FINAL REPORT

Strategy For Mapping Sensitive Resources of Rivers and Streams in EPA Region 4

Hazardous Materials Response and Assessment Division
Office of Ocean Resouces Conservationand Assessment
National Ocean Service
National Oceanic and Atmospheric Administration

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INTRODUCTION

This report presents the results of the activities for the Inland Sensitivity Mapping Project for U.S. Environmental Protection Agency Region 4 (EPA). The overall objective of the project is to assist EPA in accomplishing it's Oil Pollution Act of 1990 (OPA 90) mandates for the sensitive area mapping component of oil spill contingency planning requirements. This project, which was carried out in two phases, builds on the guidance provided by the National Oceanic and Atmospheric Administration (NOAA) to EPA Regions 5 and 9 (NOAA 1994, Michel et al. 1994). Phase I included a regional assessment of the rivers and streams of the Southeastern U.S., from which a classification scheme appropriate for inland areas was proposed. The geographic area of concern was the piedmont and coastal plain region which contains most of the facilities of concern for Oil Spill Act of 1990 planning. The specific objectives of Phase I were to:

- Evaluate existing standardized classification schemes to determine their suitability. Use of standardized schemes is preferred to creating new schemes, if possible, to benefit from previous work and improve national applications;
- Determine the flow characteristics for representative watersheds, to provide a scientific basis for classifying rivers and streams;
- Propose a classification scheme for stream reaches; and
- Evaluate existing national, regional, and state data sources for all requirements of the mapping project.

The next step was to apply the classification scheme outlined in Phase I to the Leaf River watershed in Mississippi. Field studies to verify and refine the system for the Leaf River were conducted on March 3-9, 1996. The final product of Phase II was the production of sensitivity maps at a scale of 1:100,000. These maps include the reach sensitivity classification, sensitive biological and human-use resources, potential spill sources, and potential access and collection points for response operations.

It was decided early in the project that the stream classification system would be developed for normal and seasonally high water levels (annual flooding conditions), and that extreme flood events would not be addressed. The reach classification is based on how the water and oil are expected to behave under both normal and annual flood conditions.

EVALUATION OF OTHER CLASSIFICATION SCHEMES

An extensive literature review reveals that the only sensitivity mapping approaches for response to oil spills that are currently being used in freshwater settings in North America are:

1 Environmental Sensitivity Index (ESI) shoreline rankings for lacustrine environments, developed as part of NOAA and Environment Canada projects in the Great Lakes, both of which have been ongoing since the mid-1980s;

2 ESI rankings for large rivers, such as those used by NOAA for mapping the Apalachicola and Columbia Rivers; and

3 The inland sensitive areas mapping being conducted by EPA Region 5 along the Mississippi River, on which NOAA provided extensive technical assistance. No effort has been made to-date to map small rivers and streams based on a sensitivity index classification such as the ESI.

As one progresses landward up major river courses, the streams and associated ponds and wetlands eventually become so narrow and shallow that even small spills would potentially contaminate the whole system. Therefore, from that point on upstream, it is not useful to classify the small individual components of the stream complex, such as segments of the stream banks, with regard to habitat sensitivity. Rather, the sensitivity of the system as a whole should be considered. NOAA (1994) suggested that a watershed approach emphasizing stream reaches could be used to map the sensitivity of these smaller streams. The position along the stream where the standard ESI mapping should stop and the reach classification should begin was defined as that location where the contents of a typical tank truck or rail car (20,000 gallons) would affect the entire watercourse from bank to bank, and possibly the entire water column. This study will amplify and field test the ideas expressed in that publication.

Numerous attempts have been made to classify smaller river systems for applications other than oil-spill response, such as river engineering and fisheries management. Mosley (1987) thoroughly reviewed the classification schemes that had been proposed up to that time, noting that river classifications are generally one of three types—geomorphological, whole river, or longitudinal zonation, as summarized in the following sections.

Geomorphological Classifications

Most geomorphological classifications have focused on differences in channel morphology, which are usually a function of variances in channel slope, ratio of bedload (coarse sediments transported along the channel bottom) to suspended load (clays, silts, and very fine sand), and character of discharge (e.g., flashy versus steady). For example, Popov (1964) divided river channels into six classes based on his studies in Russia:

1 non-meandering channels with transverse subaqueous sand dunes;
2 non-meandering channels with alternating bars along the sides of the channels;

3 limited meandering in which there is downstream migration of low-amplitude bends;
4 free meandering;
5 incomplete meandering; and
6 braided.

Many other systems that are similar to Popov's have been proposed . However, these systems differ from it in some details, depending upon the local conditions where the authors worked. The classification proposed by Schumm (1963), which was very similar to Popov's, was one of the first American attempts at river channel classification from a geomorphological perspective. Figures 1 and 2 present diagrammatic representations of the classifications of Rust (1978) and Brice (1983). Rust's diagram (Figure 1) shows a continuum of channel patterns with differing degrees of sinuosity (a measure of how crooked the channel is) and channel division (an important factor in oil-spill response). Brice's diagram (Figure 2) stresses the deviations within the sinuous and braided classes, which are controlled primarily by the characteristics of the sediment load carried by the stream. As pointed out by Mosley (1987), these geomorphological classifications "clearly have a powerful (if qualitative) explanatory capability, and firmly relate the river type to the factors supposed to dominate the morphology of the channel, and to its dynamics. They also tend to recognize that rivers form a continuum, rather than a series of exclusive classes."

Whole River Classifications

Whole river classifications are usually of two types, those that emphasize the *source of the water in the river*, such as spring creek sources in contrast to surface runoff (Hawkes 1975), and those that emphasize *overall physiography*. Allanson's (1965) classification of the rivers in South Africa is an illustration of the application of physiographic influences to build a whole river classification. For example, he contrasted those coastal-belt rivers that were derived from mountain regions from those that were derived from non-mountain regions.

Whole river classification can be a very useful concept because there are certain regional controls, such as bedrock and soil types, that can distinguish entire watersheds from each other. In this work on the rivers of the Southeastern United States, the fundamental difference between those rivers with sources in the piedmont and mountains (piedmont or redwater rivers) and those with sources restricted to the coastal plain (coastal plain or blackwater rivers) has been a critical factor in the development of our ideas on how to map the sensitivity of the rivers to oil spills.

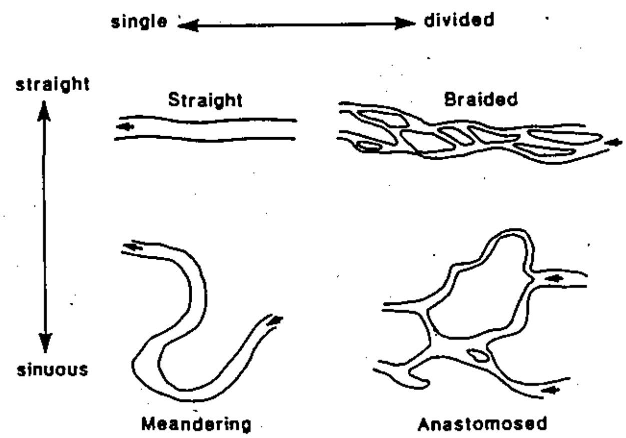


Figure 1. Rust's (1978) classification of river channels emphasizes relative straightness versus channel division.

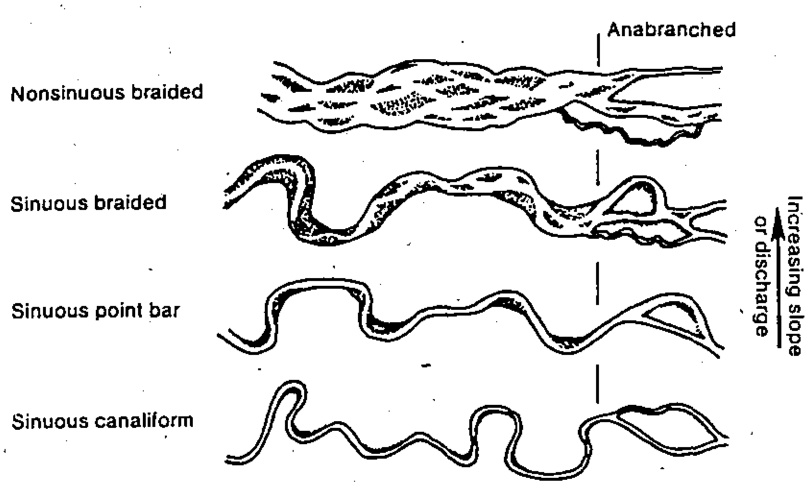


Figure 2. Brice's (1983) classification of river channels takes into account braided versus sinuosity as well as channel division (anabranching). Sinuous canaliform streams have abundant fine-grained sediments and no sandy point bars.

Longitudinal Zonation Classifications

The first and most cited efforts by geomorphologists and hydrologists to describe streams used a type of longitudinal zonation classification called the definition of stream orders. Using this technique, originated by Horton (1945) and expanded upon by Strahler (1957), the smallest tributaries in a river basin are designated Order 1; where two first-order streams join, a stream of Order 2 is formed; where two second-order streams join, a stream of Order 3 is formed, and so on. Finally, the trunk stream through which all discharge water and sediment passes is the stream segment with the highest order (Strahler 1957). Such measurements of stream order afford a simple quantitative basis for comparison of the degree of development of drainage nets among different river basins.

Biologists have also applied the longitudinal zonation approach, as the examples in Figure 3 show. Illies and Botosaneanu (1963) and Illies (1961) focused on longitudinal variation in flow characteristics of the stream (Figure 3). Ricker (1934), Huet (1954), Carpenter (1928), and Pennack (1971) used a combination of water quality and zones of predominant types of fishes (e.g., dace, trout, pickerel) to distinguish among longitudinal zones of streams. Nevins (1965; 1969) based his longitudinal zonation classification of New Zealand's rivers on a combination of hydrology, geomorphology, and sediment type.

Recent Trends in Stream Classification

Mosley (1987) pointed out that there is now a vast body of literature that demonstrates the intimate, detailed relationship between stream biota and the physical characteristics of the streams. Two recent papers verify Mosley's claim. Heede and Rinne (1990) emphasized that certain physical factors, namely 1) stream flow, 2) sediment transport, and 3) channel morphology, dictate both habitat quantity and quality for different life stages of fisheries. Hawkins et al. (1993), who defined channel geomorphic units as areas of relatively homogeneous depth and flow that are bounded by sharp gradients in both depth and flow, also related stream geomorphology and hydrology to fisheries health. They recognized the three levels of stream classification presented in Figure 4, which is based first on water current velocity and secondarily on specific reach characteristics, such as the distinction between riffles and pools. They stated that

> ...although riffles and pools do not always have sharp boundaries, they appear to represent distinctly different ecological habitats. The biota inhabiting them are markedly different in both taxonomic composition and the morphological, physiological, and behavioral traits they possess.

This combined physical/ biological approach has been useful in understanding the stream populations of insects and certain fisheries, particularly salmon and trout. We used the assumption that stream biota rely on the physical conditions that vary in a systematic way along the length of the stream, with well-defined longitudinal biozones, as the basis for focusing on stream reaches in our stream classification.

Strahler order	Illies and Botosaneanu (1963)		Illies (1961)	Ricker (1934)	Huet (1954)		Carpenter (1928)	Pennack (1971)	Nevins (1969)
0	Zone 1	Source	Eucrenon			Highland brooks	Head stream		
1	Zone 2	Rill and rivulet	Hypocrenon	Spring creek				Dace trickle	
2	Zone 3	Small stream, fed by 2+ rills	Epirhithron	Swift trout stream	Trout zone		Trout zone	Trout feeder	Mountain or torrent phase
3	Zone 4	Brook or stream, fed by 2+ small streams	Metarhithron	Slow trout stream				Trout stream	
4-6	Zone 5	Montane or piedmont river	Hyporhithron		Grayling zone	Lowland course	Minnow reach	Bass or pickerel stream	Shingle phase
6-8	Zone 6	Middle course of a river	Epipotamon	Warm river	Barbel zone		Upper reach	Catfish or carp stream	
>7	Zone 7	Lower plains course	Metapotamon		Bream zone		Lower reach		Silt phase
			Hypopotamon				Brackish estuary	Tidal stream	Tidal phase

Figure 3. River classifications based on longitudinal river zones. From Mosley (1987, Table 12.2).

