NSW
GOVERNMENT
Chief Scientist
& Engineer

The Hon Chris Hartcher MP
Minister for Resources and Energy
Special Minister of State
Minister for the Central Coast
GPO Box 5341
SYDNEY NSW 2001

Dear Minister

Following a request from your office to investigate the likelihood of hydraulic fracturing activities in NSW, my office sought advice from three experts to address the issue.

Attached are comments related to the likelihood of hydraulic fracturing in NSW provided by the three experts:

- Professor Val Pincewski, Foundation Professor and Head of School of Petroleum Engineering, University of New South Wales,
- Professor Peter Cook, Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) and University of Melbourne
- Dr Rob Jeffrey, Research Program Leader, Petroleum Engineering, CSIRO

I have also attached the individual comments of the three independent experts for your consideration.

Key messages that can be taken from the experts' comments include:

- the need to fracture is dependent on the nature of the coal (particularly its permeability), the coal seam, and the surrounding rocks
- coal seams from some basins in NSW appear from the advice to be more likely to need fracturing than others. (Such as the Permian Basins – Sydney, Gunnedah and Gloucester)
- small companies are more likely to fracc to prove production resources independent of the nature of the coal seam
- in the later stages of Coal Seam Gas developments after the high permeability coal seams or 'sweet spots' have been drilled it is more likely that wells will then be fracced to increase production
- the development of new technologies may significantly reduce the need for hydraulic fracturing in the future.

Please do not hesitate to contact me should you wish to discuss.

Yours sincerely

Mary O'Kane
NSW Chief Scientist & Engineer

Likelihood of hydraulic fracturing activities in NSW

Note: The source of the quote from the reports has been noted in the text.

- "Hydraulic fraccing has been used internationally in the petroleum industry since 1947 to stimulate oil and gas wells, allowing production at higher rates and enabling more of the in-place hydrocarbons to be recovered. Hydraulic fracturing for stimulation was first used in Australia in 1969 in the Cooper Basin". (Dr Jeffrey – Draft Report)

- Hydraulic fracturing or fraccing can be used in the coal seam gas industry to increase production. Fraccing has been used for coal seam gas production in Queensland and NSW and for coal seam gas and shale gas production overseas.

- "The purpose of the hydraulic fracture stimulation is to create and prop open a fracture in the reservoir that then provides a large surface area through which reservoir fluids can be produced and a conductive channel (the propped hydraulic fracture) through which these fluids can flow easily back to the well." (Dr Jeffrey – Draft Report)

- "Typically hydraulic fracturing can increase production by a factor of 2–5 for vertical wells and by a factor larger than 5 for multiple fracture stimulations along horizontal wells" (Dr Jeffrey – Draft Report)

1. Coal seam characteristics and local geology

- "The decision to use fraccing is dependent on the nature of the coal seam (thickness, permeability, 'gasiness'), the geological setting (prevailing stress field, depositional environment), the adjacent rock types, the proximity of aquifers and the regulatory regime.(Prof Cook) Other factors that are considered include seam thickness, stress contrasts between seam and surrounding rock layers, and the geological and structural setting of the well." (Dr Jeffrey – Draft Report)

Coal seam permeability

- "Fraccing is more likely to be used where coals are high rank (very mature), have low permeability, are hard and brittle, thick and continuous". (Prof Cook)

- "Permeability is the property of the rock that determines how easily a fluid will flow through the rock. If all other parameters are fixed, then doubling the permeability will produce double the rate of fluid flow through a rock". (Dr Jeffrey – Draft Report)

- The reservoir permeability is the primary factor that influences the decision as to whether a particular well or collection of wells should be stimulated by hydraulic fracturing:
    - The report by Dr Jeffrey (draft report) relates permeability to fracturing activities as follows:
        - Coal seams that have permeabilities above 20 or 30 millidarcys do not usually require fracture stimulation. These higher permeability coals can be produced by drilling surface to in-seam wells or vertical wells.
        - Coals below 0.1md are not economic even after fracturing from a vertical well completion.
        - The target seams for hydraulic fracturing typically have permeabilities that range between 1 and 10 md.
        - Seams that are less permeable than 1md might be produced at economic rates by drilling horizontal wells and placing multiple fractures along the well, but this has yet to be proven in Australia.

    - Professor Pinczewski also related permeability of coal seams for CSG development to requirements to fracture and current best-practice completion/stimulation methods(Palmer, International Journal of Coal Geology, 2010):

    - High-permeability seams (>20 millidarcy) requiring horizontal wells and cavity completed vertical wells.
    - Low-Permeability seams (3-20 millidarcy) requiring horizontal and fracked vertical wells
    - Tight seams (<3 millidarcy) requiring multi-lateral completions

- It is more likely that fraccing will be used in the Sydney and Gunnedah Basins and Bowen Basin where the Permian coals are relatively impermeable, than in the Surat and Clarence Moreton Basins where the Jurassic coals are quite permeable. (Drawn from Professor Cook report section a, and h)

- "If a coal seam is wet, it probably is permeable and therefore on balance is less likely to be fracced. The difference between NSW and Qld regarding wetness is a function of which sedimentary basins are being compared. Professor Cook reports that he anticipates that the coals in the Surat and Clarence-Moreton Basins on both sides of the border are wetter than the Bowen Basin in Queensland or the Sydney or Gunnedah Basins in NSW. (Please note: this comment refers to the coals and not the presence of aquifers above or below the coals" (Professor Cook – via email correspondence)

Surrounding rocks and aquifers

- "Fraccing is more likely to occur where the adjacent rocks are relatively plastic and unfavourable for the prolongation of fractures". (Professor Cook)

- Dr Jeffrey (Draft report) reported that "hydraulic fractures that are initiated in the coal will then tend to be contained to the coal because the higher stress rock layers above and below the coal act to limit the fracture growth into these rock and are often high enough so that if the hydraulic fracture does not grow into them it will reorient to become horizontal"

- "Prior to the commencement of production a plan will be drawn up for fraccing which have required amongst other things seismic and micro-seismic surveys to determine the likelihood that the coals can be safely and preferentially fractured laterally in the right direction and that there will be no vertical propagation of fractures into underlying or overlying intervals that could be detrimental to aquifers or to CSG production" Professor Cook

- "Fraccing will be used in coal seams where the fracture systems can confidently be generated for a distance for the vertical drill hole and where there is a high probability that fracturing will be limited to the coal seam and not propagate into other adjacent rocks". (Professor Cook)

- "Most well designed coal seam gas production wells will have little or no significant impact on groundwater provided best practice is followed" (Professor Cook)

2. Maturity of industry and companies

- Small companies may choose to hydraulically fracture a vertical well first because it is cheaper overall, and provides the company with a well that will produce. The company could then use this producing well to assist in attracting additional capital. (Dr Jeffrey comment on draft report)

- A vertical fractured well might cost $400,000 to $700,000 depending on the number of seams. Horizontal wells cost $1 to $2 million to drill and complete without fracturing. It is expected that horizontal wells will be fracture stimulated in the future. (Dr Jeffrey comment on draft report)

- "It is also expected that most of the fraccing will occur in the later stages of field developments after the high permeability 'sweet spots' or 'production fairways' have been drilled (5 -10 years)" (Professor Pinczewski)

- Professor Val Pinczewski reported “that horizontal wells and new technologies based on horizontal drilling which will emerge in this time frame (5-10 years) will, to a significant extent, reduce the need for hydraulic fraccing in the future.”

- Professor Val Pinczewski reported ‘that in NSW we can expect significantly fewer than 30% of CSG wells will be fractured using to-days fraccing technologies”.

3. Differences between NSW and Queensland coal seam gas extraction

- The nature and extent of fraccing activities in Queensland is strongly influenced by geology, company practice and economic. The coals in the Bowen Basin of central Queensland and more favourable for fraccing than the younger, thinner and more varied coals of the Surat and Clarence-Moreton Basin of southern and south-eastern Queensland. (Drawn from sections a and h in Professor Cook’s report)

- The comparison between NSW and Queensland is on the basis of geology, with the Bowen Basin in Queensland providing an example of the likely application of hydraulic fracturing in the contemporaneous Sydney and Gunnedah Basins. (Drawn from sections a and h in Professor Cook’s report)

4. Differences between Australia and USA gas extraction

- “The most extensive overseas experience of fraccing has been in the USA, mostly relating to shale gas production”. (Professor Cook)

- “In the US because onshore gas production has been underway for a considerable time, the high permeability targets are under production or depleted. Therefore approximately 90% of new gas wells, which are in lower permeability rock, in the US are now stimulated by hydraulic fracturing”. (Dr Jeffrey-Draft Report)

- “Australia currently has about 5,000 operating CSG wells. Fewer than 5% of these wells have been fracced”. (Professor Pinczewski)

- “In Australia, shales are likely to be productive for gas production.” (Professor Cook)

5. Differences between coal seam and shale gas

- To date NSW production is of coal seam gas and not shale gas.

- “Shale gas (also known as tight gas) provides 30% of the total gas supply for the USA” (Professor Cook)

- “Much of the public discussion of CSG is based on interpretations of US experience with fraccing of shales”. (Professor Cook)

- “There are very important differences between shales and CSG with the key difference being the need for fraccing. The vast majority, if not all, shale gas wells require some form of fraccing to produce commercially. In contrast, only a small fraction of CSG wells require fracture treatment to produce commercially.” (Professor Cook)

6. French ban of hydraulic fracturing

- “France has recently (April 2012) passed legislation banning fraccing in response to pressure from NGOs and the Opposition regarding environmental concerns.” (Professor Cook)

- Professor Peter Cook reports that “the issue is likely to end up in court as many companies have already undertaken exploration for shale gas and matters are no doubt being complicated by national elections”.

7. Use of fraccing for other mining activities

- Hydraulic fracturing is used to stimulate water wells. Dr Rob Jeffrey (draft report) does not believe this is currently being used in NSW, but it may be used in the future.

- “Hydraulic fracturing has been used since 1997 to weaken rock in coal and metal mining operations. This work is usually done before mining by preconditioning the rock so that it will fail uniformly when mining occurs. Fracturing for preconditioning in NSW is being conducted at two mines, with at least another two looking into the practice.” (Dr Jeffrey – Draft Report)

- Small hydraulic fractures are used to measure in situ stress of rocks. It is estimated by Dr Rob Jeffrey (Draft Report) that 10 stress measurements using hydraulic fracturing are made each year in NSW. This technology which involves injecting 10-100 litres of water has been used for more than 40 years across Australia.

