ORANGE COUNTY WATER AUTHORITY

WATER QUALITY BIOMONITORING PROJECT
SUMMARY REPORT FOR YEARS 2004 - 2006

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Project Overview and History

This Water Quality Biomonitoring Project was conceived in early 2004 by the Orange County Water Authority (OCWA) and implemented using Federal funding, with additional financial support from OCWA. It was designed as a comprehensive, county-wide assessment of ambient water quality in streams, using the stream biomonitoring methods developed by the NY State Department of Environmental Conservation's (NYS DEC) Stream Biomonitoring Unit. The NYS DEC has been monitoring streams throughout the state since 1972 using this method, and has been refining the methods over time. While the NYS DEC monitors water quality at a number of sites in Orange County streams and rivers, their program must cover the entire state and its resources are limited. The OCWA project provides a far more detailed water quality assessment because it includes over 160 sites. The OCWA project also includes education and training components and some additional research aimed at refining future monitoring work.

The NYS DEC methodology, like generally similar methods used in other states and around the world, is based on the idea that the living inhabitants of a stream are like canaries in a coal mine. These organisms are affected by the quality of the water in which they live, and this provides the basis for developing scientific analysis procedures to measure overall water quality. This method does not focus primarily on analyzing water for specific chemical constituents (although some basic chemistry data is collected during the process). Instead, the process is based on counting the numbers and diversity of different aquatic species to assess the biological community structure. Because some organisms are more sensitive to pollution, and others more tolerant, the presence or absence, and relative numbers, of different species provide a reliable indicator of water quality. This method has been developed and refined into a reliable, controlled scientific protocol that has been approved by the US EPA to meet Federal requirements for New York State's water quality monitoring programs. As a measure of its reliability and acceptance in the scientific community, it is also sometimes used for regulatory compliance purposes, including legal proceedings. Similar methods using macroinvertebrates are used throughout the US and elsewhere in the world.

To provide a detailed overview of the rationale for this approach and methodology, we are including here a description written by NYS DEC in their 2004 report on 30 Year Trends in Water Quality by Bode et. al. (see Literature Cited for complete citation).

THE RATIONALE OF BIOLOGICAL MONITORING (From NYS DEC report by Bode et. al., Appendix VIII, p. 373.)

Biological monitoring as applied here refers to the use of resident benthic macroinvertebrate communities as indicators of water quality. Macroinvertebrates are larger-than-microscopic invertebrate animals that inhabit aquatic habitats; freshwater forms are primarily aquatic insects, worms, clams, snails, and crustaceans.

Concept

Nearly all streams are inhabited by a community of benthic macroinvertebrates. The species comprising the community each occupy a distinct niche defined and limited by a set of environmental requirements. The composition of the macroinvertebrate community is thus determined by many factors, including habitat, food source, flow regime, temperature, and water quality. The community is presumed to be controlled primarily by water quality if the other factors are determined to be constant or optimal. Community components which can change with water quality include species richness, diversity, balance, abundance, and presence/absence of tolerant or intolerant species. Various indices or metrics are used to measure these community changes.

Assessments of water quality are based on metric values of the community, compared to expected metric values.

Advantages of using macroinvertebrates as water quality indicators:

1. they are sensitive to environmental impacts
2. they are less mobile than fish, and thus cannot avoid discharges
3. they can indicate effects of spills, intermittent discharges, and lapses in treatment
4. they are indicators of overall, integrated water quality, including synergistic effects and substances lower than detectable limits
5. they are abundant in most streams and are relatively easy and inexpensive to sample
6. they are able to detect non-chemical impacts to the habitat, such as siltation or thermal changes
7. they are vital components of the aquatic ecosystem and important as a food source for fish
8. they are more readily perceived by the public as tangible indicators of water quality
9. they can often provide an on-site estimate of water quality
10. they can often be used to identify specific stresses or sources of impairment
11. they can be preserved and archived for decades, allowing for direct comparison of specimens
12. they bioaccumulate many contaminants, so that analysis of their tissues is a good monitor of toxic substances in the aquatic food chain

Limitations

1. Biological monitoring is not intended to replace chemical sampling, toxicity testing, or fish surveys. Each of these measurements provides information not contained in the others.
2. Substances may be present in levels exceeding ambient water quality criteria, yet have no apparent adverse community impact.
3. Macroinvertebrate sampling cannot determine if water is safe for drinking.

Background

The center of Orange County is located approximately 60 miles north of New York City, and the County has an area of about 825 square miles. It is situated between the Hudson and Delaware rivers and contains areas that drain directly to these two rivers, as well as areas drained by the Wallkill River, Moodna Creek, and Quassaick Creek -- tributaries of the Hudson River --and by the Ramapo River, a tributary of the Hackensack River. The County contains approximately 241 miles of streams and rivers. Estimated land uses in Orange County are: 15% agriculture, 8% commercial, industrial, and offices; 12% parks; 26% residential; 14% community and public services; and 26% vacant (Orange County Comprehensive Plan, 2003). Risks to water quality in the streams and rivers in Orange County, as in other areas in the region, include municipal wastewater and other point-source discharges; increasing urbanization and impervious surfaces; and non-point source runoff from residential, commercial, industrial and agricultural land uses. Other key risks to water quality include development and other alterations to stream corridors and adjacent areas, including floodplains, stream buffers, and wetlands. A third set of risks is presented by changes due to invasive species, changing climate, and other factors that affect the ecology of the landscape.

Project Goals

This project is designed to provide guidance to County and local officials and other decision-makers and stakeholders, including the general public, about water quality in streams and rivers. Because virtually everything that occurs on the land has some impact on water, water quality is an excellent indicator of the overall health of the landscape and its inhabitants. This information has at least two key purposes: 1) it serves as a baseline against which future changes in water quality can be measured and compared over time; and 2) it can highlight key problem areas that warrant more detailed investigation. It should be useful to guide programmatic activities of OCWA and other County agencies, municipalities and other agencies that are responsible for key water resource-related programs, including drinking water supply, stormwater management, stream management and restoration, recreation, watershed planning, habitat protection and restoration, and meeting other land use and watershed planning goals.

The sampling points for the project include many targeted sites in streams and rivers chosen based on their relationship and proximity to key water-related resources and land uses, and to areas where stormwater management is expected to be a significant issue, including designated MS4 areas. It also includes a number of sites that were chosen with technical assistance from the US EPA, using a randomized process designed to enable statistical analysis that can predict likely water quality conditions in other streams that were not monitored. The project also has a significant educational focus. A more complete description of the site selection criteria and overall project design can be found in the 2004 OCWA Quality Assurance Project Plan (see below for more information.)

