CHAPTER 12

Impacts on Human Health

CHAPTER 12: IMPACTS ON HUMAN HEALTH

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Executive Summary

This Chapter of the scientific assessment focused on potential health impacts of four different shale gas development (SGD) scenarios. The status quo represents Scenario 0 (Reference Case), exploratory drilling representing Scenario 1 (Exploration Only), moderate drilling representing Scenario 2 (Small Gas), and lastly high gas production representing Scenario 3 (Big Gas). The scope of the study is to assess potential human health risks in the study area. International experience and scientific evidence was used to predict the potential health impacts. The following had to be done for the impact assessment: identify potential chemicals to be used, assess the potential health impacts of these chemicals, assess the potential population that could be exposed, and consider the potential pathways through which the population might be exposed.

Chemical information was obtained using international databases of most used, most detected, most toxic to human health and most likely to be transported in the environment. This Chapter presents the South African data illustrating the extent of the area that may be affected, the current size of the study population and the current health status of the study population, with a description of possible pathways through which the community might be exposed.

Different pathways for potential exposure, with air, water, noise, direct contact resulting from traffic or machine injuries, and dermal contact were considered. These were considered separately for workers and community members. The four scenarios were found to yield health risks as ranging from none, to moderate risk for the Reference Case as the current health status of the study area population faces serious challenges with infant, maternal and under-five mortality rates double that of the provincial rate. For Exploration Only, community health is expected to range between a very low risk to a moderate risk (with water as the exposure pathway) and worker health ranging from high risk (via the air pathway) to low risk, depending on the exposure pathway. For the Small Gas scenario, worker health risks range from low risks to high risks (multiple pathways). Community health risks range from low to high (where water is the exposure pathway). The Big Gas scenario results in high risks for workers from air, noise and direct contact pathways, and high risks for the community via air and water pathways, to low risks for the other pathways.

Uncertainties in the scientific evidence of chemicals to be used and health impacts that might be expected are the major restriction in the health impact section of this assessment. Chemicals included in assessing potential health impacts is based on international data and experience with regards to time for long-term health effects to be measurable is limited. Many of the chemicals used in SGD do not have sufficient health data, as chronic health effects data are available for only 8.4% of the 1173 reportedly used chemicals in the United States Environmental Protection Agency (US EPA) database. Each drilling and hydraulic fracturing (“fracking”) event is unique depending on the geology, depth

and resources available, with the chemicals and products used and the amounts or volumes used differing from well to well.

Since the activity of fracking is relatively new in relation to the time needed to assess long-term health effects as well as trans-generational effects, scientific evidence that can be used with certainty is lacking. However, information on individual chemicals used has been shown to cause long-term and transgenerational effects.

Any potential health impacts resulting from SGD will require that baseline monitoring for air and water quality. Baseline health monitoring, including additional health symptoms associated with SGD will need to be carried out prior to initiating the exploration activity to enable ascribing any future health effects to a specific cause. The additional health symptoms implies that standard health monitoring done at hospitals and clinics will not be sufficient and that additional health symptoms associated with SGD such as nose, eye and throat irritation, dermal or skin lesions, upper respiratory impacts, etc. (see Figure 12.5) be noted prior to, throughout as well as for a long time after exploration or mining has seized. Transgenerational effects as well as endocrine disrupting chemical (EDC)-related health impacts (e.g. thyroid, reproductive) as well as cancer will require long term monitoring.

The current Regulations for Petroleum Exploration and Production (Government Gazette, 2015) do not consider health in any way, and this should be recommended for inclusion.

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12.1 Introduction

According to the World Health Organisation (WHO), environmental health deals with the physical, chemical, and biological factors that can potentially affect human health through the environment (WHO, 2016).

Health impacts are often expressed as reductions in human life expectancy or as increases in adverse health effects. The World Health Organisation (WHO) uses the Disability Adjusted Life Year (DALY), as a health gap measure that accounts for potential years of life lost (YLL) due to premature death, plus equivalent years of 'healthy' life lost by virtue of being in states of poor health or disability (Prüss-Üstün et al., 2003). DALYs are typically calculated for a disease or health condition. These measures are often used to describe the current health of a population to compare different diseases and their impacts.

Health risk assessments are used to predict the potential health impacts on a population based on known or modelled chemical concentrations. According to the United States Environmental Protection Agency (US EPA) (2004, 2005), a human health risk assessment estimates the nature and probability of adverse health effects in humans who may be exposed to chemicals in contaminated environmental media, now or in the future.

The scope of this study is to predict possible health impacts due to environmental contamination as a result of unconventional oil and gas exploration and development, making use of a combination of WHO measures and health risk assessment methods.

12.2 Does hydraulic fracturing pose health risks to the people living near drilling sites?

In the USA, a financial settlement of $1.6M was reached in 2012 to compensate three families for contaminated drinking water wells. This is thought to have been the first case publicly disclosing the settlement terms as others were sealed (Associated press, Pittsburgh). Prior to this, the non-disclosures limited access to public health information.

The short answer is that do we do not know yet. Although there have been reported cases internationally and research is underway, few studies to date could provide conclusive evidence about how unconventional natural gas development affects nearby communities (Adgate et al., 2014; National Institute of Environmental Health Sciences (NIEHS), 2014). It is however the aim of this Chapter to assess possible health risks. Further, the Chapter will present what is known internationally, describe the knowledge of the health status and unique vulnerabilities of nearby communities, give an overview of the vast majority of chemicals declared for use elsewhere during such development and describe best practices within the regulatory framework of South Africa. Further, the Chapter seeks to summarise within the current uncertainties, a qualitative health risk assessment for each of the four likely SGD scenarios and conclude with some recommendations on future monitoring requirements and the current uncertainties hampering decision-making.

Concerns have been expressed that some of the many chemicals used in SGD may constitute a health impact; this section will therefore consider and describe what is known regarding potential health impacts of hydraulic fracturing ("fracking") for oil and gas as a result of potential contamination of water resources in particular. Separate chapters dealing with water (Hobbs et al., 2016), air (Winkler et al., 2016) and noise pollution (Wade et al., 2016) and waste disposal (Oelofse et al., 2016) are presented amongst the other 15 issues considered in the scientific assessment.

Occupational health is an important component regarding potential health impacts of fracking. Most of what is currently known in terms of human health impacts have been derived from studies of workers and the health risks posed to them at unconventional natural gas development sites (NIEHS, 2014). While such studies are still limited globally, ongoing efforts are made to gather more in depth details on worker health at these sites. Apart from risks associated with accidents, the NIEHS (2014) highlighted the following three risks that have been associated with occupational health risks during fracking:

- Silica sand inhalation – Silica sand (which can cause lung cancer) is used in the fracking process where workers may inhale fine silica sand particles even if they are wearing the correct personal protective equipment (PPE) (Esswein et al., 2013).
- Exposure to chemical spills – Workers may be exposed to compounds used in the fracking process during accidental spills. Depending on the chemical compounds used, it may present a variety of health risks (Newton, 2015).
- Exposure from flowback[1] operations (Esswein et al., 2014) – Field studies found that workers are exposed to high levels of volatile hydrocarbons which can be acutely toxic. According to Snawder et al. (2014), at least four workers have died as a result of exposures during flowback operations since 2010. Since then the National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) reported nine worker fatalities associated with manually gauging and sampling fluids on production and flowback tanks (NIOSH, 2016).

In addition to these health and safety issues related to the hydraulic fracturing processes, most worker fatalities in the industry are as a result of motor vehicle accidents, with 7.6 deaths per 100,000 workers recorded by Retzer et al. (2013). The Occupational Health and Safety Amendment Act (Act 181 of 1993) regulated by the Department of Labour (DoL) is available to protect the health and safety of workers in South Africa. This however does not guarantee worker safety. The DoL, together with each employer (defined in the act), are responsible according to Section 8 of the Act to provide

[1]Flowback is defined as a "water based solution that flows back to the surface during and after the completion of hydraulic fracturing" (Schramm, 2011).

workers with a safe working environment and protect workers from exposures, and to provide them with the correct PPE and equipment in order to prevent adverse health impacts as a result of accidents and operations.

12.3 Overview of international experience

In relation to health impacts of SGD, few studies have focused on long term health outcomes to include health impacts such as cancer or developmental outcomes (McDermott-Levy et al., 2013; Werner et al., 2015). Werner et al. (2015) conducted a review of the current state of the evidence of environmental health impacts of unconventional natural gas development. They noted that health outcomes reported to be in some way associated to these environmental impacts are symptoms of upper respiratory tract ailments, burning eyes, headaches, vomiting, diarrhoea, rashes, and nosebleeds. Most reported symptoms are acute, with short-term impacts, while there may be the potential for chronic, long-term impacts which have not been assessed.

Communities living near natural gas extraction sites may experience exposure to volatile organic compounds (VOCs), silica and other compounds arising both from the well completion and fracking processes as well as leaks from pipes and valves (Public Health UK, 2013; Adgate et al., 2014). Although Bunch et al. (2014) found measured VOC concentrations in the Barnett Shale production site in Texas to fall below federal and state health-based air comparison values, Macey et al. (2014) found that at sites in four of the five states (Wyoming, Arkansas, Pennsylvania, and Colorado excluding Ohio) in proximity to shale gas production analysed for 75 volatile organics, levels of eight volatile chemicals exceeded federal guidelines. These exceedances could be linked in space and time to oil and gas production sites. Goetz et al. (2015) investigated emissions from criteria pollutants and their precursors, as well as natural gas constituents, from Marcellus SGD activities. They found elevated levels of methane and ethane, with other VOCs generally not observed at elevated levels at the investigated sites. The literature provides evidence for increased air pollution impacts at a population level involving methane, VOCs and other hydrocarbons arising from the complete continuum of SGD production processes.

As stated in the US EPA report (2015), health effects include the potential for carcinogenesis, immune system effects, changes in body weight, changes in blood chemistry, pulmonary toxicity, neurotoxicity, liver and kidney toxicity, and reproductive and developmental toxicity. Evaluating potential risk to human populations would require knowledge of the specific chemicals that are present at a particular site, whether or not humans are exposed to those chemicals and, if so, at what levels and for what duration, together with the specific toxicity of the chemicals being used.

Burton et al. (2016) found that gas-well density and formation pressures best correlated with changes in water quality and not the proximity to gas-wells solely. However, Hill (2013) reported an increase in low birth weight and small for gestational age and reduced APGAR[2] scores in infants born to mothers living near SGD in Pennsylvania. McKenzie et al. (2014) found positive associations between density and proximity of natural gas wells within a 10 mile radius of maternal residence and birth prevalence of congenital heart defects and possibly neural tube defects. It is unclear if these positive associations could be due to other confounding factors and more research is required. Casey et al. (2016) found prenatal exposure to unconventional natural gas extraction activity was associated with two pregnancy outcomes. The changes associated with building and having a drilling site can have numerous impacts on community well-being. Some of these impacts may be positive. For example, a drilling operation can increase local employment rates, and result in greater access to health care. Drilling-associated activities, and a sudden influx of a large transient workforce, can also have negative impacts on a community. These may include increased noise, light, and traffic; heavier burdens on local infrastructure and resources, such as roads and hospitals; higher rates of crime and substance abuse; and changes to community character (National Institutes of Health, US Department of Health and Human Services, 2014).

Possible health impacts occur through many different pathways and are discussed in this Chapter. However many issues that impact on human health are discussed in more detail in other Chapters of this scientific assessment. Table 12.1 summarises the issues and the Chapters that deal with them.

Table 12.1: Description of potential health hazards discussed in other Chapters of the scientific assessment.