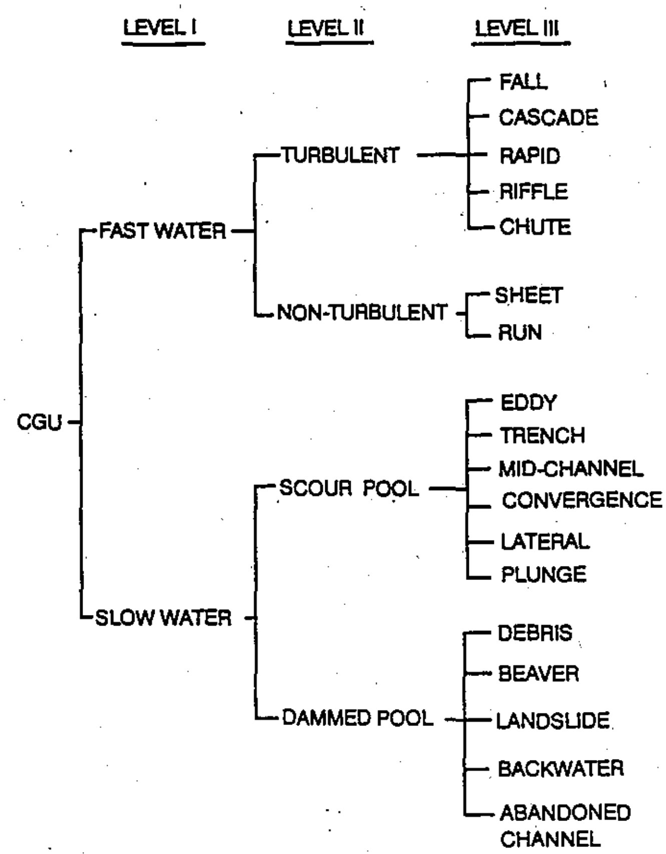


Figure 4. The classification of channel geomorphic units with increasing levels of resolution (Hawkins et al. 1993, Figure 1).

THE REACH CONCEPT

Most streams can be readily subdivided into clear-cut segments, or *reaches*, that have very distinct, uniform characteristics within that stretch of the stream. The definition of the reach type is usually based on the intended use of the reach classification . For example, in a study of the aquatic insects of a mountain stream, one single set of pool/riffles might be designated a reach, or possibly a series of very similar pool/riffle sets could be the reach. The application in this study is to define a stretch of the stream where similar spill-response modes and potential ecological and/or socioeconomic impacts from the spill are to be anticipated. However defined, the boundary of the reach is usually marked by an abrupt change in the morphology of the stream, a change commonly, but not always, brought about by a change in the stream's gradient.

There are two obvious styles of segmentation of streams:

1 A smaller type of subdivision, such as the uniform spacing of pools and riffles in a mountain stream (Keller and Melhorn 1978), or the uniform spacing of meander bends and point bars in a meandering channel (Friedkin 1945); and

2 The more widely spaced ,major changes in the morphology of the stream, such as the shifting from straight to braided to meandering reaches (Schumm 1963).

There is an extensive body of field evidence that shows that the spacing of pool/riffles and meanders is directly proportional to the channel width. Therefore, some fundamental physical law that probably relates to a type of helical flow within the water column must account for the smaller segmentation of streams. Interruptions of the patterns occur where minor geological obstructions, such as resistant bedrock ledges or glacial deposits, interfere. At the larger scale, two other factors come into play: 1) geomorphic thresholds; and 2) larger-scale geological controls.

Schumm (1973) defined a *geomorphic threshold* as "a threshold that is developed within the geomorphic system by changes in the system itself through time." As a stream evolves, certain conditions of slope and discharge develop such that the circumstances at a given point along the stream create a given stream morphology. But, as is illustrated in Figure 5, there is a range of the values of slope and discharge under which the same morphology can exist, with the stream maintaining the same morphology until the critical ratio (threshold value) of slope/ discharge is met. Within the reach that has the same morphology, features are rhythmically spaced, following the as-yet-not-completely-understood "meander law." When the threshold value is attained at some point along the stream, the stream changes abruptly to a different morphology (e.g., from braided to meandering, or from meandering to anastomosing).

Geomorphic thresholds are most commonly reached in smaller stream systems by relatively abrupt changes in gradient that are usually brought about by changes in the bedrock geology of the stream bed. Most small streams in piedmont and mountain regions are composed of a series of reaches that exhibit marked differences in gradient, resulting in striking changes in the morphology of the stream from reach to reach. As was discussed above, these marked differences in morphology and sediments among the different reaches of the stream have a strong influence on the biological makeup of the various types of reaches of the stream. Furthermore, different techniques of spill response would be required for the different reaches of the stream because of variances in water flow patterns, mixing of oil into the water column, potential and duration of oiling of banks and flood plains, and other behavioral patterns of the pollutant.

ASSESSMENT OF SOUTHEASTERN RIVERS

Literature Review

A review of literature sources available on rivers in general and on those occurring in the Southeastern U.S. in particular was completed. The more important references were categorized into nine topics:

1 Classification of streams and associated wetlands;
2 Ecology and value of bottomland hardwoods/deep water swamps;
3 Geological framework;
4 River basin morphology and ecology (including flood plains and graded streams);

5 Channel morphology;
6 North Carolina/South Carolina streams;
7 Georgia/Florida streams;
8 Alabama/Mississippi streams; and
9 Stream flows, floods, hydrology, and sediments.

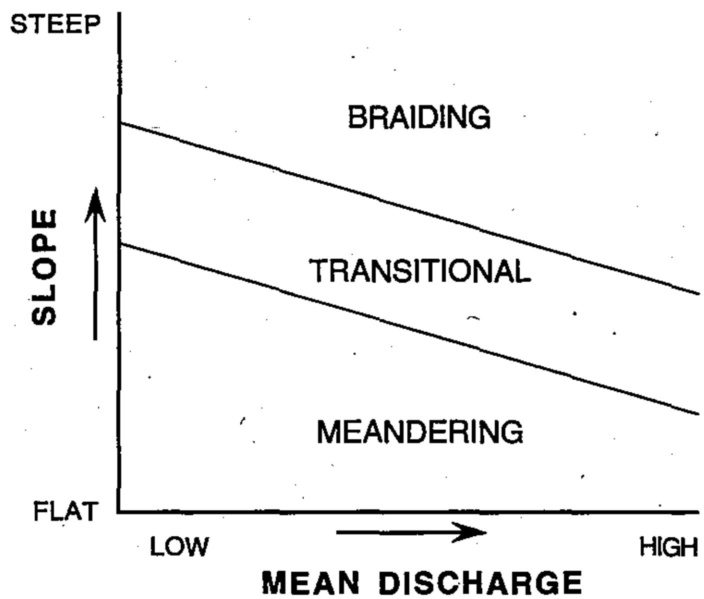


Figure 5. General relationship of slope and discharge to stream morphology. Modified after Li and Simons (1982).

There was remarkably little information on the streams in the piedmont and coastal plain region of the southeast, except on the topic of wetlands (bottomland hardwoods and swamps), that would be relevant to this project. However, no effort was made to obtain references on the harvest of sport fisheries of these rivers and streams. Literature on oil spills in rivers allows us to predict how oil would behave if spilled into the different reach types of smaller streams. However, there are fewer published accounts of oil spill responses in inland areas, compared to marine spills. Thus, there is less information on which to document and verify oil spill behavior in small rivers and streams.

A Whole River Classification

Considering the rivers of the southeastern region as a whole, they can be classified into three fundamental types on the basis of regional physiography and water source/chemistry:

1 Those streams that originate in and derive most of their waters from the mountain and piedmont physiographic provinces (here termed *piedmont rivers*);
2 Those streams that have most or all of their drainage basins located within the coastal plain physiographic province (here termed *coastal plain rivers*); and

3 The spring-fed rivers of the Florida peninsula. The Florida peninsula rivers were excluded from this study.

The physiographic provinces of the Southeastern United States are illustrated in Figure 6.

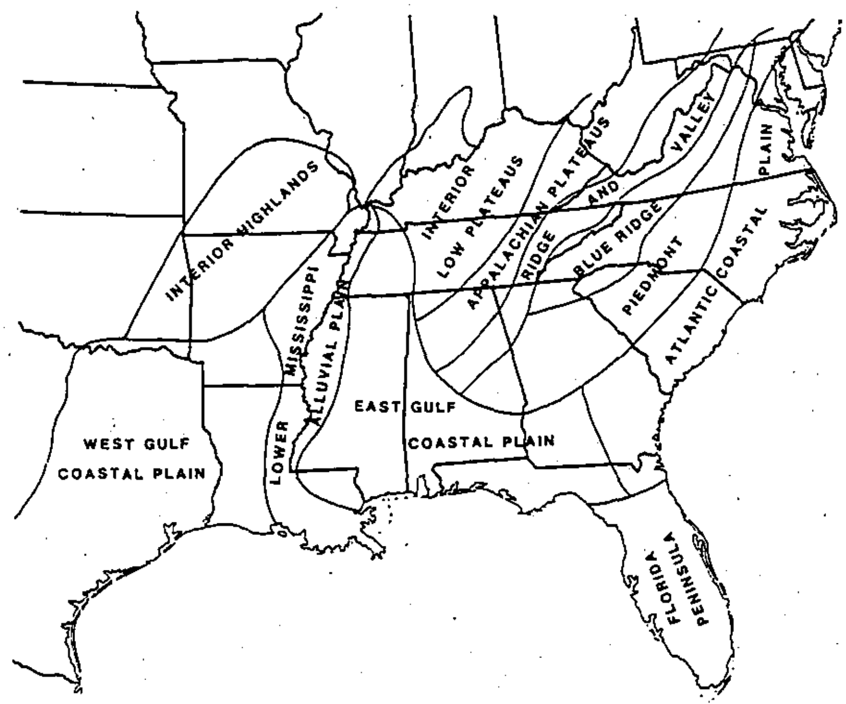


Figure 6. Physiographic provinces of the Southeastern United States (from McKnight et al. 1981, Figure 2.2).

As shown in Table 1, there are eight primary piedmont rivers in the area under study. Also listed in the table are 22 of the major coastal plain rivers in the area. These stream systems are located on the map in Figure 7. There are several fundamental differences between these two types of rivers, which are enumerated in Table 2.

Watersheds, Flood Plains, and Hydrographs

Data provided to us from the U.S. Environmental Protection Agency reach files and the U.S. Geological Survey water supply studies allow us to make some generalizations about the watershed and hydrograph characteristics of the rivers in the study area. Figure 8, derived from the EPA reach file data, shows the outline of some of the major watersheds in the North Carolina/South Carolina/Georgia area. Note the contrast in the shapes of the watersheds of the piedmont and coastal plain rivers. The watersheds of three of the major piedmont river systems in the area, the Santee, Savannah, and Altamaha rivers, have a pear-like or drumstick shape. In these river basins, the major volume of water and sediments in the basins is gathered together in the mountain and

Table 1. Major piedmont and coastal plain rivers in the Southeastern United States (see Figure 7 for locations).

