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TECHNICAL REPORT

A SURVEY OF THE BON SECOUR RIVER WATERSHED

An Overview of Land-Use Practices and Examination of the Effects of Development on the Aquatic Resources of the Basin

Coastal Program

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ALABAMA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
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JULY, 1996

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DISCLAIMER

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EXECUTIVE SUMMARY

The Bon Secour River Watershed, a basin located in a mostly rural but rapidly developing area of South Baldwin County, was surveyed for characterization of the land-use practices, soil types, topography, habitat and biological resources of the watershed. Some of the impacts of construction, real estate development and urban non-point sources on habitat and biological resources are described. Although the basin possesses a minimal amount of industrial development, the effects of storm water runoff, erosion, siltation and other problems related to non-point sources were observed to have significant impacts on the aquatic habitats of the basin. The impacts were typical of non-point related problems, i.e. turbidity and siltation from erosion, nutrient enrichment and enteric bacteria contamination.

The watershed also has experienced a significant amount of waterfront development and shoreline alteration. Many of the waterfront residences along the river have shoreline bulkheads, excavated boat slips and piers.

From the findings of this study it would appear that the most benificial course of action for diminishing harmful impacts to the watershed is for local developers, utility crews, builders and those in the general construction trades to follow the methods of Best Management Practices (BMPs) developed for the control of erosion and stormwater runoff.

INTRODUCTION

The economic development and growth of the Alabama coastal zone during the past decade has been characterized by the transformation of woodlands and pasture into subdivisions, condominiums, shopping centers and boat marinas. Recent years also have witnessed a remarkable population increase, especially in south Baldwin County. These changes have placed the pressures of urban development on waterbodies which, until recently, have been somewhat removed from the direct consequences of high population density and large expanses of commercial development.

The more conspicuous effects of "urbanization" on our aquatic resources include, but are not limited to: trash and litter washed from parking lots and streets by storm runoff, loss of natural shoreline due to bulkhead and fill development, sewage and pathogenic bacteria from aging and/or overloaded sanitary systems, surface oil sheens and oily sediments resulting from run-off contaminated with petroleum by-products. But perhaps the more serious and widespread of these effects have been decreased water clarity, increased rates of stream siltation and losses of aquatic habitat caused by erosion from land disturbance activities. (Alabama Department of Environmental Management 1989, 1994 and 1995; National Research Council 1990; U.S. Environmental Protection Agency 1991 and 1992, U.S. Fish and Wildlife Service 1990).

Over the last quarter century significant progress has been achieved in the prevention and reversal of water quality degradation both in the state of Alabama and across the United States. The majority of this improvement has been realized through increasingly stringent standards imposed on industrial and municipal point source discharges. Although these measures have been effective in controlling the waste water discharged from industrial facilities and municipal sanitary treatment plants, the National Pollutant Discharge Elimination System (NPDES) program which provided the regulatory mechanism for this has, until lately, failed to address the impacts from urban runoff and other non-point sources (U.S. Environmental Protection Agency 1991).

Increased occurrence and severity of these problems have resulted in a need for updated programs for monitoring surface waters. Furthermore, the losses of aquatic habitats and impairment of water quality have necessitated that erosion from cleared land, runoff of urban stormwater and other non-point sources of pollution be effectively controlled, especially in areas experiencing intensive real estate development (National Research Council 1990; U.S. Fish and Wildlife Service 1990).

In the pursuit of more effectual protection of the state's aquatic resources, the Alabama Department of Environmental Management (ADEM) has established a multi-year agenda of watershed surveys as a component of the Department's Coastal Resource Monitoring Strategy (Alabama Department of Environmental Management 1993). The initial guidance for the development of a methodology for watershed surveys was provided by the watershed protection approach (WPA) instituted by the U.S. Environmental Protection Agency (U.S. Environmental Protection Agency 1991 and 1992).

Monitoring and management of aquatic systems traditionally has been approached from the perspective of studying the characteristics of a waterbody and the influences of municipal and industrial development immediately proximate to the waters of interest. The majority of monitoring programs fall into three basic categories: short-term intensive surveys, monitoring of emergency episodes and long-term, routine monitoring of fixed stations (trends tracking) (National Research Council 1990).

Customarily, stream and lake surveys have focused on specific point source discharges and their receiving waters for the purpose of lessening the environmental effects of wastewater effluents (i.e., waste-load allocation studies). Although this concept has been beneficial in achieving the improvements in water quality realized over the past quarter century it does not always account for the impacts of urban development and construction. Short-term monitoring related to episodic events (i.e., oil spills, raw sewage discharges and chemical releases) has provided valuable information on acute effects of certain pollutants but has not allowed study of more subtle long-term changes (Alabama Department of Environmental Management 1993; National Research Council 1990; U.S. Environmental Protection Agency 1991 and 1992).

The strategy of regularly and periodically monitoring a network of fixed stations has been valuable for tracking long-term trends in water quality. However, routine trends monitoring is not, as a rule, designed for sampling in conjunction with storm events. Indeed, routine monitoring trips often are conducted on days of fair weather as would be the choice of most field personnel! Therefore, trends monitoring frequently fails to detect the ephemeral but significant changes in water quality that are the result of stormwater runoff from urban areas. Environmental agencies also have a tendency to conduct trends monitoring primarily for evaluating waters with regard to wastewater discharges. Consequently, short term and/or localized but serious degradation to surface water quality from non-point sources has been overlooked, if not altogether ignored. (National Research Council 1990; U.S. Environmental Protection Agency 1991).

The WPA however, emphasizes a multi-discipline approach for more effective protection of aquatic resources. This strategy includes, but is not limited to, the incorporation of land-use information, census data and municipal development plans. The WPA also makes use of a wider scope of field investigations which includes; examination of impairments to recreational uses of water and their potential as risks to human health, investigation of stormwater runoff, analyses of sediment chemistry, assessment of aquatic habitats and evaluation of shoreline alterations, the extent of stream channelization and similar modifications of waterways. Field surveys also should take into account the effects of natural forces such as storms, climatological extremes, topography and soil characteristics which have the potential for significantly influencing water quality (National Research Council 1990; U.S. Environmental Protection Agency 1991).

The WPA also emphasizes involvement of local government, businesses and, most importantly, the citizens of the watershed. Regulation by a municipal or county agency often is viewed more favorably by local residents than control at the state or federal level. Education of the business community, local officials and citizens as to the property damage (both public and private) caused by uncontrolled stormwater runoff provides a better appreciation on both sides as to the need for control of erosion and urban runoff. Finally, the results of the study should be developed into a plan for remediating existing degradation, reducing the sources of contamination and avoiding additional deterioration from future development (U.S. Environmental Protection Agency 1991; U.S. Fish and Wildlife Service 1991).

A demonstration study of the Dog River Watershed (DRW) in Mobile County was conducted in 1993 through 1995 by the ADEM Mobile Field Branch. Findings and recommendations of the study, along with the methods utilized for stream surveillance, field investigations and sampling are detailed in two published reports (ADEM 1994 and 1995). Experience obtained from the Dog River Watershed survey has allowed ADEM to refine the basic WPA strategy and develop a watershed protection approach pertinent to the drainage basins in the coastal plains of Alabama.

Valuable lessons learned from the study of the DRW include:

- Erosion from land clearing operations, construction sites, excavation, and road fill were the most significant contributors to water quality degradation (turbidity) and recent losses of aquatic habitat (siltation) in the basin.
- Trash and litter washed from parking lots and city streets create extremely unappealing esthetics and constitute a potentially severe marine debris problem.

