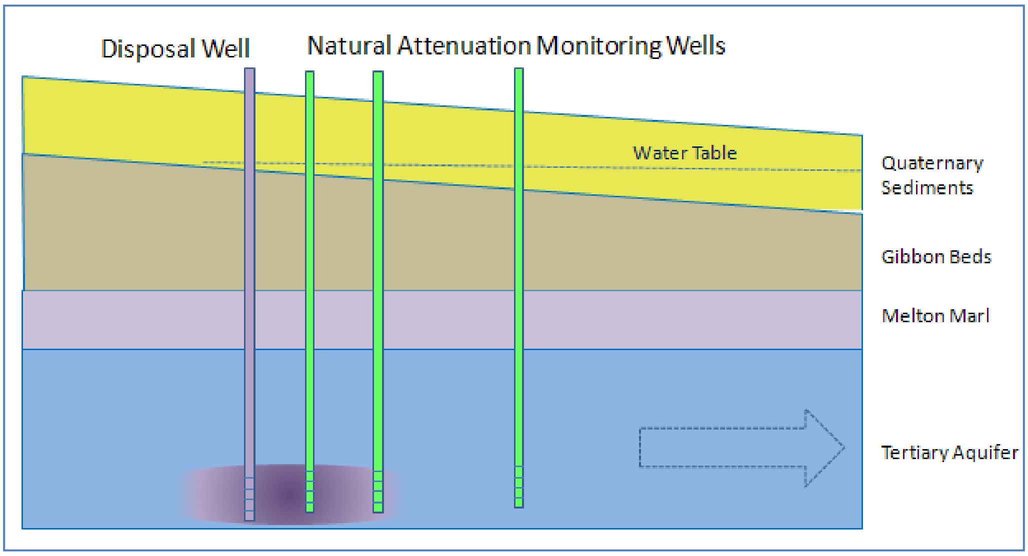

Figure 6: Disposal natural attenuation monitoring wells conceptual section.

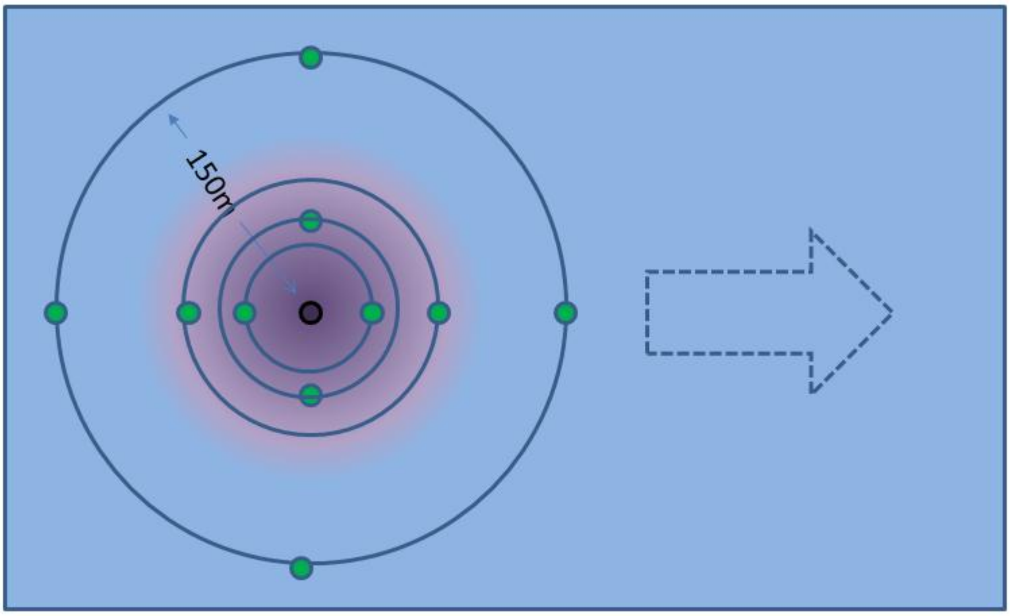

Figure 7: Disposal natural attenuation monitoring wells conceptual plan view.

5.5 Contingency Remediation

A number of methods of aquifer remediation are available as a contingency to MNA. These may be employed if MNA is found to be inadequate to address closure requirements. Further UraniumSA may choose to implement active remediation methods in order to speed lease relinquishment.

