

Review of the DRAFT  
Supplemental Generic Environmental Impact Statement  
on the Oil, Gas and Solution Mining Regulatory Program

Toxicity and Exposure to Substances in Fracturing Fluids and in the  
Wastewater Associated with the Hydrocarbon-Bearing Shale

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This review is focused on the risk of exposure and adverse impacts from wastewater generated by shale gas development. The primary sources of wastewater are: (1) hydraulic fracture fluid waste that flows back out of the well after wellbore stimulation (“flowback”) and (2) formation water that is produced along with shale gas (also called “produced water” or “production brines”). These two sources of waste combine to form shale gas wastewater streams that require careful review, consideration, and regulation by the NYSDEC.

Hydraulic fracturing flowback not only contains chemicals added during well stimulation, but also includes constituents present in the shale zone formation water that may be released during the hydraulic fracturing process. The data in the DSGEIS is insufficient to adequately evaluate this risk. The DSGEIS provides a general laundry list of chemicals that may potentially be used in hydraulic fracturing fluids; however, the actual formulation and the quantities of each chemical in use is only discussed in minimal terms. There is no information to describe the potential chemical interactions that may also result in additional contaminants formed in the wastewater.

The DSGEIS lacks sufficient information to conduct a risk assessment. A risk assessment for the hydraulic fracturing process requires an understanding of both the specific toxicity of each chemical used in fracturing or produced in waste and the quantities of each chemical used or produced, in order to estimate the potential for exposure. Neither requirement is satisfied in the DSGEIS.

Additionally, there is only scant information on the quality of the existing, in-situ formation water or the water that will be produced from the formation following hydraulic fracturing (produced water). Table 5-9 provides a small amount of data that indicates that the shale gas

formation water quality is very poor, and the produced water that flows out of the well as the gas is produced will contain a variety of toxic and carcinogenic substances, most of which are not contained in the fracturing additives. Clearly the produced water alone is a pollution source, and the addition of fracture treatment chemicals only degrades the water quality further. In my opinion, effectively *any* contamination of surface or groundwater with the combined wastewater produced (produced water and fracture fluid flowback) would render that surface or groundwater unusable for domestic purposes or, potentially, for wildlife. The level of naturally occurring radioactive material (NORM) in the water is very high and in some cases over 1000 times higher in specific contaminants loads than drinking water standards. Clearly the amount of radioactive material in the wastewater, alone, makes the shale gas wastewater a serious environmental and human health issue that must be attended to by NYS.

**I. The additives used in the hydraulic fracturing process are not well defined, and the DSGEIS essentially provides only a laundry list of chemicals that *may* be used in the process.**

The lack of information about the specific chemical components of the fracturing additives is a major concern regarding the hydraulic fracturing process. Many additives are reported simply as commercial products, without specific chemical information to show what the product is actually made of. While the full composition may have been disclosed to the regulatory agency for some of the additives (Table 5-3), only a partial chemical composition has been disclosed for others (Table 5-4). However, the lack of specific information on the identity, quantity, and use of the chemicals prevents the public, including scientists and health professionals, from assessing the risk posed by these chemicals. The chemicals are partially listed by use in Table 5-5, and a list of the approximately 258 chemicals extracted from the chemical compositions and Material Safety Data Sheets submitted to NYSDEC is presented in Table 5-6. However, this presentation is still insufficient to assess the overall potential for an impact on human health and the environment. The DSGEIS does not provide a firm list of chemicals that are allowed for use, does not verify which will actually be used, and does not describe the effects of the chemical combinations. There is no assessment of the actual range of chemicals that may be present in produced water, or in fracture flowback wastewater, or of the potential air or water pollution exposure. Quantities of the specific chemicals which can potentially be released into the environment are required for an assessment of exposure and, finally, of the risk of using these chemicals.

