NARRABRI GAS PROJECT

Produced Salt Beneficial Reuse and Disposal Study

0041-150-PLA-0006

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Executive Summary

The Narrabri Gas Project (NGP) was granted development consent by the Independent Planning Commission of NSW on 30 September 2020, subject to a number of conditions. Condition B69 required Santos to undertake a Produced Salt Beneficial Reuse and Disposal Study to the satisfaction of the Planning Secretary, prior to commencement of Phase 1 of the Project. No salt will be produced during Phase 1 and Phase 2 of the NGP, and this report identifies the strategy for maximising potential beneficial reuse and disposal options for the brine and salt that will be produced during Phase 3. It also describes the progress and results to date of the various trials, pilot studies and research programs, which are planned to continue during the next 24 to 48 months.

All produced water generated through the Phase 1 and 2 exploration and appraisal activities will be stored in the produced water and brine ponds at Leewood and treated through the existing water treatment facility. The amended treated water will continue to be beneficially reused for irrigation, construction, drilling and dust suppression, with any brine concentrate returned to the ponds. Storing the produced water and brine until Phase 3 will provide larger volumes of concentrated brine, which in turn will be more attractive and economically feasible for commercial salt extraction. The water management infrastructure approved under Phase 2 of the Project consent includes an additional 300 ML storage pond at Leewood and a water treatment plant with a capacity of up to 12 megalitres per day.

Process modelling results predict that the brine produced from the new Phase 3 reverse osmosis treatment process will have a high concentration of beneficial salts, comprising (by weight) of approximately 64 % sodium carbonates and approximately 12 % sodium chloride. The strategy to maximise beneficial reuse of the salt is currently focussing on commercial salt recovery of sodium bicarbonate, and the use of concentrated brine for acid mine drainage neutralisation and for algae farming. It may be possible to combine more than one of the beneficial reuse options currently under consideration. The period up to the commencement of Phase 3 will be used to further develop the various beneficial reuse opportunities through field trials, pilot plants and research programs. Once the details of the beneficial reuse trials and investigations are available, the results will be evaluated using a multi-criteria assessment, confirming the most feasible opportunities for execution.

The salt that cannot be beneficially reused will need to be disposed of at a suitably licenced facility. Confirmation has been received from a number of commercial operators in NSW that their licenced facilities have sufficient capacity and are prepared to accept some or all of the salt estimated to be produced from the NGP, subject to commercial agreement. This provides certainty that there are suitable waste disposal sites willing to accept the NGP salt and with enough assured collective capacity to handle the anticipated volume.

This Produced Salt Beneficial Reuse and Disposal Study will be reviewed and where relevant, updated, prior to the commencement of Phase 2. This will include a review and update of the various beneficial reuse trials and research programs, and a review of the proposed disposal options. Where applicable, the findings from the beneficial reuse trials and research programs will be incorporated into the Salt Management Plan, required under CoC B41(d)(ix), when next revised.

Acronyms and abbreviations

Acronym	Description
µg/L	micrograms per litre
AMD	Acid mine drainage
ANZECC	Australia and New Zealand Environment and Conservation Council
AS/NZS	Australian Standard/New Zealand Standard
$CaCO_3$	calcium carbonate
$CaSO_4$	calcium sulfate (gypsum)
cm	centimetre
CCC	Community Consultative Committee
CO_2	carbon dioxide
CoC	Conditions of consent for the NGP SSD 6456
CoPC	chemicals (or constituents) of potential concern
CSG	coal seam gas
DES	The QLD Department of Environment and Science
DO	dissolved oxygen
DPE	The NSW Department of Planning and Environment
DPE Water	The Water group within DPE
DPIE	The former NSW Department of Planning, Industry and Environment
EC	electrical conductivity
EIS	environmental impact statement
EMP	environmental management plan
EP Act	*Environmental Protection Act 1994* (QLD)
EPA	The NSW Environment Protection Authority
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EP&A Regulation	Environmental Planning and Assessment Regulation 2021
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cth)
EoW	end of waste
GL	gigalitre
ha	hectare
ISO	International Organisation for Standardisation
m	metre
mg/L	milligram per litre
MCA	multi-criteria analysis
ML	megalitre
ML/day	megalitre per day
ML/y	megalitre per year
mm	millimetre

Acronym	Description
Na_2CO_3	sodium carbonate
$NaHCO_3$	sodium bicarbonate
PAL	petroleum assessment lease under the PO Act
PEL	petroleum exploration licence under the PO Act
PO Act	*Petroleum (Onshore) Act 1991* (NSW)
POEO Act	*Protection of the Environment Operations Act 1997* (NSW)
POEO Regulation	Protection of the Environment Operations (General) Regulation 2009
PPL	petroleum production lease under the PO Act
PPLA	petroleum production lease application under the PO Act
PSBRDS	Produced Salt Beneficial Reuse and Disposal Study
PWMP	Produced Water Management Plan
RO	reverse osmosis
RROE	Resource Recovery Order and Exemption
SMS	Santos Management System
SSD	State significant development
TDS	total dissolved solids
µS/cm	microSiemens per centimetre
WARR Act	*Waste Avoidance and Resource Recovery Act 2011* (NSW)
WRR Act	*Waste Reduction and Recycling Act 2011* (QLD)

Table of contents

Tables

Figures

1. Introduction

1.1 Narrabri Gas Project

1.1.1 Background

Resource exploration has been occurring in the north-western area of NSW since the 1960s; initially for oil, but more recently for coal and gas. Santos NSW Pty Ltd began exploring for natural gas from coal seams in north-western NSW in 2008 and is currently conducting coal seam gas (**CSG**) exploration and appraisal activities within Petroleum Exploration Licence (**PEL**) 238, Petroleum Assessment Lease (**PAL**) 2 and Petroleum Production Lease (**PPL**) 3, located in the Gunnedah Basin about 20 kilometres (**km**) south-west of the town of Narrabri. Activities in PAL 2 have focussed on the Bibblewindi and Bohena CSG pilots, whilst recent activities in PEL 238 have focussed on the Dewhurst and Tintsfield CSG pilots.

The Narrabri Coal Seam Gas Utilisation Project (Wilga Park Power Station and associated infrastructure) operates under an existing Part 3A approval under the *Environmental Planning and Assessment Act 1979* (NSW) (**EP&A Act**). It was originally approved in 2008, with various modifications approved between 2011 and 2019. It encompasses a gas gathering system, a compressor and associated flare, a gas flow line from Bibblewindi to Wilga Park within a 10 metre (**m**) corridor with a riser at Leewood and an expansion of the existing Wilga Park Power Station from 12 to 40 megawatts.

Approval to construct the Leewood produced water and brine management ponds was granted in March 2013, with the approval for the Leewood Produced Water Treatment and Beneficial Reuse Project following in August 2015. Subject to a number of conditions, the latter permitted the construction and operation of a purpose-built, centralised water treatment facility at Leewood, to treat produced water and brine from the CSG exploration and appraisal activities.

1.1.2 Current Project

On 30 September 2020, Santos NSW (Eastern) Pty Ltd (**Santos**) obtained consent for State significant development (**SSD**) 6456 to develop the Narrabri Gas Project (**NGP**) (**the Project**). Approval EPBC 2014/7376 under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (**EPBC Act**) was granted on 24 November 2020.

The Project includes the progressive installation of up to 850 new gas wells on up to 425 new well pads over approximately 20 years and the construction and operation of gas processing and water treatment facilities.

The Project area covers about 950 square kilometres (95,000 hectares) and the Project footprint will directly impact only about 1 % of that area. It has been approved to be developed in four defined phases. These are defined under the consent, including:

- Phase 1 - exploration and appraisal;
- Phase 2 - construction activities for production wells and related infrastructure;
- Phase 3 - gas production operations; and
- Phase 4 - gas well and infrastructure decommissioning, rehabilitation and closure.

A more detailed definition of each phase is provided in the conditions of consent (**CoC**) for SSD 6456.

Phase 1 of the Project is defined in the consent as the phase of the development comprising ongoing exploration and appraisal activities in the Project area, including:

- seismic surveys;
- core and chip holes;
- construction and operation of pilot wells (up to 25 wells on up to 25 well pads across the project area); and
- pilot well ancillary infrastructure, including access tracks, gas and water gathering lines, water balance tanks, safety flaring infrastructure, utilities and services, and environmental monitoring equipment including groundwater monitoring bores.

Santos plans to continue exploration and appraisal of the resource in the near term until a final investment decision (**FID**) can be made. The exploration and appraisal activities will include continued operation of Santos' existing wells, infrastructure and facilities in PEL 238 and PAL 2, and construction and operation of new core holes, pilot wells and supporting infrastructure permitted under Phase 1.

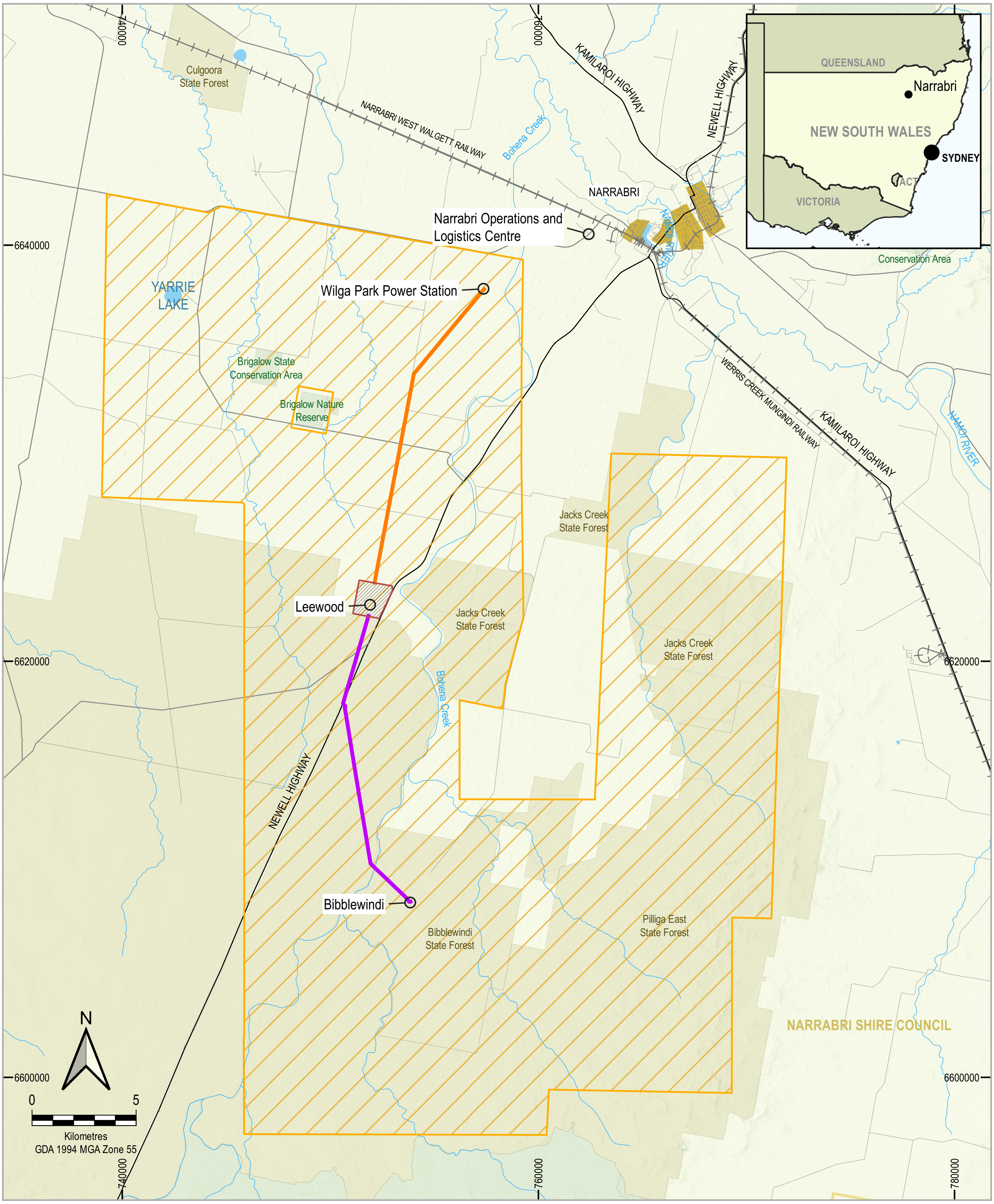
Santos' existing exploration and appraisal activities in PEL 238 and PAL 2 include the following:

- Tintsfield Pilot;
- Bibblewindi East Pilot;
- Bibblewindi West Pilot;
- Dewhurst North Pilot;
- Dewhurst South Pilot;
- Dewhurst northern and southern flow lines;
- Leewood Water Management Facility, including ponds, water treatment plant and irrigation area;
- Bibblewindi Facility, including gathering system, water balance tank, compressor and flare; and
- Bibblewindi to Leewood buried gas pipeline.

These exploration and appraisal activities will continue as part of the NGP. The initial, new-appraisal Phase 1 scope is a relatively minor extension to these existing exploration and appraisal activities. It is planned to include the construction and operation of:

- 4 coreholes;
- 6 pilot wells;
- 2 deep reservoir monitoring bores (converted coreholes);
- new shallow water monitoring bores;
- associated linear infrastructure;
- seismic surveys (length and location to be determined); and
- continued operation of Santos' existing exploration and appraisal activities.

The Project will use existing gas flow lines, risers and gas gathering systems, and some additional infrastructure to support the Project will be located in the same corridor that was part of the Wilga Park approval. Figure 1.1 identifies the location of key assets and infrastructure, and the indicative Phase 1 footprint.



Source: Geoscience Australia (2011); NSW Spatial Services (2019)

LEGEND

- Project Area
- Leewood
- Urban Areas
- State Forests
- State Conservation Area, Aboriginal Area
- Lakes and Dams
- Watercourses
- Railway
- Highways
- Major Roads
- Leewood to Wilga Park Infrastructure Corridor
- Bibblewindi to Leewood Infrastructure Corridor
- Local Government Boundary

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NARRABRI GAS PROJECT
PRODUCED SALT BENEFICIAL USE AND DISPOSAL STUDY
FIGURE 1.1 - KEY ASSETS AND INFRASTRUCTURE

1.1.3 Produced water storage

Gas trapped in coal is adsorbed onto the coal surface in cleats and joints or micro pores and held in place by reservoir and water pressures. To extract the gas, it is necessary to reduce the pressure by first removing water (produced water). Typically, water production is higher earlier in the life of a CSG field and declines as gas production increases. The quality of water extracted from a coal seam, like many forms of groundwater, can vary depending on a range of factors including age, depth and the type of geological formation.

The estimated quantity of produced water associated with the Phase 1 activities, including the operation of the existing pilots for exploration and appraisal activities in PEL 238 and PAL 2, is up to approximately 1.26 megalitre (**ML**) per day (**ML/day**). Electrical conductivity is a measure of the saltiness of water and is measured in microSiemens per centimetre (**µS/cm**). Drinking water is usually between 0 and 1,500 µS/cm and typical sea water has a conductivity value of about 50,000 -55,000µS/cm. The average salinity (electrical conductivity) of the produced water at the well head is approximately 14,836 µS/cm.

It is expected that during Phase 1 and 2 there will be adequate capacity in the ponds at the NGP's main water management facilities at Leewood to store produced water and brine. The current Leewood infrastructure, as shown in Figure 1.2, consists of the following:

- two double-lined produced water and brine storage ponds of approximately 355 ML storage capacity, each pond with two cells of approximately 150-170 ML capacity each;
- a water and brine treatment plant to manage water produced during the exploration program, including a 5 ML amended treated water storage tank;
- a storage and utilities area;
- staff amenities and car parking; and
- a 49-hectare irrigation area for beneficial reuse of amended treated water.