- Surveys of land characteristics such as topography and soil types provide valuable information regarding the severity of some problems; especially those related to erosion and siltation.
- Monitor water quality under a wide variety of conditions paying special attention to sampling storm runoff.
- Urban non-point sources have the potential to enrich sediments with heavy metals to a degree equal to, if not greater than, industrial wastewater discharges.
- Species composition and diversity of biological communities is adversely affected by non-point pollution, sometimes to a level as severe as those impacts observed near waste effluent outfalls.

Also realized through the study of the DRW is the importance of public information and involvement. Release of the study reports generated considerable public interest in the control of non-point sources and has led to the formation of a citizens' action group. Members of this group have been actively conferring with local, state and federal officials importuning a more protective approach towards local streams and the effects of development. Citizens' interaction with developers and local officials show substantial promise for improving the control of non-point source pollution.

The response by the residents of the basin has illustrated another benefit of the watershed protection approach not realized by traditional water quality studies. The WPA reduces some environmental issues to a "lowest common denominator" for many citizens. Explanation of the causes and effects attributable to various nearby everyday activities fostering the degradation of "the stream running through my neighborhood" often better communicates to the average person the significance of the effects of development than would a study performed on an industrialized stretch of river 30 miles away.

PHYSICAL CHARACTERISTICS OF THE WATERSHED

GENERAL DESCRIPTION

The Alabama Department of Environmental Management Coastal Programs' staff selected the drainage basin of the Bon Secour River as the watershed for applying the experience gained from the Dog River Watershed project. Located in Baldwin County (Figure 1), the Bon Secour River is a tidally influenced stream some eight miles in length (U.S. Army Corps of Engineers 1976 and 1990; South Alabama Regional Planning Commission 1993). The Bon Secour River Watershed (BRW) encompasses an area of approximately 30 square miles and receives drainage from numerous small tributaries (U.S. Army Corps of Engineers 1976 and 1990). Of these only Boggy Branch, Bright's Creek, Shutt Creek and Miller's Bayou are truly navigable by small watercraft for substantial portions of their lengths.

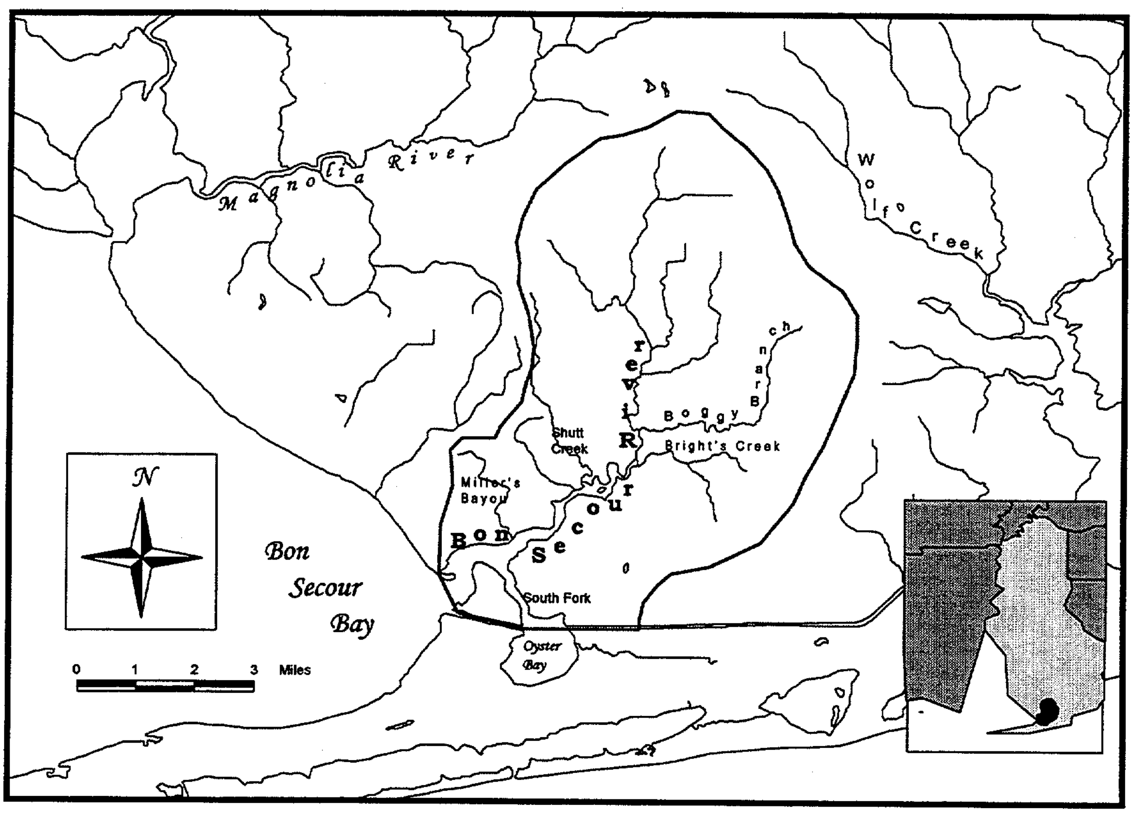


FIGURE 1
BON SECOUR RIVER WATERSHED

The Bon Secour River originates in the City of Foley and discharges to Bon Secour Bay in the southeastern corner of Mobile Bay (Figure 2). The river is approximately 2000 feet wide at its mouth, decreases to a width of 150 feet 5.5 miles upstream at the bridge crossing of Baldwin County Road 10 and then narrows to less than 50 feet in width some 0.75 miles upstream of the County Road 10 bridge (U.S. Army COE 1990).