Comments on the future prospects of fracking in the development of CSG in NSW

Val Pinczewski

23 April 2012

The following comments are based on information which is freely available to the public, information published in scientific journals and scientific/industry conferences and in personal discussions with leading industry players. The views expressed are my own.

1. Much of the public discussion of CSG is based on interpretations of US experience with fracking of shales. There are very important differences between shales and CSG. A key difference in the context of fracking is the need to frac. The vast majority, if not all, shale gas wells require some form of fracking to produce commercially. In contrast, only a small fraction of CSG wells require fracture treatment to produce commercially. Australia currently has about 5,000 operating CSG wells. Fewer than 5% of these wells have been fracked.

2. Although past decisions on how to best select well completions and stimulations for CSM have largely been on a trial-and-error basis, there is a growing consensus that better decisions are made when seam permeability and thickness form the basis for selecting the most cost effective completion and stimulation strategies. I believe that most multi-national companies and the larger local players involved in the Australian CSG industry now consider permeability and seam thickness to be crucial factors making completion and stimulation decisions.

3. For the purposes of discussion coal seams for CSG development are broadly classified as Tight (<3 millidarcy), Low-Permeability (3-20 millidarcy) and High-permeability (>20 millidarcy). The current best-practice completion/stimulation methods appear to be multi-lateral completions for Tight seams, horizontal and fracked vertical wells for Low-permeability seams, and horizontal wells and cavity completed vertical wells for High-permeability seams (Palmer, International Journal of Coal Geology, 2010).

4. In the US experience, horizontal wells (single and multi-lateral) in Low-permeability seams commonly produce at rates 3-10 time that of a fracked horizontal well. In the Australian (Bowen Basin) experience novel multi-seam horizontal wells in Low to High permeability seams outperform fracked vertical wells. Further, in High-permeability seams cavity completions can outperform fracked vertical wells. CSG well completion technology is a rapidly developing area with new methods, particularly for Tight seams, being developed rapidly. An example of this is Microhole technology where a number of small diameter radials can be rapidly drilled out of a vertical well with more than 3 radials per seam in a multi-seam accumulation eliminating the need to fracture. The overall experience suggests that a combination of horizontal wells (single and multi-lateral) together with emerging new technologies will increasingly reduce the need for current fracking technology in the future.

5. There is a generally held view in the industry in Australia that for the approved and proposed rapid expansion of the industry in Queensland and New South Wales that some 30% of all CSG wells will be fracked. It is expected that most of the fracking will occur in the later stages of field developments after all the high permeability ‘sweet-spots’ or ‘production fairways’ have been drilled (5-10 years). I believe that horizontal wells and new technologies based on horizontal drilling which will emerge in this time-frame will to a significant extent reduce the need for hydraulic fracking in the future. This is particularly true for NSW where on current indications average seam permeabilities appear to be lower than those in Queensland and where horizontal drilling technologies will therefore have a greater impact on field development. I therefore believe that in NSW we can expect that significantly fewer than 30% of CSG wells will be fractured using to-days fracking technologies.

DRAFT
Hydraulic Fracturing for Coal Seam Gas (CSG) Stimulation in New South Wales

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Introduction and Background

This report provides a description of hydraulic fracturing and general information about the use of hydraulic fracturing in Australia and New South Wales. This report has been written at the request of the Office of the Chief Scientist and Engineer of NSW.
Hydraulic fracturing has been used in the petroleum industry since 1947 (Howard and Fast, 1970) to stimulate oil and gas wells, allowing them to be produced at higher rates and allowing more of the in-place hydrocarbons to be recovered (Veatch, et al. 1989). Hydraulic fracturing for stimulation was first used in Australia in 1969, in the Cooper Basin (McGowan et al., 2007). Notes on the history of coal seam methane and fracturing in Australia are attached as Appendix A.

Whether applied to a conventional oil or gas well in a sandstone reservoir or to a coal seam methane well accessing a coal seam, the purpose of the hydraulic fracture stimulation is to create and prop open a fracture in the reservoir that then provides a large surface area through which reservoir fluids can be produced and a conductive channel (the propped hydraulic fracture) through which these fluids can flow easily back to the well. Once in place, the hydraulic fracture acts like a drain. As the pressure in the well is reduced by pumping, the low pressure penetrates along the conductive hydraulic fracture so that the reservoir fluids, which are at a higher pressure, flow from the rock through the sides of the fracture and into the propped fracture channel and then along it to the wellbore. Thus, much higher production rates can be achieved after fracturing. Production rate increases of a factor of two to five for vertical wells and by a factor larger than 5 for multiple fracture stimulations along horizontal wells, are typical. Wells that are drilled into low permeability reservoirs, which would otherwise be uneconomic, can be produced after fracturing allowing resources that would otherwise be uneconomic to be recovered.

Hydraulic fracturing is the process of creating the fracture and placing proppant into the fracture. Fracturing as discussed here is distinct from drilling operations and operations involving casing and cementing the well after it is drilled.

Current Practice for CSG Stimulation

Hydraulic fracture stimulation of CSG wells in Australia is done using several treatment designs. The fluids used range from water that has been treated to remove bacteria to gelled fluids that are water based with additives used to increase the fluid viscosity. The most common treatments would be slick water fracs with sand proppant and hybrid fracs that start with slick water and use crosslinked gel in the last part of the treatment in order to place more sand proppant in the fracture. Slick water consists of water, a bactericide, and an additive to reduce fluid friction while pumping. Occasionally, a treatment is carried out using a foam fluid in order to minimise the exposure of a water sensitive coal to water. Details of these fluid systems can be found at http://fracfocus.org/welcome and are described in a recent SPE paper by King (2012).

In addition to its use in stimulating gas and oil wells, hydraulic fracturing is used to stimulate water wells. Hydraulic fracturing is also used to weaken rock in coal and metal mining operations (van As and Jeffrey, 2000; Mills et al., 2000). This type of work is usually done before mining by preconditioning the rock so that it will fail uniformly when mining occurs. Fracturing for preconditioning is being used in NSW at several mines. Preconditioning involves pumping small volumes (up to 20,000 litres) to create fractures in the rock.

Small hydraulic fractures are used to measure in situ stress and this technology, which involves injecting 10 to 100 litres of water, has been used for more than 40 years across Australia (Enever et al., 2000).

The Decision to Fracture or Not

The reservoir permeability is a primary factor that influences the decision as to whether a particular well or collection of wells should be stimulated by hydraulic fracturing. Other factors that are considered include the seam thickness, stress contrasts between the seam and surrounding rock layers, and the geological and structural setting of the well. Early in development of a new basin, the higher permeability zones are sought. As these are found and drilled out, often without requiring any stimulation to produce the gas, the parts of the basin with lower permeability coal are developed with most of the wells requiring stimulation. An example of this on a large scale is provided by gas production in the USA. Because onshore gas production has been underway for a considerable time, the high permeability targets are under production or depleted. Therefore, approximately 90 percent of new gas wells, which are in lower permeability reservoir rock, in the US are now stimulated by hydraulic fracturing. It can be expected that as coal seam gas is developed in NSW, the number of wells requiring stimulation to be productive will increase.

This discussion assumes that an assessment of gas content and composition has been made and has indicated there is sufficient methane in the seam to warrant development and production.

Seam thickness and stress

If an individual coal seam is thin and would not contain enough gas to be a viable target for production by itself, hydraulic fracturing can be used to fracture stimulate a number of seams with one treatment. For this approach to work, the hydraulic fracture must grow with a vertical orientation and extend through the coal seams and the rock layers between the coals. This in turn requires that the minimum stress in the rock is about the same as the minimum stress in the coal and that both of these minimum stresses are horizontal. Under these stress conditions, which exist in some basins in Australia, a vertical hydraulic fracture can be grown through a number of seams and then by using a thicker gel fluid to transport the proppant, the fracture plane can be propped sufficiently to make it conductive over its height allowing water and gas to be produced from all of the seams. Reliably growing and propping such a fracture can be a challenge because the fracture may be diverted to become horizontal at the coal-rock interface and the proppant tends to settle vertically through the fluid so that the lower part of the fracture channel is well propped and highly conductive at the expense of propping and maintaining conductivity in the upper part.

Fracture stimulation of individual seams

In situ stresses along the east coast of Australia are affected by plate tectonics, which has acted to impart an east-west to northeast-southwest compression. The compression of a layered rock system will increase the stress in the stiffer rock layers (such as the siltstones and sandstones) compared to the stress in the softer coal layers. Hydraulic fractures that are initiated in the coal will then tend to be contained to the coal because the higher stress in the rock layers above and below the coal act to limit the fracture growth into these rocks and are often high enough so that if the hydraulic fracture does grow into them it will reorient to become horizontal (Enever et al., 2000). The coal seams then need to be fracture stimulated one by one. Target seams are selected based on their thickness and gas content. The decision to stimulate them or not then is made based on their permeability.

Permeability is the property of the rock that determines how easily a fluid will flow through the rock. If all other parameters are fixed, then doubling the permeability will produce double the rate of fluid flow through a rock. Average beach sand might have a permeability of 100 Darcy while concrete permeability is approximately 0.01 md, where md stands for millidarcy and 1 Darcy is equal to 1000 md. Coal seams that have permeabilities above 20 or 30 md do not usually require stimulation. These higher permeability coals can be produced by drilling surface to in-seam wells or vertical wells. Coals below 0.1 md are not economic even after fracturing from a vertical well completion. The target seams for hydraulic fracture stimulation typically have permeabilities that range between 1 and 10 md. Seams that are less permeable than 1 md might be produced at economic rates by drilling horizontal wells and placing multiple fractures along the well, but this has yet to be proven in Australia. Seams with permeabilities above 10 md are sometimes fractured because the economics of the well are improved by the stimulation.

Hydraulic fracturing can be and is used by companies of different size. The fracture stimulation is almost always carried out by a service company and the cost of the service would be similar for the same type of treatment, regardless of the size of the company. The service company can offer to design the treatment and to carry it out, so company in-house design expertise is not necessarily needed. Larger companies may be able to negotiate a lower stimulation cost by offering a larger number of wells for stimulation at one time. But such considerations are unlikely to be the deciding issue dictating whether a well is stimulated or not. The cost associated with fracture stimulations are typically reduced as more wells apply the technology and service companies compete with one another for work.

