Part I:
Standard Operating Procedures for Conducting Biomonitoring on Fish Communities in Wadeable Streams in Georgia

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Wildlife Resources Division
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Introduction

Biotic integrity has been defined by Karr and Dudley (1981) as "the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region." Since the passage of the Water Pollution Control Act of 1972, water regulatory agencies have been charged with restoring and maintaining the biological, or biotic, integrity of the nation's water resources (Karr, 1991). In the past, efforts to restore the biotic integrity of water resources have been directed primarily toward improving the chemical and physical water quality of point source effluents. Politically and logistically, monitoring point source discharges provided water regulatory agencies with an apparent means to satisfy the directives of the Water Pollution Control Act. The numeric pollution standards provided a certain degree of statistical validity and legal defensibility and were believed to be enough to protect water resources (Karr 1987). It was presumed that improvements in chemical/physical water quality would be followed by the restoration of biotic integrity. While the implementation of effluent regulatory programs improved water quality from point source discharges, this approach allowed continued degradation of a variety of aquatic resources, particularly fish populations, from nonpoint sources (Karr *et al.* 1985). Habitat alteration, flow regime modification, and changes in the trophic base of the stream biota are all detrimental impacts upon a stream that are not detected by point source monitoring programs (Karr 1987).

Continued decline in the biotic integrity of aquatic resources, despite chemical/physical water quality monitoring programs, has compelled some regulatory agencies to integrate a biological approach, or biomonitoring, into their water quality monitoring programs (Karr 1991). Karr (1987) used the term biomonitoring "to evaluate the health of a biological system to assess degradation from any of a variety of impacts of human society" rather than the traditional use of the term as it relates to toxicity testing. Since it is based on the direct observation of aquatic communities, for which traditional chemical/physical water quality monitoring programs have proved to be unreliable surrogates, biomonitoring explicitly addresses the directives of the Water Pollution Control Act to restore and maintain biotic integrity in the nation's water resources. Most of the biomonitoring programs that have been initiated by environmental regulatory agencies have consisted of sampling fish and/or macroinvertebrate communities (Ohio EPA 1987a; North Carolina Department of Environment, Health, and Natural Resources 1997; Tennessee Valley Authority 1997; Roth *et al.* 1998; Stribling *et al.* 1998).

Besides the benefit of providing a direct measure of the biotic integrity of an aquatic community, adapting biomonitoring procedures into a water quality monitoring program has several other advantages:

1) Biomonitoring is more effective than chemical/physical water quality sampling in detecting

the effects of nonpoint-source pollution and intermittent pollution events (Karr and Dudley 1981).

2) The cost of collecting biological data has been shown to be similar or less than the cost of collecting traditional water quality data. Considering the comparative usefulness of the data collected, Ohio EPA (1987a) found it less expensive to sample both fish and macroinvertebrates than to conduct either chemical sampling or bioassay evaluations.

Sampling fish communities as indicators of biotic integrity also provides the following additional benefits to a biomonitoring program (Fausch *et al.* 1990):

3) Since most fish species are long lived (2-10 years or longer) they provide a direct measure of the long-term health of the aquatic community compared to chemical/physical water quality data which measures instantaneous conditions.
4) Fish communities are sensitive to a wide array of direct stresses, including the effects of point source and non-point source pollution, sedimentation, habitat loss, riparian zone disruption, and flow modification.
5) Fish occupy positions throughout the aquatic food web and use food resources from both aquatic and terrestrial environments, providing an integrative view of the entire watershed.
6) Fish communities can be used to evaluate societal costs of degradation more directly than other taxa because their economic and aesthetic values are widely recognized.

Despite the numerous advantages, biomonitoring should not be viewed as a cure-all for water quality monitoring. The purpose of biomonitoring should not be to replace traditional chemical/physical water quality sampling or bioassay testing, but rather to be incorporated as a part of an integrated system of water quality management. Biomonitoring should be used to provide insights into the long-term biotic integrity of aquatic communities and to identify areas where chemical/physical water quality sampling and bioassay testing can be conducted more efficiently.

This document outlines the standard operating procedures (SOP) used by the Wildlife Resources Division of the Georgia Department of Natural Resources (GAWRD) to collect biomonitoring data on fish assemblages in wadeable streams in Georgia. The index of fish community health used to assess the biotic integrity of streams in Georgia is the Index of Biotic Integrity (IBI). The IBI was developed by Karr (1981) to assess the health of aquatic communities based on the functional and compositional attributes of the fish population in the midwestern United States and requires modification from the original format to reflect the differences in fish fauna between the southeastern and midwestern United States. This index provides a direct assessment of the biotic integrity of an aquatic community based on an overall evaluation of its fish population.

Ecoregions of Georgia

Traditionally, water quality standards have followed national guidelines, and the values established nationally did not recognize regional variations in water quality. Depending upon the natural variation of a region, the national water quality standards were often over- or under-protective of aquatic communities (Hughes and Larsen 1988; Hughes *et al.* 1990). Over-protective criteria are needlessly expensive and a misuse of limited restoration funds. Under-protective criteria may not provide the minimal water quality needed to support aquatic communities, especially when the long-term effects of bioaccumulation and the indirect effects of changes to the trophic structure of a system are considered (Hughes *et al.* 1990). Also, criteria for naturally occurring nontoxic pollutants, such as organic detritus and sediment, are difficult to establish with the traditional toxicological approach most water quality standards are based upon (Hughes and Larsen 1988; Hughes *et al.* 1990).

Compounding the problem of using national water quality standards was the fact that most water quality assessments were conducted in a framework based upon administrative or political purposes and did not correspond to regional characteristics that controlled water quality (Omernik and Griffith 1991). Depending upon the regulatory agency or branch of government involved, water quality assessments were traditionally conducted in frameworks such as drainage basins, hydrologic units, or political boundaries and did not consider patterns of soil type, vegetation, land forms and land use. Changes in the patterns of fish assemblages and water quality often occur within individual river basins and hydrologic units. Traditional units tended to lump dissimilar land areas and water types together, concealing true spatial variations in water quality.

The need to address these problems, as well as satisfy the directives of the Water Pollution Control Act to maintain and restore the biotic integrity of the nation's aquatic resources, led to the concept of using natural regional patterns of ecosystems, or ecoregions, as a framework for assessing spatial variation in water quality (Omernik 1987). Ecoregions are generally considered to be regions of relative homogeneity in ecological systems or in relationships between organisms and their environments. Omernik (1987) established ecoregions throughout the conterminous United States by grouping naturally similar ecosystems based upon regional patterns in soil types, potential natural vegetation, land surface forms, and general land use. This approach provides a logical basis for characterizing ranges of ecoregion conditions or qualities that are realistically attainable. Realistic attainment is a level of quality possible given a set of economically, culturally, and politically acceptable protective measures that are compatible with patterns of natural and anthropogenic characteristics within an ecoregion (Omernik 1987).

Studies throughout the United States have shown a marked correspondence between different ecoregions and patterns of biotic communities, physical habitat measures, and water quality. A study in Arkansas found that Omernik's classification reflected fundamental differences among streams in the six different ecoregions in patterns of fish assemblages, physical habitat, and water chemistry (Rohm *et al.* 1987). Of these variables, changes in fish assemblage patterns provided the most significant differences between ecoregions. Patterns of fish assemblages, macroinvertebrate communities, physical habitat measures, and water chemistry were found to correspond with the eight ecoregions established in Oregon (Whittier *et al.* 1988). Based on the results of over 9,000 fish collections, the eight ecoregions established in Oregon showed a much higher correspondence with fish assemblage patterns than either major river basins or physiographic regions (Hughes *et al.* 1987). Spatial patterns in water quality variables, ionic water chemistry, and nutrient richness were found to correspond with five ecoregions established in Ohio (Larsen *et al.* 1988). Another study used the Index of Biotic Integrity, species richness, and pollution tolerance guilds to establish significant differences in the fish assemblage patterns between ecoregions in Ohio (Larsen *et al.* 1986). Patterns of fish assemblage distribution have also been found to correspond well with four ecoregions in southern and western Wisconsin (Lyons 1989).

The results of these studies depict the strong relationship between ecoregions and patterns in fish assemblages and water quality and demonstrate the value of an ecoregional approach for evaluating data on aquatic communities. By using ecoregions to establish biomonitoring criteria that are regionally appropriate, the problem of natural spatial variation is lessened. Most importantly, the use of ecoregions as a framework for establishing biomonitoring criteria directly addresses the mandates of the Water Pollution Control Act to maintain and restore the biotic integrity of the nation's water resources (Hughes and Larsen 1988; Hughes *et al.* 1990).

Based upon the soil types, potential natural vegetation, geomorphology, and predominant land uses, six major ecoregions (Level III) have been mapped in Georgia (Griffith *et al.* 2001). These include the Blue Ridge, Piedmont, Ridge and Valley, Southern Coastal Plain, Southeastern Plains, and Southwestern Appalachians (Figure 1). More detailed information on the physiographic characteristics of each ecoregion in Georgia can be found in Standard Operating Procedures Freshwater Macroinvertebrate Biological Assessment (https://epd.georgia.gov/macroinvertebrate-bioassessment-standard-operating-procedures-sop-and-metric-spreadsheets) prepared by the Environmental Protection Division of the Georgia Department of Natural Resources, Water Protection Branch (EPD WPB) (2007).

Site Selection and Reconnaissance

Sample site selection is dependent upon the specific monitoring objectives to be addressed. Once identified, each potential sample site must undergo field reconnaissance to determine if the site is suitable for collecting biomonitoring data. This field reconnaissance should occur from at least one day up to a month prior to when the site is sampled. Sample sites must be accessible to the evaluators and equipment, be wadeable throughout the sample reach, and be representative of the stream under investigation. Sampling stations are usually located upstream (approx. 100 m) of locally modified areas, such as bridges or small impoundments, unless it is desired to assess the effects of these modifications or upstream access is limited or non-existent. In these cases, the starting point of the sample transect should be well downstream (approx. 100 m) of any of these impacts. Bridges and impoundments may alter water flow and sediment deposition, effecting major changes in the physical habitat and the fish community of the downstream area. The equipment list and data sheets needed for stream reconnaissance are included in (Appx. I).

Past studies have shown that biotic index values may show a notable decrease at, and immediately below, areas receiving point source discharges (Karr *et al.* 1985; Karr *et al.* 1986; Ohio EPA 1987a). When investigating areas of point source discharge, a control site should be located upstream from the discharge in question and at least one other sample site should be located downstream from the discharge area. The downstream site(s) should be located far enough from the point source discharge to characterize the fish community below the mixing zone where the discharged effluents enter the stream. The distance to locate the downstream site from the discharge area will depend on the size of the stream, amount of available macrohabitat, and amount of discharge into the stream (Ohio EPA 1987c). The control site should not be considered a reference site for the downstream sample site. Rather, the control site should provide the investigators with a comparison between the fish assemblages upstream and downstream of the point source. This comparison will allow investigators to determine if any detrimental effects to the downstream fish assemblage can be attributed to the discharge. Once a sample reach has been ascertained to be accessible to equipment and crew, the length of the sample site must be determined. The sample reach length must be long enough to include all the major habitat types present (e.g., riffle-run-pool sequences). Lyons (1992a) found that a single electrofishing pass at 35 times the mean stream width (MSW), covering approximately three riffle-run-pool sequences, provided meaningful estimates of species richness without the use of block nets. Lyons found stream widths easier to apply and less subjective than riffle-run-pool sequences

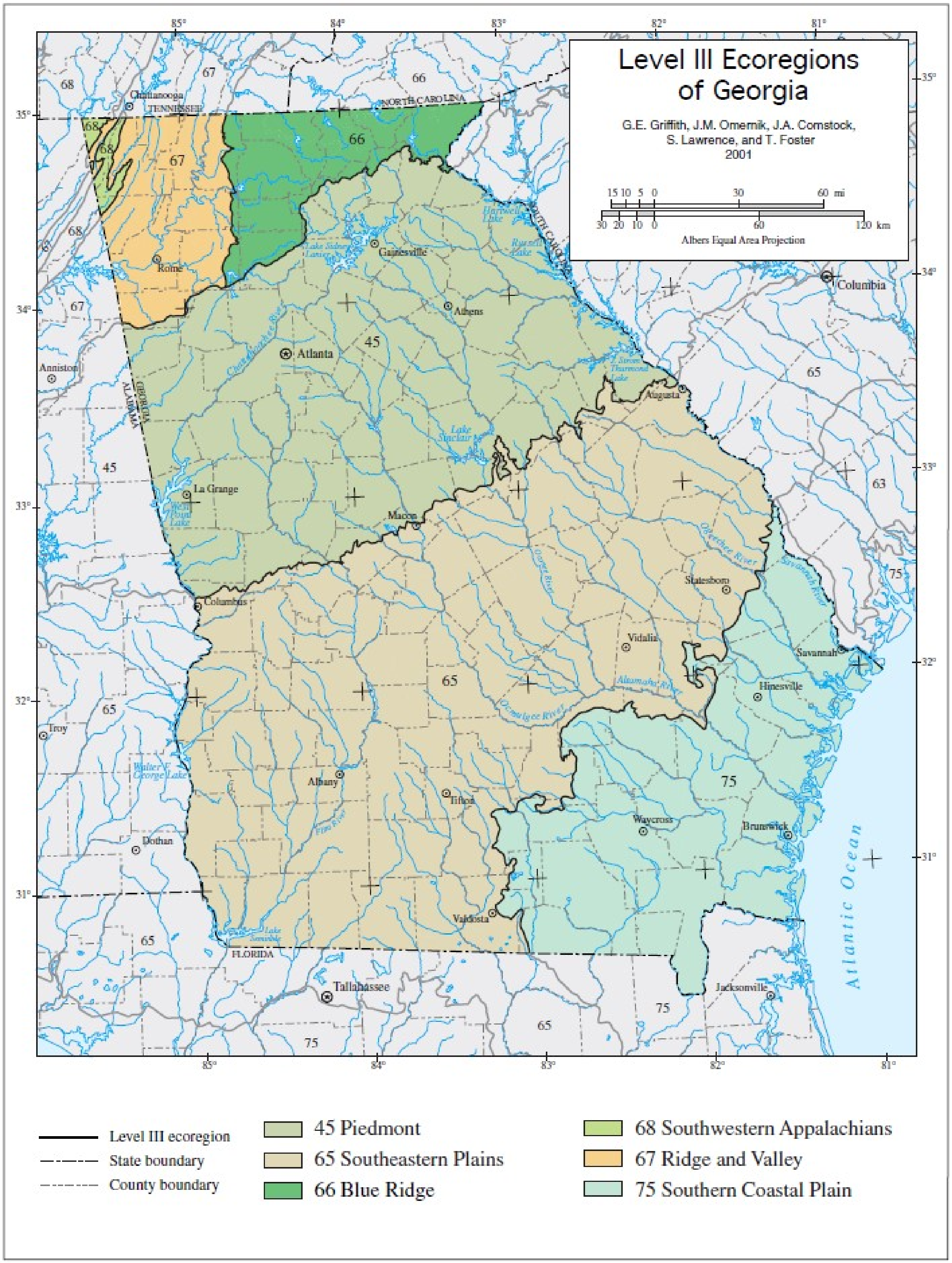

Figure 1. Level III ecoregions of Georgia (Griffith *et al.* 2001).

for determining the length of sample reaches. In a comparison of sampling techniques, Simonson and Lyons (1995) found that a single upstream electrofishing pass of 35 times the MSW adequately assessed fish species richness, abundance, and assemblage structure when compared to more intensive four-pass electrofishing removal at the same reach length.

GAWRD compared biomonitoring data collected from 125 sample reaches that were 15 times, 25 times, and 35 times the MSW. Findings showed that standard deviations for IBI scores, species richness, and habitat replication were least for data collected from sample reaches 35 times MSW. Therefore, to fully replicate major habitat types throughout the sample site and decrease variability in IBI scores, a single electrofishing pass for a length of 35 times the MSW was adopted. Due to the constraints of time and resources, a maximum sample reach of 500 meters is employed for wadeable streams in Georgia. MSW is determined by averaging the wetted stream width (Figure 2). Transects are set at 20 meter intervals from the starting location. Movement proceeds in an upstream direction, measuring the 20 m distance between each transect with a tape measure or hip chain. Upstream movement and measurements should be made in the midstream position, maintaining a close approximation to the contours of the stream. At each transect, the stream width (i.e. wetted width; Figure 2) is measured from the water's edge on one bank to the water's edge on the other bank perpendicular to stream flow. Width measurements are recorded to the nearest tenth of a meter. If, after five transects, the MSW is found to be greater than three meters, an additional five transects are measured. This process is repeated for each three-meter increment of MSW until the final reach length has been determined (i.e., measurements are taken at five transects for sites with MSW less than 3m, at ten transects for sites with MSW from 3 – 6 m, and so forth, up to a maximum of 25 transects per sample site).

Side channels should be included in the width measurement, but islands and sand and gravel bars should not, unless they have been exposed by drought and would be underwater at normal flow. When islands or bars are encountered, width measurements should be taken on each side and added together. Backwaters, sloughs, and adjacent wetlands should not be included in width measurements (Lyons 1992b). Data sheets used to determine reach length can be found in (Appx. I).

Along with stream width, at each transect the following measurements will be recorded: bankfull width, bankfull height, top bank height, bank angle, and water depth along with substrate at 1/4, 1/2, and 3/4 of the stream transect width (Figure 2). Bankfull height and water depths at 1/4, 1/2, and 3/4 are measured to the nearest hundredth of a meter. Stream width, bankfull width, and top bank height are recorded to the nearest tenth of a meter. Bank angle is recorded to the nearest degree. Substrate sizes and types are classified in Table 1.