The DSGEIS's list of 258 chemicals contains chemicals that range from relatively non-toxic (e.g., isopropyl alcohol and acetone) to compounds that are known carcinogens (e.g., benzene and acrylamide) to compounds that are strong oxidants (hydrogen peroxide, chlorine dioxide, ammonium persulfate, and diammonium peroxodisulphate), and finally compounds used to inhibit microbial (cellular) processes (e.g., 2,2-dibromo-3-nitrilopropionamide, and 2,2-dibromomalonamide). The DSGEIS recognizes that many of these chemicals can be toxic, but

provides information only on representative compounds or classes of compounds (pages 5-61 to 5-65) and two specific compounds (dioxane and formaldehyde) (pages 5-65 and 5-65). While toxicity data on many of the 256 compounds not specifically addressed may indeed be scant in the literature, additional information on the toxicity and hazards associated with these compounds is available, and should be considered. Under any circumstances, the simple listing of this very large group of chemicals falls far short of an analysis of the risks of using these chemicals in hydraulic fracturing applications. While the DSGEIS indicates that only a portion of the chemicals listed will likely be used at any one site, it is impossible for the public to understand which chemicals of this long list will be used at each site, in order to develop an assessment of the potential human health risks, or site-specific sampling plans for water quality if and when fracturing is permitted.

Below is a brief discussion of the risk concerns of some additional specific compounds. This discussion is certainly not exhaustive, and as is discussed above, it is limited to the toxicity aspect of risk assessment. The exposure aspect is impossible to assess because it is essentially ignored in the DSGEIS, and there is insufficient data available to complete an independent analysis.

**Acrylamide:** Acrylamide is a known carcinogen (Rice, 2005, Rice, J.M, Mutation Research, 580 (2005) 3-20), and it has been shown to cause tumors at multiple organ sites in both rats and mice, when given in drinking water or by other means. It is also a well-documented neurotoxin in both human and laboratory animals (LoPachin, 2004). While acrylamide is typically used to generate various polyacrylamide polymers, it has also been used as a grouting agent in the construction of reservoirs and wells and as sewer line sealing (EU, 2002). Use of acrylamide as a grouting agent requires placement of acrylamide and other chemicals into cracks, where the acrylamide will polymerize and, ideally, seal the crack. The polymerization process is often incomplete, and residues of acrylamide remain that are often orders of magnitude higher than when the polymerization is allowed to occur under controlled manufacturing conditions. At least in one case in Sweden in 1997, in which a railroad tunnel was grouted with an acrylamide product, residual acrylamide was released and resulted in worker exposure and neurotoxic effects, and cows drinking nearby water became paralyzed and died, as did fish in nearby breeding pools (Reynolds, 2002).

While residual acrylamide concentrations in manufactured polyacrylamide are generally sufficiently low not to present a serious water quality problem, use of acrylamide as a grouting agent is entirely different and has resulted in severe effects. Unfortunately, the DSGEIS does not indicate how the product will be used, although a use similar to grouting appears possible, based on the discussion in the DSGEIS. Unless the use is specified, as well as the extent of use, it is effectively impossible for the public to understand the risk that a chemical of this type would pose to human health and the environment.

This example is but one of chemicals in the list, but it is illustrative of the difficulty in evaluating the risk of the hydraulic fracturing process. In this particular case, a very toxic carcinogen and neurotoxic agent is included in a list with other chemicals (many of very low toxicity) and essentially no information is presented on how it would be used or the extent of use.

**Biocides:** Other chemicals with similar issues are the biocides, 2-bromo-2-nitro-1,2-propanediol (bronopol), 2,2-dibromo-3-nitrilopropionamide, 2,2-dibromo-malonamide, dazomet, 1,2-benzisothiazolin-3-one, dibromoacetonitrile, hydrogen peroxide, and glutaraldehyde. Each of these compounds may be used to reduce microbial activity in the hydraulic fracturing fluid. Each of these compounds offers varying amounts of toxic risk, depending on the use pattern and quantity used. While these chemicals may be used in low concentrations, the only data presented is the suggestion that up to 0.03% of the fracturing fluid would consist of biocide, although which chemicals would be used is not specified. Without these data, a risk assessment, even in a series of release scenarios, is precluded. The combination of the large number of chemicals in use is also a significant, secondary issue, since some of these chemicals can react to produce compounds with higher toxicity. Bronopol, although of low human toxicity by itself, can release nitrite, which in alkaline medium reacts with secondary amines (listed on page 5-52, Table 5-7) to produce the potent nitrosamine carcinogens. An example of a secondary amine on the list is coco-betaine, among others, indicating that such secondary reactions are possible with the reagents proposed in the hydraulic fracturing fluids. The data in the DSGEIS is insufficient to determine whether the proposed list of biocides, or secondary toxic effects of biocide chemical interactions, would pose a carcinogenic risk.

