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Stream Restoration

Floodplain Restoration: Basics, Benefits, and Practical Applications

Mark A, Gutshall, Restoration Ecologist and Ward L. Oberholtzer, P.E., Water Resources Engineer

For some years we have known that all is not well with our rivers and streams but, until recently, we focused our efforts primarily on the water channels. Through the field work we have done and observations we have made at LandStudies, Inc. in Lancaster County, Pa., coupled with the invaluable research of our colleagues, Dr. Arthur Parola at the University of Louisville, and Drs. Dorothy Merritts and Robert Walter at Franklin and Marshall College in Lancaster, we now know that much of the work to repair our streams should first be focused on the floodplains or stream valleys and the "legacy sediments" or post-European settlement alluvium that have filled them.

Floodplain restoration, as described and discussed in the following pages, is based on returning stream channels and floodplains to their historical elevations and locations and creating frequent interactions between the stream, floodplain, and groundwater. The following pages tell the story of stream systems – stream channels and their adjacent floodplains – in the Eastern United States, particularly in the region known as the Piedmont Province (In a renewed effort to restore the Chesapeake Bay to better health, the Environmental Protection Agency has especially targeted three areas in this region as major contributors of sediment and nutrient pollution to the bay: Lancaster and York counties in Pennsylvania, the Delmarva Peninsula in Delaware and the eastern shores of Maryland and Virginia, and the Shenandoah Valley in Virginia and West Virginia).

The Basics describes how stream systems are supposed to work, what happened to our stream systems when we began to settle the East Coast, and why it is important to restore them.

The Benefits describes the multiple benefits of fully functioning stream systems and how they can be realized through reconnecting the interactive components of those systems.

Practical Applications describes how different constituents have benefited from floodplain restoration and details how the golf course industry, specifically, has benefited.

THE BASICS

Legacy Sediments: A Brief History

Most people blame current agricultural practices, sewerage treatment facilities, and development – strip malls, residential subdivisions, and paved roads and parking lots – for polluted waterways and unstable streams, but a greater portion of the problem, goes back to the agricultural period of the 18th through the early 20th centuries, when erosion from large-scale forest clearing and poor farming practices dumped millions of tons of soil into Colonial streams, valleys, and floodplains. Thousands of mills

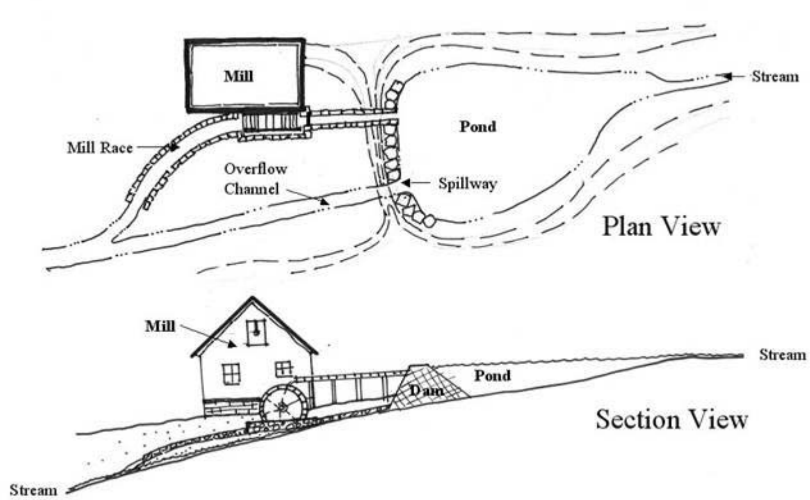

Figure 1. Mill and Dam Construction
Plan and section views make it easy to see how water slows and ponds behind dams allowing sediments to build up behind the dams.

Figure 2. Remains of Breached Dam
This photograph was taken looking downstream at the breached dam breast of a late 19th century dam in Sands Creek, Town of Hancock, New York. Note the high floodplain on the upstream side of the dam.

and dams along waterways caused ponding behind the dams and thus the deposit of additional tons of fine sediments. (See Figure 1.) These sediments, deposited throughout our stream and river valleys within the past two centuries, are what we call "Legacy Sediments."

