HOFFMAN PARK AND CRYSTAL SPRINGS STREAM RESTORATION PROJECTS: MONITORING PROJECT SUCCESS

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ABSTRACT

In 2003, the New Jersey Water Supply Authority (NJWSA) received a USEPA Targeted Watershed Grant to protect and improve surface water quality in the Raritan River Basin. NJWSA performed 40 stream visual assessments to assess overall stream health in the Spruce Run Reservoir Watershed. Two major stream restoration sites were identified during this effort: Hoffman Park and Crystal Springs. NJWSA contracted The Louis Berger Group for design, permitting and construction management.

Historically, no post-construction monitoring was performed at stream restoration projects to document project success and the need for maintenance or adaptive management. We will discuss the fact that a successful stream restoration project begins with a well-designed monitoring program.

Such a program begins with the collection of pre-construction data and continues for a significant post-construction interval. At Hoffman Park and Crystal Springs, biological (macroinvertebrate and habitat) and geomorphological monitoring began in 2004, two years prior to construction, to meet several objectives:

- Grant requirements;
- Design, modeling and permitting.

The post-construction monitoring also meets several objectives, including

- Evaluation of success;
- Evaluation of the need for additional maintenance or adaptive management; and
- Demonstrating that the projects meet permit conditions.

NJWSA's restoration monitoring program focused on the biological and geomorphological characteristics of the stream systems, including macroinvertebrate sampling, habitat assessment, and channel surveys. To a certain extent, the post-construction geomorphological monitoring was commensurate with the level of complexity of the project design and the environmental conditions (e.g. high flows) experienced post-construction. Hoffman Park was a much more complex project than Crystal Springs, and the amount of geomorphologic data collected reflects that. In addition, vegetation monitoring is being conducted at Hoffman Park to meet Highlands Preservation Area permit conditions.

Traditional monitoring for watershed restoration projects focused on water quality and quantity. This presentation will demonstrate that geomorphological monitoring is as important, if not more so, than traditional water quality monitoring to evaluate the impact and success of stream restoration projects. We will discuss the requirements for post-project monitoring to demonstrate project success.

KEYWORDS: stream restoration, geomorphology, project success

The Raritan Basin Watershed Management Project and Watershed Management Plan documented, at a HUC-8 level, the degradation of stream systems throughout the Basin and the need for stream and riparian restoration projects. Characterization and assessment projects and watershed restoration plans completed at the watershed level by NJWSA and SBMWA documented specific areas in several watersheds in need of specific restoration actions (e.g. buffer restoration, bank stabilization, crossing rehabilitation). Major issues identified by these projects included:

- sedimentation
- erosion
- undercut banks
- impaired riparian zone
- altered stream channels including straightening, channelization, and culverting.

The objective of comprehensive stream restoration is achievement of stream quality that meets the water quality, structural, and ecological objectives that are identified as appropriate to the stream, through attention to both the stream and its watershed. The selected objectives must relate to the current conditions, feasibility and effectiveness of each selected technique, funding, and the long-term commitments to maintenance and improvements. Each comprehensive stream restoration project must identify locally applicable objectives for "success."

Restoration may involve completely modifying the stream system, applying techniques to enable the stream system to heal itself, or, in some cases, waiting to see if the stream can heal itself.

The goal of restoration is to establish a 'stable' stream system. This does not mean a static system, but a system that is in dynamic equilibrium in terms of water and sediment transport. A stable stream has access to its floodplain, maintains a healthy ecosystem, does not aggrade or degrade its bed to the extent that habitat or floodplain access is damaged, and does not exhibit excessive bank erosion.

The general approach to stream restoration the NJWSA uses is detailed in the following steps:

1. selection of target stream corridor and watershed
2. identification of potential restoration activities
3. assessment of stream system health
4. identification of potential restoration sites
5. pre-restoration monitoring and detailed site investigation
6. identification of problems and causes

7. selection of restoration objectives
8. selection of restoration techniques, design and permitting
9. implementation
10. phased improvement
11. post-restoration monitoring
12. maintenance and adaptive management. This paper focuses on Steps #3, #5 and #11.

Assessment of Stream System Health and Identification of Restoration Sites

Assessment of stream system health is comprised of two components: preliminary reconnaissance and stream visual assessment. The initial reconnaissance and assessment typically covers an entire watershed or stream system (e.g. Mulhockaway Creek Watershed). Methodologies such as the United States Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) Stream Visual Assessment Protocol are suitable for this type of assessment. Sufficient information is needed to thoroughly understand the nature of the stream, the extent and causes of degradation, and the dynamic interaction of stream conditions.

NJWSA performed preliminary reconnaissance at approximately 70 road crossings within the 40 square mile Spruce Run Reservoir Watershed during the fall of 2003. The preliminary reconnaissance was performed on four stream systems – Spruce Run, Mulhockaway Creek, Rocky Run, and Willoughby Brook. Each road/stream crossing within the watershed was photographed. Based on the preliminary reconnaissance work, NJWSA developed a protocol to inventory stream conditions at road crossings.

Based on observations from the preliminary reconnaissance, staff chose locations for 40 detailed stream visual assessments using the USDA-NRCS Stream Visual Assessment Protocol (SVAP) (ftp://ftp.wcc.nrcs.usda.gov/downloads/wqam/svapfnl.pdf). The SVAP was used to perform a comprehensive assessment of stream conditions, to gather initial information regarding stream 'health', and make an overall assessment of watershed health.

The SVAP scores a site based on a set of 15 indicators, including:

- Channel condition
- Hydrologic alteration
- Riparian zone
- Bank stability
- Water appearance
- Nutrient enrichment
- Barriers to fish movement
- Instream fish cover
- Pools
- Invertebrate habitat
- Canopy cover
- Manure presence
- Salinity
- Riffle embeddedness

- Macroinvertebrates observed.

The SVAP relies heavily on relative comparison of sites, rather than a rigorous quantitative analysis; it is a screening assessment tool rather than a site-specific monitoring protocol. Each parameter is scored based on the assessor's observations of a particular reach. Therefore, the SVAP is reliant on professional judgment, making it potentially subjective. For this reason, NJWSA ensured consistency of assessors among all of the sites. Two staff members, both trained by NRCS, formed the core assessment team; at least one of these two staff members was on the assessment team for each site. Additional team members included other NJWSA staff, SBWA staff, and the 2003-2004 NJDEP AmeriCorps Watershed Ambassadors for the North & South Branch Raritan and Lower Raritan watershed management areas.

Approximately forty SVAP locations were chosen on four streams within the 40-square mile watershed draining to Spruce Run Reservoir: Willoughby Brook, Spruce Run, Rocky Run and Mulhockaway Creek. The objective was to collect enough information to assess overall stream health and to identify potential restoration sites. NJWSA staff chose sites that would help provide a comprehensive assessment of each of the four streams by identifying significant land use patterns along each stream and distributing the SVAP locations accordingly.

<u>Spruce Run SVAP Results</u>

The team performed ten assessments (hereinafter referred to as SVAPs) on the Spruce Run, beginning at the headwaters near the border of Hunterdon and Morris Counties, and extending to just north of the stream's discharge to Spruce Run Reservoir (Figure 2.2). The SVAP scores in this watershed ranged from 6.2 to 8.6 (Fair to Good, Figure 2.3). No clear trend (e.g. upstream to downstream) was seen in the scores. The lower scores tended to be due to low riparian zone, channel condition and nutrient enrichment scores.

<u>Willoughby Brook SVAP Results</u>

The team performed four SVAPs on Willoughby Brook (Figures 2.2 and 2.4). The headwaters were not assessed, as that area was overgrown and therefore inaccessible. The SVAP scores ranged from 6.4 to 7.6 (Fair to Good), with three of the sites scoring under 7.0; the site that scored 7.6 was among the first sites assessed by the team. It is possible that the assessors were conservatively high in their scoring. Again, no clear trend was seen in the scores for this stream. Three of the four sites displayed adequate riparian zones; one site scored relatively low for channel condition, another for bank stability and one for instream habitat and the presence of sediment.

