STREAM IDENTIFICATION AND MAPPING FOR WATER-SUPPLY WATERSHED PROTECTION

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ABSTRACT

The City of Greensboro conducted an inventory of streams within the jurisdiction of the City that occur within water supply watersheds. A GIS-based map was produced that shows the origins of intermittent and perennial streams, the locations of streams, and the connections of the stream network to the stormwater system. This project was precipitated by: (1) the need for identification of perennial streams for riparian buffer protection in accordance with the North Carolina Water Supply Watershed protection regulations; (2) the requirements for identification of both intermittent and perennial streams for riparian buffer protection in the Randleman Lake Watershed; and (3) anticipation of riparian buffer rules being required on all intermittent and perennial streams in the Cape Fear Basin in the future. Because of the limitations in topographic maps and the uncertainties in regulatory implementation that result, the City elected to conduct a field study to determine and map the intermittent and perennial streams.

The North Carolina Division of Water Quality protocol for identification of intermittent stream origins was tested and approved for use in mapping intermittent streams. However, there was no standard procedure for the determination of perennial stream origins for regulatory purposes. A protocol was developed and applied in the course of this project. The concept of a perennial stream utilized in the stream origin protocol is one with more fully developed geomorphologic and hydrologic features than in an intermittent stream coupled with the presence of

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macroinvertebrates that commonly require perennial flow. Also documented in this study were: (1) the impacts of urban and suburban stormflow on the characteristics of the stream network in the City of Greensboro, (2) lessons learned on the conduct of an intensive stream inventory, and (3) recommendations on scientific and regulatory applications of stream inventory and mapping.

KEYWORDS

North Carolina, Greensboro, stream, ephemeral, intermittent, perennial, geomorphology, hydrology, biology, macrobenthos.

INTRODUCTION

The City of Greensboro (City) is located in Guilford County near the headwaters of the Cape Fear River Basin in North Carolina (Figure 1). Law Engineering and Environmental Services, Inc. (LAW) was contracted by the City to develop comprehensive maps and Geographic Information System (GIS) data layers to identify and locate intermittent and perennial streams within the City's designated water-supply watershed areas. Approximately 40 square miles of the City's 110+ square mile jurisdictional area is currently located within a State of North Carolina designated water-supply watershed.

Figure 1 - Project Location Map

The stream centerline, attribute, and mapping information developed from this project will serve as the basis for determination of stream buffer and related requirements for future site development to meet water-supply watershed protection regulations and local ordinances. The data layers will be incorporated into the City's GIS and will provide a comprehensive map designed to minimize the need for site specific determinations.

Project History and Purpose

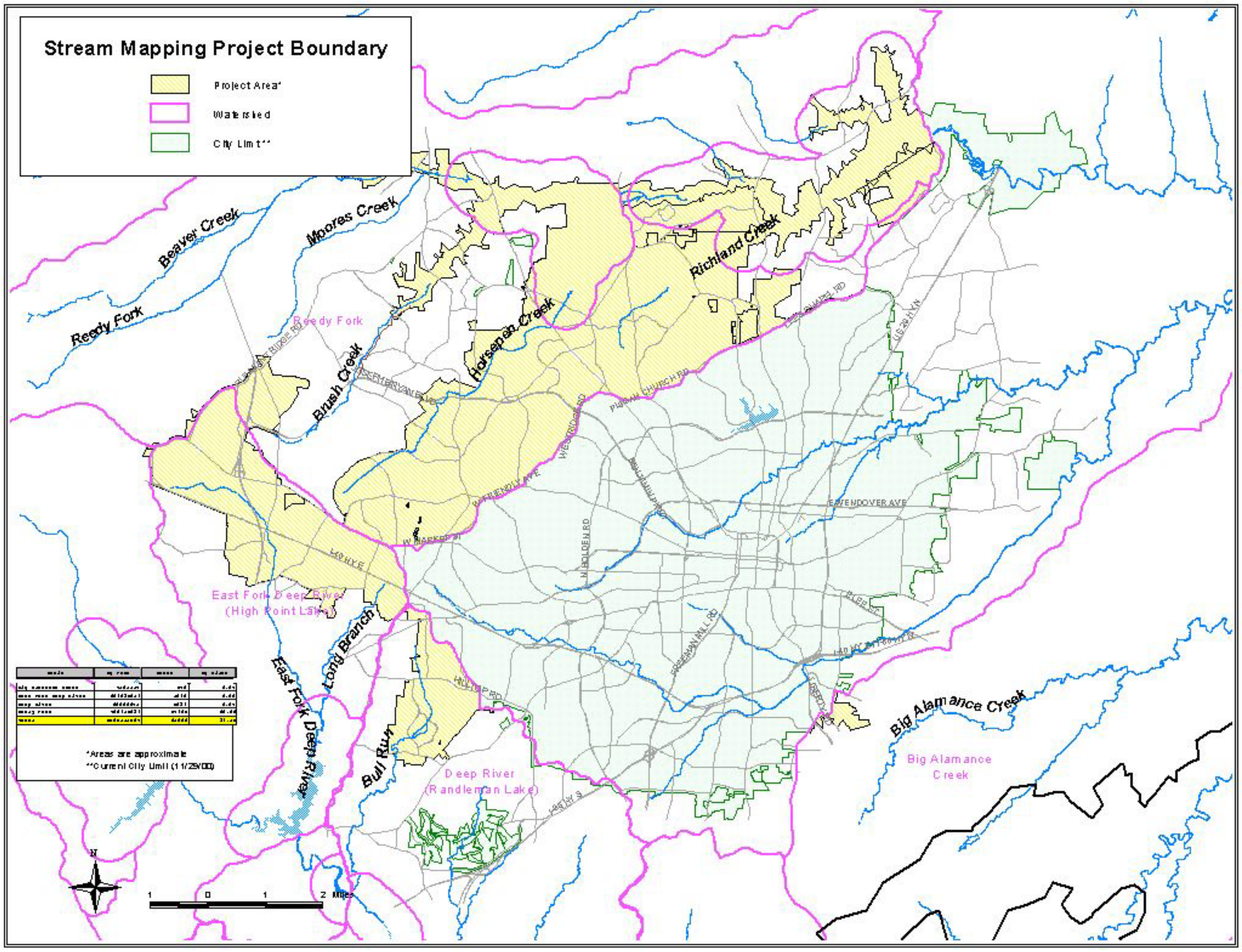
Historically, the City relied on available map sources, consisting of United States Geological Survey (USGS) 7.5-minute topographic quadrangle maps and National Resource Conservation Service (NRCS) county soil survey maps, to locate intermittent and perennial streams for planning and regulatory purposes. However, these maps are of limited utility in portraying field conditions and, as a result, frequently required field verification.

In the spring of 2000, the City committed to the development of a map to depict the location of intermittent and perennial streams within 40 square miles of the City's Water-Supply Watershed Protection Area. The primary purpose of the project was to accurately field identify and locate the beginning location of intermittent and perennial streams using a scientifically defensible methodology. The field data was incorporated into GIS layers to create a stream map.

