COASTAL ALABAMA
PILOT HEADWATER STREAM SURVEY STUDY

LEVEL II – FIELD SURVEY- DRAFT REPORT

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This Project Developed By:

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This project has been developed in support of the Alabama Coastal Nonpoint Pollution Control Program

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1. INTRODUCTION

This Coastal Alabama Pilot Headwater Stream Survey Study was developed in conjunction with Coastal Hydrology, Inc. in response to a request by Mobile County Soil and Water Conservation District (MCSWCD) and Alabama Department of Environmental Management (ADEM) for the purpose of locating, identifying and documenting baseline stream conditions for headwater streams within the ***Alabama Coastal Nonpoint Pollution Control Program*** **(*ACNPCP*)** *Management Area***,** throughout the Mobile and Baldwin County subwatersheds for coastal Alabama.

The Coastal Alabama Pilot Headwater Stream Survey was developed to locate, identify, document and assess baseline data for natural stream conditions, while also comparing any observed Land Use/Land Cover impacts in close proximity to selected headwater streams within the Mobile and Baldwin County area. The documentation of existing stream conditions may be used to reflect existing Land Uses and Land Cover (LUC), as a possible correlation of implemented management measures as Best Management Practices (BMPs) in close proximity to those surveyed stream site reaches. In addition, this Coastal Alabama Pilot Headwater Stream Survey (Headwater Stream Survey) information will be utilized to verify or plan and target any new approaches for implementation of Management Measures (MMs) described in the 1993 EPA document, *Guidance Specifying Management Measures For Sources Of Nonpoint Pollution In Coastal Waters*, as another means to address the conditions of approval for Alabama's coastal nonpoint program requirements as described by the *Alabama Coastal Nonpoint Program Findings and Conditions*, June 1998, and the *Joint Interim Decision Document*, March 2005.

Four objectives were originally developed for the implementation of this project:

1. Survey, Document and Comparatively Assess low impact "natural" headwater reference Stream segments.
2. Survey, Document and Comparatively Assess more impacted headwater stream segments.
3. Assess and correlate Land Use/Cover valuations with surveyed fluvial geomorphology and water quality parameters present in order to gage a new coastal headwaters assessment tool for these systems.
4. Derive new data and amend the 2005 *Coastal Alabama Regional Curve and Reference Reach* designs for Natural Stream Design and Restoration projects.

This regional project seeks to provide a detailed preliminary study of representative channel characteristics by surveying coastal headwater stream morphology, including multiple cross-sections, riffles, pools, and meander bends. This study has also focused on synoptic water quality parameters in conjunction with several assessment tools that may provide further data in order to compare each stream's robust attributes. An accurate physical survey of these streams was considered essential, along with consideration of surrounding land uses and statistical analysis of the data resulting from these efforts.

2. BACKGROUND

Universal physical laws govern streams, yet every stream passes in a unique way through its landscape. Gravity and water are constants, so all streams tend toward a single ideal form; however, differences in location and physical conditions create the range of forms we see. Each stream balances erosion, transport, and deposition in the context of its climate and landscape.
We may classify stream channels in terms of eight major variables: width, depth, velocity, discharge, slope, roughness of bed and bank materials, sediment load, and sediment size (Leopold, 1964). Natural systems are not random in their variation, but tend to cluster around the most likely combinations of variables based on physical and chemical laws rather than act randomly in their variation. This tendency to seek a probable balance of factors lends itself to classification (Harrelson,1994).

When any of the factors controlling stream classification change, the others will adjust along with it toward a new, balanced state. Because change is continuous, so is the process of adjustment. In streams the strongest physical medium for adjustment is the flow of water. In adjusting, the stream will show measurable change along the continuum determined by this flow (Rosgen,1994).

Local streams that traverse the southern Coastal Plain, largely across gentle gradients, often exhibit continuous changes in several parameters as they transition from one state (small bayhead stepped pools, seeps, or artesian flow) to another (exhibiting channel characteristics with meanders, pools, and riffles). They tend to develop wide floodplains to maintain channel competency, vertical stability and absorb storm runoff. Sharp boundaries, such as eastern Mobile Bay's terraced bluff landforms, tend to be the exception rather than the rule. Distinct specific events (such as coastal storm events, large trees falling into the stream, landslide/slumps across the channel, or construction and development impacts) may drive the stream's active adjustment process in a new direction. Understanding these processes of change takes both accurate measurement and scientific interpretation. The selection of stream reference sites allows opportunities to establish documentation of baseline conditions, in order to provide an accurate basis for measuring these changes. (Harrelson, 1994).

The abundance and quality of waterbodies in our coastal areas attracts tourists, retirees, and approximately over 53% of the US population. Historically, coastal urban development was carried out in high density build out scenarios that increase impervious cover, reducing natural landscapes that would buffer coastal waterways from the excess pollution. Coastal watersheds have unique ecosystems, services, and considerations compared to upland watersheds and better management tools are needed to safeguard the sensitive balance of resources, natural habitats, commodities, and people that live, work, and visit the Alabama coast.
[see http://www.cwp.org/2013-04-05-16-15-03/coastal-watersheds]

The Federal Clean Water Act provides for "maintaining the biological integrity of the nation's waters", from the mouths to the headwaters. In support of that goal the Alabama Coastal Nonpoint Pollution Control Program (ACNPCP) has been proactively involved in the development of standardized approaches to evaluate conditions for natural streams within Alabama. Our Alabama Coastal Nonpoint Source (NPS) Program identified that there is a need for a methodology that could quantify conditions and correlate Land Use/Land Cover (LUC) impacts for Alabama's coastal streams, especially in the upstream headwaters areas. In the recent past our field work had revealed that these sensitive small headwater streams were being affected or disappearing at an alarming rate. Impacts from construction activities, residential development, drought, and agricultural expansion appeared to be the primary culprits impacting the diminishment of these important sensitive waterbodies. It is well established in the referenced scientific literature that headwater streams are important to the quality of water and critical to conserve biological communities in larger streams to which these primary headwater streams are tributary.

This *Coastal Alabama Pilot Headwater Stream Surve*y Project was initiated in 2009 as a multi-year project. The tragic occurrence of British Petroleum's MC252 Gulf Oil Spill in early 2010 reprogrammed critical survey and field work, resulting in the delay of this project until it could be reinitiated, with new work occurring from 2012 into 2014. As stated previously the documented *Headwater Stream Surve*y information will be utilized to verify baseline data that may inform planning and target the implementation of Management Measures (MMs) in the 1993 EPA document, *Guidance Specifying Management Measures For Sources Of Nonpoint Pollution In Coastal Waters* and further Alabama's coastal nonpoint program to full approval. This project will also gather pertinent baseline data that may relate to conditional approval issues cited in the *Alabama Coastal Findings and Conditions* document that relate to the Agriculture, Forestry, Urban Runoff, Hydromodification, and Wetlands, Riparian Areas, and Vegetated Treatment Systems (VTS) category sections. In total, this study completed the preliminary field reconnaissance of approximately seventy 12-digit subwatersheds by walking potential streams that were evaluated for the final intensive survey assessment and data measurements. Of these, fourteen (14) headwater stream sites were selected for this comparative Coastal Alabama Pilot Headwater Stream Survey.

Headwater streams are typically considered to be first- and second-order streams (Gomi et al. 2002, Meyer and Wallace 2001), meaning streams that have no upstream tributaries (i.e.,"branches") and those that have only first order tributaries, respectively. Use of stream order to define headwater streams is problematic because stream-order designations vary depending upon the accuracy and resolution of the stream delineation (Fritz, K.M., et al. 2006.). The size of the headwater streams studied in this Project are quite small; all headwater reference streams were selected as being less than 1.0 square miles (sq.mi.) in total drainage area. Impacted streams that exhibited perennial characteristics had larger drainage areas, up to 2.3 sq.mi. Many of these selected reference streams did not show up as solid lines on USGS 1:24,000 topographic quadrangle maps, although almost all of them were indicated on county soil maps. This made the selection of our designated stream sites more difficult, as well as more intensive.

2.1 Alabama Coastal Nonpoint Pollution Control Program (ACNPCP)

During the past several years, the Alabama Department of Environmental Management–Field Operations Division-Coastal Section (ADEM-Coastal Section) has operated jointly with the Alabama Department of Conservation and Natural Resources-State Lands Division Coastal Section (ADCNR-Coastal Section) to administer and implement the Alabama Coastal Nonpoint Pollution Control Program (ACNPCP) through coordination with the NOAA-OCRM and EPA-Region IV. Also, the ADEM-External Affairs Nonpoint Source (NPS) Unit representatives have participated extensively to aid the ACNPCP's development of programmatic approaches and projects that address the implementation of Management Measures (MMs). ADEM-Coastal

Section has retained dedicated staff members since 1999 who have continued a key role in the development and implementation of this Program and vital implementation projects, in order to address the many and varied water quality-related aspects of coastal nonpoint source pollution impacts and issues. The ACNPCP has facilitated and launched a variety of actions and projects that include tracking, permitting, monitoring, restoration projects and comprehensive studies to target and implement management measures for the Riparian Areas and Wetland-related issues throughout the designated subwatersheds of Baldwin and Mobile Counties (i.e. the federally recognized ACNPCP *Coastal Management Area*). Based upon the accepted components of *ACNPCP's Project Template*, Alabama's CNPCP will target the cyclic continuation of these efforts as a high priority for these categories and issue areas, with dedication to a continuing goal to raise public awareness and to implement category–related projects. This *Headwater Stream Survey* project was developed to verify existing coastal stream conditions for low order headwater streams that may correlate to potential impacts from existing Land Use /Land Cover (LUC). This is a good example of an ADEM-Coastal Section project that illustrates the State's ongoing multi-faceted efforts to implement and enhance components of the "Wetland and Riparian Areas Management Measures" requirements described on pp 7-02 through 7-56 in Chapter 7 of the 1993 EPA document, *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (g-Guidance). Through this *Headwater Stream Survey*, ACNPCP provides tangible engineering tools that have been calibrated for use in this local region, which enable natural stream design restoration using science-based measurements. This project serves to compare likely LUC impacts by identifying, documenting, assessing and comparing baseline stream conditions for our coastal headwater streams.

2.2 Coastal Alabama Geography

Alabama's two southernmost coastal counties, Baldwin and Mobile, encompass over **2,800 sq.mi.** with terrain consisting mainly of mixed forest, evergreen forest, and agriculture-related cover types. Regional studies have shown that Urban-related land cover has steadily increased as wetland, marsh and riverine habitats have decreased in quantity and relative quality. Coastal Alabama is characterized by important habitat areas and drainages including: (1) the Mobile-Tensaw River Delta, (2) Mobile Bay, (3) the Escatawpa River, (4) the Perdido River (5) the Mississippi Coastal area and adjacent barrier islands.
[see http://www.ogb.state.al.us/gsa/coastal/OFR/DamInventory_0705.pdf]
Alabama's coastal counties contain approximately **271,000 acres (1,097 km^2)** of wetlands. This acreage represents 12.5% of the total acreage of the designated Alabama Coastal Nonpoint Pollution Control Program (ACNPCP) Management Area. An additional **400,000 acres (1,619 km^2, approximately 18%)** of coastal streams and estuarine waters are encompassed within this two county area, which possesses a unique geology and topography that makes up this deltaic and estuarine Mobile Bay complex.
[see http://adem.alabama.gov/programs/water/waterforms/2012AL-IWQMAR.pdf]
Alabama recognizes the resource value and the functioning of wetlands and riparian areas to abate NPS pollution and improve water quality in the coastal areas. At 10 miles wide and 40 miles long, the **Mobile-Tensaw River Delta (HUC 03160204)** is the largest wetland in Alabama and the second largest river delta in the nation. The delta was formed by soil deposition from the Coosa, Tallapoosa, Black Warrior, Tombigbee and Alabama Rivers. The Mobile-Tensaw River Delta includes 250,000 acres of marsh, cypress tupelo swamp and bottomland hardwoods and filters approximately 20 percent of the country's fresh water.
[see http://www.beachapedia.org/State_of_the_Beach/State_Reports/AL/Beach_Description]

As the fourth largest estuary in the nation, **Mobile Bay (HUC 03160205)** encompasses **413 sq.mi**. It is approximately 31 miles long and has a maximum width of 24 miles. Mobile Bay is a shallow estuary that provides a transition between the fresh water wetlands of the Mobile-Tensaw River Delta and the marine environment of the Gulf of Mexico. One of Mobile Bay's primary functions is as a nursery ground for many commercially and recreationally valuable species. [see http://www.beachapedia.org/State_of_the_Beach/State_Reports/AL/Beach_Description]
The southeastern mouth of Mobile Bay is framed by the Fort Morgan Peninsula. At the south-western side of Mobile Bay lies Dauphin Island. These barrier islands serve to protect the mainland and estuarine habitats by diminishing storm related wind and wave energy. Additionally, the estuarine and nearshore waters of Mobile Bay provide the nursery habitats that support a crucial multi-million dollar seafood industry for coastal Alabama.

The coastal lowlands of Alabama, with gently undulating to flat topography, basically follow the shoreline along the Gulf of Mexico, Mississippi Sound and Mobile, Perdido, and Bon Secour Bays. The ecological environments and geomorphology consist of features such as coastal streams, wetlands (i.e., tidal marsh, bay-gum and cypress swamp), two large peninsulas, a delta, lagoons, islands, and bays. The presence of a saline and/or fresh, high water table gives rise to the abundance of various wetland habitat types that are found within Alabama's coastal area. The upland unconsolidated alluvial sand, gravelly sands, and clays found along the Alabama coast, when combined with varying amounts of precipitation, cause dramatic effects on the turbidity of the shallow receiving waters in Mississippi Sound, Perdido and Mobile basins.
[see http://pubs.usgs.gov/sir/2006/5287/pdf/StatewideSummaryforAlabama.pdf]
As observed in this Project, most Headwater Streams in southern Alabama, specifically Mobile and Baldwin counties, typically originate from sloped wetland seeps or bayheads that usually initiate with a steeper gradient and transition onto wider floodplains to maintain channel competency, vertical stability and absorb storm runoff.

2.3 Context of Human Influences

These coastal riparian systems, wetlands, and estuarine ecosystems in Alabama provide critical habitat for a diverse number of fascinating wildlife, including a number of endangered species that are at potential risk because of stressors that are commonly associated with anthropogenic factors. Surveys conducted in 1998 by the Mobile and Baldwin County offices of the Alabama Soil & Water Conservation Districts (Mobile and Baldwin County Unified Assessments, 2000) indicated that 45% of Mobile County and 32% of Baldwin County were associated with developed land cover uses (e.g urban, agriculture, or pasture). Of the remainder that was classified as "forested", a major portion is not natural habitat, but is being managed for silviculture. Regional studies have shown that Urban-related land cover has steadily increased, as wetland, marsh and riverine habitats have decreased in quantity and relative quality (*Alabama Coastal Counties Wetland Conservation Plan*, 2001).

Data indicates that without sustainable management, many of these critical resources are under threat from a steadily increasing human population. Census projections illustrate that the combined Mobile conurbation (Mobile and Baldwin Counties) reached a population of 601,895 in 2005 [see http://cber.cba.ua.edu/edata/est_prj/alpop20002025.prn]. Projections of additional growth from 2005 to 2025 predict a conservative increase of over 15 % for both counties, which may result in an anticipated coastal population of over 691,989 by 2025.

Alabama's coastal riparian and riverine systems have been subjected to increasing pressure from a variety of proliferating land use-related activities, ranging from oil and gas extraction and refining, industrial construction and waste discharges, transportation needs, shipping, navigation and channel excavation, agriculture and silviculture production, commercial and recreational fishing, municipal waste treatment discharges and accidental spills, to poorly planned commercial and residential development projects that result in the degradation of these waterbodies and increase the potential harm from any of the pollutants associated with nonpoint source runoff from those identifiable land or water uses.

[see http://pubs.usgs.gov/sir/2006/5287/pdf/StatewideSummaryforAlabama.pdf]

As we have developed and implemented the Alabama Coastal Nonpoint Pollution Control Program, especially as we developed tools to address approaches for the environmental management of our coastal streams, the abundance of our waterways became evident. However it also indicated that science-based assessment and surveys were needed to provide documentation for existing conditions that could provide input for adequate planning, protection, and preservation of their health and qualities.

Referencing prior ACNPCP and ADEM WQ studies, it was noted that in some instances as much as 30% of upstream sites were compromised through time because of many of the LUC-related development actions cited above. It was noted that these impacts were occurring primarily in the low order or headwater stream reaches. Based upon applying suitable management measures pertinent to several categories, the ACNPCP undertook the task to gain more information concerning coastal headwater streams with the objective of bringing more attention to these systems, while obtaining and archiving vital Reference Reach Regional Curve data. Another focus was to document the resultant conditions associated with dominant LUC practices for Alabama's southwestern coastal streams. Understanding current conditions as they relate to the diversity and status of these coastal ecosystems provides a foundation for determining actions needed to define and restore these habitats. This valuable science-based information can be used to enhance restoration efforts and guide the development of future enforcement and regulatory permitting practices, as well.

Figure1. Baldwin County Subwatersheds with Coastal HDWTRSS Sites ⊕

Figure 2. Mobile County Subwatersheds with Coastal HDWTRSS Sites ⊕

3. SITE SELECTION AND ASSESSMENT

3.1 Characterization of Study Area

The proposed study area is located in Mobile and Baldwin Counties, Alabama within the eight 8-digit HUC sub-watersheds listed as follows:

03140106	**Perdido River**
03140107	**Perdido Bay**
03150204	**Lower Alabama River**
03160203	**Lower Tombigbee River**
03160205	**Mobile Bay**
03160294	**Mobile Tensaw Delta**
03170009	**Mississippi-Coastal**
03170008	**Escatawpa River**

This portion of the study includes identifying and documenting baseline stream characteristics and observed fluvial geomorphology throughout these eight HUC areas to assess their suitability for further study. All stream segments are entirely contained within the Gulf Coastal Plain Physiographic Province, which is characterized by broad valleys, low topographic relief, and gentle land slopes. Within the coastal region of Alabama, there are negligible differences in precipitation and runoff between study sites (Gerbert et al., 1987). Precipitation averages between 55 and 65 inches annually. Rainfall runoff values range from 18 to 30 inches annually (Gerbert et al., 1987). Coarse-textured soils are prominent throughout the province, due to prolonged exposure of marine terrace sediments. The drainage density of the middle Coastal Plain is higher and more well-established than that of the lower Coastal Plain (Miller and Robinson, 1994). The underlying geology is primarily composed of sands, clays, and organics from the Pleistocene, Holocene, and Pliocene eras.

The Level II portion of the Headwater Stream Survey study includes final site selection, identifying and documenting baseline stream fluvial geomorphology throughout these eight coastal HUC areas, and comparison of streams based on observed field site conditions and impervious cover. Following the reconnaissance during the last few years of work in coastal Alabama, the selection of these Headwater sites (see *County Subwatersheds with Coastal HDWTRSS Sites* maps on pages 10 &11 above) were based upon observed potential for "natural" conditions, as well as observable differences suitable to illustrate and contrast these selected stream reaches and drainage areas (e.g. Rural vs. Urban; and Reference vs. Impacted). Additionally, stream segments were designated as being in *Urban Areas* if located within municipal limits, or within drainage areas having greater than 10% impervious cover. Stream research generally indicates that certain zones of stream quality exist, most notably at about 10% impervious cover, where sensitive stream elements are lost from the system. A second threshold appears to exist at around 25 to 30% impervious cover, where most indicators of stream quality consistently shift to a poorer condition (e.g., diminished aquatic diversity, water quality, and habitat scores). [http://www.stormwatercenter.net]

3.2 Site Selection Criteria

This ***Pilot Headwater Stream Survey Study*** format was based on assessing existing physical conditions for selected low order headwater streams in Mobile and Baldwin counties. Field reconnaissance visits were conducted on all sites in 2012 for the Level I survey to determine suitability for inclusion in this study. Minimum criteria for inclusion in the study included the following:

1. The stream reach should be a single-thread channel, but where necessary to establish regional geomorphic and water quality characteristics, Rosgen DA (anastomosed) stream types may be included (Rosgen, 1994).

2. Beaver dams must not hydraulically impact the site. This process did not rule out beaver activity in the watershed, just at the project reach.

3. The channel must be free to naturally adjust its dimension; e.g., the channel must not be armored by riprap.

4. Sites with recent dredging and/or bank vegetation removal were eliminated.

5. All reference streams were selected as being less than 1.0 sq.mi. in total drainage area.

6. Sites selected will be located in urban and rural areas and from both impacted and natural (i.e., reference) sites. Stream segments were designated as being Urban if located within municipal limits, or within drainage areas having greater than 10% impervious cover.

7. For most sites an initial drive-through survey was completed throughout the watershed to verify that land use was not rapidly changing. Many potential sites were rejected due to the presence of swampy systems. Deeply-incised streams were not considered or recommended for inclusion for the reference segments in this survey. The bank height ratio (lowest bank height divided by the bankfull maximum depth) must be less than 1.5 for gage stations and 1.2 for reference reaches. Rosgen (1996) reported that a bank height ratio of 1.3 or greater is indicative of an unstable reach. Some of these were used for Impacted Stream segments comparisons.

Based on the findings of the Level I survey, the Level II stream sites were selected for detailed measurements and analysis of stream-reach fluvial geomorphology. These water quality data were then gathered by the ADEM project staff through 2013, with supplemental samples into the R-3 Winter rotation in early 2014, with the collected data being incorporated for bio-statistical analysis.

4. PROJECT METHODOLOGY

4.1 Development of the HDWTRSS Project:
Approaches to study Coastal Headwater Streams

A. GIS-based selection of Watersheds & Identification of potential headwater streams:
Criteria-based selection of potential reference and impacted sites.

B. Select suitable headwater streams based upon preliminary reconnaissance and observed LUC.

C. Obtain access to study all stream sites. The NRCS and local S&WCDs were invaluable in providing contacts and acquiring proper access to these stream sites.

D. Select and flag stream reaches to conduct requisite Geomorphology Survey.

E. Measure selected Water Quality parameters in three seasonal sampling rotations:
R-1 Spring/Summer, **R-2** Fall, and **R-3** Winter.

F. Measure Land Use-Land Cover parameters:
Intensive onsite and follow-up measurements, with tight scaled GIS.

G. Conduct suite of assessments and compare data for Coastal Headwater Streams.

H. Develop conclusions based upon comparisons of:
Measurable differences of stream site data, Water Quality, Land Use/ Land Cover, Project Assessments , Comparative Assessment Index, and Geomorphology.

Initial Field reconnaissance was conducted on selected headwater or low order streams throughout Mobile and Baldwin Counties, Alabama in 2012 to support the following Level II field survey, which included stream habitat assessments information (see Appendix II), fluvial geomorphology characteristics, and water quality information.

Data collected for the Level I phase during 2012 and 2013 included site characteristics (i.e., presence of permanent hydrology, channel alterations, surrounding landscape, land-uses and any noticeable impacts), photographs (not at every site), GPS location, and general physical land survey location. This was supplemented during the Level II data collection phase in 2013 with detailed channel morphology, land use/land cover and habitat assessment, including collection of water quality parameters with inferences to be based upon comparative and statistical analyses.

All statistical analyses were carried out using Project R (R version 3.0.3). Statistically significant differences were accepted at an alpha level of 0.05. Data were analyzed with parametric general linear procedures and Pearson's product-moment correlation when the assumptions of normality and homogeneity were met. When parametric assumptions were not met, the nonparametric Spearman's rank correlation and Kruskal-Wallis rank sum test analyses were used.

4.2 Stream Geomorphology
At each selected HDWTRSS stream site, a Leica TC307 Total Station and Ranger TDS data collector (with Survey Pro software by Tripod Data Systems 2005) were used to complete a longitudinal profile and cross-sections, along a minimum reach length of 20 times the bankfull width (or at least one meander wavelength). Cross-sections were surveyed at three

representative riffles, pools, runs, and glides. In some instances the reach length was not long enough to provide all of the cross-sectional information needed for comparisons. Morphological features were surveyed moving left to right, looking downstream, including top of bank, bankfull stage, edge of channel, edge of water/water surface, thalweg, and channel bottom (Harrelson et al., 1994; USGS, 1969). Permanent pins were established at some of the cross sections and tied to the longitudinal profile station. The data were downloaded from the Ranger, and the following bankfull dimensions were calculated: width, cross-sectional area, maximum depth, mean depth, ratio of width/mean depth, bank height ratio, and entrenchment ratio (riffles only). The data were then entered into Microsoft Excel for graphing and comparisons.

Longitudinal survey measurements were generally collected at the beginning of each bed feature (heads of riffles and pools) and included: thalweg, water surface, bankfull stage, and top of low bank. The slope of a line developed using bankfull indicators was compared to a best fit line through the water surface points. Leopold (1994) used this technique to verify the feature as bankfull if the two lines were generally parallel and consistent over a long reach. The data were processed the same as discussed for the cross-sectional data, and valley slope and average water surface slope were calculated.

Channel pattern was determined from the survey points and from aerial photographs, as necessary. More extensive surveys would have been needed to depict pattern statistics on many of the agricultural reaches. For that reason, aerial photos were often used to measure those parameters; however, it was not possible to determine the exact location of the stream channel on the aerials (as it was on many of the smaller reaches) because the surrounding vegetation was quite dense. In those cases, pattern measurements were based solely on the survey points.

4.2.1 Bed Material Measurements

Since most of the project sites had sand-dominated bed material, the Wolman pebble count procedure was not applied in all situations (Bunte and Abt, 2001); instead, where possible, protrusion heights from woody material were collected along the wetted bed at the represented riffle cross-section (Morris, 2012; Yochum et al., 2012). A total of one hundred samples were collected and used to document roughness and bankfull discharge.

4.2.2 Stream Classification

Each project reach was classified using the Rosgen (1994, 1996) method. The width of the floodprone area was measured from survey data or topographic maps (where survey data were insufficient due to wide, heavily vegetated floodplains). In cases where the clear survey shots could be collected across the valley, a complete cross-section was surveyed across the floodplain, and the floodprone area width was taken from this cross-section.

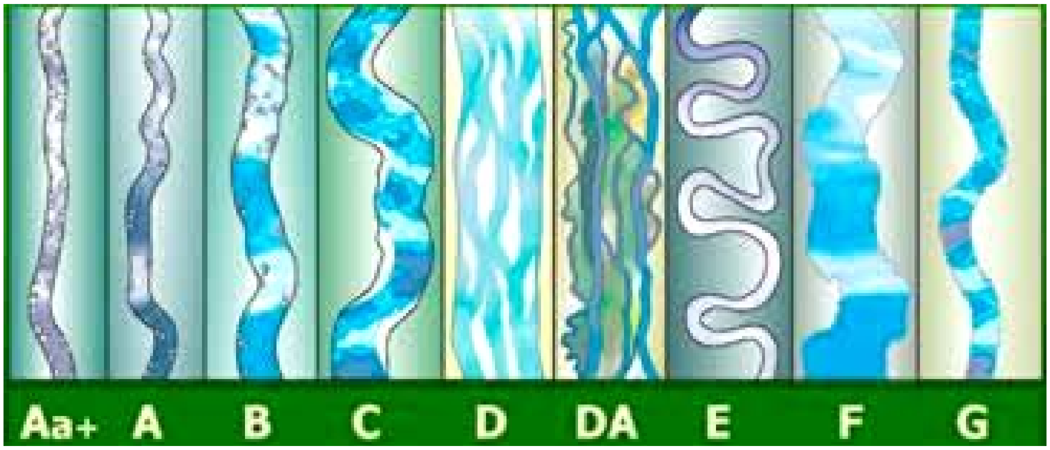


***Figure 3. Rosgen Stream Classification Planiforms*.** **US Environmental Protection Agency**.

4.3 Assessments Tools for the *Coastal Alabama HDWTRSS*

Based upon previous field work with environmental projects during the last few decades, along with interagency discussions with other environmental scientists, the Coastal NPS Program decided upon a suite of assessments that would provide calibrated measures of those important factors or indicators. These assessments were done for each selected HDWTRSS Stream Site. This would provide a numeric and measurable ***Composite Assessment Index*** for each *Coastal Alabama HDWTRSS* site. The assessments utilized for this purpose of the study are attached in Appendix II and are listed here:

A. ***Coastal HDWTRSS Land Use/ Land Cover (LUC) Assessment*** **(Form#6), 2012**
B. ***Coastal HDWTRSS Forest Canopy Assessment,*** **2008**
C. ***North Carolina Stream Identification Assessment*** **(4.0), 2010**.
D. ***ADEM Wadeable Stream Habitat Assessment*** **(FOD-I Form36), 2011**.
E. ***ACNPCP Coastal Stream Assessment*** **(Form#3), 2009**
F. ***Coastal HDWTRSS Composite Assessment Index,*** **2008**

4.3.A Coastal HDWTRSS Land Use-Land Cover (LUC) Assessment

The National Land Use/Cover categories along with observed coastal conditions helped determine the assignment of broad "**Land Use/Cover Classifications**" that were selected. These were designated in the HDWTRSS LUC Assessment, being selected for this study as:

Natural
Forested
Cleared, Select Cut, ReGen Stand, 20Yrs+
Agriculture
Cattle, Crops, Orchards, Pasture,
Urban
Transportation/Parking
Commercial
Residential,
Density – High, Medium, Low
Utilities, ROWs, and Parks, Greenspace
Waterbody

Using the **2006 National Land Cover Data (NLCD 2006)** information as a guide, these *HDWTRSS* Site conditions were selected, observed and documented onsite at each of the HDWTRSS stream sites chosen for this study [refer to http://www.mrlc.gov/nlcd11_leg.php]. These observations were reviewed and enhanced by measurements calculated with the use of GIS tools, including consultation of aerial photography and USGS topographic mapping.

Initial *Field Reconnaissance LUC* forms were developed for the prior Level I phase of the project. The data collected from these field determinations provided critical information to further develop and calibrate the current ***Coastal HDWTRSS Land Use/ Land Cover (LUC) Assessment*** **(Form#6), 2012** (HDWTRSS LUC Assessment) for this project. This HDWTRSS LUC Assessment (see Appendix II) was used to guide the final selection of the Project's coastal Headwater Streams, both Reference Streams and Impacted Stream sites. It also played a huge role for this Project by providing the GIS-reviewed HDWTRSS LUC assessment data used to derive the final HDWTRSS **Composite Assessment Index** scores for the selected sites.

4.3.B *Coastal HDWTRSS Forest Canopy Assessment*, 2008

The *Convex Spherical Forestry Densiometer* utilized to conduct the forest canopy assessment, allows accurate, one-person measurement of tree canopies. The use of this instrument and procedure generates a numeric measurement of the forest overstory density. The densiometer uses a spherical-shaped reflector mirror engraved with a cross-shaped grid of twenty-four 1/4" squares. Operation and calculation procedures were adopted based upon the CDPR-Environmental Branch manual. [see http://www.cdpr.ca.gov/docs/emon/pubs/sops/fsot00201.pdf]

4.3.C *North Carolina Stream Identification Assessment* (4.0), 2010.

The purpose of this assessment procedure, using the manual and accompanying field data form, is to identify and evaluate geomorphic, hydrological and biological stream features that distinguish between ephemeral, intermittent and perennial streams. This assessment was included to gage it's measurement of Alabama coastal headwater streams, which was integrated as an important quantitative factor into the **Composite Assessment Index** for the HDWTRSS project. (see Appendix II.)

4.3.D ADEM Field Data and Habitat Assessments for Wadeable Streams

This interconnected suite of ADEM habitat assessment procedures was integrated into the HDWTRSS project to evaluate another important set of factors. Documentation of these components (see Appendix II.) allow accurate use of the ADEM ***Glide Pool Habitat Assessment*** as a numeric value that could be calculated into the **Composite Assessment Index** score.

1) **ADEM *Gen Phys Char, Substrate & WQ Field Data Sheet* (FOD-I Form36), 2011**.http://web-server/intranet/QA/internalforms/Surface%20Water%20Field%20Data/FOD%20I-Form%2036%20Form%20Rev%203-04-11.pdf
2) **ADEM *Abbreviated Stream Flow Measurement Data Sheet* (FOD I-Form 9), 2006** http://web-server/intranet/QA/internalforms/Surface%20Water%20Field%20Data/Stream%20Flow%20Form%20%20FOD%20I%20Form%209%201-25-06.pdf
3) **ADEM *Glide Pool Habitat Assessment* (FOD I-Form 14), 2013**. http://web-server/intranet/QA/internalforms/Surface%20Water%20Field%20Data/FOD%20I-Form%2014%20Form%20Rev%202-14-13.pdf

4.3.E *ACNPCP Coastal Headwater Stream Assessment* (Form#3), 2009

These assessment procedures were developed to identify important Coastal Headwater Stream components using the accompanying field data form to identify and score geomorphic, hydrological and biological stream features that are important to evaluating coastal headwaters stream characteristics (see Appendix II).

4.3.F *Coastal HDWTRSS Composite Assessment Index*, 2008

The selection and incorporation of these 5 informative functional assessment tools allowed development of an accurate Coastal HDWTRSS Comparative Assessment Index. This project provides good science-based information that should promote further development of this preliminary tool. This **Composite Assessment Index** is a final assessment calculation that combines the selected assessment tool factors and seeks to generate an encompassing numeric factor, with a scaled minimum score of 0.0, up to a maximum score of 1.0. A zero would represent a negligible headwater coastal stream system, with a perfect score of 1.0, being an **ideal headwater stream ecosystem**.

5. WATER QUALITY: COASTAL HEADWATER STREAMS

5.1 HDWTRSS Field Project Design

Water Use designations are promulgated in ADEM Admin. Code R. 335-6-11(2008). Section **335-6-11-.01** states that "Use classifications utilized by the State of Alabama are as follows:

A. OAW Outstanding Alabama Water
B. PWS Public Water Supply
C. S Swimming and Other Whole Body Water-Contact Sports
D. SH Shellfish Harvesting
E. F&W Fish and Wildlife
F. LWF Limited Warmwater Fishery
G. A&I Agricultural and Industrial Water Supply

All streams reaches selected for this HDWTRSS project are designated as **Fish and Wildlife (F&W).**

These field protocols and standards were selected and implemented in order to complete the *Coastal Alabama Pilot Headwater Stream Survey*:

1. Base-flow was determined as the most desirable metric to gage Stream Flow for each HDWTRSS stream site. Based upon prior Stream Recon information and the small drainage area for each site, it was determined that optimum measurements would be ≥24hrs after a measurable or observable precipitation event.

2. All instrument calibrations and field techniques followed the QA/QC criteria and procedures set forth in the Alabama Department of Environmental Management's *Standard Operating Procedures and Quality Control Manual.* In-situ field measurements were taken at each headwater stream station shown in the maps on page 10 and 11 (Figures 1 and 2).

3. Cross-sectional *HDWTRSS* stream sampling sites were permanently marked and flagged using GPS positioning to facilitate locating stream reference flag-markers placed onsite.

4. All other related HDWTRSS project parameters were measured and recorded at each headwater stream site (see Table 2 below), which were permanently marked and flagged to ensure accurate site sampling replication.

5. Water quality data were recorded at each permanent field station for the selected field parameters. A multi-parameter datasonde unit (YSI Model #600XLM Multi-Parameter Water Quality Monitor®) was used to measure Dissolved Oxygen (DO), Salinity, Conductivity, pH, Temperature, and Depth. These datasonde water quality readings were recorded at mid-depth from surface of water. Turbidity measurements were conducted using the Orbeco-Hellige Turbidimeter per ADEM SOP# 2044. Other field parameters recorded at each station include air temperature, and weather conditions observations.

6. All headwater stream flow measurements were taken for each site at mid-depth using a USGS Pygmy Meter -Model 6205, which is used only for measuring shallow streams, mounted onto a USGS Top Setting Wading Rod per ADEM *SOP# 2040*. *HDWTRSS* Stream Flow calculations were determined using ADEM *Stream Flow Calculation Workbook* and these were verified calculating each cross-section sub-segment total. Subsurface Grab samples were taken at each permanent cross-sectional stream station to measure turbidity. These were taken prior to setting up the flow stations for each stream site. Sediment grain sampling was collected after the subsurface grab and Datasonde readings were completed. All sampling containers, sediment collection, and field equipment devices were examined and cleaned between each station to prevent contamination according to the applicable ADEM SOPs (Tables listed on page 22).

5.2 Field Quality Control and SOPs

The standard ADEM SOPs were followed for calibration and operation of field equipment that was used to measure the parameters recorded at these stream sites. The field staff collected duplicate measurements at 10% of the sites. These HDWTRSS water sampling procedures, including protocol-required Duplicates, were all processed by the ADEM Mobile Branch staff. Routine maintenance and calibration protocols on all instrumentation and field equipment outlined by the manufacturers were followed.

Tables 2 and 3 (below) list the water quality parameters collected at each site, and also lists the applicable ADEM *General Surface Water SOPs* for this *HDWTRSS* project. Table 2 lists the specific parameters documented and the measurable units specific for each one. Table 3 cites the appropriate SOP method reference number utilized for each of the Project parameters, including Flow, Temp., pH, Specific Cond, Turbidity, Surface Water DO, Data Sonde, and General Surface Water Sampling.

Table 1: In-Situ Parameters Recorded or Observed

In Situ Parameters	
Flow	cfs
Depth	ft.
Temp: Air and Water	ºC
pH	s.u.
Dissolved Oxygen (DO)	mg/L
Salinity	ppt
Specific Conductivity	µmhos/cm
Turbidity	NTU
Weather Conditions	observations

Table 2: ADEM Environmental Sampling SOP Documents

SOP #	Rev #	General Surface Water 2000-2099
2040	5.0	Stream Flow Abbreviated Measurement Method
2041	3.1(a)	Temperature Field Measurements
2042	4.0	pH Field Measurements
2043	4.0	Conductivity Field Measurements
2044	4.2	Turbidity Field Measurements
2045	4.0	SW Dissolved Oxygen Field Measurements
2047	1.1	Datasonde Field Measurements
2061	4.0	General Surface Water Sample Collection

5.3 HDWTRSS Field Water Quality Data

These are the HDWTRSS water quality and field measurements that were collected at each selected headwater stream site. These parameters were determined as critical to this effort, and were documented and recorded by the HDWTRSS team staff. The following 3 Tables list the Water Quality data results that were collected seasonally by ADEM staff on these 14 HDWTRSS Stream Sites:

Table 3. R1 – Late Spring/Early Summer WQ Sampling

Coastal Alabama HDWTRSS		SPRING/SUMMER-R1						
Site Names	Air Temp (°C)	Water Temp. (°C)	pH (s.u.)	Dissolved Oxygen (mg/L)	Specific Cond. (umhos/cm)	Salinity (ppt)	Turbidity (NTU)	Flow Pygmy (cfs)
UT 2 Halls Creek	29	22.2	4.7	7.8	29	0.01	2.7	0.221
UT 2 Perdido River #1	29	21.3	3.6	6.4	29	0.01	0.7	0.904
UT 2 Perdido River #2	31	22.8	3.9	6.1	30	0.01	1.3	0.632
UT 2 Wolf Creek	29	29.1	5.3	4.5	46	0.02	2.1	0.201
UT 2 Borrow Creek	29	22.1	4.4	7.9	22	0.01	1.3	0.177
North Yancey Branch	26	23.2	5.7	7	54	0.02	11.4	1.647
UT 2 Joe's Branch	27	25.1	7	5.4	176	0.08	5.3	0.015
UT 2 Red Creek #1	27	23.6	5.9	0.6	309	0.15	9.5	0.01
UT 2 Red Creek #2	28	23.7	6.4	2.4	243	0.11	11.4	0.024
UT 2 Perch Creek	30	25.9	6.55	5.43	127	0.06	13.7	0.91
Three Mile Creek	32	29.3	6.3	12.3	76	0.03	3.5	0.385
Twelve Mile Creek	30	30.5	7.9	10.8	220	0.1	3.2	0.265
UT2 Cowpen Creek	31	31.2	6.5	6.5	47	0.02	27.2	0.772
UT 2 Page Creek	25	26	6.7	6.9	116	0.05	13.7	0.025

KEY: It should be noted that all WQ Graphs and Tables in this HDWTRSS Report will use this color key to designate their primary associated Land Use Group and Stream Types:

Reference Streams	Impacted Urban	Impacted Agriculture

Table 4. R2- Autumn WQ Sampling

Coastal Alabama HDWTRSS		AUTUMN-R2						
Site Names	Air Temp (^{0}C)	Water Temp. (^{0}C)	pH (s.u.)	Dissolved Oxygen (mg/L)	Specific Cond. (umhos/cm)	Salinity (ppt)	Turbidity (NTU)	Flow Pygmy (cfs)
UT 2 Halls Creek	23	21.44	5.44	7.71	23	0.01	1.3	0.248
UT 2 Perdido River #1	25	20.3	4.75	7.77	20	0.01	0.7	0.93
UT 2 Perdido River #2	26	21.5	5.07	7.18	27	0.01	1.8	0.897
UT 2 Wolf Creek	29	26.3	5.11	4.8	45	0.02	0.9	0.189
UT 2 Borrow Creek	21.5	19.25	5.3	7.56	23	0.01	1.4	0.203
North Yancey Branch	27	22.98	6.14	7.1	58	0.03	12.1	1.612
UT 2 Joe's Branch	30	23.95	7.28	5.19	239	0.11	7.2	0.038
UT 2 Red Creek #1	21	21.13	6.3	2.59	293	0.14	6.4	0.019
UT 2 Red Creek #2	21	20.66	6.67	3.55	229	0.11	6.8	0.021
UT 2 Perch Creek	28	24.56	7.44	4.03	274	0.13	19.5	0.246
Three Mile Creek	24	23.07	6.38	5.1	82	0.04	13.75	0.396
Twelve Mile Creek	24	24.07	6.73	7.38	210	0.1	13.5	0.285
UT 2 Cowpen Creek	31	25.04	7.25	7.95	216	0.1	15.5	0.433
UT 2 Page Creek	21	18.63	7.43	7.97	113	0.05	13.5	0.027

Table 5. R3- Winter WQ Sampling

Coastal Alabama HDWTRSS		WINTER-R3						
Site Names	**Air Temp (⁰C)**	**Water Temp. (⁰C)**	**pH (s.u.)**	**Dissolved Oxygen (mg/L)**	**Specific Cond. (umhos/cm)**	**Salinity (ppt)**	**Turbidity (NTU)**	**Flow Pygmy (cfs)**
UT 2 Halls Creek	14	13.8	4.3	10.01	35	0.02	4.6	0.908
UT 2 Perdido River #1	13	12.67	4.3	9.02	21	0.01	1.2	0.838
UT 2 Perdido River #2	12	9.46	3.65	9.49	27	0.01	0.6	0.501
UT 2 Wolf Creek	14	11.58	4.66	9.26	48	0.02	0.8	0.191
UT 2 Borrow Creek	18	14.66	3.71	9.87	27	0.01	2	0.192
North Yancey Branch	21	17.16	5.67	8.67	58	0.03	12.6	1.61
UT 2 Joe's Branch	21	16.94	7.05	7.95	217	0.1	6.4	0.105
UT 2 Red Creek #1	25	19.46	6.28	1.91	353	0.17	11.4	0.046
UT 2 Red Creek #2	25	16.34	6.31	3.1	231	0.11	13	0.057
UT 2 Perch Creek	14	8.78	6.43	9.81	216	0.1	8.5	0.185
Three Mile Creek	16	11.58	6.28	10.61	76	0.04	13	0.447
Twelve Mile Creek	17	13.27	7.76	12.92	238	0.11	14.45	0.366
UT 2 Cowpen Creek	17	11.01	6.36	9.48	65	0.03	40	0.054
UT 2 Page Creek	13	11.9	6.5	11.7	111	0.05	19.8	0.047

5.3.1 Stream Flow

Stream flow measurements and observations are an integral part of interpreting water quality data, so stream flow for each headwater stream site was required as a critical part of the initial *HDWTRSS* project plan, in order to obtain the most accurate stream flow estimates using ADEM's Abbreviated Stream Velocity Measurement Method. Initially the flow measurements were attempted using a doppler unit, but in these small flow coastal headwater stream sites the USGS Pygmy Meter -Model 6205, proved more suitable for this endeavor.

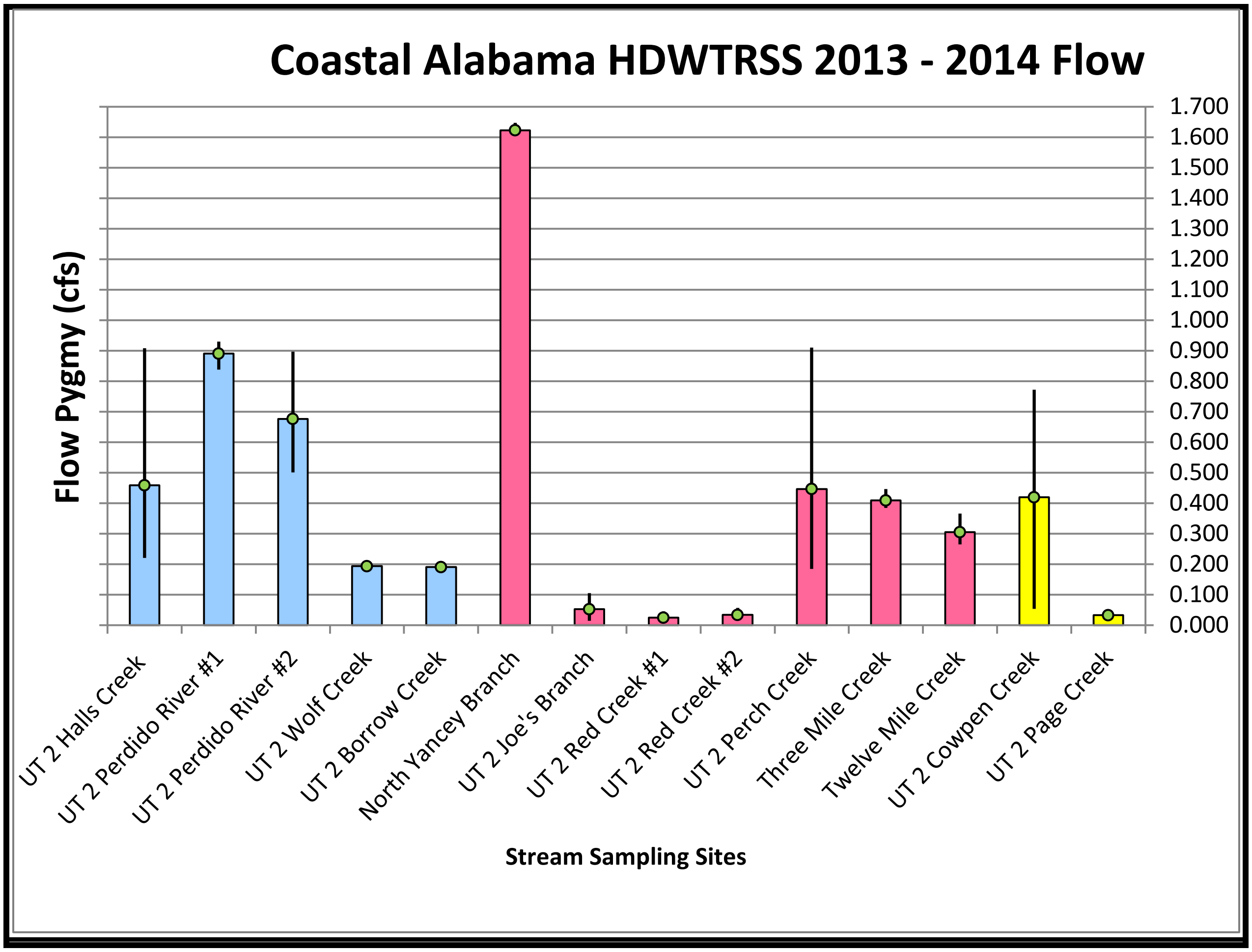


Figure4.* *Stream Flow data for HDWTRSS stream sites.

Overall Stream Flow Data

The HDWTRSS Stream Flow data ranged from low baseflow streams at 0.01 cfs up to 1.647 cfs. The stream flow data was widely distributed, with no obvious groupings or patterns for the data based upon LUC or geographic distribution.

5.3.2 Temperature

All air and water temperatures taken at the HDWTRSS stream sites were recorded in degrees Celsius (°C). The resulting raw data values show only very slight total temperature differences for either Air Temperature, or Water Temperature.

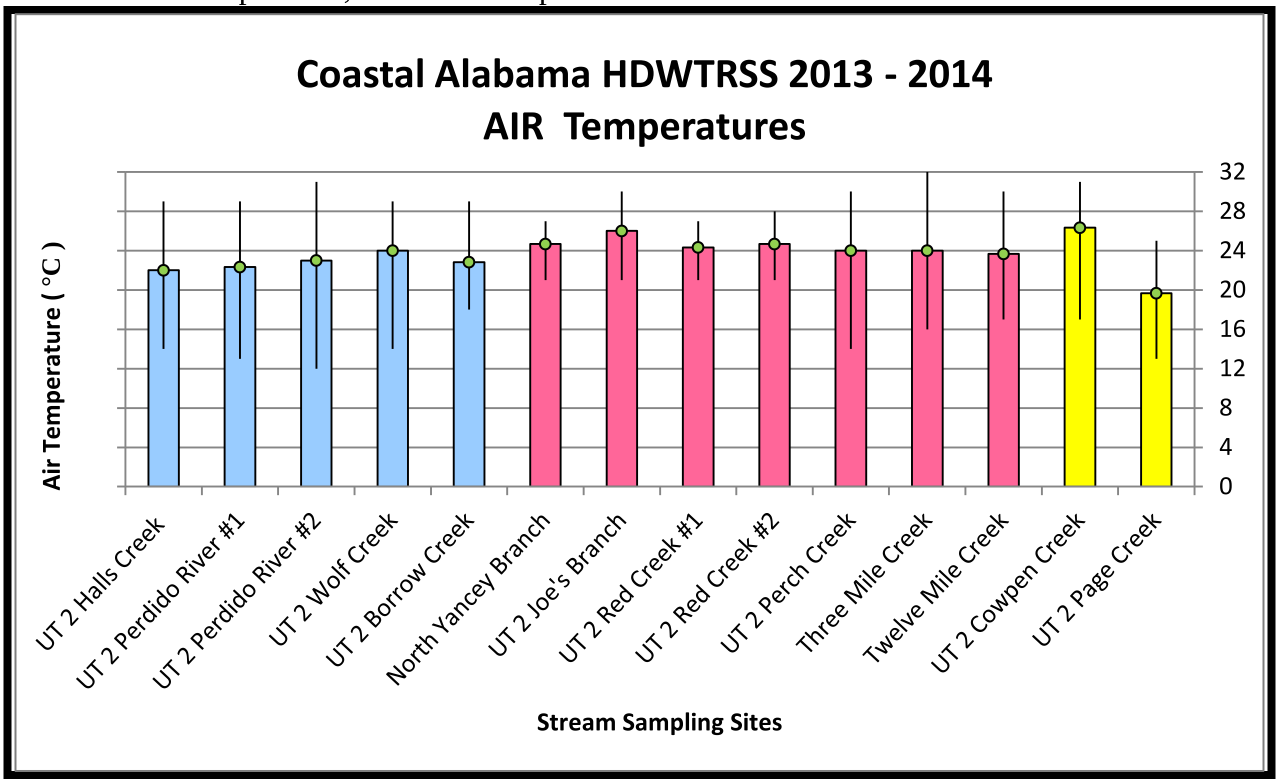


Figure 5. Air Temperature data for HDWTRSS stream sites.

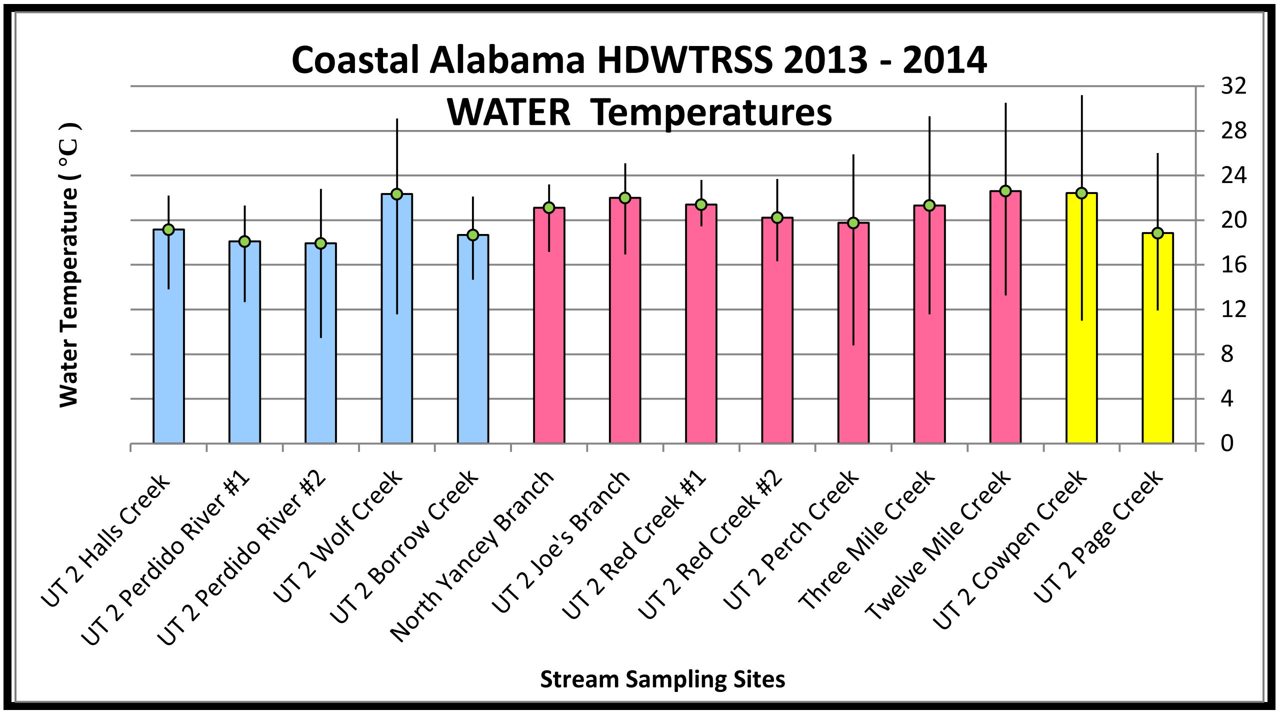


Figure 6. Water Temperature data for HDWTRSS stream sites.

Comparison of Air and Water Temperatures: Averaged Differences (±Δ)

There was no statistically significant difference in the raw temperature data for any of the selected headwater streams sites (see *Tables 3, 4, and 5 above*). The only observable data groupings for the recorded temperature data involved calculating the change (±Δ) of average mean temperature between the water and the air for each site, using the water temperature as the more stable value, minus the air temperature. It is worth noting that the calculated average of the Reference Streams temperature change **(±Δ)** value was slightly larger at -3.60°C (i.e. colder), than the averaged values of the Impacted Urban Streams and the Impacted Agriculture Streams, at -3.27°C and -2.37°C respectively. Although not overwhelming in terms of total temperature, this seems to indicate that the Reference Streams with their more complete forest canopy cover appear to maintain a cooler stream environment.

