

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

STREAM CROSSINGS

@ Kent Mason

Road and pipeline stream crossings are a necessary component of shale oil and gas infrastructure. However, stream crossings can alter stream channels, introduce sediment to streams, impact water quality, impede movement of aquatic species, degrade habitat and affect other important ecological functions. As road and pipeline networks expand across the Appalachian region, properly constructed, designed and maintained crossings can help reduce impacts to streams.



STATE OF THE RESEARCH

Research shows that road stream crossings have the potential to alter several important ecological processes, including transport of large woody debris and organic matter, sediment scour and transport, and movement of aquatic organisms.¹⁻³ Problems caused by road crossings are usually a result of:^{4,5}

- **Undersize crossings** that restrict natural stream flow, particularly during floods, causing scouring and erosion, high flow velocity, clogging and ponding.
- **Shallow crossings** with water depths too low for many organisms to move through them.

- **Perched crossings** that are above the level of the streambed at the downstream end, making it difficult for species to move upstream. Perching can result from either improper installation or from years of downstream bed erosion.
- **Lack of suitable streambed material and discontinuities** in stream-bottom habitat.

Some research has also been done on effects of pipeline crossings. Pipeline crossings can impact aquatic species and habitat by producing high levels of erosion and sedimentation during and shortly after construction, altering channels through excavation and backfilling, and damaging riparian vegetation. Although some effects can



Three main types of road stream crossings are: (A) bridges, (B) culverts and (C) fords. In general, research has shown that bridges and open-bottom culverts are preferable because they are less likely to constrict flow and because they maintain natural stream substrate. Temporary bridges can also be a good option, depending upon stream characteristics and anticipated traffic levels. Photos A and B: © Massachusetts Riverways Program. Photo C: © U.S. Forest Service.

be relatively short-term, poor design and construction techniques can cause long-term channel instability.⁶⁻⁸ Transporting toxic materials via pipeline or truck also increases the risk of spills at stream crossings; however, this issue is not addressed in this document.

The impacts of both road and pipeline crossings vary depending upon the stream characteristics, type and size of crossing structures, method of installation, and quality of maintenance.⁹ Although it is impossible to avoid all impacts associated with stream crossings, properly designed, constructed and maintained stream crossings can help reduce impacts to fish and wildlife populations, stream habitat and water quality, as well as lessen impacts associated with storm events both immediately upstream and downstream.^{1,10}



EVIDENCE OF IMPACT Movement of Organic Material and Nutrients

Road crossings can affect the movement of large woody debris, coarse and fine particulate organic matter and the nutrients that are frequently associated with this material. Large, woody debris provides habitat features and help shape channel characteristics.¹ When transport of woody debris is disrupted, it affects the distribution and abundance of diverse habitats (e.g., pools, riffles, floodplains) and changes the physical, chemical and biological characteristics of the stream.^{1,10} Undersize culverts can become clogged with debris (e.g., logs, branches, trash), which might exacerbate flooding, create barriers to movement and increase maintenance costs.¹¹

Many crossings are constructed in headwaters or small streams. Cumulatively, small streams make up the majority of stream length within a watershed, support species that are not found in larger rivers, and are highly productive.^{1,10,12,13} Headwaters also contribute significantly to downstream productivity because they recruit and transport coarse and fine organic matter



Freshwater mussels are an important part of stream ecosystems and can be affected by changes to temperature, water velocity and sediment. © Jon Golden

downstream. When crossings in headwaters disrupt the movement of materials, effects can cascade throughout the stream system, resulting in loss of habitat, declines in aquatic and terrestrial species that rely on delivery of resources from upstream, and loss of the resilience of the stream ecosystem.¹⁴⁻¹⁷