Project Work Area

The project work area encompasses approximately 38.34 square miles within the existing city limits of Greensboro (Figure 2). It includes approximately 0.27 square mile of the Big Alamance Creek Watershed, 1.17 square miles of the Brush Creek Watershed, 8.36 square miles of the Upper Randleman Lake Watershed, 2.88 square miles of the Lower Randleman Lake Watershed, and 26.83 square miles of the Reedy Fork Watershed.

Figure 2 – Stream Mapping Project Boundary



Project Objectives and Benefits

Field identification and location of intermittent and perennial streams was essential to the production of an accurate, scientifically defensible stream map. This map will be used to implement regulatory buffer requirements including:

- Water-Supply Watershed Protection stream buffer requirements;
- Randleman Lake buffer requirements (intermittent and perennial streams);
- Anticipated Cape Fear River Basin Riparian Buffer rules.

A major benefit of the map is that it will reduce, if not completely eliminate, the need for costly, site-specific determinations regarding the status of streams. In addition to the benefits associated with the protection of the City's water supply, the City will also realize further benefits. For example, by using the City map to identify stream buffers, the City can identify and evaluate areas that may provide critical habitat for wildlife and sensitive aquatic habitat. Similarly, the City can identify areas appropriate for green space and recreational use by the public. The map will also prove a resource for educational purposes. The watershed protection afforded the city will enhance the water quality downstream throughout the Cape Fear River Basin.

The digital format of the mapping and data should prove to be a useful tool for the development community to facilitate efficient identification of sensitive areas and corresponding development restrictions. The City's commitment to place the map on its website will allow developers and other interested parties to quickly reference their site of interest. As a result, developers may streamline their internal site review processes and realize cost and time savings typically associated with site assessments.

Regulatory agencies will also benefit from the City's map. Regulators now have a systematic methodology for the identification of intermittent and perennial streams. This methodology could be applied to other Piedmont watersheds and may, eventually, be modified for use in other physiographic regions throughout North Carolina and surrounding states. The data gathered in the Project Area can provide the basis for regulatory decisions regarding water-supply watershed protection, future research needs and direction, and will also supply valuable baseline data for those engaged in stream and watershed investigations. Federal and State regulatory agencies such as the U.S. Army Corps of Engineers (USACE) and North Carolina Department of Environment and Natural Resources Division of Water Quality (DWQ) may use the map for local regulatory matters such as Section 404 and 401 (of the Clean Water Act) permitting. The USACE has not responded with it's position regarding intermittent and perennial determinations on the City map, but USACE personnel have been involved as stakeholders.

Project Coordination

LAW received preliminary approval from DWQ to begin field classification of intermittent streams in the pilot sub-basins (HP01 and HP02) prior to DWQ's formal approval of the methodology. In addition, LAW began field classification of perennial streams based on verbal approval from DWQ received on October 30, 2000. Coordination with DWQ continued pending formal approval of the acceptable methodology to complete the project. DWQ maintained oversight of the fieldwork and collection of data throughout the project through several field reviews and informal project status reporting. Dr. James Gregory (North Carolina State University), a Forest and Wetlands Hydrologist, also worked closely with LAW throughout the methodology development and testing phase as well as data collection and fieldwork.

The City developed a list of stakeholders potentially interested in the project and invited those parties to attend workshops designed to demonstrate the implementation of the methodology. Interested parties included members of the development community, academia, various regulatory personnel, consultants, environmental groups and local governments. Three stakeholder meetings were conducted during the course of the project. The first meeting provided an introduction to the project and its objectives and benefits. The second meeting was conducted in the field and included a detailed demonstration of the field techniques employed for the identification and classification of streams as well as a review of representative streams. The draft GIS, stream maps, and a summary of the project results were presented at the third meeting. In addition, the City conducted two public meetings to review the intent, status, and details of the project. Project information was also developed for inclusion in the City's Internet web site.

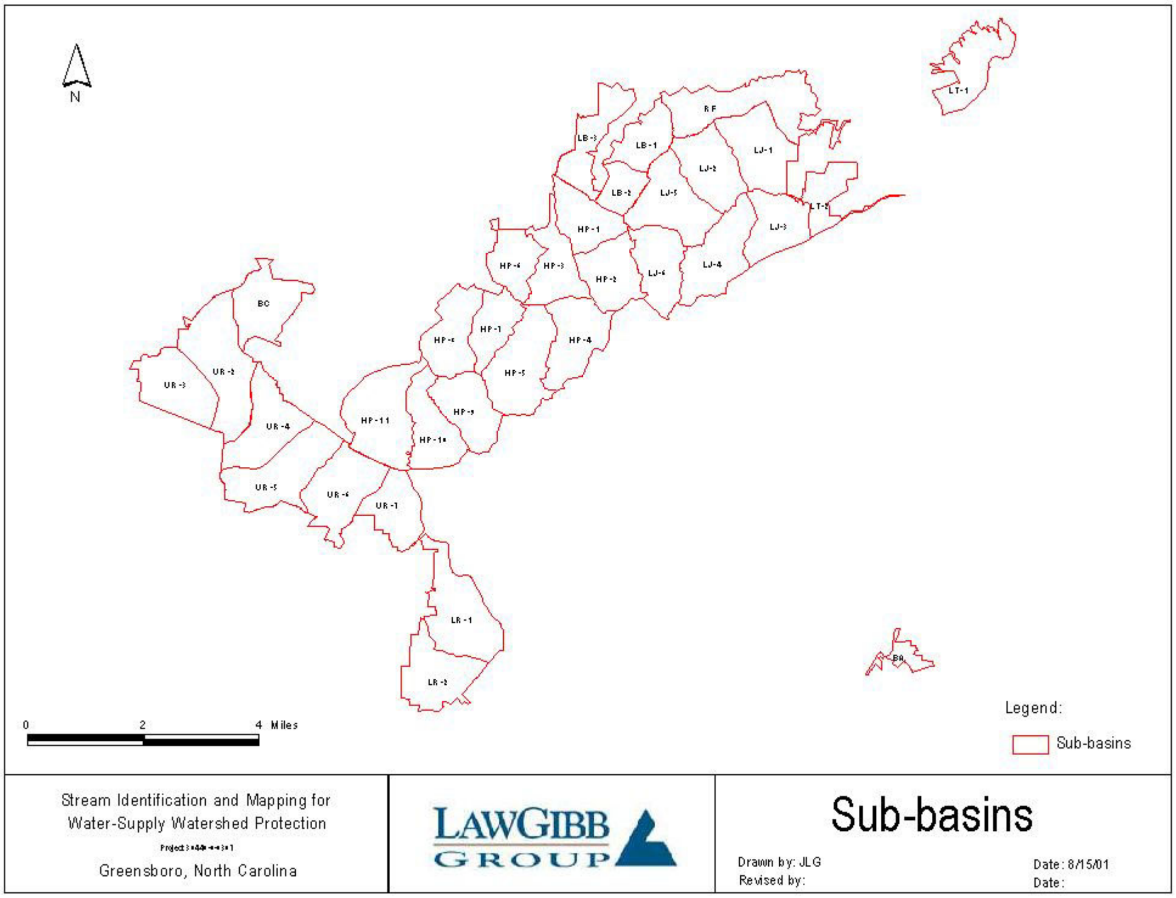
METHODOLOGY

Project fieldwork was preceded by intense study and methodology development within the project area. LAW and the City coordinated several workshops with DWQ. The workshops were designed to ensure the appropriate implementation of existing methods and to facilitate the development of modified protocols to identify intermittent and perennial streams in the City's Water-Supply Watershed Protection area. Workshops and training were conducted at numerous locations representative of the study area. Preliminary field evaluations included the participation of DWQ and Dr. James Gregory. DWQ and Dr. Gregory conducted subsequent field evaluations and reviews throughout the project.

