Science and Technical Advisory Committee
Partnership for the Delaware Estuary:
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Natural Gas Drilling in the Delaware River Basin
Comments and Questions by the STAC

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Natural gas found in the Marcellus Shale underlies about 36 percent of the Delaware River Basin (DRBC 2011), primarily in the upper half of the basin. As a National Estuary Program, the Partnership for the Delaware Estuary (PDE) is responsible for implementing the Comprehensive Conservation Management Plan (CCMP) for the Delaware Estuary, with a primary focus on the tidal portion of the Delaware River and Bay in the lower half of the basin. However, both the Partnership and the CCMP recognize the importance of the upper basin, especially for maintaining clean fresh water flows critical to the health of the Estuary. Extensive gas drilling in the upper basin using hydraulic fracturing methods has the potential to undermine key environmental protection and restoration action items of the CCMP.

The CCMP recognizes both the vast natural resources of the Delaware Estuary and River Basin and the tremendous economic value of these resources to the region. As a result, PDE strives to implement natural resource protection and restoration measures in balance with the need to maintain the working river. However, under the CCMP and the Charter for the PDE Science and Technical Advisory Committee (STAC), it is the duty of the STAC to identify potential environmental effects of human activities in the ecosystem.

This brief prepared by the STAC summarizes our scientific understanding of the potential environmental consequences of natural gas drilling and poses key scientific questions that we believe should be addressed prior to adoption of gas drilling regulations for the Delaware River Basin. Many of these questions are unresolved because environmental impact statements are currently not required for natural gas drilling in the Marcellus Formation. In assessing the current status of our knowledge of the environmental effects of gas drilling on the Delaware Estuary ecosystem, our main focus is on water resources and aquatic communities downstream.

Water Quantity

The Delaware River Basin supplies drinking water for more than 15 million people and the sustained base flow of the mainstem Delaware River is critical for a rich diversity of economically and ecologically important aquatic communities. Of special consequence to the tidal estuary, the Delaware River provides about 60% of the surface runoff and is the main reason why the Delaware Estuary is the world's largest freshwater tidal system. Many nationally rare and unique environments are present in the upper estuary, such as freshwater tidal wetlands, spawning habitat for endangered fish species, and habitat for the freshwater mussels which are the most imperiled organisms in North America. Key drinking water intakes for Philadelphia are also located in this freshwater tidal reach. With expected rates of sea level rise, our recent climate adaptation studies (PDE 2010) identified the protection of freshwater base flow in the Delaware River to be of paramount importance to help offset the expected salinity rise that threatens these natural resources. The challenge of maintaining salt balance in the upper estuary is expected to be compounded as human population grows (projected 80% increase by 2100) and demands for water withdrawals for other human activities (industries) also swell, especially during the summer when warmer temperatures will boost evapotranspiration losses.

Natural gas production from the Marcellus Shale requires millions of gallons of water per well for hydraulic fracturing. Approximately 75% of this water is not recovered and returned to the surface after the fracturing process, remaining downhole in deep shale formations well below the base of the deepest freshwater aquifers. This water is lost from the hydrologic cycle, and can be considered essentially an "out of basin" consumptive use. The cumulative effects of non-recovered hydraulic fracture water may become significant if a large number of shale gas production wells are completed in the basin, especially when added to the amount of water already leaving the basin for consumptive use. It is unclear whether and how the combined effects of water withdrawals from multiple wells within tributary watersheds will lead to local or basin-wide cumulative effects on base flow in aquifers, streams and/or the mainstem Delaware River. Currently, proposed permit rules for natural gas wells will require drilling companies to report water volumes needed, and permit review will consider the combined effects of more than 5 wells by a single company within a tributary watershed.

The STAC has identified the following questions regarding <u>water quantity</u> that we believe should be addressed prior to adoption of gas drilling regulations for the Delaware River Basin:

1. What will be the cumulative water withdrawals needed to sustain the expected development of the Marcellus Shale drilling in the Delaware River Basin?
2. How could we expect these water withdraws to change in the future?
3. How will base flows in major tributaries and the main stem Delaware River be protected?
4. How will changes to the salt line and salinity in the Delaware Estuary be monitored and managed?
5. Will withdrawals vary seasonally, and can they be managed seasonally to protect critical base flow during summer?
6. How will withdrawals be permitted and monitored to ensure protection of critical base flow in small streams in rural areas?
7. Do regulatory agencies currently have the capacity and funding to perform necessary monitoring, modeling and industry oversight of water quantity maintenance?
8. Will drilling companies be required to mitigate for any incidences of aquatic community disturbance from potential low flow impairment?
9. Are there other sources of water that drillers can use without impacting drinking water supplies in the basin, such as treated wastewater effluent, brackish or salty water from the lower estuary, or water supplies brought in from other basins?