Methods, Key Terminology and Interpretation of Findings

The rationale, methods, and data analysis used for this study adhered to procedures outlined in the Orange County Water Authority Water Quality Biomonitoring Project Quality Assurance Project Plan (the QAPP) and the Quality Assurance Work Plan for Biological Stream Monitoring in New York State by Bode *et al*., (2002). The OCWA QAPP was prepared according to US EPA requirements that all Federally-funded projects that include collection of environmental data must have such a quality assurance plan. The OCWA QAPP, essentially, used the NYS DEC QAPP by Bode et. al. as the foundation for all sampling and analysis methods, with one slight modification that's outlined in the OCWA QAPP. This was done, among other reasons, so that all findings of the OCWA project can be readily compared to NYS DEC data, because the same methods were used.

The NYS DEC methodology uses four different analyses for assessing water quality, which are known as metrics (see NYS DEC QAPP for more detailed descriptions.) These four metrics are then combined to produce one overall water quality score called the Biological Assessment Profile, or BAP. The BAP is expressed in two ways in NYS DEC's reports: a numerical value from 0-10, where 10 equals the best possible water quality; and a narrative description. The narrative descriptors are non-impacted, slightly impacted, moderately impacted, and severely impacted, each of which corresponds to a range of numerical BAP values (a BAP score of 0-2.50 is termed severely impacted; 2.51-5.00, moderately impacted; 5.01-7.50 is slightly impacted; and 7.51-10.00 is non-impacted.) In this report the numerical BAP scores are used.

The NYS DEC methodology also includes a separate metric, Impact Source Determination, or ISD, that was first applied beginning in 1994. The ISD is a ranking of the most likely cause of water quality impacts at each impacted site. The impact source categories in the NYS DEC method currently are defined as: non point source nutrient enrichment; organic -- sewage and animal waste; complex – municipal and industrial inputs; toxic; siltation; impoundment; and natural. The 2004 NYS DEC report on water quality trends by Bode et. al. notes that they expect these relatively broad ISD categories will be further defined and refined over time.

Complete physical, chemical and biological data for all monitoring sites is contained in Appendix I. For a brief explanation of methods and rationale of data collected see appendix II. A glossary of selected terms is provided in appendix III.

<u>Results</u>

Sampling data was collected at 162 unique sites from 2004-2006. Unique sites are defined as distinct monitoring sites, and this term is used to distinguish between samples collected at unique sites and the number of total sites sampled, which includes a number of samples taken at the same site in multiple years.

Total number of sites assessed from 2004 – 2006:	210
Number of unique sites assessed:	162
Number of sites assessed in more than one year:	48
Total number of sites with insufficient data for assessment:	4

<u>Summary of water quality findings</u>:

Water quality – BAP scores	Number of samples 2004-2006
7.51-10.00	44
5.01-7.50	112
2.51-5.00	46
0-2.50	4
Total sites sampled	206

<u>Interpretation of Monitoring Data</u>

Based on the current understanding of the effects of various land uses and land cover on water quality, it seems reasonable to conclude that the causes of water quality impacts include: 1) a combination of impervious surfaces (roads, parking areas, etc.), which reduce the watershed's ability to filter nutrients, sediment and other contaminants; and 2) various pollutants that are the result of widespread human activities and impacts. These pollution sources include non-point sources such as silt and sediment from construction sites; improperly sited, installed or maintained septic systems; excessive fertilizer application on lawns and farms; application of deicing materials on roads and parking areas; automotive chemicals; pet waste; and others. They also include point sources, primarily municipal wastewater discharges, which can include significant nutrient loading even when systems are operating according to their permit requirements, and also in some cases industrial discharges.

This project was not designed to generate, and the data will not support, conclusive site specific determinations about the causes of impacts at any given site. The findings do provide a starting point for identifying sites with significant problems and for planning follow up studies to identify and correct these problems. The data also provide a detailed baseline assessment of conditions around the County, which will allow for future monitoring of general trends and of changes over time.

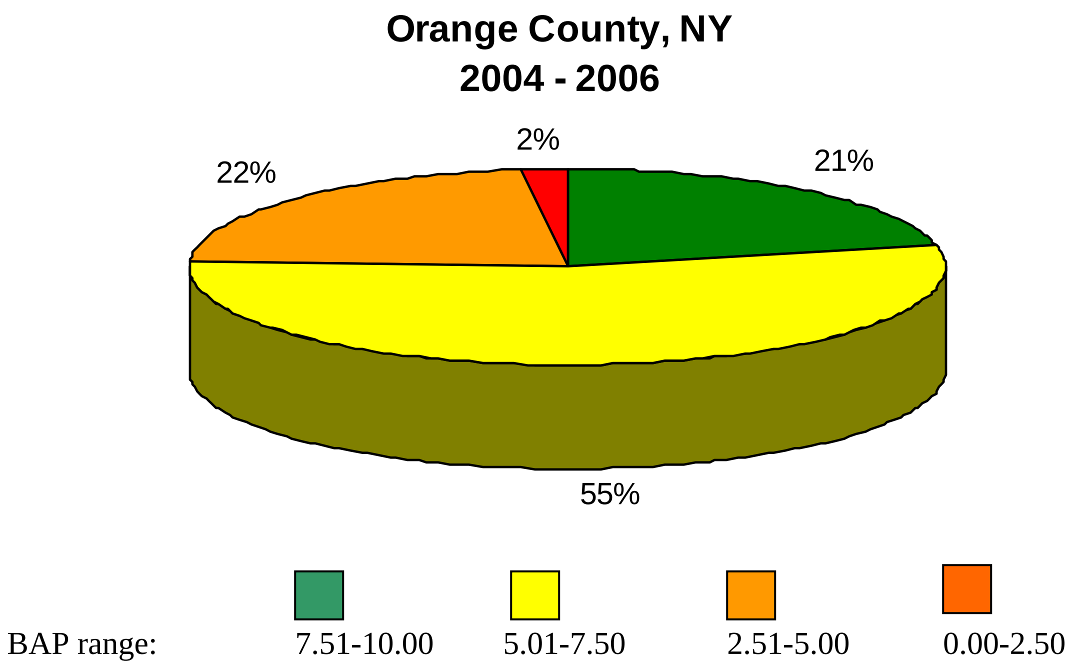

Figure Two. Distribution of BAP scores for macroinvertebrate samples across the 0-10 BAP scale developed by NYS DEC. This graph includes all sites assessed by the Orange County Water Authority from 2004-2006, including multiple samples taken at certain sites in different years. It also includes findings from a NYS DEC survey in 2002.