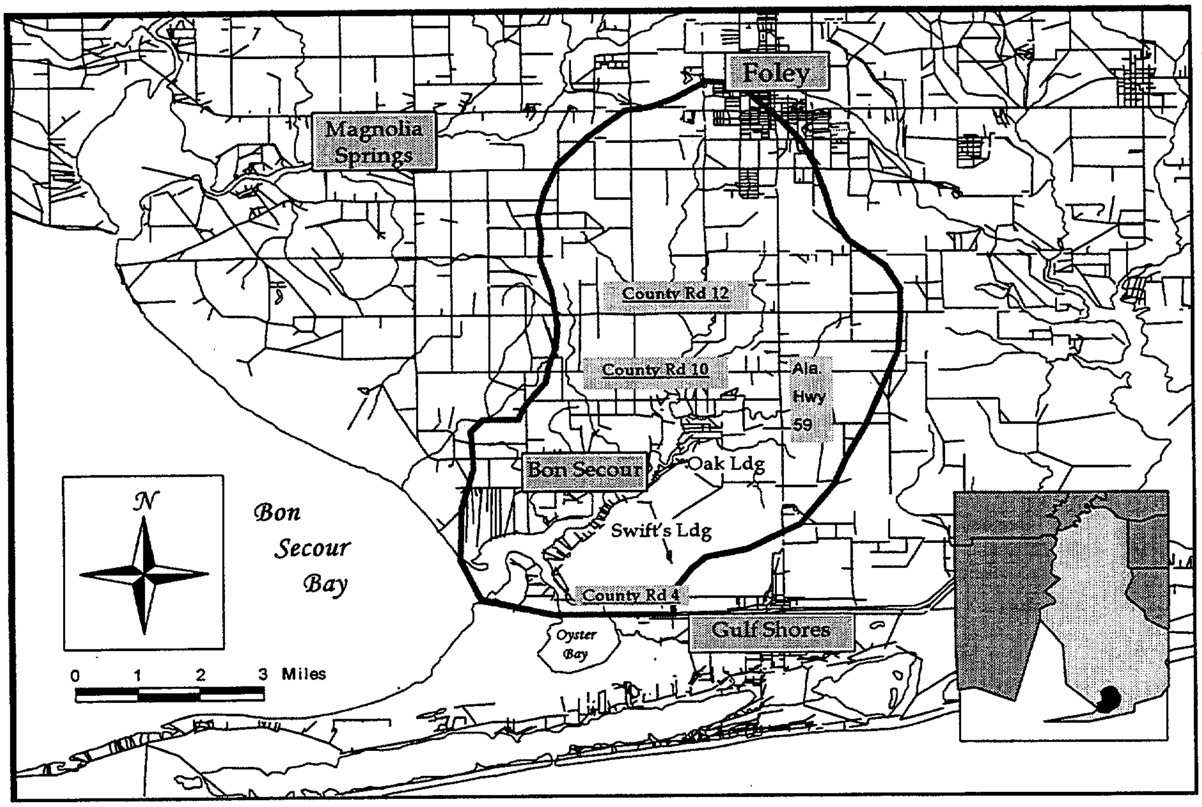


FIGURE 2
BON SECOUR RIVER WATERSHED
SHOWING TOWNS AND ROADS

The periodic tidal range at the mouth of the Bon Secour River averages 0.5 meters (1.6 ft) under normal conditions and provides this system with the largest tidal amplitude in coastal Alabama (O'Neil and Mettee 1982). This greater amount of tidal variation allows for flooding of a greater area of land than would occur with a lower tidal range. This quality together with the flat terrain is conducive to establishing more extensive tidal marsh acreage than would occur with a lesser tidal range such as that at Perdido Bay (0.2 meters/0.66 ft) or with the steeper shoreline relief such as along the upper eastern shore of Mobile Bay near Daphne.

A federally authorized navigation channel is maintained in the Bon Secour River by the U.S. Army Corps of Engineers. This project provides for a channel 10 feet deep and 80 feet wide from the Gulf Intracoastal Waterway (GIWW) in Bon Secour Bay up the Bon Secour River to river mile 3 near Swift's Landing and continuing as a channel six feet deep and eighty feet wide to river mile 4.7 immediately above Oak landing (U.S. Army Corps of Engineers 1976 and 1989).

The South Fork of the Bon Secour River, an inlet connecting Oyster Bay and the Alabama Canal of the GIWW with the river, also is a federally maintained navigation project. The South Fork is part of the original Perdido Bay to Mobile Bay portion of the GIWW but was eliminated as a route for commercial traffic around 1942 with the completion of the land cut between Oyster Bay and Bon Secour Bay (U.S. Army Corps of Engineers 1990; D. Imsand, personal communication 1995). The South Fork is still officially a Federally authorized part of the GIWW and a navigation channel 10 feet deep and 80 feet wide is maintained between the river channel and the bridge crossing at Baldwin County Road 4.

The majority of the watershed is designated as suitable for swimming and water based recreation according to the state's water use classifications. The Bon Secour River is assigned a state water use classification of swimming and other whole body water-contact sports/fish and wildlife (S/F&W) for its entire length from Bo to its source. The South Fork of the Bon Secour River, Bon Secour River west of the South Fork and Oyster Bay to the south are classified as suitable for shellfish harvesting.

The Department has assigned a water use classification of S/F&W to the tributary Boggy Branch for the entirety of its length from the Bon Secour River to its source located east of Alabama State Route 59. Other streams within the watershed Bright's Creek, Shutt Creek, Miller's Bayou and several unnamed tributaries have not been assigned a specific use classification; however, those segments are considered as fish and wildlife waters pursuant to ADEM Administrative Code (335-6-11-.01(5)). For a summary of the water quality criteria applicable to these classifications please refer to Table A-1 in the appendix.

GEOGRAPHY

The majority of the Bon Secour River Watershed lies within the Coastal Lowlands subdivision of the East Gulf Coastal Plain. The uppermost portion of the watershed reaches into the Southern Pine Hills subdivision around the City of Foley. The topography of the basin is generally flat with gently undulating plains and little relative surface relief. Surface elevations are less than 30 meters (100 ft) throughout the BRW.

CLIMATE

The climate of the BRW is essentially subtropical with long humid summers and short mild winters. The area is strongly influenced by the Gulf of Mexico which tends to moderate temperatures throughout the year (O'Neil and Mettee 1982). The summer months are especially affected by the Bermuda High, a seasonal high-pressure system that spreads over much of the eastern gulf and south Atlantic coast from May through September (O'Neil and Mettee 1982; SARPC 1993). The prevailing southerly winds produced by the Bermuda High are high in moisture content which keeps summer temperatures along the coast lower than those inland. The average afternoon high in July, the hottest month, is 32°C (90°F) and rarely reaches 38°C (100°F) which is in contrast to inland Alabama where afternoon highs regularly approach and often break the latter figure (U.S. Department of Agriculture 1964; O'Neil and Mettee 1982).

Winters are typified by prevailing northerly winds, strong frontal systems and cold, continental air masses. The oceanic nature of the climate tends to "cushion" the effects of such weather complexes and leads to mild winter temperatures ranging from average daily lows of 6°C (43°F) to average daily highs of 15°C (60°F) in January, the coldest month for the area (O'Neil and Mettee 1982).

The brevity and mildness of the winters contributes to a growing season of 300 days in the Bon Secour River Watershed. The first killing frost occurs around December 5th and the last killing frost is around February 18th (O'Neil and Mettee 1982).

GROUND WATER

Ground water resources of the watershed are abundant and of high quality (O'Neil and Mettee 1982). The permeable sands of the Pliocene-Miocene Series undifferentiated are utilized as the source of ground water for the majority of the wells in the BRW. Wells drilled into this formation usually produce adequate supplies for domestic, small business and agricultural requirements within 150 feet of the surface (ibid.). The sand beds of the Pliocene-Miocene aquifer are capable of yielding up to 2650 liters/min. (700 gallons/min.) and may produce significantly more in some instances (ibid.).

Water yielded from wells in the Pliocene-Miocene aquifer is generally of good quality, available data indicates low hardness (15-60 mg/l as $CaCO_3$), low chloride (5-15 mg/l) and low iron (less than 0.3 mg/l). However some of the shallow wells near the river and bay have the potential to produce waters containing noticeable and possibly objectionable iron discoloration and chloride taste (saltiness) during dry periods. Although salt water intrusion has become a problem for the Gulf Shores area immediately south of the BRW, this is not a problem in the BRW.

Residents of the BRW living west and north of the Bon Secour River are dependent on individual water wells. Those residents of the basin living east and south of the river are served by the Oyster Bay water distribution system, an affiliate of the Foley-Riveria Utilities water system (public water supply permit number AL-0000036).