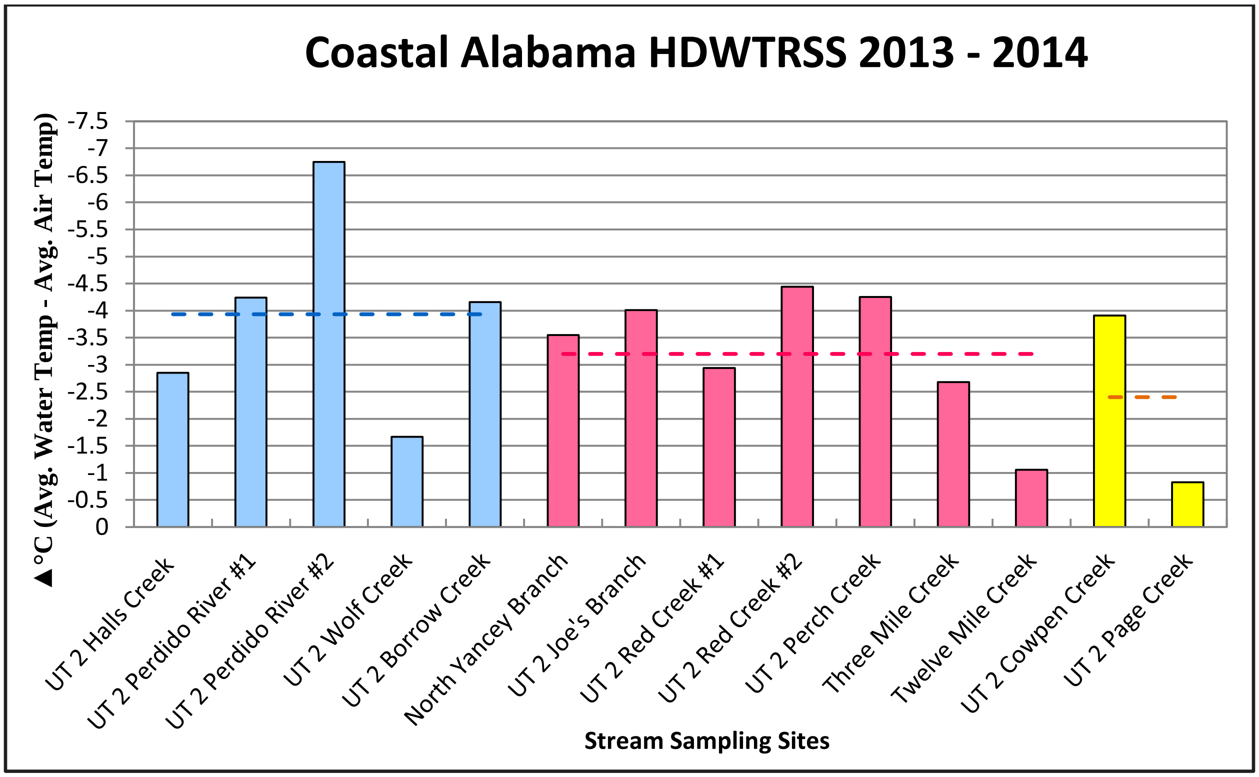


Figure 7. Comparison of Average Site Water-Air ±Δ Temp Graph for HDWTRSS stream sites

The **relative averaged temperature difference (±Δ)** shows that **Impacted Urban Streams were 9% warmer**, while the comparative difference of the **Impacted Agriculture sites** was calculated as being **34% warmer**, when compared to those averaged ±Δ values for these Reference Headwater sites.

Overall Temperature data: Air and Water

Both water and air temperatures for our coastal streams were reflective of the seasonal sampling conditions. The temperatures for all sampled headwater streams were below ADEM regulatory standards for the FISH & WILDLIFE classification, which require that "the maximum for those streams shall not exceed 90°F" (32.2°C). [**ADEM Admin. Code R. 335-6-10-.09(5)(e)3(i)**].

5.3.3 pH:

ADEM 2005 Division 6 Regulations state that for the FISH and WILDLIFE designation to which classification these stream reaches are assigned, "wastes shall not cause the pH to deviate more than one unit from the normal or natural pH, nor be less than 6.0, nor greater than 8.5.**" (ADEM Admin. Code R. 335-6-10-.09 (5).** This statement generally applies to the designated use classifications statewide. However *Alabama's 2014 §303(d) List Fact Sheet* reports that low pH is a natural condition for many native streams that flow across Alabama's Coastal Plain. "Some waterbodies in this sub-ecoregion are blackwater streams. Blackwater streams flow through primarily sandy soils, which tend to be more acidic than upland soils, and are surrounded by trees which produce tannins, such as Pines, Cedars, and Oaks. The tannins and acidic soils tend to make the water pH more acidic."
[see http://adem.alabama.gov/programs/water/wquality/2014AL303dFactSheet.pdf]

Many coastal waterbodies have geographic watershed characteristics that can cause the naturally occurring pH to be lower, at times, than the ADEM numeric criterion. These streams tend to be located in flatland areas, which can cause stream velocity to be slower than normal. Sandy soils, surrounding vegetation that produce tannins and other factors create swampy and backwater stream conditions which tend to make the waters more acidic. This is the natural state of these waterbodies and does not indicate use impairment or impact. (ADEM-Water Division, 2014).

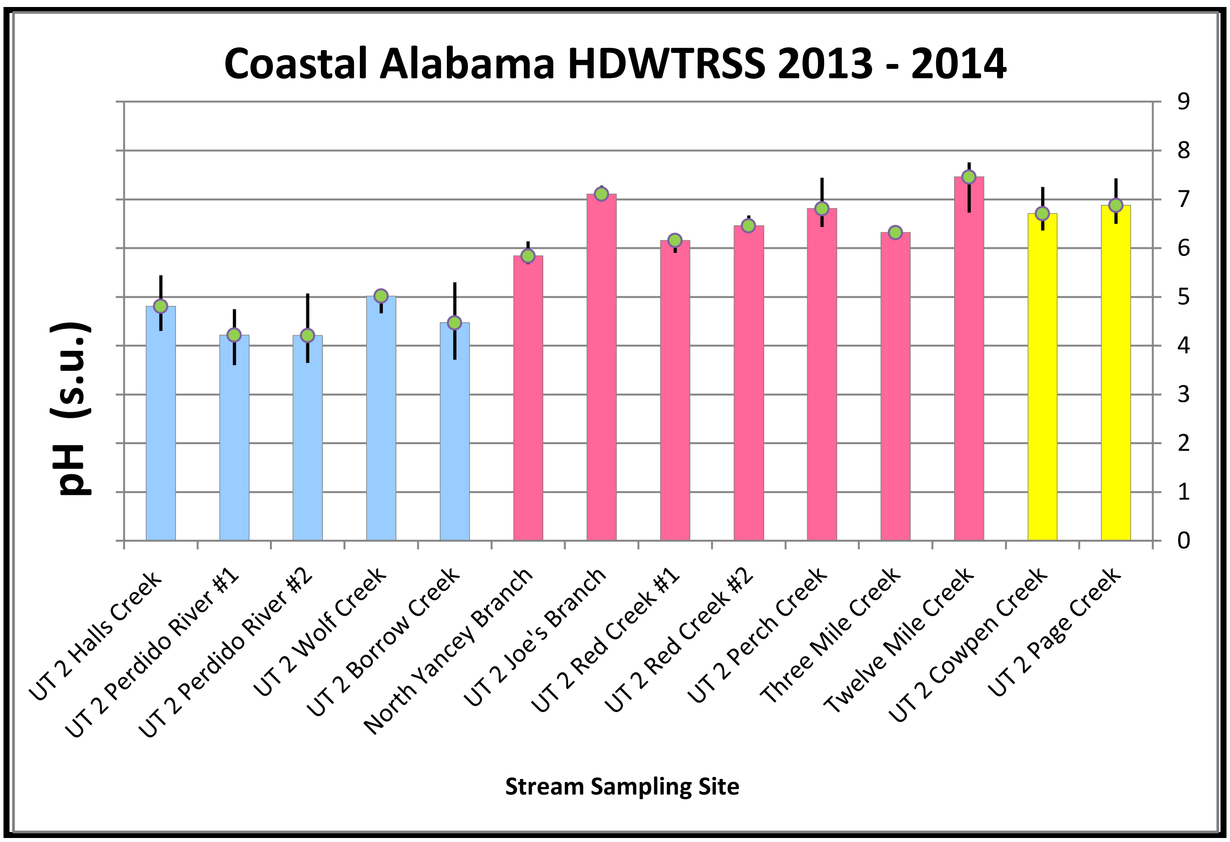


Figure 8. pH at HDWTRSS Stream Sites

Potential Reference Headwater Streams:

The natural watershed landscape for the majority of these headwater Reference Streams were primarily composed of large-parcel legacy pine plantations, with small scatterings of oaks and cedars with large native buffers, largely comprised of a sweet bay-swamp tupelo assemblage that drain across low gradient sandy soils. These coastal Reference Streams exhibited a calculated average **value of 4.55 for pH**. The observed readings ranged from a warm weather low of 3.60 standard units (s.u.), but ranging upwards to a pH of 5.44 s.u. Initial Level I reconnaissance observations and supporting field spectrophotometer readings (AquaFluor® Handheld Fluorometer preliminary tests proved ineffective due to the presence of tannins) from these sites confirmed that the Reference Streams sampled are indeed low pH "blackwater streams", as described. Therefore these coastal streams display natural characteristics of low pH, and are not viewed as impaired due to pH, based on available water quality data and information collected at these selected sites. The averaged value for each Reference Stream site was from **4.21, up to 5.02 s.u.** These streams are classified as "Fish and Wildlife" but as noted will often exhibit these lower pH values that have been adjusted for their local natural conditions. The consistency or grouping of these pH readings is a reflection of the natural environmental factors that are typically associated with these coastal Reference stream reaches.

Impacted Headwater Streams:

These streams averaged significantly higher pHs than those compared with the Reference Streams in this study. The Impacted Streams as a total group averaged at a **pH of 6.63**. This is a substantial **difference of over 2.0 standard units of pH**.

Many factors may account for this, but the most observable components that differ in the more impacted Urban Stream reaches, relate to the ubiquitous presence of limestone, gravel, and concrete-derived structures that would raise the averaged observed **pH to 6.59 s.u.** in these coastal headwater streams. These largely surficial structures are most common throughout more urbanized watersheds. These structures may range from commercial parking areas, residential driveways, and curbing, to stormwater conveyances with box culverts, armoring, gabions, and rip-rap. There were no discernable data clusters within this group.

For the Impacted Streams with surrounding agriculture land use, they exhibited slightly higher values as compared to the Urban Streams. The Agricultural Streams averaged a **pH of 6.79**, also more than 2 s.u. higher than the sampled Reference Stream sites. It is probable that basic soil amendments, associated with agricultural or land use practices surrounding these stream reaches, may play a major role for this upward shift in pH.

Overall pH:

The designated Reference Stream headwater reaches sampled exhibited pH readings that ranged from 3.60 to 5.44, with an overall average of 4.55 for those pH values. Reference Stream sites for this study included the coastal sub-watersheds of Barrow Creek (HUC 31602040103), Halls Creek (HUC 31602040104), Clear Springs Church(HUC 31401060701) and Sandy Creek (HUC 31401070201), within coastal Alabama. Interestingly, the Impacted Stream segments exhibited pH values closer to mid-range, with an average pH of 6.69 s.u. for those segments.

Statistically there was a strong negative correlation between pH and composite score for fall, spring and winter seasons (Spearman's rank correlation, p=0.00003, 0.0004, 0.00045, r=-0.8185, -0.812, -0.809, respectively), indicating the pH declined with increasing composite score.

5.3.4 Dissolved Oxygen

Dissolved oxygen (DO) concentration is an essential constituent that affects the biological health and the chemical composition of surface waters. Biological processes, oxidation, and sediment loads all may contribute to impacts associated with the measurable presence of Dissolved Oxygen in surface water (Murgulet, Cook, 2010).

ADEM 2005 Division 6 Regulations [**CHAPTER 335-6-10]** state that, "In coastal waters, surface dissolved oxygen concentrations shall not be less than (the concentrations stated below)":

SWIMMING AND OTHER WHOLE BODY WATER-CONTACT SPORTS:
5.0 mg/L, except where natural phenomena cause the value to be depressed.
(ADEM Admin. Code R. 335-6-10-.20)

SHELLFISH HARVESTING:
5.0 mg/L, except where natural phenomena cause the value to be depressed
(ADEM Admin. Code R. 335-6-10-.24)

FISH AND WILDLIFE:
5.0 mg/L, except where natural phenomena cause the value to be depressed
(ADEM Admin. Code R. 335-6-10-.27)

OUTSTANDING ALABAMA WATER:
5.5 mg/L, except where natural phenomena cause the value to be depressed
(ADEM Admin. Code R. 335-6-10-.14)

LIMITED WARMWATER FISHERY:
Dissolved oxygen (May--November): treated sewage, industrial wastes, or other wastes shall not cause the dissolved oxygen to be less than **3.0 mg/L**.
(ADEM Admin. Code R. 335-6-10-.29)

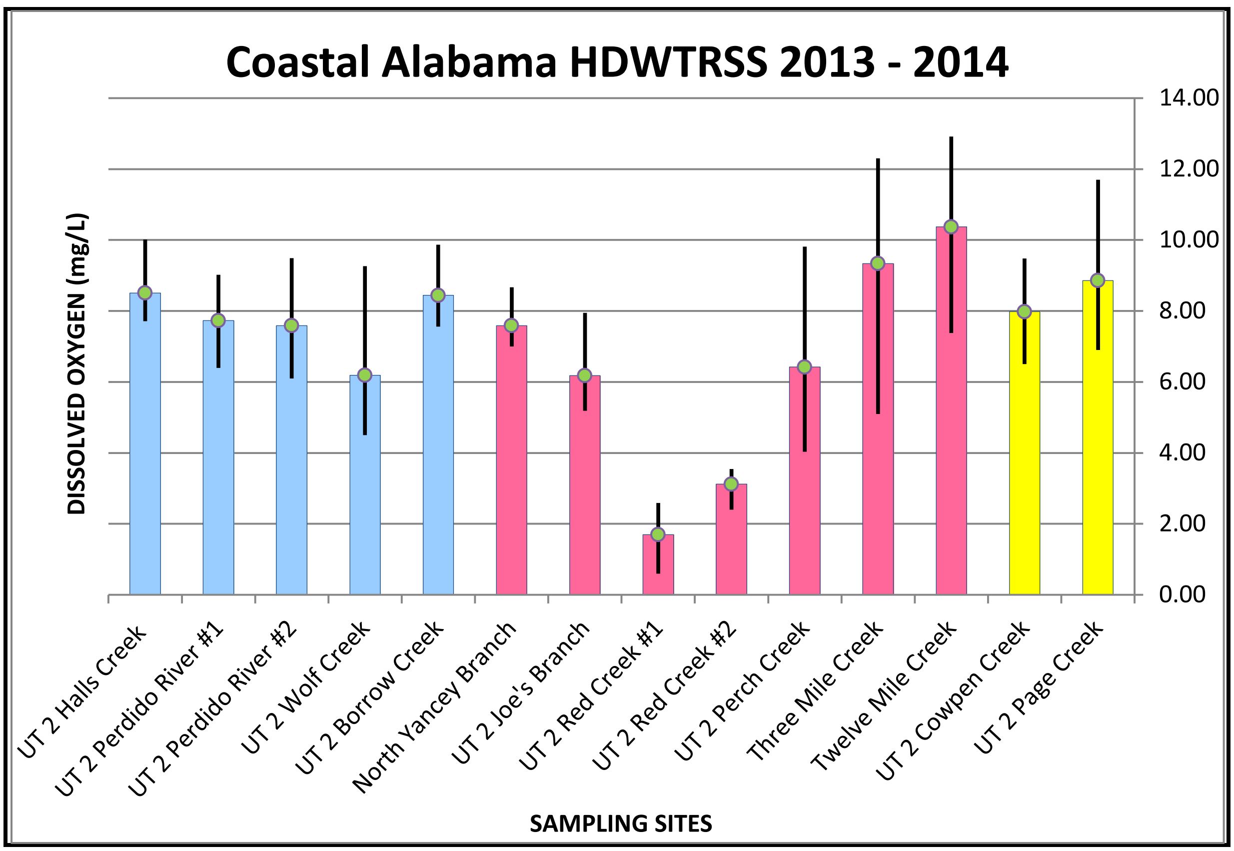


Figure 9. Dissolved Oxygen at HDWTRSS Stream Sites

Potential Reference Headwater Streams:

For this set of *in situ* samplings the Reference Streams exhibited a composite average value of 7.69 mg/L for Dissolved Oxygen. The observed DO readings ranged from warm weather lows of 4.5 mg/L to colder weather readings up to 10.1 mg/L. The averaged value for each Reference Stream site ranged from 6.1 to 8.51 mg/L. This is well within the ADEM Water Quality Standards for these coastal streams, which are classified as "Fish and Wildlife" with a requisite DO range of 5.0 to 10.0 mg/L. The consistency or grouping of these DO readings is a reflection of natural environmental factors typically associated with these Reference Stream reaches.

Although the site averages at 6.19 mg/L, the outlier sample values were below 5.0 mg/L for the UT2 Wolf Creek stream site may be determined by natural conditions. Two factors may have contributed to these lower DO readings: 1.These values were observed during warm weather conditions, as it is the southernmost study site. 2. This stream reach's upstream origins are from a shallow blackwater swamp wetland that has been modified into a small pond. The stream receives the pond's excess surface flow south of Swift Church road. Although those site readings for DO are below standards, other WQ parameters and Assessment scores provide data that allows the relative placement of this stream with our Reference Stream Group.

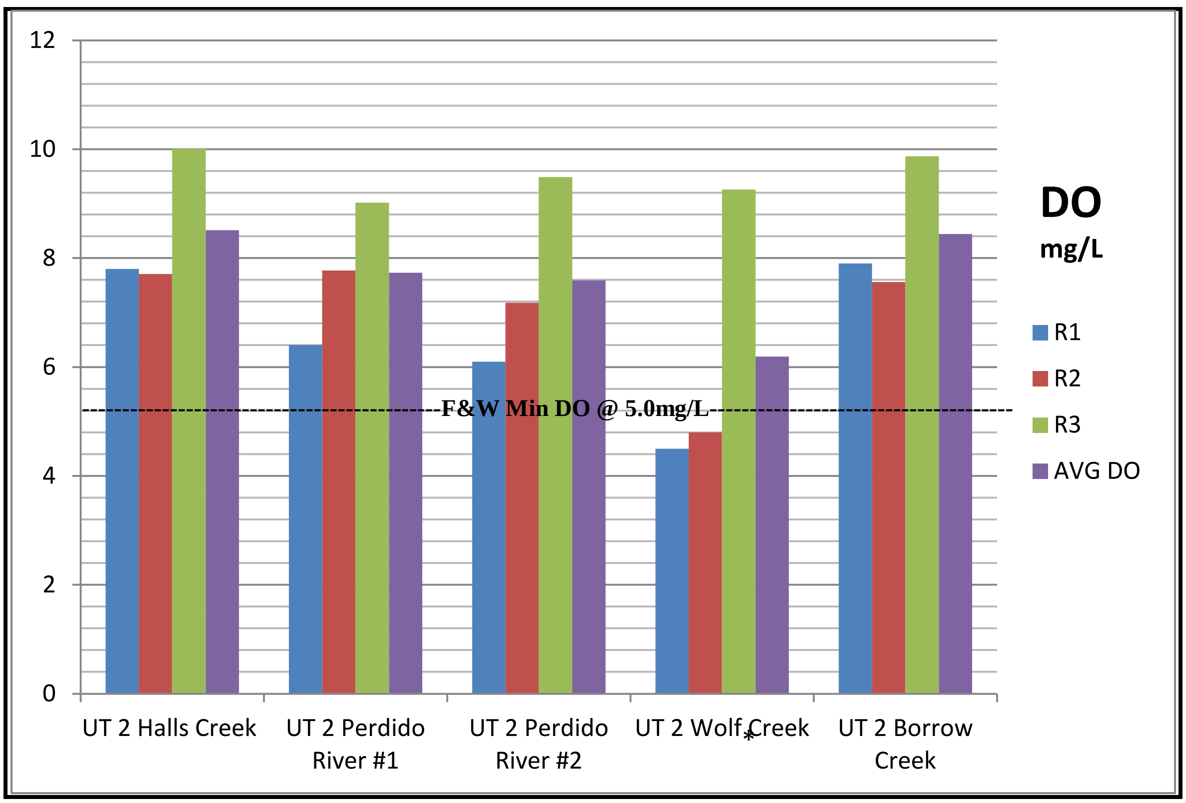


Figure 10. Dissolved Oxygen at HDWTRSS Reference Stream Sites

Impacted Headwater Streams:

For this group of DO data the Impacted Urban Streams exhibited a composite average value of 6.38 mg/L for Dissolved Oxygen. The observed DO readings ranged differently for this group and seemed to display three distinct value sets. Two Urban Streams exhibited very low DO with a total average of 2.45 mg/L. These two streams both appeared to have artesian spring origins with DO readings ranging from 0.6 to 3.55 mg/L. Three Urban Streams with more moderate DO values that averaged 6.73 mg/L, were encompassed within urban sections that had been established with more contiguous vegetative cover along their riparian buffers. The moderate DO group values may be a reflection of those environmental factors. Two Urban coastal streams exhibited rather high DO values with a total average of 9.85 mg/L, with an upper range up to 12.92 mg/L for those sites. The grouping of the DO readings for the low and high groups can be indicators of unstable, flashy urban stream conditions, especially for coastal streams. Accordingly, those urban stream sites with more saturated DO readings, exhibited destabilizing characteristics with obvious evidence of more intensive upstream impacts, e.g. failed armoring with numerous incising headcuts and plunge pools. The DO values for Agriculture Impacted Streams were within normal standards at an average value of 8.142 mg/L.

Overall DO Observations for Headwater Streams:

The Dissolved Oxygen concentrations that were sampled and recorded for the HDWTRSS revealed generally higher DO in cold weather during the R-3Winter sampling, as would be expected. Figure 11 below, reasonably depicts the expected seasonal pattern observed for DO at each of the 14 coastal headwater stream locations.

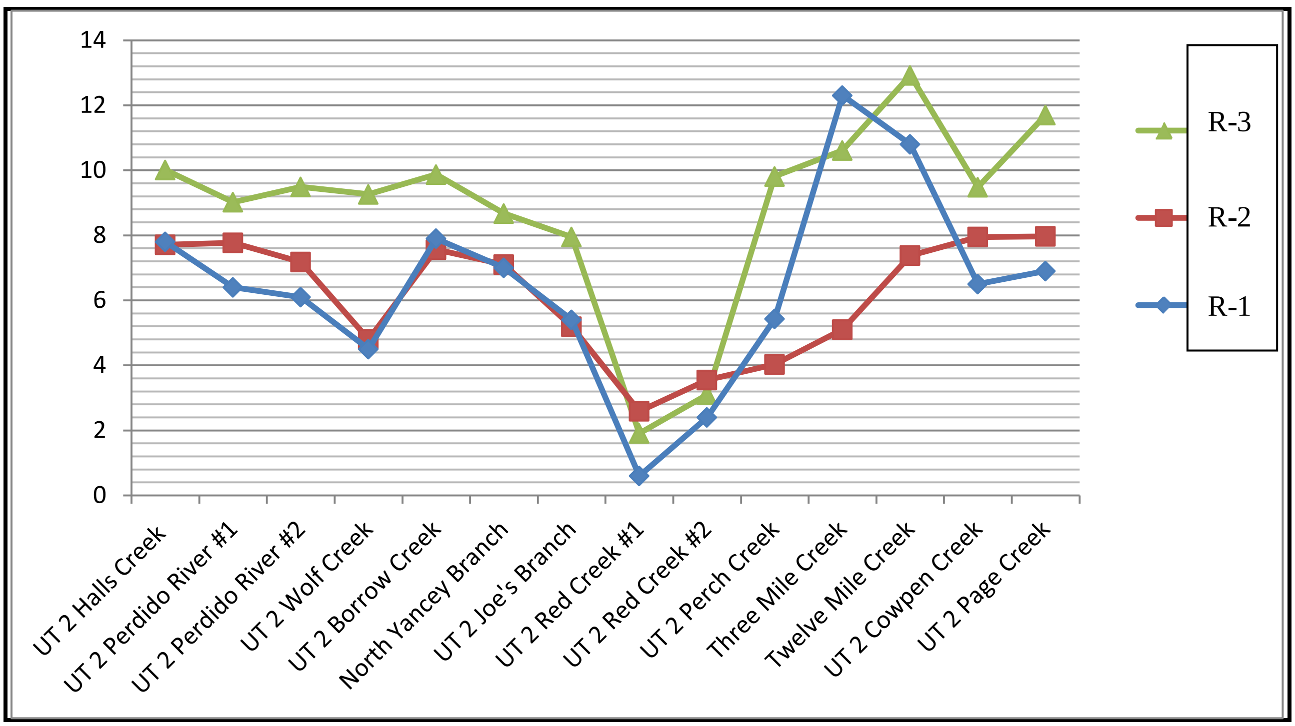


Figure 11. Seasonal Sampling shows the pattern of relative DO measurements from each site.

5.3.5 Salinity

Salinity is a measure of the relative content of mineral salts present in these coastal streams. Salts are highly soluble in surface and groundwater and can be transported with water movement. Salinity is the total of all non-carbonate salts dissolved in water, usually expressed in parts per thousand (1 ppt =1000 mg/L). It provides a direct measure of the relative influence of tidal and freshwater sources. Salinity affects the distribution, abundance and composition of biological resources [http://www.nerrs.noaa.gov/doc/siteprofile/acebasin/html/envicond/watqual/wqintro.htm]. These low salinity values illustrate that these HDWTRSS stream reaches are distinctly above tidal influences.

The ADEM Water Quality Standards provide no limiting values for salinity in these "Fish and Wildlife" designated headwater streams. The observations concerning these parameters are based upon their relative values, which were **all recorded below 0.2 ppt, or 20 mg/L**.

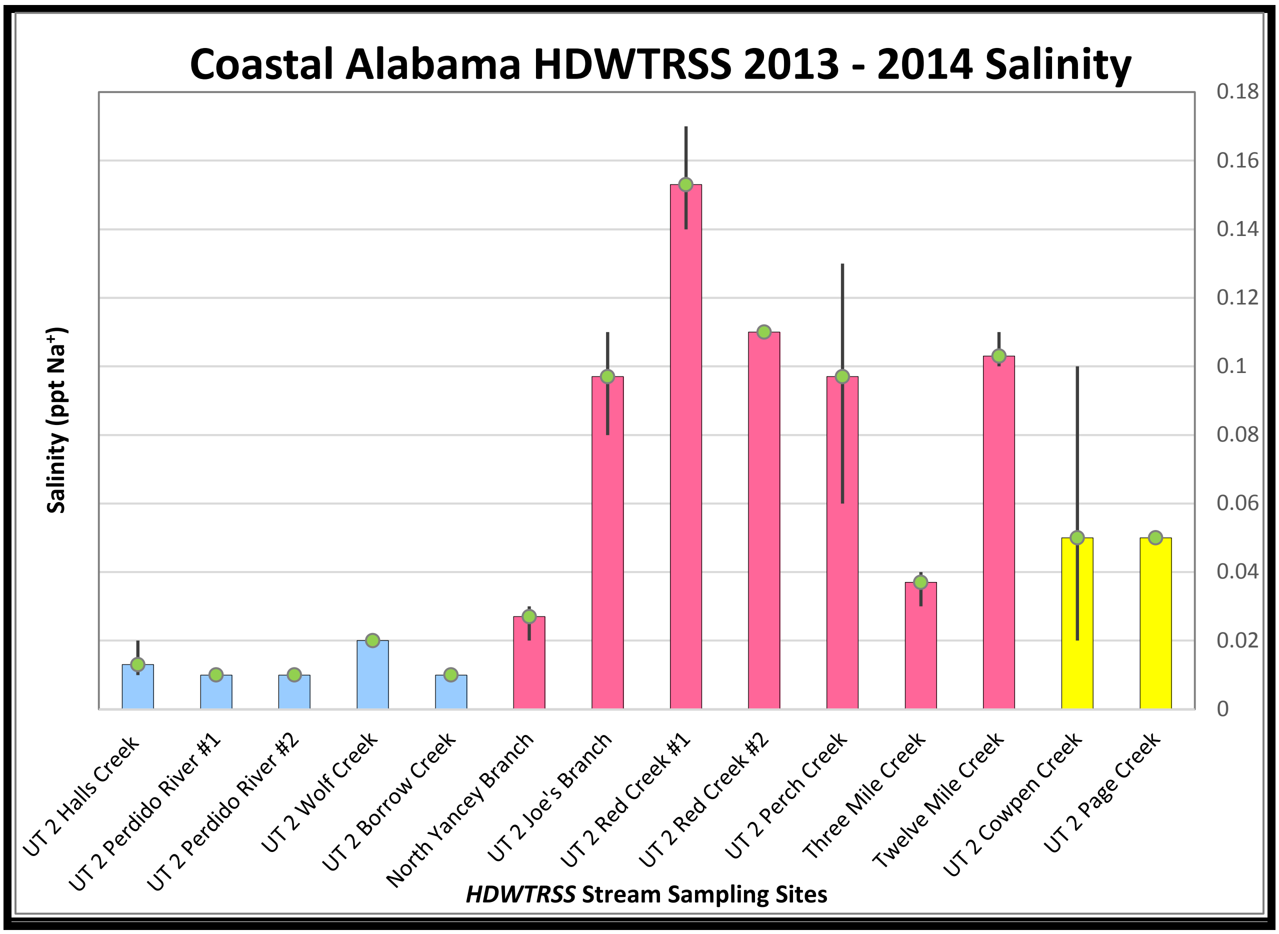


Figure 12. Salinity at HDWTRSS Stream Sites

Potential Reference Headwater Streams:

The consistency or grouping of these Salinity readings for the sampled Reference Stream sites are a reflection of natural environmental factors and minimal LUC impact effects associated with these stream reaches. The salinity readings for these selected headwater streams were observed within 0.01ppt to 0.02ppt.

Impacted Headwater Streams:

For this Impacted Urban Streams group the averaged salinity values were reported at 0.085ppt. Interestingly, they exhibit a larger value than the Impacted Agriculture steam sites sampled, which averaged salinity values at 0.05 ppt.

Overall Salinity Observations for Headwater Streams:

Based upon their relative values, the HDWTRSS sites exhibit expected differences for salinity. The raw data show rather low salinity values, as would be expected for these headwater streams. The Reference Streams data exhibited extremely low values for salinity, their combined average being less than 0.02 ppt. The Impacted Agriculture sites were observed to have an increased average of 0.03 ppt. The Impacted Urban sites averaged data showed a comparative increase of 0.065 ppt relative to the Reference Stream salinity data. These LUC-associated differences are further substantiated in the Specific Conductivity data reviewed below, in section 5.3.6.

Salinity was significantly different among stream types in all three seasons evaluated (Kruskal-Wallis rank sum test, p=0.009, 0.009, 0.007) with median values ranging for Agriculture from 0.035 – 0.75, Reference 0.01 average, and Urban streams 0.08 – 0.11 ppt.

5.3.6 Conductivity

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity in water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity [http://water.epa.gov/type/rsl/monitoring/vms59.cfm]. When conductive compounds or elements are present in surface and groundwater, they are easily transported in these primary headwater streams. Conductivity for the HDWTRSS project were measured in micromhos per centimeter (µmhos/cm) using a datasonde unit. The datasonde unit utilizes a temperature compensated specific conductivity probe for the measurement of *in situ* conductivity automatically corrected to 25°C. A good frame of reference is to evaluate the Conductivity of distilled water, which has Conductivity in the range of 0.5 to 3.0 µmhos/cm.
[http://web-server/intranet/QA/sop/pdfs/SOP%202000/SOP2041.pdf]

The ADEM Water Quality Standards provide no limiting values for Conductivity in these “Fish and Wildlife” designated headwater streams. The HDWTRSS observations concerning these parameters can be grouped by LUC-associated groupings, based upon their *in situ* values, which **ranged widely from 22.0 µmhos/cm, up to 353.0 µmhos/cm.**

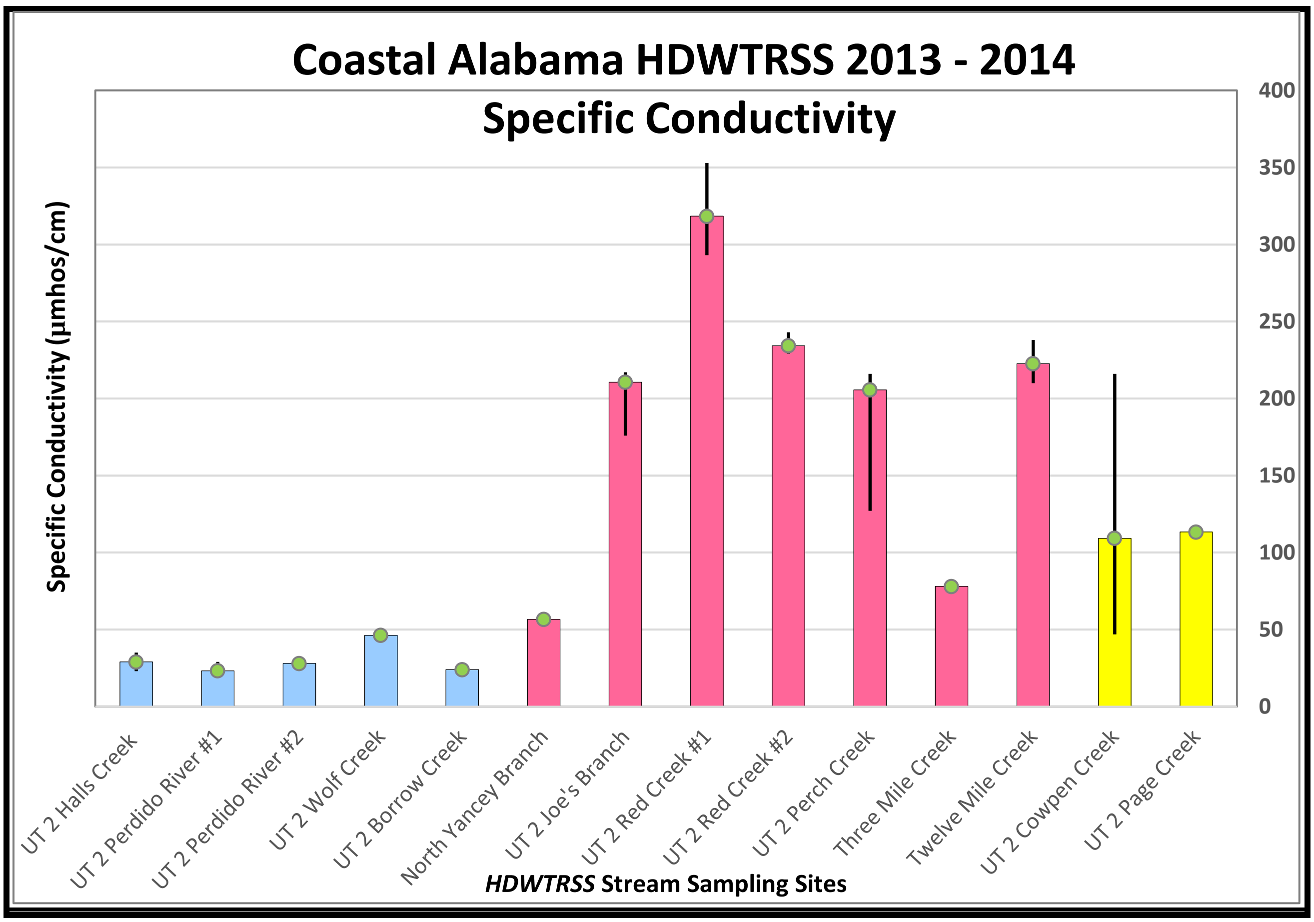


Figure 13. Specific Conductivity at HDWTRSS Stream Sites

Potential Reference Headwater Streams:

The averaged Conductivity readings for these Reference headwater streams were **calculated at 30.13 µmhos/cm**. Similar to other WQ data, the consistency of the Conductivity readings for the sampled Reference Stream sites seem to correlate to more natural environmental conditions, with minimal observed LUC impact effects.

Impacted Headwater Streams: Urban and Agriculture

For this **Impacted Urban Streams** group the averaged Conductivity values were reported at **189.48 µmhos/cm.** Again, the Impacted Urban headwater steams exhibit a larger value than the **Impacted Agriculture** steam sites sampled, which averaged Conductivity values at **111.33 µmhos/cm.** These comparisons are more dramatic in terms of basic unit of measure.

Overall Specific Conductivity

Based upon their averaged Conductivity values, the HDWTRSS sites exhibit expected differences similar to those noted for salinity. The Conductivity data show a larger contrast between the attributed LUC groupings. The **Reference Streams data exhibited lower Conductivity readings**, with their total average being at 30.13 µmhos/cm. The **Impacted Agriculture** sites recorded an increased average Conductivity at 111.33 µmhos/cm.

The Conductivity of the Agriculture stream sites yielded increased values that were **370%, larger** than the Reference Group headwater stream data. The **Impacted Urban** stream sites' averaged data (189.48 µmhos/cm) showed a comparative **increase of almost 630%**, relative to the averaged Reference Stream group data.

Based upon the field observations at the headwater stream project sites, these differences for Conductivity measurements are strong indicators of the impacts associated with more intensive land uses. It is probable that the increase in stream Conductivity values correlate with the increased percentage of impervious surfaces and associated land cover, and resulting increased runoff within the drainage of each headwater stream reach.

Specific conductance was significantly different among stream types in all three seasons evaluated (Kruskal-Wallis rank sum test, p=0.0102, 0.007, 0.008) with median values ranging for Agriculture from 82-165, Reference 23-29, and Urban streams 117-229 µmhos/cm.

5.3.7 Turbidity

Turbidity was selected for the HDWTRSS project to provide a comparable functional field measure of suspended solids that are transported by these headwater coastal streams. These suspended solids may include a varied assortment of materials, both organic and inorganic. Many principal pollutants associated with stormwater runoff into these streams may be suspended in the water column (USEPA, 1993). Suspended particles may serve as substrates for other pollutants such as pathogens and some heavy metals; thereby high Turbidity readings may indicate many problems for water quality. **Turbidity is measured in Nephelometric Turbidity Units (NTU)**, as the amount of light scattered from a sample making it a measure of the cloudiness or murkiness of the water column. Turbidity may be best described as a function of total suspended solids present in the water column. High Turbidity readings indicate a reduction in the amount of light that penetrates the water; and furthermore are indicative of high concentrations of sediment and particles that may impart negative effects on aquatic systems, both physically and biochemically (NSCU, 1994). **ADEM Admin. Code R. 335-6-10-0.9(5)(e)9 (pg 10-29) states that "**there shall be no turbidity of other than natural origin that will cause substantial visible contrast with the natural appearance of waters or interfere with any beneficial uses which they serve. Furthermore, in no case shall turbidity exceed 50 NTUs above background."

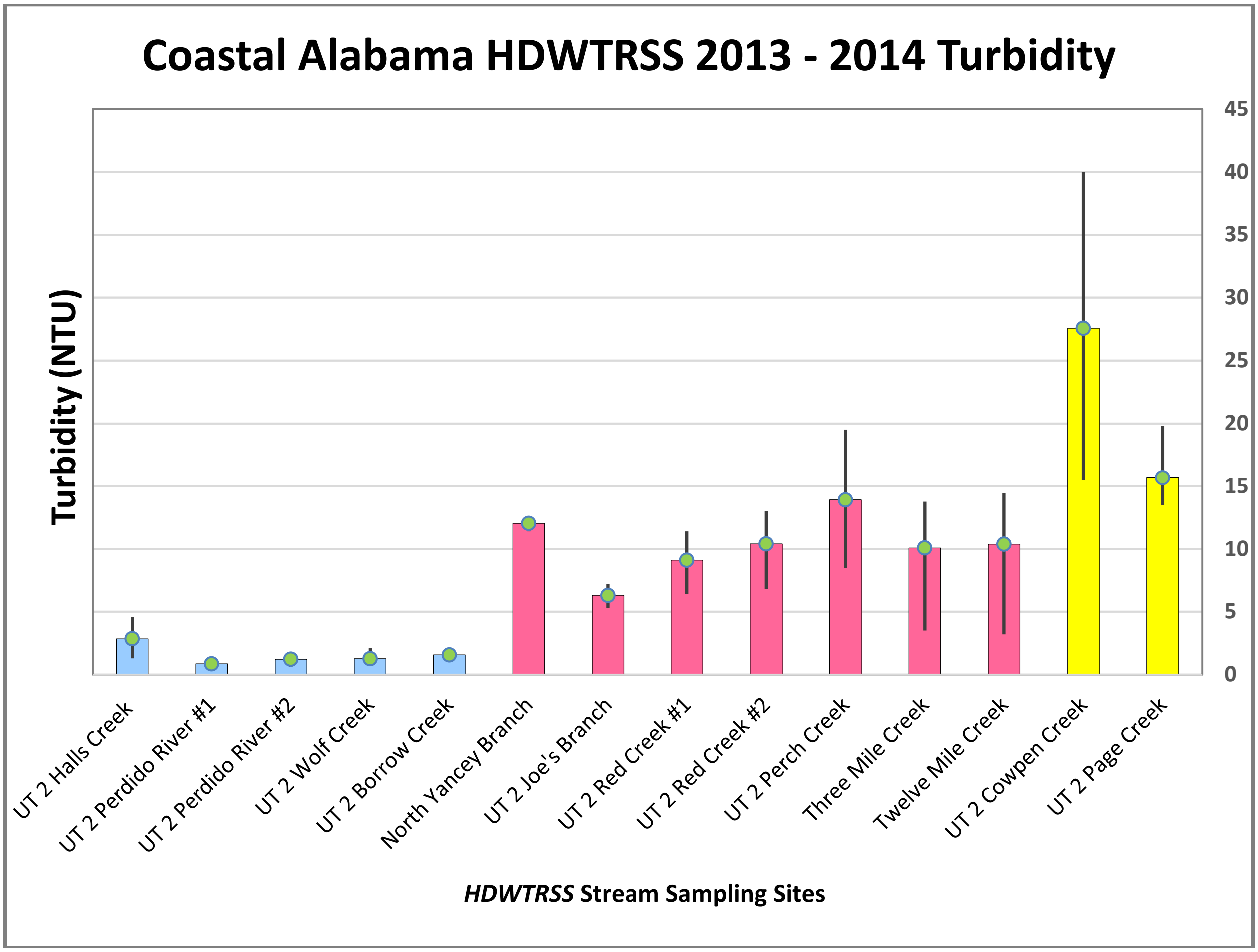


Figure 14. Turbidity at HDWTRSS Stream Sites

Potential Reference Headwater Streams:
These *HDWTRSS* Reference Streams exhibited a composite average **value of 1.56 NTU for Turbidity**. The observed readings ranged from a low of 0.6 NTU, up to a Turbidity of 4.6 NTU*. The consistency or grouping of the Reference Streams Turbidity data seem to indicate more stable environmental factors, with minimal LUC impact effects associated with these Reference stream reaches.
*this event was above normal UT2Hall Creek baseflow due to an unknown rain event within the standard precipitation interval.

Impacted Headwater Streams: Urban and Agriculture
These Urban Headwater streams averaged significantly higher Turbidity compared with the Headwater Reference Streams in this study. The Urban-Impacted Streams as a group averaged a **Turbidity of 10.31 NTU**. This is a substantial and significant **increased difference of over 660%**. Many factors may account for this, but the most observable components that differ in these more impacted Urban Stream headwater reaches, usually relate to the substantial amounts of impervious surface, reduced canopy, and alteration or hydromodification of coastal stream reaches. These impacts usually create major changes in the hydrology, increasing erosion and sedimentation, and making these streams relatively unstable. There were no discreet data clusters within the Impacted-Urban Stream group.

For those headwater streams sampled that had agriculture-related land use, the increase was even more dramatic, at an **average of 21.62 NTU, yielding an increase of over 1385%,** as compared with the HDWTRSS Reference streams. The observed characteristics that are most apparent for these impacted rural, agricultural headwater streams relate to almost complete removal of the tree canopy along the riparian zone with scant vegetative buffers, along with intensive hydromodification impacts using mis-applied BMP practices. These impacts seem to promote conditions that may cause relative instability of these headwater stream reaches. There may be opportunities to promote agricultural awareness of lower impact BMPs or practices (e.g. cross-fencing to provide or protect vegetative riparian buffers, and proper alignment and placement of stream culverts at road crossings).

Overall Turbidity
None of these HDWTRSS streams sampled within the ACNPCP Management Area exhibited Turbidity readings that exceeded the State regulatory limits for these parameters.

Turbidity was significantly different among stream types in all three seasons evaluated (Kruskal-Wallis rank sum test, p=0.009, 0.005, 0.004) with median values ranging for Agriculture from 14.5 – 29.9, Reference 1.2 – 1.3, and Urban streams 9.5 – 12.6 NTU.

6. FINAL *HDWTRSS* DATA

More than 200 tabletop mapping sites were identified as potential sites, and were field verified, during the Pilot Headwater Stream Survey conducted through September 2012. Of the 200 sites considered, field visits determined that only 144 sites were recognized as potential headwater stream systems with the remainder of the sites being found to have been obliterated or have non-existent channel features (see Appendix I for all streams documented).

Based on the 144 sites identified during the Level I Inventory, very few were selected for the final Level II stream survey assessment. Many of the sites were either not perennial in nature or there was too much disturbance upstream and downstream of the study reaches. During Level II survey, additional sites that met the necessary minimum characteristics were identified for inclusion into this study. A total of 14 sites (listed in Table 6 below) were ultimately selected for this study and they were observed and placed in 4 potential categories: Reference or Impacted, Rural or Urban; with resulting designations for Impacted Urban Streams and Impacted Agriculture Streams being grouped for comparison with the designated Reference Streams in this study.

Final Geomorphic Field Headwater Stream surveys were conducted between March 2013 and August 2013 in Baldwin and Mobile Counties. Most of the omitted field sites were hydrologically limited by not having permanent water flow year round. Other sites were impacted by channelization or upstream land use impacts (i.e., agriculture ditches and drainages) along with lack of visible evidence of channel features. There were a few sites impacted by sedimentation from unpaved roads and many were swampy in nature due to beaver activity or an extremely low gradient.

ADEM Water Quality Headwater Stream field sampling was initiated concurrently with the Geomorphic Survey work, but continued forward to collect seasonal site parameters into February of 2014.

6.1 *Selected HDWTRSS Stream Sites*

These were the 14 coastal headwater stream sites that were selected for the 2013 Coastal Alabama Pilot Headwater Stream Survey Study:

Table 6. Level II Inventory Sites during the 2013 Field Survey.

SITE NAME	HUC #	HUC NAME	TYPE	COUNTY
UT 2 Borrow Creek	31602040103	Farris Creek-Barrow Creek	R/Ru	Mobile
UT 2 Halls Creek	31602040104	Little Halls Creek-Halls Creek	R/Ru	Baldwin
UT 2 Perdido River #1	31401060701	Clear Springs Church-Perdido River	R/Ru	Baldwin
UT 2 Perdido River #2	31401060701	Clear Springs Church-Perdido River	R/Ru	Baldwin
UT 2 Wolf Creek	31401070201	Sandy Creek-Wolf Creek	R/Ru	Baldwin
North Yancey Branch	31602050205	Fly Creek	I/U	Baldwin
UT 2 Joe's Branch	31602040505	Tensaw River-Apalachee River	I/U	Baldwin
UT 2 Red Creek #1	31602040304	Red Creek-Eight Mile Creek	I/U	Mobile
UT 2 Red Creek #2	31602040304	Red Creek-Eight Mile Creek	I/U	Mobile
UT 2 Perch Creek	31602050103	Lower Dog River	I/U	Mobile
UT 2 Three Mile Creek	31602040504	Toulmins Spring Branch-Three Mile Creek	I/U	Mobile
Twelve Mile Creek	31602040504	Toulmins Spring Branch-Three Mile Creek	I/U	Mobile
UT 2 Cowpen Creek	31602050204	Lower Fish River	I/Ru	Baldwin
UT 2 Page Creek	31700080405	Spring Creek-Escatawpa River	I/Ru	Mobile

Key to observed **TYPE**: R/Ru = Reference/ Rural, I /U=Impacted/Urban, I/Ru=Impacted/Rural,
I/Ru was later changed to Impacted/Agriculture.

6.2 *HDWTRSS Stream Geomorphology*

6.2.1 Geomorphic Conditions for Selected Headwater Streams

Stream survey sites ranged in drainage area from 0.1 to 2.3 sq.mi. with reference sites selected for a maximum drainage area of 1.0 sq.mi. each. These project stream sites exhibited an impervious surface area percentage for each watershed (12-digit HUC) ranging from a minimum of 0.0% to a maximum of 47.8% (see Table 7). This provides an interesting contrast to the Land Use/Cover Assessment scores presented in Table 8 below, which are based upon the surrounding LUC estimated within the 500ft. radius for each coastal headwater stream site.

There were five reference reaches surveyed, with four being in Baldwin County and one in Mobile County. A total of seven sites were located in rural settings and the remaining five were from urban landscapes. Reference data showed a good distribution of channel sizes (i.e., bankfull width, depth and cross sectional area), along with gradient variations (i.e., 0.003 to 0.034 ft/ft) and channel pattern (Table 2). Most of the sites were classified as being E stream types with several from C and two from B types. Channel bed material was collected at each site and ranged from very fine material (i.e., clay) to coarse substrates (i.e., gravel). Even though many of the surveyed sites had sand as their primary particle size distribution, protrusion heights were collected from 7 of the 14 streambed sites to improve bed roughness calculations and bankfull discharge. Protrusion heights from the remaining seven sites were not collected due to a lack of features to measure, or material sizes that were greater than 2.0 mm.

Statistically there are strong positive correlations between channel sinuosity and composite score (Spearman's rank correlation, $p = 0.0003$, $r = -0.8185$), indicating greater channel sinuosity with a greater composite score.

Table 7. Geomorphic Stream Characteristics for the Level II study.

HDWTRSS Stream Site	Drainage Area (mi^2)	Bankfull Width (ft)	Bankfull Depth (ft)	Bankfull Cross-Sectional Area (ft^2)	Channel Material D_{50} (mm)	Water Surface Slope (ft/ft)	Channel Sinuosity	Stream Type	Impervious Cover (%) [HUC]
UT 2 Borrow Creek	0.1	7.08	0.86	6.06	15.3	0.01678	1.53	E4/5	0.0
UT 2 Halls Creek	0.5	4.97	0.77	3.85	4.99	0.00360	1.53	E4/5	0.1
UT 2 Perdido River #1	0.5	7.26	1.08	7.85	20.16	0.00365	1.30	E4/5	0.3
UT 2 Perdido River #2	0.9	6.00	1.15	6.87	19.3	0.00485	1.44	E4/5	0.3
UT 2 Wolf Creek	0.2	4.99	0.42	2.1	8.07	0.01321	1.33	E4/5	0.8
UT 2 Joe's Branch	0.1	8.22	0.74	6.05	33.3	0.03411	1.24	B4	47.8
North Yancey Branch	0.6	9.79	1.13	11.05	0.5	0.0035	1.48	E5	7.1
UT 2 Red Creek #1	0.2	4.10	0.18	0.72	0.5	0.00431	1.05	C5	2.7
UT 2 Red Creek #2	0.2	9.87	0.60	5.9	0.5	0.01265	1.29	C5	4.7
UT 2 Perch Creek	0.1	6.65	0.69	4.61	0.5	0.00426	1.17	E5	28.5
UT 2 Three Mile Creek	2.3	10.06	0.72	7.28	0.5	0.00508	1.11	C5	10.6
Twelve Mile Creek	2.1	19.74	1.46	28.77	270	0.01118	1.03	B2c	18.8
UT 2 Cowpen Creek	0.2	10.27	0.74	7.64	4.99	0.00314	1.04	C4/5	0.1
UT 2 Page Creek	0.1	6.86	0.50	3.44	0.062	0.00827	1.07	C6	0.2

6.2.2 HDWTRSS Reference Geomorphology and the Coastal Alabama Regional Curve

Figure 15 and ***Figure 16*** below, depict geomorphic reach data that is detailed in ***Appendix III*** for the 5 Reference reaches sites surveyed during this study. These five reference sites were compared with the *Alabama Riparian Reference Reach and Regional Curve* (Alabama Curve) study to determine applicability with enhancing overall curve development (USFWS, 2005).

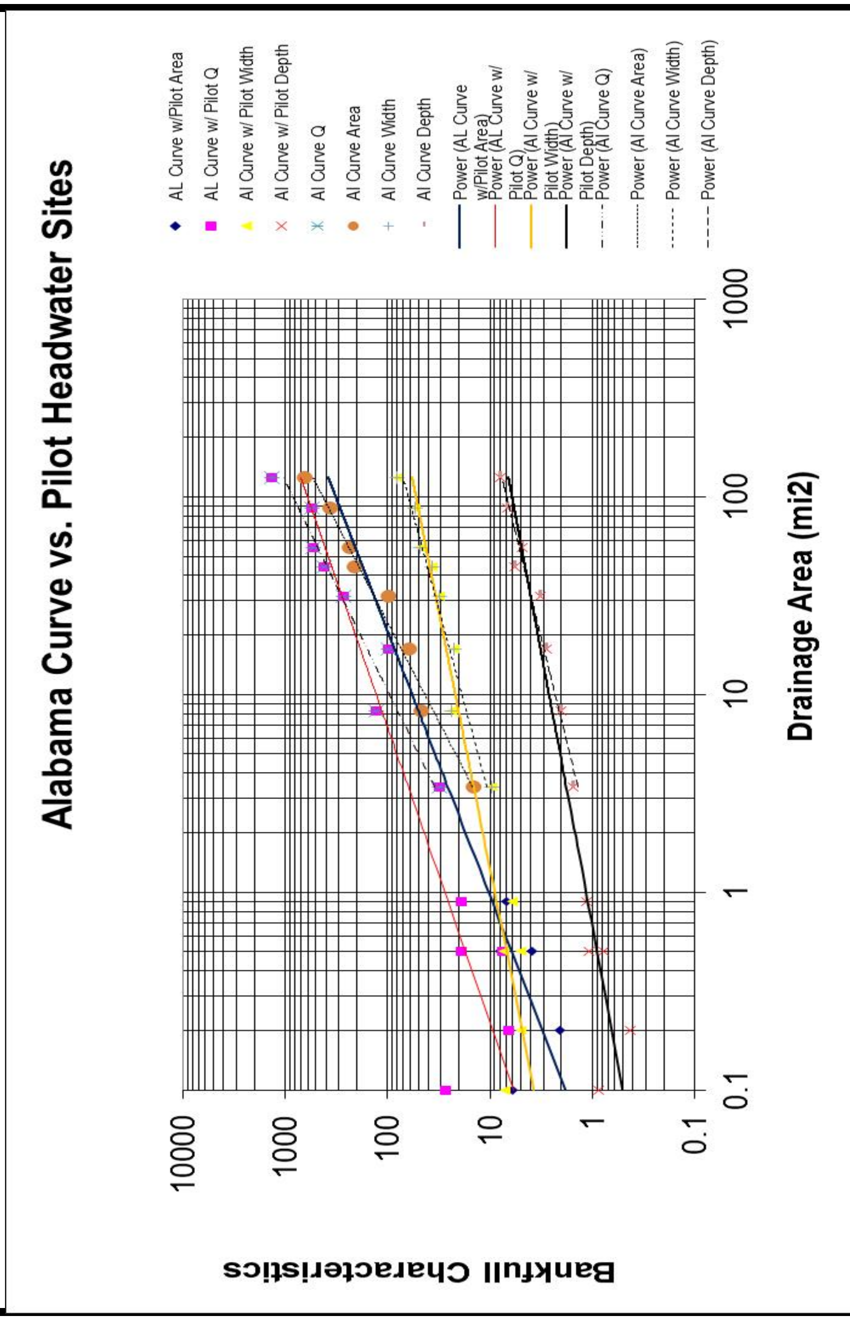
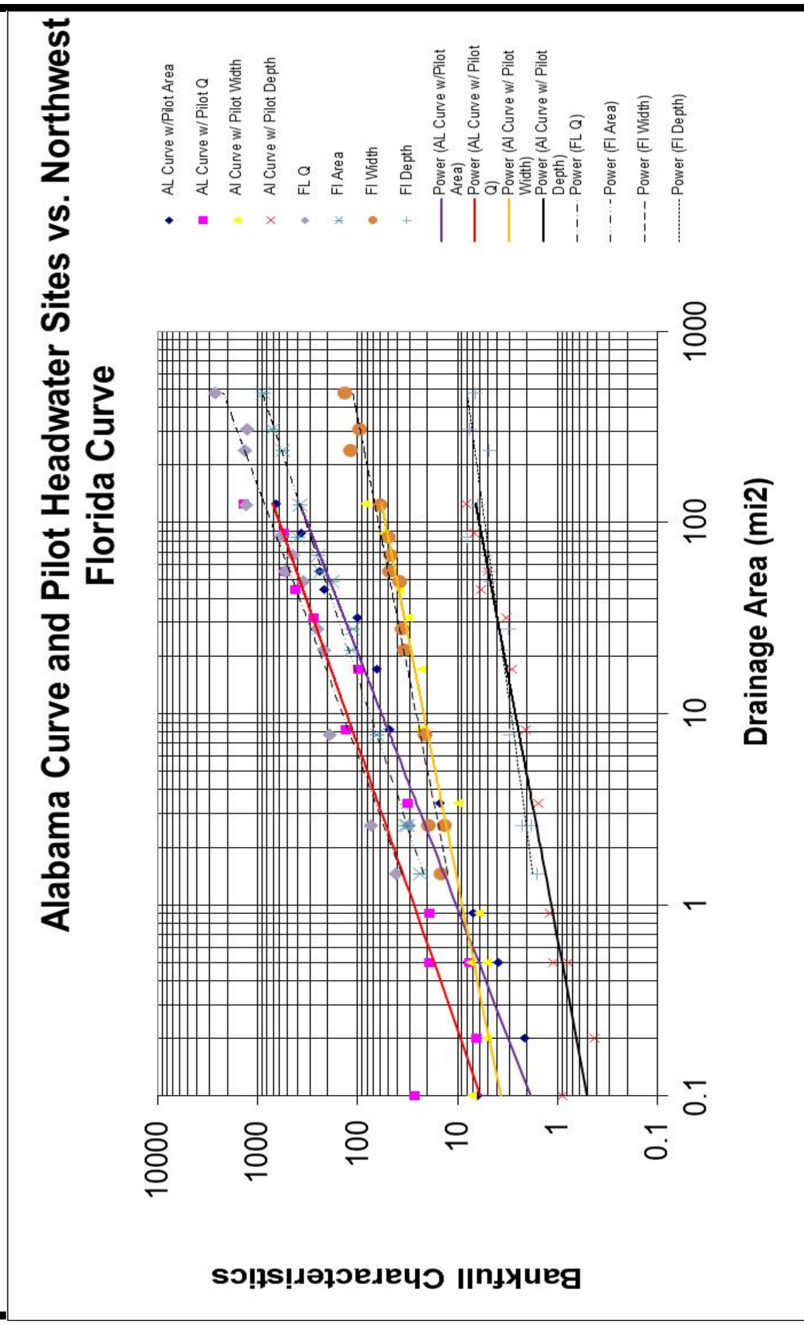


Figure 15. Alabama Curve vs. HDWTRSS Sites

Five reference sites were incorporated into the Alabama Curve and showed significant changes to the lower portion of the curve (Figure 15). In fact, when compared with the Northwest Florida Regional Curve, the Alabama Curve looks very similar (Figure 16). For bankfull discharge and width, the two curves were almost identical. Bankfull depth was only slightly smaller while the bankfull cross-sectional area was generally lower through the lower drainages.