Topic	Description of potential health hazards addressed in chapters	Chapter
Social fabric	- Known social and health problems in the study area. - ‘Boomtown’ effect with boom-bust cycle. - *Influx of workers raises the demand for housing thus negatively impacting those not working in the industry*. - Influx of people may increase crime and thus health problems. - Raised incidence of HIV/AIDS is a possibility as a result of influx of workers to the study area, increased truck traffic (water needs). - Lack of Health System responsiveness at current capacity. - Poor implementation of disaster management strategies. - Traffic resulting in raised noise pollution. - *Moving target: the communities affected by changes all the time.*	Atkinson et al. (2016)
Occupational Health	Occupational exposure to chemicals in the SGD industry poses direct health risks such as dermal and respiratory problems; however the emphasis of the Human Health Chapter is community health. Although general exposure to SGD related chemicals is covered in this Chapter, occupational exposure raises critical concerns in industries such as SGD and mining where exposure duration, concentrations and chemical combinations have different implications than	Current Chapter

[2] Apgar scale refers to a newborn baby’s clinical status within the following categories: Appearance (skin colour); Pulse (heart rate); Grimace response (reflexes); Activity (muscle tone); Respiration (breathing rate and effort) (Committee on Obstetric Practice and American Academy of Pediatrics, 2015).

Topic	Description of potential health hazards addressed in chapters	Chapter
	exposures of the general public not involved in the industry. The industry is legally responsible for protecting staff against work related exposures such as staff responsible for mixing chemical cocktails and handling equipment. Exposed workers using public transport, and having direct contact with family members or infants when returning from work, and storage of exposed protective equipment remains a concern seldom addressed effectively in low income countries such as in the study site. Furthermore, security guards and other non-chemical handling staff might not undergo the same training as those at risk of direct chemical exposure; however might help out in case of an emergency or have extended exposure periods at a low concentration without risk awareness. There is limited knowledge on the health effects of long term compounded exposure to chemicals at high concentrations.	
Human health	The health status of a population affects the resilience of that population to tolerate the introduction of new chemicals and other environmental health hazards. Communities with a negligible disease burden and sufficient access to amenities are likely to tolerate the introduction of environmental health hazards better than those who are competing for resources, have a high disease burden and have difficulty accessing basic health care such as the community in the study site. This Chapter presents the South African data of the challenges and the potential benefit of SGD in the Karoo, in light of the known challenges the Karoo population faces, including high disease burden, limited access to preventative and curative health services, arid landscape and underground water dependence, high unemployment - and poverty rates.	Current Chapter
Noise exposure	Exposure to noise through increased truck traffic for those living in the proximity to SGD. Exposure to noise from the industry for industry workers.	Toerien et al. (2016)
Air pollution	Fugitive gas emissions like methane leaking into the atmosphere exposes community to short term and long term health risks. Exposure to vehicle emissions as a result of SGD.	Winkler et al. (2016)
Waste	Exposure to hazardous waste created during the SGD process could result in health problems. In addition, the additional on-site sanitation as well as additional waste water created by the community could result in unhygienic conditions and possible health impacts if not managed properly.	Oelofse et al. (2016)
Agriculture	Health effects as a result of loss of income, financial strain.	Oettle et al. (2016)
Planning	Increased gravel roads– negative impact on farming, increased dust/air pollution. Road building requires large amounts of water thus threatening water resources in this already semi-arid area.	Van Huyssteen et al. (2016)
Water	Exposure to SGD waste water through a number of pathways could cause short and long term health effects. Pathways include contamination from surface spills, from flowback and produced water. Water shortage and threats to the current supply in the study area could have long term health implications. Contamination of current community water sources through SGD.	Hobbs et al. (2016)

12.4 Special features of the Karoo environment from an environmental health perspective

The study area under review within this scientific assessment is illustrated in Figure 12.1 below. It shows the areas within the water catchments where water resources are expected to be in shortage or are already in deficit. The possibility of water resource contamination is described in the section below, together with background information describing water supplies served to the population within the study area.

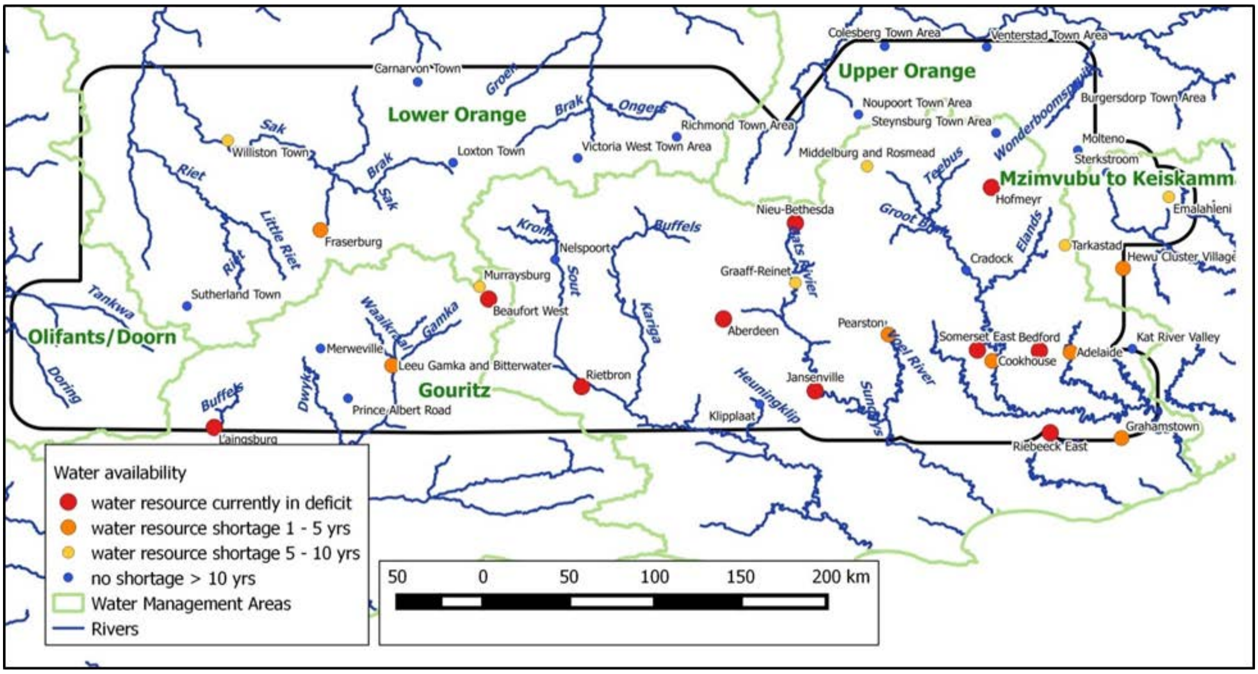
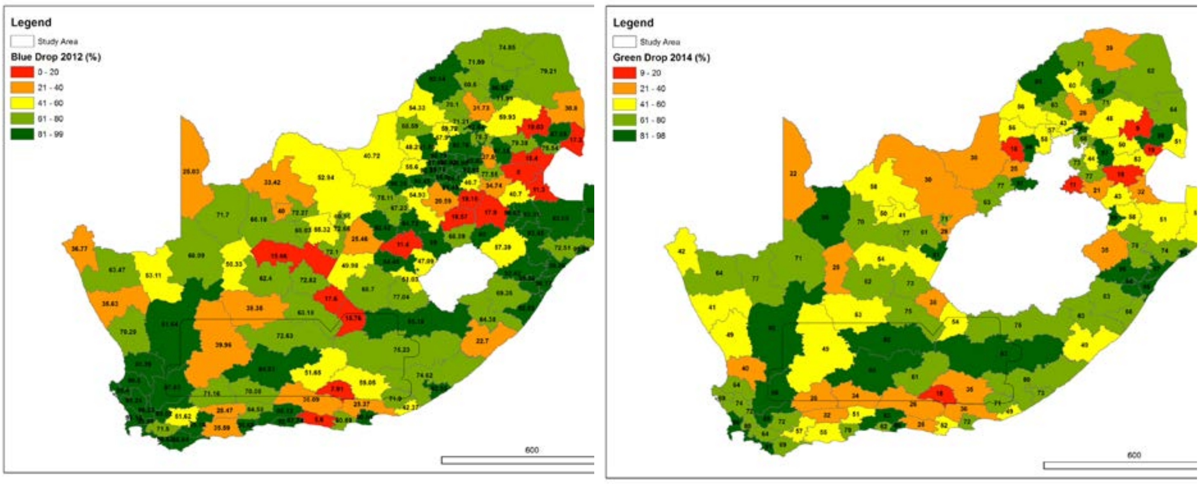


Figure 12.1: Water supply within the study area.



Blue drop status (DWS, 2012) Green drop status (DWS, 2014)

Figure 12.2: Blue Drop status (Department of Water and Sanitation (DWS), 2012) and Green Drop status (DWS, 2014) across South Africa

Blue Drop and Green Drop Programme (DWS, 2009)

The Department of Water and Sanitation (DWS) initiated the Blue and Green Drop Certification Programme, introducing incentive-based regulation for the drinking water quality management functions, respectively. The key purpose was to ensure effective management of drinking water and waste water quality and making the information public for transparency (DWS, 2009). For Blue Drop requirements, drinking water service providers must provide evidence of the following:

- adequate process control, maintenance and management;
- efficient monitoring compliance with the South African National Standard (SANS 241);
- have a failure response management programme; and
- report results to the DWS

Green Drop status for waste water treatment management is achieved if the water service authority complies with waste water legislative requirements and other best practice requirements are shown to be implemented. Similar requirements must be shown as for the Blue Drop requirements. A risk based approach is used to determine priority areas and ensure that a strategic approach is adopted to scientifically calculate priority waste water facilities for urgent regulatory intervention and tangible targets for municipalities to reduce risk.

Water use data, together with the population numbers is summarised in Digital Addendum 12A, based on the Water Authorisation Registration and Management System (WARMS) which is a national register of water users. Beaufort West, Camdeboo and to a lesser extent Ubuntu District; and head waters of two river systems: the Groot River (the Sout River and the Kariega River) and the Sundays River. The Kariega joins with the Sout River to form the Groot River at Beervlei Dam, which is a flood control dam (not a storage dam). There are two towns located on the tributaries of the Groot River and in the Beaufort West Local Municipality which are at risk to surface water contamination during the exploratory phase, namely, Murraysburg and Nelspoort. Estimates from 2011 state that Murraysburg has a population of 5 069, but its drinking water, is derived from two boreholes. In 2011, Nelspoort has an estimated population of 1 699 and derived 65% of its water from a weir on the Sout River. The remainder of Nelspoort’s water is obtained from two boreholes. Blue Drop and Green Drop scores (Figure 12.2 and text box) assessing the management of drinking water and waste water treatment facilities, respectively, demonstrated fairly good management and maintenance of the facilities. Nelspoort water treatment works (WTW) received a Blue Drop Score of 74.45% in 2012, and a Green Drop Score of 87.9% in 2011. Rietbron is located downstream of Nelspoort and, as at 2011, had a population of 1 184, with only a single borehole to supply the town with water. Steytlerville, with an estimated population of 4 017 in 2011, is located on the Groot River but 100% of the towns water supply is from two boreholes. The Groot River joins with the Kouga River downstream of Kouga Dam to form the Gamtoos River, and enters the ocean at the Gamtoos estuary.

Graaff-Reinet is located downstream of Nieu-Bethesda within the "Prospectively - high probability" zone and has a population of 35 672 (as at 2011). The population is estimated to increase by 2 000 people during the holidays. Graaff-Reinet receives surface water from the Nqweba Dam and groundwater from two wellfields: the northern wellfield located approximately 3 km north of Graaff-Reinet consisting of 13 boreholes. Graaff-Reinet received a blue drop score of 53.49% in 2012 and a green drop score of 6% in 2011. Aberdeen, as at 2011, had a population of 7 162, with the population increasing by 2 000 people during the holidays. Aberdeen is supplied by boreholes. Aberdeen had a blue drop score of 42.11% in 2012 and a green drop score of 5.3%. As at 2011 Jansenville, known as the centre of mohair sheep farming and mohair production, is located on the Sundays River, has a population of 5 612 and receives its water from 9 boreholes with a demand of 0.21 million cubic meters per annum (mcm/a). Downstream is Darlington Dam, which receives water from Gariep Dam on the Orange River via the Orange-Fish Tunnel, the Fish River, the Fish Sundays Canal and Skoenmakers River.