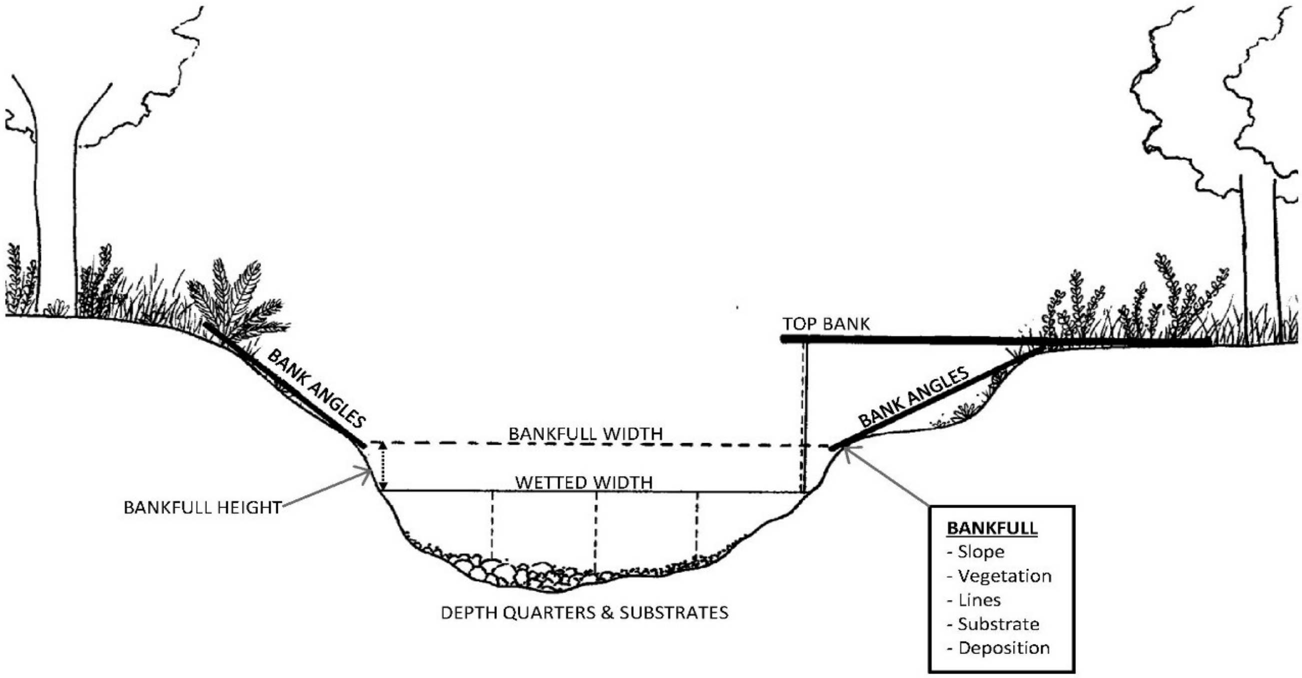

Figure 2. Stream cross section highlighting stream morphology measurements. Definitions and measurements procedures for site variables adapted from Sullivan *et al.* 1987, Harrelson *et al.* 1994, Simonson *et al.* 1994, MCCandles and Everett, 2002, Lawlor, 2004, Sherwood and Huitger, 2005. Illustration: Kelly Strychalski.

Bankfull Identifiers

I.	Slope	IV.	Vegetation
II.	Substrate	V.	Lines
III.	Deposition		

To help identify bankfull, first consider the five identifiers above (Slope, Substrate, Deposition, Vegetation, and Water Lines). Observe areas adjacent to transects if identifiers are not clearly represented.

I. **Slope** - Slope refers to the change in slope from vertical erosion that occurs over time, from the bank's direct contact with normal flow conditions. When flows exceed normal conditions, the water rises above the vertical banks and spills out on the first terrace. That first topographical change in slope is the first indicator of bankfull. Above and outward from bankfull is referred to as the flood prone zone.

II. **Substrate** - Changes in substrate are the second possible identifier to look for. As stream flow increases, water typically flows laterally over the landscape. The lateral flows move more slowly than main channel flows and have less energy to carry substrate. As a result, those substrates are deposited. When flows recede, residual sediments can easily be observed.

III. **Deposition** - The top flat part of sand and silt deposits will be the lowest extent of bankfull.

IV. **Vegetation** - Any change in the composition or amount of vegetation. Typically, perennial terrestrial vegetation will not grow below bankfull because of the variable inundation of that part of the bank. Alternatively, the observation of water washed roots is an indication of bankfull.

V. **Lines** - On hard permanent structures, e.g. boulders and bedrock, the other identifiers may be more difficult to view. In these instances, look for mosses, lichens, and mineral deposits.

Table 1. Substrate type, size, and data sheet abbreviation.

Substrate Type		
Type	**Size**	**Abbreviation**
Hardpan (Fines, Consolidated)		H
Silt/Clay/Muck (Fines, Not Gritty)		F
Sand (Gritty - up to ladybug size)	0.062-2.0mm	S
Gravel (ladybug to tennis ball)	2-64mm	G
Cobble (tennis ball to basketball)	64-256mm	C
Boulder (basketball to car)	256-4096mm	B
Bedrock (larger than a car)		R
Woody Debris	Must be stable	W
Leaves	Must be stable	L

Stream width is a measurement of the active wetted area of the stream taken from the farthest points moving away from the center of the stream, perpendicular to flow. Bankfull is the inflection point above which the stream flow would be in the floodplain and below this inflection point is considered normal flows and is the intermediary between the stream channel and the flood plain. See bankfull identifiers and (Figure 2) for bankfull location assistance. Bankfull width is recorded perpendicular to stream flow from bankfull on one bank to bankfull on the opposite bank. Bankfull depth is measured from the surface of the water vertically to bankfull. The top bank is measured from the surface of the water to the top of the second terrace. If both banks are unequal, top bank is recorded at the lower bank. Bank angle is measured by placing the bottom of a straight edge at bankfull and laying the straight edge down on the bank perpendicular to stream flow. That angle is measured using a clinometer. The endpoints (beginning and ending) of the sample reach are demarcated with flagging tape or spray paint. After final reach length is determined, slope of the entire reach is measured. Slope is assessed incrementally by using a clear flexible tube approximately 21 m in length with one meter marked off on the downstream end for measuring this difference in slope. The tube is extended down a 20 m reach of stream and must be voided of any air bubbles and filled with water before measurement proceeds. This is accomplished by using the tube to run a siphon from a bucket of water held in an elevated position at the upstream end of the tube; the water should be allowed to flow from the bucket to the downstream end of the tube until all air bubbles are removed. To assess slope, the upstream end of the tube is placed under water just below the surface, and the mark on the downstream end of the tube is placed even with the surface of the water with the end of the tube held vertically; the level of the water above the mark is measured to the nearest millimeter once the water level in the tube stabilizes. This is continued at all transects until the entirety of the reach's slopes are measured. Then, add all the individual transect slopes together for the total slope of the reach.

Once the length of the sample site has been determined and marked off, the number of riffle and pool habitats in the sample site are counted. Riffles and pools provide important habitat for different fish species due to their characteristic differences in flow, depth, and substrate. Riffles tend to be areas of high energy, with faster water flows, shallower water depths, and coarser substrate materials. Pools represent areas of less energy, with slower water flows, greater water depths, and finer substrate material. An abundance of riffle and pool habitats in a sample reach is an indication of a stream that can support a diversity of fish species. For habitat counts in wadeable streams, any area where the water surface tension is continuously broken for more than one meter in length over a substrate of cobble, boulder, gravel, and/or stable woody debris is considered a riffle. To be considered a pool, an area must have a minimum depth of at least 0.5 meter. Any pool areas with a maximum depth greater than one meter are considered deep pools. Depth of deepest pool should also be recorded while conducting habitat counts.

Riffle frequency is calculated for streams located in the Blue Ridge, Piedmont, Ridge and Valley, and the Southwestern Appalachians ecoregions. Riffles represent a source of high-quality habitat for macroinvertebrates and fish, and streams with a well-developed riffle-run complex tend to support a more diverse biotic community. The riffle frequency ratio is determined by dividing the mean distance between consecutive riffles in the sample reach by the MSW (Barbour *et al.* 1999). Distance between riffles is measured from the midpoint of the first riffle to the midpoint of the next riffle along the contour of the stream. Riffle frequency value is used to determine the score for the corresponding metric in the habitat assessment that is completed after the stream is sampled.

Channel sinuosity is calculated for streams located in the Southern Coastal Plain and Southeastern Plains ecoregions. Channel sinuosity is a measure of the bending or meandering in a stream channel. A high degree of channel sinuosity provides for diverse instream habitat fauna and better maintenance of stream flow fluctuations due to storm surges. The bends in the channel protect the stream from excessive erosion and flooding by absorbing the energy from storm surges. Bends also provide a refuge for the aquatic fauna during storm events. Channel sinuosity is determined by dividing the mean distance between consecutive bends in the sample reach by the MSW (Barbour *et al.* 1999). Distance between bends is measured from the midpoint of the first bend to the midpoint of the next bend along the contour of the stream. The value for the channel sinuosity is used to determine the score for the corresponding metric in the habitat assessment.

Latitude and longitude are determined from a hand-held GPS unit as close as possible to the downstream endpoint of the sample reach. Because of dense canopy cover at some sampling locations, latitude and longitude may need to be measured at the nearest downstream road crossing and the location noted on the reconnaissance data sheet. Conductivity and water temperature are measured at the sample site with a hand-held water quality meter. Field investigators should also determine if seining would be an appropriate sampling technique. Seining techniques can be beneficial when sampling in fast riffle habitats and when known federally protected species encounters are likely to occur. All prerequisite data are recorded on the Stream Reconnaissance Report (Appx. I), along with any observations on land use in the surrounding area and possible impacts to the stream and the adjacent riparian zone.

Sampling Procedures

A. Sampling Season

The length of the sampling season is a function of water level and temperature. Normally, biomonitoring samples in Georgia can be collected from early April until mid October, although the sampling season may be longer or shorter for a given year depending upon the local temperature and precipitation. Sampling in the early spring and late fall is normally precluded due to higher water levels and cooler water temperatures. Streams should be wadeable with a flow that allows the investigators to move in an upstream direction at a steady pace. Increased flows associated with elevated water levels decrease sampling efficiency by increasing the movement of stunned fish downstream before they can be captured. Higher turbidities associated with elevated water levels also decreases sampling efficiency by reducing the visibility of stunned fish to the netters. In general, sampling streams with a turbidity measurement greater than 35 NTUs should be avoided. However, not all elevated turbidities readings are related to increased water levels. Streams that have undergone changes to flow regimes, channel alterations, or riparian zone disruptions, may have elevated turbidities unrelated to the channel flow status, and the sampling of these impacted streams is left to the best professional judgment of the investigators. At cooler water temperatures, fish tend to move into deeper water or under heavy cover where they will be less vulnerable to capture by electrofishing gear (Ohio EPA 1987b; Tennessee Valley Authority 1997). Sampling streams with a water temperature less than 10° Celsius should also be avoided. Therefore, most sampling should occur during the summer months when water levels are generally lowest, fish populations tend to be most stable and sedentary, and pollution stresses are potentially the greatest (Ohio EPA 1987c).

B. Sampling Techniques

Electrofishing and seining techniques are used for sampling fish populations in wadeable streams in Georgia. The sampling gear to be used is dependent upon the size of the stream to be sampled.
In most situations, we generally use a single DC pulsed backpack electrofishing unit (BPEF) per 2.5 to 3 meters of stream width. These MSW bounds should be viewed as guidelines for sampling wadeable streams in Georgia and it will depend upon the individual investigator to determine the level of effort needed to adequately sample a site. For example, a small stream with an abundance of deep pool habitats may require a second or a third BPEF unit to effectively sample deeper waters. Likewise, a wide, heavily silted stream with shallow water and numerous sand bars may be sampled effectively with less effort. In these instances, best professional judgment should be used when determining how to sample a stream reach most effectively.

Prior to sampling, the electrofishing unit should be tested outside of the sample area to determine the proper control settings needed to collect fish at that site. The ability to collect fish using electrofishing equipment varies between sample sites depending upon water temperature, conductivity, bottom substrate, turbidity, and stream morphology (Kolz *et al.* 1998). Of these, water conductivity is the most important variable that affects electrofishing efficiency. Conductivity is the ability of the water to convey an electric charge and is dependent upon water temperature and ionic concentration. MicroSiemens (µS) are the preferred units of measurement. Conductivity can be either ambient (at existing water temperature), or specific (adjusted to a reference temperature). For electrofishing purposes, the meter should be measuring ambient conductivity. In streams with higher conductivities, the voltage output from the electrofishing unit should be decreased. Generally, for high conductivity water (400 to 1,600 μS), use 100 to 300 volts, for medium conductivity water (100 to 400 μS), use 400 to 700 volts, and for low conductivity water (15 to 100 μS), use 800 to 1,100 volts (Smith-Root, Inc. 1997) (see Appx. I for voltage curve that was calibrated for GAWRD's LR-20B Smith Root electrofishers and may require minor adjustments for other electrofisher units to reach the desired amperage). Sampling streams with conductivities less than 15 μS should be avoided due to decreases in sampling efficiency seen with most electroshocking equipment. To ascertain the proper control settings, the conductivity should be measured prior to testing the electrofishing unit. Control settings that produce amperages of 0.2 to 0.3 amps for the BPEF units and 1.5 to 2.5 amps for the tow barge can effectively sample fish populations without causing undue damage to the captured fish. The control settings, average amperage output, and total electrofishing time are recorded in the appropriate spaces on the stream collection report (Appx. I).

1. Sampling with a single backpack electrofishing unit.

Sampling with a single DC pulsed backpack electrofishing unit requires a minimum of two people, although three is preferable. One individual operates the backpack electrofishing unit while the other(s) work the seine, dip nets, and carry the bucket(s) used to transport captured fish. The backpack electrofishing operator should also carry a dip net. Sampling is conducted in an upstream direction to minimize the effect of substrate disturbance within the reach. The entire length of the site is sampled with the backpack unit. All habitats (pools, riffles, runs, woody debris, undercut banks, large rocks, thick root mats, etc.) should be thoroughly sampled to collect a representative sample of the fish population in the stream. An effective technique for sampling fish is to thrust the anode ring into or under the structure to be sampled, such as an undercut bank, thick root mat, or large woody debris, and then slowly withdraw the anode ring. Due to galvanotaxis or electrotaxis, the electric field draws the fish out and simplifies their capture from under such structures. As the electrofishing unit operator moves upstream, he/she should apply intermittent power to the electrofishing probe. This technique will lessen the "herding" of fish in front of the operator and out of the range of the electrofishing unit. Two crew members with dip nets walk alongside and behind the electrofishing operator to collect the stunned fish. The collected fish should be frequently transferred from the dip nets to a bucket of aerated water to lessen stress and mortality. This sampling method is not meant to provide an exhaustive survey of the fish fauna, but rather to provide a realistic sample of the fish population in that portion of the stream.

Faster than normal riffle habitats are sampled by electrofishing downstream into a seine. A ten- to fifteen-foot long minnow seine is usually adequate for this purpose. The seine is positioned perpendicular to the stream flow so that the center section of the seine forms a bag where the flow is greatest. To prevent fish from escaping underneath the seine, crew members positioning the seine may find it necessary to stand on the lead line. The electrofishing operator then works in a downstream direction toward the seine. The stunned fish are carried downstream by the current into the seine. In riffles with a lot of cobble and rock substrate, it may be necessary for the backpack electrofishing unit operator to kick around the substrate to dislodge any stunned fish that may have become caught under the rocks. When the section of the stream covered by the seine has been passed through with the electrofishing unit, the seine should be scooped up and the fish removed and placed in a bucket. Several consecutive sets using this method and moving in an upstream direction may be necessary to completely sample an entire area of riffle habitat.

2. Sampling with two or more backpack electrofishing units.

Sampling with two backpack electrofishing units requires a minimum of four people, although five people is often better: two individuals to operate the backpack electrofishing units, two individuals to handle the dip nets and seine, and one individual to carry the bucket(s) to transport the captured fish. Each electrofishing operator will sample an area ranging from one side of the stream bank to the center of the stream, so that each unit operator covers approximately one-half of the total stream area. At least one dip netter should accompany each electrofishing unit operator, following closely behind to gather any stunned fish.

When sampling a deep pool (one meter or deeper), one electrofishing unit operator should approach the pool from the upstream direction and one from the downstream direction. Keeping the pool between the electrofishing unit operators increases sampling efficiency by decreasing the avoidance of fish to a single electrofishing unit in deeper water. Large schools of fish can be sampled in a similar fashion, trapping the school between the electrofishing unit operators and lessening the effects of escape through upstream herding.

Sampling larger streams with three BPEF units should require a minimum of six people: three individuals to operate the BPEF units, three individuals to handle the dip nets, seine, and the buckets to transport the captured fish. In larger streams it may be possible to float a barge or small kayak with large fish containers rather than having individuals carry buckets. When using three BPEF units, a single BPEF unit operator should work each bank out to approximately 1/3 the width of the stream. The third BPEF unit operator should work the middle 1/3 of the stream. The middle operator should also assist in sampling large macrohabitats located along each bank, such as deep pools formed behind downed trees or in the bends of large streams. Each BPEF unit operator should carry a dip net and should also be followed by at least one dip netter.

Other procedures and electrofishing techniques are the same as when sampling with a single backpack electrofishing unit.