	Piedmont	# of Major Lakes
1	Roanoke River (piedmont/mountain)	4
2	Cape Fear River (piedmont only)	1
3	Pee Dee River (piedmont/mountain)	4
4	Santee River (piedmont/mountain)	8
5	Savannah River (piedmont/mountain)	4
6	Altamaha River (piedmont only)	2
7	Apalachicola River (piedmont/mountain)	4
8	Mobile River (piedmont/mountain)	4
	Coastal Plain	
9	Tar River (some tributaries in piedmont)	
10	Neuse River (some tributaries in piedmont)	
11	New River (strictly coastal plain)	
12	Waccamaw River (strictly coastal plain)	
13	Little Pee Dee River (some piedmont tributaries)	
14	Black River (strictly coastal plain)	
15	Cooper River (strictly coastal plain)	
16	Edisto River (strictly coastal plain)	
17	Ashepoo River (strictly coastal plain)	
18	Ogechee River (some piedmont tributaries)	
19	Canoochee River (strictly coastal plain)	
20	Satilla River (strictly coastal plain)	
21	St. Marys River (strictly coastal plain)	
22	Suwannee River (strictly coastal plain)	
23	Aucilla River (strictly coastal plain)	
24	Ochlockonee River (strictly coastal plain)	
25	Chatawhatchee River (strictly coastal plain)	
26	Yellow River (strictly coastal plain)	
27	Escambia River (strictly coastal plain)	
28	Pascagoula River (strictly coastal plain)	
29	Leaf River (strictly coastal plain)	
30	Pearl River (1 lake) (strictly coastal plain)	

piedmont regions before being transported through the coastal plain in narrow passageways. The coastal plain river drainages in between the three major piedmont rivers have a triangular shape, with the base of the triangles being located along the ocean front. Saxton and Shiau (1990) noted that the shape of the river basin affects the hydrograph characteristics of lag time, the time of rise, and the peak-flow rates (see Figure 9). The tendency of a river to flood its banks and the seasonality of such flooding are important characteristics to be familiar with when planning a spill response for a particular river basin.

More analysis is needed on this topic for future response considerations in EPA Region 4.

Table 2. Characteristics of piedmont and coastal plain rivers of the Southeastern United States.

CHARACTERISTICS	RIVER TYPE		
	PIEDMONT		COASTAL PLAIN
	in piedmont	in coastal plain	
gradient	relatively steep; rapids common	flat with only minor rapids	flat with only minor rapids
discharge	variable; typically large volume	usually large volume	variable, usually small volume
hydrograph	very flashy	flashy	steady, low flood peaks
water color	discolored to reddish because of high volume of suspended sediments	discolored to reddish because of high volume of suspended sediments	black because of tannic compounds from swamps
channel sinuosity	usually straight to slightly sinuous	meandering common	meandering with anabranching common
bottom materials	bedrock; sand	usually sandy	sandy; muddy in some areas
flood plain	very narrow; elevated high above mean water level	wide; elevated above mean water level	wide; only slightly above mean water level
associated wetlands	rare; scattered bottomland hardwoods that are only occasionally flooded; no cypress-tupelo swamps	bottomland hardwoods along channel; isolated cypress-tupelo swamps in abandoned channels	both bottomland hardwoods and cypress-tupelo swamps common and widespread; swamps commonly next to channel

The *fall line* marks the boundary between the piedmont province and the coastal plain province. At that point, the waters of the stream cut down into the older igneous and metamorphic rocks of the piedmont and usually form a zone of rapids. Seaward of the fall line, the river typically flows over a bed of unconsolidated sediments. During the Pleistocene glaciation when sea level was hundreds of feet below its present level, the "fall line" extended much further seaward. Accordingly, a valley several hundred feet deep was cut across the coastal plain and the present continental shelf as a result of the lowered ocean level. When sea level started to rise again around 14,000 years ago, reaching near its present level about 4,500 years ago, the carved valley started to aggrade (fill up) with sediments. Ever since the beginning of the aggradational phase, the rivers in the coastal plain area have migrated back and forth across the old valley, filling it in evenly with sediments. The sediments that have filled in the valley have created what is known as the *flood plain* of the river. The river might now be at any position across the valley, including against the old valley wall. The

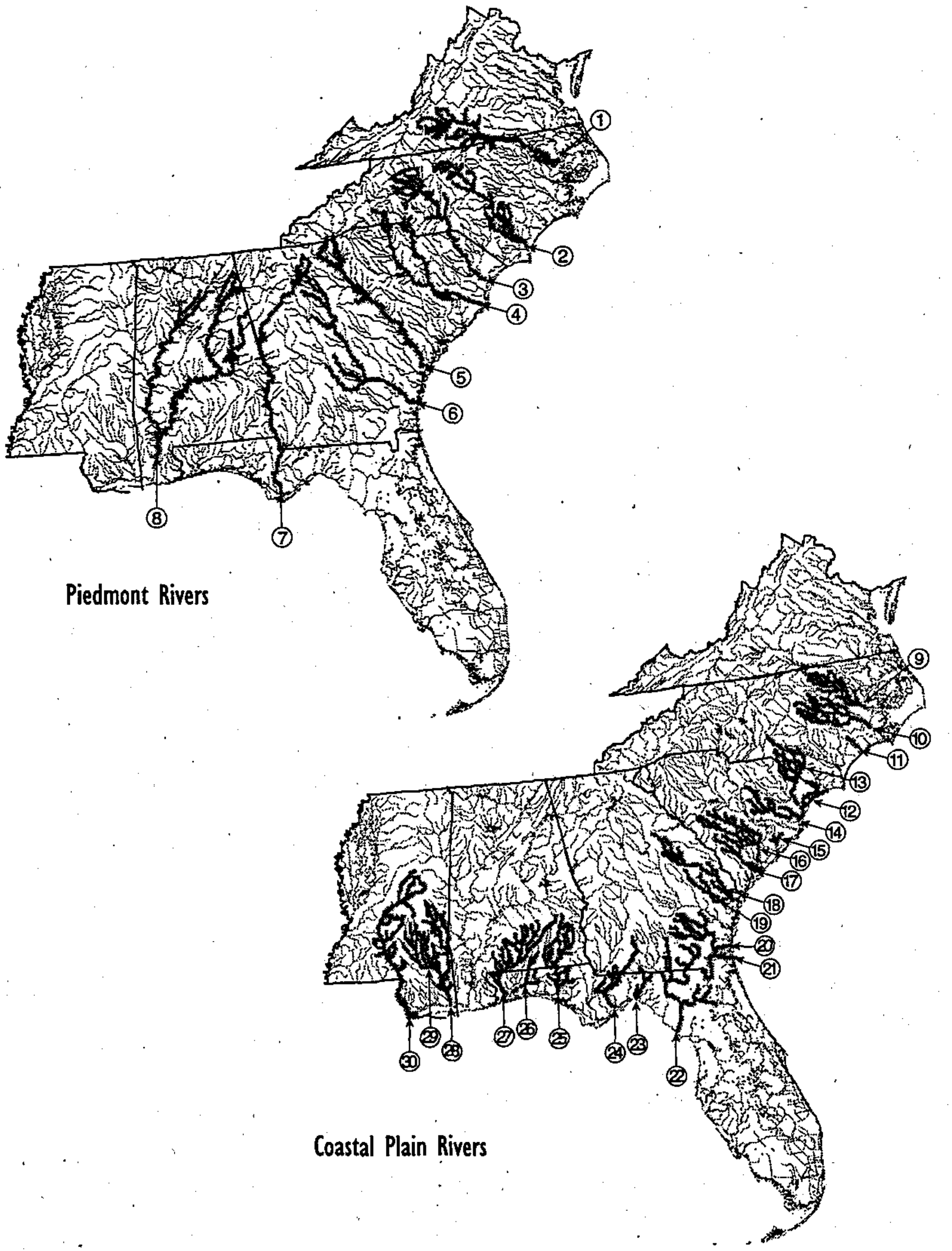


Figure 7. Location of the major piedmont and coastal plain rivers of the Southeastern United States. Streams are numbered on Table 1.

flood plains of the large piedmont rivers that cross the coastal plain of the southeastern United States are typically quite wide, several miles in some instances. The flood plains of the larger coastal plain rivers may also be more than a mile across. Because of differences in bedrock erodability and topographic variability, some rivers in the piedmont region also have minor flood plains, but these narrow flood plain zones are invariably separated by a reach of rapids located in confined, erosional valleys.

The USGS hydrographic data are highly detailed and complex and much is to be learned from river flow patterns. For this report, we concentrated on three rivers in South Carolina with which we are very familiar and where we conducted some preliminary field work: the South Fork of the Edisto River, the largest coastal plain river along the Georgia Bight, the Broad River, the main stem of the Santee River drainage basin, and the Tyger River, a moderate-sized piedmont tributary of the Broad. The hydrographs for four separate months during 1991 for these three rivers are presented in Figure 10. Note that the discharge of the two piedmont rivers is quite flashy, with severe flood peaks occurring several times during 1991, but that the South Edisto discharge was quite steady. These curves point out a major contrast between the piedmont and coastal plain rivers that can have a significant effect not only on spill response methods but also on the overall sensitivity of the two river types (discussed below).

Our preliminary explanation for the contrast in the hydrographs of the two river types has to do with different rates of infiltration and on-land water storage during and after rainfall. Generally speaking, the soils of the coastal plain, particularly the upper coastal plain, are sandy and quite permeable (i.e., they have a high infiltration capacity), whereas the lateritic clayey soils of the piedmont are not. Another factor is the abundance of swamps and bottomland hardwoods scattered throughout the coastal plain which act as large "storage tanks" for the runoff from the rains. Extensive swamps are absent from the flood plains and drainage basins of the piedmont. These two factors combined promote rapid runoff in the piedmont and slow runoff in the coastal plain, hence the striking contrast in the hydrographs presented in Figure 10.

Role of Tectonics

The role of geological structural movements (tectonics) in the evolution of river basins is considered to be a fundamental control of basin evolution, particularly in mountain regions (discussed in Arch located just north of the South Carolina/North Carolina border. This tectonic high has influenced the main stem of the Pee Dee River to turn south in its lower reaches, gathering up the drainages of several coastal plain rivers in the process and producing the atypical rectangular shape of the drainage basin. The second example occurs around the Leaf River watershed in southern Mississippi, where a tectonic bulge called the Wiggins Uplift has strongly affected the streams in the area, including the mainstem and some tributaries of the Leaf River (Figure 11). According to Burnett and Schumm (1983), the responses to this uplift include channel entrenchment, mobilization of bed and bank materials at local areas of downcutting, and increased channel activity. We were surprised to read in the canoeing guide to the Leaf River watershed (Estes et al. 1991) that there are a number of rapids, shale ledges, and gravel point bars in the channels. This is

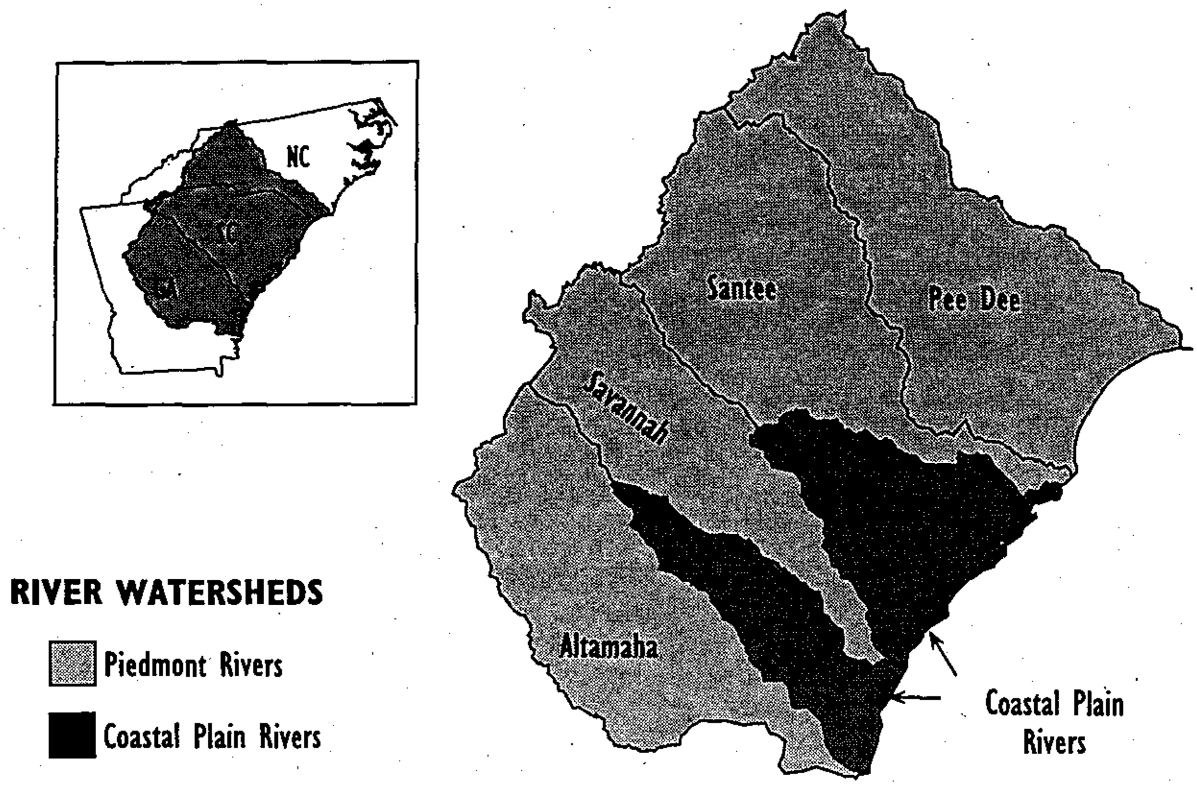


Figure 8. Watershed boundaries for the major river systems of the North Carolina/South Carolina/Georgia area. Note the pear-like shape of the piedmont river drainages.

