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Reducing Ecological Impacts of Shale Development: RECOMMENDED PRACTICES FOR THE APPALACHIANS

WATER WITHDRAWALS

@ Kent Mason

More than 1,000 species rely on the unique riverine and wetland habitats in the Appalachian region. Currently, these surface waters also serve as the primary source of water used to hydraulically fracture shale oil and gas wells. Each well uses an average of 4.4 million gallons of water, with an estimated 14 billion gallons used to date in the Marcellus play. The individual and cumulative effects of these surface and groundwater withdrawals pose a high risk to water availability, water quality, stream habitat, and species abundance and diversity.

STATE OF THE RESEARCH

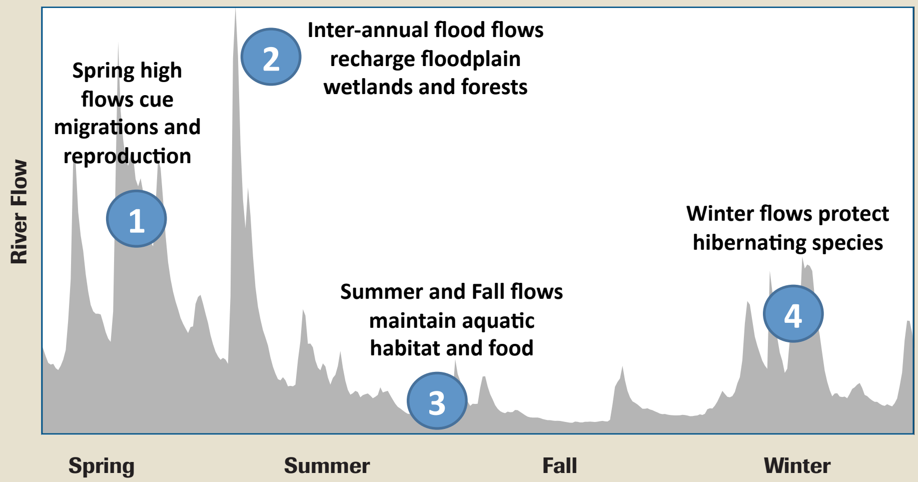
There is a substantial and rapidly growing body of research documenting ecological responses to stream flow alterations caused by water withdrawals. For several decades, managers have recognized the need to prevent water withdrawals from creating extreme low-flow conditions that result in dewatered habitat or contribute to poor water quality.[1,2] More recently, this understanding has evolved to recognize that it is the combination of daily and seasonal patterns in stream flows and the year-to-year variability that sustain channel dimensions, river velocity, streambed habitat, and riparian and floodplain vegetation. In addition to providing dynamic physical habitats, the flow regime supports the food chain interactions and water quality that define a stream's ecological integrity.[3–5]

The majority of research summarizes biological responses to altered stream hydrology caused by dam operations and water withdrawals to meet human demands, including public water supply, energy, agriculture, and other industrial needs.[3,6–8] In an effort to identify a "tipping point," or a threshold at which water withdrawals trigger a biological response, there have been a handful of experimental studies designed to monitor the response of fish and aquatic insects to incremental reductions in stream flow.[9–11] Threshold responses have also been observed during droughts by fish, aquatic insects, mussels, reptiles and amphibians.[12–17] It is difficult to aggregate these findings to universally answer the question, "How much water does a river need?" However, we do understand that the scale of ecological impact is generally proportionate to the scale of alteration.[18,19] There is also strong evidence that ecosystem responses to changes in hydrology are most similar among streams of the same size and geographic region.[19,20]

Species in the Appalachian region have evolved to synchronize critical life development stages (e.g., spawning/egg laying and rearing) with the magnitude, timing and frequency of seasonal and inter-annual flow patterns. Basin-specific studies for the Upper Ohio, Great Lakes, Susquehanna and Delaware basins document these regional flow-related needs and provide recommendations to protect them.[21–24]

The Flow Regime

The flow regime is defined as a river's naturally occurring annual and inter-annual patters of high, seasonal and low flows. In the Appalachians, streamflows are typically highest during the spring runoff and lowest during the fall and summer months. Species have evolved over millions of years to sync their life stages with the diverse patterns of water availability.



