



19 December 2025

Department of Lands, Planning and Environment
Petroleum Regulations Unit
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By email: Santos.ep161@nt.gov.au

To Whom it May Concern,

SUBMISSIONS: STO8-1: EP161 Beetaloo Basin Appraisal Pilot Environment Management Plan

1. The Environment Centre NT (**ECNT**) is the peak community sector environment organization in the NT, raising awareness among community, government, business and industry about environmental issues, holding government to account over environmental governance, and supporting community members to participate in decision-making processes and action.
2. On 19 November 2025, Santos QNT Pty Ltd (**Santos**) submitted an Environment Management Plan (**EMP**) for assessment, under the *Petroleum (Environment) Regulations 2016*. The EMP was published for comment on 21 November 2025.
3. The EMP proposes a scope of activities on the Exploration Licence EP 161. The scope of works includes the following activities:
 - (i) Clearing 87.34 hectares of remnant vegetation and previously disturbed land, along with earthworks for two new well pads;
 - (ii) Drilling and hydraulic fracture stimulation for up to 12 appraisal wells;
 - (iii) Operating, testing, maintenance and decommissioning;
 - (iv) Wastewater management that includes evaporation tank, storage tanks, drilling sumps, cutting pits and any transfer infrastructure within the well pad;
 - (v) Infrastructure and activities required to support the appraisal activities ie, water supply bores, groundwater monitoring bores, borrow pits, installation and operation of camps, bulk material transport and storage, office, workshop and storage, traffic management;
 - (vi) Incorporation of previously authorized and ongoing regulated activities (including at Inacumba and Tanumbirini well pads).
4. Santos makes clear in the EMP that this project is an appraisal project that could lead to significantly expanded onshore gas development in the Beetaloo Basin at export scale, including for “Asian LNG markets” and that the NT “could be on the cusp of a shale gas boom akin to the coal



seam gas boom”. Santos states that “the capital intensity of a greenfield shale gas industry will need to be underpinned by foreign investment and the scale of Asian LNG export markets and customers”.¹ The cumulative impacts of a production-scale onshore gas industry in the NT are likely to be very significant and could include:

- (a) The construction of up to 6000 wells drilled through complex geological formations, including the 500,000 square kilometre Cambrian Limestone Aquifer, which is the lungs of the Northern Territory and supplies water for communities, as well as the tourism, farming and pastoral industries and discharges into the Roper and Daly Rivers (as well as, potentially, the McArthur and Limmen Bight Rivers);
 - (b) The extraction of billion of litres of water from the Cambrian Limestone Aquifer; and
 - (c) The generation of up to 1.2 billion tonnes of greenhouse gas emissions in the 25 years to 2050.²
5. ECNT submits that section 50(1) of the *Environment Protection Act 2019* (NT) applies, and you should:
- (i) Refer the EMP to the NTEPA under section 50(2)(c) of the *Environment Protection Act 2019* (NT); and
 - (ii) Refuse to consider the application until the EMP is referred to the NTEPA and a decision is made on the referral, pursuant to s50(2)(a) of that legislation.
6. In addition, the EMP should be referred for assessment under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) as it has the potential to cause significant impacts to matters of national environmental significance, including threatened species and water resources.
7. Alternatively, the Minister should reject the EMP because it does not comply with the *Petroleum (Environment) Regulations 2016* (NT) for the following reasons:
- (i) Santos has not managed its environmental risks to be as low as reasonably practicable (ALARP) nor acceptable;
 - (ii) The EMP is not appropriate for the nature and scale of the regulated activity; and
 - (iii) The EMP does not contain the information required within Schedule 1.

Non-conformance with the Petroleum Environment Regulations

8. The project does not conform to applicable regulations or requirements, including the *Petroleum (Environment) Regulations 2016* (NT) (**Regulations**) that were revised in 2025, for the reasons set out below.

Many of Santos’ environmental outcomes do not satisfy the “as low as reasonably practicable” or

¹ Santos EMP, Foreword.

² Bill Hare and Thomas Houlie, [Emissions Impossible Report](#) (2023).



“acceptable” standard required by Section 3 of the Petroleum Environment Regulations.

9. Schedule 1, section 4 of the Regulations requires that an EMP must specify the environmental outcomes of the regulated activity. Section 3 of the Regulations provides a definition of an “environmental outcome” that has two-elements: an environmental outcome is an “outcome that will be achieved if the environmental impacts and environmental risks of a regulated activity are reduced to a level that is:(a) as low as reasonably practicable [“ALARP”] ; and (b) acceptable.”
10. A number of environmental outcomes for the EMP do not satisfy both elements of the definition in Section 3 of the Regulations. For example, in relation to greenhouse gases, Santos states “The environmental outcomes of the Activity are:... Maintain greenhouse gas emissions below acceptable levels.”³ Here, this environmental outcome aims for an acceptable level of emissions but does not ensure that emissions are reduced to be as low as reasonably practicable. Even if Santos were to achieve this outcome, the ALARP standard would not necessarily be met. For another example, an environmental outcome related to hydraulic fracturing and aquifers is to “Protect the quality and integrity of surface water and groundwater by preventing contamination and maintaining natural flow regimes where practicable.”⁴ This environmental outcome neither addresses nor ensures that prevention of contamination of aquifers only “where practicable” will be acceptable. To the contrary, contamination of aquifers when prevention is not practicable may not be acceptable to key stakeholders.⁵ Because these outcomes address only the practical reduction of risks, or only set an acceptable level of risk, but not both, they do not satisfy both elements of the definition of an “environmental outcome” in Section 3 of the Regulations.
11. The Minister should not approve the EMP until the environmental outcomes are redefined so that, if achieved, they will ensure that risks are managed to be both ALARP and acceptable.

Santos’ measurement criteria cannot be used to determine whether environmental outcomes are met in violation of Section 3 and Schedule 1, Section 4(c) of the Petroleum Environment Regulations

12. Section 4(c) of Schedule 1 of the Regulations states that the EMP “must specify” the “measurement criteria to be used to ensure the environmental outcomes and environmental performance standards are met.” Section 3 Part 1 of the Regulations define measurement criteria to mean “the criteria to be used in determining whether an environmental outcome or environmental performance standard has been met.” Measurement criteria for the EMP are provided in Table 62.⁶ However, many of the EMP measurement criteria provide no objective definitions or measurement that could be used to verify whether environmental outcomes are being met.
 - (i) **Water use:** In relation to impacts from the drawdown of aquifers through the use of 750 ML of water, the measurement criteria includes groundwater monitoring that shows water “quality, extraction volumes and water level are relatively unchanged, and water availability is unchanged.”⁷ This outcome does not define what constitutes “unchanged”

³ Santos, Beetaloo Appraisal EMP, Executive Summary, *Environmental outcomes*; *id.* at p. 155.

⁴ Santos, Beetaloo Appraisal EMP, p. 146.

⁵ See Santos Beetaloo Appraisal EMP, Appendix N (noting water is a primary concern amongst stakeholders, including associated cultural values).

⁶ Santos, Beetaloo Appraisal EMP, p. 141.

⁷ Santos, Beetaloo Appraisal EMP, p. 148.



and provides no objective standard to measure water availability, such as ensuring that water levels in bores within a certain distance do not change by more than 1 meter.

- (ii) **Aquifer contamination:** The measurement criteria for the environmental outcome of protecting groundwater “where practicable” from contamination due to migration of fluids between geological layers is that “Well control monitoring demonstrates adequate well control.”⁸ This provides no objective standard by which one can assess whether outcomes or performance standards are being met. For example, Santos does not define whether a single loss of well control would be acceptable, or the kinds of casing failures or losses of annulus pressure that could be considered acceptable. Furthermore, for assessing aquifer contamination, key investigation thresholds are missing. For example, for water level and salinity, temperature, and pH the “Investigation Threshold” is simply “N/A.”⁹ For BTEX, the investigation is 1 standard deviation beyond baseline,¹⁰ but the EMP does not define what years and locations will be considered baseline. For all other analytes that must be assessed (Table 4 of Appendix I to the EMP), Santos provides no other investigation criteria beyond BTEX chemicals. For example, there is no investigation threshold for metals or radionuclides. Thus, there is neither an investigation threshold for key risks nor measurement criteria that could be used to determine whether performance standards or outcomes are being met.

13. These examples are not exhaustive but illustrative of how the EMP does not use measurement criteria that satisfy the definition in Section 3 of the Regulations because they do not allow one to make a measurement that could ensure performance standards or outcomes are being achieved.

Santos has failed to demonstrate that drilling and hydraulic fracturing fluids comply with the Onshore Code of Practice

14. Schedule 1 Section 10 of the Regulations requires an EMP to (a) specify any legislative requirements applicable that are relevant to the protection of the environment; and (b) “demonstrate how those requirements will be met.” In this clause, “legislative requirements” include “the requirement to comply with an approved code of practice.”¹¹ The EMP fails to demonstrate that drilling and hydraulic fracture fluids comply with the *Code of Practice: Onshore Petroleum Activities in the Northern Territory (Code of Practice)*, an approved code of practice for the purpose of Schedule 1, for reasons detailed below in the body of the submission.

Impacts on hydrological processes, inland water quality and aquatic ecosystems

15. Hydraulic fracturing poses significant risks to surface water and groundwater. Risks to water-based environmental values were a key focus of the Pepper Inquiry. The key risks identified included:
- (i) Unsustainable groundwater use;
 - (ii) The contamination of groundwater with hydraulic fracturing fluids and wastewater from

⁸ Santos, Beetaloo Appraisal EMP, p. 146.

⁹ Beetaloo Appraisal EMP, Appendix I: Surface Water and Groundwater Management Plan, p 14, Table 5.

¹⁰ Beetaloo Appraisal EMP, Appendix I: Surface Water and Groundwater Management Plan, p 14, Table 5.

¹¹ *Petroleum (Environment) Regulations 2016*, Schedule 1, S. 10 (2025).



leaky well or from on-site surface spills; and

- (iii) The effect of any water contamination on surface and/or groundwater dependent ecosystems.

16. The EMP fails to demonstrate that the possible significant impacts to groundwater, surface water and water-dependent ecosystems would be reduced to an acceptable level. Further, due to the number of risks and potential significant environmental impacts, the EMP should be referred for assessment under the *Environment Protection Act 2019* (NT) and the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

17. ECNT notes that the information provided by Santos to assess impacts on water resources falls far short of the information requirements for assessment of the impacts of coal seam gas and coal mining on water resources (noting that the guidelines have yet to be updated to include shale gas) under the *Environment Protection and Biodiversity Conservation Act*, including:

- (a) Santos has not identified and characterized all relevant water resources;
- (b) Santos has not applied appropriate methods to investigate the risks to those water resources, including comprehensive impact pathway diagrams developed from evidence-based conceptualisations;
- (c) Santos has not addressed the uncertainties in predictions of potential impacts on water resources through appropriate data collection, analysis and discussion;
- (d) Santos has not adequately described appropriate avoidance or mitigation strategies to prevent or reduce potential impacts on water resources;
- (e) Santos has not adequately specified and justified rehabilitation strategies for water resources affected by the project;
- (f) Santos has not proposed effective monitoring and management procedures to detect and ameliorate the risk of potential impacts on water resources, and to assess the effectiveness of proposed mitigation strategies and other management measures;
- (g) Santos has not considered potential cumulative impacts from past, present and reasonably foreseeable actions.

Scientific uncertainty and significant new research

18. There is a high degree of scientific uncertainty regarding the potential impact of hydraulic fracturing on groundwater resources and associated dependencies in the area of the EMP.

- (a) New scientific information/research (much of it not yet complete) regarding the Hot Springs Valley spring complex, and possible groundwater flows/discharges from the Cambrian Limestone Aquifer to the east and north-east (Limmen Bight and McArthur River catchments) does not resolve this uncertainty but increases the risk profile of fracking activities significantly through the identification of possible contamination pathways. Furthermore, the research indicates that existing understandings of groundwater flow paths in the region (including



modelling) upon which decisions have been made to date may be fundamentally flawed.

(b) Santos has ignored this research and its implications. Santos only briefly mentions the Hot Springs Valley in the EMP,¹² but makes no further analysis about the significance of this research or its implications for fracking in the region. Santos does not mention at all new GISERA research suggesting that existing modelling of groundwater flows may be flawed. This is curious given that Santos has partly funded both of these research programs.

19. The application of the precautionary principle requires that the EMP be referred under the *Environment Protection Act 2019* (NT) and the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) for a comprehensive assessment of these risks, given these uncertainties.