Legacy sediments alter the geomorphology – *the processes by which landforms are formed and the materials of which they consist* – and the hydrology – *the cyclic movement of water over and under landforms* – of the valley bottom, producing an array of problems for the streams themselves and for the communities through which they flow. Such problems include increased sediment and unwanted nutrients in the water, bank erosion, debris jams, habitat instability and loss, and reduction of flood water detention along with increased flood levels or elevations, all of which are common in the streams of many watersheds in the Piedmont Province. Many of these problems first surfaced after the onset of urbanization.

By the mid 20th century, conservation farming practices slowed or stopped sedimentation in many streams in these watersheds. Urbanization began in the 1950s, reaching a peak in the 1970s and 1980s, before stormwater management policies were implemented.

Stormwater runoff increased dramatically with urbanization, according to models developed by the Lancaster County, Pa., Office of Engineering and others. Before urbanization, stream channels had been building up – rising in elevation, or "aggrading" – on top of deposited sediments for several centuries. But then, with large-scale sedimentation and erosion halted, these channels began cutting down through the accumulated sediments ("degrading"), commensurate with the flow forces of increased runoff and the removal or crumbling of old dams. (See Figure 2.) Stream channels today are still cutting rapidly through thick

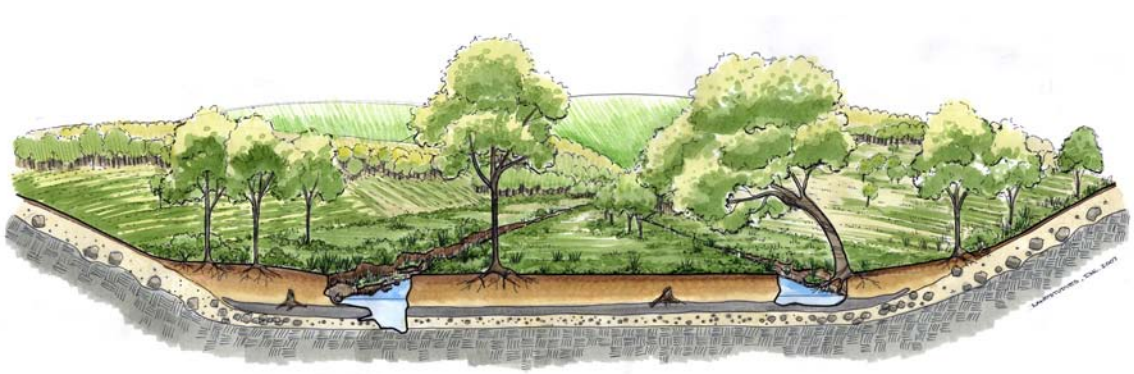

Figure 3. Existing Conditions
Stream channels are eroding or have eroded down through sediments that collected behind mill dams, leaving their alluvial floodplains high above the current base flow water elevation, and disconnecting riparian root systems from groundwater flows. The processes of frequent floodplain inundation, relieving in-channel stresses; groundwater infiltration through porous floodplain material; and nitrogen removal from groundwater through root systems and bacterial processes are lost under these conditions that are prevalent today throughout the Northeastern United States.

stacks of legacy sediments, exposing peats, sands, and gravels of the submerged, pre-settlement valley floors. (See Figure 3.)

After breaching of the dams, the channel eventually cuts down through the legacy sediments to its historical, pre-settlement floor. As a result of the increased channel depth, the gravels along the floor erode easily, allowing the stream to begin undercutting its banks also consisting of fine grained legacy sediments. In Lancaster County, Pa., for example, bank collapse and erosion now occur along at least 80 percent of the 644 miles (1036 km) of stream channels in the Conestoga watershed. We estimate that 10 percent of the sediment stored along valley floors since 1710 has been removed by channel incision and widening that closely resembles arroyo-cutting in the arid southwest (lateral bank erosion rates of >0.5 m/yr measured at multiple sites). The large volume of sediment trapped in the valley bottoms for several centuries has become a major source of suspended sediment load in local streams and in their downstream receiving water bodies during the past 35 years, and will remain so unless substantial remediation efforts are made. This same phenomenon of channel incision, channel bank erosion, and bank collapse is occurring throughout the Piedmont region of Pennsylvania and Maryland, and beyond. (See Figure 4.)