<u>Rocky Run SVAP Results</u>

The team assessed four segments on Rocky Run; the scores ranged from 6.9 to 7.7 and no clear trend was observed (Figures 2.2 and 2.5). Three of the four sites scored low for the riparian zone parameter; no other parameters were consistently low at multiple sites.

Mulhockaway Creek SVAP Results

Mulhockaway Creek has three main branches and several smaller branches. The team performed a total of twenty SVAPS in this watershed, with scores ranging from 5.6 to 7.5 (Poor to Good, Figures 2.6 and 2.7). Many sites scored low for riparian zone, bank stability, canopy cover and the presence of sediment (riffle embeddedness).

The SVAP results provided a great deal of useful information regarding the four assessed streams in the Spruce Run Reservoir Watershed. The assessment team observed several problems throughout the watershed. Many sites received low riparian zone scores due to the presence of invasive species and the lack of an adequate riparian buffer. Severe bank erosion due to high flow events was also observed at many sites. The majority of the sites scored relatively high for macroinvertebrates, particularly when the time of year (late fall and winter) was taken into account. Normally, lower scores would be expected during these seasons.

A shortfall of the SVAP is that it fails to provide a mechanism for identifying the cause of identified problems. Visual observations noted during the initial reconnaissance and during the SVAP were more useful for identifying causes than were the SVAP results. The SVAP provides an indicator, or a rating of a symptom, such as bank stability or fish habitat. Additional reconnaissance may be needed in conjunction with the SVAP to determine the actual cause of a particular problem identified through the SVAP.

Following completion of the initial set of SVAPs, staff reviewed the results and classified each site based on the need for restoration and the feasibility of restoration under this project. Some sites were classified as not feasible from a financial standpoint, while others were not contiguous and did not fit the goals of this project. From the initial set of approximately 40 sites, three restoration sites were selected.

Pre-and Post-Restoration Monitoring

Most stream restoration projects include a level of uncertainty due to the complex nature of stream systems. Historically, restoration projects were not adequately monitored; however, monitoring is critical to success. A well-designed monitoring plan will enable the project team to identify the cause of the problem, design a sound restoration project, assess progress and determine when or if additional maintenance or adaptive management are required.

There are two categories of performance monitoring to be conducted as part of a comprehensive stream restoration project – implementation and effectiveness (FISRWG, 1998). Implementation monitoring is intended to determine whether the construction met the design specifications, while effectiveness monitoring documents whether the restoration project achieved the intended environmental benefit. Both types of monitoring were implemented as part of this project.

Data gathered from ongoing monitoring efforts will be used to evaluate the effectiveness of the restoration activities and pollution prevention efforts implemented to improve the water quality and integrity of the riparian corridors and stream systems in the Raritan Basin. Monitoring for the restoration projects focused on biological, habitat, vegetative, and geomorphological assessments. Three Quality Assurance Project Plans (QAPPs) were prepared for the restoration projects.

Biological monitoring involved testing for the presence of macroinvertebrates within a stream and basing water quality ratings on the abundance and diversity of the organisms present, as well as the sensitivities of these organisms to pollutants. Due to the relatively short life cycle of the organisms within a community, impacts are easily measured and ecological changes can be seen quickly, allowing one to monitor fluctuating environmental conditions over time.

EPA’s Rapid Bioassessment Protocol was used to conduct biological monitoring and habitat assessments. Macroinvertebrate sampling stations were identified either upstream, downstream, and within the restoration reach or upstream, downstream, and at a reference reach. The data were used to obtain baseline documentation of biological health and as a benchmark for comparison to post-restoration biological and habitat data.

Geomorphological data collection involved surveying the longitudinal stream profile and channel cross sections, and determining the dominant channel material particle size using the ‘pebble count’ method. Data collected was utilized to classify the stream pre and post-restoration, for design purposes, and to evaluate intended changes and monitor for any deterioration.

The geomorphological protocols were based on the Rosgen stream classification method (1996) and other similar techniques (Harrelson, et. al, 1994). The QAPP developed for these restoration projects contains detailed information regarding these protocols. The data collected were used to assign a stream type, to design the restoration project, and to determine if the results met restoration objectives. This type of monitoring primarily falls into the implementation monitoring category, but can also be used to determine if the restoration project has met environmental objectives such as improving the stream’s access to its floodplain.

In addition, the results of geomorphology monitoring must be analyzed in multiple ways. For example, soon after construction, the results were analyzed to determine if the restoration project met design specifications. Subsequent geomorphology monitoring will focus on whether the stream system meets the desired characteristics (width/depth ratio, entrenchment ratio, slope, meander width, etc.). The stream system will change over time and may not necessarily meet the design specifications, but can still meet the desired characteristics and environmental benefits.

NJWSA began monitoring the three restoration sites during 2004.

Crystal Springs Stream Restoration Site

Introduction

SVAP sites #32 and #33 (Figure 2.2), also known as Crystal Springs, are, respectively, on the downstream and upstream side of a dirt/gravel road crossing. These two sites are near the headwaters of the Spruce Run in Washington Township, Morris County and Lebanon Township, Hunterdon County. The Spruce Run is one of the two major tributaries that feed Spruce Run Reservoir. Spruce Run is classified as a Category 1, Trout Production stream by the NJDEP. The surrounding 290-acre property was purchased by NJWSA and a consortium of governmental and nonprofit entities in 2004 for preservation as open space; it is now part of the Hunterdon County park system. The property consists of large areas of forest and forested wetlands. There are several agricultural fields on the property that are leased to a local farmer.

The Spruce Run in the Crystal Springs area flows through a flat, forested wetland area and under a small gravel access road. At the time of the SVAP in 2003, the culvert crossing consisted of three pipes that impeded fish passage and conveyance of flows and sediment.

The overall condition of the culvert system was poor, mainly due to the small size of the individual existing pipes relative to stream flow, sediment transport, and fish passage. In addition, the pipes deteriorated over time and were perched above the channel bed and water surface elevation (as observed during field reconnaissance in Fall 2004 and Winter 2005). The capacity of the individual pipes was not sufficient to convey flows and sediment under the road crossings and acted as a barrier to fish migration in a trout production stream.

Observations at this site indicated that the upstream side of this reach, SVAP #33, exhibited much different characteristics than the downstream reach, SVAP #32. The upstream portion of the reach did not exhibit typical stream morphology of riffles and pools. Large areas of sediment deposits, primarily fines and sands, were observed. The downstream portion of the reach contains gravel and cobble, with riffles and pools. The stream has access to its floodplain throughout the reach, and minimal bank erosion was observed. The riparian buffer consisted of high quality forest and wetlands.

The sedimentation observed in the upstream portion of the reach apparently was caused by two factors – the pipe culvert and upstream activities. The pipe culvert impeded water and sediment flow, as well as fish passage. A large residential development was constructed upstream of the reach approximately three to five years prior to the SVAP. The removal of a detention basin at that development during construction may have introduced a significant amount of sediment to the stream.

Pre-Restoration Monitoring and Detailed Site Investigation

Macroinvertebrate sampling, habitat assessment, substrate analyses, and geomorphology surveys were performed at Crystal Springs beginning in 2004. Three sampling locations were established at the Crystal Springs Restoration Site.

Crystal Springs Monitoring Locations	
Identifier	**Location**
P-1	Upstream of Culvert
P-2	Slightly downstream of culvert
P-3	Downstream of culvert

P-1 was located on the upstream side of the culvert system. P-2 was located slightly downstream of the culvert, and P-3 was located farther downstream. All three sampling locations were within a well-forested area containing a mix of upland and wetland habitats.

Six rounds of macroinvertebrate sampling, three habitat assessments, two substrate analyses, and one geomorphology survey were performed pre-restoration (Figure 2.14).