LAW, DWQ personnel, and Dr. Gregory developed a methodology appropriate for the determination of perennial breakpoints for the project area. Methodology development included evaluation of the geomorphology, hydrology, and biology indicative of perennial streams in representative habitats throughout the project area.

The project area was divided into hydrologic sub-basins for logistical purposes (Figure 3). However, the creation of distinct hydrologic sub-basins was at times precluded by the presence of political boundaries. The City's stormwater inventory consultant (Dewberry & Davis) delineated the majority of the sub-basins for the City stormwater inventory process. LAW tracked and followed Dewberry & Davis' inventory field effort through the project area sub-basins. Areas located outside of the Dewberry & Davis inventory area or those unavailable at the time of stream survey were subdivided by LAW into appropriate sub-basins for project management purposes based loosely on approximate hydrologic subdivisions.

Figure 3 - Project Sub-basins



Stream Identification

Two-person field teams were used for the stream identification fieldwork. Each field team included an environmental scientist with appropriate training (participated in two-day DWQ project-specific training sessions) and experience in identification of Ephemeral (E0), Ephemeral/Intermittent (EI), Intermittent/Perennial (IP), and Ephemeral/Perennial (EP) breakpoints. All team members had at least a basic understanding of the protocol required for the fieldwork. Each team was provided with a Global Positioning System (GPS) unit, pin flags, a digital camera, a soil auger or probe, and an aquatic dip net, forceps, and picking tray for the identification of benthic macroinvertebrates and other aquatic species. The field team typically worked from the upper reach of the identified potential stream channel down to the EI point and then downstream toward the IP point. Stream channels that lacked an intermittent or perennial reach were documented with Version 2.0 of the DWQ Stream Classification Method (DWQ, 2000[1]) and classified as ephemeral (E0). Field conditions occasionally supported the assignment of an ephemeral/perennial (EP) breakpoint. Once an EI, IP, or EP point was identified using the appropriate methodology, the field team identified the location using GPS. Each location was assigned a unique identifier by the field team. The three-part identifier included the sub-basin (e.g. HP01), followed by location text (e.g. nearest road name, neighborhood, landmark, etc.) and E0, EI, IP, or EP as appropriate. The team identified the point with pin flagging which included the breakpoint identifier, evaluator(s), and the date. At least two photographs (upstream and downstream with the breakpoint in view if possible) were taken using a digital camera. In addition, at least one photograph was taken of channels that warranted evaluation but were classified as ephemeral (E0) in the field.

Representative examples of the geomorphologic, hydrological, and biological indicators (e.g. sinuous channel, wrack lines, fibrous roots, etc.) described in the DWQ Stream Classification Method were also photographed and maintained in a photographic reference database. Although the field teams did not conduct exhaustive biological surveys, representative taxa observed in the field were collected, preserved, positively identified, and photographed.

Stream Channel Location

In order to maximize the efficient use of the time and resources available, stream channels were assessed if they were identified on one of the following existing data sources within the project boundaries:

1. NRCS County Soil Survey Maps
2. USGS 7.5-Minute Topographic Quadrangles
3. 1995 City Aerial Orthophotographic Maps

These sources were supplemented by the 2000 aerial photographs supplied by the City in November 2000. This approach facilitated the targeting of field efforts and helped streamline the survey process by setting limits within which breakpoints were field identified. Therefore, the project scope did not involve field investigation of the entire stream network within the project area. Field teams also investigated stream channels that were observed during normal field activities (i.e. travel to identified stream channels) but that were absent from source maps.

Field base maps by sub-basin were generated by digitally combining the corresponding USGS quadrangles and 1995 aerial orthophotographs. Hard copy NRCS maps were used in the field as an additional resource. Streams not appearing on any of the existing data sources were assumed to be ephemeral, in accordance with DWQ procedures for applying Neuse and Tar-Pamlico riparian buffer rules. Based on reliance by the State of North Carolina on these map sources (USGS, NRCS) for regulatory purposes, and LAW's field experience in the project area, LAW concurred that this approach would identify perennial and intermittent streams. However, LAW identified additional streams not shown on USGS or NRCS map sources by traversing topographically suspect areas while en route to nearby identified streams, by referencing additional maps and reports, and by using our local project experience and judgement.

Rainfall

The rate and duration of flows within stream channels is strongly influenced by weather. Significant rain events (i.e. 1 inch or more per day for 3 consecutive days) in particular may affect the consistency and accuracy of stream field classifications. However, according to the

DWQ Stream Classification Method, "The classification method has been designed with enough built in redundancy to allow for reasonably accurate ratings even after a recent rainfall." Rainfall was monitored throughout the course of the project. Monitoring efforts included the placement of portable sub-basin rain gauges for the specific time periods of the field evaluations as well as rainfall at Piedmont Triad International Airport (on the western edge of the project area). LAW used reasonable scientific discretion to assess the effects of rainfall on the subject intermittent and perennial streams. Relatively dry conditions during the project fieldwork period resulted in few weather induced delays. LAW delayed fieldwork after significant rain events for at least 48 hours before the evaluation of EI breakpoints and 72 hours before the evaluation of IP breakpoints. Minor rain events were evaluated on a case-by-case basis. In instances of minor rain events, LAW personnel exercised best professional judgement before proceeding with scheduled fieldwork.

Intermittent Stream Identification

Intermittent streams are defined as flowing only at certain times of the year, as when they receive water from surface sources or springs (USGS, 2000). Intermittent streams do not flow continuously, as a result of water losses from evaporation or seepage exceeding the available stream flow. Intermittent streams typically lack flow during dry periods and are often reduced to a series of separate pools. Consequently, they alternate throughout the year from "influent" systems, which contribute to groundwater to "effluent" systems, which receive flow from groundwater (Gordon, *et al*., 1992).

The field teams used the DWQ Stream Classification Method to identify intermittent streams. Although this was the first use of the method in the Cape Fear River basin, it has been successfully applied in the Neuse and Tar-Pamlico basins in North Carolina. The method requires the evaluation of channel geomorphology, hydrology, and biology and employs a four tiered weighted scale. The evaluator selects an appropriate rating for each field indicator and determines channel classification (i.e. ephemeral or intermittent) based on a final score.

The methodology was specifically approved for application within the Greensboro Water-Supply Watershed. The DWQ Stream Classification Form requires a rating of 19 or more points for an EI breakpoint to be established in the field (Figure 4).