12.5 Baseline health status of the population in the study area

The areas earmarked for SGD in South Africa include some of the most sparsely populated, but socio-economically deprived, districts in the country. Of the four Health Districts which comprise the localities where SGD has been proposed, all are districts with health indicators suggesting serious challenges for health care coverage (London and Willems, 2016). For example, in 2012/13, the Central Karoo district reported the highest rates of stillbirths in the country and the highest rates of early neonatal death rates in the Western Cape Province (Massyn et al., 2013). Also, under-five mortality, infant mortality and maternal mortality in the Central Karoo were reported as double the rates for the Western Cape as a whole. The nearest specialist centres are located in George and Port Elizabeth, and the distances from sites where SGD is proposed exceed 400 km for some areas. The Central Karoo had only five ambulance stations and four district hospitals in 2013 which are expected to provide emergency services for this large area.

The study area is perceived as a healthy environment, but there are many impoverished and health-compromised communities. Consideration of the potential health impacts of SGD requires recognition that the districts where SGD has been proposed are characterised both by higher levels of illness and a socio-economically deprived population. In addition, the health system is stretched by a higher burden of disease and substantial logistical challenges posed by the rural nature and geographical dispersion. In rural Pennsylvania, where SGD has taken place, health parameters have improved as a result of increased employment. Current use of fossil-fuel causes substantial ill-health from air pollution and occupational hazards. Nevertheless, health challenges still exist (lower health scores) dealing with rural conditions such as distance from medical facilities. According to Colborn et al. (2011), given the human resource constraints faced by health services in these districts and the need for high-level epidemiological and toxicological skills to detect early perturbations in health status of local populations, it is unlikely that such rural districts would have the public health capacity to track, monitor, and act upon evidence of risks (London and Willems, 2016).

The District Health Barometer (2013/14) (Massyn et al., 2014), reports that the Amathole District Municipality (DM) and the Chris Hani DM have the highest number of clinics, 153 and 147 clinics respectively, the Central Karoo DM has the least amount of clinics in the country with only eight clinics. The Central Karoo DM has a total of four District Hospitals, of which two, the Beaufort West and the Murraysburg Hospital, are located in the study area. The Central Karoo DM also has one specialised tuberculosis (TB) and psychiatric hospital located in Nelspoort. The South African Hospitals Survey 2011-12 (Code4SA 2016) states that Beaufort West Hospital received an overall performance of 60% and Murraysburg Hospital of 51%. The overall performance of the clinics was however not available in the dataset. South Africa has a total of 3 401 clinics, which is roughly equivalent to one clinic per 15 200 people.

DALYs were calculated in the study area at the ward level making use of the WHO Burden of Disease calculations (WHO, 2003) and the 2013/14 District Health Barometer Burden of Disease data (Massyn et al., 2014). These estimates are presented in Figure 12.3 and Figure 12.4 below.

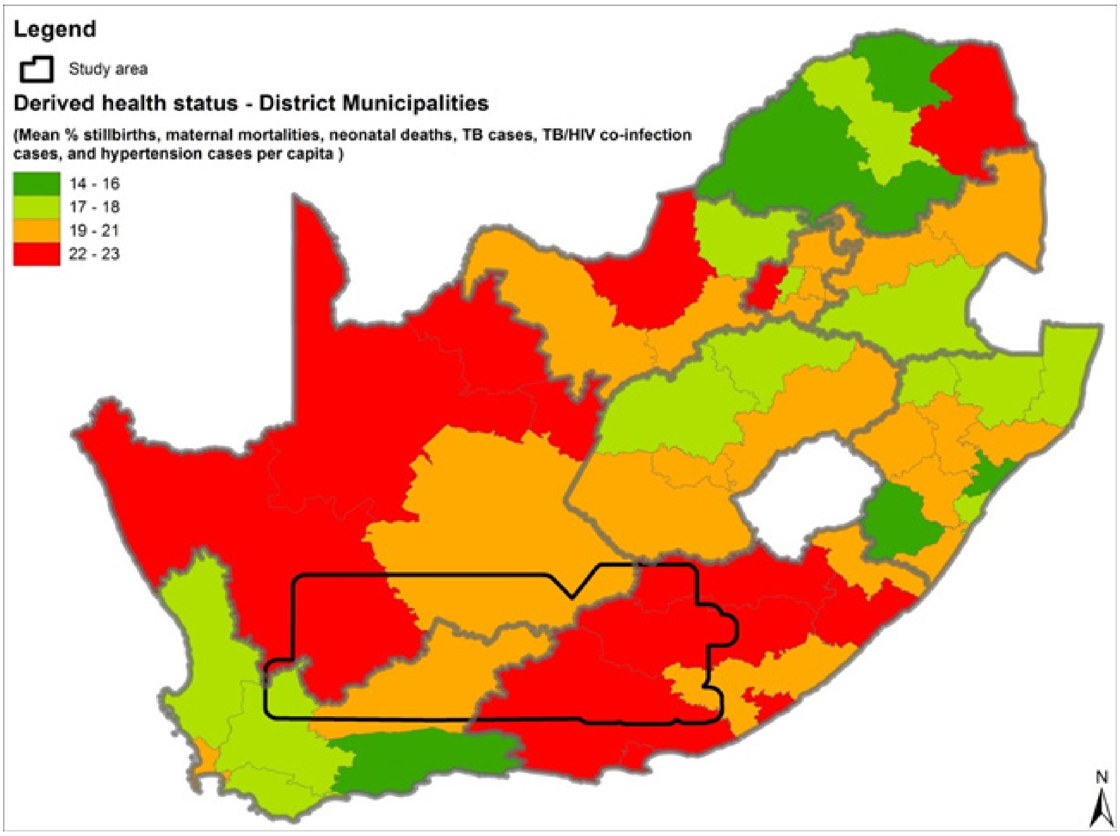


Figure 12.3: Health status of the study area relative to country.

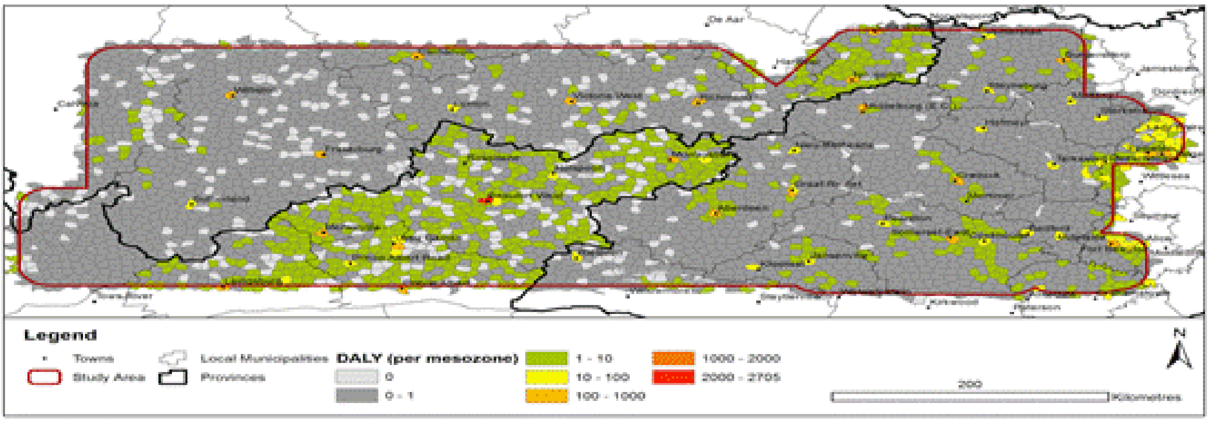


Figure 12.4: Baseline Disability Adjusted Life Years (DALYs) for the study area with low DALYs shown in most areas and the highest DALYs shown in the towns with the largest population size.

Data used to calculate DALYs included Years of Life Lost (YLL) (maps illustrating this dataset is in the Digital Addendum 12A) resulting from HIV, TB, communicable diseases, maternal deaths, perinatal deaths, nutrition causes, injuries and non-communicable diseases. Years Lived with a Disability (YLD) was calculated based on limited data that were available and accounted for HIV, TB, hypertension and mental health, along with WHO disability weights. Maps of YLL and YLD showing the differences between the municipalities, differences between YLL and YLD and how this compares to the rest of the country are shown in Digital Addendum 12B, where the data is also provided.

Figure 12.5 provides the individual DALYs per local municipality within the study area, showing that Beaufort West has the highest DALYs.

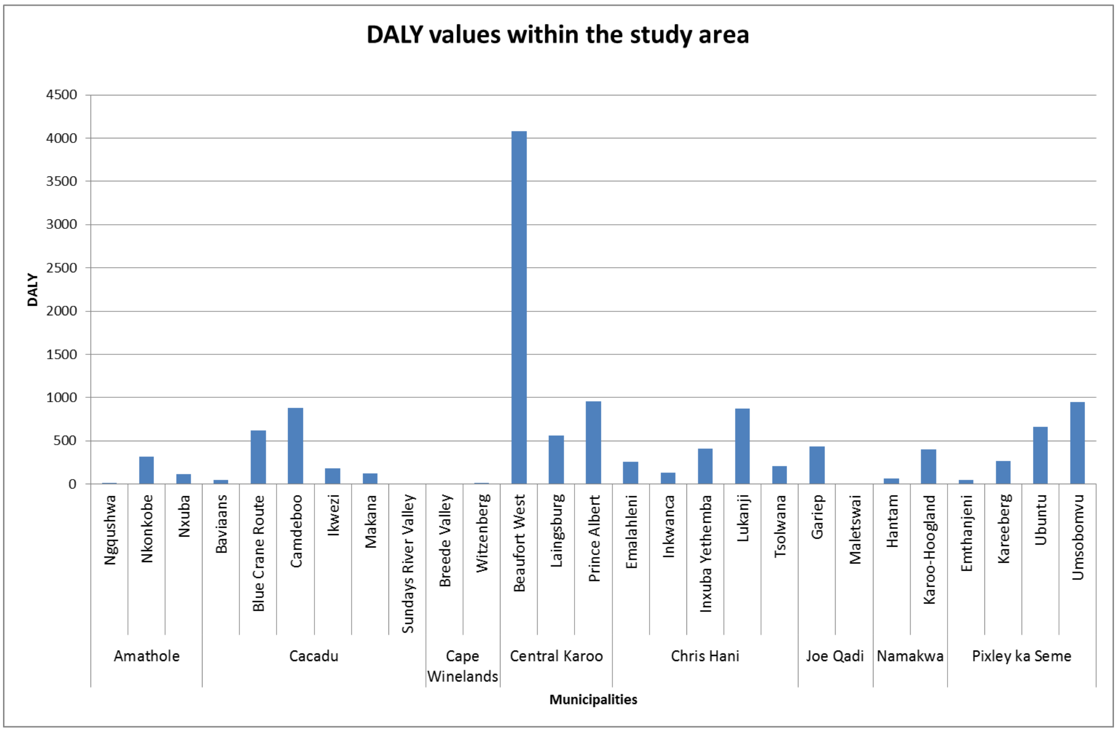


Figure 12.5: Disability Adjusted Life Years (DALYs) per local municipality within the study area.

12.6 Relevant legislation, regulation and best practice

The existing South African legislation and regulations relevant for water and health are presented in Table 12.2. SGD and its impact are covered by various legislations and regulations, governed by multiple government departments. With multiple departments tasked with overseeing compliance and monitoring, the potential for gaps exist particularly in relation to residents and worker health, financing the monitoring of health impacts and sustainable risk mitigation measures. To protect water and health in South Africa, petroleum exploration and production regulation needs to reflect the relevant principles in South Africa's Constitution. Health is indirectly implied and needs to be more explicit with sustainable approaches and financing of monitoring systems by the industry. Capacity constraints (financial resources, additional man power, and technical know-how) might be a limiting factor in many areas. The onus for financing of a formal monitoring plan and analysis costs lies with the unconventional oil and gas industry. This should entail the development of a formal sampling and analysis plan with the execution of sampling and analysis conducted by independent, credible and certified laboratories and service providers.

Table 12.2: Existing legislation and new regulations relevant for water and health.

