EVIDENCE AND RISK ASSESSMENT METHODOLOGY

4

4.1 Introduction

In many instances, hydraulic fracturing is described, especially in the media, as a uniform and immutable practice, irrespective of its geographical, geological, historical, or regulatory setting. This is partly due to a lack of readily accessible and comprehensible information or published data regarding the extent, location, methodology and technology of hydraulic fracturing. The result has been claim and counter-claim, which has led to confusion and misinformation concerning the potential risks and impacts associated with hydraulic fracturing.

The Inquiry's scope of work is set out in its Terms of Reference (Appendix 1), and requires the Panel to first, identify the environmental, cultural, economic and social risks and impacts associated with hydraulic fracturing and onshore shale gas development, and second, to identify how those risks and impacts may be managed to a level that is 'acceptable' and consistent with the principles of ecologically sustainable development (**ESD**).

4.2 Principles of ESD

The principles of ESD (see **Table 4.1**) are at the core of the Panel's analysis. The Panel has used these principles to formulate environmental objectives as an initial part of its risk assessment process and to identify mechanisms that will ensure that those objectives are achieved.

Many submissions to the Panel and many attendees at the community forums argued that given the apparent scientific uncertainty associated with the nature, extent and management of the environmental risks associated with any onshore shale gas industry, the principles of ESD, and in particular, the precautionary principle, should be applied to prevent any onshore shale gas activity from proceeding whatsoever. This is a common misconception as to the operation of the principle, a matter discussed in greater detail in Chapter 14 at Section 14.7.1.2.

Table 4.1: Principles of ESD

The precautionary principle	Where there is a threat of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. Invoking the precautionary principle requires: • a threat, based on scientific evidence, of serious or irreversible damage; and • scientific uncertainty regarding that damage.
The principle of intergenerational equity	The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.
The principle of the conservation of biological diversity and ecological integrity	Conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making.
Principles relating to improved valuation, pricing and incentive mechanisms	Relevant principles include: • that environmental factors should be included in the valuation of assets and services; • the polluter pays principle, namely, that those who generate pollution and waste should bear the cost of containment, avoidance or abatement; • that the users of goods and services should pay prices based on the full life cycle costs of providing goods and services, including the use of natural resources and assets, and the ultimate disposal of any wastes; and • that environmental goals, having been established, should be pursued in the most cost-effective way by establishing incentive structures, including market mechanisms, that enable those best placed to maximise benefits and/or minimise costs to develop their own solutions and responses to environmental problems.
The principle that decision-making should include long and short-term considerations and cumulative impacts	Decision-making processes should consider the potential for cumulative impacts and effectively integrate long-term and short-term economic, environmental, social and equitable considerations.

4.3 Evidence used by the Panel

A comprehensive bibliography of the scientific literature and reports that the Panel has considered, together with a complete list of the submissions (oral and written) provided to the Panel is located in the References and Appendix 12 respectively.

Unless otherwise indicated, all submissions received by the Inquiry have been, in the interests of fairness and transparency, published on the Inquiry's website. Where a submission is legitimately confidential, the reason for maintaining confidentiality has been provided in Appendix 12. Where necessary, the Panel has sought additional information and clarification in respect of a number of submissions (see Appendix 13). The requests and answers have been published on the Inquiry's website. All material received by the Panel has been read and considered, even if no express reference has been made to a particular submission or report in the body of this Report.

The Panel examined, among other material, the 2012 and 2016 Hunter reports, the 2014 and 2015 Hawke reports[1], the Final Report of the Australian Council of Learned Academies (**ACOLA**) *Engineering Energy: Unconventional Gas Production* published in May 2013 (**ACOLA Report**) and the reports of various reviews into unconventional gas in Tasmania, NSW, SA, WA, Victoria and Queensland.[2] Overseas, studies into hydraulic fracturing in the UK, US, Canada, NZ and South Africa have also been considered.[3] In particular, the findings from the authoritative United States Environmental Protection Agency's report (**US EPA**), *Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States* (**US EPA Report**), were taken into account.