Figure 16. Coastal Alabama Curve and HDWTRSS Reference Sites vs. Northwest Florida Curve Sites



6.3 *HDWTRSS* Project Assessments Data

These *HDWTRSS* Assessments were conducted thoroughly by the ADEM *HDWTRSS* team for each selected headwater stream site prior to the Geomorphic Surveys. Any additional information needed was observed and recorded during the R1- Spring/Summer sampling. The *HDWTRSS* Assessment forms utilized are included in ***Appendix II***. Because several of the coastal headwater stream site assessments were conducted on private lands the *HDWTRSS* Assessment Sheets may contain sensitive Personally Identifiable Information (PII); therefore, the information collected in the Assessments is presented in Table 8 below with the PII omitted.

Table 8. *HDWTRSS Site Assessment Data*

Coastal Alabama HDWTRSS		STREAM SITE ASSESSMENT SCORES				Composite HDWTRSS Assessment Index
Site Names	Canopy	Land Use/Cover	NC Stream 4.0	ADEM Habitat	AL Coastal HDWTR	
UT 2 Halls Creek	0.8038	0.865*	0.752	0.9208	0.9267	**0.854**
UT 2 Perdido River #1	0.9338	0.937*	0.720	0.9333	0.960	**0.897**
UT 2 Perdido River #2	0.880	0.887*	0.712	0.9125	0.910	**0.860**
UT 2 Wolf Creek	0.965	0.935*	0.705	0.9583	0.948	**0.902**
UT 2 Borrow Creek	0.936	0.870*	0.7626	0.9625	0.981	**0.902**
North Yancey Branch	0.8438	0.500*	0.748	0.7083	0.760	**0.712**
UT 2 Joe's Branch	0.875	0.450*	0.694	0.908	0.928	**0.771**
UT 2 Red Creek #1	0.840	0.300*	0.475	0.5542	0.606	**0.555**
UT 2 Red Creek #2	0.860	0.360*	0.629	0.5833	0.772	**0.640**
UT 2 Perch Creek	0.0125	0.230*	0.6475	0.529	0.525	**0.388**
Three Mile Creek	0.0262	0.354*	0.7266	0.5917	0.5856	**0.456**
Twelve Mile Creek	0.020	0.200*	0.795	0.3208	0.366	**0.340**
UT 2 Cowpen Creek	0.0762	0.55*	0.5035	0.554	0.523	**0.440**
UT 2 Page Creek	0.000	0.585*	0.475	0.333	0.507	**0.380**

* GIS Review Completed

Composite assessment scores showed a highly significant difference among stream types (Kruskal-Wallis rank sum test, $p=0.0082$) with median values of 0.410, 0.897, 0.555 for Agricultural, Reference, and Urban stream groups respectively.

7. SUMMARY and CONCLUSIONS

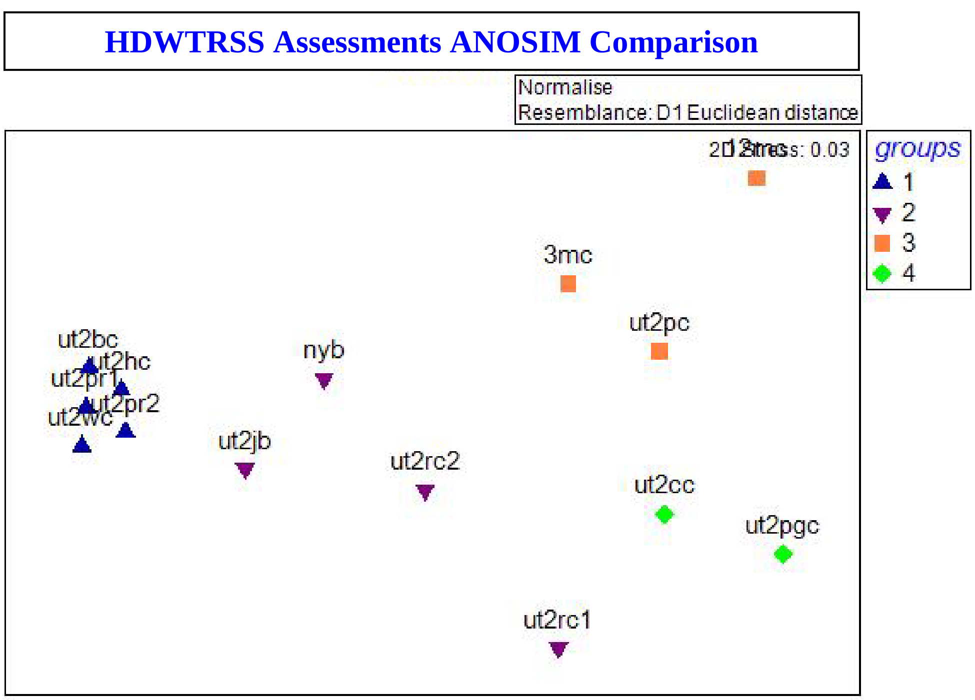
This Level II phase of the survey project was completed in FY2013 with additional WQ and QA/QC conducted by the Department in 2014, which included the 14 sites designated as meeting the criteria for inclusion in this comparative process. The primary focus of the *Coastal Alabama Pilot Headwater Streams Survey and Study* was to evaluate differences in Land-Use and Land-Cover conditions relative to those stream reach geomorphic and water environments. This project would evaluate streams relative to the observed habitat assessments and recorded water quality conditions for each selected stream site. The selection of designated “Reference Streams” was based upon determining the associated LUC impacts and the relative estimation of observed onsite conditions for those selected coastal headwater streams. A comparison of the 5 proposed ‘reference sites’, along with 9 ‘more impacted’ sites, was of particular interest for the implementation of this study.

As stated previously one of the envisioned objectives of this HDWTRSS project is the eventual development of a full spectrum tool for comparative headwater stream assessment. This project provided the selection of concise functional tools that would evaluate and inform this process, allowing science-based development of an accurate Coastal HDWTRSS Comparative Assessment Index. This project provides good information that should allow further development of this preliminary tool, so that it may be more precisely calibrated, ecologically for this region.

7. 1 HDWTRSS Sites Grouping: Analysis With PRIMER

Originally proposed as the possible Reference Sites assemblage for the HDWTRSS Project and based upon the results of the following statistical analysis for those streams, the Group 1 waterbodies are shown to exhibit relatively distinct data quality characteristics, both in Composite Assessment, and analysis of the documented water quality conditions.

Figure 17. PRIMER ANOSIM Graph and Table of HDWTRSS data.



```
Sample statistic (Global R): 0.907
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from 2522520)
Number of permuted statistics greater than or equal to Global R: 0
```

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
1, 2	0.8	0.8	126	126	1
1, 3	1	1.8	56	56	1
1, 4	1	4.8	21	21	1
2, 3	0.796	2.9	35	35	1
2, 4	0.786	6.7	15	15	1
3, 4	0.917	10	10	10	1

The ANOSIM graph above depicts the abbreviated names of the projected coastal HDWTRSS Streams in this study. The illustrated factor types are denoted by proposed Stream Type:
1 Reference Streams
2 Impacted-Urban Set I
3 Impacted-Urban Set II
4 Impacted-Agriculture

The ANOSIM is a distribution-free method of multivariate data analysis widely used by biologists and community ecologists. It is primarily employed to compare the variation in abundance and composition among sampling units in terms of the described grouping factor or experimental treatment levels. ANOSIM is simply a modified version of the Mantel Test based on a standardized rank correlation between two distance matrices. It uses a model matrix coding for group membership (or treatment levels) as the explanatory variable in an ANOVA-like analysis [see http://www.marine.usf.edu/user/djones/anosim/anosim.html].

The ANOSIM graph above depicts these four Groups for the HDWTRSS:

Table 9. HDWTRSS Groups compared using ANOSIM statistics.

Group 1	Group 2	Group 3	Group 4
Reference Streams	Impact-Urban Set I	Impact-Urban Set II	Impact-Agriculture
UT2BorrowCreek	N. Yancey's Branch	UT2 Perch Creek	UT2 Cowpen Creek
UT2 Halls Creek	UT2 Joe's Branch	Three Mile Creek	UT2 Page Creek
UT2 Perdido Creek#1	UT2 Red Creek #1	Twelve Mile Creek	
UT2 Perdido Creek#2	UT2 Red Creek #2		
UT2 Wolf Creek			

The ANOSIM analysis calculated the significance level of these streams as being <5% for all other Groups (2 through 4), which shows Reference Group 1 as being statistically distinct from all others. The analysis shows that the Impact Group 2 differs statistically from Impact Group 3 at 2.9%. It also depicts a greater statistical similarity for the Impact Group 3 and the Impact Group 4. These results show good differentiation using the selected Composite Assessment components. These analyses indicate that the Composite Assessment may provide a statistically reliable model for assessment of Coastal Headwater Streams.

Although, basic statistical modeling predicts the relative **potential** rather than **actual** stream quality, thus, the reference condition for a coastal headwater stream is ideally a high quality, non-impacted stream within that given ecoregion or sub-ecoregion. It can be expected that some individual stream reaches or segments will exhibit specific conditions that individually may depart from the predictions of the developed tools. Rather than being a shortcoming, these "outliers" may help watershed managers better understand the spectrum of interaction that occurs between the local watershed and stream dynamics.
[see http://www.stormwatercenter.net/monitoring%20and%20assessment/imp%20cover/impercovr%20model.htm]
For example, an "outlier" stream may be a result of past legacy disturbances, such as channelization, agricultural drainage, or poor forestry practices that happened many years ago to alter the landscape or the reach drainage area. In some few cases the stream reach may have established a new hydrological equilibrium, such that many of the original functions have been restored. The emulation of this progression is a major goal for stream restoration, with the hope that we can take impacted stream reaches and reclaim them economically, and in a similar manner. By comparatively studying the surrounding landscape influences, for both reference and impacted streams, we may better understand those changes associated with their structure and complex eco-processes by which they function to diminish storm event impacts, while enhancing water quality and providing important habitats that are associated with our coastal streams.

7.2 HDWTRSS Statistical Evaluations

Another objective for this HDWTRSS project was the comparison of this collected data. It is important to look at LUC-associated stressors relative to the bio-assessment tools and water quality data. It is interesting that the overall statistical analysis for these Headwater Stream parameters and data revealed that most determined values (i.e., composite assessment score, pH, conductivity, salinity, turbidity, and channel sinuosity) had significant levels of difference between the LUC-associated stream types. Based upon our limited sampling, we collected data to explore whether these streams were similar, or if they exhibited significant statistical differences. Our onsite field observations of surrounding land use and land cover suggested that the designated Reference Streams should differ significantly, as compared to the suite of selected Impacted Streams. The data indicated for these associated land uses, i.e. Reference vs. Impacted (both Urban and Agriculture), that these coastal headwater streams indeed differ and the analysis of the HDWTRSS data supported these conclusions.

7.3. *HDWTRSS* PROJECT TIMELINE

JAN 29, 20013:
Contract signed and executed by all primary parties. WORK BEGINS!

MARCH to JUNE2013:
ADEM WQ Sampling R-1 Spring-Summer Sampling

MARCH 2013:
Survey/Assessment of Sites: R-UT Joes Branch-BC /R-UT Wolf Creek-BC / R-Hubbards Landing-BC

APRIL 2013:
Survey/ Assessment of Sites: R-UT Perdido#1/ R-UT Perdidio#2 – all BC

MAY 2013:
Recon of Additional Potential Stream Sites: MC and BC

JUNE 2013:
Survey/ Assessment of Sites:
Ag-Watts Ln / U-Red Creek # 1 &2/ U-3 Mile Creek/U-12 Mile Creek/R-Borrow Creek- all MC / Ag- UT Cowpen Creek/ U- Upper Yancey Branch - BC

JULY-AUG 2013:
Follow Up Stream Assessments Data:
including Watts Ln / UT Joes Branch / Upper Yancey Branch

AUG 2013:
Contractor Survey Field Work Completed.

OCT 2013:
ADEM WQ Sampling R-2 Fall Sampling

JAN to FEB 2014:
ADEM WQ Sampling R-3 Winter Sampling

FEB 2014:
ADEM WQ Sampling Completed / HDWTRSS Field Activities Completed.

MARCH-JUNE 2014:
Water Quality Statistics Data Analysis

AUG 2014:
LUC Calibration and Data Analysis

NOV to DEC 2014:
Complete and finalize HDWTRSS Project Report

8. PROJECT BIBLIOGRAPHY

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9. PROJECT DISCLAIMERS

Confidentiality, Property Ownership, Endorsements, and Uses :

A. Personally Identifiable Information relating to the specific location and identity of the Survey participants, which includes the geographic coordinates, shall be marked as Confidential and will not be released except as HUC location.

B. Any copy of any work products relating to BMP implementation produced under this contract, which are intended for general public distribution by the Contractor or the Department, shall not include any geographical coordinates or precise locational data relating to the identity of the Survey participants.

C. All other developmental information, software design(s), and final product(s) associated with this project shall be acknowledged property of the Department.

D. Photos of the field sites were taken throughout the duration of the Project, both in the prior Stream Recon visits from the Level I phase, and the field visits during the recent Field Survey and Sampling events at these headwater stream sites.

E. Although this work was conducted and reviewed by ADEM staff and approved for submission, it may not necessarily reflect official Department policy. The mention of trade names or brand names in this document is for illustrative purposes only and does not infer any endorsement by the Alabama Department of Environmental Management, the Alabama Department of Conservation and Natural Resources, the U.S. Environmental Protection Agency, or the National Oceanic and Atmospheric Administration.

F. The authors have used references from published scientific literature to assist the interpretation of the data included in this report. Reference to any particular set of values or concentrations must not be construed as acceptance of, nor support of the value as a Federal, or State standard or criteria.

G. This project is not intended to assess water quality with respect to water quality standards or use classification(s) support. By definition, headwater streams have small contributing drainage areas resulting in limited or intermittent flow regimes which may not be representative of the stream as a whole. Therefore, the data contained within this report is not intended to be used to exemplify water quality standards or use classification calibration purposes."

11. APPENDIX II :

HDWTRSS ASSESSMENT & WQ TEMPLATE FORMS

FIELD SURVEY –STREAM ASSESSMENT TEMPLATE FORMS

Enclosed are the documents and forms that were used to conduct the field measures and activities for the HDWTRSS project:

Form 1- HDWTRSS LANDUSE_LANDCOVER FORM 2012 rcs
Form 1.1 TM- Table A2 _ Guide for Evaluation HDWTRSS LUC Assessment
Form 2 -NC Stream ID Form 4.0 HDWTRSS 2010 rcs
Form 2.1 TM-NC ID methods INT-PER streams V3.1-2005
Form 2.2 TM-NC_2010_Methodology
Form 3 -ACNPCP Coastal Stream Assessment Form w Anti Glare Grid 3.3 rcs2009
Form 4 -HDWTRSS Survey Data Form 4.2 w Anti-GlareBackground rcs 2009
Form 4.1 TM-ForestDensiometerSOP
Form 5.1 -ADEM Wadeable Stream Habitat Assessment_Form 36-2011 HDWTRSS
Form 5.2 -ADEM Glide-Pool Habitat Assessment FOD I-Form 14 Form Rev 2-14-13
Form 6 -ADEM Abbreviated Stream Flow Datasheet 2006-HDWTRSS 2010
ADEM WQ SOPs:
- SOP 2040_Flow
- SOP 2041_Temp
- SOP 2042_Ph
- SOP 2043_SpecCond
- SOP 2044_Turb
- SOP 2045_DO
- SOP 2047_DataSonde
- SOP 2061_SWCollection

XCL Form 6.1 TM- ADEM Stream Flow Calc -HDWTRSS

ADEM- Coastal Headwater Stream Survey

FORM #1 - HDWTR STREAM LUC HABITAT ASSESSMENT

rcs2009-rform6.3-JAN 2012

2012 Stream Survey LUC Habitat Assessment (*) * -Within 500ft Radius-

Stream Site: __________________________-__________________________________

HUC: ____

Date: _________________ **Area Elevation:** ________**ft.**

Site Lat: _________________ **Site Long:** ___________________

Characterize Surrounding Stream Site Habitat:

[500' radius-use stream reach midpoint as reference] (circle primary use)

res density	<.25 ac.	.25 – 1.0	> 1.0 ac.			
Urban	UrbanRes	Suburban	RuralRes	Agriculture	Forestry	Undeveloped
0	0.5	1	1.5	2.5/3	3/3.5/4/4.5	5

____

____

____

____

____

Adjacent Site Land Uses [within 500ft radius]: (note %)

URBAN AREAS

- ☐ Commerce/Industrial ____
- ☐ Transportation/Parking ____
- ☐ ROW/ Pipeline ____
- ☐ Recreation/Greenspace ___
- ☐ Residential: MF-HD____ SFHD___SFLD ____
- ☐ Agriculture / Cattle /Orchard ____ / ____/ ___
- ☐ Forestry: Cleared __ / Select Cut __ ReGen __ / Natural 20yrs+ ___
- ☐ Undeveloped / Natural ____
- ☐ Waterbody ____
- Other___________________________

TOTAL LUC SCORE: ____

☐ **-Review Sheet: Using Most Current Visual GIS Tool to Approximate Site Features____**

Coastal Alabama Pilot Headwater Stream Survey Project		
ASSIGNMENT OF LAND USE/COVER	PROPOSED VALUES/ IMPACTS within 500ft radius.	LUC DESCRIPTORS
URBAN Relative Impact @ 100%	0	COMMERCIAL, TRANSPORTATION, PARKING
Relative Impact @ 90%	0.5	RIGHT OF WAY, PIPELINE
Relative Impact @ 80-90%	0.5 - 1.0	RECREATIONAL
Relative Impact @ 80-90%	0.5 - 1.0	GREENSPACE
RESIDENTIAL		
<0.25 Acres URBAN Relative Impact @ 90%	0.5	<0.25 Acre per unit
0.25 -1.0 Acre SUBURBAN Relative Impact @ 80%	1.0	0.25 -1.0 Acre per unit
>1.0 Acres RURAL RESIDENT Relative Impact @ 70%	1.5	>1.0 Acres per unit
AGRICULTURE		
CROP /ORCHARD/CATTLE Relative Impact @ 40 to 50%	2.5 – 3.0	Value scaled upon impact observed.
FORESTRY Relative Impact @ 10 to 40%	3.0 to 4.5	Value scaled upon impact observed.
NATURAL or UNDEVELOPED Relative Impact < 10%	5.0	Largely Undisturbed
		01-2012rcs

Table A2 . Guide for Valuation of Form #6 – HDWTRSS LUC Impact Assessment

ADEM-Coastal Headwater Stream Survey Form

North Carolina Division of Water Quality – Stream Identification v. 4.0

Date:	**Project**:	**Latitude:**
Evaluator:	**Site:**	**Longitude:**
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30**	**County:**	**Other** *e.g. Quad Name*:

A. Geomorphology (Subtotal =_________)	Absent	Weak	Moderate	Strong
1[a]. Continuous bed and bank	0	1	2	3
2. Sinuosity	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool sequence	0	1	2	3
4. Soil texture	0	1	2	3
5. Stream sediment sorting	0	1	2	3
6. Active/relic floodplain	0	1	2	3
7. Depositional bars or benches	0	1	2	3
8. Braided channel	0	1	2	3
9. Recent alluvial deposits	0	1	2	3
10. Headcuts	0	1	2	3
11. Grade controls	0	0.5	1	1.5
12. Natural valley or drainageway	0	0.5	1	1.5
13. Second or greater order channel on existing USGS or NRCS map or other documented evidence.	No = 0		Yes = 3	

[a] Man-made ditches are not rated; see discussions in manual

B. Hydrology (Subtotal = _________)				
14. Groundwater flow or discharge	0	1	2	3
15. Water in channel and > than 48 hrs since rain	0	1	2	3
16. Leaflitter	1.5	1	0.5	0
17. Sediment on plants or debris	0	0.5	1	1.5
18. Organic debris lines or piles (Wrack lines)	0	0.5	1	1.5
19. Soil-based Evidence of seasonal high water table?	0	1	2	3

C. Biology (Subtotal = _________)				
20[b]. Fibrous roots in channel	3	2	1	0
21[b]. Rooted plants in channel	3	2	1	0
22. Crayfish	0	0.5	1	1.5
23. Bivalves/mollusks	0	1	2	3
24. Fish	0	0.5	1	1.5
25. Amphibians	0	0.5	1	1.5
26. Macrobenthos (note diversity and abundance)	0	1	2	3
27. Filamentous algae; periphyton	0	1	2	3
28. Iron oxidizing bacteria/fungus.	0	0.5	1	1.5
29[b]. Wetland plants in streambed	FAC = 0.5; FACW = 0.75; OBL = 1.5 SAV = 2.0; Other = 0			

[b] Items 20 and 21 focus on the presence of upland plants, Item 29 focuses on the presence of aquatic or wetland plants.
*perennial streams may also be identified using other methods. See p. 30 of manual.

Notes: (use back side of this form for additional notes.)

Sketch:

North Carolina
Division of Water Quality

Identification Methods for the Origins of Intermittent and Perennial streams

Version 3.1

Effective Date: February 28, 2005

This document should be cited as:

NC Division of Water Quality. 2005. Identification Methods for the Origins of Intermittent and Perennial streams, Version 3.1. North Carolina Department of Environment and Natural Resources, Division of Water Quality. Raleigh, NC.

Further Information can be obtained from:

North Carolina Division of Water Quality
Program Development Unit
Mail Service Center 1650
Raleigh, NC 27699-1650

(919) 733-1786

Copies of this document are available through the internet:

http://h2o.enr.state.nc.us/ncwetlands/regcert.html

Michael F. Easley, Governor

William G. Ross Jr., Secretary
North Carolina Department of Environment and Natural Resources

Alan W. Klimek, P.E. Director
Division of Water Quality

February 28, 2005

TO: All Interested Parties

FROM: Coleen Sullins, Deputy Director, NC Division of Water Quality

RE: Identification Methods for the Origins of Intermittent and Perennial Streams

The North Carolina Division of Water Quality (DWQ) has reviewed and made changes to the field methodologies used to identify the origins of intermittent and perennial streams. These changes are effective immediately and include:

1) Improvements to the field manual and rating form used to identify stream origins.

2) The addition of specific macroinvertebrate taxa that may be used to identify perennial streams.

Previously, the DWQ had used the "INTERNAL GUIDANCE MANUAL -- N.C. DIVISION OF WATER QUALITY STREAM CLASSIFICATION METHOD January 19, 1999, Version 2.0" for identifying intermittent streams, and a separate policy "Guidance for the Determination of the Origin of Perennial Streams, Version 2.3) for identifying perennial streams." During 2004, staff from the DWQ reviewed and improved both methods and solicited comments from the public. As a result both methods were combined into one document: Identification Methods for the Origins of Intermittent and Perennial Streams Version 3.1. This version was field tested during a Surface Water Identification Training and Certification (SWITC) Class during November and December 2004.

Effective immediately the methods discussed in Identification Methods for the Origins of Intermittent and Perennial Streams Version 3.1 should be used for intermittent and perennial stream origins. This document is available through the DWQ's website at: http://h2o.enr.state.nc.us/ncwetlands/regcert.html.

cc: DWQ Regional Wetland Contact
Steve Kroeger

401 Wetlands Certification Unit
1650 Mail Service Center, Raleigh, North Carolina 27699-1650
2321 Crabtree Boulevard, Suite 250, Raleigh, North Carolina 27604
Phone: 919-733-1786 / FAX 919-733-6893 / Internet: http://h2o.enr.state.nc.us/ncwetlands

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Table of Contents

"Streams are gutters down which flow the ruins of continents."
Luna Leopold

PURPOSE

The purpose of this manual and accompanying field form is to identify and score geomorphic, hydrological and biological stream features that distinguish between ephemeral, intermittent and perennial streams. Section 1 pertains details on the field method and rating form that can be used to identify intermittent or perennial streams. Version 3.1 of the manual replaces Version 2.0 (January 19, 1999) and reflects five years of additional regulatory and academic experience. Changes are limited to organization and clarification and do not result in any changes in interpretation of scores. Section 2 provides details on the procedure and information needed to determine if a stream is perennial.

SECTION 1 – Stream Identification Method and Rating Form

Introduction

A stream can be described as flowing surface water in a channel resulting from:

- *Stormflow* – increased streamflow resulting from the relatively rapid runoff of precipitation from the land as interflow (rapid, unsaturated, subsurface flow), overland flow, or saturated flow from raised near surface water tables close to the stream, or
- *Baseflow* – low flow resulting from delayed discharge of ground water into the stream between rainfall events, or
- A combination of both stormflow and baseflow, and
- Contributions of discharge from upstream tributaries as stormflow or baseflow, if present.

Streams may exhibit both stormflow and baseflow characteristics as they flow from their origins to their destinations. This manual and accompanying field form can be used to identify points on the landscape that represent stream origins as well as stream, channel and flow characteristics resulting from these varying sources of water.

Streams are drainage features that often change from ephemeral to intermittent and intermittent to perennial along a gradient or continuum—sometimes with no single distinct point demarcating these transitions. In order to distinguish ephemeral streams from intermittent ones or intermittent streams from perennial ones using the information presented in this guide, the field evaluator should have experience making geomorphic, hydrological and biological observations in headwater streams. Determinations must not be made at one point without first walking up and down the channel. This initial examination allows the evaluator to examine and study the nature of the channel, observe characteristics of the watershed, and observe characteristics that indicate what source of water (stormflow, or baseflow plus tributary discharge, if present) may predominately or solely contribute to flow. Once these observations are made, the investigator can determine the areas along the stream channel where these various sources of water (stormflow or groundwater) predominate flow and the constancy of flow (i.e. ephemeral, intermittent and perennial). As a general rule of thumb, several hundred feet (sometimes more) of channel should be walked to make these determinations. These initial observations aid in determining the magnitude (absent, weak, moderate or strong) of specific parameters.

All stream systems are characterized by interactions among hydrologic, geomorphic (physical) and biological processes. Variations in these characteristics along the length of a stream can help distinguish what source of water predominately contributes to flow. Thus, attributes of these three processes (geomorphic, hydrologic and biologic) are used in this stream identification methodology to produce a numeric score. The score is then used to assign a stream type such as “ephemeral” “intermittent” or “perennial” to the stream reach being evaluated.

Initially, the earliest versions of this manual and form were used to distinguish ephemeral, intermittent and perennial features of streams no matter where in the landscape the stream segment under consideration was located. Accordingly, the form and manual could conceivably be used on high order (e.g. 3^{rd}, 4^{th}, or higher) streams. However, these higher order streams are always perennial. Therefore, the persistence of water and flow has never been debated in these high order streams. Attributes of stream channels in headwaters or low order (1^{st}, 2^{nd}) streams can be subject to debate. Thus, this form and manual are best applied to these smaller streams. Beginning users of this manual and form should visit a variety of headwater streams, look for the geomorphic, hydrologic and biologic features discussed here, and gain experience observing the magnitude and variability of these features.

Background

The main purpose of the first version of the stream identification manual and scoring form was to derive a relationship between a score and the persistence of water or the size of a stream or river. The method has been used to distinguish ephemeral, intermittent, or perennial streams in low order (1^{st} or 2^{nd}) streams. However, characteristics found more commonly (but not exclusively) in higher order streams such as braided channels and stream levees remain in the manual.

This stream evaluation method is intended to distinguish (identify) ephemeral streams from intermittent streams and intermittent streams from perennial streams. The numerical rating system format was developed based on requests from the regulated community in North Carolina for an objective method of stream identification. In addition, this method has served as the basis of similar endeavors elsewhere e.g. Fairfax County, Virginia: (http://www.co.fairfax.va.us/dpwes/watersheds/perennial.htm) Results from over 300 individual field trials conducted in the Piedmont and Coastal Plain portions of the Neuse River Basin, North Carolina during May, June, July and August of 1998, as well as field testing conducted during December 1998 and January 1999 have supported a minimum score of 19.0 to distinguish ephemeral channels from intermittent streams. Scores less than 19.0 indicate ephemeral channels, whereas scores 19.0 or greater indicate that at least an intermittent channel is present. A score of 30 or more points is one factor that may be used to determine the presence of a perennial stream (see Section 2 – Guidance for the Determination of the Origin of Perennial Streams, page 29).

Definitions

The definitions of ephemeral, intermittent and perennial streams are found in North Carolina's administrative code and are also provided below. Complete language for the rules can be found at: (http://ncrules.state.nc.us/ncadministrativ_/title15aenviron_/default.htm) The definition of an intermittent stream refers to a stream channel only containing water for part of the year (typically winter and spring). Therefore the term "water table" that was used in the intermittent stream definition refers to the seasonal high water table in the riparian zone soil adjacent to the stream.

Ditch – 'Ditch or canal' means a man-made channel other than a modified natural stream constructed for drainage purposes that is typically dug through inter-stream divide areas. A ditch or canal may have flows that are perennial, intermittent, or ephemeral and may exhibit hydrological and biological characteristics similar to perennial or intermittent streams. 15A NCAC 02B .0233(2)(c)

Ephemeral Stream – Ephemeral (stormwater) stream means a feature that carries only stormwater in direct response to precipitation with water flowing only during and shortly after large precipitation events. An ephemeral stream may or may not have a well-defined channel, the aquatic bed is always above the water table, and stormwater runoff is the primary source of water. An ephemeral stream typically lacks the biological, hydrological, and physical characteristics commonly associated with the continuous or intermittent conveyance of water. 15A NCAC 02B .0233(2)(d)

Intermittent Stream – Intermittent stream means a well-defined channel that contains water for only part of the year, typically during winter and spring when the aquatic bed is below the water table. The flow may be heavily supplemented by stormwater runoff. An intermittent stream often lacks the biological and hydrological characteristics commonly associated with the conveyance of water. 15A NCAC 02B .0233(2)(g)

Modified Natural Stream – 'Modified natural stream' means an on-site channelization or relocation of a stream channel and subsequent relocation of the intermittent or perennial flow as evidenced by topographic alterations in the immediate watershed. A modified natural stream must have the typical biological, hydrological, and physical characteristics commonly associated with the continuous conveyance of water. 15A NCAC 02B .0233(2)(h)

Perennial Stream – Perennial stream means 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. 15A NCAC 02B .0233(2)(i)

Groundwaters – "Groundwaters" means those waters occurring in the subsurface under saturated conditions. 15A NCAC 02L .0102 (11)

Water Table – "Water table" means the surface of the saturated zone below which all interconnected voids are filled with water and at which the pressure is atmospheric. 15A NCAC 02L .0102 (27)

Perched Water Table – "Perched water table" means a saturated soil horizon or horizon subdivision, with a free water surface periodically observed in a bore hole or shallow monitoring well, but generally above the normal water table, or may be as identified by drainage mottles or redoximorphic features, and caused by a less permeable lower horizon. 15A NCAC 18A .1935 (29)

Seasonal High Water Table – "Seasonal High Water Table" means the highest level that groundwater, at atmospheric pressure, reaches in the soil in most years. The seasonal high water table is usually detected by the mottling of the soil that results from mineral leaching. 15A NCAC 02H .1002 (15)

Sources of Variability

Spatial and temporal variations in stream attributes occur within and among stream systems. Perhaps the most predominate sources of variation within a stream system are the downstream changes in stream attributes related to increasing persistence and volume of flow and the temporal variation of flow related to precipitation variability and seasonal changes in evapotranspiration. The rate and duration of flow in stream channels is influenced by climate and by recent weather. Recent (within 48 hours) rainfall can influence scoring; therefore it is *strongly* recommended that field evaluations be conducted at least 48 hours after the last known rainfall. However, please note that the identification method has been designed with redundancy to allow for reasonably accurate ratings even after a recent rainfall.

Sources of variation among stream systems are due primarily to geology or soils (physiographic province) with interactions due to precipitation and climate. For example, riffles and pools result from in-channel structures and these structures can vary between rocks and boulders in the mountains and roots and wood debris in the coastal plain. Other examples of variability include the magnitude (height) of head cuts, which are greater in watersheds with greater relief.

Ditches and Modified Natural Streams

In North Carolina it may be difficult to differentiate between a man-made ditch and a natural stream that has been modified (e.g. straightened or relocated). There are a variety of techniques that can be employed to help with this distinction. The topographic lines depicted on a USGS topographic map may indicate a natural valley in which a natural stream could be present. Generally topographic crenulations (the 'folding' of contour lines) with angles 90^o or less can be indicative of the presence of streams. In addition an NRCS county soil survey may show the presence of linear (i.e. parallel to a stream channel) soil series, which are indicative of alluvial deposits.

Suggested Field Equipment

Soil auger – used to determine if hydric soils are present.
Small net – used to catch aquatic insects.
Global Positioning System (GPS) – used to determine latitude and longitude.
Camera – used to photograph and document site features.

Scoring

When the evaluator and landowner agree that the feature under investigation is a man-made ditch, then scoring is not necessary. In addition, the evaluator may determine scoring is not necessary when best professional judgment leads the evaluator to conclude that the feature is a man-made ditch and not a modified natural stream.

Identification of stream type is accomplished by evaluating 29 different attributes of the stream and assigning a numeric score to each attribute. A scoring sheet (last page of this manual) is used to record the score for each attribute and determine the total numeric score for the stream under investigation. The sheet specifically requests information for Date, Project, Evaluator, Site, County, Other (Quad Name), and Latitude and Longitude. However any other pertinent observations should also be recorded on this sheet. These may include the amount and date of the last recent rain, hydrologic unit codes, or evidence of stream modifications. The scoring sheet is an official record, so all pertinent observations should be recorded on it.

Scores should reflect the persistence of water with higher scores indicating intermittent and perennial streams. A four–tiered, weighted scale used for evaluating and scoring each attribute addresses the variability of stream channels. The scores, “Absent”, “Weak”, “Moderate”, and “Strong” are applied to sets of geomorphic, hydrologic and biological attributes. The score given to an attribute reflects the evaluator’s judgment of the average degree of development of the attribute along a reach of the stream at least 100 ft long. These categories are intended to allow the evaluator flexibility in assessing variable features or attributes. In addition, the small increments in scoring between gradations will help reduce the range in scores between different evaluators. The score ranges were developed in order to better assess the often gradual and variable transitions of streams from ephemeral to intermittent.

Previous versions of this form used a “yes” / “no” format and was found by NC Division of Water Quality staff and by the regulated community to be inadequate to properly encompass and assess the natural variability encountered when making stream identifications in the field. “Moderate” scores are intended as an approximate qualitative midpoint between the two extremes of “Absent” and “Strong.” The remaining qualitative description of” Weak” represents gradations that will often be observed in the field.

Definitions of Absent, Weak, Moderate and Strong are provided in Table 1. These definitions are intended as guidelines and the evaluator must select the most appropriate category based upon experience and observations of the stream under review, its watershed, and physiographic region.

Table 1. Guide to scoring categories

Category	Description
Absent	The character is not observed
Weak	The character is present but you have to search intensely (i.e., ten or more minutes) to find it
Moderate	The character is present and observable with mild (i.e., one or two minutes) searching
Strong	The character is easily observable

A. Geomorphic Indicators

1. Continuous Bed and Bank

Throughout the length of the stream, is the channel clearly defined by having a discernable bank and streambed?

The bed of a stream or river or creek is the physical confine of the normal water flow. The lateral constraints (channel margins) during all but flood stage are known as the stream banks. In fact, a flood occurs when a stream overflows its banks and partly or completely fills its flood plain. As a general rule, the bed is that part of the channel below the "normal" water line, and the banks are that part above the water line; however, because water flow varies, this differentiation is subject to local interpretation. Usually the bed is kept clear of terrestrial vegetation, whereas the banks are subjected to water flow only during unusual or infrequent high water stages, and therefore can support vegetation much of the time. This indicator will lessen and may diminish or become fragmented upstream as the stream becomes ephemeral.

Strong – There is a continuous bed and bank present throughout the length of the stream channel.

Moderate – The majority of the stream has a continuous bed and bank. However, there are obvious interruptions.

Weak – The majority of the stream has obvious interruptions in the continuity of bed and bank. However, there is still some representation of the bed and bank sequence.

Absent – There is little or no ability to distinguish between the bed and bank.

2. Sinuosity

Is the stream channel sinuous throughout the reach being evaluated?

Sinuosity is a measure of a stream's "crookedness." Specifically, it is the total stream length measured along the stream thalweg (deepest part of the channel) divided by the valley length (Figure 1). The greater the number, the higher the sinuosity. Sinuosity is related to slope gradient along the channel. Natural undisturbed streams with steep channel slope gradients have low sinuosities, and streams with low channel slope gradients typically have high sinuosities.

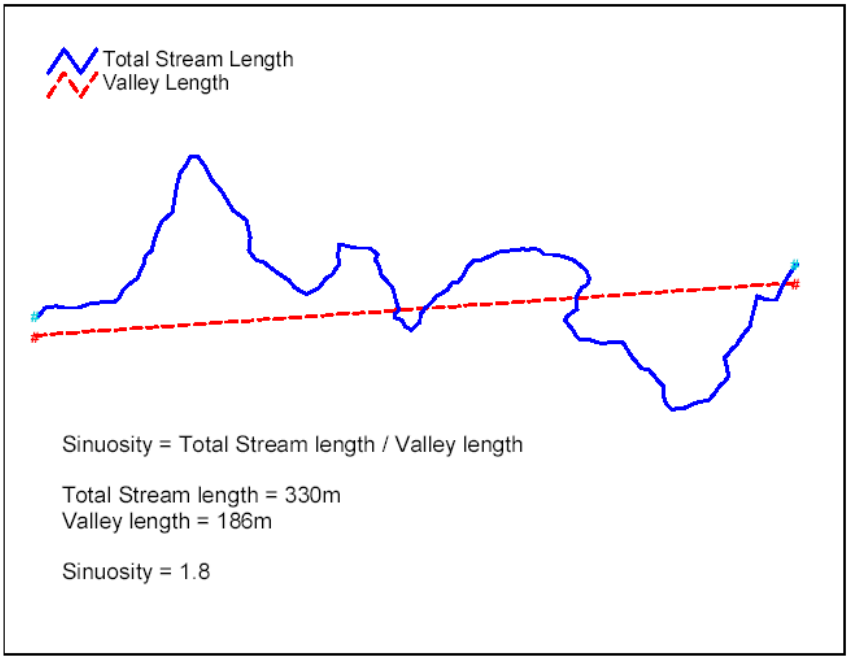

Figure 1. Stream sinuosity

Sinuosity is the result of the stream naturally dissipating its flow forces. Intermittent streams don't have a constant flow regime, and as a result generally exhibit a significantly less sinuous channel than farther downstream in the perennial stream. While ranking, take into consideration the size of the stream and its watershed, which may also influence the stream wavelength. Sinuosity should be visually estimated or measured in the field. Sinuosities of small headwater streams approximated from maps or aerial photos are usually not of sufficient accuracy. Examples are provided in Figure 2.

Strong – Ratio > 1.4. Stream has numerous, closely-spaced bends, very few straight sections.

Moderate – 1.2 < Ratio < 1.4. Stream has good sinuosity with some straight sections.

Weak – 1.0 < Ratio < 1.2. Stream has very few bends and mostly straight sections.

Absent – Ratio = 1.0. Stream is completely straight with no bends.

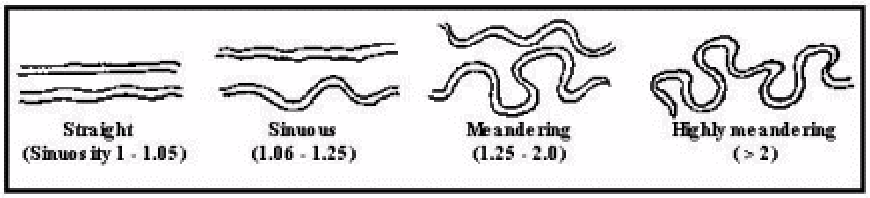

Figure 2. Examples of stream sinuosity

3. In-channel Structure -- Riffle-Pool Sequences

Is there a regular sequence of riffles and pools or other erosion/deposition structural features in the channel indicative of frequent high flows?

A repeating sequence of riffle/pool (riffle/run in lower-gradient streams, ripple/pool in sand bed streams, or step/pool in higher gradient streams) can be observed readily in perennial streams. This morphological feature is almost always present to some degree in higher gradient streams such as piedmont and mountain streams. Riffle-run (or ripple-run) sequences in low gradient streams, such as those in the coastal plain are often created by in-channel woody structure such as roots and woody debris. When present, these characteristics can be observed even in a dry stream bed by closely examining the local profile of the channel.

A riffle is a zone with relatively high channel slope gradient, shallow water, and high flow velocity and turbulence. In smaller streams, riffles are defined as areas of a distinct change in gradient where flowing water can be observed. The bottom substrate material in riffles contains the largest sedimentary particles that are moved by bankfull flow (bedload). A pool is a zone with relatively low channel slope gradient, deep water, and low velocity and turbulence. Fine textured sediments generally dominate the bottom substrate material in pools. Along the stream reach, take notice of the spacing and frequency of the riffles and pools or other types of instream structures. Riffles are more frequent in the mountain and piedmont physiographic provinces than in the coastal plain and many parts of the Triassic Basin.

Strong – Demonstrated by an even and frequent number of riffles followed by pools along the entire reach. There is an obvious transition between riffles and pools.

Moderate – Represented by a less frequent number of riffles and pools. Distinguishing the transition between riffles and pools is difficult.

Weak – Streams show some flow but mostly have areas of pools or mostly areas of riffles.

Absent – There is no sequence exhibited.

4. Soil Texture or Stream Substrate Sorting

Has channel erosional downcutting penetrated through the soil profile? Is the texture of the bottom substrate different (i.e. much coarser) than that of the soil in the adjacent floodplain? Is there evidence of sorting of the bottom substrate materials, indicative of frequent high flows?

This feature can be examined in two ways. The first is to determine if the soil texture in the bottom of the stream channel is similar to the soil texture outside the channel. If this is the case, then there is evidence that erosive forces have not been active enough to down cut the channel and support an intermittent or perennial stream. Soils in the bed of ephemeral channels typically have the same or comparable soil texture as areas close to but not in the channel. Accelerated stormflow resulting from development may produce deep, well-developed ephemeral or intermittent channels but which have little or no coarse bottom materials indicative of upstream erosion and downstream transport. The bottom substrate of intermittent or perennial streams often have accumulations of coarse sand and larger particles.

The second way this feature can be examined is to look at the distribution of the soil particles in the substrate in the stream channel. Is there an even distribution of various sized substrates throughout the reach or does partitioning or sorting occur? In the coastal plain one may need to look for size variations among sand grains – for instance, coarse versus fine sand. The occurrence of depositional features will be infrequent in intermittent streams. Perennial streams, on the other hand, tend to exhibit correspondingly larger depositional features, with cobble/gravel/boulders being localized in riffles and runs, and with accumulations of fine sediments settling out in pools.

Note, however, the usefulness of this attribute may vary among physiographic provinces. For instance, in the coastal plain or sandhills, the variability in the size of soil particles is less than in the piedmont and mountains.

Table 2. Standard USDA particle sizes

	Diameter	
Description	millimeters (mm)	inches (in.)
fine sand	0.1-0.25	.004-.01
medium sand	0.25-0.5	.01-.02
coarse/very coarse sand	0.5-2.0	.02-.08
pebbles (gravel)	2-75	.08-3.0
cobbles	75-250	3.0-9.8
stones	250-600	9.8-23.6
boulders	> 600	> 23.6

Strong – There is a well-incised channel through the soil profile with relatively coarse-textured bottom sediments compared to riparian zone soils: coarse sand, gravel, or cobbles in the piedmont; gravel, cobbles, stones, or boulders in the mountain regions, and medium or coarse sand in the coastal plain. There is a clear distribution of various sized substrates. Depositional features are present, finer particles are absent or accumulate in pools, and larger particles are located in the riffles/runs.

Moderate – There is a well-developed channel but it is not deeply incised through the soil profile. Some coarse-textured bottom sediments are present that indicates downstream transport. Relatively little sorting of fine material from coarser materials. Small depositional features are present; small pools are accumulating some sediment.

Weak – The channel is poorly developed, and incised only part way through the soil profile. Some coarse textured bottom sediments are present, but substrate sorting is not readily observed. There may be some small depositional features present on the downstream side of obstructions (large rocks, etc.).

Absent – The channel is poorly developed, very little to no coarse textured bottom sediments are present, and substrate sorting is absent. There are few to no depositional features.

5. Active/Relic Floodplain

Is there an active floodplain at the bankfull elevation or is there evidence of recent channel incision with a relic floodplain above the current bankfull elevation?

Floodplains are relatively flat areas usually located outside of or adjacent to the stream bank that accumulate organic matter and inorganic alluvium deposited during flooding. An active floodplain (at current bankfull elevation) shows characteristics such as drift lines, sediment deposited on the banks or surrounding plants, which may also be flattened by flowing water. In cases of severe channel incision (down-cutting) the stream's new floodplain may be restricted to within the channel itself and the previous but now disconnected (relic) floodplain will be harder to see (outside of the channel). In these instances, look for indicators along the sides and within the incised channel. Floodplains on smaller order, incised streams may not be continuous but rather may be present in some locations and absent in others. In many cases there should be evidence of a floodplain if the stream has perennial flow.

Strong – The area displays all of the aforementioned characteristics.

Moderate – Most of the characteristics are apparent.

Weak – The floodplain is not obvious, however some of the indicators are present.

Absent – The characteristics are not present.

6. Depositional Bars or Benches

Are there well-developed depositional benches or bars, the top of which at the transition to the bank is approximately at bankfull elevation?

When a stream channel conveys perennial flow, the forces of channel scouring and deposition create certain distinct physical erosional and depositional features, which can be readily observed. One of these features includes scoured areas along the bank above which the stream banks are much less eroded and below which little or no vegetation is present. Another feature is accumulations of sand or silt creating a bar or "bench" which may or may not be covered with vegetation. The former should be fairly continuous along the length of the stream's banks and should be seen at roughly the same elevation as the top of any sediment bars (where the stream bank slope begins to increase dramatically).

The presence of deposition bars or benches imply that the channel experiences a relatively continuous hydrologic regime and is in dynamic equilibrium with the shaping forces of its water/sediment load. The flow regime, soils and grade determine the bankfull width and morphology of the conveyance channel. The more obvious and continuous these deposition features are throughout the reach, the higher the score should be. Depositional features are often absent on very small channels. Sometimes there may be depositional features along the side of the channel, the tops of which are significantly below bankfull elevation. These features should not receive as many points as well-developed bankfull benches, but should receive some points.

> *Bankfull benches: Experience has shown that this attribute may cause confusion among persons making stream geomorphology observations, thus this attribute was renamed to "Depositional bars or benches." Bankfull flow is the stormflow volume that forms the channel and transports the greatest quantity of sediment. The bankfull (sometimes spelled as "bankful") stage can be defined as the point at which the flow just begins to enter the active floodplain. Thus there are a variety of indicators that can be used to identify this point.*

Strong – Depositional bars or benches are obvious throughout the sample reach.

Moderate – Indicators are present throughout most of the reach.

Weak – Indicators are infrequent along sampling reach.

Absent – Indications of depositional bars or benches are completely lacking.

Figure 3. Deposition bars (source: http://www.co.fairfax.va.us/dpwes/watersheds/ps_protocols.pdf)

7. Braided Channel

Is there a reach with multiple channels present in a low gradient area of sedimentation?

Braided channels occur in shallow, low gradient areas where abundant sediment has a tendency to build up across the stream creating a braided pattern of channels and an extensive floodplain. Are there two or more small stream channels that cross or "braid" over one another? This usually occurs in areas where the land flattens significantly and where there is abundant sediment supply in a wide streambed with shallow water flow.

Strong – The stream displays a braided appearance with many crossings creating many "islands".

Moderate – The stream displays a braided pattern; however, it does not cross many times and only has a few "islands".

Weak – The braided pattern is present but the stream only crosses one or two times creating only one or two "islands".

Absent – The gradient is too high such that the water is flowing too quickly in order to create a braided channel.

8. Recent Alluvial Deposits

Are there fresh deposits of alluvial materials that have been transported and deposited on surfaces in the stream channel or on the floodplain by recent high flows?

Alluvium may be deposited as sand, silt, various sized cobble, and gravel. Observe whether or not there is any recent deposition or accumulation of these substrates within the stream channel (sand and point bars) or floodplain. The amount of alluvium deposited will indicate whether water is constantly pushing substrate downstream. Keep in mind that eroding stream channels influenced by stormwater drains/outfalls may score higher than undisturbed channels for this indicator.

Strong – Large amounts of sand, silt, cobble, and/or gravel alluvium present in the channel and in the floodplain.

Moderate – Large to moderate amount of sand, silt, cobble, and/or gravel mostly present in the stream channel.

Weak – Small amounts of sand, silt, and/or small cobble present within the channel.

Absent – There are no sand or point bars present within the stream channel and no indication of overbank deposition within the floodplain.

Figure 4. Recent alluvial deposits.

Striped stick is 1.0 m long, painted in decimeters and lying on the streambed
Note: rooted herbaceous plants in streambed

9. Natural Levees

Are well developed natural levees present on the active or relic floodplain?

Levees develop on the bank top adjacent to the stream when sand is deposited relatively parallel to the top of the bank from flood flows. These result from the deposition of heavier particles immediately adjacent to the channel as flood waters leave the channel. Natural levees are broad low ridges that may be covered by vegetation or remain as bare areas. Scoring is based on the presence and length of the levee through the stream reach.

It may be necessary to distinguish between natural levees and spoil piles. Spoil piles are created when a stream is ditched, when a ditch is created, or when sediment is removed from a stream. When natural levees are present, they will occur along both stream banks in generally equal heights. However spoil piles most often occur along only one stream bank. There may be times when it is difficult to distinguish between natural levees and spoil piles, and in these cases this must be noted on the field scoring sheet.

10. Head Cut

Is there a head cut at the upstream end of the reach being evaluated? Are there one or more head cuts within the reach being evaluated?

A head cut is an abrupt vertical drop in the bed of a stream channel that is an active erosion feature. It often resembles a small intermittent waterfall (or a miniature cliff) and will have a deep pool at the base resulting from the high energy, turbulent waterfall produced during high flows. Intermittent or perennial streams sometimes begin at a head cut in the piedmont and mountains. Head cuts are transient structures of the stream and often exhibit relatively rapid upstream movement during periods of high erosion rates. Groundwater seepage may also be present from the face or base of a head cut.

Figure 5. Examples of headcuts (Striped stick is 1.0 m long, painted in decimeters)

11. Grade Control Point

Are there grade control points within the reach being evaluated?

A grade control point is a structural feature in the channel that separates an abrupt change in grade of the stream bed or a point where erosional downcutting has been stopped by an obstruction. Grade controls may be caused by bedrock outcrops (nick points), large stones or large roots which extend across the channel, or accumulations of large woody debris. Stormwater or other discharges through pipes also serve as grade control points. These structures separate an abrupt change in grade of the stream bed.

12. Natural Valley or Drainageway

Is there a well-developed stream valley at the location of the reach being evaluated compared to the degree of valley development in the ephemeral reach of the stream?

When looking at the local topography in the field (or on a U.S. Geological Survey map), does the land slope towards the channel or are the contour lines fairly close together and v-shaped or u-shaped, thereby indicating a “draw” or valley? In other words, does the land have slopes that seem to drain to or indicate a natural valley or drainage way?

13. Second (or greater) Order Channel

Is the channel reach being evaluated second or greater in order, considering all channels, including ephemeral ones, that discharge to it?

The higher the channel order, the more likely the stream is to be perennial. Stream order is best evaluated in the field, since headwater streams are poorly depicted on maps. However for the purposes of this manual, a stream channel must be approximately shown on either the most recent version of the 1:24,000 USGS topographic map or Natural Resource Conservation Service (NRCS) county soil survey. In those unusual instances where a clearly defined intermittent or perennial stream channel is not shown on either map, the field evaluator may decide that the channel is second order or greater and provide clear documented evidence.

It is often difficult to evaluate stream order on channels starting at a stormwater outfall. Based on field observations, these channels are considered 1st order. However, a review of historic data such as the County Soil Survey may indicate that the order is greater.

YES – One or more first order channels are draining into the stream above sampling reach.

NO – There are only first order channels above sampling reach.

B. Hydrologic Indicators

14. Groundwater Flow/Discharge

Does the presence of baseflow, and indicators of groundwater presence and groundwater discharge indicate a significant period of groundwater discharge to the stream ?

Baseflow Presence: Water flowing in the channel more than 48 hours after significant rainfall is clear evidence of groundwater discharge from saturated soils below the water table adjacent to the stream. Even when there is no visible flow above the channel bottom, there may likely be slow groundwater discharge into and downstream flow in the ***hyporheic zone***. *The hyporheic zone is the accumulation of coarse textured sediments in the bottom of the channel that may be up to 2-3 ft deep in small streams. A functioning part of the stream, the hyporheic zone is the site of much groundwater discharge to the stream, downstream flow, and biological and chemical activity associated with aquatic functions of the stream.*

Groundwater Table: The presence of a seasonal high water table or groundwater discharge (i.e. seeps or springs) from the bank, both above the elevation of the channel bottom indicates a relatively reliable source of baseflow to a stream. Indicators of a current water table can be observed by digging a bore hole in the adjacent floodplain approximately two feet away from the streambed. The presence of water standing in the hole above the elevation of the channel bottom after waiting for at least 30 minutes (longer for clayey soils) indicates the presence of a water table. The presence of hydric soil indicators above the elevation of the channel bottom in floodplain soils adjacent to the channel indicates the presence of a seasonal high water table that can provide a significant period of base flow. The presence of hydric soils should be determined in accordance with methods in the "*Corps of Engineers Wetlands Delineation Manual"* (1987 online ed., http://www.wes.army.mil/el/wetlands/pdfs/wlman87.pdf) or "*Field Indicators of Hydric Soils in the United States* (http://soils.usda.gov/use/hydric/).