Dowicil 75 Preservative (3,5,7-triaza-1-azoniatricyclo{3.3.1.1<sup>3.7</sup>} decane, 1-(3-chloro-2-propenyl) chloride) is an antimicrobial agent that is noted for high toxicity to aquatic organisms and algae, and releases of this compound to surface water are particularly problematic (Dow, 2008).

**Mixtures:** The list of compounds is sufficiently long that it is relatively easy to find additional examples of problematic and incompatible mixtures, in which two chemicals will mix to form a much more toxic or reactive substance. Two examples are provided here. The first example is given above for the release of nitrite. Second, the use of the large number of oxidants, particularly hydrogen peroxide, in the presence of bromide can produce compounds that are potentially carcinogenic. Bromide can react with hydrogen peroxide (or other oxidants) and produce bromine, which can ultimately react with a variety of organics to produce compounds that are potentially carcinogenic, as well as brominated and chlorinated methanes, which are listed as being found in the flowback water (Table 5-9). Other oxidants on the list include sodium hypochlorite, chlorine dioxide, and various persulfate salts.

**Aromatic hydrocarbons and solvents:** Benzene, toluene, xylenes, ethyl benzene, and a variety of other moderately water soluble aromatic compounds are listed in Table 5-6. Of these, benzene carries the greatest toxicity, due to its well-known carcinogenicity (EPA, 2008). These

compounds will tend to remain in water, and only be weakly sorbed. Again, however, the concentration and exposure routes are necessary for any risk assessment but are absent from the DSGEIS.

## **II. The DSGEIS does not demonstrate that contaminants found in produced water and/or fracture treatment flowback water are safe for environmental or human exposure.**

The additives potentially present in flowback water mentioned above indeed present serious risks. In addition, the produced water generated during the hydraulic fracturing process contains contaminants that are released from the shale and generate very poor quality water (Table 5-9). After the well is completed, and an initial hydraulic fracture stimulation is conducted, there will be a period of time where fracture treatment flowback water will dominate the wastewater regime. Formation water will also be present in the flowback wastewater stream. Over time, the amount of hydraulic fracture fluid flowback will diminish and the wastewater will become predominately produced water.

The DSGEIS provides a very limited number of flowback water samples. These samples all contain very high levels of salts, with concentrations of total dissolved solids (TDS) ranging from 1530 mg/L to 337,000 mg/L, with a median concentration of 93,200 mg/L (9.3%). While the majority of the salt is sodium chloride, the median concentration would require nearly a 200-fold dilution to meet a secondary standard of 500 mg/L for drinking water. While sodium chloride is generally considered low toxicity, groundwater contamination of 1,000 mg/L would generally remove this water source for domestic purposes.

Benzene was found in nearly half of the samples. Whether benzene originated from the fracture treatment additives or was in-situ in the formation water is unclear. However, the fact that the combined wastewater stream contains benzene, a known human carcinogen, is a substantial human health and environmental concern that should be carefully examined by NYS, especially because the concentration of benzene (mean of 479 µg/L) is approximately 100 times higher than the drinking water limit of 5 µg/L. Other aromatic compounds were also observed (e.g., toluene) that exceed the U.S. EPA drinking water limit, although benzene is the aromatic compound of greatest concern.

Bromide is present at relatively high concentrations (mean of 616 mg/L) and will react with oxidants present in the hydraulic fluids to form bromine, which can subsequently react with hydrocarbons to form reactive carcinogenic compounds.

Antimony and arsenic were observed above drinking water primary standards in a limited number of samples. Barium, with a mean concentration of 661 mg/L, is over 300 times the 2 mg/L primary drinking water standard, and was found in each of the 34 samples analyzed. The highest concentration of barium observed (15,700 mg/L) is nearly 8,000 times the drinking water standard. Barium is a major constituent in drilling fluids, but may also be present in the Marcellus Shale. Barium is known to affect cardiovascular function, and causes hypokalemia,

which results in ventricular tachycardia, among other heart ailments. The heavy metals cadmium and lead also exceed primary drinking water standards in a limited number of samples.

Mercury was not mentioned as one of the analytes detected. It appears this was not even included in the analytical scheme.