The oral submissions and feedback from the community during the Inquiry's initial round of consultations, together with the views expressed in the 'Have Your Say' forms, have also been taken into account by the Panel. The attitudes and opinions of the public towards hydraulic fracturing in the NT are directly relevant to determining how the onshore shale gas industry can earn a social licence to operate (**SLO**). A summary of the principal matters raised and discussed during the community consultations is located in Chapter 3 and is reflected in the final list of issues at Appendix 2.

Specialist consultant work on the social and economic impacts of a potential shale gas industry in the NT was commissioned by the Inquiry (see Chapters 12 and 13 respectively). Further, CSIRO was engaged to provide independent external analysis of issues associated with shale gas well integrity (see Appendix 14). That report was used as evidence in, and otherwise informed, this Report.

1 Issues Paper, p 11.

2 See, for example, the *Review of Hydraulic Fracturing in Tasmania Final Report; the Final Report of the Independent Review of Coal Seam Gas Activities in NSW (***NSW Report***); the Inquiry Into Unconventional Gas (Fracking) Final Report; the Roadmap for Unconventional Gas Projects in South Australia; Implications for Western Australia of Hydraulic Fracturing for Unconventional Gas* (**WA Report**); *the Inquiry into Onshore Unconventional Gas in Victoria Final Report; the Coal Seam Gas Review Final Report; and the Review of the Socioeconomic impacts of coal seam gas in Queensland.* The list is not exhaustive.

3 See, for example, *Shale gas extraction in the UK: a review of hydraulic fracturing* (**Royal Society Report**); *Environmental Impacts of Shale Gas Extraction in Canada; Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States* (**US EPA Report**); *Shale Gas Development in the Central Karoo: a Scientific Assessment of the Opportunities and Risks. New Zealand Parliamentary Commissioner for the Environment* (**Scholes et al. 2014**); *Report of the Nova Scotia Independent Panel on Hydraulic Fracturing* (**Nova Scotia report**); Unconventional Opportunities and Challenges: Results of the Public Review of the Implications of Hydraulic Fracturing Operations in Western Newfoundland (**Newfoundland & Labrador Report**). This list is not exhaustive.

4.4 Overview of the risk assessment process

Having regard to the most relevant, current, and available scientific literature, the Panel identified, collected, analysed, and distilled the available evidence concerning the risks and impacts associated with any onshore shale gas industry (see the final list of issues at Appendix 2). These issues were grouped into the following broad categories, or themes, during the consultation process:

- water (quality and quantity);
- land;
- greenhouse gases;
- public health;
- Aboriginal people and their culture;
- social impacts;
- economic impacts; and
- regulatory reform (including land access).

The process that the Panel has followed to assess the issues or risks associated with each theme depended on the particular nature and context of that issue or risk. During the Panel's deliberations, and taking into account the published scientific data and the submissions received, it became apparent that the biophysical (water, land and air) and public health issues were best assessed by applying a standardised multi-step risk assessment process (see Section 4.5). The Panel has assessed these risks in terms of the likelihood of the impact occurring and the consequence(s) if the impact were to eventuate. This methodology (see below for details) has been applied in Chapters 7 to 10, covering water, land, air and public health, respectively. By contrast, Aboriginal people and their culture (Chapter 11), social impacts (Chapter 12), and economic impacts (Chapter 13) were not suited to this type of assessment. Accordingly, the methods used to assess the nature of those risks are described and dealt with separately in each of their respective Chapters.

Regulatory reform (Chapter 14) is considered by the Panel to be a mitigating factor rather than a risk requiring assessment. That is, if regulation is robust in content and is effectively implemented, it should reduce the risks posed by the development of any onshore shale gas industry to an acceptable level.

4.5 Methodology for assessing risks to biophysical and public health issues

The Panel has adopted a seven-stage process for the identification, assessment, and management of risks associated with the development of any onshore shale gas industry in the NT. The process is depicted in **Figure 4.1** and is described in detail below.

Figure 4.1: Risk assessment process.

STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6	STEP 7
Environmental Value (EV) What do we want to protect? →	**Environmental Objective (EO)** What must be achieved to protect the EV to an acceptable level? →	**Risk** What risk or threat does the shale gas industry pose to achieving the EO? →	**Risk assessment** What is the consequence and likelihood of the risk or threat occurring? →	**Mitigation measure** How can the risk be managed to achieve the EO? →	**Residual risk assessment** If we implement the mitigation measure, what is the residual risk or threat? →	**Recommendations** What can the Government do to achieve the EO?

4.5.1 Identifying environmental values

Environmental values (**EV**) represent those environmental, cultural, social and economic issues of particular concern to Territorians that are considered to be in need of protection from any adverse impacts by any onshore shale gas development. Examples of environmental values are iconic landscapes, water quality and quantity, greenhouse gases, public health, community cohesion, and the maintenance of cultural connection to country. These values have been articulated and identified through the community consultation process under the themes of water, land, greenhouse gas emissions, public health, Aboriginal people and their culture, social impacts, and economic impacts. These themes have subsequently comprised the major areas of assessment for the Panel. The objective of the community consultations was to canvas public opinion as widely as possible to identify, as comprehensively as possible, the range of risk factors that could affect these values.

As noted above, the methodology used to assess cultural, social, and economic risks are dealt with in Chapters 11, 12 and 13 respectively.

4.5.2 Identifying environmental objectives

For each environmental value, the Panel has determined one or more environmental objectives (**EO**) that must be achieved to ensure that the environmental value is protected to an acceptable extent. Where possible, the Panel has identified environmental objectives that are measurable, actionable and realistic. These objectives provide performance indicators against which the environmental outcomes can be assessed. The environmental objectives that have been developed and applied to each theme, or set of risks, have been clearly identified in each of the corresponding Chapters in this Report. For example, in the case of water quality, these environmental objectives are articulated quantitatively by water quality criteria for water use (human drinking, stock watering) and/or for the protection of the aquatic environment.

4.5.3 Identifying risks

Following an extensive period of public consultation and a review of the scientific literature, the Panel identified a number of issues associated with any onshore shale gas development that may threaten the achievement of environmental objectives, and therefore, have an adverse impact on a core environmental value (see Appendix 2).

4.5.4 Assessment of risk

An assessment of risk was only undertaken if there was sufficient information or evidence to do so. In making an assessment, the Panel has assumed the application of the current regulatory regime. In the event that a risk could not be assessed, or if there was a high degree of uncertainty in the magnitude of that risk, the precautionary principle (**Table 4.1**) has been applied where there was a possibility that the consequence of the risk resulted in an unacceptable impact on the environmental value to be protected. In other words, a mitigation measure, or measures, was required to be implemented to prevent a possible unacceptable impact from occurring unless it could be proven by the acquisition of additional information that the risk did not require the original prescribed level of mitigation.

Risk may be assessed by 'qualitative' or 'quantitative' methods, as described in the Australian and New Zealand standard for risk assessment[4] and associated materials.[5] In general, a 'qualitative' risk assessment is conducted, first, to identify priority risk factors that may need to be subjected to a semi-quantitative, or a full quantitative risk assessment, depending on the availability of sufficient input data (or quantitative computer models), to enable the risk to be evaluated at a requisite level of detail. Qualitative methods use descriptive terms and expert opinion to identify and record the consequences and likelihoods of events and resultant risk. 'Quantitative' methods identify likelihoods as frequencies or probabilities, and use quantitative measurements of consequences, such as the proportion of a population, or number of species, that would be affected in a specified way at a specified level of exposure.[6]

To assist in the assessment of the biophysical (water, land and air) and public health risks associated with any onshore shale gas development, the Panel adopted a qualitative risk assessment framework that combines the estimated likelihood of an impact occurring, and the consequence(s) of that impact, to assess the resultant risk level. The resultant risk level is then used to determine if any additional mitigation measure is required to reduce the risk level to a sufficiently low (or acceptable) level should the industry proceed. As noted above, the economic impacts and the risks to Aboriginal people and their culture have been assessed differently.