Use of Fracturing During Different Phases of CSG Operations

Hydraulic fracturing can be used during nearly all phased of CSG operations.

Exploration and Characterisation: Hydraulic fracture may be applied during exploration in the form of in situ stress measurements, which are small fractures formed by injection of 10 to 100 litres of water or as DFITs (Diagnostic Fracture Injection Tests). DFITs are sometimes used in low permeability coal to obtain seam permeability and reservoir pressure. These tests then replace conventional well testing. A DFIT is a hydraulic fracture treatment that involves injecting a small volume of water, perhaps 500 to 2000 litres, and then monitoring the pressure decline after the injection stops. Analysis of this falloff data is used to extract seam permeability and reservoir pressure.

Drilling: During drilling, after a casing string is cemented into the well, it is common to drill a few metres of new hole and then pressurise this open hole to test the integrity of the cement job. The borehole is pressurised until a fracture forms at the wellbore wall. These tests are called Leakoff Tests (LOT) in the drilling industry and can also be used to estimate the in situ stress. For stress measurements, the injection period is extended and the pressure decline after injection is monitored for an extended period. Such extended leakoff tests (ELOT) might involve injecting a few thousand litres of drilling fluid into the rock to form the fracture.

Pilot Wells: In new areas, it is common to drill 3 to 5 pilot wells near one another and, if the seam permeability requires it, to hydraulically fracture the seams in each well and produce the wells together as a pilot test. Fracture treatment designs are often varied between pilots to determine an optimal stimulation for the new area and several pilots are usually set up across a new area to test different structural settings and different seams. Treatments in pilot wells are done at full scale and typically involve injection of from 100,000 to 2,000,000 Litres of fracturing fluid per well. Treatments would normally be carried out in several different coal seams in each well.

Production: Once a field is being developed for production, a number of wells will be drilled and completed. By scheduling the hydraulic fracturing of groups of these wells in one campaign, the cost per treatment can be reduced (by negotiation with the service company).

Producing Field: It is common for wells to require work over, which typically involves removing the pump from the well, cleaning the wellbore out (coal and proppant sand may enter the well through the perforations and collect below the pump), repairing the pump if required and re-installing it. Some wells may be re-fractured at this time. Re-fracturing a well involves essentially the same operation as the original fracture stimulation and quite often results in significant production increase.

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Appendix A – Notes on history of hydraulic fracturing applied to CSM in Australia

Compiled by Rob Jeffrey, CSIRO Earth Science and Resource Engineering
January 2012

1969, First Fracture Treatment in Australia: The Moomba-8 well, in the Cooper Basin of SA was stimulated by hydraulic fracturing in September 1969 (McGowen et al., 2007). Another well is believed to have been stimulated in the same area in 1968, but this has not been verified. This was not a coal seam methane stimulation.

1976, First CSM Exploration Wells: The Carra-1 and Kinma-1 wells were drilled for coal seam methane exploration and Moura-1 and Shotover-1, which were existing petroleum exploration wells, were recompleted to test coal seams in Queensland (GA, 2001).

1980-81, Gas Drainage. Four vertical wells at Leichhardt Colliery (S of Blackwater, Qld) and four vertical wells at Appin (near Wollongong, NSW) were hydraulically fractured in 1980 and 1981 by BHP (Stewart and Barro, 1982). The objective of this work was to test vertical wells as a means of draining gas from the coal before mining. Nitrogen foam fracs, with sand proppant, was used in all cases. Halliburton provided the fracturing services with equipment sourced from their existing fleet used for conventional oil and gas fracturing work in Australia (Stewart and Barro, 1982).

1989, Gas Drainage. A single vertical well was fracture stimulated in March 1989 at Central Colliery in Queensland (Seamgas report, 1989). The fracture was mined and mapped and is described by Jeffrey et al. (1992). A borate crosslinked fluid was used to place sand proppant. Dowell Schlumberger pumped the treatment using equipment already in Australia (Jeffrey et al., 1992).

1986-92, Early Coal Seam Methane. Median Oil N.L. obtained the Authority to Prospect lease 364P which was acquired by CB Resources Pty Ltd. They developed the pilot Broadmeadow Field north of Moranbah and drilled and fracture stimulated 8 wells for the purpose of producing coal seam methane (ICF Lewin report, 1988). CB Resources became North Queensland Energy (NQE) which carried out a number of exploration and pilot production trials in Queensland into the early 1990s. NQE with Capricorn Coal funded small scale fracturing trials with CSIRO at German Creek.

1980s, AGL. AGL explored for CSM in the Sydney Basin in the 1980s with production by shaft sinking and drilling of horizontal holes from the bottom of the shaft with limited success. Pacific Power took several leases in the Sydney Basin and began exploration activities in the late 1980s. Pacific Power funded CSIRO to carry out small-scale hydraulic fracturing experiments at Munmorah and Dartbrook (with Dartbrook). Amoco took over the AGL leases in the early 1990s and carried out several pilot trials involving hydraulic fracturing of vertical wells (Bocking and Weber, 1993).

Feb. 1996: First commercial production (sold into a pipeline) from holes drilled into highwall at Moura, Qld. These horizontal wells were not fracture stimulated (GA, 2001)

Dec. 1996: First commercial production from vertical CSM hydraulically fractured well fields in the Dawson Valley (GA, 2001).

1996 – 2006. Increasing commercial Production. The Geoscience Australia URL below gives a list of first commercial production by a number of companies. Commercial production started in 1996 at Dawson Valley using hydraulic fracturing (now owned by Westside Corp).Other commercial production dates are 1998 some fracturing (Santos, Fairview Field), 2000 (Origin, Peat Field), 2001 using hydraulic fracturing(AGL, Camden), 2004 SIS wells (Arrow, Moranbah), and 2006 under reaming of initial wells but now fracturing (QGC, Berwyndale).

In 1998 production of CSM was 9 million cubic feet per day and by 2001 this had increased to 22 million cfd. By 2002 this had increased further to 62 million cfd which met approximately 25% of Queensland's natural gas demand at that time (GA, 2001).

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Report for the Office of the Chief Scientist and Engineer of New South Wales

The potential application of fraccing to coal seam gas production in New South Wales

Executive summary

Fraccing (more commonly spelt fracking) is a technology commonly used to improve coal seam gas (CSG) production. It has been used extensively in Queensland and overseas, but far less in New South Wales. The decision by a company to use of fraccing is highly dependent on the nature of the coals (thickness, permeability, 'gasiness'), the general geological setting (prevailing stress field, depositional environment), the adjacent rock types, the proximity of major aquifers and the regulatory regime. Whilst there may be a high degree of local variability, in the future it is more likely that fraccing will be used in the Sydney and Gunnedah Basins (where the Permian coals are relatively impermeable) to stimulate CSG production, and less likely that it will be used in the Surat and Clarence -Moreton Basins (where the Jurassic coals are quite permeable). Fraccing is also increasingly being used to enhance the production of shale gas overseas and in the future is likely to be applied in Australia, potentially including NSW. The application of fraccing technology to CSG (and shale gas overseas) has been very successful from an economic perspective, but it has also received significant adverse publicity in recent times, with questions being raised about the possibility of aquifer contamination, groundwater drawdown and the potential triggering of earthquakes. Fraccing has been banned or at times placed under a moratorium, in some countries. However the technology is increasingly being applied in order to optimise gas production and is of commercial importance. There is a need to ensure that the public is adequately informed about the benefits and potential problems of fraccing and ensure that valid concerns are addressed.

Background

CSG production was first undertaken in NSW in the 1930's and mine gas drainage has been a feature of coal mining in the State for many years. Large scale CSG activities have only recently become of significant commercial interest. CSG (predominantly methane with very minor proportions of other gases) is generated in the coal maturation process and then trapped or adsorbed in micropores and on coal surfaces and held within the seam by hydrostatic water pressure. The gas can be released by decreasing the hydrostatic pressure and provided the coal is sufficiently permeable, the gas will flow from the seam, into the production well and to the surface. If the seam is impermeable and there in little or no gas production, horizontal drilling or hydraulic fracturing (fraccing) of the coal seam can be used to provide fracture permeability, thereby greatly enhancing gas production. Fraccing was first applied to oil and gas wells in the USA in 1947 and is now used widely by the petroleum industry, including in Australia. However fraccing is expensive and can be technically complex. Consequently there have to be clear commercial benefits before an operator will choose to frac. In some areas the operator may choose to use horizontal wells as an alternative way of improving gas production or in conjunction with fraccing. In other seams the natural permeability of the coal may be adequate to allow production of CSG without any fraccing. In some instances the geology of the coals or the surrounding rocks may be unsuitable for fraccing. Therefore each CSG prospect has to be individually assessed as to its suitability for fraccing.

Key questions relating to fraccing

a. What factors are likely to control whether or not fraccing is used?

Fraccing is more likely to be deployed where coals are high rank (very mature), have a low permeability, are hard and brittle (dependant on the composition and texture), thick and continuous, and where the adjacent rocks are relatively plastic and unfavourable for the prolongation of fractures. In other words, fraccing will be used in coals where fracture systems can be confidently generated for tens of metres or more from the vertical drill hole and where there is a high probability that fracturing will be limited to the coal seam and not propagate into adjacent rocks   Older Permian coals in the Sydney and Gunnedah basins show many of these characteristics. However there is better permeability within some of the shallower Permian intervals within the basins where fraccing may not be necessary. Additionally there may be some areas in the southern part of the Sydney Basin where the coals may be too thin to allow fraccing, though the deeper parts of the Sydney Basin are poorly known geologically and consequently the extent to which fraccing might be used in the future in those deeper areas is unclear.

Fraccing is less likely to be deployed where the coals are low rank (immature), are soft and relatively plastic (thereby inhibiting the effectiveness of the fraccing process), have a naturally high permeability (so that they will flow gas without the need for stimulation), are cut by ancient fluvial channels (into which fraccing could extend), an unfavourable regional stress field (which might result in the fractures propagating in an unfavourable direction and proximal major aquifers). Younger Jurassic coals in the NSW sections of the Clarence-Moreton Basin and in the southern extension of the Surat basin, have a number of these features are therefore fraccing is less likely to be widely used in these younger basins.

b. Do practices relating to fraccing vary between companies?