Adapted from Postel and Richter, 2003

EVIDENCE OF IMPACT

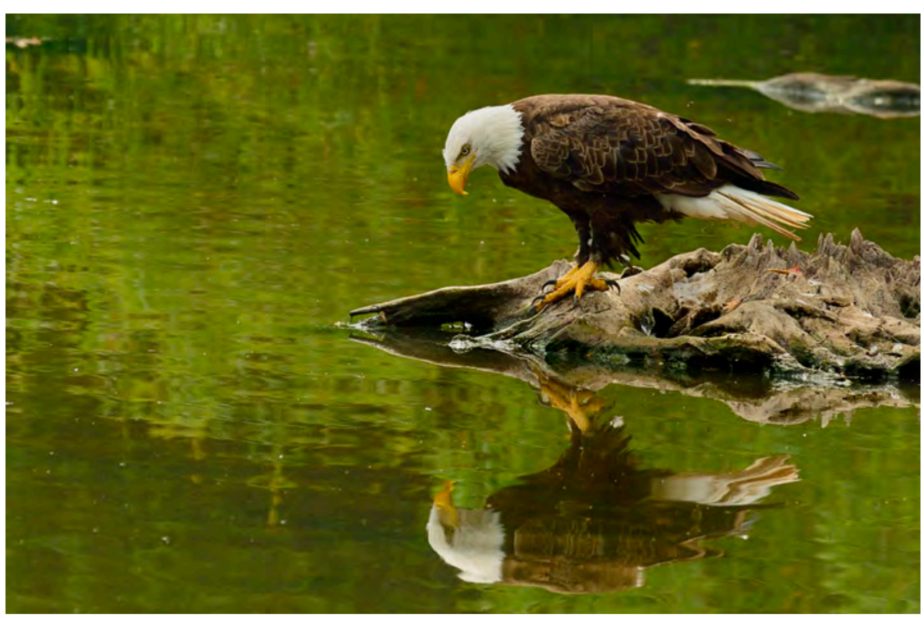
Altered Hydrology and Riverine Habitats

Surface water is the primary source of water for hydraulic fracturing fluids in the region.[25,26] Withdrawals associated with shale development have the potential to impact the magnitude and timing of seasonal flow patterns, increase the frequency and duration of low-flow conditions and decrease high flows in small stream settings.[21,26,27]

Reductions to the magnitude and changes to the timing of seasonal flow patterns can reduce the availability and diversity of stream habitats, resulting in decreased growth and abundance of fish and macroinvertebrates and, in some cases, shifts in species composition and a loss of diversity.[28–33] Declines to species like crayfish, minnows and wetland plants negatively impact wading birds, birds of prey and mammals that rely on these aquatic food sources to survive.[34–36]

Low flows are a part of natural stream flow patterns, but surface water withdrawals can increase the frequency or duration of low-flow conditions. This can dewater habitats and reduce or eliminate the connection between groundwater and surface water habitats – and between upstream and downstream river reaches. Maintaining the connection among these habitats is critical as species migrate between habitats for spawning, refuge and rearing their young. Loss of connectivity has resulted in reduced abundance and diversity of mussels, fish, reptiles and aquatic insects.[11,12,14,15,17,37-39] These conditions pose the highest risk to species and life stages with limited mobility, like freshwater mussels, developing fish and amphibian eggs, or hibernating salamanders and turtles.[12,40-43] Species with high sensitivity, like the eastern hellbender, are also at risk.[15,44,45]

Floods and high-flow pulses are also a part of natural stream flow patterns. They range from relatively small, flushing pulses of water (e.g., after a rain event) to extremely large events that only happen once every few years (e.g., large rain-on-snow events). These events inundate channels and floodplains, saturate soils for plants, clean gravels and cobbles, and cue upstream migration. The loss of high-flow events has resulted in failure of fish to complete spawning migration, the accumulation of fine sediment, decrease in riparian and wetland vegetation and poor water quality conditions.[15,46-49] In settings where dams have stored small and large flood events, ecological responses include sedimentation of instream habitat, loss of floodplain forests and wetlands and reduced groundwater recharge.[50-54]



Declines to aquatic species negatively impact birds of prey that rely on aquatic food sources to survive. © Larry Keller

Many riverine functions depend on the unique slower-moving, shallow habitats found in headwater reaches and on the edge of streams and rivers. Surface water withdrawals can cause rapid fluctuations of stream flow. This can dewater shallow habitats, stranding juvenile fish, mussels and aquatic insects.[48,55-58]