The Panel's risk assessment framework is based on the Government's risk assessment framework for resource developments.[7] The 6x6 risk matrix was condensed to three levels each for 'likelihood', 'consequence', and 'risk', namely, 'low - L', 'medium - M' and 'high - H' (**Table 4.2**). This was done because the amount of information available to the Panel meant that there was no advantage in using a more complex matrix for a qualitative risk assessment. The combinations of categories in the 6x6 matrix used to produce the 3x3 matrix applied by the Panel are contained in **Table 4.3**.

Table 4.2: Risk assessment matrix used by the Panel.

		Likelihood		
		L	**M**	**H**
Consequence (see **Table 4.4**)	H	M	H	H
	M	L	M	H
	L	L	L	M

4 AS/NZS2009.
5 AS/NZS2006.
6 A good practical introduction to the topic of risk assessment is provided in Appendix 1 of the Risk Assessment Handbook developed for use by the mining industry and published by the Australian Government as part of its *Leading Practice Sustainable Development Program for the Mining Industry* series of handbooks. Appendix 1 provides a very comprehensive overview of the application of different types of risk assessment approaches and their strengths and weaknesses: Australian Government 2016.
7 Petroleum Environment Regulations Guide, pp 26-29.

Table 4.3: Creation of condensed risk assessment matrix used by the Panel.

Element		Combination of categories [1]
Likelihood	L	Remote, Highly Unlikely, Unlikely
	M	Possible
	H	Likely, Almost Certain
Consequence	L	Minor, Moderate
	M	Serious
	H	Major, Critical, Catastrophic

1 From the Government's risk assessment framework for resource development.[8]

'Likelihood' was assigned on a quantitative or qualitative basis depending on the amount of information available. Where sufficient evidence was available from the published literature about likely probability (chance) of occurrence for a risk type (for example, a surface spill or leakage of gas from a well) in the onshore shale gas industry, the following assessments were made:

- 'L' - less than 1% probability of occurring;
- 'M' - between 1 and 10% probability of occurring; and
- 'H' - greater than 10% probability of occurring.

Where quantitative information was not available, the following qualitative thresholds were applied based on the professional judgement and experience of the Panel: 'L' - unlikely to occur, 'M' - a reasonable chance that this might occur and 'H' - a strong chance of occurring.

Each of the biophysical and public health Chapters in this Report (Chapters 7 to 10) has developed its own relevant definitions of 'consequence' for each theme (**Table 4.4**), which are generally consistent with the descriptions used in the Government's risk assessment framework for resource development.

The risk of the activity being assessed is obtained by combining the assigned 'likelihood' and 'consequence' categories in the matrix (**Table 4.2**) above to identify an overall 'L', 'M' or 'H' risk. For example, if the 'likelihood' is rated 'M' and the 'consequence' is rated 'M', the resultant risk is rated 'M'. Whereas if the 'likelihood' is rated 'L', and the 'consequence' is rated 'M', the resultant risk is rated 'L'. For example, even though the likelihood of a well blowout is very low (see Chapter 5), if this were to cause significant environmental damage, the 'consequence' would be rated 'H' and the resultant level of risk would be 'M'.

If the risk is assessed as being sufficiently low, and therefore, acceptable, generally no additional mitigation measures are needed. However, for some risks, even where the risk was identified as low, the Panel nominated measures that could further reduce the risk to a level that is as low as reasonably practicable (**ALARP**). The factors that scored 'M' or 'H' for risk require further mitigation to reduce, the risk to a level that is low and acceptable.

8 Petroleum Environment Regulations Guide, pp 26-29.

Table 4.4: Descriptions of the levels of consequence for the biophysical and public health themes.