3. Sampling with a barge electrofishing unit.

The barge electrofishing unit consists of a tow barge, pulsator, and a generator. The tow barge can be built or purchased directly from a manufacturer. The tote barge fabricated by the GAWRD consists of a PVC foam board core, two layers of fiberglass coating, and an outer gel coating. A stainless-steel plate attached to the front and bottom of the barge acts as the cathode. A control box attached to the front of the barge provides plugs for up to three electrofishing probes. Probes are attached to the control box by 50-foot cables to allow for ample movement by the probe operators.

Sampling with the barge EF unit requires a minimum of five people: two people to operate the probes, two people to net the stunned fish, and one person to navigate the tow barge. Probe operators should also carry dip nets. When sampling large streams (MSW of 10 meters or greater), three probe operators and two to three netters should be employed, for a minimum crew of six or seven people. In very large streams (approximately 15 meters or greater) using an additional BPEF unit along one or both banks will increase the sampling efficiency of the barge EF unit. The probe operators sample the area in front of the barge, covering approximately equal portions of the stream area. Netters should stay behind the barge out of the electric field, netting the stunned fish that come up behind the probe operators. Stunned fish are placed in a storage container on the tote barge. An attempt should be made to sample the entire stream area in the sample reach, though this is often difficult in larger streams. As when using BPEF units, all micro- and macrohabitats should be thoroughly sampled to obtain a representative sample of the fish community in the stream. Other procedures and electrofishing techniques are the same as when sampling a stream with multiple BPEF units.

C. Sample Processing

All stunned fish are netted and placed in buckets of aerated fresh stream water until the entire reach is sampled. Water in the buckets should be replaced frequently to reduce mortality of captured fish. For larger sites, it may be necessary to stop and process the sample several times until the entire site has been sampled. All readily identifiable fish are identified to species, counted, examined for external anomalies, and released. All sample data are recorded on the stream collection report data sheet (Appx. I). All field forms and sample tags should be printed on waterproof paper. With the exception of smaller species (i.e gambusia), fish less than 25 mm total length (approx. one inch) should be omitted during sample processing. The sampling techniques outlined in this document do not effectively sample fish less than 25 mm total length, and fish in this size range are often troublesome to identify in the field as most are usually young-of-the-year (YOY) individuals (Karr *et al.* 1986). Populations dominated by highly variable pulses of YOY fish can lead to erroneous conclusions based on inflated IBI and species richness scores. Since YOY fish have not been subjected to the conditions of the sample site for a sustained period of time, they do not fully reflect the long-term conditions at that site. The presence of adult fish implies successful recruitment within a system and is a better indication of long-term conditions in a stream (Angermeier and Karr 1986; Angermeier and Schlosser 1987). Therefore, the exclusion of fish less than 25 mm in length from the sample analysis should significantly reduce bias. Juvenile individuals greater than 25 mm total length are included in the analysis since they reflect the attributes and trophic guilds of the adult species (Niemela *et al.* 1998).

Any unidentifiable fish in the sample are counted and examined for external anomalies at the streamside and returned to the laboratory in a plastic container of 10% formalin solution for identification. Each container returned to the lab should include a waterproof tag recording the stream name, sample identification number, collection date, and total number of individuals returned. Any new species of fish collected in a drainage basin should also be retained for addition to the reference collection. The number of individuals returned to the lab should be recorded on the stream collection report data sheet.

Fish that are returned to the lab remain in the 10% formalin solution for approximately five days or until the fish are no longer floating in the preservative. For individuals larger than 10 inches, the body cavity must be cut open to allow for adequate preservation. The formalin solution is then decanted under a hood and disposed of in the proper manner and replaced with fresh water. The water should be replaced every day with fresh water for a minimum of three days or until the formaldehyde odor is gone. After the formaldehyde odor has dissipated, the water is replaced with a 70% ethanol solution and the sample is ready for identification. Any additions to the reference collection and problematic identifications will require verification by a regional ichthyologist. After verification, additions to the reference collection should be stored in separate glass jars with a completed identification label showing the scientific name, common name, stream name, sample location, ecoregion, drainage basin, county, date of collection, and the sample identification number.

<u>Presence of external anomalies.</u>

All fish collected are examined for external anomalies. Each individual with an external anomaly and the type of anomaly are recorded on the stream collection data sheet. An external anomaly is defined as the presence of skin or subcutaneous disorders that are visible to the naked eye while processing the sample (Ohio EPA 1987c; O'Neil and Shepard 1998). A high incidence of individuals with external anomalies is a good indicator of a stream impacted by sublethal chemical stresses. Ohio EPA (1987b) has found that the highest incidence of external anomalies occurs in streams subjected to industrial and municipal waste water discharges, sewer outflows, and urban runoff. Some of the more common external anomalies are (Ohio EPA 1987b):

<u>Deformities</u> - Deformities can affect the head, fins, spinal column, and stomach shape. They have a variety of causes, including toxic chemicals, viral and bacterial infections, and protozoan parasites. Fish with extruded eyes, or popeye, a malady caused by fluid accumulation behind the eye due to the presence of certain parasites, are excluded, as are fish with obvious injuries.

<u>Eroded fins</u> - Eroded fins is a chronic condition principally caused by necrosis of the fin tissue due to a bacterial infection. Erosions on the opercle and preopercle are included in this category. In certain fish species, such as darters and suckers, care must be taken not to confuse fin damage caused by spawning activity with erosion due to disease.

<u>Lesions and Ulcers</u> - Lesions and ulcers appear as open sores or exposed tissue and are usually caused by viral or bacterial infections. Prominent bloody areas on fish and physical injuries that have undergone secondary infection are included in this category.

<u>Tumors</u> - Tumors are the result of neoplastic diseases caused by viral infections or exposure to toxic chemicals. Certain parasitic infections may produce masses that appear as tumors but should not be included in this category. Parasitic masses can be squeezed and broken whereas true tumors are firm and not easily broken.

<u>Fungus</u> - Fungus usually emerges as a secondary infection to an injured or open area on a fish and appears as a white cottony growth. Fungal infections often result in further disease or death.

<u>Blindness</u> - Blindness is indicated by a milky, opaque hue to one or both eyes. Fish with missing or grown over eyes are also included in this category.

The presence of parasites is not considered an external anomaly since the infestation could be natural and not related to environmental degradation. No consistent relationship has been established between the incidence of parasitism and environmental degradation (Leonard and Orth 1986; Ohio EPA 1987b). However, external anomalies, including deformities, lesions, and open sores, that may have been caused by the presence of parasites are included.

D. Habitat Assessment

Physical habitat has been shown to be a principal factor in determining the structure of the biotic community residing in a body of water (Schlosser 1982; Fausch *et al.* 1984; Hughes and Gammon 1987; Karr *et al.* 1987). A habitat assessment is an evaluation of the quality of the physical habitat as it affects the biological communities, namely fish and macroinvertebrates, in the stream. A habitat assessment will be conducted at each sample site to supplement the findings of the biomonitoring data. It should be viewed as an explanatory tool that will help to clarify the results of the biotic indices.

The habitat assessment used by the GAWRD was developed by the (EPD WPB) (2004). It was modified from the original version developed by Barbour *et al.* (1999) for the EPA Rapid Bioassessment Protocols. This version incorporates different assessment parameters for riffle/run prevalent streams and glide/pool prevalent streams. The choice of which habitat assessment to use will depend upon where the stream is located. Streams located in the Blue Ridge, Piedmont, Ridge and Valley, and Southwestern Appalachians ecoregions are considered riffle/run prevalent streams. These ecoregions are areas of moderate to high gradient landscapes and under normal conditions can sustain water flow velocities of one foot per second or greater. Streams located in the Southern Coastal Plain and the Southeastern Plains ecoregions are considered glide/pool prevalent streams. These ecoregions are areas of low to moderate gradient landscapes that have water flow velocities rarely greater than one foot per second, except during storm events.

The physical parameters for each habitat assessment are broken into primary, secondary, and tertiary levels. Primary parameters describe those instream physical characteristics that directly affect fish and macroinvertebrate communities. Primary parameters are measured by metrics that evaluate epifaunal substrate, available cover, embeddedness in runs, velocity and depth regimes, and pool substrate and variability. Secondary parameters describe the channel morphology that directly affects the behavior of stream flow and sediment deposition. Secondary parameters are measured by metrics that evaluate sedimentation and deposition, riffle frequency, channel sinuosity, channel alteration, and channel flow. Tertiary parameters describe the banks and riparian zone surrounding the stream, which indirectly affect the type of habitat and food resources available to the aquatic community. Tertiary parameters are measured by metrics that evaluate bank stability, bank vegetative cover, and vegetative riparian zone width (Barbour *et al.* 1999).

The habitat assessment forms for riffle/run prevalent streams and glide/pool prevalent streams are included in (Appx. II). An explanation of each habitat metric and its scoring criteria is also included. Three crew members independently evaluate the habitat quality of the entire sample site. The habitat assessments are conducted after sampling and collection workup has been completed to avoid disturbing the fish population at the sample site. The final habitat assessment score for a sample site is the average of the three independent scores. If one of the total habitat scores deviates 30 or more points from the middle score, the outlier score may be discarded from the calculation of the final habitat assessment score. If all three of the scores deviate from one another by 30 or more points, the crew members conducting the habitat assessment should review their individual parameter scores while at the station. Individual scores may be revised if appropriate after the review.

E. Water Quality Measurements

Water quality parameters measured at each sample site include: turbidity, conductivity, DO, pH, total alkalinity, total hardness, and water temperature. One factor determining the concentration of dissolved oxygen in water is the elevation at the sample site. Elevation is estimated to the nearest 100-foot interval from USGS 7.5-minute topographic maps prior to leaving the office or from a GPS unit at the sample site and used to calibrate hand-held dissolved oxygen meters to the appropriate elevation. Conductivity, water temperature, and the concentration of dissolved oxygen are measured at the sample site with a handheld meter. Conductivity must be measured prior to sampling since it may be important in determining the settings on the electrofishing unit. A grab sample of water is also collected prior to sampling, in a plastic bottle, near the starting location where the bottom substrate has not been disturbed to avoid distorting the water quality measures and returned to the vehicle where the remaining water quality measurements are conducted. Total alkalinity, total hardness, and pH are measured using standard Hach kits. A turbidity meter is used to measure turbidity in NTUs to the nearest tenth. At least one digital photograph is taken showing a representative view of the sample site. All water quality measurements and the numbers of photographs taken are recorded in the appropriate spaces on the stream collection data sheet (Appx. I).

Quality Assurance/Quality Control

To improve the precision, accuracy, comparability, and representativeness of biomonitoring data, a system of quality assurance and quality control (QA/QC) needs to be implemented. Quality control refers to the routine application of procedures for attaining prescribed standards of performance when collecting in the field, conducting habitat assessments, identifying fish species, and analyzing data. Quality assurance includes quality control procedures and involves a totally integrated program for ensuring the reliability of monitoring and measurement data (United States EPA 1995). The QA/QC procedures described herein should ensure the utility of the biomonitoring data collected under the protocols outlined in this document.

A. Fish Identification and Sample Processing

All personnel involved with field identifications will be trained in a consistent manner in the identification of fish species found throughout Georgia. Fish collections from approximately 10% of the sites should be retained, as described in the section under fish processing, and returned to the laboratory for verification of fish identifications, counts, and occurrence of external anomalies (Tennessee Valley Authority 1997). Retaining every tenth sample ensures that 10% of the sample sites undergo QA/QC procedures. If it is impractical to retain the entire sample, either due to the large size of certain individuals in the sample or the large total number of individuals collected in the sample, a voucher specimen from each species identified in the field may be returned to the lab for QA/QC purposes. If no fish are collected at the sample chosen for QA/QC, then the next sample should be retained for QA/QC purposes. Samples retained for QA/QC should be recorded in the appropriate space on the stream collection report form.

In the laboratory, each crew member responsible for field identifications will independently identify and count all fish and record the occurrence of anomalies. A follow-up will consist of a meeting between crew members to discuss their results and, if necessary, resolve any problems with sample processing or fish identification.

Every site sampled should be cataloged and tracked to link the sample with the field data sheets and to follow the sample through the final disposition of the data (O'Neil and Shepard 1998). The sample cataloging/tracking system used by GAWRD includes the following information: sample identification number, stream name, major river basin, ecoregion, county, reconnaissance date, date of reconnaissance data entry, sample date, date of sample data entry, if any portion of the sample was retained, and type of sample (QA/QC, point source, reference, or special project). An example of the sample-tracking log used by GAWRD is included in (Appx. I).

B. Habitat Assessment

All personnel conducting habitat assessments will be trained in a consistent manner to ensure that the evaluations are conducted properly and to ensure standardization. Field validations comparing the independent habitat assessments of each crew member at a particular sample site will be conducted at least once a year. Any deviations, either between the individual metric scores or the total habitat assessment scores, will be discussed within the group to curtail future discrepancies.

C. Equipment Maintenance and Calibration

All sampling equipment and meters need to be maintained and calibrated in a manner consistent with the manufacturers' recommended schedules. All calibration standards and solutions need to be replaced according to the manufacturers' recommendations. A maintenance and calibration schedule should be posted in the work area where these procedures are performed. After each procedure is performed, the date and the initials of the individual that performed the procedure should be recorded on the maintenance and calibration form. If there are duplicate meters of the same type (e.g., two turbidity meters), each meter should be marked and have its own space allotted on the calibration and maintenance form.

D. Metric Calculations and Data Entry

Data collected in the field should be entered into the database as soon as possible upon returning to the lab. All data entries should be recorded in the appropriate spaces on the sample site log. All entries into the database must be verified to ensure the accuracy of the data from the field datasheets to the database. Two individuals should compare the database entries to the field datasheets, one reading off the field datasheet and the other checking the database entries. Any discrepancies between the two should be corrected and noted on the data entry QA/QC log, along with the date of the verification and the names of individuals conducting the verification. A second verification should be conducted in the same manner. A copy of the data entry QA/QC log used by the GAWRD is included in (Appx. I).

Any data calculations or counts for the IBI metrics should be conducted independently by two individuals who are familiar with the metric scoring criteria and fish guild assignments. A follow-up meeting should be held between the two individuals to determine the reason for any discrepancies and to resolve any future inconsistencies with the metric calculations.

Biotic Index Used to Measure Fish Community Condition in Georgia

The index of fish community health used to assess the biotic integrity of aquatic systems in Georgia is the Index of Biotic Integrity (IBI). The IBI was developed by Karr (1981) to assess the health of aquatic communities based on the functional and compositional attributes of the fish population. IBI indices provide a direct assessment of the biotic integrity of an aquatic community based on an overall evaluation of its fish population. Karr's IBI was developed to assess fish communities in the midwestern United States and requires modification from the original format to reflect the differences in fish fauna between the southeastern and midwestern United States.

Index of Biotic Integrity

Various methods using the structure of the fish population to assess the health of the aquatic community have been developed in the past (Fausch *et al.* 1990; Karr 1991). Several of the most accepted approaches, including the presence or absence of indicator species or guilds and the use of species richness, evenness, and diversity indices, are no longer recommended because of their theoretical, statistical, and practical flaws. One of the approaches found to be most suited for identifying areas undergoing environmental degradation was the IBI. The IBI is a multimetric index that integrates characteristics of the fish community, population, and individual organism to assess biological integrity at a sample site (Karr 1987). The IBI offers several advantages over other approaches that use fish communities to determine environmental degradation (Fausch *et al.* 1990; Karr 1991). These include: (1) it is a broadly based ecological index that assesses community structure and function at several trophic levels; (2) it gauges biotic integrity against an expectation, based on minimal disturbance in that region; (3) it is a quantitative index; (4) there is no loss of information from the constituent metrics when the total score is determined, since each metric contributes to the total evaluation of a site; (5) scores are reproducible; and (6) professional judgment is incorporated in the selection of metrics and the development of scoring criteria. Furthermore, the IBI has been shown to be a statistically valid approach for evaluating water resources and establishing regulatory policies (Fore *et al.* 1994).

The IBI offers several additional benefits when incorporated into a biomonitoring program (Karr 1991). IBI scores can be used to evaluate current conditions at a site, detect trends over time at a specific site with repeated sampling, compare sites within the same ecoregion, and, to an extent, identify the sources of local degradation. Past studies have shown the IBI to be an effective tool in identifying areas suffering from numerous types of environmental degradation. Streams undergoing the negative impacts of effluent from wastewater treatment plants (Karr *et al.* 1985; Hughes and Gammon 1987), mine drainage (Leonard and Orth 1986; Ahle and Jobsis 1996), sedimentation from agricultural and construction practices (Karr *et al.* 1987; Crumby *et al.* 1990; Rabeni and Smale 1995; Frenzel and Swanson 1996), flow modification (Bowen *et al.* 1996), and urbanization and riparian zone destruction (Steedman 1988; Schleiger 2000) have all been identified using the IBI.

The original IBI was developed by Karr (1981) to assess the health of the aquatic community in wadeable streams in the midwestern United States. It consisted of 12 measures, or metrics, which assessed three facets of the fish population: species richness and composition, trophic composition and dynamics, and fish abundance and condition. Each of the 12 metrics was scored by comparing its value to expected values determined from regional reference sites. A regional reference site is a stream located in an area of minimal human impact or disturbance that represents the least impaired conditions for a stream in that ecoregion. The 12 metrics were scored based on whether they approximated, deviated somewhat, or deviated strongly from the values of the regional reference sites and were assigned values of 5, 3, or 1 accordingly, for a maximum score of 60 and a minimum score of 12.