Note that hydric soil indicators may be poorly developed at the seasonal high water table elevation in young, coarse textured, alluvial soil materials with low concentrations of clay, iron and manganese, or floodplain soils where moving water fails to become reduced.

Seasonal high water tables are commonly found in the Coastal Plain within areas with low relief. Seeps: Seeps have water dripping or slowly flowing out from the ground or from the side of a hill or incised stream bank. Springs: Look for "mushy" or very wet, and black decomposing leaf litter nearby in small depressions or natural drainage ways. Springs and seeps often are present at grade controls and headcuts. The presence of this indicator suggests that the stream is being recharged by a groundwater source except during a period of drought. Score this category based on the abundance of these features observed within the reach.

Strong – Significant base flow is present. Spring, seep or groundwater table is readily observable throughout reach.

Moderate – Some base flow is present. Springs, seeps or groundwater table are present, but not abundant throughout reach.

Weak – Water is standing in pools and the hyporheic zone is saturated, but there is not visible flow above the channel bottom. Indicators of groundwater discharge are present, but require considerable time to locate.

Absent – Little to no water in the channel. No springs or seeps present and no indication of a high groundwater table.

15. Water in Channel and > 48 Hours Since Last Rainfall, or Water in Channel During Dry Conditions or in Growing Season[1]

It is necessary to discern stormwater inflow (resulting from precipitation within the past 48 hours) and groundwater inputs. Flow observations preferably should be taken at least 48 hours after the last rainfall. Local weather data and drought information should be reviewed before evaluating flow conditions. Perennial streams will have water in their channels year-round in the absence of drought conditions. If a stream exhibits flowing water in the height of the dry season (mid-summer through

[1] The growing season varies geographically. Growing season dates are found in county soil surveys produced by the National Resources Conservation Service or may be found at the web page of the NRCS Water and Climate Center (http://www.wcc.nrcs.usda.gov/climate/wetlands.html).

early fall in a normal year), then it probably conveys water perennially. On the other hand, a stream that does not exhibit flow during periods of increased rainfall would indicate an intermittent or ephemeral flow. Flow is more readily observed in the riffles and very shallow, higher-velocity areas of the stream. Dropping a floating object on the water surface will aid in determining if flow is present. Flow is often very hard to discern in small, shallow, very low gradient coastal plain streams.

Intermittent streams do not always have water in them. Look for water in pool areas or in holes in the streambed. Another good rule of thumb for differentiating ephemeral streams from intermittent ones is if they have water in them during dry (drought) conditions or during the growing season. The presence or type of plants and fauna as well as the dampness of the soil in the channel (look under rocks) are also good indications of the presence of water during the growing season.

Strong – Flow is highly evident throughout the reach. Moving water is easily seen in riffles and runs.

Moderate – Moving water is easily seen in riffle areas but not as evident throughout the runs.

Weak – Flow is barely discernable in areas of greatest gradient change (i.e. riffles) or floating object is necessary to observe flow.

Absent – Water present but there is no flow; dry channel with or without standing pools.

16. Leaflitter

Are leaves (freshly fallen or older leaves that may be "blackish" in color and/or partially decomposed) accumulating in the streambed?

Perennial streams (with deciduous riparian vegetation) should continuously transport plant material through the channel. Leaves and lighter debris will predominate throughout the length of non-perennial stream channels, whereas there will be little to no leaves present in the stronger flowing areas (riffles) with small accumulations on the upstream side of obstructions. This indicator may be hindered during autumn sampling between rain events. This is a secondary hydrologic indicator in which strong evidence receives fewer points than absent.

Strong – Abundant amount of leaf litter is present throughout the length of the stream.

Moderate – Leaf litter is present throughout most of the stream's reach with some accumulation beginning on the upstream side of obstructions and in pools.

Weak – Leaf litter is present and is mostly located in small packs along the upstream side of obstructions and accumulated in pools.

Absent – Leaf litter is not present in the fast moving areas of the reach but there may be some present in the pools.

17. Sediment on Plants or Debris

Is fine sediment deposited on plants or debris in the channel or on the active floodplain, indicative of recent high flows?

The transportation and processing of sediment is a main function of streams. Therefore, evidence of sediment on plants or other debris in the stream channel may be an important indicator of the persistence of flow. Note that sediment production in stable, vegetated watersheds is considerably less than in disturbed watersheds. Are plants in the stream, on the streambank, or in the floodplain covered with sediment? Look for silt/sand accumulating in thin layers on debris or rooted aquatic vegetation in the runs and pools. Be aware of upstream land-disturbing construction activities, which may contribute greater amounts of sediments to the stream channel, and can confound this indicator. Note these activities on the data sheet if these confounding factors are present.

Strong – Sediment found readily on plants and debris within the stream channel, on the streambank, and within the floodplain throughout the length of the stream.

Moderate – Sediment found on plants or debris within the stream channel although not prevalent along the stream. Mostly accumulating in pools.

Weak – Sediment is isolated in small amounts along the stream.

Absent – No sediment is present on plants or debris.

18. Organic Drift Lines (Wrack lines)

Are there accumulations of organic debris in piles or lines in the channel or on the active floodplain indicative of recent high flows?

Organic drift lines are defined as twigs, sticks, logs, leaves, trash, plastics, and any other floating materials piled up on the upstream side of obstructions in the stream, on the streambank, in overhanging branches, and/or in the floodplain that indicate high stream flows. (These lines of debris are also commonly referred to as "wrack lines.") Ephemeral streams usually exhibit fewer or no drift lines within their channels unless downstream of a stormdrain or extensive urban runoff. The magnitude of the accumulation of drift may be influenced by watershed characteristics and sources of debris. For example, streams in watersheds dominated by herbaceous vegetation may not exhibit drift lines.

Strong – Large drift lines are prevalent along the upstream side of obstructions within the channel and the floodplain.

Moderate – Large drift lines are dispersed mostly within the stream channel.

Weak – Small drift lines are present within the stream channel.

Absent – No drift lines are present.

19. Hydric Soils

Are there hydric soils present at the toe of the bank or base of head cuts above the stream bottom or well developed hydric indicators in the hyporheic zone?

Hydric soils are defined as soils that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part of the soil (Federal Register, July 13, 1994). Nearly all hydric soils exhibit characteristic morphologies that result from repeated periods of saturation or inundation, or both, for more than a few days during the growing season that results in extended periods of soil reduction. Thus the presence of well-developed hydric soil indicators in soils at the base of the bank or strongly reduced hyporheic zone materials provides strong evidence of extended annual periods of base flow.

Soils with sufficient periods of inundation or saturation and that contain significant amounts of clay or silt and significant amounts of iron and manganese will develop color features indicative of extended saturation and reduction. These features are commonly referred to as redoximorphic features and include mottling and gleying (low chroma). Soils immediately adjacent to the stream bed along the stream bank may have redoximorphic features if persistent groundwater discharge is present. Use a Dutch auger or Oakfield probe to obtain a 12 to 14-inch deep core and examine the soil pedon for mottles and low chroma. These features indicate that a seasonal water table is commonly present and that the channel is at least intermittent. Look for redoximorphic features several inches below the surface. Note that non-soil (i.e. relatively young) alluvial accumulations of coarse sand, gravel, and cobble in the stream bank or hyporheic zone, will not develop hydric soil indicators.

Mineral soils which are exposed to atmospheric oxygen in the soil profile will have some degree of oxidation occurring and as a result will have bright red, orange, or yellow matrix colors (Figure 6). Saturated soils, such as those found in the streambeds of perennial streams, have limited or no contact with oxygen, will remain reduced and subsequently have a very dull color chroma or may be gleyed completely (dull gray hues or chroma throughout the soil ped (Figure 6). The soil sample should be representative of the major stream bed/bank soil type observed throughout the sample reach. If necessary, use the Munsell Color Charts book to determine the chroma of the soil matrix. The soil matrix is defined as the dominant soil constituent (>50%). Low chroma values (< 2) or gleyed soils indicate continual saturation, while brightly colored soils or mottles (> 2) indicate only short periods of wetting, typical of intermittent or ephemeral streambed soils or upland soils. Table 2 provides a key for scoring.

Table 3. Scoring redoximorphic features

Redoximorphic feature	Score (see form)
Strong - Gleyed soils	1.5
Moderate - Matrix chroma of 1	1.5
Weak - Matrix chroma of 2	1.5
Absent - Matrix chroma of 2.5 or greater.	0

Upland Soil

Hydric soil depicting gleying

Hydric soil depicting mottling

Figure 6. Photographs of hydric and nonhydric soils.

C. Biological Indicators

20. Fibrous Roots

Are fibrous roots present near the surface of the hyporheic zone in the thalweg of the stream?

Fibrous roots are non-woody, small diameter (< 0.25 in), shallow wide spreading roots that often form dense masses in the top few inches of the soil. Roots in the root mass consist of many roots with generally equal diameters. Fibrous roots of woody plants are those which function in water and nutrient uptake. Since oxygen is needed for respiration, fibrous roots are intolerant of water, unless they are roots of water tolerant plants. Thus, in areas of stream bottom substrates where water is persistent or frequent high energy flows disturb the bottom substrate, fibrous roots may be infrequent or even absent. A higher score is given for the absence of fibrous roots. Observe the bottom (or edge) of the stream and determine if very small (fibrous) roots are present. Note that during extended growing season, or dry periods, fast growing fibrous roots may grow across the bottom of a stream that would not be present during normal flow conditions. Note that this indicator refers to fibrous roots of upland plants rather than aquatic plants that may be growing in the channel.

21. Rooted Plants in Streambed

Are rooted plants growing in the hyporheic zone in the thalweg area of the stream?

This attribute relates flow to the absence of rooted plants, since flow will often act as a deterrent to plant establishment by removing seeds or preventing aeration to roots (see No. 20 Fibrous Roots above). A higher score is given for the absence of rooted plants. Focus should be on the presence of plants in the bed or thalweg of the stream and plants growing on any part of the bank of the stream should not be considered. Note, however, there will be exemptions to this attribute. For example, rooted plants can be found in shaded perennial streams with moderate flow but in all cases these plants will be water tolerant (OBL, FACW; see No. 29 – Wetland Plants in Streambed, page 27). Cases where rooted upland plants are present in the streambed may indicate ephemeral or intermittent flow.

Figure 7. Rooted plants in streambed

22. Crayfish

Most species of crayfish are associated with aquatic or wet environments such as streams and wetlands. A small net can be used to examine small pools, under rocks, under logs, sticks or within leaf packs in the stream for crayfish. Crayfish associated with small holes in the muddy streambank or "chimneys" (roughly cylindrical chimneys) on the muddy bank or floodplain may be indicators of wet soils (wetlands) rather than streams.

23. Bivalves

Clams cannot survive outside of water, thus one should examine the streambed or look for them where plants are growing in the streambed. Also, look for empty shells washed up on the bank. Some bivalves (e.g., Fingernail clams; Figure 8) can be pea-sized or smaller. Since clams require a fairly constant aquatic environment in order to survive, the search for bivalves can be conducted while looking for other benthic macroinvertebrates. A small net may be useful.

Figure 8. Fingernail claims

24. Fish

Fluctuating water levels of intermittent streams provide unstable and stressful habitat conditions for fish communities. When looking for fish, all available habitats should be observed, including pools, riffles, root clumps, and other obstructions (to greatly reduce surface glare, the use of polarized sunglasses is recommended). In small streams, the majority of species usually inhabit pools and runs. Fish should be easily observed within a minute or two. Also, fish will seek cover once alerted to your presence, so be sure to look for them slightly ahead of where you are walking along the stream. Check several areas along the stream sampling reach, especially underneath undercut banks. In most cases, fish are indicators of perennial streams, since fish will rarely inhabit an intermittent stream.

25. Amphibians

Salamanders and tadpoles can be found under rocks, on streambanks and on the bottom of the stream channel. They may also appear in the benthic sample. Frogs will alert you of their presence by jumping into the water for cover, usually following an audible “squeak”. Frogs and tadpoles typically inhabit the shallow, slower moving waters of the pools and near the sides of the bank. Amphibian eggs, also included as an indicator, can be located on the bottom of rocks and in or on other submerged debris. They are usually observed in gelatinous clumps or strings of eggs.

Figure 9. Salamander

26. Benthic Macroinvertebrates

The larval stages of many aquatic insects are good indicators that a stream is perennial because a continuous aquatic habitat is required for these species to mature. Use a small net and sample a variety of habitats including water under overhanging banks or roots, accumulations of organic debris (e.g. leaves) and the substrate. Note both the quantity as well as the diversity of your macroinvertebrate sample on the field form when scoring. Details on specific macroinvertebrate taxa that indicate perennial flow can be found in Section 2 – Guidance for the Determination of the Origin of Perennial Streams" (page 29).

Caddisfly: *Diplectrona sp*

Stonefly*: Eccoptera sp*.

Figure 10. Benthic macroinvertebrates

27. Presence of Filamentous Algae and Periphyton

These forms of algae are attached to the substrate. They are visible as a pigmented mass or film, or sometimes hairlike growths on submerged surfaces of rocks, logs, plants and any other structure within the stream channel. These life forms require an aquatic environment to persist. Periphyton growth is influenced by chemical disturbances such as increased nutrient (nitrogen or phosphorus) inputs and physical disturbances such as increased sunlight to the stream from riparian zone disturbances.

28. Iron Oxidizing Bacteria/Fungus

In slow moving (or stagnant) areas of the stream, are there clumps of “fluffy” rust-red material in the water? Additionally, on the sides of the bank (or in the streambed) are there red or rust colored stains (usually an “oily sheen” or “oily scum” will accompany these areas) on the soil surface? These features are often (although not exclusively) associated with groundwater. Iron oxidizing bacteria/fungus in streams derives energy by oxidizing iron, originating from groundwater, in the ferrous form (Fe^{2+}) to the ferric form (Fe^{3+}). In large amounts, iron-oxidizing bacteria/fungus discolors the stream substrate giving it a red appearance. In small amounts, it can be observed as an oily sheen on the water’s surface. This indicates that the stream is being recharged from a groundwater source, and these features are most commonly seen at seeps or springs.

Filmy deposits on the surface or banks of a stream are often associated with the greasy "rainbow" appearance of iron oxidizing bacteria. This is a naturally occurring phenomenon where there is iron in the groundwater. However, a sudden or unusual occurrence may indicate a petroleum product release from an underground fuel storage tank. One way to differentiate iron-oxidizing bacteria from oil releases is to trail a small stick or leaf through the film. If the film breaks up into small islands or clusters, it is most likely bacterial in origin. However, if the film swirls together, it is most likely a petroleum discharge.

Figure 11. Iron oxidizing bacteria. Figure on right depicts iron bacteria on a twig.

29. Wetland Plants in Streambed

The U.S. Army Corp of Engineers wetland delineation procedure utilizes a plant species classification system upon which soil moisture regimes can be inferred (Table 4). This same system can be used to infer the duration of soil saturation in stream channels. Small, low gradient, low velocity intermittent and perennial streams with adequate sunlight will often have OBL and FACW wetland plants or submerged aquatic vegetation growing in the stream bed. All wetland designations are defined by *National List of Plant Species That Occur in Wetlands: Southeast Region 2*. 1988. U.S. Fish and Wildlife Service. (http://wetlands.fws.gov/plants.htm) Submerged Aquatic Vegetation (SAV) grows completely underwater (for instance Coontail -- *Ceratophyllum demersum*)

Table 4. Indicator categories of wetland plants.

Code	Wetland Type	Comment
OBL	Obligate Wetland	Occurs almost always (estimated probability 99%) under natural conditions in wetlands.
FACW	Facultative Wetland	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
FAC	Facultative	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
FACU	Facultative Upland	Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).
UPL	Obligate Upland	Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. If a species does not occur in wetlands in any region, it is not on the National List.

History of the Stream Identification Manual and Forms.

Version 1.0 **–** Method was originally derived to correlate scores with the persistence of water. Low scores would indicate stream channels in the upper portions of watersheds (low order streams), and the highest scores would indicate major rivers (high order streams).

Version 2.0 **–** Effective January 19, 1999. The method was termed the NC Stream Classification Method and was adapted as a result of HB 1257 (Stream Identification for Buffer Rules); 2000-2001 Session of the NC General Assembly. The Stream Technical Advisory group evaluated Version 1.0 of the form and recommended the use of the modified form for use by the DWQ.

Version 3.0 **–** Added considerable amount of explanatory material and restructured the rating form. Issued for public comment: September 21, 2004. Version 3.0 was developed during the summer and fall of 2004. Version 3.0 was used in the development of Version 3.1.

Version 3.1 **–** Effective February 28, 2005. Minor editions and corrections resulting from a test of the Version 3.0 material during the Surface Water Identification Training and Certification (SWITC) Class; November 15-17, 2004 and December 8-9, 2004. Version 3.1 incorporated the “Guidance for the Determination of the Origin of Perennial Streams.”

SECTION 2 – Guidance for the Determination of the Origin of Perennial Streams

Background

A Stream Technical Advisory Committee (TAC) was established by the DWQ in December 1998 to provide technical, scientific input related to the definitions of streams and waterbodies in the Neuse River basin. The TAC approved a stream classification methodology that evaluates the geomorphology, hydrology and biology of stream features to determine the origin of intermittent streams as well as narrative definitions for these stream types (NCDWQ 1999).

The DWQ utilizes a numerical cutoff of 19 points with this evaluation form as an appropriate value to classify a stream as at least “intermittent”. However, DWQ has not previously utilized a numerical cutoff for the perennial threshold. Currently, the DWQ relies on a policy to describe the thresholds between an intermittent and a perennial channel which suggests that investigators use the presence of biological indicators such as fish, crayfish (in channel), amphibians, mussels (clams) or large (multi-year) tadpoles as perennial stream indicators. This internal policy has proven to be effective in many instances such as intermittent/perennial determinations during unusual flow periods (such as extreme drought) and in some ecoregions of North Carolina (Triassic Basin and coastal plain streams). In addition, DWQ’s water supply watershed protection rules, which are implemented by local governments, and compensatory stream mitigation requirements are affected by whether a stream is perennial or intermittent. This provides another reason for DWQ to develop and utilize a more scientifically valid definition for perennial streams.

Recent and on-going Investigations

As part of a recent investigation for the City of Greensboro, personnel with Law Engineering and Environmental Services (now MacTec Environmental Services), with the support of DWQ personnel, used a modification of the DWQ stream classification method and recommend a numerical cutoff for a perennial stream origin in the piedmont of 30 points (Lawson, et al. 2002). In addition, DWQ biologists have been looking for the presence of long-lived aquatic species as reliable determinants for perennial channels. These investigations suggest that the presence of a select group of benthic macroinvertebrates that require water for their entire life cycles (rheophilic taxa) is a reliable method to determine the origins of perennial channels. A proposed list of these organisms is included with this policy revision (Tables 5 and 6). The DWQ is currently conducting an investigation of the ecological functions of intermittent stream channels. Results from this federally funded investigation also have corroborated the technique of using a suite of rheophilic aquatic insect taxa to determine perennial stream origins.

Revised DWQ Policy for the Definition of Perennial Stream Origins

A perennial stream is defined as a well-defined channel that contains water year round during a year of normal rainfall[2] with the aquatic bed located below the water table for most of the year (15A NCAC 2B.0100). This definition also notes that perennial streams exhibit the typical biological, hydrological, and physical characteristics commonly associated with the continuous conveyance of water.

A stream channel is perennial when any of the following criteria are met:

1. Biological indicators such as fish, crayfish (in channel), amphibians (larval salamanders and large, multi-year tadpoles), or clams are present. If only crayfish or fingernail clams are present, a numerical value of at least 18 on the geomorphology section of the most current version of the DWQ stream classification form is required.

OR

2. A numerical value of at least 30 points is determined from the most recent version of the DWQ stream identification form[3].

OR

3. More than one benthic macroinvertebrate that requires water for entire life cycles are present as later instar larvae[4]. A list of the benthic organisms commonly collected by DWQ biologists during perennial stream determinations are shown in Tables 5 and 6.

DWQ staff suggest that a stream be examined using these three criteria in the sequence above – namely, a field examination should first look for criterion 1 and then criterion 2. If the channel does not meet either of these two criteria and the field biologist believes the channel to be perennial, then the third criterion should be utilized – however identification by a well-trained aquatic entomologist is required for the proper use of this criterion. In most instances, the use of either of the first two criteria should be sufficient to make a stream determination.

[2] Normal Rainfall is defined as the 30 year average, provided by NOAA National Climatic Data Center, computed at the end of each decade. These data are available as annual and monthly means.
[3] Use of this form requires Division-based or approved training (or appropriate certification in accordance with GS 143-214.25
[4] Recognition and/or identification of these organisms will require Division-based or approved training.

Table 5. Ephemeroptera, Plecoptera and Trichoptera (EPT) perennial stream indicator taxa

	Ephemeroptera (Mayflies)	Plecoptera (Stoneflies)	Trichoptera (Caddisflies)
Family:	Baetidae	Peltoperlidae	Hydropsychidae
	Caenidae	Perlidae	Lepidostomatidae
	Ephemerellidae	Perlodidae	Limnephilidae
	Ephemeridae		Molannidae
	Heptageniidae		Odontoceridae
	Leptophlebiidae		Philopotamidae
	Siphlonuridae		Polycentropidae
			Psychomyiidae
			Rhyacophilidae

Table 6. Additional indicators of perennial stream features.

	Megaloptera	Odonata	Diptera	Coloptera	Mollusca
Family:	Corydalidae	Aeshnidae	Ptychopteridae	Elmidae	Unionidae
	Sialidae	Calopterygidae		Psephenidae	Ancylidae
		Cordulegastridae			Planorbidae
		Gomphidae			Pleuroceridae
		Libellulidae			
Family & ***Genus:***			Tipulidae *Tipula* sp.	Dryopidae *Helichus* (adult)	

Special Provision for Coastal Plain Streams

Reduced topography, which causes fewer channel forming features, can make the geomorphology section of the stream form problematic in the Middle Atlantic Coastal Plain and Southeastern Plains (Griffith et. al. 2002) – approximately east of I-95. In this area, biology should take precedence over geomorphology for determining a stream. Therefore the criteria should be utilized in the following sequence: 1, 3, and then 2.

History of the *Guidance for the Determination of the Origin of Perennial Streams*

Version 1.0 – Developed in 1997/1998. Fish, salamanders, turtles, crayfish and multiyear (large) tadpoles were used as indicators.

Version 2.1 – Added Stoneflies, Mayflies and Caddisflies

Version 2.2 – Added section about the coastal plain

Version 2.3 – Added taxa lists (Tables 5 and 6)

Version 2.4 – Effective February 28, 2005. Added tables of macroinvertebrate taxa found in perennial streams. Issued for public comment October 13, 2004.

List of References

Griffith, G.E., Omernik, J.M., Comstock, J.A., Schafale, M.P., McNab, W.H., Lenat, D.R., MacPherson, T.M., Glover, J.B. and Shelburne, V.B. 2002. Ecoregions of North and South Carolina (color poster with map, descriptive text, summary tables and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,500,00).

Lawson, J., R. Darling, D. Penrose, and J.D. Gregory. 2002. Stream Identification and Mapping for Water-Supply Watershed Protection. In Proceedings, Watershed 2002, February 23-27, 2002, Fort Lauderdale, FL.

APPENDIX – Comparison Between Version 2.0 and 3.1 Scoring Forms.

VERSION 2.0 FORM	Versions 3.x Forms
Primary Field Indicators	
I. Geomorphology	
1) Is there a riffle-pool sequence?	3. In-channel structure: riffle-pool sequence
2) Is the USDA texture in streambed different from surrounding terrain?	4. Soil texture – Substrate sorting (Renamed attribute)
3) Are natural levees present?	9. Natural Levees
4) Is the channel sinuous?	2. Sinuosity
5) Is there an active (or relic) floodplain present?	5. Active/relic floodplain
6) Is the channel braided?	7. Braided channel
7) Are recent alluvial deposits present?	8. Recent alluvial deposits
8) Is there a bankfull bench present?	6. Depositional bars or benches
9) Is a continuous bed & bank present?	1. Continuous bed and bank
10) Is a 2nd order or greater channel (as indicated on topo map and/or in field) present?	13. Second or greater order channel on <u>existing</u> USGS or NRCS map
II. Hydrology	
1) Is there a groundwater flow/discharge present?	14. Groundwater flow/discharge
III. Biology	
1) Are fibrous roots present in streambed?	20. Fibrous roots in channel
2) Are rooted plants present in streambed?	21. Rooted plants in channel
3) Is periphyton present?	*27. Filamentous algae; periphyton (Version 2.0 items combined)
4) Are bivalves present?	23. Bivalves
Secondary Field Indicators	
I. Geomorphology	
1) Is there a head cut present in channel	10. Headcuts
2) Is there a grade control point in channel	11. Grade Control
3) Does topography indicate a natural drainage way?	12. Natural Valley and drainageway
II. Hydrology	
1) Is this year's (or last's) leaf litter present in streambed?	16. Leaflitter
2) Is sediment on plants (or debris) present	17. Sediment on plants
3) Are wrack lines present?	18. Organic debris lines or piles (Wrack lines)
4) Is water in channel and >48 hrs. since last known rain? 5) Is there water in channel during dry conditions or in growing season?	15. Water in channel and > 48 hrs since rain. or Water in channel – dry or growing season (Version 2.0 items combined)
6) Are hydric soils present in sides of channel (or in headcut)	19. Hydric soils (redoximorphic features) present?
III. Biology	
1) Are fish present?	24. Fish
2) Are amphibians present?	25. Amphibians
3) Are aquatic turtles present?	DELETED (No aquatic turtles ever scored)
4) Are crayfish present?	22. Crayfish
5) Are macrobenthos present?	26. Macrobenthos
6) Are iron oxidizing bacteria/fungus present?	28. Iron oxidizing bacteria/fungus
7) Is filamentous algae present?	*27. Filamentous algae; periphyton
8) Are Wetland Plants in Streambed?	29. Wetland plants in streambed

North Carolina Division of Water Quality – Stream Identification Form; Version 3.1

Date:	**Project:**	**Latitude:**
Evaluator:	**Site:**	**Longitude:**
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30*	**County:**	**Other** *e.g. Quad Name:*

A. Geomorphology (Subtotal =_________)	Absent	Weak	Moderate	Strong
1[a]. Continuous bed and bank	0	1	2	3
2. Sinuosity	0	1	2	3
3. In-channel structure: riffle-pool sequence	0	1	2	3
4. Soil texture or stream substrate sorting	0	1	2	3
5. Active/relic floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Braided channel	0	1	2	3
8. Recent alluvial deposits	0	1	2	3
9[a] Natural levees	0	1	2	3
10. Headcuts	0	1	2	3
11. Grade controls	0	0.5	1	1.5
12. Natural valley or drainageway	0	0.5	1	1.5
13. Second or greater order channel on existing USGS or NRCS map or other documented evidence.	No = 0		Yes = 3	

[a] Man-made ditches are not rated; see discussions in manual

B. Hydrology (Subtotal = _________)				
14. Groundwater flow/discharge	0	1	2	3
15. Water in channel and > 48 hrs since rain, **or** Water in channel -- dry or growing season	0	1	2	3
16. Leaflitter	1.5	1	0.5	0
17. Sediment on plants or debris	0	0.5	1	1.5
18. Organic debris lines or piles (Wrack lines)	0	0.5	1	1.5
19. Hydric soils (redoximorphic features) present?	No = 0		Yes = 1.5	

C. Biology (Subtotal = _________)				
20[b]. Fibrous roots in channel	3	2	1	0
21[b]. Rooted plants in channel	3	2	1	0
22. Crayfish	0	0.5	1	1.5
23. Bivalves	0	1	2	3
24. Fish	0	0.5	1	1.5
25. Amphibians	0	0.5	1	1.5
26. Macrobenthos (note diversity and abundance)	0	0.5	1	1.5
27. Filamentous algae; periphyton	0	1	2	3
28. Iron oxidizing bacteria/fungus.	0	0.5	1	1.5
29[b]. Wetland plants in streambed	FAC = 0.5; FACW = 0.75; OBL = 1.5 SAV = 2.0; Other = 0			

[b] Items 20 and 21 focus on the presence of upland plants, Item 29 focuses on the presence of aquatic or wetland plants.

Notes: (use back side of this form for additional notes.)

Sketch:

North Carolina
Division of Water Quality

Methodology for Identification of Intermittent and Perennial Streams and Their Origins

Version 4.11
Effective Date: September 1, 2010

This document should be cited as:

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Further Information can be obtained from:

North Carolina Division of Water Quality
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1650 Mail Service Center
Raleigh, NC 27699-1650

(919) 733-1786

Copies of this document are available through the internet:
http://portal.ncdenr.org/web/wq/swp/ws/401/waterresources/streamdeterminations

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SECTION 1 – Stream Identification Methodology

Introduction

This stream identification methodology is intended to guide natural resource professionals in the identification of ephemeral, intermittent and perennial streams using geomorphic, hydrologic and biological stream features. This manual and accompanying field form can be used to identify points on the landscape that represent stream origins and to determine whether a stream is ephemeral, intermittent or perennial in reaches that are some distance downstream of an origin. The manual focuses on headwater streams and the characteristic features of low-order streams wherever they occur in a watershed. Section 1 provides the background and scientific justification for the methodology. Section 2 outlines the field method and use of the rating form. Section 3 provides details on additional procedures for determination of a perennial stream.

Version 4.11 of the manual replaces Version 3.1 (February 28, 2005) and reflects five years of regulatory and academic experience gained since the version 3.1. Clarifications and edits were made in several areas throughout the document to provide additional background on the methodology and improve readability of the manual. Changes to the indicators in the methodology were made for clarification purposes only and do not affect the total scores for stream evaluations or the stream determination made by professionals using the methodology. Changes made to indicators and scoring on the stream form from version 3.1 to 4.11 can be found at http://portal.ncdenr.org/web/wq/swp/ws/401/waterresources/streamdeterminations on the DWQ website.

Purpose and Need

The *Methodology for Identification of Intermittent and Perennial Streams and Their Origins* and numerical rating system were developed in response to requests from the North Carolina regulated community for an objective method to identify ephemeral, intermittent and perennial streams. The need for a stream identification methodology resulted from implementation of the Neuse River Basin Riparian Buffer Rules mandating buffers on all intermittent and perennial streams in the basin. The methodology has since been implemented for other river basins in the state that have riparian buffer rules as well as for stream identification related to stream mitigation. The definitions of ephemeral, intermittent and perennial streams are part of the North Carolina Administrative Code (NCAC) and the methods are tailored to these regulatory definitions. Complete language for the rules can be found at:
http://reports.oah.state.nc.us/ncac.asp?folderName=\Title%2015A%20-%20Environment%20and%20Natural%20Resources

The regulatory definitions of streams and related terms are below. Citation of the appropriate section of the North Carolina Administrative Code (NCAC) is shown in parentheses following each definition.

'Stream' means a body of concentrated flowing water in a natural low area or natural channel on the land surface. [15A NCAC 02B .0233(2)(k)]

'Channel' means a natural water-carrying trough cut vertically into low areas of the land surface by erosive action of concentrated flowing water or a ditch or canal excavated for the flow of water. [15A NCAC 02B .0233(2)(a)]

'Ditch or canal' means a man-made channel other than a modified natural stream constructed for drainage purposes that is typically dug through inter-stream divide areas. A ditch or canal may have flows that are perennial, intermittent, or ephemeral and may exhibit hydrological and biological characteristics similar to perennial or intermittent streams. [15A NCAC 02B .0233(2)(c)]

'Ephemeral (stormwater) stream' means a feature that carries only stormwater in direct response to precipitation with water flowing only during and shortly after large precipitation events. An ephemeral stream may or may not have a well-defined channel, the aquatic bed is always above the water table, and stormwater runoff is the primary source of water. An ephemeral stream typically lacks the biological, hydrological, and physical characteristics commonly associated with the continuous or intermittent conveyance of water. [15A NCAC 02B .0233(2)(d)]

'Groundwaters' means those waters occurring in the subsurface under saturated conditions. [15A NCAC 02L .0102 (11)]

'Intermittent stream' means a well-defined channel that contains water for only part of the year, typically during winter and spring when the aquatic bed is below the water table. The flow may be heavily supplemented by stormwater runoff. An intermittent stream often lacks the biological and hydrological characteristics commonly associated with the conveyance of water. [15A NCAC 02B .0233(2)(g)]

'Modified natural stream' means an on-site channelization or relocation of a stream and subsequent relocation of the intermittent or perennial flow as evidenced by topographic alterations in the immediate watershed. A modified natural stream must have the typical biological, hydrological, and physical characteristics commonly associated with the continuous conveyance of water. [15A NCAC 02B .0233(2)(h)]

'Perched water table' means a saturated soil horizon or horizon subdivision, with a free water surface periodically observed in a bore hole or shallow monitoring well, but generally above the normal water table, or may be identified by drainage mottles or redoximorphic features, and caused by a less permeable lower horizon. [15A NCAC 18A .1935 (34)]

'Perennial stream' means 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. [15A NCAC 02B .0233(2)(i)]

'Seasonal High Water Table' means the highest level that groundwater, at atmospheric pressure, reaches in the soil in most years. The seasonal high water table is usually detected by the mottling of the soil that results from mineral leaching. [15A NCAC 02H .1002 (15).]

Note that the definition of an intermittent stream refers to a stream only containing water for part of the year (typically winter and spring). Therefore the term “water table” that was used in the intermittent stream definition refers to the seasonal high water table in the riparian zone soil adjacent to the stream.

Development and Implementation Process

A Stream Technical Advisory Committee (TAC) was established by the North Carolina Division of Water Quality (NC DWQ) in December 1998 to provide technical and scientific input related to the definitions of streams and waterbodies in the Neuse River Basin for use in applying the riparian buffer rules. The TAC created the narrative stream definitions above and evaluated and approved a stream identification methodology, developed by NC DWQ, that evaluates geomorphic, hydrologic and biological stream features to determine the origins of intermittent streams

The system of scoring stream features and developing minimum total scores for stream identification were established based on the results from over 300 individual field trials conducted in the piedmont and coastal plain portions of the Neuse River Basin, North Carolina. Field testing conducted during May, June, July and August of 1998 and during December 1998 and January 1999 consistently supported a minimum total score of 19.0 to distinguish ephemeral streams from intermittent streams. Scores less than 19.0 indicate ephemeral streams, whereas scores 19.0 or greater provide sufficient evidence that at least an intermittent stream is present. A score of 30.0 or more points is one method that may be used to determine the presence of a perennial stream. Alternate procedures for perennial stream identification are documented in Section 3 – Guidance for the Determination of Perennial Streams.

Since the adoption of the first version of the stream identification manual in 1999, improvements and clarifications have been made in subsequent versions based on scientific literature and investigation as well as on experience and recommendations from the natural resource community using the methodology. Prior to the implementation of a revised manual, the manual is submitted to a 60-day public review period. All comments and suggestions collected over the review period are considered and incorporated when applicable. Following final revisions, the final manual version is adopted with an effective date and made available for all users.

To date, the NC DWQ Stream Identification Methodology has served as the basis for similar endeavors elsewhere across the country, e.g. Fairfax County, Virginia (http://www.fairfaxcounty.gov/dpwes/watersheds/ps_protocols.pdf); the Athens-Clarke County, Georgia, Department of Transportation and Public Works (http://www.athensclarkecounty.com/documents/pdf/publicworks/stream_id_manual.pdf); State of Oregon US Army Corps of Engineers (USACE); South Carolina Department of Health and Environmental Control, and Tennessee Department of Environment and Conservation.

History of the Stream Identification Manual and Forms

Version 1.0 – Unpublished. The Stream Identification Method was originally developed to correlate scores with the persistence of water. Low scores would indicate streams in the upper portions of watersheds (low order streams), and the highest scores would indicate major rivers (high order streams).

Version 2.0 – Effective January 19, 1999. The method was termed the NC Stream Classification Method and was adopted as a result of HB 1257 (Stream Identification for Buffer Rules), 2001-2002 Session of the NC General Assembly. The Stream Technical Advisory Committee evaluated and revised Version 1.0 of the form and recommended the use of the modified form by the NC DWQ.

Version 3.0 – Added considerable amount of explanatory material and restructured the rating form. Version 3.0 was developed during the summer and fall of 2004, and issued for public comment September 21, 2004. Version 3.0 was used in the development of Version 3.1.

Version 3.1 – Effective February 28, 2005- Minor edits and corrections resulting from a test of the Version 3.0 material during the Surface Water Identification Training and Certification (SWITC) Class; November 15-17, 2004 and December 8-9, 2004. Version 3.1 incorporated the "Guidance for the Determination of the Origin of Perennial Streams."

Version 4.11 – Effective September 1, 2010. Edits, clarifications and corrections resulting from a test of the Version 3.1 material during the Surface Water Identification Training and Certification (SWITC) Classes in 2006, 2007 and 2008. Title change from "*Identification Methods for the Origins of Intermittent and Perennial Streams"* to **"**Methodology for Identification of Intermittent and Perennial Streams and their Origins."

Scientific Justification

A stream can be described as flowing surface water in a channel resulting from five sources of water discharge to the stream from the adjacent landscape (Figure 1). Baseflow or normal low flow in a stream between rainfall events is provided by two of those sources, *groundwater discharge* into the channel and *unsaturated drainage from the soil moisture zone* above the water table to the groundwater zone. During and shortly after rainstorms, the increased flow in the channel known as stormflow is provided by *direct channel precipitation,* surface runoff as *overland flow*, and rapid unsaturated flow through the soil (*interflow*) directly to the stream or to the groundwater zone. Increased groundwater discharge also provides a contribution to stormflow.

Streams may exhibit both stormflow and baseflow characteristics as they flow from their origins to their destinations. However, the seasonal or continual presence of baseflow defines a stream as intermittent or perennial, respectively. The North Carolina stream definitions do not require water to be flowing, but only prescribe that water be present to meet the definition of intermittent or perennial flow for regulatory purposes. Also, within the regulatory framework, an intermittent or perennial stream origin is defined as a specific location in a stream. However, in most cases, stream origins usually occur as transition zones in which the location and length of the zone is subject to fluctuations in groundwater levels and precipitation. Frequently, streams change from ephemeral to intermittent and intermittent to perennial along a gradient or continuum — sometimes with no single distinct point demarcating these transitions (Figure 2).

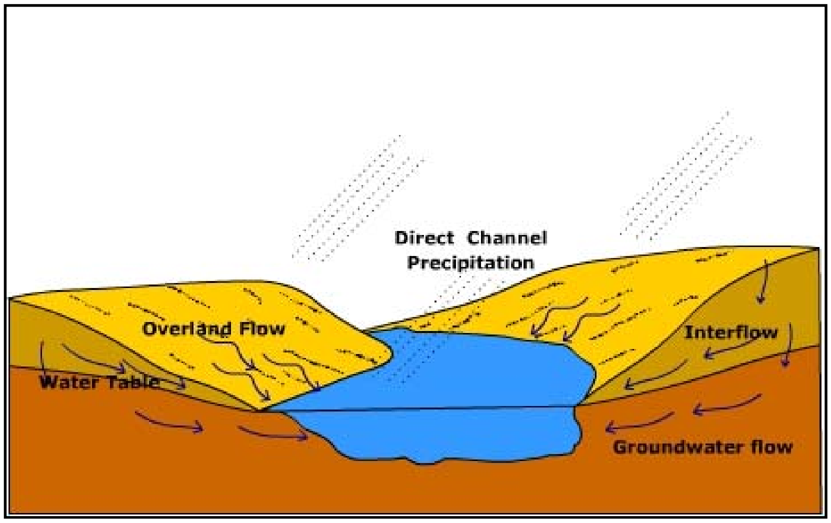

Figure 1: Streamflow sources (Ritter 2008)

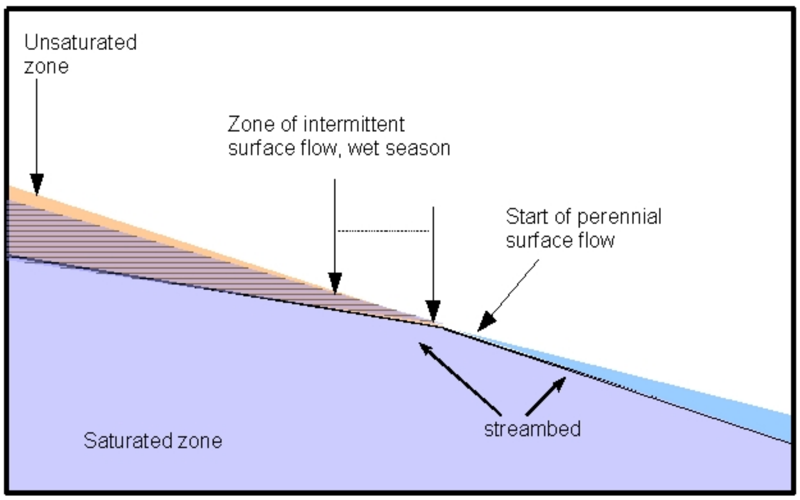

Figure 2: Illustration of perennial and intermittent surface flow intersecting groundwater. Adapted from Winter et al. 1998 http://pubs.usgs.gov/circ/circ1139.

In North Carolina, some streams follow that pattern and transition from ephemeral to intermittent to perennial, but in many cases, they do not. The transition in flow duration varies by landscape and general trends can be observed by geologic province, i.e., mountains, piedmont and coastal plain (Russell, unpublished report, 2008a).

The presence or absence of permanent stream flow defines the hydrologic, geomorphic and biological character of streams. Hence, stream systems can be characterized by interactions among hydrologic, geomorphic (physical) and biological processes. Similar to the downstream continuum of ephemeral to intermittent to perennial stream flow, physical and biological characteristics follow the same pattern in response to flow volume and duration. The term "flow duration" used in this manual refers collectively to ephemeral, intermittent and perennial flow as described as one of the five components of flow regime (Poff and Ward 1989; Richter et al. 1996; Walker et al. 1995). Variations in physical and biological characteristics along the length of a stream can help distinguish what source of water predominately contributes to flow. The fundamental source of water for intermittent and perennial stream baseflow as defined in the North Carolina Administrative Code (NCAC) is groundwater resulting from the intersection of the water table with the streambed. This definition is consistent with those of several other federal and state government agencies as well as many academic organizations (Moore 2003; Jackson et al. 2005; Beaudry et al. 2006; U.S. Army Corps of Engineers 2007,Wilson 2003).

As baseflow becomes more persistent in the downstream direction, stream discharge, both stormflow and baseflow, increases and stream characteristics related to geomorphic, hydrologic and biological processes are more readily observed. For example, stream bedforms, such as gravel bars and pool-riffle sequences, are much more defined in perennial streams than in intermittent streams due to increased sediment supply as well as transport and depositional processes. Furthermore, aquatic organisms respond to the availability of habitat formed and maintained by geomorphic and hydrologic processes and vary depending on the persistence of water and streamflow.

Stream characteristics and commonly observable features resulting from geomorphic, hydrologic and biological processes are used in this stream identification methodology to produce a numeric score. Attributes serve as indicators that can be observed independently of each other, although they are not intended to independently determine stream flow duration. The total score of all indicators provides the means for stream determination. The score is then used to assign a stream type of “ephemeral”, “intermittent”, or “perennial” to the stream reach being evaluated.

SECTION 2 - Stream Identification Field Method and Rating Form

Suggested Field Equipment

Aquatic net and shallow white pan – used to catch and examine benthic macroinvertebrates and aquatic vertebrates. A small aquarium net and plastic container lid may suffice if carrying full-size equipment is not feasible.

Global Positioning System (GPS) – used to determine coordinates of the stream origin or of a stream reach.

Camera – used to photograph and document site features.

Munsell Soil Color Charts (Munsell 2000) – used to determine the soil matrix chroma when looking for soil-based evidence of a seasonal high-water table.

Field Indicators of Hydric Soils of the United States (USDA 2010)– used to help determine the presence of a high water table.

Soil auger – used to extract soils.

National List of Vascular Plant Species that Occur in Wetlands: 1996 National Summary (U.S. FWS 1997) - used to determine the indicator status of plants found in and adjacent to the streambed.

Basic rules for making stream determinations:

Do not evaluate a stream within 48 hours of rainfall that results in surface runoff.

Generally, it takes about 48 hours for increased streamflow resulting from precipitation to attenuate. Delaying a stream determination following rainfall helps to eliminate visual bias associated with observing water in a stream that may not currently have baseflow. Also stormflow may obscure many of the channel features that need to be observed and evaluated.

Review information on stream to be evaluated.

Gather and review available information regarding the area and location of the stream. The use of U.S. Geological Survey (USGS) topographic maps, Natural Resources Conservation Service (NRCS) soil survey maps, geology maps and/or high resolution topographic data (e.g., LiDAR-based) or aerial photography may help provide information when conducting the field investigation. Other important data may include land use/land cover or current construction activity in the area. To assist in evaluating whether flow in the stream is typical, current streamflow at nearby gauges, recent rainfall compared to normal, and drought status information is useful.

Become familiar with the characteristics of headwaters streams in the region of interest.

Beginning users of this manual and form should visit a variety of headwater streams, look for the geomorphic, hydrologic and biological features discussed here, and gain experience observing the magnitude and variability of these features. The field evaluator is strongly encouraged to attend the four-day stream identification methodology class, taught by the NC DWQ and/or NC State University, pass the written and field exams, and to have familiarity with geomorphic, hydrologic and biological characteristics in headwater streams.

Walk to the upstream extent of the feature when feasible.

Evaluating the degree of development of many of the Stream Identification Method indicators involves comparing the stream reach of interest to upstream portions of the stream. Headwater streams are often discontinuous with segments with very poorly developed channels where baseflow flows under the surface. Therefore, an apparent perennial or intermittent stream origin may not be the actual origin. Continue walking upstream towards the ridge top until you are certain that you have observed the entire drainageway to its origin.

Evaluate at least 100 ft of stream to determine average conditions.

Determinations must not be made by observing one location in a stream, but rather should be made by observing a reach of stream. Generally, at least one hundred feet (sometimes more) of channel should be walked to make observations. This initial examination allows the evaluator to examine and study the nature of the channel, noting the presence or absence of bedforms, dominant sediment size, dominant stream processes, and characteristics that indicate the predominant source of water (stormflow, baseflow, tributary discharge, and the presence of benthic macroinvertebrates and/or vegetation). These initial observations also aid in determining the magnitude (absent, weak, moderate or strong) of specific parameters.

Scoring

Identification of stream flow duration is accomplished by evaluating 26 different attributes of the stream and assigning a numeric score to each attribute. A scoring sheet (included on the last page of this manual) is used to record the score for each attribute and determine the total numeric score for the stream under investigation. The sheet specifically requests information for Date, Project, Evaluator, Site, County, Other (Quad Name), and Latitude and Longitude. However any other pertinent observations should also be recorded on this sheet. These may include the amount and date of the last recent rain, hydrologic unit codes, or evidence of stream modifications. The hardcopy or digital scoring form is an official record, so all pertinent observations should be recorded on the form.

The total score is intended to reflect the persistence of water with higher scores indicating intermittent and perennial streams. A four–tiered, weighted scale used for evaluating and scoring each attribute addresses the variability of streams. The categories (and their accompanying numerical scores), “Absent”, “Weak”, “Moderate”, and “Strong” are applied to sets of geomorphic, hydrologic and biological attributes. The score given to an attribute reflects the evaluator’s judgment of the average degree of development of the attribute along a reach of the stream at least 100 ft long. These categories are intended to allow the evaluator flexibility in assessing variable features or attributes. The small increments in scoring between gradations help reduce the range in scores between different evaluators. The score ranges were developed in order to better assess the often gradual and variable transitions of streams from ephemeral to intermittent.
Definitions of Absent, Weak, Moderate and Strong are provided in Table 1. These definitions are intended as guidelines and the evaluator must select the most appropriate category based upon experience and observations of the stream under review, its watershed, and physiographic region. “Moderate” scores are intended as an approximate qualitative midpoint between the two extremes of “Absent” and “Strong.” The remaining qualitative description of “Weak” represents gradations that will often be observed in the field.

Table 1: Guide to scoring categories

Category	Description
Absent	The character is not observed
Weak	The character is present but you have to search intensely (i.e., ten or more minutes) to find and evaluate it
Moderate	The character is present and observable with brief (i.e., one or two minutes) searching and evaluation
Strong	The character is easily observable and quickly evaluated

Sources of Variability

Sources of spatial variation among stream systems are due primarily to geology, soils, and land cover and their interactions with precipitation and climate. For example, riffles, steps and pools are in-channel structures that vary by woody debris inputs, sediment size and sediment transport rates. Cobble, gravel and boulders are more common in the mountains and roots and woody debris are more common in the coastal plain. Other examples of variability include the magnitude (height) of headcuts, stream gradient and sediment supply.

Temporal variations in flow are related to seasonal changes in precipitation and evapotranspiration, as well as recent precipitation and snowmelt events. Because recent precipitation can have an effect on stream flow, and therefore can influence scoring, it is strongly recommended that field evaluations be conducted at least 48 hours after hydrology-altering events, when conditions would be considered “normal” or representative for the season.

However, please note that the identification method was designed with redundancy among the indicators to allow for reasonably accurate ratings even after a recent precipitation.

Ditches and Modified Natural Streams

In many parts of North Carolina it may be difficult to differentiate between an artificial feature (e.g. ditch or canal) and a natural stream that has been modified (e.g. straightened or relocated). There are a variety of techniques that can be employed to help make this distinction. The topographic lines depicted on a USGS topographic map may indicate a natural valley in which a natural stream could be present. Parallel topographic contour crenulations (V-shaped contour lines) with angles of 90^o or less can be indicative of the presence of a stream. Features located outside of a natural crenulation (i.e. moving across a slope rather than perpendicular to it) may not be natural or, alternatively, may be a relocated stream. Additionally, NRCS county soil survey maps often show the presence of linear soil mapping units, which are indicative of alluvial deposits and the presence of a stream. If the feature in question is determined to be artificial, scoring is not necessary for buffer rule applications in North Carolina since those rules do not apply to ditches. The exception is the Randleman Watershed Buffer Rules (see rules).

Field Form Indicators and Descriptions

A. Geomorphic Indicators

1. Continuity of Channel Bed and Bank

Throughout the length of the reach, is the stream clearly defined by having a discernable bank and streambed?

The bed of a stream is the channel bottom and the physical confine of the “normal” baseflow or low water flow. Streambanks are vertical or sloped areas rising from the bed of the channel and are the lateral constraints (channel margins) of flow during all stages but flood stage. Flooding occurs when a stream overflows its banks and partly or completely fills its floodplain. As a general rule, the bed is that part of the channel at or near "normal" flow, and the banks are that part above the water line. However, because discharge varies, this differentiation is subject to local interpretation. Usually the bed is clear of terrestrial vegetation, while the banks are subjected to water flow only during high stages, and therefore can support vegetation much of the time. This indicator will lessen and may diminish or become fragmented upstream as the stream becomes ephemeral.

Strong – The stream has a well developed channel with continuous bed and bank present throughout the length of the reach.

Moderate – The majority of the stream channel has a continuous bed and bank. However, there are obvious interruptions.

Weak – The majority of the stream channel has obvious interruptions in the continuity of bed and bank. However, there is still some representation of the bed and bank sequence.

Absent –The stream has a very poorly developed channel in which little or no bed and bank can be distinguished.

2. Sinuosity of Channel Along Thalweg

What is the extent of stream sinuosity throughout the reach being evaluated?

Sinuosity is a measure of a stream's "curviness." Specifically, hydraulic sinuosity is the sinuosity related to the hydraulic factors of water behavior rather than the influence of topography (Mueller 1968). Sinuosity is measured as the total stream length measured along the stream thalweg (the deepest part of the channel or the low flow channel) divided by the straight line valley length (Figure 3) (Mueller 1968; FISRWG 1998). The higher the result, the greater the sinuosity (Figure 4). The sinuosity of a stream is one way the stream maintains a constant gradient along the channel. Typically, natural, undisturbed streams with steep gradients have low sinuosity, and streams with low gradients have high sinuosity. The size of the stream and its contributing watershed area (a surrogate for discharge) are related to the stream gradient and sinuosity: usually the larger the stream, or stream order, the higher the sinuosity (Stall and Fok 1968). Intermittent streams do not have constant flow year-round, and as a result may have a less sinuous channel than perennial streams. Sinuosity should be visually estimated or measured in the field, rather than from aerial photography.

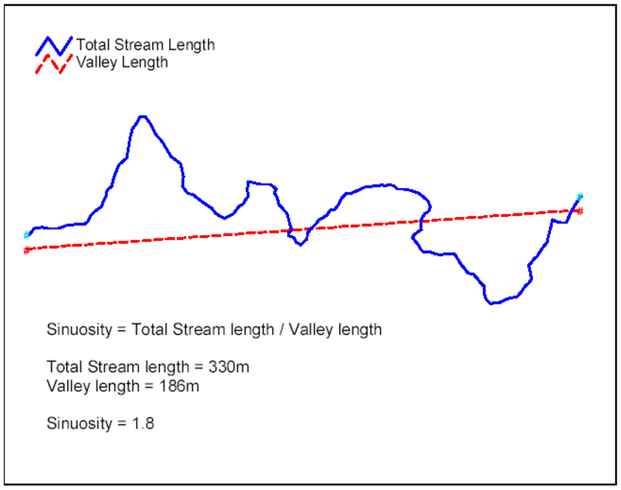

Figure 3: Stream Sinuosity (FISRWIG 1998).

Strong – Ratio > 1.4. Stream has numerous bends, very few straight sections.

Moderate – 1.2 < Ratio < 1.4. Stream has some bends with a few straight sections.

Weak – 1.0 < Ratio < 1.2. Stream has very few bends and numerous straight sections.

Absent – Ratio = 1.0. Stream is completely straight with no bends.

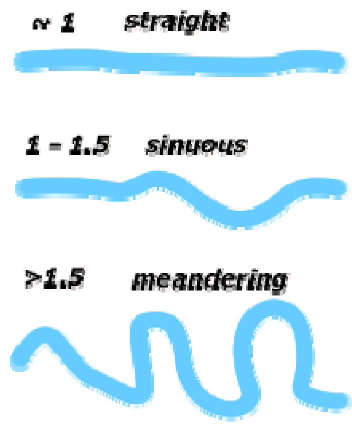

Figure 4: Sinuosity ratio as defined by Allen (1970)

3. In-channel structure: Riffle-Pool, Step-Pool, Ripple-Pool sequence

Is there a regular sequence of riffles and pools or other erosion/deposition structural features in the channel indicative of frequent high flows?

At low flows, a riffle is a zone of turbulent, shallow flow (similar to a rapid in larger streams). The substrate in riffles consists of the coarser sediment sizes in the stream. A pool is a zone of tranquil, deep-water flow. Finer sediments may dominate the bed material in pools if a fine textured sediment supply exists. In steep (slope > 2-4%) mountain and piedmont streams, step-pool sequences are typically formed instead of riffle-pool sequences.

A repeating sequence of riffle-pool (or riffle-run or ripple-pool in sand bed streams, or step-pool in higher gradient streams) is usually observed in perennial streams where the bed material is larger than coarse sand (Leopold 1994). Riffle-run sequences in low gradient streams, such as those in the coastal plain, are often created by in-channel wood such as roots and woody debris. Ripple-run sequences are often found in low gradient, hydraulically smooth streams where the bed consists of fine sand or silt (Gordon et al. 1994). When present, these bedform characteristics can be observed even in a dry stream bed by closely examining the local profile of the channel (Figure 5).