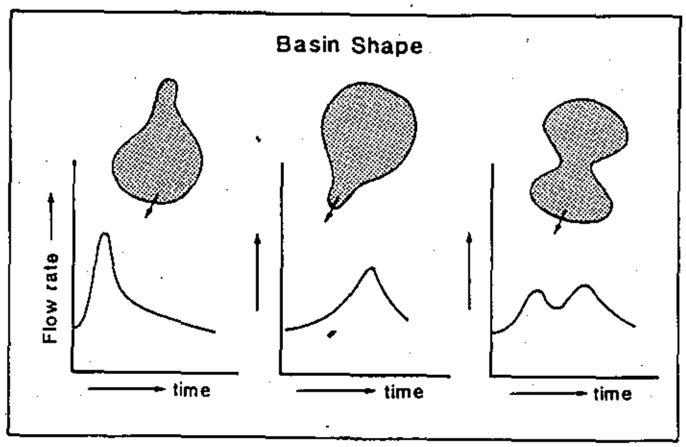


Figure 9. Effect of river basin shape on hydrograph shape and time of rise. From Saxton and Shiau (1990, Figure 18).

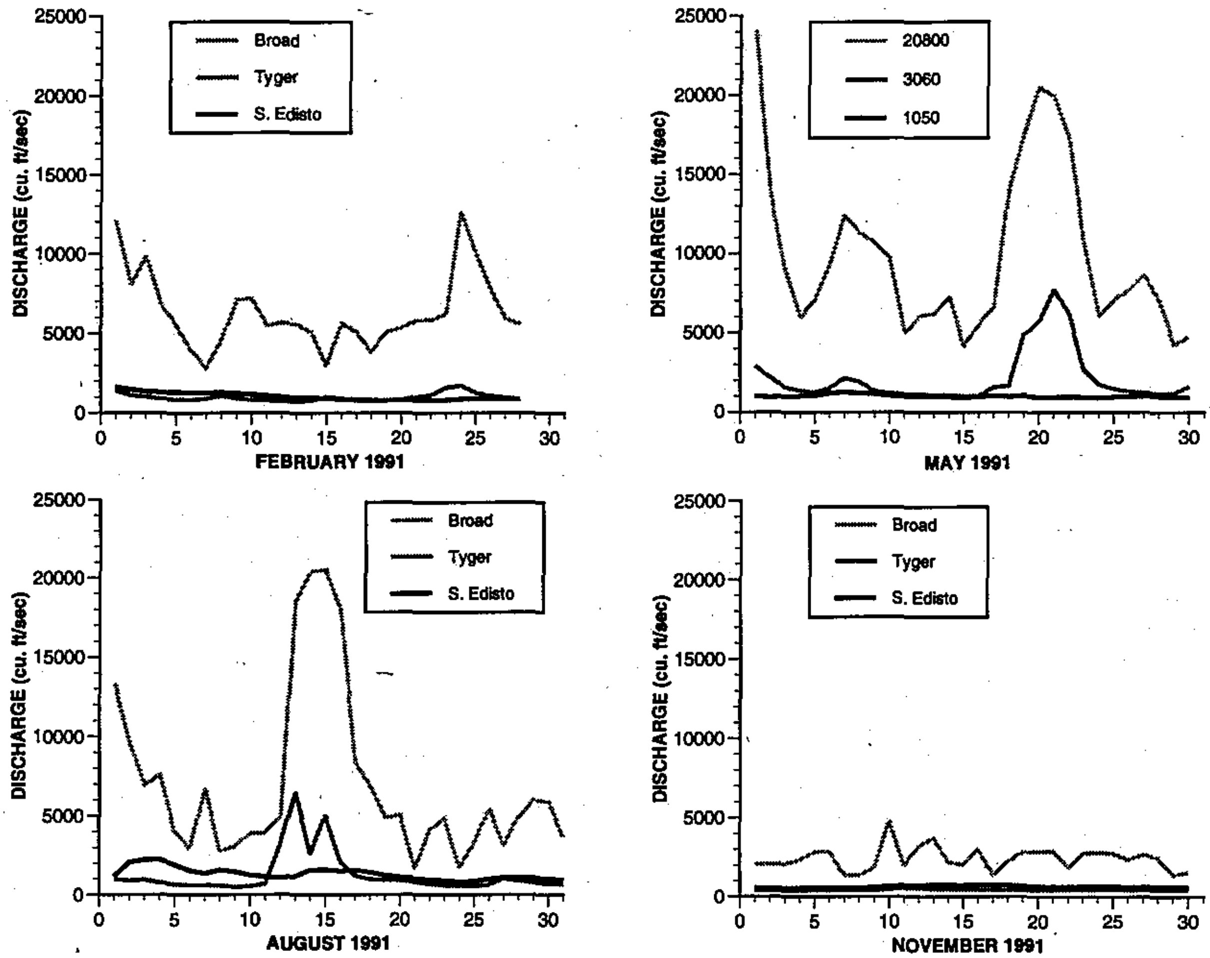


Figure 10. Monthly hydrographs for the Broad, Tyger, and South Edisto rivers in South Carolina for 1991. Note the flashy nature of the two piedmont rivers (Broad and Tyger) and the steady discharge of the South Edisto, which is located mostly in the coastal plain.

undoubtedly in response to the local tectonic activity on the Wiggins Uplift and has made for some very interesting reach-type variations in that watershed.

Field Work Completed—South Carolina

Once the regional overview was finished, we selected representative rivers in South Carolina to classify into reach types and verify in the field. We obtained the 1:24,000 USGS topographic maps for the entire length of the South Fork of the Edisto River, as well as for the mainstem of the river all the way to the ocean. Before going into the field, we classified the reaches of the river based on the topographic maps and previous field experience in the area. We then spent two days in the field visiting 19 sites along the entire length of the South Fork. We felt that this work gave us a good understanding of the coastal plain-type river, but realized that the piedmont rivers would show

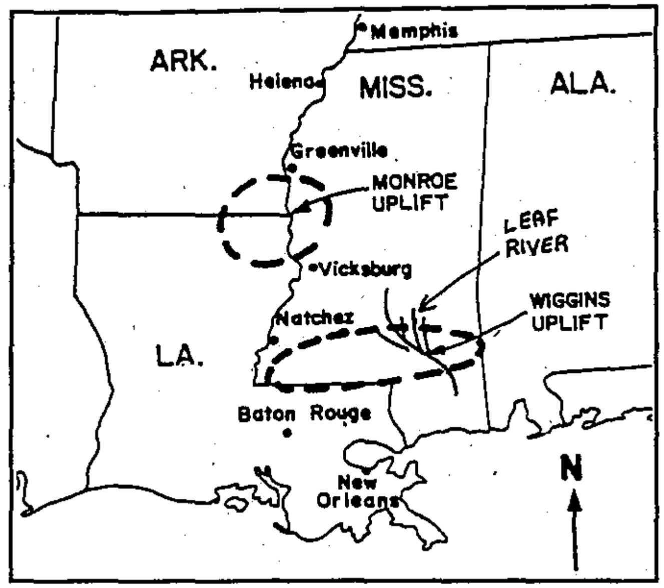


Figure 11. Tectonic uplifts in Mississippi (Monroe and Wiggins Uplifts). Note that the drainage of the Leaf River cuts across the Wiggins Uplift.

some significant differences. Next, we classified the reaches of about one -third of the Tyger River and a portion of the Broad River (on 1:24,000 USGS topo sheets), both of which are located in the middle piedmont region (see Figure 12 for location of field studies). These reach classifications were also checked in the field, with stops at nine locations. Later, 14 more field sites were visited along three coastal plain rivers (Little Pee Dee, Black, and Lynches) and three piedmont rivers (Santee, Great Pee Dee, and Catawba; Figure 12).

Field Work Completed—Leaf River Watershed, Mississippi

Before going in the field, the reaches of the mainstem of the Leaf River and Gaines Creek, one of its tributaries, were classified according to a Reach Sensitivity Index (RSI) worked out in Phase I of the project (for South Carolina rivers). This classification was based on study of 1:24,000 USGS topographic maps. We visited the field site on March 3-9, 1996, and carried out the following tasks:

1 Ground inspection of 68 stations, including locating boat ramps and collection sites.
2 An overflight of the watershed.
3 Extensive ground and aerial photography.
4 Analysis of the most recent vertical aerial photography of the river system at the Department of Transportation archives in Jackson, Mississippi.
5 Based on all of the above information, the reaches of the Leaf River mainstem, and most of its major tributaries (Okatoma Creek, Gaines Creek, Tallahala Creek, Bouge Homa Creek, and Thompson Creek) were classified according to their sensitivity to oil spill impacts. The field maps used were 1:24,000 USGS topographic maps.

Upon returning to the office, the RSI classifications as well as potential access and collection point for response operations were transferred to 1:100,000 scale maps.

A SENSITIVITY MAPPING STRATEGY

Introduction

There was no scheme for mapping the sensitivity of smaller streams to oil pollution before this study. The work on Phase I of this project was aimed at producing a working hypothetical sensitivity index for the rivers of the piedmont and coastal plain of the Southeastern U.S., based on a regional overview of the river types and some field investigations of representative streams in South Carolina. We have found no reason to change the basic concept of the watershed approach presented by NOAA (1994), which was to map the reaches of the streams with respect to their degree of sensitivity to oil pollution. The Reach Sensitivity Index (RSI) presented in the Phase I report served as the start-up template for the mapping project of the Leaf River watershed. The original RSI was modified and expanded only slightly based on our observations in the Leaf River watershed.

Key Components of Reach Sensitivity

After considerable deliberation and field testing, we believe that the definition of the sensitivity of the reaches of the smaller rivers and streams of the Southeastern U.S. to oil spills should be based on two primary criteria:

1 The degree of difficulty anticipated for the containment and recovery of the oil; and

2 The sensitivity and vulnerability of the associated wetlands.

Containment and Recovery. The key factors related to containing and recovering oil spilled in smaller rivers and streams that have been considered in our definition of environmental sensitivity of stream reaches are discussed below.

1 Navigation—Whether or not the stream is navigable by motorized small boats is an important issue, which is taken into account in our sensitivity classification. On most of the navigable piedmont and coastal plain rivers in the Southeastern U.S., boat ramps are fairly closely spaced so access by jon boats or motorized inflatables would be possible.