The deleterious impacts of legacy sediments on stream systems and their receiving waters are numerous and seriously affect groundwater recharge, flooding, water quality, aquatic environments, and native vegetation. Prehistoric floodplain areas that are naturally intended to store water and filter nutrients are now filled with legacy sediments. Streambeds that are perched above their historical gravel levels interrupt the natural interplay between stream flow and groundwater recharge. Clays and sediments built up between the gravels and current, historically formed bank tops (often misnamed "floodplains") prevent flows in the channel or on the surfaces of the legacy sediments from re-charging the aquifer, especially in limestone streams. Flow, sediment and nutrients are directed, instead, into the channel and transported into its downstream receiving waters.

The sediments now filling former groundwater recharge areas contribute to many of our current flooding problems. Individuals and entire communities grapple with frequent nuisance flooding, and often worse, because 1) less water is able to enter the aquifer as groundwater recharge, and instead is added to stream flow, and 2) legacy sediments have now filled the former floodplains, which used to serve as a storage area for water. As a result, many millions of acre-feet of storage space for groundwater have been filled and lost in watersheds.

Gravels that once served as channel beds still convey groundwater. Because modern streams are perched above the gravels upon which they once flowed, the streams no longer receive the flow of cold groundwater they once did, but rely mostly on warm runoff. The groundwater still flows along the gravels below the existing streambed. A stream that is detached from its historical gravels and base flow has impaired aquatic resources.

Figure 4. Channel Bank Erosion and Exposed Legacy Sediment. Channel bank erosion and exposed legacy sediments are evident after dam removal in Mount Holly Springs, PA.

Old floodplains hold pre-settlement, 17th century seed-beds, which can re-germinate under the proper conditions. Today's stream and floodplain degradation and erosion remove the historical seedbed and replace suitable, usually native, floodplain and riparian buffer vegetation with opportunistic, often invasive and unwanted species. This same erosive process removes or destroys historical and archeological evidence that also resides in the historical floodplain.

Floodplains and stream banks that typically should be less than 15 to 24 inches (0.3 to 0.6 m) above the gravels or bedrock are, because of legacy sediments, three to 20 feet (1 to 6 m) high. The result is bank erosion during storm events and long-term effects on fish and other aquatic life due to increased turbidity that persists from the beginning to end of precipitation events.

The legacy sediments stored along streams and abnormally high stream banks contain massive amounts of phosphorus, which is released during channel erosion. Additionally, artificially high banks separate plant root zones from the nitrogen in groundwater. Thus, instead of nitrogen being taken up by plants, groundwater flowing through the sediments transports the nitrates, along with phosphates, into streams. Bacterial processes also assist in denitrification and nitrate reduction, but elevated floodplains seldom experience the saturated conditions and carbon, associated with the root zones and woody debris along the river bottom, that facilitate this process.

The Realities of Stream and Floodplain Restoration

Many stream "restoration" efforts in the Piedmont region show limited success because the effects of legacy sediments are not considered (See Table 1, which compares observed erosion rates in Pennsylvania and Maryland watersheds with those predicted by a widely used model that does not account for legacy sediments).

Table 1. Measured vs. predicted "problem area" erosion rates from stream banks in various areas of Pennsylvania and Maryland

Creek (County or State)	Length of Stream Studied (feet)	Measured Erosion Rates (tons per year) for study area	Predicted "Problem" Area Erosion Rates* (tons per year) for study area
Choconut (Susquehanna)	7,920	50,000	110 – 2,194
Codorus - East Branch (York)	5,410	2,070	90 – 1,794
Codorus Creek- South Branch Granary Rd. (York)	2,200	2900	56 – 1,122
Codorus Creek- South Branch SBCC 026 (York)	400	450	9 – 180
Codorus Creek- South Branch SBCC 015 (York)	550	578	8 – 160
Codorus Creek- South Branch SBCC 025 (York)	600	1200	15 – 300
Codorus Creek- South Branch Phase I (York)	1,770	1,083	15 – 304
Codorus Creek- South Branch Phase II (York)	2,050	500	15 – 298
Codorus Creek- South Branch Phase III (York)	4,170	2,180	33 – 654
Conewago (Adams)	800	8,000	20 – 400
Cowanshannock (Armstrong)	80	31	1 – 20
Cowanshannock (Armstrong)	50	52	1 – 20
Crabby (Chester)	400	1,444	4 – 80
Long Draught Branch (Maryland)	1,607	427	19 - 380
Octoraro -West Branch (Lancaster)	1,650	1,200	4 – 84
Meetinghouse Creek Nickel Mines Run Stewart Run Total for Octoraro WBR Headwaters (Lancaster)	43,058 53,704 60,429 157,191	4,764-5,928 5,195-6,438 4,415-5,459 14,374-17,825	188 – 3,766 206 – 4,110 187 – 3,744 573 – 11,458
Santo Domingo (Lancaster)	193	80	2 – 32
Spencer Run (Blair)	16,250	3,200-3,900	133 – 2,666
Stony Run (Maryland)	1,392	912	12 – 238
Trout Run (Chester)	50	20.5	1 – 20