Values	Low	Medium	High
Water • quantity • quality • aquatic ecosystems	Localised spill or leak from a primary containment that is confined within existing disturbed area; no impact on surface water or groundwater quality; short-term (one week) impact on water availability (quantity); no impact on aquatic ecosystems (surface or groundwater dependent).	Spill or leak that escapes physical containment of existing disturbed area and spreads to nearby land surface or waterway; minor contamination of groundwater that is insufficient to trigger public or environmental health concerns; no adverse impact on aquatic ecosystems; drawdown of water table so that water can no longer be accessed by existing installed bores for a short period of time (~ one month).	Major off-site release or spill with large footprint area, potentially also including surface waterways; contamination of groundwater requiring remediation; adverse impact on aquatic ecosystems; drawdown of water table so that water can no longer be accessed by existing installed bores and/or degradation of water quality so that water resource is no longer suitable for its original beneficial use.
Land • biodiversity • visual amenity • disturbance	Impacts of limited significance [1] confined to the existing approved disturbed area, without affecting the terrestrial biodiversity, ecosystem or amenity values of the broader region. 1 Assuming that the initially approved area did not contain high value biodiversity or significant habitat area for rare and endangered species.	Impacts extending beyond approved disturbed area, with detectable effects on the terrestrial biodiversity, ecosystem or amenity values of the broader region able to be restored by natural recovery processes.	Widespread impacts, with material effects on the terrestrial biodiversity, ecosystem or amenity values of the broader region, requiring active remedial intervention.
Air emissions • climate change • greenhouse gas emissions	Increase in greenhouse gas emissions in the gas field that are deemed moderate (that is, less than 0.1% of global emissions).	Increase in greenhouse gas emissions in the gas field that are deemed serious (that is, less than 0.5% of global emissions).	Increase in greenhouse gas emissions in the gas field that are deemed major (that is, greater than 0.5% of global emissions).
Public health • water • air	Medical treatment for injury or condition by a health practitioner, with only minor temporary impact, or prediction from a formal health risk assessment that chemical exposures would not exceed relevant health-based guideline values.	Medical treatment for injury or condition by a specialist or health practitioner, with impact lasting more than a week but less than three weeks, or prediction from a formal health risk assessment that chemical exposures could exceed relevant health-based guideline values, but by no more than tenfold to one hundredfold (within conventional safety factors built into such values).	Serious but temporary injury or condition of members of the public, with lasting effects over three weeks requiring specialist medical assistance, or prediction from a formal health risk assessment that chemical exposures could exceed a relevant health-based guideline value by more than one hundredfold.

4.5.5 Potential additional mitigation measures

For risks that were initially assessed as unacceptable (namely, 'M' or 'H'), the Panel has identified measures that, if implemented, will potentially further reduce the 'likelihood' or 'consequence' of the risk so that the reassessed residual, or remaining, risk will meet the environmental objective and be acceptable. Such measures could include increased and/or more rigorous monitoring, improved compliance, more robust regulation, improved enforcement, or the implementation of world-leading practice guidelines.

The Panel did not use the 'as low as reasonably practicable' (or **ALARP**) test to determine what an acceptable level of risk is. The ALARP test is frequently used in assessing whether all reasonably practicable measures are, or will be, in place to control or mitigate a potential risk or impact. However, the ALARP test only requires that the level of residual risk associated with an activity be balanced against the mitigation measures needed to control that risk in terms of 'money, time or trouble'. The Panel's view is that other matters must also be considered when determining whether the extent of mitigation provided by ALARP is sufficient in order to be acceptable.

In determining what an acceptable level of risk is, the Panel considered the principles of ESD (including the precautionary principle), relevant international standards, and the unique social and cultural conditions that exist in the NT. As alluded to above, the application of the precautionary principle does not mean that any onshore shale gas development cannot proceed whatsoever in the absence of full scientific certainty. Rather, the application of the precautionary principle means that, assuming the worst, the maximum level of mitigation must be implemented until contrary evidence is obtained. Where the Panel has concluded that the residual risk is still 'medium' or 'high', notwithstanding the implementation of all potential mitigation measures, then the action has been assessed as 'unacceptable'.

Consideration of the principles of ESD may require that certain areas are declared 'no go zones', or that additional safeguards must be put in place before the remaining risk can be assessed as 'acceptable'. It should be noted the principles of ALARP and of acceptability are both addressed in the Petroleum Environment Regulations where it is stated that, "*when deciding whether to approve an EMP, the Minister must be reasonably satisfied that environmental impacts and environmental risks will be reduced to a level that is both ALARP and acceptable*".[9]

The Panel reassessed each risk assuming that the mitigation measures identified in Step 5 (see **Figure 4.1**) have been implemented. The Panel then considered whether the residual risk is likely to be sufficiently low, and therefore, acceptable. Each of the biophysical and human health chapters have developed their own definition of what is considered 'acceptable' based on the best available scientific information. These definitions have been fully documented in each of the corresponding chapters, with a summary compilation provided for convenience in **Table 4.5**. In general terms, 'acceptable' could be considered to equate to the 'low' category of risk documented in **Table 4.4**.