SOIL ASSOCIATIONS OF THE WATERSHED

Aerial photographs from the Soil Survey of Baldwin County published by the the Natural Resources Conservation Service (NRCS), formallly known as the U.S. Soil Conservation Service, (U.S. Department of Agriculture 1964) were examined by ADEM coastal program staff for determining soil types within the watershed. Soils in the upland portions of the watershed are primarily sandy loam type soils; the lowland areas of the basin are distinguished either by hydric soils (muck) that drain poorly or sandy soils that drain excessively fast. More specifically the NRCS classifies the soils in the lower lying areas of the watershed as the Lakewood-St. Lucie-Leon Association The soils of the higher, upland areas of the watershed are designated as Marlboro-Faceville-Greenville Association and Norfolk-Klej-Goldsboro Association. Distribution of the soil types in the BSW is illustrated in Figure 3 and descriptions of soil characteristics are provided in Table 1.

The Lakewood-St. Lucie-Leon Association is found along the lower Bon Secour River south of County Road 10 and extends landward one-half to a mile in from the river. This association is found over approximately 20-25 percent of the lands of the BRW. This soil association has poor drainage qualities making it unsuitable for agricultural activities and extensive construction.

The Marlboro-Faceville-Greenville Association makes-up approximately 15-20 percent of the watershed area. This soil association is found in the upper northwest part of the watershed. The majority of the development in this area is agricultural and includes several large row crop operations. Soil scientists consider this unit to be well drained and to have few, if any, limitations on its suitability for agriculture (U.S. Department of Agriculture 1980).

The Norfolk-Klej-Goldsboro Association covers approximately 60-65 percent of the land within the basin. These soils are found throughout the eastern half of the watershed and extend southwesterly across the river near Baldwin County Road 12 to just north of the town of Bon Secour. Soil scientists also classify this association as being very appropriate for agriculture.

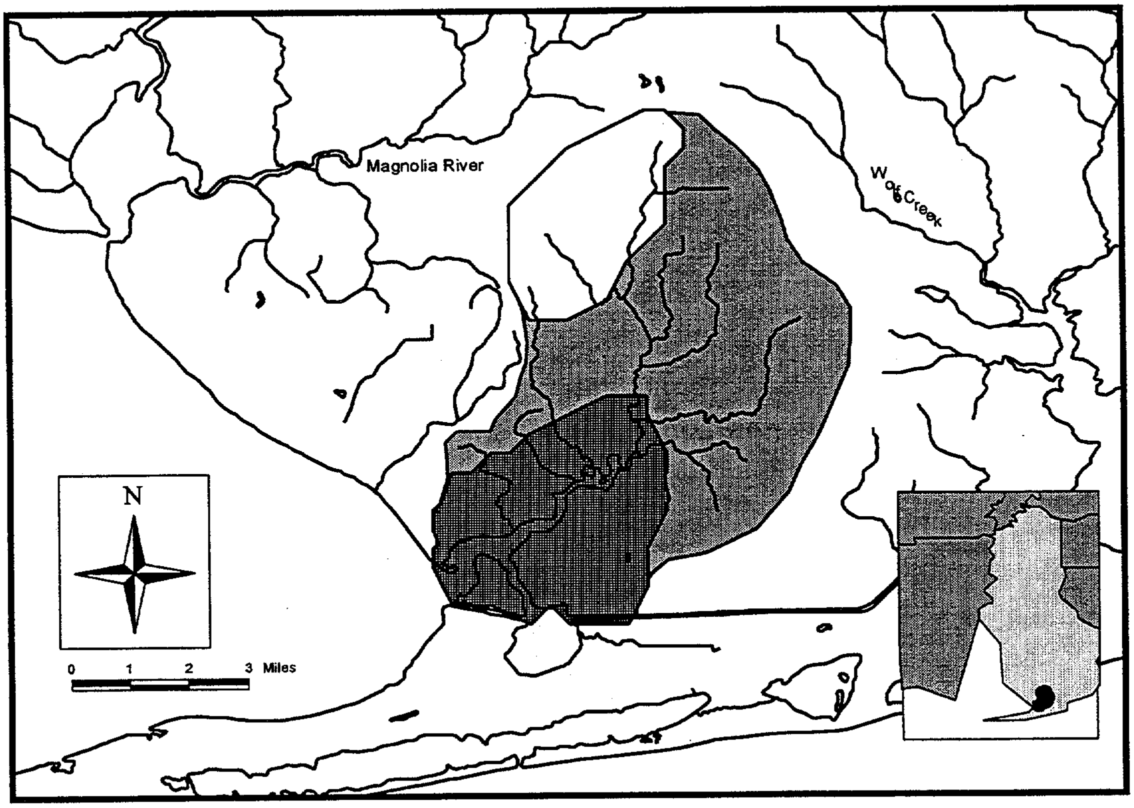


Figure 3

Soil Asociations of the Bon Secour River Watershed

Legend Lakewood-St. Lucie-Leon

Marlboro-Faceville-Greenville

Norfolk-Klej-Goldsboro

Table 1

Soil Associations of the Bon Secour River Watershed

Lakewood-St. Lucie-Leon

This association is commonly found along lakes, rivers and bays. These soils tend to either drain too fast because of a high content of sand or they drain very poorly due to a cemented sand layer and muck. Muck may be more than a meter deep in some locations of the watershed; these areas may be of such poor drainage that standing water is present much of the year.

Land composed of this association is suitable for recreation and light residential development although some drainage modifications might be necessary. Typical vegetation found on these soils include slash pine, loblolly pine, gallberry and myrtle. Prickly pear cactus and palmetto may be found on the drier, more sandy locations; pitcher plants, sundew and butterworts occur on the wetter muck areas.

Marlboro-Faceville-Greenville

This association is found on the level and gently sloping uplands in the northwestern corner of the basin. Soils of this association are grayish-brown fine to very fine sandy loam intermixed with dark red and brown loam. These soils are well drained and suitable for agriculture.

Agricultural operations on these soils are highly productive if properly managed. Corn, soybeans and potatoes are the crops commonly grown on these soils. This association also is well suited for use as pasture.

Norfolk-Klej-Goldsboro

The level and gently sloping uplands of the eastern half of the basin are covered with this association. These soils are dark grayish-brown fine sandy loam mixed with dark grayish-brown loamy sand. Overall, these soils are well drained but depressions in level areas and bottom lands along small streams may drain poorly.

These soils are highly suitable for crops such as corn, soybeans, wheat and pecans. This soil association also is well adapted for flower nurseries, bulb farms and other horticultural operations. Numerous poultry and beef cattle farms are located on these lands.

ECONOMIC DEVELOPMENT AND LAND USE IN THE WATERSHED

HISTORICAL OVERVIEW

The community of Bon Secour was named by Jacques Cook, a Frenchman from Montreal, in honor of Cathedral Notre Dame de Bon Secour, the oldest cathedral in Montreal. A hunting and fishing lodge was built in 1702 by Iberville Bienville and Serigney Le Moyne, the founders of the city of Mobile (Fairhope Courier 1996).

Historic development within the BRW initially occurred along the lower reaches of the river in and around the community of Bon Secour. The early settlers were attracted by the abundant fisheries resources of Bon Secour Bay, safe harborage offered by the river and suitability of the area for agriculture. Homesteaders of the more inland portion of the watershed also made the Town of Foley a center of business and commerce in the early years of colonizing the basin. As agricultural development progressed Foley became the center of population, commerce and finance in the immediate area. Nowadays, Foley continues as the most active area of commercial development and business activity in the watershed.