Impact Source Determination – Findings

According to the ISD findings, at nearly half of the impacted sites (sites with BAP scores of 7.50 or lower) identified in this project, the most likely predominant cause of impact was non point source nutrient enrichment. The remaining sites were influenced by one or more of the following: organic/sewage effluent, complex municipal/industrial inputs, toxins, siltation or impoundment effects. The ISD and other data indicate that impacts at several sites may be related to wastewater discharges from municipal treatment systems. Based on the information available, it seems that this may fit with a larger regional and nationwide trend. Many wastewater collection and treatment systems that were first built in the 1970s and 1980s (after passage of the 1972 Clean Water Act created a major source of Federal funding) are now reaching a point where they need major upgrades or replacement, and this aging infrastructure is believed to be the source of significant water quality problems at a number of locations in NY State (see NYS DEC 30 Year Trends in Water Quality by Bode et. al., p. 3)

Education and Training

As part of this project a number of educational workshops, presentations and training programs have been provided for various audiences. These programs include presentations to a conference of the Hudson River Watershed Alliance, and the annual Ramapo River Watershed conference; a hands-on demonstration and education workshop for members of the Orange County 4H Program, many of whom used this as part of their project for the 2007 Orange County Fair; a talk and demonstration for the Wallkill River Watershed Management Plan advisory committee; a 2 ½ day training workshop for educators and other interested participants; and a presentation to the Board of Directors of OCWA. Additional educational programs are included in the workplan for the remainder of the project (see below for more information.)

2007 Sampling

31 sites were sampled in 2007, almost all of which were monitored in at least one previous year. Most of these sites were selected to follow up on significantly impacted sites discovered in previous years, and several were selected to augment the data available from reference sites, which will be used in the development of the Orange County model community structure, described below.

Additional Project Elements

Several additional project elements are included in the full scope of work for this project. These tasks will be completed in 2008.

1) Establish a model macroinvertebrate community structure based on local conditions in Orange County: The NYS DEC's methods include comparison of the biological community sampled at each site to the ideal community structure that would be expected at pristine, non-impacted sites – the model community structure. The DEC's Percent Model Affinity (PMA) metric, however, is based on a statewide average of model communities found in streams around the state. The US EPA and others have recommended that interpretation of biological stream survey data will be improved and refined by use of model communities tailored to each region. To address this issue, the work plan includes development of a regional reference model community for Orange County, NY. This

reference community will be based on statistical analysis of the specific macroinvertebrate communities found at reference stream sites, which are locations in parks or protected areas with very high water quality. The analysis and establishment of the model community will follow methods outlined in Novak and Bode (1992) and Barton (1996). This locally-based model community structure is expected to refine the analysis and interpretation of future stream biomonitoring results. This project will include applying the new model community structure to data from a selected number of monitoring sites to test its effect on the overall water quality score.

2) Apply Nutrient Biotic Index (NBI) to Orange County monitoring findings: In 2005-2006, after the OCWA stream monitoring project began, Alexander Smith and Robert Bode, senior staff at the NYS DEC's Stream Biomonitoring Unit, finalized a new analysis method called the Nutrient Biotic Index (NBI.) This method will be used from now on by DEC, in addition to the other analysis procedures that are combined to produce the Biological Assessment Profile (BAP.) The NBI is designed to measure the impact of excessive nutrient loading on the biological community, as an indictor of water quality impacts from nutrients including nitrogen and phosphorus. Excessive amounts of these nutrients cause overgrowth of algae and other aquatic vegetation and are one of the more common and significant sources of water pollution and overall impact to water quality. The NBI analysis technique, now that it has been finalized and is available, will be applied to existing raw data for selected OCWA monitoring sites to provide additional information about the causes of impacts at each site.

3) Diatom analysis: The original workplan and QAPP for this project included the potential to analyze diatoms (a certain group of single celled organisms) to provide additional detail about water quality at selected sites. Diatom analysis is particularly useful for gaining a more refined understanding of nutrient loading impacts. Diatoms have been collected at all monitoring sites, and based on overall findings to date the diatom samples from 15 sites have been selected for analysis.

4) Ongoing monitoring program – collaboration with Orange County Land Trust and other organizations: One of the recommendations of this report is that OCWA work with other agencies and organizations to implement an ongoing stream biomonitoring program in Orange County. One approach that can potentially support and enhance ongoing monitoring is to involve trained volunteers for certain tasks. While there are major limitations involved with using volunteers to perform macroinvertebrate identification tasks and other analyses, field collection of samples is a relatively straightforward process that should be appropriate for volunteers assuming that adequate training and quality control is provided. This approach, in addition to providing important public participation and education opportunities, can also reduce the cost of ongoing monitoring because collection of samples in the field is a significant portion of the total monitoring cost for each sample.

OCWA has begun exploring the potential to work with other organizations to implement a sampling program that includes trained volunteers. If implemented, this plan is likely to include some additional training and oversight, a quality control program, and exploration of additional funding mechanisms to support monitoring, such as funds from MS4 communities (which are legally required to implement public participation programs focusing on water quality) and other sources.

<u>5) Final report, including comparison of NYS DEC and other available data with OCWA findings</u>: The tasks described above, monitoring results from the 2007 sampling season, data available from NYS DEC for certain sites and other information will all be presented in a final report that will complement this report. This report will include a full analysis of water quality trends over time for OCWA sites that have also been monitored by NYS DEC, and will provide an opportunity to present additional graphics summarizing all findings from 2004-2007.

<u>Data visualization</u>: In addition to the tasks described above, there is discussion underway among members of the project team, and with outside colleagues, about the potential to display this data and interpret it using visualization tools. One example of this approach is to use different colors to depict water quality on stream segments upstream of each monitoring site. In this scheme, water quality in the stream for some distance upstream of each site would be shown using the color associated with the appropriate water quality score. This approach might also be extended to visually depict the water quality impact of land areas upstream of each site as well, which could reasonably be considered to be contributing to and related to the monitoring findings at each site. (Relating land use to water quality in the stream would depend also on details of the water quality findings – for example, if a point source wastewater discharge was indicated as the likely source of impact, land use would be less relevant to water quality than if the source is related to non-point source runoff.) This concept remains formative and needs considerable testing and development but it will potentially be an important means of communicating information and of relating water quality findings to upstream land use, discharges, or other potential impact sources.