**Radioactivity:** Only a limited amount of information on radioactivity is available for the flowback water, and it comes from just 8 wells in PA and WV, but the maximum concentrations found are very high, exceeding drinking water standards by several orders of magnitude. The EPA maximum contaminant level (MCL) for gross alpha in drinking water is 15 pCi/L; for radium total alpha (226 and 228) is 5 pCi/L; and for uranium is 30 ug/L. The maximum concentrations (Table 5-10) observed in the samples from PA and WV are: gross alpha - 18,950 pCi/L; for total alpha radium - 1,810 pCi/L; uranium concentrations were not specified. The greatest ratio of concentration observed to the drinking water MCL is for gross alpha and is 1,263 times the drinking water limit. No median concentrations were provided in Table 5-10. Additionally, no data were presented on how the NORM constituents change over time in the flowback water, although it is presumed that the NORM constituents will increase as the water changes from being primarily the fracturing fluid water to consisting primarily of the produced water.

Thus, if drinking water were contaminated with as little as 0.1% of certain shale gas wastewater, it would constitute a violation of a drinking water standard. The small percentage of wastewater that can cause serious contamination supports an argument that effectively *any* contamination caused by shale gas wastewater would be considered unacceptable. The lack of information on the expected wastewater characteristics from the New York section of the Marcellus Shale is a substantial deficiency in the DSGEIS, since it does not provide site-specific water quality data with respect to either the radioactivity that may be present in flowback and produced water or the concentration of other constituents that may prove problematic.

**Concerns about the available analytical work on the flowback water:** The list of chemicals found in the flowback water (Table 5-9) does not provide much assurance of the quality of information on the chemical composition of the flowback water and is simply a list of analytes that were found in a limited number of samples. While the analytical methods were not specified, they were apparently standard multi-residue methods that examined certain classes of compounds (e.g., EPA method 8270 and 8260 for organics, a metal scan, gross alpha radioactivity, metals and several anions). It appears that certain analytes potentially present in the fracturing fluids could not have been measured using those methods. Basically, if a gas production company is putting a chemical into a subsurface system that has the potential to contaminate surface water or usable aquifers, the company should be required not only to indicate the list of those chemicals and the quantities of each used, but also to monitor the quantities of those chemicals that are found in the wastewater.

For example, the DSGEIS admits that several of the monomers used in the process, either added directly or present as unreacted monomer in the polymer used, were not included in the analyses. (DSGEIS page 5-108: “Since this analysis targeted a polymerized reaction product and not the individual monomers, it is unclear from these data how much of the monomers, if any, occurred in the flowback.”) Many other compounds were not measured in the flowback water analysis, including alcohols (e.g., the high use alcohol, methanol), amines, glycols (only one sample analyzed, but with high detection limits, 2 ppm), glycol ethers, the larger polycyclic aromatic hydrocarbons--many compounds of which are carcinogenic--organic acids, and the toxic biocides. Only one sample contained acrylamide as an analyte, and although it was not found, the measurement of acrylamide requires special methods (EPA Method 8032A). No information was provided on the method used for the determination, and no information was provided on even whether acrylamide was used in this specific well.

The observation of 4-nitroquinoline-1-oxide in the flowback water deserves some explanation. This highly carcinogenic compound was reported in all of the samples analyzed. In Table 5-9, it was included with the surrogates, and it may well have been added during analysis of the water samples. However, Table 5-9 does not indicate where it may have originated (as was done for other surrogates in the analytical method, such as 2-fluorobiphenyl). If this compound was indeed found in the flowback water, it would have serious implications for the health of workers as well as risk assessments for drinking water contamination. The concentrations observed (1,422-48,336 mg/L) are extremely high, with the highest being nearly 5% by weight. This concentration is substantially higher than the total organic carbon in the highest samples (1,080 mg/L), so it is unlikely that this compound was present in the flowback water. However, presence of the compound in the flowback is what Table 5-9 indicates, and the compound is also included in Table 5-8 as a parameter observed in flowback water from PA and WV. The explanation of its presence is necessary. Several quinoline compounds are noted in Table 5-7, although the presence of 4-nitroquinoline-1-oxide is unusual. It should also be noted that several of the surrogate compounds added during the water analyses (e.g., deuterated nitrobenzene) are also present in that table, but clearly would not be present in the flowback water.

Thus, despite the assertion that many of these chemicals are non-toxic and were not observed, the data suggests that effectively very little information is available to assess whether they would be present in quantities sufficient to adversely affect groundwater, if the wastewaters or the fracturing fluids were to leak in the wells to near-surface groundwater or surface water.