* These values were calculated using lateral erosion rates of 1.0×10^{-2} to 2.0×10^{-1} meters/year as suggested by Evans *et al*, 2003.

Figure 5. Pre-Settlement and Restored Conditions
Stable, pre-settlement stream and floodplain systems were characterized by: a low, porous floodplain in close contact with surface water in the stream channel, allowing for frequent inundation of the floodplain during high flows; riparian vegetation with roots zones in contact with ground water that enabled groundwater denitrification through root uptake and bacterial processes; and a channel bed composed of cobble and gravel, which helped protect the underlying bedrock from erosive flow forces.

In order to restore a stream, we must first understand what the stream looked like before settlement and land-clearing. (See Figure 5.)

Most streams will never be fully restored to their pre-settlement state, but we argue that any remediation effort must "connect" a stream to its pre-settlement valley floor, where feasible, otherwise the primary functions and interaction of the stream and floodplain are lost. The streams may continue to incise downward and erode laterally. In essence, the banks of most streams in the Piedmont, as they exist today, were determined not by what is required to carry prevailing loads of water and sediment, but rather by the heights of hundreds of centuries-old mill dams that were built to use water power throughout the region. In other words, the current channel geometries (bank height and channel width) are merely temporary as a result of the streams evolution to stability from the previous historical impacts.

Post-settlement, historical land-use impacts on watersheds must be taken into account in any stream restoration effort. In the Pennsylvania Piedmont, most streams are perched above their historical bed elevations, and restoration of various reaches of the watershed must be completed in a specific order if the restoration is to be effective. For example, if a downstream reach is perched above the historical bed elevation, the reach immediately upstream should not be restored until the downstream reach is corrected to its historical base elevation which includes ensuring the channel bed is located immediately within the gravels/bedrock and groundwater. It is fundamentally necessary, then, to identify which reaches have streambeds that are too high and which are at the historical bed elevation. Frequently, the location of historical stream bed levels requires trenches or subsurface investigation. Other typical problems include existing dams or culverts and utility cross-

ings that prevent streams from reaching their historical bed elevations. Stream restoration is difficult to complete with long-term stability if the stream is perched above its historical elevation, regardless of efforts to stabilize stream banks. Another important factor in implementing long-term restoration is to restore stream systems that are producing and transporting coarse – grained or large bed material that must not be transported to maintain a stable profile and maximize aquatic habitat including spawning areas for trout. The restored reaches are designed to only transport the finer material for all flows including the flood events and not the large material carried under degraded conditions.

Our belief is that flow increases resulting from urbanization may require a wider floodplain and not a deeper channel. Flooding and bank erosion will not be exacerbated because of urbanization or development along streams restored in this manner, because shallow and wide floodplains maintain a relatively consistent low energy even for the larger flow events thus reducing transport of coarse grained particles. Stormwater best management practices (BMPs) may be required to address water quality and pollutant loads prior to entering the stream system. However, the frequent interaction of the floodplain will allow sediments and nutrients in the stream to access the floodplain and reduce the load carried to downstream waters.

THE BENEFITS

The benefits of stream and floodplain restoration are numerous and interconnected. Some of the benefits of restoration, such as reduced sediments and nutrients, reduced downstream flooding, and increased wetland acreage and function, are apparent soon after the restoration is complete. Others appear over time. And still others may never be visible, but their positive effects nevertheless will be operative.