Summary of Findings

Note: These findings describe water quality data for all sites sampled from 2004-2006, which includes certain sites sampled in multiple years, and the percentages below reflect all of this aggregated data.

- The majority of stream sites sampled -- 55 percent – fell into the BAP range of 5.01-7.50, exhibiting a macroinvertebrate community significantly altered from the pristine state. This is considered good water quality and does not limit fish survival, it may limit fish propagation.
- 22 percent of sites fell into the BAP range of 2.51-5.00. Water quality in this range is described by NYS DEC as often limiting to fish propagation, but usually not to fish survival.
- 21 percent of stream sites sampled fell into the BAP range of 7.51-10.0, indicating very good water quality that will not limit fish survival or propagation.
- 2 percent of sites sampled fell into the BAP range of 0-2.50, indicative of very poor water quality, which impedes both fish propagation and survival.
- Water quality category adjustments were made for 26 sites because the sites were located at headwaters, were influenced by an impoundment, or had an outlying metric score.

- Nearly half of the impacted sites were influenced by non point source nutrient enrichment; the remaining sites were influenced by one or more of the following: organic/sewage effluent, complex municipal/industrial inputs, toxins, siltation or impoundment effects, according to the Impact Source Determination findings.

For definitions of impact categories, see appendix IV. Consistent with the OCWA findings, the 2002 DEC assessment of NY State concluded that the most likely cause of impact at the majority of sites, as shown by Impact Source Determination, was nonpoint source nutrient enrichment (52% of sites in 2002, and 47% in the OCWA study).

206 of the sites sampled by OCWA were fully assessed (the remainder were found to be unsuitable for full assessment based on field conditions.) 26 of these were located near headwaters or below an impoundment or wetland. These habitats influence the macroinvertebrate community structure, so an erroneous assessment of impacted water quality can occur (Bode *et. al*., 2002). NYS DEC has developed criteria to adjust the water quality score for samples collected at these particular habitats, and these adjustments were applied to those 26 sites in this survey.

<u>Next Steps</u>

- Establish an ongoing monitoring program to revisit selected sites, with a goal of covering most of the established sites at least once every five years. Refine the existing network of sites to determine which ones may be of lower priority for various reasons. Maintain the current process of site selection, using the site selection criteria developed for this project with some additional refinements, to identify additional priority sites for monitoring to augment and complete the existing network of sites. In addition, consider using probability-based methods of site selection.

- Coordinate these monitoring efforts with the New York State DEC Stream Biomonitoring Unit to eliminate duplication and maximize program efficiency.

- Work with municipalities and other stakeholders to determine appropriate follow-up measures, including sampling sites for 2008 and steps to address water quality issues at specific sites where significant impacts have been found.

- Produce yearly water quality assessment reports and link these reports, and other aspects of the program, to assist the MS4 communities, including Orange County itself, in effectively meeting their regulatory requirements and responsibilities. Work with municipalities, including MS4s and others, to determine what can be done by local municipalities, the appropriate role for OCWA, and how other agencies and organizations can be involved. Use the stream monitoring program as a key vehicle for meeting specific MS4 requirements including public participation, illicit discharge detection and elimination, and post-construction monitoring of stormwater management facilities.

Additional Recommendations

- Explore creative partnerships and funding sources for ongoing monitoring, including the potential to work with MS4 communities, water districts, wastewater districts, stormwater districts, and other municipal entities to collaborate on funding, public education and participation, and other aspects of an ongoing, comprehensive monitoring program.

- Test the potential to use trained volunteers to collect samples, thereby reducing costs, while using professional analysts for sample analysis and reporting to maintain quality control and comparability with NYS DEC data. Work with community groups and other stakeholders to develop stream visual assessment initiatives to complement and help guide biomonitoring work.

- Continue to build partnerships with academic, research, and education organizations including the Black Rock Forest Consortium, colleges and schools in the region, the Hudson River Estuary Program, the Highlands Environmental Research Institute, the CUNY Institute for Sustainable Cities, SUNY colleges at New Paltz and Syracuse, Mount Saint Mary College, and others. Explore the benefits of participating in the Lotic Scene Investigation program, which matches college interns with a professional stream monitoring assessment project to provide intensive field experience and classroom study. This approach can leverage OCWA and other local funding sources by attracting outside funding based on the educational value. (The program was developed by J. Kelly Nolan of Watershed Assessment Associates LLC, a Principal Investigator for this project.)

- Work with the Orange County Municipal Planning Federation, Orange County Citizens Foundation, Hudson Valley Regional Council, Hudson River Estuary Program, and other organizations and agencies involved with planning and development to explore how to utilize the findings of this study to support improved land use planning and development policies in Orange County. Explore ways to use the findings and overall approach of this project to support using low-impact development practices for new development.

- Consider the potential benefits of a county-wide volunteer stream monitoring and public outreach coordinator position. Through this position and/or other mechanisms, provide annual training and regular outreach programs targeted for municipal officials, watershed groups, recreational and sporting organizations, consulting planners and engineers, landowners, and other audiences about the general principles of stream ecology, how streams are affected by land use and human activities, and about utilizing the findings of stream biomonitoring studies for decision-making.

Stream Name	STATION ID	BAP 2004	BAP 2005	BAP 2006	Municipality
Unnamed tributary	0900_003		6.10		Middletown
Monhagen Brook	0900_005			4.07	Middletown
Monhagen Brook	0900_005		4.60		Middletown
Monhagen Brook	0900_006			6.68	Middletown
Monhagen Brook	0900_006		5.50		Middletown
Quassaic Creek	1100_001	6.70			Newburgh (city)
Neversink River	1300_001		5.90		Port Jervis
Delaware River	1300_002		8.40		Port Jervis
Satterly Creek	2089_001	4.60			Blooming Grove
Satterly Creek	2089_002		6.40		Blooming Grove
Unnamed tributary	2089_003		5.30		Blooming Grove
Moodna Creek	2089_004		5.60		Blooming Grove
Moodna Creek	2089_004	5.10			Blooming Grove
Cromline Creek	2089_005	7.10			Blooming Grove
Perry Creek	2089_006			6.85	Blooming Grove
Perry Creek	2089_006		4.87		Blooming Grove
Perry Creek	2089_007		5.90		Blooming Grove
Perry Creek	2089_007			7.40	Blooming Grove
Cromline Creek	2089_008			4.16	Blooming Grove
Cromline Creek	2089_008		4.70		Blooming Grove
Satterly Creek	2089_009	5.50			Blooming Grove
Black Meadow Creek	2201_001		3.12		Chester (v)
Black Meadow Creek	2201_001	3.30			Chester (v)
Black Meadow Creek	2201_001			4.60	Chester (v)
Seeley Brook	2289_002	5.60			Chester
Unnamed tributary	2289_003	6.90			Chester
Trout Brook	2289_005		6.50		Chester
Seeley Brook	2289_008		7.90		Chester
Seeley Brook	2289_008			6.75	Chester
Seeley Brook	2289_009	5.60			Chester
Dock Hill Creek	2401_001		7.80		Cornwall-on-Hudson
Dock Hill Creek	2401_001			7.67	Cornwall-on-Hudson
Idlewild Creek	2489_001			8.34	Cornwall
Moodna Creek	2489_002		7.60		Cornwall
Woodbury Creek	2489_003		7.30		Cornwall
Idlewild Creek	2489_004			7.09	Cornwall
Idlewild Creek	2489_004	5.30			Cornwall
Unnamed tributary	2489_006			8.20	Cornwall