2 Water flow patterns—Small rocky streams have turbulent flow that would mix oil into the water column, making the oil difficult to recover. In larger streams and rivers, where the channel is straight, oil is expected to flow with the stronger current and thus flow more down the center of the channel or smear along the down-wind bank. In comparison, in meandering streams and rivers, the water flow patterns are more complicated and oil slicks are more likely to contact alternating banks and/or accumulate in low-flow zones, making protection and recovery strategies somewhat more difficult to implement.

3 Stream size—On small streams, response options can be very different and require much less specialized equipment than larger streams and rivers. Under- and overflow dams, filter fences, earthen dams, etc. can be built on site using local materials. For larger streams, specialized equipment, boats for deployment, etc. are needed to contain and recover spilled oil.

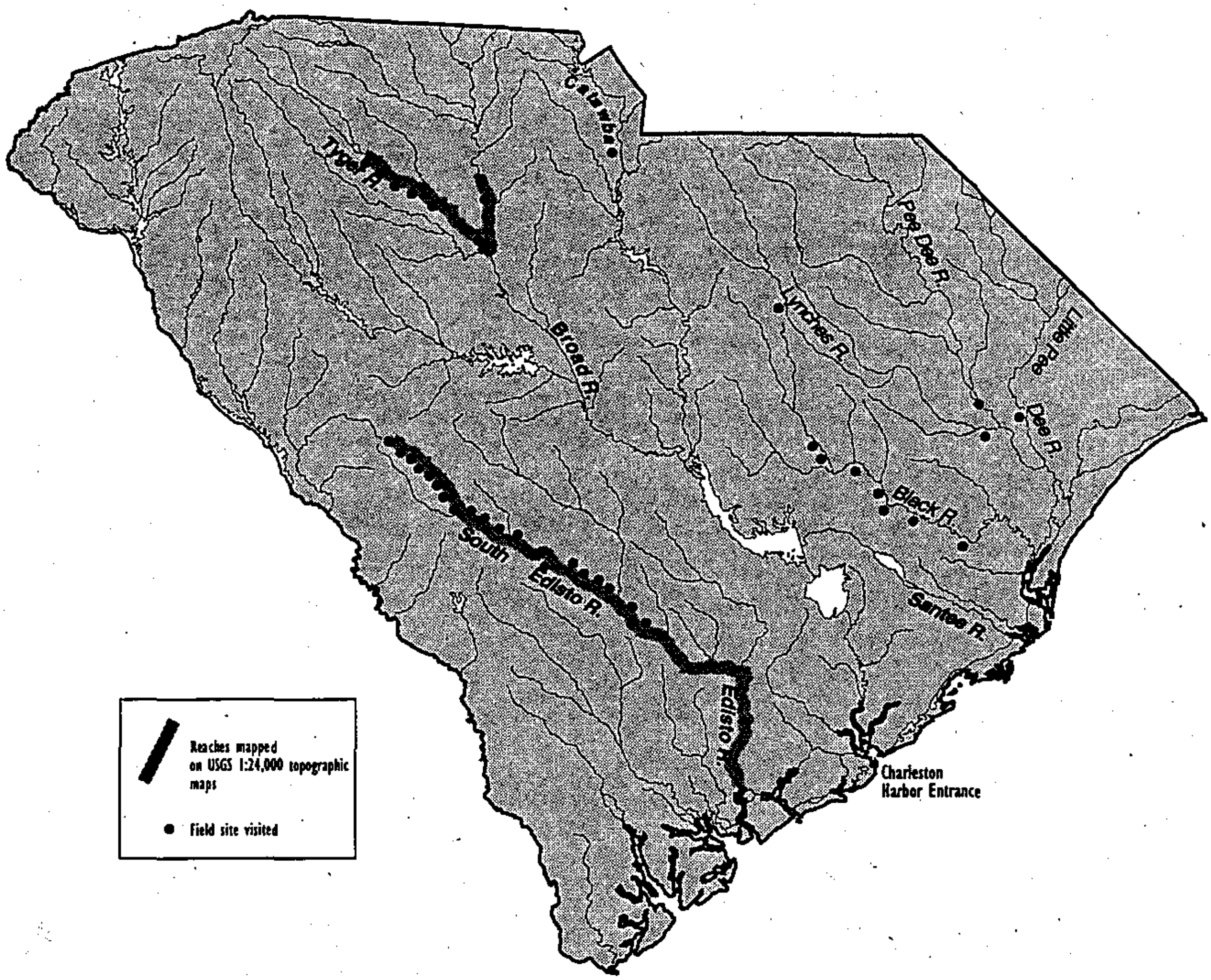


Figure 12. Location of river studies carried out in South Carolina.

4 Occurrence of suitable collection points—Effective booming strategies include deflecting oil to a collection point where the oil is trapped and recovered. Optimal collection points would be features such as clay banks, sand bars, solid revetments, and boat ramp areas. Stream types can be differentiated according to whether they are likely to have these features.

5 Channel leakage and bifurcation—In places where the water easily escapes the confinement of a discrete channel and there is no bank to deflect the oil to, containment becomes much more difficult than it would be in a channel with well-defined banks. Furthermore, if the channel abruptly breaks up into a number of smaller channels with a multitude of directions in which the oil can flow, that also decreases the likelihood of containment and recovery.

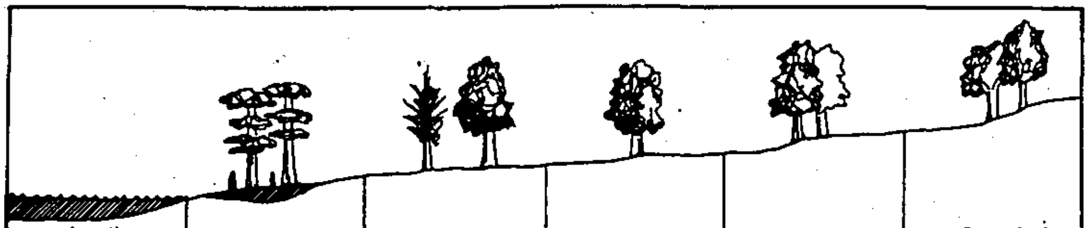
6 Residence time—The longer the oil remains in the environment, the more likely it is to do harm. Habitats such as quiet water swamps would tend to retain oil and be difficult to clean up.

Wetland Sensitivity and Vulnerability. The second criteria used to delineate sensitivity of stream reaches is the abundance of sensitive and vulnerable wetlands within the reach and the potential for oil to leave the main channel of the stream and impact the wetland. We differentiate between *vulnerability*, which is the potential for being exposed to oil because of the physical location of the wetland, and *sensitivity*, which is how the wetland type is expected to be affected by exposure to oil. In general, stream banks in the southeast are either muddy sand or sandy mud, and those that without wetlands are not particularly sensitive to oil-spill impacts. Freshwater marshes are rare in the piedmont and coastal plain river systems of the Southeastern U.S., the dominant wetland type being *bottomland hardwood ecosystems*. Clark and Benforado (1981), Mitsch and Gosselink (1986), and Taylor et al. (1990) described the zonation of the bottomland hardwood ecosystems relative to the main channel of the stream. Six zones were described, ranging from Zone I, the permanently wet stream or river itself, to Zone VI, a transition zone between the floodplain and the uplands that is rarely flooded (Taylor et al. 1990).

A generalized floodplain cross-section showing the different zones of the bottomland hardwood system and descriptions of the conditions in each zone is given in Figure 13. These zones have very distinct plant assemblages, as is shown in Table 3. Clearly, Zones II and III are the most vulnerable of the zones to oil pollution, because they are the areas most frequently flooded. Zones IV and V are considerably less vulnerable. In terms of oil behavior, oil entering Zones II and III would be on the water surface for a long time and if mixed into the water column, it would impact the abundant aquatic life there, such as insects, frogs, salamanders, and both juvenile and adult fishes. Because of the denseness of the vegetation, size of the trees, and abundant litter of limbs and downed trees, this would be a very difficult habitat to clean up after a spill. In the less probable event that oil is carried into the upper zones (IV and V), the oil left behind would typically be on unsaturated silt/ clay soils where the oil could be cleaned up relatively easily. Consequently, with respect to oil-spill response considerations, Zones II and III have a higher rank on the sensitivity scale than Zones IV and V.

Taylor et al. (1990) discussed in detail the functions and values of the bottomland hardwood ecosystem. Key functions include their contribution to community dynamics, surface water storage (as discussed above), and groundwater storage. They are valuable as fish and wildlife habitat, providers of food chain support by exporting detritus, controllers of erosion, and protectors of water quality, among other values. In general, the lower zones rank higher in terms of their functions and values than the upper zones, and are thus more sensitive to long-term impacts from oil spills.

Adams et al. (1983) discussed the oil-spill sensitivity of the wetlands in the response area for the Louisiana Offshore Oil Port. A team of biologists with oil spill experience ranked four wetland habitats—freshwater swamps, freshwater marshes, freshwater aquatic beds, and open freshwater—with respect to sensitivity to oil spill impacts. Of these four habitats, freshwater swamps received the highest possible rank (most sensitive) for habitat recovery, persistence of oil, and cleanup damage, and they received the highest overall priority ranking of the four habitat types.



	I	II	III	IV	V	VI
Zone	Aquatic ecosystem	Bottomland hardwood ecosystem — Floodplain				Bottomland upland transition
Name	Open water	Swamp	Lower hardwood wetlands	Medium hardwood wetlands	Higher hardwood wetlands	Transition to uplands
Water modifier	Continuously flooded	Intermittently exposed	Semipermanently flooded	Seasonally flooded	Temporarily flooded	Intermittently flooded
Flooding frequency, % of years	100	~100	51-100	51-100	11-50	1-10
Flooding duration, % of growing season	100	~100	>25	12.5-25	2-12.5	<2

Figure 13. Zonal classification of bottomland forest wetlands showing average hydrologic conditions. From Mitsch and Gosselink (1986, Figure 14-6; after Clark and Benforado 1981).

For purposes of the river reach classification discussed in this report, we have combined Zones II and III into one class that will be henceforth referred to as *cypress-tupelo swamps*, because two readily recognizable tree species, bald cypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*) are the predominant vegetation of the two classes (Table 3). Zones IV and V are also lumped into a single class that shall be referred to as *upper bottomland hardwood forests*. Again, of the two classes, the *cypress-tupelo swamps* are thought to be considerably more vulnerable and sensitive to long-term oil spill impacts than *upper bottomland hardwood forests*.

A Theory of Flood Plain Vulnerability/Sensitivity. Considering flood plains as a whole, one could deduce that the lowest part of the flood plain is the most vulnerable to oil spill impacts because it is more likely to be flooded, and , hence, brought into contact with the oil. Furthermore, the most sensitive wetlands, *cypress-tupelo swamps*, are on the lowest portions of the flood plain.

Our observations of piedmont and coastal plain rivers in South Carolina revealed striking differences in many attributes of the two river types (summarized in Table 2), in addition to the hydrograph dissimilarities discussed above. This contrast was particularly exemplified by two of the rivers we studied in the field for this project, the Tyger and the South Edisto, which are about the same size in terms of stream width and discharge (see hydrographs of the two rivers in Figure 10). The differences between the *flood plains* of the two streams was of particular importance.

Table 3. Selected tree and shrub species occurring in bottomland hardwood forests of the Southeastern United States. From Taylor et al. (1990; after Larson et al. 1981).