Figure 4 - DWQ Stream Classification Form

NCDWQ Stream Classification Form

Project Name:	Stream Identification and Mapping for Water Supply Watershed Protection	River Basin:	Cape Fear	County:	Guilford	Evaluator:
DWQ Project Number:		Nearest Named Stream:		Latitude:		Signature:
Date:		USGS QUAD:		Longitude:		Location/Directions:

***PLEASE NOTE:** *If evaluator and landowner agree that the feature is a man-made ditch, then use of this form is not necessary. Also, if in the best professional judgement of the evaluator, the feature is a man-made ditch and not a modified natural stream—this rating system should not be used**

Primary Field Indicators: *(Circle One Number Per Line)*

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Riffle-Pool Sequence?	○ 0	○ 1	○ 2	○ 3
2) Is The USDA Texture In Streambed Different From Surrounding Terrain?	○ 0	○ 1	○ 2	○ 3
3) Are Natural Levees Present?	○ 0	○ 1	○ 2	○ 3
4) Is The Channel Sinuous?	○ 0	○ 1	○ 2	○ 3
5) Is There An Active (Or Relic) Floodplain Present?	○ 0	○ 1	○ 2	○ 3
6) Is The Channel Braided?	○ 0	○ 1	○ 2	○ 3
7) Are Recent Alluvial Deposits Present?	○ 0	○ 1	○ 2	○ 3
8) Is There A Bankfull Bench Present?	○ 0	○ 1	○ 2	○ 3
9) Is A Continuous Bed & Bank Present? *(*NOTE : If Bed & Bank Caused By Ditching And **WITHOUT** Sinuosity Then Score=0*)*	○ 0	○ 1	○ 2	○ 3
10) Is A 2nd Order Or Greater Channel (As Indicated On Topo Map And/Or In Field) Present?	○ Yes=3	○ No=0		
PRIMARY GEOMORPHOLOGY INDICATOR POINTS:		**#VALUE!**		

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is There A Groundwater Flow/Discharge Present?	○ 0	○ 1	○ 2	○ 3
PRIMARY HYDROLOGY INDICATOR POINTS:		**#VALUE!**		

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fibrous Roots Present In Streambed?	○ 3	○ 2	○ 1	○ 0
2) Are Rooted Plants Present In Streambed?	○ 3	○ 2	○ 1	○ 0
3) Is Periphyton Present?	○ 0	○ 1	○ 2	○ 3
4) Are Bivalves Present?	○ 0	○ 1	○ 2	○ 3
PRIMARY BIOLOGY INDICATOR POINTS:		**#VALUE!**		

Secondary Field Indicators: *(Circle One Number Per Line)*

I. Geomorphology	Absent	Weak	Moderate	Strong
1) Is There A Head Cut Present In Channel?	○ 0	○ 0.5	○ 1	○ 1.5
2) Is There A Grade Control Point In Channel?	○ 0	○ 0.5	○ 1	○ 1.5
3) Does Topography Indicate A Natural Drainage Way?	○ 0	○ 0.5	○ 1	○ 1.5
SECONDARY GEOMORPHOLOGY INDICATOR POINTS:		**#VALUE!**		

II. Hydrology	Absent	Weak	Moderate	Strong
1) Is This Year's (Or Last's) Leaflitter Present In Streambed?	○ 1.5	○ 1	○ 0.5	○ 0
2) Is Sediment On Plants (Or Debris) Present?	○ 0	○ 0.5	○ 1	○ 1.5
3) Are Wrack Lines Present?	○ 0	○ 0.5	○ 1	○ 1.5
4) Is Water In Channel ***And*** >48 Hrs. Since Last ***Known*** Rain? *(*NOTE: If Ditch Indicated In #9 Above Skip This Step And #5 Below*)*	○ 0	○ 0.5	○ 1	○ 1.5
5) Is There Water In Channel During Dry Conditions Or In Growing Season)?	○ 0	○ 0.5	○ 1	○ 1.5
6) Are Hydric Soils Present In Sides Of Channel (Or In Headcut)?	○ Yes=1.5	○ No=0		
SECONDARY HYDROLOGY INDICATOR POINTS:		**#VALUE!**		

III. Biology	Absent	Weak	Moderate	Strong
1) Are Fish Present?	○ 0	○ 0.5	○ 1	○ 1.5
2) Are Amphibians Present?	○ 0	○ 0.5	○ 1	○ 1.5
3) Are AquaticTurtles Present?	○ 0	○ 0.5	○ 1	○ 1.5
4) Are Crayfish Present?	○ 0	○ 0.5	○ 1	○ 1.5
5) Are Macrobenthos Present?	○ 0	○ 0.5	○ 1	○ 1.5
6) Are Iron Oxidizing Bacteria/Fungus Present?	○ 0	○ 0.5	○ 1	○ 1.5
7) Is Filamentous Algae Present?	○ 0	○ 0.5	○ 1	○ 1.5

8) Are Wetland Plants In Streambed? *(* NOTE : If Total Absence Of All Plants In Streambed As Noted Above Skip This Step UNLESS SAV Present*).*	SAV	Mostly OBL	Mostly FACW	Mostly FAC	Mostly FACU	Mostly UPL
	○ 2	○ 1	○ 0.75	○ 0.5	○ 0	○ 0
SECONDARY BIOLOGY INDICATOR POINTS:			**#VALUE!**			

TOTAL POINTS** (Primary + Secondary)=* **#VALUE!** ***(If Greater Than Or Equal To 19 Points The Stream Is At Least Intermittent)

In order to supplement field EI determinations for later evaluation and comparison, additional data was collected at each breakpoint including:

- degree of bedrock exposure;
- canopy coverage;
- apparent stormwater influence/channel modifications;
- water color and odor;
- conductivity;
- weather conditions;
- antecedent rainfall; and
- miscellaneous/anecdotal information.

Perennial Stream Identification

As stated in the Neuse River Basin Riparian Buffer Rules (15 NCAC 2B.0233), perennial refers to "A well-defined channel that contains water year round during a year of normal rainfall with the aquatic bed located below the water table for most of the year. Groundwater is the primary source of water for a perennial stream, but it also carries stormwater runoff. A perennial stream exhibits the typical biological, hydrological, and physical characteristics commonly associated with the continuous conveyance of water." Several regulatory definitions of perennial and intermittent streams have been summarized by the U.S. Environmental Protection Agency (EPA, 1999).

Although perennial streams are consistently defined as containing water throughout the year, except for infrequent periods of drought (USGS, 2000), no readily applicable methodology for determining the point where a stream changes from intermittent to perennial had been developed prior to this project. The field teams relied on the presence of key biological indicators to determine the perennial start point of stream channels. Biological survey methods were based on the Ephemeroptera, Plecoptera, and Trichoptera (EPT) Method (DWQ, 1997) and the DWQ Biological Reconnaissance Form (DWQ, 2000[2]). This method is designed as a rapid sampling technique and is not intended to be an exhaustive biological survey. The collection method focused on the identification of Primary and Secondary Perennial Indicators of the benthic community that typically require perennial conditions. Once indicator organisms were found, the field team supplemented the perennial determination with an evaluation of the channel using the DWQ Stream Classification Method along with additional data and field observations (). Since many of the biological indicators are intolerant of the environmental stresses typically encountered in urban conditions, highly modified and impacted urban streams necessitated less reliance upon biology for establishment of the perennial start point. In highly impacted systems where biology was correspondingly weak, geomorphologic and hydrological indicators gathered via the DWQ Stream Classification Method along with pertinent, documented field observations took precedence in the determination of IP or EP breakpoints.