All produced water extracted during Phase 1 and 2 will be treated via the existing water treatment facility and the brine produced will be stored in brine ponds until Phase 3 of the Project. The amended treated water has been approved for beneficial reuse on site (drilling, construction, dust suppression and certain rehabilitation activities) and for irrigation of the 49-hectare area. The use of the amended treated water for crop irrigation within a 25-km radius from Leewood is currently the subject of an application to the NSW Environment Protection Authority (**EPA**) for a Resource Recovery Order and Exemption (**RROE**).

Figure 1.2 - The existing produced water and brine storage ponds at Leewood

It is noted that the water management infrastructure approved under Phase 2 of the SSD 6456 consent includes an additional 300 ML storage pond at Leewood (two cells of approximately 150 ML capacity) and a water treatment plant with a capacity of up to 12 ML/day. Any managed release of treated water to Bohena Creek during appropriate flow conditions (i.e. when the flow in the creek equals or exceeds 100 megalitres per day) is also approved as part of Phase 2.

1.2 Purpose and scope

This report presents the results of the Produced Salt Beneficial Reuse and Disposal Study (**Salt Study**) which Santos has undertaken in accordance with the performance measures of CoC B37 and the requirements of CoC B69 and CoC B41(d)(ix).

It is to be noted that no solid salt will be produced during Phase 1 and 2 of the Project and that all brine will be stored in ponds at the Leewood facility. As such, this Salt Study identifies the strategy for maximising potential beneficial reuse and disposal options for the brine and salt that will be produced during Phase 3. It describes the progress to date of the various trials and investigations that are planned to continue during the next 24 to 48 months.

The Salt Study also fulfils the requirement of Project commitment 19.2 in the Project's Environmental Impact Statement (**EIS**) by describing how the solid salt product would be disposed of at an appropriately licenced facility in accordance with regulatory requirements. If this were to occur, this would be the option of last resort, in accordance with the NSW waste hierarchy.

This revision of the Salt Study is applicable to Phase 1 only and will be reviewed and, where relevant, updated prior to the commencement of Phase 2. This update will include the results of the various beneficial reuse trials and research programs, a defined strategy for the beneficial reuse of brine and salt, and include any proposed disposal options. Where applicable, the results and outcomes from the beneficial reuse trials and programs will be incorporated into the Salt Management Plan, required under CoC B41(d)(ix), when that plan is due to be revised. The Salt Management Plan is currently incorporated as section 7 of the Produced Water Management Plan (**PWMP**).

Note that in accordance with CoC A23, the staged approach in the development of the Salt Study was approved by the Planning Secretary on 14 April 2021. The staging applies to the majority of the management plans, strategies and protocols required to be prepared and approved prior to Phase 1, and a copy of the staging approval letter is included in the Environmental Management Strategy for the Project.

1.3 Preparation of this report

This report has been prepared by Mr. Mark Vile of Onward Consulting Pty Ltd, approved by the former NSW Department of Planning, Industry & Environment (**DPIE**) on 17 February 2021 as a suitably qualified expert for the preparation of the Water Management Plan for the NGP, which includes the Salt Management Plan. The Salt Study and the Salt Management Plan are interlinked and cannot be considered separately. Mr. Vile was assisted by Mr. Servaes van der Meulen of Onward Consulting Pty. Ltd. in the development of this report. GHD completed the process and brine chemistry modelling as an input into this report.

1.4 Consultation

As required by consent condition B69, this Salt Study has been prepared in consultation with the EPA, Narrabri Shire Council (**Council**) and the owner of any waste facilities that could be used for the disposal of salt and/or brine, with the primary objective to inform and involve all listed stakeholders during each stage of Salt Study development.

The comments received from the EPA on Revision A of the Salt Study centred around ensuring a relevant RROE is in place for beneficial reuse of brine, The comments provided by Council were more of a general nature, related to ongoing consultation and the support of local industries,

The consultation correspondence and responses to the comments are presented in Appendix A.

1.5 Structure of this report

This report has been structured as follows:

Section 1	Introduces the Project and the context, scope, purpose and objectives of this Salt Study report, and provides details of the current produced water storage and treatment arrangement
Section 2	Outlines the regulatory framework regarding the management and the disposal of solid salt in NSW and QLD, and lists the compliance conditions in full
Section 3	Provides details of the proposed produced water treatment during Phase 3 of the Project, and the expected salt and brine volumes and compositions

Section 4	Provides a multi-criteria analysis framework which will be used for the evaluation of the feasible salt and brine beneficial reuse option(s) identified to date
Section 5	Lists and evaluates the potential beneficial reuse options strategy for the salt and brine produced during Phase 3 of the Project
Section 6	Considers and evaluates the potential disposal options strategy for waste salt and brine
Section 7	Provides a summary conclusion of the report, detailing the strategy to maximise beneficial reuse options during Phase 3 of the Project
Section 8	Glossary
Section 9	References
Appendix A	Consultation records
Appendix B	NSW and QLD waste classification threshold criteria
Appendix C	Disposal facilities letters of commitment

1.6 Distribution

A copy of the approved Salt Study will be made available to all Santos personnel via the Santos intranet. In accordance with consent condition D13(a), the Salt Study will also be made publicly available on the Project website following approval by the NSW Department of Planning and Environment (**DPE**). Any subsequent revision of the Salt Study approved by the DPE will be made publicly available on the website, and the superseded version will be removed to ensure the information is kept up to date in accordance with CoC D13(b).

Note that any printed copies of this Salt Study are uncontrolled.

2. Regulatory framework and requirements

This section provides a summary of the respective NSW and QLD State legislation directly relevant to the management of any salt and brine produced by the Project. It further provides an overview of the applicable consent conditions, and any measures, standards, policies and guidelines that apply. Note that there is no Commonwealth legislation that is applicable to the disposal or beneficial reuse of salt and brine, generated through the treatment of produced water. Queensland legislation is discussed since the option for beneficial reuse or disposal within QLD could be considered.

2.1 NSW legislation

2.1.1 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (NSW) (**POEO Act**) regulates pollution through the control of an environment protection licence (**EPL**). Activities requiring an EPL are listed in Schedule 1 of the Act and include petroleum exploration, appraisal and production. Santos is the holder of EPL 20350 for its current petroleum activities in the Narrabri area. The POEO Act also:

- defines 'waste' for regulatory purposes;
- establishes management and licensing requirements for waste;
- defines offences relating to waste and sets penalties; and
- establishes the ability to set various waste management requirements via the Protection of the Environment Operations (Waste) Regulation 2014; and
- defines the various classes of waste in NSW in Section 49 of Schedule 1.

There are several EPL 20350 conditions that relate to waste management, however there are no conditions with specific requirements related to the management, beneficial reuse or disposal of salt and brine.

2.1.2 Protection of the Environment Operations (Waste) Regulation 2014

The Protection of the Environment Operations (Waste) Regulation 2014 (**Waste Regulation**) allows the EPA to protect human health and the environment, and provides a platform for a modern and fair waste industry. It includes strict thresholds for environment protection licences, and outlines the waste levy system. The Waste Regulation is supported by the Waste Levy Guidelines, addressed below in section 2.4.6. The ‘waste levy’ aims to reduce the amount of waste being landfilled and promote recycling and resource recovery. Certain licensed waste facilities are required to pay a contribution for each tonne of waste received at the facility, and the guidelines specify how to calculate waste levy liabilities or deductions and outline the EPA's requirements for records, surveys and reports.

Clause 71 of the Waste Regulation (known as the ‘proximity principle’) provides that waste generated in NSW (other than restricted solid waste) must not be transported to any place, in or outside of NSW, unless that place can lawfully be used to accept the waste and one of the following applies:

- the place is 150 kilometres or less (measured in a straight line) from the premises of origin of that waste; or

- the place is more than 150 kilometres from the premises of origin and is the closest or second closest to those premises that can lawfully be used for the disposal of that waste[1].

While this requirement was subsequently found to be unlawful as acknowledged by the NSW EPA in August 2017, Santos has evaluated landfills in NSW and QLD which are licenced to accept the type and volume of waste to be generated by the Project, with consideration of the proximity principle. Refer to section 6 for further details.

2.1.3 Waste Avoidance and Resource Recovery Act 2011

The *Waste Avoidance and Resource Recovery Act 2011* (NSW) (**WARR Act**) promotes waste avoidance and resource recovery to achieve a continual reduction in waste generation. The NSW waste management hierarchy, as presented in Figure 2.1, underpins the objectives of the WARR Act. The hierarchy establishes a set of priorities for the efficient use of resources and provides a foundation to transfer to a circular economy:

- Avoid - choose a process so as to avoid the production of the waste;
- Reduce - review the process and raw materials to reduce the waste;
- Reuse - reuse as much as possible in the process to minimise the waste;
- Recycle - use the waste stream as a raw material in a different process or as an alternative source of energy/fuel;
- Treatment - appropriately treat waste and/or neutralise residuals; or
- Disposal - dispose of waste responsibly using appropriate methods.

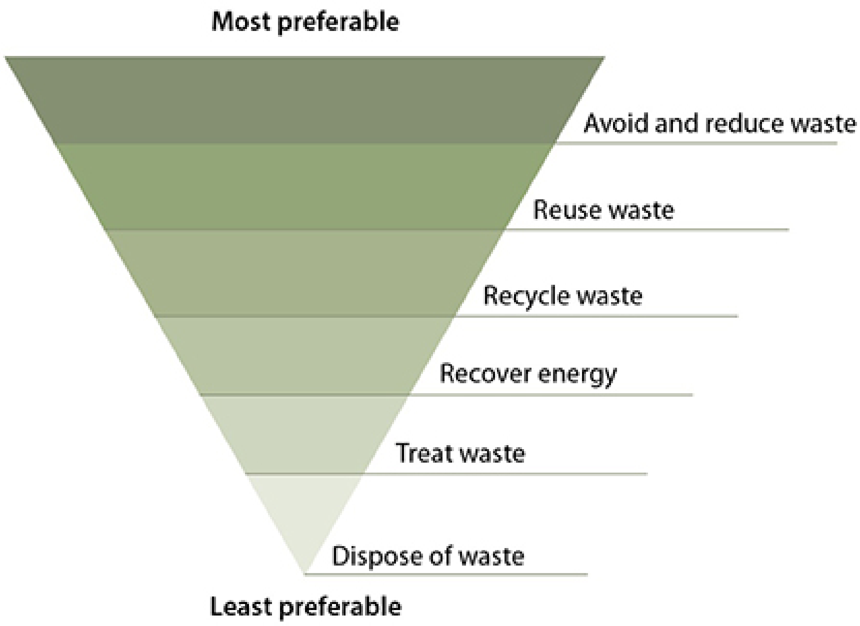

Figure 2.1 - NSW waste management hierarchy

[1]The EPA has recognised that the proximity principle contravenes section 92 of the Australian Constitution and has therefore not enforced it. The EPA acknowledged this publicly at a NSW parliamentary inquiry in August 2017: https://www.parliament.nsw.gov.au/lcdocs/transcripts/2014/Transcript%20-%2017%20August%202017%20-%20CORRECTED.pdf

2.2 QLD legislation

2.2.1 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (QLD) (**EP Act**) is the primary legislation that controls the management of waste in Queensland. The EP Act deals primarily with protecting the environment and managing the pollution impacts of activities, including managing the impacts of waste after it has been generated. Waste is defined in the EP Act as anything that is left over, or an unwanted by-product, from an industrial, commercial, domestic or other activity; or surplus to the industrial, commercial, domestic or other activity generating the waste.

A waste can be approved as an end of waste resource if it meets specified quality criteria for specified use prior to it going to the end user. As per Section 13 of the EP Act, if a waste is approved as an end of waste resource under the *Waste Reduction and Recycling Act 2011,* it is no longer considered a waste for the purposes of the EP Act until it is disposed or otherwise illegally dumped or littered.

2.2.2 Waste Reduction and Recycling Act 2011

The *Waste Reduction and Recycling Act 2011* (QLD) (**WRR Act**) contains a suite of measures to reduce waste generation and landfill disposal and to encourage recycling. The key provisions of the WRR Act include:

- a requirement for Queensland Government agencies and local governments to prepare waste management plans;
- introduction of product stewardship arrangements for any waste products that are identified as a growing problem for landfill in the future; and
- strengthened littering and illegal dumping offences, including public reporting of vehicle-related littering offences.

The WRR Act is underpinned by the QLD waste hierarchy, which is identical to the NSW hierarchy.

The end of waste (**EOW**) framework (refer section 2.3.6) under Chapter 8 and 8A of the WRR Act promotes resource recovery opportunities and aims to transform the perception of waste from being seen as waste to being valued as a resource. The EOW framework consists of:

- EOW codes that relate to any registered resource producers for a code; and
- EOW approvals considered on a trial basis for reusing waste as resources for which an EOW code has not been developed for the waste.

2.2.3 Waste Reduction and Recycling (Waste Levy) Amendment Act 2019

The *Waste Reduction and Recycling (Waste Levy) Amendment Act 2019* (QLD) which came into force on 1 July 2019, amended the WRR Act, imposing a waste levy on 39 of the 77 Queensland local government areas intended to disincentivise the practice of long-distance transport of interstate waste for disposal in Queensland. The waste levy aims to achieve the following:

- reduce the amount of waste going to landfill and encourage waste avoidance;
- provide a source of funding to enable better resource recovery practices;
- provide certainty and security of feedstocks for advanced technology; and
- facilitate industry investment in resource recovery technology.

The Category 1 and 2 regulated waste levies for the 2021/2022 financial year are respectively $165 and $115 per tonne. The QLD classification of the waste salt is further discussed in section 6.1.2.

2.2.4 Environmental Protection Regulation 2019

The regulated waste classification provisions of the Environmental Protection Regulation 2019 (QLD) (**EP Regulation**) are used to identify and appropriately manage the risks associated with various wastes and associated waste management activities. Schedule 9 of the EP Regulation provides a list of regulated wastes and their default category, wastes that are not regulated waste, and categorisation thresholds for solid and liquid tested waste.

Waste generators are responsible for classifying their waste into a risk-based category by either:

- adopting a default waste category from Part 1 of Schedule 9 of the EP Regulation; or
- organising sampling and testing of their waste by an appropriately qualified person to demonstrate an appropriate risk-based category in accordance with section 43 of the EP Regulation.

Regulated waste is subject to tracking requirements, and for any regulated waste originating from outside QLD, the requirements of Chapter 5, Part 9, Subdivision 2 ('Transportation into Queensland') would apply. This triggers a number of responsibilities on the transporter and the receiver.

2.3 Development Consent SSD 6456

Consent conditions B37 and B69 of SSD 6456 are directly relevant to the Salt Study. Table 2.1 specifies where each of the requirements of these conditions are addressed in this report.

As stated in sections 1.2 and 1.3, it should be noted that the Salt Study and the Salt Management Plan required under CoC B41(ix) are closely associated and the majority of the CoC requirements are comparable. Since no salt but only brine will be produced during Phase 1 of the Project, a number of the conditions and requirements of the Salt Management Plan will not be applicable until Phase 2. The Salt Management Plan for Phase 1 is included as section 7 of the Produced Water Management Plan.

