15.0
Brine and salt management

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#	Department Condition		Description	Completion date	Status
	Pre-Dec 2012	Post-Dec 2012			
48	49 x		Confirmation that salt regulated waste facility is approved	October 2014	○
49			Construction of the first regulated waste facility cell	October 2015	○

● Commitments completed
○ Commitments work in progress
△ Evergreen Commitments
● Firm deliverables for that month

Treatment of CSG water using reverse osmosis technology results in 97% recovery of treated water for beneficial use. However, the by-products of brine concentrate and associated salt require their own management plan. QGC is developing two effective solutions in parallel – the first is the establishment of a Regulated Waste Facility to contain mixed salts in an engineered landfill and the second is the technical and economic feasibility of Selective Salt Recovery to separate various industrial grade salt products for re-sale.

QGC's approach to CSG water management is to maximise its beneficial use. The reverse osmosis (RO) treatment plants produce 90% usable water for potential beneficial use. The residual 10% (RO reject) is further treated, recovering another 7 to 8% of usable water yielding a small remaining concentrated brine stream. QGC can safely store aggregate water brine in dedicated ponds until late 2018.

QGC is progressing with its base case brine management solution of mechanical crystallisation and disposal to a regulated waste facility (RWF) and Selective Salt Recovery (SSR) in parallel and will complete FEED for both solutions in December 2013.

15.1 DEHP REQUIREMENTS

QGC is following the DEHP's Coal Seam Gas Water Management Policy (2012) which sets out the brine prioritisation hierarchy for managing saline waste based on two key priorities:

- Priority 1 – Brine or salt residues are treated to create usable products wherever feasible; and
- Priority 2 – After assessing the feasibility of treating the brine or solid salt residues to create usable and saleable products, disposing of the brine and salt residues in accordance with strict standards that protect the environment.

In resolving the management of brine and salt as part of the management of CSG water, the Policy states operators must demonstrate that Priority 1 has been fully considered and determined not to be feasible prior to considering Priority 2. For any proposal using a method of managing brine or solid salts that is lower than Priority 1, the operator must demonstrate why alternative approaches could not be used.

The following alternatives are being evaluated:

- Regulated Waste Facility (RWF) – Mechanical crystallisation and long-term containment of mixed salt products in an engineered landfill is QGC's base case as described in QCLNG's EIS. Concept design has been undertaken to define key parameters, site selection activities have identified a number of preferred locations and pre-FEED activities are underway to accurately define all elements of the solution.
- Selective Salt Recovery (SSR) concept – QGC has undertaken pilot plant investigations to assess the technical viability of the separation of various salts into industrial grade products that would enable commercialisation. The pilots demonstrated the process was technically feasible with attention then turning to preliminary front-end engineering design to scale up the pilot process, confirm technical design for the full-sized facility and determine commercial feasibility.

- Ocean Outfall – QGC does not consider this approach viable, given firstly the proximity of a World Heritage Site (The Great Barrier Reef) and the difference in chemical composition of the brine and ocean water and secondly the pipeline distance through densely populated areas.
- Reinjection of brine into a natural underground structure – QGC does not consider this approach viable on its tenements, as it has not yet been able to identify an underground structure which is:
  - Large enough;
  - Does not contain groundwater; and
  - Geologically isolated from aquifers.

In July 2011, QGC outlined its approach to brine management in a submission to an Australian Senate hearing. The base case outlined in the submission was for brine to be managed by crystallisation with long-term storage of salts in a RWF on QGC-owned land. However, QGC explained that it was also pursuing a potentially better salt management solution by actively investigating the feasibility of technical and commercial SSR.

15.2 REGULATED WASTE FACILITY (RWF)

Following completion in 2012 of preliminary engineering design for a Regulated Waste Facility (RWF), pre-FEED is now being undertaken in four streams:
- Site selection;
- Mechanical crystalisers;
- Site layout and design; and
- Best available technology analysis.

QGC is proceeding with the base case of placing salt into a purpose-built licensed and regulated waste disposal facility on QGC-owned land until such time as SSR is proven to be technically and commercially feasible.

A block flow diagram of the proposed infrastructure associated with the RWF is provided in Figure 15-1.

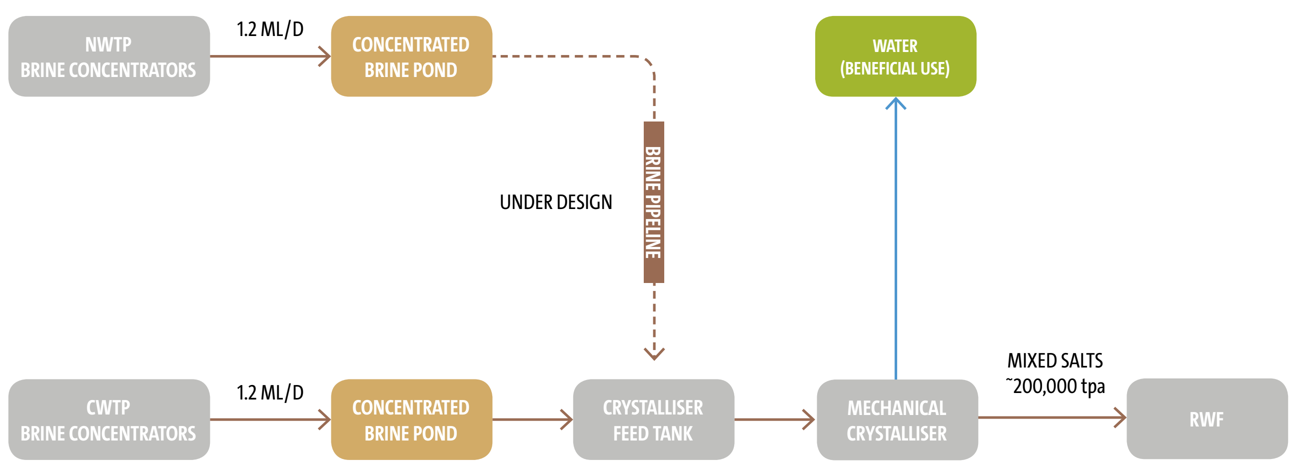

Figure 15-1 – RWF block flow diagram

15.2.1 PROPOSED LOCATION

The proposed RWF site would be located on QGC-owned land close to the Kenya WTP near Miles. Site selection processes have identified Kangra Hills (about 200 m south of Orana 1 pond and the Kenya WTP) as the preferred site for the RWF. A site location map is provided in QGC's Stage 2 WMMP (Figure 6-2) and Appendix CC.