Species	Ecological Zone II	III	IV	V	VI
Taxodium distichum (bald cypress)	x	x			
Nyssa aquatica (water tupelo)	x	x			
Cephalanthus occidentalis (buttonbush)	x	x			
Salix nigra (black willow)	x	x			
Planera aquatica (water elm)	x	x			
Forestiera acuminata (swamp privet)	x	x			
Acer rubrum (red maple)		x	x	x	x
Fraxinus caroliniana (water ash)		x	x		
Itea virginica (Virginia willow)		x			
Ulmus americana var. floridana (Florida elm)		x	x		
Quercus laurifolia (laurel oak)		x	x	x	
Carya aquatica (bitter pecan)		x	x		
Quercus lyrata (overcup oak)		x	x		
Styrax americana (smooth styrax)		x			
Gleditsia aquatica (water locust)		x	x		
Fraxinus pennsylvanica (green ash)		x	x		
Diospyros virginiana (persimmon)		x	x	x	x
Nyssa sylvatica var. biflora (swamp tupelo)		x			
Amorpha fruticosa (lead plant)		x	x		
Betula nigra (river birch)		x	x		
Populus deltoides (eastern cottonwood)		x	x		
Baccharis glomeruliflora (groundsel)			x	x	x
Cornus foemina (stiff dogwood)		x	x		
Viburnum obovatum (black haw)			x		
Celtis laevigata (sugarberry)			x	x	x
Liquidambar styraciflua (sweetgum)			x	x	
Acer negundo (box elder)			x	x	
Sabal minor (dwarf palmetto)			x	x	
Gleditsia triacanthos (honey locust)			x	x	x
Ilex decidua (possum haw)			x	x	x
Crataequs viridis (green hawthorn)			x		
Quercus phellos (willow oak)			x	x	x
Platanus occidentalis (sycamore)			x	x	x

Tyger (piedmont river) – High, narrow flood plain, several feet above the mean water level of the stream. No *cypress-tupelo swamps* present. *Upper bottomland hardwood forests* present in places but not common. Sediments usually sandy.

South Edisto (coastal plain river) – Low, relatively wide flood plain, commonly only inches above the mean water level of the stream. *Cyprus-tupelo swamps* present in extensive areas across the flood plain. *Upper bottomland hardwood forests* present on hammocks and around the edges of the flood plain. Sediments muddy and organic rich.

We believe the high flood plains of the piedmont river are the result of the flashy discharge of the stream. After heavy rains, the river rises quickly to a high level and sediments are transported up on top of the flood plain, building it up because of both the extreme water level and the large transporting capacity the stream has for sediments. In our field work on the Tyger, we could see evidence that sand had been deposited all the way across the narrow flood plain during a recent flood.

The coastal plain rivers, on the other hand, have a steady discharge minus the ultra-high water levels and the flood plains are not built up so high. With the low banks on the main channel, the river frequently "leaks" into the adjacent *cypress-tupelo swamps*.

Thus, in general, piedmont river flood plains are less sensitive to oil-spill impacts than are coastal plain river flood plains. Although located in the coastal plain, many of the streams in the Leaf River watershed, including the mainstem, have elevated flood plains similar to those of the piedmont rivers of South Carolina. Typical Leaf River morphology Figure 14) has a flood plain 15-20 feet above the present normal river level, presumably because of neotectonic activity of the Wiggins Uplift (see Figure 11). The flood plains contain numerous uplifted and isolated oxbow lakes. There are at least two other coastal plain rivers with rather high banks: the St. Marys and Suwannee rivers in Florida, both of which flow across the slowly uplifting Ocala Arch.

A REACH CLASSIFICATION SCHEME FOR THE SOUTHEASTERN U.S.

The RSI classification in Table 4 relates the reaches of the piedmont and coastal plain rivers and streams of the Southeastern U.S. to oil-spill sensitivity. The characteristics of the classes are presented in matrix form in Table 5. The classification scale is 1-10, with the most sensitive reaches ranked 10. Diagrammatic sketches of the different reach classes are presented in Figure 16. Key determinants of rank were difficulties anticipated for containing and recovering the spilled oil and wetland sensitivity and vulnerability. We define a navigable stream as one on which it is relatively easy to operate a motorized jon boat or inflatable craft.

Assuming this ranking is a true measure of the sensitivity of Southeastern U.S. small rivers and streams, it is clear that, as a class, coastal plain rivers are much more sensitive than are piedmont rivers. As Figure 17 shows, all of the piedmont rivers in South Carolina we have studied have

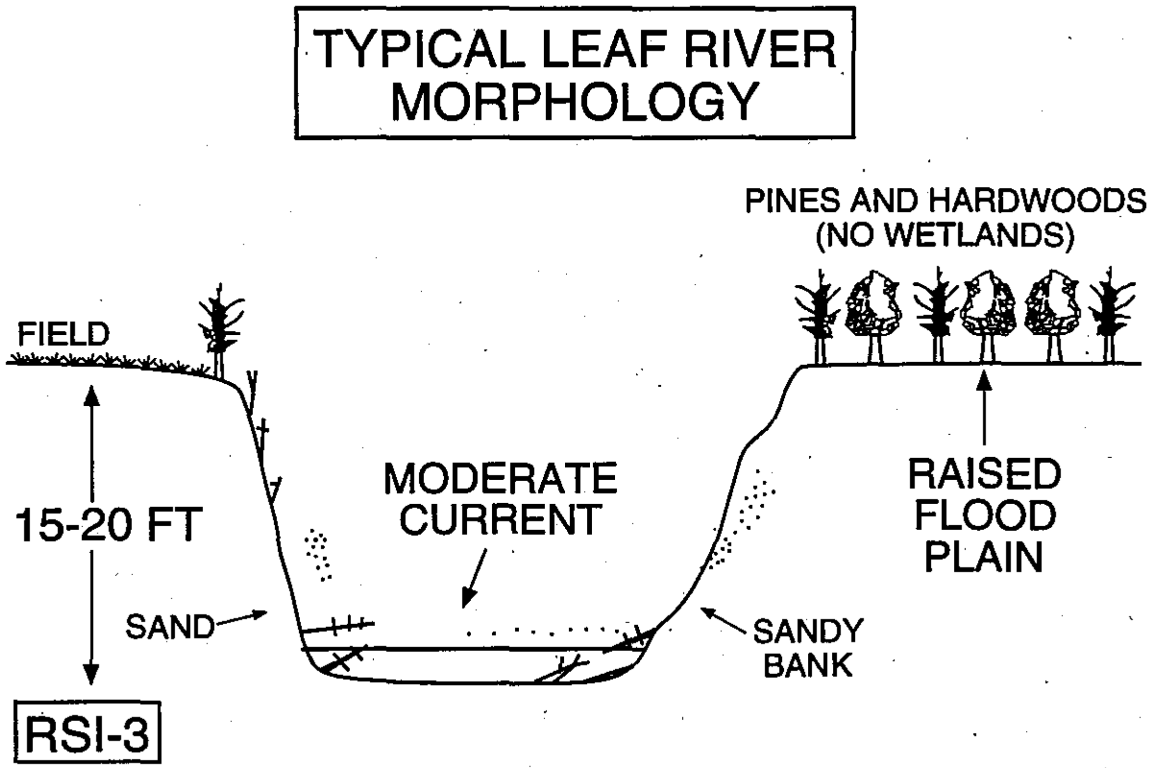


Figure 14. Typical Leaf River morphology. Flood plain has been raised tectonically under the influence of the Wiggins uplift (see Figure 11).

reaches that are classified 1-6 where they are flowing within the piedmont region. However, all reaches of the coastal plain rivers in South Carolina are classed 7-10 where the river is flowing in the coastal plain. The headwaters of coastal plain rivers that occur within the piedmont have reaches classed 1-4. We do not yet have enough observations to comment on those reaches of piedmont rivers that occur within the coastal plain. These conclusions are based on observations made mostly in South Carolina. Because of the tectonic uplift of the Leaf River watershed and the resulting high flood plains, most of the stream reaches are classified 1-6, with class 3 being very common. The exception is the headwater streams that are furthest away from the center of the Wiggins Uplift, where classes 9-10 predominate. Classes 7 and 8 were not present in the Leaf River watershed.

SUGGESTED STUDY APPROACH

The following approach is suggested for future RSI mapping projects of specific watersheds:

1 Complete review of all pertinent literature.

2 Examine representative watershed hydrographs for clues about flood plain characteristics.

3 Purchase complete coverage of USGS 1:24,000 scale topographic maps.

4 Classify representative reaches of the mainstem and tributaries (RSI) using the 1:24,000 topographic maps before going into the field. This will indicate whether or not other library or data sources need to be consulted should it become evident new reach types are present.

5 Conduct field survey, which involves the following:
   a. Visit all ground access points, such as bridge crossings and boat ramps, taking photographs and examining sediments and associated wetlands.
   b. If possible, inspect the latest vertical aerial photographs (infrared, if available). Using these photographs, classify the reaches of the major streams in the watershed deemed relevant to the project, using the 1:24,000 scale maps.
   c. Overfly area in small aircraft (high-wing Cessna or helicopter) to verify and complete RSI classifications, locate boat ramps and potential collection sites, etc. Photograph representative reach classes.

6 Transfer field data to final maps (1:100,000 scale maps in the case of the Leaf River).

7 Data on biological and human-use resources are treated in the same fashion as has been done for NOAA ESI mapping projects (see NOAA 1994 for complete discussion of these techniques).

Table 4. Proposed oil-spill sensitivity classification of the reaches of the small rivers and streams of the Southeastern U.S.

RSI CLASS	REACH DESCRIPTION	BASIS FOR RANKING
1	Quiet water pools with low-sensitive banks.	No vulnerable wetlands. Oil could be recovered from water surface or collected against low-sensitive banks.
2	Small, non-navigable channel with moderate currents and low-sensitive banks.	No vulnerable wetlands. Underflow dam could be constructed or oil could be collected against low-sensitive banks.
3	Navigable channel with moderate currents and low-sensitive banks.	No vulnerable wetlands. Oil could be collected against low-sensitive banks. More difficult than RSI-2.
4	Small, non-navigable channel with rapids over bedrock.	No vulnerable wetlands. Oil would be moved quickly through area with water column impacts likely. Underflow dam a remote possibility if stream is small enough.
5	Navigable channel with rapids over bedrock.	No vulnerable wetlands. Oil could not be collected and would move quickly through area. Water column impacts greater than those of RSI-4, with significant fish kills likely.
6A	Small, non-navigable channel with associated low-vulnerable *upper bottomland hardwoods.*	*Upper bottomland hardwoods* and rare *cypress-tupelo swamps* present but not highly vulnerable because of elevated or remote location. Collect oil against low-sensitive channel banks.
6B	Navigable channel with associated low-vulnerable *upper bottomland hardwoods.*	*Upper bottomland hardwoods* and rare *cypress-tupelo swamps* present but not highly vulnerable because of elevated or remote location. Collect oil against low-sensitive channel banks.
7	Navigable. Low gradient and variable currents (usually <1.5 knots). Wide and low flood plain. Stream hugs old valley wall with steep banks composed of muddy sediments or bedrock against the wall. Other side of channel has leakage of waters into an associated wide *cypress-tupelo swamps.*	Highly sensitive wetlands present on one side of the stream that are vulnerable to oiling. It should be possible to collect oil against the low-sensitive banks adjacent to the high wall.
8	Navigable. Low gradient and variable currents (usually <1.5 knots) with flow mostly confined to relatively straight channel with well-defined low banks. Wide and low flood plain. Associated wide *cypress-tupelo swamps.*	Highly sensitive wetlands present on both sides of stream that are vulnerable to oiling at normal high water. Because of channel confinement of the main flow of the stream, may be possible to direct oil to a collection point further downstream.

Table 4. Continued.