Since regional reference conditions are used to define metric expectations, the IBI has proven to be adaptable to regions outside the midwestern United States while retaining the ecological framework of the original IBI (Fore *et al.* 1994). Karr's original 12 metrics have been previously modified for use in other regions throughout the United States (Miller *et al.* 1988) and North America (Steedman 1988; Lyons *et al.* 1995), Europe (Oberdoff and Hughes 1992), Australia (Harris 1995), and Africa (Hugueny *et al.* 1996). Due to regional differences in the fish fauna and community structure between the southeastern and midwestern portions of the United States, several of the metrics originally proposed by Karr (1981) required modification for use in streams in the southeastern United States. (Table 2) shows a comparison between Karr's original metrics and those developed for streams in Georgia.

Stream location was one of the most important natural factors to consider in adapting Karr's original IBI to Georgia. Georgia contains six major ecoregions (Level III, Figure 1) and 14 major drainage basins as identified by the (EPD WPB) (Figure 3). Within a single drainage basin, differences between ecoregions in gradient, soil type, vegetative cover, and mineral content can lead to significant differences in the species richness and composition of the fish community. For example, a stream located in the Blue Ridge Mountains ecoregion of the Chattahoochee drainage basin will differ significantly in the physical characteristics and fish fauna from a stream located in the Southeastern Plains ecoregion of the same drainage basin. Likewise, different drainage basins located in the same ecoregion can differ significantly in species richness and composition. For streams located in the Flint drainage basin in the Piedmont ecoregion, a maximum of four benthic invertivore species could be encountered. In comparison, 10 or more benthic invertivore species could be collected from a stream in the Coosa drainage basin in the Piedmont ecoregion. To address the differences in fish fauna and community composition found between ecoregions and drainage basins within Georgia, GAWRD has established, or working to establish, scoring criteria for each major drainage basin or basin group within an ecoregion.

Stream size was another important natural factor to consider when investigating the structure and function of the fish community. In the past, stream order has been used frequently as a measure of stream size. However, due to a lack of consistency in map sizes and classification systems, stream order has not proven to be a universally applicable unit for comparing stream size (Huges and Omernik 1981). Upstream drainage basin area has been shown to be a better predictor of fish assemblage patterns (Hughes and Gammon 1987; Maret *et al.* 1997), species diversity (Statzner and Higler 1985), and the physical and habitat characteristics of a stream (Hughes and Omernik 1981).

Streams with larger drainage basin areas naturally have increased species richness over streams with smaller drainage basin areas. To incorporate this trend in metric scoring, Maximum Species Richness (MSR) graphs were developed for the species richness metrics (metrics 1 – 6, Table 2). MSR graphs were derived by plotting the number of species collected for a given metric against the log (base 10) transformed values of the drainage basin area. Simple linear regression was then used to establish the relationships between the number of species and drainage basin area for each metric, and to determine the x-intercepts of those relationships. Lines delineating the 95th percentile for each metric were determined with quantile regression using the x-intercepts established in the previous step; where data allowed, lines delineating the 5th percentile were also drawn using the same method. The area between the two lines was trisected using the method developed by Lyons (1992b). Data points falling above the middle trisection scored a 5, those falling in the middle trisection scored a 3, and those falling below the middle trisection scored a 1. Differences in species richness and composition required that separate MSR plots be developed for each major basin or basin group within an ecoregion.

Species composition is less reliant on stream size than species richness. Scoring for the species composition metrics (metrics 7 – 12, Table 2) was determined by plotting the data for a given metric against the log (base 10) transformed value of the drainage basin area. Horizontal lines delineating the 95th and the 5th percentiles were calculated and the area between the lines was trisected.

Metrics 1- 6 evaluate species richness at a site. These metrics assess the health of the major taxonomic groups and habitat guilds of fishes, the availability of spawning habitat and food resources, and the diversity of the fish community.

Metric 1. Total number of native fish species. This metric is a count of all the native fish species in the sample. The total number of native species collected is one of the most powerful metrics in determining stream condition because of the direct correlation between environmental conditions and the number of fish species present in warmwater assemblages (Ohio EPA 1987b). Highly diverse fish communities often contain intolerant species that are typically unable to cope with perturbations to habitat and water quality (Niemela *et al.* 1998). Hybrids and non-native species are not included in this metric, as their presence does not give an accurate assessment of long-term biotic integrity. Rather, their abundance may indicate a loss of biotic integrity to the system. An abundance of hybrids in a sample indicates that reproductive isolation among species may have been altered by environmental degradation (Karr *et al.* 1986). The prevalence of non-native species, especially top carnivores (gamefish) and cyprinids (baitfish) is generally indicative of areas with high human population density and/or recreational use (Whittier *et al.* 1997).

Metric 2. Total number of benthic invertivore species. This metric is a count of all the species of darters, madtoms, and sculpins in the sample. Benthic habitats are highly susceptible to degradation from the effects of siltation, flow modification, and reduction in dissolved oxygen levels from the accumulation of organic matter. Due to their specificity for feeding and reproducing in benthic habitats, benthic invertivore species tend to be highly sensitive to environmental degradation (Ohio EPA 1987b). The natural paucity of darter species in some drainage basins in Georgia required modification from Karr's (1981) original metric to include madtom and sculpin species (Table 2). Madtom and sculpin species display a benthic orientation like darters and their inclusion is in keeping with the concept of this metric as a measure of the benthic environment available for feeding and reproduction.

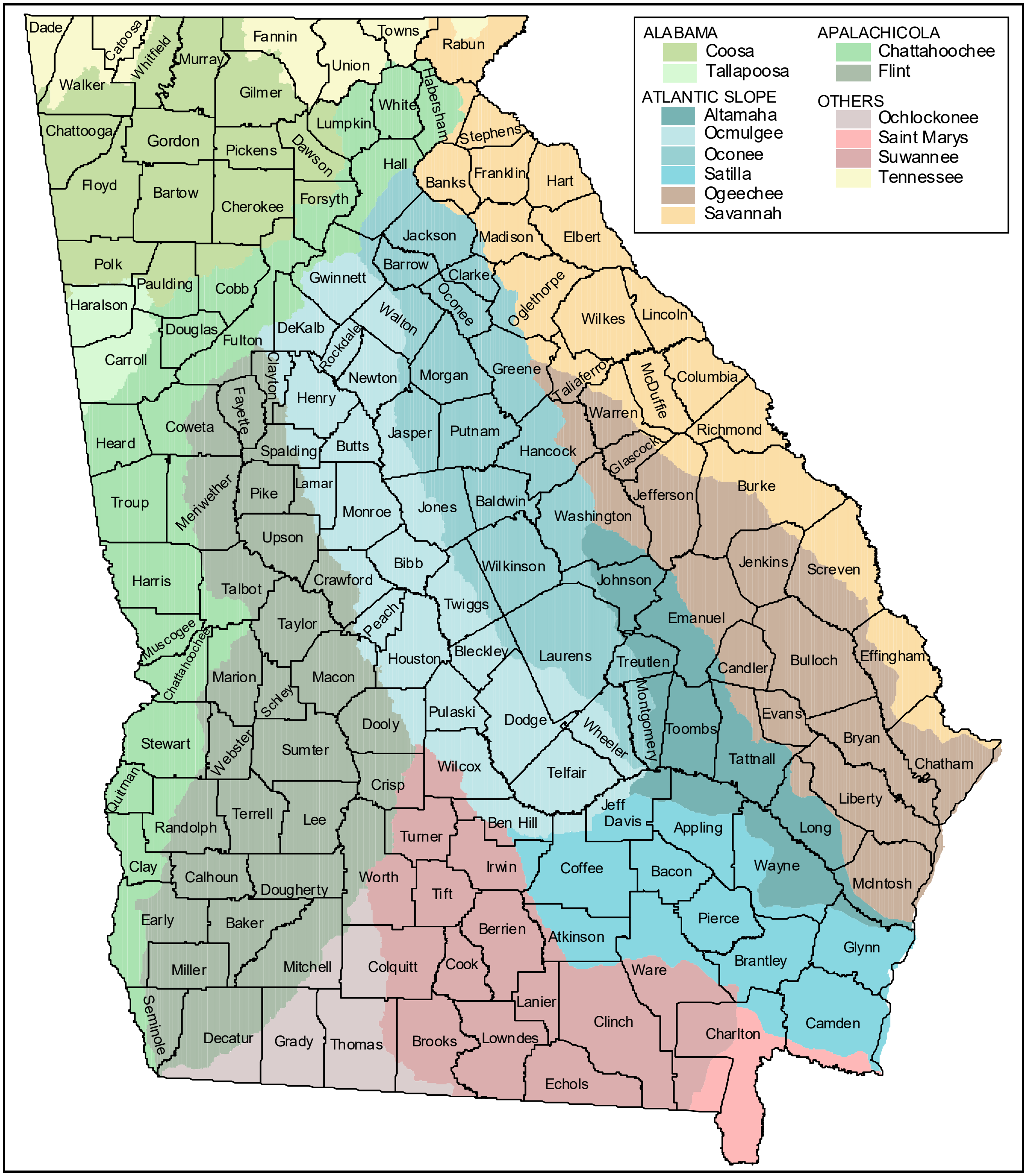

Figure 3. Georgia's fourteen major drainage basins.

Table 2. Comparison of the IBI metrics developed by Karr (1981) for wadeable streams in the midwestern United States and those developed by the Georgia Department of Natural Resources for wadeable streams in the Piedmont ecoregion of Georgia.

Karr (1981)	**Georgia Department of Natural Resources**
Species Richness	
1. Total number of fish species	1. Total number of native fish species
2. Total number of darter species	2. Total number of benthic invertivore species
3. Total number of sunfish species	3. Total number of native sunfish species (DBA < 15 sq. miles) Total number of native centrarchid species (DBA $\geq$ 15 sq. miles)
	4. Total number of native insectivorous cyprinid species
4. Total number of sucker species	5. Total number of native round-bodied sucker species
5. Total number of intolerant species	6. Total number of sensitive species (DBA < 15 sq. miles) Total number of intolerant species (DBA $\geq$ 15 sq. miles)
Species Composition and Trophic Dynamics	
6. Proportion of individuals as green sunfish	7. Evenness
7. Proportion of individuals as omnivores	8. Proportion of individuals as *Lepomis* species
8. Proportion of individuals as insectivorous cyprinid species	9. Proportion of individuals as insectivorous cyprinid species
9. Proportion of individuals as top carnivore species	10. Proportion of individuals as generalist feeders and herbivore species (DBA < 15 sq. miles) Proportion of individuals as top carnivore species (DBA $\geq$ 15 sq. miles)
	11. Proportion of individuals as benthic fluvial specialist species
Fish Abundance and Condition	
10. Total number of individuals in the sample	12. Number of individuals collected per 200 meters
11. Proportion of individuals as hybrids	
12. Proportion of individuals as diseased fish	13. Proportion of individuals with external anomalies

Metric 3. Total number of native sunfish / centrarchid species. Karr's (1981) original metric, the total number of sunfish species, required modification due to the increase in species richness of the centrarchid family in the southeastern United States and the abundance of sunfish species found in small streams in Georgia. In headwater streams, Karr's original metric was retained. In Georgia, the sunfish group includes all species of *Acantharchus, Ambloplites, Centrarchus, Enneacanthus,* and *Lepomis. Pomoxis* species are not included, as their presence in headwater streams is usually indicative of a stream impoundment. Sunfish hybrids and non-native species, such as the redbreast sunfish in the Tennessee and Alabama drainage basins, are also excluded from this metric. Sunfish species generally prefer quiet pool habitats near some form of instream cover. Preferred food items include terrestrial and aquatic insects, although some species of sunfish, such as the rock bass and shadow bass, feed predominately on fish as adults. The habitat and feeding preferences of most sunfish species make this metric an effective measure of the losses of instream cover and pool habitat and of the decreases in the terrestrial food supply due to the disruption of the riparian zone (Ohio EPA 1987b). Pools often act as sinks for the accumulation of toxins and suspended sediments in streams and are therefore highly susceptible to the effects of water quality and habitat degradations (Niemela *et al.* 1998).

In wadeable streams with a drainage basin area greater than 15 square miles this metric was modified to include all species of native centrarchids. This includes all the species in the sunfish group, plus all native species of *Micropterus* and *Pomoxis*. Centrarchids represent all levels of the food web, and the presence of a diverse centrarchid population is indicative of a healthy trophic structure within the aquatic community. Centrarchid species inhabit a variety of stream habitats from pools to shoals and are generally collected near some form of instream cover. The centrarchid family also includes several species that are highly intolerant to habitat and water quality degradations, such as the smallmouth bass and the shoal bass. The presence of these species is indicative of healthy environmental conditions within a stream.

Metric 4. Total number of native insectivorous cyprinid species. This metric is a count of the number of species of the Cyprinidae family, in the sample, that feed extensively as insectivores. This group includes 64 species from 15 different genera in Georgia. Cyprinid species that feed extensively on plant material, such as the stoneroller species, or that regularly utilize both plant and animal food sources, such as the golden shiner and the bluehead chub, are not included in this metric. Insectivorous cyprinid species are abundant in all sizes of water bodies in Georgia, from the smallest streams to the largest rivers. Insectivorous cyprinid species are specialized feeders, whose presence provides a measure of the diversity of the aquatic macroinvertebrate community (Niemela *et al.* 1998). Different species of insectivorous cyprinids also feed at different levels of the water column, so a variety of insectivorous cyprinid species in a sample is indicative of a diverse aquatic macroinvertebrate community and a healthy trophic structure of the fish community within a stream. Insectivorous cyprinid species can occur in diverse types of habitats over a diverse array of substrates (O'Neil and Shepard 1998), thus providing a measure of the quality of instream cover and bottom substrates. Many insectivorous cyprinid species spawn by broadcasting their eggs over the stream bottom where they can develop in the interstices of sand, gravel, and cobble substrates, or by depositing their eggs in rocky crevices. Due to their specificity for clean substrates and a silt-free environment for successful reproduction, this metric also assesses the availability of suitable spawning habitat in a stream. Insectivorous cyprinids also include several species that are highly intolerant to the effects of habitat and water quality degradation. Samples collected by the GAWRD displayed a marked decrease in the diversity of insectivorous cyprinid species at sites undergoing habitat and water quality degradation. Whittier *et al.* (1997) found that minnow species richness declined in areas undergoing increased urbanization.

Metric 5. Total number of native round-bodied sucker species. This metric is a count of the number of round-bodied species in the Catostomidae family in the sample. In Georgia, round-bodied suckers include all species of *Catostomus, Erimyzon, Hypentelium, Minytrema,* and *Moxostoma.* Catostomids represent a small, but important, family of fishes in Georgia. Most catostomid species are sensitive to physical and chemical habitat degradation. In his study on the various effects of land use on fish communities, Schleiger (2000) found catostomids to be sensitive to habitat modification, sedimentation, and changes in water quality. Gammon (1976) found that species of *Moxostoma* and *Hypentilium* were better indicators of water quality in large rivers than any other species group. Most round-bodied sucker species reproduce as broadcast spawners over gravel or cobble substrates and feed extensively on benthic macroinvertebrates, thus providing another benthic-oriented species metric in the index. In addition, the relatively long-life span of most Catostomid species provides a long-term assessment of past and present environmental conditions (Ohio EPA 1987b).

Metric 6. Total number of intolerant / sensitive species. A separate scoring criterion was developed for this metric between headwater streams and larger wadeable streams. At sample sites with an upstream drainage basin greater than 15 square miles, this metric is a count of all the species in the sample that have been designated as intolerant to the effects of environmental degradation.

Environmental degradation includes the effects of chemical pollution, sedimentation, flow modification, habitat alteration, and riparian zone disruption. This metric distinguishes between sites of good and exceptional biotic integrity since species designated as intolerant should have disappeared by the time a stream has been degraded to the fair category (Karr *et al.* 1986). Tolerance rankings were based upon mean IBI scores (minus metric 6) for each species designation used by other IBI studies in the southeastern United States (Bowen *et al.* 1996; Tennessee Valley Authority 1996; North Carolina DEHNR 1997; O'Neil and Shepard 1998; Schleiger 2000), regional ichthyological texts, and reviews from regional ichthyologists. Species ranked as intolerant include members of the families Cyprinidae, Ictaluridae, Catostomidae, Cyprinodontidae, Centrarchidae, and Percidae.

Since many of the species designated as intolerant do not naturally inhabit smaller streams, this metric was modified for use in headwaters streams to include all species that have been designated as either an intolerant or a headwater intolerant species, collectively termed sensitive species (Ohio EPA 1987b). Species designated as headwater intolerant are species normally found in smaller streams that are intolerant to the effects of environmental degradation and/or stream desiccation. Most headwater intolerant species require permanent pool or riffle habit. Thus, the presence of headwater intolerant species at a site can help distinguish between permanent streams and those with ephemeral characteristics (Ohio EPA 1987b). The absence of headwater intolerant species at a site indicates a stream undergoing stress due to habitat or water quality degradations or loss of habitat due to lack of water. Species designated as headwater intolerants include members of the families: Petromyzonidae, Cyprinidae, Ictaluridae, Cyprinodontidae, Centrarchidae, and Percidae. Species ranked as intolerants and headwater intolerants are indicated in the fish list for each ecoregion (Parts II – IV).

Metrics 7 – 11 measure the species composition and trophic dynamics at a site. These metrics assess the quality of the energy base and the flow of energy through a stream community and offer a means to quantitatively evaluate the shift toward more generalized foraging that occurs with increased habitat degradation. These metrics also provide a measure of the availability of suitable spawning habitat in the stream.

