A Sustainable Chesapeake

BETTER MODELS FOR CONSERVATION

Edited by David G. Burke and Joel E. Dunn

THE CONSERVATION FUND

The case study you have downloaded is highlighted below. Other case studies from this Chapter of *A Sustainable Chesapeake: Better Models for Conservation* can be individually downloaded. The editors encourage readers to explore the entire Chapter to understand the context and sustainability principles involved with this and other featured case studies. The full publication contains 6 Chapters in total: Climate Change Solutions, Stream Restoration, Green Infrastructure, Incentive Driven Conservation, Watershed Protection and Stewardship.

CHAPTER 2 STREAM RESTORATION

A “Soft” Design Approach to Stream Restoration

Riparian Buffers at Work in the Urban Watershed of Alexandria’s Kingstowne Stream

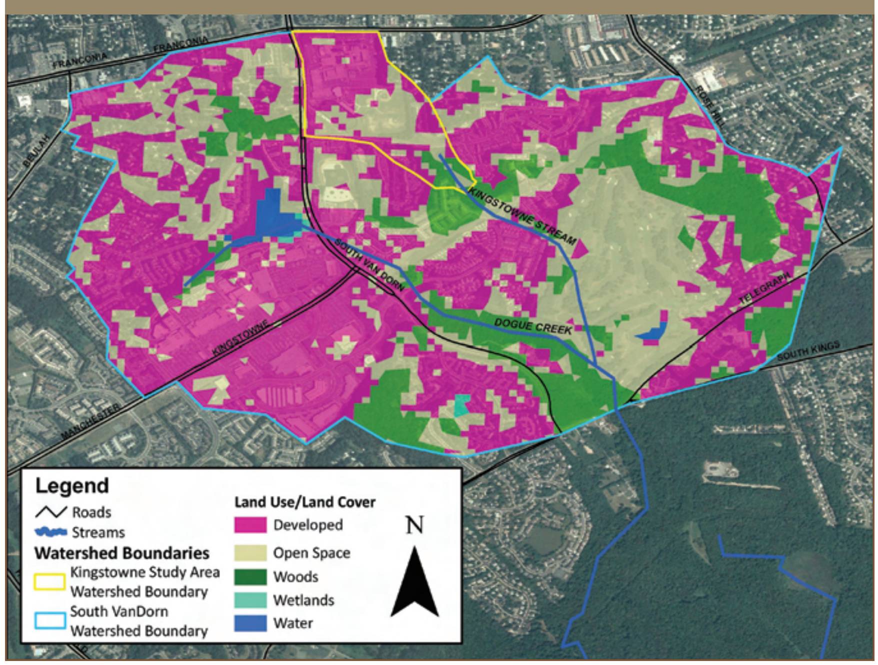
The Kingstowne restoration project incorporates a mix of “soft” and traditional design practices to stabilize the stream featuring gentle stream meanders; a more fully developed riparian buffer and reconnecting the incised channel to its natural floodplain.

CASE STUDY SUMMARY

Kingstowne Stream in Alexandria, Virginia, is a main tributary of Dogue Creek, which feeds into the Potomac River six miles south of the confluence. The South Van Dorn watershed, which includes Kingstowne Stream, is highly urbanized with over 54% of the surface being impervious to water. This stream was considerably damaged by the results of upstream development, particularly along the South Van Dorn Street corridor where natural vegetation was replaced with buildings, parking lots and roads. These changes lead to less infiltration of stormwater in the soil and subsequent “flashy flows” in the stream. Stream bank sediments and attached nutrients were being eroded and carried downstream to the wetlands of Huntley Meadows, the Potomac River and the Chesapeake Bay. These impacts are further accentuated by changes to the climate, such as increasingly intense storm events that produce unusually high volumes of runoff from impervious surfaces.

In 1998, the Northern Virginia Soil and Water Conservation District (NVSWCD) partnered with Fairfax County Department of Public Works and Environmental Services, the U.S. Department of Agriculture’s (USDA) Natural Resources Conservation Service, Urban Assistance Program, and two citizens groups to implement a demonstration project on Kingstowne Stream that would serve as a model for a “soft” design approach to address erosion and pollution problems.