RSI CLASS	REACH DESCRIPTION	BASIS FOR RANKING
9A	Small, non-navigable meandering channel with abundant leakage points into associated *cypress-tupelo swamps* and ox-bows.	Highly vulnerable *cypress-tupelo swamps* present on both sides of channel. Points of leakage difficult to close. Recovery and storage very difficult. Access by foot.
9B	Navigable meandering channel with abundant leakage points into associated *cypress-tupelo swamps* and ox-bow lakes.	Highly vulnerable *cypress-tupelo swamps* present on both sides of channel. Multiple points of leakage difficult to close. Recovery and storage very difficult. Access by boat.
10A	Small, non-navigable anastomosing channel with abundant leakage points into adjacent *cypress-tupelo swamps*.	Highly vulnerable *cypress-tupelo swamps* present on both sides of channel. Multiple points of leakage difficult to close. Recovery and storage very difficult. Access by foot.
10B	Navigable anastomosing channel with abundant leakage points into associated *cypress-tupelo swamps*.	Highly vulnerable *cypress-tupelo swamps* present on both sides of channel. Multiple entry points of leakage difficult to close. Recovery and storage very difficult. Access by boat.

Table 5. Characteristics of the different sensitivity classes for rivers and streams (compare with Table 4).

SENSITIVITY CLASS	Current Velocity			high flood plain/banks	low flood plain/banks	Flood Plain		hugs valley wall	associated cypress-tupelo swamps	no associated wetlands	periodically flooded bottom-land hardwoods	bedrock rapids	straight	low sinuosity	high sinuosity	anastamosing	navigable	non-navigable	Bottom Type		
	high	int.	low			wide	narrow												sand	rock	mud
1			x	x		x	x			x							x		x	x	x
2		x		x			x			x			x	x	x			x	x	x	x
3		x		x		x	x			x			x	x	x		x		x		x
4	x			x			x			x		x	x					x	x	x	
5	x			x		x	x			x		x	x				x		x	x	
6A		x		x			x				x		x	x	x			x	x		x
6B		x		x		x					x		x	x	x		x		x		x
7		x			x	x		x	x		x						x		x		x
8		x			x	x			x		x		x	x			x		x		x
9A		x			x	x	x		x		x				x			x	x		x
9B		x			x	x			x		x				x		x		x		x
10A		x			x	x	x		x		x					x		x	x		x
10B		x			x	x	x		x		x					x	x		x		x

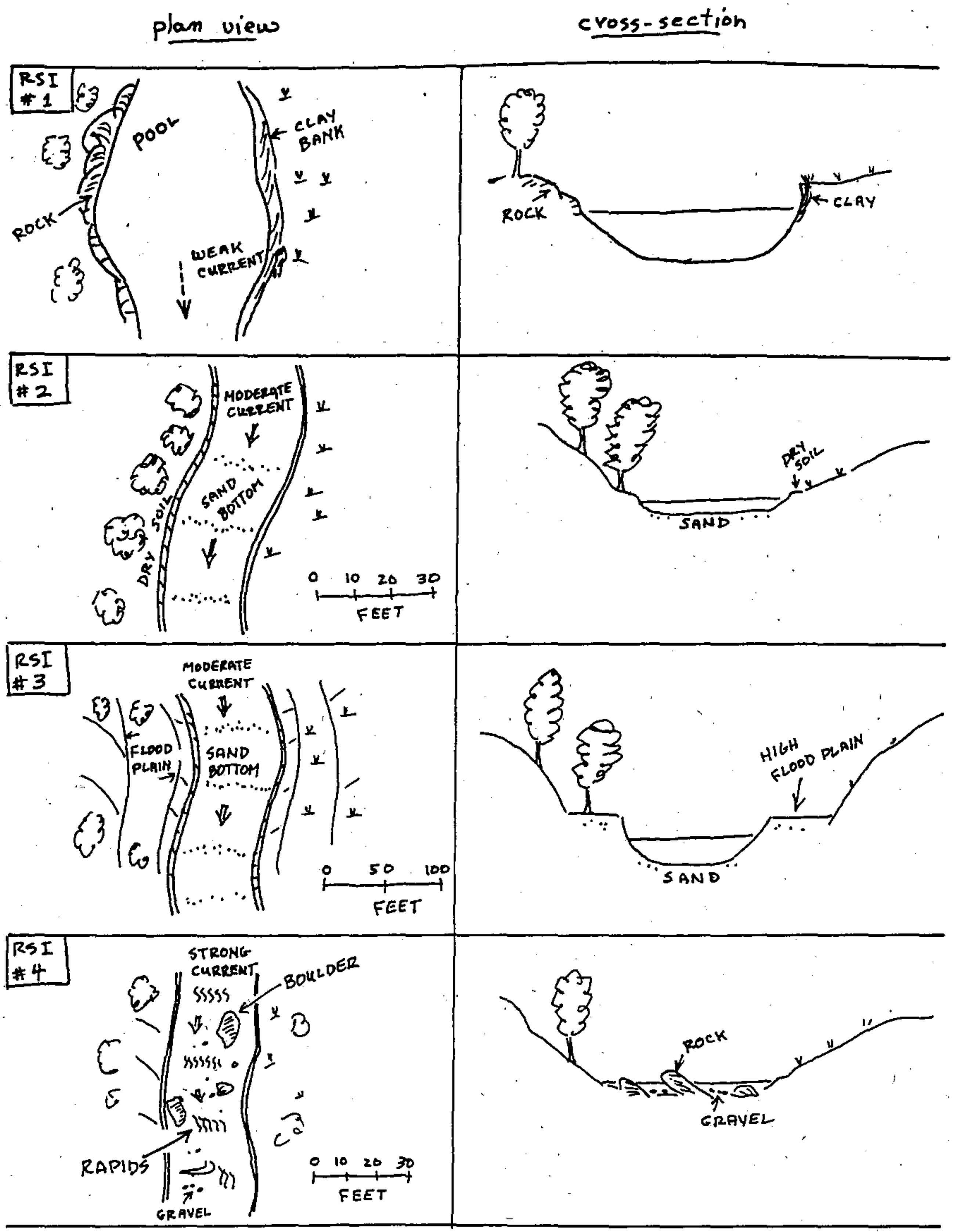
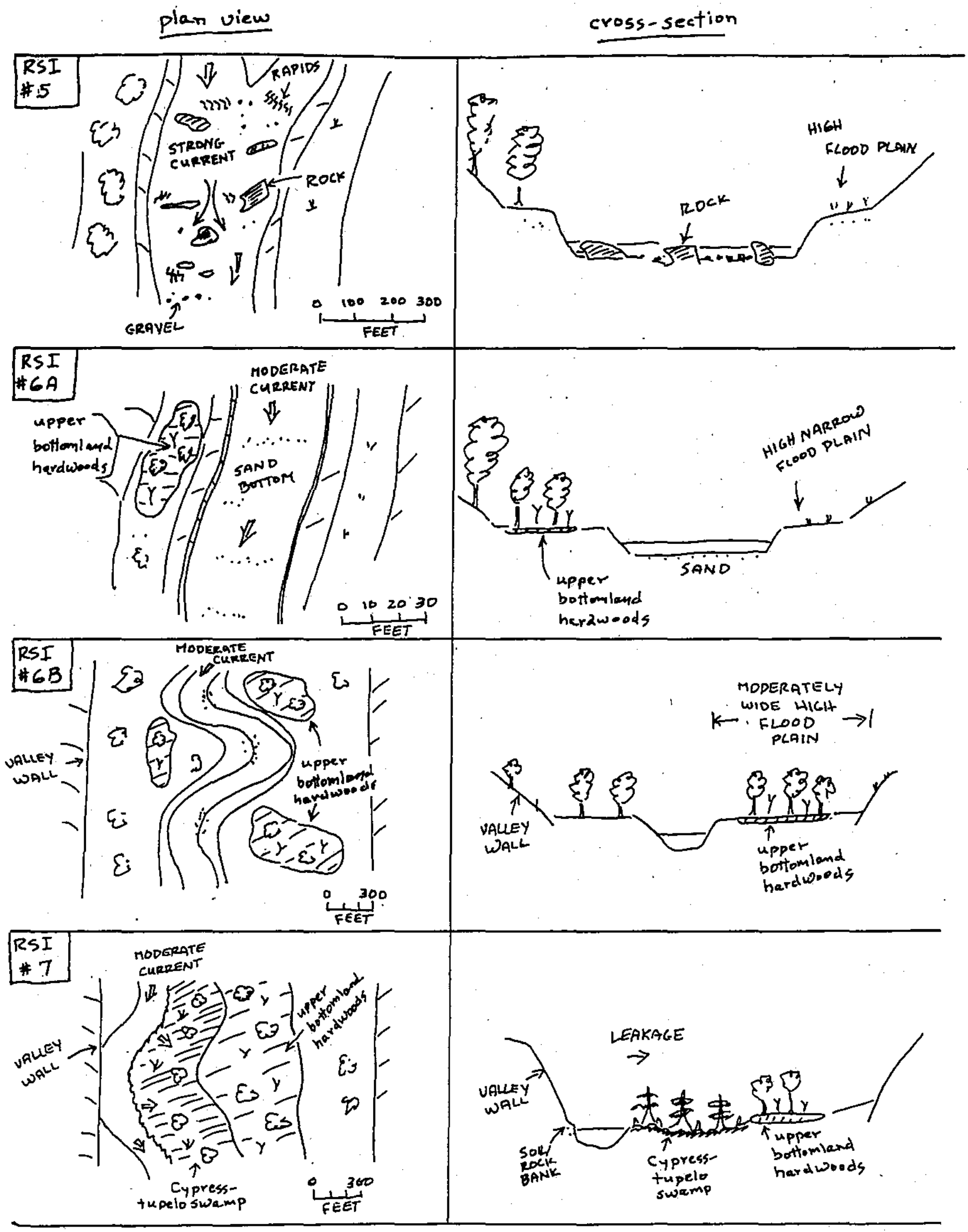


Figure 15. Diagrammatic sketches of the different classes of the reach sensitivity index (RSI) to oil spills.



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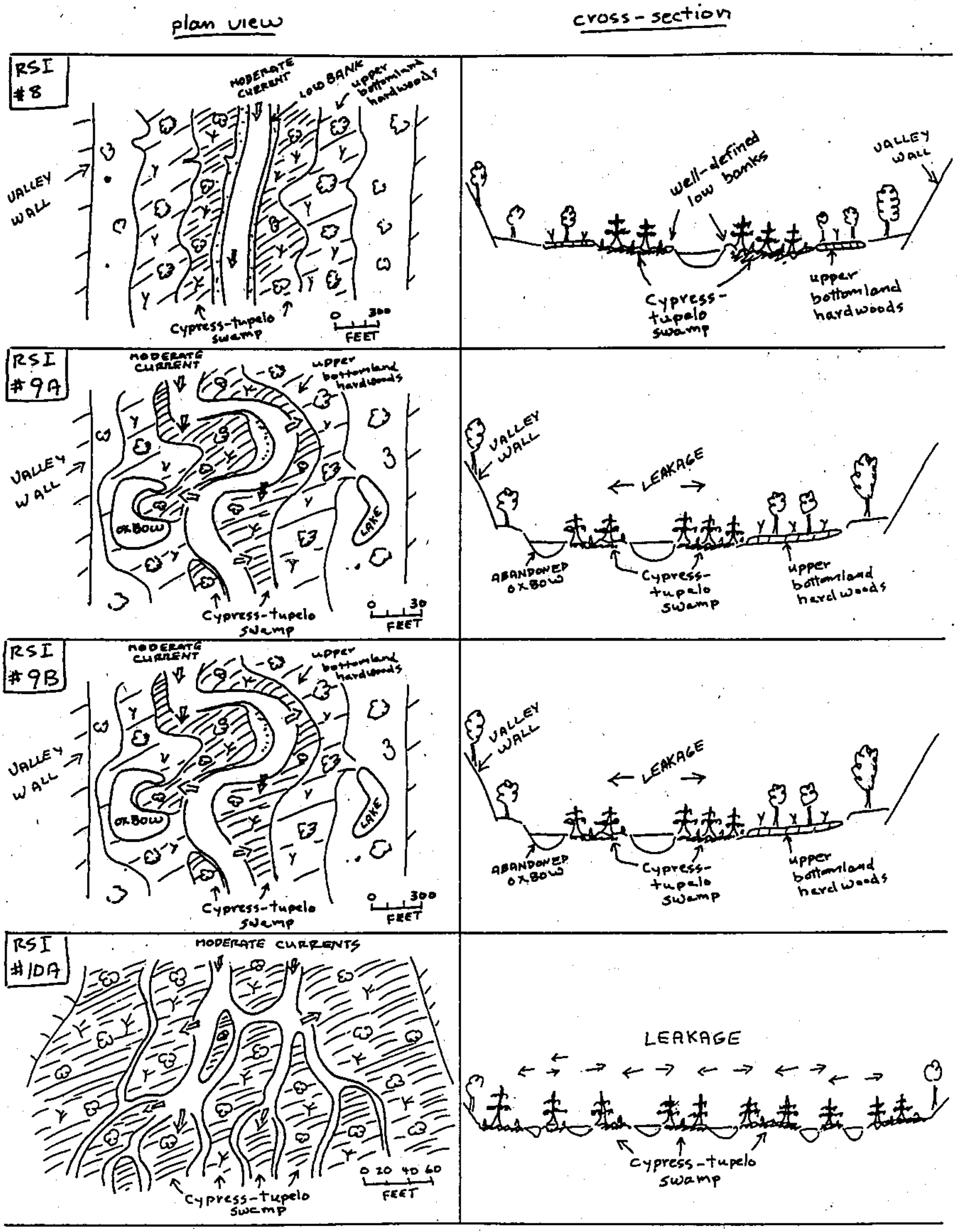