Table 2.1 - Development consent conditions

SSD 6456 consent conditions directly relevant to this Salt Study	Section reference
Consent condition B37 states that Santos must ensure that the development complies with the following management performance measures related to salt management:	
• maximise beneficial reuse of produced salt, as far as reasonable and feasible;	Section 5
• classify produced salt in accordance with the EPA's *Waste Classification Guidelines*;	Section 6.1.1
• store produced salt on-site within weather-proof structure, prior to off-site transport for reuse or disposal; and	Section 6.1.3
• dispose salt waste not able to be beneficially reused to appropriately licenced waste facility.	Section 6.1
Consent condition B69 states that prior to the commencement of Phase 1, Santos must undertake a Produced Salt Beneficial Reuse and Disposal Study to the satisfaction of the Planning Secretary. The study must:	This report

SSD 6456 consent conditions directly relevant to this Salt Study	Section reference
a) be prepared by a suitably qualified and experienced person/s;	Section 1.3
b) be prepared in consultation with the EPA, Council and the owner of any waste facilities identified under (c)(iv);	Section 1.4 Appendix A
c) include:	
(i) detailed assessment of salt volumes and composition, including chemicals of potential concern;	Section 3.2 Section 6.1.3
(ii) an assessment of reasonable and feasible beneficial use options;	Section 5
(iii) a strategy for maximising beneficial reuse of identified reasonable and feasible reuse options; and	Section 5
(iv) a strategy for disposal of any produced salt that is not able to be beneficially reused, including demonstration that occupiers of waste facilities can lawfully accept, and will permit, the volume and composition of salt waste produced by the development for disposal at their premises.	Section 6

2.4 Relevant measures, strategies, policies and guidelines

2.4.1 National Waste Policy - less waste, more resources

The 2018 National Waste Policy provides a framework for collective action by businesses, governments, communities and individuals until 2030. The National Waste Policy provides five circular economy principles which underpin waste management, recycling and resource recovery:

- avoid waste;
- improve resource recovery;
- increase use of recycled material and build demand and markets for recycled products;
- better manage material flows to benefit human health, the environment and the economy; and
- improve information to support innovation, guide investment and enable informed consumer decisions.

The National Waste Policy guides continuing collaboration between all Australian governments, business and industry. It does not remove the need for governments, businesses and industries to implement tailored solutions in response to local and regional circumstances, but it complements and supports the implementation of these.

The National Action Plan creates targets and actions to implement the 2018 National Waste Policy. Of the listed targets and actions, the one most relevant to the salt and brine produced by the NGP is the target to achieve an 80 % average recovery rate from all waste streams by 2030.

2.4.2 Controlled Waste NEPM

The National Environment Protection (Movement of Controlled Waste between States and Territories) Measure 1998 (the **Controlled Waste NEPM**) provides a national framework for developing and integrating state and territory systems for managing the movement of trackable (controlled) wastes between states and territories. It aims to minimise the potential for adverse impacts associated with the interstate movement of such waste on the environment and human health.

The salt and brine from the produced water treatment are not listed as controlled wastes in Parts 1 and 2 of Schedule 1 of the Waste Regulation, and as such the Controlled Waste NEPM does not apply.

2.4.3 NSW Circular Economy Policy 2019

NSW's circular economy principles capture the intent of the National Waste Policy principles and go beyond waste management. The NSW Government has developed the Circular Economy Policy to deliver positive economic, social and environmental outcomes. The circular economy is about changing the way products are produced, assembled, sold and used to minimise waste and to reduce the environmental impact. The circular economy can also be great for business; by maximising the use of valuable resources, and by contributing to innovation, growth and job creation.

2.4.4 NSW Waste and Sustainable Materials Strategy 2041

The WARR Act commits the NSW Government to refreshing and updating its waste strategy every five years - to review and continually improve the state's policies and targets for waste reduction and landfill diversion. The NSW *Waste and Sustainable Materials Strategy 2041: Stage 1 – 2021-2027*, which updates the previous *Waste Avoidance and Resource Recovery Strategy 2014-2021*, focuses on the environmental benefits and economic opportunities in how we manage our waste, as well as waste reduction and recycling. The updated strategy sets out the actions that will be taken in the first stage of the strategy to 2027 and the targets that have been adopted as part of the National Waste Policy Action Plan (refer to section 2.4.1).

2.4.5 NSW Waste Classification Guidelines

The EPA's *Waste Classification Guidelines* (2014) (**Waste Classification Guidelines**) have been developed to help waste generators classify the wastes they produce. The guidelines are a step-by-step process for classifying waste into one of special waste, liquid waste, hazardous waste, restricted solid waste, general solid waste (putrescible), or general solid waste (non-putrescible). Generators and waste facilities must ensure they classify their waste carefully in accordance with the procedures in the guidelines.

The NSW classification of the waste salt is further addressed in section 6.1.1.

2.4.6 NSW Waste Levy Guidelines

The EPA's *Waste Levy Guidelines* (2018) contain specific legal requirements which occupiers of scheduled waste facilities must meet in addition to their obligations under the POEO Act and the Waste Regulation. The *Waste Levy Guidelines* include how waste is measured to calculate levy liability, when certain levy deductions can be claimed, and how records, surveys and reports are required to be made, kept and provided to the EPA in order for the occupier to fulfil their obligations.

2.4.7 QLD Waste Management and Resource Recovery Strategy

Queensland's *Waste Management and Resource Recovery Strategy* published in 2020 aims to promote more sustainable waste management practices that reduce the amount of waste produced by business, industry and households. It provides the strategic framework for Queensland to become a zero-waste society, where waste is avoided, reused and recycled to the greatest possible extent.

The strategy sets a number of targets for 2050, including a recovery of 90 % of waste from landfill. It further sets three strategic priorities to help drive a fundamental shift in the way waste is managed in Queensland and support the transition to a zero-waste society, by:

- reducing the impact of waste on the environment and communities;
- transitioning towards a circular economy for waste; and
- building economic opportunity.

2.4.8 QLD End of Waste Guideline

The EOW Guideline provides guidance for using or intending to reuse a waste as a resource under the EOW framework under the WRR Act. The EOW framework recognises the value of waste by providing a process for the development of new markets for recovered waste materials in Queensland. It provides certainty about when, and under what circumstances, a waste ceases to be waste and is considered a resource. Under the EOW framework, a waste can be deemed a resource under an EOW code or an EOW approval. EOW codes relate to any registered resource producer for the respective codes and an EOW approval relates to only the holder of the approval. An EOW approval is issued to a single holder for the purpose of trialling the use of a waste as a resource to provide proof of concept.

2.4.9 QLD Overview of regulated waste categorisation

The QLD Department of Environment and Science (**DES**) information sheet *Overview of regulated waste categorisation* (2022) (**Waste Categorisation Overview**) outlines the process for sampling and testing waste to demonstrate an appropriate risk-based category in accordance with section 43 of the EP Regulation.

The purpose of the information is to outline the regulated waste categorisation provisions of Chapter 5, Part 1 and Schedule 9 of the EP Regulation for waste generators and receivers. It is to be noted that the document is intended for guidance and does not take the place of, or overrule, the relevant legislation.

Waste classification in QLD is further addressed in section 6.1.2.

3. Brine and salt production

3.1 Phase 1 and 2

3.1.1 Produced water composition at the well head

The quality of the produced water extracted from a coal seam can vary depending on a range of factors including age, depth and the type of geological formation. The average salinity of produced water generated during exploration and appraisal activities within the Project area to date from the Maules Creek Formation and Blackjack Group is around 19,000 µS/cm.

As part of the approved water quality monitoring program, Santos has collected a large number of representative samples from NGP appraisal wells to characterise the produced water composition. Specifically, the produced water was heated in the laboratory to 180 degrees Celsius to simulate the thermal process used during water treatment. During heating, some salt in the produced water decomposes, while the remainder becomes a solid salt product.

A summary of the chemical analysis results is provided in Table 3.1 (GHD, 2021). It should be noted that not all water samples were analysed for all parameters.

Table 3.1 - Produced water composition at the wellhead

Parameter	Unit	# samples	Mean	10th %ile	90th %ile
Physicochemical					
pH	-	321	8.0	7.2	8.7
Electrical conductivity	µS/cm	319	14836	10426	19400
Solids (dissolved)	mg/L	255	9765	6500.5	14400
Solids (dissolved) @180ºC	mg/L	82	**11675**	7259	15090
Ion balance	-	166	3.76	0.135	9.57
Biochemical oxygen demand (5 day)	mg/L	51	7	2	20
Chemical oxygen demand	mg/L	51	1788	2	3810
Dissolved organic carbon	mg/L	221	5.83	1	19.32
Dissolved anions					
Alkalinity (CO_3)	mg/L $CaCO_3$	231	715	152.5	1846
Alkalinity (HCO_3)	mg/L $CaCO_3$	335	8518	4374	12314
Alkalinity (OH)	mg/L $CaCO_3$	198	<1	<1	<1
Alkalinity (total)	mg/L $CaCO_3$	135	8972	4308	12960
Bromide	mg/L	207	4.44	2.73	5.55
Chloride	mg/L	335	1396	830	1794
Fluoride	mg/L	75	4.86	2.12	6.73
Iodide	mg/L	51	0.13	0.025	0.206
Sulfur (total)	mg/L	34	4.15	0.1	9.75
Cyanide (total)	mg/L	43	0.004	0.004	0.004

Parameter	Unit	# samples	Mean	10th %ile	90th %ile
Dissolved cations					
Calcium (total)	mg/L	284	19	4	43
Magnesium (total)	mg/L	166	6.48	2.67	11
Potassium (total)	mg/L	335	213	30.1	230
Sodium (total)	mg/L	334	4360	2621	6257
Hardness (total)	mg/L $CaCO_3$	115	88	22	211
Silica as SiO_2	mg/L	24	19.8	16.7	24.7
Silicon (total)	mg/L	35	10.9	10.04	11.66
Silicon (acid soluble)	mg/L	17	8.38	6.86	9.28
Nutrients					
Ammonia-nitrogen	mg/L	57	9.6	3.0	16.4
Nitrate-nitrogen	mg/L	192	3.03	0.05	5
Nitrite-nitrogen	mg/L	251	0.05	0.01	0.04
Nitrogen (TKN)	mg/L	220	25.6	4.93	54.9
Nitrogen (total)	mg/L	226	23.6	4.4	47.8
Phosphorus (total)	mg/L	34	0.28	0.032	0.60
Total metals & trace elements					
Aluminium (total)	mg/L	226	3.52	0.02	7.67
Antimony (total)	mg/L	226	0.0008	0.0001	0.00206
Arsenic (total)	mg/L	226	0.011	0.0029	0.0225
Barium	mg/L	226	8.53	3.42	15.4
Beryllium (total)	mg/L	224	0.0010	0.001	0.001
Boron (total)	mg/L	226	0.64	0.20	1.3
Cadmium (total)	mg/L	226	0.0109	0.0001	0.03494
Chromium (total)	mg/L	226	0.0118	0.0006	0.03608
Chromium (VI)	mg/L	57	<0.01	< 0.01	< 0.01
Cobalt (total)	mg/L	224	0.0018	0.0001	0.00559
Copper (total)	mg/L	226	0.053	0.00452	0.137
Iron (total)	mg/L	223	18.4	0.26	25.9
Lead (total)	mg/L	17	0.02	0.0004	0.033
Lithium (total)	mg/L	17	1.69	1.252	2.16
Manganese (total)	mg/L	225	0.27	0.0017	0.256
Mercury (total)	mg/L	226	0.0006	0.0001	0.0015
Molybdenum (total)	mg/L	226	0.00	0.0001	0.01321
Nickel (total)	mg/L	226	0.0065	0.0001	0.0167
Selenium (total)	mg/L	226	0.02	0.0005	0.0514
Strontium (total)	mg/L	226	2.61	0.60	4.76
Thallium (total)	mg/L	17	0.00	0.0005	0.0009
Tin (total)	mg/L	17	0.00	0.0005	0.00318
Uranium	mg/L	226	0.00	0.0001	0.0009
Vanadium (total)	mg/L	55	0.01	0.005	0.0184
Zinc (total)	mg/L	226	0.05	0.00292	0.162

At an average total dissolved solids (**TDS**) value at the well head of 11,675 mg/L, the estimated volume of salt held within the produced water during the Phase 1 appraisal activities, including existing pilot wells, is approximately 14.44 tonnes per day. The total salt estimate over a predicted 5 year period to be held within the existing produced water and brine ponds, is approximately 26,360 tonnes. This is in addition to the approximately 8,600 tonnes from existing exploration and appraisal activities.

While no salt will be produced during Phase 1, Table 3.2 provides estimated volumes of salt held within the produced water for Phase 1, including existing pilot wells.

Table 3.2 - Phase 1 salt estimates

Period	Produced water	Solid salt
Average daily	1.26 ML	14.44 tonnes
Average monthly	36 ML	440 tonnes
Total Phase 1	2200 ML	26,360 tonnes

Note: The estimated values in the table are subject to adjustments as the PSBRDS is updated and revised.

3.1.2 Feed pond water composition

All produced water extracted during Phase 1 and 2 will be treated via the existing 1.5 ML/day[2] reverse osmosis (**RO**) water treatment facility at Leewood. No salt will be produced during this period and all brine will be stored in the brine ponds until Phase 3 of the Project. Although it is expected that there will be adequate capacity in the existing ponds, should it be required, the infrastructure approved under Phase 2 of the SSD 6456 consent includes an additional 300 ML storage pond at Leewood, with two cells of approximately 150 ML capacity.

With continued treatment of the stored produced water, and due to evaporation and the addition of legacy brine, it is expected that the salinity in these ponds will increase over time. A number of physical, chemical and biological processes may also effect a change in the concentrations of some parameters in the stored water. The predicted quality of the water from the feed pond to the water treatment plant is provided in Table 3.3. It should be noted that the reported values in the table are different from previous actual sampling data and are based on modelling of the feed pond performance (GHD, 2021).

[2], The RO plant capacity approved as part of the Leewood Produced Water Treatment and Beneficial Reuse Project in August 2015 is 1.5 ML/day, although the operational capacity of the RO plant is greater than 1.5 ML/day.

Table 3.3 - Predicted feed water composition

Parameter	Units	Mean	90th %ile
Physicochemical			
pH	-	9.37	9.45
Electrical conductivity [2].	µS/cm	16,690	20,620
Solids (dissolved) - sum of ions [2]	mg/L	14,540	18,060
Total suspended solids (TSS)	mg/L	19.4	37.3
Biochemical oxygen demand (5 day) [1]	mg/L	N/A	N/A
Chemical oxygen demand [1]	mg/L	N/A	N/A
Dissolved organic carbon	mg/L	6.03	19.14
Dissolved anions			
Alkalinity (CO_3)	mg/L $CaCO_3$	2,692	4,156
Alkalinity (HCO_3)	mg/L $CaCO_3$	5,014	5,097
Alkalinity (OH)	mg/L $CaCO_3$	1.36	2.42
Alkalinity (total)	mg/L $CaCO_3$	8,630	11,140
Bromide [1]	mg/L	N/A	N/A
Chloride [1]	mg/L	1,697	2,185
Fluoride [1]	mg/L	N/A	N/A
Iodide	mg/L	0.13	0.21
Sulphate (total) [1]	mg/L	N/A	N/A
Cyanide (total) [1]	mg/L	N/A	N/A
Dissolved cations			
Calcium (total)	mg/L	16.8	21.3
Magnesium (total)	mg/L	6.51	11.07
Potassium (total)	mg/L	214	231
Sodium (total)	mg/L	4,896	6,349
Nutrients			
Ammonia-Nitrogen [1]	mg/L	N/A	N/A
Nitrate-Nitrogen	mg/L	0.02	0.53
Nitrite-Nitrogen	mg/L	0.010	0.010
Phosphorus (total)	mg/L	0.057	0.37
Total metals & trace elements			
Aluminium (total)	mg/L	0.056	0.050
Antimony (total) [1]	mg/L	N/A	N/A
Arsenic (total) [1]	mg/L	N/A	N/A
Barium	mg/L	2.35	3.76
Beryllium (total) [1]	mg/L	N/A	N/A
Boron (total)	mg/L	0.64	1.3
Cadmium (total) [1]	mg/L	N/A	N/A
Chromium (total) [1]	mg/L	N/A	N/A
Hexavalent chromium [1]	mg/L	N/A	N/A
Cobalt (total) [1]	mg/L	N/A	N/A
Copper (total) [1]	mg/L	N/A	N/A
Iron (total)	mg/L	0.18	0.26
Lead (total) [1]	mg/L	N/A	N/A
Lithium (total) [1]	mg/L	N/A	N/A
Manganese (total)	mg/L	0.054	0.052
Mercury (total) [1]	mg/L	N/A	N/A
Molybdenum (total) [1]	mg/L	N/A	N/A
Nickel (total) [1]	mg/L	N/A	N/A
Selenium (total) [1]	mg/L	N/A	N/A
Silica as SiO_2	mg/L	19.9	24.9
Silicon (total) [1]	mg/L	N/A	N/A
Silicon (acid soluble) [1]	mg/L	N/A	N/A
Strontium (total)	mg/L	1.97	2.48
Thallium (total) [1]	mg/L	N/A	N/A
Tin (total) [1]	mg/L	N/A	N/A
Uranium [1]	mg/L	N/A	N/A
Vanadium (total) [1]	mg/L	N/A	N/A
Zinc (total)	mg/L	0.050	0.082

Notes:

1. These values were not calculated as part of process chemistry modelling across the pond. Note that only parameters important for RO performance were modelled through the feed pond and the water treatment facility. Typically, a value of 0% removal for highly soluble analytes and 50% removal were used for the remaining parameters.
2. Values for major analyte ratios (i.e. the Na to Cl ratio which is a measure of the sodium chloride to sodium carbonate ratio) align with the mean values presented in Table 3.1. To maintain the ion balance, chloride is modified. Additionally, the value of TDS (sum of ions) is based on the individual analyte values.

