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Stream restoration

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Nontraditional solutions deliver multiple benefits for municipalities

Stream restoration and shoreline stabilization provide valuable results for municipalities required to meet assigned waste load allocations for phosphorus, nitrogen, and sediment. **Ashley Hall**, **Daniel Proctor**, **Karen Hall**, **Josh Running**, and **Travis Crayosky** of Stantec Inc. explain the environmental, financial, and practical benefits of employing these two nontraditional stormwater practices in the Commonwealth of Virginia, United States.

Localities with Municipal Separate Storm Sewer System (MS4) Permits in the state of Virginia, United States (US), have been pushed hard to meet their assigned Waste Load Allocations (WLAs) given in Total Maximum Daily Loads (TMDLs). MS4s are named in TMDLs that have been developed for hundreds of impaired watersheds. These local TMDLs have challenging reductions, but the current TMDL-related pressure point for Virginia MS4s is the Chesapeake Bay TMDL, which assigns WLAs for phosphorous, nitrogen, and sediment.

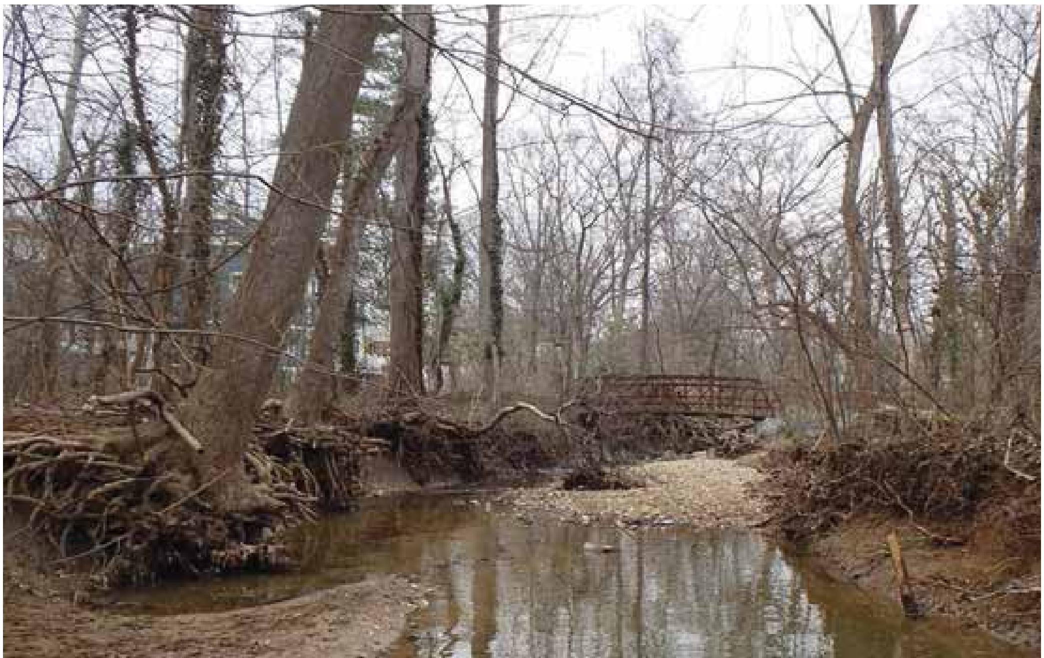
The Chesapeake Bay has its own Special Condition in Virginia's MS4 permits, with a firm deadline to meet the WLAs for nutrient and sediment reductions by 2028, as detailed in the General Virginia Pollutant Discharge Elimination System Permit (VPDES) for Discharges of Stormwater from Small Municipal Separate Storm Sewer Systems, Section 1.C: Special condition for the Chesapeake Bay TMDL. This objective is also integrated into Virginia's commitments to the Environmental Protection Agency (EPA) to clean up the Chesapeake Bay.

The financials for meeting these goals started off dire as cost estimates returned were higher than anticipated and there were no dedicated funds for TMDL implementation at the time.

Many MS4s initially struggled to find enough projects to meet the reductions and then quickly fit them into long-term funding plans to be approved by elected officials who were surprised by the financial consequences of the MS4 permits. As a result, a search led by local government officials (with support from contracted consultants) ensued for innovative practices that would bring multiple visual benefits to the public.