Existing SA Legislation	Department	Relevant Principles and Sections for Water and Health
Constitution of the Republic of South Africa, 1996	Department of Justice	**Relevant Bill of Rights:** - right to an environment not harmful to health and wellbeing (Section 24) - right to sufficient food & water (Section 27(1)(b)) - right to just administrative action (Section 33) - - right to access to information (Section 32)
National Environmental Management Act, Act 107 of 1998 (NEMA)	Department of Environmental Affairs	**Relevant components:** - Responsibility for the environmental health and safety consequences of a policy, programme, project, product, process, service or activity exists throughout its life cycle. - DWA is a member of multi-stakeholder committee for environmental coordination under NEMA - Chapter 1: National Environmental Principles: Section 2 Principles are all relevant - NEMA Principles including: o Public participation o Polluter pays o Precautionary principle o Cradle to Grave o Environmental justice o Integrated and holistic approaches
National Water Act, Act 36 of 1998 (NWA)	Department of Water Affairs	**Chapter 1: Interpretation and Fundamental Principle of the Act:** - Sustainability and equity are identified as central guiding principles in the protection, use, development, conservation, management and control of water resources. These guiding principles recognise the basic human needs of present and future generations, the need to protect water resources, the need to share some water resources with other countries, the need to promote social and economic development through the use of water and the need to establish suitable institutions in order to a thieve the purpose of the Act.
Mineral and Petroleum Resources Development Act, Act 28 of 2002 (MPRDA)	Department of Mineral Resources	**References to Water Management:** - ‘‘(1) The holder[3] of a prospecting right, mining right, retention permit**, [or]** mining permit, or previous holder of an old order right or previous owner of works that has ceased to exist, remains responsible for any environmental liability, pollution, **[or]** ecological degradation, the pumping and treatment of extraneous **water**, compliance to the conditions of the environmental authorisation and the management and sustainable closure thereof, until the Minister has issued **[an]** a closure certificate in terms of this Act to the holder or owner concerned.’’; and - ‘‘(5) No closure certificate may be issued unless the Chief Inspector and **[the Department of Water Affairs and Forestry]** each government department charged with the administration of any law which relates to any matter affecting the environment have confirmed in writing that the provisions pertaining to health and

[3] "Holder" means a holder of an exploration or production right granted in terms of Sections 80 and 84 of the Act, respectively (MPRDA).

Existing SA Legislation	Department	Relevant Principles and Sections for Water and Health
		safety and management pollution to **water** resources, the pumping and treatment of extraneous **water** and compliance to the conditions of the environmental authorisation have been addressed.''
Regulations for Petroleum Exploration and Production 2015		**Relevant sections for water include:** 1) "**well examination schemes**" are required to by competent and independent persons to assess "risks to the health and safety of persons from the well or anything in it, or from strata, to which the well is connected, have been assessed and are within acceptable levels." - Holder[2] must prevent **well design** risks to health and safety of persons from the well or anything in the well, or in strata to which the well is connected. - Holder must address **fracking fluids management** to ensure assessment of potential environmental and health risks of fracking fluids and additives in both diluted and concentrated form. - During **fracking**, a holder must conduct operations in a manner that does not pose a risk to public health, life, property and the environment. 2. **Water Resource Monitoring;** (described under Best Practices) 3. **Management of Water** – provides detail on: - water balance; - protection of water resources; and - water use. 4. **Management of Spillage** (described under Best Practices)
National Environmental Management: Waste Amendment Act , Act 26 of 2014 (NEMWA)	Department of Environmental Affairs	**Relevant principle:** - Schedule 3 Category A: Hazardous waste (four wastes from petroleum refining, natural gas purification and pyrolytic treatment of coal: (c) wastes from natural gas purification and transportation)
Health Act (Act No. 61 of 2003)	Department of Health	**General, non-specific, relevant principles:** - supports the constitution in terms of everyone having a right to an environment not harmful to health and well-being (Section 24). - water quality monitoring is referenced in terms of municipal health services provisions – no other mention of water.

12.7 Best practice guidelines, mitigation and monitoring requirements

The safety and health of employees, contractors and the general public, as well as the environment, is critical throughout every stage of SGD. Regulation, monitoring, prevention and control strategies are crucial to minimise public health impacts associated with SGD. Globally, legislation is used to regulate various types of pollution as well as to mitigate the adverse effects of pollution. In order to protect public health, the emissions and effluents from SGD into the air, water and land or soil have to be prevented, minimised, or at least controlled. In other words public health protection involves the regulation, prevention and control of human exposure via environmental impact pathways (e.g. air, water, soil, land). Pollution can be minimised by adopting practices that involves (i) recycling, (ii) reusing, (iii) waste minimisation, (iv) mitigation, (v) prevention, and (vi) composting (Owa, 2013). Apart from the abovementioned practices, pollution control devices such as a dust collection system e.g. bag houses, cyclones, etc. could be used to minimise air pollution. According to Roy et al. (2014), SGD-related emissions of nitrogen oxide (NOX) and VOC to the air could be reduced up to 85% and 88% respectively with the correct mitigation measures. Pollution control can also include waste water treatment e.g. sedimentation (primary treatment); activated sludge bio filters (secondary treatment, also used for industrial waste water); aerated lagoons; constructed wetlands (also used in urban runoff); and industrial waste water treatment e.g. ultra-filtration, to minimise water pollution (Owa, 2013).

To protect the environment and prevent negative health impacts, SGD in South Africa will need to comply with best international practices and best international regulatory requirements. To protect health, there needs to be a holistic best practice approach incorporating health, environment and social-economic factors. In this section we highlight some of the key best practices linked to water and health that should be incorporated into this holistic approach.

From an occupational health and safety perspective, there is a hierarchy of measures to be taken to mitigate worker exposure and subsequent health impacts (International Association of Oil and Gas Producers- International Petroleum Industry Environmental Conservation Association (OGP-IPIECA), 2009; 2013). These are summarised in Figure 12.6.

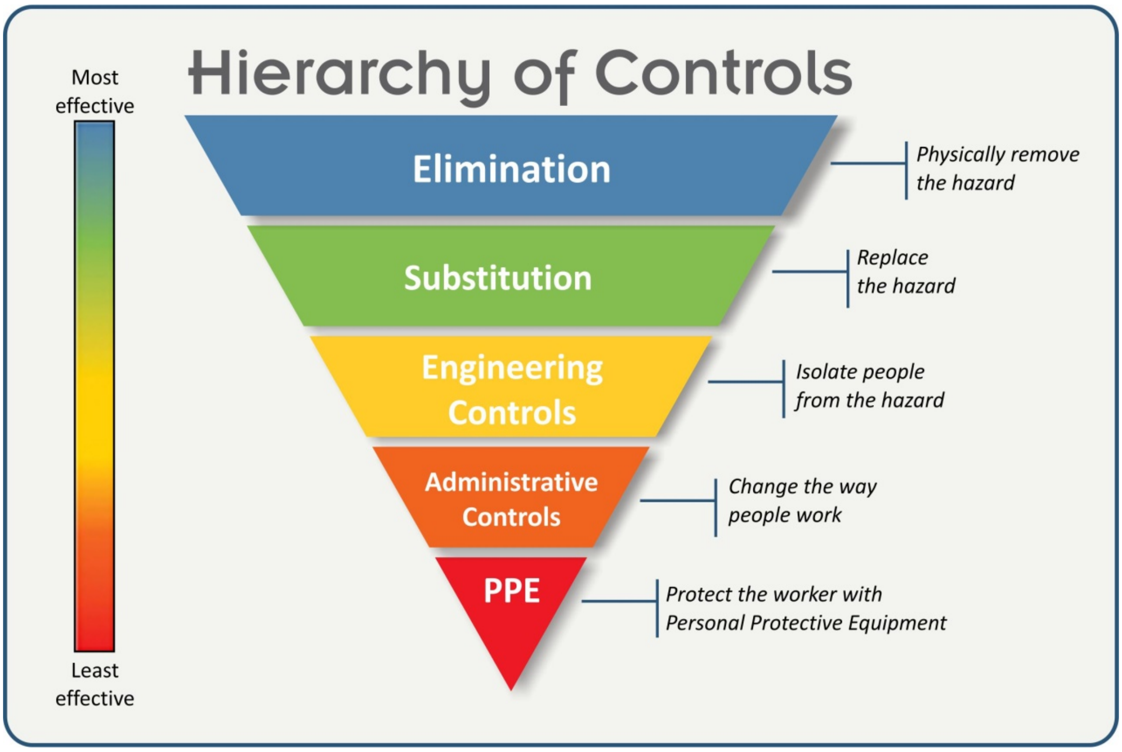


Figure 12.6: Hierarchy of Pollution Controls for SGD (Source NIOSH, 2015).

Over-reliance on industry self-regulation is limited particularly in the event of non-compliance with safety standards and best practice, therefore approaches South Africa considers, should not only include the American Petroleum Institute (API, 2011) industry standards, but those recently published internationally by the European Union (EU), United States (US) and United Kingdom (UK). These include:

- the **International Energy Agency's (IEA)** 2012 report Golden Rules for an Age of Gas: World Energy Outlook Special Report on Unconventional Gas (Golden Rules Report; http://www.lea.org/publications/freepublications/publication/WEO2012_GoldenRulesReport.pdf);
- the **European Commission's** 2012 Report on Potential Risks from Fracking entitled Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing in Europe;
- the current and developing standards of the **United States of America's Federal Environmental Protection Agency** (US EPA) relevant for water including oil and gas extraction guidelines (https://www.epa.gov/eg/oil-and-gas-extraction-effluent-guidelines) and oil and gas water stormwater permitting (https://www.epa.gov/npdes/oil-and-gas-stormwater -permitting#undefined); and
- the **United Kingdom's Department of Energy and Climate Change's (UK DECC)** July 2013 Guidance about shale gas and hydraulic Fracturing (fracking; https://www.gove.uk/government/uploads/system/uploads/attachment_data/file/225826/About_Shale_gas_and_and_hydraulic_fracking.pdf.

Best practices and standards for environmental and health protection (social-economic factors are addressed in other Chapters) need to address the following areas:

1. **Appropriate Regulatory Framework and Compliance Structures**

A key best practice is to ensure the regulatory framework protects water from fracking activities in the short and long run that will protect the health of workers, children, residents, and tourists. Currently, as highlighted in Table 12.1, the legislation is fragmented particularly in relation to protection of health from fracking related issues. For example, health – with particular reference to the Health Act (Act No. 61 of 2003) - is missing from the South African Government Gazette No. 38855 (2015) on MPRDA (28/2002): Regulations for Petroleum Exploration and Production which specifies the requirements for petroleum exploration and production.

2. **Baseline Data, Public Access to Information and Disclosure**

Detailed information needs to be provided to the public before SGD begins and during the extraction process. This includes access to baseline information on ground and surface water quality, water supply and characteristics (i.e. that is compliance with the 2015 Regulations for Petroleum

Exploration and Production “baseline water quality assessment” requirement). Best practice is that this information is conducted two to five years prior to drilling. This information then allows for adequate monitoring and compliance with standards and regulations. Transparency and impartial monitoring are essential. For example, SGD companies in the US are able to publically disclose the chemical additives in their fracking fluid for each well on the Chemical Disclosure Registry - *FracFocus*[4] - managed by Ground Water Protection Council and Interstate Oil and Gas Compact Commission.

Furthermore, the OGP- IPIECA Good practice guidelines for the SGD (2013) and their drilling fluids and health risk management - A guide for drilling personnel, managers and health professionals in the oil and gas industry (2009) provide recommendations for worker health monitoring which would need to be extended to monitoring community health symptoms. Monitoring should be financed by the unconventional oil and gas industry but sampling and analysis should be carried out by independent certified and credible service providers. Where possible, capacity building and improved health care could form part of the social responsibility plan of the unconventional oil and gas industry.

3. **Site Characterisation and Location**

Best practices for well site location are required to prevent contamination of underground drinking water from fracking fluid and contamination of surface waters. The Regulations for Petroleum Exploration and Production (Government Gazette, 2015) include specifications for:

Site preparation: The area in respect of which an exploration or production right is granted must be prepared in accordance with the Environmental Authorisation- and the approved Environmental Impact Assessment Regulations; and

Site contamination: A holder must at all times, prevent the contamination of the environment by providing a suitably designed impermeable site underlay system and making site drainage arrangements.