Kingstowne Stream Restoration
Fairfax County, Virginia



Comparison of Restoration Features Used in 3 Separate Stream Case Studies Featured in this Publication			
	"Hard" Design Approach (Stony Run—see case study)	"Soft" Design Approach (Kingstowne—this case study)	"Seepage Wetland" Design Approach (Wilelinor—see case study)
Major Restoration Features:	➤ Cross vanes ➤ J-hook vanes ➤ Imbricated riprap ➤ Two-stage channels ➤ Step-pools	➤ Dry detention pond ➤ Plunge pools ➤ Soft meanders ➤ Live stakes ➤ Riparian buffer ➤ Step-pools (diverse cobble substrate)	➤ Sand berms ➤ Seepage reservoirs ➤ Off-line ponds ➤ Riffle weirs ➤ Shallow, aquatic step pools

RESOURCE MANAGEMENT CHALLENGE

Fairfax County streams are facing a variety of serious problems, including the loss of riparian buffers, altered hydrology caused by an increase in impervious surfaces, and water quality degradation including increased sediment and nutrient loads from polluted runoff.[1] These challenges have resulted directly from high density urban development over the past 50 years, where conservation and stream health were not a significant consideration. In addition, the amount of rain falling in the heaviest downpours has increased approximately 20 percent in the Southeast in the past century, and this trend is very likely to continue, with the largest increases in the wettest places.[2]

Fairfax County also has several stormwater regulatory challenges. These include requirements under the Chesapeake Bay Preservation Ordinance, Virginia Pollutant Discharge Elimination System (VPDES)/Municipal Separate Storm Sewer System (MS4) permits, Total Maximum Daily Loads (TMDLs) triggered by state and federal impaired waters listings, and sediment reduction goals under the Potomac River Tributary Strategy. Both the environmental and regulatory challenges facing the County have resulted in efforts to restore streams.

There is a substantial body of research that details the ability of restored streams and adjacent riparian buffers to store sediment, to retain and transform nutrients and other toxic substances, and to create stable stream ecosystems.[3,4,5,6,7,8] Nevertheless, there is a paucity of post-restoration monitoring, and many water resource agencies do not have data indicative of stream restoration performance as a best management practice for reducing nitrogen and sediment export from urban watersheds.[9,10] Subsequently, there is low confidence in the ability of stream restoration designs approaches to achieve desired water quality goals, which is the most commonly stated goal for stream restoration projects in the Bay watershed.[11] Post-restoration monitoring is needed to determine the effectiveness of the soft design approach to the restoration of water quality in the stream.

CONSERVATION VISION

To protect downstream resources and to maintain compliance with the county's federal, state, and local regulatory agencies, the NVSWCD embraced a "soft" design approach to the Kingstowne Stream restoration as a new way to manage stormwater. The soft approach used mild stream meanders, cobble stone step-pools, and a wide riparian buffer to slow the flow of water in the stream to a baseflow discharge of 0.11 cubic feet per second. This slower baseflow prevents the rushing water from scouring the stream banks and carrying nutrient and sediment pollution downstream. The Conservation District is currently planning Phase II of the project, which will restore the stream another 2,500 feet downstream.[12]

IMPLEMENTATION RESOURCES

The total cost of the 1,000 foot stream restoration project was $527,000 (adjusted to 2008 dollars), which is $527 per linear foot. The Chesapeake Bay Water Quality Improvement Fund provided a $150,000 grant for the project through the NVSWCD that was

Watershed Characteristics

- 72 acres in the Coastal Plain (South Van Dorn watershed is 1,146 acres)
- 54% covered by impervious surface (48% for South Van Dorn)
- 58% of the land is developed; 35% is open space; 6% is wooded

Kingstowne Stream Restoration: Generalized Site Plan - *Fairfax County, Virginia*

matched by Fairfax County. The grant funding derived from the Virginia Water Quality Improvement Act of 1997, which was enacted in response to the need to finance nutrient reduction strategies for the Chesapeake Bay and its tributaries. Federal and State agencies are the most frequent primary funders of stream restoration projects.[13,14] In addition, urban, headwater streams receive the largest share of river restoration dollars and effort in the United States.[15]

The Fairfax County Department of Public Works and Environmental Services, Office of Capital Facilities managed the effort as a "storm drainage improvement project" with design support from the USDA's Natural Resources Conservation Service, Urban Assistance Center. This greatly reduced the overall project cost.