Figure 5 - Supplemental Information for Perennial Determination

Greensboro Stream Identification and Mapping for Water-Supply Watershed Protection
Additional Information for Intermittent and Perennial Stream Location Determination

Time: ________ Subbasin: ________ Stream ID: ________ Photo #s: ________

Exposed Bedrock

	Distance from breakpoint (feet)	
○ absent		No exposed bedrock
○ weak	________	Exposed bedrock rare (e.g. one or two very small exposed areas.)
○ moderate	________	Several areas with exposed bedrock, one or two areas may be large.
○ strong	________	Exposed bedrock common.

Canopy Cover

○ absent	No shading
○ weak	Mostly full sun, few shaded areas
○ moderate	Good shading with some breaks for light penetration
○ strong	Canopy is full with very few breaks for light penetration

Channel Modification

○ absent	No stormwater outfalls or channel modifications
○ weak	One stormwater outfall or minor channel modification
○ moderate	From 2 to 5 stormwater outfalls or some channel modifications
○ strong	More than 5 stormwater outfalls or significant channel modifications

Water Color

○ clear
○ cloudy
○ other ________
○ N/A

Water Odor

○ Yes ________
○ No
○ N/A

Weather Conditions

____

Rainfall

____

Drainage Area Acreage

____

Subbasin Percent Urbanized

____

Conductivity (uS/cm)

____

Biological Information for Intermittent / Perennial Determination

________ Mayflies (Ephemeroptera)
________ Stoneflies (Plecoptera)
________ Caddisflies (Trichoptera)

Primary Perennial Indicators

Ephemeroptera	Plecoptera	Trichoptera
☐ Baetidae	☐ Eccoptura spp.	☐ Hydropsychidae
☐ Stenonema spp.		☐ Psilotreta spp.
		☐ Neophylax spp.
		☐ Diplectrona spp.
		☐ Chimarra spp.

Secondary Perennial Indicators

________ Hellgrammites (Corydalidae)
________ Snails (Gastropoda)
________ Crayfish (Decapoda)
________ Leeches (Hirudinea)
________ Clams (Bivalvia)
________ Beetles (Coleoptera)
________ Two-lined salamander (*Eurycea bilinea*

Biomass

Abundant	> 10
Common	3 – 9
Rare	1 – 2

________ Dragonflies (Anisoptera)
________ Craneflies (nematocera)
________ Segmented Worms (Oligochaeta)
________ Damselflies (Zygoptera)
________ Midgeflies (Chironomidae)
________ Amphipods (Amphipoda)

Miscellaneous / Anecdotal Information

____

The perennial breakpoint was established at the point where key biological indicators, if present, were located. The field team then evaluated the reach downstream using Version 2.0 of the DWQ Stream Classification Method along with additional information and field observations. The channel was evaluated for approximately 200 feet or until an obvious geomorphologic feature and/or change was encountered, whichever occurred first. A rating score was documented for each IP and EP. Once the point was established, it was marked and recorded using a hand-held GPS unit.

Modified Streams

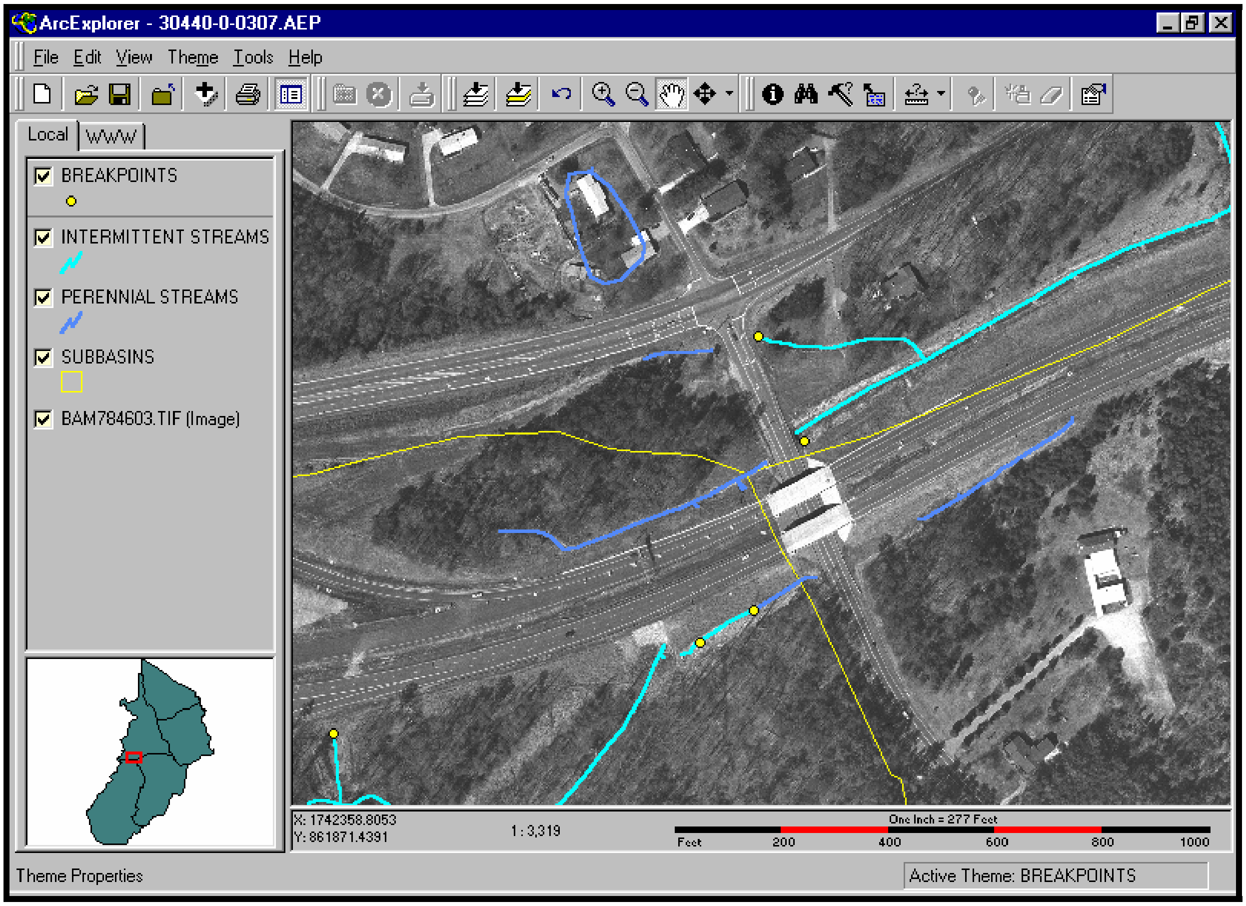
Development within watersheds typically results in the modification of streams. Given the level of development within the Project Area, modified stream channels are common. Stormwater conveyance systems, retention ponds, and similar structures directly alter the character and flow regime of streams. These modified systems often lack traditional EI and/or IP breakpoints. Certain urban stream channels change directly from an ephemeral to perennial channel without an identifiable intermittent phase. Perennial discharges are often present at stormwater management system outfalls. As a result, it is possible for a stream channel to have an EP breakpoint. The status of the stream channels observed in the field was documented and noted by the field team.