Stream Name	STATION ID	BAP 2004	BAP 2005	BAP 2006	Municipality
Idlewild Creek	2489_007	8.50			Cornwall
Idlewild Creek	2489_007			7.72	Cornwall
Woodbury Creek	2489_008			7.30	Cornwall
Woodbury Creek	2489_008		8.20		Cornwall
Unnamed tributary	2489_009		8.30		Cornwall
Unnamed tributary	2489_009			7.15	Cornwall
Moodna Creek	2489_010			7.13	Cornwall
Moodna Creek	2489_010		7.70		Cornwall
Mineral Spring	2489_011	8.10			Cornwall
Idlewild Creek	2489_012			5.80	Cornwall
Idlewild Creek	2489_012	6.60			Cornwall
Baby Brook	2489_013			7.60	Cornwall
Pakanasink Creek	2600_001	7.30			Crawford
Dwaar Kill	2600_002	7.20			Crawford
Shawangunk Kill	2600_003		7.25		Crawford
Shawangunk Kill	2600_003	7.90			Crawford
Pakanasink Creek	2600_004		5.30		Crawford
Pakanasink Creek	2600_004			6.56	Crawford
Pakanasink Creek	2600_005			8.30	Crawford
Dwaar Kill	2600_006			7.00	Crawford
Dwaar Kill	2600_007			3.10	Crawford
Basher Kill	2800_001		7.30		Deerpark
Gold Creek	2800_002		5.24		Deerpark
Shingle Kill	2800_003		7.90		Deerpark
Neversink River	2800_005			8.30	Deerpark
Neversink River	2800_005	8.10			Deerpark
Neversink River	2800_006			9.30	Deerpark
Neversink River	2800_006	8.70			Deerpark
Bush Kill	2800_007			7.25	Deerpark
Bush Kill	2800_007		8.00		Deerpark
Basher Kill	2800_008		5.40		Deerpark
Otterkill	3089_003	6.10			Goshen
Wallkill	3089_004		2.90		Goshen
Otterkill	3089_005		6.32		Goshen
Rio Grand	3089_006		0.95		Goshen
Rio Grand	3089_007		3.20		Goshen
Rio Grand	3089_008			1.80	Goshen
Rio Grand	3089_008		1.97		Goshen
Black Meadow Creek	3089_009			6.81	Goshen

Stream Name	STATION ID	BAP 2004	BAP 2005	BAP 2006	Municipality
Shawangunk Kill	3200_001	6.70			Greenville
Otterkill	3489_001		3.40		Hamptonburgh
Otter Creek	3489_002		6.05		Hamptonburgh
Highland Brook	3601_001	6.80			Highland Falls
Crows Nest Brook	3689_001		5.50		Highlands
Unnamed tributary	3689_002	7.50			Highlands
Rutgers Creek	3889_001		6.85		Minisink
Unnamed tributary	3889_002		4.20		Minisink
Unnamed tributary	3889_002	3.70			Minisink
Unnamed tributary	3889_003		6.90		Minisink
Unnamed tributary	3889_003	7.10			Minisink
Rutgers Creek	3889_004	7.50			Minisink
Indigot Creek	3889_005			8.00	Minisink
Ramapo River	4001_001		5.95		Monroe (v)
Ramapo River	4001_001	4.60			Monroe (v)
Ramapo River	4001_002	7.90			Monroe (v)
Ramapo River	4003_001		6.30		Harriman
Unnamed tributary	4005_001	5.20			Kiryas Joel
Unnamed tributary	4089_003	7.80			Monroe
Unnamed tributary	4089_005		4.70		Monroe
Unnamed tributary	4089_005			4.83	Monroe
Unnamed tributary	4089_006	8.40			Monroe
Unnamed tributary	4089_007	8.80			Monroe
Wallkill	4205_002			5.04	Walden
Tin Brook	4205_005		7.00		Montgomery (v)
Wallkill	4289_003		4.50		Montgomery
Tin Brook	4289_004	5.80			Montgomery
Wallkill	4289_005			4.45	Montgomery
Wallkill	4289_005		4.20		Montgomery
Wallkill	4289_006		1.17		Montgomery
Wallkill	4289_006			3.93	Montgomery
Wallkill	4289_006			3.87	Montgomery
Tin Brook	4289_007		5.70		Montgomery
Tin Brook	4289_007			5.80	Montgomery
Wallkill	4289_008			5.70	Montgomery
Wallkill	4289_009			3.26	Montgomery
Shawangunk Kill	4489_002		5.40		Mount Hope
Little Shawangunk Kill	4489_003	7.40			Mount Hope
Quassaic Creek	4600_001		4.80		Newburgh