Cumulative Effects to Downstream Water

Water withdrawals for hydraulic fracturing are high volume, occur over a short period of time and are typically concentrated near well sites to minimize transportation costs.[59,60] In the Appalachian region, small streams and tributaries have been increasingly targeted to support hydraulic fracturing operations.[25] The concentrated timing and location of withdrawals in small stream settings increases the likelihood of cumulative impacts to downstream hydrology, water availability and aquatic habitat.[27,44,59,61-63] Unlike many industrial water withdrawals that return a large proportion of the withdrawal volume back into the river after use and treatment, the majority of water withdrawn for hydraulic fracturing is injected into deep underground formations and is not available for downstream use.[64,65]

The cumulative decrease in water availability might also result in increased contaminant concentrations and reduced downstream water quality.[11,21–23,61]

Surface Water Access and Diversion

Water for hydraulic fracturing is typically collected by driving water trucks to surface water access points on streams, rivers and lakes and diverting water using a large hose.[66] This practice might include construction of new access roads, staging areas adjacent to stream access points and well pads that can accommodate several 20,000-gallon portable tanks.[66] There is also a risk of transferring aquatic invasive species through this equipment, particularly if screens are not used and equipment is not properly cleaned between sites.[67] Without landscape-scale planning and protection of ecological buffers, conversion of forests and wetlands to accommodate this infrastructure might result in loss of habitat, bank erosion, sedimentation and changes to water quality.[68]

Diversions might also include the construction and use of dams or weirs to pool water. Dams and weirs create barriers that can inhibit the movement of aquatic life, interrupt the formation of habitat and trap sediment.[69-73]

Each well uses an average of 4.4 million gallons of water. This water is transported from local stream and groundwater sources to the well pad with trucks or pipelines. © Susquehanna River Basin Commission

CONSERVATION PRACTICES AND SCIENTIFIC SUPPORT

Scientific literature supports practices that reduce the ecological risks of individual and cumulative water withdrawals. The following practices are derived from management and guidance documents developed by state agencies, scientific/conservation organizations, and industry groups.

Plan at the Watershed Scale

Scientific literature supports planning at the watershed scale to reduce risks from water withdrawals. Risks vary by water source and are dependent on a number of factors, including the size of the water body (stream, lake or reservoir), time of year, and the sensitivity of the potentially affected species.[19,21-24]

Studies show risks can be reduced by using these factors to classify streams within a region and assigning protections within a watershed planning hierarchy. In support of this concept, water withdrawal locations should take into account:

- geographic, seasonal and inter-annual difference in water availability;[19,59,74]

Water withdrawals have the potential to impact seasonal flow patterns and connectivity between mainstem and side channel habitats. © Kent Mason

Protecting Ecosystem Flow Needs

The Susquehanna, Delaware, Upper Ohio and Great Lakes basins each have regionally specific, science-based flow recommendations to protect the unique needs of habitats and species throughout the year. To see the basin specific reports, click here.

Eastern brook trout (top right), dusky salamander (above) and the northern water shrew (left), thrive in headwater habitats in the Central Appalachians eating aquatic insects and small fish and living in stream beds and banks.

- existing uses, such as public water supply, agriculture and recreation;[59,60]
- sensitive species and habitats;[19,21–23]
- the potential to use low-quality water supplies (e.g., abandoned mine drainage (AMD).[75,76]

Existing conservation practices include coordinating with resource agencies, research institutions and communities at both the regional and local scale to design water withdrawal programs that consider human and ecological needs and reduce the potential for site-specific and cumulative impacts.[77] Centralized management of water supplies can reduce the overall footprint of infrastructure and reduce truck traffic.[59] Planning can also take into account the location of low-quality water supplies and provide incentives for using these water sources.[78]

Limit Alteration to Hydrology

Scientific literature strongly supports protecting the flow regime by using science-based limits of alteration to environmental flow components including "typical" seasonal flows, low flows, high flow pulses and floods.[19,79,80] Where detailed assessments of environmental flow needs cannot be conducted in the near-term, a presumptive standard might be used in the interim to minimize risk.[81]

Because of the important contribution to the stability of downstream water quantity and quality, use of headwater and groundwater resources should be limited.[68,82–87] If groundwater supplies are used, a good understanding of local rates of recharge is necessary to limit maximum pumping rates and quantity and to avoid depleting groundwater and connected surface water resources.[88]

Existing conservation practices include considering the timing and location of withdrawals and potential impacts to existing water needs, downstream aquatic and riparian habitats, fish and wildlife. Locating withdrawals downstream from headwater areas because they are more susceptible to dewatering and designing intake structures so that they do not harm fish and other aquatic organisms can reduce risks.