Metric 7. Evenness. Evenness measures the equity of the proportion of each species in the sample. In general, the greater the equity between species in a sample, the more diverse and healthier the fish community should be. Evenness is measured by comparing the observed diversity in a sample to a theoretical maximum diversity. Evenness values approaching 100 indicate a more diverse community, while smaller evenness values indicate a less diverse community. Certain species, usually the more pollution tolerant species, can dominate the fish community in degraded environments at the expense of other less tolerant species. As the proportions of the dominant species increase, the evenness of the fish community decreases. In these situations, the total diversity of the fish community can be reduced even without a loss of species richness due to the increase in relative abundance of one or more species. Evenness is calculated by:

$$[H / \ln (S)] \times 100$$

Where H = Shannon-Wiener diversity index

S = total number of species collected.

The Shannon-Wiener diversity index is calculated by:

$$- \sum (n_i/N) \ln (n_i/N)$$

Where n_i = number of individuals of a species

N = total number of individuals in the sample.

The evenness metric replaces Karr's original metric, the proportion of green sunfish, in the sample. Most other regional studies have replaced the proportion of green sunfish metric with the proportion of tolerant species metric. Sampling by the GAWRD indicated that the proportion of tolerant species metric provided little utility in streams in Georgia, especially at larger sites. Often degraded sample sites were dominated by species that were not traditionally ranked as pollution tolerant species. Sites receiving nutrient enrichment and those located in highly urbanized areas were often dominated by *Lepomis* species. Degraded headwater sites were often dominated by omnivorous cyprinid species, such as the bluehead or dixie chub. Replacing the tolerant species metric with the evenness metric avoids awarding these degraded sites with a higher metric score. Some sites have been degraded to the point where few individuals, even pollution tolerant individuals, remain. Elevated evenness scores at these sparsely populated sites are not indicative of a highly diverse fish community. Therefore, to avoid awarding highly degraded sites with a high evenness score, if less than 100 individuals are collected, this metric automatically receives a score of one.

Metric 8. Proportion of individuals as *Lepomis* species. This metric measures the proportion of individuals in the sample that are *Lepomis* species. Non-native species and *Lepomis* hybrids are included in this metric. While the species richness of the sunfish population is used as a measure of instream cover and pool habitat (metric 3), an over abundance of *Lepomis* species is indicative of a site undergoing habitat and water quality degradation. Samples collected by the GAWRD show that *Lepomis* species can dominate sites undergoing anthropogenic perturbations, especially the effects of nutrient enrichment, urbanization, and flow modification. An aquatic community dominated by *Lepomis* species is indicative of a decrease in the diversity of the macroinvertebrate community and of suitable spawning habitat for broadcast spawners. At some severely stressed sites the proportion of individuals as *Lepomis* species exceeded 90% of the entire sample. O'Neil and Shepard (1998) also found that *Lepomis* species could dominate disturbed streams in Alabama, sometimes exceeding 50% of the sample. Paller *et al.* (1996) found that the proportion of *Lepomis* species significantly differed between disturbed and undisturbed sample sites in coastal plain streams in South Carolina. This metric automatically receives a score of one if the number of native sunfish at a site equals zero.

Metric 9. Proportion of individuals as insectivorous cyprinids. This metric measures the proportion of the sample that is comprised of individuals that are insectivorous cyprinids. The majority of cyprinid species found in the southeastern United States are insectivores and they usually comprise the dominant trophic guild in surface waters (O'Neil and Shepard 1998). The abundance of insectivorous cyprinids in a sample reflects the variability of the macroinvertebrate food base (Karr *et al.* 1986). Increased degradation of habitat and water quality will lead to a decrease in the diversity of the aquatic insect community in a stream. When the aquatic insect community becomes dominated by only a few taxa, the specialized insectivorous species will be replaced by generalist species more suited to exploit the new food base (O'Neil and Shepard 1998). Sampling by the GAWRD indicates that, at sites undergoing anthropogenic stress, the proportion of insectivorous cyprinids markedly decreased, approaching zero percent at severely degraded sites. Sampling by the North Carolina Department of the Environment, Health, and Natural Resources (1997) found similar results at sites undergoing nutrient enrichment.

Metric 10. Proportion of individuals as generalist and herbivores / top carnivores. Due to natural variation in the trophic structure of aquatic communities related to stream size, a separate scoring criterion was developed for metric 10 between headwater and larger wadeable streams. At headwater streams, this metric measures the proportion of individuals in the sample that are designated as generalist feeders and herbivores. Generalist feeders are those species that consume both plant and animal materials (including detritus) and can utilize both types of food sources. This metric evaluates the shift in trophic composition of the fish community in streams with degraded physical and chemical habitat. As food resources become less reliable in degraded environments, generalist feeders frequently become the dominant members of the fish community since their opportunistic foraging habits convey a competitive advantage over more specialized feeders (Karr *et al.* 1986). Degraded headwater streams in Georgia are often dominated by such generalist species as the bluehead chub, dixie chub, and mosquitofish. Nutrient enrichment is a primary disturbance that can cause a shift in the trophic composition of the fish community. Therefore, this metric also includes those species that feed primarily as herbivores, such as the stoneroller species, whose increased numbers in a sample are often associated with elevated nutrient levels (Tennessee Valley Authority 1997; O'Neil and Shepard 1998).

At wadeable sites with a drainage basin greater than 15 square miles, this metric measures the proportion of individuals in the sample that function as top carnivores in the fish community. Top carnivores include all species that feed primarily upon fish, other vertebrates, and crayfish as adults. Omnivores or generalist species that may opportunistically feed upon fish or crayfish are not included. An abundance of top carnivores is indicative of a healthy and trophically diverse fish community (Karr *et al.* 1986). The presence of top carnivores also indicates the availability of instream cover and pool habitat at a sample site (Schleiger 2000). Samples collected by the GAWRD show that top carnivores usually comprise about four to ten percent of the fish population in a healthy, trophically diverse aquatic community. However, at some highly degraded sites the proportion of top carnivores may comprise 20 to 30% of the fish population. To reflect this trend of an over abundance of top carnivores at sites with a degraded aquatic community, the standard trisection method required modification. A pyramid scoring method was developed where an increasing proportion of top carnivores resulted in a higher metric score up to a threshold proportion, beyond which an increase in the proportion of top carnivores resulted in a lower metric score.

Metric 11. Proportion of individuals as benthic fluvial specialists. This metric measures the proportion of the sample that is comprised of individuals that are ranked as benthic fluvial specialists. Benthic fluvial specialists include all species of benthic invertivores (darter, madtoms, and sculpins), round-bodied suckers, and subterminal mouth insectivorous cyprinid species. Benthic fluvial specialists are insectivorous species that forage on the stream bottom for benthic macroinvertebrates and species that may depend on specific benthic substrates for reproduction. An abundance of benthic fluvial specialists at a site is indicative of a diverse aquatic macroinvertebrate community. Many benthic fluvial specialist species reproduce by broadcasting their eggs over the stream bottom where they can develop in the interstices of sand, gravel, and cobble substrates without parental care. Due to their specificity of clean benthic substrates for foraging and reproduction, the proportion of benthic fluvial specialist species assesses the availability of suitable benthic habitat at a site. Bowen *et al.* (1998) found that the proportion of benthic fluvial specialist species was an important indicator of the trophic diversity of the fish community in their study on the flow-regulated portion of the Tallapoosa River in Alabama.

Metrics 12 and 13 evaluate the population density and the condition of the fish community.

Metric 12. Number of individuals collected per 200 meters. This metric evaluates population density as the number of individuals collected, standardized to 200 meters of sample reach. Population density is calculated by dividing the total number of fish collected by the reach length (35 times the mean stream width) and multiplying this value by 200. Environments that have sustained chemical and/or physical degradation generally contain fewer fish. A low abundance of fish is indicative of sites undergoing direct toxic effects or long-term disruptions in the normal trophic relationships of the fish community (Ohio EPA 1987b). However, samples collected by the GAWRD have shown that the effects of impoundments, urbanization, and nutrient enrichment, along with other types of perturbations, may lead to increases in the population of *Lepomis* species in a degraded stream. Therefore, to avoid rewarding degraded sites with a higher metric score for the number of individuals collected, when metric 8 (the proportion of individuals as *Lepomis* species) scores a 1, all individuals of *Lepomis* species are excluded from the calculation of metric 12. Mosquitofish, a pollution tolerant species that can dominate fish samples from highly degraded headwater streams, are also excluded from metric 12, as are hybrids and any non-native species in the sample.

Metric 13. Correction Factor: Proportion of individuals with external anomalies. This metric measures the proportion of individuals in the sample that have deformities, eroded fins, lesions, and/or tumors (DELT anomalies). Bacterial, viral, and fungal infections, neoplastic diseases, and chemical pollution may cause DELT anomalies. A high proportion of individuals with DELT anomalies in a stream is indicative of an environment degraded by chemical pollution, excessive siltation, and overcrowding (Ohio EPA 1987b). A marked correspondence has been documented between the proportion of individuals with DELT anomalies and increasing stream degradation, making this metric useful in identifying impacted areas where other structural indices or metrics (e.g., species richness, CPUE, biomass) may indicate a higher quality environment (Leonard and Orth 1986; Ohio EPA 1987b). The presence of parasites is not included as a DELT anomaly since a consistent relationship has not been established between the incidence of parasitism and environmental degradation (Leonard and Orth 1986; Ohio EPA 1987b; Schleiger 2000). However, DELT anomalies that may have been caused by the presence of parasites are included. Individuals with fin or other external damage due to spawning activity are not included and professional judgment must be used when assessing DELT anomalies during the spawning season (North Carolina DEHNR 1997). Individuals that suffered physical damage due to collecting techniques (e.g., hemorrhaging due to electrofishing) are also excluded from this metric.

Sampling by the GAWRD indicates that a significant proportion of individuals in a sample with DELT anomalies is uncommon in Georgia. Lyons (1992b) found similar results in establishing an IBI for warmwater streams in Wisconsin. He retained the proportion of individuals with DELT anomalies as a metric by using it as a correction factor to the total score at sites that exceeded a maximum allowable proportion of DELT anomalies in the sample. We have incorporated Lyons's usage of the DELT metric as a correction. At sites where the proportion of individuals with DELT anomalies exceed a maximum allowable proportion; four points are subtracted from the total of the previous 12 metrics. At sites where the proportion of individuals with DELT anomalies is less than a maximum allowable proportion, no change is made to the total of the previous 12 metrics. The 90th percentile from plots of the proportion of individuals with DELT anomalies against the log transformed drainage basin area was used to determine the maximum allowable proportion. The 90th percentile has previously been used (Ohio EPA 1987b) to determine the break between scores of 3 and 1 for the DELT metric.

Based on their total IBI score, sample sites are then assigned to one of five integrity classes, ranging from excellent to very poor. A sixth integrity class, no fish, was added for sites where no fish were collected. Integrity classes, along with their appropriate attributes and IBI scoring range, are listed in (Table 3).

Table 3. Total IBI scores, integrity classes, and the attributes of those classes (modified from Karr 1981 and Schleiger 2000).

Total IBI Score (sum of the 13 metric ratings)	Integrity Class	Attributes
60-52	Excellent	Comparable to the best ecoregional reference conditions; all regionally expected species for the habitat and stream size, including the most intolerant species are present with a full array of size classes; significant proportion of the sample composed of benthic fluvial specialist and insectivorous cyprinid species; number of individuals abundant, representing a balanced trophic structure.
50-44	Good	Species richness somewhat below expectation, especially due to the loss of the most intolerant forms; good number of individuals, with several species of suckers, minnows, and benthic invertivores present; trophic structure shows some signs of stress.
42-34	Fair	Species richness declines as some expected species are absent; few, if any, intolerant or headwater intolerant species present; trophic structure skewed toward generalist, herbivorous, and *Lepomis* species as the abundance of insectivorous cyprinid and benthic fluvial specialist species decreases.
32-26	Poor	Sample dominated by generalist, herbivorous, and *Lepomis* species; proportion of non-native species and hybrids increases; intolerant and headwater intolerant species absent; benthic fluvial specialist and insectivorous cyprinid species in low abundance or absent; growth rates and condition factors commonly depressed and diseased fish are often present; number of individuals in low abundance.
24-8	Very Poor	Few fish present, mostly generalist and *Lepomis* species; condition factors poor as unhealthy and juvenile individuals dominate the sample; fish with disease, eroded fins, lesions, and tumors common.
No Fish		No fish collected in the sample.

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Appendix I – GAWRD Data Sheets and Logs

Stream Reconnaissance Equipment List

Clip boards (2)
Pencils (4+)
Backpack
Batteries (8AA, 4c)
Field first aid kit
Flagging spray paint (2 pink, 2 camo)
Rangefinder
Handheld GPS
Depth Staffs (as needed)
Gradient tube and bucket
Stream list/ Sites to Recon
Waders (breathables, boots, rain gear, snake chaps)

Recon data sheets (20)
Pencil sharpener
Calculator (2)
50 m Measuring tape (2)
Flagging tape
Clinometer
Zubat (i.e. limb saw)
YSI (calibrated)
Stadia rod
Cooler
Camera
SARP Culvert Tablet or data sheets

Stream Collection Equipment List (BPEF)

Recon box (1 complete kit)
Backpack Electrofishing units
BPEF batteries
Pigtails and rattails
Formalin box with Formalin
95% ETOH
Seines
Backpacks for gear
Aerators (bubblers or Medusa)
Extra air stones
Fish viewing tanks (large and small)
Waders, gravel guards, felt and rubber boots, belts

Digital camera
County maps

Peterson's field guide
Cooler with ice
Reference collection needs list
Field first aid kit
Rain gear
Snake chaps

Delorme Atlas
Anodes and cathodes
Battery chargers
Dip nets
Fish collection jars
5g Buckets
Sorting buckets in NRS pack
Extra batteries C, D, AA
Genetics kit
YSI (calibrated)
Water quality box / Hach kits
-Turbidimeter -Alkalinity
-pH -Hardness
-Jars (2)
Metal clip boards 3 habitat 1 collection
Glide-pool/riffle-run habitat assessment
Year binder
-Recon reports
-Stream collection reports
-Habitat assessment forms
-Fish Species Characteristics
Go Fish collection list

Stream Collection Equipment List (Barge)

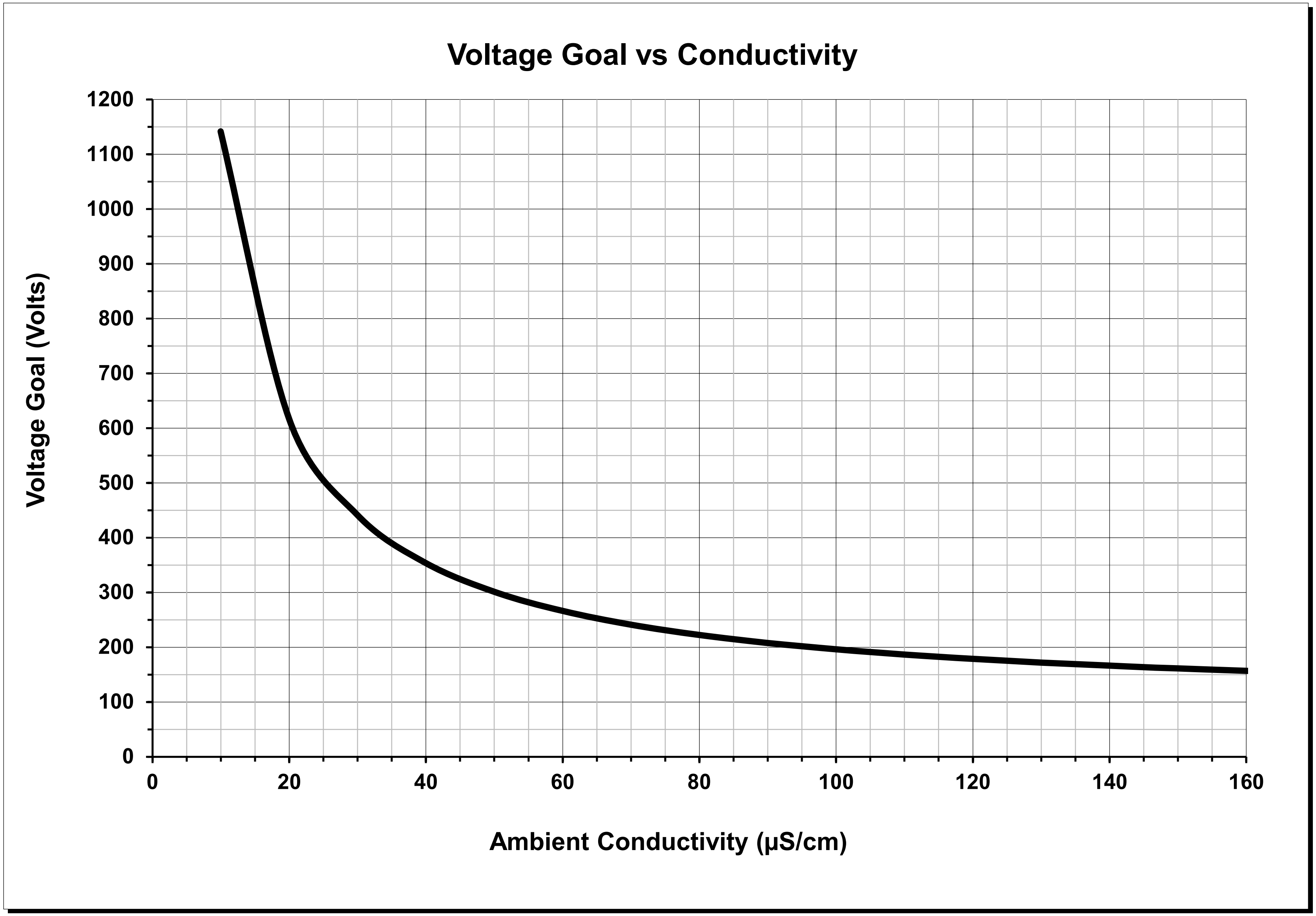
Barge
Generator:
- Spare Gas
- Oil (10W-30)