Initially, development of the watershed was either agricultural, low density residential or somehow related to commercial fishing. Development in recent years has been more directed towards light commercial businesses (i.e. retail merchants, restaurants, etc.), shopping malls and subdivisions (SARPC 1980 and 1993). More recently, development within the BRW has spread along the eastern side of the basin to the south of Foley. New construction is a widely diverse mixture of residential subdivisions, retail trade businesses and golf courses. This trend towards non-agricultural development is certain to continue and accelerate in the near future (Friend et al 1982; SARPC 1993).

Commercial fishing was the basis of the economy of the watershed during the 19th century and early 20th century. Today, fishing and seafood processing in Bon Secour has developed into a considerable industry ranking among the top twenty U.S. ports with the annual value of landings exceeding $10 million (Friend *et al* 1982). Shrimp catches regularly comprise approximately one-half of the annual commercial landings and 80 percent of the dockside value. Exceptionally good harvests may account for as much as 70 percent of the poundage and over 90 percent of the value of commercial fisheries landed (ibid.). Oysters and blue crabs are the second and third most economically valuable species, respectively, landed at commercial docks in the basin (Friend et al 1982; SARPC 1993).

Agriculture has been the historic cornerstone of the economy in Baldwin County and has played a vital role in the development of the BRW. The mild climate and suitability of soils present favorable conditions for a variety of agricultural operations in the watershed (U.S. Department of Agriculture 1964; Friend et al 1982; SARPC 1993). Agriculture in the BRW began in the 19th century with small farms primarily producing potatoes, corn, beans, wheat and melons for local markets (U.S. Department of Agriculture 1964).

Agricultural development of the watershed began a rapid progression towards larger operations in the years immediately following World War I. The advancement of mechanized cultivation, improved packing and preservation methods and more expeditious distribution combined with the immigration of large numbers of people to Baldwin County from the midwestern states contributed to the growth of farming in the basin (U.S. Department of Agriculture 1964; Friend et al 1982). Accompanying this increased agricultural activity was a shift towards crops well suited to large scale mechanized operations. For the past half-century corn, wheat, potatoes and soybeans have been the most extensively cultivated row crops in the basin and surrounding area. The most common orchard crop grown in the basin are pecans (Friend et al 1982; SARPC 1993).

INDUSTRIAL FACILITIES

The BSW contains no major industrial facilities or municipal wastewater treatment plants. However, there are several businesses engaged in the processing and packaging of fish, shrimp, oysters and other seafood resources. Six of these are sizable facilities collectively processing six to eight million pounds of product annually (SARPC 1980; Friend et al. 1982). These operations produce significant volumes of process wastewater from peeling and deveining shrimp, shucking and washing oysters, cooking crabs and freezing fish. The treated wastewater from these processors is discharged to the Bon Secour River under the conditions and limitations of NPDES permits issued to each facility by the Department. Names, locations and permit conditions of these facilities are listed in Appendix A.

Historically, several gravel and sand mining operations have been operated within the watershed; however, these operations appear to be converting to golf courses and driving ranges as the non-farming population increases.

There are three boat repair yards in the basin, one located on the river just above the mouth of Bright's Creek, one on the east bank above the South Fork and the other on the South Fork. Although these are relatively small operations compared to those in Bayou La Batre and Mobile, they are important to the local economy. These facilities provide convenient repair and overhaul services to the commercial fishing fleet of Bon Secour without the need to cross Mobile Bay, an undertaking which not only adds to the cost of boat maintenance but also to vessel downtime (U.S. Army Corps of Engineers 1990).

As was the case with the Department's survey of the Dog River Watershed, the absence of heavy industrial development, increasing residential population and intensely active real-estate development make this watershed a good example for studying water quality degradation as primarily mediated by non-point sources.

LAND-USE SURVEY

Having reviewed the available information regarding land-use and development, soil characteristics, water quality and biological resources of the BSW the next step was to conduct initial surveys of the watershed and examine current land-use practices within and their potential for degrading water quality and causing losses of aquatic habitat. Land reconnaissance of the watershed by motor vehicle was begun in January 1995 and continued through September 1995. The findings of these efforts were compared to the aerial photographic information from the NRCS Soil Survey, land use-data from the *Water Quality Management Plan for Mobile and Baldwin Counties* (South Alabama Regional Planning Commission 1980) and current land-use maps supplied by the South Alabama Regional Planning Commission.

The findings of these reconnaissance inspections indicate that the watershed has changed considerably in the thirty years since the NRCS report and that development, for the most part, is following along the course indicated by information supplied by the South Alabama Regional Planning Commission (i.e., retail businesses, light commercial, residential subdivisions and multiple unit housing). The most conspicuous change to the landscape relative to the aerial photos of the NRCS survey is the appearance of significant acreage of parking lots, large commercial structures, residential construction and other impervious cover.

Such developments were completely absent in the aerial photos of the NRCS soil survey of 1964. The land-use maps in *Water Quality Management Plan for Mobile and Baldwin Counties* (South Alabama Planning Commission 1979) indicate a trend towards increased residential and commercial development in the basin 20 years ago; in particular the eastern half. However, such construction then was single unit residential, small retail stores and service type businesses such as garages. More recent construction has predominantly been large retail sales enterprises, dining establishments, lodging facilities and multiple unit housing. The more extensive commercial developments are presently concentrated near Foley in the northeastern corner of the watershed and extend south towards Boggy Branch. Especially notable are the expansive developments of retail sales businesses along Alabama State Highway 59.

Another visible contrast with past land-use is that the numerous developments in the eastern side of the basin along Highway 59 have displaced large areas of forest and farm lands. The increasing demand for commercial property in the area has made it more profitable for owners of agricultural and timber operations to sell land to builders than to grow crops. Accompanying this shift of land-use is an increased amount of parking lots, paved roads and other impervious cover. Changes which result in reduced storm water detention and increased urban run-off.

Also evident during the land reconnaissance was the proliferation of recreational facilities (golf courses) in the eastern portions of the basin. In more than one case, courses and driving ranges have been constructed on old abandoned borrow pits.

Those lands along Boggy Branch and County Road 10 east of the river and the property in the immediate vicinity of the river above the County Road 10 bridge have undergone a considerable amount of development, primarily subdivisions and waterfront residences. Land-use in this area, as determined from the 1941 USGS topographic map (15 minuite series) and aerial photos of the 1964 soil survey, was either agricultural or forest until the 1970's. The few residents of the area were primarily farmers, commercial fishermen or worked in businesses supporting agriculture and fisheries. However, the majority of the development of the past two decades has been non-farming/non-fishing residential construction. A significant amount of this development is waterfront residential, whereas in the past, only those families engaged in fishing and boat repair lived along the water.

The developmental trends in the eastern part of the BRW are not followed in those lands west of the Bon Secour River. The area immediately around the Bon Secour Community and to the north along Baldwin County Road 65 is still predominantly agricultural and low density residential. The emphasis for the residential developers though, has been to build on waterfront property due to the inclination of homebuyers to pay a premium for such land. This has resulted in a considerable alteration of the shoreline due to the tendency of waterfront residents to install protective bulkheads, excavate boat slips and construct piers. In constrast to the eastern half of the BRW, there appears to have been little increase in the amount of impervious cover in the western half when referencing present land-use to the conditions existing 20 more years ago.

The majority of the commercial development in the western half of the BRW is centered around the community of Bon Secour. Most of these enterprises are involved with the fishing trades (i.e., processing and selling catches, boat maintenance, fuel sales, etc.); however, there are a few general merchandise establishments, machine shops and automobile garages located in Bon Secour and along Baldwin County Road 12 in the vicinity of County Road 65.