A combination of the following practices can improve protection of the flow regime. Annual low-flow and drought conditions can be protected using a minimum flow requirement, which requires withdrawals to cease under a predetermined low flow condition (also called a passby flow).[74,89] The seasonality of a stream, or "typical" seasonal flow conditions might be protected using a withdrawal cap or a total volume of withdrawal that will not be exceeded either by an individual user or by the combination of all upstream users.[24,89] In the Appalachian region, science-based recommendations have been developed for the Susquehanna, Upper Ohio, Great Lakes and Delaware River basins.[21–24]

Another approach that has been successfully used to minimize the risk of alteration is to reduce demand by prioritizing the use and re-use of lower-quality water supplies.[59,75] This includes recycling flow-back water, reusing close to 100 percent of produced water, and using AMD and other low-quality sources (e.g., purchasing municipal effluent).[26,59,75,76,78,90,91] Across the Appalachian region, the reuse of produced water alone can reduce freshwater demands by 10 to 30 percent.[59]

Determine Baseline Conditions and Monitor

Scientific literature emphasizes the importance of conducting a natural resources inventory and collecting baseline data prior to any new withdrawal to document the ecological condition, determine the appropriate protections and provide a comparison for post-development conditions.[92] Baseline hydrology can be estimated using existing gage data or modeling tools.[93,94]

When translating an estimated or predicted baseline condition to water

The eastern hellbender is America's largest aquatic salamander. Hellbenders are sensitive to sedimentation and other impacts to stream health. © Steve Kruitbosch withdrawal permit conditions (e.g., passby flow or a withdrawal cap), estimation uncertainties should be accounted for by incorporating an appropriate safety factor.[26] Prediction uncertainties are highest in headwater systems and for low-flow conditions.[26,94] Streams where withdrawals occur should be monitored to refine estimates of water availability. The timing and volume of actual withdrawals should be reported and compared to any changes in biological condition.[19,92]

Existing conservation practices include conducting a natural resources inventory, collecting baseline data, monitoring streams where withdrawals occur, and reporting the timing and volume of actual withdrawals.

TNC Recommended Conservation Practices

Based on scientific literature and existing practices, The Nature Conservancy recommends the following practices:

- **Manage water allocation at the basin scale** by (1) accounting for social and environmental needs and cumulative use, (2) reporting permitted and actual withdrawals, (3) monitoring for site-specific hydrologic and biological conditions, and (4) instituting timely enforcement mechanisms.

- **Reduce surface and groundwater consumption** by requiring water conservation practices and accountability across the supply chain and by maximizing the use and re-use of lower-quality water sources.

- **Reduce or eliminate withdrawals where and when they individually or cumulatively risk adverse ecological impacts.** Specifically withdrawals should:
  - avoid sensitive habitats including headwater and intermittent streams, high-value streams and streams with rare or sensitive species;
  - limit alteration to the flow regime using regional science-based recommendations, when available – in the absence of regionally specific recommendations, a precautionary standard can be used;
  - not diminish groundwater recharge rates;
  - maintain existing water quality and not further impair water quality by diminishing stream flow.

- **Minimize impacts from access and diversion** by (1) co-locating water supply and storage facilities, (2) incorporating a safety factor to account for uncertainty in estimates of surface water availability, (3) avoiding the construction of new dams or weirs to create slack water pools, (4) limiting the maximum instantaneous rate of withdrawal from a stream, and (5) using appropriate procedures to minimize risk of transferring invasive aquatic species.

These recommendations are part of a suite of recommended practices intended to avoid and reduce impacts of shale development on Appalachian habitats and wildlife. These practices might need to be adapted to incorporate new information, consider operational feasibility, and comply with more stringent regulatory requirements that might exist.

Visit nature.org/shale-practices-refs for a list of references used in this document

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The Nature Conservancy is a science-based organization working globally to protect ecologically important lands and waters for nature and people. The Conservancy has assessed the ecological impacts of energy development in the Appalachians and advanced strategies and tools that reduce those impacts. This collection of documents stems from research by The Nature Conservancy that evaluated the scientific support for existing management practices related to surface impacts of shale development. The Nature Conservancy gratefully acknowledges generous financial support from the Colcom Foundation and the Richard King Mellon Foundation.