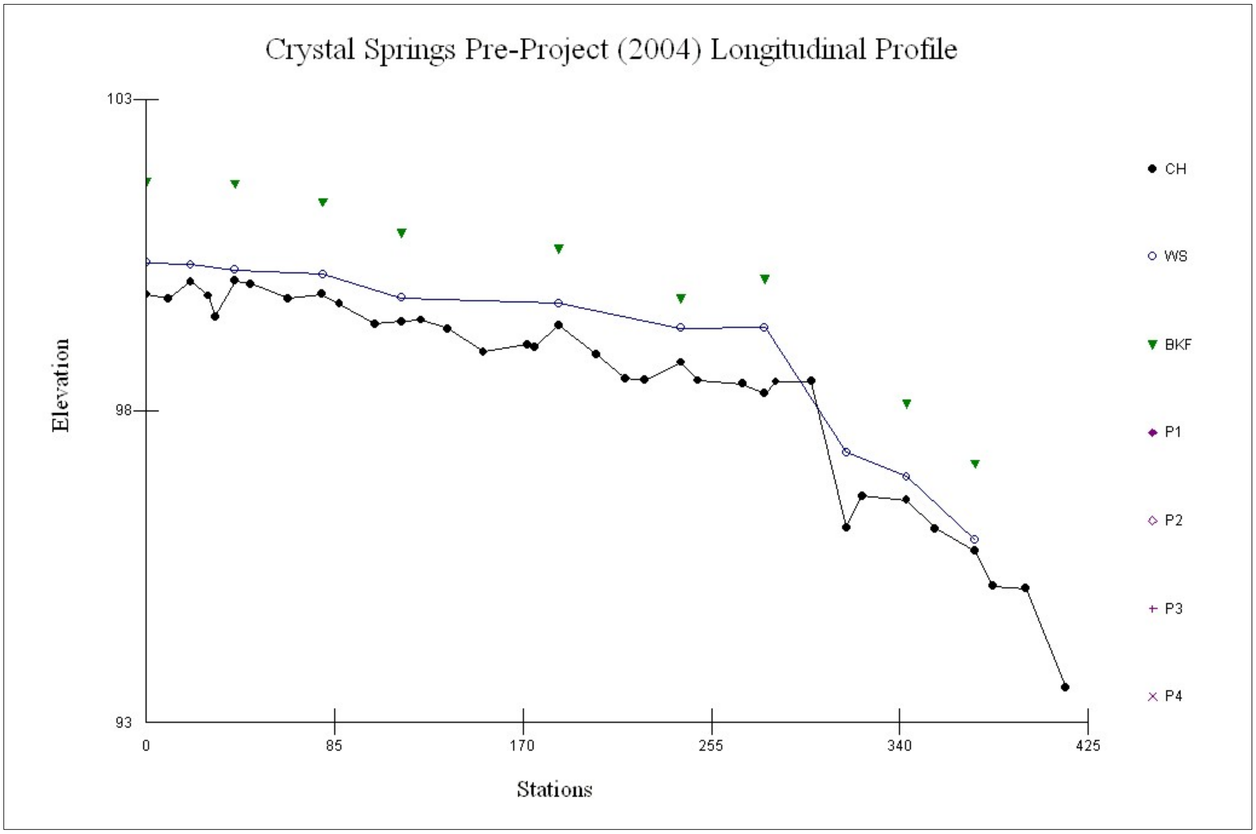
Crystal Springs: Summary of Pre-Restoration Monitoring			
Macroinvertebrates	**Habitat**	**Geomorphology**	**Substrate Analysis**
Summer 2004 Fall 2004 Spring 2005 Summer 2005 Fall 2005 Spring 2006	October 2004 Fall 2004 Fall 2005	June 2004	June 2004 February 2005

The Crystal Springs macroinvertebrate sites were generally classified as non-impaired and moderately impaired as indicated by the NJ Impairment Score.

The habitat assessment indicated sub-optimal conditions at P-1 and P-2 and optimal conditions at P-3. This indicates, to a certain extent, the ability of the stream to recover from the effects of the culvert a certain distance downstream.

The pre-restoration geomorphology survey confirmed the visual observations of the lack of appropriate riffle-pool spacing. The pre-restoration longitudinal profile that the reach above the culvert is relatively flat, then below the culvert the gradient increases.

Crystal Springs Stream Restoration Project
Pre-Project Longitudinal Profile - 2004



CH – thalweg WS – water surface elevation LBKF/RBKF – left/right bankfull depth
LTOB/RTOB – left/right top of bank P1 – P4 – Other features

Design and Permitting

At Crystal Springs, a combination of restoration options was identified, including no action and culvert replacement.

Reconstruction of the culvert in-kind would have remedied the structural deficiency but would not have addressed traffic safety, hydraulics, sediment transport, or fish passage issues. Therefore, NJWSA and the Louis Berger Group (LBG, consultant) proposed replacing the existing three-pipe culvert system with a six-foot wide, three-sided natural bottom box culvert structure with guard rails, which will address structural issues, traffic safety issues, and provide necessary sediment and flow conveyance and fish passage. Wing walls were specified on both the upstream and downstream faces of the culvert structure for scour protection and improved hydraulics.

Rather than implementing restoration techniques on the upstream portion of the reach to establish a riffle-pool system, NJWSA opted to take a “wait and see” position to see if replacement of the culvert would be an adequate change to enable the Spruce Run to heal itself.

LBG developed the construction plans and specifications.

Post-Restoration Monitoring

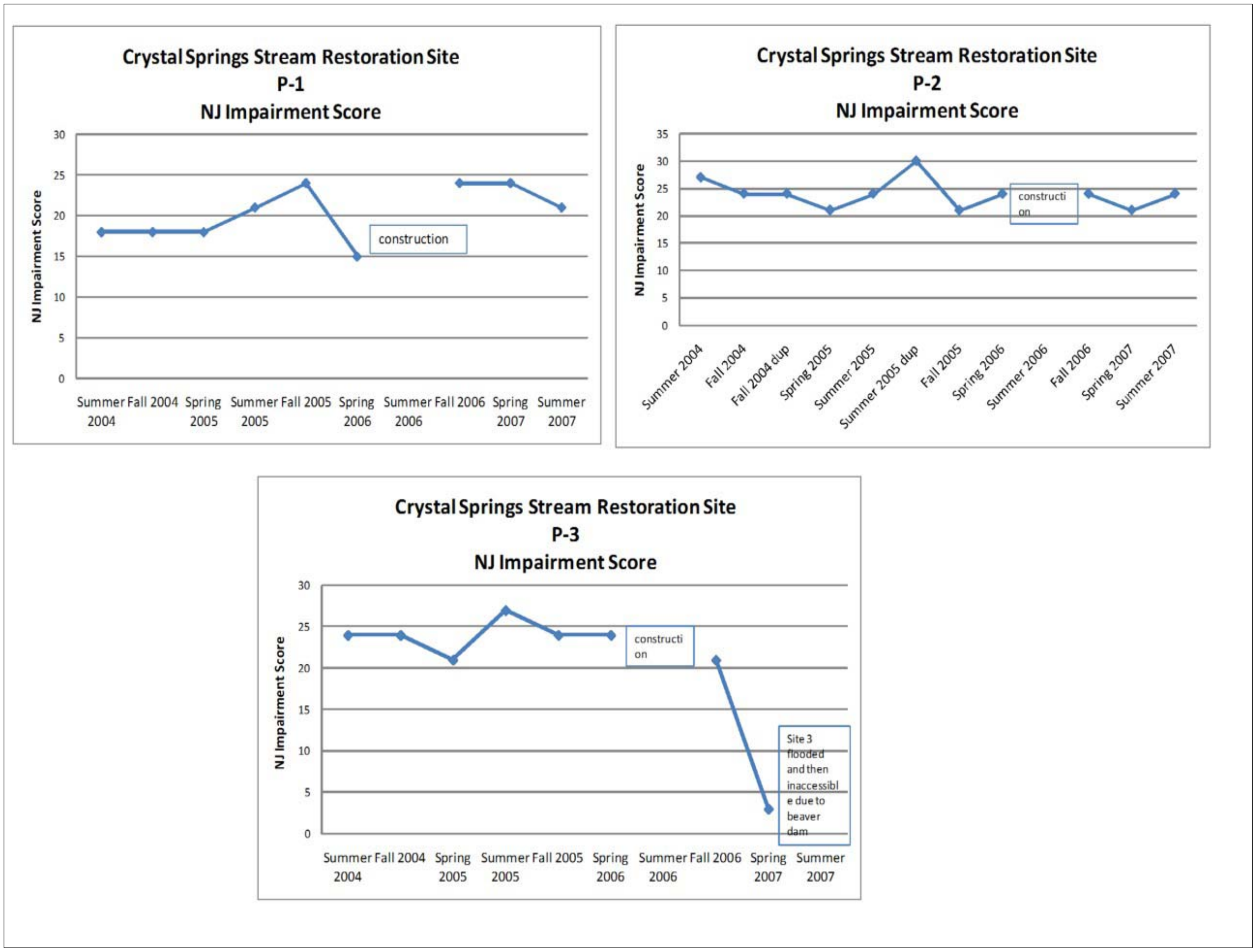
A total of three macroinvertebrate sampling events were completed prior to the end of the grand period. Habitat assessments were also performed during this time. One post-restoration geomorphology survey was conducted in 2007; a second is scheduled for early 2008. Geomorphology monitoring has been conducted less frequently at Crystal Springs than at Hoffman Park due to the difference in the complexity of the projects. The large storms of late 2006 and early 2007 did not appear to impact Crystal Springs to the extent that they did Hoffman Park.