Ideal projects would ideally have easy support from all stakeholders and have clear environmental benefits with a low cost relative to the amount of pollutants removed. In Virginia, phosphorus has traditionally been marked as a unique type of currency for benchmarking stormwater practices. In the most general terms, the presence of phosphorus represents stormwater pollution from multiple sources (construction sites, treatment plants, etc.) and can be traded as a nutrient credit among point sources and nutrient bankers.

The success of a project can be measured, to an extent, by the pounds of phosphorus removed along with the overall cost of the project, providing a data point in terms of dollars per pound of removed phosphorus ($/lb-P). While this figure represents a gross estimate, not accounting for maintenance costs, community



The above image shows Dead Run before the stream restoration project began. Photo by Stantec benefit, improved infrastructure, etc., it provides a tangible starting point that allows for consistent tracking of results.

During the search for innovative practices, Virginia MS4s collectively found that conventional stormwater structural practices – detention basins, constructed wetlands, bioretention, and permeable pavement, for example – posed a challenge as far as cost and scale was concerned. They discovered that these traditional practices would have to number in the hundreds in order to meet their WLAs, would eventually become a maintenance nightmare, and would have a very high dollar-per-pound removal rate. Faced with the insurmountable challenge of installing such a high number of practices in a short timeframe, many MS4s were considering buying credits and walking away from the maintenance and logistics.

FACED WITH THE INSURMOUNTABLE CHALLENGE OF INSTALLING SUCH A HIGH NUMBER OF PRACTICES IN A SHORT TIMEFRAME, MANY MS4S WERE CONSIDERING BUYING CREDITS AND WALKING AWAY FROM THE MAINTENANCE AND LOGISTICS.

However, Virginia's MS4s soon identified two nontraditional practices that had the potential to achieve similar quantities of pollutant reductions as numerous structural stormwater practices in one project at a more cost-effective removal rate: stream restoration and shoreline management. In both practices, sediment and associated nutrients are directly prevented from entering waterbodies, with additional ecological uplift added through natural processes that can be designed into the project. Addressing the stream and shoreline erosion also improves other conditions for MS4 permit holders, such as designing for climate resiliency, reducing flooding impacts, protecting existing infrastructure, and increasing public access to green spaces.

Stream restoration

Urbanization has significantly affected waterways, with increases in impervious areas spiking stormwater discharges and peak flows. These stormwater discharges are conveyed to receiving channels with high velocities and shear stresses that cause erosion, channel incision, and overall degradation of the natural stream system. While upland stormwater practices can alleviate some of these symptoms through flow controls, streams are still vulnerable to impacts from urbanization and stormwater discharges.

Stream channel erosion releases sediment into waterways, along with the associated nutrients bonded to the soil particles. Additionally, urbanization's effects on streams have caused disconnection from floodplains as well as decreased contact time and a reduced ability for nutrient uptake by streams and riparian vegetation. These sediment and nutrient loads were noted contributors to the degradation of the Chesapeake Bay and its many tributaries. Sediment can impair benthic communities that rely on stable stream cobble and gravel substrates for habitat colonization. Excess nutrients, coupled with warm temperatures, create algae blooms and the resultant hypoxic conditions currently found within parts of the Chesapeake Bay.