Stream Name	STATION ID	BAP 2004	BAP 2005	BAP 2006	Municipality
Quassaic Creek	4600_004	6.30			Newburgh
Quassaic Creek	4600_005	7.30			Newburgh
Gidneytown Creek	4600_007	9.20			Newburgh
Unnamed tributary	4600_008		5.20		Newburgh
Unnamed tributary	4600_008			5.20	Newburgh
Moodna Creek	4800_003			6.02	New Windsor
Moodna Creek	4800_005			5.70	New Windsor
Unnamed tributary	4800_006		5.50		New Windsor
Unnamed tributary	4800_007			5.45	New Windsor
Unnamed tributary	4800_007		4.90		New Windsor
Unnamed tributary	4800_007	5.60			New Windsor
Silver Stream	4800_011			4.90	New Windsor
Silver Stream	4800_011		4.10		New Windsor
Moodna Creek	4800_012			5.28	New Windsor
Moodna Creek	4800_012		6.00		New Windsor
Quassaic Creek	4800_013			4.40	New Windsor
Quassaic Creek	4800_013		5.10		New Windsor
Unnamed tributary	5089_001	6.90			Tuxedo
Ramapo River	5089_002			5.50	Tuxedo
Ramapo River	5089_003		5.30		Tuxedo
Ramapo River	5089_004		4.54		Tuxedo
Unnamed tributary	5089_005		8.20		Tuxedo
Unnamed tributary	5089_005	8.10			Tuxedo
Arden Brook	5089_007			7.25	Tuxedo
Arden Brook	5089_007		7.80		Tuxedo
Ringwood River	5089_008			6.30	Tuxedo
Ringwood River	5089_008		7.00		Tuxedo
Masonic Creek	5200_001		3.72		Wallkill
Masonic Creek	5200_001	3.60			Wallkill
Wallkill	5200_002		3.10		Wallkill
Unnamed tributary	5200_003		6.90		Wallkill
Unnamed tributary	5200_005	7.00			Wallkill
Masonic Creek	5200_006	7.00			Wallkill
Mannayunk Kill	5200_007	6.90			Wallkill
Unnamed tributary	5200_008			8.40	Wallkill
Unnamed tributary	5200_008	8.40			Wallkill
Unnamed tributary	5200_009		6.50		Wallkill
Shawangunk Kill	5200_010			7.90	Wallkill
Shawangunk Kill	5200_010	7.90			Wallkill

Stream Name	STATION ID	BAP 2004	BAP 2005	BAP 2006	Municipality
Monhagen Brook	5200_014				Wallkill
Unnamed tributary	5200_015			6.37	Wallkill
Unnamed tributary	5405_001	6.70			Warwick
Wawayanda Creek	5489_001		6.43		Warwick
Browns Creek	5489_002		6.00		Warwick
Quaker Creek	5489_003		2.53		Warwick
Unnamed tributary	5489_004	6.90			Warwick
Unnamed tributary	5489_004			8.00	Warwick
Unnamed tributary	5489_004		9.69		Warwick
Wawayanda Creek	5489_006	8.50			Warwick
Unnamed tributary	5489_007	8.20			Warwick
Browns Creek	5489_008	7.80			Warwick
Longhouse Creek	5489_009		7.10		Warwick
Wawayanda Creek	5489_010		3.90		Warwick
Wheeler Creek	5489_011			5.97	Warwick
Wheeler Creek	5489_011		4.80		Warwick
Pochuck Creek	5489_012		5.10		Warwick
Unnamed tributary	5489_014	8.30			Warwick
Wallkill	5489_016			4.76	Warwick
Wallkill	5489_016		5.23		Warwick
Wawayanda Creek	5489_017			6.30	Warwick
Wawayanda Creek	5489_017		5.40		Warwick
Unnamed tributary	5489_019			4.94	Warwick
Unnamed tributary	5489_019		6.57		Warwick
Wawayanda Creek	5489_020			5.37	Warwick
Black Meadow Creek	5489_021	6.30			Warwick
Monhagen Brook	5600_001		4.50		Wawayanda
Rutgers Creek	5600_002			6.55	Wawayanda
Monhagen Brook	5600_003			5.58	Wawayanda
Monhagen Brook	5600_003		4.00		Wawayanda
Monhagen Brook	5600_003	3.00			Wawayanda
Indigot Creek	5600_004			7.00	Wawayanda
Monhagen Brook	5600_005			5.56	Wawayanda
Monhagen Brook	5600_005		4.55		Wawayanda
Wallkill	5600_006			4.97	Wawayanda
Mineral Spring	5889_001	6.80			Woodbury
Woodbury Creek	5889_002			5.80	Woodbury
Woodbury Creek	5889_002	5.20			Woodbury
Woodbury Creek	5889_002		5.70		Woodbury

Stream Name	STATION ID	BAP 2004	BAP 2005	BAP 2006	Municipality
Woodbury Creek	5889_007		6.40		Woodbury
Unnamed tributary	5889_009			6.70	Woodbury
Unnamed tributary	5889_009		7.49		Woodbury
Woodbury Creek	5889_010			4.16	Woodbury
Woodbury Creek	5889_010		3.30		Woodbury
Woodbury Creek	5889_011			5.60	Woodbury
Unnamed tributary	5889_013			6.60	Woodbury
Unnamed tributary	5889_014			4.98	Woodbury

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Appendix 1

Rationale of Data Collected and Methods

Physical

The *physical survey* is essential to a stream study because aquatic fauna often have specific habitat requirements independent of water composition, and alterations in these conditions affect the overall quality of a water body (Giller and Malmqvist, 1998). Additionally, the physical characteristics of a stream affect stream flow, volume of water within the channel, water temperature, and absorbed radiant energy from the sun.

Testing sites are evaluated for: stream depth, width, and current speed; aquatic vegetation; percent substrate and embeddedness; and percent stream canopy cover. Site photos were taken of the upstream and downstream area and are included with the physical and chemical data.

W*ater temperature* directly affects both the nature of aquatic fauna and species diversity; temperature tolerance is organism specific, and the reproductive cycle (including timing of insect emergence and annual productivity) will vary within different temperature ranges. Temperature can also affect organisms indirectly as a consequence of oxygen saturation levels. As water temperature rises, the metabolism of aquatic organisms increases, with an attendant increase in their oxygen requirements. At higher water temperatures, however, the oxygen carrying capacity of water decreases because of a diminished affinity of the water for oxygen.

Optimal water temperature ranges and lethal limits of water temperature vary among different organisms. The ratio of Plecoptera to Ephemeroptera (individuals and numbers of species) has been found to drop as the annual range of temperature increases (Hynes, 1970). The optimal temperature range for Brook trout is 11-16 ^{0} Celsius with an upper lethal limit of 24^{0} Celsius (Hynes, 1970). NYS DEC does not have a water quality standard for water temperature.

Temperature was recorded using a Hydrolab Quanta probe.

Velocity was calculated at the time of macroinvertebrate collection because an optimal macroinvertebrate collection site has a velocity between 0.45 and 0.75 meter/second. Velocity was determined by averaging the time it takes a float to travel a marked distance midstream and near each bank, and dividing the distance of the course by the average time.