Erosion and Sedimentation

Road and pipeline construction at stream crossings can introduce large volumes of sediment into streams, both during construction and over the long term if streambed and bank scour increases as the channels readjust.^{2,17-21} Poor installation techniques and inadequate soil stabilization can intensify scouring, erosion and downstream sedimentation, and increase the risk of crossing failure during storm events.^{1,22,23} The effects of construction can last from a few weeks to many years.^{3,6,17,19,21} Without proper crossing design and maintenance, what might have been short-term effects can cause long-term issues.^{3,17,21} Moreover, the removal of stream-side vegetation for the development of pipeline and road corridors can increase erosion and raise water temperatures.^{8,21}

Effects of sedimentation include changes to physical stream characteristics; water quality; and the behavior, physiology,

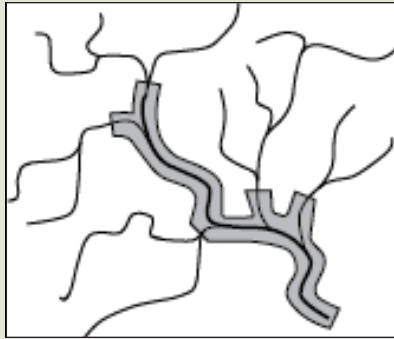
abundance, diversity, and community structure of aquatic and semi-aquatic species.^{1-3,6,12,17-20,23,24} The severity of effects on fish and other aquatic organisms vary with the amount of suspended sediment, duration and timing of exposure, location and volume of sediment deposited.^{17,20,23,25}

Fish are sensitive to increased levels of sedimentation during all stages of life, but might be most sensitive to sedimentation during early development, when eggs and larvae are immobile.^{24,26} The accumulation of fine sediment can fill pool habitats and plug spawning gravels, which affects many species of fish by adversely affecting suitability of spawning sites, egg development and larval fish emergence.^{8,12,18,19,21,23}

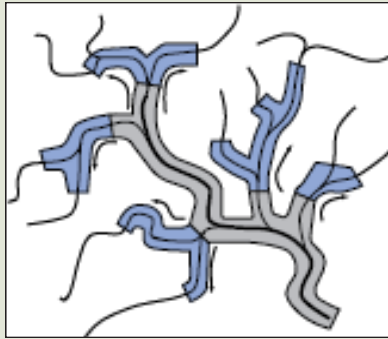


The spotted darter and other aquatic species depend upon stream habitats potentially impacted by road and pipeline stream crossings. © Conservation Fisheries Inc.

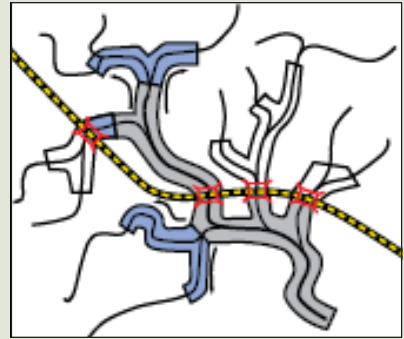
Example of stream crossings as a barrier to fish passage



For most of the year, brook trout typically inhabit the main stem of a stream network.



During spawning season, adults move into headwater tributaries to mate and deposit eggs.



Improperly designed and maintained stream crossings can impede brook trout from reaching spawning areas.

Adapted from Figure 1.25 in USFS Stream Simulation Working Group Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings.

Barriers to Aquatic Organism Passage

Many aquatic species need to move along the stream network to access areas for feeding, reproduction, and refuge from extreme conditions, including temperature and velocity.^{1,4,10,11} The ability to access thermal refuges is especially important for cool-water species, such as brook trout. As stream habitat is lost and degraded, the ability of aquatic species to move along streams might become even more important for maintaining healthy populations.^{1,11}

Mammals, reptiles, amphibians and other animals also depend upon the ability to move along streams and adjacent riparian habitats.^{13,27-31} When crossings impede or block movement within these corridors, some species might have to cross roads or pipeline corridors, becoming more vulnerable to predation and road mortality.⁴

Road crossings can create physical barriers to species movement within streams. Differences in elevation between a culvert and the streambed (i.e. perched culverts), clogged or collapsed culverts, low water depths, high water velocities or turbulence, and lack of continuous natural substrate can act as barriers.^{1,11,23,32,33} A study in