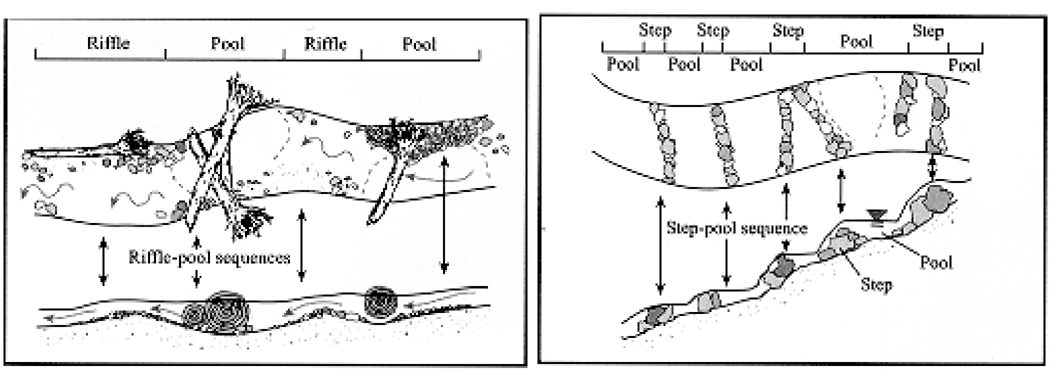

Figure 5: Riffle-pool and step-pool stream morphologies (Church 1992).

Strong – Stream has a frequent number of riffles followed by pools along the entire reach. There is an obvious transition between riffles and pools.

Moderate – Stream has less frequent number of riffles and pools. Distinguishing the transition between riffles and pools is difficult.

Weak – Stream has some structure but dominated by areas of pools or areas of riffles.

Absent – No sequence is observed.

4. Particle Size of Stream Substrate

Has downcutting penetrated through the soil profile such that the distribution of sediment size in the stream substrate is relatively coarser than the adjacent floodplain or streamside area?

Well developed streams that have eroded through the soil profile often have substrate materials dominated by larger sediment sizes, e.g., coarse sand, gravel and cobble, relative to floodplain sediments and adjacent soils (Table 2). Similar sediment sizes in the stream bed and the adjacent stream side area indicate that stream forming processes have not been consistent enough to cut into the soil profile and form an intermittent or perennial stream (Figure 6a). The bed in ephemeral channels is typically soil, have the same or similar soil texture as areas adjacent to the stream, and often have differentiated soil horizons. The bed of intermittent or perennial streams is often comprised of coarser sediment relative to the adjacent bank area or floodplain due to consistent stream-forming flows that have transported finer particles downstream as the channel has eroded downward (Figure 6b).

The usefulness of this attribute may vary among physiographic provinces. For instance, in the coastal plain or Sand Hills, the differences in particle sizes between the channel substrates and the channel bank/riparian zone soils are often less than in the piedmont and mountains.

Strong – The channel is well-developed through the soil profile with relatively coarse streambed sediments compared to riparian zone soils: coarse sand, gravel, or cobbles in the piedmont; gravel, cobbles, or boulders in the mountains, and medium or coarse sand in the coastal plain. Particle size differs greatly between the stream substrate and adjacent land.

Moderate – There is a well-developed channel but it is not deeply incised through the soil profile. Some coarse sediment is present in the streambed in a continuous layer. Particle size differs somewhat between the stream substrate and adjacent land.

Weak – The channel is poorly developed through the soil profile. Some coarse sediment is present in the streambed but is discontinuous. Particle size differs little between the stream substrate and adjacent land.

Absent – The channel is poorly developed, very little to no coarse sediment is present. There is no difference between particle size in the stream substrate and adjacent land.

Figure 6a. Ephemeral Stream Bed (NC DWQ)

Figure 6b. Perennial Stream Bed (NC DWQ)

Figure 6: Examples of Sediment Sizes in the Substrate

5. Active/Relict Floodplain

Is there an active floodplain at the bankfull elevation or is there evidence of recent stream incision with a relict floodplain (terrace) above the current bankfull elevation?

Floodplains are relatively flat, depositional areas adjacent to streams composed of alluvial material. In undisturbed streams, the elevation of the floodplain is roughly equivalent to bankfull elevation. An active floodplain abuts and parallels the stream and is a continuum of the stream bank (Figure 7). Floodplains accumulate organic matter and mineral alluvium deposited during receding flood waters. An active floodplain shows characteristics such as surface scour, drift lines, sediment deposited on the banks or surrounding plants and plants flattened by flowing water. In many cases there should be evidence of a floodplain if the stream has perennial flow and the floodplain becomes more continuous and developed as the stormflow volume and sediment transport increase downstream.

Occasionally, small, shallow ephemeral or intermittent channels in relatively broad, flat valley bottoms that are predominantly erosion/transport systems may have a floodplain formed of residual soil over which stormwater often flows. Such floodplains usually are not accumulating alluvium like floodplains farther downstream and should not receive the same score that one might apply to a floodplain formed by depositional processes.

Strong – The area displays all of the aforementioned characteristics. The floodplain consists of coarse- to fine-textured alluvium (check with soil auger) and is relatively wide and continuous on either or both sides of the stream.

Moderate – Most of the characteristics are apparent. The floodplain is not continuous on either or both sides of the stream.

Weak – The floodplain is not obvious, however some of the indicators are present. Small, infrequent segments of floodplain are present.

Absent – The characteristics are not present.

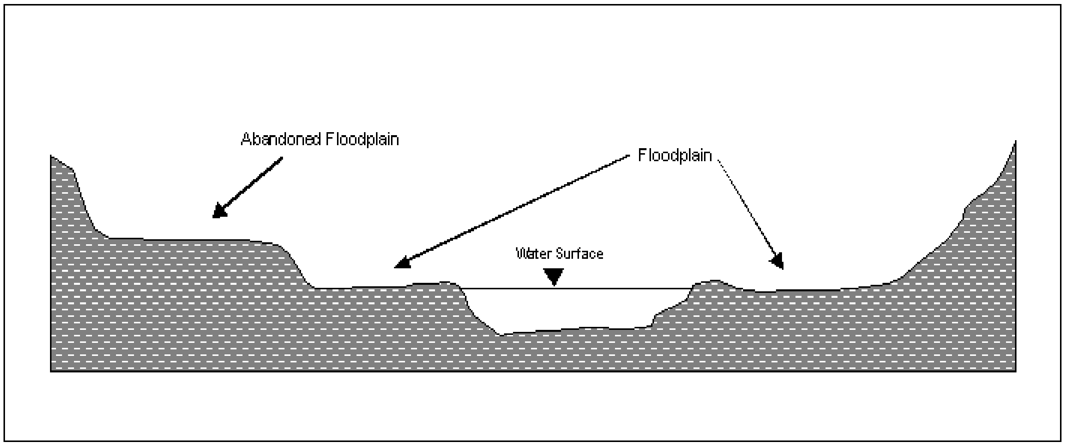

Figure 7: Illustration of abandoned floodplain relative to stream and active floodplain (Source unknown).

6. Depositional Bars or Benches

Are depositional (alluvial) bars and/or benches present in the stream?

When a stream conveys perennial flow, channel processes create distinct erosional and depositional features which can be readily observed. Bars are sediment storage areas in streams located along the margins or the middle of the stream (Figure 8). Point bars are located on the inside of bends in meandering streams, alternate bars are located along the sides of streams and are typical of streams with low sinuosity. Medial or midpoint bars are typical of streams that lack the capacity to transport their sediment load. The presence of depositional bars implies that the channel experiences relatively continuous sediment transport and deposition. The more obvious and continuous these depositional features are throughout the reach, the higher the score should be. Depositional features are often absent or subtle in very small, low order channels due to low sediment supply and/or steeper stream gradients.

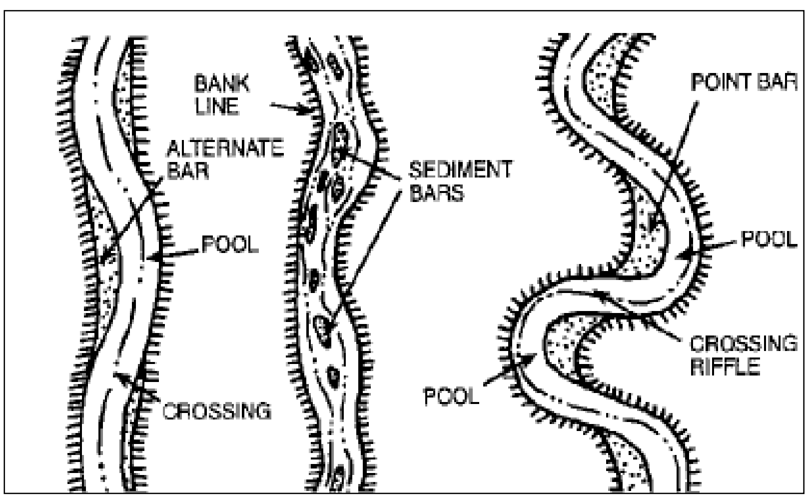

Figure 8: Plan view of depositional bars in streams (Ohio Stream Management Guide).

Bankfull benches (Figure 9) are located along the margins of the stream and are usually associated with deposition and scour resulting from bankfull flows in deeply incised streams. In stable streams, bankfull flow is the flow within the stream banks just before it spills over into the floodplain. In incised streams, the traditional, i.e., return interval of 1.5-2 years, bankfull flow does not spill over onto the floodplain, and sediment transport related to bankfull flow is not deposited on the floodplain, but rather in the stream along the margins. Over time, the scour of the bankfull flow and/or the deposition of sediment from receding bankfull flows accumulate, resulting in a bench on one or both of the stream margins. The presence of a bankfull bench is an indicator that the stream experiences bankfull flows and subsequent sediment transport and deposition usually associated with perennial streams.

Figure 9: Bankfull bench and related stream features (USACE 2005).

Strong – Depositional bars or benches are obvious throughout the sample reach.

Moderate – Indicators are present throughout most of the reach.

Weak – Indicators are infrequent along sampling reach.

Absent – Indicators are completely lacking.

7. Recent Alluvial Deposits

Are there fresh deposits of alluvial materials that have been transported and deposited on surfaces in the stream or on the floodplain by recent high flows?

Alluvial material in streams with intermittent and perennial flow is constantly being transported and deposited, or reworked, over time. Fresh alluvial deposits absent of vegetation and leaves or debris are observable following recent high flows in the stream and on the floodplain and are indicative of streams that have a sediment supply and flow needed to transport and deposit that sediment. Alluvium may consist of silt, sand, gravel, and/or various sized cobble. However, smaller sediment sizes are typically deposited last during receding flows so they may be more visible. Observe if there is any recent deposition of alluvium in the stream (Figure 10), on point bars or medial bars, or on the floodplain. Recent alluvial deposits may also be observed overlying floodplain vegetation, or at the crest or downstream end of a point bar.

Strong – Large amounts of fresh alluvium present in the channel and/or on the floodplain.

Moderate – Large to moderate amount of fresh alluvium present in the stream.

Weak – Small amounts of fresh alluvium present within the channel.

Absent – There are no recent alluvial deposits present within the stream or on the floodplain.

Figure 10: Recent alluvial deposits. Striped stick is 1.0 m long, painted in decimeters and lying on the streambed.

8. Headcuts

Is there a headcut at the upstream end of the reach being evaluated? Are there one or more headcuts within the reach being evaluated?

A headcut is an abrupt vertical drop in the bed of a stream that is an active erosional feature. It often resembles a small intermittent waterfall (or a miniature cliff) and may have a deep pool at the base resulting from scour. Intermittent or perennial streams sometimes begin at a head cut in the piedmont and mountains. Headcuts are transient structures of the stream and often exhibit relatively rapid upstream movement during periods of high flow. Groundwater seepage may also be present from the face or base of a head cut (Figures 11, 12).

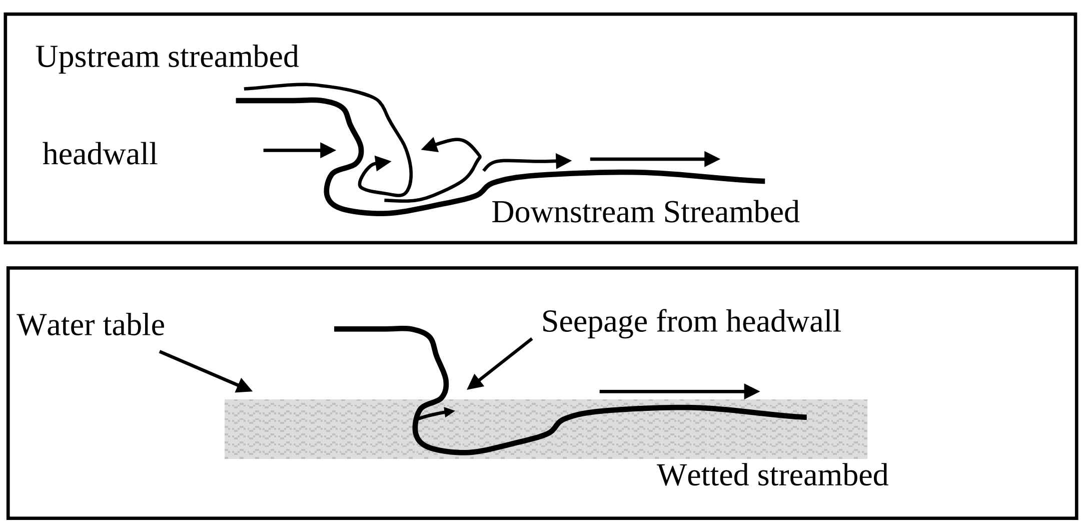

Figure 11: Headcut formation (Modified from Ken Fritz, EPA)

Strong –One or more obvious headcuts are present in the stream. Groundwater seepage may be present at the base of the headcut.

Moderate – One or more small headcuts are obvious and present in the stream.

Weak – One small headcut is present in the stream.

Absent – No headcuts are present.

Figure 12: Examples of Headcuts (NC DWQ, 2004)

9. Grade Control

Is there grade control within the reach being evaluated?

A grade control point is a structural feature in the channel that separates an abrupt change in grade of the stream bed, or a point where a headcut has been stopped by an obstruction (Figure 13). Grade controls may consist of bedrock outcrops, large boulder and cobble clusters, large roots that extend across the channel, or accumulations of large woody debris. Pipes can also be considered grade control, i.e. perched culverts, piped channels, or sewer lines crossing the channel. Grade controls may decrease the rate of headcut migration by providing an obstruction that is more resistant than the surrounding stream material. Grade control is dependent on the forming material and its residence time in the location. Bedrock will typically be more resistant to erosion (and therefore be in that location longer) relative to keyed in (stable) large wood. It may be difficult to decide what to call a headcut that is temporarily stopped by roots or debris. Is it a headcut or a grade control? Rate such features as either headcut or grade control, not both.

Strong –Exposed bedrock, boulder and cobble clusters and/or large wood jams are present in the channel and appear to be acting as relatively permanent grade control.

Moderate –Some exposed bedrock, boulder and cobble clusters, and/or large wood and roots are present in the channel and appear to be acting as grade control, but only with moderate longevity.

Weak – No bedrock, few to no boulder clusters, and/or few to no roots or wood are present but some may be acting as short-term grade control.

Absent – No grade control structures are in the stream.

Figure 13: Example of grade control in Umstead State Park, Wake County NC (Susan Howard 2007).

10. Natural Valley

Is there a well-developed valley at the location of the reach being evaluated?

A valley is an extended depression in the Earth's surface that is usually bounded by uplands, hills or mountains and is commonly occupied by a river or stream. Valley formation results from erosion or gradual wearing down of the land by wind and water. In river valleys for example, the river acts as an erosional agent by grinding down the rock or soil and creating a valley. Valley shapes vary but are typically steep-sided canyons or broad plains and their form is dependent on the erosional agent, the slope of the land, local and regional rock or soil material and time (Briney 2009).

In North Carolina, current valley formation and maintenance results from water erosion. The frequency and magnitude of water flowing over the land surface over time, in conjunction with the erodibility of underlying rock and soil material, determine the degree of valley formation. This indicator addresses the degree of valley development due to water as an erosional agent. In the continuum of a single valley, the degree of development of that valley usually increases in the downstream direction. Variation in the signature of a well-developed valley occurs across geologic provinces.

When looking at the local topography in the field, does the land slope towards the channel thereby indicating a “draw” or valley? In other words, does the land have slopes that seem to drain to or indicate a natural valley?

Strong – Well defined valley indicated by all surrounding land sloping downward to the valley bottom or stream.

Moderate – Defined valley indicated by most of the surrounding land sloping downward to the valley bottom or stream.

Weak –Subtle valley indicated by some of the surrounding land sloping downward to the valley bottom or stream.

Absent – No indication of surrounding land sloping to the valley bottom or stream. Channel located on side slope indicative of an artificial channel or stream relocation.

11. Second (or Greater) Order Channel

Is the channel reach being evaluated second order or greater, considering all intermittent and perennial channels that discharge to it?

The higher the channel order, the more likely a stream is to be perennial. Determine the order of the reach being evaluated in accordance with the Strahler Stream Order method (Strahler 1952), considering all intermittent and perennial stream segments that discharge to the evaluation reach. Due to inaccurate depiction of headwaters streams on maps, ground reconnaissance of the stream upstream of the reach being evaluated is preferred, when feasible. Use evidence of intermittent or perennial stream segments upstream of the evaluation reach on a USGS 1:24,000 topographic map or NRCS county soil survey map (printed version) when ground reconnaissance is not feasible. It is often difficult to evaluate stream order on channels that have been altered by upstream development. This indicator should be based on the natural condition of the stream network, when possible. Review of historic data such as a topographic or soils map that predates the development may be helpful. If such information is not available, then base the stream order determination on the current situation.

YES – The reach being evaluated is second (or greater) order based on intermittent or perennial stream segments discharging to it.

NO – The reach being evaluated is part of a first order stream or stream order cannot be determined.

B. Hydrologic Indicators

12. Presence of Baseflow

Does the presence of flow more than 48 hours after rainfall that produces runoff and evidence of groundwater discharge into the evaluation reach indicate a significant period of baseflow in the stream?

Water flowing in the channel more than 48 hours after rainfall that produces runoff is clear evidence of baseflow supplied by groundwater discharge from saturated soils below the water table adjacent to the stream. Even when there is no visible flow above the channel bottom, there may be slow groundwater discharge into, and downstream flow through, the hyporheic zone (Figure 14). The hyporheic zone is the accumulation of coarse-textured sediments in the bed and sides of the channel that may be up to 2-3 ft deep in small streams. A functioning part of the stream, the hyporheic zone is the site where much of the groundwater discharge to the stream occurs, the source of downstream flow, and the location of biological and chemical processes associated with aquatic functions of the stream.

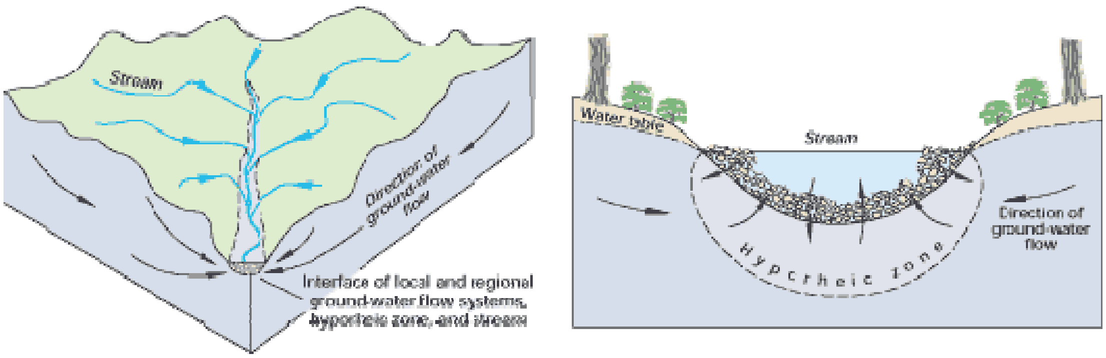

Figure 14: Illustration of groundwater flow and hyporheic zone (Winter et al.,1998).

The presence of a seasonal high water table or groundwater discharge (e.g., seeps or springs) from the bank above the elevation of the channel bottom indicates a relatively reliable source of baseflow to a stream.

Strong – Water is present and flowing in the thalweg region of the channel throughout the evaluation reach and there is significant baseflow through the riffles or other shallow zones. Evidence of groundwater discharge into the channel or a groundwater table above the thalweg is readily observable throughout the reach.

Moderate – Water is present in the thalweg region of the channel throughout the evaluation reach and there is a small amount of baseflow through the riffles or other shallow zones. Evidence of groundwater discharge into the channel or a groundwater table slightly above the thalweg is observable in the reach but not abundant throughout the reach.

Weak – Water is standing in pools and the hyporheic zone is saturated, but there is not visible flow through the riffles or other shallow zones of the thalweg. Evidence of groundwater discharge is present, but requires considerable time to locate. The groundwater table is at or slightly above the level of water in the pools.

Absent – There is little to no visible water in the thalweg region of the channel. There is no evidence of groundwater discharge into the channel and the groundwater table is at or below the deepest parts of the channel.

13. Iron Oxidizing Bacteria

In slow moving (or stagnant) areas of the stream, are there clumps of "fluffy" rust-red material in the water, on the sides of the bank or in the streambed? Are there red or rust-

colored stains on the soil surface and/or an "oily sheen" or "oily scum" on the water surface?

Iron oxidizing bacteria derive energy by converting iron in the ferrous form (Fe^{2+}) to the ferric form (Fe^{3+}), which then combines with oxygen to produce iron oxide, essentially rust. Since the reaction is dependent on oxygen presence it is more likely to be found in areas of the wetted channel where oxygen-poor groundwater is just reaching the surface. Iron oxidizing bacteria can be detected in these areas by looking for the iron oxide waste product, often appearing as a rusty red or orange material in "fluffy" clumps or as a stain within the wetted channel where groundwater enters (Figure 15). Staining can be visible in channels without water present as well. The bacteria can also produce an oily sheen on the water surface that breaks apart when disturbed, though other bacteria can produce a similar sheen. However, a sudden or unusual occurrence may indicate a petroleum product release from an underground fuel storage tank. One way to differentiate iron-oxidizing bacteria from oil releases is to trail a small stick or leaf through the film. If the film breaks up into small islands or clusters, it is most likely bacterial in origin. However, if the film swirls together, it is most likely a petroleum discharge.

Strong – Abundant iron oxidizing bacteria is observed.

Moderate – Some iron oxidizing bacteria is observed.

Weak – Very little iron oxidizing bacteria is observed.

Absent – No iron oxidizing bacteria is observed.

Figure 15: Iron oxidizing bacteria. Figure on right depicts iron bacteria on a twig.

14. Leaf litter

Is leaf litter accumulating in the streambed?

Perennial streams with riparian vegetation should continuously transport plant material through the channel. Leaves and lighter debris are typically present throughout the length of non-perennial streams, whereas little to no leaves are present in streams with constant or near-constant flow. This indicator may be more difficult to discern during autumn, especially between rain events in areas with deciduous riparian vegetation. Accumulations of organic debris, including leaves, on the upstream side of obstructions are another indicator and are not considered to be leaf litter.

Strong – Abundant amount of leaf litter is present throughout the length of the stream. Greater than 80% of the active channel is covered with leaves and the thalweg substrate is not visible.

Moderate – Leaf litter is present throughout most of the stream's reach with some accumulation beginning on the upstream side of obstructions and in pools. Between 25% and 80% of the active channel bottom is covered with leaves and portions of the thalweg is visible.

Weak – Leaf litter is present and is mostly accumulated in pools.. Between 5% and 25% of the streambed is covered with leaves and most of the thalweg is visible.

Absent – Leaf litter is not present in the fast moving areas of the reach but there may be some present in the pools. Less than 5% of the active channel bottom is covered with leaves. The thalweg is swept clear of leaf litter and the substrate is continuously visible throughout the assessment reach.

15. Sediment on Plants or Debris

Is fine sediment deposited on plants or debris in the channel or on the active floodplain, indicative of recent high flows and suspended sediment transport?

The transportation and processing of sediment is a main function of streams. Therefore, evidence of fine sediment on plants or other debris in the stream may be an important indicator of the persistence of flow and the transport of suspended sediment. Note that sediment production and delivery to streams in stable, vegetated watersheds is usually less than in disturbed watersheds. Look for silt and clay accumulation in thin layers on debris or rooted aquatic vegetation, and on plants and debris on the bank and floodplain immediately adjacent to the stream. Note any upstream land-disturbing activities that may contribute greater amounts of sediment to the stream.

Strong – Fine sediment found readily on plants and debris within the stream, on the streambank, and within the floodplain throughout the length of the stream.

Moderate – Fine sediment found on plants or debris within the stream although not prevalent along the stream.

Weak – Fine sediment is isolated in small amounts along the stream.

Absent – No sediment is present on plants or debris.

16. Organic Drift Lines

Are there accumulations of organic debris in piles or lines in the channel or on the active floodplain indicative of recent high flows?

Organic drift lines are defined as twigs, sticks, logs, leaves, and any other floating materials piled up on the upstream side of obstructions in the stream, on the streambank, in overhanging branches, and/or in the floodplain that indicate high stream flows. Ephemeral streams usually exhibit fewer or no drift lines within their channels unless downstream of a storm drain or areas with high runoff potential. The magnitude of the accumulation of drift may be influenced by watershed characteristics and sources of debris. For example, streams in watersheds dominated by herbaceous vegetation may not exhibit drift lines.

Strong – Large drift lines are prevalent along the upstream side of obstructions within the channel and the floodplain.

Moderate – Large drift lines are dispersed mostly within the channel.

Weak – Small drift lines are present within the channel.

Absent – No drift lines are present.

17. Soil-based Evidence of a Seasonal High Water Table

Is there evidence of a seasonal high water table in the soil at the toe of the stream bank, or the base of a head cut above the elevation of the thalweg of the evaluation reach?

The presence of a seasonal water table in the soil above the thalweg elevation is evidence of groundwater discharge into the channel that sustains an annual extended period of baseflow. In soils with fluctuating water tables near the surface, the level of the seasonal high water table is routinely estimated from soil color variation in soils with silts and clays that have iron and manganese oxides. When the soil is unsaturated and aerobic, chemically oxidizing conditions in the soil water produce oxidized forms of iron and manganese that are precipitates that coat soil particles and produce brown, yellow, and red colors. When the soil is saturated and anaerobic, chemically reducing conditions in the soil water produce reduced forms of iron and manganese that are colorless ions in solution. Gray or neutral low chroma soil colors result because the colors of the soil particles are visible. In sandy soils with very low clay content, long periods of saturation result in accumulation of organic matter that coats the sand grains and produces dark low chroma colors.

In soils with frequent, long periods of saturation the oxidation/reduction reactions of iron and manganese produce color variations called redoximorphic features (formerly called mottles). The degree of development of redoximorphic features is indicative of the frequency and duration of periods of soil saturation. Weakly developed redoximorphic features in the soil at the toe of the bank above the channel bed are common in intermittent streams and indicate the level of the seasonal high water table. Strongly developed redoximorphic features are common in the soils at the toe of banks and in the streambed sediments of perennial streams. Ephemeral streams have oxidized soils in the bed and bank. Types of redoximorphic features are: (1) depleted matrix – matrix color has chroma ≤ 2; (2) depletions – zones of low chroma (≤ 2) within a matrix of higher chroma; (3) concentrations - soft masses or pore linings; zones of accumulation of oxidized iron and manganese, bright yellow, orange, or red colors (Figure 16).

Soil colors are identified with Munsell soil color charts. The matrix color of a soil ped is the color of more than 50% of the face of a broken ped. Use a soil auger to obtain at least three 6-8 inch cores in the toe of the bank above the thalweg elevation in a riffle or shallow zone of the channel. Look for redoximorphic features below by breaking open chunks of soil (peds). Note that non-soil such as relatively young alluvial accumulations of coarse sand, gravel, and cobble in the stream bank or hyporheic zone will not have redoximorphic features or other hydric soil indicators.

YES – In the soil of the stream bank or base of a headcut within at least six inches above the average elevation of riffles or other shallow zones in the thalweg is found a soil layer at least two inches thick that has at least one indicator of a seasonal high water table.

NO – In the soil of the stream bank or base of a headcut within at least six inches above the average elevation of riffles or other shallow zones in the thalweg is found no indicator a seasonal high water table.

Common indicators of a seasonal high water table include but are not limited to:

- More than 60% of the ped face is gleyed, i.e. color is on a gley page of the Munsell
- More than 60% of the ped face is chroma ≤ 2 with or without concentrations
- In streams with floodplains, more than 60% of the ped face is chroma ≤ 4 with 10% or more redox concentrations
- More than 60% of the ped face is chroma ≤ 2 with 10% or more of redox depletions
- In a sandy soil, more than 70% of the sand grains are coated with organic matter
- In a sandy soil, there is streaking or splotches of organic matter
- The soil has mucky mineral texture

16a. Upland Soil (chroma >3) (NC DWQ)

16b. Hydric soil depicting gleying (chroma<2) (NC DWQ)

16c. Low chroma soil with redox concentrations (NC DWQ)

16d. Redox concentrations in sandy soil. (NC DWQ)

Figure 16: Example of Soil Features

C. Biological Indicators

18. Fibrous Roots in Streambed

Are fibrous roots present near the surface of the hyporheic zone in and around the thalweg of the stream?

Fibrous roots are non-woody, small diameter (< 0.10 in), shallow, wide-spreading roots that often form dense masses in the top few inches of the soil. Roots in the root mass can be numerous and are generally of equal diameters. Fibrous roots of plants are those which function in water and nutrient uptake. The persistent presence of water would not allow for oxygen exchange in the roots of water-intolerant plants, limiting the growth of fibrous roots. Frequent high-energy flows that disturb the substrate will also limit their growth. Therefore, a higher score is given for the absence of fibrous roots.

Observe the streambed in or near the thalweg of the stream and determine if very small (fibrous) roots are present. Note that during an extended growing season or dry periods, fast growing fibrous roots may grow across the bottom of a stream that would not be present during normal flow conditions.

Strong – A strong network of fibrous roots is persistent in the stream thalweg and surrounding area.

Moderate – A discontinuous network of fibrous roots is present in the stream thalweg and surrounding area.

Weak – Very few fibrous roots are present anywhere in the streambed.

Absent – No fibrous roots are present.

19. Rooted Upland Plants in Streambed

Are rooted upland plants growing in or near the thalweg area of the stream?

This attribute relates flow to the absence of rooted plants, since flow will often act as a deterrent to plant establishment by removing seeds or preventing aeration to roots. A higher score is given for the absence of rooted plants. Focus should be on the presence of upland (i.e. FAC or drier as listed in the *National List of Vascular Plant Species that Occur in Wetlands: 1996 National Summary* (U.S. FWS, 1997) plants in or near the thalweg of the stream. Plants growing on any part of the bank of the stream should not be considered. Note, however, there will be exceptions to this attribute. For example, rooted plants can be found in shaded perennial streams with moderate flow but in most cases these plants will be water tolerant (FACW or wetter), in which case they should be considered under indicator 26, Wetland Plants in Streambed. Cases where rooted upland plants are present in the streambed may indicate ephemeral or intermittent flow.

Strong –Rooted plants are observed and cover over 75% of the streambed.

Moderate – Rooted plants are observed and cover approximately 20-75% of the streambed.

Weak – Rooted plants are observed and cover less that 20% of the streambed and most are in the thalweg.

Absent – No rooted plants are observed.

20. Benthic Macroinvertebrates

“Benthic macroinvertebrates” is a broad term applied to many different types of invertebrates that live on or within the stream substrate. In a broad sense, this term can be applied to a wide range of animals that live in this zone. *Crayfish and mollusks are assessed separately in this method, so this indicator is meant to assess primarily aquatic insects (i.e., mayflies, stoneflies, caddisflies, hellgrammites, midges), amphipods, isopods, and annelids (worms and leeches).*

The larval stages of many aquatic insects (Figure 17) are well-established indicators of flow duration since a continuous aquatic habitat is required for these species to mature. Though insects are defined in part by having three pairs of legs, this characteristic can be difficult to see or non-existent in some larvae. There is great variability in appearance, from legless, soft, “wormlike” or “maggotlike” forms (e.g., true flies [Order Diptera]); grub-like forms with variably hardened body sections and obvious legs (e.g., caddisflies [Order Trichoptera] and some beetle larvae [Order Coleoptera]); to more complex and distinctive body forms (e.g., mayflies [Order Ephemeroptera], stoneflies [Order Plecoptera], hellgrammites [Order Megaloptera], and dragonflies and damselflies [Order Odonata]). In general, caddisflies, mayflies, stoneflies, and damselflies are very good indicators of at least intermittent (and in many cases, perennial) flow. These are discussed more fully in Section 3 – Guidance for the Determination of Perennial Streams.

Examine rocks and sticks in the stream and use a small net to sample a variety of habitats including riffles, pools, roots, undercut banks, leaf packs and the substrate. Note both the quantity as well as the diversity of the macroinvertebrate sample on the field form when scoring.

Strong – Abundance and/or a large diversity of macroinvertebrates are present and readily found.

Moderate – Several macroinvertebrates (abundance and/or diversity) are present and found relatively quickly.

Weak – One or two macroinvertebrates are present OR several tolerant macroinvertebrates (e.g., amphipods) are present.

Absent – No macroinvertebrates are present.

Caddisfly: *Diplectrona sp*

Stonefly*: Eccoptera sp.*

Figure 17: Benthic Macroinvertebrates

21. Aquatic Mollusks

Aquatic mollusks are invertebrate animals with a soft body enclosed at least partially by a hardened shell, such as clams, mussels, snails, and limpets. Bivalves (mollusks with two shells, Class Bivalvia) include clams or mussels, and are often highly dependent on water presence for survival. Snails (mollusks with a coiled shell, Class Gastropoda) can have either gills (and therefore more dependent on the presence of well-oxygenated water) or primitive lungs (and therefore are “air breathers” that are more tolerant of drier conditions). Gilled snails can be identified by the presence of an operculum (somewhat hardened plate) that closes off the opening of the snail’s shell, and generally the shells are “right-handed”, i.e., the opening is on the right when held facing you and the point of the shell is up. Lunged snails will never have an operculum and they are generally “left-handed”. Limpets (Class Gastropoda, Family Ancylidae) are a type of lunged snail with a cone-like shell (not coiled as in other snails) though they are thought to obtain oxygen mainly through diffusion over their entire body surface (Voshell 2002). To find mollusks, one should examine various habitats: hard substrates, such as sticks and rocks for clams and snails, silty areas of the stream bed for clams, leaves for limpets and aquatic plants for snails. Fingernail clams (Figure 18) are often smaller than pea-sized, so careful examination may be required to find them in the silty substrates they prefer. A small net may be useful and the mollusk search may be part of the larger search for macroinvertebrates. Scoring of the indicator includes abundance and/or diversity.

Strong – Abundance and/or a large diversity of mollusks are present and readily found.

Moderate – Several mollusks are present and found relatively quickly.

Weak – One or two mollusks are present.

Absent – No mollusks are present.

Figure 18: Fingernail claims (NC DWQ 1998)

22. Fish

Fluctuating water levels of intermittent streams provide unstable and stressful habitat conditions for fish communities. When looking for fish, all available habitats should be observed, including pools, riffles, root clumps, and other obstructions. In small streams, the majority of species usually inhabit pools and runs. Fish should be easily observed within a minute or two. Fish will seek cover once alerted to your presence, so be sure to look for them slightly ahead of where you are walking along the stream. Check several areas along the stream sampling reach, especially underneath undercut banks. In most cases, fish are indicators of perennial streams, since fish will rarely inhabit an intermittent stream. *Gambusia* (mosquitofish) should not be considered as a perennial indicator due to their extremely short life cycle and tolerance for stressful conditions, such as low oxygen levels, but may be considered as present for this indicator.

Strong – Many fish (>3) are readily observed.

Moderate – Several fish (2-3) are observed.

Weak – One fish is observed.

Absent – No fish are observed.

23. Crayfish

Most species of crayfish are associated with aquatic or wet environments such as streams and wetlands. A small net can be used to examine small pools, under rocks, under logs, sticks or within leaf packs in the stream for crayfish. Crayfish associated with small holes or “chimneys” in the muddy streambank or floodplain may be indicators of wet soils (wetlands) rather than streams. The presence of chimneys should not be considered for this metric.

Strong – Several (3 +) or very large crayfish are present and were found quickly.

Moderate – A few (1-2) crayfish are present.

Weak – One crayfish is present.

Absent – No crayfish are present.

24. Amphibians

Amphibians such as salamanders, frogs, and toads require water, or at least moist conditions, for egg laying and larval development. Many salamander species’ immature, gilled larvae require aquatic environments until they transform to adults. All frogs and toads lay their eggs in fresh water and tadpoles (the larval form of toads and frogs) require water for development.

Older (>1 year old) salamander larvae can be a very good indicator of relatively permanent waters. Abundance of one species (Southern Two-Lined Salamanders, *Eurycea cirrigera*) has been found to be positively correlated with watershed area in headwater streams, and the presence of >1 year-old larvae was found to be an indicator of perennial water (Johnson et al. 2009). This same study did not find any larval salamanders in any ephemeral streams, suggesting that their presence, regardless of age, suggests at least intermittent flow.

The tadpoles of many species of frogs and toads require 2-3 months before final metamorphosis to adult occurs. However, the very large tadpoles of the American Bullfrog (*Rana catesbeiana*), River Frog (*Rana heckscheri*), and Carpenter Frog (*Rana virgatipes*) require a year or more before metamorphosis to adults. When large specimens of these species are found, it is a strong indicator of the presence of water over several seasons.

Seasonality may have to be considered when assessing this indicator. Many species of salamanders in the piedmont and coastal plain areas of NC have a relatively short larval stage and develop from egg to adult over a single fall-to-spring period, so their presence may not be as strong of an indicator of perennial flow during this time of the year in this area of the state unless species can be definitively identified. In the mountain ecoregion of NC, salamander diversity is much higher with more varied life histories, including many more species with longer larval stages, so this rule of thumb may not apply in these areas of the state. Many tadpoles develop from egg to adult over the summer, suggesting that their presence during this time of year is a strong indicator of perennial flow, as this is usually the driest portion of the year.

Salamanders (Figure 19) and tadpoles can be found under rocks, on stream banks and on the bottom of the stream. They may also appear in the benthic sample. Frogs and tadpoles typically inhabit the shallow, slower moving waters of the pools and near the sides of the bank. Amphibian eggs, also included as an indicator, can be located on the bottom of rocks and in or on other submerged debris. They are usually observed in gelatinous clumps or strings of eggs.

Figure 19: Salamander

Strong – Abundance and/or a large diversity of amphibians are present and readily found.

Moderate – A few (2-3) amphibians are present and found relatively quickly.

Weak – One amphibian is present.

Absent – No amphibians are present.

25. Algae

Benthic algae are photosynthetic organisms that live on substrates in the stream, such as on rocks, sticks, leaves, or plants. These algae can take the form of long, hair-like filaments, a crust-like coating, or as an invisible (but palpable) slimy biofilm growing on appropriate substrates. The most commonly seen in streams include blue-green algae (actually more accurately classified in the bacterial phylum Cyanobacteria), green algae (algal division Chlorophyta), and diatoms (algal division Bacillariophyta) (Stevenson, 1996). Benthic algal abundance is strongly influenced by the amount of sunlight reaching the stream, relative rate of stream discharge, availability of appropriate substrates, and level of nutrient enrichment. Look for green or blue-green filaments or mats, or golden brown "crusts" on appropriate substrates within the wetted channel. Also feel submerged rocks, plants, leaves, sticks, or other available substrates; a "slimy" coating can indicate a biofilm consisting of a mix of diatoms, other algae, bacteria, and fungus that is collectively referred to as periphyton, and should also be considered when rating this indicator.

Strong – Abundant algae is observed throughout the reach.

Moderate – Some algae is observed in a few locations in the reach.

Weak – Very little algae is observed through the reach.

Absent – No algae is observed through the reach.

20a. Filamentous algae, Source: www.duluthstreams.org

20b. Filamentous algae Source: www.aquafiber.com

Figure 20: Algae

26. Wetland Plants in Streambed (FACW and wetter)

The U.S. Army Corp of Engineers wetland delineation procedure utilizes a plant species classification system upon which soil moisture regimes can be inferred. This same system can be used to infer the duration of soil saturation in streams. Small, low gradient, low velocity intermittent and perennial streams with adequate sunlight will often have OBL (obligate wetland) and FACW (facultative wetland) plants, aquatic bryophytes such as *Fontanalis*, or submerged aquatic vegetation growing in the stream bed. All wetland designations are defined by *National List of Vascular Plant Species that Occur in Wetlands: 1996 National Summary* (U.S. FWS 1997).

OBL: Obligate Wetland, occurs almost always (estimated probability 99%) under natural conditions in wetlands.

FACW: Facultative Wetland, usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.

FAC: Facultative, Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).

FACU: Facultative Upland, Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).

UPL: Obligate Upland, Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. If a species does not occur in wetlands in any region, it is not on the National List.

SECTION 3 – Guidance for the Determination of Perennial Streams

Background

The NC DWQ utilizes a numerical cutoff of 19 points with this evaluation form as an appropriate value to classify a stream as at least "intermittent". As part of an investigation for the City of Greensboro, personnel with Law Engineering and Environmental Services (now MacTec Environmental Services), with the support of NC DWQ personnel, used a modification of the NC DWQ stream classification method and recommended a numerical cutoff for a perennial stream origin in the piedmont of 30 points (Lawson, et al. 2002).

Recent and on-going Investigations

NC DWQ biologists have been looking for the presence of long-lived aquatic species as reliable determinants for perennial channels. These investigations suggest that the presence of a select group of benthic macroinvertebrates that require water for their entire life cycles (aquatic taxa) is a reliable method to determine the origins of perennial channels. A proposed list of these organisms is included with this policy revision (Tables 2 and 3). The NC DWQ is currently completing an investigation of the ecological functions of intermittent streams. Results from this federally funded investigation also have corroborated the technique of using a suite of aquatic insect taxa to determine perennial stream origins. Additionally, research related to headwater stream mapping is defining physical and hydrologic characteristics of intermittent and perennial origins.

NC DWQ Policy for the Definition of Perennial Stream Origins

A perennial stream is defined as a well-defined channel that contains water year round during a year of normal rainfall[1] with the aquatic bed located below the water table for most of the year (15A NCAC 2B.). This definition also notes that perennial streams exhibit the typical biological, hydrologic, and physical characteristics commonly associated with the continuous conveyance of water.

A stream is perennial when any of the following criteria are met:

1. Biological indicators such as fish (except *Gambusia)*, crayfish (in channel), amphibians (larval salamanders and large, multi-year tadpoles), or clams are present. If only crayfish or fingernail clams are present, a numerical value of at least 18 on the geomorphology section of the most current version of the NC DWQ stream classification form is required.

   OR

2. A numerical value of at least 30 points is determined from the most recent version of the NC DWQ stream identification form[2].

   OR

[1] Normal Rainfall is defined as the 30 year average, provided by NOAA National Climatic Data Center, computed at the end of each decade. These data are available as annual and monthly means.
[2] Use of this form requires Division-based (NC DWQ) or approved training (or appropriate certification in accordance with GS 143-214.25)

3. More than one benthic macroinvertebrate that requires water for their entire life cycles are present as later instar larvae[3]. A list of the benthic organisms commonly collected by NC DWQ biologists during perennial stream determinations are shown in Tables 2 and 3.

NC DWQ staff suggest that a stream be examined using these three criteria in the sequence above – namely, a field examination should first look for criterion 1 and then criterion 2. If the channel does not meet either of these two criteria and the field biologist believes the channel to be perennial, then the third criterion should be utilized, however identification by a well-trained aquatic entomologist is required for the proper use of this criterion. In most instances, the use of either of the first two criteria should be sufficient to make a stream determination.

Table 2: Ephemeroptera, Plecoptera and Trichoptera (EPT) perennial stream indicators

Order:	**Ephemeroptera (Mayflies)**	**Plecoptera (Stoneflies)**	**Trichoptera (Caddisflies)**
Family:	Baetidae	Peltoperlidae	Hydropsychidae
	Caenidae	Perlidae	Lepidostomatidae
	Ephemerellidae	Perlodidae	Limnephilidae
	Ephemeridae		Molannidae
	Heptageniidae		Odontoceridae
	Leptophlebiidae		Philopotamidae
	Siphlonuridae		Polycentropidae
			Psychomyiidae
			Rhyacophilidae

Table 3: Additional indicators of perennial streams

	Megaloptera	**Odonata**	**Diptera**	**Coleoptera**	**Mollusca**
Family:	Corydalidae	Aeshnidae	Ptychopteridae	Elmidae	Unionidae
	Sialidae	Calopterygidae		Psephenidae	Ancylidae
		Cordulegastridae			Planorbidae
		Gomphidae			Pleuroceridae
		Libellulidae			
Family & ***Genus:***			Tipulidae *Tipula* sp.	Dryopidae *Helichus* (adult)	

[3] Recognition and/or identification of these organisms will require Division-based (NC DWQ) or approved training.

Special Provision for Coastal Plain Perennial Streams

Reduced topography, which causes fewer channel-forming features, can make the geomorphology section of the stream form problematic in the Middle Atlantic Coastal Plain and Southeastern Plains ecoregions (Griffith et. al. 2002) – approximately east of I-95. In this area, biology should take precedence over geomorphology for determining a stream. Therefore the criteria should be utilized in the following sequence: 1, 3, and then 2.

History of the Guidance for the Determination of the Origin of Perennial Streams

Version 1.0 – Developed in 1997/1998. Fish, salamanders, turtles, crayfish and multiyear (large) tadpoles were used as indicators.

Version 2.1 – Added stoneflies, mayflies and caddisflies

Version 2.2 – Added section about the coastal plain

Version 2.3 – Added taxa lists (Tables 5 and 6)

Version 2.4 – Effective February 28, 2005. Added tables of macroinvertebrate taxa found in perennial streams. Issued for public comment October 13, 2004.

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NC DWQ Stream Identification Form Version 4.11

Date:	**Project/Site**:	**Latitude:**
Evaluator:	**County:**	**Longitude:**
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30**	**Stream Determination (circle one)** **Ephemeral Intermittent Perennial**	**Other** *e.g. Quad Name*:

A. Geomorphology (Subtotal =________)	**Absent**	**Weak**	**Moderate**	**Strong**
1[a.] Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel	No = 0		Yes = 3	

[a] artificial ditches are not rated; see discussions in manual

B. Hydrology (Subtotal = _________)				
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?	No = 0		Yes = 3	

C. Biology (Subtotal = _________)				
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed	FACW = 0.75; OBL = 1.5 Other = 0			

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes:

Sketch:

Alabama Coastal Nonpoint Pollution Control Program

ADEM- Coastal Headwater Stream Survey

COASTAL HDWTR STREAM SITE ASSESSMENT FORM # 3

rcs2009

COASTAL ALABAMA HDWTR STREAM ASSESSMENT				/ /
Stream Site:			**Photos Taken: Y/N**	**US / DS**
Stream Name:			**HUC:**	
Observed Stream Order: 1ST / 2ND / 3RD / SPRING / Other:				
StreamFlowStatus:	**NotPresent 0**	**P-Pools-NF 1**	**P-NMsr Flow 3**	**P- Flowing 5**
SubjWater Clarity:	**CSB 0**	**Clouded 1-2**	**Tannic 3-4**	**Clear 5**
HYDROMODIFICATION: (Score x 2)				
NATURAL	**5**	**WOODED, LIGHT INCISION w RIPARIAN BUFFER INTACT**		
LIGHT	**4**	**SOME INCISION/SOME STRAIGHTENING, SOME BUFFER IMPACTS**		
MODERATE	**3**	**MOD. BUFFER IMPACTS, MODERATE INCISION &/OR MODERATE STRAIGHTENING**		
STRONG	**2**	**STRONG BUFFER IMPACTS, HEAVY INCISION & CHANNEL STRAIGHTENING; -RESIDENTIAL/LT.COMM/URBAN**		
SEVERE	**1**	**ENGINEERED TRAPEZOID CANAL-ARMORED; -HEAVY RESIDENTIAL/COMM/URBAN**		
RIPARIAN BUFFER:	**LB-Buffer Width**		**RB-Buffer Width**	
(x2) 5	**3**	**2**	**1**	**0**
NATURAL MAST Spp/ SHRUB / HERBACEOUS/ GRAVEL or STONE / CURB, SIDEWALK /CONCRETE, ASPHALT				
% _____ _____ _____		_____	_____ _____	_____ _____
BANK COVER: (%)	**VEG------------------------------> LESS VEG--------------------------------->NO VEG**			
ROOTWEB/ ROOTWEBwSCOUR(H,M,L) / INCISION&orSCOUR / GABBION / RIPRAP / CONCRETE				
5	**4.5 / 4 / 3.5**	**3 / 2.5 / 2**	**1.5 / 1.25**	**0.5 0**
% ___	___	___	___	___ ___ **LB**
% ___	___	___	___	___ ___ **RB**
STREAMBED: (%)	**5 NATURAL ___**	**CS CHANNELCOMP:**	**5 -Natural SINGLE Channel**	
	3 SHAPED ___		**4 -Natural Channel w/ some Braids**	
	2 RIPRAP ___		**3 –OverWide/Multi-Braided Channels**	
	1 ARMORED___		**2 - Incised/Shaped Single Channel**	
			1 -Armored SINGLE Channel	
CHANNEL SUBSTRATES: (%)	**5**	**4**	**2**	**1**
	EvenSorted/ Gravel-Sand-Clay /SAVs	**LessSortedBed/ Sand-Clay/ Less SAVs**	**UnsortedBedLoads/ or Scoured Channel**	**Armored**
				Total= /55

ADEM- Coastal Headwater Stream Survey Form

Form #4

HDWTRSS STREAM SITE SURVEY DATA

rcs2009-ver2.0

Coastal Headwater Stream Survey Data - 4.2					
Station Name/#	**Date**	**Time**		**Latitude**	**Longitude**
HUC #	**Stream Name**			**County**	**State**
				MoCo / BaCo WaCo / EsCo	AL / MS / FL
Watershed Name					
TURNER FLUOROMETER READING				**WayPoint #:**	**Accuracy/** **Elevation/**
Site Description:					
Habitat: Wooded / Forestry / Ag / Urban - Residential - Commercial - Park / Other _______					
Observed Stream Order: 1ST / 2ND / 3RD / SPRING /Other					
Site Set Pin	**BenchSetting**			**UpStream Pin**	**DwnStream Pin**
Y / N					
Valley Length (VL)	**Stream Length (SL)**			**Meander λ (#)**	**# Riffle / Pools***
*	*			*	/
Meander Radii (0.0ft.)	[Set Pin @ Bankfull and measure radius @ opposite Bankfull curvature in feet- use at least 3 measures and calculate $\bar{X}$.]				
# 1					
# 2					
# 3					
# 4					
# 5					
Stream Meander Band Width XS =$\bar{X}$					
Canopy Measure	[Measure number of 'cells' with Canopy Cover –> **US & DS** @ XS]				
	#1	**#2**	**#3**	**#4**	
US					
DS					
Canopy Composition: Trees____ Shrubs____ Herb_____				Estimate%_______	
Observed Stream Inputs: Y / N Type: __ Pipes @ __ dia. / Road – G – P / DfS: ____					
Other Impacts:					

Stream Riffles XS				
RB / LB				
	#1	**#2**	**#3**	**#4**
VL / SL of Riffle	/	/	/	/
Flood Plain Rod				
XS Tape				
Bank Top Rod				
XS Tape				
Bankfull Rod				
XS Tape				
R/L EOW Rod				
XS Tape				
Channel Rod				
XS Tape				
Thalweg Rod				
XS Tape				
Channel Rod				
XS Tape				
R/L EOW Rod				
XS Tape				
Bankfull Rod				
XS Tape				
Bank Top Rod				
XS Tape				
Flood Plain Rod				
XS Tape				

Stream Pool XS

RB / LB				
	#1	**#2**	**#3**	**#4**

*Data Sheet- Stream Glide/Pool PROFILE (SL)

-UpStream- STRUCTURE	POSITION	VL Measure	SL Measure	Depth &Notes
Glide / Pool / Meander	U / L / B / Run			

VL / SL of Pool	/	/	/	/
Flood Plain Rod				
XS Tape				
Bank Top Rod				
XS Tape				
Bankfull Rod				
XS Tape				
R/L EOW Rod				
XS Tape				
Channel Rod				
XS Tape				
Thalweg Rod				
XS Tape				
Channel Rod				
XS Tape				
R/L EOW Rod				
XS Tape				
Bankfull Rod				
XS Tape				
Bank Top Rod				
XS Tape				
Flood Plain Rod				
XS Tape				

Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
Glide / Pool / Meander	U / L / B / Run			
TOTALS:	**Glides:**	**Meanders**	**LB:**	**GRuns:**
	Pools:		**RB:**	**PRuns:**

STREAM SITE DRAWING:

STANDARD OPERATING PROCEDURE
Instructions for the Calibration and Use of a Spherical Densiometer

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KEY WORDS

Physical habitat assessment, Canopy density, Overstory density

APPROVALS

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Environmental Monitoring Branch organization and personnel, such as management, senior scientist, quality assurance officer, project leader, etc., are defined and discussed in SOP ADMN002.

1.0 INTRODUCTION

The physical habitat conditions of a stream are assessed when determining the integrity of a wadeable stream. Estimation of canopy cover contributes to the assessment. A densiometer is used to measure the amount of surface water that is covered by shade from streamside vegetation.

1.1 Purpose

This Standard Operating Procedure (SOP) describes the method to quantify canopy density using a spherical densiometer.

1.2 Definitions

1.2.1 Canopy density- the thickness and consistency of plant foliage

1.2.2 Overstory- the overhead foliage

1.2.3 Transects- a mark or line cut across the width of the stream, representing the measuring point

1.2.4 Sampling point – a selected riffle or transect from which to collect the sample and also collect physical habitat data

2.0 MATERIALS

2.1 Spherical densiometer

3.0 PROCEDURES

The methodology described in this document was modified from the Forest Densiometer Instruction Sheet.

3.1 Choosing Sites

3.1.1 Follow procedures described in SOP FSWA013.00 or the project protocol to determine the sampling points at which to take densiometer measurements (site determination and transect location).

3.1.2 Take four densiometer readings from the center of each of the 11 transects while facing north, south, east and west. Average these four readings.

3.1.3 Facing up stream, keep the instrument leveled (indicated by the round level in the lower right-hand corner). Hold the densiometer far enough away from your body so that your head is just outside the grid (12-18" away). Maintain the densiometer approximately 1 foot above the water.

3.13 There are a total of 24, 1/8" x 1/8" squares in the grid. Each square represents an area of canopy opening (sky image or unfilled squares) or canopy cover (vegetation image or filled squares). Count the number of canopy opening squares. If there are squares that are only partially filled, these can be added to make a complete square.

3.1.4 The uncovered area is determined by multiplying the number of squares by 4.17. Subtract this number from 100% to determine overstory density in %.

e.g. 100% - (10 unfilled squares x 4.17) = 58.3% overstory density

3.1.5 If more than half of the canopy area is open sky the counting process can be reversed. Count the filled square areas that are covered by the canopy. Multiply by 4.17 to obtain the estimated overstory density directly in percent.

i.e. Number of filled squares x 4.17 = % overstory density

4.0 SPHERICAL DENSIOMETER STORAGE

The spherical densiometer is designed for rugged field use. To store, close the lid and securely fasten the clasp.

5.0 CLEANING THE DENSIOMETER

Clean the face of the densiometer by dusting with a soft cloth.