NJWSA plans to continue monitoring for these parameters for at least another two years to document project success.

Crystal Springs: Summary of Post-Restoration Monitoring			
Macroinvertebrates	**Habitat**	**Geomorphology**	**Substrate Analysis**
Fall 2006 Spring 2007 Summer 2007 Fall 2007 Spring 2008 (planned)	Fall 2007 Spring 2008	March 2007 Spring 2008	November 2007 Spring 2008

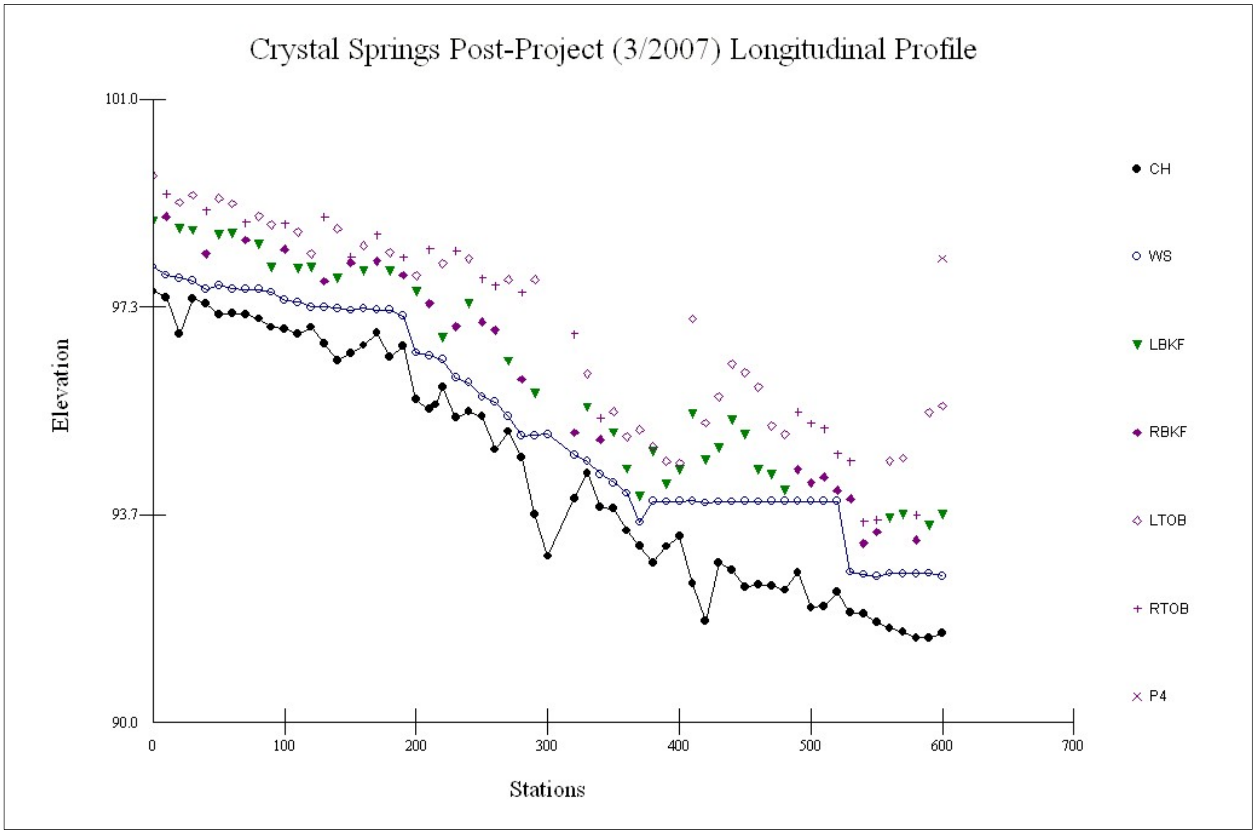
The macroinvertebrate sampling has not indicated any significant changes to the NJ Impairment score at the Crystal Springs sites, with the exception of P-3. This site was impacted by the construction of two large beaver dams slightly downstream in Winter 2006/2007. In Spring 2007, water at the sampling site was much deeper than it had been previously, and in Summer 2007, the water was too deep to allow sampling and lacked velocity. NJWSA will continue to monitor the impacts of these beaver dams to the restoration project.

Crystal Springs
New Jersey Impairment Scores (Macroinvertebrates)



The geomorphology survey indicated that a more natural riffle-pool sequence is being re-established upstream of the culvert, as hoped. Visual observations confirmed this.

Crystal Springs
Post-Project Longitudinal Profile - 2007



CH – thalweg WS – water surface elevation LBKF/RBKF – left/right bankfull depth LTOB/RTOB – left/right top of bank P1 – P4 – Other features

Hoffman Park Stream Restoration Project

Introduction

SVAP site #21 is located within Hoffman Park, approximately one mile downstream of the Old Farm Road site on the same tributary of Mulhockaway Creek. Located within the eastern portion of Hoffman Park, the reach consists of a headwater tributary that flows through a forested canopy and is adjacent to active agricultural lands. One road crossing intersects the reach, which provides access for foot traffic, emergency vehicles, and a farmer who leases and cultivates the Park's land. The upstream portion of the reach was located upstream of a pipe culvert under a dirt road; the downstream portion of the reach exhibited much different characteristics than the upstream reach.

The pipe culvert that divided the two reaches prevented the natural flow of water and sediment through the stream, and also prevented fish passage. The last was of great concern, as the Mulhockaway is classified as a FW-Trout Production (Category 1) stream by the NJDEP. The culvert was also in imminent danger of failure, which would have prevented emergency access to that section of the park. The culvert system consisted of two active pipes: a 3-foot diameter steel pipe and a 2-foot by 1-foot elliptical shaped concrete pipe. Two inactive pipes were also buried at the crossing.

The upstream section of the reach appeared to have been straightened, probably during the time that the property was utilized for agricultural purposes. There was some bank erosion in this area, and significant sediment deposition. During the two years of observations by NJWSA, staff viewed numerous changes in the pattern of deposition.

