6 LAND CONTAMINATION

6.1 INTRODUCTION

This chapter provides responses to submissions received on the Queensland Curtis LNG (QCLNG) Project's draft environmental impact statement (EIS) related to land contamination of the Gas Field Component.

Where changes to the Project description, as detailed in *Volume 2, Chapters 7* and *11*, have impacted land contamination, or where additional information is available on impacts, these and subsequent mitigation measures are described.

6.2 RESPONSES TO SUBMISSIONS

Table 3.6.1 provides a summary of the submissions received on land contamination of the Gas Field, and a response to those submissions.

Table 3.6.1 Responses to Submissions on the Draft EIS

Issue Raised	QCLNG Response	Relevant Submissions(s)
Detail the method for treatment or disposal of salt contaminated geosynthetic liners in ponds.	Refer to *Sections 6.4.5 and 6.4.6*	32
Identify the entity responsible for long-term management of any landfill	Refer to *Section 6.4.9*	32
Describe the purpose and composition of drilling muds, potential impacts, management and disposal.	Refer to *Section 6.5*	32, 19
Describe the hydraulic fracturing process, including chemicals used, management of Associated Water, potential impacts and mitigation measures.	Refer to *Section 6.6*	12, 32, 19
Describe pond decommissioning, including a groundwater monitoring program around ponds	Refer to *Section 6.4.6*	32
Discuss the potential for long-term contamination of land from pond decommissioning, including potential area of contamination	Refer to *Sections 6.4.5, 6.4.6 and 6.4.7*	32
Describe the design, construction, operation and management of a salt landfill. Landfill is not supported	Refer to *Section 6.4.9*	32, 34, 36

6.3 ADDITIONAL ASSESSMENTS OF LAND CONTAMINATION

The draft EIS described the potential for land contamination from various sources. Further detail is provided in the supplementary environmental impact statement (sEIS) on the potential for land contamination from the following sources, as described in the draft EIS.

- Associated Water management
- saline brine processing, storage and transport
- drilling of wells (e.g. mud management)

The sEIS also considers the following sources of potential land contamination, which are not described in the draft EIS:

- hydraulic fracturing
- chemicals used in weed management, cleaning and for corrosion retardation
- sewage management
- borrow pits
- secondary salinity.

This chapter describes the mechanisms of potential release, and impacts from, each of the above sources of contamination, and the mitigation measures required.

6.4 ASSOCIATED WATER MANAGEMENT

The facilities required for the management of Associated Water are described in *Volume 2, Chapter 7* of the sEIS. Management of Associated Water has the potential to cause an increase in salinity on the land through:

- unplanned release of untreated water from transfer, storage and treatment infrastructure
- seepage from storage of untreated water and brine
- seepage during storage and handling of crystalline salt

6.4.1 Water Treatment Plants

Potential salinity impacts from the water treatment plants WTPs include:

- direct seepage of saline water from the desalination plant as a result of the activities conducted at the plant
- localised flooding of the plant resulting in release of saline solution (although diluted)
- unplanned spills of saline water from the plant.

A Hazard and Operability (HAZOP) study and detailed risk analysis of WTPs will be conducted to identify potential causes of unplanned releases of untreated and treated Associated Water. From this analysis, methods will be developed to reduce to as low as is reasonably practicable the likelihood and impact of all unplanned releases.

WTPs will not be constructed within the 1:100 year floodplain unless bunded to the appropriate level. Each WTP is likely to be composed of multiple modular water treatment units customised for variable water quality and quantity. Concrete slabs will be raised from the ground and bunded to protect them from flooding.

Storage and handling of water treatment chemicals is described in *Volume 3, Chapter 17* of the draft EIS.

6.4.2 Water Pipelines

Any failure of a water gathering line, trunkline or collection header has the potential to release Associated Water. Detailed design of water pipelines has not been completed, but it is envisaged that sections of water pipelines will be controlled by isolation valves. The potential volume of water released due to pipe failure will relate to:

- the pipe diameter
- volume of water contained in the pipe
- distance of this particular piece of pipe to isolation valves
- height of the failure point relative to the rest of the pipeline
- flow rates
- the time it takes to isolate the line.

Based on the above variables, with a distance of 30 km between isolation valves, the estimated volume of water that may be released is between 40 kL and 10,000 kL.

A detailed hazard identification and risk assessment will be conducted to determine the probability and modes of water pipeline failure and identify methods to mitigate impacts. In areas of high risk, such as watercourse crossings, additional mitigation measures will be considered, such as crossing methods, pipeline durability and isolation valves near crossing points. QGC will investigate the feasibility of horizontal direction drilling, where required, at watercourse crossings. These measures will seek to reduce the risk of a direct release of Associated Water from a water pipeline in the vicinity of a watercourse.

6.4.3 Residual Water in Gas Pipelines

Low-point drain sumps (LPDS) will be sited along the gathering lines with the specific aim of removing water. There is likely to be a significant number of LPDS throughout the Project area. Without appropriate management, potential for salinity impacts from LPDS include seepage of saline water directly into soils or surface waters. All water manually drained from LPDS (approximately 100 litres per week per LPDS) will be tested for salinity by means of an electrical conductivity (EC) meter prior to being drained. Water with total dissolved solids (TDS) less than 500mg/L will be released to land. Water with

TDS between 500 to 2000 mg/L will be captured for use in dust suppression or removal to untreated water storage ponds. Water with TDS above 2000 mg/L will be removed to untreated water storage ponds. All fines will be captured and placed in a sump, which will be allowed to dry out before refilling.

6.4.4 Water at Wells

An estimated 6,000 wells will be drilled over the life of the Project. At each well head, a wellhead separator will be installed. Potential salinity impacts at the wellhead include:

- Associated Water may leak directly from the well head as a consequence of poor maintenance practice.
- Excess water and any fine material that has settled in the drill pit may be irrigated onto nearby land. The excess water and fine material may have elevated salinity. There will be approximately 950 kL per well over the life of the well.
- Associated Water may infiltrate soils during the work-over well flush process to reinstate production. The operation takes approximately three days and may be required every two years.

Wells will be monitored to detect leaks by appropriate instrumentation at the wellhead, in pipelines and at the receiving pumping stations. Where failures result in sudden pressure drops, emergency measures can be initiated to minimise losses by shutting-off wellheads, pipelines and or pumps.

6.4.5 Untreated Water Storage Ponds

Untreated water storage comprises infield buffer storages, regional storage ponds, collection header ponds and raw water ponds. The total area of new, untreated water storages proposed for the QCLNG Project is approximately 180 ha. This is described in detail in *Volume 2, Chapter 7*. Pond design principles and construction methodology are described in *Volume 2, Chapter 11*.

Contamination may occur through the seepage of saline water to soils, surface waters or groundwater. The following mitigation measures will minimise the potential for contamination from untreated water storage ponds:

- lining of all ponds with a geosynthetic or clay liner
- using ponds to balance water flows and not for evaporation, thus decreasing the total volume and pressure head on the lining
- minimising the number and footprint of ponds
- appropriate siting of ponds in low-risk environments where possible
- monitoring ponds to detect any saline water migration and development of measures to be initiated should salt migration above prescribed levels be detected
- a detailed decommissioning plan.

6.4.5.1 *Lining of Ponds*

As described in *Volume 2, Chapter 11*, all ponds will be lined with either geosynthetic materials or clay. Liners are used to reduce seepage losses from Associated Water storage facilities. Appropriate monitoring and leak detection measures will be installed where required. Clay-lined ponds will be constructed with a clay embankment with a low-permeability clay core. The inner slopes of the clay-lined pond embankments may be protected from wave erosion by installing a compacted gravel pavement over a geotextile membrane. Depending on the soil properties, a well-constructed, engineered clay liner would be sufficient to reduce infiltration of Associated Water into the subsurface over the active life of the pond.

QGC will conduct geotechnical and hydrogeological research (to the degree considered necessary) of all proposed pond sites to determine the appropriate liner required. Where geotechnical investigations demonstrate that a clay liner will limit seepage losses to an acceptable level, this will be preferred over geosynthetic liner. QGC proposes to use geosynthetic materials (e.g. HDPE) to line all infield buffer storages (where these are ponds) and regional storage ponds. These are small ponds, ranging from 0.2 ha to 1 ha, with a capacity of between 10 ML and 60 ML. QGC will consider the use of tanks as infield buffer storages.