6.0 REFERENCES

Forest Densiometer Instruction Sheet
Robert E. Lemmon, FOREST DENSIOMETERS
5733 SE Cornell Dr.
Bartlesville, OK 74006
(918) 333-2830

ADEM-Coastal Headwater Stream Survey Form

ADEM - FIELD OPERATIONS DIVISION

WATER QUALITY FIELD DATA SHEET

Trip Name__________________________ ***Station #***__________________________

Visit Date____________ ***Visit Time***____________ ***Collector Names***__________________

□ TRIP BLANK COLLECTED Date: Time (24hrs): Comments:

COMMENTS	(For COC Purposes: D.O =)
ALAWADR ACTIVITIES	□ Field Form: *This Form* □ Sample Collection □ Field Form: *Field Blank* □ Field Form: *Replicate (# 1)* □ Sample Collection *Replicate (# 1)* □ Sample Collection: *Field Blank*

WATER QUALITY INDICATORS	***Water Odors*** (Select One)	***Surface Oils*** (Select One)	***Water Color*** (Select One)
	□ Normal/None □ Chemical □ Raw Sewage □ Treated Sewage □ Fishy □ Anaerobic □ Petroleum	□ None □ Slick □ Flecks □ Globs □ Sheen	□ Clear □ Grey □ Lt .Tannic □ Green □ Purple □ Dk. Tannic □ Muddy □ Red (Dye) □ Chalky □ Blue

WEATHER & FLOW CONDITIONS

Now	***Weather***	*Past 24 hrs*
□	Clear / Cloudless	□
□	Partly Cloudy	□
□	Mostly Cloudy	□
□	Cloudy	□
□	Fog	□
□	Light Rain / Drizzle	□
□	Rain	□
□	Thunderstorms	□
□	Freezing Precipitation	□

Flow Stage

□ Flood (out of banks)
□ Above Normal
□ Normal
□ Low
□ Dry
□ Unknown

Heavy Rain in last 7 Days?

□ Yes □ No □ Unknown

Velocity

□ Swift >3 ft / Sec
□Moderate 1.5 – 3 ft / Sec
□ Slow <1.5 ft / Sec
□ Not Flowing

Biological Indicators

(Select all that apply)

□ Macroinvertebrates
□ Fresh Beaver Sticks
□ Fish
□ Snails
□ Mussels
□ Crayfish

Only Need to Enter Checked entries into ALAWADR

FIELD MEASURES (FM) (REP @ 10% OF STATIONS)

Parameter	***Value***	***Replicate***	***Blank***	***Unit***
Time of FM				*hrs (24hrs)*
Time of Sample Collection				*hrs (24hrs)*
Air Temp.		*N/A*	*N/A*	*℃*
Datalogger Serial#		*N/A*	*N/A*	*N/A*
Depth of FM	□ Surface	□ Mid-Depth	□ ________	ft
Water Temp.			*N/A*	*℃*
pH			*N/A*	*s.u.*
D.O.			*N/A*	*mg/L*
Conductivity				*umhos/cm @25 C*
Total Depth @ FM Point			*N/A*	*ft*
Tubidity Meter #		*N/A*	*N/A*	*N/A*
Turbidity				*NTU*
Volume Chl a Filtered				*mL*

SAMPLES COLLECTED
(FYI ONLY -NO ENTRY INTO ALAWADR NEEDED)

□ Conventional Lab Parameters
□ Metals
□ Hardness
□ Chlorophyll_a
□ TOC
□ Fecal Coliform
□ Ecoli
□ Enterococcus
□ Organics
□ AGPT

Was Flow Measured?

□ Yes - ADEM: Abbrev Meter (*cfs*) □ Yes -USGS: Gauge (*cfs*) □ Yes - Facility (*mgd*)
□ No - Not wadeable (too deep) □ No -Flow conditions hazardous □ No - Flow not visible
□ No - Pools/Dry Streambed □ No -Visible but not measurable □ No - Braided/Swamp
□ Data Collected but Lost/Deleted/Corrupted □ No -Meter Malfunctioned □ No - Not Required

Flow--Meter #

Flow (*cfs*) or (*mgd*)

SAMPLE COLLECTION (SELECT ONE PER COLLECTION METHOD) (REP @ 5% OF STA)

GRAB SAMPLE	□ Direct to Jug/Jar □ Using Sampler □ Using Pump	***Relative Sampling Depth:*** □ Surface □ Mid-Depth □ Bottom ***Actual Sampling Depth:*** □ ________ ft
COMPOSITE SAMPLE	□ Integrated Vertical □ Discrete Horizontal □ Discrete Vertical	***Collection Depth Zone:*** □ Photic Zone □ Halocline ***Actual Sampling Depth:*** □ ________ ft ***Relative Sampling Depth:*** □ Surface □ Mid-Depth □ Bottom □ Surf/Mid/Bottom

ADEM-FIELD OPERATIONS-MONTGOMERY BRANCH
GLIDE/POOL HABITAT ASSESSMENT FIELD DATA SHEET

Habitat Parameter	Category: Optimal	Suboptimal	Marginal	Poor
1 **Instream Cover**	> 50% mix of snags, submerged logs, undercut banks, or other stable habitat; rubble, gravel may be present.	50-30% mix of stable habitat; adequate habitat for maintenance of populations.	30-10% mix of stable habitat; habitat availability less than desirable.	<10% stable habitat; lack of habitat is obvious.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2 **Pool Substrate Characterization**	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3 **Pool Variability**	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4 **Man-made Channel Alteration**	No Channelization or dredging present.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization (>20 years) may be present, but not recent.	New embankments present on both banks; channelization may be extensive, usually in urban or agriculture lands; and > 80% of stream reach is channelized and disrupted.	Extensive channelization; banks shored with gabion or cement; heavily urbanized areas; instream habitat greatly altered or removed entirely.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5 **Sediment Deposition**	<20% of bottom affected; minor accumulation of fine and coarse material at snags and submerged vegetation; little or no enlargement of islands or point bars.	20-50% affected; moderate accumulation; substantial sediment movement only during major storm event; some new increase in bar formation.	50-80% affected; major deposition; pools shallow, heavily silted; embankments may be present on both banks; frequent and substantial sediment movement during storm events.	Channelized; mud, silt, and/or sand in braided or non-braided channels; pools almost absent due to deposition.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
6 **Channel Sinuosity**	Bends in stream increase stream length 3 to 4 times longer than if it was in a straight line.	Bends in stream increase stream length 2 to 3 times longer than if it was in a straight line.	Bends in stream increase the stream length 2 to 1 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7 **Channel flow Status**	Water reaches base of both lower banks and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel.	Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8 **Condition of Banks**	Banks stable; no evidence of erosion or bank failure; <5% affected.	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% affected.	Moderately unstable; 30-60% of banks in reach have areas of erosion.	Unstable; many eroded areas; "raw" areas frequent along straight section and bends; on side slopes, 60-100% of bank has erosional scars.
Score ______	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
9 **Bank Vegetative Protection (each bank)**	> 90% of the stream bank surfaces covered by vegetation.	90-70% of the streambank surfaces covered by vegetation.	70-50% of the stream bank surfaces covered by vegetation.	<50% of the streambank surfaces covered by vegetation.
Score (LB) ______	10 9 8	7 6	5 4 3	2 1 0
Score (RB) ______	10 9 8	7 6	5 4 3	2 1 0
10 **Grazing or other disruptive pressure (each bank)**	Vegetative disruption, through grazing or mowing, minimal or not evident; almost all plants allowed to grow naturally.	Disruption evident but not affecting full plant growth potential to any great extent; >1/2 of the potential plant stubble height remaining.	Disruption obvious; patches of bare soil or closely cropped vegetation common; <1/2 of the potential plant stubble height remaining.	Disruption of stream bank vegetation is very high; vegetation has been removed to $\leq$ 2 inches average stubble height.
Score (LB) ______	10 9 8	7 6	5 4 3	2 1 0
Score (RB) ______	10 9 8	7 6	5 4 3	2 1 0
11 **Riparian vegetative zone Width (each bank)**	Width of riparian zone >60 feet; human activities (i.e., parking lots, roadbeds, clearcuts, lawns, or crops) have not impacted zone.	Width of riparian zone 60 - 40 feet; human activities have impacted zone only minimally.	Width of riparian zone 40 - 20 feet; human activities have impacted zone a great deal.	Width of riparian zone <20 feet; little or no riparian vegetation due to human activities.
Score (LB) ______	10 9 8	7 6	5 4 3	2 1 0
Score (RB) ______	10 9 8	7 6	5 4 3	2 1 0
12 **Riparian ZoneVegetative Quality (each bank)**	Over 80% of riparian surfaces consist of normal, expected plant community for given sunlight and habitat conditions (e.g., native plants, trees, understory shrubs, or nonwoody macrophytes). Minimal disturbance.	>50% to 80% of riparian zone is undisturbed (normal, expected plant community for given sunlight and habitat conditions). Some disruption of community observed.	25% to 50% of riparian zone is undisturbed (normal, expected plant community for given sunlight and habitat conditions). Disruption is obvious.	Less than 25% of riparian zone is undisturbed (normal, expected plant community for given sunlight and habitat conditions).
Score (LB) ______	10 9	8 7 6	5 4 3	2 1 0
Score (RB) ______	10 9	8 7 6	5 4 3	2 1 0

ADEM-Field Operations Division
Abbreviated Stream Flow Measurement Datasheet

Station # ______________________

Date ______________________

Conducted By: ______________________

Start Time: ____________ hrs

Finish Time: ____________ hrs

Meter Type: AA Pygmy

Meter Number: ____________

Passed Spin Test: Before Yes No

After Yes No

Measurement Number**	**Actual Tape Reading**	**Depth (ft)**	**Revolutions**	**Seconds**	Velocity	Flow
Bank LB / RB						
#1						
# 2						
# 3						
#4						
#5						
#6						
#7						
#8						
#9						
#10						
#11						
#12						
#13						
#14						
#15						
Bank LB / RB						

Stream Flow ____________

**7-10 readings across the stream

For use if Acoustic Doppler Meter is not available.

STREAM FLOW MEASUREMENT BY ADEM ABBREVIATED STREAM VELOCITY MEASUREMENT

SOP #2040

Rev. 5.0

VERSION DATE: 02/05/14

PREPARED BY:		**DATE**	2/5/2014
REVIEWED BY:	**Branch Chief**	**DATE**	02/05/14
APPROVED BY:	**Quality Assurance Manager**	**DATE**	2/5/2014

Alabama Department of Environmental Management

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TABLE OF CONTENTS

PREFACE

This Standard Operating Procedures (SOP) Manual supersedes all Departmental SOPs relating to the methods addressed and is designed to be periodically reviewed and updated. The primary purpose of this document is to establish and maintain uniform operational and quality control guidance. The compliance with these procedures is essential to produce reliable data. Any deviation from this SOP must be documented and approved by the Project QA/QC Coordinator and/or project supervisor.

DISCLAIMER

This document has been prepared for use by the staff of the Alabama Department of Environmental Management (ADEM). Mention of trade names or commercial products does not constitute endorsement or recommendation for use. No portion of this manual is intended to supersede any Departmental policy memorandum issued by the Director or Deputy Director.

NOTE:

Any alpha suffix added to the version date indicates the incorporation of corrections for non-critical typographic errors or formatting, i.e., no methodology changes were incorporated.

STREAM FLOW MEASUREMENT BY ADEM ABBREVIATED STREAM VELOCITY MEASUREMENT METHOD

1 SCOPE AND APPLICABILITY

1.1 Stream flow measurements and observations are an integral part of interpreting water quality data. When a stream flow is requested as part of the project plan, one of the comment options listed below is applicable and recorded on the field data sheet or field notebook to indicate that:

1.1.1 A flow was measured;

1.1.2 A stream flow was obtained from an active USGS stream gauge; OR

1.1.3 No flow was measured because:

1.1.3.1 meter malfunctioned;

1.1.3.2 not wadeable (Not wadeable means that the stream is deeper than chest-wader depth. If the stream depth indicated on the datasheet is <3.5 ft, an explanation of no flow measurement is necessary);

1.1.3.3 stream flow conditions hazardous, too high/swift water or dangerous weather;

1.1.3.4 no visible flow (i.e., the water does not appear to be moving downstream-this can be verified in the creek by stirring up the bottom slightly and watching where the turbidity cloud goes); OR

1.1.4 An abbreviated stream flow measurement was attempted but:

1.1.4.1 flow visible, but no flow detectable; OR

1.1.4.2 no visible flow and none detected.

2 SUMMARY OF METHOD

2.1 This method describes the procedure used to obtain a stream flow estimate using ADEM's Abbreviated Stream Velocity Measurement Method.

3 DEFINITIONS

3.1 AA Meter – a vertical axis current meter used to measure the velocity of flowing water. The larger of the two current meters, is used to measure deeper streams and/or streams with high velocities.

3.2 Pygmy Meter – a vertical axis current meter used to measure the velocity of flowing water. Scaled to two-fifths the size of the AA meter, the pygmy meter is used on shallow streams and/or streams with low velocities.

3.3 ADV (Acoustic Doppler Velocimeter) - an electronic current meter used to measure the velocity and calculate the total flow of flowing streams. The ADV can be used in deep, fast flow as well as in slower flow with water as shallow as one inch.

3.4 Top-setting rod – a wading rod used for measuring stream depth and setting the in-situ position of the current meter. Current meter position is made on the scale hand-piece located at the top of the rod. The position is automatically set at six-tenths of stream depth.

4 HEALTH & SAFETY WARNINGS

4.1 Care should be taken to prevent slipping on rocks or stepping into a deep hole. Staff making flow measurements in areas with the potential for deep water should be able to swim and should wear flotation devices. Members of the sampling team should never leave an individual alone in the stream unless depth, velocity and substrate conditions are determined to be safe.

4.2 General field health and safety warnings apply.

5 PERSONNEL QUALIFICATIONS

5.1 No employee shall conduct this flow measurement until he/she has actual field experience and has successfully demonstrated the ability of making the measurements under the supervision of a senior staff member.

5.2 Each new Departmental employee shall accompany an experienced field employee on as many field trips as possible to experience the differing types of field situations to which the new employee may be required to participate.

5.3 During this training period the new employee will be permitted to perform all facets of field investigations, including sampling, under the direction and supervision of senior technical staff members.

6 EQUIPMENT AND SUPPLIES

Measure Flow with ADV:

Flow Meters (ADV)	Measuring Tape & Stake
Top-setting Rod	Extra AA Batteries

Measure Flow with Pygmy or AA:

Stopwatch	WD-40 or other light machine oil
Head Phones	Flow Meters (AA or Pygmy)
Paper/pencil	Flow Clipboard

Flow Measurement Recording Form or Logbook (*Rite-in-Rain*)

Estimated Flow using Bucket:

Bucket or other large container with graduated volume ticks and/or a known volume.

Stopwatch or timer	Paper/pencil

Estimated Flow using Float:

Measuring tape	Float (such as a ball or plastic bottle)
Points of reference (flagging, trees, etc.)	Paper/pencil
Stopwatch or timer	

7 ABBREVIATED STREAM VELOCITY MEASUREMENT METHOD

7.1 Selecting a Meter Type

7.1.1 The ADV should be considered the primary flow meter for stream flow measurements. It can be used in deep, fast flow as well as in slower flow with water as shallow as one inch.

7.1.2 The AA or Pygmy meters should only be used when an ADV is unavailable for use before leaving on a trip.

7.1.3 The AA meter can be used in most cases unless the stream velocity is too low to move the AA meter cups or the depth is too shallow to allow the submersion of half the AA meter cups.

7.1.4 Use the Pygmy Meter only for shallow streams where the water depth will not cover at least 50% of the AA meter cup and/or velocities are too slow to turn the AA meter cups.

7.1.5 For the AA and the Pygmy, the rule of thumb is that when measuring velocities, at least 50% of the meter cup height should be submerged.

7.2 Selecting a Measurement Location

7.2.1 Select a reach of stream containing the following characteristics. It is usually not possible to satisfy all of these conditions but select the best possible reach.

- A straight reach with the threads of velocity parallel to each other.
- A flat streambed profile.
- A stable streambed that is free of large rocks, weeds, and protruding obstructions which would create turbulence. If an island divides the stream in an otherwise best situation, conduct two separate flows using the island as the right bank for one flow and the left bank for the other flow. The tape can be strung across the entire width of the creek.

7.3 Making a Flow Measurement

7.3.1 Using the ADV (Primary method)

7.3.1.1 Select a cross-section and determine the width of the stream by stretching a measuring tape across the stream.

- The measuring tape should be stretched at a 90º angle to the direction of stream flow.
- The left and right banks are determined by facing downstream ("go with the flow") – left bank is then on your left hand and right bank on your right hand.
- Walk across the stream and read the tape measurement at which the stream water and the bank meet on the opposite bank.
- Subtract the two bank readings to get the stream width.

7.3.1.2 Determine the increments between velocity readings to provide 7 to 10 readings across the width of the stream by dividing the stream width by ten (10). This gives the distance to move between the velocity readings.

Example: The left bank of the stream is at 1 foot and the right bank of the stream is at 21 feet. This gives you a 20-foot stream width. Divide that by 10 and your distance between measurements will be every 2-feet (i.e., take velocity readings at 3 ft, 5 ft, 7ft, etc. until you get to the right bank at 21 ft) giving you nine stream velocity readings. It is acceptable to move the interval slightly if the in-stream substrate is interfering with the ADV readings.

7.3.1.3 Begin by measuring the depth & then setting the rod depth.

- Stand facing upstream on the downstream side of the tape.
- Based on the increments you calculated above (in 7.3.3), go to the position for the first stream velocity reading (bank measurement + increment). Place your top-setting rod at this position and using the hash marks on the rod, determine the depth of the stream by reading off the downstream side of the rod. Estimate your depth to the hundredth place (0.00) (Note: single lines are 0.1 ft.; double lines are 0.5 ft; triple lines are 1.0 ft.) Using the scale on the handgrip of the top-setting rod, adjust the rod holding the meter to read the depth you just measured. This will place the meter at the appropriate six tenths of the depth from the surface.

7.3.1.4 Begin the velocity measurement

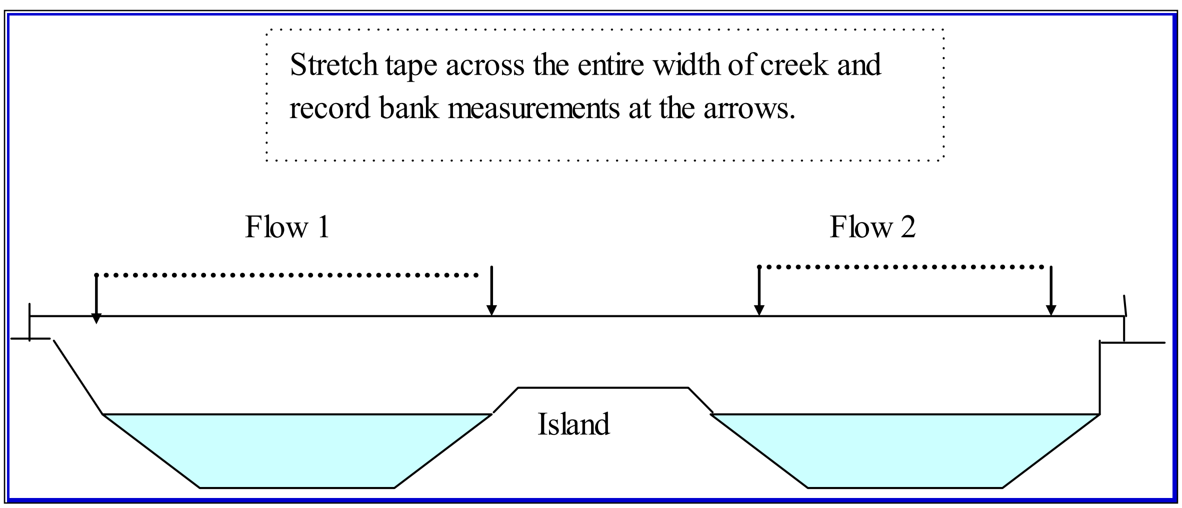
- The meter is to remain perpendicular to the tape throughout the flow measurement. Although a velocity angle of +/-20 degrees is desirable, it is more important that the meter remain perpendicular to the tape. This means that in some streams, the flow may have a negative or high angle.
- Turn the ADV on. Press ENTER to display the Main Menu.
- Press 3 to Start Data Run and display the Data File Menu.
- Press 1 and enter a file name. To enter text names, use the same method as mobile phones (e.g., press 2 four times for "C"; 2-A-B-C). Press 9 to accept the name.
- Press 2 and enter the operator's initials. Press 9 to start the flow measurements.
- At the "Press QC Menu" screen, press enter to continue.
- At the "Automatic QC Test" screen, press 1 to run the test. Follow the directions on the handset. NOTE: The Automatic QC Test MUST be run before every stream flow.
  - If any warnings are issued, you are given the option to repeat the test. The manufacturer recommends repeating the test at least once after you verify that the probe and sampling volume are well away from any underwater obstacles.
  - Press 1 to end the test or 2 to repeat it.
  - The ADV **must PASS** the automatic QC test within 3 attempts. If it fails to pass after three tries, the meter is malfunctioning or stream conditions are not favorable for ADV use. The ADV <u>cannot</u> be used for that particular station during that trip. However, the QC test should be run at all of the following

stations. Data collected without a successful QC test is suspect and should not be entered into ALAWADR.

- Flows must also be rejected if the mean SNR in the flow summary is <4.

- In the Starting Edge screen, enter the location, depth, and starting edge using the marked buttons on the keypad. Note that LEW/REW stands for Left/Right Edge of Water. Press Next Station to continue.
- Enter the location and depth. When the station information is complete, and the probe is at the correct depth and orientation, press the Measure button.
- An updating display will show the measured velocity. Keep the probe as steady as possible. On completion of the averaging time, a summary will be displayed. Press 1 to accept and go to the next station or depth, or press 2 to repeat this measurement. These steps will be repeated for all stations until End Section is pressed.
  - Make sure probes are level and even after placement in the water. Re-check the tightness of the screw if necessary.
  - To end the flow measurement, press End Section. The ending-edge information will be displayed; enter the information for this edge. Press Calc Discharge to compute the total cross-sectional discharge for all completed stations. Press 0 to return to the Main Menu. **You must always return to the Main Menu to make sure that all data is saved.**

7.3.2 Using the AA or Pygmy Meter



7.3.2.1 Select a cross-section and determine the width of the stream by stretching a measuring tape across the stream.

- The measuring tape should be stretched at a 90º angle to the direction of stream flow.
- Write down on the first line of the Abbreviated Stream Flow Measurement Datasheet (Example on Page 8), the tape measurement at which the stream water and the bank meet. This should be the bank that is closest to the zero mark on the

tape. Determine the left/right banks and indicate that next to tape measurement you just wrote down.

- The left and right banks are determined by facing downstream ("go with the flow") – left bank is then on your left hand and right bank on your right hand.
- Walk across the stream and read the tape measurement at which the stream water and the bank meet on the opposite bank.
- Subtract the two bank readings to get the stream width.

7.3.2.2 Determine the increments between velocity readings to provide 7 to 10 readings across the width of the stream by dividing the stream width by ten (10). This gives the distance to move between the velocity readings.

Example: The left bank of the stream is at 1 foot and the right bank of the stream is at 21 feet. This gives you a 20-foot stream width. Divide that by 10 and your distance between measurements will be every 2-feet (i.e., take velocity readings at 3 ft, 5 ft, 7ft, etc. until you get to the right bank at 21 ft) giving you nine stream velocity readings.

7.3.2.3 Begin by measuring the depth & then setting the rod depth.

- Stand facing upstream on the downstream side of the tape.
- Based on the increments you calculated above (in #3), go to the position for the first stream velocity reading (bank measurement + increment). Write the number from the tape corresponding to this position on the second line under the column heading Tape.
- Place your top-setting rod at this position and using the hash marks on the rod, determine the depth of the stream by reading off the downstream side of the rod. Estimate your depth to the hundredth place (0.00) (Note: single lines are 0.1 ft.; double lines are 0.5 ft; triple lines are 1.0 ft.) Write the depth under the column heading Depth.
- Using the scale on the handgrip of the top-setting rod, adjust the rod holding the meter to read the depth you just measured. This will place the meter at the appropriate six tenths of the depth from the surface.

7.3.2.4 Begin the velocity measurement by counting the number of revolutions made by the spinning meter for a period between 40 and 70 seconds.

- Start the stopwatch simultaneously with the first signal or 'click', counting "zero", not "one."
- After a minimum of 40 seconds have passed, stop the stopwatch on a click. The count that you end on is the number of revolutions. (It is fairly infrequent that the click will happen at exactly 40 sec.)
- Record the number of revolutions under the column-heading Revolutions.
- Read the time to the nearest second
- Record the number of seconds on the stopwatch under the column-heading Seconds.

7.3.2.5 Continue the depth and velocity measurements at the predetermined incremental points as described above until you get to the opposite bank.

7.3.2.6 When the measurements are completed, record the tape measurement where the water surface and the opposite bank meet. Note whether it is the left or right bank.

8 ESTIMATED STREAM VELOCITY METHOD

8.1 <u>Bucket Method</u>

8.1.1 In situations where flow is not measureable with handheld ADV or other method (such as discharge from a pipe, or stream flow out of a culvert underneath a road), flow can be measured manually. This is accomplished by measuring the time it takes to fill a container of a known volume.

8.1.2 Typically, it only works in fairly low flow situations in which the stream of water/effluent flows from a location where a bucket can be placed in order to capture the entire amount of flow.

8.1.3 Procedure

8.1.3.1 Find a suitable location where the container can be properly placed to capture the entire stream of flow.

8.1.3.2 Stopwatch in hand, begin capturing flow in container. Start timing immediately as container is placed to capture flow.

8.1.3.3 Stop timing when container is full or at a known volume.

8.1.3.4 Repeat this process at least three times and record all values.

8.1.3.5 Calculate the corresponding flow rate by using the equation

$$Q = \Delta V / \Delta t$$

where

Q = flow,

ΔV = change in volume, and

Δt = change in time (See example in Sec 10.3).

8.1.3.6 Average the measurements to determine the estimated flow rate.

8.2 <u>Float Method</u>

8.2.1 In situations where flows cannot be obtained using a handheld ADV or other measurement device, it is possible to roughly estimate stream flow/discharge based on channel geometry and velocity.

8.2.2 This entails estimating the cross-sectional area of the channel, using a float, and timing the amount of time it takes to travel a designated distance. Since this only takes into account surface velocity at one location in the stream of flow, results can fluctuate greatly depending on the variability across the entire channel and along the length of the reach measured.

8.2.3 This is the least accurate estimate of flow available and should only be used when all other methods are not feasible.

8.2.4 Procedure

8.2.4.1 Estimate the cross-sectional area of the channel. For instance, for a rectangular-shaped channel, multiply the average width (ft) by the average depth (ft) to yield an area in ft^2. If the stream is wadeable, take 10-12 depth measurements across a representative transect to find the average depth.

- Average width can be found by estimating width at 10 increments along the designated length and taking the average (e.g., average the widths at every 5 feet of a 50 foot segment).

8.2.4.2 Designate a distance over which stream velocity will be measured (e.g. 50' or 75') and mark the upstream and downstream boundaries. The more uniform the channel over this length, the better. A long, straight segment is ideal.

8.2.4.3 Stopwatch in hand, place the float at the upstream boundary and being timing as soon as it is released in the middle of the channel. Stop timing once the float reaches the downstream boundary.

8.2.4.4 Repeat this measurement a minimum of three times and calculate the average time. If the float hits an obstruction or reaches a bank, do not that measurement, and repeat measurement.

8.2.4.5 Compute stream velocity (v) in ft/s by dividing the length of the designated segment by the average time (See example in Sec 10.4.1).

8.2.4.6 Calculate flow (Q) by multiplying the cross-sectional area (A) from step 1 by the average measured velocity (v) (See example in Sec 10.4.2).

9 TROUBLESHOOTING

9.1 ADV

9.1.1 All meters shall be examined before and after each discharge measurement. The examination shall include the vanes and shaft for damage or wear.

9.1.2 Make sure no mud, debris or in-stream vegetation has built up, blocking the beams.

9.1.3 Check the yellow protective film. Make sure it is still intact and no debris has built up behind it.

9.1.4 Make sure probes are level and even after placement in the water. Re-check the tightness of the screw if necessary.

9.2 AA and Pygmy Meters

9.2.1 All meters shall be examined before and after each discharge measurement. The examination shall include the meter cups or vanes, pivot and bearing, and shaft for damage, wear or faulty alignment. Meter balance and alignment shall be checked prior to any use in the field.

9.2.2 Meters shall be cleaned and oiled daily when in use. Surfaces that shall be cleaned and oiled, on a quarterly basis, are the pivot bearing, pentagear teeth and shaft, cylindrical chart bearing, and thrust bearing at the cap.

9.2.3 Visually inspect the current meter. Remove any exterior obstruction that might be hindering the cup's rotation.

9.2.4 Carefully remove the flow pin. Using WD-40, thoroughly spray the pivot bearing to remove sand and other debris that may cause friction on the flow pin. Gently wipe the flow pin, lubricate and re-assemble.

9.2.5 Open the cap for the contact chamber. Check the wire “whisker” to make sure it just touches the spin shaft only when the angled point rotates around. Spray WD-40 in the interior to lubricate the pentagear, and then replace the cap. Run the spin test.

9.2.6 The Top Setting Wading Rod should be cleaned and examined before and after each discharge measurement including a check on the sliding rod and lock set mechanism.

9.2.7 Instruments that do not pass the spin test using a pin that is in good condition and have been properly cleaned may have to be sent to USGS for repair.

10 DATA ACQUISITION, CALCULATIONS, & DATA REDUCTION REQUIREMENTS

10.1 General

10.1.1 Stream Flow calculations must be completed before data can be entered in the applicable database for reporting.

10.1.2 All stream flows shall be expressed in cubic feet per second (CFS) or the metric equivalent cubic meters per second (CMS).

10.1.3 Time records associated with flow measurement shall be kept in local time, and shall be recorded to the nearest 5 minutes.

10.1.4 All measurements shall be traceable both to the individual making the measurement and the equipment utilized.

Note for estimated flows: Flow (Q) is typically measured in cubic feet per second (cfs) and facility wasteflow in millions of gallons per day (mgd). Unit conversions will usually be required when using the methods in Sec 8.1 and 8.2.

10.2 Flow Calculation for AA and Pygmy

10.2.1 An EXCEL Workbook (FOD I-Form 9) has been created that will calculate the flow using the appropriate equations when all of the data from the stream flow worksheet are entered into the appropriate blanks. Appropriate data entry quality assurance shall be conducted when using this method of calculation.

10.2.2 The flow result may also be calculated using the equation listed below (with or without the corresponding meter’s rating table). Note that the velocity is calculated different depending on whether an AA or Pygmy meter was used during the measurement.

10.2.3 Equation:

Flow = Depth * Velocity* ((Tape b-Tape a)/2)

where:

Pygmy Meter Velocity = [0.9604 *(Rev/Sec)] + 0.0312

AA Meter Velocity = [2.2048*(Rev/Second)] + 0.0178

Depth= distance (ft) from surface to bottom at location where velocity is measured

Tape b= Measurement on cross-sectional tape from previous reading (or bank)

Tape a= Measurement on cross-sectional tape from next reading (or bank)

10.3 Flow Calculation Example for Estimated Bucket Method

10.3.1 The white buckets that many of the FOD employees use are graduated in liters (L). The following is an example of how to manually calculate flow using a white FO bucket:

Measurement 1: Flow filled to 10 L mark on bucket in 5 seconds.

Measurement 2: Flow filled to 10 L mark on bucket in 4 seconds.

Measurement 3: Flow filled to 10 L mark on bucket in 7 seconds.

Average time = (Σ of measurement times) / (# of measurements)
= (5+4+7)/3
= 5.33333 seconds

10.3.2 Volumetric Flow (Q) = ΔVolume / ΔTime
= 10 liters/5.33333 seconds = 1.875 L/s

Since 1 L = 0.0353147 ft^3, then:

1.875 L/s * (0.0353147 ft^3/L) = **0.0662 cfs**

10.4 Flow Calculation Example for Estimated Float Method

10.4.1 A non-wadeable stream has an average width of 13.5’ and an average depth of 3.75’. There is a long uniform segment of the stream that spans 100’. The following velocity measurements were observed:

Velocity Measurements:

Measurement 1: A bottle took 99 seconds to travel the 100’ length.

Measurement 2: A bottle took 88 seconds to travel the 100’ length.

Measurement 3: A bottle took 94 seconds to travel the 100’ length.

Cross-sectional area = length (l) x width (w) = 13.5 ft x 3.75 ft = 50.625 ft^2

Average time (t) = (Σ of measurement times) / # of observations
= (99+88+94)/3 = 93.66667 seconds

Velocity (v) = distance (d) / time (t)
= 100 ft / 93.66667 sec = 1.0676 ft/sec

10.4.2 Calculated estimated flow by Q = v * A,

where

Q is flow in cfs,

v = velocity in ft/s, and

A is cross-sectional area in ft^2:

$Q = 1.0676$ ft/sec x 50.625 ft² = **54.05 cfs**

11 DATA AND RECORDS MANAGEMENT

Stream flow ADV printouts, measurement logbooks and datasheets are archived in the applicable station file.

12 QUALITY CONTROL & QUALITY ASSURANCE

12.1 Acoustic Doppler Velocimeter (ADV)

12.1.1 To ensure the proper functioning of the ADV, the Automatic QC Test MUST be run **before** every stream flow.

12.1.2 At the "Press QC Menu" screen, press enter to continue.

12.1.3 At the "Automatic QC Test" screen, press 1 to run the test. Follow the directions on the handset.

12.1.4 If any warnings are issued, you are given the option to repeat the test. The manufacturer recommends repeating the test at least once, after you verify that the probe and sampling volume are well away from any underwater obstacles.

12.1.5 Press 1 the end the test or 2 to repeat it.

12.1.6 **The ADV must PASS the automatic QC test within 3 attempts.** If it fails to pass after three tries, the meter is malfunctioning or stream conditions are not favorable for ADV use. **The ADV cannot be used** for that station Data collected without a successful QC test is suspect and should not be entered into ALAWADR.

12.1.7 **If the the SNR is <4 the flows must be rejected.** Per the manual, flows collected when the SNR <4 are unreliable and should not be used.

12.2 AA and Pygmy Meters Spin Testing

Note: Spin tests should be conducted in a place where there is no wind (Including an Air Conditioner Fan). Wind will dramatically increase the time the meter spins giving a false spin test result.

12.2.1 The meter should be held level while spin testing and should be conducted in the vehicle to avoid wind effects. It is recommended that the vehicle air conditioner fan be shut off during the spin test.

12.2.2 The AA meter has a raising-nut under the cups to prevent them from resting on the pin when the meter is not in use. This should be unscrewed to allow the cups to rest on the pin and to spin freely.

12.2.3 The pygmy meter does not have a raising nut. Instead it has a shipping pin (brass colored and dull pointed) and a flow pin (silver colored and sharply pointed). The shipping pin should be installed in the meter at any time the meter is not being used. This prevents dulling the point of the flow pin.

12.2.4 Give the cups a vigorous spin and time how long it spins with a stopwatch.

12.2.5 The AA passes the spin test if it spins for longer than 2.0 minutes (USGS, 1989) and comes to a gradual, smooth stop.

12.2.6 The pygmy passes the spin test if it spins for longer than 45 seconds and comes to a smooth stop (USGS, 1989).

12.2.7 Log the date, time, station, type meter tested, duration of spin-test, and tester's initials in the yellow logbook.

12.2.8 Spin tests should be conducted before each flow measurement made and after the final flow measurement of the day.

12.2.9 If the meter does not pass the spin test see Section 8.2 to troubleshoot. If it cannot pass the spin test, the meter should not be used.

13 REFERENCE

ADEM 2013 (as amended). Standard Operating Procedures #9021 Field Quality Control: Measurements and Samples, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

USGS 1969. "Discharge Measurements at Gaging Stations," Hydraulic Measurement and Computation Book, Book II, United States Department of Interior, US Geological Survey (USGS), Washington, D.C.

USGS 1989. Office of Surface Water Technical Memorandum No. 89.07: Policy to Ensure the Accurate Performance of Current Meters. US Geological Survey (USGS), Washington, D.C.

ADEM-Field Operations Division
Abbreviated Stream Flow Measurement Datasheet

Station # ____________________ Start Time: ____________ hrs

Date ____________________ Finish Time: ____________ hrs

Conducted By: ____________________ Meter Type: ☐ AA ☐ Pygmy

Meter Number: ____________

Passed Spin Test: Before ☐ Yes ☐ No

After ☐ Yes ☐ No

Measurement Number**	Actual Tape Reading	Depth (ft)	Revolutions	Seconds	Velocity	Flow
Bank **LB / RB**						
#1						
#2						
#3						
#4						
#5						
#6						
#7						
#8						
#9						
#10						
#11						
#12						
#13						
#14						
#15						
Bank **LB / RB**						

Stream Flow ____________

**7-10 readings across the stream

revised 1-25-06 vjh

14 CHANGE TRACKING

Rev. Date (Review Date) Rev.#	Approved By:	Detail of Approved Change
02/06/06		Original Version
2/20/07 Rev 1.0	Brien Diggs/ Lynn Sisk	Annual review. Corrected non-critical typos and formatting un-related to methods addressed. Deleted Section 5.2 referencing the 3 months experience requirement. Corrected Sections 11.4.1 & 11.5.1 by dividing into two sections each to clarify appropriate location to conduct field spin tests. Modified Section 7.1 to clarify the criteria for selecting a flow meter. Modified Section 7.3.4 by incorporating the "Note" from the 5th bullet into bullet 2 to clarify the note.
04/09/07 Rev 1.1	Sandy Gibson	Critical Procedure Change: Calibration times for AA and pygmy meters changed for consistency with USGS documented calibration procedures.
02/29/08 Rev 2.0	Brien Diggs	Annual review. Added section on Acoustic Doppler Velocimeter. Added QC on Velocimeter-Sec 11.6.
02/29/08a (1/22/09) Rev 2.0	R. Williams	Annual review. Corrected non-critical typo in section 7.5.4. Made non-critical formatting changes.
01/31/12 Rev. 3.0	G. Curvin	Periodic review. Made non-critical formatting and grammatical changes. Modified the following sections: 1; 7; 8; 9.2.1; 10; and 11. Deleted Section 9.1.4.
12/10/12 Rev. 4.0	G. Curvin	Periodic review. Made non-critical formatting and grammatical changes. Modified Section 6 for equipment. Added the following sections for Estimated Flows: 8; 10.1.4—Note; 10.3; and 10.4.
02/05/14 Rev. 5.0	J. Worley	Periodic review. Made non-critical formatting and grammatical changes. Added the following Sections: 7.3.1.4, Bullet 1—meter positioning; 7.3.1.4, Bullet 7, Hash mark 4—SNR<4; and 12.1.7—SNR<4. Modified the following Sections: 7.3.1.4, Bullet 7, Hash mark 3—failure of QC test; and 12.1.6—rejection of meter use by station visit.

IN-SITU SURFACE WATER QUALITY FIELD MEASUREMENTS --TEMPERATURE--

SOP #2041

VERSION DATE: 03/25/09a

Revision 3.1

PREPARED BY: ______________________ **DATE** 01/13/2011

REVIEWED BY: ______________________ **DATE** 01/13/11
Branch or Division Chief

APPROVED BY: ______________________ **DATE** 1/13/2011
Quality Assurance Manager

Alabama Department of Environmental Management

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PREFACE

This Standard Operating Procedures (SOP) Manual supersedes all Departmental SOPs relating to the methods addressed and is designed to be periodically reviewed and updated. The primary purpose of this document is to establish and maintain uniform operational and quality control guidance. The compliance with these procedures is essential to produce reliable data. Any deviation from this SOP must be documented and pre-approved by the Project QA/QC Coordinator and/or project supervisor.

DISCLAIMER

This document has been prepared for use by the staff of the Alabama Department of Environmental Management (ADEM). Mention of trade names or commercial products does not constitute endorsement or recommendation for use. No portion of this manual is intended to supersede any Departmental policy memorandum issued by the Director or Deputy Director.

NOTE:

Any alpha suffix added to the version date indicates the incorporation of corrections for non-critical typographic errors or formatting, i.e., no methodology changes were incorporated.

IN-SITU SURFACE WATER QUALITY FIELD MEASUREMENTS—TEMPERATURE

1 SCOPE AND APPLICATION

1.1 *In-situ* surface water temperature is generally conducted at all sites utilizing field equipment. If meters are used they are pre- calibrated and post-calibrated/verified with all calibrations recorded in a dedicated logbook or calibration database.

1.2 Quality assurance procedures for temperature field test instrument calibration are an essential part of this standard operating procedure. Included in this document are: calibration and maintenance intervals, and utilization of a log book or database to record calibration and maintenance data.

2 SUMMARY OF METHOD

2.1 At each site, representative field samples are taken at the appropriate depth or measured directly in-stream within the main channel flow. If a datasonde is being used, the probe is allowed to remain at depth until readings stabilize before recording. Measurements obtained that appear to be out of the normal ranges will result in calibration verification or re-calibration of all specific equipment and retesting.

2.2 All meters/sondes are calibrated/verified prior to pre-deployment in a controlled environment. This should occur within 24 hours prior to the first field measurement. Upon returning to base from the field, the meters/sondes are brought to the laboratory to equilibrate. The duration of equilibration time depends on the temperature differential between outdoor and indoor conditions. As a rule, when outside temperatures exceed 90°F (32°C) or below 50°F (10°C), post-calibration/verification takes place the following day after return to base. When outside temperatures are between 90°F (32°C) and 50°F (10°C), the meter/sonde may be calibrated/verified on the same day once sufficient time (>2hrs) has passed to allow for temperature equilibration. All calibration/verification parameters are recorded in a dedicated logbook or calibration database.

2.3 Generally field measurements made for the purpose of comparison with water quality standards are measured at mid depth (for stations of less than or equal to 3 feet). Stations that have a depth greater than 3 feet but less than 10 feet, a minimum of 3 measurements should be collected at the surface (0.2 m), mid-depth, and the bottom. For stations with a total depth of greater than 10 feet, measurements should be obtained at the depths prescribed in sampling plan and/or at 5 feet.

3 DEFINITIONS

NIST- National Institute of Science and Technology

APHA – American Public Health Association document. Cited as reference for "Standard Methods for the Chemical Analysis of Water and Wastes"

4 HEALTH & SAFETY WARNINGS

General field health and safety warnings apply.

5 INTERFERENCES

N/A

6 PERSONNEL QUALIFICATIONS

6.1 No employee shall conduct this technique until he/she has actual field experience and has successfully demonstrated the ability of conducting this technique under the supervision of a senior staff member.

6.2 Each new Departmental employee shall accompany an experienced field employee on as many as possible of the differing types of sampling situations the employee may be called upon to conduct.

6.3 During this training period, the new employee will be permitted to perform all facets of field investigations, including sampling, under the direction and supervision of senior technical staff members.

7 EQUIPMENT AND SUPPLIES

7.1 **Thermometer**- Dial or digital thermometers are used to measure the air temperature and water temperature at a site.

7.2 **Multiprobe datasondes-** multiprobe units with and without storage capability are a tool used for the collection of field parameter measurements including temperature.

7.3 **pH meters**- Temperature compensated pH meters may be used for the measurement of in situ pH and temperature.

7.4 **Conductivity meters-**Temperature compensated specific conductivity meters may be used for the measurement of *in situ* conductivity automatically corrected to 25 degrees Celsius and temperature.

8 TEMPERATURE MEASUREMENT

8.1 <u>Calibration</u>

8.1.1 Calibrations must be performed in compliance with APHA Standard methodology and instrument specific calibration methods.

8.1.2 Crosschecks with a calibrated NIST-certified thermometer must be made at least annually.

8.1.3 A logbook or database is maintained with each thermometer number and each thermistor device and recorder property number. All calibration information, individuals making the calibrations, and dates of calibration/verification are recorded.

8.1.4 Multiprobe-specific calibration logbooks, datasheets, and/or databases must be maintained to create a traceable record of calibration and maintenance. Yearly, these records should be transcribed into an Excel Spreadsheet or scanned to be inserted into FileNet.

8.2 Quality Control

8.2.1 All thermometers (including dial, digital, probe of pH and conductivity meters, or integrated piece of a multi-parameter meter) must be calibrated/verified annually with a NIST-certified thermometer at 25°C. Thermometers are adjusted to display what a calibrated thermometer displays in an ambient temperature medium.

8.2.2 These instruments must be compared against a NIST-verified thermometer (0.1°C) on a weekly basis to verify calibration. Any instrument varying greater than ±1 from the standard must be recalibrated.

8.2.3 Annually NIST-verified thermometers are calibrated against a NIST-certified thermometer.

8.2.4 A visual observation is made before using a thermometer/thermister in the field to insure that it has not been damaged.

8.2.5 Dial type thermometers should not have a broken face cover or otherwise show damage.

8.3 Single Measurements

8.3.1 Allow the temperature measuring device (thermometer or probe) enough time to equilibrate to outside temperature when removed from a vehicle.

8.3.2 Air temperature should be taken with a dial or digital type thermometer in a shady area if possible. If possible suspend the thermometer in the air to equilibrate the thermometer (do not stick the probe into the soil to measure the air temp as this will measure the soil temperature instead)

8.3.3 Insert thermometer or probe *in-situ* when possible or in a grab sample of adequate size to obtain an accurate reading.

8.3.4 Swirl the thermometer or probe in the sample for a few seconds and take a reading when the indicator stabilizes

8.3.5 Read the value to the nearest 1°C.

8.4 Water Column Profile Measurement by Datasonde

8.4.1 Allow the instrument to equilibrate to *in situ* conditions and the concentration to stabilize before storing the measurement.

8.4.2 Single water column measurements are made at mid-depth (for stations of less than or equal to 3 feet) to allow comparison with water quality standards.

8.4.2.1 For water column depths greater than 1 m (3 feet) but less than 3 m (10 feet), a minimum of 3 measurements should be collected, at the surface (0.2 m), mid-depth, and the bottom.

8.4.3 Profile measurements are recorded at multiple depths in the water column starting at the surface (0.2-0.3 m depth), 1.0 m, 1.5 m, and 2.0 m, continuing at 1-meter intervals and ending with a reading at the maximum depth. Readings may be recorded at 5-meter intervals from 30 meters depth to the bottom, if little change is observed in readings.

8.4.4 Measurements at each interval are saved in the multiprobe datalogger. Additional information may also be entered and saved in the data logger.

8.4.5 During travel between each station, personnel should return multiprobes to a bucket or tube of water to keep the probes wet.

9 SAMPLE HANDLING AND PRESERVATION

N/A

10 TROUBLESHOOTING

N/A

11 DATA ACQUISITION, CALCULATIONS, & DATA REDUCTION REQUIREMENTS

N/A

12 DATA AND RECORDS MANAGEMENT

12.1 All field analyses must be traceable to the specific individual performing the analyses and to the specific equipment utilized. This information shall be entered into the field records for all field analyses performed by departmental personnel.

12.2 All maintenance and calibration records for field measurement equipment shall be kept so that they are similarly traceable.

12.3 Time records shall be kept in local time and shall be recorded to the nearest five minutes, unless the proximity of the station necessitates more discrete time measurement.

13 QUALITY CONTROL & QUALITY ASSURANCE

13.1 Duplicate measurements for field quality control must be made at the frequency outlined in *SOP #9021 Field Quality Control: Measurements and Samples*.

13.2 Field equipment shall be inspected and tested before being used in the field.

13.3 The Quality Assurance Coordinator or their designee shall periodically audit field records to ensure that duplicate temperature field measurements are within prescribed limits (± 1°C).

13.4 The Quality Assurance Coordinator or his designee shall immediately inform the appropriate supervisor of any problems detected during these audits so that they may be rectified.

14 REFERENCE

ADEM. 2010 (as amended). Standard Operating Procedures #9021 Field Quality Control: Measurements and Samples, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

APHA. 1998. Standard Methods for the Examination of Water and Wastewater, 20th Edition, 2-60, Method 2550. American Public Health Association (APHA), Washington, D.C.

USEPA. 1979. Methods for Chemical Analysis of Water and Wastes, Method 170.1, US Environmental Protection Agency (USEPA), Atlanta, GA.

15 CHANGE TRACKING

Rev. Date Rev. #	Approved By:	Detail of Approved Change
02/06/2006		Original Version
02/20/2007 Rev 1.0		Annual review. Corrected non-critical typos and formatting un-related to methods addressed. Deleted Section 6.2 referencing the 3 months experience requirement.
03/03/08 Rev 2.0		Annual review. Modified Sec 2.2; 8.1.4; and 8.4.3. Added Sec 2.3; 8.4.2.1; and digital thermometers.
02/27/09 Rev. 3.0		Annual review. Modified Sec 1.1, 1.2, and 8.1.3 to include calibration database. Modified Sec 2.3. Added Sec 2.2.
03/25/09 Rev. 3.1	M. Sullivan	Made non-critical typographical and formatting changes. Modified Sec 8.1 and 8.2 to reflect annual verification of thermometers. Split Sec 8.3 into Sec 8.3 and 8.4 to separate water and air thermometer procedures.
03/25/09a Rev. 3.1	H.Cox	Periodic review. Made non-critical typographical and formatting changes.
03/25/09a (02/22/11) Rev. 3.1	H. Cox	Periodic review—No changes.
03/25/09a (03/25/13) Rev. 3.1	G. Curvin	Periodic review—No changes.

In-Situ Surface Water Quality Field Measurements
--pH--

SOP #2042

Revision 4.0

VERSION DATE: 03/04/13

PREPARED BY:	[signature]	**DATE**	3/4/2013
REVIEWED BY:	[signature] **Branch or Division Chief**	**DATE**	3/07/13
APPROVED BY:	[signature] **Quality Assurance Manager**	**DATE**	3/5/2013

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IN-SITU SURFACE WATER QUALITY FIELD MEASUREMENTS—PH

1 SCOPE AND APPLICATION

1.1 *In-situ* surface water pH is generally conducted at all sites utilizing field equipment that is pre- and post-calibrated with all calibrations recorded in a dedicated logbook or calibration database.

1.2 Quality assurance procedures for pH field test instrument calibration are an essential part of this standard operating procedure. Included in this document are: calibration and maintenance intervals; environmental conditions necessitating recalibration; and utilization of a log book or database to record calibration and maintenance data.

2 SUMMARY OF METHOD

2.1 At each site, representative field samples are taken at the appropriate depth or measured directly in-stream within the main channel flow. If a datasonde is being used, the probe is allowed to remain at depth until readings stabilize before recording. Measurements obtained that appear to be out of the normal ranges will result in calibration verification or re-calibration of all specific equipment and retesting.

2.2 Only electronic (portable) meters with provisions for temperature compensation and temperature resistant combination electrodes may be used.

2.3 All meters/sondes are calibrated for pre-deployment in the controlled environment of the laboratory. This should occur within 24 hours prior to the first field measurement. Upon returning to base from the field, the meters/sondes are brought to the laboratory to equilibrate. The duration of equilibration time depends on the temperature differential between outdoor and indoor conditions. As a rule, when outside temperatures exceed 90°F (32°C) or are below 50°F (10°C), post-calibration/verification takes place the following day after return to base. When outside temperatures are between 90°F (32°C) and 50°F (10°C), the meter/sonde may be calibrated/verified on the same day once sufficient time (> 2 hrs) has passed to allow for temperature equilibration. All calibration parameters are recorded in a dedicated logbook or calibration database.

2.4 Generally field measurements made for the purpose of comparison with water quality standards are measured at mid-depth (for stations of less than or equal to 3 feet). Stations that have a depth greater than 3 feet but less than 10 feet, a minimum of 3 measurements should be collected at the surface (0.2 m), mid-depth, and the bottom. For stations with a total depth of greater than 10 feet, measurements should be obtained at the depths prescribed in sampling plan and/or at 5 feet.

2.5 Be aware of what might be considered a high or low pH result value. A general rule of thumb for surface waters is to re-check the pH if the value obtained is less than 6.0 (which may be normal in areas with tannic waters) or greater than 8.5. A comment should be made in the field notes stating that the sample was re-checked and found reproducible and any possible reasons for the high or low value. In case of an apparent pH water quality standard violation, the meter should be re-calibrated using buffers bracketing the obtained result and then the sample should be re-analyzed.

3 DEFINITIONS

APHA – American Public Health Association document. Cited as reference for "Standard Methods for the Chemical Analysis of Water and Wastes"

4 HEALTH & SAFETY WARNINGS

4.1 General field health and safety warning apply.

5 INTERFERENCES

5.1 The glass electrode, in general, is not subject to solution interferences from color, turbidity, colloidal matter, oxidants, reductants or high salinity.

5.2 Errors due to the presence of sodium at pH levels greater than 10 can be reduced or eliminated by using a "low sodium error" electrode.

5.3 Coatings of oil material or particulate matter can impair electrode response. Remove these coatings by gentle wiping, followed by a distilled water rinsing.

5.4 Temperature effects on the electrometric measurement of pH are controlled by using instruments having temperature compensation or by calibrating the electrode - instrument system at the temperature of samples.

6 PERSONNEL QUALIFICATIONS

6.1 No employee shall conduct this technique until he/she has actual field experience and has successfully demonstrated the ability of conducting this technique under the supervision of a senior staff member.

6.2 Each new Departmental employee shall accompany an experienced field employee on as many as possible of the differing types of sampling situations the employee may be called upon to conduct.

6.3 During this training period, the new employee will be permitted to perform all facets of field investigations, including sampling, under the direction and supervision of senior technical staff members.

7 EQUIPMENT AND SUPPLIES

Multiprobe Kit

Spare pH probes

Multiprobe/data logger battery chargers

NIST Verified Thermometer

Fresh pH solutions (4, 7, 10)

pH Meter

Temperature Compensated Probe

7.1 **Multiprobe datasondes-** multiprobe units with and without storage capability may be used to measure *in situ* pH.

7.2 **pH meters**- Temperature compensated pH meters may be used for the measurement of *in situ* pH.

8 pH MEASUREMENT

8.1 By Meter

8.1.1 Calibration

8.1.1.1 Allow the instrument to equilibrate to ambient temperature when it has been in a vehicle. (Note: In extremely cold weather the meter should be kept in the heated portion of the vehicle until used.)

8.1.1.2 Follow the equipment manufacturer's instructions for calibration at a minimum of two points that bracket the expected pH of the samples using standard buffer solutions of known pH values (e.g., 4, 7, and 10).

8.1.1.3 Verify calibration at each station by checking the value obtained for the pH 7 buffer. If the meter reads outside of the 6.9 to 7.1 range (± 0.1) for the pH 7.0 buffer, recalibrate using the standard re-calibration method. Document the pH 7 checks in the meter logbook.

8.1.1.4 A logbook for each pH meter is maintained and labeled with the ADEM property number. The logbook shall include dates, times, calibration verification records, repairs made and persons conducting the calibration/maintenance.

8.1.2 Quality Assurance

8.1.2.1 Check the meter before each field trip for any mechanical or electrical failures, weak batteries and cracked or fouled electrodes. Coatings of oil material or particulate matter can impair electrode response. Remove these coatings by gentle wiping, followed by a distilled/de-ionized water rinsing.

8.1.2.2 The small containers used for transporting pH buffer solutions in the field (e.g., 4, 7, and 10) shall be refilled with fresh stock solution prior to each sampling trip.

8.1.2.3 Duplicate analyses shall agree within ± 0.1 pH units.

8.1.2.4 A logbook for each pH meter must be maintained and labeled with the ADEM property number of the meter. All field and office calibrations and repairs must be recorded in the logbook indicating the date, repairs made, person making repairs, and calibration records for each meter.

8.1.3 Measurement

8.1.3.1 Allow the instrument to equilibrate to ambient temperature when it has been in a vehicle.

8.1.3.2 Rinse the electrode with distilled/de-ionized water and wipe gently with a clean paper towel.

8.1.3.3 Immerse the electrode in-situ when possible or in a grab sample (250 ml minimum) and swirl the electrode at a constant rate until the indicator reaches equilibrium. The rate of stirring used should minimize the air transfer rate at the air-water interface of the sample.

8.2 By Datasonde

8.2.1 Calibration

8.2.1.1 The datasonde is calibrated prior to taking measurements as outlined in the manual that accompanies the instrument. These calibrations are performed in compliance with APHA Standard methodology and instrument instruction manuals

8.2.1.2 Multiprobes require both "pre-calibration" in the laboratory prior to a sampling event and a "post-calibration verification/confirmation" in the laboratory following the sampling event. The target calibration parameter should fall within the acceptance criteria for that parameter It is very important that the calibration be done in a temperature and pressure controlled environment using a clamp and a stand, to avoid human temperature interferences.