CONSERVATION STRATEGY

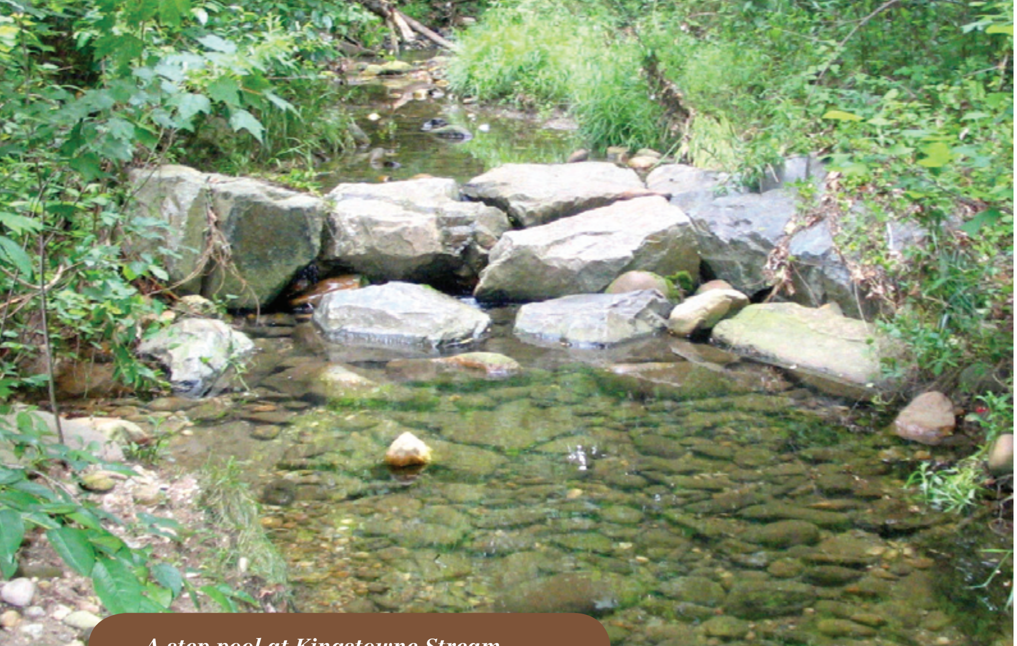
The following section details the six principle restoration design components that contributed to water quality improvement in Kingstowne Stream.

- **Dry Detention Ponds:** Dry detention ponds, designed to dry out between storm events, are depressions or basins created by excavation or berm construction that temporarily store runoff and release it slowly to streams, attenuating peak flows resulting from storms. The key water quality functions of dry detention ponds are delivered through the reduction of water velocity, which removes suspended particles via settling and helps reduce stream channel incision, bank erosion, and loss of in-stream habitat structures that is typical of streams in urban areas.[16]

  Grassed surfaces, such as those present at Kingstowne, require periodic mowing. However, they may trap sediments and infiltrate stormwater more effectively when compared with smooth surfaces such as concrete. Further, nitrogen and phosphorus may be removed via settling of particulate forms, as well as plant and microbial uptake. Phosphorus may also sorb to soil particles. Significant removal of nitrate is unlikely because the aerobic soil conditions are not favorable to microbial denitrification.

- **Plunge Pools:** Plunge pools are simply basins used to slow flowing water. A small, deep plunge pool dissipates energy as water enters the pool from its upland source. Beyond reducing flow velocities, plunge pools create habitats for aquatic species. There is little question about the effectiveness of plunge pools as they have been used for many years as an important water management technique.

- **Soft Meanders:** Meanders are bends that give a snake-like appearance to the reach of a stream. A stream reach is said to be meandering if its length is at least 1.5 times the length of the valley through which it passes. Any reach that exceeds the length of the valley can be taken as evidence of meandering, but 1.5 is the standard minimum used to confirm meandering activity. As with plunge pools and detention ponds, the key water quality functions of soft meanders are delivered through the lower flow velocity. The Kingstowne steam restoration plan called for a greater meander ratio than the existing stream and added measures to stabilize the bank and streambed.