Material for ponds constructed from clay would normally be sourced from an internal borrow pit within the pond footprint. Where geosynthetic liner is required, the pond floor would be lined by welding together geosynthetic sheets using fusion and extrusion welding methods and anchoring them at the crest of the embankments. Quality-assurance testing will be conducted on welds and intermitted liner surfaces to reduce the leak potential. Generally, geosynthetic liners are up to three orders of magnitude less permeable than a well constructed clay liner, and thus provide a better containment barrier for Associated Water with high concentrations of solute contaminates. Geosynthetic liners have a predictable level of permeability performance. The geosynthetic liner will be applied where initial investigation of pond siting indicates insufficient suitable low-permeability clays for containment of Associated Water.

As the seepage is anticipated to be negligible, analysis may not be conducted for geosynthetic-lined ponds. Because the analysis is based on in-situ soil properties, it will be specific to each pond.

6.4.5.2 *Water Balancing*

Exploration and appraisal (E&A) ponds will evaporate stored water until such time as they are decommissioned or converted to regional storage ponds for balancing water flows. Evaporation ponds constructed under existing Environmental Authorities will serve the dual function of evaporation and water balancing. These ponds have been and will be designed to meet criteria set by the Department of Environment and Resources Management (DERM) and have a minimum 20-year design life. QGC does not consider the decommissioning of these ponds, in the short term, to be a reasonable option given that the design criteria used were prescribed by DERM. Where ponds are no longer required as part of the water balancing and evaporation network, all remaining water will be pumped from the pond, which will be decommissioned as described in *Section 6.4.6*.

All other untreated water storage ponds (infield buffer storages, regional storage, raw water and collection header ponds) described in *Volume 2, Chapter 7* will balance water flows between wells and the WTPs. They will not function as evaporation ponds. It is not expected that salts will accumulate in these ponds to the same levels as they would in an evaporation pond, due to short storage time.

6.4.5.3 Collection Header Pond Footprint

The footprint of collection header ponds is approximately 25 ha per pond or 50 ha in total excluding existing ponds (or 100 ha including existing ponds). They represent approximately half of the total footprint of proposed untreated water storage ponds. It is anticipated that collection header ponds will comprise two sections, one for balancing water flows and the other providing 30-day storage in case of disruption to the water transfer and treatment network. The section for balancing water flows will occupy approximately 15 per cent of the total area required or between 7.5 ha and 15 ha. The remaining 85 per cent (42.5 ha to 85 ha) will be subject to water flows only in an emergency. There will be limited potential for salt accumulation in emergency storages. The need for liner and the type of liner required for the emergency storage section of collection header ponds will be determined case-by-case using a risk-based approach.

The total area of potentially salt-contaminated untreated water storages, excluding the portion of the collection header ponds designed for emergency storage, is estimated at 70 ha to 120 ha.

6.4.5.4 Infield Buffer Storages

QGC is currently assessing the feasibility of using water tanks of approximately 1 ML to 5 ML capacity as infield buffer storages. This may be achieved by minimising the number of storage days in each infield buffer, while minimising the risk of overtopping. Use of tanks instead of ponds for infield buffer storages would reduce the risk of seepage of saline water, compared to a lined pond. Buffer storages will require high-level alarms to notify operators of potential overtopping due to disruption of water pumps or water gathering lines.

6.4.5.5 Appropriate Siting of Ponds

Ponds will, as far as reasonably practicable, not be sited:

- on soils with high permeability
- above shallow alluvial aquifers
- adjacent to major watercourses

- below the 1:100 year flood level
- in areas where endangered species could be at risk from contamination.

Where ponds are sited below the 1:100 year flood level, the four-sided embankments will be designed to withstand a flood.

There is less flexibility for location of infield buffer storages and regional storage ponds, but they have a much smaller footprint than collection header and raw water storage ponds (refer *Volume 2, Chapter 7*), which are constrained by land access as well as environmental, social and geotechnical factors. If for any reason a pond must be located in an area with high-permeability soils, it will be constructed with the appropriate imported clay or geosynthetic lining.

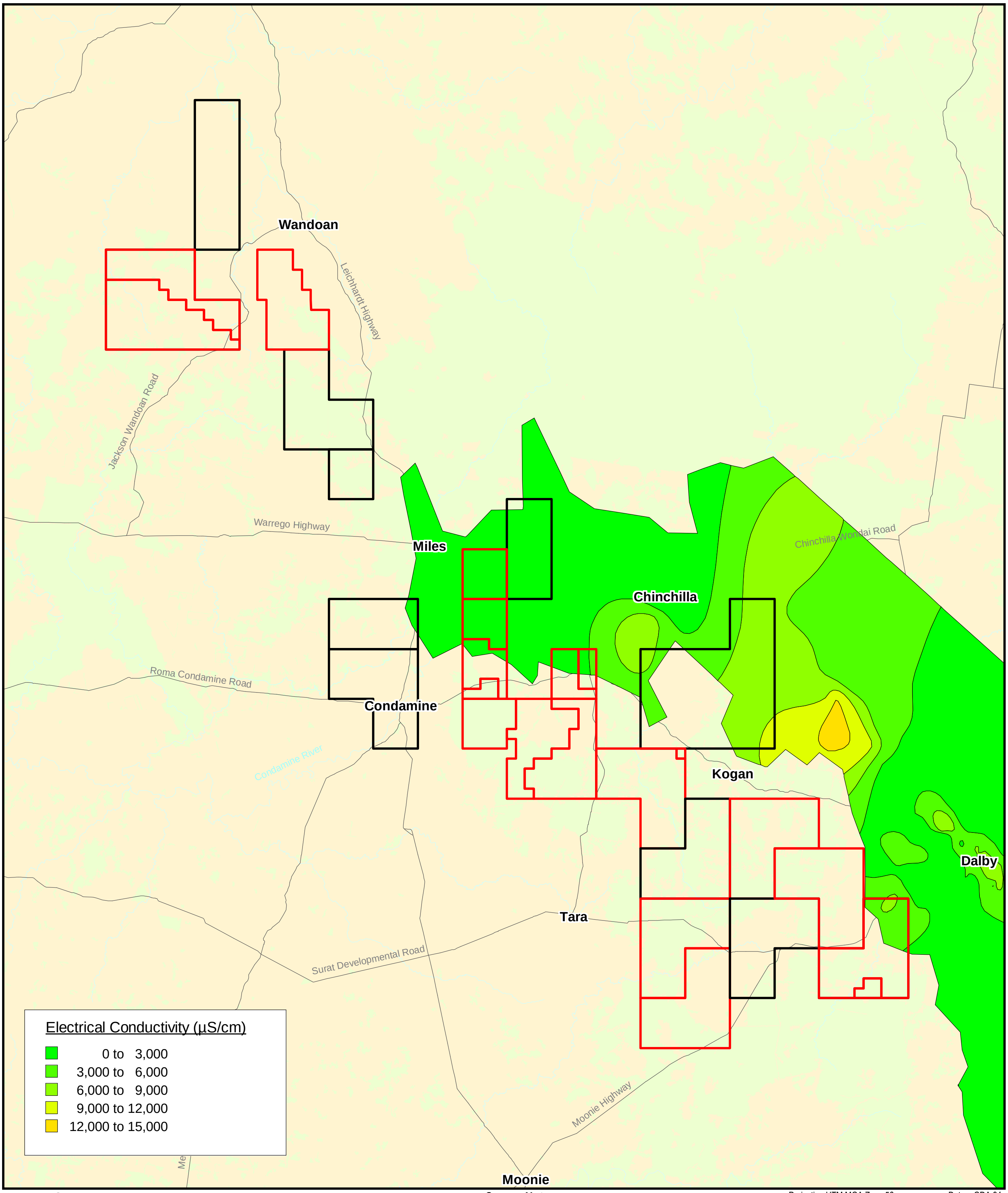
The shallow alluvial aquifers underlying QGC's tenements occur in alluvium associated with creeks and rivers or potentially in locations where there is direct recharge from alluvium or rainfall to sedimentary formations, such as Bungil, Mooga or Gubberamunda sandstone. *Figure 3.6.1* shows the total area of the Gas Field that has shallow alluvial aquifers associated with alluvium of the Condamine River and its tributaries. Approximately 72,000 ha or 15 per cent of the Gas Field is situated above shallow alluvial aquifers. Ponds that are not located in shallow aquifer zones have a lower probability of saline water seepage into groundwater aquifers.

6.4.5.6 Monitoring

Monitoring and inspection of ponds will take place in accordance with QGC's Standard Ponds Operating Procedures[1], Ponds Operational Plan Guide[2] and individual pond operating plans and monitoring procedures. These detail routine pond inspections and monitoring as per *Table 3.6.2*. For clay-lined ponds, geophysical surveys (e.g. electromagnetics or resistivity) and installation and monitoring of piezometers in the pond walls and in bores around the ponds, where considered necessary, will act as early warning systems for potential seepage and for safety purposes. Annual pond inspections will be conducted by a suitably qualified person and reported to DERM in accordance with the *Environmental Protection Act 1994* (Qld).