3.2 Phase 3

During Phase 3, it is expected that up to 37.5 gigalitres (**GL**) of produced water will be extracted at a peak rate of 10 ML/day, consistent with the estimated total produced water volume for the life of the Project as presented in the EIS. A new RO water treatment facility will be constructed at the Leewood site, with a design capacity to treat up to 12 ML/day of produced water.

The four key stages of the water treatment process which will influence the brine and salt volumes produced from the treatment of produced water are:

- Stage 1 pre-treatment to remove dissolved solids and protect membrane treatment processes;
- Stage 2 removal of salt using RO technology. Approximately 83% of the produced water feed to the RO plant will leave this treatment stage as treated water (permeate), with the remaining 17% being brine. This recovery rate is a 13% improvement on this stage of the treatment process described in the EIS, and exceeds the 80 % National Waste Policy target as described in section 2.4;
- Stage 3 treatment of brine to recover treated water (distillate) by thermal technologies, thereby reducing the brine volume and increasing its concentration. The distillate will be added to the treated water (permeate) produced from the RO plant; and
- Stage 4 removal of a solid salt product from concentrated brine using salt crystallisation technology. Residual distillate will be recovered during the salt crystallisation process and added to the treated water (permeate) produced from the RO plant.

Figure 3.1 provides an overview of the proposed Phase 3 produced water treatment process showing the four stages listed above and the relative volumes produced from each treatment stage. The volume of brine produced from the RO process is expected to be approximately 17 % of the produced water inflows to the water treatment process, and the rate of brine production will vary over the life of the Project based a number of factors, including produced water rates from the field and pond levels.

The total volume of salt which will be produced from the brine generated through the treatment process is dependent on the water chemistry of the produced water (feed water) and the recovery rate that is achieved through the water treatment process. Based on the modelling, the combined treated water stream (permeate plus distillate) is expected to have a salinity of 231 mg/L. Therefore, a small amount of salt will be contained in the treated water whilst the remaining salt will be contained in the brine stream, which in turn is processed through the salt crystalliser.

The quantity contained within the treated water is approximately 2% of the total salt volume, while remaining within the treated water specification. This treated water can then be amended and stored, to be used for beneficial uses including dust suppression, construction, drilling, crop irrigation and stock watering, with the latter subject to an RROE application, or alternatively released to Bohena Creek (subject to certain restrictions and limitations).

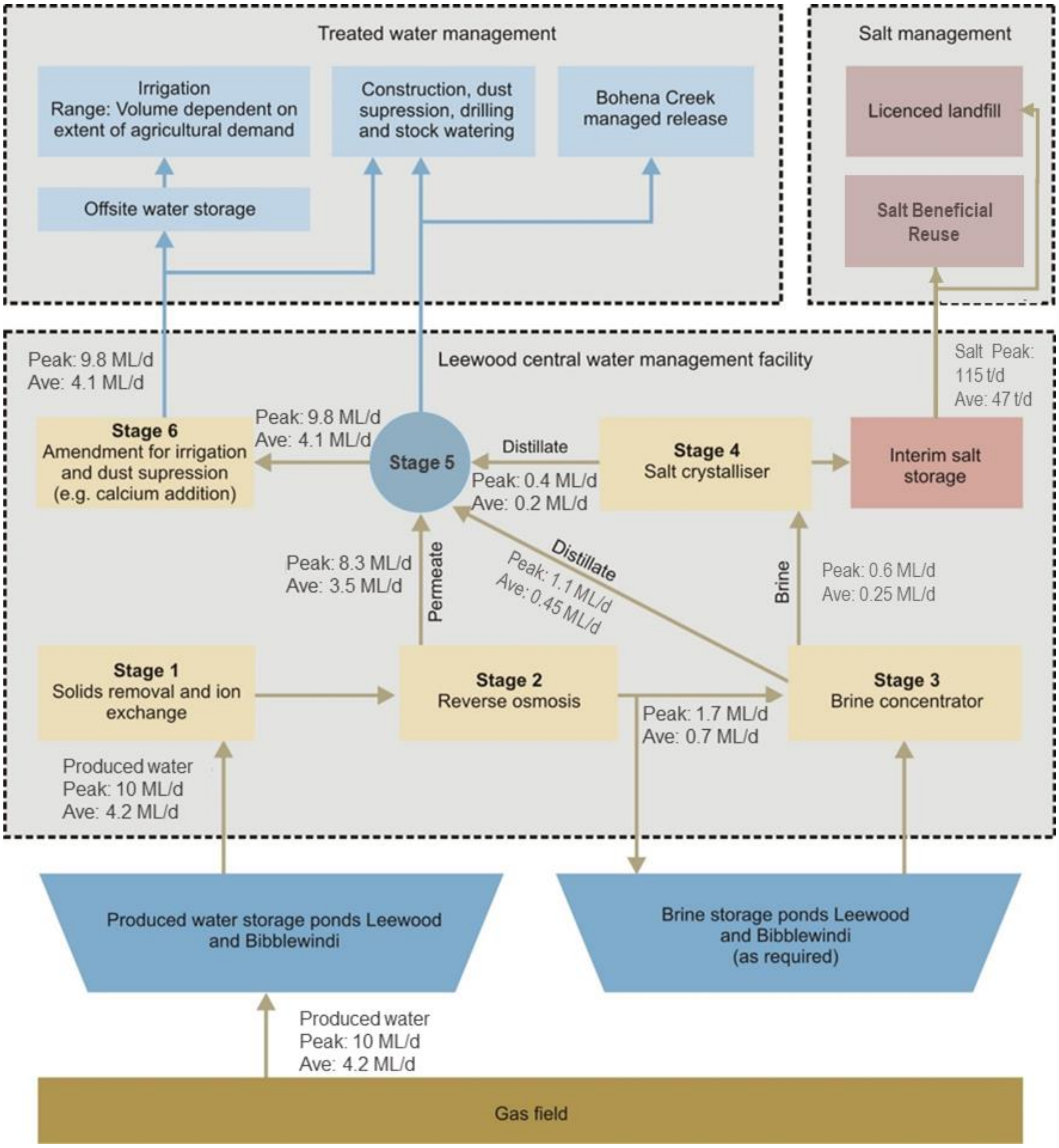

Figure 3.1 - Overview of the Phase 3 produced water treatment process

3.2.1 Predicted brine composition

The analytical results of the produced water samples collected from exploration and appraisal wells through the approved monitoring program were used to develop a feed specification for the Phase 3 water treatment plant. Water process modelling was undertaken using OLI Studio: Stream Analyser software to predict the brine composition (GHD, 2021). The expected brine composition which will be produced through the treatment process is provided in Table 3.4.

Note that the predicted values in the table are different from previous actual sampling data and are based on steady-state modelling of the new proposed water treatment plant performance. This difference is likely to be explained by the Leewood ponds containing a mix of legacy brine and produced water; the pond chemistry and the chemical processes within the ponds; and the effects of evaporation on the water quality over time.

The dominant ions which are predicted to be present in the brine are bicarbonate, carbonate and sodium, demonstrating that the dominant salts that will be present in the brine are sodium carbonate and sodium bicarbonate.

Table 3.4 - Predicted brine composition

Parameter	Units	Mean	90th %ile
pH	pH	8.9	9.0
Electrical conductivity	µS/cm	64,060	77,220
Solids (dissolved) [1]	mg/L	83,220	102,400
Total suspended solids	mg/L	0.0	0.0
Alkalinity (CO3) [1]	mg/L	15,380	25,240
Alkalinity (HCO3) [1]	mg/L	28,500	29,570
Alkalinity (OH)	mg/L	2.6	5.3
Alkalinity (total) [1]	mg/L	49,130	66,490
Dissolved organic carbon	mg/L	32	101
Total organic carbon	mg/L	32	101
Aluminium	mg/L	0.04	0.04
Barium	mg/L	4.6	4.5
Boron	mg/L	2.5	5.0
Calcium	mg/L	25	24
Chloride [1]	mg/L	9,646	9,796
Iron	mg/L	1.1	1.5
Magnesium	mg/L	38	64
Manganese	mg/L	<LOR	<LOR
Total nitrogen	mg/L	0.17	3.0
Total phosphorus	mg/L	0.003	1.8
Potassium	mg/L	1,208	1,284
Silica	mg/L	113	140
Sodium [1]	mg/L	27,980	35,930
Strontium	mg/L	10	10
Sulfate	mg/L	11.1	8.2
Zinc	mg/L	0.050	0.162

Notes:

1. Values for major analyte ratios (i.e. Na to Cl ratio which is a measure of the sodium chloride to sodium carbonate ratio) align with the mean values presented in Table 3.1. To maintain the ion balance, chloride is modified. Additionally, the TDS (sum of ions) is based on the individual analyte values.

3.2.2 Predicted salt composition

Process modelling has been undertaken to support the Salt Study to predict the chemical composition of the salt which will be produced from the processing of brine through a crystalliser (GHD, 2021). The predicted salt composition is provided in Table 3.5.

Table 3.5 - Predicted salt composition

Parameter / substance	Units	90th %ile
Moisture content	% total mass	15
Liquid phase pH	-	9.5-10.7
Sodium carbonate monohydrate	% total mass	64
Sodium chloride	% solid mass	12
Aluminium	mg/kg	0.0038
Arsenic	mg/kg	0.69
Barium	mg/kg	49
Beryllium	mg/kg	0.06 (LoD) [1]
Boron	mg/kg	27
Cadmium	mg/kg	1.1
Calcium	mg/kg	257
Chromium as CrO_4^{2-}	mg/kg	1.1
Chromium (VI)	mg/kg	0.6 (LoD) [1]
Cobalt	mg/kg	0.18 (LoD) [1]
Copper	mg/kg	4.2
Fluoride	mg/kg	410
Iron	mg/kg	16
Lead	mg/kg	1.0
Lithium	mg/kg	66
Magnesium	mg/kg	685
Manganese	mg/kg	0.000016
Mercury	mg/kg	0.046
Molybdenum	mg/kg	0.40
Nickel	mg/kg	0.51
Potassium	mg/kg	13,855
Selenium	mg/kg	1.5
Silica as SiO_2	mg/kg	1,508
Strontium	mg/kg	111
Zinc	mg/kg	4.9
Bromide	mg/kg	338
Sulphate as SO_4^{2-}	mg/kg	88
Uranium	mg/kg	0.02 (LoD) [1]
Vanadium	mg/kg	0.56

Notes:

1. These values are over-estimates as the limit of detection (LoD) is used.

Note that the ratio for major analytes align with the mean values presented in Table 3.1 in order to maintain the ion balance whilst the raw water TDS (sum of major ions) is based on the 90th percentile values. Note that the sodium carbonate to sodium chloride ratio as presented in Table 3.1 is based on the mean value for each well sample. This will be different to a flow-weighted average which may vary between 60-80% sodium carbonate monohydrate depending on which wells are producing at the time.

As shown in Table 3.5, it is estimated that the salt consists of approximately 64% (by weight) of sodium carbonate, with a further 12% as sodium chloride, both of which are potential beneficial salts. The remaining 24% is comprised of approximately 15 % entrained moisture, with the remaining 9% a variety of other non-commercial salts.

Although the predicted salt composition is based on modelling, the composition of the produced salt will be monitored over the life of the Project once salt production commences during Phase 3.

3.2.3 Predicted salt volume

During Phase 3, the brine stream which is primarily composed of sodium carbonate and sodium bicarbonate will be converted to salt, predominantly sodium carbonate. Based on a mean produced water TDS value at the well head of 11,675 mg/L (refer to Table 3.1) and a total produced water volume of up to 37.5 GL over the life of the Project, the total volume of salt that will be produced is approximately 430,000 tonnes.

This is consistent with a total volume of salt of approximately 430,500 tonnes, as estimated in the EIS.

4. Multi-criteria analysis

Santos has developed a multi-criteria analysis (**MCA**) framework which will be used for the evaluation of the feasible salt and brine beneficial reuse option(s) which have been identified to date. When applied consistently and transparently, MCA is a suitable approach for filtering options before applying more detailed quantitative analysis. The MCA process will also be used to select the preferred disposal option(s) for the waste salt produced by the NGP that cannot be beneficially reused. The beneficial reuse options and the options for disposal are further discussed in sections 5 and 6 respectively.

It should be noted that the beneficial reuse and disposal options are still in the development stages, with concept studies and field trials continuing over the next 24 to 48 months. As such, the MCA evaluation process will not be applied to any of the options until the options have been further defined.

The indicative schedule for the beneficial reuse trials against the Project key milestones is provided in Figure 5.1.

4.1 Evaluation criteria

Evaluation criteria were developed and formulated so that a balanced evaluation of the proposed beneficial reuse and disposal options can be achieved. The key criteria with associated descriptions which will underpin the MCA framework are provided in Table 4.1.

Table 4.1 - Evaluation criteria

Criteria	Description
Environment and compliance	Meets project conditions including maximising beneficial reuse and Santos sustainability targets
Schedule	Production of suitable feedstock (brine or salt) commences within approximately 3 years of FID
Financial	Has an economic benefit for the Narrabri Gas Project
Reputational	Builds local and national reputation for delivering on commitments
Flexibility (including scalability)	Ability of the technology and commercial partners to adapt to changes in feedstock quality and quantity
Operability	The ease and reliability with which the proposed systems can be operated
Safety	Meets Santos safety requirements

5. Beneficial reuse strategy

Apart from the beneficial reuse options for treated and amended treated produced water, including dust suppression, drilling and construction, irrigation, stock watering (subject to an RROE) or a release to Bohena Creek (under specific circumstances), Santos has identified a range of potential beneficial reuse options for up to 100% beneficial reuse of the brine and salt produced by the NGP. These are further detailed below.

5.1 Beneficial reuse of brine

There are a number of potential beneficial reuse options that have been considered as part of this Salt Study which utilise the salts contained within the brine stream, being:

- neutralisation of acid mine drainage (**AMD**);
- algae farming for agricultural feedstock; and
- regeneration of solvent extraction organics for zirconium separation.

5.1.1 Acid mine drainage neutralisation

AMD represents a significant undertaking for the mining industry worldwide due to the challenges associated with neutralising the acid heap leach within the containment structure, while managing the risk of impacts to water and soil. Its active treatment involves the addition of alkaline reagents to increase the pH and precipitate the dissolved metals.

Santos has been collaborating with Aeris Resources Limited (**Aeris**), a mining and exploration company headquartered in Brisbane, QLD, to assess the potential to use the alkaline salt produced from the NGP to neutralise heap leach materials at one of its operational assets in central NSW, prior to covering the site with non-acid forming waste rock and rehabilitating to the final landform.