A step pool at Kingstowne Stream

- **Riparian Buffers:** Riparian buffers are generally defined as areas containing plants and other organisms adjacent to water. A swath of riparian vegetation along a channel bank provides some measure of protection from the erosive forces of water flowing through the stream valley and along the channel margins. It may also lower stream temperature and reduce sediment and nutrient transport. A 30-meter (100-foot) buffer width can provide very good control of nitrogen, including nitrate, and trap sediments under most circumstances.[17] The Kingstowne Stream restoration has the largest riparian buffer of the three case studies presented in this publication, with an average width of 268 feet.
- **Live Stakes:** Live stakes are sections of branches, like willow branches, without twigs or leaves that may be pounded directly into very soft soil; pilot holes must be made in harder soils. The roots of plants grow into the soil and bind the soil particles together, thereby reducing erosion. In addition to stabilizing the stream bank, live stakes that develop into living plants that can provide sources of organic matter for denitrification.
- **Cross Vanes and Diverse Cobble Substrate:** Cross vanes are rock structures placed below the water to control stream flow direction. The cross vanes, also act as grade control structures that reduce near-bank shear stress, velocity and stream power and increases the energy in the center of the channel. The diverse cobble substrate used at Kingstowne acts as firm substrate that helps reduce erosion of the stream banks. Used together cross vanes and diverse cobble substrate create step-pools that increase hydrodynamic diversity, lower stream velocity, and create habitat.

RESULTS

"Before the restoration, the water used to be black, like an oil slick, after it rained. Now we have fish in the stream, it's kind of nice walking along here." – Local Resident

NVSWCD and its partners made significant improvements to the Kingstowne Stream. In total, they restored 1,000 feet of the stream reach. They installed dry detention ponds, plunge pools, soft meanders, riparian buffers, cross vanes and cobblestone substrate. These actions restored the natural function of the stream and slowed the flow of water running through the stream in heavy precipitation events, which reduced pollution and improved other water quality indicators.

To investigate the efficacy of stream restoration approaches to improve water quality, stream water samples and field measurements were collected by the author at upstream and downstream monitoring points, separated longitudinally by 600 feet, of restored stream length. The upstream sample location was selected as close as possible to the beginning of the project reach where additional discharge inputs ceased. Monitoring was conducted bimonthly between mid-October 2007 and April 2008, primarily during baseflow conditions. The data provided evidence of in-stream nitrogen processing and improved water quality within the restored reach at Kingstowne.

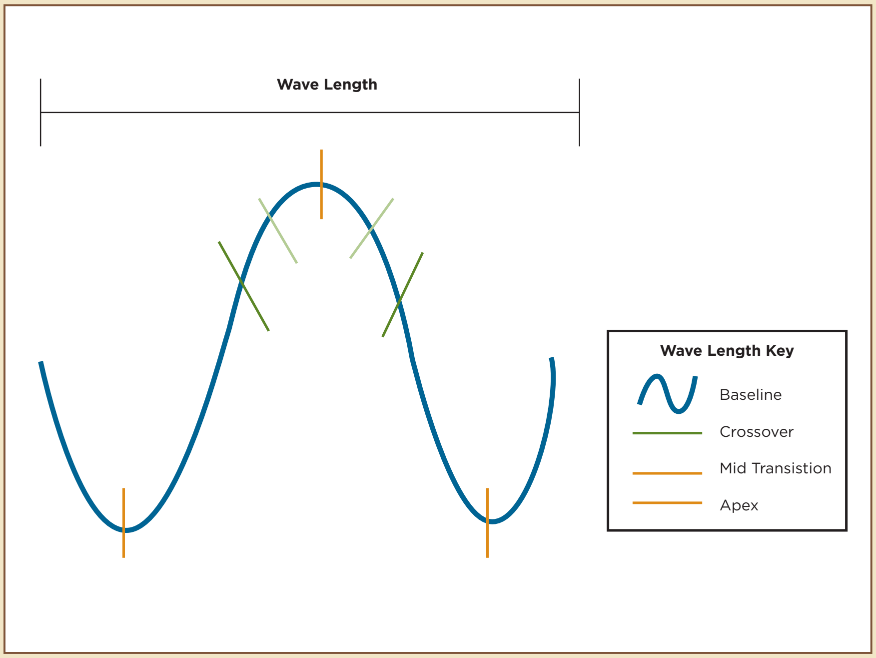
The following water quality criteria were found to have statistically significant differences between upstream and downstream concentrations:

Average nitrate-N: 4.49 milligrams per liter (mg/L) at the upstream monitoring location; 4.09 mg/L at the downstream monitoring location. These concentrations are twice as high as typical nitrogen pollutant concentrations for urban stormwater of 2.0 mg/L.[18] The average difference between upstream and downstream concentrations of nitrate-N was 0.40 mg/L ($t(14) = 6.701$, $p = 0.000$), resulting in a 10% overall removal efficiency of nitrate-N.