8.2.1.3 After returning from a sampling trip, bring the sonde, cable and hand unit into the laboratory. The duration of equilibration time depends on the temperature differential between outdoor and indoor conditions. As a rule, when outside temperatures exceed 90°F (32°C) or fall below 50°F (10°C), post-calibration/verification takes place the following day after return to base. When outside temperatures are between 90°F (32°C) and 50°F (10°C), the meter/sonde may be calibrated/verified on the same day once sufficient time (>2hrs) has passed to allow for temperature equilibration.

8.2.1.4 Sequential day trips require only one pre-calibration before the 1st day trip and a daily post-check following the post-calibration/verification guidelines set forth in 8.2.1.3.

8.2.1.5 Multiprobe-specific calibration logbooks, datasheets or calibration database must be maintained to create a traceable record of calibration and maintenance. Yearly, files not stored in a database housed on a departmental server and non-electronic records must be transcribed into an Excel spreadsheet or scanned to be inserted into FileNet

8.2.2 Quality Assurance

8.2.2.1 For pre-deployment calibration, the instrument readings will be recorded after the sonde has been adjusted/calibrated. This will verify the instrument accepted the calibration. If the sonde fails any of the parameters, fix the probe and re-calibrate or schedule it for repairs and do not use for trip.

8.2.2.2 Following the last measurement of the sampling event, a post-calibration check of the multiprobe is conducted in the laboratory and all calibration parameters are recorded.

8.2.2.3 For post-deployment verification/confirmation, record the instrument reading prior to <u>any</u> calibration. Do not calibrate the first pH standard without first checking the second. If post-calibration/verification of the multiprobe should fail for one or more parameters, the validity of the data must be determined.

8.2.2.4 All calibrations, maintenance and repairs must be documented in the calibration record that accompanies each instrument.

8.2.2.5 Recharging the multiprobe's data storage unit is maintenance that occurs prior to any data collection event.

8.2.2.6 Visual observations and periodic cleansings of the multiprobe units are conducted.

8.2.3 Water Column Profile Measurement

8.2.3.1 Allow the instrument to equilibrate to *in situ* conditions and the concentration to stabilize before storing the measurement. For the HydroLab probe, the recommended stabilization time is 5-10 minutes to allow the sonde to equilibrate to the *in situ* temperature.

8.2.3.2 Single water column measurements are made at mid-depth (for stations of less than or equal to 3 feet) to allow comparison with water quality standards.

8.2.3.3 For water column depths greater than 1 m (3 feet) but less than 3 m (10 feet), a minimum of 3 measurements should be collected, at the surface (0.2 m), mid-depth, and the bottom.

8.2.3.4 Profile measurements are recorded at multiple depths in the water column starting at the surface (0.2-0.3 m depth), 1.0 m, 1.5 m, and 2.0 m, continuing at 1-meter intervals and ending with a reading at the maximum depth. Readings may be recorded at 5-meter intervals from 30 meters depth to the bottom, if little change is observed in readings.

8.2.3.5 Measurements at each interval are saved in the multiprobe datalogger. Additional information may also be entered and saved in the data logger.

8.2.3.6 During travel between each station, personnel should return multiprobes to a bucket or tube of tap water to keep the probes wet. Do not use distilled/deionized water for storage purposes; it will shorten the life expectancy of the probe.

9 Sample Handling and Preservation

N/A

10 Troubleshooting

N/A

11 Data Acquisition, Calculations, & Data Reduction Requirements

11.1 pH shall be reported to the nearest 0.1 standard pH unit. Readings that show two or more decimal places should be rounded to the nearest tenth.

12 Data and Records Management

12.1 All field analyses must be traceable to the specific individual performing the analyses and to the specific equipment utilized. This information shall be entered into the field records for all field analyses performed by departmental personnel.

12.2 All maintenance and calibration records for field measurement equipment shall be kept so that they are similarly traceable.

12.3 Time records shall be kept in local time and shall be recorded to the nearest five minutes, unless the proximity of the station necessitates more discrete time measurement.

13 Quality Control & Quality Assurance

13.1 Replicate measurements for field quality control must be made at the frequency outlined in SOP #9021 Field Quality Control: Measurements and Samples.

13.2 Field equipment shall be inspected and tested before being used in the field.

13.3 The Quality Assurance Coordinator or their designee shall periodically audit field records to ensure that replicate pH field measurements are within prescribed limits (± 0.1 su).

13.4 The Quality Assurance Coordinator or his designee shall immediately inform the appropriate supervisors of any problems detected during these audits so that they may be rectified.

14 Reference

Annual Book of ASTM Standards. 1976. Part 31, "Water", Standard D1293-65, p. 178.

ADEM. 2010 (as amended). Standard Operating Procedures #9021 Field Quality Control: Measurements and Samples, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

APHA. 1995. Standard Methods for the Examination of Water and Wastewater, 19th Edition, 4-65, Method 4500 B and H. American Public Health Association (APHA), Washington, D.C.

USEPA. 1979. Methods of Chemical analysis of Water and Wastes (pH), Method 150.1, U.S. Environmental Protection Agency (USEPA), Atlanta, GA..

15 CHANGE TRACKING

Rev. Date (Review Date) Rev. #	Approved By:	Detail of Approved Change
02/06/2006 Rev. 0		Original Version
02/20/2007 Rev 1.0		Annual review. Corrected non-critical typos and formatting un-related to methods addressed. Added "Note" in preface section. Deleted Section 6.2 referencing the 3 months experience requirement. Modified 8.2.1.2 to include an alternative "post calibration verification/confirmation" as applicable.
03/03/08 Rev 2.0		Annual review. Modified Sec 2.3; 8.2.1.2; 8.2.2.1; 8.2.1.4; and 8.2.3. Added Sec 2.4 and 8.2.13.
02/27/09 Rev. 3.0		Annual review. Made non-critical formatting changes. Modified the following sec: 1.1; 1.2; 2.4; 8.2.1.3 -8.2.1.5; 8.2.2.1-8.2.2.3; 11.1. Added Sec 2.3 concerning calibration.
02/27/09 (01/13/11) Rev. 3.0	H.Cox	Periodic review—No changes.
03/04/13 Rev. 4.0	J. Worley	Periodic review. Made non-critical formatting changes. Modified Sec 2.3 to include lower extreme temperatures. Modified Sec. 13.1 and 13.3 to reflect replicate readings.

IN-SITU SURFACE WATER QUALITY FIELD MEASUREMENTS -- CONDUCTIVITY (COND.)--

SOP #2043

Revision 4.0

VERSION DATE: 03/04/13

PREPARED BY:	[signature]	**DATE**	3/4/2013
REVIEWED BY:	[signature] Branch or Division Chief	**DATE**	03/07/13
APPROVED BY:	[signature] Quality Assurance Manager	**DATE**	3/5/2013

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PREFACE

This Standard Operating Procedures (SOP) Manual supersedes all Departmental SOPs relating to the methods addressed and is designed to be periodically reviewed and updated. The primary purpose of this document is to establish and maintain uniform operational and quality control guidance. The compliance with these procedures is essential to produce reliable data. Any deviation from this SOP must be documented and pre-approved by the Project QA/QC Coordinator and/or project supervisor.

DISCLAIMER

This document has been prepared for use by the staff of the Alabama Department of Environmental Management (ADEM). Mention of trade names or commercial products does not constitute endorsement or recommendation for use. No portion of this manual is intended to supersede any Departmental policy memorandum issued by the Director or Deputy Director.

NOTE:

Any alpha suffix added to the version date indicates the incorporation of corrections for non-critical typographic errors or formatting, i.e., no methodology changes were incorporated.

IN-SITU SURFACE WATER QUALITY FIELD MEASUREMENTS—CONDUCTIVITY

1 SCOPE AND APPLICATION

1.1 Conductivity, preferred by Standard Methods (1995) to the term "specific conductance, is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions and on the temperature of measurement.

1.2 *In-situ* surface water conductivity is generally conducted at all sites utilizing field equipment that is pre- and post-calibrated with all calibrations recorded in a dedicated logbook or calibration database.

1.3 Quality assurance procedures for conductivity field test instrument calibration are an essential part of this standard operating procedure. Included in this document are: calibration and maintenance intervals; environmental conditions necessitating recalibration; and utilization of a log book to record calibration and maintenance data.

2 SUMMARY OF METHOD

2.1 A portable conductivity meter, Wheatstone bridge type or equivalent is utilized.

2.2 At each site, representative field samples are taken at the appropriate depth or measured directly in-stream within the main channel flow. If a datasonde is being used, the probe is allowed to remain at depth until readings stabilize before recording. Measurements obtained that appear to be out of the normal ranges will result in calibration verification or re-calibration of all specific equipment and retesting.

2.3 All meters/sondes are calibrated for pre-deployment in the controlled environment of the laboratory. This should occur within 24 hours prior to the first field measurement. Upon returning to base from the field, the meters/sondes are brought to the laboratory to equilibrate. The duration of equilibration time depends on the temperature differential between outdoor and indoor conditions. As a rule, when outside temperatures exceed 90°F (32°C) or is below 50°F (10°C), post-calibration/verification takes place the following day after return to base. When outside temperatures are below 90°F (32°C) or above 50°F (10°C), the meter/sonde may be calibrated/verified on the same day once sufficient time (> 2 hrs) has passed to allow for temperature equilibration. All calibration parameters are recorded in a dedicated logbook or calibration database.

2.4 Generally field measurements made for the purpose of comparison with water quality standards are measured at mid-depth (for stations of less than or equal to 3 feet). Stations that have a depth greater than 3 feet but less than 10 feet, a minimum of 3 measurements should be collected at the surface (0.2 m), mid-depth, and the bottom. For stations with a total depth of greater than 10 feet, measurements should be obtained at the depths prescribed in sampling plan and/or at 5 feet.

3 DEFINITIONS

APHA – American Public Health Association document. Cited as reference for "Standard Methods for the Chemical Analysis of Water and Wastes"

4 HEALTH & SAFETY WARNINGS

General field health and safety warnings apply.

5 INTERFERENCES

5.1 Coatings of oil material or particulate matter can impair electrode response. Remove these coatings by wiping/cleaning using a cleaning instrument provided by the manufacturer, followed by a distilled water rinsing.

5.2 Temperature effects on the electrometric measurement of conductivity are controlled by using instruments having temperature compensation and assuring that the appropriate temperature compensation mode is selected.

6 PERSONNEL QUALIFICATIONS

6.1 No employee shall conduct this technique until he/she has actual field experience and has successfully demonstrated the ability of conducting this technique under the supervision of a senior staff member.

6.2 Each new Departmental employee shall accompany an experienced field employee on as many as possible of the differing types of sampling situations the employee may be called upon to conduct.

6.3 During this training period, the new employee will be permitted to perform all facets of field investigations, including sampling, under the direction and supervision of senior technical staff members.

7 EQUIPMENT AND SUPPLIES

Spare conductivity probes	Conductivity Meter
Data Logger	Fresh conductivity standards
Multiprobe/data logger battery chargers	NIST Verified Thermometer

7.1 **Multiprobe datasondes-** multiprobe units with and without storage capability are a tool used for the collection of field parameter measurements including conductivity.

7.2 **Conductivity Meters-** Temperature compensated conductivity meters may be used for the measurement of *in situ* conductivity.

8 Conductivity Measurement

8.1 By Meter

8.1.1 Calibration

8.1.1.1 Conductivity meter calibration is verified against known fresh standards. The standards used are ones that are anticipated to bracket expected field measurements prior to each field trip.

8.1.1.2 When in the field, the meter(s) shall be checked daily with known fresh standards.

8.1.1.3 Re-use of standards is not permissible.

8.1.1.4 The obtained value must be within 10% of the known standard value. If the result is outside of this range, then the cell constant must be re-calculated before the instrument can be used. Consult the instruction manual for specifics on this procedure. The general procedure is outlined below in Section 8.1.2.

8.1.1.5 A logbook for each conductivity meter is maintained and labeled with the ADEM property number. The logbook shall include dates, times, calibration verification records, repairs made and persons conducting the calibration/maintenance.

8.1.2 Determine the cell constant for the meter probe.

8.1.2.1 Rinse the conductivity cell with at least three portions of a 0.01 M KCL solution.

8.1.2.2 Adjust the temperature of a fourth portion to 25.0 ± 0.1°C.

8.1.2.3 Measure the conductivity of this portion (CR), and calculate the inverse (1/CR = R)

8.1.2.4 Calculate the cell constant (k):

$$k = R\,(C1 + C2)$$

where:

C1 is the theoretical conductivity of the 0.01 M KCL solution and;

C2 is the conductivity of the lab water used to make the solution.

If k = 0.980 - 1.020; no corrections to the meter readings are necessary.

If k = 0.949 - 0.979 or 1.021 - 1.049; multiply all meter readings by the cell constant.

If k ≤ 0.948 or ≥ 1.050; check probe and/or meter for cleaning or replacement.

8.1.3 Quality Control

8.1.3.1 The meter must be checked before each trip including a check of the batteries, making sure the conductivity cells are clean and check the conductivity against known fresh standards near the anticipated field values.

8.1.3.2 Duplicate field analyses shall agree within ± 10 percent. Results within 1% of the true value should be obtained when using satisfactory equipment.

8.1.4 Measurement

8.1.4.1 Verify that the meter is set to read out a temperature compensated value at 25°C. For non-temperature compensated meters, refer to the instrument instructions for temperature corrected conductance calculations (See Section 11).

8.1.4.2 Allow the instrument to equilibrate to ambient temperature when it has been in a vehicle.

8.1.4.3 Rinse the sensor with distilled/de-ionized water and wipe gently with a clean paper towel.

8.1.4.4 Immerse the sensor in-situ when possible or in a grab sample (250 ml minimum). Initially swirl the sensor in the sample then hold until the indicator reaches equilibrium.

8.2 By Datasonde

8.2.1 Calibration

8.2.1.1 The datasonde is calibrated prior to taking measurements as outlined in the manual that accompanies the instrument. These calibrations are performed in compliance with APHA Standard methodology and instrument instruction manuals.

8.2.1.2 For salinity no calibration is needed. The sonde should be verified against the appropriate standard.

8.2.1.3 Multiprobes require both "pre-calibration" in the laboratory prior to a sampling event and a "post-calibration verification/confirmation" in the laboratory following the sampling event. The target calibration parameter should fall within the acceptance criteria for that parameter It is very important that the calibration be done in a temperature and pressure controlled environment using a clamp and a stand, to avoid human temperature interferences.

8.2.1.4 After returning from a sampling trip, bring the sonde, cable and hand unit into the laboratory. The duration of equilibration time depends on the temperature differential between outdoor and indoor conditions. As a rule, when outside temperatures exceed 90°F (32°C) or fall below 50°F (10°C), post-calibration/verification takes place the following day after return to base. When outside temperatures are between 90°F (32°C) and 50°F (10°C), the meter/sonde may be calibrated/verified on the same day once sufficient time (>2hrs) has passed to allow for temperature equilibration.

8.2.1.5 Sequential day trips require only one pre-calibration before the 1st day trip and a daily post-check following the post-calibration/verification guidelines set forth in 8.2.1.3.

8.2.1.6 Multiprobe-specific calibration logbooks, datasheets or calibration database must be maintained to create a traceable record of calibration and maintenance. Yearly, files not stored in a database housed on a departmental server and non-electronic records must be transcribed into an Excel spreadsheet or scanned to be inserted into FileNet

8.2.2 Quality Assurance

8.2.2.1 For pre-deployment calibration, the instrument readings will be recorded after the sonde has been adjusted/calibrated. This will verify the instrument accepted the calibration. If the sonde fails any of the parameters, fix the probe and re-calibrate or schedule it for repairs and do not use for trip.

8.2.2.2 Following the last measurement of the sampling event, a post-calibration check of the multiprobe is conducted in the laboratory and all calibration parameters are recorded.

8.2.2.3 For post-deployment verification/confirmation, record the instrument reading prior to any calibration. Do not calibrate the first pH standard without first checking the second. If post-calibration/verification of the multiprobe should fail for one or more parameters, the validity of the data must be determined.

8.2.2.4 All calibrations, maintenance and repairs must be documented in the calibration record that accompanies each instrument.

8.2.2.5 Recharging the multiprobe's data storage unit is maintenance that occurs prior to any data collection event.

8.2.2.6 Visual observations and periodic cleansings of the multiprobe units are conducted.

8.2.3 Water Column Profile Measurement

8.2.3.1 Allow the instrument to equilibrate to in situ conditions and the concentration to stabilize before storing the measurement.

8.2.3.2 Single water column measurements are made at mid-depth (for stations of less than or equal to 3 feet) to allow comparison with water quality standards.

8.2.3.3 For water column depths greater than 1 m (3 feet) but less than 3 m (10 feet), a minimum of 3 measurements should be collected, at the surface (0.2 m), mid-depth, and the bottom.

8.2.3.4 Profile measurements are recorded at multiple depths in the water column starting at the surface (0.2-0.3 m depth), 1.0 m, 1.5 m, and 2.0 m, continuing at 1-meter intervals and ending with a reading at the maximum depth. Readings may be recorded at 5-meter intervals from 30 meters depth to the bottom, if little change is observed in readings.

8.2.3.5 Measurements at each interval are saved in the multiprobe datalogger. Additional information may also be entered and saved in the data logger.

8.2.3.6 During travel between each station, personnel should return multiprobes to a bucket or tube of tap water to keep the probes wet.

9 SAMPLE HANDLING AND PRESERVATION

N/A

10 TROUBLESHOOTING

N/A

11 Data Acquisition, Calculations, & Data Reduction Requirements

11.1 Report conductivity readings as follows:

11.1.1 Results shall be expressed in micromhos/centimeter (µmhos/cm) corrected to 25°C.

11.1.2 Report results to the nearest ten units for readings under 1,000 µmhos/cm and the nearest 100 units for readings over 1,000 µmhos/cm.

11.1.3 If the instrument is not automatically temperature compensating the readout value record the actual sample temperature (t) when the measurement is made and refer to the instrument instructions for temperature corrected conductance calculations or use the formula below.

$$C \text{ corrected} = C \text{ measured} \div [1+0.0191(t-25)].$$

12 Data and Records Management

12.1 All field analyses must be traceable to the specific individual performing the analyses and to the specific equipment utilized. This information shall be entered into the field records for all field analyses performed by departmental personnel.

12.2 All maintenance and calibration records for field measurement equipment shall be kept so that they are similarly traceable.

12.3 Time records shall be kept in local time and shall be recorded to the nearest five minutes, unless the proximity of the station necessitates more discrete time measurement.

13 Quality Control & Quality Assurance

13.1 Replicate measurements for field quality control must be made at the frequency outlined in SOP #9021 Field Quality Control: Measurements and Samples.

13.2 Field equipment shall be inspected and tested before being used in the field.

13.3 The Quality Assurance Coordinator or their designee shall periodically audit field records to ensure that replicate conductivity field measurements are within prescribed limits (± 10%).

13.4 The Quality Assurance Coordinator or his designee shall immediately inform the appropriate supervisors of any problems detected during these audits so that they may be rectified.

14 Reference

ADEM. 2010 (as amended). Standard Operating Procedures #9021 Field Quality Control: Measurements and Samples. Alabama Department of Environmental Management (ADEM), Montgomery, AL.

Annual Book of ASTM Standards. 1976. Part 31, "Water", Standard D1125-64, p. 120.

APHA. 1998. Standard Methods for the Examination of Water and Wastewater, 20th Edition, 2-44, Method 2510. American Public Health Association (APHA), Washington, D.C.

15 CHANGE TRACKING

Rev. Date (Review Date) Rev. #	Approved By:	Detail of Approved Change
02/06/2006		Original Version
02/20/2007 Rev 1.0		Annual review. Corrected non-critical typos and formatting un-related to methods addressed. Added "Note" in preface section. Deleted Section 6.2 referencing the 3 months experience requirement. Modified 8.2.1.2 to include an alternative "post calibration verification/confirmation" as applicable.
03/03/08 Rev 2.0		Annual review. Modified Sec 2.3; 8.2.1.3; 8.2.2.1; 8.2.3.4. Added Sec 2.4; 8.2.1.2; and 8.2.3.3.
02/27/09 Rev. 3.0		Annual review. Made non-critical formatting changes. Modified Sec 1.2; 2.4; 8.1.2; 8.2.2. Added Sec 2.3-Calibration.
02/27/09 (01/13/11) Rev. 3.0	H. Cox	Annual Review—No Changes.
03/04/13 Rev. 4.0	J. Worley	Periodic review. Made non-critical formatting changes. Modified Sec. 2.3 for extreme temperatures. Changed "duplicate" to "replicate" in Sec. 13.1 and 13.3.

SURFACE WATER QUALITY FIELD MEASUREMENTS
--TURBIDITY--

SOP #2044

VERSION DATE: 03/18/14

Rev. 4.2

PREPARED BY:	[signature]	**DATE**	3/18/14
REVIEWED BY:	[signature] **Branch or Division Chief**	**DATE**	03/18/14
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SURFACE WATER QUALITY FIELD MEASUREMENTS—TURBIDITY

1 SCOPE AND APPLICATION

1.1 Turbidity of surface waters is measured using Nephelometric turbidimeters (measures the intensity of scattered light at 90° to the incident beam) that meet the design specifications of SM2130.

1.2 Surface water turbidity is generally conducted at all sites utilizing field equipment that is pre- and post-calibrated with all calibrations recorded in a dedicated logbook or database.

1.3 Quality assurance procedures for turbidity field test instrument calibration are an essential part of this standard operating procedure. Included in this document are: calibration and maintenance intervals; environmental conditions necessitating recalibration; and utilization of a log book to record calibration and maintenance data.

2 SUMMARY OF METHOD

2.1 At each site, representative field samples are taken at the appropriate depth or measured directly in-stream within the main channel flow. If a datasonde is being used, the probe is allowed to remain at depth until readings stabilize before recording. Measurements obtained that appear to be out of the normal ranges will result in calibration verification or re-calibration of all specific equipment and retesting.

2.2 All meters are calibrated on the same day and prior to the first measurement. The following morning all meters should be pre-calibrated for that day and post-calibrated for the previous field day. All calibrations are recorded in a dedicated logbook.

3 DEFINITIONS

APHA – American Public Health Association document. Cited as reference for "Standard Methods for the Chemical Analysis of Water and Wastes".

4 HEALTH & SAFETY WARNINGS

General field health and safety warnings apply.

5 INTERFERENCES

5.1 Dirty glassware and the presence of air bubbles give false results.

5.2 Scratches, fingerprints, condensed humidity (fog), and water droplets on the cuvette will artificially increase your turbidity measurement.

5.3 For the best results, measure the turbidity immediately without altering the original sample conditions such as temperature or pH (SM 1998).

6 PERSONNEL QUALIFICATIONS

6.1 No employee shall conduct this technique until he/she has actual field experience and has successfully demonstrated the ability of conducting this technique under the supervision of a senior staff member.

6.2 Each new Departmental employee shall accompany an experienced field employee on as many as possible of the differing types of sampling situations the employee may be called upon to conduct.

6.3 During this training period, the new employee will be permitted to perform all facets of field investigations, including sampling, under the direction and supervision of senior technical staff members.

7 EQUIPMENT AND SUPPLIES

Turbidity Secondary Standards

HACH Turbidity meter

Turbidity Primary Standards

Orbeco Hellige Turbidity meter

Turbidimeters-A portable nephelometric turbidimeter provides USEPA recognized and APHA accepted turbidity measurements (i.e., HACH Turbidimeter).

8 TURBIDITY MEASUREMENT

8.1 2100P Portable Turbidimeter

8.1.1 Calibration

8.1.1.1 Follow the manufacturer's instructions for calibration using *Formazin* or *StablCal Stabilized Formazin* Primary Standards. Be sure to strictly adhere to these instructions. This procedure must be performed at least once per quarter and more often if experience indicates the need or the instrument fails calibration verification (Section 8.1.2).

8.1.1.2 GELEX secondary standards should be re-valued on a quarterly basis at the same time the meter is calibrated with *Formazin* or *StablCal Stabilized Formazin* Primary Standards. The acceptable ranges should be recorded so the acceptable values are within ±5% of the read value. Record date, time, user name and obtained values in the meter log book.

8.1.2 Quality Assurance

8.1.2.1 The meter should be checked before each trip. Batteries and sample cells are checked and replaced as needed. Do not attempt to clean sample cells. Replace worn or scratched vials with new ones.

8.1.2.2 Verify calibration against GELEX Secondary Standards in the 0-10, 0-100 and 0-1000 NTU ranges. All readings must fall within the acceptable range.

8.1.2.3 At a minimum, calibration must be verified before the start of each day's run or at the first station of the day. It is recommended that calibration be checked after lunch break and periodically thereafter. Meters that return secondary standard values outside of the standard ranges (±5%) cannot be used. See Section 9.1 for further information.

8.1.3 Measurement

8.1.3.1 Collect a representative sample in a clean container. Immediately prior to filling the turbidity cell, gently invert the sample to mix. Do not shake. This will introduce air bubbles into the sample and skew the results.

8.1.3.2 Fill a sample cell, taking care to handle the sample cell by the top to avoid leaving fingerprints on the sides of the glass.

8.1.3.3 Once filled, wipe the sides and bottom of the cell with a lint free cloth to remove water drops and fingerprints.

8.1.3.4 Insert the sample cell into the meter making sure to align the orientation marks on the cell and the chamber (make sure the meter is on a level surface and out of direct sunlight). Avoid settling of the sample prior to measurement.

8.1.3.5 If available, use the "auto range" and "signal average" modes to display your result.

8.2 2100Q Portable Turbidimeter

8.2.1 Calibration

8.2.1.1 Follow the manufacturer's instructions for calibration using *Formazin* or *StablCal Stabilized Formazin* Primary Standards. Be sure to strictly adhere to these instructions. This procedure must be performed at least once per quarter and more often if experience indicates the need or the instrument fails calibration verification (Section 8.2.2).

8.2.1.2 2100Q turbidimeters have internal memory. The meter's calibration is verified using a *Formazin* 10 NTU verification standard. Once the meter is calibrated against the primary standards it will automatically go into verification mode. The default verification standard is 10 NTU. The acceptable range is automatically stored within the meter's memory and will indicate a pass or fail when checked. The acceptable range for the 2100Q is within 10% of 10 NTU as the manufacturer suggests.

8.2.1.3 No log book is required if the calibrations and verifications are downloaded to an excel spreadsheet using the USB connection. If the data will not be stored and downloaded electronically, record date, time, user name and obtained values in the meter log book.

8.2.2 Quality Assurance

8.2.2.1 The meter should be checked before each trip. Batteries and samples cells are checked and replaced as needed. Do not attempt to clean sample cells, replace worn or scratched vials with new ones.

8.2.2.2 Verify calibration against the *Formazin* 10 NTU verification standard. The meter will display "passed" or "failed" and the acceptable range will be displayed on the screen. If the meter has passed the verification standard, an "OK" will appear on the top left side of the screen. If the meter has failed the verification standard, a "?" will appear and the meter should not be used until it passes.

8.2.2.3 At a minimum, calibration must be verified before the start of each day's run or at the first station of the day. It is recommended that calibration also be checked after lunch break and periodically thereafter. Meters that return verification outside of the standard range (±10%) cannot be used. See Section 9.2 for further information.

8.2.3 Measurement

8.2.3.1 Collect a representative sample in a clean container. Immediately prior to filling the turbidity cell, gently invert the sample to mix. Do not shake. This will introduce air bubbles into the sample and skew the results.

8.2.3.2 Fill a sample cell, taking care to handle the sample cell by the top to avoid leaving fingerprints on the sides of the glass.

8.2.3.3 Once filled, wipe the sides and bottom of the cell with a lint free cloth to remove water drops and fingerprints.

8.2.3.4 Insert the sample cell into the meter making sure to align the orientation marks on the cell and the chamber (make sure the meter is on a level surface and out of direct sunlight). Avoid settling of the sample prior to measurement.

8.2.3.5 If available, use the "auto range" and "signal average" modes to display your result.

8.3 Orbeco Hellige model 966

8.3.1 Calibration

8.3.1.1 Follow the manufacturers instructions for calibration using *AMCO Clear (40 NTU), RO lab water* and *opaque ink (0 NTU)* Primary Standards. Be sure to strictly adhere to these instructions. This procedure must be performed at least once per field day and more often if experience indicates the need.

8.3.1.2 Record date, time, user name and obtained values in the meter log book.

8.3.2 Quality Assurance

8.3.2.1 The meter is checked before each trip. Batteries are checked and sample cells are cleaned and checked for scratches. Spare batteries and extra sample vials are included in the turbidimeter case.

8.3.2.2 At a minimum, the meter must be calibrated before the start of each day's run or at the first station of the day and again as experience dictates.

8.3.3 Measurement

8.3.3.1 Collect a representative sample in a clean container. Immediately prior to filling the turbidity cell, gently invert the sample to mix. Do not shake. This will introduce air bubbles into the sample and skew the results.

8.3.3.2 Fill a sample cell, taking care to handle the sample cell by the top to avoid leaving fingerprints on the sides of the glass.

8.3.3.3 Once filled, wipe the sides and bottom of the cell with a lint free cloth to remove water drops and fingerprints.

8.3.3.4 Insert the sample cell into the meter making sure to align the orientation marks on the cell and the chamber (make sure the meter is on a level surface and out of direct sunlight). Avoid settling of the sample prior to measurement.

8.3.3.5 If available, use the "auto range" and "signal average" modes to display your result.

9 CALIBRATION VERIFICATION GUIDELINES

9.1 Hach 2100P Turbidimeter

9.1.1 All three secondary GELEX standards must be checked daily.

9.1.2 The 0-10 GELEX standard must pass within ±5% when read to the nearest 0.1 NTU using standard rounding. If the meter fails to pass this check, the validity of the data is questionable and therefore should not be used or entered into ALAWADR.

9.1.3 Both the 0-100 and 1-1000 GELEX standards must pass within ±5% when read to the nearest 1 NTU using standard rounding. If the meter fails to pass either of these checks, the validity of the data is questionable and therefore should not be used or entered into ALAWADR.

9.2 Hach 2100Q Turbidimeter

9.2.1 Only the *Formazin* 10 NTU verification standard must be checked daily.

9.2.2 The *Formazin* 10 NTU verification standard must pass within ±10% when read to the nearest 1 NTU using standard rounding as the manufacturer suggests. If the meter fails to pass this check, the validity of the data is questionable and therefore should not be used or entered into ALAWADR.

10 SAMPLE HANDLING AND PRESERVATION

Turbidity should be determined as soon as possible after the sample is taken.

11 TROUBLESHOOTING

11.1 Handle sample cells only by the top to avoid dirt and fingerprints within the light path.

11.2 Discard sample cells if scratched or etched.

11.3 Apply a small amount of silicone oil to a cloth to help negate the effects of any small scratches on the sample cell. Avoid applying excess oil because it may attach dirt and contaminate the sample compartment of the instrument. Use a soft, lint-free cloth, spread the oil uniformly and wipe off excess. The cell should appear to be nearly dry with little or no visible oil.

11.4 Hach turbidimeters work best under ambient temperatures. Drastic changes in temperature, too cold or too hot conditions and the secondary standards may not fall within acceptable ranges. If the secondary standards are falling outside of the acceptable range and temperature is the suspected issue, wait 30-60 minutes and try again. If the meter still does not pass, do not use.

11.5 In the field, if the meter will not pass the secondary standards check, do not use it. After returning to the office, but before checking the samples into the lab, use the iced sample to collect turbidity readings, using an alternate meter. Samples will need to be warmed in the vials to avoid condensation. Make sure the alternate meter used, passes the secondary standards check before any readings are taken.

11.6 If the sample is too turbid to read and/or the meter is blinking "999", the sampler should first ensure that the *auto range* is enabled. Then the sampler may do either of the following:

1. Dilute the sample and run it again; or
2. Add the parameter to the COC and have the lab run it.

If option "2" is selected, the sampler needs to notify the receiving laboratory of this addition as turbidity has a short holding time (48 hours).

12 DATA ACQUISITION, CALCULATIONS, & DATA REDUCTION REQUIREMENTS

Report turbidity readings as follows:

Turbidity Range (NTU)	Report to the Nearest (NTU)
0-9.99	0.1
≥10	1

13 DATA AND RECORDS MANAGEMENT

13.1 All field analyses must be traceable to the specific individual performing the analyses and to the specific equipment utilized. This information shall be entered into the field records for all field analyses performed by departmental personnel.

13.2 All maintenance and calibration records for field measurement equipment shall be kept so that they are similarly traceable.

13.3 Time records shall be kept in local time and shall be recorded to the nearest five minutes, unless the proximity of the station necessitates more discrete time measurement.

14 QUALITY CONTROL & QUALITY ASSURANCE

14.1 Replicate measurements for field quality control must be made at the frequency outlined in SOP #9021, Field Quality Control Measurements and Samples.

14.2 Field equipment shall be inspected and tested before being used in the field.

14.3 The Quality Assurance Coordinator or their designee shall periodically audit field records to ensure that duplicate turbidity field measurements are within prescribed limits (± 5%).

14.4 The Quality Assurance Coordinator or his designee shall immediately inform the appropriate supervisor of any problems detected during these audits so that they may be rectified.

15 REFERENCE

ADEM. 2013 (as amended). Standard Operating Procedures #9021 Field Quality Control: Measurements and Samples, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

APHA. 1998. Standard Methods for the Examination of Water and Wastewater, 20th Edition, 2-9, Method 2130. American Public Health Association (APHA), Washington, D.C.

16 CHANGE TRACKING

Rev. Date (Review Date) Rev. #	Approved By:	Detail of Approved Change
02/06/06		Original Version
02/20/07 Rev 1.0		Annual review. Corrected non-critical typos and formatting un-related to methods addressed. Added "Note" in preface section. Deleted Section 6.2 referencing the 3 months experience requirement.
03/12/08		Annual review—no changes.
02/05/09 Rev 2.0	G. Logiudice	Annual review. Changed non-critical formatting. Added Note under Sec. 8. Added Sec. 8.2 Orbeco Hellige model 966 instructions.
01/13/11 Rev. 3.0	H. Cox	Periodic review. Made non-critical grammatical and formatting changes. Section 1.2 added "or database".
01/24/12 Rev. 4.0	G. Curvin	Periodic review. Made non-critical grammatical and formatting changes. Changed title of document. Added the following sections: 7—meter; 8.2; 9; and 11.4. Modified the following sections: 8.1.1; 8.1.2; 8.3; 11.2; 11.5; and 12.
04/25/13 Rev. 4.1	G. Curvin	Changed "should" to "must" in the following sections: 8.1.1.1; 8.2.1.1; and 8.3.1.1.
04/25/13 (02/05/14) Rev. 4.1	G. Curvin	Periodic review—no changes.
03/18/14 Rev. 4.2	M. Sullivan	Added Sec. 11.6 to conform with information posted on the intranet.

IN-SITU SURFACE WATER QUALITY FIELD MEASUREMENTS --DISSOLVED OXYGEN (DO)--

SOP #2045

Revision 4.0

VERSION DATE: 02/27/09

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REVIEWED BY:	Fred Leslie **Branch or Division Chief**	**DATE**	02/27/09
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PREFACE

This Standard Operating Procedures (SOP) Manual supersedes all Departmental SOPs relating to the methods addressed and is designed to be periodically reviewed and updated. The primary purpose of this document is to establish and maintain uniform operational and quality control guidance. The compliance with these procedures is essential to produce reliable data. Any deviation from this SOP must be documented and approved by the Project QA/QC Coordinator and/or project supervisor.

DISCLAIMER

NOTE:

Any alpha suffix added to the version date indicates the incorporation of corrections for non-critical typographic errors or formatting, i.e., no methodology changes were incorporated.

IN-SITU SURFACE WATER QUALITY FIELD MEASUREMENTS—DISSOLVED OXYGEN

1 SCOPE AND APPLICATION

1.1 Dissolved oxygen (DO) concentrations in surface waters depend on the physical, chemical and biochemical activities in the waterbody. The analysis for DO is a key test in water pollution control.

1.2 The three methods for DO analysis applied by the Department are the Winkler titration-Azide modification, the electrometric methods using membrane electrodes and the luminescent optical probe (LDO). The titrimetric method is based on the oxidizing property of DO while the membrane electrode procedure is based on the rate of diffusion of molecular oxygen across a membrane. The LDO probe uses excited luminescent material and emitted light.

1.3 If meters are used, they are pre-calibrated and post-calibration/verification with all calibrations recorded in a dedicated logbook or in the appropriate calibration database.

1.4 Quality assurance procedures for instrument calibration are an essential part of this standard operating procedure. Included in this document are: calibration and maintenance intervals; environmental conditions necessitating recalibration; and utilization of a logbook or calibration database to record calibration and maintenance data.

2 SUMMARY OF METHOD

2.1 At each site, representative field samples are taken at the appropriate depth or measured directly *in-situ* within the main channel flow. If a datasonde is being used, the probe is allowed to remain at depth until readings stabilize before recording. Measurements obtained that appear to be out of the normal ranges will result in calibration verification or re-calibration of all specific equipment and retesting.

2.2 All meters/sondes are calibrated on the same day and prior to the first measurement. Following the last measurement of the sampling event, a post-calibration/verification of the multiprobe is conducted and all calibration parameters are recorded in a dedicated logbook or calibration database.

2.3 All meters/sondes are calibrated for pre-deployment in the controlled environment of the laboratory. This should occur within 24 hours prior to the first field measurement. Upon returning to base from the field, the meters/sondes are brought to the laboratory to equilibrate. The duration of equilibration time depends on the temperature differential between outdoor and indoor conditions. As a rule, when outside temperatures exceed 90°F (32°C) or below 50°F (10°C), post-calibration/verification takes place the following day after return to base. When outside temperatures are between 90°F (32°C) and 50°F (10°C), the meter/sonde may be calibrated/verified on the same day once sufficient time (> 2 hrs) has passed to allow for temperature equilibration. All calibration parameters are recorded in a dedicated logbook or calibration database.

2.4 Generally field measurements made for the purpose of comparison with water quality standards are measured at mid depth (for stations of less than or equal to 3 feet). Stations that have a depth greater than 3 feet but less than 10 feet, a minimum of 3 measurements should be collected at the surface (0.2 m), mid-depth, and the bottom. For stations with a total depth of greater than 10 feet, measurements should be obtained at the depths prescribed in sampling plan and/or at 5 feet.

3 DEFINITIONS

N/A

4 HEALTH & SAFETY WARNINGS

General field health and safety warnings apply.

5 INTERFERENCES

5.1 The Winkler method with the azide modification is applicable for use with most wastewater and surface waters that contain nitrate nitrogens and not more than 1 mg/L of ferrous iron. Other reducing or oxidizing materials should be absent.

5.2 The azide modification is not applicable for the following samples: (a) samples containing sulfite, thiosulfate, polythionate, appreciable quantities of free chlorine or hypochlorite; (b) samples high in suspended solids; (c) samples containing organic substances which are readily oxidized by free iodine in an acid solution; (d) untreated domestic sewage; (e) biological flocs; and (f) samples with color which interferes with endpoint detection.

5.3 Most of the common interferences in the Winkler procedure may be overcome by use of a dissolved oxygen probe from a meter or multiprobe.

6 PERSONNEL QUALIFICATIONS

6.1 No employee shall conduct this technique until he/she has actual field experience and has successfully demonstrated the ability of conducting this technique under the supervision of a senior staff member.

6.2 Each new Departmental employee shall accompany an experienced employee on as many as possible of the differing types of sampling situations the employee may be called upon to conduct.

6.3 During this training period, the new employee will be permitted to perform all facets of field investigations, including sampling, under the direction and supervision of senior technical staff members.

7 EQUIPMENT AND SUPPLIES

Multiprobe Kit

Spare pH probes	Barometer
Spare D.O. Membranes & electrolytic solution	Multiprobe/data logger battery chargers

Dissolved Oxygen Kit

Manganese Sulfate	Sulfuric Acid
Azide Iodide Solution	0.0375 *N* Sodium Thiosulfate Solution
Burette	500 mL Erlenmeyer
300mL BOD glass bottles and stoppers	0.5% Starch Indicator Solution

Multiprobe datasondes- multiprobe units with and without storage capability are a tool used for the collection of field parameter measurements.

8 DISSOLVED OXYGEN MEASUREMENT

8.1 D.O. Meters/Multi-probes

8.1.1 Calibration

8.1.1.1 The datasonde is calibrated prior to taking measurements as outlined in the manual that accompanies the instrument. These calibrations are performed in compliance with APHA Standard methodology and instrument instruction manuals (See Sections 8.1.4, 8.1.5 and 8.1.6).

8.1.1.2 Multiprobes require both "pre-calibration" in the laboratory prior to a sampling event and a "post-calibration verification/confirmation" in the laboratory following the sampling event. The target calibration parameter should fall within the acceptance criteria for that parameter It is very important that the calibration be done in a temperature and pressure controlled environment using a clamp and a stand, to avoid human temperature interferences.

8.1.1.3 After returning from a sampling trip, bring the sonde, cable and hand unit into the laboratory. The duration of equilibration time depends on the temperature differential between outdoor and indoor conditions. As a rule, when outside temperatures exceed 90°F (32°C) or fall below 50°F (10°C), post-calibration/verification takes place the following day after return to base. When outside temperatures are between 90°F (32°C) and 50°F (10°C), the meter/sonde may be calibrated/verified on the same day once sufficient time (>2hrs) has passed to allow for temperature equilibration.

8.1.1.4 Sequential day trips require only one pre-calibration before the 1st day trip and a daily post-check following the post-calibration/verification guidelines set forth in 8.2.1.3.

8.1.1.5 Multiprobe-specific calibration logbooks, datasheets or calibration database must be maintained to create a traceable record of calibration and maintenance. Yearly, files not stored in a database housed on a departmental server and non-electronic records must be transcribed into an Excel spreadsheet or scanned to be inserted into FileNet.

8.1.2 Quality Assurance

8.1.2.1 Meters and multi-probes should be checked before each field trip for any mechanical or electrical failures, weak batteries, cracked or fouled probes, air bubbles or holes in the probe membrane, and cracks or excessive paint chipping on the LDO cap. If the membrane is dried out, replace and soak in tap water for at least 8 hours before calibrating the instrument (soak longer if recommended by the manufacturer's instructions for the probe). If the LDO cap is cracked or has lost its protective paint, it must be replaced.

8.1.2.2 For pre-deployment calibration, the instrument readings will be recorded after the sonde has been adjusted/calibrated. This will verify the instrument accepted the calibration. If the sonde fails any of the parameters, fix the probe and re-calibrate or schedule it for repairs and do not use for trip.

8.1.2.3 Following the last measurement of the sampling event, a post-calibration check of the multiprobe is conducted in the laboratory and all calibration parameters are recorded.

8.1.2.4 For post-deployment verification/confirmation, record the instrument reading prior to <u>any</u> calibration. Ex. Do not calibrate the first pH standard without first checking the second. If post-calibration/verification of the multiprobe should fail for one or more parameters, the validity of the data must be determined.

8.1.2.5 All calibrations, maintenance, and repairs must be documented in the calibration record that accompanies each instrument.

8.1.2.6 Recharging the multiprobe's data storage unit is maintenance that occurs prior to any data collection event.

8.1.3 Water Column Measurement

8.1.3.1 Allow the instrument to equilibrate to *in situ* conditions and the concentration to stabilize before storing the measurement. For the LDO probe, the recommended stabilization time is 5-10 minutes to allow the sonde to equilibrate to the *in situ* temperature.

8.1.3.2 Single water column measurements are made at mid-depth (for stations of less than or equal to 3 feet) to allow comparison with water quality standards.

8.1.3.3 For water column depths greater than 3 feet but less than 10 feet, a minimum of 3 measurements should be collected, at the surface (0.2 m), mid-depth, and the bottom.

8.1.3.4 Profile measurements are recorded at multiple depths in the water column starting at the surface (0.2-0.3 m depth), 1.0 m, 1.5 m, and 2.0 m, continuing at 1-meter intervals and ending with a reading at the maximum depth. Readings may be recorded at 5-meter intervals from 30 meters depth to the bottom, if little change is observed in readings.

8.1.3.5 Measurements at each interval are saved in the multiprobe datalogger. Additional information may also be entered and saved in the data logger.

8.1.3.6 During travel between each station, personnel should return multiprobes to a bucket or tube of tap water to keep the probes wet. Do not use distilled/deionized water for storage purposes.

8.1.4 *Multi-Probe Calibration by Winkler Method-Azide Modification:*

8.1.4.1 Hydrolab and YSI integrated probes must be calibrated in the laboratory (pre-calibration) prior to being taken into the field and again at the end of the sampling trip (post-calibration/verification) in the laboratory (or other appropriate temperature controlled location).

8.1.4.2 Record all calibration information in the instrument logbook or calibration database to include: Pre- or Post-, date, time, measurement prior to calibration, measurement after calibration, person completing calibration.

8.1.4.3 Calibrate by modified Winkler titration method following all directions contained in the instrument instruction manual.

- At least 24 hrs prior to calibration fill a bucket with distilled/de-ionized filtered water.
- Prior to calibration, gently place the meter probe in the bucket to avoid aeration.
- Collect two replicate samples of distilled/de-ionized filtered water by siphoning them from the bottom of a bucket into 300 ml BOD bottles, allowing the bottles to be filled to overflowing for approximately 10 seconds.
- Measure the water temperature.
- Determine the dissolved oxygen of these two samples using the modified Winkler titration method. The replicate analyses should agree within ±0.2 mg/L; if not, repeat analysis.
- Adjust the meter/sonde reading to the average value of the two samples measured by Winkler. Verify the measurement of the D.O. concentration using the meter/sonde.

8.1.5 Multi-Probe Calibration by Moist Air Method

8.1.5.1 Hydrolab and YSI integrated probes should be calibrated in the laboratory (pre-calibration) prior to being taken into the field and checked at the end of each day (post-calibration) in the laboratory.

8.1.5.2 Calibrate the YSI probe following all directions contained in the instrument instruction manual for calibration in a moist air environment (100% relative humidity).

- Place the sensor into a calibration cup containing approximately 1/8 inch of water which is vented by loosening the threads.
- Allow the temperature and oxygen pressure in the cup to equilibrate for 10 minutes.
- Select *Calibrate* from the main menu.
- Select Optic T-Dissolved Oxy (or appropriate parameter).
- Select ODO sat % and then 1-Point (or appropriate parameter).
- Enter the barometric pressure in mmHg determined by an NIST traceable barometer.
- Press *Enter*.
- When the values displayed show no significant change for 30 seconds, press *Enter*. The sonde will indicate the calibration has been accepted.

- Press *Enter* to return to the main calibration screen.

8.1.5.3 Individual logbooks, calibration database, or datasheets must be maintained for each meter with property numbers or serial numbers. Record all repair, maintenance, and calibration information to include: Pre- or Post-, date, time, D.O. measurement, the D.O. value from the saturation table (at the corresponding temperature and atmospheric pressure), person completing calibration.

8.1.5.4 Re-calibration of the units should be conducted at a frequency specified by the manufacturer, or if an unusual or unexplained change in readings is noted.

8.1.5.5 Hydrolab and YSI integrated multi-probes should be post-calibrated by the same method chosen for pre-calibration. Some YSI models require that the calibration of the meter should be checked against the modified Winkler titration method every 3-4 hours during use.

8.1.5.6 Record the calibration values in the instrument logbook or calibration database.

8.1.6 Multi-Probe Calibration by Air-Saturated Water Method

8.1.6.1 HydroLab LDO probes should only be calibrated in the laboratory (pre-calibration) prior to being taken into the field and checked at the end of the sampling trip (post-calibration/verification) in the laboratory. It is very important that the calibration be done in a temperature and pressure controlled environment.

8.1.6.2 After returning from a sampling trip, bring the sonde, cable and hand unit into the laboratory for equilibration. The duration of equilibration time depends on the temperature differential between outdoor and indoor conditions. As a rule, when outside temperatures exceed 90°F (32°C) or fall below 50°F (10°C), post-calibration/verification takes place the following day after return to base. When outside temperatures are between 90°F (32°C) and 50°F (10°C), the meter/sonde may be calibrated/verified on the same day once sufficient time (>2hrs) has passed to allow for temperature equilibration.

8.1.6.3 Calibrate the DO probe following all directions contained in the instrument instruction manual for calibration in a temperature-stabilized air-saturated water environment. In the laboratory, this is typically done by allowing the calibration water to equilibrate at least 12 hours after being run from a faucet or decanted from an opened water bottle.

- Take a 1/2 gallon bottle and fill 50% with water. Use water that has been at equilibrium with atmospheric pressure for at least 12 hours, i.e., unseal/open any bottled water or draw water from a tap well in advance of calibration.
- Make sure the water in the bottle is close to temperature equilibrium with the calibration environment.
- Seal the bottle and shake it very vigorously for 40 seconds.
- With the sonde positioned with sensors facing upright and firmly secured in a stand, pour the water into the calibration cup, fully submersing the Hach LDO sensor cap and the temperature sensor. Make sure the water comes close to the top of the calibration cup.

- Place the calibration cup cap upside down (concave upward) on top of the calibration cup to cover the calibration cup. This stops the exchange of air and allows the local environment to equilibrate.
- Do not tightly seal or it will raise the barometric pressure in the calibration cup.
- Make sure that the calibration cup is not in direct sunlight or in the presence of a heat or light source that could change the temperature in the calibration cup.
- Determine the barometric pressure for entry as the calibration standard. Use wall mounted NIST traceable barometer. The barometric pressure needs to be in mmHg.
- Wait 3-5 minutes to assure that the luminescent dissolved oxygen sensor material has reached the same temperature as the water bath.
- Enter the barometric pressure in the field provided.
- Click CALIBRATE. A "Calibrate Successful!" screen will be displayed.

8.1.6.4 Individual logbooks, calibration database, or datasheets must be maintained for each meter with property numbers and serial numbers. Record all repair, maintenance, and calibration information to include: Pre- or Post-, date, time, D.O. measurement, the D.O. value from the saturation table (at the corresponding temperature and atmospheric pressure-use laminated charts), person completing calibration.

8.2 <u>D.O. by Sample Collection and Titration</u>

8.2.1 Sample Collection

8.2.1.1 If collecting a sample, use a standard sewage sampler (D.O Canister) wherever possible with two 300 ml BOD bottles. This equipment automatically fills the BOD bottle to overflowing for approximately 10 seconds.

8.2.1.2 If conditions require that the sample be collected by hand, care must be taken to prevent turbulence and the formation of bubbles when filling the bottle (gently tapping on the side of the bottle with the ground glass top is useful to release small bubble trapped against the sides of the bottle).

8.2.1.3 Use only the Azide Modification of the Winkler Titration to analyze the sample.

8.2.2 Winkler Titration-Azide Modification

8.2.2.1 The sample is treated with manganous sulfate ($MnSO_4$), an alkali-iodide-azide reagent ($KOH+KI+NaN_3$), and finally sulfuric acid (H_2SO_4). The initial precipitate of manganous hydroxide, $Mn(OH)_2$ combines with the dissolved oxygen in the sample to form a brown precipitate, manganoic hydroxide, $MnO(OH)_2$. Upon acidification, the manganoic hydroxide forms manganic sulfate, which acts as an oxidizing agent to release free iodine from the potassium iodide. The iodine which is stoichiometrically equivalent to the dissolved oxygen in the sample is then titrated with sodium thiosulfate.

8.2.2.2 Three bottles are used to contain the reagents. They are labeled (1) manganous sulfate solution; (2) alkaline-iodide-azide solution; and (3) concentrated sulfuric acid. Starch solution (0.5%) and sodium thiosulfate (0.0375 *N*) are stored in separate bottles.

8.2.2.3 To the water sample in the BOD bottle, add 2.0 ml of manganous sulfate solution followed by 2.0 ml of alkaline iodide-azide solution; stopper with care to exclude air bubbles, and mix well by inverting the bottle several times.

8.2.2.4 When the precipitate settles (to approximately ½ the bottle volume), add 2.0 ml of concentrated sulfuric acid, re-stopper the bottle and mix by inverting the bottle several times. Complete the analysis within 45 minutes.

8.2.2.5 Transfer entire contents (300 ml) of the bottle into a 500 ml wide mouth flask, or other suitable vessel, and titrate with 0.0375 *N* solution of sodium thiosulfate to a pale straw color. Add 1-2 ml of starch solution and continue to titrate to the first disappearance of the blue color. NOTE: When low D.O. is known or expected, or in discolored samples, the starch may be added prior to titration.

8.2.2.6 Occasionally, a dark brown or black precipitate persists in the bottle after the addition of the acid. This precipitate will dissolve if the solution is kept for a few minutes longer than usual; or if particularly persistent, add a few more drops of acid.

8.2.2.7 Calculation

Each ml of 0.0375 *N* sodium thiosulfate titrant used is equivalent to 1 mg/L DO.

8.2.2.8 Dissolved Oxygen Field Kits

- The D.O. field kits shall be refilled with standardized sodium thiosulfate (0.0375 N) before each field trip. Each solution in the kit shall be checked for clarity and volume, and replenished or replaced if necessary. The sodium thiosulfate shall be re-standardized weekly.
- A logbook shall be maintained with all D.O. field kit numbers. Individual logbooks shall be maintained for each D.O. meter and integrated meter with property numbers and serial numbers. All calibrations, reagent replacements, and repairs shall be noted. This should include the date, activity and the name of the person conducting the activity.

9 SAMPLE HANDLING AND PRESERVATION

N/A

10 TROUBLESHOOTING

N/A

11 DATA ACQUISITION, CALCULATIONS, & DATA REDUCTION REQUIREMENTS

11.1 Results for dissolved oxygen measurements shall be reported to 0.1 mg/L (ppm). Readings that show two or more decimal places should be rounded to the nearest tenth.

12 DATA AND RECORDS MANAGEMENT

12.1 All field analyses must be traceable to the specific individual performing the analyses and to the specific equipment utilized. This information shall be entered into the field records for all field analyses performed by Departmental personnel.

12.2 All maintenance and calibration records for field measurement equipment shall be kept so that they are similarly traceable.

12.3 Time records shall be kept in local time and shall be recorded to the nearest five minutes, unless the proximity of the station necessitates more discrete time measurement.

13 QUALITY CONTROL & QUALITY ASSURANCE

13.1 Field equipment shall be inspected and tested before being used in the field.

13.2 Any time a D.O. measurement is outside of the water quality criterion either verify calibration or repeat the field measurement, if possible.

13.3 The Quality Assurance Coordinator or his designee shall periodically audit field records to ensure that duplicate field analyses are within the prescribed limits of ±0.2 mg/L.

13.4 The Quality Assurance Coordinator or his designee shall immediately inform the appropriate supervisors of any problems detected during these audits so that they may be rectified.

14 REFERENCE

ADEM. 2010 (as amended). Standard Operating Procedures #9021 Field Quality Control: Measurements and Samples, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

APHA. 1995. Standard Methods for the Examination of Water and Wastewater, 19th Edition, 4-96, Method 4500-O. American Public Health Association (APHA), Washington, D.C.