Water Quality

Approximately 25% of the water used for hydraulic fracturing is recovered at the well sites. Chemical compounds, are added to the hydraulic fracturing water to clean the well casing perforations, prevent corrosion and scaling, reduce biofouling, and allow the fracture fluid to better penetrate the formation. There are more than 100 chemicals that can be used for these purposes, some of which are proprietary and not known to the public. Fracturing water is mixed uniquely, according to the drilling conditions for each site and the exact combinations and amounts of chemical additives can differ from well to well.

In addition, fluid that is returned to the surface after the fracturing process (called "flowback") contains dissolved solids from the natural formation brines. These include high levels of NaCl, a variety of metals such as Ba, Sr and Mg that may be present in sufficient concentrations to have toxic effects, and radioactivity levels above background (Soeder and Kappel, 2009). There are therefore many questions regarding safety and environmental protection at on-site drilling operations, the transport of flowback fluids to wastewater treatment sites, and the eventual fate of chemicals, total dissolved solids (TDS) and radioactivity following wastewater treatment at sites far removed from the drill pads. Current plans for monitoring water quality in surface and ground water appear limited to the immediate area where drilling will occur and are focused on the first few years of drilling and production, rather than long-term, cumulative impacts at the tributary and basin scale.

The STAC has identified the following questions regarding water quality that we believe should be addressed prior to adoption of gas drilling regulations for the Delaware River Basin:

10. How will spills or permit violations be monitored and detected? What actions will be taken if a spill or violation occurs? If TDS sensors detect an anomaly, is there a rapid mobilization plan and infrastructure/capacity to quickly respond with more intensive monitoring, and if so by who?
11. Will monitoring be sufficient to detect the wide array of contaminants potentially spilled or running off at well pad sites, such as barite used in drilling muds? Can the STAC be provided with a full list of compounds in fracking fluid formulas?
12. What assurance is there that the BACI (before-after-control-impact) monitoring approach will be intensive enough to capture isolated spill incidents in small streams (currently planned for annual sampling up to 5 years, after the initial drilling operations)? If wells are operating for decades, how will long-term monitoring be sustained?
13. For spills or other water quality impacts at drilling sites, what is the damage assessment and mitigation plan?
14. If cumulative water quality impacts are detected downstream from more than one well or more than one company, how will the responsible party(s) be determined?
15. How will total suspended solids (TSS) be monitored? How will changes in storm water runoff be monitored and how will cause be determined?
16. Where will fracking fluids generated in the Delaware River Basin be treated? Will the Delaware River Basin receive frac fluids from other areas?
17. Which of the toxic chemical compounds will be detoxified by treatment, and which will not? Wastewater treatment typically does not remove metals or radioactivity, for example.
18. Is there a monitoring plan for facilities that will treat frac fluids and along travel routes between sources and treatment plant areas?

19. Will fracking fluid treatment vary seasonally, and can it be managed seasonally to rely less on summer dilution and protect critical aquatic life histories as appropriate in the vicinity of waste treatment sites?
20. If dilution is used to achieve nontoxic endpoints following wastewater treatment, what will be the combined annual (seasonal preferred) increase in total chemical loads and total dissolved solutes per wastewater treatment facility? Per tributary watershed? Per the whole basin?
21. Could total dissolved solutes in the flowback fluid, which can be 6 to 10 times saltier than seawater, collectively contribute to specific conductance in rivers and salinity in the estuary? If so, how will this be offset to maintain salinity regime in the estuary?
22. What is the likely timeline for fracking fluid generation? Will there be a peak in the near future followed by a tapering of waste treatment needs following well installations, or will there be a continuing need to treat wastewater in the long term?
23. How will state and federal regulatory agencies monitor and maintain water quality and salinity in the tidal Delaware Estuary?
24. If wastewater treatment plants receive leachate from landfills, which have accepted drill cuttings from gas well development, how will the leachate be analyzed for levels of radioactivity prior to being accepted by treatment plants for eventual discharge into waters of the Delaware River Basin?
25. How will wastewater treatment plants analyze each shipment of wastewater for levels of radioactivity before being accepted for treatment and discharge into waters of the Delaware basin?
26. What level of radioactivity in wastewater will be considered acceptable for discharge into waters of the Delaware River Basin?
27. Will regulatory agencies have the capacity and be funded sufficiently to perform necessary monitoring, modeling and oversight of water quality maintenance?
28. How will drilling companies be required to mitigate for water quality mediated disturbances to either aquatic communities or human communities?