Current agricultural land-use in the western half of the watershed primarily is dedicated to row crops (soybeans, corn and wheat), pecan orchards and pasture land. Land-use determined by way of reconnaissance of the area estimated that approximately 10 square miles of the western basin are under cultivation. Much of the acreage under cultivation is quite productive, 2 crops per year is common, and appears to be well managed relative to tillage practices and erosion control as evidenced by the minimal amount of siltation in streams adjacent to crop land.

STREAM AND SHORELINE SURVEYS

Having initiated land reconnaissance of the watershed and cursory examination of potential impacts to its waters, the next step was to survey the basin from the water for the purpose of determining the categories and extent of shoreline development and further identifying the nature of possible degradation in water quality.

ADEM personnel inspected each stream of the BSW. The Bon Secour River, Boggy Branch, Shutt Creek and the South Fork were surveyed to the upper limits of their navigable waters. The shallow upper stream reaches and otherwise non-navigable waters were examined at bridge crossings and, in some cases, by walking the stream course. During these surveys the types of development along the stream bank were noted, vegetation communities were categorized, gross characteristics of the stream were observed, *in situ* parameters were measured and water samples were collected.

As was done during the Dog River Watershed Survey, special effort was made to sample streams of the basin during times of base flow and following storm events. The stream/shoreline surveys and storm water sampling commenced on January 18, 1995 and continued through September 28, 1995. The locations of the sampling stations are shown in Figure 4. Descriptions of the stations are given in Table 2 and a list of parameters for which water samples were analyzed is in Table 3.

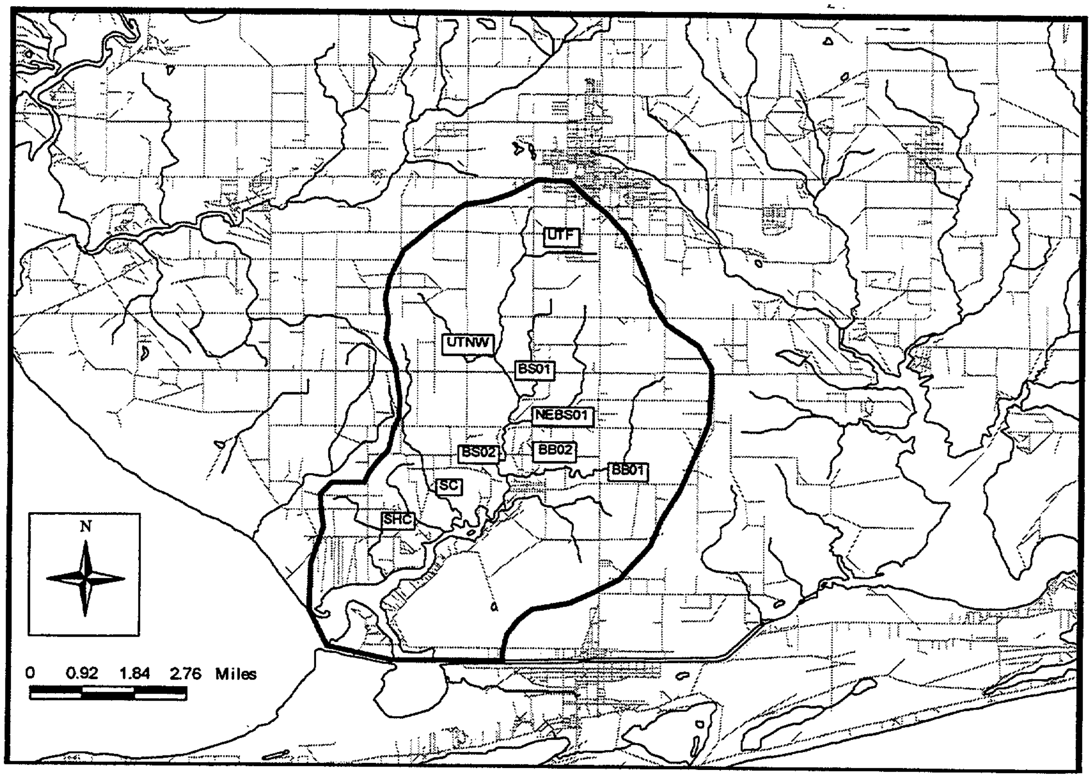


FIGURE 4
Water Quality Monitoring Stations

TABLE 2
Locations of Stations Monitored for Water Quality

BS01	Bon Secour River at Baldwin County Road 12 Bridge
BS02	Bon Secour River at Baldwin County Road 10 Bridge
UTNW	Unnamed Tributary to Bon Secour River at Baldwin County Road 65 Bridge
UTF	Unnamed Tributary to Bon Secour River at South Cedar Street in Foley
NEBS01	Unnamed Tributary to Bon Secour River at Riverwood Drive
NEBS02	Unnamed Tributary to Bon Secour River at Baldwin County Road 20
BB01	Boggy Branch at Alabama State Highway 59
BB02	Boggy Branch approximately 0.5 miles upstream of mouth
SC	Shutt Creek at Baldwin County Road 10
SHC	Schoolhouse Creek at Baldwin County Road 10 near Swift School

Table 3
Parameters Measured for Stream Samples

Field Measurements	Laboratory Analyses
Water Temperature	Turbidity
Dissolved Oxygen	Ammonia
pH	Total Kjeldahl Nitrogen (TKN)
Conductivity	Nitrate
Salinity	Phosphate
	Fecal coliforms

FINDINGS OF THE STREAM SURVEYS

UPPER BASIN

For the purpose of describing the conditions found during the stream surveys, the stretch of the Bon Secour River beginning at Baldwin County Road 12, extending upstream (northward) to Foley and including the unnamed tributaries draining to the Bon Secour River shall be referred to as the upper basin of the BRW. These tributaries to the river are, for the most part, intermittent streams with flow only during periods of significant rainfall. The unnamed tributary draining the northwestern part of the watershed (UTNW) is an exception flowing during all seasons, albeit sluggish in the late summer.

The upper reaches of the Bon Secour River are surrounded by fields under cultivation in row crops, pecan orchards, pasture lands or woods. In most cases, the lands immediately along the streambanks are still somewhat natural with significant stands of trees and natural vegetation. These characteristics appear to have benefited the river in that little of the effects of siltation or other non-point source pollutants were observed as was the case with Dog River.

The upper basin receives substantial volumes of urban stormwater runoff from the neighborhoods in southwest Foley and the numerous commercial developments along Highway 59. Station UTF was monitored for determining the effects of drainage from large areas of impervious cover and high density of motor vehicle traffic. Trash, floating debris and other visible impacts of urban runoff were minimal following storm events and practically non-existent the majority of the time.

Marked increases of stream turbidity were observed in the river at County Road 12 (station BS01) and in the northwest unnamed tributary at County Road 65 (station UTNW) following heavy rainfalls. These losses of water clarity were more noticeable during the winter and spring than they were for the summer and fall. This appeared to be associated with the greater amount of exposed cropland existing during the times of field preparation and crop planting versus the coverage and soil stabilization provided by crops during the growing season. The observed increases of turbidity in the upper watershed were short lived; significant improvements in water clarity being evident within 48 hours of a storm event.