Sediment and Nutrient Reduction

Sediment and nutrient reductions were calculated for the recently completed New Street Ecological Park Restoration Project on the Santo Domingo Creek in the Lititz Run watershed. Figures 6 through 10 show the project area before, during, and after restoration. Prior to restoration, based on measurements from monumented cross sections, 193 linear feet of the Santo Domingo Creek contributed, in only four months, 27.8 tons of sediment to downstream receiving waters. Those tons of sediment were calculated to contain 34.6 pounds of phosphorus and 96.3 pounds of nitrogen– the nutrients that contribute to the decline of the Chesapeake Bay as well as its upstream waters.

The 900-foot restoration, by virtue of cutting down the floodplain to a more natural elevation, immediately eliminated from the watershed 7,800 tons of sediment that contained more than 8,930 pounds of phosphorus and 26,080 pounds of nitrogen. The newly created wetland pockets will help trap incoming sediments and vegetatively filter incoming nutrients, adding to the long-term benefit of sediment and nutrient reduction.

Figure 6. Santo Domingo Creek in New Street Park, Lititz, PA - Before Restoration. The existing stream was channelized, unstable and eroding both vertically and horizontally.

Figure 7. Santo Domingo Creek in New Street Park, Lititz, PA - During Construction. Aerial view shows the new, meandering channel under construction as water continues to flow through the existing straightened channel.

Figure 8. Santo Domingo Creek in New Street Park, Lititz, PA - During Construction. The man is standing on restored floodplain, now attached to the restored channel. The old floodplain elevation, created by the deposition of legacy sediments, can be seen behind him.

Figure 9. Santo Domingo Creek in New Street Park, Lititz, PA - Post Restoration Restored Condition. The restored site during a late spring storm event.

Groundwater Recharge

As water from high stream flows comes out of the newly restored channel and onto the attached floodplain, the water collects in the created wetland areas, where it is vegetatively filtered and allowed to move slowly down through the soil to recharge the groundwater supply.

Stormwater Management

Stream corridor and floodplain restoration can be viewed as an ecologically harmonious, alternative method to address municipal stormwater management issues, including the National Pollutant Discharge Elimination System, known as NPDES II. A complete stream corridor and floodplain restoration immediately eliminates the sediments and nutrients held in the highly erosive, artificially high stream banks. Over the long term, the frequent flooding into the floodplain and the use of wetland areas throughout the floodplain helps trap and filter incoming floodwaters, thus eliminating not only excess water but also water-borne sediments and pollutants from downstream receiving waters.

Wetland Creation

Wetland pockets created along the length of a restoration have multiple benefits, including improved water quality, flood control, groundwater recharge, and wildlife habitat. Water from high flows settles in the wetlands, where water-borne sediments can drop out, nutrients can be used by the wetland plants, and nuisance flooding can be abated. Water in the wetlands gradually filters through the ground, recharging groundwater systems. Well-vegetated wetlands are prime habitat for a wide variety of aquatic and terrestrial wildlife.

Regional Flood Reduction

Wetland pockets and an expanded, accessible floodplain help alleviate nuisance flooding both in the immediate restoration area and downstream as well. During high flows, water that used to add to the downstream flow is now dispersed and slowed through the restoration site, where it filters slowly down through the soil. Acre-feet of sediment that filled the river valleys are now available for flood storage. This volume of flood storage created may total 50 to 100 acre-feet of storage equal to many stormwater management facilities

Riparian Buffer

Native plants, both herbaceous and woody, provide many benefits to the stream itself and to the water that moves into the floodplain. Trees and shrubs help shade the stream, keeping it cooler and healthier for aquatic wildlife. Leaf litter from these woody plants also provides a source of food for macroinvertebrate life in the stream. Herbaceous plants in the wetland pockets help reduce nutrients through nitrogen uptake.

Figure 10. Santo Domingo Creek in New Street Park – Post Restoration Restored Condition. The restored site during a late winter storm event. Notice the restored floodplain receiving flood flows in the now-attached floodplain, where the energy of high flows is dissipated and storage and infiltration can occur.

Wildlife Habitat Improvement

A cleaner stream, wetland pockets, and a variety of native plants create and improve habitat for both in-stream and terrestrial wildlife, starting with the macroinvertebrate life in the stream and continuing up the food web to birds and mammals (One day after workers vacated the completed New Street Ecological Park restoration site, we had our first-ever great egret sighting). The newly naturalized site will provide food, cover, and nesting sites for a variety of species.