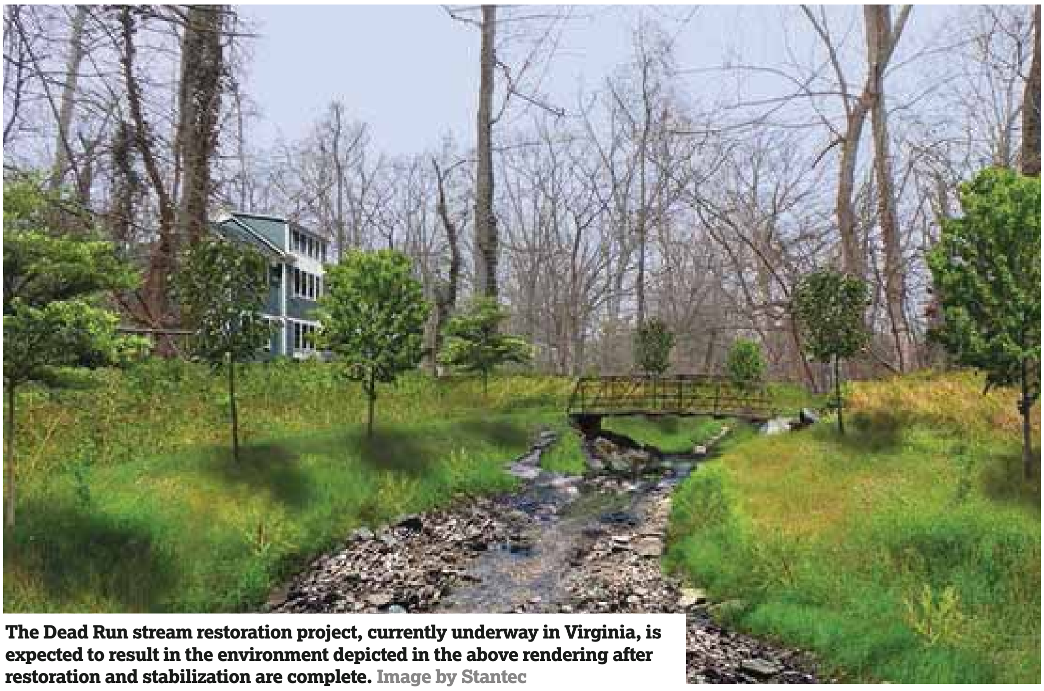
The practice of urban stream restoration seeks to reduce the loss of sediment and associated nutrients from the stream channel while stabilizing the stream channel to withstand new watershed conditions and other environmental factors. A stream restoration project can vary greatly depending on the existing conditions and the desired outcome. In some instances, erosion reduction is all that is warranted for a project. In other cases, the stream restoration project may initially be undertaken for erosion concerns, but then it may be further enhanced to endure future considerations such as recurrent flooding or upcoming development.

All aspects of the stream and its watershed are reviewed prior to designing a stream restoration project. Key considerations include topography and geology, along with constraints such as bedrock. Existing utilities – sewer mains and laterals, fiber optics, and electrical – are also frequent constraints that must be considered and addressed as part of the design.

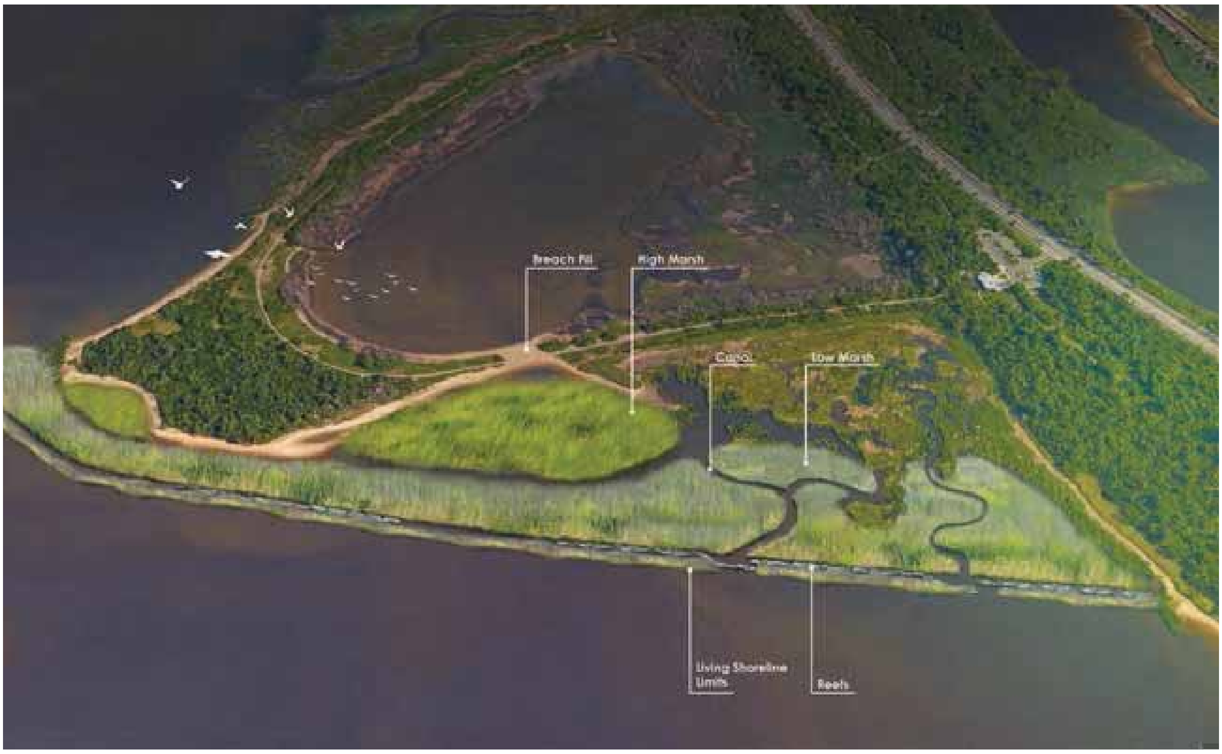
Floodplain analysis is also a major consideration. The design of a stream restoration project has the ability to impact the mapped flood zones and thereby influence Federal Emergency Management Agency (FEMA) mapping, insurance rates, and property values. Sourcing of materials for these projects is also a key project consideration. Local, state, and federal regulatory agencies typically prefer to see onsite materials used where possible such as root balls from trees, native soils, and harvested streambed materials. Large rock structures are typically installed to help direct flows and provide for grade controls. Visits to quarries to view boulder choices are common, and hauling costs need to be considered.