Although significant increases of turbidity from clay fines are noticeable during times of high flow, the upper portion of the Bon Secour River Watershed appears not to be plagued by the predicament of high loads of suspended solids and accelerated siltation. Land reconnaissance of the basin indicates this evidently is attributable to the effective erosion control measures practiced by local farmers contrasted to the efforts of real-estate developers and construction contractors. However, the situation in the middle and lower reaches of the river is somewhat different as will be discussed later in this report.

The bacterial quality of the waters in the upper part of the basin also changes in response to weather events and streamflow. As is the case with many waterbodies, fecal coliform counts were observed to increase at stations UTNW and BS01 and station UTF following a significant rainfall (greater than one-half inch).

The fecal coliform counts at station UTNW are indicative of the potential for bacterial contributions from pasture land drainage. This is a characteristic of runoff from cattle pastures and has been documented in other studies of non-point source pollution (South Alabama Regional Planning Commission 1979; US Environmental Protection Agency 1991 and 1992). Although the flow from these streams, such as the unnamed tributary at County Road 65, might be perceived as inconsequential compared to the flow of the main channel, such inputs are capable of significantly affecting the quality of a larger stream.

The variability observed for fecal coliform counts at station UTF, sharp rapid increases followed by a swift decline is more characteristic of non-point source contributions (droppings from birds and domestic animals) than flows from broken sewer mains (National Research Council 1990; South Alabama Regional Planning Commission 1979; US Environmental Protection Agency 1991 and 1992; US Fish and Wildlife Service 1991).

The data for station UTF and UTNW indicate that both urban runoff and pasture drainage represent consequential sources of enteric bacteria to the watershed. It was observed throughout this study that the Bon Secour River at County Road 12 experienced difficulty acheiving its state water use classification due to fecal coliform counts exceeding the standard for swimming and other whole body water-contact sports. Only in the late summer when rainfall was minimal and stream flow at a low level did the upper reach of the Bon Secour River meet all standards for its use classification.

Concentrations of nutrients (nitrate and phosphate) also showed a relationship to rainfall and seasons. Nutrients in the streams of the upper basin were observed to be present in higher concentrations at times following heavy rains relative to concentrations during base flow; furthermore, such concentrations were higher during the winter and spring, the times of tilling, fertilizing and planting, than during the summer and fall, the seasons of growing and harvest when fertilizers are actively removed by growing crops or are simply not applied.

MIDDLE BASIN

The middle portion of the watershed, as discussed here, is that segment of the BRW south of Baldwin County Road 12 extending south to, and including, Boggy Branch. The streams in this area flow throughout the year and are influenced by the periodic tide relative to variations of water level and salinity.

Extensive waterfront residential development has occurred along Boggy Branch and on the Bon Secour River from the mouth of Boggy Branch to approximately one-half mile upstream of the County Road 10 bridge. Consequently, much of this section of the BRW has undergone a considerable amount of shoreline alteration. As is typical with waterfront residences, many of the homes have, at the least, a pier built out from the streambank. Boat houses, gazebos and mooring slips also are common along lower Boggy Branch and the river.

Although development has become increasingly dense in recent years, the area is afforded excellent vegetation coverage from a diverse assortment of native trees and shrubs. The banks along the river, Boggy Branch and an unnamed tributary (NEBS) north of County Road 10 have healthy stands of swamp tupelo (*Nyssa sylvatica*), red maple (*Acer rubrum*), sweet gum (*Liquidamber styraciflua*) and bald cypress (*Taxodium distichum*). Dominant shrub species are wax myrtle (*Myrica cerifera*), yaupon (*Ilex vomitoria*) and pepper bush (*Clethra alnifolia*). On the slightly higher ground longleaf pine (*Pinus palustrus*) becomes the dominant overstory species with an understory of groundsel trees (*Baccharis halimifolia*), marsh elder (*Iva frutescens*), St. John's wort (*Hypericum fasciculatum*) and saw palmetto (*Serenoa repens).*

This part of the basin has seen rapid commercial growth along Alabama Highway 59. The numerous and varied business operations have resulted in noticeable modifications to the tributaries draining to the river, primarily in the form of numerous culverts and paved drainage courses. These changes have been accompanied by a significant increase of the amount of impervious cover and, consequently increased stormwater runoff to nearby streams. At the present, these alterations have been concentrated along the upper reaches of Boggy Branch and an unnamed tributary (NEBS) draining commercial developments in the vicinity of County Road 12 and Highway 59.

The most apparent modification to these streams and the stretch of the Bon Secour River between them is accelerated rate of silt accumulation compared to the upper basin. Although work on the commercial facilities was largely completed by the time the BRW study commenced, the effects of clearing extensive acreage, the associated site preparations and general construction activities were clearly evident. Boggy Branch, the Bon Secour River above County Road 10 and the unnamed tributary north of County Road 10 have been the recipients of bountiful subsidies of sand and silt. The increased sediment bedload has resulted in a somewhat dynamic and continually shifting bar and shoal formations in some locations; especially in the river above County Road 10 and in the unnamed tributary (NEBS) draining lands to the northeast of the river.

The bacterial quality of the waters in the middle segment of the basin was moderately better than the streams of the upper basin; changes in response to rainfall, runoff and streamflow were apparent. The pattern of increasing counts of fecal coliforms following rainstorms, then declining to a lower "backround" number as stream levels fell, was observed throughout the study at the monitoring sites on the unnamed northeastern tributary to the Bon Secour River (station NEBS01) and on Boggy Branch (stations BB01 and BB02). On the average, the bacterial numbers at each site increased by a factor of approximately 10 immediately after storm events and then returned to nominal values within 48 hours. This pattern, observed in studies of stormwater runoff and other non-point sources, is representative of drainage from pastures, fields and woodlands (National Research Council 1990; South Alabama Regional Planning Commission 1979; US Environmental Protection Agency 1991 and 1992; US Fish and Wildlife Service 1991).

Although the counts were enhanced for short periods after rainstorms, the bacterial criteria for the designated use-classification of each stream (swimming for Boggy Branch and the river; fish & wildlife for the unnamed tributary) were met 80 percent of the time sampled. Sampling conducted at times of base flow or at least 72 hours after a rainstorm indicated that these waters achieved their designated use-classification 100 percent of the time.

Data for inorganic nutrients (ammonia, TKN, nitrate and phosphate) in the waters of the middle basin were not particularly remarkable. Concentrations did not appear to be greater than average values expected for coastal lowland streams and there was no observed relationship to rainfall and seasons.

LOWER BASIN

The lower part of the watershed, as discussed here, is that segment of the BRW south of Boggy Branch extending southwest to Bon Secour Bay and including Bright's Creek, Shutt Creek, Schoolhouse Creek, Miller's Bayou and the South Fork of the Bon Secour River. The water level and salinity of streams in the lower basin are markedly influenced by the periodic tide and maintain a pronounced brackish or estuarine quality throughout the year.

During the late summer/early fall dry season Shutt Creek and Schoolhouse Creek become intermittant in nature with no flow except after rainstorms. However, for the last one mile and one-half mile respectively, tidal influence maintains a depth of 3 to 5 feet of water in these streams. This changes their characteristics froma flowing tannic water streams to mildly brackish inlets with salinity of 3-5 parts per thousand.

The lower reaches of the Bon Secour River and its tributaries are bordered by waterfront residences, a few small commercial lodging operations and the various enterprises involved in the commercial fisheries industry. At the time of this survey there were three boat repair and drydock facilities along the river and at least half a dozen operations for the offloading and processing of catches.