1 Standard Ponds Operating Procedures, PRO-W-PCR-001, Rev [1], September 2009

2 Ponds Operational Plan Guide, PRO-T-PLN-004, Rev 1, February 2009



Legend:

Gas Fields - Petroleum Lease/Petroleum Lease Application

Gas Fields - Authority to Prospect

Source Note:
1:250,000 Topographic vector copyright Geoscience Australia

Projection UTM MGA Zone 56 Datum GDA 94

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Kilometres

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QUEENSLAND CURTIS LNG
A BG Group business

ERM
Environmental Resources Management Australia Pty Ltd

Project	Queensland Curtis LNG Project		
Client	QGC - A BG Group business		
Drawn	Unidel	sEIS Volume 3	Figure 3.6.1
Approved	CDP	File No:	QC02-T-MA-00138
Date	10.12.09	Revision	Supplementary

Title **Shallow Alluvial Aquifers**

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Table 3.6.2 Pond Monitoring and Inspections

Aspect of Monitoring	Monitoring Frequency
Water level	Daily, continuous (using a monitoring device) or following a specified event [1]
Groundwater level	Quarterly
Embankment seepage	Annually
Liner seepage	Monthly or quarterly
Spillway inspection (occurs before 1 November each year)	Annually
Hydrological structures	Annually
Embankment	Annually
Pipework and valves	Weekly
Pond water quality	Quarterly
Groundwater Quality	Continuous (using a monitoring device) or monthly
Rainfall	Daily
Wind Speed	Daily
Evaporation	Daily
Environmental impacts	Following a specified event [1]
Exceptions / Unusual Events	At each event

1 Includes:

- Heavy rainfall (defined as a total depth greater than 20 mm in a 24-hour period)
- Protracted dry spell (defined as no rain for 90 days)
- Water level reaching a critical height (e.g. mandatory operating level, mandatory reporting level)

Geosynthetic-lined ponds will generally have appropriate leak-detection and monitoring systems, which may include under-liner drainage systems. They will be constructed to quality assurance and control standards, including hole-detection surveys at the completion of liner placement. Where monitoring indicates the presence of seepage, QGC will install site-specific groundwater monitoring systems where appropriate. Monitoring and control systems will be constructed for each pond to provide information about water levels and volumes and any seepage. Monitoring systems will be automated, except for infield buffer storages, regional storage and exploration ponds.

Each pond will be subject to a risk analysis and hydrogeological evaluation to determine the potential for seepage. Where required, aquifer monitoring wells (indicatively, up to 100 m deep depending on geological conditions at a particular site) and shallow monitoring wells, nominally 2 m to 12 m deep, will be installed. QGC does not propose to install aquifer monitoring wells at infield buffer storages, regional storage and E&A ponds. Monitoring wells will be located in aquifers that may receive seepage from ponds and will provide an early indication of potential seepage by measuring water quality over time. Shallow wells will be located adjacent to ponds and will provide information about any potential seepage from beneath pond lining or from embankments.

Subsoils in the Gas Field are often sodic or saline and natural salt accumulation and movement has occurred over time. Natural salinity or sodicity levels may be used as a guide to establishing acceptable levels of salt migration and concentration from the basal area of QGC's ponds. An appropriate trigger value will be established in consultation with regulatory authorities. Where these values are exceeded, QGC will initiate measures to prevent further salt migration or accumulation. This may include decommissioning ponds and installation of seepage-collection drains (where not already installed).

Where there is potential for contamination of surface waters from pond seepage, water monitoring sites will be located downstream and upstream of the pond. The parameters to be monitored include electrical conductivity, suspended solids, bicarbonate, sulfate, chloride and sodium.

6.4.6 Decommissioning

QGC will develop a decommissioning plan for all ponds, including the development and application of the following guidelines.

- The pond will be dewatered by pumping water to another water storage pond or to the WTP. After the pond has been dewatered for decommissioning, there will be no more driving head so the potential for spread of any saline seepage in the horizontal plane will rapidly cease. Without the driving head, the horizontal flow will rapidly cease.
- Clay liners, geosynthetic liners and any contaminated soils will be gathered at a high point in the pond footprint or transferred to another pond scheduled for decommissioning. This will reduce the footprint of contaminated materials within each pond.
- Pond embankments will be levelled and material used to cover the pond floor. This will ensure that the pond no longer impounds any water.
- Diversion drains surrounding the pond may be retained to divert any clean water runoff from the decommissioned pond area.
- A capillary break layer will be installed over the pond footprint to prevent capillary rise of salts into any soil cover.
- A clay layer will be installed over the capillary break layer to minimise seepage from rainfall and runoff. It is expected that this would have a minimum thickness of 0.3 m.
- A growth medium/topsoil will be installed over the clay layer in a convex shape to prevent pooling of rainfall and runoff. It is expected that this would have a minimum thickness of 0.1 m.
- The growth medium will be planted with species suited to the climate and with roots that will not penetrate the clay or capillary break layers. These species will take up water from the growth medium and minimise the volume of water seeping into the clay or capillary break layers.

QGC has undertaken modelling for the decommissioning of an existing evaporation pond, which indicates that, after the pond is dewatered, the driving head for seepage will be removed and the migration rate of any seepage bulb will slow and stop in underlying and adjacent unsaturated, extremely weathered rock strata. This and the retained very-low hydraulic conductivity of the underlying unsaturated strata should limit the possibility of saline water flowing downwards to deeper aquifers after decommissioning.

Where monitoring during the life of the pond indicates the potential for soils and aquifer contamination post decommissioning, an ongoing monitoring plan will be implemented. It is possible any shallow monitoring wells that existed prior to decommissioning will be removed. However, these will be replaced by a network of shallow monitoring wells in surficial soils around the site of the decommissioned pond. Deep monitoring bores will not be removed and will continue to provide data on aquifer water quality after decommissioning.

All decommissioned ponds will be subject to routine monitoring of surrounding erosion and vegetation, including vegetation established during the decommissioning process, for any evidence of scalding or die-off due to migration of salts.

QGC will continue to monitor shallow bores, deep bores, soils and vegetation surrounding ponds for a period agreed with regulatory authorities or until there is no evidence of seepage of saline materials.

6.4.6.1 Options for Decommissioning

Pond decommissioning will be an ongoing process. Initially, existing E&A ponds (constructed under current petroleum licenses) may be decommissioned, and lessons learned will guide strategies and approaches for decommissioning the ponds proposed for the QCLNG Project. QGC will investigate options for pond decommissioning. These include:

- capping and containing contaminated soils on site
- transferring contaminated soils and liners to a purpose-built secure landfill, which could include the salt-disposal landfill
- recycling and reuse of geosynthetic materials.

Saline material and liners could be removed to a landfill and the pond site could be rehabilitated using material from pond walls and by creating a capping layer to reduce infiltration of surface water into the subsoils with higher saline concentrations. This option could require transporting some contaminated material to a landfill. Depending on the amount of material removed, some in- situ material may remain with elevated salt levels above pre-pond use. As such, long-term monitoring and management may be required.

6.4.7 *Brine Ponds and Brine Evaporation Basin*

Brine concentration involves evaporating water from the brine in a dedicated evaporation pond. The process produces high-saline slurry with typical total dissolved solids (TDS) of 100,000 mg/L to 150,000 mg/L.

Brine pond and brine evaporation basin design and construction are described in *Volume 2, Chapter 11*. The expected footprint of brine ponds and brine evaporation basins is described in *Volume 2, Chapter 7*.

To minimise seepage from the brine infrastructure, a composite liner system is preferred. This could comprise a geomembrane over a compacted clay liner or a geomembrane over a geotextile clay liner (GCL). The liner system will be determined on a case-by-case basis. A GCL is a system of geotextiles that contain a layer of very low-permeability clay between the geotextiles. Alternatively, a 600 mm-thick clay liner would result in minimal seepage from these ponds. The GCL in composite with an overlying geomembrane liner results in a very low-permeability liner system.

Brine ponds and brine evaporation basins will have appropriate leak-detection and monitoring systems, including under-liner drainage systems. The function of the GCL is to prevent vertical seepage collected by the drainage system beneath the geomembrane liner. Due to the very low permeability of the clay in the GCL, any flow detected through the geomembrane is expected to be minimal. The composite action of the two liners should result in a lower permeability than the combined permeability of the two components. Seepage rates through such a system can be lower than one litre per hectare per day.

6.4.8 *Pond Failure and Pond Overtopping*

Potential overtopping of the pond embankment during high rainfall could result in saline water flowing directly into surface waters or soils. An uncontrolled discharge from a pond may impact shallow groundwater quality, if shallow aquifers are present at that specific location. It could also affect soil salinity and structure, depending on the quality of the released water.