Mechanical crystallisers will be installed at the Kenya WTP to produce a mixed waste salt from the concentrated brine which could be transported to the RWF.

For the Northern gas fields' Northern WTP, a brine pipeline to Kenya WTP will be installed, with mechanical crystallisation at the Kenya site.

15.2.2 APPLICABLE CODES

Conceptual design has adopted minimum standards for design, operation and rehabilitation for conventional Queensland landfill facilities accepting general waste and/or some regulated waste for co-disposal and addressing risk areas associated with solid salt disposal. Reference is also made to industrial waste guidelines for facilities in Victoria and New South Wales.

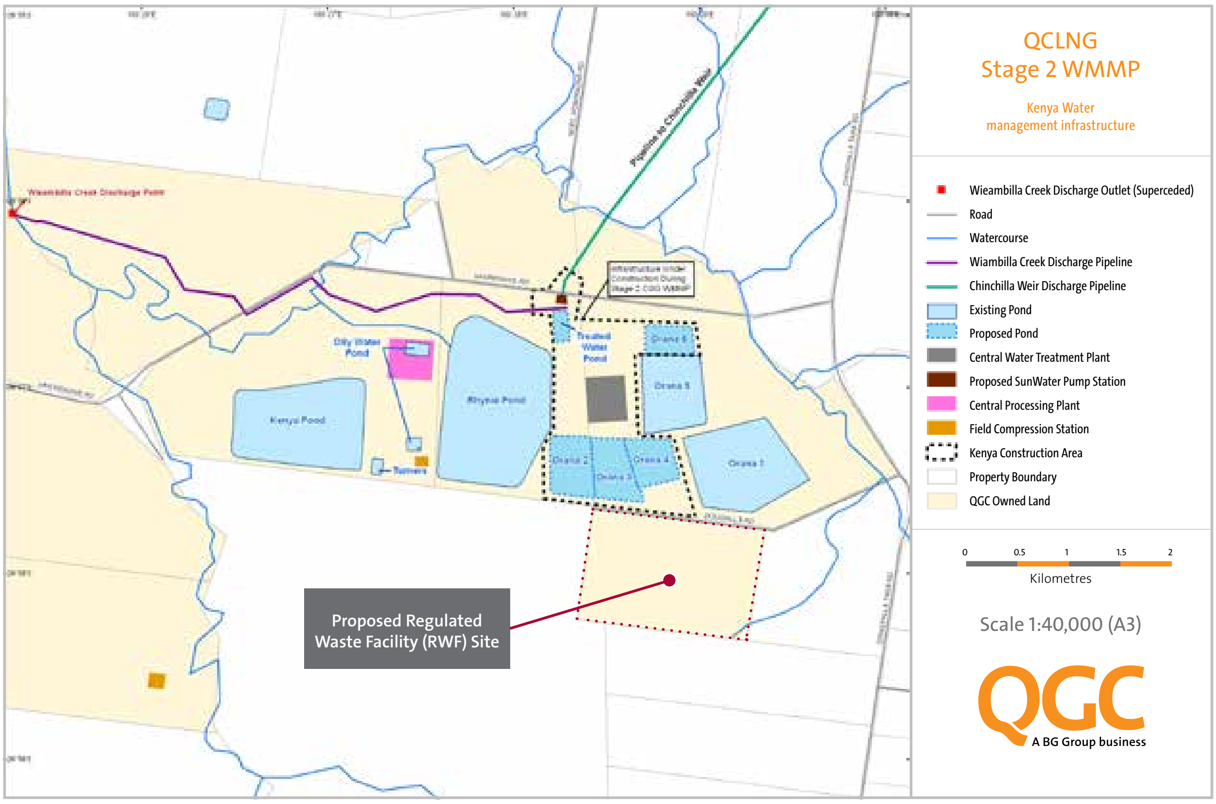

Figure 15-2 – Kenya water management and infrastructure

Guideline	Relevant Act	Section
DEHP Guideline (2010) ERA 60-Waste Disposal Landfill siting, design, operation and rehabilitation	Environmental Protection Act 1994 (Qld)	**Ch 5A**
DEHP Guideline (2010) Environmental Act 1994 – Oreparing an environmental management plan for coal seam gas activities	Environmental Protection Act 1994 (Qld)	**Ch 5A**
	Petroleum and Gas (Production and Safety) Act 2004 (Qld)	**Ch 3**
	Environmental Protection Act 1970 (VIC)	**Ch 10**
Best Practice Guidelines for Landfills Accepting Category C Prescribed Industrial Waste, prepared by EPA Victoria and dated April 2007		
Draft Environmental Guidelines for Industrial Waste Landfilling, prepared by NSW Environmental Protection Authority, dated April 1998	Waste Minimisation and Management Act 1995 (NSW)	
	Waste Minimisation and Management Regulation 1996 (NSW)	
	Pollution Control Act 1970 (NSW)	
DEHP (2010) Coal Seam Gas Water Management Policy	Environmental Protection Act 1994 (Qld)	**Ch 5A**
	Petroleum and Gas (Production and Safety) Act 2004 (Qld)	**Ch 3**
EA PEN10002027	Environmental Protection Act 1994 (Qld)	

Table 15-1 – Guidelines used in RWF conceptual design

15.2.3 SIZING AND PHASING

An RWF conceptual design study has been completed based on salt production of about 4.5 million tonnes for the life of the project.

The RWF monocell design strategy is based on the 'dry tomb' concept in that the objective for minimising environmental impacts is to minimise the amount of leachate or brine generated during the life of the facility and to maintain the solid salt within the monocell containment system.

Key objectives in developing a regulated waste disposal facility include:

- To ensuring that the monocell(s) are located above the local groundwater table;
- To minimise the monocell(s) footprint; and
- To rehabilitate the monocell(s) progressively as each is filled.