Strategic Regional Environmental Baseline Assessment – remaining uncertainties

20. In response to Pepper Inquiry recommendations, the NT Government commissioned the Strategic Regional Environmental and Baseline Assessment (**SREBA**) to address key knowledge gaps regarding hydrogeological connectivity in the Beetaloo Basin.

21. Following an independent review of the SREBA, Currell and Ndehedehe¹³ found that there are critical data and knowledge gaps remaining, and as a result, there is ongoing uncertainty about the likely impacts of fracking on aquifers, springs and rivers in the NT, including the Mataranka Hot Springs and the Roper River.

22. In summary, Currell and Ndehedehe found that:

Considerable uncertainty remains regarding key aspects of the CLA [Cambrian Limestone Aquifer] (and wider NT) groundwater resources, such as the timing, mechanisms and rates of groundwater recharge and discharge, the dependence of these flows on climatic and other variables, the level of connectivity between different aquifer units and (sub-)basins, and the tolerance of ecosystems – both above ground and subterranean – to changes in groundwater flows, levels, and quality.¹⁴

23. They also found that preliminary data indicates areas of substantial connectivity between deep aquifer units and shallow Cambrian Limestone Aquifer and/or springs. Even if separation exists between shale gas layers and aquifers as noted in the EMP, this can change as a result of hydraulic fracturing or associated seismic activity.

24. The report notes there is a lack of groundwater monitoring bore coverage (and thus baseline data) in key areas, including data to characterise the groundwater level behaviour and flow gradients in the aquifer units below the Cambrian Limestone Aquifer. The SREBA area is of considerable size, warranting an extensive bore monitoring network to collect data and improve our understanding of groundwater in the area.¹⁵

¹² Santos EMP, p 110.

¹³ Prof. Matthew Currell and Dr Christopher Ndehedehe, SREBA Expert Review – Groundwater, (2023).

¹⁴ Matthew Currell, Sue Jackson & Christopher Ndehedehe 'Risks in the current groundwater regulation approach in the Beetaloo region, Northern Territory, Australia', *Australasian Journal of Water Resources*, (2024) DOI: 10.1080/13241583.2023.2297949.

¹⁵ Currell and Ndehedehe (2023), p 1.



25. Currell and Ndehedehe confirm that substantial additional data and analysis is required to fully assess the extent of connectivity and likely behaviour of deep and shallow aquifers, and impact that the extraction of groundwater could have on interconnectivity and groundwater movement. This analysis is built upon further in the **attached** expert reports and the body of the submission below.

The significance of Hot Springs Valley

26. The SREBA revealed new scientific knowledge involving the existence of a series of springs in Hot Springs Valley on Tanumbirini Station, likely sourced from deeper Mezoproterozoic formations, which has serious implications for hydraulic fracturing activities in the region and risks associated with it. ECNT estimates that this spring complex is less than 50 kilometres from Santos’ proposed new well pads at Jiberu and Newcastle South, and is less than 40 kilometres from Santos’ Mount Brown well (noting that activities associated with this well are to be incorporated into the EMP).

27. Specifically, while the Cambrian Limestone Aquifer is generally isolated from deeper aquifers by aquitards, the SREBA noted that there is the “potential for active connection between deep (gas-bearing) and shallow formations” including at Hot Springs Valley where “faulting may provide a connection between the Beetaloo Sub-basin to the surface.”¹⁶

28. Hot Springs Valley is located within the catchments of the Limmen Bight River, and the SREBA report stated that this area warranted “further monitoring and investigation”.

29. In September 2022, detectable and correlated concentrations of methane and ethane were detected in the air surrounding Hot Springs Valley (including at Clint’s Gorge) on Tanumbirini, approximately 30-40 kilometres from the proposed well pads. Methane bubbles were identified near the spring vent indicating possible association with Beetaloo Sub-basin gas exploration targets. The SREBA Regional Report states:

“the CLA is generally isolated from deeper aquifers by extensive aquitards (basalts and the Cox Formation) but there are restricted areas where it is potentially in contact with deeper aquifers. There are a few areas where there is potential for active connection between deep (gas-bearing) and shallow formations, but one area (Hot Springs Valley, which is not part of the CLA) has been identified where faulting may provide a connection between the Beetaloo Sub-basin to the surface.”

30. Hot Springs Valley has the highest recorded water temperature (65C) of any spring in the NT and was identified during the GBA and GISERA programs “as an area of interest”. The groundwater source could be from at least 1000 metres below groundwater, suggesting the source as a deeper formation underlying the area, noting that “without further geophysical investigation (eg seismic), the source of these springs remains poorly understood.”¹⁷

31. Another spring nearby (Lagoon Creek Gorge spring) has a lower temperature (42C) suggesting the source could be 200-500m below ground level. The SREBA opined that the source could be the

¹⁶ “Regional Report: Strategic Regional Environmental and Baseline Assessment for the Beetaloo Sub-basin”, NT Government, 2023, Page 12.

¹⁷ Ibid, page 86.



Bessie Creek Sandstone.¹⁸

32. The SREBA also suggested that detectable concentrations of methane and ethane in the air surrounding one of the springs in the complex (Beauty Creek hot spring) indicated a thermogenic source, and GISERA recommended further investigations of the gas source given the likely implications of their findings (ie potential interaction of the deep regional system with surface hydrology and ecosystems). The SREBA stated “until the groundwater source and discharge mechanism are better conceptualized, it is recommended that a monitoring program be implemented. This program would ensure ongoing collection of baseline water quality and quantity data, in addition to relevant ecological and greenhouse gas data.”¹⁹
33. Hot Springs Valley is within the Limmen Bight River catchment. While in September 2022 (the late dry season), streamflow was observed not to reach the Cox River downstream (which becomes part of the Limmen river), it is part of this river system and likely discharges into the river during periods of higher flow and rainfall. Water from the hot springs complex that is not evaporated may be lost “through infiltration into the riverbed of the downstream watercourse” and possibly into the aquifer.²⁰
34. There are significant data gaps involving the Cox and Limmen Bight Rivers downstream of Santos’ proposed fracking operations (and the Hot Springs Valley). No current or historical gauging data exists for the Cox River, and the only gauging site on the Limmen River is 50 kilometres downstream and has been dormant since 1987. It is unclear whether and to what extent a comprehensive groundwater monitoring program has been implemented.
35. The SREBA concluded that the petroleum industry should prioritise investigations of the Hot Springs Valley area, especially those companies undertaking work within 50 kilometres of the springs.²¹ Santos’ proposed fracking activities are located within 50 kilometres of the springs and very close to creeks that discharge into the Cox/Limmen River systems.
36. Hot Springs Valley is associated with a large number of geological faults and naturally fractured zones which can create natural pathways for contamination due to pre-existing cracks and weaknesses in the rock. Fracking activities create new fractures, which can then link up with these natural fault networks, creating extensive pathways for contamination of productive groundwater in shallower aquifers (like the Cambrian Limestone Aquifer) and dependencies (like Hot Springs Valley and the Cox/Limmen Rivers). Connected fault systems allow injected fracking fluids, produced gas/brine and/or hypersaline aquifer water to travel upwards towards aquifers.
37. Slow contamination of groundwater can occur along fault zones, and research suggests that “hydraulic fracturing should not be carried out near potentially conductive faults, and impacts should be monitored for long timespans.”²²

¹⁸ Ibid, page 86.

¹⁹ Ibid, page 86.

²⁰ Ibid, p 102.

²¹ Ibid, p 108.

²² Gassiat et al, “Hydraulic fracturing in faulted sedimentary basins: numerical simulation of potential contamination of shallow aquifers over long time scales”, *Water Resources Research*, (2013) 49(12), <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2013WR014287>.



38. Frery et al²³ have published peer-reviewed research demonstrating that a number of geological faults/fractures associated with the Hot Springs Valley complex, and underlying Tanumbirini Station, could become pathways for contamination of groundwater and groundwater dependencies (see Table 7 below).

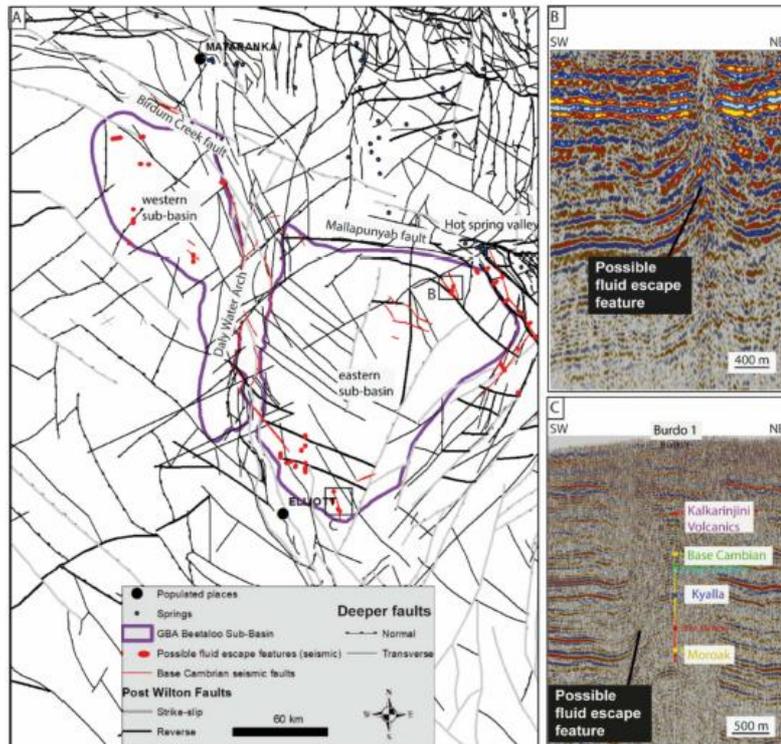


Figure 7. Potential fluid or gas escape features localised on the seismic reflection profiles of the Beetaloo Sub-basin. (A) location of the possible fluid escape features on a map view with the interpreted traces of the deep faults reactivated post-Cambrian, the post-Wilton faults [48], and the location of the surface springs. (B,C). Examples of potential fluid escape features on seismic reflection lines respectively in the northeast and southern parts of the eastern Beetaloo Sub-basin (lines MID92-58 and 89-20).

39. They state, in relation to the Hot Springs Valley complex that the springs suggest “active circulation to at least 650 metres below ground surface along conduits with relatively good permeability.”²⁴
40. They also state, in relation to the OT Downs fault system underlying the region that “fault segments linked to those systems, especially around fault termination or relay zones, may be triggered and currently openly acting as a conduit for deep fluids and gas leakage directly to the surface”.²⁵
41. GISERA has been undertaking further research in relation to the Hot Springs Valley complex in order to collect baseline data to comprehensively characterize the springs, stating that “environmental data capture at these springs has been limited to date due to their remote location” and further studies are needed “to provide a baseline prior to any potential development

²³ Frery et al, “Fault-Related Fluid Flow Implications for Unconventional Hydrocarbon Development, Beetaloo Sub-Basin (Northern Territory, Australia)”, *Geosciences* 2022, 12(1), <https://doi.org/10.3390/geosciences12010037>.

²⁴ Ibid, p 19.

²⁵ Ibid, p 21.



of gas resources in the nearby Beetaloo Sub-basin.”²⁶ It is noted that this research is incomplete, and the final report is not expected for some months (pers comm, Cindy Ong, CISRO).

42. The available evidence suggests an increased degree of risk to groundwater and groundwater dependent ecosystems arising from hydraulic fracturing activities in this area. However, Santos’ EMP contains no analysis of the significance of the faults/fractures associated with the Hot Springs Complex, the risk to groundwater associated with these faults, and there is no contaminant pathway or impact pathway modelling in the EMP. The EMP makes a very brief and misleading reference in an Appendix about the significance of faults: “Faults in the region generally do not extend to shallow formations, reducing the risk of fluid migration. The potential for aquifer connectivity, particularly between the CLA and the Roper Group, is an important consideration for water resource management within the Beetaloo Sub-basin.”²⁷ The EMP refers to a desktop analysis undertaken by AECOM (which has not been published), and does not reference the extensive research outlined above, nor the ongoing GISERA program of work. The Chemical Risk Assessment undertaken for the project (Appendix D), does not address these potential impact pathways.
43. ECNT refers to the expert report of Professor Matthew Currell (**attached**). Professor Currell states that the EMP has the potential to change the permeability and structure of the Velkerri Formation (the shale gas target) during hydraulic fracturing. He notes that this may lead to enhanced connectivity with, and movement of hydrocarbons into, the overlying and underlying sandstone aquifers of the Roper Group. He notes in particular the possible impacts on the Hot Springs Valley complex, which may suffer reduced water quality and/or quantity as a result of the activity.
44. Santos’ EMP should not be approved until this research is completed and synthesized as this would constitute development of gas resources prior to a baseline being collected. Contaminant and impact pathway modelling, and a conceptual groundwater model (including connection with deeper aquifers) must be undertaken once an adequate baseline is obtained. This should be undertaken as part of a comprehensive environmental impact assessment under both the *Environment Protection Act 2019* (NT) and the *Environment Protection Biodiversity Conservation Act 1999* (Cth).