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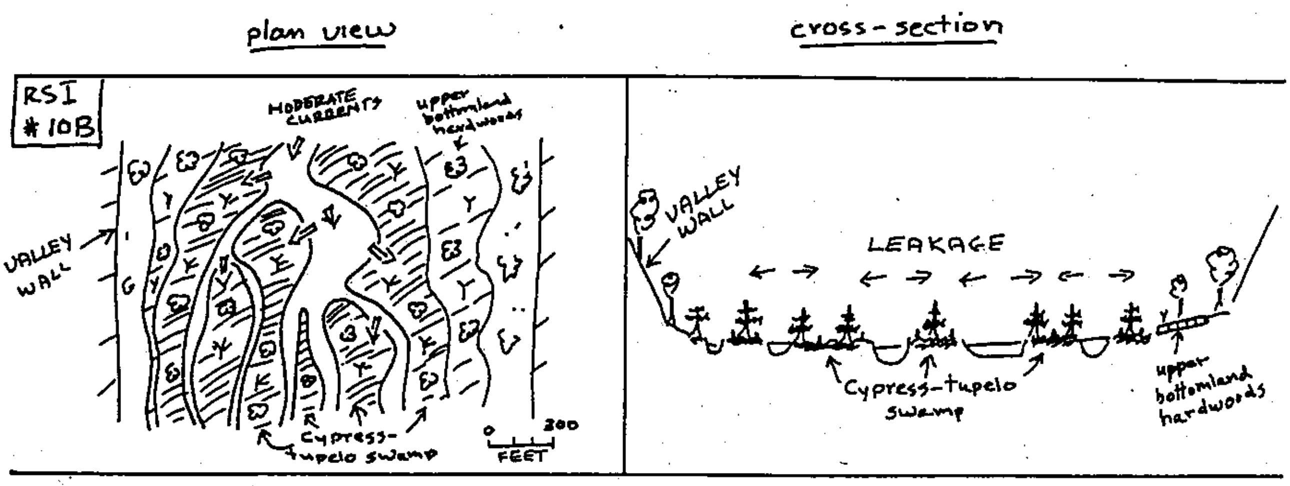

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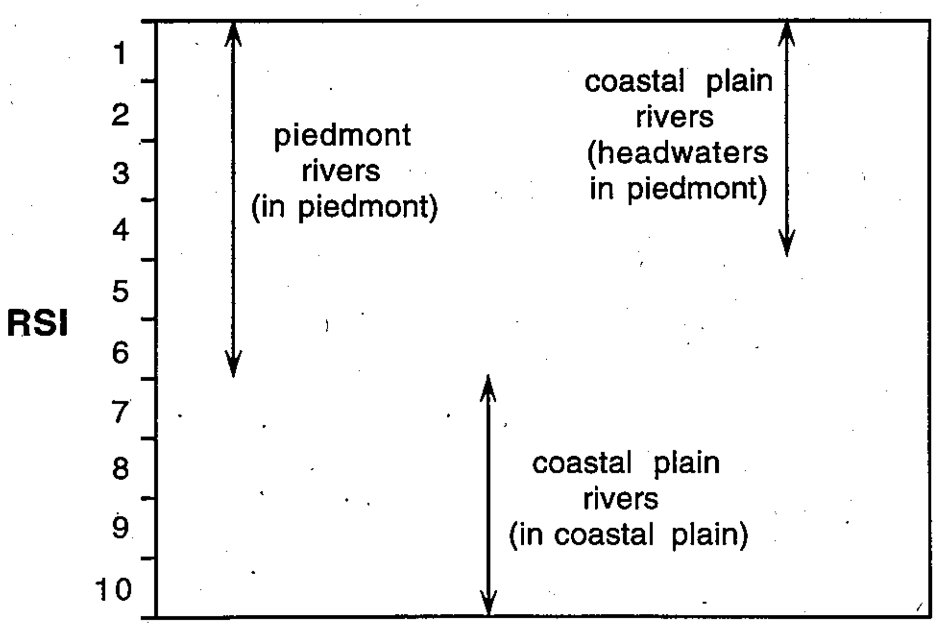

Figure 16. RSI ranking for piedmont and coastal plain rivers in South Carolina.

CONCLUSIONS

1 No previously published classifications of streams adequately address the issue of oil-spill response. The classification used in this project is based on *stream reach sensitivity* to oil spills.

2 The key components of *reach sensitivity* are:
  a. The degree of difficulty anticipated for the containment and recovery of the oil; and
  b. the sensitivity and vulnerability of the associated wetlands.

3 The key factors in containment and recovery are:
  a. Navigation;
  b. Water flow patterns;
  c. Stream size;
  d. Occurrence of suitable collection points;
  e. Channel leakage and bifurcation; and
  f. Oil residence time.

4 *Bottomland hardwood ecosystems* are the most vulnerable and sensitive wetlands present in any abundance along the small rivers and streams of the southeastern USA. Of these, the *cypress-tupelo swamps* are considered to be both more vulnerable and more sensitive to oil-spill impacts than the associated *upper bottomland hardwoods.*

5 The distinction between *piedmont* (redwater) and *coastal plain* (blackwater) rivers was a critical factor in developing ideas on how to map sensitivity of small rivers and streams to oil spills.

6 Relative elevation of associated flood plains was a key element in stream reach sensitivity. Higher, less sensitive flood plains occurred:
  a. Along streams with a flashy discharge; and
  b. Along streams recently uplifted by tectonic activity

7 In the Leaf River Watershed, the *least* sensitive reaches were:
RSI-1—Quiet water pools with low-sensitive banks; and
RSI-2—Small, non-navigable channels with moderate currents and low-sensitive banks.
The <u>most</u> sensitive reaches were:
RSI-9A—Small, non-navigable meandering channels with abundant leakage points into adjacent *cypress-tupelo swamps* and ox-bows;and
RSI-10A—Small, non-navigable anastomosing channels with abundant leakage points into adjacent *cypress-tupelo swamps*.

8 The RSI scale devised in Phase I for South Carolina applied equally well to the Leaf River, with only minor modifications. This indicates that the RSI scale may be applicable to all small rivers and streams throughout the piedmont and coastal plain regions of the southeastern USA.

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APPENDIX A:

STATUS REPORT ON DATA SOURCES FOR INLAND AREA MAPPING, EPA REGION 4

DATA SOURCES FOR INLAND AREA MAPPING EPA REGION 4

The following tables list the data sources being evaluated for use in mapping the Leaf River, Mississippi watershed. Some of the key data sources have not yet been received, thus we have not been able to evaluate their utility for this prototype and the full-scale mapping effort for the entire region.

There are three important data layers that are not likely to be available within the time frame of this project: pipelines, floodplains, and wetlands. The Office of Pipeline Safety is working with industry to develop databases on pipeline corridors, but the timeline for completion is well beyond the scheduled end of Phase II. Pipeline data are very complex, and there are many problems with data completeness and accuracy. We strongly recommendthat EPA rely on OPS to resolve these problems and obtain the pipeline data when OPS and industry agree that the data are suitable for release.

For floodplains, the Federal Emergency Management Agency (FEMA) is progressing with data automation, but slowly. A strictly digital "Q3 Flood Data" layer is being compiled for 800 counties in the U.S. by July 1996. Some Mississippi counties are likely to be included in this FEMA list. We will keep in contact with FEMA's contractor to determine when counties in the Leaf River watershed are available, so we can evaluate the use of these data.

Wetlands from the National Wetlands Inventory are not available at the 1:100,000 scale and only four of the 63 1:24,000 scale quads required to map the river reaches are in digital form. Our only other option for getting wetlands data is to use the old 1974 Land Use/Land Cover data, which is a nationwide data set and is available from the USGS. These data contain standard generalized categories (Anderson Level 1) and include a wetland class. The lack of NWI data, even in paper copy for some areas, is a critical problem in field-verification of the reach classification and the final map product. We are currently evaluating the 1974 Land Use/Land Cover data as an alternative.

The table is divided into: 1) data layers for our use in devising the river reach classification; and 2) data layers for inclusion in the map and digital deliverable. Key data for our classification analysis are the EPA River Reach (RF3) for the three hydrologic units in the watershed, the soils and geology data from MARIS, and the gaging stations (5) and associated discharge data from the USGS in Jackson, Mississippi. We have also received a price list from the USGS for digital elevation model (DEM) data for the study area. All of the 1:24,000 scale quadrangles are available, but only one 1:100,000 scale quadrangle is available for the watershed. These data may be processed for slope and aspect characteristics, which may support the river reach classification scheme as well as provide insight into the geological trends in the watershed. We are awaiting a decision to purchase these data.

RIVER REACH CLASSIFICATION:

THEME	SOURCE	STATUS
1. River Reach (RF3)*	EPA	IN
2. Hydrologic Units	USGS MARIS	IN Waiting for new media
3. Watershed Boundaries*	MARIS	Waiting for new media
4. County Soils	MARIS	Waiting for new media
5. STATSGO (soil associations)	MARIS	Waiting for new media
6. Geologic Formations	MARIS	Waiting for new media
7. Wetlands*	NWI	Not Received
8. Flood Plains*	FEMA	To date, digital data not available from State Distribution Center (FEMA has a designated site in each state)
9. Slope	DEM (USGS Eros Data Center)	Waiting for approval to purchase data
10. Gaging Stations (and data)	U.S. Geological Survey (Jackson, MS)	Download on February 7, from ftp site

* Data layers also for map/digital product.

MAP AND DIGITAL PRODUCT:

THEME	SOURCE	STATUS
1. Major Land Resource Areas	MARIS	Waiting for new media
2. Wellhead Protection Areas	MARIS	Waiting for new media
3. National Forests	MARIS	Waiting for new media
4. Quad Boundaries	USGS	IN
5. Managed Lands	TIGER 92	IN
6. Threatened and Endangered Species	NHP	Received via email
7. Sensitive Areas	MARIS	Waiting for new media
8. Facilities/Spill Sources	EPA	Not Received
9. Pipelines	OPS	Not Received
10. Archaeological and Historical Sites	Mississippi Department of Archives and History	IN
11. Water Intakes	Mississippi Department of Environmental Quality (Office of Land and Water Resources)	Not Received
12. Accesses and Collection Points	RPI	Collect during field work
13. Transportation	TIGER 92	IN
14. Miscellaneous Data from two National Forests	U.S. Forest Service (Bienville and De Soto National Forests)	Not Received

APPENDIX B:

BIBLIOGRAPHY ON OIL SPILLS IN RIVERS AND STREAMS

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