9 Petroleum Environment Regulations Guide, pp 7-8.

Table 4.5: Acceptability criteria for the biophysical and public health themes.

Theme	Criterion	Measures of Acceptability
Water quantity - groundwater	Extraction of groundwater does not does not result in sustained drawdown of the water table that would compromise supply of water for domestic or stock use, or adversely affect groundwater dependent ecosystems.	• Extraction (in total) does not exceed 20% of sustainable yield from an aquifer system. • Local sustained drawdown of potable or stockwater bores does not exceed 1m.
Water quantity - surface water	Extraction of water does not exceed 20% of flow at any time.	Low likelihood that water use will exceed 20% of flow at any time.
Water quality – groundwater	The current highest value use of the water will not be compromised.	• Australian drinking water quality criteria. • Australian livestock watering quality criteria.
Water quality – surface water	The current highest value use of the water will not be compromised.	• Australian drinking water quality criteria. • Australian livestock watering quality criteria. • Australian and New Zealand (ANZECC/ ARMCANZ) criteria for the protection of aquatic ecosystems.
Land-biodiversity and ecosystem health	• No regional-scale impact on terrestrial biodiversity values. • Maintenance of overall terrestrial ecosystem health, including the provision of ecosystem services, at the regional scale.	• Exclusion ('no go zones') of any shale gas development from areas where regional conservation values are very high. • No introduction or spread of any declared weeds. • No increase in fire frequency in production areas. • Minimal clearing of native vegetation and avoidance of critical habitats. • Roads and pipelines designed to minimise disruption to surface water flow.
Land-amenity	• Shale gas surface infrastructure should not become a highly visible feature of the landscape. • The volume of heavy-vehicle traffic should not have an unacceptable impact on landscape amenity and place identity.	• No impact on the physical appearance of the NT's most scenic and highly visited outback landscapes. • Minimal visibility of shale gas infrastructure from public roads in areas where development occurs.
Greenhouse gas emissions	• Minimise greenhouse gas emissions. • Minimise fugitive methane emissions.	• Offset life cycle greenhouse gas emissions in Australia from shale gas produced in the NT to ensure no net emissions. • Set a methane concentration limit that is equivalent to methane emissions that are 1.7% of dry production.
Public health-air and water	Based on site-specific Human Health Risk Assessments, communities will not be exposed to water-borne or airborne chemical emissions that exceed relevant health-based guideline values.	Exposure concentration less than Australian and international water and air quality guidelines for specific chemicals.
Public health-stress	No measurable impacts on mental health or other amenity-based criteria that are directly attributable to any onshore shale gas production operations.	Hospital admission data or other relevant health survey data show that health issues are not significantly different to pre-development baseline values.

The complete risk assessment matrixes developed by the Panel for assessing the biophysical and public health risks are provided for reference in Appendix 3. The contents of these matrixes show the successive steps of the process and the estimated residual risk if the required mitigation measures are implemented.

4.6 Recommendations

Based on the outcomes of the risk assessment, the Panel has made recommendations to the Government that, if implemented, the Panel believes will reduce the risks to an acceptable level. If the Panel finds that specific risks cannot be reduced to an acceptable level, this is stated. In a number of cases, the Panel has recommended that a strategic regional environmental and baseline assessment (**SREBA**) (see Chapter 15) must be undertaken to provide the additional scientific knowledge and baseline information required before a final risk assessment can be made.