NT Government groundwater model possibly flawed

45. The EMP’s analysis of impacts on groundwater (and in particular the Cambrian Limestone Aquifer), and groundwater dependent ecosystems rests on an assumption that groundwater flows in a north-westerly direction, discharging at the Mataranka Hot Spring and the Flora River hot spring complexes (and then into the Roper and Daly rivers).
46. This is due to reliance on the NT Government’s Daly-Roper (DR) model, which is a coupled numerical surface water—groundwater flow model. The model was developed to assess the hydrogeological system response at basin scale and to predict flow rates within the Daly River and the Roper River drainage systems, including the base flow contribution from the Cambrian

²⁶ GISERA, Project Order: Environmental baseline characterization of the springs in Hot Springs Valley, NT”, <https://gisera.csiro.au/research/surface-and-groundwater/environmental-baseline-characterisation-of-the-springs-in-hot-springs-valley-nt/>.

²⁷ Appendix J: Environmental Assessment Report, page 19.



Limestone Aquifer which sustains flow during the dry season. Development of the DR model commenced in 2004 and has undergone multiple extensions.²⁸

47. The SREBA Regional report states that the DR model would be “the main scientific tool used for assessing water extraction scenarios for the area that covers the Beetaloo Sub-basin.²⁹ The model was the tool used to underpin the Georgina Wiso Water Allocation Plan, which allocates water (including to petroleum) from the Georgina and Wiso Basins (part of the Cambrian Limestone Aquifer). Recommendations 7.7 and 7.8 of the Pepper Inquiry required that water allocation plans be declared in the Beetaloo Basin and that they include provision that adequately control both the rate and volume of water extraction by the gas companies.
48. Santos relies on this model and its assumptions in assessing groundwater impacts (including on groundwater dependent ecosystems), stating for example that “the aquifer discharges into the Roper River ... north-west of the Beetaloo Basin, supporting important groundwater-dependent ecosystems”.³⁰
49. New research being undertaken by GISERA suggests that this model (upon which decisions about fracking and its impacts on groundwater have been based) may be fundamentally flawed.³¹
50. The study is in relation to groundwater in the “eastern extension” of the Beetaloo Sub-basin. The area of study includes a large area in the vicinity of Santos’ current and proposed operations, with the outer study area including parts of EP161.
51. The project order states:
 - (a) “this newly identified eastern extension ... was not entirely included in these research programs and the potential impacts on water resources and water dependent ecosystems from unconventional gas exploration and development in this area remains poorly understood”;
 - (b) “the fault zones within the eastern extension host geological sequences that are folded, faulted and displaced and may host potential pathways for contaminants to leak into the overlying Cambrian Limestone Aquifer (CLA) hosted in the Georgina Basin”;
 - (c) “the boundary of the McArthur and Georgina Basins coincide with numerous springs and waterholes amongst the headwaters of the Limmen Bight and McArthur Rivers that are known to be ecologically and culturally important but are poorly characterized”;
 - (d) “the previous work in the region has suggested that there is the potential for connectivity between the CLA and surface features, but the source aquifers of these springs and waterholes have not been previously investigated”;

²⁸ Knapton, A. (2020). Upgrade of the Coupled Model of the Cambrian Limestone Aquifer and Roper River Systems, Technical Report 57/2020. Prepared by CloudGMS for Northern Territory Department of Environment, Parks and Water Security, Northern Territory Government. Palmerston, Northern Territory.

²⁹ Beetaloo SREBA Regional Report, p 51.

³⁰ Santos EMP, p 84.

³¹ GISERA Project Order 38, “Groundwater connectivity between the CLA and the surface in the Eastern Beetaloo Sub-basin extension”, <https://gisera.csiro.au/research/surface-and-groundwater/groundwater-connectivity-in-the-eastern-extension-of-the-beetaloo-sub-basin/>.



- (e) The IESC has given advise emphasizing the “importance of collecting adequate pre-development groundwater and surface water quality data, and local shale investigations of the connectivity from the surface to the gas bearing layers”;
 - (f) The GBA reports assessing the risks of unconventional gas development did not include the eastern extension;
 - (g) An environmental baseline assessment of springs in Hot Springs Valley, NT, showed that some flow out of the region is to the north east rather than to the Roper River.
52. The project order states that the DR model “used a no flow boundary along this edge of the Cambrian Limestone Aquifer and so forces the model to have a flow direction toward the Roper River.” The project order also states that “the assessments conducted on the potential impacts of unconventional gas development have assumed a north-westerly groundwater flow direction to the Roper River and have not considered that there may be a northern or eastern component to the flow.”
53. This research program is incomplete, but the findings may reveal that the basis of our understanding of groundwater flows and impacts has been incorrect, including in the region of Santos’ operations. It is noted that GISERA notes there are other risks associated with faulting in the region that could “provide a connection between the gas resource and the springs that could be activated by hydraulic stimulation”.³²
54. The consequences of this research are very significant for the entire risk profile of fracking, including in the vicinity of Santos’ operations:
- “The Georgina Wiso Water Allocation Plan (Northern Territory Government, 2023) makes the assumption that all water north of the Alexandria-Wonarah basement high flows to the north-west to discharge to the Roper River and that the CLA is isolated from the layers below by the APV (Antrim Plateau Volanics). These assumptions are reasonable at the regional scale of the Georgina Basin but may not be accurate at the local scale of the eastern Beetaloo Sub-basin extension. The risks to water related assets from unconventional gas developments that have been assessed by GBA, SREBA and IESC are based on these same assumptions. If the assumptions are not correct then the risk profile for the eastern Sub-basin may need to be reconsidered.”³³
55. The project order proposes work be undertaken including the “development of an initial conceptual hydrogeological model of the aquifer systems and potential pathways to the surface through integration of multiple lines of evidence (eg geological, hydrogeological, hydrochemical and geophysical data).³⁴
56. Santos’ EMP should not be approved until this research is completed and synthesized as this would constitute development of gas resources prior to a baseline being collected, in a very high risk context. Contaminant and impact pathway modelling, and a conceptual groundwater model (including connection with deeper aquifers) must be undertaken once an adequate baseline is

³² Ibid, page 8.

³³ Ibid, page 8.

³⁴ Ibid, page 8.



obtained. This should be undertaken as part of a comprehensive environmental impact assessment under both the *Environment Protection Act 2019* (NT) and the *Environment Protection Biodiversity Conservation Act 1999* (Cth).

Unsustainable water extraction

57. Santos has a licence to extract 193ML of groundwater per annum, but proposes to apply to increase this entitlement to 750ML per annum (although this increased volume is not yet authorised). Santos proposes to extract up 2.35GL of water per annum in total for the duration of the EMP (approximately 3 years). This is a significant increase in water extraction in an area with episodic and rare recharge.
58. Groundwater extraction is stated to be in accordance with the allocation for petroleum activities in the Georgina Wiso Water Allocation Plan (**WAP**), which allocated a total of 10,000ML/year for petroleum activities across the Basin). Accordingly, Santos' proposed licence would comprise 7.5% of the annual petroleum activity allocation in the plan. Santos should be required to substantiate why it requires such a significant proportion of the available petroleum allocation for the EMP appraisal activities. ECNT notes that, if this appraisal project is successful, Santos proposes significant expansion of its operations in the Beetaloo Basin. Assuming annual water extraction per well (62.5ML), and an eventual export-scale operation of 500 wells on EP161, this could increase water use to approximately 31GL per annum in the area, well in excess of the Georgina Wiso WAP allocation for petroleum.
59. In ECNT's view, the Georgina Wiso WAP is flawed and allocates an unsustainable amount of groundwater from the Cambrian Limestone Aquifer. It relies on very coarse data, particularly regarding recharge rates and mechanisms in the plan area, noting that recharge in the Anthony Lagoon and Gum Ridge Formations varies significantly with precipitation, topography, karstic features, overlying rock and sediment formations. The annual recharge estimate in the WAP appears to be a gross overestimate, noting that recharge for this basin is low and episodic. There was a very significant recharge event in 1974 of over 20,000GL which has skewed the average. If the median is used instead, the annual recharge is actually 0.5GL. Recharge is thus considerably lower than the long-term average in most years (and may be negligible under the current climate), except for rare events where rainfall and recharge far exceeds the long-term average. Accordingly, Santos' proposed annual extraction would exceed the median annual recharge and is likely to be unsustainable.
60. As discussed above, it is possible that the Georgina Wiso WAP is flawed in its reliance on the DR model (which assumes that groundwater flow moves in a north westerly direction towards Mataranka Springs). Accordingly, there is a possibility that extraction in this area could impact other springs and waterways (including the Hot Springs and/or the Cox and Limmen Bight Rivers).
61. Santos inconsistently states any localized drawdown from water extraction would be temporary (in the EMP), and also that the project is "unlikely to cause water drawdown".³⁵ There is no modelling to support this assertion, on either a local or regional scale. The local impacts of drawdown are glossed over or ignored. This could include impacts on water supply for Tanumbirini Homestead

³⁵ Appendix J: Environmental Assessment Report.



(located only 3.4km away), livestock water supply (including via bores and turkeys nests), for threatened species (such as the critically endangered northern blue tongue skink, where water drawdown is listed as a risk to that species in the EMP),³⁶ and local groundwater dependent ecosystems.

62. The EMP does not sufficiently address the impacts of extracting 2.35 billion litres of water over a relatively short timeframe, nor does it explore the water balance, hydrogeology and characterization of groundwater dependent ecosystems to understand the effects of such extraction.
63. There is insufficient exploration of the potential impacts of groundwater extraction at a significantly higher rate and the EMP does not appropriately address the cumulative impacts of the proposed water extraction along with other existing or proposed water extraction in the region.

Impacts on groundwater dependent ecosystems

64. Santos' analysis of impacts on groundwater dependent ecosystems is flawed and inadequate.
65. Groundwater dependent ecosystems have only been identified within a 5 kilometre radius of the well pads. This is a clearly insufficient area, given the possible large area of impact in the case of groundwater or surface water contamination.
66. A number of high value groundwater dependent ecosystems are identified within this 5km radius consistent with the location of the project within a significant floodplain, including melaleuca forests, riparian woodland and *corymbia bella* (ghost gum) woodland. Santos assumed these extensive ecosystems will not be impacted because they are likely accessing a perched groundwater system. The connection between these groundwater dependent ecosystems and deeper aquifers needs to be better characterized to estimate any contribution to shallower/perched aquifers and springs, seeps and surface water. Santos has not undertaken any assessment of the risk to these systems from surface water contamination.
67. Santos states that "there is also a range of small wetlands associated with springs, sinkholes and minor depressions in the generally flat landscape." These are potential groundwater dependent ecosystems, and should be surveyed and assessed.
68. Within a 50 kilometre radius, there is a range of groundwater dependent ecosystems, including the Hot Springs Valley complex. GBA research data suggests these springs (including Clint's Gorge) are very biodiverse in terms of aquatic ecology.³⁷ A total of two species of freshwater turtle, 17 species of fish, and 27 species of aquatic vertebrates were observed and identified during two field visits by the GBA aquatic ecology team. A total of 61 species was recorded from the site, similar to the species richness near Mataranka Hot Springs (80 species). Santos has not assessed the impacts to these ecologically significant ecosystems. The GBA terrestrial ecology team did not visit the Hot Springs Valley area, so there is a likelihood that there is even greater species diversity at this site, if

³⁶ Appendix J: Environmental Assessment Report.

³⁷ Davis, J, Gillespie, G, Cuff, N, Garcia, E, Andersen, A, Young, L, Leiper, I, Ribot, R, Kennard, M, Pintor, A, Bonney, S, and Wedd, D (2021). Beetaloo GBA Region Baseline Survey Program. Research Institute for Environment & Livelihoods, Charles Darwin University, Darwin, Australia.



it were to be surveyed.