Compared to the USA, fraccing is a relatively immature technology in Australia. Nonetheless it has been widely used for many years in conventional oil and gas production in a number of Australian basins, and more recently in Queensland for CSG. The fraccing process is largely undertaken by specialist service companies and consequently there is no inherent reason why a minor CSG company should necessarily adopt lower standard s for the operation than a major CSG company. A larger company is perhaps likely to be more concerned about reputational damage arising from poor practices by a contractor, than might be the case for a smaller company. Differences in procedures exist between the fraccing service companies, with some having a preference for one technique over another, or a preferred fracture stimulation fluid. All service companies are expected to undertake their operations to API standards with some major companies also applying their own additional standards. Some of the examples of CSG practices and consequences offered by for example in the film "Gaslands" illustrate potential problems that can arise, though it is important to point out that the examples used are probably extreme examples that do not represent the 'norm' for CSG operations in the USA or anywhere else. Can things go wrong in a CSG operation? The answer is of course yes but the risks are well understood and managing them is a standard part of procedures.

c. What are the fraccing requirements in the life of a CSG project?

A CSG exploration program is undertaken to identify the so called 'sweet spots' within a basin, where the coals are gassy, the geological structures are favourable and where drilling is most likely to result in a commercial find. Once a suitable prospect has been identified, a well will be drilled, then cased and any aquifer cemented off. If the coal is permeable, then a lateral horizontal well may be drilled to facilitate production. If on the other hand there is insufficient natural permeability then the coals may need fraccing to create permeability and optimise CSG production. Seismic and microseismic surveys may be undertaken to determine the likelihood that the coals can be safely and preferentially fractured and that there will be no vertical propagation of fractures into underlying or overlying intervals that could be detrimental to aquifers or to CSG production.

The fraccing process involves high pressure injection of the fraccing fluid (mainly water, but with various chemical additives) with sand or glass beads (as the proppant). This hydraulic fracturing induces fractures in the preferred lateral direction whilst the proppant serves to keep the fractures open and transmissive. The process is carefully monitored because it is important to ensure that fractures do not extend into aquifers, which can make it difficult or even impossible to depressurize the seam (by pumping water out) to enable the methane to desorb. Once the fracture pattern has been established and adequate permeability developed, the fraccing fluids are flowed back to the wellbore where they are pumped to the surface and stored ready for reuse or are disposed of at an approved site. This procedure can be undertaken in a single step of a few days in duration or incrementally over several days to a maximum of a couple of weeks.

Once the fracture permeability is established, CSG production can commence. It is necessary to monitor the CSG geochemically and also the producing formation using microseismic surveys to image the fracture pattern and any changes (such as fracture extensions) that might occur during production. In addition, the hydrogeology and hydrochemistry of the adjacent area is monitored to ensure there is no contamination. After the initial fraccing phase, normally it is not necessary to undertake any further fraccing at a later stage, though it may be necessary to remediate (clean out) the well and the producing formation This may require a workover rig but no additional fraccing. If fractures extend further than is desirable, steps can be taken to remediate the formation by for example cementing the “overfractured” area.

The normal production pattern in a fracced CSG well is that production of gas rapidly peaks in the early stage of extraction (perhaps a matter of just a few weeks) and then slowly declines over many months or several years until finally the late extraction phase is reached, the well becomes uneconomic and production is concluded. The well is then cemented, or abandoned in some other approved way, or potentially used for monitoring purposes.

d. Can fraccing impact on groundwater resources?

Most well designed CSG production wells will have little or no significant impact on groundwater, provided best practice is followed. Nonetheless fraccing can have significant unintended impacts on groundwaters through contamination by chemicals used in the fraccing fluid if the original fraccing fluid is not adequately back-produced at the start of production and/or leaks into an overlying or underlying aquifer through vertical induced fractures or unrecognised faults. In addition coals are depressurized by the extraction of water from the seam as part of the CSG production process; if fracturing extends out of the coal into an aquifer, then dewatering of the coal may result in drawdown of the water table. Methane can also leak into an aquifer. In some instances this can arise from natural leakage and there are a number of instances of this in Australia. It can also happen as a result of incorrect fraccing or from leakage of methane from wells. In confined spaces this can result in asphyxiation or explosion and therefore steps are taken to minimise the risk of this happening. In the USA there is a requirement to carry out remedial action if the concentration of methane in the groundwater is in excess of 28mgm/L (a limit set by the US Department of Interior). In the Gunnedah Basin and some parts of the southern Sydney Basin high concentrations of carbon dioxide can be encountered in some coal scenes, which might result in some acidification of groundwater if there were to be any significant leakage into aquifers. The definitive publicly available report on CSG and groundwater is that of the US National Research Council, published in 2010.

e. What are the chemicals in the fraccing fluid?

A wide range of chemicals are used in fraccing fluids, with the decision on which to use depending on the composition of the groundwaters , the nature of the fracturing to be developed, the structure of the coals and the preference of the service provider. The definitive study of fraccing fluids was released in 2011 by the US Congress. It reported that *"14 oil and gas service companies used more than 2500 hydraulic fracturing products containing 750 chemicals and other components....More than 650 of those products contained chemicals that are known or possible human carcinogens regulated under the Safe Water Drinking Act listed as hazardous air pollutants".* Appendix A lists the 650 chemicals used many of them carcinogenic. Whilst this sounds alarming, in fact most of them are rarely used or are in such dilute quantities that they do not constitute a significant hazard. The most widely used constituents (as reported in the 2011 US Congress Report) are summarised below in Table 1. Most US states have disclosure requirements for fraccing fluids.

Table 1. Chemical Components Appearing Most Often in Hydraulic Fracturing Products Used Between 2005 and 2009 (US Congress Report 2011)

(Number in brackets indicates the number of fraccing products that contain the chemical)

Methanol (Methyl alcohol) (342)
Isopropanol (Isopropyl alcohol, Propan-2-ol) (274)
Crystalline silica - quartz (SiO_2) (207)
Ethylene glycol monobutyl ether (2-butoxyethanol) (126)
Ethylene glycol (1,2-ethanediol) (119)
Hydrotreated light petroleum distillates (89)
Sodium hydroxide (Caustic soda) 80 (33)

An important point to make about fluid composition is that the US Congress report is concerned with fraccing for shale gas; compositions of CSG –related fraccing fluids are likely to differ quite significantly from those used in shale gas. Origin (www.origintogether.com) reports that its fraccing fluid for CSG production is typically composed of 97.4% water and 2.6% additives (see Table 2).

Table 2. Composition of fraccing fluid additives (reported by Origin, 2012)

Water 86-97%
Quartz sand 2-13%
Sodium hypochlorite 0.01-0.02%
Sodium hydroxide 0.002-0.1%
Acetic acid 0-0.1%
Potassium chloride 0.75-1.3%
Calcium chloride 0-0.0002%
MEA borate 0-0.1%
Guar Gum 0-0.2%
Sodium chloride 0-0.004%
Enzyme 0- 0.0002%
Sodium thiosulphate 0-0.04%

Obviously some components of fraccing fluids can have an adverse impact if present in aquifers in high concentrations, but for the most part there is likely to be sufficient dilution within the aquifer that concentrations will not exceed legal limit. In addition service providers are working to use smaller quantities of additives and develop more benign additives. Nonetheless fraccing fluid composition and the possibility of leakage into aquifers clearly is a sensitive issue, particularly where people and communities are dependent on groundwaters

f. Can fraccing cause earthquakes?

Fraccing produces small fractures within the target coal which in turn produce microseismic events which can be detected using sensitive instruments, but are generally far too small to be felt by humans. However recently in northwest England, following shale gas-related fraccing, significant though non-destructive earthquakes were felt over quite a wide region of northwest England and the company was required to cease all fraccing. In 2011 the UK

Parliament commissioned a study into the earthquakes, which concluded (April 2012) that they were related to fraccing. However the study also considered that the risk of damaging induced earthquakes was low and that it was reasonable to resume fraccing though with a number of new safeguards regarding seismic monitoring and operating procedures. Fraccing has now been resumed in the UK. In some instances the water produced from CSG wells is re injected into a geological reservoir using containing non-potable water. Injection of any fluid into the subsurface has the potential to produce movement on a pre-existing fault that could in turn result in seismic activity which may be felt by local communities. To avoid this, care has to be taken to avoid injecting at too high a pressure.

g. What is the experience of fraccing internationally?

The most extensive overseas experience of fraccing has been in the USA, mostly relating to shale gas production. A number of States have had moratoriums on fraccing from time to time (for example Pennsylvania and New York) in response to environmental concerns. A number of state and federal studies have been undertaken, that for the most part have found in favour of continued fraccing. Nonetheless the technique is controversial and there has been significant opposition from affected communities and NGOs. The recent film "Gaslands" served to reinforce the controversy in the minds of many people, with spectacular footage of flames coming from water taps, for example. The gas industry has countered with a number of points regarding what it sees as the inaccuracy of the film. France has recently (April 2012) passed legislation banning fraccing in response to pressure from NGOs and the Opposition, regarding environmental concerns. The issue is likely to end up in court as many companies have already undertaken exploration for shale gas and matters are no doubt being complicated by national elections.

h. What is the Queensland experience with fraccing and how might it compare with future NSW practices in CSG?

As pointed out earlier, the nature and extent of fraccing activity in Queensland is strongly influenced by geology, company practice and economics. Some CSG projects do not use fraccing and rely on the extensive use of horizontal wells for optimising permeability. The coals in the Bowen Basin of central Queensland are more favourable for fraccing than the younger thinner and more varied coals of the Surat and the Clarence –Moreton Basin of southern and southeastern Queensland. Therefore much of the comparison between NSW and Queensland has to on the basis of geology, with the Bowen Basin providing a Queensland example of the likely application of the technology in the contemporaneous Sydney and Gunnedah Basins, whereas the younger Surat and Clarence –Moreton Basins in Queensland provide examples not only of technology deployment in these basins in the NSW equivalent, but also of what can be achieved without the use of fraccing. The Queensland experience has clearly demonstrated throughout, the need for more effective communication of the challenges and the benefits of CSG production to the local and regional communities. Queensland has introduced strict regulatory requirements regarding fraccing and also the additives used in the fraccing fluid, as well as requirements for geochemical and geophysical monitoring conditions. NSW may benefit from examining the applicability of those regulations to NSW, including perhaps any need to revise them to fit with specific NSW conditions.

i. Are there other potential impacts from fraccing?