15 CHANGE TRACKING

Rev. Date (Review Date) Rev. #	Approved By:	Detail of Approved Change
02/06/2006		Original Version
05/05/2006 Rev 1.1		13.3 The Quality Assurance Coordinator or his designee shall periodically audit field records to ensure that duplicate field analyses are within the prescribed limits of ±0.2 mg/L. Reason: Correction of Typographical Error
02/20/2007 Rev 2.0		Annual review. Corrected non-critical typos and formatting un-related to methods addressed. Added "Note" in preface section. Deleted Section 6.2 referencing the 3 months experience requirement. Modified 8.1.1.2 to include an alternative "post calibration verification/confirmation" as applicable. Modified Section 1.2 to include reference to the LDO probe.
03/03/08 Rev 3.0		Annual review. Added post-calibration information throughout SOP. Modified Sec 8.1.2, 8.1.3, 8.1.4, and 8.1.5. Added Sec 8.16.
08/14/08 Rev. 3.1		Corrected non-critical typos and formatting un-related to methods addressed. Added bulleted list to Sec. 8.1.5.2. Changed "DO probe" to "YSI probe" in Sec. 8.1.5.2. Moved Sec 8.1.5.7 to Sec 8.1.1.4.
02/27/09 Rev. 4.0		Periodic review. Corrected non-critical formatting. Modified the following sections: 1.3; 1.4; 2.2; 8.1.1.2-8.1.1.5; 8.1.2.2-8.1.2.6; 8.1.4.2; 8.1.5.3; 8.1.5.6; 8.1.6.2; 8.1.6.4; and 11.1.
02/27/09 (01/13/11) Rev. 4.0	H. Cox	Periodic review. No changes
02/27/09 (03/25/13) Rev. 4.0	S. Hicks	Periodic review. No changes

IN-SITU SURFACE WATER QUALITY FIELD MEASUREMENTS --BY DATASONDE--

SOP #2047

Rev. 1.1

VERSION DATE: 03/08/11

PREPARED BY:	[signature]	**DATE**	3-8-11
REVIEWED BY:	[signature] **Branch or Division Chief**	**DATE**	03/08/11
APPROVED BY:	[signature] **Quality Assurance Manager**	**DATE**	3/9/2011

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In-Situ Surface Water Quality Field Measurements by DataSonde

PREFACE

This Standard Operating Procedures (SOP) Manual supersedes all Departmental SOPs relating to the methods addressed and is designed to be periodically reviewed and updated. The primary purpose of this document is to establish and maintain uniform operational and quality control guidance. The compliance with these procedures is essential to produce reliable data. Any deviation from this SOP must be documented and approved by the Project QA/QC Coordinator and/or project supervisor.

DISCLAIMER

This document has been prepared for use by the staff of the Alabama Department of Environmental Management (ADEM). Mention of trade names or commercial products does not constitute endorsement or recommendation for use. No portion of this manual is intended to supersede any Departmental policy memorandum issued by the Director or Deputy Director.

NOTE:

Any alpha suffix added to the version date indicates the incorporation of corrections for non-critical typographic errors or formatting, i.e., no methodology changes were incorporated.

IN-SITU SURFACE WATER QUALITY FIELD MEASUREMENTS BY DATASONDE

1 SCOPE AND APPLICATION

1.1 This procedure covers the use of multi-parameter data sondes for monitoring of *in situ* water quality including real-time measurement, profiling, and unattended data logging. *In situ* water quality parameters may include dissolved oxygen (DO), temperature, pH, and conductivity. This procedure also applies to use of data sondes for monitoring dye tracer.

1.2 Quality assurance procedures for instrument calibration are an essential part of this standard operating procedure. Included in this document are: calibration and maintenance intervals; environmental conditions necessitating recalibration; and utilization of a logbook or calibration database to record calibration and maintenance data.

2 SUMMARY OF METHOD

2.1 All sondes are calibrated prior to the first measurement on the first day of the sampling event. Following the last measurement of the sampling event, a post-calibration/verification of the multiprobe is conducted and all calibration parameters are recorded in a dedicated logbook or calibration database.

2.2 All sondes are calibrated for pre-deployment in the controlled environment of the laboratory. This should occur within 24 hours prior to the first field measurement. Upon returning to base from the field, the sondes are brought to the laboratory to equilibrate. The duration of equilibration time depends on the temperature differential between outdoor and indoor conditions. As a rule, when outside temperatures exceed 90°F (32°C) or below 50°F (10°C), post-calibration/verification takes place the following day after return to base. When outside temperatures are between 90°F (32°C) and 50°F (10°C), the meter/sonde may be calibrated/verified on the same day once sufficient time (> 2 hrs) has passed to allow for temperature equilibration. All calibration parameters are recorded in a dedicated logbook or calibration database.

2.3 Discrete field measurements made for the purpose of comparison with water quality standards are measured at mid depth (for stations of less than or equal to 3 feet). Stations that have a depth greater than 3 feet but less than 10 feet, a minimum of 3 measurements should be collected at the surface (0.2 m), mid-depth, and the bottom. For stations with a total depth of greater than 10 feet, measurements should be obtained at the depths prescribed in sampling plan and/or at 5 feet.

2.4 Continuous (diel) dissolved oxygen measurements are typically made at 30 minute intervals, though intervals can vary depending on battery power and length of deployment at fixed depths in the water column over a 24-72 hour period, deployed as near mid-channel as possible.

3 DEFINITIONS

4 HEALTH & SAFETY WARNINGS

General field health and safety warnings apply. In addition, safety precautions should be followed in the deployment of data sondes. For unattended deployment in wadeable systems, data sondes should only be deployed and retrieved under safe flow/stage conditions. When deploying from a boat, standard boating safety procedures should be followed.

5 INTERFERENCES

5.1 Dissolved Oxygen

5.1.1 Since the LDO probe measures DO using light, any fouling on the tip of the probe will give false readings. Remove fouling by gentle wiping, followed by a distilled water rinsing.

5.2 Conductivity

5.2.1 Coatings of oil material or particulate matter can impair electrode response. Remove these coatings by wiping/cleaning using a cleaning instrument provided by the manufacturer, followed by a distilled water rinsing.

5.2.2 Temperature effects on the electrometric measurement of conductivity are controlled by using instruments having temperature compensation and assuring that the appropriate temperature compensation mode is selected.

5.3 pH

5.3.1 The glass electrode, in general, is not subject to solution interferences from color, turbidity, colloidal matter, oxidants, reductants or high salinity.

5.3.2 Errors due to the presence of sodium at pH levels greater than 10 can be reduced or eliminated by using a "low sodium error" electrode.

5.3.3 Coatings of oil material or particulate matter can impair electrode response. Remove these coatings by gentle wiping, followed by a distilled water rinsing.

5.3.4 Temperature effects on the electrometric measurement of pH are controlled by using instruments having temperature compensation or by calibrating the electrode - instrument system at the temperature of samples.

6 PERSONNEL QUALIFICATIONS

6.1 No employee shall conduct this technique until he/she has actual field experience and has successfully demonstrated the ability of conducting this technique under the supervision of a senior staff member.

6.2 Each new Departmental employee shall accompany an experienced employee on as many as possible of the differing types of sampling situations the employee may be called upon to conduct.

6.3 During this training period, the new employee will be permitted to perform all facets of field investigations, including sampling, under the direction and supervision of senior technical staff members.

7 EQUIPMENT AND SUPPLIES

Multiprobe Kit

Data Logger	LDO Replacement Caps
Spare D.O. Membranes & electrolytic solution	Multiprobe/data logger battery chargers
Spare conductivity probes	NIST Verified Thermometer
Spare pH probes	Fresh pH solutions (4, 7, 10)
Fresh conductivity standards (1413um/cm, 12,880 um/cm)	

Multiprobe datasondes- multiprobe units with and without storage capability are a tool used for the collection of field parameter measurements.

8 DATASONDE GENERAL PROCEDURES

8.1 Calibration

8.1.1 The multi-parameter data sonde is calibrated prior to taking measurements as outlined in Sections 9 or 10. These calibrations are performed in compliance with APHA Standard methodology and instrument instruction manuals. However, because the sonde is a multi-probe unit, additional care must be taken to prevent cross-contamination of calibration standards. Similarly, calibration of multiple sonde units requires cross contamination prevention procedures. Specifically, following immersion of the sonde probes into each calibration standard, all probes should be thoroughly rinsed between each parameter and the excess liquid shaken off or blotted dry with a lint-free wipe.

8.1.2 Multi-parameter data sondes require both "pre-calibration" in the laboratory prior to a sampling event and a "post-calibration verification/confirmation" in the laboratory following the sampling event. The target calibration parameter should fall within the acceptance criteria (Section 11) for that parameter. It is very important that the calibration be done in a temperature and pressure controlled environment using a clamp and a stand, to avoid human temperature interferences.

8.1.3 Conductivity standards are much more sensitive to cross contamination/dilution than other standards; therefore, prior to immersion in a conductivity standard, all probes should be thoroughly rinsed and completely dried with lint-free wipes or compressed air.

8.1.4 The recommended order for calibration of the individual probes on a multi-parameter sonde is as follows:

1. DO
2. Conductivity
3. pH
4. Rhodamine

8.1.5 After returning from a sampling trip, bring the sonde, cable and hand unit into the laboratory for equilibration. The duration of equilibration time depends on the temperature differential between outdoor and indoor conditions. As a rule, when outside temperatures exceed 90°F (32°C) or fall below 50°F (10°C), post-calibration/verification takes place the following day after return to base. When outside temperatures are between 90°F (32°C) and 50°F (10°C), the meter/sonde may be calibrated/verified on the same day once sufficient time (>2hrs) has passed to allow for temperature equilibration.

8.1.6 Sequential day trips require only one pre-calibration before the 1st day trip and a daily post-calibration/verification following the post-calibration/verification guidelines set forth in Section 11.

8.1.7 Multiprobe-specific calibration logbooks, datasheets or database must be maintained to create a traceable record of calibration and maintenance. Yearly, files not stored in a database housed on a departmental server and non-electronic records must be transcribed into an Excel spreadsheet or scanned to be inserted into FileNet.

8.2 Quality Assurance

8.2.1 Multi-parameter data sondes should be checked before each field trip for any mechanical or electrical failures, weak batteries, cracked or fouled probes, air bubbles or holes in the probe membrane, and cracks or excessive paint chipping on the LDO cap. If the membrane is dried out, replace and soak in tap water for at least 8 hours before calibrating the instrument (soak longer if recommended by the manufacturer's instructions for the probe). If the LDO cap is cracked or has lost its protective paint, it must be replaced.

8.2.2 For pre-deployment calibration, the instrument readings will be recorded after the sonde has been adjusted/calibrated. This will verify the instrument accepted the calibration. If the sonde fails any of the parameters, fix the probe and re-calibrate or if unsuccessful, try replacing probes or schedule it for repairs and do not use for trip.

8.2.3 During travel between each station, personnel should return multiprobe to a bucket or tube of tap water to keep the probes wet. Do not use distilled/deionized water for storage purposes. Long-term storage in pH of 4.0 is recommended.

8.2.4 Following the last measurement of the sampling event, a post-calibration/verification of the multiprobe is conducted in the laboratory and all calibration parameters are checked and recorded. If post-calibration check of the multiprobe should fail for one or more parameters, the trip's data must be qualified.

8.2.5 If a post-calibration/verification and a pre-deployment calibration are to be conducted simultaneously, each parameter must be checked completely prior to any calibration.

For example: Do not calibrate the 7.0 pH standard after checking it, without first checking the 4.0 or the 10.0 standard.

8.2.6 All calibrations, maintenance, and repairs must be documented in a calibration record that accompanies each instrument or housed on a departmental server.

8.2.7 Recharging the multiprobe's data storage unit is maintenance that occurs prior to any data collection event.

8.3 Methodology

8.3.1 *Discrete Measurement: Wadeable or Non-Wadeable Grab-Shallow*

8.3.1.1 Discrete measurement entails observing monitoring data via display unit or laptop computer as data is collected by the sonde. This data may be recorded on a field sheet or logged to the internal memory of the sonde if so equipped. Logged data should be downloaded to a laptop or desktop computer as soon as possible. It is also recommended that download files be backed up in a separate location (USB thumb drives work very well for this).

8.3.1.2 Discrete field measurements made for the purpose of comparison with water quality standards are taken at measured mid depth (for stations of less than or equal to 3 feet). If the sonde can not be used to determine the measured mid depth (lacking/non-functional depth sensor, sensor not at the distal end of the sonde), the crew member should use the flow top-setting rod to measure mid depth.

8.3.1.3 For water column depths greater than 3 feet but less than 10 feet, a minimum of 3 measurements should be collected, at the surface (0.2 m), mid-depth, and the bottom

8.3.1.4 Allow the instrument to equilibrate to in situ conditions and the concentration to stabilize before storing the measurement. For the LDO probe, the recommended stabilization time is 5-10 minutes to allow the sonde to equilibrate to the in situ temperature.

8.3.2 *Discrete Measurement: Nonwadeable Boat or Nonwadeable Grab-Deep*

8.3.2.1 Profiling involves real-time monitoring or individual measurements at several depths through a water column. Profiling is especially useful for documenting water column gradients or stratification of in situ parameters or for evaluating complete mix conditions in dye tracer studies. Profiling deployments are generally conducted by hand to provide the movement of the sonde through the water column; however, profiling can also be conducted using mechanical/ electrical wench or reel type devices. In profiling applications, the multi-parameter data sonde should contain a depth sensor which is calibrated for depth. Profiling data must be logged to the internal memory of the sonde or data logger.

8.3.2.2 Profile measurements are recorded in the datalogger at multiple depths in the water column starting at the surface (0.2-0.3 m depth), 1.0 m, 1.5 m, and 2.0 m, continuing at 1-meter intervals and ending with a reading at the maximum depth. Readings may be recorded at 5-meter intervals from 30 meters depth to the bottom, if little change is observed in readings.

8.3.2.3 In fast moving waters it may be necessary to attach weight to the sonde. Weights should always be attached to the probe guard or sonde body, not the individual probes. If attached to the probe guard, weights should be secured in such a way that the weights and attachments do not interfere with probe operation. In all real-time and profiling applications, especially when the sonde is weighted, it is important to ensure that the profiling cable is securely attached to the baling harness of the sonde to prevent a disconnection of the sonde and potential loss or damage to the sonde.

8.3.3 *Continuous Monitoring*

8.3.3.1 Continuous monitoring entails pre-programming and deployment of a sonde at a specific location to log monitoring data in the absence of observation by a field investigator.

8.3.3.2 Unattended deployments are useful for collecting data at regular intervals over extended monitoring periods, frequently up to 3 – 4 days. However, since only limited checks of the data are recorded by hand during the deployment, it is critical that the sonde be correctly programmed.

8.3.3.3 Programming of the sonde should follow the manufacturer's procedures for unattended deployment. The sonde should be programmed in the lab prior to a field study and is typically accomplished either by the sonde's display unit or by laptop computer.

8.3.3.4 Programming requires input of a start data/time, deployment duration, data log file name, and monitoring interval. This information should also be noted on a field datasheet or logbook. The field datasheet or log book should also include the sonde identifier, the date/time of initial deployment, date/time of retrieval, deployment location, and sonde depth.

8.3.3.5 Further instructions for deployment can be found in SOP #2048 Continuous Monitoring of Surface Water Quality Using Datasondes.

9 HydroLab® Multi-Probe Calibration Procedures

9.1 HydroLab sondes should only be calibrated in the laboratory (pre-calibration) prior to being taken into the field and checked at the end of the sampling trip (post-calibration/verification) in the laboratory. It is very important that the calibration be done in a temperature and pressure controlled environment.

9.2 The post-calibration/verification does not require instrument recalibration. Simply check your readings against your standards and record the results.

9.3 Individual logbooks, calibration database, or datasheets must be maintained for each meter with property numbers and serial numbers. Record all repair, maintenance, and calibration information to include: Pre- or Post-, date, time, measurements, the standards and person completing calibration.

9.4 <u>Sonde Calibration Set-Up</u>

9.4.1 Turn on the computer in the Lab where you are calibrating.

9.4.2 Log in using your UserID and password.

9.4.3 Carefully connect the HydroLab sonde to the interface cable attached to the computer.

9.4.4 Secure your sonde in the stand provided with the sensors oriented pointing toward the ceiling.

9.4.5 Attach the calibration cup to sonde.

9.4.6 When the desktop appears, double-click the Hydras3LT shortcut

9.4.7 In the Hydras3LT startup screen, select [Terminal Mode]. Parameter data will begin scrolling on the screen.

9.5 Calibrate: Dissolved Oxygen

9.5.1 *Calibration by Air-Saturated Water Method* (LDO probes only)

9.5.1.1 Calibrate the DO probe following all directions contained in the instrument instruction manual for calibration in a temperature-stabilized air-saturated water environment. In the laboratory, this is typically done by allowing the calibration water to equilibrate at least 12 hours after being run from a faucet or decanted from an opened water bottle. Unseal/open any bottled water or draw water from a tap well in advance of calibration.

9.5.1.2 Take a 1/2 gallon bottle and fill 50% with equilibrated water. Seal the bottle and shake it very vigorously for at least 40 seconds.

9.5.1.3 With the sonde positioned with sensors facing upright and firmly secured in a stand, pour the water into the calibration cup, fully submersing the Hach LDO sensor cap and the temperature sensor. Make sure the water comes close to the top of the calibration cup, near the threads of the cup. **Very important**: DO NOT hold the sonde in your hand while calibrating for dissolved oxygen. It is VERY sensitive to temperature, and body heat will affect the dissolved oxygen readings.

9.5.1.4 Place the calibration cup cap upside down (threads upward) on top of the calibration cup to cover the calibration cup. This stops the exchange of air and allows the local environment to equilibrate.

9.5.1.5 Do not seal the cap or it will raise the barometric pressure in the calibration cup.

9.5.1.6 Make sure that the calibration cup is not in direct sunlight or in the presence of a heat or light source that could change the temperature in the calibration cup.

9.5.1.7 Determine the barometric pressure for entry as the calibration standard. Use wall mounted NIST traceable barometer. The barometric pressure needs to be in mmHg. (Inches of Hg x 25.4 = mm Hg)

9.5.1.8 Wait 3-5 minutes to assure that the luminescent dissolved oxygen sensor material has reached the same temperature as the water bath. From the Hydras3LT screen, check to make sure the water temperature has stabilized.

9.5.1.9 In the "Hydras3LT" screen, using the arrow keys, key over to [Calibrate] and select the [Enter] key.

9.5.1.10 Key over to [LDO] and select the [Enter] key.

9.5.1.11 Key over to [LDO%:Sat] and select the [Enter] key.

9.5.1.12 Enter the calculated barometric pressure and select the [Enter] key. The screen will read "Calibration Complete". If calibration is unsuccessful, troubleshoot and recalibrate or send in for repairs.

9.5.1.13 In the Hydras3LT screen, note the values scrolling up for DO, when stabilized, record the calibrated values for both mg/L and percent saturation.

9.5.2 *Calibration by Moist Air Method* (Clarke cell Membrane probes)

9.5.2.1 Use water that has been at equilibrium with atmospheric pressure for at least 12 hours, i.e., unseal/open any bottled water or draw water from a tap well in advance of calibration.

9.5.2.2 With the sonde positioned with sensors facing upright and firmly secured in a stand, pour the water into the calibration cup until the water is in even with the top of the rubber o-ring which secures the DO membrane. Make sure the water comes as close to the top of the probe as possible without going over the top of it.

9.5.2.3 Place the calibration cup cap upside down (threads upward) on top of the calibration cup to cover the calibration cup. This stops the exchange of air and allows the local environment to equilibrate.

9.5.2.4 Do not tightly seal or it will raise the barometric pressure in the calibration cup.

9.5.2.5 Make sure that the calibration cup is not in direct sunlight or in the presence of a heat or light source that could change the temperature in the calibration cup.

9.5.2.6 Determine the barometric pressure for entry as the calibration standard. Use wall mounted NIST traceable barometer. The barometric pressure needs to be in mmHg. (Inches of Hg x 25.4 = mm Hg)

9.5.2.7 Wait 3-5 minutes to assure that the dissolved oxygen sensor has reached the same temperature as the water bath. From the Hydras3LT screen, check to make sure the water temperature has stabilized.

9.5.2.8 In the Hydras3LT screen, using the arrow keys, key over to [Calibrate] and select the [Enter] key.

9.5.2.9 Key over to [DO] and select the [Enter] key.

9.5.2.10 Key over to [DO%:Sat] and select the [Enter] key.

9.5.2.11 Enter the calculated barometric pressure and select the [Enter] key. The screen will read "Calibration Complete". If calibration is unsuccessful, troubleshoot and recalibrate or send in for repairs.

9.5.2.12 In the Hydras3LT screen, note the values scrolling up for DO, when stabilized, record the values for both mg/L and percent saturation.

9.6 <u>Check: Temperature</u>

9.6.1 Use a Primary or Secondary NIST Thermistor

9.6.2 Without disturbing the water in the cup from the DO calibration, insert the thermometer near the sonde's temperature probe.

9.6.3 Record the standard reading from the thermometer.

9.6.4 Record the temperature reading of the water in the cup read from the Hydras 3LT software.

9.6.5 This is only a check, only the manufacturer can change the calibration.

9.7 <u>Calibrate: Conductivity</u>

9.7.1 Use a 2-point calibration: 0 and 1413 μmhos.

9.7.2 Thoroughly dry the probes with a lint-free cloth or compressed air.

9.7.3 In the Hydras3LT screen, key over to [Calibrate].

9.7.4 Key over to [Cond].

9.7.5 Key over to [SpCond: µS/cm].

9.7.6 Enter the specific conductivity standard of "0". The screen will read "Calibration Complete".

9.7.7 In the Hydras3LT screen, note the values scrolling up for conductivity, when stabilized, record the value.

9.7.8 Rinse the probe twice with 1413 standard.

9.7.9 Pour fresh 1413 standard into the calibration cup until the liquid covers the probe. Make sure there are no air bubbles in the measuring chamber of the conductivity probe. With the sonde positioned with sensors facing upright and firmly secured in a stand, allow the sonde to begin reading. Wait for the conductivity readings to stabilize.

9.7.10 In the Hydras3LT screen, key over to [Calibrate].

9.7.11 Key over to [Cond].

9.7.12 Key over to [SpCond: µS/cm].

9.7.13 Enter the specific conductivity standard of "1413". The screen will read "Calibration Complete". If calibration is unsuccessful, troubleshoot and recalibrate or send in for repairs.

9.7.14 In the Hydras3LT screen, note the values scrolling up for conductivity, when stabilized, record the value.

9.8 Calibrate: pH

9.8.1 Use a 2-point calibration 7.0 and either 4.0 or 10.0 standard pH buffer; use the third as a check during pre-calibration.

9.8.2 Rinse the probe twice with 7.0 standard

9.8.3 With the sonde positioned with sensors facing upright and firmly secured in a stand, pour the 7.0 standard pH buffer into the calibration cup until the pH probe fully submersed.

9.8.4 Make sure that the calibration cup is not in direct sunlight or in the presence of a heat or light source that could change the temperature in the calibration cup. Very important: DO NOT hold the sonde in your hand while calibrating for pH. It is VERY sensitive to temperature and body heat will affect the pH readings.

9.8.5 Wait 3-5 minutes or until the readings stabilize, to assure that the pH sensor has reached the same temperature as the standard solution.

9.8.6 In the Hydras3LT screen, key over to [Calibrate].

9.8.7 Key over to [pH/ORP].

9.8.8 Key Over to [pH:Units].

9.8.9 Enter the pH standard of "7.0". The screen will read "Calibration Complete".

9.8.10 Carefully remove the sonde from the stand, pour the pH 7.0 standard from the calibration cup, and rinse the cup and probes with room temperature DI water.

9.8.11 Rinse the calibration cup with the either the 4.0 or 10.0 standard pH buffer, and re-fill the calibration until the pH probe is fully submersed.

9.8.12 With the sonde positioned with sensors facing upright and firmly secured in a stand, pour the 4.0 or 10.0 standard pH buffer into the calibration cup and allow the pH readings in the Hydras3LT screen to stabilize. Very important: DO NOT hold the sonde in your hand while calibrating for pH. It is VERY sensitive to temperature and body heat will affect the pH readings.

9.8.13 In the Hydras3LT screen, key over to [Calibrate].

9.8.14 Key over to [pH/ORP].

9.8.15 Key Over to [pH:Units].

9.8.16 Enter the standard pH buffer of "4.0" or "10.0". The screen will read "Calibration Complete". If calibration is unsuccessful, troubleshoot and recalibrate or send in for repairs.

9.8.17 Carefully remove the sonde from the stand, pour the out either the 4.0 or 10.0 standard pH buffer from the calibration cup, and rinse the cup and probes with room temperature DI water.

9.8.18 Rinse the calibration cup with the third pH buffer, 4.0 or 10.0, whichever one you did not calibrate with, and fill the calibration cup to the threads.

9.8.19 Secure the sonde in the stand provided with the sensors oriented pointing toward the ceiling and allow the pH readings in the Hydras3LT screen to stabilize. Very important: DO NOT hold the sonde in your hand while waiting for it to stabilize. It is VERY sensitive to temperature, and body heat will affect the pH readings.

9.8.20 Do not calibrate this reading; it is only a check. Record the value.

9.9 <u>Calibrate: Depth (Performed at the sampling site)</u>

9.9.1 Hold sonde above water line

9.9.2 Using Surveyor- Push [Setup/Cal]

9.9.3 Choose [Calibrate]

9.9.4 Choose [Sonde]

9.9.5 Scroll to [Dep25 feet] or [Dep100 meters] and choose [Select]

9.9.6 Enter "0.0"

9.9.7 The screen will read "Calibration Successful!"

10 YSI® MULTI-PROBE CALIBRATION PROCEDURES

10.1 YSI sondes should only be calibrated in the laboratory (pre-calibration) prior to being taken into the field and checked at the end of the sampling trip (post-calibration/verification) in the laboratory. It is very important that the calibration be done in a temperature and pressure controlled environment.

10.2 If at any time during the calibration process the display screen shows "out of range Accept Anyway?", this is an indication that something is very wrong and the operator needs to correct the problem. If the operator selects "YES" and over-rides the warning then the data collected for that specific parameter after that calibration is suspect and likely cannot be used.

10.3 The post-calibration/verification does not require instrument recalibration. Simply check your readings against your standards and record the results.

10.4 Individual logbooks, calibration database, or datasheets must be maintained for each meter with property numbers and serial numbers. Record all repair, maintenance, and calibration information to include: Pre- or Post-, date, time, measurements, the standards and person completing calibration.

10.5 In the calibration procedures outlined below, there are references to a "live screen". A live screen is indicated by a small rotating black circle in the upper right corner of the 650 display. This is important because there are times during the calibration procedure when the screen will not show current live readings possibly leading to errors in data recording.

10.6 <u>Calibrate: Dissolved Oxygen</u>

10.6.1 Calibration by Moist Air Method

10.6.1.1 Clark cell probe (Membrane electrode)

- For 600XLM and Pro-plus units, place the sensor into a calibration cup containing approximately 1/8 inch of water which is vented by loosening the threads. Make sure that the DO and temperature probes are not immersed in the water. For 600QS units, this can be done by placing the sonde in a 500 mL Nalgene plastic jar.

  Note: there are other methods of accomplishing a moisture saturated air environment. In all cases though, the probes should **not** be immersed in water and the moisture saturated environment **must** be vented to ambient pressure.
- With the unit on, displaying live readings, allow the temperature and oxygen pressure in the cup to equilibrate for 10 minutes. This should also allow the air in the cup to reach moisture saturation.
- While the sonde is equilibrating read and record the barometric pressure in mm of Hg. (inches of Hg x 25.4 = mmHg)
- Based on the barometric pressure and the live temperature reading on the sonde, estimate the DO standard in mg/l from the calibration database or from the DO saturation table. This calibrated pH reading should be recorded in the calibration database or on the calibration sheet. This information must be entered in the calibration database or on the calibration sheet.
- After the unit has equilibrated for at least the required 10 minutes and the live readings are stable, switch the unit to calibration mode and proceed with the "DOsat%" calibration. The operator will be prompted to enter the current barometric pressure in mm Hg. Once the barometric pressure has been entered, the unit will begin a 40 second count down. At the end of that countdown, the unit will automatically calibrate the DO. The numbers displayed for DO mg/l and %saturation after the calibration is complete should be recorded in the calibration database or on the calibration sheet. If the calibration was successful, the mg/l reading should be very close to (if not exactly the same as) the DO standard

estimated from the calibration database or from the saturation tables. The % saturation reading should equal the ambient pressure divided by 760 mutiplied by 100. Example: (764/760) x 100 = 100.5)

10.6.1.2 ODO (Optical probe)

- Place the sensor into a calibration cup containing approximately 1/8 inch of water which is vented by loosening the threads.
- Allow the temperature and oxygen pressure in the cup to equilibrate for 10 minutes.
- Select *Calibrate* from the main menu.
- Select Optic T-Dissolved Oxy (or appropriate parameter).
- Select ODO sat % and then 1-Point (or appropriate parameter).
- Enter the barometric pressure in mmHg determined by an NIST traceable barometer.
- Press *Enter*.
- When the values displayed show no significant change for 30 seconds, press *Enter*. The sonde will indicate the calibration has been accepted.
- Press *Enter* to return to the main calibration screen.
- Record the values for both mg/L and percent saturation.

10.7 Check: Temperature

10.7.1 Temperature readings on the YSI data sondes cannot be calibrated by the operator. However, the temperature reading does need to be checked against a primary or secondary NIST certified thermometer before each use. This should be conducted as part of the calibration procedure.

10.7.2 Place the sonde and the NIST thermometer in a water bath of sufficient depth to completely immerse the sonde temperature probe. With the unit displaying live readings, allow enough time for the temperature readings to stabilize and record both readings in the calibration database or on the calibration sheet. The readings should be within 1°C of each other.

10.8 Calibrate: Conductivity and Salinity

10.8.1 Use a 1-point calibration: 1,413 µmhos/cm or 12,880 µmhos/cm potassium chloride standard solution

10.8.1.1 Choose the conductivity/salinity standard that more closely matches the conductivity/salinity expected in the waters to be assessed.

For example: Use 1413 µmhos/cm for fresh water and 12880 µmhos/cm for brackish or salt water applications.

10.8.1.2 Thoroughly rinse the probe with the conductivity standard. This is usually accomplished by placing a small amount of the standard in the calibration cup and then shaking the sonde and cup vigorously. Discard the used rinse solution.

10.8.1.3 Fill the calibration cup with enough conductivity standard to completely immerse the conductivity electrodes (location of these electrodes will depend on the model being used).

10.8.1.4 In the calibration menu, select "Conductivity" then select "SpConductivity". When prompted enter your chosen standard conductivity in mmhos (not umhos). This may be confusing because even if the unit display is set up to read in umhos, the calibration must still be entered in mmhos.

10.8.1.5 Press "enter"

10.8.1.6 When a live display screen appears, press "enter" again to calibrate the specific conductivity. The calibration was successful if the display conductivity reading now matches the conductivity standard. The calibrated conductivity reading should be recorded in the calibration database or on the calibration sheet.

10.9 Calibrate: pH

10.9.1 Use a 2-point calibration 7.0 and either 4.0 or 10.0 standard pH buffer.

10.9.1.1 Rinse the probe with 7.0 standard. This is usually accomplished by placing a small amount of the standard in the calibration cup and then shaking the sonde and cup vigorously. Discard the used rinse solution.

10.9.1.2 Fill the calibration cup with enough pH 7.0 standard to completely immerse all probes.

10.9.1.3 From the pH calibration menu, select the 2-point calibration option. When prompted for the first pH, key in 7.00 then press "Enter". A live screen will appear indicating all current readings. When the pH reading has stabilized press "Enter" again to calibrate. The display should indicate a pH of 7.0 or very close to it (within 1 or 2 hundredths). This calibrated pH reading should be recorded in the calibration database or on the calibration sheet. Press "Enter" again to continue on to the second pH calibration point. The operator will now be prompted to key in the second calibration point.

10.9.1.4 Before keying in the second calibration point, the operator must conduct the same rinse procedure using the second calibration standard. When the rinse is complete, fill the calibration cup with the second standard and immerse the probes in the solution

10.9.1.5 Key in the second pH standard (4.00 or 10.00). Press "Enter". A live screen will appear indicating all current readings. When the pH reading has stabilized press "Enter" again. The display should now indicate a pH matching your second standard or very close to it (within 1 or 2 hundredths). This calibrated pH reading should be recorded in the calibration database or on the calibration sheet.

10.9.1.6 After completing the two point calibration described above, a pH reading should be recorded using the third pH standard not used in the calibration (4.00 or 10.00). Be sure to use the same rinse procedure used in the calibration process. This third reading is also recorded in the calibration database or on the calibration sheet and should be within 0.1 su of the standard. This check of the third standard is recorded in the event that pH levels encountered during the sampling event fall outside the expected range. If this third standard check falls outside of the 0.1 su criterion, the entire pH calibration should be repeated.

10.10 Calibrate: Depth (Performed at the sampling site)

10.10.1 Hold sonde above water line

10.10.2 From the calibration menu select "Pressure-Abs"

10.10.3 When prompted to enter depth, key in 0.0 and press "Enter".

10.10.4 When the live screen appears displaying active parameter measurements press "Enter" again to calibrate depth to 0.0.

10.11 Calibrate: Rhodamine

10.11.1 For all Rhodamine calibration procedures, be certain that the standard and sensor are thermally equilibrated prior to proceeding with the calibration. Use a 2-point calibration, 0 and 100 µg/L Rhodamine WT solution.

10.11.2 In the EcoWatch screen, select "Calibrate".

10.11.3 Select "Optic-T Rhodamine".

10.11.4 Select "2 point" calibration

10.11.5 Rinse the probe twice with deionized or distilled water.

10.11.6 Pour fresh deionized or distilled water into the calibration cup until the liquid covers the probe.

10.11.7 Enter the concentration of the first Rhodamine standard in µg/L, "0". Press "Enter" and the screen will wait for the instrument to stabilize and then display the real-time readings.

10.11.8 Press "3" to activate the wiper 1-2 times to clean the optics to remove any bubbles.

10.11.9 Press "Enter" to calibrate the 0 µg/L Rhodamine when the readings are stable.

10.11.10 In the EcoWatch screen, note the value for Rhodamine, and when it stabilizes record the value.

10.11.11 Press "Enter" to continue.

10.11.12 Rinse the probe twice with 100 µg/L standard.

10.11.13 Pour fresh 100 µg/L standard into the calibration cup until the liquid covers the probe.

10.11.14 Enter the value of the second Rhodamine standard in µg/L, "100". Press "Enter" and the screen will wait for the instrument to stabilize and then display the real-time readings.

10.11.15 Press "3" to activate the wiper 1-2 times to clean the optics to remove any bubbles.

10.11.16 Press "Enter" to calibrate the 100 µg/L Rhodamine when the readings are stable.

10.11.17 In the EcoWatch screen, note the value for Rhodamine, and when stabilized record the value.

10.11.18 The screen will say calibrated. Press "Enter" to continue back to the calibration menu.

11 POST CALIBRATION/VERIFICATION GUIDELINES

11.1 Dissolved Oxygen

11.1.1 Sonde reading should be within 3% of the standard during post-calibration/verification. Use the ± 0.2 mg/L guideline only if you calibrated to an exact standard (i.e., Winkler titration or enter the value from the %Sat Tables)

For example: In the calibration database, the post-calibration/verification of DO may not pass the 0.2 mg/L guideline but still will fall within the accepted 3%. If the sonde was calibrated using %saturation, this would be acceptable. Since the DO in mg/l is only a calculation when calibrating using %saturation, the difference can be attributed to slight calculation differences in the equipment and not actual failure of the sensor.

11.1.2 If sonde **fails** post-calibration/verification, you must note the following in the ALAWADR **trip comments**: "Post verification of dissolved oxygen did not meet the required acceptance criteria (± 3%) or (±0.2mg/L). The difference between the verification reading and the standard was +/- _____." The sampler must fill in the blank with the appropriate value from the calibration record.

11.2 Temperature

11.2.1 Sonde reading should be within 1°C of the standard during post-calibration/verification.

11.2.2 If sonde **fails** post-calibration/verification, you must note the following in the ALAWADR **trip comments**: "Post verification of temperature did not meet the required acceptance criteria (± 1°C). The difference between the verification reading and the standard was +/- _____." The sampler must fill in the blank with the appropriate value from the calibration record.

11.3 Conductivity

11.3.1 If using a two-point calibration, both standards must be checked during the post-calibration/verification.

11.3.2 Sonde reading should be within 10% of the standard during the post-calibration/verification.

11.3.3 If sonde **fails** post-calibration/verification for one/either standard, you must note the following in the ALAWADR **trip comments**: "Post verification of conductivity did not meet the required acceptance criteria (± 10%). The difference between the verification reading and the standard was +/- _____." The sampler must fill in the blank with the appropriate value from the calibration record.

11.4 pH

11.4.1 All 3 standard pH buffers must be used in the pre-deployment calibration procedure-2 used in the calibration and 1 to check, this ensures all values (4.0-10.0) fall within the QAQC range.

11.4.2 If the 3rd standard pH buffer check does not fall within 0.1 units of the standard, the pH sensor needs to be successfully recalibrated, maintenanced, replaced, or if still unable to pass, sent in for repair.

11.4.3 Both of the pH buffer calibration standards used in the pre-calibration must be checked during the post-calibration/verification.

11.4.4 Sonde reading must be within 0.1 units of the standard pH buffer during the post-calibration/verification. If sonde **fails** post-calibration/verification for either standard pH buffer, you must note the following in the ALAWADR **trip comments**: "Post verification of pH did not meet the required acceptance criteria (+/- 0.1). The difference between the verification reading and the standard was +/- _____." The sampler must fill in the blank with the appropriate value from the calibration record.

11.5 Rhodamine

There are no post-calibration/verification guidelines for this parameter.

12 SAMPLE HANDLING AND PRESERVATION

13 TROUBLESHOOTING

13.1 Procedure for dead batteries: If the batteries fail after calibration but before the post-check, replace the batteries immediately. Continue to sample or if finished, proceed to the post-calibration/verification. Note in the calibration book or database that the batteries were changed prior to post-calibration/verification. Most scientific equipment will "shut down" with a small amount of battery life left to preserve the data and calibration information. Replacing the batteries immediately will ensure no data loss or disruption of normal procedures.

Note: All instruments must be post-calibrated/verified even if the batteries must be changed in order to accomplish this.

13.2 Refer to the equipment manufacturer's instructions for other troubleshooting problems.

14 DATA ACQUISITION, CALCULATIONS, & DATA REDUCTION REQUIREMENTS

14.1 Results for dissolved oxygen measurements shall be reported to at least 0.1 mg/L (ppm).

14.2 Results for conductivity shall be expressed in micromhos/centimeter (µmhos/cm) corrected to 25°C. If the instrument is not automatically temperature compensating the readout value record the actual sample temperature (t) when the measurement is made and refer to the instrument instructions for temperature corrected conductance calculations or use the formula below.

$$C \text{ corrected} = C \text{ measured} \div [1+0.0191(t-25)].$$

14.3 Results for pH shall be reported at least to the nearest 0.1 standard pH unit.

15 DATA AND RECORDS MANAGEMENT

15.1 All field analyses must be traceable to the specific individual performing the analyses and to the specific equipment utilized. This information shall be entered into the field records for all field analyses performed by Departmental personnel.

15.2 All maintenance and calibration records for field measurement equipment shall be kept so that they are similarly traceable.

15.3 Correct errors in calibration logbooks by one line through the entry, correction written next to the change, and initials.

15.4 Time records shall be kept in local time and shall be recorded to the nearest five minutes, unless the proximity of the station necessitates more discrete time measurement.

16 QUALITY CONTROL & QUALITY ASSURANCE

16.1 Field equipment shall be inspected and tested before being used in the field.

16.2 Duplicate measurements for field quality control must be made at the frequency outlined in SOP #9021 Field Quality Control: Measurements and Samples.

16.3 The Quality Assurance Coordinator or his designee shall periodically audit field records to ensure that duplicate field analyses are within the prescribed limits.

16.4 The Quality Assurance Coordinator or his designee shall immediately inform the appropriate supervisors of any problems detected during these audits so that they may be rectified.

17 REFERENCE

ADEM. 2013 (as amended). Standard Operating Procedures #2048 Continuous Monitoring of Surface Water Quality Using Datasondes, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2010 (as amended). Standard Operating Procedures #9021 Field Quality Control: Measurements and Samples, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

APHA. 1998. Standard Methods for the Examination of Water and Wastewater, 20th Edition, 4-96, Method 4500-O. American Public Health Association (APHA), Washington, D.C.

18 CHANGE TRACKING

Rev. Date (Review Date) Rev. #	Approved By:	Detail of Approved Change
02/26/10 Rev. 0	G. Logiudice J. Davies	Original Version
01/14/11 Rev. 1.0	H. Cox	Periodic review. Made non-critical grammatical and formatting changes. Modified section 8.3.1.2 to include how to find measured mid-depth in the absence of an end-of-probe depth sensor.
03/08/11 Rev. 1.1	G. Curvin	Periodic review. Added verbiage about what to if the sonde failed post calibration. This was added to the following sections: 11.1.2; 11.2.2; 11.3.3; and 11.4.4.
03/08/11 (03/25/13) Rev. 1.1	G. Curvin	Periodic review—No changes.

GENERAL SURFACE WATER SAMPLE COLLECTION

SOP #2061

Revision 4.0

VERSION DATE: 02/05/14

PREPARED BY:	Scott Hicks	**DATE**	2/5/2014
REVIEWED BY:	**Branch Chief**	**DATE**	02/05/14
APPROVED BY:	**Quality Assurance Manager**	**DATE**	2/5/2014

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TABLE OF CONTENTS

PREFACE

This Standard Operating Procedures (SOP) Manual supersedes all Departmental SOPs relating to the methods addressed and is designed to be periodically reviewed and updated. The primary purpose of this document is to establish and maintain uniform operational and quality control guidance. The compliance with these procedures is essential to produce reliable data. Any deviation from this SOP must be documented and approved by the Project QA/QC Coordinator and/or project supervisor.

DISCLAIMER

This document has been prepared for use by the staff of the Alabama Department of Environmental Management (ADEM). Mention of trade names or commercial products does not constitute endorsement or recommendation for use. No portion of this manual is intended to supersede any Departmental policy memorandum issued by the Director or Deputy Director.

NOTE:

Any alpha suffix added to the version date indicates the incorporation of corrections for non-critical typographic errors or formatting, i.e., no methodology changes were incorporated.

GENERAL SURFACE WATER SAMPLE COLLECTION

1 SCOPE AND APPLICATION

This method describes sample collection procedures for surface water.

2 SUMMARY OF METHOD

Surface water samples may be collected using a variety of methods depending on the depth, current and characteristics of the water column. Regardless of the method used, precautions should be taken to ensure the sample collected is representative of the current conditions.

3 DEFINITIONS

3.1 Grab Sample – An individual sample collected at one location over a period not exceeding 15 minutes. Grab samples shall be used to characterize the medium at a particular location at one instant in time.

3.2 Discrete Composite Sample – A sample collected at discrete points at specified depth(s) within a vertical or horizontal track and composited prior to laboratory analysis.

3.3 Integrated Vertical Composite Sample – A sample collected through a known area of water column (i.e., submersible or peristaltic pump and hose).

4 HEALTH & SAFETY WARNINGS

4.1 General field, health and safety warnings apply.

4.2 Any sample either known or thought to be hazardous shall be so identified on both the sample container and the field sample collection record. Information explaining the hazard, (i.e., corrosive, flammable, poison) shall be listed. This is necessary not only from a safety perspective, but is also useful to the analytical laboratory in helping to prevent contamination of the analytical equipment and the associated down time.

5 INTERFERENCES

5.1 All material and/or equipment coming into contact with the sample must be constructed of media that meet the requirements of the targeted parameter to prevent contamination and any other contribution rendering the sample unrepresentative of the conditions intended for sampling.

6 PERSONNEL QUALIFICATIONS

6.1 No employee shall conduct this technique until he/she has actual field experience and has successfully demonstrated the ability of conducting this technique under the supervision of a senior staff member.

6.2 Each new Departmental employee shall accompany an experienced field employee on as many field trips as possible to experience the differing types of field situations to which the new employee may be required to participate.

6.3 During this training period, the new employee will be permitted to perform all facets of field investigations, including sampling, under the direction and supervision of senior technical staff members.

6.4 Depending on the project for which the samples are collected, a 40 hr hazardous waste safety training course may be required along with the annual 8 hr updates.

7 EQUIPMENT AND SUPPLIES

Glass and/or Plastic Sample Containers	Van Dorn Sampler
Labeling Tape	Peristaltic Pump
Pencil/Marking Pen	Clean, disposable tubing
Cooler with ice	Paper Towels
Chain-of-Custody Form(s)	Wash Water
Submersible Pump and Hose Apparatus	Equipment Cleaning Supplies
Teflon Bailer	Antibacterial Soap
Kemmerer Sampler	Disposable Gloves
Bucket	Compositing Container

8 EQUIPMENT SELECTION

8.1 Any equipment or sampling techniques utilized to collect a sample shall be acceptable as long as they do not compromise sample integrity or sample representativeness of the water body sampled.

8.2 The Quality Assurance Project Plan (QAPP) or Plan of Study should be reviewed prior to equipment selection.

8.3 All equipment coming into contact with the sample must be made of a material that meets the requirements of the targeted parameter.

9 BOAT POSITIONING

9.1 The sampling station should be identified either on a map or by GPS in the boat. This information should be available to crew members in the field.

9.2 Nonwadeable water quality measurements and water quality sample collections should be gathered from an anchored boat in the deepest part of the channel at each sampling site. The deepest point in a channel is found by performing a transect scan with a depth finding sonar device, beginning at a point close to one bank and transverse perpendicular to the opposite bank. Note the deepest point achieved during this transect. Then anchor at the deepest point observed.

9.3 Wind, current and depth of a station should be considered in the positioning of the anchor and collection of the sample. The boat is positioned with the bow upstream into the current; however, wind can make this position difficult to maintain. If this is the case, allow the wind to position the anchored boat and then collect samples upstream. Take care not to allow the anchor rope to influence the sample integrity.

9.4 Nonwadeable water conditions such as long depths, high flows or high winds may make anchoring unadvisable in maintaining safety and sampling integrity. In this case, a drift sample is the best option. Point the bow of the boat facing upstream in the main channel and allow the current to drift the boat. When the boat and sampling devices are traveling in tandem with the current, the sampling devices will drop in the water column more easily and accurately. Sometimes the speed of the current may make multiple passes over the sampling area necessary in order to collect all the sample required.

9.5 Always carry and have immediately available a cutting tool that has the ability to cut the anchoring line the sampler is using in case of emergency, such as being hung up or having an underwater object snagging the line and pulling the anchor point down.

10 SAMPLE COLLECTION

General

10.1.1 A wide variety of conditions may exist at a sampling location and requires that best professional judgment be used regarding methodology for collection of representative samples.

10.1.2 Before sampling is conducted, an initial reconnaissance should, if feasible, be made to locate suitable sampling location (s) in the event that these locations are not identified in the QAPP or Plan of Study.

10.1.3 Sampling sites should be in areas that exhibit the greatest degree of cross-sectional homogeneity. Additionally, stream samples should be collected in the thalweg.

10.1.4 When collecting a series of samples in close proximity to each other always collect the most downstream location first to prevent substrate disruption.

10.1.5 Sample containers shall be used that are appropriate to the matrix and targeted laboratory analyses.

10.1.6 Containers should be rinsed twice with a small sample aliquot prior to sample collection (exceptions would include if the container is certified pre-cleaned, if preservatives are present in the sampling container or for certain analyses, such as, oil and grease).

10.1.7 All container rinsate should be disposed of downstream from the sampling point.

10.1.8 Adequate sample volume shall be collected to allow the analyzing laboratory to conduct duplicate and/or other required quality control analyses as dictated by the applicable laboratory method.

10.1.9 Allow 1-2 inches of air space for adequate sample mixing (except for volatile organic analysis, raw water samples and bioassay samples).

10.1.10 Sample Agitation

1. If a representative jug (“Field Parameters” jug) is used to collect sample water for further processing, the representative jug must be inverted before taking each aliquot. For example, the “Field Parameters” bottle is inverted prior to pouring an aliquot into the DRP filter reservoir and again prior to pouring an aliquot into the dissolved metals reservoir.
2. With composited photic zone samples, the sample container must be agitated or stirred prior to taking each aliquot. For example, the composite sample is stirred (agitated) prior to pouring an aliquot into the chlorophyll *a* graduated cylinder and again prior to pouring an aliquot into the “iced” sample container.

Direct Grab Sample

10.1.11 Enter the waterbody downstream of the intended sampling point to avoid disturbances and introduction of bottom sediments or other potential contaminants into the sample source.

10.1.12 Samples are collected by positioning the mouth of the container upstream or into the current, away from the collector's hand, in front of the collector's position and away from the side of the sampling platform or boat. Please note: estuarine waterbodies may require the creation of artificial current by moving the container horizontally in the direction that it is pointed (towards the upstream).

10.1.13 The sampling depth is typically between 6-12 inches below the water surface for non-wadeable waters or mid-depth and mid-channel for wadeable waters unless otherwise stated in the QAPP or Plan of Study.

Non-Direct Grab Samples

10.1.14 Weighted Bottle Frame

10.1.14.1 Place bottle in a weighted frame and lower the device to the desired depth using a rope.

10.1.14.2 Face the bottle mouth upstream by swinging the sampling device first downstream and then allowing it to drop into the water without slack in the rope.

10.1.14.3 Pull the sampling device rapidly upstream and out of the water without dislodging dirt or other material from the bridge or sampling platform.

10.1.14.4 Retrieve the sampler with a small amount of water, rinse the bottles, if appropriate (see Section 9.1.5), and repeat the procedure to fill the sample bottles.

10.1.15 Bucket

10.1.15.1 A clean bucket may be used to collect a sample directly or for compositing a sample for redistribution to multiple sample containers.

10.1.15.2 The bucket should be rinsed twice with the sample water prior to collection of sample.

10.1.16 Scoop

10.1.16.1 Scoops may be used for reaching out into a body of water to collect a surface water sample.

10.1.16.2 The scoop could be used directly to collect and transfer a sample to another sample container or it may be attached to an extension device for greater access.

10.1.16.3 The scoop must be made of a material that meets the requirements of the parameter being investigated.

10.1.17 Discrete Samplers

10.1.17.1 The Alpha Van Dorn Sampler is useful for sampling at specified depths. They are made in both a horizontal and vertical design with the horizontal most used for discrete point sampling at a given depth. The vertical bottle design is typically used for stratification studies with multiple or single samplers suspended by cable. Samples can be drawn off by means of a drain in the upper portion of the sampler.

10.1.17.2 Kemmerer Bottle is useful for general-purpose sampling at specified depths. In operation, the open sampler is lowered on a graduated rope to the desired depth that assures complete flushing of the bottle as it is lowered. Both ends of the bottle are closed by means of a messenger and the undisturbed sample is brought to the surface. Samples can be drawn off by means of a drain in the lower stopper.

10.1.18 Peristaltic Pumps

10.1.18.1 Pumps can be used to sample water from a water column.

10.1.18.2 Collection of a vertical composite sample is achieved through use of metal conduit and clean disposable tubing.

10.1.19 Composite by Pump and Hose

10.1.19.1 Prior to collecting the sample, the hose apparatus is purged of any retained water by continuously lowering and raising the pump through the photic zone for an interval of 1-2 minutes.

10.1.19.2 Lowering and raising of the pump should be at the approximate rate of one meter every five seconds.

10.1.19.3 The pump intake should be located well upstream of the pump outlet at all times during clearing.

10.1.19.4 Rinse the compositing container with sample water, and empty the rinse water downstream of the pump intake.

10.1.19.5 Collect approximately 20 liters of composite from the targeted vertical area, such as, photic zone or entire water column.

10.1.19.6 Rinse a plastic scoop with water from the composite sample, and then stir the composite sample thoroughly.

10.1.19.7 Use the scoop to extract aliquots for samples; stir the sample before taking each aliquot.

10.1.20 Bailers

10.1.20.1 Teflon bailers may also be used for water column sampling.

10.1.20.2 The bailer is lowered through the water column.

10.1.20.3 Water is continually displaced through the bailer until the desired depth is reached.

10.1.20.4 Upon retrieving, a bottom check-valve prohibits loss of sample.

Swimming Beaches

10.1.21 Grab Sample

10.1.21.1 Wade into the swimming area until the total water depth is 2-3 feet.

10.1.21.2 Position the mouth of the bottle away from the collector’s hand and body.

10.1.21.3 Create an artificial current by moving the bottle horizontally in the direction it is pointed.

10.1.21.4 The sampling depth should be 6-12 inches below the water surface.

11 SAMPLE HANDLING AND PRESERVATION

11.1 Samples must be preserved immediately upon collection (in the field) in order to maintain integrity unless otherwise allowed by the specific analysis method. All samples preserved with chemicals shall be clearly identified by indicating on the sample container and field chain-of-custody record that the sample is preserved.

11.1.1 Samples should be handled in the following order:

1. Processed samples (DRP, Chlor_*a*, etc.): Process DRP before processing any other sample (Chlor_*a*, metals, etc).
2. Non-acidified samples.
3. Acidified samples.

11.1.2 At a minimum, all samples should be on ice within 30 minutes of sample collection. All samples preserved with chemicals shall be gently inverted several times after the chemical addition. This is done to thoroughly mix the chemical with the sample.

11.2 All samples must be fully identified either by writing directly on the container or by using waterproof pen on a label. This information should include station location information, date, time (if more than one sampling time from this location), preservative name, collector's initials and analyses requested (optional).

11.3 Samples must be transported nestled in ice and held below 4°C during transport unless allowed by the specific analysis method. Samples must not be allowed to submerge in ice water.

11.4 Samples shall be delivered to the analyzing laboratory with sufficient time to allow the analysis of the parameter with the shortest holding time. The elapsed time between sample collection and the initiation of laboratory analyses shall be within the prescribed time allowed for each individual analysis.

11.5 When necessary during field studies, field cleaning should be performed as outlined in the specific sample collection SOP and SOP #9025. Any deviations from the cleaning procedures should be documented.

11.6 All sampling equipment must be cleaned as specified in SOP #9025 Field Equipment Cleaning Procedures after field use and before storage. Such equipment must be inspected and tested before each field use and any necessary repairs shall be made and documented.

12 TROUBLESHOOTING

N/A

13 DATA ACQUISITION, CALCULATIONS, & DATA REDUCTION REQUIREMENTS

N/A

14 DATA AND RECORDS MANAGEMENT

14.1 All samples collected must be fully identified and chain-of-custody maintained. See SOP #9040, Station, Sample Identification and Chain of Custody Procedures.

14.2 All sample collection activities shall be traceable, through field records or notes, to the person/crew collecting the sample. All maintenance and calibration records for sampling equipment shall be kept so that they are similarly traceable.

15 QUALITY CONTROL & QUALITY ASSURANCE

Duplicate samples, as well as trip and equipment blanks, must be collected in compliance for field quality control procedures. Blank and duplicate samples must be collected and analyzed at the frequency outlined in SOP #9021 Field Quality Control: Measurements and Samples.

16 REFERENCE

ADEM. 2013 (as amended). Standard Operating Procedures #9021 Field Quality Control: Measurements and Samples. Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2013 (as amended). Standard Operating Procedures #9025 Field Equipment Cleaning Procedures. Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2014 (as amended). Standard Operating Procedures #9040 Station, Sample Identification and Chain of Custody Procedures. Alabama Department of Environmental Management (ADEM), Montgomery, AL.

17 CHANGE TRACKING

Rev. Date (Review Date) Rev. #	Approved By:	Summary of Modifications
02/06/06		Original Version
02/14/07 Rev 1.0		Annual review. Corrected non-critical typos and formatting un-related to methods addressed. Added "Note" in preface section. Deleted Section 6.2 referencing the 3 months experience requirement. Re-worded Section 10.4 to clarify the first sentence "Samples shall be delivered to the analyzing laboratory with sufficient time to allow the analysis of the parameter with the shortest holding time."
02/27/09 Rev. 1.0		Periodic review—no changes
01/14/11 Rev. 2.0	H. Cox	Periodic review. Made non-critical grammatical and formatting changes. Added Sec. 10.1.1. Modified Sec. 10.3 so that it is more specific concerning sample transport requirements.
02/22/11 Rev. 2.1	M. Sullivan	Added Sec. 10.1.2—inversion of sample after adding chemical preservatives.
02/14/13 Rev. 3.0	K. Gilliland	Periodic review. Made non-critical grammatical and formatting changes. Added Sec. 9—Boat Positioning.
02/05/14 Rev. 4.0	S. Hicks	Periodic review. Made non-critical grammatical and formatting changes. Added Sec. 9.1—boat site location and Sec. 10.1.10—inversion of field sample container. Modified Sec. 10.1.3 to include the thalweg as a location.

Stream Flow Calculation Worksheet

Station#
Date

meter type AA
meter #

	TAPE (FT)	DEPTH (FT)	REV	SEC	VELOCITY	FLOW
bank						

flow Q =
0.0 cfs