Invasive Species Removal

Creating a more natural stream channel and floodplain and establishing the site with native plants results in the elimination of invasive species and helps discourage invasive, non-native plant species from overrunning the site. Extremely frequent flooding and long-term ponding (similar to beaver dams) minimize the type and frequency of invasive plant species capable of handling those conditions.

Aesthetic Enhancement

The naturalized landscape produces lush green vegetation, bright flowers, and seeds and nuts that look good and attract a variety of butterflies, birds, and other wildlife species.

Topsoil Generation

One of the immediate economic benefits that comes from excavating an abnormally high floodplain is the generation of high-quality, nutrient-rich topsoil. The topsoil removed from the New Street Park restoration site had an estimated retail value of $120,000 (It took 600 tri-axle truckloads, valued at $200 per truckload, to remove the 7,800 tons of soil excavated from the site).

Nutrient Trading Credit Generation

In Pennsylvania, there is great potential to generate financially viable credits through the implementation of stream and floodplain restoration projects. The Pennsylvania Nutrient Trading Program seeks to economically address NPDES compliance issues through the generation, buying and selling of nutrient credits. Stream and floodplain restoration projects significantly reduce the nutrients and sediments contributed to downstream waters through stream bed and bank erosion and subsequently has the potential to generate credits for sale.

PRACTICAL APPLICATIONS

Municipal governments, local watershed associations, private landowners, water authorities, developers, and others have used stream and floodplain restoration to expand and improve fisheries, improve water quality, reduce flooding, manage stormwater, generate nutrient trading credits, improve aquatic and terrestrial wildlife habitat, and enhance recreational and environmental education opportunities.

The golf course industry, in particular, has benefited from stream and floodplain restoration in correcting serious and often destructive problems of poor water quality, stream bank erosion and collapse, channel stabilization, and flooding. As a number of golf course personnel have discovered, this type of restoration can also improve play through channel relocation, wetland creation, improved and expanded native plant communities, and improved aesthetics.

Golf courses are rapidly evolving into biologically valuable, open-space opportunities for municipal and regional benefit. For example, flood reduction, reduced erosion, and water quality improvement achieved through floodplain restoration are benefits that extend far beyond the boundaries of the golf course. Wetland banking and regulatory compliance for stormwater management, water usage, and other water-related issues also contribute to the added value for golf courses and their surrounding communities resulting in mutually beneficial environmental partnerships.

Some years ago, Audubon International recognized that, with stewardship-based management, golf courses hold enormous value as environmental havens. The Audubon Society certifies golf courses that demonstrate they are maintaining the highest degree of environmental quality in several areas including environmental planning, wildlife and habitat management, outreach and education, chemical use reduction and safety, water conservation, and water quality management.

The Environmental Institute for Golf (http://www.eifg.org/) is the philanthropic arm of the Golf Course Superintendents Association of America and is "committed to strengthening the compatibility of the game of golf with our natural environment."

Golf & The Environment, according to its web site (www.golfandenvironment.com), "is a partnership of the United States Golf Association, The PGA of America, and Audubon International dedicated to the game of golf and the protection and enhancement of our natural environment."

The Pennsylvania Environmental Council has published the Golf Course Water Resources Handbook of Best Management Practices (LandStudies Inc. and PEC, 2009) to help golf course superintendents increase their opportunities to improve their water resource management. Floodplain restoration is included as a BMP. Because of its multiple benefits, floodplain restoration helps address at least half of the other BMPs at the same time (riparian buffer installation, groundwater recharge, reduced water usage, reduced chemical usage, increased naturalized acreage, erosion control, etc.).

Many golf courses in the piedmont region of the United States are taking advantage of the multiple benefits associated with floodplain restoration. From environmentally aware clubs such as the Saucon Valley Country Club in eastern Pennsylvania to the prestigious Tournament Players Course Potomac at Avenel Farms in Maryland, floodplain restoration has improved their game and their communities.

The following are four recent examples.

Bedford Springs Golf Course - Stream and Floodplain Restoration

Bedford County, PA

The golf course associated with the historic Bedford Springs Resort was still in use, but many of the course features were threatened by flooding and erosion which impacted 12 separate holes along Shober's Run. LandStudies worked with the golf course architect, Forse Design, to incorporate the restoration of the floodplain and stream corridor into the overall design for the golf course. The project involved excavating the floodplain to original elevations to provide storage volume during storm events and to reconnect the floodplain with the stream system. Cart crossings were realigned and designed to accommodate the restoration. The result was 6,800 linear feet of stream restored to a natural flow pattern, 10 acres of created wetlands, and thousands of native plant species planted to restore the floodplain ecosystem. (See figures 11 and 12.)