Modelling is able to predict the movement of water during a pond failure. The impact of pond failure would be dependent on the volume of water released, salt concentration of the water and the nature of the receiving environment. Ponds will be designed so that, under modelled storm events, spills are unlikely to occur during the operating life of the storages and, if they did occur, in the worst-case scenario are estimated to only marginally exceed trigger investigation levels for drinking water, livestock or agricultural use temporarily.

Ponds constructed with greater than 10 ML capacity and which will store Associated Water with a salinity measured as electrical conductivity greater than 4,000 µS/cm will be regulated storages and will be constructed in accordance with Environmental Authority (EA) requirements and with guidelines set out in the *The Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (2009)*. In particular, these guidelines set out spillway and diversion channel sizing requirements for various hazard ratings. The majority of QGC's ponds will be regulated storages.

A referable dam is defined by regulation as one that would, in the event of failure, put the population at risk. This is determined by conducting a Failure Impact Assessment. Such a dam is assigned a Category 1 or Category 2 failure impact rating and is considered "referable" under the provisions of the *Water Act 2000 (Qld)*.

Dams that have not been assessed as having a Category 2 failure impact rating must be assessed every five years if they are more than 8 m high and have a storage capacity of:

- more than 500 megalitres
- more than 250 megalitres and a catchment area more than three times the maximum surface area of the dam at full supply level.

If there is no population at risk, a dam is not referable and therefore not subject to the provisions of the *Water Act 2000.*

QGC expects that approximately 10 of its proposed ponds may be "referable". All ponds that meet the criteria of "referable dams" will be designed to the required standard to minimise the risk of failure as low as reasonably practicable. Based on a risk analysis of all other ponds, including an assessment of salinity levels, other ponds may be subject to the design criteria for "referable dams".

6.4.9 Salt-Disposal Landfills

Salt-disposal landfills will be required as default options for the long-term management of salt generated from the water treatment processes that cannot be sold or transported offsite for beneficial use by others. Salt landfill design and construction is described in *Volume 2, Chapter 11*. The expected footprint of salt-disposal landfills is described in *Volume 2, Chapter 7*. Where a brine evaporation basin is converted into a salt-disposal landfill, it will be constructed to meet the necessary design, construction and operational standards.

QGC has not developed a detailed design, construction and operations plan for salt-disposal landfills. These plans will be developed after a thorough risk analysis of potential landfill locations, including soils, geotechnical and hydrogeological investigations.

The following generic guidelines will be considered in the design, construction and operation of a landfill.

- Selecting a suitable site for the landfill would involve preferentially selecting an elevated site in the landscape with no nearby shallow groundwater or sensitive receptors. Low permeability in situ clay soils would be preferred for the site. There should be no geological faults or shear zones under or within 20 m of a landfill.

- The base composite liner would comprise a compacted clay liner of appropriate thickness and permeability, with a geomembrane liner over the top and under-drainage. The geomembrane liner would be selected based on its predicted long-term integrity. Suitably formulated and stabilised geosynthetic is expected to last for many centuries in a stable chemical and temperature environment, which is to be expected in a monofill (salt-contaminated material only) landfill. The liner system would be installed under an effective quality control and assurance system.

- The base liner for the salt-disposal landfill would be constructed at an appropriate distance from the long-term regional groundwater elevation relative to the top of the base liner. The subgrade of the proposed landfill site will be assessed to confirm that the permeability meets the required standards.

- The base liner would also include a drainage layer over the top of the liner system that would be sloped to a number of sumps. The drainage layer would be designed to convey the peak long-term flow rate expected through the overlying salt. To limit the hydraulic head, and hence the seepage rate through the base liner, the floor grade of the liner and drainage system would be at least 1.5 per cent towards collection pipes, and at least 1 per cent along drainage pipes to the sumps. Depending on the materials of the drainage layer, the geomembrane liner would have a protection layer, which may be incorporated with the drainage layer.

- The sumps would comprise an area in the low points of the landfill base where leachate may accumulate over time and be appropriately lined. The sump may be designed with a riser pipe to facilitate lowering of a pump into the sump to extract any accumulated leachate. The sump would also include an alarm to notify the operator when leachate has accumulated and needs to be extracted. Pumps will not be installed permanently in the sumps due to the effect of saline leachate on mechanical equipment after extended periods. The leachate sump riser would be large enough in diameter to allow maintenance access down to the bottom of sump, if required.

- QGC's preference is to use any landfill for the disposal of saline waste products only (i.e. a monofill landfill). The construction of a monofill landfill eliminates the risk of organic processes in the salt, and hence the leachate from the landfill is expected to be at an ambient temperature and to remain at a relatively constant pH. These two factors will limit the risk of significant impact on the liner system and will result in long-term durability and functionality of the composite liner system.

- The risk of blockage due to biological or chemical clogging of the drainage system is considered low, due to the expected stable chemical conditions in the landfill and the absence of biological matter in the monofill landfill. To maintain this very low risk of blockage, the drainage pipes will be provided with airlocks to limit the potential for air ingress into the drainage system, thereby maintaining the chemical environment in the landfill.

- The capping design for a landfill will be based on observed hydrological and vegetation conditions at a site, as well as ongoing investigations and research by QGC. A possible design could consist of capping comprising a composite liner overlain by at least 750 mm of fill. The overlying fill would include a topsoil layer for the promotion of vegetation on the surface. The vegetation would be maintained to limit the effect of potential surface erosion and to evapotranspire infiltration from rainfall in the cover soil. The fill layer may also include subsoil drainage features, where appropriate, to manage the risk of accumulation of subsoil seepage and to reduce the likelihood of infiltration through the liner system.

- The liner system for the cap could comprise a composite liner of suitable thickness, compacted clay overlain by a geomembrane or an alternative equivalent liner system. A liner system is intended to limit infiltration into the underlying salts and thereby limit the risk of generation of leachate from the salt. The underside of the composite liner could include a capillary break layer to reduce the risk of upward migration of salts into the liner and potentially into the cover soils. The capillary barrier may be constructed from either natural or geosynthetic materials that are durable over the long term in the salt environment. The cap would be constructed under an effective quality control and assurance system to meet the intent of the design and ensure the integrity of the liner system.

- The surface of the cap should be shaped to shed rainfall runoff, thereby reducing the risk of infiltration and subsequent leachate generation. The minimum surface grade of the cap should be in the order of 1 per cent. The surface runoff would collect in drains, where appropriate, and be directed off the landfill. Drains should be designed to minimise erosion and include an additional layer of geomembrane to further reduce the risk of infiltration into the cover soils.

- The landfill could be filled in cells, so that each cell can be filled and capped over a short period to limit the amount of rainfall impinging on the salt, and in turn the risk of leachate generation. Interim batters would be covered with interim caps to further reduce the likelihood of rain hitting the salt in the filled cells. Interim caps may comprise soil liners, geosynthetic liners or a combination of these.

- The salt should be placed in approximate horizontal layers and nominally compacted before the next layer is placed. Compaction of the salt is expected to reduce the permeability of the salt and limit the risk of settlement of the salt and hence deformation of the cap.

- Leachate from the landfill is expected to be a low-volume, high-salinity liquid. Any accumulated liquid would be batch-extracted from sumps by suitable mechanical equipment. The collected leachate would be stored in polymeric tanks and then placed in a small evaporation sump during the dry weather months, to remove moisture from the leachate before returning crystallised salt to the landfill. The design of the evaporation sump would conform to the same criteria as the brine evaporation basins.

An Operational Management Plan will be prepared for the salt landfill. It will include:

- site operational procedures
- corrective action procedures
- emergency and safety procedures.

A Site-Based Management Plan (SBMP) will also be developed for the operational phase of the salt landfill. The SBMP will include:

- environmental monitoring requirements
- stormwater procedures
- site training requirements.

A closure plan and a post-closure plan will be developed for the salt landfill. QGC will be responsible for the long-term management of any landfills. Management would be required, in agreement with the relevant regulatory authority, until such time as the landfill no longer poses a risk of soil or water contamination. QGC will supply the necessary financial assurance to ensure that any landfill can be successfully decommissioned beyond QGC's operating tenure. QGC may employ a contractor to manage the landfill. The post-closure plan for the landfill will identify who is responsible for managing the landfill and over what timeframe.

6.4.10 Remediation of Contaminated Sites

Contamination from salination (primarily chloride and sodium) may occur through accidental release of untreated Associated Water or brine. Remediation will be required where the concentration and location of contamination risks impacting environmental values.