The fraccing operation itself may result in additional disruption to a landowner including additional site disturbance, extra vehicle movements and added noise. The Colorado School of Public Health reported that it had detected chemical such as benzene within half a mile of some fraccing wells in Colorado. This may point to poor operational procedures rather than a flaw in the fraccing process itself. In the case of fraccing associated with shale gas, the question has been raised whether elevated radon emissions could arise as a result of the fraccing process. The USEPA is currently examining this issue but will not be reporting on the issue until 2014. This has not been raised as an issue in the case of CSG-related fraccing.

j. How do shale gas and CSG fraccing differ?

Shale gas or tight gas as it is also known has become an increasingly important component of the global energy picture in the last decade and particularly in North America where it now provides more than 30% of the total gas supply for the USA. It is also receiving increased attention in Europe. Fraccing has been critical to the development of the otherwise tight and impermeable fine grained mudstones and shales that are found in many sedimentary basins and much of the controversy regarding fraccing has arisen through shale gas development rather than through CSG. This is largely because much more extensive and less selective fraccing is carried out in shale rocks. By comparison fraccing associated with CSG is carefully restricted to the coal seam. In Australia, shales likely to be productive for tight gas are found in a number of basins such as the Cooper Basin in South Australia (where there has already been some exploration). It is likely that suitable rocks occur in NSW, but to date there has been no major commercial drivers in Australia for shale gas development as conventional gas and CSG is abundant. However it is likely that in the future there will be increased interest in shale gas in eastern Australia and a consequential increase in fraccing to enable its development.

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Appendix A. Chemical Components of Hydraulic Fracturing Products, 2005-2009

(Final number in the row indicates number of fraccing products that contain the chemical)

1-(1-naphthylmethyl)quinolinium chloride 65322-65-8 1
1,2,3-propanetricarboxylic acid, 2-hydroxy-, trisodium salt, dihydrate 6132-04-3 1
1,2,3-trimethylbenzene 526-73-8 1
1,2,4-trimethylbenzene 95-63-6 21
1,2-benzisothiazol-3 2634-33-5 1
1,2-dibromo-2,4-dicyanobutane 35691-65-7 1
1,2-ethanediaminium, N, N'-bis[2-[bis(2-hydroxyethyl)methylammonio]ethyl]-N,N'-bis(2-hydroxyethyl)-N,N'-dimethyl-,tetrachloride 138879-94-4 2
1,3,5-trimethylbenzene 108-67-8 3
1,6-hexanediamine dihydrochloride 6055-52-3 1
1,8-diamino-3,6-dioxaoctane 929-59-9 1
1-hexanol 111-27-3 1
1-methoxy-2-propanol 107-98-2 3
2,2`-azobis (2-amidopropane) dihydrochloride 2997-92-4 1

2,2-dibromo-3-nitrilopropionamide 10222-01-2   27
2-acrylamido-2-methylpropanesulphonic acid sodium salt polymer   1
2-bromo-2-nitropropane-1,3-diol 52-51-7   4
2-butanone oxime 96-29-7 1
2-hydroxypropionic acid 79-33-4   2
2-mercaptoethanol (Thioglycol) 60-24-2   13
2-methyl-4-isothiazolin-3-one 2682-20-4   4
2-monobromo-3-nitrilopropionamide 1113-55-9   1
2-phosphonobutane-1,2,4-tricarboxylic acid 37971-36-1 2
2-phosphonobutane-1,2,4-tricarboxylic acid, potassium salt 93858-78-7   1
2-substituted aromatic amine salt *   1
4,4'-diaminodiphenyl sulfone 80-08-0   3
5-chloro-2-methyl-4-isothiazolin-3-one 26172-55-4   5
Acetaldehyde 75-07-0   1
Acetic acid 64-19-7   56
Acetic anhydride 108-24-7   7
Acetone 67-64-1   3
Acetophenone 98-86-2   1
Acetylenic alcohol *   1
Acetyltriethyl citrate 77-89-4   1
Acrylamide 79-06-1   2
Acrylamide copolymer *   1
Acrylamide copolymer 38193-60-1   1
Acrylate copolymer *   1
Acrylic acid, 2-hydroxyethyl ester 818-61-1   1
Acrylic acid/2-acrylamido-methylpropylsulfonic acid copolymer 37350-42-8   1
Acrylic copolymer 403730-32-5   1
Acrylic polymers * 1
Acrylic polymers 26006-22-4   2
Acyclic hydrocarbon blend *   1
Adipic acid 124-04-9   6
Alcohol alkoxylate *   5
Alcohol ethoxylates *   2
Alcohols *   9
Alcohols, C11-15-secondary, ethoxylated 68131-40-8   1
Alcohols, C12-14-secondary 126950-60-5   4
Alcohols, C12-14-secondary, ethoxylated 84133-50-6   19
Alcohols, C12-15, ethoxylated 68131-39-5   2
Alcohols, C12-16, ethoxylated 103331-86-8   1
Alcohols, C12-16, ethoxylated 68551-12-2   3
Alcohols, C14-15, ethoxylated 68951-67-7   5
Alcohols, C9-11-iso-, C10-rich, ethoxylated 78330-20-8   4
Alcohols, C9-C22 *   1
Aldehyde *   4
Aldol 107-89-1   1
Alfa-Alumina *   5
Aliphatic acid *   1
Aliphatic alcohol polyglycol ether 68015-67-8   1
Aliphatic amine derivative 120086-58-0   2
Alkaline bromide salts *   2

Alkanes, C10-14 93924-07-3 2
Alkanes, C13-16-iso 68551-20-2 2
Alkanolamine 150-25-4 3
Alkanolamine chelate of zirconium alkoxide (Zirconium complex) 197980-53-3 4
Alkanolamine/aldehyde condensate * 1
Alkenes * 1
Alkenes, C>10 alpha- 64743-02-8 3
Alkenes, C>8 68411-00-7 2
Alkoxylated alcohols * 1
Alkoxylated amines * 6
Alkoxylated phenol formaldehyde resin 63428-92-2 1
Alkyaryl sulfonate * 1
Alkyl (C12-16) dimethyl benzyl ammonium chloride 68424-85-1 7
Alkyl (C6-C12) alcohol, ethoxylated 68439-45-2 2
Alkyl (C9-11) alcohol, ethoxylated 68439-46-3 1
Alkyl alkoxylate * 9
Alkyl amine * 2
Alkyl amine blend in a metal salt solution * 1
Alkyl aryl amine sulfonate 255043-08-04 1
Alkyl benzenesulfonic acid 68584-22-5 2
Alkyl esters * 2
Alkyl hexanol * 1
Alkyl ortho phosphate ester * 1
Alkyl phosphate ester * 3
Alkyl quaternary ammonium chlorides * 4
Alkylaryl sulfonate * 1
Alkylaryl sulphonic acid 27176-9 5
Alkylbenzenesulfonic acid * 1
Alkylethoammonium sulfates * 1
Alkylphenol ethoxylates * 1
Almandite and pyrope garnet 1302-62-1 1
Aluminium isopropoxide 555-31-7 1
Aluminum 7429-90-5 2
Aluminum chloride * 3
Aluminum chloride 1327-41-9 2
Aluminum oxide (alpha-Alumina) 1344-28-1 24
Aluminum oxide silicate 12068-56-3 1
Aluminum silicate (mullite) 1302-76-7 38
Aluminum sulfate hydrate 10043-01-3 1
Amides, tallow, n-[3-(dimethylamino)propyl],n-oxides 68647-77-8 4
Amidoamine * 1
Amine * 7
Amine bisulfite 13427-63-9 1
Amine oxides * 1
Amine phosphonate * 3
Amine salt * 2
Amines, C14-18; C16-18-unsaturated, alkyl, ethoxylated 68155-39-5 1
Amines, coco alkyl, acetate 61790-57-6 3
Amines, polyethylenepoly-, ethoxylated, phosphonomethylated 68966-36-9 1
Amines, tallow alkyl, ethoxylated 61791-26-2 2

Amino compounds	*	1
Amino methylene phosphonic acid salt	*	1
Amino trimethylene phosphonic acid	6419-19-8	2
Ammonia	7664-41-7	7
Ammonium acetate	631-61-8	4
Ammonium alcohol ether sulfate	68037-05-8	1
Ammonium bicarbonate	1066-33-7	1
Ammonium bifluoride (Ammonium hydrogen difluoride)	1341-49-7	10
Ammonium bisulfate	7783-20-2	3
Ammonium bisulfite	10192-30-0	15
Ammonium C6-C10 alcohol ethoxysulfate	68187-17-7	4
Ammonium C8-C10 alkyl ether sulfate	68891-29-2	4
Ammonium chloride	12125-02-9	29
Ammonium fluoride	12125-01-8	9
Ammonium hydroxide	1336-21-6	4
Ammonium nitrate	6484-52-2	2
Ammonium persulfate (Diammonium peroxidisulfate)	7727-54-0	37
Ammonium salt	*	1
Ammonium salt of ethoxylated alcohol sulfate	*	1
Amorphous silica	99439-28-8	1
Amphoteric alkyl amine	61789-39-7	1
Anionic copolymer	*	3
Anionic polyacrylamide	*	1
Anionic polyacrylamide	25085-02-3	6
Anionic polyacrylamide copolymer	*	3
Anionic polymer	*	2
Anionic polymer in solution	*	1
Anionic polymer, sodium salt	9003-04-7	1
Anionic water-soluble polymer	*	2
Antifoulant	*	1
Antimonate salt	*	1
Antimony pentoxide	1314-60-9	2
Antimony potassium oxide	29638-69-5	4
Antimony trichloride	10025-91-9	2
a-organic surfactants	61790-29-8	1
Aromatic alcohol glycol ether	*	2
Aromatic aldehyde	*	2
Aromatic ketones	224635-63-6	2
Aromatic polyglycol ether	*	1
Barium sulfate	7727-43-7	3
Bauxite	1318-16-7	16
Bentonite	1302-78-9	2
Benzene	71-43-2	3
Benzene, C10-16, alkyl derivatives	68648-87-3	1
Benzenecarboperoxoic acid, 1,1-dimethylethyl ester	614-45-9	1
Benzenemethanaminium	3844-45-9	1
Benzenesulfonic acid, C10-16-alkyl derivs., potassium salts	68584-27-0	1
Benzoic acid	65-85-0	11
Benzyl chloride	100-44-7	8
Biocide component	*	3