Aquatic Life

Aquatic organisms are arguably the most diagnostic for ecosystem health because they depend on water quantity, water quality and healthy biological processes that are integrated over the large spatial scales. Air quality, groundwater quality, and forest integrity also affect aquatic animals and plants. A diverse array of aquatic plants and animals live in headwater streams, rivers and the tidal estuary, and moving downstream along this river continuum their health and fitness is increasingly representative of larger spatial areas. In these areas, short-lived animals and plants (periphyton, macroinvertebrates) are exceptionally good at detecting short-term disturbances from water impairment, whereas long-lived animals and plants (marsh grasses, freshwater mussels, fish) are diagnostic of long-term, cumulative impairments. Preliminary studies suggest a potential impact from drilling operations that can impact aquatic organisms (Anderson, 2010; www.ansp.org/research/pcer/projects/marcellus-shale-prelim/).

The current monitoring framework outlined in draft rules for natural gas permitting includes aquatic life surveys in surface waters immediately downstream of drilling operations. The endpoints being considered consist of periphyton and macroinvertebrates, which are relatively standardized within existing state regulations.

The STAC has identified the following questions regarding the protection of aquatic life that we believe should be addressed prior to adoption of gas drilling regulations for the Delaware River Basin:

29. At well sites and in tributary watersheds, how frequently will aquatic organisms be monitored, and by who?
30. Will the BACI (before-after-control-impact) monitoring approach be extended to span the length of a well site? Will long-lived aquatic life be assessed?
31. How will aquatic life impairment be monitored at broader spatial scales, such is in the larger tributaries, mainstem Delaware River, and in the Delaware Estuary?
32. For spills or other aquatic life impacts at drilling sites, and collectively across larger areas, what is the damage assessment and mitigation plan?
33. If cumulative aquatic life impacts are detected downstream from more than one well or more than one company, how will the responsible party(s) be determined?
34. Is there a drilling well or pad density within a watershed that is above a threshold of impairment (conversely is there a level below which there is minimal impairment)?
35. Will aquatic life be monitored at (and downstream of) water withdrawal sites (if surface water) to discern any effects of changing flows?
36. Will aquatic life be monitored in the vicinity of wastewater treatment sites that receive frac fluids?
37. Will long-term bioaccumulation of metals, radioactivity and other toxic compounds be included in the BACI monitoring plan, especially near waste treatment facilities?
38. Will bioaccumulation of metals and other toxic compounds in commercial shellfish (oysters) be monitored in the tidal estuary?
39. Will aquatic life be monitored seasonally?
40. Are state and federal regulatory agencies considering ways to monitor and maintain aquatic life in the tidal Delaware Estuary (e.g., effects of small salinity changes on oyster populations)?
41. Will regulatory agencies have the capacity and be funded sufficiently to perform necessary monitoring, modeling and oversight of aquatic life condition?
42. How will drilling companies be required to mitigate for any incidences of aquatic community impairment, locally and collectively across large areas?

<u>Forest Loss</u>

In our recent climate adaptation study (PDE 2010), the protection of forests in headwater areas of the Delaware River Basin was regarded as a top priority for maintaining drinking water and ecosystem integrity into the future. Extensive natural gas drilling in these critical forested areas is expected to significantly decrease forest cover and lead to a highly altered and fragmented landscape. Each well pad requires at least 5 acres of clearing, and greater forest losses occur from the roads and pipelines needed to connect drilling sites to the gas supply network. The hydrology can also be irreversibly altered. This landscape transformation has many local environmental impacts, such as forest fragmentation effects of species with broad home ranges, local air, noise and light pollution, and decreased litter inputs and increased TSS runoff in streams. We presume that local impacts will be addressed in some manner, and our focus from an estuary perspective is on the cumulative effects downstream and into the future.

The STAC has identified the following questions regarding the protection and mitigation of <u>forest loss</u> that we believe should be addressed prior to adoption of gas drilling regulations for the Delaware River Basin:

43. What entity will monitor and assess the collective changes in forested area and forest fragmentation across the Delaware River Basin?
44. Are there any well density limits or planning efforts to set limits on the total acreage of forests that are cleared or degraded across the Delaware River Basin?
45. Are plans in place to monitor and mitigate for any biological effects of forest cover loss on instream water temperatures, pH, storm water increases, leaf litter and instream habitat complexity decreases, and stream flashiness?
46. Will drilling companies be given some incentive to establish re-forestation projects in areas of the basin as mitigation for loss of forest cover due to well pad, pipeline, and road development?
47. Is there a mitigation plan to offset or restore the collective ecosystem service losses associated with landscape changes to these upland habitats, such as carbon sequestration and maintenance of source water quantity and quality?

Considering the economic pressures driving the rapid development of natural gas industries in the Delaware River Basin, and resulting pressure on regulatory agencies to quickly develop and implement regulations, the STAC is concerned that these important scientific questions will go largely unaddressed.

The STAC and its affiliated technical work groups is available and able to help provide solutions to our knowledge gaps regarding the most effective prevention, response and mitigation actions for natural gas drilling activities in the Delaware River Basin. STAC membership is comprised of scientists from diverse sectors and states. The STAC can be engaged via the contacts listed below.

STAC Contacts

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