On the downstream face of the culvert system, the pipes were perched approximately five feet above the channel bed elevation. The width of the berm (perpendicular to channel flow) that serves as the dirt access road across the floodplain was approximately 40 feet. The culvert system did not adequately convey flows and sediment during flow events. In addition, the perched culvert outlet posed a barrier to fish passage. The constriction of the floodplain at the location of the crossing resulted in bank erosion and widening of the channel above the culvert system.

Downstream of the road crossing, the channel was deeply incised with vertical banks and no accessible floodplain. This portion of the reach was classified as an F4 stream type according to Rosgen's stream classification. At several locations, trees had fallen into the channel where the banks had failed. Shallow, concentrated flow that drained wetland areas adjacent to the stream on the historical floodplain had eroded headcuts in two locations along the left bank (looking downstream), which were actively migrating towards the wetland areas.

During normal flows, water was routed below the access road via the culvert system and followed a nearly straight, northeasterly course through the reach. The stream abruptly turns west near the railroad tracks and follows a straight course adjacent to the railroad tracks until turning north, where flows are conveyed under the railroad tracks via two large box culverts. During flood events, the hydraulically deficient culvert system caused backwater behind the road crossing, which eventually acted as a weir as flows spilled over the road. It is likely that under normal conditions with a hydraulically adequate system, flows would over top the banks upstream of the culvert system and access the natural floodplain where the channel is stable and only several feet deep. Instead, flows over topped the culvert system at the road crossing and were concentrated in an eastward direction onto the access road. As a result, a large scour hole formed in the access road, which would have continued eroding in the upstream direction until the berm that served as the access road was breached.

High flows diverted at the culvert system were conveyed toward an historical borrow pit area located east of the reach. The borrow pit, which is no longer active, supports an emergent marsh wetland and Highlands open waters. As a result of this diversion, a headcut was eroding at the uphill end of the borrow pit. A large amount of sediment was deposited where the diverted water entered the low-gradient borrow pit, forming the beginning of a delta system. At the downhill end of the area, a channel, which was created to drain the pit, conveyed flows in a ditch adjacent to the railroad tracks and eventually discharged into the main channel.

The existing conditions of the stream channel and road crossing provided poor aquatic habitat and little area for riparian recruitment. In addition, the unstable system was continuing to evolve. Additional impacts to valuable wetland habitat adjacent to the stream were anticipated if no actions were taken.

Pre-Restoration Monitoring and Detailed Site Investigation

The Hoffman Park restoration project was the most complex of the three restoration sites in the South Branch Project area. Macroinvertebrate sampling, habitat assessment, substrate analysis, and geomorphology surveys were performed. Five sampling locations were established.

Hoffman Park Monitoring Locations	
Identifier	**Location**
HP-1	Upstream property boundary, upstream of restoration reach
HP-2	Upstream side of culvert, within restoration reach
HP-3	Downstream of culvert, within restoration reach
HP-4	Downstream of road culvert, near railroad culvert, downstream of restoration reach
HP-5	Downstream of railroad culvert, downstream of restoration reach

HP-1 was located upstream of the reach within a forested area, beyond the park property boundary. This section of the stream was obviously straightened sometime in the past. HP-2 was located on the upstream side of the culvert system within the reach. The riparian corridor adjacent to this site was comprised of meadow and forest. HP-3 was located downstream of the culvert system within the reach. This sampling site was located in an area that was very incised. HP-4 was located slightly downstream of the reach in a forested area. This site was in an incised location but the stream’s movement is constrained in this spot due to the presence of the railroad berm. HP-5 was located downstream of the railroad culvert in an area that was very incised and had significant sediment deposition.

Six rounds of pre-restoration macroinvertebrate monitoring, three habitat assessments, one geomorphology survey, and two events of substrate analysis were performed at Hoffman Park.

Hoffman Park: Summary of Pre-Restoration Monitoring			
Macroinvertebrates	**Habitat**	**Geomorphology**	**Substrate Analysis**
Summer 2004 Fall 2004 Spring 2005 Summer 2005 Fall 2005 Spring 2006	Summer 2004 Fall 2004 Summer 2005	July 2004	July 2004 September 2004

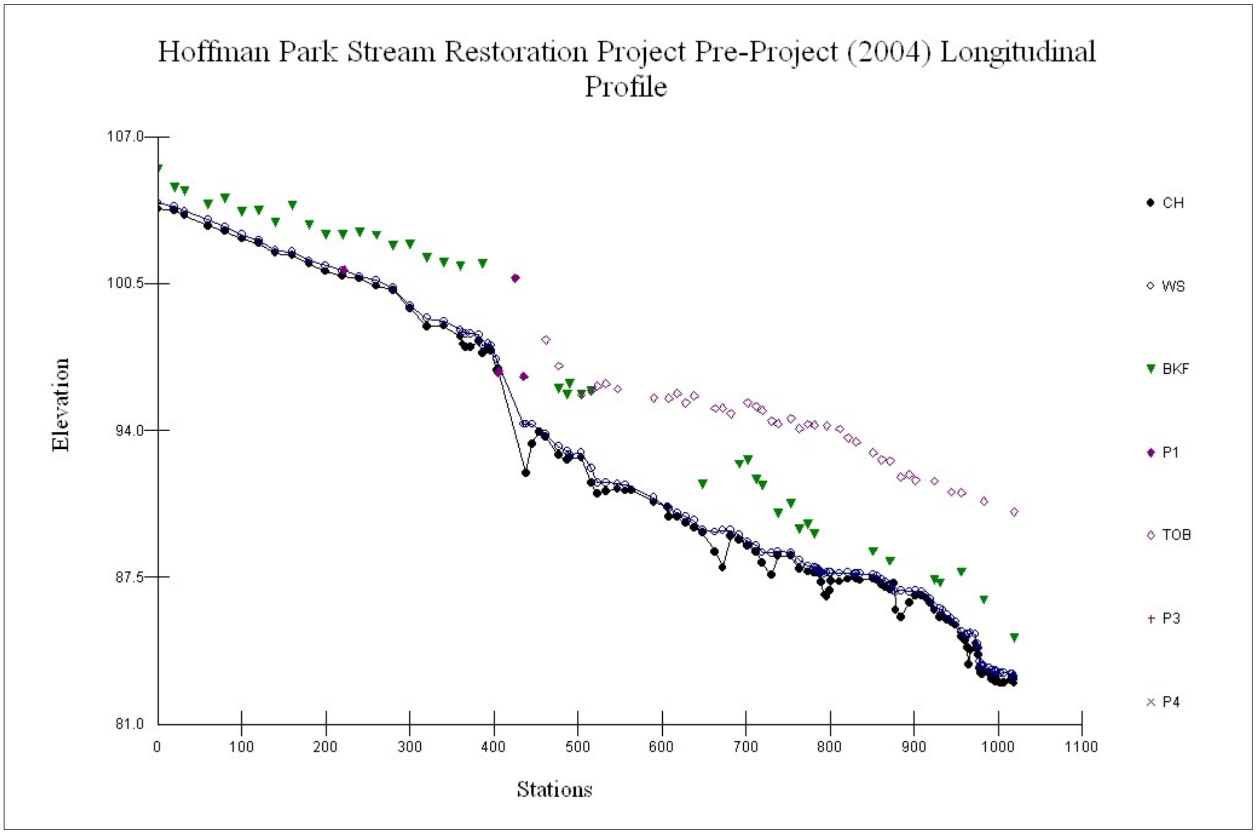
For the most part, the New Jersey Impairment scores for Hoffman Park were surprisingly high, when the degraded nature of the stream system was considered. Most samples rated non-impaired or moderately impaired.

The habitat assessment indicated sub-optimal or marginal habitat. The conflict between these two sets of data may be because Mulhockaway Creek is generally a high water quality stream (Category 1, Trout Production). The relatively high Impairment score may indicate that the macroinvertebrate community was affected more by water quality than by stream channel conditions.