69. The EMP does not adequately assess the impacts on stygofauna in the project area, noting that the nearest records are located 17 kilometres away and stating “given the absence of detections and the spatial separation from known occurrences, it is considered unlikely that stygofauna are present within the Project Area.” This assumption must be tested by a stygofaunal survey on all current and future groundwater monitoring bores.
70. ECNT refers to the report of Dr Ryan Vogwill (**attached**), which sets out a number of risks associated with impacts to groundwater dependent ecosystems which have not been reduced to ALARP.
71. ECNT makes the following recommendations consistent with Dr Ryan Vogwill’s analysis:
 - (a) All exploration wells should be drilled to a Category 9 (or above) standard of well construction incorporating cement casing from the shale formation to the surface, as per Pepper Inquiry recommendation 5.3 (NT Government 2018). Current Santos well design does not have cement to surface stipulated around the 5 ½” production casing (see pg. 65 Fig. 11 of EMP);
 - (b) Detailed seismic survey across the area to identify the locations of minor fractures and faults that may be activated or act as existing conduits;
 - (c) Baseline surface gas survey in all existing bores and oil gas wells, the latter of which need to be also evaluated for current well seal status;
 - (d) Installation of groundwater monitoring network in the target aquifers, including aquifer testing, typically this occurs in the context of other development before a water licence approval and also noting the large increase currently not approved as part of the current water licence;
 - (e) Extended constant rate aquifer tests (minimum 72hrs) should be carried out on all groundwater abstraction bores, and data should be collected from a comprehensive monitoring bore network that should be installed for all GDE types once a holistic assessment is completed. During testing discharge water should be frequently monitored (e.g. every 30 mins) for water quality parameters such as pH and salinity as this can provide important additional data. Robust estimates of hydraulic conductivity need to be available so a more defensible and preferably precautionary groundwater model can be developed/presented (see item 9 below);
 - (f) A network of nested piezometers or a set of monitoring bores (targeting shallower aquifer units at each site ~<1km) should be established. The groundwater monitoring network should include (recommendations 7.1 and 7.3 SERBA) multilevel monitoring bores. This should include one site that covers aquifers likely to be accessed (e.g. Anthony Lagoon Beds, Gum Ridge Formation, Unnamed Sandstone, Bukalara Sandstone) The deeper aquifers (e.g. Bukalara Sandstone, Moroak Sandstone and Bessie Creek Sandstone) may require a more pragmatic approach to monitoring and obtaining deeper groundwater heads via techniques such as drill stem tests conducted over deeper aquifer zones should be employed. Connections between the formations above and below the Cambrian Limestone need to be better established,



- including the Bessie Sandstone unit underlying the Velkerri Formation (target gas zone). A hydrograph of groundwater levels at each current monitoring site would be a helpful inclusion;
- (g) A bore census for water quality and gas at all pre-existing bores and in exploration/monitoring bores (see above) that should be installed before any approval is given to better understand the current hydrogeological conditions. This should include a methane isotopes sampling program to differentiate between biogenic and thermogenic sources of methane;
 - (h) A detailed assessment of the distribution and groundwater dependency of GDEs is required. The first stage of the GDE toolkit (Richardson et al., 2011a) needs to be applied at all project locations at a minimum. If GDEs are detected then application of Part 2 of the GDE toolkit (Richardson et al., 2011b). This will ensure the impact assessment will include all possible drawdown receptors. To be explicit all 3 broad groups of GDEs - Aquatic (pools, springs, soaks, seeps etc), Subterranean (stygo fauna and troglod fauna) and Terrestrial (groundwater dependent vegetation) need to be assessed. These investigations should be completed prior to any further disturbance. Note that this should include a stygo faunal survey on all current and future groundwater monitoring bores and that linked cultural values should also be considered;
 - (i) A groundwater model (that has undergone a sensitivity analysis, incorporating the data suggested herein) needs presenting, incorporating conceptual mechanisms (i.e. fault/fracture water and gas transport) by which any impacts may manifest. Once this is completed and a more robust impact assessment is presented, the potential impact area may increase, in which case the receptor survey from the dot point above may need to be increased;
 - (j) The following is a list of recommendations that should also be addressed in the context of the fault seal analysis:
 - a. Gas logging during all drilling both for water bores and hydrocarbon wells;
 - b. Water quality needs evaluation in deep aquifers prior to HFS, the area has unexplored water resources that could be impacted;
 - c. Pressure monitoring in bores screened in the deep aquifer (i.e. the proposed Grant/Poole groundwater monitoring bores) with real time pressure monitoring during hydraulic stimulation should be considered. This type of monitoring is a more reliable way of assessing how the transient pressure during hydraulic fracture stimulation propagates and impacts on deep aquifers located in critical areas, particularly near faults and fractures;
 - d. Monitoring of breakouts and drilling induced tensile fractures during drilling;
 - e. Fracture stability assessment should be conducted as a routine. Maximum bounds for stimulation pressure require site specific thresholds based on a consideration of both the stress state and reservoir type;
 - f. Fracture propagation modelling, G Function analysis and interpretation, stress barriers assessment. Stress barriers, not just geomechanical contrasts, are required for fractures to be contained within the hydraulic stimulation zone. There needs to be more detailed consideration of minimum horizontal stress in the cap rock and this needs to be completed for all areas where hydraulic stimulation is proposed.



72. ECNT submits that the EMP demonstrates that the risk of cross-contamination of high value groundwater aquifers (eg the Gum Ridge aquifer) with hydrocarbons and other contaminants of potential concern have not been reduced to ALARP.
73. ECNT refers to the report of Professor Matthew Currell (**attached**), which states that the EMP has not sufficiently considered this risk. Professor
74. Professor Currell refers to research indicating that approximately 2 to 20% of wells within a given unconventional gas development region experience well integrity breaches (median rate 13%)³⁸ and notes that:

Well integrity breaches are a major issue associated with shale gas development. They are one of the primary pathways by which contaminants (predominantly hydrocarbons) can cross-contaminate aquifers in areas of shale gas development (Vengosh et al., 2014; Lackey et al., 2021). This contamination pathway has been documented to have affected important water supply aquifers with contaminants introduced into wells in multiple cases in the United States (Darrah et al., 2014; Llewellyn et al., 2015; Whyte et al., 2021).

75. ENCT notes media commentary regarding a decision not to prosecute Beetaloo Energy for its failure to appropriately isolate aquifers in the vicinity of Santos' operations, namely the Anthony Lagoon and Gum Ridge Formations.³⁹ In ECNT's view, the Anthony Lagoon Formation and the Gum Ridge Formation aquifers (while both part of the CLA) should not be considered a single hydrostratigraphic unit, but separate units. It is unclear whether Santos proposes to isolate the Anthony Lagoon and Gum Ridge formations from each other as required by the Code of Practice. This should be clarified/required.
76. Professor Currell (**attached**) notes the difficulty of cementing the gas wells' annular space through the Gum Ridge aquifer – the major water supply for the region, stating:

This is due to the karstic nature of the aquifer, whereby the rock matrix contains significant fractures and caverns into which fluids flow and are easily 'lost' into the aquifer matrix. This typically results in an inability to maintain fluid circulation during drilling through the unit. In some cases, fluids lost during drilling through the Gum Ridge aquifer have been identified as re-emerging at the surface through sink-holes (Deslandes et al., 2019). This highlights the complex permeability pathways fluids take during the drilling process in the aquifer.

Successful return of fluids to the surface is vital to effective well cementing. Most water bores in the Gum Ridge aquifer are not cemented throughout the aquifer, due to fluid loss. If successful cementing of gas wells through the Gum Ridge Formation is not achieved or is incomplete, this will leave the aquifer vulnerable to contamination. Without a protective cement barrier, any casing deformation events or degradation of production and/or intermediate casings over time may allow hydrocarbons to migrate into the aquifer.

A specific scenario that could lead to contamination of groundwater would be the inflow of pressurized hydrocarbons from the Kyalla Formation (which sits above the target Velkerri Formation) into the wellbore during drilling, which could then migrate upwards and enter the Gum Ridge aquifer. This risk will be of considerable likelihood if continuous cementing to protect

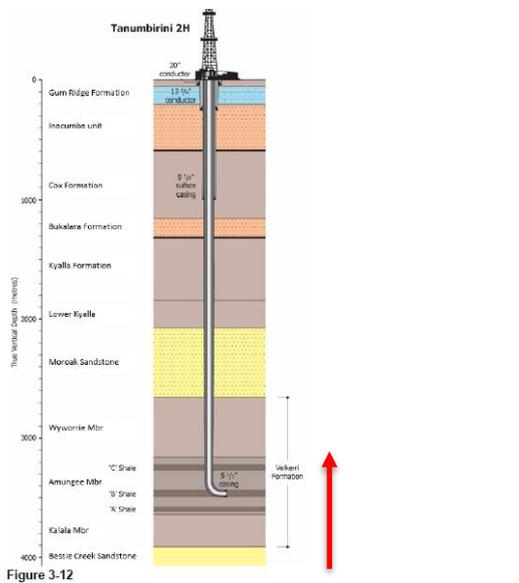
³⁸ Davies, R.J., et al., 2014. Oil and gas wells and their integrity: Implications for shale and unconventional resource exploitation. *Marine and Petroleum Geology* 56: 239-254.

³⁹ <https://www.abc.net.au/news/2025-10-14/alleged-environmental-law-breach-nt-beetaloo-basin-gas-company/105854186>.



the aquifer is not achieved and could occur either before the wells are completed (i.e., during drilling into the Kyalla Formation) or, after the construction of the intermediate casing around the Kyalla Formation, which is designed to prevent cross contamination.”

77. Santos previously notified, under Regulation 23, of the existence of a previously unknown aquifer, the “Inacumba Aquifer”, on EP161 which triggered a change in the existing environment. The EMP was modified to address this change to appropriately mitigate risks in accordance with regulatory requirements with respect to the drilling of the Tanumbirini 2H well. Santos amended its relevant EMP, and committed to isolate the Inacumba unit with “cemented 9-5/8 surface casing”, among other measures. A schematic diagram illustrating the locations of proposed casing shoes relative to stratigraphy in the EMP for STO2-S is below.



78. A Technical Report from the NT Water Resources Division explains the identification of the new Inacumba aquifer at Tanumbirini Station.⁴⁰ It states that this significant aquifer is believed to extend over an area of at least 1500 square kilometres (previously thought to be the Bukalara Sandstone). The aquifer is productive, and capable of pumping up to 15 litres per second. Minor water level response was detected from the overlying Gum Ridge Formation. Recharge is likely to be sporadic, only occurring in very wet years. A possible avenue for recharge is downward seepage from the Gum Ridge Formation. The report states that “further investigation is required to determine its recharge and discharge regime.”

79. The discovery of a new aquifer should prompt a changed management and regulatory response. The Code of Practice requires all aquifers in the area to be isolated from the surface and each other and any hydrocarbon bearing zones using appropriate barriers. Monitoring of barriers and casing condition must be carried out in accordance with a well operations management plan. Multi-level observation bores must be installed and groundwater monitored in accordance with the *Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin*.

80. Santos does not mention the Inacumba Aquifer at all its in EMP, and this absence has not been

⁴⁰ Water Resources Division Technical Report 20/2020, “Identification of the new Inacumba aquifer at Tanumbirini Station.”



explained. Instead, there is a reference to an “unnamed sandstone” which may correspond with this unit. There is no specific reference to isolation of this aquifer during well construction and it is unclear whether it will be so isolated. Santos has indicated in the EMP that it only considers the Cambrian Limestone Aquifer to constitute an aquifer (and by extension does not propose to monitor the Inacumba aquifer). There is no indication that Santos is proposing to construct and use multi-level observation bores in accordance with the *Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin*.

Contaminants and risks to surface water and groundwater

81. If site containment is breached, contaminated water may be mobilised within temporary overland stormwater flow events into surrounding ephemeral waterways and groundwater. This impact pathway was identified as being of low likelihood but high consequence in the Beetaloo by the IESC (2024) who noted that such events could cause significant harm to aquatic ecosystems.