The site footprint is subdivided into 12 discrete monocells, each with a mixed salt capacity equal to 20 months' production. During site establishment, fencing, access roads and storm water infrastructure will be constructed. The estimated overall site footprint is 100 ha with an estimated total monocell area of approximately 40 ha.

In the following pages, an overview of the RWF concept is presented. Figure 15-3 shows the conceptual RWF layout and its key features. Figures 15-4, 15-5 and 15-6 illustrate the barrier design for the base and walls, along with the capping design for each monocell. Figure 15-7 shows a cross-section with each of these three components in place.

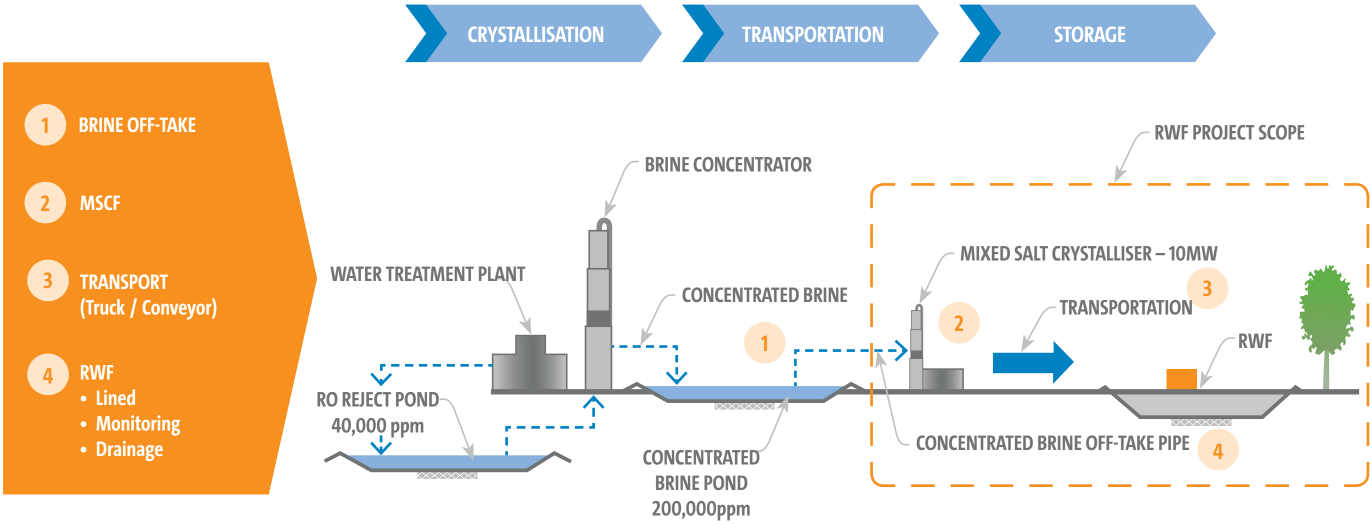

Figure 15-3 – Conceptual RWF layout

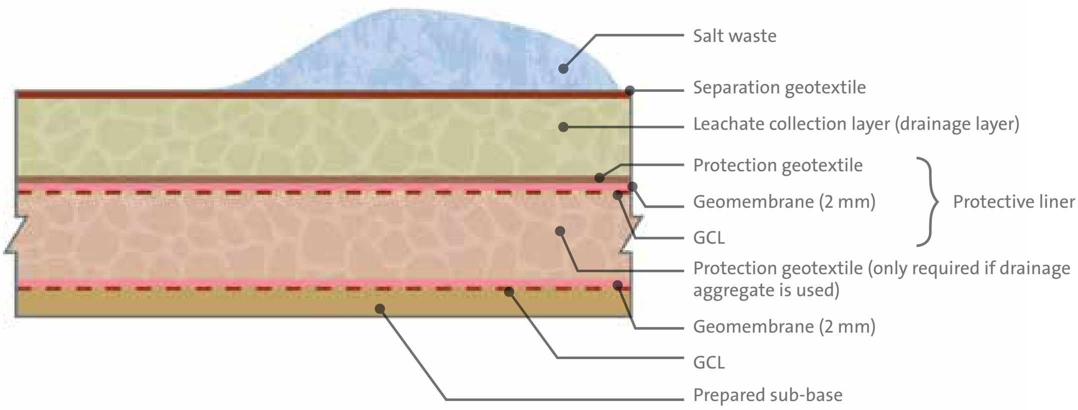

Figure 15-4 – Conceptual RWF base barrier design

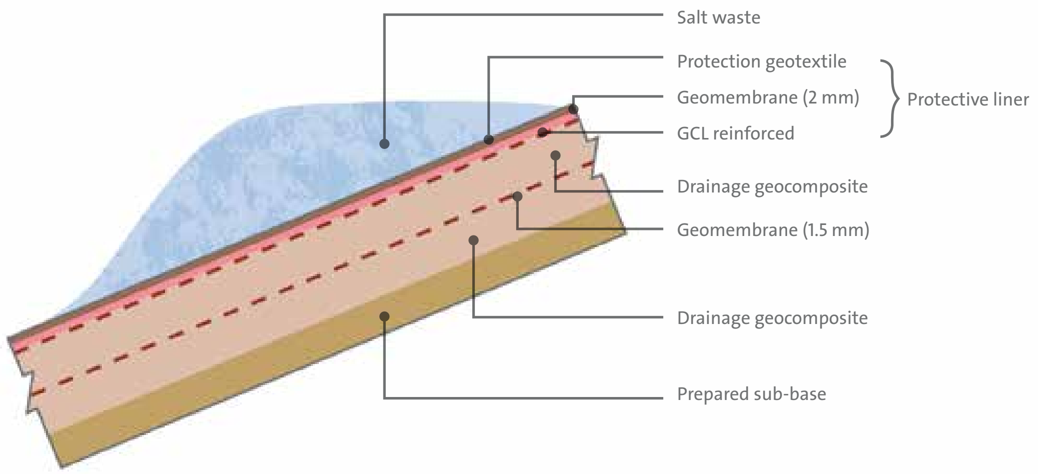

Figure 15-5 – Conceptual RWF wall barrier design

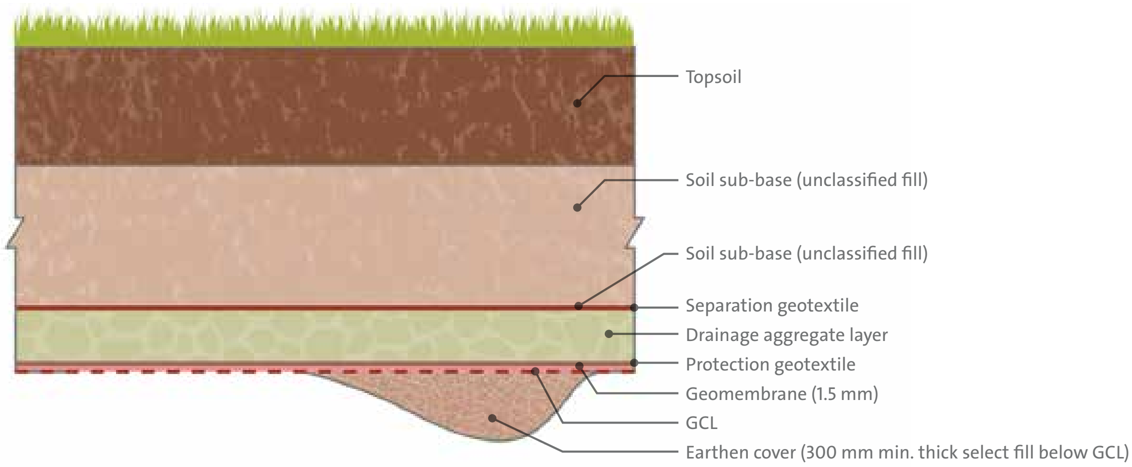

Figure 15-6 – Conceptual RWF capping design

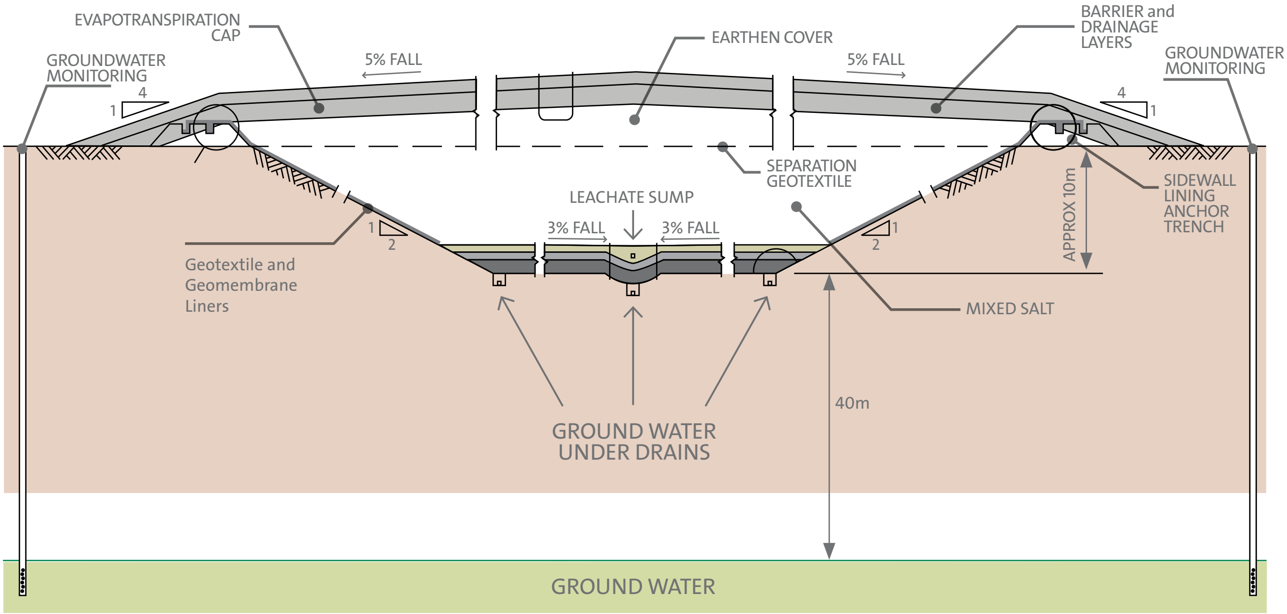

Figure 15-7 – RWF monocell cross-section

The first monocell area would be cleared and grubbed, followed by excavation and installation of groundwater, leak detection and primary and secondary leachate barrier and collection systems. These systems will include ongoing water quality monitoring.

As this monocell is being filled, construction would commence on the next monocell. Excavated material would be used for capping previously filled monocells followed immediately by rehabilitation work.

This sequential excavation, construction, filling and rehabilitation process would continue with storm water infrastructure and access roads extended as required.

During the RWF post-closure period, ongoing works will include:

- Final cap inspection for erosion or slumping with corrective action as necessary;
- Stormwater drain and pond inspection for erosion and silting with corrective action as necessary;
- Leachate removal from leachate extraction risers;
- Leachate monitoring in the leak detection systems and from the subsurface drainage system;
- Environmental monitoring and groundwater and surface water testing; and
- Corrective actions as necessary.

15.2.4 GROUNDWATER AND GEOTECHNICAL INVESTIGATIONS

As part of the pre-FEED activities, site specific investigations at Kangra Hills have been undertaken to confirm key design criteria including the following:

- Detailed topographical studies;
- Targeted geotechnical studies;
- Targeted hydrogeological assessment, including groundwater level and quality investigations and modelling;
- Surface hydrology assessments; and
- Confirmation of environmental and operational buffer requirements.

Results will contribute to further activities such as development of CAPEX/OPEX estimates, operational and maintenance plans for comparison against brine management alternatives.

15.2.5 BEST AVAILABLE TECHNIQUE (BAT)

As part of the pre-FEED process a Best Available Techniques (BAT) process is underway. This process provides a structured methodology for development of a BAT assessment and chosen option justification. Outcomes of the BAT assessment will be integrated into the RWF pre-FEED design and QGC's risk management processes.

The BAT process assists with the difficult challenge of balancing environmental performance and financial cost while streamlining the evaluation process for determining the most appropriate engineering solution project. The BAT assessment is essentially an option analysis, involving high-level cost/benefit analysis and an appraisal of the advantages and disadvantages of each option.