Further measures include:

- Geologic and hydrologic mapping and risk analysis to demonstrate geologic suitability and the presence of an appropriate confining zone to inhibit vertical migration of contaminants.
- Identification of existing wellbores, determination of the integrity of those wellbores (i.e. casing, cement, plugs, etc.), and mitigation where necessary.
- Estimation of full life cycle fresh water use.
- Estimation of full life cycle waste water volumes and assessment of the ability of the various disposal options to safely handle these volumes without adverse effects on the environment or human health.

[4] FracFocus website: http://fracfocus.org/

- Comprehensive assessment of potential impacts to water resources used to supply fracking base fluid.
- Baseline water testing.
- Ongoing monitoring of potentially affected ground and surface waters (API, 2011).

4. **Isolating Wells, Preventing Leaks, Preventing Spillage, and Preventing Worker Risks**

Planning and prevention are key and need to be clearly supported by legislation. For instance, the US EPA (2015) explored spill containment and mitigation measures in an analysis of spills related to fracking activities and a section of the document is dedicated to this subject. They also mention that the API has a guidance document *Practices for Mitigating Surface Impacts Associated with Hydraulic Fracturing* (API, 2011). The document describes practices currently used in the oil and natural gas industry to minimise potential surface environmental impacts. New Brunswick in Canada has rules for industry on responsible environmental management of oil and natural gas activities (Government of New Brunswick (GNB), 2013).

Drilling practices health risk management: A guide for drilling personnel, managers and health professionals in the oil and gas industry (IPIECA, OGP Report Number 396).

Further measures for preventing surface water contamination are outlined in the Australian 2013 best practices from the Camden Health Impact Assessment (HIA) document (Environmental Risk Sciences (EnRiskS), 2013[5]). These include:

- Construction of silt fences and other erosion control measures that would be implemented to minimise surface erosion.
- A water management system, including water gathering lines where necessary, will be employed to enable collection, management and appropriate reuse of water produced as a result of the drilling, fracture stimulation and production operations including the storage of saline production water in storage tanks.
- Infrastructure will be inspected and audited following a flood event to ensure that all elements are operating effectively, and necessary rehabilitation works are carried out immediately.
- Gas wells will be located at a minimum distance of 100 m from creeks or other water bodies (not located uphill from the well).
- Appropriate crossing locations will be selected on dry creek beds for the installation of gathering lines and the area rehabilitated suitably following any earthworks.

[5] EnRiskS (2013) has these references: DTIRIS, 2012a. Code of Practice for Coal Seam Gas. Fracture Stimulation Activities. NSW Department of Trade and Investment, Regional Infrastructure and Services. Available at: http://www.resources.nsw.gov.au/ community-information/coal-seam-gas/cop;
DTIRIS, 2012b. Code of Practice for Coal Seam Gas. Well Integrity. NSW Department of Trade and Investment, Regional Infrastructure and Services. Available at: http://www.resources.nsw.gov.au /communityinformation/ coal-seam-gas/cop).

- Under-boring would be used for the installation of gas gathering lines where permanent water flows occur and for crossings of watercourses in the vicinity of the Mount Annan Botanic Gardens.
- Rehabilitation of areas where earthworks have taken place to a surface profile similar to the original profile, particularly where gathering lines have been installed by either trenching or under-boring. Rehabilitation works would be in accordance with AGL Energy Ltd.'s established and proven Landscape and Rehabilitation Management Sub Plan (LRMSP) as detailed in the existing Environmental Management Plan (EMP).
- Saline water produced from the wells will be stored either in lined drill pits or water storage tanks (majority). Bunding will be in place around lined pits to reduce the potential for saline waters contained within the pits to be liberated during a flood. The water level and quality of water stored within the lined drill pits will be monitored regularly to ensure sufficient space is available for rainfall contribution and to ensure that the quality of the water is acceptable for proposed future uses.

Management of spillage:

The Regulations for Petroleum Exploration and Production (Government Gazette, 2015) indicates that:

(1) A spillage of fracking fluids or flowback in excess of 50 litres must be reported to the designated agency within 24 hours of occurrence.
(2) A spillage of fracking fluids, additives, or flowback, used or generated during or after fracking operations must be cleaned up immediately.
(3) An incident involving the spilling of a harmful substance that flows or may flow into a water resource must be dealt with in accordance with Sections 19 and 20 of the NWA (1998), and Sections 28 and 30 of the NEMA (1998).

5. **Responsible Water Use, Storage Treatment and Disposal**

The Regulations for Petroleum Exploration and Production (Government Gazette, 2015) cover water use requirements as well as storage, treatment and disposal.

Jordaan (2014) highlights several best practices for avoiding water contamination and pollution that strengthen the current regulations. For example:

Implement minimum depth limitations on fracking. An appropriate minimum depth limitation prevents fracking above a certain depth and is based on local geology and the risk of communication with fresh water aquifers. In the Karoo such a limitation must account for the complex hydrogeology and *the prior experience of groundwater travelling long distances. In this context, the limitations of the proposed fracking regulations are insufficient (Jordaan, 2014: 24).*

Store and dispose of produced and waste water lawfully and safely. To the extent that this is not already regulated under the NWA and NEMWA, regulations must set and enforce appropriate standards for safe water storage, extending to the use of storage tanks instead of open pits, and appropriate technology for waste water treatment. Regulations must consider the availability and proximity of fresh water supplies and disposal options, implement control measures for volatile organic compound (VOC) emissions from flowback and produced water and enforce the operator's responsibility in accordance with developing best practice standards (Jordaan, 214:29).

6. **Compliance Monitoring and Enforcement**

The South African Regulations for Petroleum Exploration and Production (Government Gazette, 2015) specify what needs to be carried out with regards to water resource monitoring:

Water resource monitoring

(1) An applicant or holder must appoint an independent specialist to conduct a hydro-census fulfilling the standard requirements of the department responsible for water affairs which indicates potentially affected water resources, on at least, a 3 kilometres radius from the furthest point of potential horizontal drilling, as well as identify priority water source areas and domestic groundwater supplies indicated on relevant geo-hydrological maps.

(2) An applicant or holder must prepare and submit, together with the water use licence application, to the department responsible for water affairs, a proposed water resource monitoring plan, for approval. The plan must at least identify-

(a) the sampling methodology;
(b) the monitoring points;
(c) the monitoring parameters;
(d) the monitoring frequency; and
(e) the reporting frequency.

(3) The monitoring plan contemplated in sub -regulation (2) must be submitted to the competent authority for consideration, as part of the application for Environmental Authorisation.

(4) Water samples collected as part of the monitoring plan contemplated in sub-regulation (2) must be analysed by an accredited laboratory and the holder must submit the results and their interpretation to the designated agency and the department responsible for water affairs within 7 days after receipt thereof.

(5) The results must at least include a detailed description of the sampling and testing conducted, including duplicate samples, the chain of custody of the samples and quality control of the testing.

(6) A full water monitoring report must be included in the EMPr required in terms of the Environmental Impact Assessment Regulations, 2014.

(7) A holder must, after conducting a baseline water quality assessment, continue with monitoring in accordance with the approved plan and must-

> *(a) have the water resources subjected to sampling, analysis and interpretation of water quality and changes in water levels by an independent specialist approved by the designated agency in accordance with the approved plan contemplated in sub –regulation (2);*
>
> *(b) submit the results of the analysis and interpretation to the designated agency and the department responsible for water affairs within 7 days of receipt of the analysis and interpretation; and*
>
> *(c) submit the monitoring assessment reports in accordance with the approved monitoring plan contemplated in sub -regulation (2).*

(8) (a) The designated agency, Council for Geoscience, Council for Scientific and Industrial Research, designated local authorities or the department responsible for water affairs, may collect samples of fluids encountered in the exploration or production area (water or hydrocarbons, at depth or at the surface) for their own analysis and interpretation.

> *(b) The holder must allow site access to the authorities mentioned in paragraph (a) for the purpose of collecting the samples.*

(9) Data collected as contemplated in this regulation must be published except where it may be shown to directly relate to the availability of petroleum and commercial value of the holder's acreage.

(10) Groundwater aspects must be recorded and reported according to the department responsible for water affairs' Standard Descriptors for Geosites.

(11) The holder must capture the water resource data generated.

Additional sections dealing with well construction (Chapter 8) and operational maintenance (Chapter 9) are provided in detail in the Gazette, with relevant monitoring requirements including the following points:

Management of Operations

- *Hydraulic Fracturing Equipment*

- *Mechanical Integrity Tests and Monitoring*
- *Hydraulic Fracturing Fluid Disclosure*
- *Fracture and Fracturing Fluid Containment*
- *Fracturing Fluids Management*
- *Management of Flowback and Produced Fluids*
- *Transportation of Fluids*
- *Fluids Storage*
- *Hydraulic Fracturing Operations*
- *Post Hydraulic Fracturing Report*
- ***Management of Water***
- *Water Balances*
- *Protection of Water Resources*
- *Water Use*
- ***Management of Waste***
- *General*
- *Waste Management*
- ***Management of Pollution Incidents***
- *Management of Spillage*
- ***Management of Air Quality***
- *Fugitive Emissions*
- *Fugitive Dust*
- *Noise Control*

Although management of environmental quality which includes air and water quality as well as waste disposal and spills, the health of community members and workers in the SGD industry are not specifically mentioned in the regulations. This is a shortcoming which should be addressed where health symptoms should be monitored for both workers (as part of occupational health responsibilities of the employer) and community members. The type of health symptoms that are associated with exposure to contaminants of SGD and the extra vehicle traffic should also be monitored by local clinics/health facilities and fed back into national monitoring systems.

Health monitoring systems, as well as regulatory processes, requires a system of linking to current evidence-based research and findings which would mean having a system in place for overseeing this with perhaps national research institutions. Again financing of such initiatives should be through the unconventional oil and gas industry. Additionally, capacity building and improved health care facilities could form part of the social responsibility plan of the unconventional oil and gas industry.

12.8 Key potential impacts and associated chemical risks

Chemicals found in association with fracking includes over 1100 chemicals, although only an average of 14 are reported to be used in a single well (US EPA, 2015). A comprehensive list of chemicals found in fracking waters and their corresponding toxicity, cancer and endocrine disrupting chemical (EDC) data are presented in Digital Addendum 12C. Digital Addendum 12F provides links to additional electronic peer reviewed literature and databases on various aspects associated with SGD.

The list of chemicals was developed based on US (US EPA, 2015) and Australian (EnRiskS, 2013) environmental knowledge including reported usage, percentage of times detected, persistence in the environment and toxicity of health impacts. Subsequently, removing the close to 50 chemicals that are specified in the regulations to be prohibited for use in South Africa (Government Gazette, 2015) from the most toxic and frequently found chemicals, the list was shortened to 74 chemicals that were considered. These chemicals together with the EDCs (total 132) are shown in Digital Addendum 12D.

Produced water is naturally occurring water that is found in the source rock and can contain inorganic chemicals not found in fracking fluid. These chemicals were not included in Digital Addendum 12D, but are of potential concern and include: arsenic, strontium, barium, nickel, lead, iron, bromine, iodine, fluoride, uranium and other radioactive chemicals.

The Endocrine Disruption Exchange (TED-X) created a database where health effect data were organised into several categories, focusing on the main organs and systems that have been identified as being potentially impacted by chemicals used in fracking. A total of 12 categories were used to describe the health effects associated with these chemicals. Of the 650 chemicals detected in fracking fluids presented in the multistate TED-X database (2013), the majority (375) were able to cause skin and eye irritations, with 366 causing respiratory symptoms. Table 12.3 summarises the health effects and the number of chemicals known to contribute to those symptoms.

Table 12.3: Specific health effects associated with 650 chemicals known to be used in hydraulic fracturing process (Summarised from TED-X, 2013).