Bis(1-methylethyl)naphthalenesulfonic acid, cyclohexylamine salt 68425-61-6 1
Bishexamethylenetriamine penta methylene phosphonic acid 35657-77-3 1
Bisphenol A/Epichlorohydrin resin 25068-38-6 5
Bisphenol A/Novolac epoxy resin 28906-96-9 1
Borate 12280-03-4 2
Borate salts * 5
Boric acid 10043-35-3 18
Boric acid, potassium salt 20786-60-1 1
Boric acid, sodium salt 1333-73-9 2
Boric oxide 1303-86-2 1
b-tricalcium phosphate 7758-87-4 1
Butanedioic acid 2373-38-8 4
Butanol 71-36-3 3
Butyl glycidyl ether 2426-08-6 5
Butyl lactate 138-22-7 4
C10-C16 ethoxylated alcohol 68002-97-1 4
C-11 to C-14 n-alkanes, mixed * 1
C12-C14 alcohol, ethoxylated 68439-50-9 3
Calcium carbonate 471-34-1 1
Calcium carbonate (Limestone) 1317-65-3 9
Calcium chloride 10043-52-4 17
Calcium chloride, dihydrate 10035-04-8 1
Calcium fluoride 7789-75-5 2
Calcium hydroxide 1305-62-0 9
Calcium hypochlorite 7778-54-3 1
Calcium oxide 1305-78-8 6
Calcium peroxide 1305-79-9 5
Carbohydrates * 3
Carbon dioxide 124-38-9 4
Carboxymethyl guar gum, sodium salt 39346-76-4 7
Carboxymethyl hydroxypropyl guar 68130-15-4 11
Cellophane 9005-81-6 2
Cellulase 9012-54-8 7
Cellulase enzyme * 1
Cellulose 9004-34-6 1
Cellulose derivative * 2
Chloromethylnaphthalene quinoline quaternary amine 15619-48-4 3
Chlorous ion solution * 2
Choline chloride 67-48-1 3
Chromates * 1
Chromium (iii) acetate 1066-30-4 1
Cinnamaldehyde (3-phenyl-2-propenal) 104-55-2 5
Citric acid (2-hydroxy-1,2,3 propanetricarboxylic acid) 77-92-9 29
Citrus terpenes 94266-47-4 11
Coal, granular 50815-10-6 1
Cobalt acetate 71-48-7 1
Cocaidopropyl betaine 61789-40-0 2
Cocamidopropylamine oxide 68155-09-9 1
Coco bis-(2-hydroxyethyl) amine oxide 61791-47-7 1
Cocoamidopropyl betaine 70851-07-9 1

Cocomidopropyl dimethylamine 68140-01-2 1
Coconut fatty acid diethanolamide 68603-42-9 1
Collagen (Gelatin) 9000-70-8 6
Complex alkylaryl polyo-ester * 1
Complex aluminum salt * 2
Complex organometallic salt * 2
Complex substituted keto-amine 143106-84-7 1
Complex substituted keto-amine hydrochloride * 1
Copolymer of acrylamide and sodium acrylate 25987-30-8 1
Copper 7440-50-8 1
Copper iodide 7681-65-4 1
Copper sulfate 7758-98-7 3
Corundum (Aluminum oxide) 1302-74-5 48
Crotonaldehyde 123-73-9 1
Crystalline silica - cristobalite 14464-46-1 44
Crystalline silica - quartz (SiO2) 14808-60-7 207
Crystalline silica, tridymite 15468-32-3 2
Cumene 98-82-8 6
Cupric chloride 7447-39-4 10
Cupric chloride dihydrate 10125-13-0 7
Cuprous chloride 7758-89-6 1
Cured acrylic resin * 7
Cured resin * 4
Cured silicone rubber-polydimethylsiloxane 63148-62-9 1
Cured urethane resin * 3
Cyclic alkanes * 1
Cyclohexane 110-82-7 1
Cyclohexanone 108-94-1 1
Decanol 112-30-1 2
Decyl-dimethyl amine oxide 2605-79-0 4
Dextrose monohydrate 50-99-7 1
D-Glucitol 50-70-4 1
Di (2-ethylhexyl) phthalate 117-81-7 3
Di (ethylene glycol) ethyl ether acetate 112-15-2 4
Diatomaceous earth 61790-53-2 3
Diatomaceous earth, calcined 91053-39-3 7
Dibromoacetonitrile 3252-43-5 1
Dibutylaminoethanol (2-dibutylaminoethanol) 102-81-8 4
Di-calcium silicate 10034-77-2 1
Dicarboxylic acid * 1
Didecyl dimethyl ammonium chloride 7173-51-5 1
Diesel * 1
Diesel 68334-30-5 3
Diesel 68476-30-2 4
Diesel 68476-34-6 43
Diethanolamine (2,2-iminodiethanol) 111-42-2 14
Diethylbenzene 25340-17-4 1
Diethylene glycol 111-46-6 8
Diethylene glycol monomethyl ether 111-77-3 4
Diethylene triaminepenta (methylene phosphonic acid) 15827-60-8 1

Diethylenetriamine 111-40-0 2
Diethylenetriamine, tall oil fatty acids reaction product 61790-69-0 1
Diisopropylnaphthalenesulfonic acid 28757-00-8 2
Dimethyl formamide 68-12-2 5
Dimethyl glutarate 1119-40-0 1
Dimethyl silicone * 2
Dioctyl sodium sulfosuccinate 577-11-7 1
Dipropylene glycol 25265-71-8 1
Dipropylene glycol monomethyl ether (2-methoxymethylethoxy propanol) 34590-94-8 12
Di-secondary-butylphenol 53964-94-6 3
Disodium EDTA 139-33-3 1
Disodium ethylenediaminediacetate 38011-25-5 1
Disodium ethylenediaminetetraacetate dihydrate 6381-92-6 1
Disodium octaborate tetrahydrate 12008-41-2 1
Dispersing agent * 1
d-Limonene 5989-27-5 11
Dodecyl alcohol ammonium sulfate 32612-48-9 2
Dodecylbenzene sulfonic acid 27176-87-0 14
Dodecylbenzene sulfonic acid salts 42615-29-2 2
Dodecylbenzene sulfonic acid salts 68648-81-7 7
Dodecylbenzene sulfonic acid salts 90218-35-2 1
Dodecylbenzenesulfonate isopropanolamine 42504-46-1 1
Dodecylbenzenesulfonic acid, monoethanolamine salt 26836-07-7 1
Dodecylbenzenesulphonic acid, morpholine salt 12068-08-5 1
EDTA/Copper chelate * 2
EO-C7-9-iso-, C8-rich alcohols 78330-19-5 5
Epichlorohydrin 25085-99-8 5
Epoxy resin * 5
Erucic amidopropyl dimethyl betaine 149879-98-1 3
Erythorbic acid 89-65-6 2
Essential oils * 6
Ethanaminium, n,n,n-trimethyl-2-[(1-oxo-2-propenyl)oxy]-,chloride, polymer with 2-propenamide 69418-26-4 4
Ethanol (Ethyl alcohol) 64-17-5 36
Ethanol, 2-(hydroxymethylamino)- 34375-28-5 1
Ethanol, 2, 2'-(Octadecylamino) bis- 10213-78-2 1
Ethanoldiglycine disodium salt 135-37-5 1
Ether salt 25446-78-0 2
Ethoxylated 4-nonylphenol (Nonyl phenol ethoxylate) 26027-38-3 9
Ethoxylated alcohol 104780-82-7 1
Ethoxylated alcohol 78330-21-9 2
Ethoxylated alcohols * 3
Ethoxylated alkyl amines * 1
Ethoxylated amine * 1
Ethoxylated amines 61791-44-4 1
Ethoxylated fatty acid ester * 1
Ethoxylated nonionic surfactant * 1
Ethoxylated nonyl phenol * 8
Ethoxylated nonyl phenol 68412-54-4 10

Ethoxylated nonyl phenol 9016-45-9   38
Ethoxylated octyl phenol 68987-90-6   1
Ethoxylated octyl phenol 9002-93-1   1
Ethoxylated octyl phenol 9036-19-5   3
Ethoxylated oleyl amine 13127-82-7   2
Ethoxylated oleyl amine 26635-93-8   1
Ethoxylated sorbitol esters *   1   2
Ethoxylated undecyl alcohol 127036-24-2   2
Ethyl acetate 141-78-6   4
Ethyl acetoacetate 141-97-9   1
Ethyl octynol (1-octyn-3-ol,4-ethyl-) 5877-42-9   5
Ethylbenzene 100-41-4   28
Ethylene glycol (1,2-ethanediol) 107-21-1   119
Ethylene glycol monobutyl ether (2-butoxyethanol) 111-76-2   126
Ethylene oxide 75-21-8   1
Ethylene oxide-nonylphenol polymer *   1
Ethylenediaminetetraacetic acid 60-00-4   1
Ethylene-vinyl acetate copolymer 24937-78-8   1
Ethylhexanol (2-ethylhexanol) 104-76-7   18
Fatty acid ester *   1
Fatty acid, tall oil, hexa esters with sorbitol, ethoxylated 61790-90-7   1
Fatty acids *   1
Fatty alcohol alkoxylate *   1
Fatty alkyl amine salt *   1
Fatty amine carboxylates *   1
Fatty quaternary ammonium chloride 61789-68-2   1
Ferric chloride 7705-08-0 3
Ferric sulfate 10028-22-5   7
Ferrous sulfate, heptahydrate 7782-63-0   4
Fluoroaliphatic polymeric esters *   1
Formaldehyde 50-00-0   12
Formaldehyde polymer *   2
Formaldehyde, polymer with 4-(1,1-dimethyl)phenol, methyloxirane and oxirane 30704-64-4 3
Formaldehyde, polymer with 4-nonylphenol and oxirane 30846-35-6   1
Formaldehyde, polymer with ammonia and phenol 35297-54-2   2
Formamide 75-12-7   5
Formic acid 64-18-6   24
Fumaric acid 110-17-8   8
Furfural 98-01-1   1
Furfuryl alcohol 98-00-0   3
Glass fiber 65997-17-3   3
Gluconic acid 526-95-4   1
Glutaraldehyde 111-30-8   20
Glycerol (1,2,3-Propanetriol, Glycerine) 56-81-5   16
Glycol ethers *   9
Glycol ethers 9004-77-7   4
Glyoxal 107-22-2   3
Glyoxylic acid 298-12-4 1
Guar gum 9000-30-0   41