The objective of a BAT assessment is to identify the option that minimises environmental risk to as low as reasonably practical. Key identified risks can be managed from the outset.

An indicative timeline for the RWF project is provided in Figure 15-8.

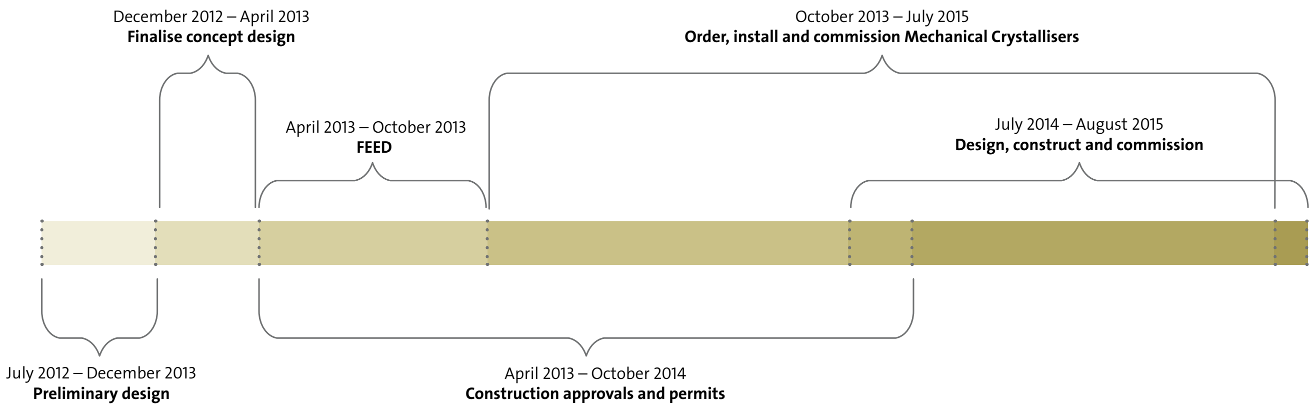

Figure 15-8 Regulated Waste Facility Timeline

15.2.6 PERMITTING APPROACH

Environmental Authority (EA) PEN100020207 for Kenya Walloon area and PEN101741410 Woleebee Creek authorises QGC to carry out gas field development and related activities which includes management of CSG water and brine for the purposes of the Environmental Protection Act 1994 (QLD) (EP Act).

See Figure 15-8 for RWF permitting and construction timeline.

	Estimated end date
Concept design finalised	Q3 2013
Detailed design finalised for RWF	Q4 2014
Site establishment	Q3 2015
Design and construction of crystallisers	Q2 2016
Construction of first cell	Q2 2016
Pipeline commissioned (all segments)	Q4 2016

Table 15-2 – RWF permitting and construction timeline

15.3 ALTERNATIVE BEING PURSUED – SELECTIVE SALT RECOVERY (SSR)

The Selective Salt Recovery (SSR) Project prospectively offers QGC one of the best environmental outcomes in brine management. While it is the preferred outcome, it is not yet technically nor commercially proven.

The concentrated brine stream is likely to contain about 210,000 mg/kg of total dissolved solids made up primarily of sodium bicarbonate, sodium carbonate, and sodium chloride.

The SSR Project aims to separate the salts and recover commercial grade sodium chloride (salt) and sodium carbonate (soda ash). The fractional crystallisation process on sodium bicarbonate/carbonate streams and on sodium chloride streams (and the other impurities requiring pre-treatment) is technically unproven on a commercial scale–using all three streams containing all three components in the ratios present in CSG water.

QGC formed a $20 million collaboration with APLNG and Arrow Energy trialling four separate pilot plant technologies. The trials began in July 2011 with results suggesting the process is technically viable. Pilot evaluation phases shortlisted two preferred technologies. Phase 2 pilot assessments are being undertaken to confirm removal pathways for a range of impurities to ensure commercial grade products are produced. Preliminary front-end engineering will then be undertaken to scale up the pilot plant designs to full-scale facilities, further assess technical capability and confirm commercial viability. Trial photos are presented in Figure 15-9.

Figure 15-9 – SSR Pilot Plant and bench testing

The Phase 1 Brine Pilot Program objectives were:

- To determine process and equipment requirements to produce suitable commercial quality and yield of selected salts (sodium bicarbonate or sodium carbonate and sodium chloride);
- To determine quantity and quality of waste stream generated to determine disposal options;
- To determine operating parameters and costs (labour, fuel, power, reagents); and
- To apply scale-up factors on capital and operating cost estimates to determine the viability of one or more SSR plants.

Outcomes of the pilot program identified compounds within the salts requiring pre-treatment to ensure industrial grade product quality is maintained. A block flow diagram of the full-scale SSR process is provided in Figure 15-10.

QGC, APLNG and Arrow will continue their collaboration approach during the pre-FEED for SSR to ascertain the technical and commercial viability of a centralized SSR facility for all three projects. This scope includes:

- A concentrated brine pipeline network transporting concentrated brine to a single processing location. With amendment approval in October 2012 to the Queensland Petroleum and Gas Act 2004, permission for brine pipelines to cross tenements has been provided;
- A single full-scale SSR plant located at Bellevue, south of the Condamine Power Station. Site location plans are provided in the Stage 2 WMMP's Appendix CC.
- Export to market approach;
- Disposal of residual 5% waste; and
- Disposal of condensate.

A delivery timeline for the SSR facility is shown in Figure 15-11.

If QGC changes its brine disposal base case, a WMMP amendment will be lodged with The Department.

