Indicators of Hydrologic Permanence in Headwater Streams of South Carolina

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ABSTRACT. Headwater streams represent the majority of channel length in most river networks (Nadeau and Rains, 2007). Because of their small size and position in the landscape headwater streams are prone to natural drying and are often not well characterized on maps or in hydrographic databases (Hansen, 2001; Colson et al., 2008). Aspects of drying or flow permanence (volume, duration, and frequency of flow) are fundamental properties used in classifying streams (Poff and Ward, 1989; Uys and O'Keefe, 1997). Streams can be coarsely divided into three basic flow permanence classes: perennial, intermittent, and ephemeral.

In South Carolina, waters of the state are defined in the State Pollution Control Act (S.C. Code Ann. § 48-1-10(2)). This definition explicitly includes streams. State Regulation 61-68, *Water Classifications and Standards* (SCDHEC, 2008) goes on to define ephemeral and intermittent streams and declares them to be waters of the state. Headwater streams at a minimum are important to regulators because they have the potential to convey pollutants and floodwaters downstream.

Pollutants are typically considered the result of point source discharges, such as discharge pipes from industrial and domestic wastewater treatment plants. However, pollutants also come from non-point sources such as storm water runoff. The federal Clean Water Act (CWA) and associated regulations, along with state statutes and regulations give state and federal regulators authority to control pollution in waters. Stream class has relevance to some water pollution control programs (e.g., Blinn and Kilgore, 2001; Cummins and Wilzbach, 2005; Svec et al., 2005). For example, in South Carolina, the State Forestry Commission requires best management practices (or BMPs) in order to qualify for a silvicultural exemption under §404(f) of the CWA. BMPs include streamside buffer zones with requirements that differ according to stream class. These riparian buffers are important in managing non-point source pollutants in a watershed. In the case of silviculture, the pollutant of concern is sediment. At the local level, some counties in South Carolina have buffer ordinances that also have requirements that vary by stream class.

In 2006 the US Supreme Court heard challenges to federal authority to protect headwater streams under the CWA. Following the court's ruling, in 2007 the US Environmental Protection Agency and US Army Corps of Engineers issued joint guidance (USEPA and USACE, 2007) that indicated the agencies would assert jurisdiction over headwater streams that were "relatively permanent" or "waters that typically (e.g., except during drought) flow year-round or waters that have a continuous flow at least seasonally (e.g., typically 3 mo)." Any non-navigable tributaries that were deemed not relatively permanent would undergo independent evaluation to determine significant nexus to traditionally navigable waters. Significant nexus evaluations would include consideration of hydrologic factors like volume, duration, and frequency of flow; and, consideration of certain physical characteristics of the tributary, etc.

Regulators in other states, such as North Carolina, have authority over stream buffer zones. In North Carolina, this authority was borne out of a legislative mandate to protect stream buffers as a means of nutrient management. Requirements for buffer zones vary by stream class. Knowledge of the class of a stream can also shift choice of assessment methods and expectations (e.g., Boulton et al., 2000; Gensemer et al., 2008).

An existing method that was developed for classifying streams in North Carolina is the *Methodology for Identification of Intermittent and Perennial Streams and Their Origins*, Version 4.11 (NCDWQ, 2010), hereafter referred to as the NC method. The NC method is a rapid, field indicator-based method, like the USACE's wetland delineation method. This type of method supports the need of regulators to make timely decisions, based on observations that can be made at the time of the site visit without need for repeated visits or long-term study in most cases. Briefly, the NC method uses ordinal scoring of 26 geomorphologic, hydrologic, and biologic attributes. The

attribute scores are summed and compared to thresholds to assign a flow permanence class. Evaluators can also classify a stream as perennial based solely on the presence of particular biological indicators.

With financial assistance from USEPA Region 4 through a Wetland Program Development Grant Award (Cooperative Agreement Number CD96458907-0), the South Carolina Department of Health and Environmental Control conducted a study to evaluate the appropriateness of the NC method for South Carolina. Our study objectives were to investigate 1) whether the NC method scores could differentiate stream classes in South Carolina; 2) accuracy; 3) seasonal stability; 4) relationships between scores, aspects of flow permanence and drainage area; 5) most important attributes or parameters; and 6) approaches for calibrating and fine-tuning.

We evaluated 51 headwater stream reaches no less than 100 feet in length distributed between Piedmont (34) and Southeastern Plains (17) Level III Ecoregions during both late summer–early fall (dry season) and late winter-early spring (wet season). For each ecoregion, reaches were distributed among four probabilistically–selected 12-digit hydrologic units (HUs) that included predominantly forested public lands. Within each HU, up to five reaches on each of two tributaries were selected with drainage areas ranging from approximately 3.3 to 113 ha. In addition to the 26 attributes of the NC method, we recorded measures of bankfull width and bankfull depth. Timing of dry and wet conditions for 32 of the reaches (15 in Piedmont and 17 in Southeastern Plains) was continuously recorded using electrical resistance (ER) dataloggers (Fritz et al., 2006). Flow permanence classifications by NC method scores were compared to two independent classifications. Flow permanence class was assigned to all reaches using observations of baseflow at wet and dry season visits, hereafter referred to as PERM 1. Flow permanence class was also assigned to 32 of the reaches using ER data according to South Carolina regulatory definitions (SCDHEC, 2008), hereafter referred to as PERM 2. This study was among the first to evaluate effectiveness of the NC method scores for South Carolina and was the first we are aware of to assess relationships to measures of flow duration and frequency.

One-way analysis of variance revealed NC method scores for ephemeral sites (PERM 1) were significantly different from scores from both intermittent and perennial sites, but intermittent and perennial site scores did not differ significantly from one another. This supports previous findings from forested headwater streams in other areas of the contiguous US (Fritz et al., 2008). Percent disagreement in classifying streams between NC method scores, PERM 1 and PERM 2 ranged from approximately 39 to 53% with only one misclassification by more than one category of difference. Dry and wet season scores were strongly correlated, indicating the method was seasonally stable. Scores had positive nonlinear relationships with maximum recorded wet duration and proportion of record wet, but were not related to drying frequency. Drainage area followed the same pattern and was correlated with NC method scores.

Attributes that were most important in discriminating among PERM1 classes were identified using random forest classification (Breiman, 2001; Culter and others, 2007). Presence of baseflow in the dry season was the most important attribute identified in a random forest model that correctly classified 89.4% of streams, as expected because it corresponds with the differentiation of classes in PERM1. Other important attributes or parameters were macrobenthos, rooted upland plants, bankfull width, and ecoregion. NC geomorphology attributes were not considered important in the model.

The rapid, field indicator-based approach of the NC method has strong scientific basis and is a foundation from which to build a protocol for South Carolina. Adding measures such as bankfull width, weighting sites by ecoregion, or shifting thresholds may be warranted modifications. Additional datasets that use direct hydrologic measurements to validate rapid, field indicator-based protocols are needed to support their use and for calibration and fine-tuning. Additional data is also needed from other ecoregions and land use types over multiple years of varying rainfall.

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