Many MS4s have successfully restored stream channels and reported the amount of sediment and nutrients (nitrogen and phosphorus) effectively removed from downstream receiving waters, and ultimately from the Chesapeake Bay. The amount of sediment and nutrients that is credited to the project for purposes of the Chesapeake Bay TMDL is determined using the Chesapeake Bay Program's assembled Expert Panel guidance document, which describes the practice, recommends removal rates, and outlines qualifying criteria.

Projects are credited using four primary protocols. The majority of a stream restoration project's credit comes from the prevented mass of sediment and nutrients that is annually lost from eroding streambanks. This figure is estimated using a predictive model that considers susceptibility to erosion and dimensions of the stream, and it may be verified with bank pin measurements. Other protocols account for reductions achieved through nutrient processing by denitrification and nutrient



The Dead Run stream restoration project, currently underway in Virginia, is expected to result in the environment depicted in the above rendering after restoration and stabilization are complete. Image by Stantec



An aerial rendering of Jamaica Bay illustrates shoreline stabilization tactics in New York. Photo by Stantec

absorption through floodplain reconnection. Regenerative practices used on intermittent and perennial streams to slow flows and increase floodplain interaction are also credited as a stream restoration practice.

Shoreline management

The transport of sediment along shorelines is an essential process in tidal environments, but in areas where erosion rates are more excessive, it can also be detrimental. At a natural rate, eroding shorelines provide tidal habitats through accretion of natural sediments. On the other hand, the rate of shoreline erosion can be dramatically increased due to sea level rise, increased frequency in storm events, shoreline development, and increased commercial and recreational activities. Areas of larger erosion are problematic from a water quality perspective, where shoreline sediments and accompanying nutrients are deposited into the receiving waterbody. Considering the sediment and nutrient issues within the Chesapeake Bay, the contribution of this source should not be overlooked. In many of the same ways as stream restoration, stabilizing eroding tidal banks can result in a beneficial sediment and nutrient reduction.

Several management practices can be used to address shoreline erosion and improve water quality. Traditionally, shoreline erosion has been approached using structural practices, such as seawalls, bulkheads, and riprap revetments, but these practices can create other sediment transport and scour issues and can limit habitats for tidal ecosystems and vegetation. Shoreline management practices that incorporate water quality benefits are often referred to as living shorelines. A living shoreline practice incorporates nature-based designs where feasible, with nonstructural features such as marsh creation, beach nourishment, and vegetated banks. However, when hydrodynamic conditions warrant further protection to achieve stability, a hybrid design using structures (i.e., breakwaters or rock sills) can be incorporated to adequately resist wave erosion while maintaining natural coastal processes. A shoreline management project can also be enhanced to accommodate recreational and resiliency benefits.