Drilling fluids

82. The 2025 Onshore Code of Practice states that the “protection of aquifers requires the following to be achieved:...(e) drilling fluids must be designed to minimise environmental harm.”⁴¹ Additionally, when “drilling through local aquifers and until these aquifers are isolated by a minimum of two verified barriers, then... chemicals or other substances that could leave a residual toxic effect in the aquifer must not be added to the drilling fluid.”⁴² Santos’ measurement criteria for drilling fluids to ensure environmental performance standards and outcomes are met include “Drilling reports include details of all additives...and demonstrate that they were not considered to be ecologically toxic.”⁴³

83. Santos’ drilling reports indicate that some of Santos’ drilling fluids may not minimise environmental harm, may leave a residual toxic effect in the aquifer, and are ecologically toxic. The following substances in Santos’ proposed drilling fluids show risks of being ecologically toxic:

- (a) Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione (Cas No. 533-74-4):⁴⁴ This substance was evaluated as one of the existing drilling fluids proposed by Santos,⁴⁵ and is listed in Santos’ use of the Halliburton Barahib Plus Soup Mix,⁴⁶ and the Halliburton “KCl/Polymer Mud System.”⁴⁷ Santos list of chemical data sheets does not appear to provide an independent toxicity assessment for this substance. However, the same company doing the risk assessment for the EMP, EHS Support, lists a quantitative and qualitative tier 3 assessment for this substance, and notes it is also sometimes called “Dazomet.”⁴⁸ EHS notes Dazomet degrades rapidly into “Methylisothiocyanate (MITC)” and thus EHS when

⁴¹ Code of Practice: Onshore Petroleum Activities in the Northern Territory (“2025 Onshore Code of Practice”), cl. B.4.2.1.

⁴² 2025 Onshore Code of Practice, cl. B.4.10.2.

⁴³ Santos, Beetaloo Appraisal EMP, p. 144.

⁴⁴ Santos, Beetaloo Appraisal EMP, Appendix D, Table 7 Existing Drilling Fluid and Cementing Chemicals.

⁴⁵ *Id.*

⁴⁶ Santos, Beetaloo Appraisal EMP, Appendix D, Attachment D (Chemical data sheet attached to Appendix D, p. 1541 of 2450).

⁴⁷ Santos, Beetaloo Appraisal EMP, Appendix D, Attachment D (Chemical data sheet attached to Appendix D, p. 1726 of 2450).

⁴⁸ EHS Support, Qualitative and Quantitative Tier 3 Assessment, p. 1 (Oct. 2020) https://www.santos.com/wp-content/uploads/2021/04/Dazomet_Tier3.pdf (“Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione (dazomet) is a component in a drilling fluid product (DEXTRID® LTE) used as a fluid loss additive in the following fluid systems: • KCl/Polymer Mud System” and others).



studying residual drilling fluids assesses both Dazomet and MITC together.⁴⁹ EHS concluded that “Dazomet exhibits high acute toxicity to aquatic organism, particularly to fish” and “MITC exhibits a higher acute toxicity to fish compared to dazomet.” Concerningly, MITC also “does not degrade in freshwater by hydrolysis and it is also not readily biodegradable.”⁵⁰ Other EMPs in the NT have also reported on the toxicity of dazomet, finding that the toxicity of Tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione is “Very high.”⁵¹ Given that this substance has a high toxicity and that the substance it degrades into, MITC, is even more toxic to aquatic organisms and is persistent, it could be considered ecologically toxic.

- (b) Glutaraldehyde – Santos conducted a tier 2 assessment for Glutaraldehyde for avian receptors and found no unacceptable impacts.⁵² Glutaraldehyde is listed as one of the substances in Santos’ “Existing Drilling Fluid and Cementing Chemicals.”⁵³ It is used as a “biocide.”⁵⁴ According to international guidelines, such as the US EPA and International Programme on Chemical Safety, “Glutaraldehyde is considered toxic to fish, aquatic invertebrates, oysters, and shrimp and should not be discharged to water bodies.”⁵⁵ Australian guidelines note that Glutaraldehyde is “moderately toxic to aquatic animals and moderately to highly toxic to algae,” but its impact on the environment may be higher if not broken down by bacteria.⁵⁶ Santos appears to provide no data on bacteria degradation of Glutaraldehyde in its groundwater or flowback fluids. A CSIRO report on the toxicity of drilling fluids in hydraulic fracturing operations notes that “degradation products of some biocides have been reported to be more toxic and/or persistent than their parent compounds,” and detection of both “parent and transformation products in wastewaters and receiving waters” is needed to understand impact.⁵⁷ The same report lists this substance as one that is “very toxic.”⁵⁸

Hydraulic fracture fluids

84. Clause B.4.13.1 of the 2025 Onshore Code of Practice state that “Hydraulic fracture stimulation and flowback operations must ... ensure protection of aquifers is maintained during all operations phases for hydraulic stimulation and flowback.” Clause B.4.13.2 on mandatory requirements states “Hydraulic fracture stimulation activities must be designed to not impact aquifers.” Clause B.4.13.3(f) on preferred requirements states “As far as reasonably practicable, fluids with the

⁴⁹ EHS Support, Qualitative and Quantitative Tier 3 Assessment, p. 2 (Oct. 2020) https://www.santos.com/wp-content/uploads/2021/04/Dazomet_Tier3.pdf.

⁵⁰ *Id.* at p. 6.

⁵¹ Tamboran, Regulation 22 Modification Notice – Tam1-3 – Additional DH Drilling Chemicals and updated Appendices, APPENDIX E Chemical Risk Assessment – AECOM 2024, Beetaloo Exploration and Appraisal Program – Hydraulic Fracturing Chemical Risk Assessment, Appendix E Chemical Risk Assessment – Drilling Fluid p. 1 of 2 (9 Aug. 2024).

⁵² Santos, Beetaloo Appraisal EMP, Appendix D, p. 9.

⁵³ Santos, Beetaloo Appraisal EMP, Appendix D, Table 7.

⁵⁴ Santos, Beetaloo Appraisal EMP, Appendix D, Attachment A.

⁵⁵ Agency for Toxic Substances and Disease Registry (US), Toxicological Profile for Glutaraldehyde (2017) <https://www.ncbi.nlm.nih.gov/books/NBK591667/>.

⁵⁶ Department of Climate Change, Energy, the Environment and Water, Glutaraldehyde: Sources of emissions, <https://www.dccceew.gov.au/environment/protection/npi/substances/fact-sheets/glutaraldehyde-sources-emissions>.

⁵⁷ Department of Agriculture, Water and the Environment, Bureau of Meteorology, Geoscience Australia, Bioregional Assessments, CSIRO, Qualitative (screening) environmental risk assessment of drilling and hydraulic fracturing chemicals for the Isa GBA region, p. 16 (2020) <https://www.bioregionalassessments.gov.au/sites/default/files/gba-isa-stage2-appendix-chemicalscreening-final.pdf>.

⁵⁸ Department of Agriculture, Water and the Environment, Bureau of Meteorology, Geoscience Australia, Bioregional Assessments, CSIRO, Qualitative (screening) environmental risk assessment of drilling and hydraulic fracturing chemicals for the Isa GBA region, p. 15, Table 7 “Chemicals of ‘potentially high concern’ that are not persistent (P) or bioaccumulative (B), and very toxic (T)” (2020) <https://www.bioregionalassessments.gov.au/sites/default/files/gba-isa-stage2-appendix-chemicalscreening-final.pdf>.



lowest toxicity should be used in hydraulic stimulation, and the concentrations used should be the minimum required to facilitate effective operations.”

85. The list of proposed chemicals to be used in Santos’s hydraulic stimulation activities includes those in Attachment A to Appendix D: Chemical Risk Assessment. These substances carry the following risks to aquifers and may be toxic for the following reasons:

- (a) Siloxanes and Silicones, di-Me, reaction products with silica (Cas Nos. 67762-90-7, 63148-62-9, 67762-90-7): Siloxanes are added to hydraulic fracturing fluids as defoaming agents and surfactants.⁵⁹ These chemicals have low water solubility, are hydrophobic and, in the case of cyclic siloxanes, are volatile.⁶⁰ Siloxanes are of potentially high concern to aquatic organisms due to their persistence and bioaccumulative and highly toxic nature.⁶¹ A joint report by the Australian Government and CSIRO (“**2020 CSIRO Report**”) concluded that these chemicals,

“if used at shale, tight and deep coal gas operations, will require a more detailed quantitative ERA [Environmental Risk Assessment] to be undertaken with realistic exposure scenarios in which the quantitative ERA assesses and models the likelihood and consequence of a risk event occurring, identifies and evaluates control and mitigation measures (e.g. what controls are in place to address the identified risk and how effective are these controls), and monitors to ensure controls and management strategies are adequate to prevent impacts on the environment.”⁶²

Santos’ list of “Standard Hydraulic Fracturing System Chemicals” includes “Siloxanes and Silicones, di-Me, reaction products with silica,” and Santos assessed the toxicity of this substance using the safety data sheet for polydimethylsiloxanes (“**PDMS**”).⁶³ Santos’ safety data sheet is based on a 2019 NICNAS assessment report that did not find high ecotoxicity associated with PDMS.⁶⁴ However, the 2020 CSIRO report lists PDMS as one of the five chemicals of all those studied that are not likely to be “easily degraded (persistent), are bioaccumulative (potentially can accumulate in organisms), and exhibit very high acute toxicity to aquatic organisms (P, B, T chemicals)...Such chemicals are considered a high concern/risk to the environment, as they can pose serious harm to aquatic ecosystems if released and require specific controls to prevent their release into the environment.”⁶⁵

⁵⁹ Department of Agriculture, Water and the Environment, Bureau of Meteorology, Geoscience Australia, Bioregional Assessments, CSIRO, Qualitative (screening) environmental risk assessment of drilling and hydraulic fracturing chemicals for the Isa GBA region, p. 16 (2020) <https://www.bioregionalassessments.gov.au/sites/default/files/gba-isa-stage2-appendix-chemicalscreening-final.pdf>.

⁶⁰ *Id.*

⁶¹ *Id.*

⁶² *Id.* at p. 16-7.

⁶³ Santos, Beetaloo Appraisal EMP, Appendix D, Table 1.

⁶⁴ Santos, Beetaloo Appraisal EMP, Appendix D, Attachment D (Safety data sheet for Siloxanes And Silicones, Dimethyl, Reaction Products With Silica (Cas Rn 67762-90-7) Dimethyl Siloxanes And Silicones (Cas Rn 63148-62-9)).

⁶⁵ Department of Agriculture, Water and the Environment, Bureau of Meteorology, Geoscience Australia, Bioregional Assessments, CSIRO, Qualitative (screening) environmental risk assessment of drilling and hydraulic fracturing chemicals for the Isa GBA region, p. 12 (2020) <https://www.bioregionalassessments.gov.au/sites/default/files/gba-isa-stage2-appendix-chemicalscreening-final.pdf>. See also M. Nendeza, “Hazard assessment of silicone oils (polydimethylsiloxanes, PDMS) used in antifouling-/foul-release-products in the marine environment”, *Marine Pollution Bulletin* 54: 1190–1196 (2007) (while soluble fractions of this substance can have low toxicity, at “higher exposures, undissolved silicone oil films or droplets can cause physical–mechanic effects with trapping and suffocation of organisms); D. Feng et al., “The effects of model polysiloxane and fouling-release coatings on embryonic development of a sea urchin



- (b) Hydrotreated light petroleum distillate⁶⁶ (CAS No. 64742-47-8).⁶⁷ Santos plans to use this chemical to “ease chemical addition” at volumes of up to 718 liters per stage, making it the wet chemical constituent with the sixth highest concentration in the hydraulic fracturing injected fluid by volume (.0522% of the total injected).⁶⁸ Other EMPs in the Territory have acknowledged that the toxicity of this chemical “Based on Chronic” exposure is “High.”⁶⁹ The 2020 CSIRO Report also gives this substance its highest toxicity rating of “Toxicity = ≤ 1 mg/L (***)”.⁷⁰ The 2020 CSIRO Report further notes that this substance is one that “can pose serious harm to aquatic ecosystems if released and require specific controls to prevent their release into the environment.”⁷¹ Concerningly, the Santos EMP provides a different conclusion that this chemical “Does not meet the screening criteria for toxicity,” and “Ecological Hazard - Low concern”⁷² without explaining why this conclusion contradicts the toxicity assessment of the 2020 CSIRO report and other EMPs in the NT. The Santos EMP conducts a Tier 2 analysis for this chemical only “based on the potential for inhalation exposures to workers during hydraulic fracturing activities,”⁷³ but does not conduct an ecological impact assessment for this substance if released from a surface or subsurface spill.
- (c) Alcohols, C6-C12, ethoxylated propoxylated (“AEP”) :⁷⁴ The Santos EMP acknowledges that this chemical has “moderate chronic toxicity to aquatic life.”⁷⁵ In 2024, CSIRO analysed AEP from the Kyalla 117 well site in the Beetaloo, and found that “for water samples from the Kyalla 117 storage pond, AEP did not completely degrade,” with 40% of AEP remaining in the pond after a three month incubation, suggesting AEP “may be resistant to abiotic degradation” even if it is readily catabolised by a diverse range of microorganisms.⁷⁶ Thus, AEP can be both moderately toxic and persistent in the environment.
- (d) Coco alkyldimethyl oxide (CAS No. 61788-90-7).⁷⁷ Santos conducted a Tier 2 assessment for avian exposure and found there were no unacceptable exposures.⁷⁸ Santos acknowledges that it is “Moderately toxic to aquatic organisms” and “Does meet the

(*Arbacia punctulata*) and a fish (*Oryzias latipes*),” *Aquatic Toxicology*, Vol. 110-11: 162-9 (2012) (leachate of PDMS from coatings applied to marine vessels associated with mortality to mysid shrimp); S. Sariatin et al., “Toxicological Evaluation of Siloxanes by *In Silico* Approaches” *Istanbul Journal of Pharmacy*, 55(2): 233-244 (2025) (evaluating the in-silico toxicological profile of sixteen different siloxanes, commonly regarded as safe, and “questioning their potential risks and the validity of the current safety perception”).