Guar gum derivative * 12
Haloalkyl heteropolycycle salt * 6
Heavy aromatic distillate 68132-00-3 1
Heavy aromatic petroleum naphtha 64742-94-5 45
Heavy catalytic reformed petroleum naphtha 64741-68-0 10
Hematite * 5
Hemicellulase 9025-56-3 2
Hexahydro-1,3,5-tris(2-hydroxyethyl)-s-triazine (Triazine) 4719-04-4 4
Hexamethylenetetramine 100-97-0 37
Hexanediamine 124-09-4 1
Hexanes * 1
Hexylene glycol 107-41-5 5
Hydrated aluminum silicate 1332-58-7 4
Hydrocarbon mixtures 8002-05-9 1
Hydrocarbons * 3
Hydrodesulfurized kerosine (petroleum) 64742-81-0 3
Hydrodesulfurized light catalytic cracked distillate (petroleum) 68333-25-5 1
Hydrodesulfurized middle distillate (petroleum) 64742-80-9 1
Hydrogen chloride (Hydrochloric acid) 7647-01-0 42
Hydrogen fluoride (Hydrofluoric acid) 7664-39-3 2
Hydrogen peroxide 7722-84-1 4
Hydrogen sulfide 7783-06-4 1
Hydrotreated and hydrocracked base oil * 2
Hydrotreated heavy naphthenic distillate 64742-52-5 3
Hydrotreated heavy paraffinic petroleum distillates 64742-54-7 122
Hydrotreated heavy petroleum naphtha 64742-48-9 7
Hydrotreated light petroleum distillates 64742-47-8 89
Hydrotreated middle petroleum distillates 64742-46-7 3
Hydroxyacetic acid (Glycolic acid) 79-14-1 6
Hydroxyethylcellulose 9004-62-0 1
Hydroxyethylethylenediaminetriacetic acid, trisodium salt 139-89-9 1
Hydroxylamine hydrochloride 5470-11-1 1
Hydroxypropyl guar gum 39421-75-5 2
Hydroxysultaine * 1
Inner salt of alkyl amines * 2
Inorganic borate * 3
Inorganic particulate * 1
Inorganic salt * 1
Inorganic salt 533-96-0 1
Inorganic salt 7446-70-0 1
Instant coffee purchased off the shelf * 1
Inulin, carboxymethyl ether, sodium salt 430439-54-6 1
Iron oxide 1332-37-2 2
Iron oxide (Ferric oxide) 1309-37-1 18
Iso amyl alcohol 123-51-3 1
Iso-alkanes/n-alkanes * 10
Isobutanol (Isobutyl alcohol) 78-83-1 4
Isomeric aromatic ammonium salt * 1
Isooctanol 26952-21-6 1
Isooctyl alcohol 68526-88-0 1

Isooctyl alcohol bottoms 68526-88-5 1
Isopropanol (Isopropyl alcohol, Propan-2-ol) 67-63-0   274
Isopropylamine 75-31-0   1
Isotridecanol, ethoxylated 9043-30-5   1
Kerosene 8008-20-6   13
Lactic acid 10326-41-7   1
Lactic acid 50-21-5   1
L-Dilactide 4511-42-6   1
Lead 7439-92-1   1
Light aromatic solvent naphtha 64742-95-6   11
Light catalytic cracked petroleum distillates 64741-59-9   1
Light naphtha distillate, hydrotreated 64742-53-6 1
Low toxicity base oils *   1
Maghemite *   2
Magnesium carbonate 546-93-0   1
Magnesium chloride 7786-30-3   4
Magnesium hydroxide 1309-42-8   4
Magnesium iron silicate 1317-71-1   3
Magnesium nitrate 10377-60-3   5
Magnesium oxide 1309-48-4   18
Magnesium peroxide 1335-26-8   2
Magnesium peroxide 14452-57-4   4
Magnesium phosphide 12057-74-8   1
Magnesium silicate 1343-88-0   3
Magnesium silicate hydrate (talc) 14807-96-6   2
Magnetite *   3
Medium aliphatic solvent petroleum naphtha 64742-88-7   10
Metal salt *   2
Metal salt solution *   1
Methanol (Methyl alcohol) 67-56-1   342
Methyl isobutyl carbinol (Methyl amyl alcohol) 108-11-2   3
Methyl salicylate 119-36-8   6
Methyl vinyl ketone 78-94-4   2
Methylcyclohexane 108-87-2   1
Mica 12001-26-2   3
Microcrystalline silica 1317-95-9   1
Mineral *   1
Mineral Filler *   1
Mineral spirits (stoddard solvent) 8052-41-3   2
Mixed titanium ortho ester complexes *   1
Modified alkane * 1
Modified cycloaliphatic amine adduct *   3
Modified lignosulfonate *   1
Monoethanolamine (Ethanolamine) 141-43-5   17
Monoethanolamine borate 26038-87-9   1
Morpholine 110-91-8 2
Mullite 1302-93-8   55   1
N,N-dimethyl-1-octadecanamine-HCl *   1
N,N-dimethyloctadecylamine 124-28-7   3
N,N-dimethyloctadecylamine hydrochloride 1613-17-8   2

n,n'-Methylenebisacrylamide 110-26-9 1
n-alkyl dimethyl benzyl ammonium chloride 139-08-2 1
Naphthalene 91-20-3 44
Naphthalene derivatives * 1
Naphthalenesulphonic acid, bis (1-methylethyl)-methyl derivatives 99811-86-6 1
Natural asphalt 12002-43-6 1
n-cocoamidopropyl-n,n-dimethyl-n-2-hydroxypropylsulfobetaine 68139-30-0 1
n-dodecyl-2-pyrrolidone 2687-96-9 1
N-heptane 142-82-5 1
Nickel sulfate hexahydrate 10101-97-0 2
Nitrilotriacetamide 4862-18-4 4
Nitrilotriacetic acid 139-13-9 6
Nitrilotriacetonitrile 7327-60-8 3
Nitrogen 7727-37-9 9
n-Methylpyrrolidone 872-50-4 1
Nonane, all isomers * 1
Non-hazardous salt * 1
Nonionic surfactant * 1
Nonyl phenol ethoxylate * 2
Nonyl phenol ethoxylate 9016-45-6 2
Nonyl phenol ethoxylate 9018-45-9 1
Nonylphenol 25154-52-3 1
Nonylphenol, ethoxylated and sulfated 9081-17-8 1
N-propyl zirconate * 1
N-tallowalkyltrimethylenediamines * 1
Nuisance particulates * 2
Nylon fibers 25038-54-4 2
Octanol 111-87-5 2
Octyltrimethylammonium bromide 57-09-0 1
Olefinic sulfonate * 1
Olefins * 1
Organic acid salt * 3
Organic acids * 1
Organic phosphonate * 1
Organic phosphonate salts * 1
Organic phosphonic acid salts * 6
Organic salt * 1
Organic sulfur compound * 2
Organic titanate * 2
Organiophilic clay * 2
Organo-metallic ammonium complex * 1
Other inorganic compounds * 1
Oxirane, methyl-, polymer with oxirane, mono-C10-16-alkyl ethers, phosphates 68649-29-6 1
Oxyalkylated alcohol * 6
Oxyalkylated alcohols 228414-35-5 1
Oxyalkylated alkyl alcohol * 1
Oxyalkylated alkylphenol * 1
Oxyalkylated fatty acid * 2
Oxyalkylated phenol * 1

Oxyalkylated polyamine * 1
Oxylated alcohol * 1
Paraffin wax 8002-74-2 1
Paraffinic naphthenic solvent * 1
Paraffinic solvent * 5
Paraffins * 1
Perlite 93763-70-3 1
Petroleum distillates * 26
Petroleum distillates 64742-65-0 1
Petroleum distillates 64742-97-5 1
Petroleum distillates 68477-31-6 3
Petroleum gas oils * 1
Petroleum gas oils 64741-43-1 1
Phenol 108-95-2 5
Phenol-formaldehyde resin 9003-35-4 32
Phosphate ester * 6
Phosphate esters of alkyl phenyl ethoxylate 68412-53-3 1
Phosphine * 1
Phosphonic acid * 1
Phosphonic acid 129828-36-0 1
Phosphonic acid 13598-36-2 3
Phosphonic acid (dimethlamino(methylene)) 29712-30-9 1
Phosphonic acid, [nitrilotris(methylene)]tris-, pentasodium salt 2235-43-0 1
Phosphoric acid 7664-38-2 7
Phosphoric acid ammonium salt * 1
Phosphoric acid, mixed decyl, octyl and ethyl esters 68412-60-2 3
Phosphorous acid 10294-56-1 1
Phthalic anhydride 85-44-9 2
Pine oil 8002-09-3 5
Plasticizer * 1
Poly(oxy-1,2-ethanediyl) 24938-91-8 1
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched (Nonylphenol ethoxylate) 127087-87-0 3
Poly(oxy-1,2-ethanediyl), alpha-hydro-omega-hydroxy 65545-80-4 1
Poly(oxy-1,2-ethanediyl), alpha-sulfo-omega-(hexyloxy)-, ammonium salt 63428-86-4 3
Poly(oxy-1,2-ethanediyl),a-(nonylphenyl)-w-hydroxy-, phosphate 51811-79-1 1
Poly-(oxy-1,2-ethanediyl)-alpha-undecyl-omega-hydroxy 34398-01-1 6
Poly(sodium-p-styrenesulfonate) 25704-18-1 1
Poly(vinyl alcohol) 25213-24-5 2
Polyacrylamides 9003-05-8 2
Polyacrylamides * 1
Polyacrylate * 1
Polyamine * 2
Polyanionic cellulose * 2
Polyepichlorohydrin, trimethylamine quaternized 51838-31-4 1
Polyetheramine 9046-10-0 3
Polyether-modified trisiloxane 27306-78-1 1
Polyethylene glycol 25322-68-3 20
Polyethylene glycol ester with tall oil fatty acid 9005-02-1 1