The risk that any accidental release of Associated Water presents is dependent on the volume of the release, the concentration of the salts and the location and extent of the release. QGC will establish protocols for responding to release events and developing remedial action plans, based on the above factors. This will include the necessary and appropriate liaison strategies with DERM and other regulatory agencies and stakeholders.

A generic remediation process would be undertaken in the following order:

- control or stop the source of the release
- undertake emergency response works, as necessary
- delineate the contaminated area through site observation/investigation
- assess the risk to environmental values from contamination
- initiate a monitoring program
- develop a remediation strategy to lower the risk to the environment
- implement remediation

- monitor the site to ensure concentrations of salts return to pre-spill levels. Where ongoing monitoring identifies concentrations not returning to background levels, reassess the potential risk and the remediation strategy.

Depending on the risk posed, remediation strategies could include:

- identify the source and introduce processes and procedures to prevent further spills, determine the extent of contamination to soil and groundwater against baseline values and undertake a risk assessment as soon as practical following the spill
- remove areas of gross salinity by excavation of soils with electrical conductivity values greater than background conditions or other agreed level with regulatory agencies and transport to or place in a geosynthetic-lined containment area
- extract the impacted groundwater (dependent on depth of groundwater and contamination depth) and place into geosynthetic-lined holding ponds
- reinstate the area by applying a soil ameliorant such as gypsum on surface soils
- monitor groundwater and surface water as necessary in the area for an agreed period post-remediation
- record the location of the spill for future reference and management.

6.4.11 Environmental Management Register and Contaminated Land Register

Activities that have been identified as likely to cause land contamination are listed in Schedule 3 of the Environmental Protection Act 1994 (Queensland). Under the EP Act, landowners and local government must inform DERM if land has been or is being used for a notifiable activity. Land that has been or is being used for a notifiable activity is recorded on the Environmental Management Register (EMR), which is maintained by DERM.

Currently, the operation of a brine evaporation basin and salt-disposal landfill do not meet the criteria of a notifiable activity. However, should these activities be declared notifiable, QGC will comply with all regulatory requirements.

The Contaminated Lands Register (CLR) is managed by DERM under Section 540 of the *EP Act* (Qld). A contaminated land assessment is conducted as part of the rehabilitation process and decommissioning stage only when a notifiable activity or environmentally relevant activity (ERA) has been completed. The assessment will be conducted by suitably qualified persons to determine if the land should be placed on the CLR. Land is recorded on the CLR when scientific investigation shows it is contaminated and actions are needed to remediate or manage the land. In general, individual parcels of land may be placed on the CLR where contamination present on a site poses an unacceptable risk to human health or the environment.

Without conducting the required contaminated land assessment, it is uncertain whether brine evaporation basins or salt-disposal landfills will be listed on the CLR. However, should they be listed on the CLR, QGC will comply with all regulatory requirements.

Typical regulatory requirements for parcels of land on the CLR include:

- additional environmental assessment and reporting
- detailed environmental or health risk assessments
- remediation activities and monitoring
- any other works required to mitigate environmental or health and safety risks.

6.4.12 Conclusions on Associated Water Management

The following unplanned releases of Associated Water are considered to have the potential for a significant adverse impact:

- pond breaks
- pipe burst associated with a water pipeline.

Risk assessments will be conducted during detailed design to identify the necessary design, construction and operational requirements to reduce the risk of these events to as low as reasonably practicable.

Activities considered to have a low risk of adverse impact, given that effective monitoring and mitigation measures are in place, include:

- seepage of saline water down-slope of Associated Water storage ponds as a normal consequence of operations
- controlled spillway discharge from Associated Water or treated water storage ponds
- direct seepage of saline water from engineered geosynthetic or clay-lined infrastructure as a normal course of operations
- direct seepage of saline water from brine ponds and brine evaporation basins as a normal course of operations
- accidental spills of Associated Water from operating procedures at the WTP.

Procedures for identifying and implementing effective monitoring and management procedures to prevent releases of Associated Water with a low potential impact are described in *Section 6.4*.

6.5 DRILLING CHEMICALS

A number of drilling fluids may be used where the formations become difficult to drill, such as highly unstable formations. The most common fluids consist of water-based polymers. These are widely used in consumer products and are valued for drilling because they absorb as much as 200 to 300 times their mass in water while retaining their binding capability. The most common form used in the petroleum and gas industry is sodium polyacrylate. Polyacrylate is non-toxic.

The drilling fluids are readily biodegradable when exposed to air in UV sunlight. Because they are long-chain polymers, they are not readily absorbed into the soil, although they are readily soluble in water. When they are returned to the drilling sump, air and sunlight will decompose the fluids. QGC will remediate drilling sumps by turning over and air drying. Any traces of the original polymers should be completely degraded.

6.6 HYDRAULIC FRACTURING

Hydraulic fracturing is used to create fractures that extend from a borehole into rock formations, which are typically maintained by a proppant, a material such as grains of sand that prevents the fractures from closing. The method is informally called “fracing”. Hydraulic fracturing is used to increase or restore the rate at which fluids, such as gas or water, can be produced from the desired formation. By creating fractures, the reservoir surface area exposed to the borehole is increased. The fracture, which is kept open using a proppant such as sand or ceramic beads, provides a conductive path connecting a larger area of the reservoir to the well, thereby increasing the area from which fluids can be produced from the desired formation.

6.6.1 Radioactive Tracers Used for Fracing

Radioactive (RA) tracers will be used in fracing trials to ascertain whether water, and hence gas flows, can be improved. The number of trials required will depend on gas flows across QGC’s tenements. RA tracers are used to assess the success of the fracing. They are particularly useful for multilayered formations, such as those found in the interbedded coal seams of the Walloon Group coal measures, to identify the degree of fracing in specific seams.

The RA tracers are synthetically created by imbedding heavy metal seeds into ceramic or resin beads (the proppant), which are similar in size and specific gravity to rounded sand grains being used to prop open the hydraulic fracture. The active tracer bead contains a known and consistent activity level which is suitable for formation logging. The beads are composed of various radioactive isotopes of Scandium, Antimony and Iridium oxides (Sc-46, Sb-124 or Ir-192 respectively) and different beads are used in order to distinguish between different formations.

The tracer is introduced into the well via a low-pressure pump that adds the tracer beads to low-pressure, pre-mixed, sand-laden fracturing fluids. The fracturing fluids containing the tracer are then subjected to high-pressure pumping and injected into the well. The concentration of beads per volume of sand is extremely low, with only one bead on average per 2.3 kg of sand particles. In most cases, the beads become proppants, along with any sand particles, and naturally degrade within the formation. Any flowback of particles from the well are diverted to the standard in-ground sump at the well site, where they can be captured and kept under water or covered (with 0.6 m of soil) until any residual radioactivity has depleted. It should be noted that no radioactivity can be transferred from the beads to water, and hence storage underwater is the initial preferred safe-waste medium. Water retained within the sump or soil will be used to cover any residual waste should the water dry up. This is done in order to remove any likelihood of particles being removed. Although the beads have a short half-life of less than 90 days, lined sumps used for RA tracer waste will be isolated by fencing and safety sign posting, warning that the site is off limits for 12 months in order to ensure that the beads are inert.

The radioactivity of the beads is added at a rate of 41 MBq or 1 Ci per tonne of sand, where the beads are injected at <5Bq/gm. At this rate, the radioactivity is less than a Coleman lamp sock (133 Bq), 1kg of coffee (1 kBq) or a household smoke detector (30 kBq). RA tracers have been used for 35 years and 1,000 tracer operations are conducted annually worldwide. The *United States Environmental Protection Agency* does not classify the materials as hazardous waste. The US Nuclear Regulatory Commission, (2003) has stated that an environmental assessment was conducted which concluded a Finding of No Significant Impact (FONSI) for RA tracers, and that they approved the onsite disposal request to bury RA tracer waste from well-logging into shallow earthen (soil) pits . Queensland Health licences the use and disposal of all RA materials. QGC will comply with all Queensland Health requirements.

6.6.2 Chemicals Used in Fracing

Fracing will require the pumping of treated water and gelling agents, which fracture a formation and carry the proppants. *Table 3.6.3* presents the estimated concentrations and volumes of water treatment chemicals and gels based on a requirement of 1,200 kL of fracing fluid per well.

Table 3.6.3 Estimates of Fracing Fluids Required

Frac Fluid / Gel	Concentration	Volume per well (L)
Biocide for Frac Fluid	~0.05%	600
Acid pH adjustment	~0.1%	1,200
Biocide for Frac Gel	~0.05%	600
Gelling agents (guar gum)	10%	120,000
Gel breaker (salt)	0.005%	60
Surfactant	0.05-0.1%	600-1,200
Caustic 50% pH adjustment	0.1-0.2%	1,200-2,400
Acid 50% pH adjustment	0.1-0.2%	1,200-2,400

In addition to the above, small amounts of other gels and breakers may be used. In some instances, salts may be added to fracing fluids to enable an emulsion to form.