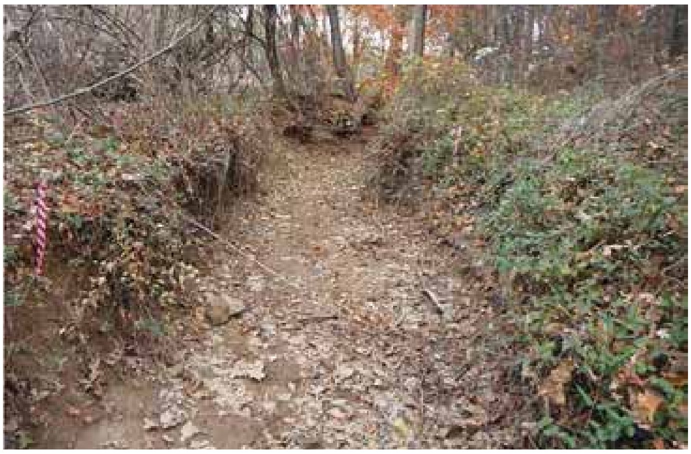
All aspects of the shoreline and the surrounding area are reviewed when conceptualizing a shoreline management project including the current rate of erosion of the shoreline banks, existing geologic conditions, wave heights, nearby infrastructure, and construction access (land and water). The presence of migrating birds, submerged aquatic vegetation, archaeological sites, bald eagles, anadromous fish, other threatened and endangered species, federal navigation channels, and leased oyster beds are some of the common obstacles noted for Virginia projects. Such obstacles are surmountable but have unique restrictions that are incorporated into the design and construction for projects.

The amount of sediment and nutrients prevented from entering a waterbody as the result of a shoreline management activity can be quantified toward water quality goals such as TMDL WLAs. Like the one convened for stream restoration, the Chesapeake Bay Program convened an Expert Panel to define the dominant methods in which shoreline management achieves sediment and nutrient reductions to waterways. For many shoreline management projects, there are steep or rapidly eroding banks that require immediate protection. The prevented loss of sediment (Protocol 1) is where the most substantial sediment and nutrient reductions are achieved. Estimates of sediment and nutrient reductions are based on measured erosion rates, bank heights, and soil conditions (bulk density and chemical constituency). Depending on the project, further sediment and nutrient removal may also be quantifiable through the creation of tidal marsh due to such processes as denitrification, nutrient uptake from biomass production, and sediment accretion (Protocols 2-4).

THE MAJORITY OF A STREAM RESTORATION PROJECT'S CREDIT COMES FROM THE PREVENTED MASS OF SEDIMENT AND NUTRIENTS THAT IS ANNUALLY LOST FROM ERODING STREAMBANKS.

Disputed issues regarding credit

In addition to setting technical standards on how to quantify sediment and nutrient reductions for stream restoration and shoreline management practices, the respective Expert Panels also addressed various concerns raised by opponents to using the practice for meeting WLA requirements in addition to legitimate issues raised by unbiased parties. Among



others, these concerns included dissatisfaction in the location of the obtained pollutant reductions, the fear of taking reduction credit for sediment that would never be fully transported to the Chesapeake Bay, and indirectly supporting bank armoring under the guise of environmental restoration that could limit other desirable natural processes.

The treatment processes described by the protocols are mechanisms contained within the stream channels or nearshore tidal areas themselves versus within upland areas of the watershed, as in other stormwater practices. For years, regulatory agencies had been encouraging the avoidance of placing stormwater facilities within jurisdictional areas, and the crediting of these practices seemed to conflict with this objective. Furthermore, it was questioned whether it would be acceptable to achieve the permit-mandated WLA well downstream from the point of discharge covered by the MS4 permit – or within a different hydrologic setting altogether. Thanks to a diverse range of stakeholder involvement in the Expert Panels, which included regulatory agencies, these concerns were thoroughly discussed, and a reasonable consensus was achieved. This resolution was in large part due to acknowledgement that pollutant reductions would indeed be achieved, which was the primary objective of the WLAs. The Chesapeake Bay was widely indiscriminate as to where the pollutant reduction occurred. But local waterways still had to be protected, too, so limitations were placed on the watershed locations of the treatment practices with respect to the credited MS4 location.

It was also understood that some of the eroded sediment from stream banks might be deposited along the downstream areas and never actually be transported to the Chesapeake Bay. This potential was addressed using the EPA's modeling tools for the Chesapeake Bay TMDL and establishing delivery ratios for various tributaries, along with similar checks and balances, to avoid over-counting sediment and nutrient reduction potentials. Since shoreline management practices are contained within the actual estuary itself, the same concern was not applicable, but the need to reconcile the allowable credits with respect to the EPA modeling was identified. Maximum achievable sediment and nutrient reduction loads were established within given segments of the contributing tributaries to avoid overestimation.