⁶⁶ Santos, Beetaloo Appraisal EMP, p. 15, Table 5.

⁶⁷ Santos, Beetaloo Appraisal EMP, Appendix D, Table 1, p. 61.

⁶⁸ Santos, Beetaloo Appraisal EMP, Appendix D, Attachment A.

⁶⁹ Tamboran, Shenandoah South EMP, Appendix E, Appendix A, “Chemical Risk Assessment Hydraulic Fracture Stimulation Fluid – HAL Hybrid” (assessment for CAS No. 64742-47-8, Hydrotreated light petroleum Distillate).

⁷⁰ Department of Agriculture, Water and the Environment, Bureau of Meteorology, Geoscience Australia, Bioregional Assessments, CSIRO, Qualitative (screening) environmental risk assessment of drilling and hydraulic fracturing chemicals for the Isa GBA region, p. 15, Table 6 (2020) <https://www.bioregionalassessments.gov.au/sites/default/files/gba-isa-stage2-appendix-chemicalscreening-final.pdf>.

⁷¹ *Id.* at p. 14.

⁷² Santos, Beetaloo Appraisal EMP, Appendix D, Table 1, p. 61.

⁷³ Santos, Beetaloo Appraisal EMP, Appendix D, p. 8.

⁷⁴ Santos, Beetaloo Appraisal EMP, p. 15, Table 5.

⁷⁵ Santos, Beetaloo Appraisal EMP, Appendix D, Table 2.

⁷⁶ CSIRO, *Fate of hydraulic fracturing chemicals and geogenic compounds in surface facilities and in the subsurface*, p. 73 (2024) <https://gisera.csiro.au/wp-content/uploads/2024/05/CSIROs-GISERA-final-report-NT-fate-of-HF-chemicals.pdf>.

⁷⁷ Santos, Beetaloo Appraisal EMP, Appendix D, Table 2 Evaluation of Coil Tubing Hydraulic Fracturing System Chemicals Beetaloo McArthur Basin, Northern Territory Chemical Risk Assessment

⁷⁸ Santos, Beetaloo Appraisal EMP, Appendix D, p. 9.



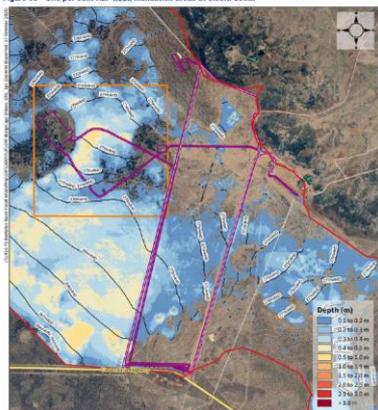
screening criteria for toxicity.”⁷⁹ The 2020 CSIRO report ranks this substance to have a “Toxicity = ≤ 1 mg/L,” the most toxic ranking.⁸⁰ The 2020 CSIRO report also gives this substance its highest bioaccumulation ranking in a list of substances that are persistent or bioaccumulative and harmful to very toxic.⁸¹

This list is not exhaustive, but illustrative, of how substances in Santos’ hydraulic fracturing fluids can potentially be toxic and impact aquifers in contravention of the 2025 Onshore Code of Practice.

Wastewater spills and risks in respect of inter-aquifer connectivity

86. ECNT notes that both of the proposed well pads (and indeed much of EP 161) are located in the middle of a floodplain. Santos has modelled the impacts of 1 in 100 year flooding events in assessing the risk of flooding. ECNT notes that this level of flooding would effectively surround the well pads with floodwaters, some of this water flowing a reasonably high velocities (see image below with respect to Jibera South). This raises serious questions about the ability of Santos to expand fracking operations in this area, and also raises the risk profile regarding spills from the current activities significantly.

Figure 33 - One per cent AEP flood inundation areas at Jibera South



87. ECNT notes that 1 in 100 year flood modelling may not be appropriate for this site. It is unclear, for example, how many years of data Santos is relying upon in using this modelling, and it is possible that this data does not contain the largest possible events that could occur in terms of rainfall. Climate change is influencing how often flooding occurs, and rainfall events are expected to become more intense in the future in the Northern Territory. In ECNT’s view, Santos should be required to assess flood risk using a 0.1% Annual Exceed Probability (1 in 1000 year) modelling standard.

88. ECNT attaches a report by Dr Grant Hose (**attached**) assessing the environmental impacts and risks (specifically, regarding wastewater spills and risks in respect of inter-aquifer connectivity). Professor Hose’s view is that the program poses substantial risk to subterranean aquatic ecosystems, and these have not been adequately characterized and mitigated by the strategies

⁷⁹ Santo, Beetaloo Appraisal EMP, Appendix D, Table 1.

⁸⁰ Department of Agriculture, Water and the Environment, Bureau of Meteorology, Geoscience Australia, Bioregional Assessments, CSIRO, Qualitative (screening) environmental risk assessment of drilling and hydraulic fracturing chemicals for the Isa GBA region, p. 15, Table 6 (2020) <https://www.bioregionalassessments.gov.au/sites/default/files/gba-isa-stage2-appendix-chemicalscreening-final.pdf>.

⁸¹ *Id.*



outlined in the EMP, and Santos has not adequately addressed how the requirements of the Code of Practice have been addressed.

89. Professor Hose disagrees with Santos' risk assessment at Appendix O, including because he considers the impacts of aquifer contamination would be "extensive" or "irreversible" because once contaminated, it is difficult to remediate an aquifer back to its pre-contamination state.
90. Professor Hose that the Chemical Risk Assessment (Appendix D) is deficient in the following key respects:
- (a) The EMP does not consider the risks posed by the release of drilling fluids, hydraulic stimulation fluids, flowback waters, produced waters and other solutions into groundwater that could arise from well failure or leakage;
 - (b) The chemical risk assessment does not address the impacts of drilling or other fluids to groundwater ecosystems;
 - (c) It is not possible to assess the toxicity of drilling fluids and therefore the risk associated with them because chemicals are only provided in general terms;
 - (d) When toxic chemicals are mixed, the effects of the mixture may be greater than the summed toxicity of the constituent parts;
 - (e) Mallants et al⁸² recommend the use of direct toxicity assessment to characterise the toxicity of flowback waters;
 - (f) Golding et al⁸³ showed that toxicity of flowback water from shale gas wells in the Beetaloo was chronically toxic to eight freshwater species and that a large proportion of that toxicity was due to unidentified chemicals and effects from the mixture of organic and inorganic chemicals and radionuclides (NORMS) in the water;
 - (g) The EMP does not consider the ecological risk of the mixtures;
 - (h) Salinity is also a considerable risk, and may be acutely toxic to freshwater invertebrates.
91. Professor Hose makes the following recommendations:
- (a) That the chemical risk assessments outlined in Appendix D of the EMP be revised to consider the entry of drilling fluids, hydraulic stimulation fluid and flowback waters into aquifers and the impact of that event on groundwater ecosystems;
 - (b) That the effect of relevant mixtures of chemicals used in the Program be tested to

⁸² Mallants D, Kirby J, Golding L, Apte S, Williams M. (2022). Modelling the attenuation of flowback chemicals for a soil-groundwater pathway from a hypothetical spill accident. *Sci. Total Environ.*, 806: 150686. <https://doi.org/https://doi.org/10.1016/j.scitotenv.2021.150686>.

⁸³ Golding LA, Kumar A, Adams MS, Binet MT, Gregg A, King J, McKnight KS, Nidumolu B, Spadaro DA, Kirby J. K. (2022). The influence of salinity on the chronic toxicity of shale gas flowback wastewater to freshwater organisms. *J. Hazard. Mater.*, 428: 128219. <https://doi.org/https://doi.org/10.1016/j.jhazmat.2022.128219>.



determine their toxicity to aquatic biota. This should be done using direct toxicity assessment (DTA) and include the various drilling fluids, hydraulic stimulation fluids, flowback waters, produced waters and other solutions;

- (c) A survey of groundwater biota be undertaken in the EMP with sampling sites in and close to the development area for the purpose of identifying the presence of any short-range endemic groundwater fauna that may be present in the study area and at risk from the Program.

92. ECNT notes that the EMP and the Chemical Risk Assessment (Appendix D) contains a very limited analysis of Santos' groundwater monitoring and flowback fluid monitoring data. From a brief analysis of the available data:

- (a) The Chemical Risk Assessment briefly extracts in table form some of the characteristics of flowback water at Santos' Tanumbirini well paid. This data is selective, but nevertheless demonstrates a high concentration of metals and gross alpha (radioactivity). For example, the gross alpha in flowback water was 2.29 bq/L (compared with the recommended screening value in drinking of 0.5bq/L). The boron level in flowback water was 24,400 ug/L (compared with the recommended removal limit of 900 ug/L);
- (b) Santos' "Drilling EMP Annual Groundwater Monitoring Data Review 2023" shows a number of exceedances in heavy metals after exploration activities, including barium. There is a number of analytes with a rising trend.

93. Professor Currell (**attached**) notes that the EMP Wastewater Management Plan (Appendix F) contains "indicative" flowback water quality, containing elevated levels of hydrocarbons, nitrogen, certain metals and radionuclides. Professor Currell states:

"Without the raw chemical concentration data from flowback samples at the site (covering a full suite of analysed organic and inorganic compounds) and proper documentation of the number and type of samples on which the data in the table are based, it is difficult to verify the full suite of water quality parameters that would be expected in flowback fluid from the project. The contaminants noted above – as well as arsenic, boron and lead, were significantly enriched in flowback water analyses presented in other EMPs in the Beetaloo Basin (such as the Amungee project to the west of EP161; Origin 2022) and should thus be considered likely contaminants of potential concern (CoPC)."

94. Santos should be required to provide an assessment of existing groundwater monitoring and flowback fluid data on EP161.

95. ECNT notes that Santos relies heavily on an unpublished report undertaken by AECOM in 2025 "Groundwater Desktop Self Assessment Technical Report – Santos EP161 McArthur Appraisals". This should be made public.

96. In relation to assessing the risks to groundwater from a hypothetical release from tanks, Santos relies on a report from 2019. This is inadequate, particularly given the significant body of research that has been undertaken since that time (including the SREBA, GBA program, and GISERA program). An updated assessment must be undertaken of the risks to groundwater from tank releases.



97. Santos states that it does not propose to undertake any surface water monitoring because “no permanent or ephemeral surface water bodies are present within two point five kilometres and two point seven kilometres of the two wells pads.” This is insufficient and risky, given:
- (a) the two well pads are located within a floodplain and where surface water during flooding or heavy rainfall could discharge into these creeks and into the Cox/Limmen Bight River watershed;
 - (b) the close proximity of the well pads to the Tanumbirini homestead (approximately 3.4 kilometres at the closest point);
 - (c) the Chemical Risk Assessment states that a catastrophic release from the largest tank could impact an area of up to 220 hectares (or 2.2 kilometres squared) putting the potential zone of impact very close to the nearest waterways;
 - (d) the Wastewater Management Plan states that “during exceptionally heavy rainfall, the freeboard [on tanks] may be temporarily exceeded”, suggesting a significant spill risk;
 - (e) Santos does not propose to cover wastewater tanks during evaporation/treatment (inconsistent with the recommendations of the Pepper Inquiry), creating a significant spill risk;
 - (f) Santos does not acknowledge the risk of contamination of groundwater via recharge points at “seasonal creeks”. Noting the close proximity of some streams and drainage depressions, it is possible that surface water contamination could seep into the aquifer via these points.
98. Santos should be required to prepare and implement a surface water monitoring plan to detect spills and their risks to sensitive receptors.
99. Professor Currell (**attached**) recommends that Santos should be required to undertake a proper analysis of risks associated with spills and leaks requiring detailed source-pathway-receptor modelling to identify the major impact pathways that likelihood of these being completed during different stages of development, including the implications for ecosystems. Professor Currell notes that there is some scenario modelling in the MEP that looks at the likelihood of complete risk pathways, including infiltration of spilled wastewater into groundwater, and the potential radius of impact that would occur under various spill sizes (eg Appendix D, Attachment B). However this modelling does not involve detailed site-specific soil and shallow aquifer characteristics and hydraulic parameters, or the key sources of potential spill and leak events.
100. The effective protection of groundwater resources from contamination (or drawdown) relating to shale gas development depends on the collection of baseline groundwater data from any potentially impacted aquifers, including multi-level wells monitoring the bottom, middle and top of the aquifer – as outlined in the Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo sub-basin (2018).
101. As noted above, Santos’ proposed groundwater monitoring regime also appears to be deficient. Santos has not demonstrated it proposes to comply with requirements to install



multilevel monitoring bores for each aquifer, incorrectly stating that the Cambrian Limestone Aquifer (Gum Ridge and Anthony Lagoon Formations) is the only aquifer in the area:

“At the location of the proposed activities, the CLA is the only aquifer present (Anthony Lagoon and Gum Ridge formations). No other formations in this area are classified as aquifers.”