The Tritton Copper Operations, located near the towns of Nyngan and Cobar, is operated by Tritton Resources Pty Ltd, a subsidiary of Aeris. The operation consists of two underground mines, the Tritton Underground Mine and the Murrawombie Underground Mine. Copper is extracted from the mined ore at the Murrawombie heap leach operation. The process to remove copper from the heap leach material is to leach the ore with acidic water. When the copper has been leached from the ore the heap leach material has a low pH of 2 to 3 and contains elevated concentrations of water-soluble metal(oids) and major ions. Before a soil cover system can be placed over the heap leach material the actual acidity must be neutralised. Neutralisation can be done with the alkaline brine to bring the material to pH 8. Increasing the pH of the heap leach material results in the immobilisation of water-soluble metal(oids), mainly as hydroxides. After the heap leach material is neutralised an additional dose of fine limestone on the surface and an oxide waste rock/soil cover will be placed over the heap leach material. Geochemical assessment work has already been done to demonstrate that oxide waste rock materials (from a proposed open pit cut back at Murrawombie) is geochemically benign and can be used as a cover material for final rehabilitation of the heap leach material.

Santos and Aeris commenced a laboratory scale neutralisation trial in 2017 on bulk samples of Murrawombie heap leach materials using brine produced during the NGP appraisal program. The laboratory trials showed that alkaline brine produced from the NGP could significantly reduce the acidity and concentrations of many of the dissolved metals/metalloids in seepage and surface runoff from the bulk heap leach materials (RGS, 2020). The sodium carbonate-rich brine produced from NGP has demonstrated effectiveness at neutralising pH and significantly reducing the concentration of most metals and metalloids when compared with other conventional neutralising chemicals, such as sodium hydroxide [$NaOH$], calcium hydroxide [$Ca(OH)_2$] and calcium carbonate [$CaCO_3$].

Aeris submitted an application to the EPA in February 2019 to vary EPL 4501 for the Tritton Copper Operations to permit the use of brine water concentrate from the NGP on the Murrawombie heap leach pads to support mine closure and rehabilitation. The application was submitted to permit a field trial to confirm the findings of the laboratory scale trial. The Notice of Variation of the EPL was issued on 25 August 2021, allowing a field trial scheduled to commence in 2021, for a period not exceeding 12 months (refer to Figure 5.1).

Following the EPL variation, the EPA added Tritton Resources Pty Ltd (EPL 4501) as a waste receiver site and Santos Leewood Ponds (EPL 20350) as a waste producer site to the NSW Online Waste Tracking System. The field trial commenced in November 2021 with the appropriate waste tracking and transport certificates in accordance with the EPA's requirements. The trial will continue for a period not exceeding 12 months, in accordance with section 8 of EPL 4501.

This Salt Study will be updated once the AMD field trials have been completed, the final results are available and an evaluation has been completed. This update will coincide with the review prior to the commencement of Phase 2 and will provide the specific details if AMD will form part of the brine and salt beneficial reuse strategy. This will include brine and salt volume estimates to be beneficially reused in this way.

5.1.2 Algae farming

Algaculture or algae farming is a form of aquaculture involving the farming of species of algae which has been in commercial scale production since the 1960s. It is a fast-growing industry providing a variety of products including food ingredients, natural food colorants and dyes, fertiliser, livestock supplements, bioplastics, chemical feedstock (raw material), pharmaceuticals, and algal fuel (biofuel). While the majority of commercial operations underway are located internationally, a number of pilot and commercial operations have recently been established in south-west Queensland to produce high-value nutraceutical and food supplements products and food protein from marine microalgae.

In January 2020 the University of Queensland (UQ) completed a series of experiments at the UQ Algae Energy Farm at Pinjarra Hills investigating the commercial viability of beneficial algae production at both laboratory and pilot scale using brine from several onshore gas producers. The results from the experiments indicated that a 40 % reduction in required nutrient inputs for algae farming could be achieved when produced water is used. Further experiments are expected to demonstrate that the farmed algae will be able to remove up to 60 % of the carbonate salts from brine similar to the expected brine quality from the NGP. The study found that domestic interest exists for the use of brine for algal farming to produce agricultural feedstock from the algae, with numerous commercial operations having recently been established throughout Australia and internationally.

While this opportunity provides a significant benefit in providing a beneficial reuse stream for the sodium bicarbonate from the Narrabri development, the opportunity would also have the potential of reducing the Project's environmental footprint by reducing emissions of CO_2 through the replacement of depleted carbonate. Discussions are continuing to determine the feasibility of algae cultivation using NGP brine as a potential beneficial use option with a field trial scheduled to commence in 2022 (refer to Figure 5.1), pending regulatory approvals.

This Salt Study will be updated once the algae farming field trials have been completed and the final results are available and have been evaluated. This update will coincide with the review prior to the commencement of Phase 2 and will provide the specific details if algae farming will form part of the brine and salt beneficial reuse strategy. This will include the estimated volumes of brine and salt to be beneficially reused in this way.

5.1.3 Regeneration of solvent extraction organics

Solvent extraction is a common procedure in organic chemistry and mining and is often used to separate organic solvents from water. In some applications, washing the organic solvents with sodium carbonate can assist the separation from the aqueous solution. As an example, this process can be used for the regeneration of the solvent in zirconium production.

Santos has identified a number of potential end users that utilise this technology within Australia that could potentially use the NGP sodium bicarbonate by-product to regenerate solvent extraction organics in their operations. Initial contact has been made with the proponents for a proposed zirconium processing facility to discuss the potential to utilise salt from the NGP for regeneration of the solvent extraction organics used in the process. While this represents a significant opportunity for the NGP, the detailed application of this option has not been developed sufficiently at this time to properly evaluate the feasibility at a commercial scale.

The reviewed and updated Phase 2 Salt Study will define if the regeneration of solvent extraction organics will form part of the part of the brine and salt beneficial reuse strategy. This will include the estimated volumes of brine and salt to be beneficially reused in this way.

	2021				2022				2023				2024			
Brine beneficial reuse trials	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
Narrabri Gas Project – Key milestones																
FEED, detailed design & assurance																
Meet CoC for Phase 2																
NGP Phase 2 sanction																
Natural Soda FEED																
Engineering and concept design																
Commercial discussions																
Algae farming																
Pilot trial																
Reporting																
Commercial discussions																
Aeris Resouces - heap leach trial																
Field trials																
Reporting																
Commercial discussions																
Option evaluation / MCA																
Evaluate trial results																
Evaluate commercial options																
Formulate preferred reuse alternatives																
Update Salt Study																
Submit revised Salt Study																
Execute preferred reuse alternatives																

Note:
This schedule excludes the approvals for the beneficial reuse alternatives.

Figure 5.1 - Indicative schedule of brine beneficial reuse trials

5.2 Commercial salt recovery

There is high potential for commercial salt extraction from the NGP brine. As shown in section 3.2.2, the dominant salts which are predicted to be present within the NGP salt are sodium carbonate [Na_2CO_3], which represents approximately 64 % (by weight) of the salt produced, and sodium chloride [NaCL], which represent approximately 12 % of the salt produced. Sodium carbonate production can be converted to sodium bicarbonate [$NaHCO_3$] with the addition of carbon dioxide [CO_2] and water, as represented in the following equation:

$$Na_2CO_3 + H_2O + CO_2 \rightarrow 2\ NaHCO_3$$

Sodium carbonate, commonly known as soda ash, is produced either via natural or synthetic processes. Globally, 30% of soda ash is produced from natural sources and 70 % is from synthetic processes. Soda ash is predominantly used in glass manufacturing. Additional uses include chemical manufacture, soap and detergents, flue gas desulfurisation, pulp and paper processing and water treatment. All soda ash used within the Australian market is imported.

Sodium bicarbonate, commonly referred to as ‘baking soda’ or ‘bicarb of soda’, is manufactured by reacting aqueous soda ash with CO_2, with 1 tonne of soda ash producing approximately 1.6 tonnes of sodium bicarbonate. The predominant uses of sodium bicarbonate include food, personal care, pharmaceuticals, stockfeed and water treatment. There is currently no domestic production of sodium bicarbonate. It should be noted that there is a potential opportunity to utilise waste CO_2 from the gas processing facility for the production of sodium bicarbonate.

There are a number of alternative salt recovery processes and beneficial reuse opportunities that are possible considering the predicted NGP salt composition. These have been summarised in Table 5.1, together with an initial evaluation of their commercial prospects. However, considering the salt is 64 % (w/w) sodium carbonate, commercial soda ash and baking soda production would be the most feasible option. This is further described in section 5.2.1.

Opportunities to use brine as a feedstock for the production of a range of other chemicals (e.g. sodium hydroxide, sodium hypochlorite or hydrochloric acid) may be assessed at a later stage, pending the volumes and concentration of brine stored in the ponds.

In comparison, it has been identified that the opportunities in QLD for beneficial reuse of salt products recovered from CSG produced water from the Surat and Bowen basins are constrained by the chemical composition of the brine stream, with the lower-value sodium chloride making up a large portion of the total volume. The natural variations in water quality across various fields means that maintenance of brine feed quality is expected to be difficult to maintain, resulting in a relatively high proportion of waste salt (University of Queensland, 2020).

Table 5.1 - Available technologies for salt recovery

Industrial process	Details	Commercial prospect
Carbonation route for sodium bicarbonate	Water from the WTP feed pond is concentrated via a membrane process (i.e. nanofiltration and reserve osmosis) CO_2 gas in then used to convert sodium carbonate to sodium bicarbonate via a carbonation tower	High
Sodium carbonate monohydrate (Na_2CO_3 .H2O) route	Sodium carbonate monohydrate is a water insoluble sodium source than can easily be converted to other sodium compounds by heating (calcination) Brine is concentrated then crystallised thermally at >90ºC Crystallisation is the process in which a solid is formed from a homogenous liquid or gaseous phase. Process is used by the US trona industry after trona (a non-marine evaporite mineral) has been calcined (heated) **Variants**: Dosage using caustic soda to convert bicarbonate to carbonate versus thermal destruction of bicarbonate Variation of the recycle streams to reduce waste amounts Recrystallisation of product to improve purity Potential to recover sodium chloride but very likely to be uneconomic	Medium
Sodium carbonate decahydrate ($Na_2CO_3.10H_2O$) route	Brine is concentrated then crystallised under vacuum <20 to 30ºC, and then decahydrate is converted to monohydrate via calcination **Variants**: Dosage using caustic soda to convert bicarbonate to carbonate versus thermal destruction of bicarbonate Variation of the recycle streams to reduce waste amounts Recrystallisation of product to improve purity Potential to recover sodium chloride but very likely to be uneconomic	Medium
'Gossage' process with recycling of lime reagent	Addition of a lime to brine to produce sodium hydroxide (NaOH) (50%wt) and sodium chloride (as salt waste or product) Gossage process is sodium hydroxide and calcium carbonate ($CaCO_3$) formed by heating sodium carbonate with calcium hydroxide ($Ca(OH)_2$) Calcium carbonate is recovered and reused by calcination (relatively energy intensive especially if water needs to be driven off via thermal evaporation) The sodium hydroxide and sodium chloride streams would need to be further concentrated for sale Used historically to produce caustic soda Potentially applicable for NGP as very little sodium chloride is contained in water, therefore minimal thermal water evaporation is required	Medium
Trona / nahcolite solar evaporation route	Evaporation ponds are shallow lined basins which utilise solar energy to naturally evaporate water and precipitate salt crystals which are harvested and washed Saturated brine is concentrated in evaporation ponds and crystalliser ponds to selectively crystallise salts out of fully saturated brine Unlikely to be feasible due to very large footprint required	Low
Solvay and other modified Solvay processes	Brine purification: brine concentration by evaporation, removal of impurities, filtration, ammonia gas absorption Sodium bicarbonate formation: carbonation, ammonium ions formed from ammonia, sodium bicarbonate precipitated from sodium and bicarbonate ions Sodium carbonate formation: suspended sodium bicarbonate is removed from carbonation tower and heated at 300°C to produce sodium carbonate, carbon dioxide is recycled Ammonia (NH_4) recovery: Calcium oxide (CaO) in lime slaker reacts with water to form calcium hydroxide, calcium hydroxide reacts with ammonium chloride (NH_4Cl) separated out of the carbonating tower, ammonia is recycled No realistic way to reprocess and reuse NaCl or lime Likely to be more beneficial at higher chloride levels as significant volumes of NaCl and $CaCO_3$/lime are required for the Solvay process	Low
Chlor-alkali processes	Saturated brine (H_2O + NaCl) is used as a feedstock for the chlor-alkali process Sodium chloride is converted to sodium and chlorine gas (Cl_2) via electrolysis Sodium reacts with water to produce sodium hydroxide and hydrogen gas (H_2) Can recycle HCl to increase chloride content Many variations recycling various waste streams such as NaCl or HCl Low NaCl concentrations (12% w/w) present in NGP brine	Low
Hydrochloric acid (HCl) addition to create NaCl salt	Hydrochloric acid added to destroy all alkalinity and crystallisation to produce sodium chloride Very large volumes of hydrochloric acid must be trucked in, only feasible with an onsite chlor-alkali plant Not feasible with an alkaline dominated chemistry	Low
Continuous or standard ion exchange (IX) processes	Reversible interchange of ions between a solid and a liquid Conducted in continuous or batch mode, with most water treatment IX processes run in continuous mode Continuous IX processes take place in a column or vessel containing a deep bed or ion exchange resin beds Resins are conventionally classified as cation exchange resins, anion exchange resins, special chemical groups and adsorbents Many variants but unlikely to be feasible for the NGP brine	Low
Recovery of high price low concentration salts/minerals	Rubidium, caesium, indium, germanium etc. Most of these salts are more readily available at higher purities/concentrations in ores or other waste streams making it unlikely to be feasible for the NGP	Low

Note:
1. The industrial process is generally named after the company or the final product.
Not all options and opportunities for salt recovery that were considered as part of the Salt Study have been listed in the table.

5.2.1 Commercial soda ash and baking soda production

Santos contacted a number of commercial salt producers to gauge interest in a sodium carbonate and sodium bicarbonate recovery process for the NGP. Consistent feedback from potential partners centred around concerns with the relatively small scale of the Project, the security and consistency of the feedstock (brine) and the early stage of the Project. It was considered that the scale of any operation would be better suited to sodium bicarbonate rather than soda ash production.

Santos announced in July 2020 that it had signed a Memorandum of Understanding (MOU) with Natural Soda to use salt removed from produced water as part of the NGP. Natural Soda would process brine through a cooling crystallisation process to produce a high-quality sodium bicarbonate. Bicarb-saturated brine is brought into the process at high temperatures and cooled repeatedly, causing crystals to form and 'fall out' of the solution. Excess water is then removed via high-speed centrifuges (spin dryers). The resultant damp crystal matrix is further dried, screened, packed and stored on site in a weather-proof structure prior to transport.

Since execution of the MOU, Santos has been collaborating with Natural Soda in the development of a concept design for the plant, based on a 1 ML/d facility. Work is continuing on the overall design, with a view to developing a commercially viable model for sodium bicarbonate production from NGP brine for Phase 3, based on the predicted brine chemistry.

A number of potential salt producers expressed concerns regarding the certainty of brine feedstock, with the peak early water production and tailing off over time not considered ideal to support continuous commercial operation at scale. This may be overcome by using intermediate concentrated brine storage ponds to balance and improve the consistency of the feed rate to a sodium bicarbonate manufacturing facility, and to increase feed stock by constructing the additional 300 ML storage pond approved under Phase 2 of the SSD 6456 consent.

5.3 Combination of brine and salt beneficial reuse options

The evaluation of beneficial reuse options for the brine and salt produced from the NGP has demonstrated that a number are potentially technically feasible. The preferred strategy however may be the combination of some of the options: maximising the potential for commercial salt recovery through the Natural Soda process, followed by the beneficial reuse of the remaining salts for heap leach neutralisation and algae farming. Any waste streams from the Natural Soda sodium bicarbonate production process would be returned to brine ponds

These opportunities would reduce total CO_2 emissions by consuming CO_2 through the Natural Soda sodium bicarbonate production process, consuming CO_2 through the algae farming process and reducing the energy requirement for the thermal concentrator and the salt crystalliser.