Methods of aquifer remediation include:

- Active Natural Attenuation – Entails inducing flow of mining fluid through barren rock near the mining zone by pumping in order to consume reagents and dilute the mining fluid.
- Groundwater sweep - Mining fluid is pumped from the ore zone to be replaced by inflowing natural groundwater. The extracted mining solution must then be reused elsewhere or disposed of.
- Pump, treat and re-injection - Mining fluid is pumped to the surface, treated through neutralization, reverse osmosis or electrodialysis and then re-injected into the aquifer. The treatment process produces a waste stream which must be disposed of.
- Mixing - Entails pumping and reinjection of mining fluid to mix or homogenized the mining fluid and reduced concentration hotspots.
- Addition of remediation agents – Remediation agents may be injected into the aquifer to re-establish reducing conditions and to neutralize mining fluids.

6 Summary of Groundwater Monitoring Plan

A summary of the groundwater monitoring plan proposed for the Mullaquana ISR FT is presented in the Table 6 below.

The groundwater monitoring comprises two separate monitoring activities with deferent aims:

1 -Detection of excursions – The aim of this monitoring program is to ensure that mining fluid and liquid waste does not move outside the target aquifers during the trial. In a successful trial mining fluid will not be observed at these wells. Detection of fluids will serve as a trigger for remedial action.

2- Observation of Natural Attenuation – The aim of this monitoring is to provide data to assess the rate of natural attenuation of mining fluids and liquid waste within the aquifer. Monitoring wells are placed in close proximity to wellfields and disposal wells, and mining fluid will be detected at these wells within the duration of the trial.

6.1 Excursion Monitoring

Two wells will be installed into the Quaternary aquifer, one at the wellfield and one at the disposal site. These will be sampled monthly for Excursion Control Parameters (ECPs) to ensure that mining solution does not move into this non-target aquifer.

Nominally 6 wells will be installed into the Tertiary aquifer at the perimeter of the mining zone approximately 150m from the wellfield. These will be sampled monthly for ECPs to ensure that mining solution does not move beyond the mining zone during operation.

ECPs will be determined following baseline monitoring at monitoring wells. ECPs are likely to be SO4, pH and U concentrations.

6.2 Natural Attenuation Observation Monitoring

Five Wellfield Natural Attenuation Observation Wells will be installed down gradient from the wellfield at distances of 10, 20, 40, 80 and 150m. These will be sampled for a full analytical suite to provide data to assess natural attenuation of mining fluid.

Up to ten Liquid Waste Natural Attenuation Observation Wells will be installed in an array surrounding the Liquid Waste injection well. Wells will be positioned 20, 40, 80 and 150m from the injection well. These will be sampled for a full analytical suite to provide data to assess natural attenuation of liquid waste.

The analytical suite is presented in Table 7.

Table 6: Monitoring Summary

	Wellfield				Liquid Waste			
	Purpose	**number of wells**	**Analytical suite**	**frequency**	**Purpose**	**number of wells**	**Analytical suite**	**frequency**
Quaternary Aquifer	Detection of mining fluid excursion	1	ECPs	monthly	Detection of liquid waste excursion	1	ECPs	monthly
Tertiary Aquifer	Detection of mining fluid excursion	6 (Approx)	ECPs	monthly				
	Natural Attenuation Observation	5	Full Suite	monthly	Natural Attenuation Observation	8	Full Suite	monthly

Table 7: Natural Attenuation Observation Analytical Suite.

Physico-chemical parameters	**Dissolved Metals**
pH Value	Arsenic
Total Dissolved Solids @180°C	Barium
Suspended Solids (SS)	Beryllium
Chemical Oxygen Demand	Boron
Major and minor anions	Cadmium
Hydroxide Alkalinity as $CaCO_3$	Cobalt
Carbonate Alkalinity as $CaCO_3$	Chromium
Bicarbonate Alkalinity as $CaCO_3$	Copper
Total Alkalinity as $CaCO_3$	Iron (ferrous)
Sulfate as SO_4^{2-}	Manganese
Sulfide as S^{2-}	Mercury
Chloride	Nickel
Fluoride	Lead
Major and minor cations	Vanadium
Calcium	Zinc
Magnesium	Aluminium
Sodium	Bismuth
Potassium	Lithium
Strontium	Silver
	Thorium
	Tin
	Uranium
	Radium -226

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