Chemical

Dissolved Oxygen (DO) level is a function of water turbulence, diffusion, and plant respiration. The EPA recommends that dissolved oxygen levels remain above 11 mg/l during embryonic and larval stages of salmonid production and above 8 mg/l during other life stages (EPA, 1987). The NYS DEC standard for dissolved oxygen for class C(T) and C(TS) stream is 6 mg/L and 7 mg/L respectively.

A significant drop in DO concentration can occur over a 24-hour period, particularly if a waterbody contains a large amount of plant growth. Oxygen is released into the water as a result of plant photosynthesis during daylight; dense plant growth within a stream can therefore elevate the DO level significantly. At night photosynthesis ceases and DO may drop to levels maintained by diffusion and turbulence. A pre-dawn DO level will, in this case, reflect the lowest DO concentration in a 24 hour period and thus provide important data on the overall health of the system.

DO was measured using a Hydrolab Quanta probe.

It is also important to consider *percent oxygen saturation*, since dissolved oxygen levels vary inversely with water temperature. Percent saturation is the maximum level of dissolved oxygen that would be present in the water at a specific temperature in the absence of other influences, and is determined by calculating the ratio of measured dissolved oxygen to maximum dissolved oxygen for a given temperature. (The calculation is also standardized to altitude or barometric pressure.) Percent oxygen saturation falls when something other than temperature, such as dissolved solids or bacterial decomposition, affects oxygen levels.

A healthy stream contains near 100 percent oxygen saturation at any given temperature (Hynes, 1970). Trout are particularly sensitive to even a slight drop in oxygen saturation and will migrate away from streams when oxygen saturation falls. Similarly, certain macroinvertebrates are sensitive to varying saturation levels and because the ability of these organisms to migrate away from the changing conditions is limited a drop in saturation can be lethal. NYS DEC has not adopted percent oxygen saturation as a water quality standard.

Specific Conductance or Conductivity is a measure of the ability of an electrical current to pass through a stream; it is dependent on both the concentration of dissolved electrolytes within the water and water temperature. When inorganic ions are dissolved in water, conductivity increases. Organic ions, such as phenols, oil, alcohol and sugar, can decrease conductivity (EPA, 1997). Warmer water is also more conductive and, therefore, conductivity is reported for a standardized water temperature of 25 degrees Celsius. Measurements are reported in microsiemens per centimeter (µS/cm).

In the United States, freshwater stream conductivity readings vary greatly from 50-1,500µS/cm. The conductivity of most streams remains relatively constant, however, unless an extraneous source of contamination is present. A failing septic system would raise conductivity because of its chloride, phosphate, and nitrate content, while an oil spill would lower conductivity.

An Hydrolab Quanta probe was used to measure conductivity.

The *pH* is a measure of a stream's acidity. A desirable pH for salmonid is 6.5-8.5. An Hydrolab Quanta probe used to obtain pH. The NYS DEC standard for pH is 6.5-8.5.

Biological

Macroinvertebrates are collected by kick net and the specimens are preserved. Pollution-sensitive *macroinvertebrates*, a food source for trout, require similar chemical parameters as trout. The relative numbers of different macroinvertebrate groups indicate the overall health of an ecosystem. Perhaps more importantly, macroinvertebrate data demonstrate the effects of problems that may not be detected by chemical testing.

The NYS DEC Stream Biomonitoring Unit has utilized stream biological monitoring and water quality analysis since 1972 but the biological profiles and water quality assessments are not a part of the state's standards. They serve as a "decision threshold" to determine the need for further studies.

The Environmental Protection Agency recommends that states and tribes with biomonitoring experience adopt biological criteria into water quality standards to provide a quantitative assessment of a waterway's designated and supportive use. Currently only five states have done so; NY is not one of these states.

The four family indices, or metrics, that are recommended by the NYS DEC Biomonitoring Unit to provide a biological profile and overall stream water quality assessment are listed below. Family level identification using the four family indices has a prediction placement rate for proper water quality impact assessment within the NYS DEC four tier level of impact assessment of 92% (Smith and Bode, 2004).

Family Richness: The total number of families found in the sample.

EPT richness: The number of families in the three most pollution sensitive orders – Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies)- that are present.

Biotic index: The product of the quantity of a particular macroinvertebrate found and its assigned biotic value (pollution tolerance value).

Percent model affinity, PMA: A comparison of the number of identified macroinvertebrates to a New York model "non-impacted" community, based on percent abundance in seven major groups.

A Biological Assessment Profile, as outlined by the DEC, is obtained from the four metrics by converting each metrics' score to a 0-10 water quality scale and calculating their mean. The mean score identifies the water quality impact as: non-, slightly, moderately, or severely impacted. [For definitions of each category, see appendix IV]. The DEC surmises the ability of each of the above water qualities to support fish and their propagation, but a particular family or species of fish is not identified. This is significant because trout are sensitive to small amounts of pollutants and slight ecological changes, whereas bass or carp, having a higher tolerance to pollutants and ecological changes, are not.

It is prudent to remember that an index is a means to convey information about the status of a water body, but should not be used exclusive of its component metrics and data (EPA, 1999). [For complete definitions of indices see appendix IV]

Appendix II -- Glossary

Anthropogenic: caused by man

Assessment: a diagnosis or evaluation of water quality

Benthic: located on the bottom of a body of water or in the bottom sediments or pertaining to bottom-dwelling organisms

Benthos: organisms occurring on or in the bottom substrate of a waterbody

Biomonitoring: the use of biological indicators to measure water quality

Diel cycle: referring to the 24 hr day

Impact: a change in the physical, chemical, or biological condition of a waterbody

Impairment: a detrimental effect caused by an impact

Index: a number, metric, or parameter derived from sample data used as a measure of water quality

Intolerant: unable to survive poor water quality

Macroinvertebrate: a larger-than-microscopic invertebrate animal that lives at least part of its life in aquatic habitats

Non point source: diffuse pollution sources (i.e., without a single point of origin or not introduced into a receiving stream from a specific outlet)

Periphyton: are algae that grow on a variety of submerged substrates, such as rocks, plants or debris, in lakes or streams

Point source: a stationary location or fixed facility from which pollutants are discharged or emitted. Also, any single identifiable source of pollution, e.g., a pipe, ditch, ship, ore pit, factory smokestack

Rapid bioassessment: a biological diagnosis of water quality using field and laboratory analysis designed to allow assessment of water quality in a short turn-around-time; usually involves kick sampling and laboratory subsampling of the sample

Station: a sampling site on a waterbody

Stenotherms: organisms having a very narrow thermal tolerance and preferring cooler temperatures

Survey: a set of sampling conducted in succession along a stretch of stream

Tolerant: able to survive poor water quality

Appendix III – Exerpts from NYS DEC QAPP

NYS DEC Family Level Macroinvertebrate Indices

Family richness: This is the total number of macroinvertebrate families found in a riffle kick sample. Expected ranges for 100-organism sub samples of kick samples in most streams in New York State are: greater than 13, non-impacted; 10-13, slightly impacted; 7-9, moderately impacted; less than 7, severely impacted.