Pulsator Unit
Holding Container for Fish
Portable Aerators
Formalin
County Maps
Extra Batteries (A & C)
Hanging Scale
Digital Camera
Stream Collection Reports
Copy of Recon Reports
Waders ect
Habitat Assessment Report (3)
Backpacks (2)

BPEF Probes (4):
Extension Cables
Seines (2):
- 10 Foot and 15 Foot

Dipnets (as needed)
Fish Sorting Containers
Collection Jars (3 per site)
Collection Labels
Rubber Gloves
Digital Scale (2)
Water quality box
- Turbidimeter
- Alkalinity
- pH
- Hardness
- Jars (2)

Waist Belts
Metal Clipboards
Fish Species List
Pencil (4+) (w/ Sharpener)


Voltage Goal vs Conductivity
Voltage Goal (Volts)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
20
40
60
80
100
120
140
160
Ambient Conductivity (µS/cm)

Stream Reconnaissance Report

Site ID:	Stream Name:	County:	
Date:	Time:	Ecoregion:	Basin:
Point of Assessment: ______________________________			
GPS ID (accuracy<20ft.):	Lat*:	Long*: --	
GPS Location: ☐ start ☐ end ☐ bridge	Reach Location: ☐ US xing ☐ DS xing ☐ Combination		
☐ QAQC ☐ Pot Ref SP______________________________			
Evaluators:			

H$_2$O Temp (˚C):	DO (mg/L):	SPC (µS):	Salinity (ppt):
# Pools in Reach:	Deepest Pool = __________m		
# Riffles in Reach**:	Riffle Frequency =		
# Bends in Reach**:	Channel Sinuosity =		
Discharge (m^3/s):	Entered CFS :		
Reach Length = Mean Stream Width ________m X 35 = ________m			
Shocker: 1=1BPEF 2=2BPEF 3=3BPEF 4=4BPEF 5= Barge 6= Barge+BPEFs 7= Boat	Seine : Yes / No		

Riparian Zone Impacts	Channel Slope	Total:_______				
☐ Silviculture ☐ Row Crop Agriculture ☐ Animal Production Agriculture ☐ Landfill ☐ Urban / Suburban ☐ Land Application System (LAS) ☐ Land Disturbing Activity (LDA) ☐ Ponds/Lakes/Reservoirs		0-20	20-40	40-60	60-80	80-100
	0-100					
	100-200					
	200-300					
	300-400					
	400-500					

Comments____

____

____

____

____

____

____

____

____

*Latitude and Longitude are recorded as decimal degrees **Riffles above fall line; Bends below fall line

Transects	20m	40m	60m	80m	100m	0-3 MSW
Width	____m	____m	____m	____m	____m	Σwidth______m
Bank full Width	____m	____m	____m	____m	____m	
Bank full Height	____m	____m	____m	____m	____m	
Top Bank	____m	____m	____m	____m	____m	
Bank Angle	____L /____R	____L /____R	____L /____R	____L /____R	____L /____R	
Depth/ Subs USLB M USRB	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	Avg. Width ____________m

Five transects 0 – 100 m from start

Five transects 101 – 200 m from start

Transects	120m	140m	160m	180m	200m	3-6 MSW
Width	____m	____m	____m	____m	____m	Σwidth______m
Bank full Width	____m	____m	____m	____m	____m	
Bank full Height	____m	____m	____m	____m	____m	
Top Bank	____m	____m	____m	____m	____m	
Bank Angle	____L /____R	____L /____R	____L /____R	____L /____R	____L /____R	
Depth/ Subs USLB M USRB	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	Avg. Width ____________m

Five transects 201 – 300 m from start

Transects	220m	240m	260m	280m	300m	6-9 MSW
Width	____m	____m	____m	____m	____m	Σwidth______m
Bank full Width	____m	____m	____m	____m	____m	
Bank full Height	____m	____m	____m	____m	____m	
Top Bank	____m	____m	____m	____m	____m	
Bank Angle	____L /____R	____L /____R	____L /____R	____L /____R	____L /____R	
Depth/ Subs USLB M USRB	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	Avg. Width ____________m

Riffle /Bend Frequency						
Riffle/Bend @ Meter #						

Substrate Type		
Hardpan (Fines, Consolidated)	**H**	
Silt/Clay/Muck (Fines, Not Gritty)	**F**	
Sand (Gritty - up to ladybug size)	**S**	Sand= 0.062-2.0mm
Gravel (ladybug to tennis ball)	**G**	Gravel=2-64mm
Cobble (tennis ball to basketball)	**C**	Cobble=64-256mm
Boulder (basketball to car)	**B**	Boulder=256-4096mm
Bedrock (larger than a car)	**R**	
Woody Debris	**W**	Must be stable
Leaves	**L**	Must be stable

Five transects 301 – 400 m from start

Transects		320m	340m	360m	380m	400m	9-12 MSW
Width		____m	____m	____m	____m	____m	Σwidth______m
Bank full Width		____m	____m	____m	____m	____m	
Bank full Height		____m	____m	____m	____m	____m	
Top Bank		____m	____m	____m	____m	____m	
Bank Angle		____L /____R	____L /____R	____L /____R	____L /____R	____L /____R	
Depth/ Subs	USLB M USRB	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	Avg. Width ____________m

Five transects 401 – 500 m from start

Transects		420m	440m	460m	480m	500m	12-15 MSW
Width		____m	____m	____m	____m	____m	Σwidth______m
Bank full Width		____m	____m	____m	____m	____m	
Bank full Height		____m	____m	____m	____m	____m	
Top Bank		____m	____m	____m	____m	____m	
Bank Angle		____L /____R	____L /____R	____L /____R	____L /____R	____L /____R	
Depth/ Subs	USLB M USRB	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	____m/____ ____m/____ ____m/____	Avg. Width ____________m

Stream Collection Report

Site ID:	Stream Name:	County:	
Date:	Time:	Ecoregion:	Basin:
Collectors:			
Photo(s):			

Water Quality

Water Temp (°C):	D.O. (mg/L):	SPC (µS):					Salinity (ppt):
pH:	Total Hardness (ppm):	Channel Slope Total:_______					
Discharge (cfs):	Turbidity (NTU):		0-20	20-40	40-60	60-80	80-100
Alkalinity (ppm):		0-100					
Comments:		100-200					
		200-300					
		300-400					
		400-500					

Electrofisher

BPEF Barge (sec): 1_________ 2_________ 3_________ 4_________ 5________	Σsec:

Species List

Total	# Kept	Species	Abundance	DELTs

Total	# Kept	Species	Abundance	DELTs

DELTs List

Abbr.	DELT	Abbr.	DELT	Abbr.	DELT	Abbr.	DELT
D	Deformities	**AW**	Anchor Worm	**BL**	Blind	**E**	Emaciated
EF	Eroded Fins	**LE**	Leeches	**F**	Fungus		
L	Lesions	**EX**	Pop-Eye	**I**	Ich		
BS	Black Spot	**T**	Tumors	**WP**	White Parasite		

Threatened and Endangered Species Mortality Log

Species	Mortalities	Comments

Site No.

Data Sheet	Entered By	Date		QAQC1	Date		QAQC2	Date
Master Form Data								
Recon Data								
Gradient								
Transect Data								
RF/Sin Calc.								
Field Data								
Shock Time								
Habitat Data								
Fish Data								
Fish #								

Comments:

GAWRD Sample Tracking Log

Site ID	Stream Name	Basin	County	Ecoregion	Recon Date	Sample Date	Sample Retained (yes/no)	Sample Type (PS / NPS / QAQC Reference / Other)

Appendix II – Habitat Assessments

Riffle-Run Habitat Assessment

Site ID:	Date:
Stream Name:	
Assessor:	

Habitat Parameter	Score	Notes									
Epifaunal Substrate/ Instream Cover		LWD	DP	SP	OS	LR	UB	TRM	DMB	DR	RU
Embeddedness											
Velocity/ Depth Combinations											
Channel Alteration											
Sediment Deposition											
Riffle Frequency											
Channel Flow Status											
Bank Vegetative Protection Left Bank Right Bank	LB RB										
Bank Stability Left Bank Right Bank	LB RB										
Riparian Vegetative Zone Left Bank Right Bank	LB RB										
Field Total →											
Final Score											

1. Epifaunal Cover / Instream Cover

Measures the amount of substrates that are available as cover for aquatic organisms. A wide variety and/or abundance of submerged structures in the stream provide fish and macroinvertebrates with many niches, thus increasing the habitat diversity. As the variety and abundance of cover decreases, habitat structure becomes monotonous, diversity decreases, and the potential for recovery following disturbance decreases. Riffles and runs offer a variety of substrate sizes and flows and provide the most stable habitat in high-gradient streams. **Possible Habitat Types:** Fallen Trees / Large Woody Debris (**LWD**), Shallow Pools > 0.5 m (**SP**), Deep Pools > 1.0 m, Overhanging Shrubbery in water (**OS**), Large Rocks (**LR**), Undercut Banks (**UB**), Thick Root Mats (**TRM**), Dense Macrophyte Beds (**DMB**), Deep Riffles (**DR**), Long Runs with Cobble / Large Rock Substrate (**RU**)

A. Stable and available habitats expected for stream type make up > 70% of reach. Stream exhibits a well developed riffle-run complex.
   1. **Seven** habitat types common; stable substrate dominated by softball size cobble and boulder stones……………………………………………….**20**
   2. **Five** habitat types common, additional habitat types rare; stable substrate dominated by boulder stones………………………………………….…**18**
   3. Less than **four** habitat types present, stable substrate dominated by gravel stones and boulders/bedrock and/or stable woody debris…………………..**16**

B. Stable and available habitats expected for stream type make up 40-70% of reach.
   1. **Seven** habitat types common; stable substrate dominated by softball size cobble and boulder stones…………………………………………………**15**
   2. **Five** habitat types common, additional habitat types rare; stable substrate dominated by gravel and boulder stones...… ..…………………..**13**
   3. Less than **four** habitat types present; stable substrate dominated by gravel stones and boulders/bedrock and/or stable woody debris…………..**11**

C. Stable and available habitats expected for stream type make up 20-40% of reach.
   1. **Seven** habitat types common; stable substrate dominated by softball size cobble and boulder stones……………………………………….…**10**
   2. **Five** habitat types common, additional habitat types rare; stable substrate dominated by gravel and boulder stones…………..……………..**8**
   3. Less than **four** habitat types present, stable substrate dominated by gravel stones and boulders/bedrock and/or stable woody debris…………....**6**

D. Stable and available habitats expected for stream type make up < 20% of reach. Riffles or runs are virtually nonexistent, no cobble substrate.
   1. **Two** habitat types common, additional habitat types rare; substrate dominated by gravel and sand/silt, short runs……………………………..**4**
   2. **Two** habitat types only; substrate dominated by gravel and sand/silt, short runs……………………………………………………………………..**3**
   3. **One** habitat type common, additional habitat types rare; substrate . dominated by small gravel and sand/silt with short runs, no riffles………...**2**
   4. **One** habitat type only; substrate dominated by small gravel and sand/silt with short runs, no riffles……………………………………………..…**1**
   5. **No** habitat types present; substrate dominated by sand/silt with no runs…….**0**

2. Embeddedness in Run Areas

Measures the degree to which cobble, boulders, and other rock substrates are surrounded by **fine** sediment and silt. Embeddedness relates directly to the suitability of the stream substrate as habitat for macroinvertebrates and for fish spawning and egg incubation.

Fine sediments range from 0.062mm to 2mm in size. Silt particles measure less than 0.062mm. Sediment and silt particles smaller than 2mm can be distinguished using "texture by feel techniques" employed in soil surveys.

A. Little or no embeddedness present by fine sediment and/or silt surrounding and covering rocks.
   1. < 10% embeddedness……………………………………………..…**20**
   2. 10% embeddedness by sediment………………………………..……**19**
   3. 10% embeddedness by sediment and silt……………………..…...**18**
   4. 20% embeddedness by sediment…………………………………..…**17**
   5. 20% embeddedness by sediment and silt……………………..…...**16**

B. Fine sediment and silt surrounds and fills 25 – 50 % of the living spaces around and in between gravel, cobble, and boulders.
   1. 30% embeddedness by sediment……………………………….……**15**
   2. 30% embeddedness by sediment and silt…………………………....**14**
   3. 40% embeddedness by sediment………………………….……....**13**
   4. 40% embeddedness by sediment and silt…………………………..…**12**
   5. 50% embeddedness by sediment……………………………………..**11**

C. Fine sediment and silt surrounds and fills 50 - 75 % of the living spaces around and in between gravel, cobble, and boulders.
   1. 50% embeddedness by sediment and silt……………………………**10**
   2. 60% embeddedness by sediment…………………………………....**9**
   3. 60% embeddedness by sediment and silt…………………………...**8**
   4. 70% embeddedness by sediment…………………………………....**7**
   5. 70% embeddedness by sediment and silt…………………………...**6**

D. Fine sediment and silt surrounds and fills more than 75 % of the living spaces around and in between gravel, cobble, and boulders.
   1. 80% embeddedness by sediment……………………………………...**5**
   2. 80% embeddedness by sediment and/or silt………………………...**4**
   3. 90% embeddedness by sediment……………………………………...**3**
   4. 90% embeddedness by sediment and/or silt ………………………..**2**
   5. 100% embeddedness by sediment………..……………………………**1**
   6. 100% embeddedness by sediment and/or silt..………………………..**0**

3. Velocity / Depth Combinations

Measures a stream's characteristic velocity/depth regime. Patterns of velocity and depth are included for high-gradient streams as an important feature of habitat diversity. There are four combinations of velocity and depth that are characteristic of high quality riffle/run prevalent streams. These are: (1) slow-deep, (2) slow-shallow, (3) fast-deep, and (4) fast-shallow. The depth criterion used to distinguish shallow from deep is 0.5 meter; the velocity criterion used to distinguish slow from fast is 0.3 m/sec. The occurrence of these four patterns relates to a stream's ability to provide and maintain a stable aquatic environment.

A. A complex stream system that exhibits a heterogeneous combination of all velocity/depth patterns.
   1. All **four** velocity/depth patterns are present…..…………………………… **20**
   2. All patterns present, but one may not be well defined………….……….. ..**18**
   3. All patterns present, but more than one may not be well defined…………..**16**

B. Stream is less heterogeneous, displaying fewer of the velocity/depth patterns.
   1. Only **three** of the four velocity/depth patterns are present…………………**15**
   2. **Three** of the four patterns are present, but one may not be well defined... ...**13**
   3. **Three** of the four patterns are present, but more than one may not be well defined...……………………………………………………………….….**11**

C. Stream becomes more homogeneous. Sediment deposition and/or channel alteration is resulting in the loss of certain velocity/depth patterns.
   1. Only **two** of the four velocity/depth patterns are present……………………**10**
   2. **Two** of the four patterns are present, but one is not be well defined..……….**8**
   3. The fast-shallow of the shallow regime is missing………………………..….**6**

D. A simple stream system that is heavily affected by the restriction of water flow due to sediment deposition and/or channel alteration, resulting in a monotonous velocity/depth pattern.
   1. Only **one** of the four velocity/depth patterns is present, usually dominated by the slow-deep pattern……………….……………………………………….…….**5**
   2. Stream heavily affected by sediment; very little if any flow, dominated by the slow-shallow pattern………………………………………………………**3**
   3. No flow regime present; stream nearly dry or pooled up ...……………..…...**0**

4. Channel Alteration

Measures any large-scale alteration in stream morphology that affects flow, instream habitat, and/or sedimentation rates. Channel alteration is present when artificial embankments, riprap, and other forms of artificial bank stabilization or structures are present; when the stream is very straight for significant distances due to dredging activities; when dams, culverts, or bridges are present; or when other morphological changes have occurred.

A. Stream flows a normal and natural meandering pattern with a well developed riffle/run complex. Alteration is absent.
   1. No evidence of disturbance; riffles as wide as the stream and extend twice the stream width; stable substrate dominated by cobble, boulders and/or bedrock……………………………………………………………...**20**
   2. No evidence of disturbance; riffles as wide as stream but do not extend twice the stream width; stable substrate of cobble, boulder and/or bedrock………………………………………………………………**18**
   3. No evidence of disturbance; riffles not as wide as the stream……………**16**

B. Some stream straightening, dredging, artificial embankments, or dams present but NO evidence of recent alteration activities. Alteration probably occurred more than 20 years ago. Stream appears to be in the process of recovery.
   1. Less than 10% of reach has channel disturbance……………………….....**15**
   2. 10% of reach has channel disturbance….………………………………**14**
   3. 10% - 20% of reach has channel disturbance……..…..……………...…**13**
   4. 20% - 30% of reach has channel disturbance...………………………...**12**
   5. 30% - 40% of reach has channel disturbance..…...………………………**11**

C. 40 to 80% of the stream reach has been altered or channelized. Alteration may have occurred less than 20 years ago.
   1. 40% - 50% of reach has channel disturbance..……………………………**10**
   2. 50% - 60% of reach has channel disturbance…..…..……………………….**9**
   3. 60% - 70% of reach has channel disturbance..……….………………….**8**
   4. 70% - 80% of reach has channel disturbance..……….…………………….**7**
   5. 80% - 90% of reach has channel disturbance…..…………...………………**6**

D. Instream habitat highly altered. More than 80% of the stream reach has been altered. Alteration may be recent (<10 years).
   1. >90 % of reach has channel disturbance…………..……………………….**5**
   2. Channel reach 100% disturbed; straight with no artificial embankments……………………………………………………...**3**
   3. Channel reach 100% disturbed; straight with some artificial embankments……………………………………………………...**1**
   4. Banks 100% shored by gabion, cement, and/or riprap....…………………...**0**

5. Sediment Deposition

Relates to the amount of sediment that has accumulated and the changes that have occurred to the stream bottom as a result of deposition. Sediment deposition may cause the formation of islands, point bars (areas of increased deposition usually along the inner bank of a meander that increase in size as the channel is diverted toward the outer bank) or shoals, or result in the filling of pools and runs. High levels of sediment deposition are symptoms of an unstable environment that may be unsuitable for many organisms.