Average dissolved oxygen: 8.57 mg/L at the upstream monitoring location; 9.49 mg/L at the downstream monitoring location, resulting in an average difference of 0.93 mg/L ($t(11) = -3.013$, $p = 0.012$). Most aquatic fauna require dissolved oxygen concentrations greater than 5 mg/L for survival. Low dissolved oxygen also promotes accelerated release of phosphorus and toxins from sediments.

Average pH: 7.49 upstream monitoring location; 7.35 downstream

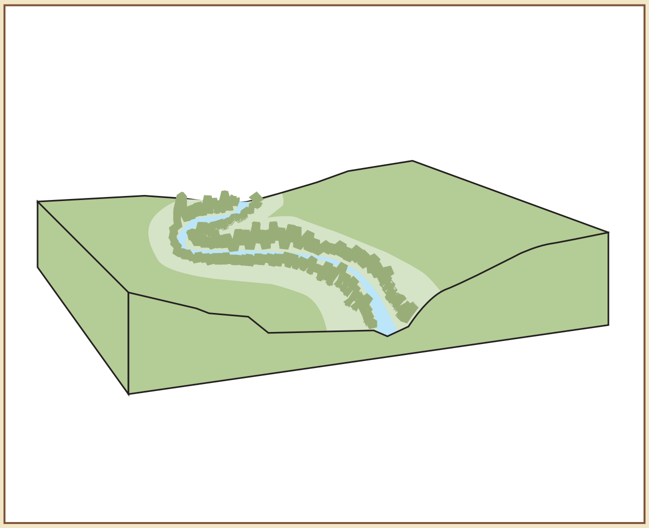
Kingstowne Stream Restoration Meander Schematic



Note: This drawing is a representation of the actual stream cross section restoration and is not to scale. This pattern is repeated through the length of the restoration project.

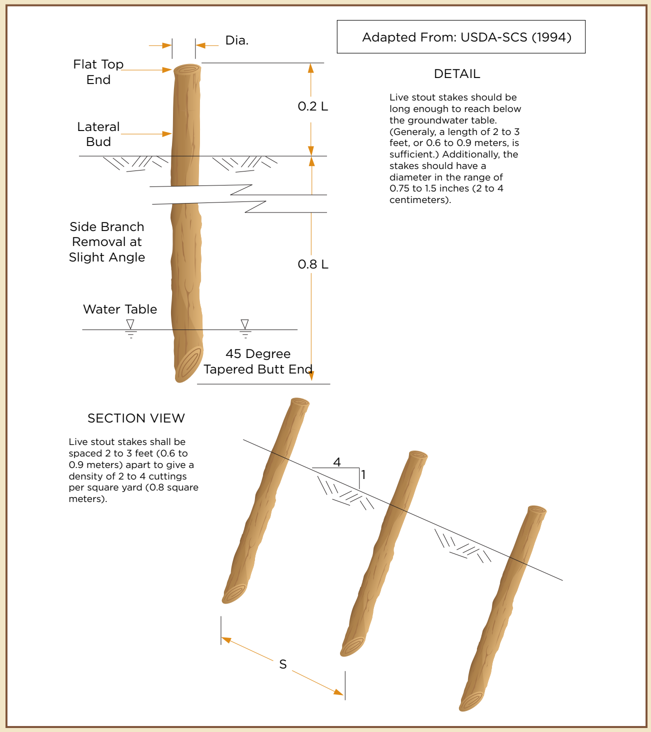
This schematic drawing represents a plan view of the meander pattern repeated at Kingstowne Stream restoration. The "crossover, "mid-transition" and "apex" segments of the restoration plan have engineering specifications and cross section drawings that give detailed information about how grading and slopes, substrate composition, rock placement, riparian plantings and other features should be configured.

Kingstowne Stream Riparian Buffer Photo and Schematic



A 30-meter (100-foot) buffer width can provide very good control of nitrogen, including nitrate, and trap sediments under most circumstances.[16] The Kingstowne Stream restoration has the largest riparian buffer of the three case studies presented in this publication, with an average width of 268 feet. Wider buffers widths of 100-300 feet provide greater habitat benefits for a variety of wildlife.

Kingstowne Stream Riparian Live Stakes Photo and Schematic



monitoring location (t(11) = 4.690, p = 0.001).