Family EPT richness: EPT denotes the orders of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera). These are considered to be mostly clean-water organisms, and their presence generally is correlated with good water quality (Lenat, 1987). The number of EPT families found in a 100-organism sub sample is used for this index. Expected ranges from most streams in New York State are: greater than 7, non-impacted; 3-7, slightly impacted; 1-2, moderately impacted; and 0, severely impacted.

Family Biotic Index: The family-level Hilsenhoff Biotic Index is a measure of the tolerance of the organisms in the sample to organic pollution (sewage inputs, animal wastes) and low dissolved oxygen levels. It is calculated by multiplying the number of individuals of each family by its assigned tolerance value, summing these products, and dividing by the total number of individuals. On a 0-10 scale, tolerance values range from intolerant (0) to tolerant (10). Values are listed in Hilsenhoff (1988); additional values for non-arthropods are assigned by the NYS Stream Biomonitoring Unit. The most recent values are listed in the Quality Assurance document (Bode et al., 2002). Ranges for the levels of impact are: 0-4.50, nonimpacted; 4.51-5.50, slightly impacted; 5.51-7.00, moderately impacted; and 7.01-10.00, severely impacted.

Percent Model Affinity: This is a measure of similarity to a model non-impacted community based on percent abundance in 7 major groups (Novak and Bode, 1992). Percentage similarity is used to measure similarity to a community of 40% Ephemeroptera, 5% Plecoptera, 10% Trichoptera, 10% Coleoptera, 20% Chironomidae, 5% Oligochaeta, and 10% Other. Ranges for the levels of impact are: >64, non-impacted; 50-64, slightly impacted; 35-49, moderately impacted; and <35, severely impacted.

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Biological Assessment Profile: Conversion of Index Values to Common 10 Point Scale.

The Biological Assessment Profile of index values, developed by Phil O'Brien, Division of Water NYS DEC, is a method of plotting biological index values on a common scale of water quality impact. Values from the four indices defined previously are converted to a common 0-10 scale using the formulae in the NYS DEC Quality Assurance document (Bode *et al*., 2002).

Water Quality Impact Categories

(Editor's note: BAP numerical ranges were inserted below by OCWA in brackets for clarity)

Non-impacted [BAP range 7.51-10.0]: Indices reflect very good water quality. The macroinvertebrate community is diverse, usually greater than 13 families in riffle habitats. Mayflies, stoneflies, and caddisflies are well represented; EPT family richness is greater than 7. The biotic index value is 4.50 or less. Percent model affinity is greater than 64. Water quality should not be limiting to fish survival or propagation. This level of water quality includes both pristine habitats and those receiving discharges which minimally alter the biota.

Slightly impacted [BAP range 5.01-7.50]: Indices reflect good water quality. The macroinvertebrate community is slightly but significantly altered from the pristine state. Family richness usually is 10 -13. Mayflies and stoneflies may be restricted, with EPT values of 3-7. The biotic index value is 4.51-5.50. Percent model affinity is 50-64. Water quality is usually not limiting to fish survival, but may be limiting to fish propagation.

Moderately impacted [BAP range 2.51-5.00]: Indices reflect poor water quality. The macroinvertebrate community is altered to a large degree from the pristine state. Family richness usually is 7-9. Mayflies and stoneflies are rare or absent, and caddisflies are often restricted; EPT richness is 1-2. The biotic index value is 5.51-7.00. The percent model affinity value is 35-49. Water quality often is limiting to fish propagation, but usually not to fish survival.

Severely impacted [BAP range 0-2.50]: Indices reflect very poor water quality. The macroinvertebrate community is limited to a few tolerant Families. Family richness is less than 7. Mayflies, stoneflies, and caddisflies are rare or absent; EPT richness is 0. The biotic index value is greater than 7.01-10. Percent model affinity is less than 35. The dominant species are almost all tolerant, and are usually midges and worms. Often 1-2 species are very abundant. Water quality is often limiting to both fish propagation and fish survival.

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NYS DEC Methods for Impact Source Determination

Definition: Impact Source Determination (ISD) is the procedure for identifying types of impacts that exert deleterious effects on a waterbody. While the analysis of benthic macroinvertebrate communities has been shown to be an effective means of determining severity of water quality impacts, it has been less effective in determining what kind of pollution is causing the impact. Impact Source Determination uses community types or models to ascertain the primary factor influencing the fauna.

Development of methods: The method found to be most useful in differentiating impacts in New York State streams was the use of community types, based on composition by family and genus. It may be seen as an elaboration of Percent Model Affinity (Novak and Bode, 1992), which is based on class and order. A large database of macroinvertebrate data was required to develop ISD methods. The database included several sites known or presumed to be impacted by specific impact types. The impact types were mostly known by chemical data or land use. These sites were grouped into the following general categories: agricultural nonpoint, toxic-stressed, sewage (domestic municipal), sewage/toxic, siltation, impoundment, and natural. Each group initially contained 20 sites. Cluster analysis was then performed within each group, using percent similarity at the family or genus level. Within each group four clusters were identified, each cluster usually composed of 4-5 sites with high biological similarity. From each cluster a hypothetical model was then formed to represent a model cluster community type; sites within the cluster had at least 50 percent similarity to this model. The method was tested by calculating percent similarity to all the models, and determining which model was the most similar to the test site. New models are developed when similar communities are recognized from several streams.

Use of ISD methods: Impact Source Determination is based on similarity to existing models of community types. The model that exhibits the highest similarity to the test data denotes the likely impact source type, or may indicate “natural”, lacking an impact. In the graphic representation of ISD, only the highest similarity of each source type is identified, and similarities that are within 5% of the highest. Similarities less that 50% are considered less conclusive. The determination of impact source type is used in conjunction with assessment of severity of water quality impact to provide an overall assessment of water quality.

Limitations: These methods were developed for data derived from 100-organism subsamples of traveling kick samples from riffles of New York State streams. Application of the methods for data derived from other sampling methods, habitats, or geographical areas would likely require modification of the models.