Reliance upon biological indicators was occasionally inappropriate in highly modified systems. Many of the organisms selected as perennial indicators are relatively intolerant of the environmental stresses encountered in urban conditions (e.g. poor water quality, channel scouring) and, therefore, were difficult to locate in relatively developed watersheds. Determinations in such areas required less reliance upon biological indicators for establishment of the IP or EP breakpoint and more dependence on geomorphologic and hydrologic factors. Therefore, in the absence of adequate biological indicators, the team used best professional judgement based upon the data gathered via the DWQ Stream Classification Method and pertinent, documented field observations to determine the IP or EP breakpoint. Observations included conductivity measurements as a general appraisal of water quality. Elevated conductivity values are generally indicative of high pollutant loads and impaired biological conditions.

Stream Mapping

The primary mapping tool utilized on the project was the Geographic Information System (GIS) (Figure 6). For the stream mapping process, TSC1 GPS units were used to obtain spatial location (X-Y coordinate) data. The TSC1 software included a data dictionary used in the field to record not only GPS positions but also GIS information. The GPS data logger's dictionary (custom-made database previously designed and transferred to the data logger) was used to input attribute data. After each feature was located, attribute data was entered into the Asset Surveyor data logger to provide descriptive information about the point attributes. This attribute data became the database for the points collected and this information was incorporated into the stream coverage. In addition, the manually completed DWQ Stream Classification Forms including original signatures, additional information, and site-specific comments as well as upstream and downstream digital images were scanned into the GIS as hotlinks.

Figure 6 - Geographic Information System



Global Positioning System

GPS data collection was divided into three phases: mission planning, fieldwork, and office processing. The objective of the mission planning phase was to define significant aspects of the project so that performance could be effective and efficient under reasonably foreseeable conditions. Heavy canopy coverage and potentially obscured areas were frequently encountered. Therefore, planning efforts were directed at determining satellite availability at various locations, Position Dilution of Precision (PDOP) constraints, and optimal hours for favorable satellite configuration.

Field teams began the data collection process following the optimum observation periods determined in mission planning. The data dictionary was designed to reflect the format of the DWQ Stream Classification Form. The field team collected data using both the data logger data dictionary and DWQ Stream Classification Forms. After the necessary features were collected, the file was reviewed, saved, and closed. Paper data forms were signed, dated and scanned using “Tagged Image File Format” (*.tif). A trained team member transferred the data from the TSC1 Asset Surveyor data logger to a Personal Computer using Pathfinder Office software.

Stream Breakpoint Field Locations

Once suspect intermittent channels were located, the field team evaluated approximately 200 feet of the channel using the DWQ Stream Classification Form. The field team continued to rate the channel until a score of at least 19 was attained. The EI was located within the rated section. If an obvious breakpoint feature was present (e.g. headcut, stormwater outfall, confluence of channels, etc.), the breakpoint was established at the feature as appropriate. In the absence of obvious features the field team exercised best professional judgement and/or located the point at the approximate mid-point of the evaluated reach. Once the EI was established the DWQ Stream Classification Form data was entered into the data logger and it was marked and recorded using a hand-held GPS unit.

Following EI determination the field team progressed downstream conducting biological surveys for key indicators in order to establish the IP. The IP was established at the location supportive of the upstream-most key biological indicators. The field team also completed the DWQ Stream Classification Form and collected additional information to document the IP. Once the IP was established, the DWQ Stream Classification Form data was entered into the data logger and it was marked and recorded using a hand-held GPS unit. If key biological indicators were absent, yet perennial conditions appeared to exist, the field team relied upon ratings using Version 2.0 of the DWQ Stream Classification Method, additional information and observations, and best professional judgement to locate the IP or EP.

RESULTS

A total of 463 breakpoints (237 EI, 127 IP, and 99 EP) were identified in the project area. The average score for the EI breakpoints was 22.5, with a standard deviation of 3.0 (Table 1) The maximum score was 32.5 and the minimum score was 19.0 (which is considered the lowest possible score by DWQ convention for a point to qualify as an EI breakpoint). The average IP breakpoint score was 30.9, with a standard deviation of 3.5. The maximum score was 41.0 and the minimum score was 23.0. The average EP breakpoint score was 29.5, with a standard deviation of 4.3. The maximum score was 38.5 and the minimum score was 18.25.

Table 1 Summary of Scores by Breakpoint Type

		EPHEMERAL / INTERMITTENT (EI)				EPHEMERAL / PERENNIAL (EP)				INTERMITTENT / PERENNIAL (IP)			
		AVG.	S.D.	MAX.	MIN.	AVG.	S.D.	MAX.	MIN.	AVG.	S.D.	MAX.	MIN.
PRIMARY	GEOMORPHOLOGY	8.65	2.14	16.00	4.00	11.27	2.93	18.00	4.00	12.23	2.51	18.00	6.00
PRIMARY	HYDROLOGY	1.16	0.49	3.00	0.00	1.92	0.83	3.00	0.00	2.05	0.52	3.00	0.00
PRIMARY	BIOLOGY	5.18	1.46	11.00	1.00	6.61	1.66	11.00	2.00	6.58	1.52	10.00	3.00
PRIMARY	PRIMARY	14.99	2.49	22.00	10.00	19.80	3.66	27.00	12.00	20.86	2.93	29.00	12.00
SECONDARY	GEOMORPHOLOGY	1.67	0.86	4.50	0.00	1.27	0.73	3.00	0.00	1.48	0.75	3.50	0.50
SECONDARY	HYDROLOGY	4.12	0.95	7.00	1.00	5.46	1.04	8.00	2.50	5.56	0.86	8.00	3.50
SECONDARY	BIOLOGY	1.69	0.97	4.50	0.00	3.00	1.34	6.25	0.50	2.98	1.02	6.25	0.50
SECONDARY	SECONDARY	7.49	1.46	12.00	4.25	9.73	1.94	14.25	5.50	10.01	1.51	14.50	6.75
	SCORE	22.48	3.00	32.50	19.00	29.53	4.28	38.50	18.25	30.87	3.47	41.00	23.00

Note that the minimum EP score was below the DWQ minimum score for EI breakpoints. This low score represents the only instance of a less than intermittent score (18.25) for a perennial stream. Despite its weakly developed channel and correspondingly low score, this small stream supports a strong biological community fed by weak, yet perennial groundwater flow along with favorable water-quality and habitat conditions.

Primary geomorphology scores for the EI, IP, and EP breakpoints averaged 8.7, 12.2, and 11.3 respectively. Primary hydrology scores for the EI, IP, and EP breakpoints averaged 1.2, 2.1, and 1.9. Primary biology scores for the EI breakpoints averaged 5.2 while both IP and EP breakpoints averaged 6.6. The total primary indicator scores for the EI points were lower than the scores noted for the EP and IP points. 95% of the EI scores were between 12.5 and 17.4. In contrast, the EP and IP scores were between 16.1 and 23.5, and 17.9 and 23.8, respectively.

EI breakpoints and their corresponding IP breakpoints were often relatively close such that the distances between intermittent and perennial stream reaches in the Project Area were generally relatively short. A direct correlation of this phenomenon to the results of the field evaluations was not determined.