The geomorphology surveys indicated that the stream was very incised, and that there was a significant change in gradient from the top of the restoration reach to the end of the reach.

In the case of Hoffman Park, geomorphology surveys were also conducted for two reference reaches. Reference reaches, because they are similar in physiographic settings to the reach but are minimally impacted by natural and human disturbance, are important to the planning, implementation, and monitoring of the restoration project. They represent, as closely as possible, the desired outcome of the restoration effort. Baseline data on the structure and functions of the reach, as expressed by geomorphic data, provided a point from which to compare and measure future changes.

Hoffman Park Stream Restoration Project
Pre-Restoration Longitudinal Profile - 2004



CH – thalweg   WS – water surface elevation LBKF/RBKF – left/right bankfull depth LTOB/RTOB – left/right top of bank P1 – P4 – Other features

Design and Permitting

NJWSA retained the Louis Berger Group (LBG) for design and permitting of the Hoffman Park restoration project.

The purpose of the Hoffman Park restoration project was to:

- Correct severe environmental degradation caused by the channel instabilities;
- Prevent further degradation from occurring;
- Protect and enhance water quality within this reach designated as FW2-TP(C1) (public potable water supply, trout production, category 1); and
- Protect and enhance aquatic, riparian, and wetland habitat.

The objectives of the restoration project were to:

- Create a stable stream channel and accessible bankfull benches for flood stage flows;
- Manage headcuts, or vertical breaks in slope, that threaten to destroy habitat or divert their hydrologic sources;
- Reduce stream bed and bank erosion;

- Improve flow and sediment conveyance and fish passage;
- Improve water quality; and
- Improve park access.

Three alternatives - No action, Stream Bank Stabilization and Natural Channel Design - were analyzed to determine if an alternative restoration design could further minimize impacts while meeting the goals.

Steam Restoration project Using Natural Channel Design Alternative

The Natural Channel Restoration Alternative involved partially filling the existing channel and then constructing a stable stream with more stream feet (greater sinuosity) and an associated floodplain bench wide enough to provide adequate fluvial stability and floodplain function. Land disturbance in the form of cut and fill was necessary within the riparian and instream areas for the implementation of this alternative. The immediate results of the Natural Channel Restoration Alternative included: restored fluvial functions and improved stream and riparian zone stability, fish habitat improvement and passage upstream of the existing culvert system, and improvements in potential wood turtle habitat. Long-term results of the alternative included: reduced sediment load entering Mulhockaway Creek and Spruce Run Reservoir, improved public and emergency access to Hoffman Park, and maintenance of a natural riparian setting within Hoffman Park.

A key element of a successful stream restoration design includes adequate characterization of the cause of stream degradation, taking into consideration watershed scale issues as well as local issues. Evaluation of the reach revealed that the stream was currently unstable as it moved toward a new equilibrium with changing watershed and local floodplain/channel conditions.

Specific constraints related to the property had an impact on the design and the construction timeline, including the presence of wetlands and bog turtle and wood turtle habitat. The proposed stream alignment and associated bankfull bench were positioned to minimize impacts to these resources.

The following sections describe the elements of the selected restoration project design:

Access Road Crossing Replacement: Reconstruction of the culvert system "in-kind" would have remedied the structural deficiency and park access issues, but would not have addressed hydraulics, stream stability, sediment transport, or fish passage issues. Therefore, LBG and NJWSA replaced the existing culvert system with a pre-cast arch culvert with a natural channel bottom that spans the bankfull bench, addressing structural issues, safety issues, and providing the necessary sediment and flow conveyance and fish passage. The arch culvert spans 32 feet and has a 16-foot wide span.

Dimension, Pattern, and Profile Restoration Design Elements; The former stream channel was evolving as a result of local and watershed scale changes. Restoration elements designed to stabilize the stream system included adjusting the stream sinuosity and slope, creating a bankfull bench, and decreasing the slope of the banks. The intent of this type of design is to restore the natural physical stream functions, thereby restoring the native habitat conditions.

Reference Reach Design Approach: The appropriate dimension, pattern, and profile of the channel were designed according to the onsite drainage area in relation to channel measurements from stable reference streams in the vicinity of the Mulhockaway Creek Watershed. Three reference reaches were identified for the Hoffman Park Stream Restoration project based on a review of aerial photographs, soil surveys and topographic maps. Data from two of the reference reaches were collected to support the design of the restoration project. The third reference reach was not accessible due to its location on private property. The surveyed reference streams have similar drainage areas, are situated in similar watershed positions, and have matching soil types.

Natural Restoration Design Elements*:* Data collected at the restoration reach was compared to data collected at the reference streams. Based on the results of the analysis, LBG determined that the slope, depth to width ratio, and entrenchment ratio of the existing channel required adjustment. Determining the appropriate geometry that can effectively transport the discharge generated from the contributing watershed and the stream's sediment load over time, without significant deposition or aggradation required an iterative approach of integrating the data collected at the stable reference streams with data collected at the reach. Dimensionless ratios were developed from the reference reach data to quantitatively describe specific channel attributes. By relating the existing drainage area to the reference drainage area, a range of pool and riffles, depths, widths, slopes, and bankfull bench widths were established for the reach.

The analysis established that the existing channel required an extension in linear stream feet to distribute a water surface slope and consistently transport sediment at a rate appropriate for the location of the stream within the watershed and landform. The former stream channel valley is not a natural landform feature. The existing valley was cut to allow the channel to flow west along the foot of the rail line embankment into the adjacent stream valley. Reference reach observations were used to develop the appropriate bench widths and channel planform geometry. The sinuosity of the former channel was increased to achieve a channel slope consistent with the reference reach range relationship of channel slope to sediment particle size. The valley bench width alignment was positioned to minimize impacts to adjacent Highlands resource areas, such as wetlands and upland forested areas. The reference reach data was also used to determine the appropriate spacing of bed features such as pools, runs, riffles, and glides.

Instream Structures Restoration Design Elements: Since the water surface slope of the restored channel under the bridge is steeper than a truly natural stream, and portions of the restored channel require redirection and dissipation of near bank flow forces, the design utilized four types of instream structures: rock vanes, cross vanes, root wads, and log vanes.

Rock Vanes: Two rock vanes were installed within the reach. These structures serve to decrease stress in the near-bank region, thereby reducing bank erosion, while promoting scouring in the downstream pool which will enhance aquatic habitat.

Cross Vanes: Three cross vanes were installed upstream and downstream of the arch culvert. The cross vane is used in this design to control the stream grade, stabilize stream slope, and focus the flow of water and sediment away from the culvert foundation and roadway embankment. A secondary feature of the cross vane is the reduction of flood stage beneath the culvert. In addition to the benefits of the cross vanes to the stability of the channel, the structures also provide aquatic habitat by maintaining a scour pool at the downstream end of the structure and a riffle at the upstream end of the structure.

Root Wads: Eight root wads were installed into the stream banks on the outside of meander bends to improve bank stability as well as enhance habitat complexity. The tree roots reduce the energy environment along the bank, making the bank less susceptible to erosion.

Log Vanes: The log vane was used in this design to redirect focused flow away from outer meander banks, which maintains bank stability, reduces erosion of the banks, and ultimately prevents down valley channel migration. In addition to the benefits of the log vanes to the stability of the channel, the structures provide aquatic habitat by maintaining a scour pool downstream of the structure and a riffle at the upstream end of the structure. Downstream of the each log vane, root wads were installed into the bank to provide additional bank stabilization and habitat.

Headcut Treatment and Wetland Protection Measures: Approximately 200 feet downstream of the road crossing, an eroded gully had formed where concentrated overland flow from an adjacent field eroded the stream bank of the incised channel. The restoration of the active headcut consisted of grading back the existing bank slopes of the eroding gully and creating a floodplain interceptor. The floodplain interceptor halted the up-valley migration of the headcut and allowed the overland flow to infiltrate into the ground water table before reaching the floodplain bench of the restored channel.