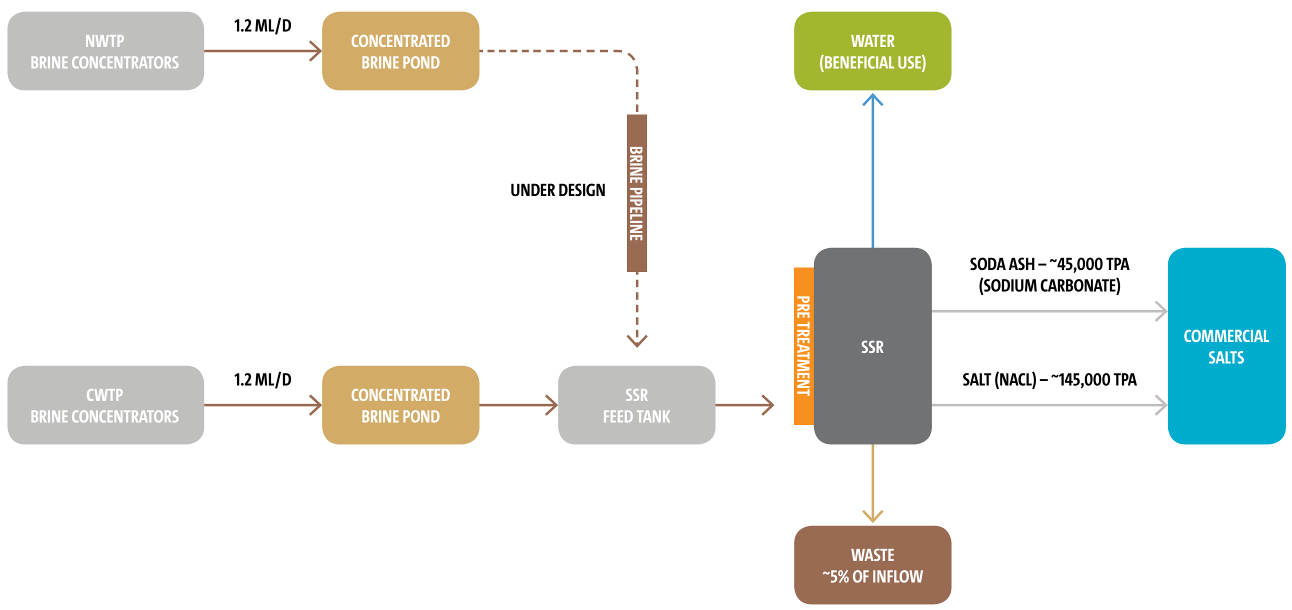

Figure 15-10 – SSR Block Flow Diagram

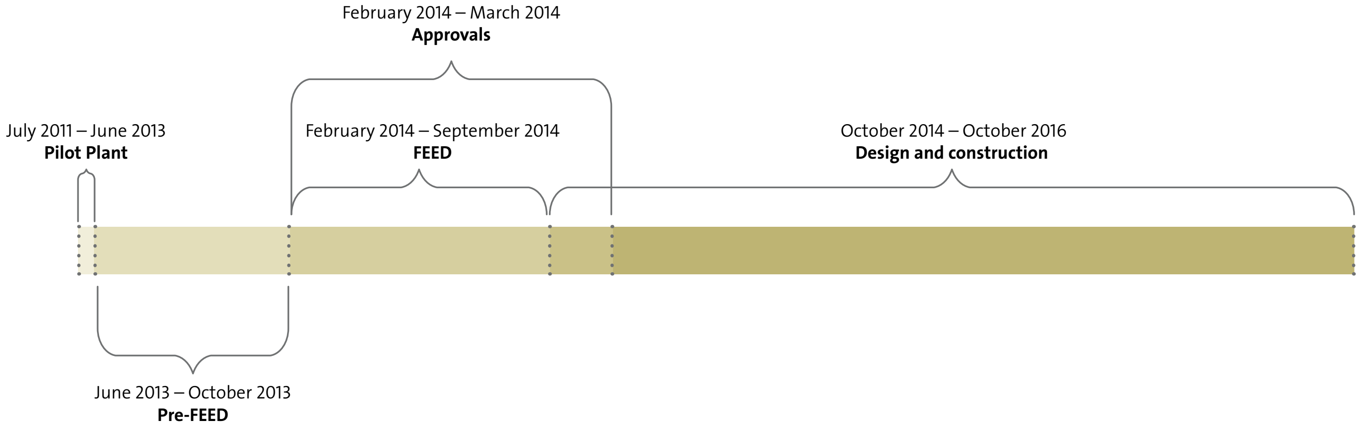

Figure 15-11 – Selective Salt Recovery Timeline

15.4 BRINE PRODUCTION VOLUMES (ANNUAL)

QCLNG Project brine production volumes are expected to be considerable, varying in direct proportion to raw CSG water extraction and its total dissolved salts (TDS) content. Field Development Plan forecasts (FDP) of predicted raw water volumes are updated regularly as more data becomes available. Chemical analysis of the most recent raw water production allows for predicted brine and salt production to be updated.

Figure 15-12 and Figure 15-13 show predicted annual Concentrated Brine (CB) volumes over time for each Water Treatment Plant. In line with raw water production profiles, concentrated brine production peaks in the early years and then declines.

15.5 SALT PRODUCTION TONNAGES

Currently, salt production estimates for the project are unchanged from the Draft EIS (July 2009) document showing about 4.5 million tonnes of salt (or 4.0 million tonnes removing the 15% moisture content) over the life of the project. In the Supplemental EIS (July 2010), QGC estimated some 5.4 million tonnes.

15.6 CONCENTRATED BRINE COMPOSITION

As estimated chemical analysis of the total concentrated brine stream based on the combined weighted average from the Kenya WTP and Northern WTP is provided in the QGC Stage 2 WMMP's Appendix CC.