The following water quality criteria were not statistically significant but did demonstrate consistent trends between upstream and downstream monitoring points:

Average ammonia-N: 0.02 mg/L at the upstream monitoring location; 0.02 mg/L at the downstream monitoring location (Z = -1.621, p = 0.105).

Average TSS: 2.40 mg/L at the upstream monitoring location; 2.98 mg/L at the downstream monitoring location (Z = -1.000, p = 0.317).

Average temperature: 10.40 °C at the upstream monitoring location; 9.55 °C at the downstream monitoring location (t(11) = 1.711, p = 0.115).

Average specific conductivity: 0.33 microSiemens (mS/cm) at the upstream monitoring location; 0.33 (mS/cm) at the downstream monitoring location (Z = -1.099, p = 0.272).

Baseflow pollutant loads were calculated for the sum of nitrate-N and ammonia-N concentrations (total N) and TSS in pounds per day (lbs/day) and kilograms per day (kgs/day) for comparison to traditional Total Maximum Daily Loads (TMDLs).[19]

Kingstowne Stream Results	
Mean Difference Between Upstream and Downstream:	-0.40 mg/L nitrate-N -0.00 mg/L ammonia- N +0.58 mg/L TSS +0.93 mg/L DO -0.85 °C
Statistically Significant Results:	*Upstream/downstream comparison:* nitrate-N, DO and pH *Stream comparison:* nitrate difference greater than "hard" design

Removal efficiencies were also calculated in pounds per foot per year (lbs/ft/yr) for comparison to Chesapeake Bay Program removal efficiencies for urban stream restoration.[20] These pollutant loads and efficiency claims are rough estimations based on limited hydraulic monitoring (primarily baseflow conditions) without consideration of rainfall characteristics, runoff patterns, and total annual flow volume passing through the reach.

KEYS TO SUCCESS

- **Leadership:** Northern Virginia Soil and Water Conservation District, Federal, State, and Local government provided leadership and resources to restore the stream.
- **Methodology:** Used environmentally friendly methods to treat stream erosion problems in a highly urbanized area, including:
  - Gentle meanders that connect the stream with its adjacent floodplain;
  - Step-pool sequences constructed with cross vanes of diverse substrate; and
  - A wide, native riparian buffer.
- **Goal Setting:** Channel stability is an important goal for urban streams, but "tension often exists between the dynamism needed for ecological objectives and erosion and flood control interests. Risks associated with uncertain channel response can be reduced by the use of controls such as drop structures or sedimentation basins."[21] The detention pond above the restored reach at Kingstowne addresses these risks by minimizing the impacts of flashy flows that result from peak discharges/storm events.
- **Research and Monitoring:** Studies support the methods used in this project. Subsequent monitoring data, although limited, provided evidence that the stream restoration worked.

PHOTOS AND FIGURES

All photos by Maura Browning

Page 53: Figure, Burke Environmental Associates/The Conservation Fund, using Google Earth image

Page 55: Figure (top), Burke Environmental Associates/The Conservation Fund, adapted graphic by Fairfax County Virginia Department of Public Works and Environmental Service, Office of Capital Facilities, using Google Earth image

Page 57: Figure (top), adapted from a graphic by Fairfax County Virginia Department of Public Works and Environmental Service, Office of Capital Facilities; figure (bottom), FISRWG 1998[22]

Page 58: Figure, adapted from Maryland Department of Environment 2000[23]

Water Quality Statistical Abbreviations

The statistical abbreviations used in the water quality summary above have the following meanings:

- t = The t-test is the most commonly used method to evaluate the difference in means between two groups. The number in parenthesis is the number of pairs used in that particular paired t-test e.g. t(14) = 3.821.
- p = p-value. The p-value is a statistical measure for the probability that the results observed in a study could have occurred by chance. Conventionally, a p-value of 0.05 (5%) or below is accepted as being statistically significant.
- z = The z-value used in this summary is the statistic resulting from the nonparametric Wilcoxon test for significance. The Wilcoxon test can be used as an alternative to the t-test when the population cannot be assumed to be normally distributed.

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Pollutant Load and Removal Efficiencies for Kingstowne Stream

	Baseflow Pollutant Load (lbs/day)	Baseflow Pollutant Load (kg/day)	Baseflow Removal Efficiency (lbs/ft/yr)	CBP Removal Efficiency (lbs/ft/yr)
Total N	2.46	1.12	1.14	0.02
TSS	2.52	1.14	-	2.55

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