Biostabilization Measures*:* The restoration project resulted in the disturbance and removal of existing vegetation along Mulhockaway Creek within the limits of disturbance. A planting plan was prepared to mitigate for the anticipated impacts to the upland forest buffer and creek banks, and to provide for the long-term stabilization of the creek banks following construction.

Permitting

Hoffman Park is located within the New Jersey Highlands Preservation Area. In 2004, New Jersey passed the Highlands Water Protection and Planning Act. The act strictly limits activities in the Highlands area, including prohibiting any disturbance to Highlands Open Waters or within 300 feet of a Highlands Open Water. There are no specific exemptions for restoration of streams. There was no way to accomplish the Hoffman Park restoration project while meeting the literal intent of this prohibition. The Hoffman Park Highlands Preservation Area Approval (HPAA) Permit Application included a request for a Waiver for the Protection of Public Health and Safety.

NJWSA received the HPAA for the restoration project in June 2006, including the waiver. In this manner, NJDEP was able to allow stream restoration (a clear environmental benefit) in a legally defensible manner, rather than denying the permit due to the buffer provisions of the law. The Hoffman Park restoration project served as a test case for the HPAA process, as it was the first HPAA given by NJDEP to any Highlands project.

The HPAA contained several conditions, including the requirement for vegetation monitoring and the limitations on construction timing due to the trout production classification of Mulhockaway Creek.

Development in the watershed and human induced disturbances such as channelization and crossing construction were critical to understanding current conditions and formulating restoration project objectives. Understanding conditions at multiple scales, combined with the comprehensive approach to site identification, allowed NJWSA to take a broader approach to stream restoration on Mulhockaway Creek. The channel reconstruction at Hoffman Park coupled with the riparian restoration project at Old Farm Road address the same goal of managing instream sediment transport and runoff.

Post-Restoration Monitoring

Following construction, macroinvertebrate sampling was conducted three times a year for a total of three sampling rounds prior to the end of this project period. Habitat assessments were also performed during this time. Geomorphology surveys have been conducted at regular intervals. As of the end of the grant period, three geomorphology surveys and one substrate analysis had been conducted. NJWSA plans to continue monitoring for these parameters for at least another two years to document success, although the macroinvertebrate monitoring will likely be reduced to twice per year to reduce the costs.

Hoffman Park: Summary of Post-Restoration Monitoring			
Macroinvertebrates	**Habitat**	**Geomorphology**	**Substrate Analysis**
Fall 2006 Spring 2007 Summer 2007 Fall 2007 Spring 2008 (planned)	Fall 2007 Spring 2008	November 2006 January 2007 May 2007 Spring 2008	November 2006 November 2007

In addition, the HPAA permit requires three years of vegetation monitoring to ensure an 85 percent survival rate of all planted material. The first vegetative survey will be conducted in late 2007.

The macroinvertebrate sampling has not indicated any significant changes to the NJ Impairment score at the Hoffman Park sites. At HP-2 a decreasing trend in the score has been observed since construction, but the score immediately after construction was surprisingly high..

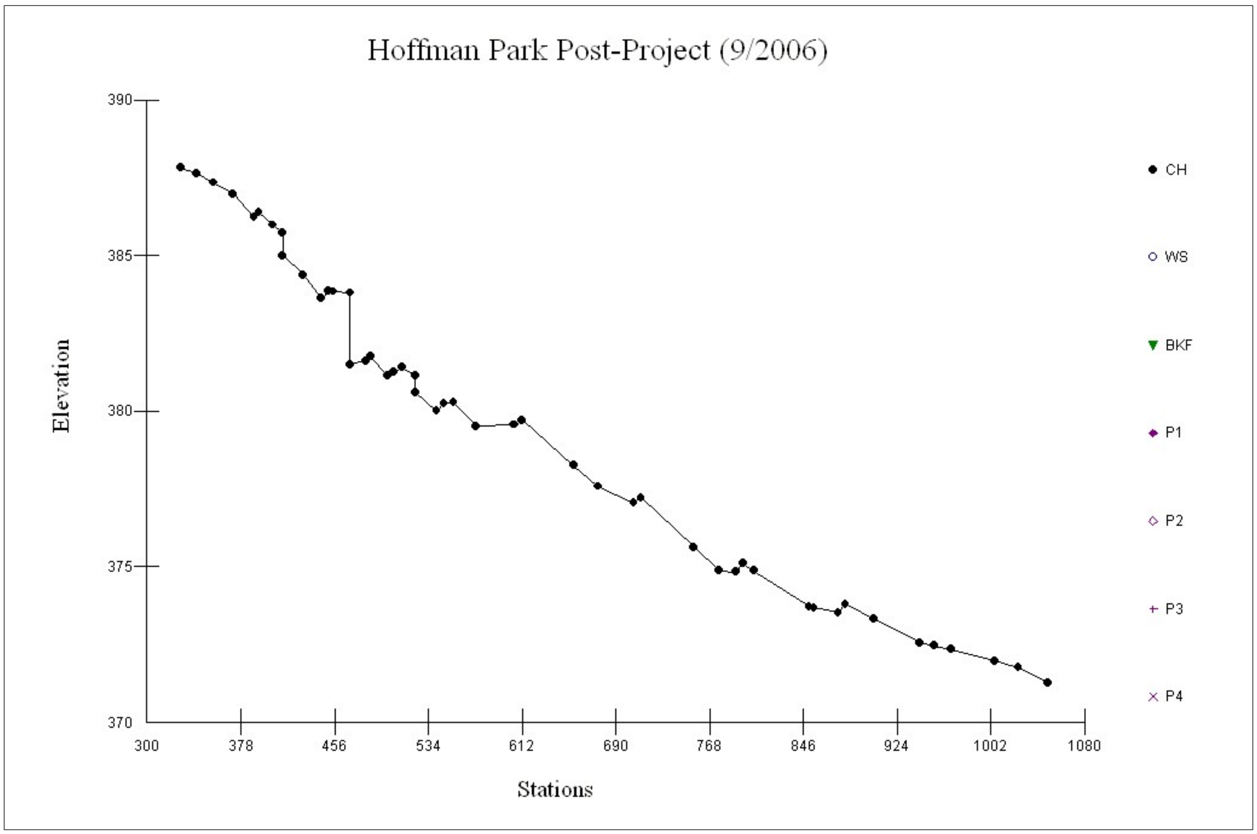
Although fish surveys were not performed, NJWSA has noted the presence of many more fish in the stream than were observed prior to the restoration project.

Hoffman Park Stream Restoration Project
New Jersey Impairment Scores (Macroinvertebrates)

The habitat assessment indicated an improvement in the scores following the implementation of the restoration project. No assessments were conducted during Summer 2006 due to construction; therefore there is a break in the data reflecting construction..