A. No enlargements of islands/point bars present; <20% of the stream bottom affected by gravel or sand accumulation.
   1. No deposition detected, especially in pool habitats……………………….**20**
   2. <10% sediment deposition with accumulation in pools only………..…..…..**19**
   3. <10% sediment deposition with accumulation in pools and runs only……**18**
   4. 10% - 20% sediment deposition with gravel and/or coarse sand ………...**17**
   5. 10% - 20% sediment deposition with fine sand and/or silt ……….………**16**

B. 20% - 40% of the stream bottom affected by gravel, sand, and/or silt accumulation; increased deposition in pools and runs; some new increase in bar and island formation.
   1. 20% - 30% sediment deposition with gravel and/or coarse sand…...… …**15**
   2. 20% - 30% sediment deposition with fine sand and/or silt…………..……**14**
   3. 30% - 40% sediment deposition with gravel and/or coarse sand……....…**12**
   4. 30% - 40% sediment deposition with fine sand and/or silt……………..…**11**

C. 40% - 60% of the stream bottom affected with increased deposition in pools. Number of shallow pools increases. Runs and riffles highly impacted by sand, silt, and fine gravel. Recent deposits of gravel, sand, and silt observed on old and new point bars, islands, and behind obstructions. Formation of few new bars/islands is evident and old bars are deep and wide; deposition at bends obvious.
   1. 40% - 50% sediment deposition with gravel and/or coarse sand…..……...**10**
   2. 40% - 50% sediment deposition with fine sand and/or silt……….....……....**9**
   3. 50% - 60% sediment deposition with gravel and/or coarse sand…..……....**8**
   4. 50% - 60% sediment deposition with fine sand and/or silt……..………....**7**

D. >60% of the stream bottom affected with heavy deposition from fine gravel and sand at stream bends, obstructions, and/or pools. Extensive deposits of fine sand and/or silt on old and new bars, islands, and along banks in straight channels. Riffle and pool habitats are reduced or absent due to substantial deposition.
   1. 60% - 70% sediment deposition with gravel and/or coarse sand.……..……**5**
   2. 60% - 70% sediment deposition with fine sand and/or silt……..………...…**4**
   3. 70% - 80% sediment deposition with gravel and/or coarse sand…………..**3**
   5. >80% sediment deposition with gravel and/or coarse sand………………...**1**
   6. >80% sediment deposition with fine sand and/silt……………………..……**0**

6. Riffle Frequency

Estimates the frequency of occurrence of riffles and thus the heterogeneity occurring in a stream. Riffles are a source of high-quality habitat and diverse fauna; therefore, an increased frequency of occurrence greatly enhances the diversity of the stream community. In some streams, a longer reach than that designated for sampling may need to be evaluated to adequately score this metric.

Riffle Frequency = Mean Distance Between Riffles / Mean Stream Width

Riffle frequency is determined during stream reconnaissance.

A. Occurrence of riffles relatively frequent. Deep pools may be present and riffles are deep enough to allow passage of fish.
   1. Riffles are continuous; run-to-riffle ratio = 1-2…………………...……**20**
   2. Run-to-riffle ratio = 3-4………………………………………………..…**19**
   3. Run-to-riffle ratio = 5…………………………………………………..…**18**
   4. Run-to-riffle ratio = 6……………………………………………………..**17**
   5. Run-to-riffle ratio = 7…………………………………………………..…**16**

B. Occurrence of riffles less frequent; adequate depth in pools and riffles.
   1. Run-to-riffle ratio = 8……………………………………………………..**15**
   2. Run-to-riffle ratio = 9...………………………. ……...………………...**14**
   3. Run-to-riffle ratio = 10…………………………………...…………….**13**
   4. Run-to-riffle ratio = 12………………………………………………….**12**
   5. Run-to-riffle ratio = 14………………………………………………….**11**

C. Occasional riffle; variable bottom contours may provide some habitat.
   1. Run-to-riffle ratio = 16………………………………………………….**10**
   2. Run-to-riffle ratio = 18…………………………………………………...**9**
   3. Run-to-riffle ratio = 20…………………………………………………...**8**
   4. Run-to-riffle ratio = 22……………………………………………….....…**7**
   5. Run-to-riffle ratio = 24…………………………………………………...**6**

D. Generally all flat water; any riffles present will be shallow; essentially a straight and uniform stream depth; riffles are not deep enough to provide free passage for fish.
   1. Run-to-riffle ratio = 25…………………………………………………...**4**
   2. Run-to-riffle ratio = 26 – 30……………………………………………...**3**
   3. Run-to-riffle ratio > 30 with some shallow riffles and short runs.…………**2**
   4. No riffles present within stream reach……………….………………..……**0**

7. Channel Flow Status

Evaluates the degree to which the channel is filled with water when the stream reach is sampled. The flow status will change as the channel enlarges or as flow decreases due to dams and other obstructions, diversion for irrigation, drought, or aggrading stream bottoms with actively widening channels. This is a seasonal parameter. A decrease in water will wet smaller portions of the streambed, thus decreasing available habitat for aquatic organisms. Use the vegetation line on the lower bank as your reference point to estimate channel flow status.

A. Water reaches the base of both lower banks and minimal amount of channel substrate is exposed.
   1. 100% of channel is full……………………………………………………**20**
   2. > 90% of channel is full…………………………………………………...**18**

B. Water fills > 50% of the available channel (or < 50% of channel substrate is exposed).
   1. 80% - 90% of channel is full ……………………………………………..**17**
   2. 70% - 80% of channel is full ……………………………………………..**15**
   3. 60% - 70% of channel is full ……………………………………………..**13**
   4. 50% - 60% of channel is full ……………………………………………..**11**

C. Water fills 20% - 50% of the available channel and/or riffle substrates are mostly exposed.
   1. 40% - 50% of channel is full.………………………………………………**9**
   2. 30% - 40% of channel is full ………………………………………………**7**
   3. 20% - 30% of channel is full.…………………………………………….. .**5**

D. Very little water in the channel and mostly present as standing pools
   1. 10% - 20% of channel is full ………………………………………………**3**
   2. < 10% of channel is full ……………………………………………………**2**
   3. Water present as isolated standing pools…………………………………...**1**
   4. Channel is dry………………………………………………………………...**0**

8. Bank Vegetative Protection

Measures the amount of the stream bank that is covered by vegetation. This parameter supplies information on the ability of the bank to resist erosion as well as some additional information on the uptake of nutrients by the plants, the control of instream scouring, and stream shading. Banks that have full, natural plant growth are better for fish and macroinvertebrates than are banks without vegetation protection or those shored up with concrete or riprap.

Four factors to consider when scoring bank vegetative protection: (1) Is the vegetation native or introduced? (2) Is the vegetation planted or natural? (3) Is the upper story, understory, and ground cover vegetation well balanced? (4) During which season are you conducting this assessment?

Determine left or right bank by facing downstream. Score banks separately.

A. More than 90% of the stream bank surface is covered by healthy, living vegetation. A variety of different types of vegetation is present (e.g. trees, shrubs, understory, and nonwoody macrophytes). Any bare or sparsely vegetated areas are small and evenly dispersed.
   1. 100% plant cover on stream bank……...…………………………...………..**10**
   2. >90% plant cover on stream bank...…………………………………...………**9**

B. A variety of vegetation is present and covers 70 - 90% of stream bank surfaces, but one class of plants is not well represented. Some open areas with unstable substrate are present. Disruption evident but not affecting full plant growth potential. Few barren or thin areas are present.
   1. 90% plant cover on stream bank.....………………………………………...…**8**
   2. 80% - 90% plant cover on stream bank……………………………….……....**7**
   3. 70% - 80% plant cover on stream bank with fewer plant species…….…….**6**

C. 50 - 70% of stream bank surface is covered by vegetation; typically composed of scattered shrubs, grasses, and forbes. Disruption obvious, with patches of bare soil and/or closely cropped vegetation common.
   1. 60% - 70% vegetation cover; typically of shrubs, grasses, and forbes……..**5**
   2. 50% - 60% vegetation cover; typically of shrubs, grasses, and forbes……..**4**

D. Less than 50% of the stream bank surface covered by vegetation. Disruption of vegetation is prevalent. Any shrubs or trees on bank exist as individuals or widely scattered clumps.
   1. 40% - 50% vegetation cover with many bare spots/rock…………….. ……**3**
   2. 30% - 40% vegetation cover with many bare spots/rock…….……..………**2**
   3. 20% - 30% vegetation cover with many bare spots/rock….………..………**1**
   4. < 20% vegetation cover…………………………………………………….…**0**

9. Bank Stability

Measures whether the stream banks are eroded or have the potential for erosion. Steep banks are more likely to collapse and suffer from erosion than gently sloping banks and are therefore considered to be unstable. Signs of erosion include crumbling, unvegetated banks, exposed tree roots, and exposed soil. Eroding banks cause sediment deposition and may reduce instream cover.

Determine left or right bank by facing downstream. Score banks separately.

A. Bank stable; erosion absent or minimal, with little potential for future problems. Slopes are generally less than 30º. Banks may be reinforced by rock thus increasing the slope to >30º while providing stability.
   1. No evidence of erosion or bank failure……………………………………**10**
   2. Less than 10% of bank affected by erosion……………………..……….**9**

B. Moderately stable bank; small areas of erosion or bank slumping visible. Most areas are stable with only slight potential for erosion at flood stages. Slopes up to 40º. Banks may be reinforced by rock thus increasing the slope to >40º while providing stability.
   1. 10% - 20% of bank has erosional areas…………….……………………..**8**
   2. 20% - 30% of bank has erosional areas……………………………………**7**
   3. 30% - 40% of bank has erosional areas……………………………………**6**

C. Moderately unstable bank; frequency and size of raw areas are such that high water events have eroded some areas of the bank. Medium size areas of erosion or bank slumping visible. Slopes up to 60º. High erosion potential during floods.
   1. 40% - 50% of bank has erosional areas…………………………………….**5**
   2. 50% - 60% of bank has erosional areas…………………………………….**4**
   3. 60% - 70% of bank has erosional areas…………………………………….**3**

D. Unstable bank; mass erosion and bank failure are evident; erosion and pronounced undercutting present at bends and along some straight channel areas. Slopes > 60º are common. Areas of distinct slumping visible. Many raw areas are present and 70% – 100% of bank has erosional scars.
   1. 70% - 80% of bank has erosional areas…………………………………….**2**
   2. 80% - 90% of bank has erosional areas…………………………………….**1**
   3. >90% of bank has erosional areas……………………….…………………**0**

10. Riparian Vegetation Zone Width

Measures the width of natural vegetation from the edge of the upper stream bank out through the floodplain. The riparian vegetative zone serves as a buffer zone to pollutants entering a stream from runoff; controls erosion; and provides habitat and nutrients to the stream. Narrow, far less useful zones occur when roads, parking lots, fields (currently in use), heavily used paths, lawns, bare soil, rocks, or buildings are near the stream bank. When evaluating this metric, look for breaks in the riparian zone that allow sediment to pass through the zone.

Human activities that impact the riparian zone include: Parking Lots (**PL**), Paved Roads (**PR**), Dirt Roads (**DR**), Row Crop Agriculture (**RCA**), Animal Production Agriculture (**APA**), Silviculture (**S**), Residential Activities (**RA**), and Commercial/Industrial Activities (**CIA**)

Determine left or right bank by facing downstream. Score banks separately.

A. Width of riparian vegetation zone > 18 m (> 60'). Human activities have not impacted the zone.
   1. With no breaks……………………………………...…………………..**10**
   2. With breaks; breaks are narrow and widely spaced…..……………………**9**

B. Width of riparian vegetation zone 12 – 18 m (40 – 60'). Human activities have impacted the zone only minimally.
   1. With no breaks……………………………...……………………………**8**
   2. With breaks ………………………………... …………………………**7**

C. Width of riparian vegetation zone 6 – 12 m (20 – 40'). Human activities have impacted the zone a great deal.
   1. With no breaks…………………………...……………………………**6**
   2. With narrow breaks widely spaced…………………………………………**5**
   3. With breaks common throughout riparian zone…………….……….…..**4**

D. Width of riparian zone < 6 m (<20'). Little or no riparian vegetation due to human activities.
   1. Riparian vegetation zone less than 20' wide with no breaks…………..…..**3**
   2. Riparian vegetation zone less than 20' wide with breaks……………………**2**
   3. No riparian vegetation zone present. Canopy cleared to the edge of the stream bank. Surrounding area covered with grass/pasture…………………**1**
   4. Riparian vegetation zone absent. Vegetation cleared to the edge of the stream bank and the surrounding area is covered with pavement, concrete or some other artificial covering……………………………………………**0**

Glide-Pool Habitat Assessment

Site ID:	Date:
Stream Name:	
Assessor:	

Habitat Parameter	Score	Notes									
Bottom Substrate / Available Cover		LWD	DP	SP	OS	LR	UB	TRM	DMB	DR	RU
Pool Substrate Characterization											
Pool Variability											
Channel Alteration											
Sediment Deposition											
Channel Sinuosity											
Channel Flow Status											
Bank Vegetative Protection Left Bank Right Bank	LB RB										
Bank Stability Left Bank Right Bank	LB RB										
Riparian Vegetative Zone Left Bank Right Bank	LB RB										
Field Total→											
Final Score											

1. Bottom Substrate / Available Cover

Measures availability of substrates that can be used as refugia for aquatic organisms. A wide variety and/or abundance of submerged structures in the stream provide macroinvertebrates w/ a large number of niches, thus increasing the diversity of the aquatic community. As the variety and abundance of cover decreases, habitat structure becomes monotonous, diversity decreases, and the potential for recovery following disturbance decreases.

Possible Habitat Types:
Fallen Trees / Large Woody Debris (**LWD**), Deep Pools (**DP**), Shallow Pools (**SP**), Overhanging Shrubbery in stream (**OS**), Large Rocks (**LR**), Undercut Banks (**UB**), Thick Root Mats (**TRM**), Dense Macrophyte Beds (**DMB**), Deep Riffles with lots of turbulence (**DR**), Long Runs with cobble / large rock substrate (**RU**)

A. Stable and available habitats make up > 70% of reach
1. **Seven** habitat types common…………………………………………….....**20**
2. **Six** habitat types common, additional habitat types rare…………………..**19**
3. **Five** habitat types common, additional habitat types rare………………….**18**
4. **Four** habitat types common, additional habitat types rare…………………**17**
5. Less than **four** habitat types present……………………………………..**16**

B. Stable and available habitats make up > 50% of reach
1. **Seven** habitat types common……………………………………………...**15**
2. **Six** habitat types common, additional habitat types rare…………………..**14**
3. **Five** habitat types common, additional habitat types rare………………….**13**
4. **Four** habitat types common, additional habitat types rare…………………**12**
5. Less than **four** habitat types present……………………………………..**11**

C. Stable and available habitats make up < 50% of reach
1. **Seven** habitat types common……………………………………………….**10**
2. **Six** habitat types common, additional habitat types rare……………………**9**
3. **Five** habitat types common, additional habitat types rare…………………..**8**
4. **Four** habitat types common, additional habitat types rare…………………..**7**
5. **Three** habitat types common, additional habitat types rare…………………**6**

D. Two habitats or less common
1. **Two** habitat types common, additional habitat types rare…….……………**5**
2. **Two** habitat types only and common……………………………………..**4**
3. **One** habitat type common, additional habitat types rare……………………**3**
4. **One** habitat type only and common………………………………………**2**
5. **One** habitat type rare……………………………………………………...**1**
6. **No** available habitat in the reach……………………………………………**0**

2. Pool Substrate Characterization

Evaluates the type and condition of bottom substrates found in pools. Firmer sediments and rooted aquatic plants support a wider variety of organisms than a pool substrate dominated by mud or bedrock and no plants

A. A mixture of predominately firm substrate material, including gravel and firm sand; root mats and/or submerged vegetation common. Substrate consists of:
1. Gravel, firm sand, root mats, and/or submerge vegetation……………......**20**
2. Gravel, root mats, and/or submerged vegetation…………………………**19**
3. Firm sand, root mats and/or submerge vegetation………………………..**18**

B. A heterogeneous mixture of soft substrates, including soft sand, mud, or clay; root mats and/or submerged vegetation present. Substrate consists of:
1. Soft sand, mud, clay, root mats, and/or submerged vegetation…………...**15**
2. Soft sand, mud, root mats, and/or submerged vegetation…………………**14**
3. Soft sand, clay, root mats, and/or submerged vegetation…………………**12**
4. Clay, mud, root mats, and/or submerged vegetation……………………...**11**

C. Homogeneous substrate consisting of sand, mud, or clay; root mats sparse; submerged vegetation lacking. Substrate consists of:
1. All sand bottom with few root mats………………………………………**10**
2. All mud bottom with few root mats…………………………………….....**8**
3. All clay bottom with few root mats………………………..…………...**6**

D. Homogeneous substrate consisting of sand, mud, clay, or bedrock with no root material. Substrate consists of:
1. All sand bottom with no root material……………………………………...**5**
2. All mud bottom with no root material……………………………………...**3**
3. All clay bottom with no root material………………………………………**1**
4. All bedrock or hardpan clay bottom………………………………………..**0**

3. Pool Variability

Rates the overall mixture of pool types according to size and depth. Increased pool variability in a stream accommodates a diverse aquatic community consisting of a variety of species and age classes. In streams with low sinuosity and monotonous pool characteristics, very little instream habitat variety exists to support a diverse community. The four basic types of pools are **large-shallow, large-deep, small-shallow, and small-deep**. Any pool dimension greater than half the width of the stream is a large pool. Small pools have length and width dimensions less than half the width of the stream. Pools with depths greater than 1.0m are considered to be deep pools. Shallow pools are 0.5m to 1.0m deep. Aeration occurs at any area where the stream surface is broken (e.g. dams, water falling over woody debris, riffles).