One of the largest points of contention was that crediting these practices would indirectly encourage a vast hardening of natural systems. Other environmental value is present within natural stream and shoreline conditions that should not be ignored for the sake of sediment and nutrient reduction. If a dangerously narrow interpretation were applied, much of the science behind the protocols would suggest no difference between replacing an eroded stream with a fully restored system, versus a concrete or riprap-lined channel. Likewise, it was questioned whether or not replacing an eroded shoreline with a riprap revetment or vertical bulkhead should be allowed. Unintended consequences could result in adverse effects to the same ecosystems intended to be protected, so the protocols contain qualifying criteria and minimum standards to avoid such situations where possible. To achieve sediment and nutrient reduction credits, stream restoration is required to use natural channel design methods, and shoreline management must incorporate living shoreline principles.

Summary

Stream restoration and shoreline management can be exceptional practices that accomplish reductions of sediment and nutrient loadings to local waterbodies for relatively low cost compared to other conventional stormwater practices. Accessible eroding stream channels and shorelines on public lands may be limited for some MS4s. In urban communities, adjacent residents must be willing stakeholders in the project. The disruption of natural areas in an already urbanized community and the willingness to provide easements can be sensitive issues; therefore, early public outreach is essential in having a project proceed without major delays or cost escalation.

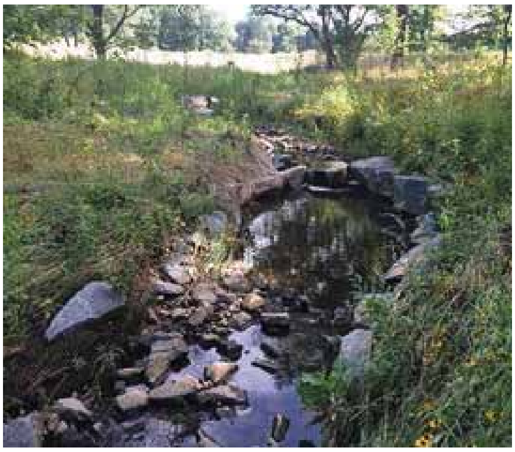
When implementing these projects, the MS4 will be responsible for maintaining the project integrity. Maintenance of these projects is anticipated to be low; however, every project is different, and the use of these practices for WLA compliance is still early. The initial guidance for monitoring and verification of stream restoration projects was set at 5 years, and the first general permit to require Virginia MS4s to act on the Chesapeake Bay TMDL was issued in 2013, so some projects are now approaching the first 5-year window. As time advances, it is thought that the verification process may need to be more frequent and more prescriptive. The agencies have the discretion to prolong the monitoring of these projects, requesting resolution of issues such as invasive species, vegetation die-off, scour at structures, or excessive sediment deposition, among others. Having a knowledgeable consultant or other party to review and defend a project can be important in making sure that the project is not monitored for an unnecessary period of time.

The science and crediting protocols of these practices is also under continuous review in Virginia and for the Chesapeake Bay Program. The Expert Panels are subject to reconvene and reassess recommendations if determined necessary. While it might be challenging to keep up with the Chesapeake Bay Program's methodologies, the science behind stream restoration and shoreline management is fundamental. These practices not only improve water quality but also bring a suite of additional benefits to the community. As communities are challenged to build with resilience and replace aging infrastructure, stream restoration and shoreline management will continue to be the leading options for multifaceted solutions.

Authors' Note

Stantec Senior Engineer Ashley Hall, located in Richmond, Virginia, specializes in water resources engineering including watershed analysis, stormwater management planning and design, low impact development, municipal separate storm sewer system permit support, and TMDL implementation.

Stantec's Water Resources Manager Daniel Proctor, Water Resources Engineer Karen Hall, Associate and Senior Environmental Planner Josh Running, and Principal Travis Crayosky work out of the company's Williamsburg, Virginia, office. Proctor has more than a decade of experience in planning, designing, and managing complex environmental and engineering projects. Karen Hall has experience in multiple aspects of stormwater management and water resources engineering. Running has nearly 20 years' experience and serves as the firm's national technical lead for ecosystems restoration. Crayosky has more than 20 years of experience specializing in ecosystem restoration projects that include stream and wetland assessment, restoration design, regulatory permitting, construction management, and monitoring and reporting activities.



(Left to right): The images show three stages -- before, during, and after -- of a stream restoration project in Fairfax County, Virginia. Stantec provided restoration services for a Piney Run tributary that extends from the Fairfax County Park Authority-owned Banks Property to Old Telegraph Road near Hayfield Road. Stantec completed various assessments, wetland and ecological surveys, macroinvertebrate sampling, conceptual design, detail design, permitting, and construction drawings. Photos by Stantec