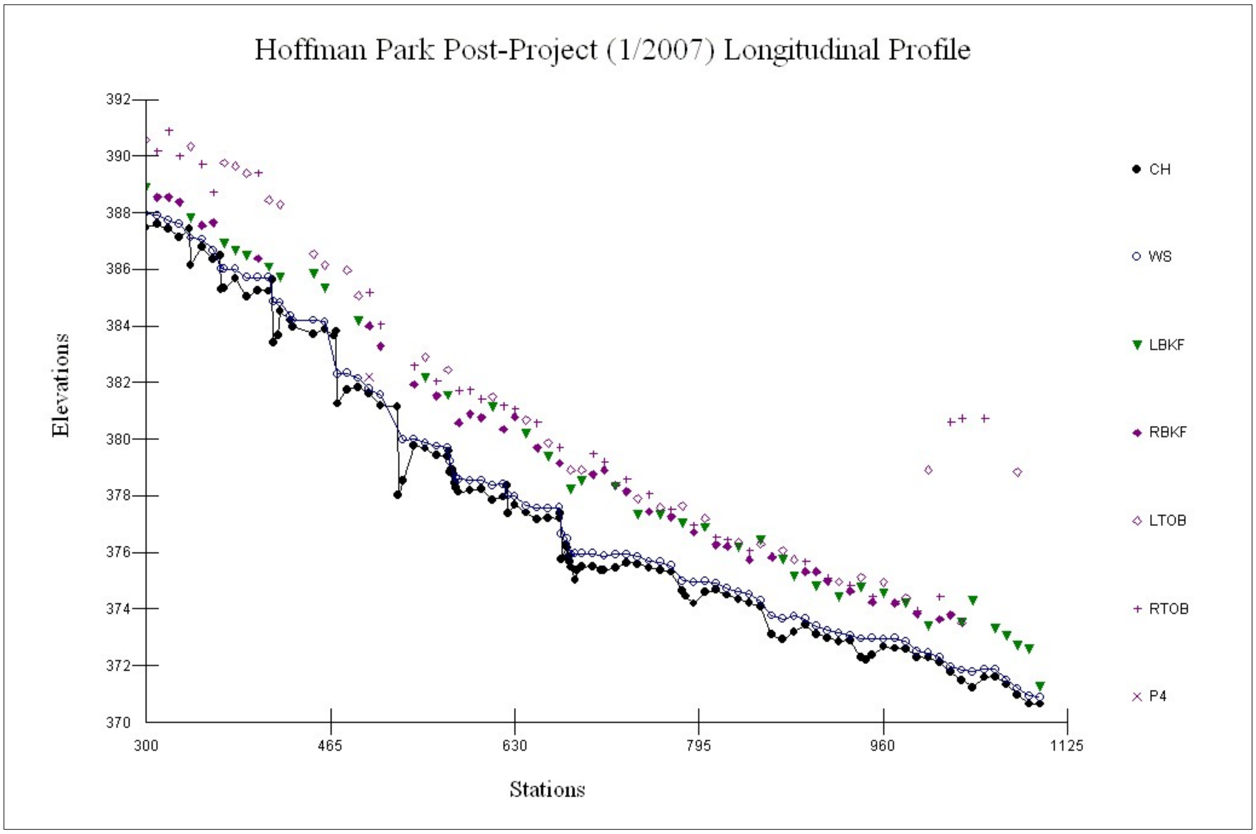
The geomorphology surveys show the gradual dissipation of gradient through the restoration reach. The surveys also show that the stream is no longer incised.

Hoffman Park Stream Restoration Project
Post-Restoration Longitudinal Profile – 9/2006



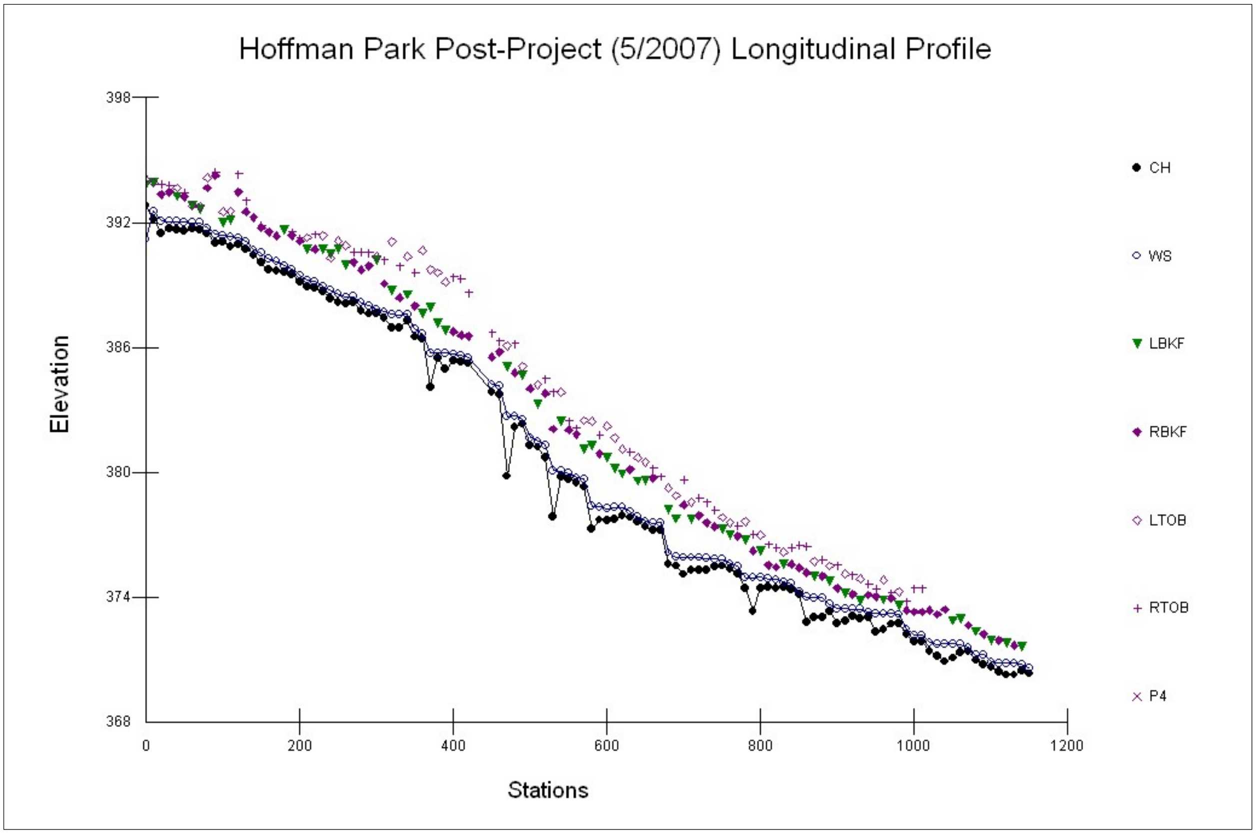
CH – thalweg   WS – water surface elevation LBKF/RBKF – left/right bankfull depth
LTOB/RTOB – left/right top of bank P1 – P4 – Other features

Hoffman Park Stream Restoration Project
Post-Restoration Longitudinal Profile – 1/2007



CH – thalweg WS – water surface elevation LBKF/RBKF – left/right bankfull depth
LTOB/RTOB – left/right top of bank P1 – P4 – Other features

Hoffman Park Stream Restoration Project
Post-Restoration Longitudinal Survey – 5/2007



CH – thalweg WS – water surface elevation LBKF/RBKF – left/right bankfull depth
LTOB/RTOB – left/right top of bank P1 – P4 – Other features

It should be noted that only one year has passed since the end of major construction activities at Hoffman Park. In addition, NJWSA has performed two rounds of adaptive management at the site. Although all possible precautions were taken to minimize impacts to the stream from the adaptive management activities, it is possible that these activities affected the macroinvertebrate community.

The Hoffman Park restoration project has received two awards since its completion. The NJ Association for Floodplain Management (NJAFM) honored the Hoffman Park Stream Restoration project at their October 2006 conference with the "Outstanding Floodplain Management Award for exemplary vision and realization of the Hoffman Park Stream Restoration Project". In 2007, the American Council of Engineering Companies of New Jersey presented the Award for Engineering Excellence to NJWSA and LBG for "fostering Excellent Engineering Design" on the Hoffman Park restoration project.

Conclusion

With the challenges, complexities and system variables inherent in a "natural" design it is imperative that a comprehensive monitoring program, both pre and post construction, becomes part of the original design and contract. This is the only way that any kind of management of the constructed project can be implemented. These monitoring programs need to be part of the original scope of work and spell out realistic and location pertinent goals to be effective. Undoubtedly this will increase the cost of the whole project, but it is incumbent upon the restoration community to educate the clients interested in these types of projects.

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