Santos is continuing to explore these and other options to maximise feasible beneficial reuse possibilities during Phase 3. At the same time, a salt disposal strategy is being developed to ensure that any remaining salt waste produced from the NGP can be legally disposed of at an appropriately licenced facility, noting that disposal would be the least preferred option, in accordance with the NSW waste hierarchy.

Santos will define a strategy for the brine and salt beneficial reuse at the completion of the trials, and incorporate this in the reviewed and updated Salt Study, to be approved prior to the commencement of Phase 2.

6. Disposal strategy

6.1 Salt disposal

Santos is developing a salt disposal strategy to ensure that all salt waste produced from the NGP during Phase 3 can be legally disposed of at appropriately licenced facilities, in the event that any or all of the beneficial reuse options that are being considered ultimately prove to be not commercially feasible. However, in accordance with the NSW and QLD waste hierarchies, salt disposal is the least preferred option, and there are a number of potentially feasible salt recovery processes and beneficial reuse opportunities that are being evaluated for both the NGP salt and the brine.

A key consideration in the assessment is whether or not a facility has the necessary licencing for disposal of the salt based on the waste classification. Waste is classified based on the requirements within the individual States and Territories in Australia, and a common system of waste classification does not (yet) exist. In that regard, consideration has only been given to waste classification requirements for landfill disposal of salt in NSW and QLD.

Apart from disposal, the classification of waste also dictates the regulatory requirements in terms of storage, transportation, and the applicable waste levy. The classification of the waste salt for NSW and QLD is detailed in the sections 6.1.1 and 6.1.2 respectively, with an evaluation of any chemicals of concern in the waste salt in section 6.1.3. This is followed by a review and assessment of the facilities which may be suitable for the disposal of the waste salt.

6.1.1 Waste classification in NSW

The following classes of waste in NSW are defined as follows in Section 49 of Schedule 1 of the POEO Act:

- general solid waste (non-putrescible);
- general solid waste (putrescible);
- hazardous waste;
- liquid waste;
- restricted solid waste; and
- special waste.

The Waste Classification Guidelines specify the steps which must be followed to classify the waste salt from the Project. The predicted salt composition from the Project (the 90th percentile values presented previously in Table 3.4) has been assessed against the relevant criteria for each of the waste classes, with the detailed comparison against the Waste Classification Guidelines criteria presented in Table B1 in Appendix B.

The results of the comparison in Table B1 shows that the waste salt from the Project satisfies the requirements to be classified as general solid (non-putrescible) waste in NSW.

6.1.2 Waste classification in QLD

Waste classification in QLD is completed in accordance with the waste categorisation provisions under Chapter 5, Part 1 and under Schedule 9 of the EP Regulation. The EP Regulation includes a risk-based waste classification framework where regulated waste is classified as either:

- Category 1 regulated waste (highest risk);
- Category 2 regulated waste (moderate risk); or
- Not-regulated waste / general waste (lowest risk).

Appendix 1 of the Waste Categorisation Overview reproduces the relevant sections and schedules of the EP Regulation and specifies the types of regulated waste and their default waste classification. The waste salt produced from the NGP would be classified as item 40 '*non-toxic salts, including, for example, saline effluent*' for which the default waste classification is Category 2 regulated waste. The default categorisation for regulated waste applies unless the waste generator takes action to determine if a lower risk category applies to the waste. The process for this reclassification is to:

- identify relevant parameters, if any, and sample the waste;
- test the waste; and
- compare the test result to the thresholds for the relevant waste categories.

The predicted salt composition from the Project (the 90th percentile values presented previously in Table 3.4) has been assessed against the relevant criteria for each of the waste classes, with the detailed comparison against the Waste Categorisation Overview criteria presented in Table B2 in Appendix B. This indicates that the salt waste would in all likelihood not exceed the threshold for non-regulated waste for disposal in QLD, and would therefore be classified as 'Not-regulated waste' for the purpose of landfill disposal.

6.1.3 Chemicals of potential concern

Condition B69(c)(i) requires the Salt Study to include a detailed assessment of salt volumes and composition, including chemicals (or constituents) of potential concern (**CoPCs**). Depending on the industry, process, site history or exposure pathway, CoPCs generally include one or more of the following:

- heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc);
- petroleum hydrocarbons (referred to as total recoverable hydrocarbons);
- benzene, toluene, ethylbenzene and xylene (collectively referred to as BTEX);
- polycyclic aromatic hydrocarbons (PAHs);
- organochlorine pesticides (OCPs);
- organophosphate pesticides (OCPs);
- polychlorinated biphenyls (PCBs);
- volatile organic compounds (VOCs);
- asbestos; and
- cyanide.

The best way to assess the risk of CoPCs in the waste salt is a comparison against the criteria detailed in the schedules of the *National Environment Protection (Assessment of Site Contamination) Measure* (**ASC NEPM**). The ASC NEPM provides a national risk-based framework for the assessment of site contamination in Australia. Table 6.1 lists the applicable ASC NEPM health investigation levels (**HILs**) and the Ecological Investigation Levels (**EILs**). HILs are defined as the concentration of a contaminant above which further appropriate investigation and evaluation will be required. EILs depend on specific soil physicochemical properties and are based on methodology developed by the CSIRO. Note that only those parameters are listed for which both a predicted salt waste and either a HIL or EIL was available.

The comparison provided in Table 6.1 confirms that the levels of CoPCs in the predicted waste salt are far below the ASC NEPM criteria. This aligns with item 379 in DPIE's Assessment Report for the Project, which states that the Water Expert Panel[3] (**WEP**) accepts that the COPC's and other potential contaminants are able to be effectively treated with the proposed reverse osmosis treatment system, and that risks are able to be effectively managed subject to stringent design, management and monitoring.

Irrespective of the COPCs finding, all salt will be stored on-site within a weather-proof structure, prior to off-site transport for reuse or disposal.

Table 6.1 - Identification of CoPCs

Parameter	Predicted salt waste concentration (mg/kg)	ASC NEPM criteria	
		HIL [1] (mg/kg)	EIL [2] (mg/kg)
Arsenic	0.69	3,000	160
Beryllium	0.06 (LoD) [3]	500	-
Boron	27	300,000	-
Cadmium	1.1	900	
Chromium as CrO_4^{2-}	1.1	-	670
Chromium (VI)	0.6 (LoD) [3]	3600	-
Cobalt	0.18 (LoD) [3]	4,000	-
Copper	4.2	240,000	320
Lead	1.0	1,500	1,800
Manganese	0.000016	60,000	
Mercury	0.046	730	
Nickel	0.51	6,000	460
Selenium	1.5	10,000	-
Zinc	4.9	400,000	1,200

Notes:

1. ASC NEPM Schedule B7. HIL criteria for commercial/industrial premises have been used.
2. ASC NEPM Schedule B1. EIL criteria for commercial and industrial premises have been used.

[3] Due to significant community concerns about land and water impacts, the Department established an independent Water Expert Panel for the Project.

6.1.4 Licenced waste disposal facilities

A review has been completed of the potential landfills in NSW and QLD which are licensed to dispose of general solid (non-putrescible) waste and non-regulated waste respectively, including public and commercial facilities. The review indicated that whilst all public licensed landfills could lawfully accept and dispose of the salt waste, they may not have the capacity to or be prepared to accept it.

A number of commercial landfill facility operators were invited to participate in an Expression of Interest (**EoI**) process, with a response received from five operators, confirming their ability to dispose of the waste salt that is not able to be beneficially reused. This was subject to finalisation of commercial negotiations and other arrangements, keeping in mind that salt production will not commence until Phase 3. As such, these arrangements do not need to be finalised for several years. The revised and updated Salt Study for Phase 3 will re-evaluate the disposal options through a follow-up EoI process.

Each landfill operator has confirmed that they can receive the total volume of 430,000 tonnes waste salt, which provides enough assured collective capacity for all waste salt produced from the NGP.

All public and commercial facilities have been listed in Table 6.2, together with an assessment of suitability for disposal. The EPLs of each of the suitable disposal facilities allows the disposal of the NGP waste salt based on the expected waste classifications.

6.1.5 Purpose built salt repository

There are currently no salt repositories which have been purpose-built to manage salt produced from the NGP or other coal seam gas operations, either in NSW or QLD. Santos is currently working with a number of providers to investigate potential opportunities associated with a purpose-built salt repository in Narrabri or the wider region.

Negotiations are also ongoing with local councils to ascertain whether an agreement can be reached for the disposal of waste salt from the NGP at a local landfill facility, although based on the current capacities of the existing facilities, it is unlikely that this option will advance in the near future but will continue to be investigated prior to Phase 3.

6.2 Brine disposal through reinjection

The Report of the Water Expert Panel, included as Appendix G to the DPIE Assessment Report, refers to the option of reinjection of produced water in QLD, subject to the requirement to minimise and mitigate any impacts on environmental values. Reinjection will be evaluated during Stage 3 as a potentially suitable option for the residual produced water or waste brine after completion of the commercial salt recovery processes, subject to regulatory approvals. Apart from the revisions prior to Phase 2 and 3, this Salt Study will be reviewed and updated prior to Phase 4 to include the outcomes of this evaluation.

Table 6.2 - Evaluation of suitable waste salt disposal facilities

Option	Name	Landfill location	NSW / QLD	Owner / Operator	Public / commercial	Distance by road (km)	Comments	Suitable disposal option (Yes/ No)
1	Narrabri Waste Management Facility	Yarrie Lake Road, Narrabri, NSW 2390	NSW	Narrabri Shire Council	Public	17	May not have the capacity or be prepared to accept some or all of the waste salt	No
2	Gunnedah Waste Management Depot	418 Quia Road, Gunnedah	NSW	Gunnedah Shire Council	Public	75	May not have the capacity or be prepared to accept some or all of the waste salt	No
3	Moree Waste Management Facility	Evergreen Road (off the Newell Highway)	NSW	Moree Plains Shire Council	Public	120	May not have the capacity or be prepared to accept some or all of the waste salt	No
4	Yarraman Landfill Controlled Waste Facility	Mungindi Road, Moree, NSW 2400	NSW	Moree Plains Shire Council	Public	130	May not have the capacity or be prepared to accept some or all of the waste salt	No
5	Tamworth Waste Management Facility [1]	123A Forest Rd, North Tamworth NSW 2340	NSW	Tamworth Regional Council	Public	140	May not have the capacity or be prepared to accept some or all of the waste salt	No
6	Walgett Waste Management Centre	Rubbish Tip Rd, Walgett NSW 2832	NSW	Walgett Shire Council	Public	155	May not have the capacity or be prepared to accept some or all of the waste salt	No
7	Coonamble Waste Landfill	Quambone Road, Coonamble NSW 2829	NSW	Coonamble Shire Council	Public	151	May not have the capacity or be prepared to accept some or all of the waste salt	No
8	Gilgandra Waste Facility	100 Pines Drive, Gilgandra NSW 2827	NSW	Gilgandra Shire Council	Public	165	May not have the capacity or be prepared to accept some or all of the waste salt	No
9	Uralla Landfill	Tip Road, Uralla NSW 2358	NSW	Uralla Shire Council	Public	180	May not have the capacity or be prepared to accept some or all of the waste salt	No
10	Armidale Waste Management Facility	108 Long Swamp Rd, Armidale NSW 2350	NSW	Armidale Regional Council	Public	200	May not have the capacity or be prepared to accept some or all of the waste salt	No
11	Armidale Regional Waste Management Facility	Waterfall Way, Armidale	NSW	Armidale Regional Council	Public	190	May not have the capacity or be prepared to accept some or all of the waste salt	No
12	Kemps Creek Engineered Landfill Facility	1725 Elizabeth Drive Kemps Creek, Sydney	NSW	Suez	Commercial	510	Confirmation of commitment received, subject to commercial negotiations. Can receive the total volume of waste salt	**Yes**
13	Woodlawn Bio-Reactor Landfill	619 Collector Rd, Tarago NSW	NSW	Veolia	Commercial	640	Confirmation of commitment received, subject to commercial negotiations. Can receive the total volume of waste salt	**Yes**
14	Ti Tree Bioreactor	Champions Way, Willowbank QLD	QLD	Veolia	Commercial	552	Confirmation of commitment received, subject to commercial negotiations. Can receive the total volume of waste salt	**Yes**
15	Westrex Jackson	40742 Warrego Hwy, Jackson QLD	QLD	Westrex	Commercial	520	Confirmation of commitment received, subject to commercial negotiations. Can receive the total volume of waste salt	**Yes**
16	We Kando Waste Facility	Engine Road, Chinchilla, QLD	QLD	We Kando	Commercial	497	Confirmation of commitment received, subject to commercial negotiations. Can receive the total volume of waste salt	**Yes**
17	Swanbank	426 Swanbank Rd, Swanbank QLD	QLD	Remondis	Commercial	568	No conformation received	No
18	New Chum	100 Chum St, New Chum QLD	QLD	Cleanaway	Commercial	575	No conformation received	No

Notes:

1. There are a number of smaller landfills within the Tamworth Regional Council area, including Barraba, Manilla and Nundle. However, these landfills generally service the local community only.

7. Conclusion

No salt will be produced during Phase 1 and Phase 2 of the NGP, and all produced water generated through the exploration and appraisal activities will be stored in the produced water and brine ponds at Leewood, and treated through the existing water treatment facility. The amended treated water will continue to be beneficially reused for irrigation and dust suppression, with any brine concentrate returned to the ponds. Should it be required, the water management infrastructure approved under Phase 2 of the SSD 6456 consent includes an additional 300 ML storage pond at Leewood, with two cells of approximately 150 ML capacity.

The strategy to maximise the beneficial reuse of the identified feasible reuse options is to store the produced water and brine until Phase 3, which will provide larger volumes of concentrated brine, which in turn will most likely be more attractive and economically feasible for commercial salt extraction.

Process modelling results predict that the brine produced from the new Phase 3 RO treatment process will have a high concentration of beneficial salts, comprising of approximately 64 % (by weight) sodium carbonates and approximately 12 % sodium chloride. The strategy to maximise beneficial reuse of the salt is currently focussing on commercial salt recovery of sodium bicarbonate, and the use of concentrated brine for acid mine drainage neutralisation and for algae farming, though other opportunities exist and will continue to be evaluated. It may be possible to combine or apply more than one of the preferred beneficial uses currently under consideration. The period up to the commencement of Phase 3 will be used to further develop the various beneficial reuse opportunities through field trials, pilot plants and in-depth studies. Once the details of the beneficial reuse trials and investigations are available, the results will be evaluated using a multi-criteria assessment to confirm the most feasible opportunities for execution.

The salt that cannot be beneficially reused will need to be disposed of at a suitably licenced facility. Confirmation has been received from a number of commercial operators that their licenced facilities have sufficient capacity to accept some, or all of the salt estimated to be produced from the NGP.

This Salt Study will be reviewed and where relevant, updated, prior to the commencement of Phase 2. This will include the results of the various beneficial reuse trials and research programs, and a defined strategy for the beneficial reuse of brine and salt, and include any proposed disposal options. Where applicable, the results and outcomes from the beneficial reuse trials and research programs will be incorporated into the Salt Management Plan, required under CoC B41(d)(ix), when next revised.