Symptoms or effects	Number of chemicals
Skin and eye	375
Respiratory	366
Gastric and liver	308
Brain and neurological	202
Immunological	151
Kidney	154

Cardiac	173
Cancer	85
Developmental	83
Reproductive	91
Other (e.g. weight changes, death)	177

Over 78% of the chemicals are associated with skin, eye or sensory organ effects, respiratory effects and gastrointestinal or liver effects. The brain and nervous system can be harmed by 55% of the chemicals. These health effect categories are likely to appear immediately or soon after exposure. They include symptoms such as burning eyes, rashes, coughs, sore throats, asthma-like effects, nausea, vomiting, headaches, dizziness, tremors, and convulsions. Other affects, including cancer, organ damage, and harm to the endocrine system, may not appear for months or years later. Between 22% and 47% of the chemicals were associated with these possibly longer-term health effects. Forty-eight percent of the chemicals have health effects in the category labelled 'Other'. The 'Other' category includes such effects as changes in weight, or effects on teeth or bones, for example, but the most often cited effect in this category is the ability of the chemical to cause death.

12.9 Potential sources or pathways for environmental pollution from SDG

For the purposes of the risk assessment matrix, six impact pathways were assessed and two receiving human environments were identified. The two receiving human environments are workers who often have direct exposure on the wellpad through SGD activities and often have a higher risk, and ultimately the indirectly exposed community, often located further away from the SGD activities.

12.10 Air pathway exposures

Methane and VOC emissions are the main contaminants from SGD processes (US EPA, 2014), whereby people may be exposed via the air pathway. Natural gas leakage can occur throughout the entire unconventional oil and gas development and production process (Chimowitz et al., 2015), Crystalline silica sand delivered by trucks to the drilling site releases silica dust into the air, where workers can be exposed (Esswein et al., 2013). Workers experience the most direct exposure; however, silica dust may also be an air contaminant of concern to nearby residents.

12.10.1 Worker

Air pollution is thought to be one of main routes of exposure for workers involved in unconventional oil and gas development to a range of potentially hazardous chemicals. There is a proven association between respiratory exposure to silica dust and the development of silicosis, a progressive lung disease (Shonkoff et al., 2014) and other diseases such as chronic obstructive pulmonary disease, tuberculosis, kidney disease, autoimmune conditions, and lung cancer (Centers for Disease Control and Prevention (CDC), 2002). Emissions of methane and other hydrocarbons have been noted in relation to SGD operations, both from the wells and related infrastructure such as production tanks, valves, pipelines and collection facilities (Adgate et al., 2014). Methane emissions may be a marker for the release of other potentially toxic volatile hydrocarbons, such as benzene, toluene, ethylbenzene and xylenes, collectively referred to as BTEX, released during well development and production (Korfmacher et al., 2013). As is discussed in Winkler et al. (2016), occupational exposure to air pollutants is very likely and the consequences are substantial. The use of heavy diesel trucks, stationary engines and associated rig equipment for SGD will lead to occupational health risks at the well site due to emissions of diesel exhaust, nitrogen dioxide (NO_2), particulate matter (PM), VOCs, hydrogen sulphide (H_2S) and silica.

12.10.2 Community

There is evidence of potential environmental exposure to chemical contaminants associated with SGD. Many studies highlight the risk of contaminants being transported in ambient air at concentrations of pollutants known to be associated with increased risk of morbidity and mortality (Shonkoff et al., 2014). The study presents air pathways either from emissions on site from drilling, processing, well completions, servicing, and other gas production activities or emissions off-site from transportation of water, sand, chemicals, and equipment to and from the wellpad (Shonkoff et al., 2014).

12.11 Water pathway exposures

12.11.1 Worker

Figure 12.7 provides a schematic representation of the fate and transport associated with SGD and possible contamination of drinking water sources. Water contamination with chemicals used in SGD is not the most likely exposure pathway for workers involved in SGD, but chemicals such as H_2S gas may contaminate water samples. According to the IPIECA (2009) guide for drilling fluids and health risk management, these gases must be closely monitored and treated to eliminate hazardous exposure to personnel.

12.11.2 Community

An increasing body of studies suggest that water contamination risks exist through a variety of environmental pathways (Table 12.4), most notably during waste water transport and disposal, and via poor zonal isolation of gases and fluids due to structural integrity impairment of cement in gas wells (Shonkoff et al., 2014). The main potential pathways of water and land pollution during SGD as identified by Shonkoff et al. (2014) are:

- Accidental spillages during the mixing and transport of drilling and SGD chemicals before being injected into the well;
- Leaks from failure or inadequacy of well casings in the upper part of the well. With cement failures reported to occur in 2–50% of all wells (Shankoff et al., 2014), a large number of pollution incidents in the US have been due to this sort of failure. This has allowed methane and fracking chemicals to migrate into groundwater, drinking water or nearby properties, sometimes causing explosions, evacuations necessitating the replacement of water supplies,
- Fissures in rock, potentially accentuated by the SGD process, leading to contamination of important groundwater reserves, potentially contaminating drinking water, springs etc.,
- Leaks from storage and treatment of the large volumes of flowback water produced,
- Leaks from transport of flowback water, and
- Inadequate treatment of flowback prior to discharge, and leaks from reinjection of flowback into the ground (where permitted). Flowback contains the substances added to facilitate SGD, combined with salts, hydrocarbons, heavy metals and naturally occurring radioactive materials present in the rock. Flowback waters should be treated before any release into the environment.

Waste water from fracking operations contains toxic elements originating in the shale and from chemicals used in the fracking treatment including total dissolved solids, volatile substances, arsenic, bromide, naturally occurring radioactive materials, and heavy metals such as arsenic, barium, beryllium, uranium, and zinc (Chermak and Schreiber, 2013; Burton et al., 2016). Harkness et al. (2015) attributed the high bromide and chloride content in the waste water to the brine from the shale reservoir. Rowan et al. (2011) demonstrated that high salinity mobilises radionuclides, increasing exposure to radioactive isotopes such as radium 226. This study also demonstrated that, while the quality of groundwater may not be directly associated with proximity to gas wells, it is impacted by the high density of gas wells in an area. In the Barnett Shale region, the highest density of gas wells is located in the highest pressure gradient region. A high density of gas wells treated in a small area may cause an intersection of pressure cones in the subsurface, possibly increasing the reservoir pressure and/or fracture treatment pressure and affecting the integrity of the vertical wellbore.

In addition to the oil and shale gas related waste water, on-site sanitation and additional sewage loads to waste water treatment facilities from a growing community (as a result of job creation and opportunities), will present an additional load to the already overloaded waste water treatment systems. This in turn could cause untreated sewage to join the rivers and streams or enter the groundwater system, possibly polluting already scarce water sources and causing possible human health impacts or unhygienic conditions, with subsequent human health impacts.

Table 12.4: Four steps in SGD processes where water resources may become contaminated (Source: US EPA, 2015).

Chemical mixing	Spills of fracking fluids
Well injection	Subsurface migration of fracking fluids or formation fluids
Flowback and produced water	Spills of flowback or produced water
Waste water treatment and waste disposal	Discharge of untreated or inadequately treated waste water and inappropriate disposal of waste solids

Flowback and produced water are recognised as likely to contain many potentially hazardous chemicals (including fracking chemicals, petroleum condensates, metals, and naturally occurring radioactive material (NORM) and must be safely stored in open ponds prior to removal for treatment or discharge. Typically, formation water is highly mineralised at such pressure/temperature conditions (>20 g/L total salinity) and should be termed “brine”. In addition, produced water can contain a number of dissolved and trace substances, such as heavy metals, aromatic hydrocarbons, dissolved gases and NORM. In SGD, produced water is extracted along with natural gas, as "flowback", and must be disposed of.

Inorganic chemicals not included in the fracking fluid need to be considered as they can result from SGD due to the geology and presence of aerated water i.e. arsenic, boron, barium, and beryllium, for example.

Studies assessed surface and groundwater samples using reporter gene assays in human cell line were conducted in Colorado. Water samples collected from the more intensive areas of SGD exhibited statistically significantly more estrogenic, anti-estrogenic, or anti-androgenic activity than references sites with either no operations or fewer operations (Kassotis et al., 2014). The concentrations of chemicals detected were in high enough concentrations to interfere with the response of human cells to male sex hormones and oestrogen. This study indicated that EDCs are a potential health concern in SGD operations, and supports the screening for EDC activity.

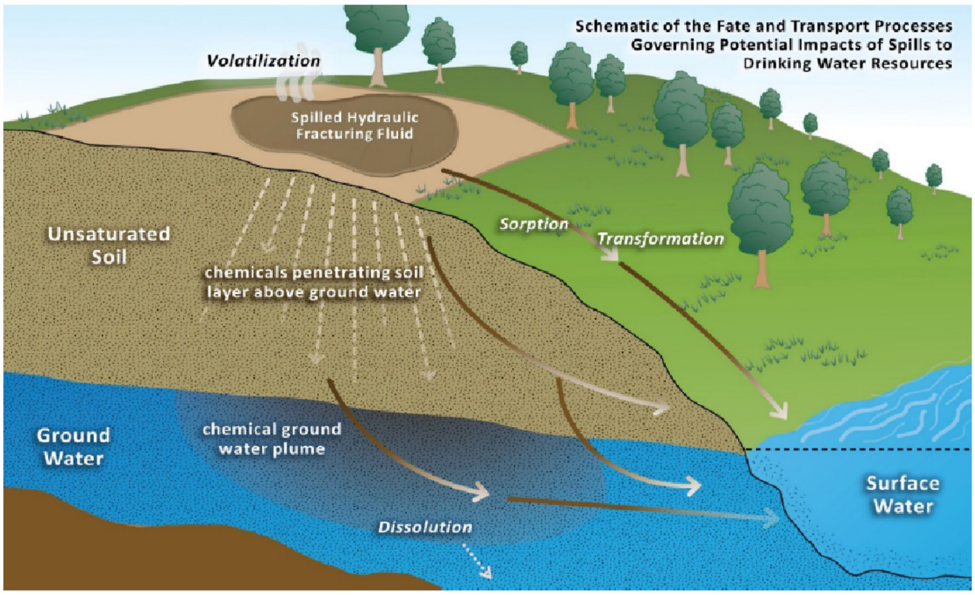


Figure 12.7: Fate and transport schematic for a spilled fracking fluid showing the potential pathways that spilled chemicals can impact water resources. Source: US EPA 2015.

The potential for fracking to result in contaminated groundwater is not well understood. Recent studies have shown that groundwater contamination may be caused by poor well construction with leaks caused by ruptured wellbore casings (Burton et al., 2016). Results showed that higher concentrations of certain groundwater constituents are probably related to SGD in the study area and that beryllium, in the specific study area formation, could be used as an indicator variable for evaluating fracking impacts on regional groundwater quality. The study also showed that well density and formation pressures correlate to change in regional water quality whereas proximity to gas wells, by itself, does not.

12.11.3 Exposure to fracking chemicals via spills

As reported in the review by Kassotis et al. (2015); in 2013, spills were reported at 1% of Colorado wells (550 spills at 51 000 active wells) and it has been estimated that 50% of surface spills contaminate groundwater (Gross et al., 2013). An analysis of permitted Pennsylvania wells suggests a similar total spill rate of 2% (103/5 580 active wells) (Souther et al., 2014).

Based on primary catchments, Figure 12.8 illustrates the area of extent of possible impact on the water supply outside the study area (indicated by the blue arrows) if a spill were to occur within the study area.