The biocides and surfactants require the highest level of control. They are normally used as a crystalline product and added to the tanks to deter bacteria from degrading the mixed gel (guar gum and water). Bacteria (especially in elevated temperatures) will quickly digest the guar gum and the gel will lose its viscosity. The biocides and surfactants will be contained in sealed plastic bags that dissolve in the tank make-up water, and so should require no human contact Operators will be trained in the storage and handling of biocides and surfactants.

One of the biocides that may be used is hypochlorite solution (bleach), which is added directly to water prior to adding any other additive to eliminate bacteria already present. This is the same process as used in domestic swimming pool chlorination. Removing bacteria protects gels and reduces potential downhole issues by not introducing bacteria into the formation.

Surfactants will enhance the characteristics of gas flowing to the wellbore by reducing the surface tension between the water and gas molecules in the formation. Any surfactants used in the fracing fluids will be returned to surface via the annulus (well borehole) and will be piped to a lined sump, where exposure to air and sunlight will enhance degradation. These sumps will be retained for future use and the remaining soil monitored to ensure any residual chemicals are within acceptable levels before burial. If unacceptable, the material will be removed to an approved waste disposal facility.

Environmental Precautionary Measures (EPM) are generally described in relation to the prevention of chemicals entering sewers, waterways or low areas and impacting aquatic or soil organisms. In most cases, all fluids used require EPM to avoid losses and will be managed via a site management plan. QGC will apply all relevant standards and requirements for health and safety, transport, storage, handling, use and disposal.

The potential ecological impact is based on the biodegradability of the chemicals and is rated as either high (readily) or low (slowly). Biodegradability rating applies to less than a third of the chemicals used and therefore all other chemicals will require stringent controls. QGC will comply with all relevant guidelines for minimising impact to human health and the environment from the use of fracing chemicals.

6.7 OTHER CHEMICALS AND HYDROCARBONS

Any other chemicals or hydrocarbons not described in *Volume 3, Chapter 6* of the draft EIS are described below.

6.7.1 Fertilisers

Where required, fertiliser may be used to aid the process of rehabilitation. Experience to date with the rehabilitation of QGC's existing activities indicates that fertiliser application has not been beneficial for plant production, hence it is uncertain whether fertiliser will be used in the future. The amount of fertiliser generally used is approximately 10 kg per hectare.

6.7.2 Weed Management Chemicals

Weed management is an issue of concern to QGC and communities in areas where it operates. Chemicals are required to control the spread of weeds.

If managed incorrectly, weed management chemicals may be released to non-target environments or crops and potentially be ingested by humans. Contamination may occur as a result of:

- release into a watercourse
- residual spray blowing onto crops or non-target species
- livestock grazing in recently sprayed areas
- residual spray in close proximity to a house on a windy day.

The following mitigation measures will be utilised to prevent or minimise the impacts from chemicals for weed management:

- Spraying will not occur on days where the wind speed exceeds 10 km/h.
- Landholders will be consulted about the types and application rates of chemicals to be used.
- Cattle should remain out of the area to which chemicals have been applied for at least 10 days.
- The Material Safety Data Sheet (MSDS) of each chemical will be consulted to determine whether the chemical can be used near riparian areas.

Table 3.6.4 provides examples of the type of weed species that may occur, the weed management chemicals used, rate of use, potential impacts and mitigation measures.

Table 3.6.4 Weed Management Chemicals

Species for Treatment	Method of Application	Product	Rate	Ecological Issues (according to MSDS)	Mitigation Measures
Acacia/Eucalypt regrowth (stem diameter >10mm and height >1m)[1]	Basal bark and cut stump	Access	1:60 (diesel)	Should be applied with caution in riparian zones	Stock to remain out of area for at least 10 days after treatment. Foliar spray not to be supplied in strong breeze/wind (i.e. more than 10 km/h).
Acacia/Eucalypt regrowth (stem diameter <10mm and height <1m) [1]	Foliar Spray (complete coverage)	Grazon DS	500mL/100L water and surfactant	Can be toxic to aquatic organisms; should be applied with caution in riparian zones	Stock to remain out of area for at least 10 days after treatment. Foliar spray not to be supplied in strong breeze/wind (i.e. more than 10 km/h).
Large dense areas of Acacia/Eucalypt regrowth[1]	Areas under 100 ha or along pipeline should be applied by hand	Grazlan	1.5g/m2	Be cautious of neighbouring root zones	Be cautious of runoff to neighbouring crops.
Mother of Millions	Foliar Spray (complete coverage)	Grazon DS	500mL/100L water and surfactant	Cautious with overspray on retained species.	Remove stock from area.
African Boxthorn	Basal bark and cut stump	Access	1:60 (diesel)	Should be applied with caution in riparian zones	Stock to remain out of area for at least 10 days after treatment. Foliar spray not to be supplied in strong breeze/wind (i.e. more than 10 km/h).
Balloon Cotton Bush	Foliar Spray	2,4D Amine	320ml/100L water		Remove stock from area.
Noogoora Burr	Foliar Spray	Starane 200	75mL/100L water		
Cockspur	Foliar Spray	Grazon DS	350mL/100ml water		

Species for Treatment	Method of Application	Product	Rate	Ecological Issues (according to MSDS)	Mitigation Measures
Lantana	Foliar Spray, Basil Bark and Cut Stump, Splatter Gun	Access, Hotshot, Roundup	1.60 (diesel)		
African Lovegrass	Foliar spray	Roundup	Recommended rates		Remove stock from riparian zones, limit spraying in windy conditions, be aware of nearby crops.
Giant Rats Tail Grass	Giant Rats Tail Grass	Access, Roundup Biactive			Remove stock from area (5-10 days), limit spraying in windy conditions, be aware of nearby crops.
Parthenium	Foliar Spray	Tordan 75D	125mL/100L water	Vehicle/equipment washdown critical to avoid transferring to other sites	
Tree Pear/Prickly Pear	Foliar Spray Stem Injection	Access Roundup	1:60 (diesel)		

1 Acacia or Eucalypt regrowth would be encouraged, except where a cleared area is required, such as directly above a pipeline.

6.7.3 Sewage Treatment

Sewage treatment and the potential to contaminate land from the irrigation of treated effluent or the unplanned release from the sewage treatment process at camps is discussed in *Volume 3, Chapter 16* of the supplementary EIS.

6.7.4 Cleaning Products

Small volumes of chemicals are present in products that will be used for floor polishing, glass cleaning, as disinfectants, surface cleaners, oven cleaners and bleaches. Minimal quantities of these products will reach the environment.

Washing powder, dishwashing detergent and laundry powder will make up the largest quantity of chemicals in use at camp sites. These will be processed through the onsite sewage treatment plants (STP). The STP will treat the effluent and chemicals by breaking down the composition using microorganisms in the plant. Most chemicals will be removed through the sedimentation phase by attaching themselves to sediment and settling to the bottom. They will then be removed in the de-sludging process as biosolids. Biosolids will be disposed of at a licensed waste disposal or recycling facility. The final treated effluent will have a low level of residual chemicals and any impact from irrigation of treated sewage is expected to be negligible. The dilution of chemicals within the camps will be high, as all services including grey water run through the STP treatment process, in turn increasing its effectiveness.

The majority of chemical components in use at camps are classified as biodegradable and therefore will be broken down by the STP and the environment.

6.7.5 Corrosion Inhibitor

In order to prevent the corrosion of the steel pipelines, a corrosion inhibiter will be added. CSG contains on average 0.22 mol% CO_2 which reacts with water to produce carbonic acid. The acid can react with the pipe and leads to corrosion. A water-soluble inhibitor may be added to the Associated Water prior to the field compression station (FCS) and removed at the central processing plant (CPP). On average, 415 litres per day of inhibitor will flow from the FCS into the CPPs, which is approximately 1 per cent of the total volume of water exiting the CPP. The water will be captured in a geosynthetic-lined pond prior to transfer to the WTP. The inhibitor will be compatible with WTP equipment.

The concentrated inhibitor is readily biodegradable at a rate of approximately 25 per cent per month, however, it is bioaccumulative and ecotoxic. QGC will use, as a minimum, the standard EPM to prevent the inhibitor from entering watercourses or low areas, where it may impact microbial activity and aquatic and soil organisms. However, given its low concentration in any discharged water, it is unlikely to cause any discernable effect should it be accidentally released. The inhibitor is totally soluble in fresh water and totally dispersible in most produced brines. The maximum salt concentration in the Associated

Water is well below the 5 per cent threshold for 100 per cent dispersibility and the corrosion inhibitor will therefore be dissolved in Associated Water.