4.6.1 Quantitative risk assessment

A qualitative risk assessment process has been used by the Panel to filter the range of risk factors identified during the consultation process. However, by their very nature, qualitative risk assessments cannot adequately address situations where the level of complexity is such that a numerical or quantitative assessment is needed. An example is the prediction of the consequence of a leak from a gas extraction well on groundwater quality at a stock watering bore located several kilometres away. A qualitative assessment (see, for example, Chapter 7) may be able to indicate the risk of a leak occurring, but in the absence of a groundwater computer model containing specific local information about rock type, aquifer water quality, groundwater movement, volume and composition of the leak, together with possible dilution and decomposition processes occurring, it is not possible to infer, with any level of certainty, what the future water quality will be at the watering bore and, therefore, what the consequence is (for example, of contaminant concentrations being above or below the National Health and Medical Research Council (**NHMRC**) Australian drinking water guidelines). This is where a quantitative risk assessment is required. The principles of quantitative risk assessment, as applied to estimating the public health impacts of chemical exposures, are outlined in Chapter 10 (Section 10.1).

A good example of a quantitative assessment is the National Chemicals Risk Assessment (**NCRA**) for chemicals used in the extraction of CSG commissioned in 2012 by the Australian Department of the Environment and Energy. The NCRA was prepared in collaboration with the National Industrial Chemicals Notification and Assessment Scheme (**NICNAS**) and CSIRO.[10] The NCRA was commissioned because of the increased scientific and community interest in better understanding the risks of chemical use by the CSG industry. It aims to develop an improved understanding of the occupational, public health and environmental risks associated with chemicals used in drilling and extraction of CSG in an Australian context. This is the only independent assessment that has been completed in Australia of the risks posed to the aquatic environment and human health by CSG drilling and by the chemicals used for the extraction of CSG (with analogous implications for many of the chemicals used for the extraction of shale gas).

The NCRA is a large and complex scientific undertaking. At the time it was commenced, no comparable assessment had been undertaken in Australia or overseas, and new models and methodologies had to be developed and tested for the deterministic (quantitative) risk assessment of CSG chemicals. The US EPA has subsequently undertaken its own assessment of the risk of shale gas extraction to drinking water resources, and there are many parallels between the two approaches.[11] It is noted, however, that the US EPA review is restricted to the assessment of potential impacts on drinking water from a human health perspective and does not extend to the broader aquatic environment, unlike the NCRA.

The NCRA considers the potential risks to the environment (surface and near surface water environments) of 113 chemicals identified as being used for CSG extraction in Australia from the period 2010 to 2012.[12] Risk factors addressed include the transport, storage and mixing of chemicals, and the storage and handling of water pumped out of CSG wells (flowback or produced water) that can contain residual amounts of the chemicals used. Although the extraction process for CSG differs from extraction of shale gas (as described in Chapter 5 and see also the Issues Paper), there are many similarities between the two types of gas extraction in the associated infrastructure and in the surface handling of chemicals and wastewater. The Panel notes that geogenic chemicals (that is, those extracted from the coal seam and contained in the produced water) are not included as part of the NCRA. Assessment of contamination of soil, or

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10 Australian Department of the Environment and Energy 2017 a-f.
11 US EPA Report.
12 Australian Department of the Environment and Energy 2017 a-f.

impacts on terrestrial plants or animals by leaks or spills of chemicals or wastewaters are also not part of the scope of the NCRA.

Rather, the focus of the NCRA is on the impacts of surface discharges (spills or leaks) on surface water and near-surface groundwater, extending to potential downgradient effects on surface water through overland flow or discharge of the shallow groundwater into surface waterways. The reason for this priority is that international studies have shown that the greatest risk to human health and the environment is from spills or releases of chemicals during surface activities, such as transport, handling, storage, and the mixing of chemicals. The potential effect of chemicals injected into deeper groundwater on near-surface aquifers was not part of the initial assessment; although, this aspect has subsequently been addressed by an extension of the work.[13]

The findings from the NCRA significantly strengthen the evidence base and increase the level of knowledge about the chemicals used in CSG extraction in Australia and, therefore, similarly inform the shale gas industry, which utilises many similar types of chemicals. This information improves the understanding of which chemicals can continue to be used safely, and which chemicals are likely to require extra monitoring, industry management, and regulatory consideration.

Further details of content and specific findings from the NCRA are presented and discussed in Chapters 7 (Water) and 10 (Public health), where it is used as evidence for the Panel's assessments of risk for these topics.

13 Mallants et al. 2017.