Field Data Review

The field data collection included evaluations of geomorphology, hydrology, biology, and site-specific conditions observed by the field team. Quality control procedures included review of at least ten percent of each of the breakpoint type determinations (EI, IP, and EP) as well as the ephemeral channel determinations (E0) by the LAW Principal Scientist. A licensed surveyor checked fourteen percent of the location information with an independent mapping grade GPS receiver. Ninety-one percent of the points were found to be within acceptable limits. A 0-2 meter (m) variance was considered acceptable given the limits of accuracy (approximately 1m) for each individual unit. As a result, the maximum location discrepancies between the two units should not exceed 2m. Location discrepancies greater than 2m were likely the result of uncertainties in the relocation of specific breakpoints due to the loss of markers in the field.

Breakpoint Field Review

At least ten percent of each of the three (EI, IP, EP) breakpoint determination types in each completed group of sub-basins were reviewed in the field. In addition, at least ten percent of the ephemeral (E0) only channel determinations were field reviewed. Breakpoints were randomly selected by the Principal using random selection computer software. The Principal reevaluated all field parameters at the selected field locations to confirm the previous result, provide additional notes, and document observed conditions. Only those breakpoint reviews that resulted in stream reclassifications, rating differences of more than 10 points, or that generated location differences of more than 100 feet warranted corrective action. Corrective action included consultation between the original evaluator and the Principal to resolve discrepancies.

A total of 97 breakpoint determinations, equating to 21% of the total 463, and 14% (36 of 256) of the ephemeral channel determinations were reevaluated in the field. Non-significant scoring differences ranging from 0 to 7.5 points were noted for the field determinations with no net effect on either the channel classification or the breakpoint location. Possible reasons for the observed rating differences include normal variability between different evaluators, different antecedent weather conditions (including significant rainfall events), changed field conditions (new land development projects), and fluctuations in water quality. No corrective action was effected in these cases.

Corrective actions were applied to 24 (18%) of the total 132 locations reviewed in the field. Nineteen of these resulted in reclassifications or modifications to the mapping effort. These changes to about 3% of the total determinations were consistent with the limitations of the methodology which contemplates variability between reviewers and significant annotation on the field forms.

DISCUSSION

Streams are characterized by progressive changes in geomorphology, hydrology, and biology as one travels downstream (Gordon *et al*., 1992). Vannote *et al*., (1980) suggest that this gradient creates physical conditions that result in predictable biological communities. Thirty-two field indicators of stream (fifteen primary, seventeen secondary) geomorphology, hydrology, and biology are listed in Version 2.0 of the DWQ Stream Classification Method. There are ten primary geomorphology indicators, one primary hydrology indicator, and four primary biology indicators. The secondary indicators include three geomorphology, six hydrology, and eight biology indicators. The four-tiered weighted scale is designed to address the variability associated with diverse stream channels and provides the evaluator with a flexible methodology for the assessment of varied stream habitats.

Key Field Indicators

Although it is necessary to evaluate numerous indicators to accurately classify EI, IP, and EP breakpoints, a number of specific, key field indicators were identified that consistently corresponded with intermittent and/or perennial conditions.

Geomorphologic indicators reveal the response of the channel to the transfer of water and sediment downstream. Although no single indicator seemed to correspond to the EI breakpoint, the average Primary Geomorphology scores for EI breakpoints were between 6.5 and 10.8. In comparison, the Primary Geomorphology scores for the EP and IP breakpoints were higher with 95% of the EP points scoring between 8.3 and 11.1, and 95% of the IP points scoring between 9.7 and 14.7.

Hydrological indicators reflect the channel's interaction with surface and subsurface flow. Hydric soils in the sides (or headcut) of a channel appeared particularly useful as indicators of intermittent or perennial conditions. 83.3% of the EI breakpoints had hydric soils. Further, many of the channels that lacked hydric soils were difficult to sample due to channel modifications (e.g. armoring) or had undergone recent disturbances. Recently disturbed channels were especially difficult to assess. Stormwater flows and associated rapid erosion and downcutting of the channel complicated the evaluation of soils. In some cases stormwater flows resulted in severe downcutting that appeared to reach the water table. As a result, the perennial breakpoint in some urban streams may be moving upstream.

Biological indicators appeared to best indicate flow conditions in streams. Benthic macroinvertebrates proved to be a good indicator of the EI breakpoint, with approximately 83.7% of the EI points exhibiting at least a "weak" score on the macrobenthos indicator. Amphipods were ubiquitous throughout the project area in various habitats and were especially common at EI breakpoints. Fewer amphipods were observed at perennial breakpoints.

The primary perennial biological indicators (EPT) were especially useful in the establishment of perennial breakpoints in relatively undisturbed streams. Members of the Trichoptera family Hydropsychidae were found in both undisturbed streams and highly modified urban streams. As a result, they were useful indicators throughout the project area. Stoneflies (Plecoptera), generally considered exceptional indicators of superior water quality, were rarely observed.

Although the field teams did not conduct extensive water quality examinations, conductivity measurements were made and general descriptions of water quality conditions (i.e., channel modifications, water color and odor) were noted. Suspect water quality conditions were observed throughout the Project Area, particularly in urban settings. These streams typically exhibited elevated conductivity values (i.e. >300µmhos), relatively weak macrobenthic populations, and often exhibited increased turbidity and odor.

The secondary perennial indicators were much more common in the study area and often contributed to the determination of the perennial breakpoint. Several organisms or groups of organisms were typically observed before the establishment of the IP or EP. Although considered a secondary perennial indicator, bivalves were occasionally found in small numbers in streams that were classified as intermittent. Crayfish were commonly observed in intermittent and perennial streams. In intermittent systems they were often observed in isolated pools located far from flowing water. Due to their widespread distribution throughout intermittent and perennial habitats, crayfish may be less reliable indicators of perennial conditions. Conversely, the two-lined salamander (*Eurycea bislineata*) was rarely encountered during the study. Most individuals were detected during supplementary biological investigations conducted downstream of the established perennial breakpoint.

Map Comparisons

Stream channels were included in the project if they were identified on NRCS Soils Maps, USGS 7.5-Minute Topographic Quadrangles, or 1995 City Aerial Orthophotographic Maps. These sources were later supplemented with 2000 City Aerial Orthophotographic Maps as necessary. It should be noted that these maps were not designed to accurately classify streams according to detailed, scientific methodology. Moreover, it is very difficult to maintain up to date maps in areas undergoing rapid development and urbanization. Discrepancies between mapped streams and field determinations were common. Each map had individual limitations regarding stream coverage.

For example, the majority of fieldwork for the development of the NRCS Soils Maps was completed in the period from 1969 to 1975. The map was issued in December 1977. As a result, the NRCS Maps, though relatively accurate in the depiction and location of channels, are outdated. Further, the NRCS maps do not accurately depict intermittent and perennial channels, with perennial channels typically located further downstream than field conditions indicated. The USGS 7.5 Minute Topographic Quadrangle coverage of the project area is also outdated. Most of the USGS Quadrangles were revised in 1994 with original planimetry and topography dating back to 1948 and 1951 respectively. Furthermore, many show perennial streams only and do not depict intermittent streams. Although more up to date, the 1995 and 2000 City Aerial Orthophotographic Maps are difficult to interpret because stream channels and extraneous topographic relief features are often impossible to differentiate.