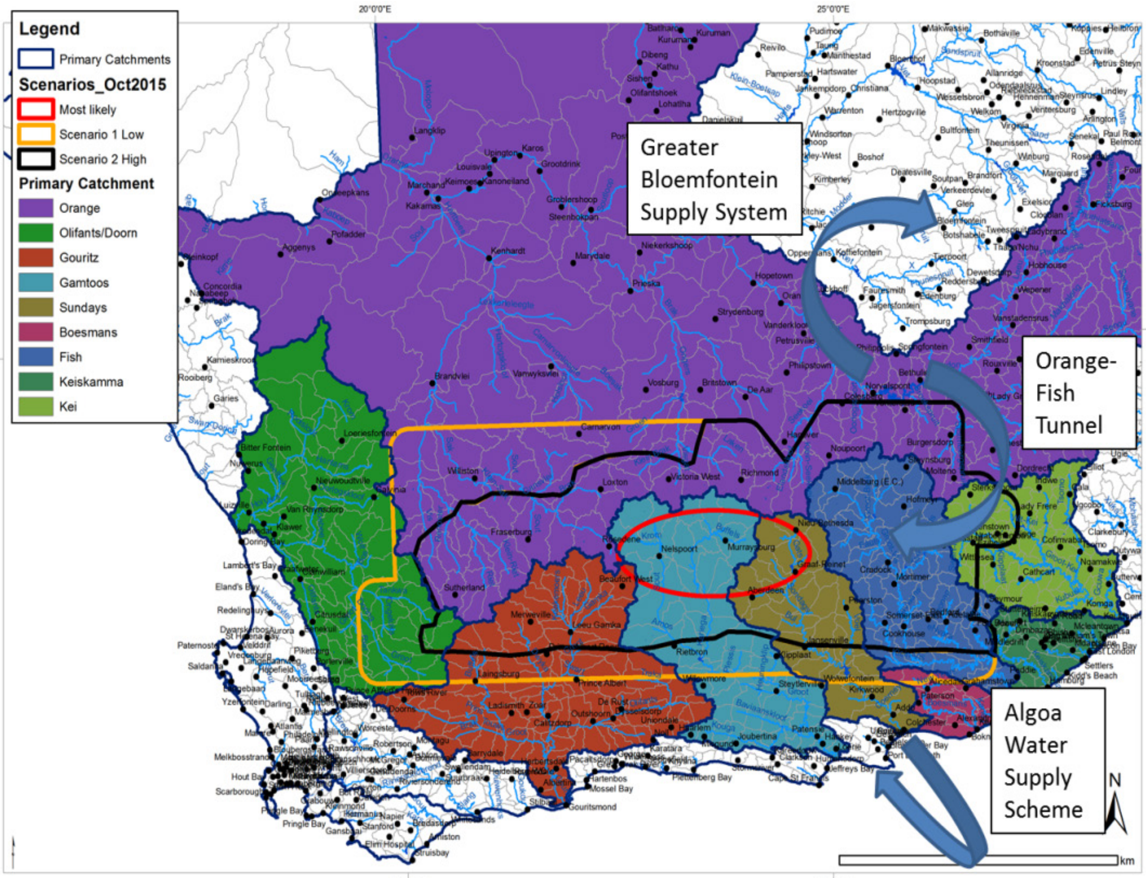


Figure 12.8: Water catchment areas possibly impacted in total study area

12.12 Noise pathway exposures

As discussed in Wade et al. (2016), the most significant noise sources during SGD are the increased traffic flow and plant noise. Traffic noise disturbs rural communities due to constant traffic flow to and from site (Weigle, 2010). Each single wellpad requires approximately 1000 truck trips, with the process usually running day and night for approximately one to two months (–Xiphu, 2012; Weigle 2010).

12.12.1 Worker

According to the WHO (2011) the health end-points of environmental noise include cardiovascular disease, cognitive impairment, sleep disturbance, tinnitus and annoyance. There is evidence for associations between noise exposure and adverse reproductive outcomes such as low birth rates (Ristovska et al., 2014). Workers are exposed directly to unsafe levels of noise (above 80db - see Wade et al., 2016) through drilling operations and exposure to generators, however through mitigation these levels can be reduced to acceptable levels with the use of sound damping boxes and PPE.

12.12.2 Community

Noise nuisance from SGD activities from the wellpad and from road traffic can affect the community even at low levels around 45db (Fahy and Walker, 1998), which can result in sleep disturbances.

12.13 Direct physical contact (traffic or machine injury)

12.13.1 Worker

As stated earlier in the occupational health section, the majority of worker fatalities in the industry are as a result of motor vehicle accidents accounting for nearly 40% of all work-related fatalities, with 7.6 deaths per 100 000 workers, which is equivalent to one death per 13 157 workers (Mason et al., 2015; Retzer et al., 2013). An overall fatality rate of 27.5 deaths per 100 000 workers was recorded by NIOSH (2012) in the US industry, a total that is more than seven times the death rate for all other industries (3.9 for all US workers). After vehicle accidents, the next most common fatal events were explosions (8%), workers caught or compressed in moving machinery or tools (7%), and falls (6%) (NIOSH, 2012). In South Africa, the occupational injury and fatality rates are considerably higher than developed countries with five times the fatality rate and four and a half times the accident rates of the developed countries. According to the DoL data, South Africa had a fatality rate of 19.2 per 100 000 workers and an accident rate of 14 626 per 100 000 workers (Haupt et al., 2008).

12.13.2 Community

It is expected that an increase in traffic on the roads will result in an increase in car accidents in the study area. In the US, vehicle accidents measurably increased in conjunction with SGD (Graham et al., 2015). According to surveys carried out in a SGD area in Texas (Rahm et al., 2015), vehicular accidents increased 26% from 2009 to 2013 when SGD began. In Pennsylvania the increase in vehicular traffic accidents attributed to SGD ranged from 7 - 49% (Food & Water Watch, 2013).

12.14 Dermal exposure to chemicals

12.14.1 Worker

Worker exposures to hydrocarbons and chemicals used in the fracking processes can occur during SGD, resulting in dermatitis and skin irritations. This could take place during accidental spills or improper waste disposal.

12.14.2 Community

Although unlikely, dermal exposure to chemicals from SGD may occur through bathing in water contaminated with chemicals.

12.15 Light pollution

Light pollution was listed as a possible health impact pathway; however it was not covered in this Chapter.

12.16 Risk Ranking

Different methods of risk ranking or prioritisation have been described in the literature with summaries provided below. This human health risk assessment takes into account community and worker health via different environmental impact pathways including, water, air, noise, direct and dermal.

Different ranking systems were used internationally to assess the potential health risks. The US EPA (2015) used a Multiple Criteria Decision Analysis (MCDA) by means of a database of 1 173 chemicals associated with fracking, the frequency of use data (692 chemicals) or the measured concentrations found in flowback or produced water (75 chemicals) and toxicology data (421 chemicals) together with physicochemical data (515 chemicals). Chemicals not included in the analysis were those considered to be proprietary or identified as business confidential information.

The MCDA resulted in 37 chemicals used in fracking fluid ranked from high to low with propargyl alcohol scoring the highest overall hazard potential score. This chemical was used in 33% of wells and had one of the lowest reference doses (representing the most toxic), being hydrophilic, it would likely be transported in water. Twenty-three chemicals were detected in flowback and produced water of which ten were also used in fracking fluid. Benzene, pyridine and naphthalene scored the highest total hazard potential scores, all with low reference doses (which indicates high toxicity), detected frequently and moderate physicochemical properties for their transport to water.

The Australian Ranking System used in the Camden HIA (EnRiskS, 2013) looked at where concentrations of chemicals found in produced water exceeded drinking water quality guidelines. As drinking water quality guidelines are derived to allow for a lifetime exposure with no adverse health effects expected they were used as surrogate reference doses and compared to the measured concentrations. If a ratio is greater than one, it indicates the potential for adverse health effects. A limited number of chemicals were predicted to be at concentrations higher than drinking water guidelines. These include Tetrakis(hydroxymethyl)phosphonium sulphate (THPS), benzoalkonium chloride, citric acid, (which are drilling chemicals) and medium length total petroleum hydrocarbons (TPHs) C15-C28.

Boyle et al. (2016) describe a hazard ranking methodology used for the Maryland Marcellus Shale Public Health Study to assess the potential public health impacts for eight hazards associated with the SGD process. The system is based on a modified ranking process described by Witter et al. (2010).

This process allows for systematic evaluation of identified hazards to allow for recommendations to minimise the hazards.

12.17 How health risks were assessed for the scientific assessment

Potential health risks were ranked according to the *likelihood of exposure* and *likelihood of a consequence* as a result of such exposure, and provide a qualitative assessment of the potential health risks in the study area as a result of SGD. It was used to rank both occupational related risks to workers, as well as the communities in the study area.

Figure 12.9 shows the risk ranking matrix in which aspects such as fate and transport of chemicals contributed to the likelihood of exposure for the different scenarios. Table 12.5 gives an explanation of the likelihood of consequence to community health when exposed. Likely exposures of moderate consequences to worker health may result in transient effects that may require medical treatment such as respiratory effects. Similarly, a very likely exposure to a severe consequence will result in death or significant injury.

Likelihood of exposure	*Likelihood of consequence*						
			None	**Slight**	**Moderate**	**Substantial**	**Severe**
			1	***2***	***3***	***4***	***5***
	Highly likely	5	VL	L	M	H	E
	Very likely	4	VL	L	M	H	E
	Likely	3	VL	L	M	M	M
	Not likely	2	VL	L	L	L	L
	Extremely unlikely	1	VL	VL	VL	VL	VL

VL – Very Low Risk	L – Low Risk	M – Moderate Risk	H – High Risk	E – Extreme Risk

Figure 12.9: Risk ranking matrix.

Table 12.5: Description of consequences used for ranking risks.

Consequence					
	None	**Slight**	**Moderate**	**Substantial**	**Severe**
	1	2	3	4	5
Off-site human health issues (Chronic)	No adverse long term health effects associated with low level environmental exposures	Minor transient health effects	Transient effects that may require medical treatment such as respiratory effects, more significant irritation	Permanent health effects that require extended medical treatment and or permanent disability	Death or significant injury likely to result in death

12.18 Limits of acceptable change

According to the WHO (2001) and US EPA the limits of acceptable change are often prescribed depending on the type of health impact. For instance a long-term impact such as developing cancer will have a lower level of acceptable change than an infection from a pathogen.

The WHO (2001) presents the following with regards to acceptable change:

"The US Environmental Protection Agency (EPA) typically uses a target reference risk range of 10^{-4} to 10^{-6} for carcinogens in drinking water (Cotruvo, 1988), which is in line with World Health Organization (WHO) guidelines for drinking water quality which, where practical, base guideline values for genotoxic carcinogens on the upper bound estimate of an excess lifetime cancer risk of 10^{-5} (WHO, 1993). In the UK, for example, the Health and Safety Executive (HSE) adopted the following levels of risk, in terms of the probability of an individual dying in any one year: 1 in 1000 as the 'just about tolerable risk' for any substantial category of workers for any large part of a working life. • 1 in 10,000 as the 'maximum tolerable risk' for members of the public from any single non-nuclear plant. • 1 in 100,000 as the 'maximum tolerable risk' for members of the public from any new nuclear power station. • 1 in 1,000,000 as the level of 'acceptable risk' at which no further improvements in safety need to be made."

The South African Water Quality Guidelines developed by the DWS (1996) are divided into different volumes according to the various water uses, namely, domestic recreational, industrial, agricultural water used for irrigation, agricultural water used for livestock watering and agricultural water used for aquaculture. These guidelines make use of the "fitness for use" concept which is a judgment of how suitable the quality of water is for its intended use. These guidelines are currently being revised to be more aligned with international best practices and the NWA (1998). The revised guidelines will be specifically risk based and site specific making them appropriate for future water quality assessments in areas should fracking take place. Currently the South African water quality guidelines do not make allowance for the type of chemicals that are used in fracking practices.

The domestic water use or drinking water quality guidelines are relevant to human health in this chapter as water quality for the environment is dealt with in Hobbs et al. (2016). The South African National Standards (SANS) for drinking water is the regulatory standard, or guideline, that the Water Law specifies for compliance monitoring purposes. The SANS-241(2015) drinking water limits are risk based with the standard for each determinand derived to safeguard the health of the consumer over a life-time consumption and to be protective of susceptible subpopulations. Table 12.6 lists the determinands included in the standards with the frequency of monitoring specified. These standards also do not specify the chemicals associated with fracking. This would need to be considered in monitoring programmes should SGD take place.

Table 12.6: SANS- 241 (2015a; b).