6.8 BORROW PITS

Borrow pits may generate salinity, depending on the soil properties of the disturbed area. They may leach soluble salts from exposed soil material on to the land and into the adjacent surface watercourses. QGC will rehabilitate borrow pits through recontouring to prevent pooling of overland water flows and the reinstatement of stockpiled topsoils. Pits will not be located in the vicinity of sensitive receptors. Bunding will be installed to redirect surface runoff from the pits.

6.9 SECONDARY SALINITY

Secondary salinity may occur as a result of altering shallow groundwater levels or flows, thereby mobilising salts to the soil surface.

Secondary salinity has occurred in Queensland since the commencement of land use changes in the 1800s, with documented salinity problems by the State Government as early as the 1950s. This is most likely due to land clearing for agriculture. The production of CSG, as with any other activity that changes a landscape from its natural vegetated state, has the potential to cause secondary salinity.

QGC's activities may cause secondary or dryland salinity as a result of a hydrogeological response to the:

- clearing of native vegetation from the landscape and the replacement of that native vegetation with shallow-rooted crops and native pastures
- construction of roads and infrastructure hardstand areas
- use of water for dust suppression.

Clearing vegetation allows more water to enter the groundwater system, causing water levels to rise, which results in stored salt being mobilised both in and between catchments. Clearing of remnant vegetation is likely to have greater potential to mobilise salts than clearing of non-remnant vegetation.

Of the total estimated Project footprint, approximately 9,500 ha is considered to be remnant vegetation. Clearing will occur as multiple, discrete clearings across approximately 468,000 ha. Any secondary salinity occurring as a result of QGC's activities is likely to be isolated and very limited. QGC plans to progressively rehabilitate approximately half of the cleared footprint. Nevertheless, achieving the pre-clearing vegetation characteristics, such as deep-rooted (rehabilitated) vegetation, may take years.

Secondary salinity is known to develop where significant levels of primary salinity in the landscape, such as that found in the soils of the Project area, are mobilised as a result of changes in land use such as a vegetation clearing.

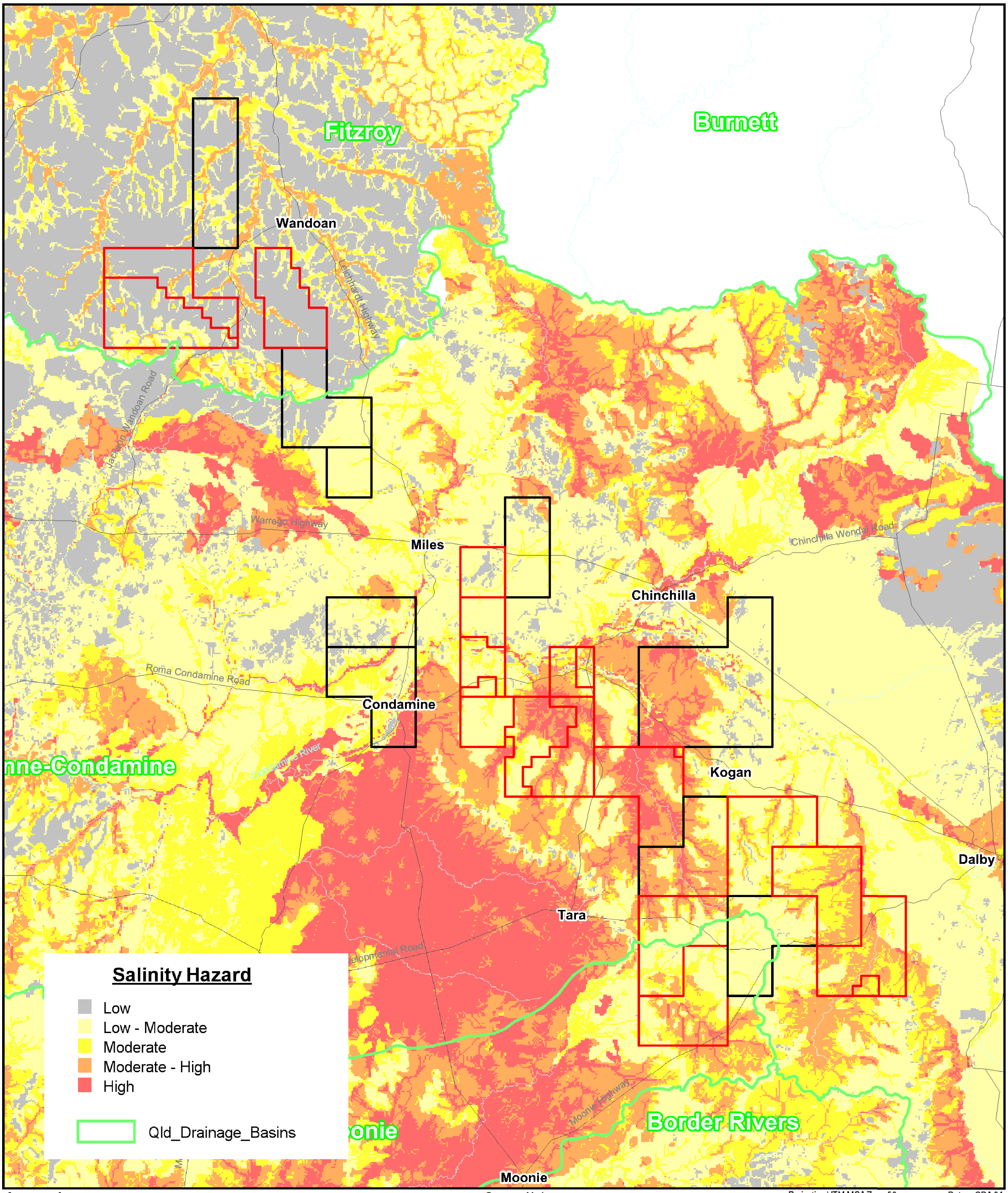
Figure 3.6.2 identifies the potential salinity hazard of the Gas Field, based on information produced by Searle *et al.,* (2007) for the Queensland Murray Darling basin and the Fitzroy basin. Clearing vegetation in high-hazard areas would increase the risk of secondary salinity. Approximately 125,000 ha or 26.5 per cent of the Gas Field has a moderate-high or high salinity hazard rating.

Figure 3.6.3 identifies the subsoil salinity constraint for the Gas Fields.

Approximately 35 per cent of the Gas Field has a moderate-to-severe salinity constraint due to subsoil salinity. This occurs on land with grey-brown cracking clays, sandy texture contrast soils (dispersive) or loamy texture contrast soils (dispersive) as the major soil management groups.

Salinity at or near the surface is not considered a significant constraint in the Project area. However, activities that disturb the saline soil and bring it to the surface may result in salts being leached and mobilised within the landscape.

Salt naturally occurs in the landscape of the Gas Fields, particularly in many of the soils, and may have been mobilised by historical vegetation clearing in the area.



Legend:

Gas Fields - Petroleum Lease/Petroleum Lease Application

Gas Fields - Authority to Prospect

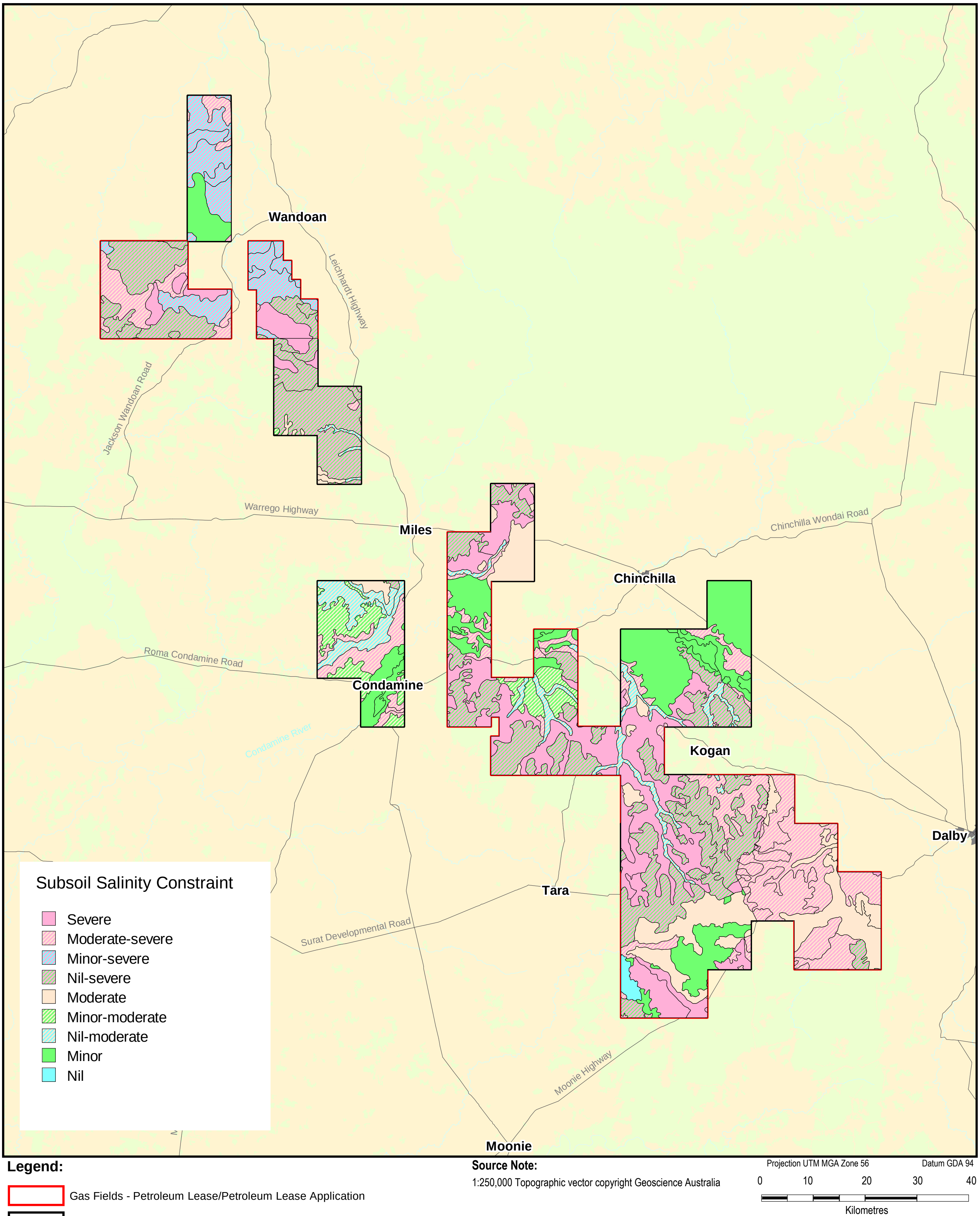
Source Note:
1:250,000 Topographic vector copyright Geoscience Australia
Salinity Hazard Data supplied by (C)Copyright DERM 2009

Projection UTM MGA Zone 56 Datum GDA 94

0 10 20 30 40
Kilometres

N

QUEENSLAND CURTIS LNG A BG Group business	Project Queensland Curtis LNG Project		Title **Salinity Hazard Rating**
	Client QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn Unidel	**sEIS Volume** 3 **Figure** 3.6.2	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved CDP	File No: QC02-T-MA-00142	
	Date 16.12.09	Revision Supplementary	



Legend:

Gas Fields - Petroleum Lease/Petroleum Lease Application

Gas Fields - Authority to Prospect

Source Note:
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QUEENSLAND CURTIS LNG, A BG Group business	Project: **Queensland Curtis LNG Project**		Title: **Subsoil Salinity Constraints**
	Client: **QGC - A BG Group business**		
ERM, Environmental Resources Management Australia Pty Ltd	Drawn: Unidel	**sEIS Volume** 3 **Figure** 3.6.3	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved: CDP	File No: QC02-T-MA-00139	
	Date: 11.12.09	Revision: Supplementary	

6.9.1 Salinity Management

QGC will adopt a risk-based approach to managing secondary salinity. QGC will identify areas that are more susceptible to secondary salinity based on known soil and topographic or geographic features that may promote secondary soil salinity once shallow groundwater flows are altered.

Where QGC's activities might result in secondary salinity, impacts are likely to be localised to the many small, discrete clearances associated with Gas Field development.

A Salinity Management Plan will be developed that aims to prevent secondary salinity from occurring or, where it has occurred, identifies rehabilitation methods. This will be based on employing geomorphology assessment techniques to determine where potential secondary salinity may occur. There are many possible contributors to increasing soil salinity in the area of the gas fields. Nevertheless, QGC will attempt to identify areas of salinity that may be attributed to its activities. Management of salinity on land not owned by QGC will require co-operation with the landowner.

Some of the salinity management tools that QGC may adopt include:

- retain and/or establish trees
- increase groundcover
- intercept and reuse pumped groundwater
- select appropriate location for water storages (refer to *Section 6.4.5.5*)
- minimise seepage from water storages (refer to *Section 6.4.5*)
- minimise the volume of saline water used for dust suppression
- consider shallow groundwater hydrology in infrastructure design and construction
- consider shallow groundwater hydrology in road design and construction.

Options for remediation of contaminated sites include:

- treat surface soil
- fence salt affected areas and allow vegetation regrowth
- dispose of pumped groundwater to ponds
- install surface drainage
- install subsurface drainage.

This is not an exhaustive list, and other management solutions may be implemented. The above options are described in further detail below.

6.9.1.1 *Retain and/or Establish Vegetation*

Trees reduce the shallow groundwater level by absorbing water through the roots and releasing it through evapotranspiration. Retaining remnant vegetation and or establishing vegetation (without irrigation), including crops such as lucerne, will help to prevent the surface expression of salts.

Retaining or establishing vegetation will have the greatest benefit in groundwater transmission and recharge areas. Planting in discharge areas is not advisable due to the high salt concentrations. In areas of high groundwater recharge, native vegetation should be protected, maintained and rehabilitated if necessary. Typically, these are areas in the upper parts of catchments on hills and ridge-tops with shallow soils.

6.9.1.2 *Increase Groundcover*

The improvement of groundcover on a soil surface aims to reduce evaporative capillary rise and reduce the amount of water drained into the watertable. The groundcover can be increased using native species, perennial pastures or cropping. Increasing groundcover can be used to both prevent and remediate salinity.

6.9.1.3 *Intercept and Reuse Pumped Groundwater*

Where groundwater level rise has resulted (or has the potential to result) in the surface expression of salts, groundwater bores can be used to intercept and reduce groundwater flows. Groundwater bore locations depend on a variety of factors, such as the extent of the aquifer, ability of the aquifer to drain water freely, the diameter and design of the bore and the pumping interference from other bores. If suitable, the water can be reused in the surrounding area for irrigation or stock.

6.9.1.4 *Control Water used for Dust Suppression*

Dust control with water will be considered in context of the landform and location to groundwater level, drainage lines and sensitive receptors. To minimise water volumes used for dust suppression, QGC will seek to stabilise the soil structure by increasing groundcover. QGC does not intend to use Associated Water for dust suppression with TDS greater than 2,000 mg/L.

6.9.1.5 *Consider Hydrology in Infrastructure Design*

The compaction of land to create infrastructure hardstand areas and roads can initiate secondary salinity by restricting groundwater movement. The road and hardstand areas are susceptible to damage from processes associated with salinity. Hardstands and roads will be constructed to minimise salinity impacts through a site assessment prior to designing and constructing infrastructure and hardstands roads in high-risk landscapes.

6.9.1.6 *Fence off Salt-Affected Areas*

Fencing off salt-affected areas will allow for natural regrowth, which increases the groundcover and reduces the evaporative capillary rise. The site will be excluded from stock grazing and anthropological change. QGC considers this to be a short-term option requiring significant monitoring and will generally be used only for small sites (<1ha). Other rehabilitation techniques will be used in combination with fencing and regrowth.

6.10 CONCLUSION

This chapter has identified potential sources of land contamination from the following activities:

- Associated Water management
- saline brine processing, storage and transport
- drilling of wells (e.g. mud management)
- hydraulic fracturing
- chemicals used in weed management, cleaning and corrosion inhibitor.
- sewage management
- borrow pits
- secondary salinity.

Mitigation measures have been presented to minimise as low as reasonably practicable the potential for land contamination. Associated Water management, including unplanned release of Associated Water, brine evaporation and salt disposal, presents the greatest potential for long-term land contamination. QGC will conduct risk assessments and develop and implement the appropriate design, construction and operations standards to minimise the potential for land contamination from these sources. A number of design, construction and operational methods for untreated water storage ponds, brine storages and salt landfills have been presented. QGC considers these to be a robust framework against which detailed design, construction and operational requirements will be developed.

QGC is investigating options for disposal of salt other than in a salt landfill. However, should a landfill be required, its design, construction, operation and decommissioning will minimise any potential for contamination. QGC accepts responsibility for the long-term management of any salt-disposal landfill.

With effective management and mitigation measures, it is not expected that any significant land contamination will occur. If contamination was to occur, QGC would remediate all contaminated sites.