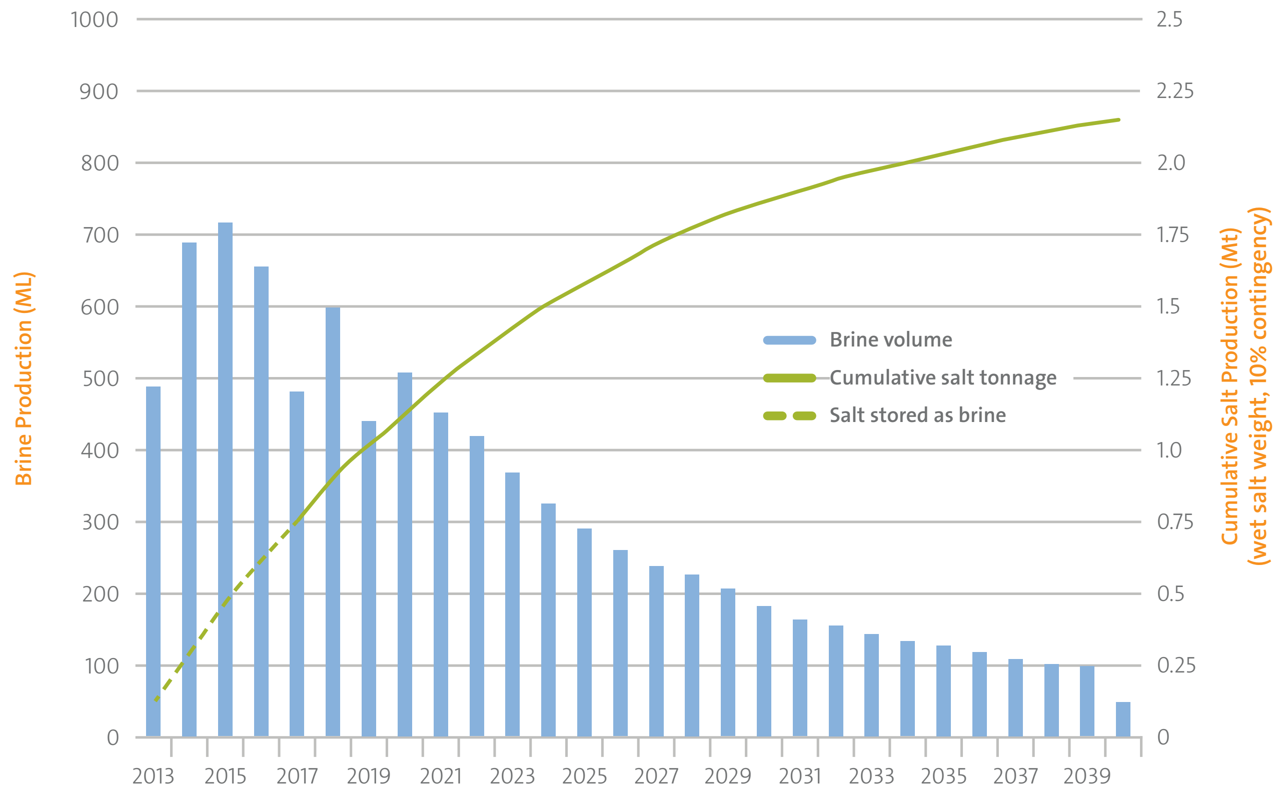

Figure 15-12 – CWTP concentrated brine production forecast

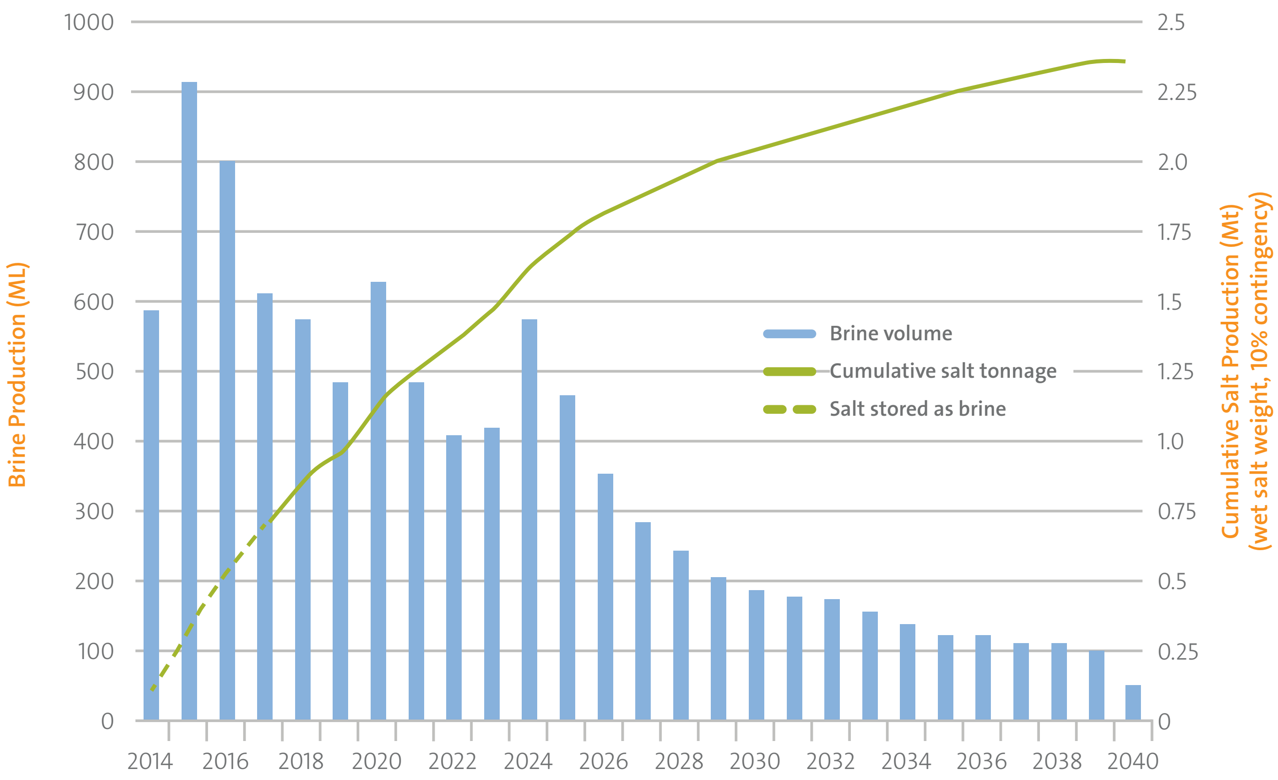

Figure 15-13 – NWTP concentrated brine production forecast

15.7 BRINE PONDS

For each Water Treatment Plant, one lined pond will store RO reject and is required for the life of the facility as buffer storage between the RO plant and the Brine Concentrator (BC) for use during plant shutdowns. Given the expected 90% availability for the brine concentrator, these ponds are likely to remain empty unless needed as buffer storage.

Additional ponds are being designed to store concentrated brine from the brine concentrators to hold peak flows (relevant in the initial years) before they are fed at a lower feed rate into the crystallisers. This lower feed rate allows the size of the crystallisers to be optimised over field life. These ponds will hold some level during the first 15 to 20 years. Figure 15-14 provides an overview of how the ponds will be used.