This assertion is incorrect, noting in particular the recently discovered Inacumba Aquifer (see above) and the other aquifers underlying the CLA. Failing to install multilevel monitoring bores for each aquifer would constitute a breach of the Onshore Gas Code of Practice. Santos has previously been advised that aquifer isolation was required when the Inacumba aquifer was discovered.

102. Professor Currell (**attached**) notes other deficiencies with the groundwater monitoring regime:

Currently, there is one active monitoring bore at the Jibera South site, screening the high-value aquifer of the region – the Gum Ridge aquifer. However, the monitoring bore screens the entire length of the formation from 144 m to 276 m below surface (i.e., a screened interval of more than 120 m). This is a very long screen interval for a monitoring bore, and data from the bore would not provide detailed depth-specific information about water quality changes occurring during hydraulic fracturing and other site activities. This monitoring well is also un-cemented, probably due to the difficulties described above with fluid loss that makes effective cementing of wells difficult. This issue not only creates a high level of risk for cross contamination of the aquifer during drilling and hydraulic fracturing (compared to non-karstic aquifers where cementing is straightforward), but also makes the task of effectively monitoring and early detection of impacts in the aquifer much more challenging, as water samples collected from the well will integrate and average the groundwater input from across the full thickness of the aquifer. Short-screened wells monitoring groundwater level and quality near the base of the formation (the highest risk zone for contaminant input) should be present to enable early detection and mitigation of contamination impacts. This does not appear to be part of the planned monitoring program in the EMP. The monitoring and data collection program in the EMP thus does not align with the following recommendation of the Pepper Inquiry (re-iterated in the Guideline):

“That prior to the grant of any further exploration approvals, in order to minimise the risk of groundwater contamination from leaky gas wells:

- Where a well is hydraulically fractured, monitoring of groundwater be undertaken around each well pad to detect any groundwater contamination using multi-level observation bores to ensure full coverage of the horizon, of any aquifer(s) containing water of sufficient quality to be of value for environmental or consumptive use;
- All existing well pads are to be equipped with multilevel observation bores;

In the monitoring plan of the EMP, it is proposed that the Control Monitoring Bore(s) for the Newcastle South well pad will be constructed less than six months prior to the drilling of gas wells on the pad – in contradiction to the Guideline and Pepper Inquiry recommendations (which cite six months as the minimum period required for baseline data). Santos argue that this is reasonable, as monitoring bore data would still be collected at least six months before the commencement of hydraulic fracturing (as opposed to drilling). However, the risk of contamination incidents taking place may be



just as high during the drilling of the gas wells - for example, via the risk pathway described above and in Figure 1, whereby hydrocarbons enter the wellbore when drilling through the Kyalla Formation and migrate into the Gum Ridge aquifer. In fact, given the highly seasonal rainfall patterns in the NT, at least one year of baseline data should be collected prior to drilling, to capture seasonal variability in groundwater conditions.

Impacts on terrestrial ecosystems and matters of national environmental significance

103. ECNT submits that the project is likely to have a significant impact on a number of threatened species (matters of national environmental significance), necessitating referral under the *Environment Protection and Biodiversity Conservation Act*.
104. Santos' assessment of impacts on matters of national environmental significance is deficient. Santos relies primarily on a desktop species assessment, with a single biodiversity survey being undertaken in December 2024 at the site.
105. Furthermore, the desktop assessment appears only to have assessed populations *within* the project area, rather than within a particular radius (eg 50 kilometres). This has excluded key, ecologically significant, areas that could be impacted by the project (for example, via surface and groundwater contamination) and may be critical habitat for a range of threatened species, such as Hot Springs Valley (and Clint's Gorge), and various creeks and waterways. A Protected Matters Report is **attached** and demonstrates a larger range of threatened species that may be impacted than was assessed by Santos, including the endangered Gulf Snapping Turtle and endangered Freshwater Sawfish. Santos should be required to undertake a more comprehensive assessment of impacts on threatened species within an expanded area (a 50km radius), and undertake comprehensive biodiversity surveys of all relevant species, including of the following species.

Gouldian Finches

106. There are a number of records of Gouldian Finches within, or within a 50km radius of the project area. Many records date recently, from GBA and SREBA studies.
107. Gouldian Finches are listed as endangered under the EPBC Act.
108. According to the Commonwealth Significant Impact Guidelines, a significant impact is one which is important, notable or of consequence in the context of the environment which is impacted and the extent of the impact. For critically endangered and endangered species, the Guidelines provide that an action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will (amongst other things):
 - (a) reduce the occupancy of the species;
 - (b) fragment an existing population into two or more populations;
 - (c) adversely affect habitat critical to the survival of a species;
 - (d) modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.



109. The conservation advice for the Gouldian finch states that they feed almost exclusively on grass seed and depend on a relatively small number of grass species which seed at different times of the year. It notes that vegetation change through altered fire regimes and grazing are the most likely causes of past declines in populations and pose a key threat. A 2006 recovery plan also notes climate change is a key potential threat to the Gouldian Finch as it is “likely to affect the timing and amount of wet season rainfall, potentially impacting on Gouldian finch populations by increasing the frequency or intensity of wildfires or by favouring some grass species over others that may not be palatable to Gouldian Finches”. Gouldian finches are unique in their nesting habits, as they exclusively nest in tree hollows or holes in termite mounds. They are semi-nomadic, and move through the landscape seeking food and surface water sources.
110. Given the large number of records of Gouldian Finches in the vicinity of the project, and the large amount of suitable habitat such as woodlands and surface water sources (including springs, streams and waterholes), ECNT submits that the Gouldian finch population is likely to be an important population and that the habitat on Tanumbirini is likely to be habitat critical to the survival of the species. Santos has not substantiated its claim that nesting and breeding habitat is unlikely to be found in the project area, and it seems very likely given the number of records of Gouldian Finches that breeding is occurring within the vicinity of the project area. Further surveys should be undertaken of the species to understand its importance, including possible breeding and foraging habitat.
111. Fragmentation of this habitat is possible through land clearing and the construction of roads and tracks. Contamination of surface water and groundwater may pose a significant risk to this Gouldian Finch population. There may also be a significant risk to Gouldian finches from open wastewater tanks on the project area (see further the expert report of Dr Grant Hose regarding the shortcomings of the chemical risk assessment and the significant risk to ecosystems). While Santos claims that the risk to avian species is low, during the dry season when surface water sources are scarce, open wastewater tanks pose an increased risk to birds.⁸⁴ These risks would likely be exacerbated by climate change which will change rainfall patterns in this region. These risks need to be comprehensively assessed following more extensive surveys for Gouldian finch populations.

Northern blue-tongued skink

112. The northern blue-tongued skink is listed as critically endangered under the EPBC Act.
113. The EMP incorrectly states that the occurrence of the northern blue-tongued skin is only “possible” within the project area. In fact, according to NT Government records (NR maps) there are two records of northern blue-tongued skinks in the immediate vicinity of the project area (from 1988) and the existence of suitable habitat on the project area suggests they are likely to occur there.
114. The distribution of the Northern Blue-tongued Skink ranges across northern Australia from Eighty Mile Beach WA, across the Kimberley and the Top End of the Northern Territory to approximately the Gregory Downs/Cloncurry area in western Queensland.

⁸⁴ Lee, A.T.K, Geary, C., Wright, D.R., Dear, W.R.J. 2019, [Vulnerability of birds to contaminated water sources in the Karoo region of South Africa](#). *Ostrich: Journal of African Ornithology*. DOI: 10.2989/00306525.2019.1638846.



115. The Northern Blue-tongued Skink occurs in a wide variety of ecosystems, including from sandstone plateaus and gorges, limestone ranges, granite, basalt and dolerite hills, glacial shale undulations, sand plains, sandy waterways, swamps, cracking clay floodplains and coastal flats. Vegetation associations include riparian forest, vine scrub, monsoon rainforest, pandanus-lined gorges, melaleuca forest, eucalypt woodland and savanna, sparse and dense shrubland, and spinifex and tussock grassland. Most, but not all, detections have occurred near seasonal or permanent water.
116. Northern Blue-tongued Skink abundance can be high, but locally heterogeneous in areas that are free of cane toads and individuals can be active at any time of the day or night when temperatures are suitable.
117. Northern Blue-tongued Skinks maintain discrete home ranges of 2-12 ha (average 4 ha) containing multiple core habitat patches, and often return to the same sleeping site. The species is more active, transversing across longer distances during the warmer tropical season where food is more abundant than during the cooler dry season.
118. All remnant populations of the Northern Blue-tongued Skink within the distribution of the cane toad are important populations for sustaining this species and providing a source population for dispersing individuals to support recovery.
119. The Northern Blue-tongued Skink Conservation Advice states that areas of dense vegetation that provide cool and moist conditions within otherwise inhospitable landscapes, constitutes habitat critical to the survival of the Northern Blue-tongued Skink. In ECNT's submission, the proposed action area, in part, may contain habitat critical to the survival of the species. It is likely that cool and moist conditions arise, particularly seasonally, within the region given inundation of floodplains and minor streams.
120. The project could impact the Northern Blue-Tongued Skin in a number of ways. Drawdown of the aquifers in the area from groundwater extraction could adversely affect their habitat (ECNT notes that no drawdown analysis has been undertaken by Santos). Contamination of groundwater or surface water could similarly impact this population on or downstream of the project area (particularly in dense vegetation thickets associated with floodplain and riparian habitats. These risks need to be comprehensively assessed following more extensive biodiversity surveys.

Carpentarian Grasswren

121. ECNT refers to the report of Henry Stoetzel, **attached**.
122. In December 2024, fauna surveys undertaken on Tanumbirini Station recorded an individual identified in the survey results as "grass wren" within the family Maluridae. The taxonomic identification was not resolved to species level. However, the authors state that the most plausible candidate species within the genus is the Carpentarian grasswren.
123. If so, this would be a highly significant record. The project area is approximately 100km west of the historically recognized range of the Carpentarian Grasswren and 350km from any known population.
124. The Carpentarian Grasswren is endangered, has a very restricted range, and has been regarded as locally extinct since 2000. The authors state that "a confirmed detection in 2024 would



therefore represent the first record in more than 25 years and would constitute a finding of major conservation importance for the Northern Territory where the species is most threatened”.

125. The authors state that “independent verification of this record is essential”, and note that habitat characteristics at the site are consistent with those known to support the species elsewhere in its range.

126. The report recommends the implementation of a targeted verification program to resolve the status of the record. Such surveys are necessary to confirm or refute the presence of the Carpentarian Grasswren at the site and to ensure that decisions are informed by robust, evidence-based information.

Mertens Water Monitor

127. The EMP does not mention that there are two records of Mertens Water Monitor (per NR maps) within the vicinity of the project area, nor is there any assessment of the impacts on this endangered species. Surveys must be undertaken, and an assessment of risks to any likely or known population thoroughly assessed.

Impacts on atmospheric processes (greenhouse gas emissions)

128. ECNT submits that the project will have significant climate impacts, and is not consistent with the Northern Territory’s policy objective of achieving net zero emissions by 2050.

129. Santos claims that the total anticipated greenhouse gas emissions from the project are 27,741 tonnes of carbon dioxide equivalents in total. This is a very significant under-estimate, taking into account similar sized exploration projects in the Beetaloo Basin. For example, Tamboran’s estimated scope 1 emissions from its similar scale Shenandoah Project EMP were 400,000 tonnes of carbon dioxide equivalents over 3 years.