8. Glossary

Term	Definition[4]
Council	Narrabri Shire Council
Department	NSW Department of Planning and Environment (DPE)
EIS	The Environmental Impact Statement titled Narrabri Gas Project Environmental Impact Statement, dated 31 January 2017, submitted with the development application, including the response to submissions and supplementary response to submissions, and the additional information provided to the Department in support of the application
Gas compression facility	A facility that houses multiple compressor units, either nodal or hub compressors or a mixture of both used to increase the pressure of gas for the purpose of transmission; may be collocated with a gas treatment facility and/or water management facility
Gas field infrastructure	All Project-related infrastructure, excluding the Leewood facility, Bibblewindi facility and the road upgrades required under SSD 6456
Gas well	Pilot wells and production wells
Gathering lines	Pipelines used to transfer gas and produced water from wells
Linear infrastructure	Project related infrastructure of a linear nature including gas and water gathering lines, gas and water pipelines, access tracks, power lines, communication lines and other service lines
Major facilities	Leewood facility and Bibblewindi facility
Managed release scheme	The managed release of treated water into Bohena Creek as one of the beneficial uses of produced water[5]
Material harm	Material harm to the environment is defined in Section 147 of the POEO Act
Minimise	Implement all reasonable and feasible mitigation measures to reduce the impacts of the Project
Mitigation	Activities associated with reducing the impacts of the development
Controlled Waste NEPM	*National Environment Protection (Movement of Controlled Waste between States and Territories) Measure 1998*
Petroleum Assessment Lease 2 (PAL 2)	A PAL is required to hold the exclusive right to prospect for petroleum and to assess any petroleum deposit over a specified area of land in NSW. A lease allows the holder to maintain a title over a potential area, without having to commit to further exploration. The holder can, however, continue prospecting operations and to recover petroleum in the course of assessing the viability of commercial mining. PAL 2 is held by Santos NSW Pty Ltd.
Petroleum Exploration Licence 238 (PEL 238)	Before exploring for minerals or petroleum in NSW, an explorer must first obtain a Petroleum Exploration Licence (PEL) under the *Petroleum (Onshore) Act 1991*. An exploration licence gives the licence holder exclusive rights to explore for petroleum or specific minerals within a designated area but it does not permit mining, nor does it guarantee a mining or production lease will be granted. PEL 238 is held by Santos NSW Pty Ltd.
Petroleum Production Lease 3 (PPL 3)	A petroleum production lease gives the holder the exclusive right to extract petroleum within the production lease area during the term of the lease. PPL 3 is held by the following titleholders:

[4] The majority of the definitions are as provided in the Development Consent for SSD 6456.

[5] Note that there will be no discharge to Bohena Creek for Phase 1.

Term	Definition[4]
	• Santos QNT Pty Ltd; • Santos NSW (Hillgrove) Pty Ltd; and • Santos NSW (Eastern) Pty Ltd.
Petroleum production lease application (PPLA)	A petroleum production lease gives the holder the exclusive right to extract petroleum within the production lease area during the term of the lease. Development consent under the *Environmental Planning and Assessment Act 1979* must be in place before a petroleum production lease can be granted. Santos, on behalf of it joint venture partner lodged four petroleum production lease applications under the PO Act in May 2014 for the Project area, being PPLAs 13, 14, 15 and 16. The ownership of the application is held by Santos NSW Pty Ltd.
Pilot well	A well for gas and water extraction, for the purpose of exploration, appraisal and assessment of the gas field potential
Planning Secretary	Planning Secretary under the EP&A Act, or nominee
Production well	A well for gas and water extraction, for the purpose of commercial gas production and/or use
Project area	The area of approximately 95,000 hectares that encompasses the Project
Project footprint	The area of surface expression being about 1,000 hectares occupied by the infrastructure components of the Narrabri Gas Project
Project-related infrastructure	All infrastructure and other structures associated with the development. This includes linear infrastructure and non-linear infrastructure, surface infrastructure and subsurface infrastructure, major facilities, wells and well pads and other gas field infrastructure
Salt Study	The Produced Salt Beneficial Reuse and Disposal Study (this report)
Waste Classification Guidelines	*Waste Classification Guidelines* (NSW)
Waste Regulation	*Protection of the Environment Operations (Waste) Regulation 2014* (NSW)
Well	Pilot wells and production wells
Well pad	An area of up to 1 hectare in size upon which the gas wells are to be located, with the area decreasing to no more than 0.25 hectares following rehabilitation[6], or other area as may be approved in the Field Development Plan

[6] Workover activities will be contained within the operational area of the well pad area of around 0.2 ha, with an additional laydown area that could be approximately 0.2 ha in size.

9. References

DES (2022). *Overview of regulated waste categorisation. Information sheet - Regulated waste*. QLD Department of Environment and Science, ESR/2019/4749. Version 3.01.

GHD (2021). *Narrabri Gas Project WTP Early FEED Salt Beneficial Reuse and Disposal - Process Modelling*. Santos document number: 7099-150-MMM-0002, prepared for Santos Ltd.

Natural Soda (2019). *Our Unique Process*, www.naturalsoda.com/about-us/our-unique-process/, accessed 22 July 2021.

National Environment Protection Council (1999). *National Environment Protection (Assessment of Site Contamination) Measure 1999. Schedule B(1) Guideline on the Investigation Levels for Soil and Groundwater*. NEPC, Adelaide, Australia.

National Environment Protection Council (2011). *National Environment Protection (Assessment of Site Contamination) Measure. Schedule B(5)b. Guidelines on the Australian methodology to derive Ecological Investigation Levels in contaminated soils*. NEPC, Adelaide, South Australia.

National Environment Protection Council (2011). *National Environment Protection (Assessment of Site Contamination) Measure. Schedule B(5)c. Soil quality guidelines for arsenic, chromium III, copper, DDT, lead, naphthalene, nickel and zinc.* NEPC, Adelaide, South Australia.

NSW EPA (2014). *Waste Classification Guidelines - Part 1: Classifying Waste.*

NSW EPA (2018). *Waste Levy Guidelines.*

RGS Environmental (2020), *Murrawombie Laboratory Scale Heap Leach Neutralisation Trial*.

Robertson A., Maddocks G., Kelly B. and Sheppard I (2018). *Application of a Coal Seam Gas Waste Product as part of the Rehabilitation Program for a Copper Heap Leach Operation*. In Proceedings of the 11th International Conference on Acid Rock Drainage and International Mine Water Association Conference, Pretoria, South Africa, pp 231-236, 10-14 September 2018.

University of Queensland (2020). *Independent Review: Brine and salt management*. *Section 6, Queensland Gas: end-to-end water use, supply and management*. UQ, Centre for Natural Gas.

Appendix A - Consultation records

Santos

Management Plan Consultation Feedback Form

DOCUMENT TITLE:	**Produced Salt Beneficial Reuse and Disposal Study (Condition B69)**
STAKEHOLDER:	**NSW Environment Protection Authority (EPA)**
CONSULTATION RELEASE DATE:	**1 December 2021**
COMMENTS DUE DATE:	**Mid Jan 2022**

General Feedback	
Key Issues	Although assessed and approved by the EPA, a Resource Recovery Order/Exemption for the Heap Leach Pad Remediation Trial using soda ash brine from the Narrabri Gas Project needs to be attained i.e. the application of waste to land from EPL20350 to EPL4501.
Suggestions for improvement	The plan can be strengthened by replacing loose language and indeterminate terms, such as, 'should, where reasonable, may', as these words point at best practice but are not definitive or binding.
	All beneficial reuse of produced water occurs on Leewood premises under existing approvals for Phase 1. No waste exemptions are required for existing approved activities.

Section	**Type**	**Specific Feedback** *Detail specific issues with certain sections in the document*
5.1.1	Note	*Acid mine drainage neutralisation trial* A Notice of Variation of EPL 4501 was issued on the 25 August 2021, allowing for Tritton Copper Mine to permit the use of soda ash brine water concentrate from the Narrabri Gas Project on the Murrawombie heap leach pads to support mine closure and rehabilitation. The Heap Leach Pad Remediation Trial was scheduled to commence in 2021, for a period not exceeding 12 months. It should be noted that Santos will be required to work with Aeris Resources (Tritton Resources PtyLtd), assisted by the EPA, to apply for a Resource Recovery Order / Exemption for the transport and use of soda ash brine waste material between premises.

Management Plan Consultation Feedback Form

Page 1 of 1

Our Reference: DLA:MH:1950357
Your Reference: SSD-6456-PA-22
Contact Name: Donna Ausling

NARRABRI SHIRE
DISCOVER THE POTENTIAL

explore NARRABRI region

Ms Cassie Hay
Senior Environmental Advisor – Onshore Oil and Gas
Santos Ltd
32 Turbot Street
BRISBANE QLD 4000

Email: Cassie.Hay@santos.com

Thursday, 27 January 2022

Re: Narrabri Gas - Post Approval (SSD-6456-PA-22) – Produce Salt Beneficial Reuse and Disposal Study; Waste Management Plan; Rehabilitation Management Plan-Council Feedback

Dear Ms Hay

Thank you for the opportunity to provide comment on the abovementioned Plans. Council's consolidated feedback in this regard is provided herewith:

Produced Salt Beneficial Reuse and Disposal Study

It is noted that the submitted report identifies a number of businesses that will support to waste management activities that are currently located outside of the Region. These businesses are therefore encouraged, wherever reasonably practicable, to establish site operations within the Narrabri Local Government Area (LGA).

Transportation of waste materials (to be reused) does not appear to have been identified in previous Transport Management Plans for Santos. Consequently, any model to utilise the nominated by-product materials may be subject to a separate approvals process.

The Report mentions several negotiations with local Councils to dispose of waste. The particulars of these consultations have not been included in Appendix A, with details currently 'blank'. Since project inception there have been a number of changes to staff within the waste area across the Region, including within the Narrabri Shire Council. On this basis, Santos is encouraged to conduct routine and regular consultations with relevant Council personnel to ensure that lines of communication are maintained and available technical expertise can appropriately inform project decision-making processes.

Narrabri Shire Council
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Version: 1, Version Date: 28/01/2022

Print Date: 28 January 2022, 12:30 PM

Council is also currently investigating opportunities to increase the capacity of the Narrabri Landfill. As a consequence, ongoing communication with Council's Waste Division is recommended.

Council has been consistent in endeavouring to diversify the economy of the Narrabri Shire. It is considered that the gas industry would add the existing agriculture, mining and education industries to broaden and strengthen the economic base of the Shire. Council is in the process of developing an industrial estate titled the 'Northern NSW Inland Port' (N2IP) and is currently working with the NSW government as it investigates Narrabri Shire as a Special Activation Precinct (SAP).

With the commencement of a gas industry, N2IP and the SAP would welcome the attraction and arrival of a range of ancillary businesses that either use gas as a feedstock, or for the provision of cheaper base energy. Similarly, ancillary businesses able to use by-product generated from the extraction of gas is an industry category that both Council is committed to attracting to the Narrabri Shire. Council is of the opinion that ancillary industries such as algae farming, a zirconium processing facility and sodium bicarbonate would prosper in Shire, particularly given proximity to the source of the by-product. Therefore, strong consideration should be given to the establishment of any business that requires gas for energy, feedstock or any specialist by-product reuse ancillary organisation.

Waste Management Plan (Phase 1)

As detailed above, given the dynamic nature of waste management and associated environmental requirements, ongoing and routine liaison is needed with Council's Waste and Water Divisions. This approach will ensure that Council's Water Treatment and Waste Facilities can appropriately manage the volume and product type that will be disposed offsite. It is acknowledged that such premises have been identified throughout the Report as the receiving facility.

Rehabilitation Plan (Phase 1)

It is noted that the objectives of this Plan are:

- To ensure rehabilitation works address relevant regulatory requirements;
- To present the final end land-uses and preliminary completion criteria;
- To describe rehabilitation works proposed during Phase 1;

- To provide guidance on how topsoil and subsoil is managed to conserve the seed bank, nutrients and to promote the natural establishment of vegetation that will be self-sustaining in the long-term; and
- To establish a rehabilitation monitoring program to track progress of rehabilitation.

In relation to section 4.7 of the Plan, your attention is drawn to the NSW Department of Primary Industries (DPI) State Significant Agricultural Land (SSAL) Mapping Project. Further information in relation to this initiative is available from https://www.dpi.nsw.gov.au/agriculture/lup in the event that the development footprint intersects SSAL land.

Sections 6 - 7 of the draft Plan (pp.27 - 29) currently contains a series of referencing errors which require attention.

Thank you for the opportunity to provide feedback. Should you require any additional information or clarification in relation to this matter you are invited to contact Council's Strategic Planning Team or the undersigned on (02) 6799 6866, or by emailing council@narrabri.nsw.gov.au.

Yours faithfully

Donna Ausling
A/Director Planning, Strategy & People

Produced Salt Beneficial Reuse and Disposal Study (Revision A) – Responses to stakeholder consultation feedback

Stakeholder	Section #	Section heading	Existing text	Comment	Draft response
EPA	General	N/A	No specific text reference	The plan can be strengthened by replacing loose language and indeterminate terms, such as, 'should, where reasonable, may', as these words point at best practice but are not definitive or binding.	The whole document has been reviewed, and where applicable, the terms 'should', 'would', 'where reasonable' and 'may' have been strengthened. Note that the terms 'should', 'would', 'where reasonable' and 'may' are used extensively in the consent conditions. Since the relevant conditions have been reproduced in full in this document, in these instances the above terms have been retained.
EPA	General	N/A	No specific text reference	All beneficial reuse of produced water occurs on Leewood premises under existing approvals for Phase 1. No waste exemptions are required for existing approved activities.	Noted.
EPA	5.1.1	Acid mine drainage neutralisation	Aeris submitted an application to the EPA in February 2019 to vary EPL 4501 for the Tritton Copper Operations to permit the use of brine water concentrate from the NGP on the Murrawombie heap leach pads to support mine closure and rehabilitation. The application was submitted to permit a field trial to confirm the findings of the laboratory scale trial. The Notice of Variation of the EPL was issued on 25 August 2021, allowing a field trial scheduled to commence in 2021, for a period not exceeding 12 months.	Although assessed and approved by the EPA, a Resource Recovery Order/Exemption for the Heap Leach Pad Remediation Trial using soda ash brine from the Narrabri Gas Project needs to be attained i.e. the application of waste to land from EPL 20350 to EPL 4501. *Acid mine drainage neutralisation trial* A Notice of Variation of EPL 4501 was issued on the 25 August 2021, allowing for Tritton Copper Mine to permit the use of soda ash brine water concentrate from the Narrabri Gas Project on the Murrawombie heap leach pads to support mine closure and rehabilitation. The Heap Leach Pad Remediation Trial was scheduled to commence in 2021, for a period not exceeding 12 months. It should be noted that Santos will be required to work with Aeris Resources (Tritton Resources Pty Ltd), assisted by the EPA, to apply for a Resource Recovery Order / Exemption for the transport and use of soda ash brine waste material between premises.	Santos will work with the EPA to ensure that a Resource Recovery Order & Exemption is in place.
Narrabri Shire Council	General	N/A	No specific text reference	It is noted that the submitted report identifies a number of businesses that will support (sic) to waste management activities that are currently located outside of the Region. These businesses are therefore encouraged, wherever reasonably practicable, to establish site operations within the Narrabri Local Government Area (LGA)	Noted. Santos will continue consultation with local businesses and operations to maximise local support, where reasonable and feasible.
Narrabri Shire Council	General	N/A	No specific text reference	Transportation of waste materials (to be reused) does not appear to have been identified in previous Transport Management Plans for Santos. Consequently, any model to utilise the nominated by-product materials may be subject to a separate approvals process.	Noted. Any transport of waste materials from with the Project will be fully approved and/or licenced.
Narrabri Shire Council	General	N/A	No specific text reference	The Report mentions several negotiations with local Councils to dispose of waste. The particulars of these consultations have not been included in Appendix A, with details currently 'blank'. Since project inception there have been a number of changes to staff within the waste area across the Region, including within the Narrabri Shire Council. On this basis, Santos is encouraged to conduct routine and regular consultations with relevant Council personnel to ensure that lines of communication are maintained, and available technical expertise can appropriately inform project decision-making processes. Council is also currently investigating opportunities to increase the capacity of the Narrabri Landfill. As a consequence, ongoing communication with Council's Waste Division is recommended	Noted. Santos will continue consultation with Council and local businesses and operations to maximise local support, where reasonable and feasible. The consultation correspondence with the disposal facilities is contained in Appendix C.
Narrabri Shire Council	General	N/A	No specific text reference	Council has been consistent in endeavouring to diversify the economy of the Narrabri Shire. It is considered that the gas industry would add the existing agriculture, mining and education industries to broaden and strengthen the economic base of the Shire. Council is in the process of developing an industrial estate titled the 'Northern NSW Inland Port' (N2IP) and is currently working with the NSW government as it investigates Narrabri Shire as a Special Activation Precinct (SAP).	Noted.