Figure 11. Shobers Run at Bedford Springs Resort – Before Restoration

Figure 12. Shobers Run at Bedford Springs Resort - After Restoration

Saucon Valley Country Club - Stream and Floodplain Restoration

Lehigh County, PA

Most of Saucon Creek and its tributaries have been constricted, built up and developed with infrastructure affecting the long-term stability of channel reaches within the Country Club site. The challenge was to provide a long-term solution that could be designed, permitted and constructed prior to the 2009 U.S. Women's Open. The goal of the project was to reduce non-point source pollution, including sediment and thermal pollution. This was achieved by restoring and stabilizing the stream channel and stream bank and improving the natural floodplain function. The project also re-established wider, more continuous vegetated riparian corridors using native vegetation. The result is improvements in aquatic and riparian habitats, migratory fish passage and wildlife corridors. This project also improved the golf course aesthetics and protects the property and infrastructure from damage from storm events and erosion. (See figures 13 and 14.)

TPC Potomac at Avenel Farms - Stream and Floodplain Restoration

Potomac, MD

Flooding and Channel instability along Rock Run made the course unplayable during PGA events. The challenge was to provide solutions for long-term stability and flood mitigation while enhancing play and improving the aesthetics as part of the course renovation in anticipation of a major 2010 PGA event.

LandStudies worked directly with PGA designers to integrate the restoration of Rock Run into the reconstruction of the course. The goal was to improve the aesthetic of Rock Run

Figure 13. Saucon Creek at Saucon Valley Country Club – Before Restoration

Figure 14. Saucon Creek at Saucon Valley Country Club – After Restoration

Figure 15. Rock Run at TPC Potomac at Avenel Farms, Potomac, MD – Before Restoration

Figure 16. Rock Run at TPC Potomac at Avenel Farms, Potomac, MD – After Restoration

while providing stormwater management, reforestation, wetland mitigation and protection of course features during flood events. (See figures 15 and 16.) The result was 7,800 linear feet of stream restoration, 12 acres of floodplain restoration, 9 acres of created wetlands, reduction in the 2, 10, and 100year flood elevations, and native trees and plants were established to restore the floodplain ecosystem.

Mark Gutshall is the founder of LandStudies, a recognized leader in the field of environmental restoration and land planning. He has more than 24 years' professional experience in designing, permitting, and constructing ecological restoration projects in the Mid-Atlantic region. Mr. Gutshall researches and advocates pioneering land development and management techniques that are functional, cost effective, and environmentally beneficial. He has been a leading voice in the acceptance of "legacy sediments" along stream corridors as a major contributor of sediment and nutrient pollution in waterways throughout the Piedmont physiographic province. He also has been a groundbreaker in adopting regional or watershed-wide natural resource management as an effective way to create partnerships among private, public, regulatory, non-profit, and educational interests. His innovative approach to natural resource management and land planning has earned accolades for both himself and LandStudies. Mr. Gutshall has been responsible for the management and execution of numerous golf course planning and restoration projects.

Ward Oberholtzer is a Professional Engineer with expertise in applied stream morphology, hydrology/hydraulics, bridge scour, fluvial geomorphology, river mechanics and sediment transport investigations. In the last 9 years, he has worked for or closely with the Maryland State Highway Administration's Office of Bridge Development and the Structural Hydraulics Unit on projects within all of the Physiographic Regions within Maryland. Mr. Oberholtzer has spent the last 13 years concentrating on the review and design in application of fluvial morphology with and

without bridges/roadway crossings, historical analysis, fish passage, bridge scour, stream stability, stream/floodplain restoration, river mechanics and bedload/sediment transport. He has completed and reviewed stream stability designs from the planning phase and conceptual design through final design and provided construction management and post-construction monitoring studies. He has made numerous presentations to the American Society of Civil Engineers and the Transportation Research Board “Hydrology, Hydraulics & Water Quality” on the application of stream morphology and stream/floodplain restoration on waterway crossings.

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