### **III. The DSGEIS fails adequately to consider scenarios where contamination of surface or groundwater may occur.**

Because of the highly elevated radioactivity, it is reasonable to assume that, in many cases, the key water quality component of concern will be radioactivity, although the fracturing process additives and other components of the produced water are also serious concerns.

There are at least four scenarios (among many) that should be considered for potential leaks or spills of gas wastewater, including flowback and produced water

1. **Movement of the contaminated water upward following fracture of the shale.** This is a hydrology problem mostly and has been considered by others (see Myers report to NRDC). However, because the chemical composition of the total radioactivity is not presently known (radium is apparently not a major component, and uranium is not specified), it is impossible to know how much of the radionuclides will sorb onto soils or chemically precipitate in the pipes. We do not know what constituents carry the radioactivity, but many, if not most, are subject to changes in oxidation state, which are likely to affect the solubility. The solubility of certain radionuclides is indeed affected by chloride, and as that is diluted, the solubility of the remaining alpha emitters may change and be lowered. Changing solubility is an important point, but since we do not know what the chemistry is of the radioactive source, the changes in solubility are unknown, and without that information, we must assume that the solubility is unchanged with salinity or temperature. Since radioactivity is of such importance, full assessment of the geochemistry of the radionuclides present in the groundwater is required.
2. **Spills during flowback or removal of produced water.** Spills during wastewater removal (flowback and/or production brines) can be due to either leakage of the piping system or flow around the piping system that intercepts a potential drinking water source. This leakage may not even be known until it intercepts a monitoring well. As in other cases, the problem created would depend on the amount and toxicity of the water that is released. It might be argued that contamination by this wastewater could largely be remediated by a pump and treat technology, but the low solubility of many radionuclides suggests that there are likely to be continued releases of radionuclides from the sorbed state for a very long time. This type of slow release is a characteristic of arsenic contamination of groundwater systems. Arsenic is only slowly removed from the groundwater system since a large percentage of it is sorbed onto the matrix and released over a long period of time. Once an aquifer has been contaminated with arsenic, cleaning up that aquifer to restore domestic uses can be a very long-term problem. The same problem is likely for an aquifer contaminated with the wastewater that will be produced by hydraulic fracturing.
3. **Surface spills during hauling or piping of the wastewater.** As before, the problem created will depend on where the water goes, how much seeps into soil, and whether the contaminated wastewater is in communication with surface or groundwater. It will also depend on the toxicity and rate of migration of the specific compounds released.
4. **Leaks from surface impoundments.** A slow, undetected leak is a potentially very large problem, since it can occur for a long time, and move downward. This risk militates in favor of using above-ground steel tanks for flowback storage (where spills are very easily detected) or, if impoundments are permitted, for improving the quality of the lined ponds which will contain the flowback. From experience in Nevada with liners, leaks are



common, and it is prudent to assume that all liners leak and to include leak detection systems in surface impoundment liners. If properly installed, the leak detection system will improve the odds that, if and when a leak occurs, it can be rapidly detected and fixed. A remediation safety plan will also require inclusion of a plan where to put the wastewater remaining in the impoundment when the leak was detected, as well as a determination of the extent of the contamination, and a plan to remediate that contamination.

In each case, the potential for contamination is large, and if it occurs during a storm or during mid-winter (when it seems that most accidents are more likely to occur), the impact could be significant.

For spills of the fracturing fluid constituents, two primary accidents should be considered.

1. **Spills during transportation of the fracturing fluid chemicals.** This has been discussed in the DSGEIS, but is always a consideration, particularly in remote areas, where road access may be difficult and when weather conditions are poor.
2. **Spills at the site during mixing, unloading, or adding the chemicals to the hydraulic fracturing water.** These types of spills are generally smaller than an undetected leak in an impoundment, but are relatively common. Each site needs to have trained staff and plans both for minimizing spills and, when they occur, for immediately cleaning them up and legally disposing of the residue.

#### **IV. The DSGEIS inadequately analyzes necessary groundwater monitoring.**

Because the types of contamination from the combined flowback and formation water would be so severe, groundwater monitoring requirements are critical to protecting domestic drinking water wells, particularly those near a gas well site and those that can be potentially contaminated by release of flowback water (See Myers hydrology report). New monitoring wells should be drilled in appropriate locations between the source of contamination and the drinking water well, and samples should be tested on a quarterly basis (to obtain one full year's worth of data) prior to any drilling, hydraulic fracturing, or storage of flowback. The quarterly monitoring will not only establish baseline conditions, but also provide an indication of the seasonal changes in the groundwater quality.