130. ECNT refers to the report of Dr Penny Sackett (**attached**). Dr Sackett’s view is that Santos may have significantly under-estimated its greenhouse gas emissions by a factor of 16. Specifically, Dr Sackett states:

- (a) Emissions are under-estimated with only values for vegetation clearing, fugitives and non-routine flaring given;
- (b) A GWP of 28tCO₂e is used in scope 1 estimates, where as an estimate of 29.8 should be used;
- (c) A similar exploration and assessment project (Amungee NW Delineation Program) operating on EP98 in the NT, estimated a total of 522,172tCO₂-e;
- (d) An estimate of the greenhouse gas emissions released on combustion of the EP 161 unrisked 2C contingent gas resource would be equivalent to 92.7 million tonnes (Mt) of carbon dioxide equivalents. This is approximately 4 times the annual emissions of the NT, and these emissions would affect localities in the NT equally through increasingly adverse impacts of resultant climate disruption;



- (e) Strong climate change impacts are already being experienced across the Northern Territory, and will be catastrophic if emissions are not curbed;
 - (f) Every tonne of greenhouse gases emitted into the atmosphere worsens climate change;
 - (g) It is not the date that net zero is reached that will determine the degree of deterioration of the Territory's future climate, but the total amount of GHG emissions released between now and when net zero is released.
131. Santos must be required to undertake a thorough greenhouse gas assessment and assessment of the climate impacts of the project, including likely and foreseeable cumulative impacts. ECNT submits that this should include the estimate for the combustion of the EP161 unrisked 2C contingent gas resource (92.7 million tonnes), which ECNT says is an activity that may occur in or near the permit area.
132. Santos should be required to offset (via the purchase of ACCUs) all scope 1, 2 and 3 emissions for the project, consistent with Recommendation 9.8 of the Pepper Inquiry. This must be mandatory.
133. The EMP would, based on the above, clearly have a significant impact on atmospheric processes and climate change specifically in the Northern Territory, and should be referred for assessment under the *Environment Protection Act 2019* (NT) and *Environment Protection Biodiversity and Conservation Act 1999* (Cth).

Impacts on human health

134. ECNT notes that the project is located only 3.4km from Tanumbirini homestead, where staff from the station live and work. The project will involve significant, possibly continuous flaring from the wellheads.
135. Significant research has been undertaken since the Pepper Inquiry indicating that there are significant adverse human health impacts associated with shale gas fracking.⁸⁵ For example, research suggests that communities within 5 kilometres of flaring experience shorter average length of gestation and a 50% higher chance of having a preterm birth.⁸⁶ Flares emit known carcinogens like benzene, which is linked to cancer, anemia, and birth defects, and poses a measurable risk to residents up to five kilometres away. There is a strong association between proximity to flares and respiratory and skin disorders, including worsening asthma in children and other pulmonary problems.
136. Schedule 1, Section 4A(2) of the Regulations requires a "a full human health risk assessment relating to the chemicals or other substances used in the course of hydraulic fracturing." Section 4A of the Regulations states that "a full human health risk assessment is an assessment that takes into account the following instruments": (a) Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards published by the Environmental Health

⁸⁵ Haswell et al, "The risks of oil and gas development for human health and wellbeing: a synthesis of evidence and implications for Australia", 2023.

⁸⁶ Cushing LJ, Vavra-Musser K, Chau K, Franklin M, Johnston JE. 2020. Flaring from unconventional oil and gas development and birth outcomes in the Eagle Ford Shale in south Texas. *Environ Health Perspect* 128(7):77003, PMID: 32673511, 10.1289/EHP6394.



Standing Committee; (b) National Environment Protection (Assessment of Site Contamination) Measure 1999 published by the National Environment Protection Council; (c) National Chemical Risk Assessment Guidance Manual published by the National Environment Protection Council; and (e) any other guideline, measure or document specified by the Minister.

137. Santos' human health risk assessment fails to satisfy the requirements of Schedule 1, Section 4A(2) and the instruments in Section 4A of the Regulations for the following reasons:

- (a) The human health risk assessment fails to identify the concentrations of pollutants released into the environment by a surface spill or subsurface release.

The *National Chemical Risk Assessment Guidance Manual* listed in Section 4A requires a risk assessment to estimate the quantity of pollutants released and the predicted environmental concentration in receiving environments.⁸⁷ The concentration and distribution of a pollutant, including fluctuations over time, is an "initial requirement for exposure assessment" and one of the "principal determinants of the level of exposure."⁸⁸

Santos assessment of uncontrolled releases fails to predict the concentration of drilling or frack fluid contaminants in the environment, particularly if they are released into subsurface formations or aquifers. Santos primary study of spills or uncontrolled releases is Appendix D, Attachment B that discusses volumes of fluids released and the hectares a spill might cover, but not the concentrations of chemicals released into the environment.⁸⁹ Santos also presents a contaminant screening methodology in Appendix F: Wastewater Management's Appendix C, but this study focuses only on risks related to "residual drilling material" for "on-site burial."⁹⁰ Lastly, Appendix J provides an environmental impact assessment of project impacts, but its description of operational impacts describes no impacts from drilling or hydraulic fracturing and does not provide concentrations of chemicals from surface or subsurface releases either.⁹¹

- (b) Santos' risk assessment does not assess risks to human health from substances released into drinking water aquifers, which represents an exposure pathway to people.

A full human health risk assessment must assess risks to human health where there is a complete exposure pathway.⁹² A pathway "may be considered 'complete' where there is [1] documented evidence of a source (i.e. presence of one or more [chemical of potential concern (COPC)] ...; [2] there is evidence that the COPCs are actually released from their sources; [3] that there are transport pathways and mechanisms that could convey the

⁸⁷ See, e.g., National Environment Protection Council, [National Chemical Risk Assessment Guidance Manual](#), p. 27. See also, Environment Protection and Heritage Council, *Environmental Risk Assessment Guidance Manual for industrial chemicals*, p. 50 (2012) ("An initial requirement for exposure assessment is an understanding of the presence (or absence) of an agent and its concentrations and distribution, including any fluctuations over time") (emphasis added); *id.* at p. 47 (A CSM [conceptual site model] may be based on diagrams or flow charts, but it **must be supplemented with detailed information on COPC concentrations in various media**, transfer characteristics, and receptor characterization") (emphasis added).

⁸⁸ *Environmental Health Risk Assessment (EHRA), Guidelines for Assessing Human Health Risks from Environmental Hazards*, p. 50.

⁸⁹ Santos, Beetaloo Appraisal EMP, Appendix D, Attachment B, *Potential Risk to Groundwater from Hypothetical Water Tank Releases*.

⁹⁰ Santos, Beetaloo Appraisal EMP, Appendix F, Appendix C, p. 23.

⁹¹ Beetaloo Appraisal EMP, Appendix J, p. 48.

⁹² See, e.g., EHRA, *Guidelines for Assessing Human Health Risks from Environmental Hazards*, supra n. 88, p. 46. ("A fundamental concept of risk assessment is that there must be plausible evidence of an exposure pathway linking the source of contamination and the exposed population. Where this linkage exists, an assessment of the nature and significance of the exposure pathway is required to determine the level of risk and the extent to which the proposed pathway is 'complete'").



COPCs from source to the various sites where ‘receptors’ are located; and that [4] the potential for human contact has been established for contaminated environmental media (air, water, soil food, surfaces) at each point in the transport chain.”⁹³ When surface spills pose a risk to shallow soils and aquifers, then the CSIRO report supporting the *National assessment of chemicals associated with coal seam gas extraction in Australia* concludes that contaminant pathway modelling must be done for the different receiving environments across the project landscape such as wells, wetlands, and creeks.⁹⁴

The EMP found potential complete exposure pathways to humans other than on-site workers only in relation to the burial of residual drilling muds.⁹⁵ The “potentially complete exposure pathways that require further consideration could include ingestion of groundwater” contaminated by burial of residual drilling muds if certain conditions are met.⁹⁶ The EMP’s chemical risk assessment also studied complete exposure pathways, but did so only in relation to surface spills, and found the only complete exposure pathway to be workers’ dermal contact and inhalation of chemicals.⁹⁷

The EMP has not completed a full human health impact assessment. This is due to a failure to assess human health impacts from contamination of drinking water aquifers from subsurface events, including loss of fluid circulation during well drilling or well control during fracturing, which represent potentially complete exposure pathways. Professor Hose notes that “the release of drilling fluids to the CLA is likely.”⁹⁸ Professor Currell similarly notes that the “pathways” by which the activities can “negatively impact water and its dependent users and ecosystems” includes “Well integrity problems, encountered during and following the project, [that] may lead to the cross-contamination of high value groundwater aquifers (e.g. the Gum Ridge aquifer), with hydrocarbons and other contaminants of potential concern (CoPC).”⁹⁹ Dr Vogwill also notes that aging wells “can create pathways for contaminants to reach the potable groundwater resources” and that the many different pathways for fracking activities to contaminate aquifers “will vary on a site by site and case by case basis but Reagan et al. (2015) conclude they are all possible. Hence these issues need to be assessed on case by case basis.”¹⁰⁰

Failure to isolate aquifers, which could result in contamination, is not a remote risk. Santos has failed to isolate the Gum Ridge Formation in the past. For example, in 2018, at the Inacumba North Lease Pad, Santos recorded a failure to isolate the drinking water aquifer,

⁹³ EHRA, *Guidelines for Assessing Human Health Risks from Environmental Hazards*, supra n. 88, p. 46.

⁹⁴ CSIRO, *National assessment of chemicals associated with coal seam gas extraction in Australia Technical report number 8 Human and environmental exposure conceptualisation: Soil to shallow groundwater pathways*, p. 115 (2017) (Exposure assessment of chemicals leaking from surface sources into soil and shallow groundwater **requires contaminant pathway modelling from the chemical source (such as low-rate leakage from surface ponds containing flowback and produced water) to different receiving environments (such as water wells, rivers, and wetlands) across the landscape**) (emphasis added).

⁹⁵ Santos, Beetaloo Appraisal EMP, Appendix F, Appendix C, p. 28-29.

⁹⁶ Santos, Beetaloo Appraisal EMP, Appendix F, Appendix C, p. 29.

⁹⁷ Santos, Beetaloo Appraisal EMP, Appendix D, p. 6.

⁹⁸ Expert Report of Dr. Hose at p. 6 (“Given that the release of drilling fluids to the CLA is likely, and that the Chemical Risk Assessment does not adequately address the impacts of drilling and other fluids to groundwater ecosystems, the current chemical risk assessment as outlined in Appendix D of the EMP fails to adequately address all risks of the Program to the environment”).

⁹⁹ Dr. Currell, Analysis of potential water impacts: Santos Beetaloo Basin Appraisal Pilot (EP161) (“**Expert Report of Dr. Currell**”), p. 1 (15 Dec. 2025).

¹⁰⁰ Hydro Geo Enviro Pty Ltd., “Hydrogeological Assessment Of Santos Qnt Beetaloo Basin Appraisal Pilot – Environmental Management Plan,” p. 16-7 (17 Dec. 2025).



the Gum Ridge Formation: the “drilling of the groundwater bore RN040931” resulted in “the failure to isolate the Gum Ridge Formation and the Bukulara Sandstone in that bore. This connectivity is potentially inconsistent with the Minimum Construction Requirements for Water Bores in Australia (3rd edition).”¹⁰¹

- 138.** The human health impact assessment should be redone by assessing risks to human and ecological receptors in the event of a subsurface event including loss of drilling circulation material, loss of well integrity during or after fracturing, or failure to isolate aquifers.

Conclusion

139. In summary, ECNT submits that the EMP should be rejected.
140. Alternatively, Environment Centre NT submits that the EMP is likely to have a significant environmental impact including on matters of national environmental significance and should be referred for assessment under the *Environment Protection Act 2019* (NT) and the *Environment Protection Biodiversity Conservation Act 1999* (Cth).

Attachments

- (a) Report of Professor Grant Hose;
- (b) Report of Dr Ryan Vogwill;
- (c) Report of Henry Stoetzel;
- (d) Report of Professor Matthew Currell;
- (e) Report of Distinguished Professor Penny Sackett.

For more information, please contact Kirsty Howey on Kirsty.howey@ecnt.org.

Yours sincerely,

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¹⁰¹ <https://environment.nt.gov.au/media/docs/onshore-gas/emp/reportable-incidents/quarter-3-2018-19/santos-recordable-incident-water-bore-monitoring-q3-2018-19-tanumbirini-south-inacumba-north-south.pdf>.