Polyethylene polyammonium salt 68603-67-8   2
Polyethylene-polypropylene glycol 9003-11-6   5
Polylactide resin *   3
Polyoxyalkylenes *   1
Polyoxyethylene castor oil 61791-12-6   1
Polyphosphoric acid, esters with triethanolamine, sodium salts 68131-72-6   1
Polypropylene glycol 25322-69-4   1
Polysaccharide *   20
Polyvinyl alcohol *   1
Polyvinyl alcohol 9002-89-5   2
Polyvinyl alcohol/polyvinylacetate copolymer *   1
Potassium acetate 127-08-2   1
Potassium carbonate 584-08-7   12
Potassium chloride 7447-40-7   29
Potassium formate 590-29-4   3
Potassium hydroxide 1310-58-3 25
Potassium iodide 7681-11-0   6
Potassium metaborate 13709-94-9   3
Potassium metaborate 16481-66-6   3
Potassium oxide 12136-45-7   1
Potassium pentaborate *   1
Potassium persulfate 7727-21-1   9
Propanol (Propyl alcohol) 71-23-8   18
Propanol, [2(2-methoxy-methylethoxy) methylethoxyl] 20324-33-8   1
Propargyl alcohol (2-propyn-1-ol) 107-19-7   46
Propylene carbonate (1,3-dioxolan-2-one, methyl-) 108-32-7   2
Propylene glycol (1,2-propanediol) 57-55-6   18
Propylene oxide 75-56-9   1
Propylene pentamer 15220-87-8   1
p-Xylene 106-42-3   1
Pyridinium, 1-(phenylmethyl)-, ethyl methyl derivatives, chlorides 68909-18-2   9
Pyrogenic silica 112945-52-5   3
Quaternary amine compounds *   3
Quaternary amine compounds 61789-18-2   1
Quaternary ammonium compounds *   9
Quaternary ammonium compounds 19277-88-4   1
Quaternary ammonium compounds 68989-00-4   1
Quaternary ammonium compounds 8030-78-2   1
Quaternary ammonium compounds, dicoco alkyldimethyl, chlorides 61789-77-3   2
Quaternary ammonium salts *   2
Quaternary compound *   1
Quaternary salt *   2
Quaternized alkyl nitrogenated compound 68391-11-7   2
Rafinnates (petroleum), sorption process 64741-85-1   2
Residues (petroleum), catalytic reformer fractionator 64741-67-9   10
Resin 8050-09-7   2
Rutile 1317-80-2   2
Salt of phosphate ester *   3
Salt of phosphono-methylated diamine *   1
Salts of oxyalkylated fatty amines 68551-33-7   1

Secondary alcohol * 7
Silica (Silicon dioxide) 7631-86-9 47
Silica, amorphous * 3
Silica, amorphous precipitated 67762-90-7 1
Silicon carboxylate 681-84-5 1
Silicon dioxide (Fused silica) 60676-86-0 7
Silicone emulsion * 1
Sodium (C14-16) olefin sulfonate 68439-57-6 4
Sodium 2-ethylhexyl sulfate 126-92-1 1
Sodium acetate 127-09-3 6
Sodium acid pyrophosphate 7758-16-9 5
Sodium alkyl diphenyl oxide sulfonate 28519-02-0 1
Sodium aluminate 1302-42-7 1
Sodium aluminum phosphate 7785-88-8 1
Sodium bicarbonate (Sodium hydrogen carbonate) 144-55-8 10
Sodium bisulfite 7631-90-5 6
Sodium bromate 7789-38-0 10
Sodium bromide 7647-15-6 1
Sodium carbonate 497-19-8 14
Sodium chlorate 7775-09-9 1
Sodium chloride 7647-14-5 48
Sodium chlorite 7758-19-2 8
Sodium cocaminopropionate 68608-68-4 2
Sodium diacetate 126-96-5 2
Sodium erythorbate 6381-77-7 4
Sodium glycolate 2836-32-0 2
Sodium hydroxide (Caustic soda) 1310-73-2 80
Sodium hypochlorite 7681-52-9 14
Sodium lauryl-ether sulfate 68891-38-3 3
Sodium metabisulfite 7681-57-4 1
Sodium metaborate 7775-19-1 2
Sodium metaborate tetrahydrate 35585-58-1 6
Sodium metasilicate, anhydrous 6834-92-0 2
Sodium nitrite 7632-00-0 1
Sodium oxide (Na2O) 1313-59-3 1
Sodium perborate 1113-47-9 1
Sodium perborate 7632-04-4 1
Sodium perborate tetrahydrate 10486-00-7 4
Sodium persulfate 7775-27-1 6
Sodium phosphate * 2
Sodium polyphosphate 68915-31-1 1
Sodium salicylate 54-21-7 1
Sodium silicate 1344-09-8 2
Sodium sulfate 7757-82-6 7
Sodium tetraborate 1330-43-4 7
Sodium tetraborate decahydrate 1303-96-4 10
Sodium thiosulfate 7772-98-7 10
Sodium thiosulfate pentahydrate 10102-17-7 3
Sodium trichloroacetate 650-51-1 1
Sodium tripolyphosphate 7758-29-4 2

Sodium xylene sulfonate 1300-72-7 3
Sodium zirconium lactate 174206-15-6 1
Solvent refined heavy naphthenic petroleum distillates 64741-96-4 1
Sorbitan monooleate 1338-43-8 1
Stabilized aqueous chlorine dioxide 10049-04-4 1
Stannous chloride 7772-99-8 1
Stannous chloride dihydrate 10025-69-1 6
Starch 9005-25-8 5
Steam cracked distillate, cyclodiene dimer, dicyclopentadiene polymer 68131-87-3 1
Steam-cracked petroleum distillates 64742-91-2 6
Straight run middle petroleum distillates 64741-44-2 5
Substituted alcohol * 2
Substituted alkene * 1
Substituted alkylamine * 2
Sucrose 57-50-1 1
Sulfamic acid 5329-14-6 6
Sulfate * 1
Sulfonate acids * 1
Sulfonate surfactants * 1
Sulfonic acid salts * 1
Sulfonic acids, petroleum 61789-85-3 1
Sulfur compound * 1
Sulfuric acid 7664-93-9 9
Sulfuric acid, monodecyl ester, sodium salt 142-87-0 2
Sulfuric acid, monooctyl ester, sodium salt 142-31-4 2
Surfactants * 13
Sweetened middle distillate 64741-86-2 1
Synthetic organic polymer 9051-89-2 2
Tall oil (Fatty acids) 61790-12-3 4
Tall oil, compound with diethanolamine 68092-28-4 1
Tallow soap * 2
Tar bases, quinoline derivatives, benzyl chloride-quaternized 72480-70-7 5
Tergitol 68439-51-0 1
Terpene hydrocarbon byproducts 68956-56-9 3
Terpenes * 1
Terpenes and terpenoids, sweet orange-oil 68647-72-3 2
Terpineol 8000-41-7 1
Tert-butyl hydroperoxide 75-91-2 6
Tetra-calcium-alumino-ferrite 12068-35-8 1
Tetraethylene glycol 112-60-7 1
Tetraethylenepentamine 112-57-2 2
Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione (Dazomet) 533-74-4 13
Tetrakis (hydroxymethyl) phosphonium sulfate 55566-30-8 12
Tetramethyl ammonium chloride 75-57-0 14
Tetrasodium 1-hydroxyethylidene-1,1-diphosphonic acid 3794-83-0 1
Tetrasodium ethylenediaminetetraacetate 64-02-8 10
Thiocyanate sodium 540-72-7 1
Thioglycolic acid 68-11-1 6
Thiourea 62-56-6 9

Thiourea polymer 68527-49-1   3
Titanium complex *   1
Titanium oxide 13463-67-7   19
Titanium, isopropoxy (triethanolaminate) 74665-17-1   2
Toluene 108-88-3   29
Treated ammonium chloride (with anti-caking agent a or b) 12125-02-9   1
Tributyl tetradecyl phosphonium chloride 81741-28-8   5
Tri-calcium silicate 12168-85-3   1
Tridecyl alcohol 112-70-9   1
Triethanolamine (2,2,2-nitrilotriethanol) 102-71-6   21
Triethanolamine polyphosphate ester 68131-71-5   3
Triethanolamine titanate 36673-16-2   1
Triethanolamine zirconate 101033-44-7   6
Triethanolamine zirconium chelate *   1
Triethyl citrate 77-93-0   1
Triethyl phosphate 78-40-0   1
Triethylene glycol 112-27-6   3
Triisopropanolamine 122-20-3   5
Trimethylammonium chloride 593-81-7   1
Trimethylbenzene 25551-13-7   5
Trimethyloctadecylammonium (1-octadecanaminium, N,N,N-trimethyl-, chloride) 112-03-8   6
Tris(hydroxymethyl)aminomethane 77-86-1   1
Trisodium ethylenediaminetetraacetate 150-38-9   1
Trisodium ethylenediaminetriacetate 19019-43-3   1
Trisodium nitrilotriacetate 18662-53-8   8
Trisodium nitrilotriacetate (Nitrilotriacetic acid, trisodium salt monohydrate) 5064-31-3   9
Trisodium ortho phosphate 7601-54-9   1
Trisodium phosphate dodecahydrate 10101-89-0   1
Ulexite 1319-33-1   1
Urea 57-13-6   3
Wall material *   1
Walnut hulls *   2
White mineral oil 8042-47-5   8
Xanthan gum 11138-66-2   6
Xylene 1330-20-7   44
Zinc chloride 7646-85-7   1
Zinc oxide 1314-13-2   2
Zirconium complex *   10
Zirconium dichloride oxide 7699-43-6   1
Zirconium oxide sulfate 62010-10-0   2
Zirconium sodium hydroxy lactate complex (Sodium zirconium lactate) 113184-20-6 2

* *Components marked with an asterisk appeared on at least one MSDS without an identifying CAS number.*