A. All pool sizes (area and depth) present and mixed.
1. All sizes evenly mixed and below areas of aeration ……………………..**20**
2. All sizes evenly mixed; found below and above aeration areas …………**18**
3. All sizes evenly mixed above areas of aeration or aeration lacking ……..**16**

B. Majority of pools are deep; very few shallow pools present.
1. Large and small deep pools evenly mixed and below areas of aeration…..**15**
2. Majority of pools are large-deep and below areas of aeration ..…...……..**14**
3. Large and small deep pools evenly mixed above and below areas of aeration ……………………...…………………………………….....**13**
4. Majority of pools are large-deep; found above and below areas of a aeration ……………...…………………….………………………………**12**
5. Majority of pools are large-deep above areas of aeration or aeration lacking………………………………………………………………..**11**

C. Shallow pools are more prevalent than deep pools.
1. Large and small shallow pools evenly mixed and all below areas of aeration ...…………………………..…………………………………..**10**
2. Majority of pools are large-shallow and below areas of aeration ...……….**9**
3. Large and small shallow pools evenly mixed above and below areas of aeration ………………………………….…………………………….…**8**
4. Majority of pools are large-shallow and found above and below areas of aeration …………………………………………………………….……**7**
5. Majority of pools are large-shallow above areas of aeration or aeration lacking ..……………………………………………………………….**6**

D. Majority of pools small-shallow or pools absent.
1. Majority of pools are small-shallow and below areas of aeration …………**5**
2. Majority of pools are small-shallow above and below aeration areas ……..**4**
3. Majority of pools are small-shallow above areas of aeration or aeration lacking ..….…………………………………………………………...**2**
4. Pools absent from sample reach……………………..……………………...**0**

4. Channel Alteration

Measures any large-scale alteration of instream habitat that affects stream sinuosity and causes scouring. Channel alteration is present when artificial embankments, riprap, and other forms of artificial bank stabilization or structures are present; when the stream is very straight for significant distances due to dredging activities; when dams, culverts, or bridges are present; or when other morphological changes have occurred.

A. Stream flows a normal and natural meandering pattern. Alteration is absent.
1. No evidence of disturbance with bends/runs frequent; bend angles average >60°.. . ……………………………………………...…**20**
2. No evidence of disturbance with bends/runs frequent; bend angles average 40° - 60°…………………………………………….**18**
3. No evidence of disturbance with bends/runs frequent; bend angles average <40°……………………………...……………..…**16**

B. Some stream straightening, dredging, artificial embankments, or dams present but NO evidence of recent alteration activities. Alteration probably occurred more than 20 years ago. Stream appears to be in the process of recovery.
1. Less than 20% of reach has channel disturbance……………………….…**15**
2. 20% - 40% of reach has channel disturbance…..………………..…………**14**
3. 40% - 60% of reach has channel disturbance………..………………...…**13**
4. 60% - 80% of reach has channel disturbance...…………………………...**12**
5. 80% - 100% of reach has channel disturbance...…..……………………..…**11**

C. Stream has been altered or channelized. Alteration probably occurred less than 20 years ago.
1. Less than 20% of reach has channel disturbance…………...…………..……**10**
2. 20% - 40% of reach has channel disturbance…..…..…………………………..**9**
3. 40% - 60% of reach has channel disturbance...……….……………………..**8**
4. 60% - 80% of reach has channel disturbance...…………….……………….…..**7**
5. 80% - 100% of reach has channel disturbance...…..………...……………**6**

D. Instream habitat highly altered. More than 80% of the stream reach has been altered. Alteration may be recent (<10 years).
1. >90 % of reach has channel disturbance…………...……………………….…….**5**
2. Channel reach 100% disturbed; straight with no artificial embankments…………………………………………………….…...**3**
3. Channel reach 100% disturbed; straight with some artificial embankments…………………………………………………….…...**1**
4. Banks 100% shored by gabion, cement, and/or riprap....…………………...**0**

5. Sediment Deposition

Relates to the amount of sediment that has accumulated and the changes that have occurred to the stream bottom as a result of deposition. Sediment deposition may cause the formation of islands, point bars (areas of increased deposition usually at the beginning of a meander that increase in size as the channel is diverted toward the outer bank) or shoals, or results in the filling of pools and runs. High levels of sediment deposition are symptoms of an unstable environment that may be unsuitable for many organisms.

A. No enlargements of islands/point bars present; <30% of the stream bottom affected by sand or silt accumulation.
   1. <20% sediment deposition with accumulation in pools only……..……….**20**
   2. <20% sediment deposition with accumulation in pools only……………..**19**
   3. 20% - 30% sediment deposition with gravel and/or coarse sand…………**18**
   4. 20% - 30% sediment deposition with fine sand and/or silt……..…………**17**

B. 30% - 60% of the stream bottom affected by sand and/or silt accumulation; increased deposition in pools and runs; some new increase in bar and island formation.
   1. 30% - 40% sediment deposition with gravel and/or coarse sand....…..……**15**
   2. 30% - 40% sediment deposition with fine sand and/or silt.….……………**14**
   3. 40% - 50% sediment deposition with gravel and/or coarse sand..………...**13**
   4. 40% - 50% sediment deposition with fine sand and/or silt……..……..……**12**
   5. 50% - 60% sediment deposition with gravel and/or coarse sand……..……**11**

C. 60% - 80% of the stream bottom affected with increased deposition in pools. Number of shallow pools increases. Instream habitats smothered by sand, silt, and fine gravel. Deposits of gravel, sand and silt observed on old and new point bars, islands, and behind obstructions. Formation of few new bars/islands is evident and old bars are deep and wide; deposition at bends obvious.
   1. 50% - 60% sediment deposition with fine sand and/or silt….……………**10**
   2. 60% - 70% sediment deposition with gravel and/or coarse sand…………...**9**
   3. 60% - 70% sediment deposition with fine sand and/or silt…...……………**8**
   4. 70% - 80% sediment deposition with gravel and/or coarse sand………..…**7**
   5. 70% - 80% sediment deposition with fine sand and/or silt…….…….……..**6**

D. >80% of the stream bottom affected with heavy deposition from fine gravel and sand at stream bends, constrictions, and/or pools. Extensive deposits of fine sand and/or silt on old and new bars, islands, and along banks in straight channels. Few pools are present due to siltation.
   1. 80% - 90% sediment deposition with gravel and/or coarse sand.……..……..**4**
   2. 80% - 90% sediment deposition with fine sand and/or silt…..……………**3**
   3. >90% sediment deposition; pools almost absent…...………………………**1**
   4. 100% sediment deposition; pools absent due to substantial deposition; bottom silt moves with almost any flow above normal……………………..…**0**

6. Channel Sinuosity

Evaluates the meandering or sinuosity of the stream. A high degree of sinuosity provides for diverse habitat and fauna, and the stream is better able to handle surges when the stream fluctuates as a result of storms. The absorption of this energy by bends protects the stream from excessive erosion and flooding. In some streams, a longer reach than that designated for sampling may need to be evaluated to adequately score this metric.

Channel Sinuosity = Mean Distance Between Bends / Mean Stream Width

Channel sinuosity is determined during stream reconnaissance.

A. Occurrences of bends relatively frequent. Pools and other instream habitats abundant throughout the sample reach.
   1. Run-to-bend ratio = 1-2 ……………………………………………..**20**
   2. Run-to-bend ratio = 3-4……………………………………………**19**
   3. Run-to-bend ratio = 5……………………………………………..**18**
   4. Run-to-bend ratio = 6……………………………………………..**17**
   5. Run-to-bend ratio = 7……………………………………………..**16**

B. Occurrence of bends infrequent. Adequate pool and other instream habitats throughout reach.
   1. Run-to-bend ratio = 8……………………………………………..**15**
   2. Run-to-bend ratio = 9..……………………………………………**14**
   3. Run-to-bend ratio = 10……………………………………………**13**
   4. Run-to-bend ratio = 12……………………………………………**12**
   5. Run-to-bend ratio = 14……………………………………………**11**

C. Occasional bends; variable bottom contours may provide some habitat.
   1. Run-to-bend ratio = 16……………………………………………**10**
   2. Run-to-bend ratio = 18……………………………………………..…**9**
   3. Run-to-bend ratio = 20……………………………………………..**8**
   4. Run-to-bend ratio = 22…………………………………………….…**7**
   5. Run-to-bend ratio = 24………………………………………...…...**6**

D. Essentially a straight stream of uniform depth. Sample reach has most likely been straighten or channelized. Instream cover and pool habitat lacking.
   1. Run-to-bend ratio = 25……………………………………...………**4**
   2. Run-to-bend ratio = 26 – 30………………………………..…………**3**
   3. Run-to-bend ratio = 30 ……………………………...…………..**2**
   4. No bends within stream reach ……………………………………...**0**

7. Channel Flow Status

Evaluates the degree to which the channel is filled with water when the stream reach is sampled. The flow status will change as the channel enlarges or as flow decreases due to dams and other obstructions, diversion for irrigation, drought, or aggrading stream bottoms with actively widening channels. This is a seasonal parameter. A decrease in water will wet smaller portions of the streambed, thus decreasing available habitat for aquatic organisms. Use the vegetation line on the lower bank as your reference point to estimate channel flow status.

A. Water reaches the base of both lower banks and minimal amount of channel substrate is exposed.
   1. 100% of channel is full……………………………………………………**20**
   2. > 90% of channel is full……………………………………………………...**18**

B. Water fills > 50% of the available channel (or < 50% of channel substrate is exposed).
   1. 80% - 90% of channel is full ………………………………………………..**17**
   2. 70% - 80% of channel is full ………………………………………………..**15**
   3. 60% - 70% of channel is full ………………………………………………..**13**
   4. 50% - 60% of channel is full ………………………………………………..**11**

C. Water fills 20% - 50% of the available channel and/or riffle substrates are mostly exposed.
   1. 40% - 50% of channel is full…………………………………………………**9**
   2. 30% - 40% of channel is full …………………………………………………**7**
   3. 20% - 30% of channel is full…………………………………………………...**5**

D. Very little water in the channel and mostly present as standing pools
   1. 10% - 20% of channel is full …………………………………………………**3**
   2. < 10% of channel is full ………………………………………………………**2**
   3. Water present as isolated standing pools…………………………………...**1**
   4. Channel is dry……………………………………………………………….....**0**

8. Bank Vegetative Protection

Measures the amount of the stream bank that is covered by vegetation. This parameter supplies information on the ability of the bank to resist erosion as well as some additional information on the uptake of nutrients by the plants, the control of instream scouring, and stream shading. Banks that have full, natural plant growth are better for fish and macroinvertebrates than are banks without vegetation protection or those shored up with concrete or riprap.

Four factors to consider when scoring bank vegetative protection: (1) Is the vegetation native or introduced? (2) Is the vegetation planted or natural? (3) Is the upper story, understory, and ground cover vegetation well balanced? (4) During which season are you conducting this assessment?

Determine left or right bank by facing downstream. Score banks separately.

A. More than 90% of the stream bank surface is covered by healthy, living vegetation. A variety of different types of vegetation are present (e.g. trees, shrubs, understory, and nonwoody macrophytes). Any bare or sparsely vegetated areas are small and evenly dispersed.
   1. 100% plant cover on stream bank……...…………………………...………..**10**
   2. >90% plant cover on stream bank...……………………………...………**9**

B. A variety of vegetation is present and covers 70 - 90% of stream bank surfaces, but one class of plants is not well represented. Some open areas with unstable substrate are present. Disruption evident but not affecting full plant growth potential. Few barren or thin areas are present.
   1. 90% plant cover on stream bank.....…………………………………...…**8**
   2. 80% - 90% plant cover on stream bank……………………….…….……...**7**
   3. 70% - 80% plant cover on stream bank with fewer plant species……..……**6**

C. 50 - 70% of stream bank surface is covered by vegetation; typically composed of scattered shrubs, grasses, and forbes. Disruption obvious, with patches of bare soil and/or closely cropped vegetation common.
   1. 60% - 70% vegetation cover; typically of shrubs, grasses, and forbes……..**5**
   2. 50% - 60% vegetation cover; typically of shrubs, grasses, and forbes………**4**

D. Less than 50% of the stream bank surface covered by vegetation. Disruption of vegetation is prevalent. Any shrubs or trees on bank exist as individuals or widely scattered clumps.
   1. 40% - 50% vegetation cover with many bare spots/rock…………….. ..……**3**
   2. 30% - 40% vegetation cover with many bare spots/rock……..……..….……**2**
   3. 20% - 30% vegetation cover with many bare spots/rock…..………..….……**1**
   4. < 20% vegetation cover……………………………………………………..……**0**

9. Bank Stability

Measures whether the stream banks are eroded or have the potential for erosion. Steep banks are more likely to collapse and suffer from erosion than gently sloping banks and are therefore considered to be unstable. Signs of erosion include crumbling, unvegetated banks, exposed tree roots, and exposed soil. Eroding banks cause sediment deposition and may reduce instream cover.

Determine left or right bank by facing downstream. Score banks separately.

A. Bank stable; erosion absent or minimal, with little potential for future problems. Slopes are generally less than 30º. Banks may be reinforced by rock thus increasing the slope to >30º while providing stability.
   1. No evidence of erosion or bank failure……………………………………**10**
   2. Less than 10% of bank affected by erosion……………………….……….**9**

B. Moderately stable bank; small areas of erosion or bank slumping visible. Most areas are stable with only slight potential for erosion at flood stages. Slopes up to 40º. Banks may be reinforced by rock thus increasing the slope to >40º while providing stability.
   1. 10% - 20% of bank has erosional areas……………..……………………..**8**
   2. 20% - 30% of bank has erosional areas……………………………………**7**
   3. 30% - 40% of bank has erosional areas……………………………………**6**

C. Moderately unstable bank; frequency and size of raw areas are such that high water events have eroded some areas of the bank. Medium size areas of erosion or bank slumping visible. Slopes up to 60º. High erosion potential during floods.
   1. 40% - 50% of bank has erosional areas…………………………………….**5**
   2. 50% - 60% of bank has erosional areas…………………………………….**4**
   3. 60% - 70% of bank has erosional areas…………………………………….**3**

D. Unstable bank; mass erosion and bank failure are evident; erosion and pronounced undercutting present at bends and along some straight channel areas. Slopes > 60º are common. Areas of distinct slumping visible. Many raw areas are present and 70% – 100% of bank has erosional scars.
   1. 70% - 80% of bank has erosional areas…………………………………….**2**
   2. 80% - 90% of bank has erosional areas…………………………………….**1**
   3. >90% of stream bank has eroded………………………………...………**0**

10. Riparian Vegetation Zone Width

Measures the width of natural vegetation from the edge of the upper stream bank out through the floodplain. The riparian vegetative zone serves as a buffer zone to pollutants entering a stream from runoff; controls erosion; and provides habitat and nutrients to the stream. Narrow, far less useful zones occur when roads, parking lots, fields (currently in use), heavily used paths, lawns, bare soil, rocks, or buildings are near the stream bank. When evaluating this metric, look for breaks in the riparian zone that allow sediment to pass through the zone.

Human activities that impact the riparian zone include: Parking Lots (**PL**), Paved Roads (**PR**), Dirt Roads (**DR**), Row Crop Agriculture (**RCA**), Animal Production Agriculture (**APA**), Silviculture (**S**), Residential Activities (**RA**), and Commercial/Industrial Activities (**CIA**)

Determine left or right bank by facing downstream. Score banks separately.

A. Width of riparian vegetation zone > 18 m (> 60'). Human activities have not impacted the zone.
   1. With no breaks……………………………………..…………………..**10**
   2. With breaks; breaks are narrow and widely spaced…..……………………**9**

B. Width of riparian vegetation zone 12 – 18 m (40 – 60'). Human activities have impacted the zone only minimally.
   1. With no breaks…………………………...…………………………..…**8**
   2. With breaks ………………………………... …………………………**7**

C. Width of riparian vegetation zone 6 – 12 m (20 – 40'). Human activities have impacted the zone a great deal.
   1. With no breaks………………………...……………………………**6**
   2. With narrow breaks widely spaced………………………………………**5**
   3. With breaks common throughout riparian zone…………….……...…..**4**

D. Width of riparian vegetation zone < 6 m (<20'). Little or no riparian vegetation due to human activities.
   1. Riparian vegetation zone less than 20' wide with no breaks…..…….…….**3**
   2. Riparian vegetation zone less than 20' wide with breaks……….………..**2**
   3. No riparian vegetation zone present. Canopy cleared to the edge of the stream bank. Surrounding area covered with grass/pasture…………….....**1**
   4. Riparian vegetation zone absent. Vegetation cleared to the edge of the stream bank and the surrounding area is covered with pavement, concrete, or some other artificial covering…………………………..……..**0**