The draft SGEIS suggests that monitoring can be discontinued one year after closure of the gas well. Since groundwater moves so slowly, this short period of time (one year) is insufficient to establish whether the groundwater has been contaminated, and at least 5 years of data should be required, as a permit requirement, following closure of the gas well. This period of monitoring is particularly important for protection of rural drinking water wells, since most rural homes rely on such wells, which are rarely tested. At least 5 years of groundwater monitoring at locations between the contamination source and the drinking water well are required to ensure that the homeowner learns of the risk of drinking water contamination before that contamination has

begun. Increases in chloride are likely to be the first indicator of contaminated water, and significant increases in chloride (relative to a yearly fluctuation) will show if that domestic aquifer has been contaminated. If contamination is suspected, a full analysis of the water should be conducted. The monitoring and analysis should be pre-paid by the gas developer for the full period of analysis.

## **Concluding Comments**

The DSGEIS falls short of an adequate assessment of the risk of using the fracturing additives for hydraulic fracturing of the Marcellus Shale in New York. It similarly falls short of assessing the risk of formation waters contaminated with high levels of TDS, heavy metals, and radioactivity, which will be transported to the surface both as a component of the flowback and during production. Specifically the following summary points should be considered:

### **I. Hydraulic Fracturing Additives**

- The additives used in the hydraulic fracturing process are not well defined and the DSGEIS essentially provides only a laundry list of approximately 258 chemicals that *may* be used in the process.
- There is effectively no indication of the toxicity of each chemical, and insufficient information is provided that would allow the public to understand the hazard associated with individual or groups of chemicals.
- There is no clear indication of how much of each chemical will be used, and this lack of information is particularly troubling, because it eliminates the ability of the public to understand the risk of using effectively all of these chemicals.
- Certain of these chemicals will react with others and produce secondary products that are particularly problematic. Again, the lack of information on which chemicals will be used eliminates the opportunity to conduct a reasonable risk assessment for use of these chemicals.

**Recommendation #1.** A more complete listing of the use rates of these chemicals is required, as well the quantities of chemicals that will be used.

**Recommendation #2.** NYSDEC appears to place no restrictions on use of any of the chemicals, even though certain of these chemicals (e.g., acrylamide and benzene) pose significant risks, including carcinogenicity. NYSDEC should re-evaluate use of these 258 chemicals and propose use restrictions on the most toxic of the group.

### **II. Gas wastewater:**

- The flowback water (containing both the shale fracturing water and the produced water) that will carry contaminants from the shale and the fracturing additives is likely to be highly contaminated with metals, salts, and radioactivity that, in some

cases, are greater than 1,000 times the drinking water standards. This level of contamination is sufficiently high that *any* level of contamination of surface and groundwater is unacceptable.

**Recommendation # 3.** NYSDEC needs to develop a much better data set on the expected concentrations of contaminants in the gas wastewater, and should require disclosure of both the identities of the chemicals being produced in the waste as well as the amounts of those chemicals.

### III. Chemical analysis and monitoring issues:

- Many, if not most, of the hydraulic fracturing additives are not included as analytes in standard chemical analyses of flowback water. If a chemical is being injected into the subsurface (and thus has the potential to contaminate surface or accessible groundwater), that chemical should be measured in the flowback and in samples of groundwater withdrawn from strategically located monitoring wells.

**Recommendation #4.** The NYSDEC should require that the identity of the hydraulic fracturing additives be revealed at each specific well, and require the gas production entities to establish monitoring methods for those chemicals, as well as a protocol and plan for their monitoring.

**Recommendation #5.** Monitoring of wells for these contaminants should be conducted at least for a full year (monthly or at least quarterly sampling) before drilling begins to provide a baseline for seasonal changes in water quality.

**Recommendation #6.** Following plugging and abandonment of a gas well, monitoring should be required for a minimum of 5 years, with a special emphasis on testing for those contaminants that will move the most rapidly (e.g., chloride). Prior to installation of these gas recovery wells, site-specific plans for cleanup of contamination should be developed by the operator and approved by NYSDEC.

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