Stakeholder	Section #	Section heading	Existing text	Comment	Draft response
Narrabri Shire Council	General	N/A	No specific text reference	With the commencement of a gas industry, N2IP and the SAP would welcome the attraction and arrival of a range of ancillary businesses that either use gas as a feedstock, or for the provision of cheaper base energy. Similarly, ancillary businesses able to use by-product generated from the extraction of gas is an industry category that both Council is committed to attracting to the Narrabri Shire. Council is of the opinion that ancillary industries such as algae farming, a zirconium processing facility and sodium bicarbonate would prosper in Shire, particularly given proximity to the source of the by-product. Therefore, strong consideration should be given to the establishment of any business that requires gas for energy, feedstock or any specialist by-product reuse ancillary organisation.	Noted. Santos will continue to support the establishment of supporting industries or ancillary operations within the Narrabri Shire, especially those that can use the Project's by-products such as brine and salt.

Appendix B - Waste classification threshold criteria

Table B1 - Comparison of predicted salt chemistry against NSW waste classification criteria

Parameter	Predicted salt waste concentration (mg/kg)	Maximum values of specific contaminant concentration (SCC) for classification without TCLP [1]	
		General solid waste [2] (mg/kg)	Restricted solid waste (mg/kg)
Arsenic	0.069	100	400
Benzene	N/A	10	40
Benzo(a)pyrene	N/A	0.8	3.2
Beryllium	0.06 (LoD) [3]	20	80
Cadmium	1.1	20	80
Carbon tetrachloride	N/A	10	40
Chlorobenzene	N/A	2,000	8,000
Chloroform	N/A	120	480
Chlorpyrifos	N/A	4	16
Chromium (VI) [4]	0.6 (LoD) [3]	100	400
m-Cresol	N/A	4,000	16,000
o-Cresol	N/A	4,000	16,000
p-Cresol	N/A	4,000	16,000
Cresol (total)	N/A	4,000	16,000
Cyanide (amenable)	N/A	70	280
Cyanide (total)	N/A	320	1,280
2,4-D	N/A	200	800
1,2-Dichlorobenzene	N/A	86	344
1,4-Dichlorobenzene	N/A	150	600
1,2-Dichloroethane	N/A	10	40
1,1-Dichloroethylene	N/A	14	56
Dichloromethane	N/A	172	688
2,4-Dinitrotoluene	N/A	2.6	10.4
Endosulfan	N/A	60	240
Ethylbenzene	N/A	600	2,400
Fluoride	410	3,000	12,000
Fluroxypyr	N/A	40	160
Lead	1.0	100	400
Mercury	0.046	4	16
Methyl ethyl ketone	N/A	4,000	16,000
Moderately harmful pesticides (total)	N/A	250	1,000
Molybdenum	0.4	100	400
Nickel	0.51	40	160

Parameter	Predicted salt waste concentration (mg/kg)	Maximum values of specific contaminant concentration (SCC) for classification without TCLP [1]	
		General solid waste [2] (mg/kg)	Restricted solid waste (mg/kg)
Nitrobenzene	N/A	40	160
C6 - C9 petroleum hydrocarbons	N/A	650	2,600
C10 - C36 petroleum hydrocarbons	N/A	10,000	40,000
Phenol (non-halogenated)	N/A	288	1,152
Picloram	N/A	60	240
Plasticiser compounds	N/A	20	80
Polychlorinated biphenyls	N/A	<50	<50
Polycyclic aromatic hydrocarbons (total)	N/A	200	800
Scheduled chemicals	N/A	<50	<50
Selenium	1.5	20	80
Silver	N/A	100	400
Styrene (vinyl benzene)	N/A	60	240
Tebuconazole	N/A	128	512
1,2,3,4- Tetrachlorobenzene	N/A	10	40
1,1,1,2-Tetrachloroethane	N/A	200	800
1,1,2,2-Tetrachloroethane	N/A	26	104
Tetrachloroethylene	N/A	14	56
Toluene	N/A	288	1,152
1,1,1-Trichloroethane	N/A	600	2,400
1,1,2-Trichloroethane	N/A	24	96
Trichloroethylene	N/A	10	40
2,4,5-Trichlorophenol	N/A	8,000	32,000
2,4,6-Trichlorophenol	N/A	40	160
Triclopyr	N/A	40	160
Vinyl chloride	N/A	4	16
Xylenes (total)	N/A	1,000	4,000

Notes:

1. Aluminium, barium, boron, chromium (0 and III oxidation states), cobalt, copper, iron, manganese, vanadium and zinc have not been listed with values in this table and need not be tested for.
2. Values are the same for general solid waste (putrescible) and general solid waste (non-putrescible).
3. These values are over-estimates as the limit of detection (LoD) is used.
4. These limits apply to chromium in the +6 oxidation state only.

Table B2 - Comparison of predicted salt chemistry against QLD categorisation thresholds

Parameter	Predicted salt waste concentration (mg/kg)	Categorisation threshold concentrations	
		Not regulated waste (mg/kg)	Category 2 regulated waste (mg/kg)
Inorganic species			
Antimony	No data	<9	9 - 36
Arsenic	0.069	<300	300 - 1,200
Barium	49	<4,500	4,500 - 18,000
Beryllium	0.06 (LoD) [1]	<90	90 - 360
Boron	27	<20,000	20,000 - 80,00
Cadmium	1.1	<90	90 - 360
Chromium (VI)	0.6 (LoD) [1]	<300	300 - 1,200
Copper	4.2	<220	220 - 880
Lead	1.0	<300	300 - 1,200
Mercury	0.046	<80	80 - 320
Molybdenum	0.4	<117	117 - 468
Nickel	0.51	<1,200	1,200 - 4,800
Selenium	1.5	<700	700 - 2,800
Silver	N/A	<117	117 - 468
Vanadium	0.56	<117	117 - 468
Zinc	4.9	<400	400 - 1,600
Anions			
Cyanide (total)	N/A	<240	240 - 960
Fluoride	410	<930	930 – 3,720
Organic species			
Petroleum hydrocarbons			
C6 - C9 petroleum hydrocarbons	N/A	<950	950 - 3,800
C10 - C36 petroleum hydrocarbons	N/A	<5,300	5,300 - 21,200
Polycyclic aromatic hydrocarbons			
Benzo(a)pyrene	N/A	<3	3 - 12
Polycyclic aromatic hydrocarbons (total)	N/A	<300	300 - 1,200
Monocyclic aromatic hydrocarbons			
Benzene	N/A	<5	5 - 20
Toluene	N/A	<1,470	1,470 - 5,880
Ethylbenzene	N/A	<17	17 - 68
Xylenes (total)	N/A	<174	174 - 696
Styrene (vinyl benzene)	N/A	<1,800	1,800 - 7,200
Chlorinated hydrocarbons			

Parameter	Predicted salt waste concentration (mg/kg)	Categorisation threshold concentrations	
		Not regulated waste (mg/kg)	Category 2 regulated waste (mg/kg)
Carbon tetrachloride	N/A	<2	2 - 8
Chlorobenzene	N/A	<84	84 - 336
Chloroform	N/A	<1	1 - 4
1,2-dichlorobenzene	N/A	<540	540 - 2,160
1,4-dichlorobenzene	N/A	<8	8 - 32
1,2-dichloroethane	N/A	<1	1 - 6
1,1-dichloroethylene	N/A	<69	69 - 276
Dichloromethane	N/A	<105	105 - 420
1,1,1,2-Tetrachloroethane	N/A	<6	6 - 24
1,1,2,2-Tetrachloroethane	N/A	<6	6 - 24
Tetrachloroethylene	N/A	<24	24 - 96
1,1,1-Trichloroethane	N/A	<2,430	2,430 - 9,720
1,1,2-Trichloroethane	N/A	<0.45	0.45 - 1.8
Trichloroethylene	N/A	<1	1 - 5
Vinyl chloride	N/A	<0.18	0.18 - 0.72
Phenols			
2,4,5-Trichlorophenol	N/A	<1,890	1,890 - 7,560
2,4,6-Trichlorophenol	N/A	<19	19 - 76
Cresol (total)	N/A	<4,000	4,000 - 16,000
Phenols (total)	N/A	<40,000	40,000 - 160,000
Nitroaromatics and ketones			
2,4-dinitrotoluene	N/A	<5	5 - 20
nitrobenzene	N/A	<15	15 - 60
methyl ethyl ketone	N/A	<8,100	8,100 - 32,400
Specific persistent organic pollutants (POPs)			
2,4-D	N/A	<210	210 - 840
Aldrin and Dieldrin (total)	N/A	<10	10 - 40
organochlorine pesticides(total)	N/A	<50	50 - 200
organophosphate pesticides (total)	N/A	<250	250 - 1,000
polychlorinated biphenyls (PCBs)	N/A	<2	2 - 50
per- and poly-fluoroalkyl substances (PFAS)	N/A	0	-
persistent organic pollutant (other)	N/A	<50	50 - 200
pH	9.5-10.7	6.5 - 9	2 - <6.5 or >9 - 12.5

Notes:

1. These values are over-estimates as the limit of detection (LoD) is used.

Appendix C - Disposal facilities letters of commitment

WestRex

ABN: 95 633 180 864

31st December 2020

Namoi Waste Corp
54-56 Wee Waa Road
NARRABRI NSW 2390

Dear Jack,

WestRex has reviewed the information supplied by Namoi Waste Corp and based on prior results for Santos Nth NSW drill activity and fluids regarding salt impacted waste from Narrabri. Based on the review of the material, we can receive this waste to our Jackson Facility for treatment and processing.

Acceptance of this material is as per the licence held by WestRex allowing receival for treatment under ERA 55. WestRex will utilise a methodology to receive and treat the material through either bioremediation, chemical reduction, pH adjustment, stabilisation and or fixation.

- the approximate quantities forecast – Up to 430,500 tonnes of salt will be produced over 25 years,
- averaging 1,430 tonnes per month

To assist with fast processing of the loads at our facility, please notify the facility the afternoon prior to delivery. Please ensure your driver quotes the reference number detailed below for this waste acceptance when arriving on site. Additionally, please ensure that this material is identified as the following on all Waste Tracking and Transport documentation (required for regulated wastes). Westrex must receive copies of all relevant waste permits prior to receival of any material (consignment authority).

Westrex reference: WSJC20201231
Description: Salt impacted drill fluids and solids
Volume: up to 20,000 tonnes per annum

Our Jackson facility address is 40742 Warrego Hwy, Jackson 4426. The facilities operating hours are 7 days per week, 365 days a year, 24 hours a day. The Jackson facility's registered plan and license details are as follows:

Description:
Lot 28 on BRW 122,
DES Environmental Authority: EPPR01050513

Should you require any further information please do not hesitate to contact myself direct.

Yours Sincerely,

David Powell

General Manager
Mobile: 0478 323 219

Naracor Pty Ltd T/as Namoi WasteCorp
ABN: 9771 44 916 923 ACN: 144 916 923

54-56 Wee Waa Rd
Narrabri
NSW 2390

Ph: (02) 6792 47666
Email: admin@namoiwastecorp.com.au

Dear Sir/Madam,

Salt Disposal for Narrabri Gas Project

This letter is to confirm that Naracor Pty Ltd (Namoi WasteCorp) has entered into discussions with Santos Ltd, for the disposal of any salt that is not able to be beneficially reused, for the Narrabri Gas Project (the Project).

It is acknowledged that up to 430,500 tonnes of salt waste is anticipated to be produced from the project, averaging 1,430 tonnes per month, and that assessment by GHD indicates that the predicted chemistry of the salt waste complies with the general solid (non-putrescible) waste requirements for disposal in NSW.

Namoi WasteCorp can confirm that the following licensed disposal facilities have confirmed they are able to take the volume and composition of salt waste produced by the development for disposal at their premises.

Licenced Facility	Location	Owner of Facility	Estimated Cost	Licence
Westrex, Jackson	Jackson, QLD	Westrex	Disposal cost is $450/t	EPPR01050513
Elizabeth Drive Landfill Facility	Kemps Creek, NSW	Suez	$690/t	EPL 4068
Wekando, Chinchilla	Chinchilla, QLD	Wekando	TBA	EPPR03467515

See Attachment 1 for letters from these facilities.

The facilities listed above have suitable licencing, design and sufficient capacity to accept the full volume of salt waste that may be required by the Narrabri Gas Project.

Namoi WasteCorp also confirms that we will continue to work with Santos to discuss additional disposal and beneficial salt reuse options for the project, for Santos to deliver a final solution prior to commencement of Phase 2 of the Narrabri Gas Project.

Kind regards,

Jack Campbell
Manager

NAMOI WASTECORP
...Creating a cleaner future

Suez Recycling & Recovery Australia
PO Box 50
Kemps Creek NSW 2178
Office phone number: 02 4774 8866

12th January 2021

Cleanaway
47 Raven St
Kooragang NSW 2304

Attention: Mr Craig Hall

Disposal of de-watered salt sludge at the Suez landfill, Kemps Creek

Hi Craig

Subject to review of analytical testwork reports received and assuming there would be no other known or suspected contaminants, I wish to confirm we can accept the de-watered sludge material described at the Suez Landfill, Kemps Creek consistent to the NSW EPA Waste Classification Guidelines, Part 1 Classifying Wastes - November 2014 edition.

A copy of the Suez landfill, Kemps Creek landfill operators licence is attached with this letter for your reference.

For acceptance at the Suez Kemps Creek landfill the sludge must meet the acceptance criteria as a solid spadeable waste. The landfill is not licensed or permitted to accept liquid wastes or slurries.
Suez are willing to accept the spadeable salt sludge volumes mentioned however I cannot give confirmation our facilities are able to accept the wastes over the twenty five year lifetime period of the project.

Please contact me if you would like to discuss the matter of the project with me in further detail.

SUEZ is strongly committed to the safety of their employees and customers that enter any SUEZ site, therefore please ensure you read the attached overweight vehicle warning notice. We also do not accept tip over axle semi trailers at any SUEZ facility.

Kindest regards,

G Jordan

Geoff Jordan

Suez Recycling & Recovery Australia

1725 Elizabeth Drive, Kemps Creek NSW 2178
Mobile phone: 0401 980 443

25/1/2021

Dear Sir/Madam,

Re: Santos Narrabri EOI - Landfill Concept Pricing

This letter is to confirm that Veolia Environmental Services (Australia) Pty Ltd (Veolia) has entered into discussions with Santos Ltd (Santos), for the disposal of any salt that is not able to be beneficially reused, for the Narrabri Gas Project (the Project).

It is acknowledged that up to 430,500 tonnes of salt waste is anticipated to be produced from the project, averaging 1,430 tonnes per month, and that assessment by GHD indicates that the predicted chemistry of the salt waste complies with the general solid (non-putrescible) waste requirements for disposal in NSW.

Veolia can confirm that the following licensed disposal facilities have the capacity to accept the volume of salt waste produced by the project for disposal, subject to implementing suitable operational and environmental controls, and gaining relevant regulatory approval.

Licenced Facility	Location	Owner of Facility	Additional Facility Details including EPL
Woodlawn Bio-Reactor Landfill	Tarago	Veolia	Mechanical biological treatment facility. EPL 11436
Ti-Tree Bio-Energy	Ti Tree	Veolia/JJ Richards	Thermal and mechanical waste reprocessing and treatment - General, organic, regulated & medical waste EPPR00573913

The facilities listed above have sufficient capacity to accept the full volume of salt waste that may be required by the Narrabri Gas Project.

In addition to offsite disposal, Veolia confirms we have commenced working with Santos to investigate the potential of building a purpose-built cell with Narrabri, subject to gaining relevant approvals.

Veolia also confirms that we will continue to work with Santos to discuss additional disposal and beneficial salt reuse options for the project, for Santos to deliver a final solution prior to commencement of Phase 2 of the Narrabri Gas Project.

Kind regards,

Bao Quach

Head of Sales & Business Development, Australia - WASTE
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Southbank 3006 VIC Australia
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+0418 738 142