Table 2 — Physical, aesthetic, operational and chemical determinands

1	2	3	4
Determinand	**Risk**	**Unit**	**Standard limits**
Physical and aesthetic determinands			
Colour	Aesthetic	mg/L Pt-Co	≤ 15
Conductivity at 25 °C	Aesthetic	mS/m	≤ 170
Total dissolved solids	Aesthetic	mg/L	≤ 1 200
Turbidity	Operational [a]	NTU	≤ 1
	Aesthetic	NTU	≤ 5
pH at 25 °C [b]	Operational	pH units	≥ 5 to ≤ 9,7
Chemical determinands — macro-determinands			
Free chlorine as Cl_2 [d]	Chronic health	mg/L	≤ 5
Monochloramine [cd]	Chronic health	mg/L	≤ 3
Nitrate as N [ef]	Acute health	mg/L	≤ 11
Nitrite as N [efg]	Acute health	mg/L	≤ 0,9
Combined nitrate plus nitrite [efg]	Acute health		≤1
Sulfate as SO_4^{2-}	Acute health	mg/L	≤ 500
	Aesthetic	mg/L	≤ 250
Fluoride as F^-	Chronic health	mg/L	≤ 1,5
Ammonia as N	Aesthetic	mg/L	≤ 1,5
Chloride as Cl^-	Aesthetic	mg/L	≤ 300
Sodium as Na	Aesthetic	mg/L	≤ 200
Zinc as Zn	Aesthetic	mg/L	≤ 5
Chemical determinands — micro-determinands			
Antimony as Sb	Chronic health	µg/L	≤ 20
Arsenic as As	Chronic health	µg/L	≤ 10
Barium as Ba	Chronic health	µg/L	≤ 700
Boron as B	Chronic health	µg/L	≤ 2 400
Cadmium as Cd	Chronic health	µg/L	≤ 3
Total chromium as Cr	Chronic health	µg/L	≤ 50
Copper as Cu	Chronic health	µg/L	≤ 2 000
Cyanide (recoverable) as CN^-	Acute health	µg/L	≤ 200
Iron as Fe	Chronic health	µg/L	≤ 2 000
	Aesthetic	µg/L	≤ 300
Lead as Pb	Chronic health	µg/L	≤ 10
Manganese as Mn	Chronic health	µg/L	≤ 400
	Aesthetic	µg/L	≤ 100
Mercury as Hg	Chronic health	µg/L	≤ 6
Nickel as Ni	Chronic health	µg/L	≤ 70
Selenium Se	Chronic health	µg/L	≤ 40
Uranium as U	Chronic health	µg/L	≤ 30
Aluminium as Al	Operational	µg/L	≤ 300
Chemical determinands — organic determinands			
Total organic carbon as C	Chronic health	mg/L	≤ 10
Trihalomethanes [h]			
Chloroform	Chronic health	µg/L	≤ 300
Bromoform	Chronic health	µg/L	≤ 100
Dibromochloromethane	Chronic health	µg/L	≤ 100
Bromodichloromethane	Chronic health	µg/L	≤ 60
Combined trihalomethane [h]	Chronic health		≤ 1
Total microcystin [i]	Chronic health	µg/L	≤ 1
Phenols	Aesthetic	µg/L	≤ 10

Table 3 — Frequency of analyses for determinands identified during the risk assessment exceeding the numerical limits in SANS 241-1

1	2	3	4
Risk	**Frequency**	**Infrastructure optimization**	**Infrastructure change**
Acute health – 1	Weekly	Ensure optimized functioning of infrastructure	If problem is not resolved, obtain necessary infrastructure
Acute health – 2	Monthly		
Chronic health	Monthly		
Aesthetic	Monthly		
Operational	Weekly		

12.19 Risk assessment

Four SGD scenarios were assessed as per the scope of the scientific assessment. These include:

Scenario 0: Reference Case (health status with no drilling)

Scenario 1: Exploration Only

Scenario 2: Small Gas

Scenario 3: Big Gas

The risks were ranked according to the likelihood of exposure for each of the scenarios and the severity of the consequence. The risk ranking results are shown in Table 12.7, followed by Table 12.8 describing the selection of ranking.

Different pathways for potential exposure, with air, water, noise, direct contact resulting from traffic or machine injuries, and dermal contact were considered. These were considered separately for workers and community members. Without mitigation, the four scenarios were found to yield health risks as ranging from none, to moderate risk for the Reference Case as the current health status of the study area population faces serious challenges with infant, maternal and under-five mortality rates double that of the provincial rate. For Exploration Only, community health is expected to range between a very low risk to a moderate risk (with water as the exposure pathway) and worker health ranging from high risk (via the air pathway) to low risk, depending on the exposure pathway. For the Small Gas scenario, worker health risks range from low risks to high risks (multiple pathways). Community health risks range from low to high (where water is the exposure pathway). The Big Gas scenario results in high risks for workers from air, noise and direct contact pathways, and high risks for the community via air and water pathways, to low risks for the other pathways. Mitigation measures involve engineering based interventions, PPE, or the containment of spills and will have a reduction in the likelihood of exposure, thereby reducing the risk ranking in each scenario.

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Table 12.7: Health risk assessment of four SGD scenarios for different exposure routes.

Impact	Receiving Environment	Scenario	Location	*Without mitigation*			*With mitigation*		
				Consequence	**Likelihood**	**Risk**	**Consequence**	**Likelihood**	**Risk**
Air pathway exposure	Worker	Reference Case	On the wellpad	Slight	Extremely unlikely	Very low	Slight	Extremely unlikely	Very low
		Exploration Only		Severe	Very likely	High	Substantial	Unlikely	Moderate
		Small Gas		Severe	Very likely	High	Substantial	Unlikely	Moderate
		Big Gas		Severe	Very likely	High	Substantial	Likely	Moderate
	Community	Reference Case	10 km from a town	Slight	Likely	Very low	Slight	Likely	Very low
		Exploration Only		Moderate	Likely	Low	Slight	Likely	Very low
		Small Gas		Substantial	Likely	Moderate	Moderate	Likely	Low
		Big Gas		Substantial	Likely	Moderate	Moderate	Likely	Low
Water pathway exposure	Worker	Reference Case	On the wellpad	Slight	Extremely unlikely	Very low	Slight	Extremely unlikely	Very low
		Exploration Only		Moderate	Likely	Low	Moderate	Very unlikely	Low
		Small Gas		Moderate	Likely	Low	Moderate	Not Likely	Low
		Big Gas		Moderate	Very likely	Low	Moderate	Likely	Low
	Community	Reference Case	From a formal and informal water source and supply	Substantial	Not likely	Moderate	Moderate	Not Likely	Low
		Exploration Only		Substantial	Not likely	Moderate	Moderate	Not Likely	Low
		Small Gas		Severe	Likely	High	Substantial	Not Likely	Moderate
		Big Gas		Severe	Highly likely	High	Substantial	Likely	Moderate
Noise pathway exposure	Worker	Reference Case	On the wellpad	None	Extremely unlikely	None	None	Extremely unlikely	None
		Exploration Only		Severe	Very likely	High	Substantial	Likely	Moderate

Impact	Receiving Environment	Scenario	Location	*Without mitigation*			*With mitigation*		
				Consequence	**Likelihood**	**Risk**	**Consequence**	**Likelihood**	**Risk**
		Small Gas		Severe	Very likely	High	Substantial	Likely	Moderate
		Big Gas		Severe	Very likely	High	Substantial	Likely	Moderate
	Community	Reference Case	5 km from a residential area	None	Extremely unlikely	None	None	Extremely unlikely	None
		Exploration Only		Moderate	Unlikely	Low	Moderate	Unlikely	Low
		Small Gas		Moderate	Likely	Low	Moderate	Unlikely	Low
		Big Gas		Moderate	Very likely	Low	Moderate	Likely	Low
Direct physical contact (traffic/ machine injury)	Worker	Reference Case	On the wellpad or road	Extreme	Very unlikely	Low	Severe	Very unlikely	Low
		Exploration Only		Extreme	Not likely	Low	Severe	Very unlikely	Low
		Small Gas		Extreme	Likely	High	Severe	Not Likely	Moderate
		Big Gas		Extreme	Likely	High	Severe	Not Likely	Moderate
	Community	Reference Case	Road network	Extreme	Very unlikely	Low	Severe	Very unlikely	Low
		Exploration Only		Extreme	Very unlikely	Low	Severe	Very unlikely	Low
		Small Gas		Extreme	Unlikely	Low	Severe	Unlikely	Low
		Big Gas		Extreme	Unlikely	Low	Severe	Unlikely	Low
Dermal through chemical exposure	Worker	Reference Case	On the wellpad or road	None	Extremely unlikely	None	None	Extremely unlikely	None
		Exploration Only		Moderate	Likely	Low	Moderate	Not Likely	Low
		Small Gas		Moderate	Very likely	Low	Moderate	Likely	Low
		Big Gas		Moderate	Very likely	Low	Moderate	Likely	Low
	Community	Reference Case	From a formal and informal water source	None	Extremely unlikely	None	None	Extremely unlikely	None

Impact	Receiving Environment	Scenario	Location	*Without mitigation*			*With mitigation*		
				Consequence	**Likelihood**	**Risk**	**Consequence**	**Likelihood**	**Risk**
		Exploration Only	and supply	Moderate	Extremely unlikely	Very low	Moderate	Extremely unlikely	Very low
		Small Gas		Moderate	Very unlikely	Low	Moderate	Extremely unlikely	Very low
		Big Gas		Moderate	Not likely	Low	Moderate	Very unlikely	Low

Table 12.8: Summary health risk assessment of four SGD scenarios.

Scenario	Description on selection of ranking
Reference Case	Health risks ranged from **none to moderate** risk as the current health status of the study area population faces serious challenges with infant, maternal and under-five mortality rates double that of the provincial rate. Greater TB and HIV rates and lower life expectancies are found, however drilling related health risks are considered as negligible.
Exploration Only	Community health is expected to range between a **very low to moderate** risk (with water as the exposure pathway). As ten vertical wells will be drilled with 100Ml drilling and fracking fluid produced. Reported spillage in international literature varied between 1-4%. Assuming similar spillage rates, the consequence is considered to be high but the likelihood of exposure is considered unlikely. Worker health ranges from **high risk** (via the air pathway) **to low risk**, depending on the exposure pathway. *With mitigation the likelihood of exposure is reduced in each scenario*[6].
Small Gas	Worker health risks range from **low to high** (multiple pathways). Community health risks range from **low to high** (where water is the exposure pathway). Around 60 vertical wells will be drilled, six times as much production water and chemicals and is therefore considered to have a high consequence, with a possible likelihood, and is therefore classified as a **moderate** risk.
Big Gas	Workers health risks resulted in **high risks** from air, noise and direct contact pathways, and **high risks** for the community via air and water pathways, to low risks for the other pathways. Five hundred and fifty vertical wells will be drilled – assuming a 1-4% spillage, the likelihood of exposure is considered to be very likely.

12.20 Limitations, recommendations and conclusion

Many of the chemicals used in SGD do not have sufficient health data to make decisions - in the extensive US EPA assessment chronic health data was only available for 8.4% of the 1 173 reportedly used chemicals. Each drilling and fracturing event is custom-designed depending on the geology, depth and resources available. The chemicals and products used and the amounts or volumes used can differ from well to well.

As the activity of fracking is relatively new in relation to the time needed to assess long-term health effects as well as trans-generational effects, scientific evidence that can be used with certainty is severely lacking.

Any potential health impacts resulting from SGD will require that baseline monitoring for air and water quality. Baseline health monitoring, including additional health symptoms and blood or urine tests associated with SGD will need to be carried out prior to initiating the exploration activity to enable ascribing any future health effects to a specific cause. The additional health symptoms implies

[6] Note that mitigation is expected to reduce the likelihood of exposure assuming any spillage to be contained to a certain degree.

that standard health monitoring done at hospitals and clinics will not be sufficient and that additional health symptoms associated with SGD such as nose, eye and throat irritation, dermal or skin lesions, upper respiratory impacts, etc. (see Table 12.4) be noted prior to, throughout as well as for a long time after exploration or mining has seized. Transgenerational effects as well as EDC -related health impacts (e.g. thyroid, and reproductive effects) as well as cancer will require long term monitoring.

As mentioned earlier in the Chapter, health protection is not sufficiently and explicitly covered in the legislation where SGD is concerned and will need to be addressed.

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12.22 Digital Addenda 12A – 12F

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