By 2015, each water treatment plant's planned concentrated brine storages should only reach around 50% to 70% full before commencement of off-take from these ponds to crystallisers and RWF.

Name of regulated dam	Status	Spillway capacity (m^3/s)	Maximum surface area (ha)	Maximum operational volume (ML)	Design storage allowance (m^3)	Mandatory reporting level (RL m)	Maximum depth of dam (m)
Orana 2* (CB Pond)	Approved by DEHP for construction start**	3.2	18.3	1,280	165,000	319.45	13.2
Orana 3 (CB Pond)	Approved by DEHP for construction start**	4.5	20.0	1,040	185,000	319.45	10.3
Total Storage				**2,320**			
Orana 4*** (RO Reject Pond)	Approved by DEHP for construction	4.4	15.6	752	139,155	319.45	9.4

** ORA-C-011-RPT_0 Table 3*
*** Final approval pending submission of final design details*
**** ORA-C-005-RPT_0 Table 3*

Table 15-3 – Kenya Brine Ponds under Environmental Authority PEN 100020207

Name of regulated dam	Status	Spillway capacity (m^3/s)	Maximum surface area (ha)	Maximum operational volume (ML)	Design storage allowance (m^3)	Mandatory reporting level (RL m)	Maximum depth of dam (m)
NWTP 3 (RO Reject Pond)	Currently under design	–	~11.5	~600	–	–	–
NWTP 4 (CB Pond)	Currently under design	–	~28	~1,200	–	–	–

Table 15-4 – Woleebee Creek Brine Ponds under Environmental Authority PEN 101741410

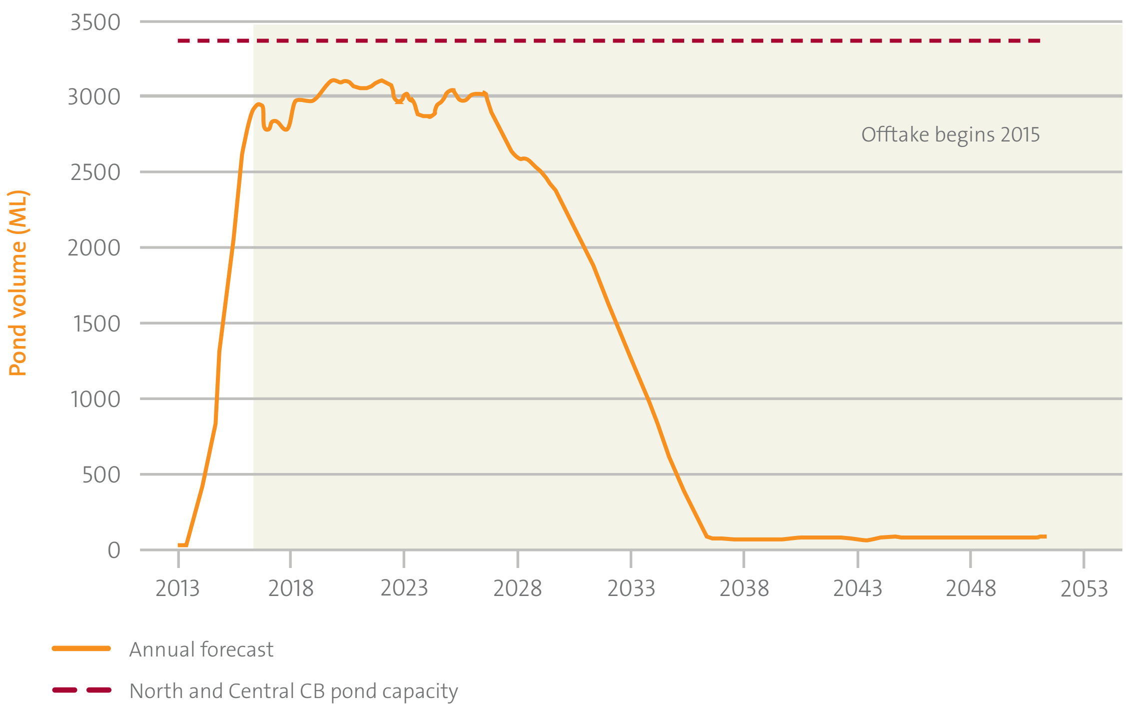

Figure 15-14 – CWTP and NWTP Concentrated Brine Pond volume and capacity

15.8 EA APPROVALS AND APPLICABLE CODES

Brine ponds are likely to constitute high hazard regulated dams and will be required to comply with relevant conditions of EA PEN 100020207 Section D – Dams (Kenya) and EA PEN 101741410 Section C – Dams (Woleebee Creek) (Refer QGC's Stage 2 WMMP Appendix CC). In particular:

- (C6/D6) 'All regulated dams must be designed by and constructed under the supervision of a suitably qualified and experienced person in requirements with the most recent version of the 'Manual for Assessing Hazard Categories and Hydraulic Performance of Dams', (DEHP 2010) as amended from time to time.'
  - Design reports for Kenya brine ponds (Orana 2, 3 and 4) were completed, certified by a suitably qualified person and submitted to DEHP.

15.9 SUMMARY

Major activities that have been undertaken include:

- Development of base case for brine management involving crystallisation with the long-term storage of salts in a regulated waste storage facility on QGC-owned land;
- Completion of preliminary engineering design;
- The establishment of a $20 million alliance with APLNG and Arrow Energy trialling four separate pilot plant technologies for Selective Salt Recovery:
  - Site selection; preferred site selected based on multi-criteria optional analysis;
  - Brine pipeline; preferred alignment selected. Landowner negotiations initiated.
  - Pre-FEED; competitive pre-FEED being undertaken; and
  - Design envelopes; OLI chemical modelling completed
- Stage 1 Selective Salt recovery pilots 100% completed. Stage 2 piloting being undertaken to confirm removal pathways of impurities; and
- Technical feasibility outcomes of the piloting process prompted development of a Stage 2 Collaboration Agreement between the parties involving detailed engineering, commercial and contractual structuring of a full-scale SSR facility.

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● Commitments completed
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The above commitments are aimed at satisfying Condition 49g x