A cursory comparison between USGS 7.5-minute Quadrangle stream (blueline) coverage and field-verified City of Greensboro stream coverage is summarized in Table 2. The table displays the total stream length (intermittent and perennial) for each sub-basin. Note that comparison between USGS coverage and City coverage is somewhat difficult because the USGS coverage does not classify or distinguish water bodies, therefore, they are included in the overall stream length calculations for USGS Quadrangles. Water bodies are not included in the City stream length calculations. In addition, the USGS coverage does not reflect recent changes (e.g., piping of streams, creation of ponds) that have occurred in the sub-basins. The GIS-based map accurately displays the origins of intermittent and perennial streams based upon scientifically based field investigations and accurate mapping equipment with the most recent version of the stream network available.

Table 2 - Stream Length Comparison

SUB-BASIN	USGS 7.5’ QUAD (linear feet)	PROJECT (linear feet)

SUB-BASIN	USGS 7.5' QUAD (linear feet)	PROJECT (linear feet)
BA	9,257	8,885
BC	19,034	25,810
HP01	19,325	21,452
HP02	16,648	14,261
HP03	15,297	21,077
HP04	21,796	15,312
HP05	25,101	31,582
HP06	21,885	15,525
HP07	21,551	19,077
HP08	15,881	20,745
HP09	10,028	14,962
HP10	16,369	18,799
HP11	45,272	26,486
LB01	43,361	11,989
LB02	8,982	9,024
LB03	70,597	2,174
LJ01	47,493	42,511
LJ02	22,455	27,498
LJ03	31,776	29,033
LJ04	17,081	24,356
LJ05	22,229	26,868
LJ06	13,560	31,440
LR01	42,182	33,431
LR02	41,553	34,828
LT01	17,126	9,467
LT02	17,150	11,022
RF	79,535	37,375
UR02	25,942	29,904
UR03	17,628	16,483
UR04	18,116	23,995
UR05	22,506	26,430
UR06	21,447	20,140
UR07	9,280	10,899

Applicability of the Stream Classification Methodology

The DWQ Stream Classification Method for determination of the EI breakpoint may be successfully applied in a variety of habitats. The methodology proved effective in the evaluation of both natural and modified streams. However, modified streams in urban areas should be evaluated with care. Streams subject to significant storm flows and degraded water quality often exhibit a host of conflicting indicators. For example, accelerated channel erosion may result in inflated scores for certain indicators (e.g., continuous bed and bank, recent alluvial deposits, rooted plants in streambed) and understated scores for other indicators (e.g., riffle-pool sequence, channel sinuosity, biological indicators). In highly degraded streams the biota was often depleted or absent and, therefore, did not contribute significantly to intermittent stream origin determination.

Similarly, the perennial stream determination methodology (IP, EP) can be effectively employed in numerous environments. In highly degraded streams with correspondingly weak benthic macroinvertebrate populations, evaluators relied on geomorphology and hydrology data gathered via the DWQ Stream Classification Form to supplement perennial determinations. This approach was necessary to allow for flexibility in the IP or EP determination in highly modified or degraded streams and enabled the field team to evaluate site-specific variables and conditions that may have affected the location of the perennial breakpoint. The average IP breakpoint score for the project area is 30.8 with a standard deviation of 3.5. The average EP breakpoint score is 29.4 with a standard deviation of 4.2. Therefore, in urbanized streams with degraded biological conditions a score of 27 or greater on the DWQ Stream Classification Form may be indicative of initial perennial conditions. However, this score should not be considered a reliable benchmark. Interestingly, several perennial channels exhibited relatively low scores (i.e. <27) but supported healthy benthic macroinvertebrate populations indicative of perennial conditions. Small springs with weak channel characteristics, but positive groundwater flow and favorable habitat conditions regularly supported diverse biological communities.

The reevaluation of selected streams typically resulted in minor rating differences. These differences were often attributed to normal variability between evaluators, different antecedent weather conditions, altered field conditions (i.e. construction), and fluctuations in water quality. However, a number of differences were likely the result of natural, seasonal variability.

Populations of biological indicators, in particular, seem to vary with seasonal conditions. Observations of benthic macroinvertebrates, plants, algae, bacteria, and fungi suggest that these organisms experience spatial and temporal variations throughout the year. Certain species of benthic macroinvertebrates commonly undergo stages of alternating dormancy and activity in response to environmental conditions. In addition, the presence of a strong hyporheic zone can affect the distribution of specific hyporheic organisms and aquatic plants. It has been suggested that the ecological boundary of streams may lie well within the streambed (Gordon *et al*., 1992). The HP05_Elderwood channel exemplifies these characteristics. A significant area of exposed bedrock near its headwaters characterizes the channel. The bedrock exposure is apparently acting as a dam and contributing to the presence of a substantial hyporheic zone upstream that supports a number of taxa associated with perennial conditions (i.e. caddisflies). These perennial indicator organisms can be found in habitats that, initially, appear intermittent. Nevertheless, careful analysis of the geomorphology, hydrology, and biology of streams throughout the project area by multiple, properly trained evaluators resulted in consistent identification of perennial breakpoints in a variety of habitats and conditions.

Recommendations

A comprehensive analysis of the data collected during the project is necessary for the evaluation of the stream identification procedures and mapping methodology. This data will prove invaluable for the continued application of the methodology to similar watersheds in the Piedmont region. The methodology could eventually provide the basis for similar projects throughout North Carolina and the Southeast. Specifically, detailed analysis of the data may provide additional information regarding the relative importance of individual indicators and the establishment of a minimum score for the identification of perennial breakpoints lacking biology. In addition, new procedures may be developed to address unusual circumstances often encountered in the field (e.g. modified channels). Local weather conditions (especially rainfall and temperature), hydrologic basin size and condition (especially percent impervious surface area), and local stormwater management features may also provide indicators of ephemeral, intermittent, or perennial flow as well as potential relative lengths of these channel segments.

It may be helpful for similar projects in the future to establish a standard procedure for the reevaluation of selected breakpoints that are difficult to evaluate due to highly modified conditions, recent disturbances in the drainage area, or similar unusual conditions. Evaluations in different seasonal conditions, if possible, are particularly useful.

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REFERENCES

Gordon, N.D., McMahon, T.A., and Finlayson, B.L. (1992). Stream Hydrology: An Introduction for Ecologists. John Wiley, New York.

North Carolina Department of Environment and Natural Resources, Division of Water Quality (1997). Standard Operating Procedures, Biological Monitoring.

North Carolina Department of Environment and Natural Resources, Division of Water Quality (2000 [1]). Interim, Internal DWQ Policies on Stream Mitigation Options and Associated Macrobenthos Monitoring.

North Carolina Department of Environment and Natural Resources, Division of Water Quality (2000 [2]). Biological Reconnaissance Form.

United States Environmental Protection Agency (1999). Background Information for Mountaintop Mining / Valley Fill Environmental Impact Statement. S. Shamel, EPA Region III.

United States Geological Survey (2000). Standards for National Hydrography Dataset at http\\www.usgs.gov\

Vannote, R.L., Minshall, G.W., Cummins, K.W., Sedell, J.R., and Cushing, C.E. (1980). The River Continuum Concept. *Can. J. Fish. Aquat. Sci.* 37: pp.130-137.

Water Resources Research Institute of UNC (2000). *WRRI News* No. 325. ISSN 0549-799X. James Gregory, North Carolina State University.