Vermont of 1,501 culverts found that less than 6 percent of those crossings allowed full passage of aquatic species.⁴

Crossings that are passage barriers can have immediate and long-term consequences.¹ Isolation of populations caused by road-crossing structures might cause declines in many aquatic species and reduce long-term population survival by decreasing gene flow and increasing the likelihood of local extinction.^{1,10,11}

Fish often show changes in behavior, physiology and reproductive success as a result of the effects associated with inadequate stream crossings.^{2,6,12} Even partially passable barriers can delay migrations and cause physiological stress.^{1,10,32-34}

Other aquatic species have a large range of habitat requirements and movement capabilities – some, like mussels, are practically immobile; some only move relatively short distances; and some, like crayfish, crawl instead of swim. Thus, the effects of stream crossings as a barrier to movement are highly variable among aquatic species.^{18,35,36} The best way to minimize impacts to all species is to avoid changing stream width, gradient and substrate.^{1,37}



CONSERVATION PRACTICES AND SCIENTIFIC SUPPORT

Scientific literature supports reducing the impacts of stream crossings through proper design, construction and maintenance practices. The following practices are derived from management and guidance [documents](#) developed by state agencies, scientific/conservation organizations and industry groups.

Top Resources for Road-Stream Crossings:



CLICK

U.S. Forest Service: Aquatic Organism Passage



CLICK

UMass: River and Stream Continuity Project



CLICK

Vermont Fish & Wildlife Department: Aquatic Organism Passage at Road/Stream Crossings

Learn more about the ecological impacts of [roads](#) and [pipelines](#) and practices that can reduce them.

Minimize the Number of Stream Crossings and Avoid Sensitive Habitats

Scientific literature suggests that by minimizing the number of stream crossings throughout the region, the overall impact on aquatic species and stream health can be lessened.^{1,18,23,35,38,39} Using existing crossings is one way to reduce the number of crossings; however, crossings might need to be upgraded to ensure they can accommodate the expected volume and type of traffic. Proper placement of crossings on a landscape scale can help avoid disturbances to hydrologic connectivity and critical habitat areas.^{1,8,39} One study recommends leaving 500 meters upstream and downstream between identified fish spawning beds and culvert locations.¹²

Existing conservation practices include consolidating infrastructure, upgrading existing crossings rather than constructing new crossings when possible, and locating roads and pipelines so as to reduce the number of crossings needed. Crossings should avoid highly sensitive areas, including headwater streams, wetlands and critical species habitat. Temporary bridges can be cost-effective and less environmentally degrading to streams if used properly.

Design and Construct Stream Crossings that Maintain Natural Stream Functions

Scientific literature shows that properly designed and maintained stream crossings can lessen impacts to fish and wildlife populations, stream habitat and water quality; decrease erosion and sedimentation locally and downstream; and reduce the risk of failure during storms.^{1,11} Several factors influence proper design and construction methods, including stream width, slope, velocity, and flow; soil type and slope; landscape characteristics; and the volume and type of anticipated traffic.^{8,11,23} Although crossings that are designed to high standards might cost more upfront, they typically require less maintenance and are more likely to withstand major storm events.^{11,37,40}

Existing conservation practices include designing and constructing crossings that provide water depths, velocities, bottom substrates and channel characteristics that are comparable to the natural stream. Specifically:

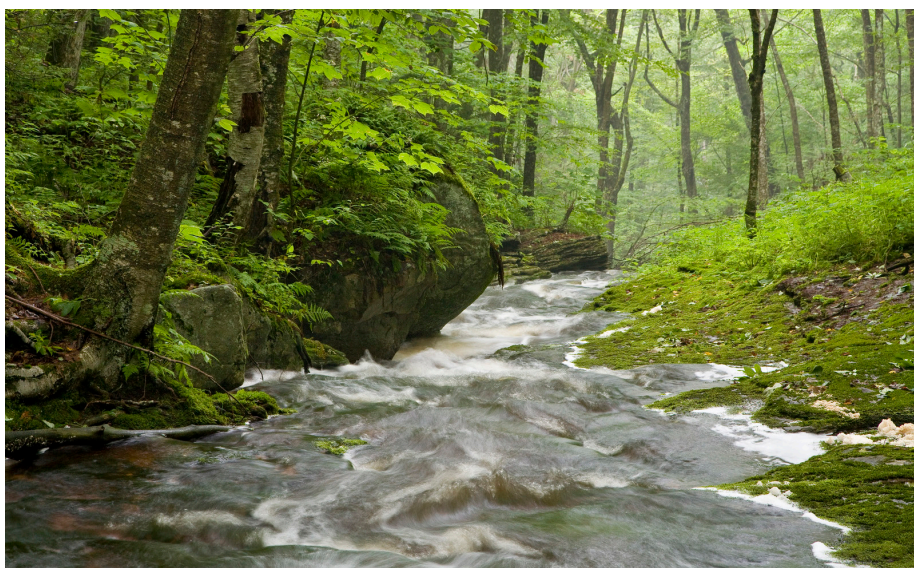
1. Use effective erosion and sediment control methods during and after construction to prevent impacts downstream and scouring above and below the crossing. Promptly revegetate stream banks after construction.

2. Construct crossings perpendicular to the stream channel.
3. Design crossings to preserve natural stream flow patterns and habitat characteristics, and allow passage for aquatic species. Crossings should provide comparable water depth and velocity conditions upstream and downstream. Avoid slopes greater than 3 to 5 percent and increasing or decreasing water velocity.
4. Construct crossings that are at least 120 percent of bankfull width so they are large enough to handle regularly occurring high-flow events and under lower flow conditions, provide a corridor for safe passage for reptiles, amphibians and small mammals.
5. With possible exception of extremely low traffic areas, fords should be avoided, especially when sensitive species are present.
6. Maintain natural streambed substrate by using bridges, open-bottom culverts, or embedded closed-bottom culverts.
7. Suspended pipelines should provide adequate clearance for high-flow events and floating debris. Buried pipelines should be below scouring depth.
8. Properly monitor and maintain stream crossings throughout the lifetime of the structure.

Limit Construction during Critical Periods

Scientific literature suggests that aquatic species are particularly vulnerable to the negative effects of sedimentation during [critical lifecycle periods](#).^{8,20,23} Construction during wet periods (e.g., spring thaw, heavy rains) increases the risk of severe erosion and sedimentation.⁴¹ Extra forms of erosion control can provide additional protection if construction is unavoidable during these times.³⁶

Existing conservation practices include constructing road and pipeline crossings during periods of low flow and avoiding critical lifecycle periods to minimize sedimentation impacts to fisheries and wildlife.



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Inventory Stream Characteristics and Monitor Crossings

Scientific literature encourages collecting pre- and post-development data to better assess impacts and identify valuable habitats and species.² Monitoring and maintenance of crossings are crucial in avoiding mass erosion events caused by crossing failures.³⁷

Existing conservation practices include collecting information on channel characteristics, aquatic species and water quality before and after crossings are built. Continue to monitor stream crossings and perform any needed maintenance at least once annually – ideally before spring high flows. Crossings should also be assessed for damage after large storm events.

TNC Recommended Conservation Practices

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

-  **Consolidate infrastructure and use existing crossings** to minimize the number of new stream crossings.
-  When developing new road crossings, **construct crossings that are at least 120 percent of bankfull width and that maintain natural streambed substrate** by using bridges, open-bottom culverts or embedded closed-bottom culverts. Crossings should allow for dry passage and provide comparable water depth and velocity conditions upstream and downstream.
-  Temporary bridges may be used if they are able to withstand the anticipated traffic load. Fords should be avoided, especially when sensitive species are present.
-  When constructing pipeline crossings, **use installation techniques that minimize the amount of sediment released into the stream and maintain adequate flow** to protect aquatic species.
-  **Inspect regularly** and keep free of debris to reduce risk of flooding.

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](https://www.nature.org/shale-practices-refs) for a list of references used in this document