Along the northwest bank of the river, between Schoolhouse Creek and Miller's Bayou, is the center of local commercial fisheries operations. This strech of river is the "old"waterfront for the town of Bon Secour and has been developed as a residential and business community many years longer than other towns and neighborhoods of the watershed. Extensive pier and berthing accomodations have been constructed over the years but no ongoing construction of such structures were observed during the study.

Recent or active waterfront construction appears to be concentrated along the southwest bank of the Bon Secour River between Bright's Creek and the mouth of the South Fork. Most of the waterfront development within the lower basin is of the single unit residential type, although there are several new multiple-unit structures on Plash Island. Development of this property has, so far, proceeded with a minimum of clearing and timber cutting, thereby affording good vegetation coverage by native trees and shrubs along the waterfront. Storm runoff from hard paved surfaces and other impervious cover is considerably less along these streams compared to the tributaries in the upper two thirds of the BRW.

The lower BRW still possesses a significant amount of wetlands. Large stands of pine savannah interspersed with small bogs and tannic ponds are found along much of the lower river and the South Fork. Especially notable is the area of pine woods behind the southeast shoreline and extending to well inland past Baldwin County Road 6.

Other wetlands noted in the lower BRW are the stands of sawgrass (*Cladium jamaicense*) and spike grass (*Distichlis spicata*) around the mouth of Bright's Creek and along both banks of the river near the confluence of Bright's Creek. Immediately downstream are several sizeable stands of giant cordgrass (*Spartina cynosuroides*) and black needlerush (*Juncus roemerianus*) along the northwest bank of the river and surrounding Shutt Creek. Farther downstream are numerous small but substantial stands of *Spartina* and *Juncus* near Miller's Bayou and along the opposite bank.

The attribute of well vegetated streambanks and a somewhat more natural drainage within the lower basin appears to be a benefit to aquatic habitats and water quality in this area. Turbidity and siltation were far less noticeable than in the waters of the upper two thirds of the watershed. Although runoff of stormwater from tilled fields caused distinct increases of turbidity in Shutt Creek and Schoolhouse Creek, these increases were short lived and there was none of the severe sedimentation observed in the middle section of the watershed.

Severe storm events were noted to cause considerable short-term increases of fecal coliforms in Shutt Creek and Schoolhouse Creek. As with the streams in the upper and middle basins the bacterial counts rose by a factor of 10 on the average. However, Shutt Creek and Schoolhouse Creek were found to have counts of fecal coliforms consistently high enough (greater than 1000 colonies per 100ml) to constitute a potential problem with meeting their state water use-classification of fish and wildlife. On the other hand, this appears not to have impaired the suitability of the lower Bon Secour River for swimming because fecal coliform counts in the river near Miller's Bayou met the bacterial criterion despite the high numbers in the tributaries.

As with the waters of the middle basin, data for inorganic nutrients (ammonia, TKN, nitrate and phosphate) in the waters of the lower basin were not particularly remarkable. Concentrations did not appear to be greater than average values expected for coastal lowland streams and there was no observed relationship to rainfall and seasons.

A tabular summary of all water quality data is presented in the Appendix.

SEDIMENT CHEMISTRY OF THE WATERSHED

Unlike the Dog River Watershed, there was a good record of sediment chemistry data for this system. Historical data was supplied by the US Army Corps of Engineers (1976) in their survey of the river prior to performing maintenance dredging. Review of the Corps data indicated no evidence of contaminated sediments in the BRW at the time. More recent sediment chemistry data was found in a survey conducted by ADEM (1991) of shipyards in coastal Alabama, including those on the Bon Secour River. This survey revealed the presence of relatively clean sediments along the middle and lower reaches of the river. It was decided to investigate the sediment chemistry of tributaries and of sites on the river more proximate to residential areas.

The general characteristics of the sediments in the watershed include silica sands and silts mixed with aluminum rich clays. Sediments in the tributaries and along the open shoreline of the river are coarser sands mixed with silt. Those sediments in the broader deeper waters of the main river channel are finer grained sands combined with silts and clays. Near the mouth of the Bon Secour River sediments are predominantly sand mixed with some silt.

SEDIMENT CHEMISTRY SURVEY

Examination of sediments can offer insight into past conditions as well as indicating the present "pollution climate" because sediments represent a temporally integrated record of chemical conditions in a watershed. Many contaminants entering a watershed become sequestered in the sediments. This particularly is the case with estuarine watersheds as salt water promotes adsorption and precipitation of materials dissolved in the fresh water entering the system.

The objective of the sediment sampling program was to determine the concentrations of metals and the presence of excessive metal enrichment. These results were compared to a survey of natural estuarine sediments in the Alabama coastal zone which established the existence of statistically significant relationships between aluminum and eight trace metals: arsenic, barium, cadmium, chromium, copper, lead, nickel and zinc (Alabama Department of Environmental Management, 1991). These relationships may be utilized to identify unnatural concentrations of metals in estuarine sediments (Schropp and Windom, 1988 and ADEM, 1991).

This method of interpretation is based on the naturally occurring relationships between aluminum and other metallic elements. The basis for this method is that aluminum occurs naturally in all estuarine sediments and the concentrations of other metals tend to vary proportionally with the concentration of aluminum. These naturally occurring proportions of metals relative to aluminum have been reported by several investigators, Turekian and Wedepohl (1961), Taylor (1964), Duce et al (1976) and Schropp and Windom (1988) to be fairly constant. These relationships allow for the use of aluminum as a reference element or "normalizing factor" for identification of sediments enriched by anthropogenic activities. This concept has been used to examine metal pollution in the Savannah River estuary (Goldberg, 1979), lead pollution in the Mississippi River (Trefey et al., 1985) and metal pollution in Florida estuaries (Schropp and Windom, 1988). Additional detail regarding this technique may be found in Schropp and Windom (1988) and ADEM (1991 and 1992).

Materials and Methods

On September 28, 1995 sediment samples were collected from five sites in the watershed, three locations on Bon Secour River and one each on Shutt Creek and Boggy Branch (Figure 5). Stations were selected to be representative of overall stream conditions and not localized or isolated problems such as boat slips, dredged channels and storm drains. Station depth was between 1.0 and 1.5 meters at each site.

Sediment cores were retrieved with an Ogeechee Sand Pounder™ core sampler (Wildlife Supply Co., cat. no. 2427-A20) equipped with a cellulose-acetate-butyrate liner tube. Sediment for metal analyses was taken from the upper five centimeters (2 inches) of each core, placed in an acid-washed glass jar and capped with a Teflon lined lid. Samples were collected in triplicate, two samples for immediate processing and the third sample for "archiving" in a freezer for future analyses in case of widely varying results between the first two.

Sample analyses began with oven-drying of sediments at 60 degrees Celsius. Weighed portions (250 mg) of each sample were placed in Teflon bombs and subjected to a total digestion process in a solution of nitric acid, hydrofluoric acid and perchloric acid at 120 degrees Celsius. Analyses were performed with a Perkin-Elmer 3030-B atomic absorption spectrophotometer (AA) equipped with a flame furnace for Al, Fe and Zn and a graphite furnace for As, Ba, Cd, Cr, Cu, Pb, Ni and Sn. A Leeman Labs Model PS-200 automated mercury analyzer was utilized for Hg analyses.

The mean values of the analyses of replicate samples were utilized as data for statistical comparisons. Statistical procedures employed in this study are detailed in Sokal and Rohlf (1969) and Filliben (1975).

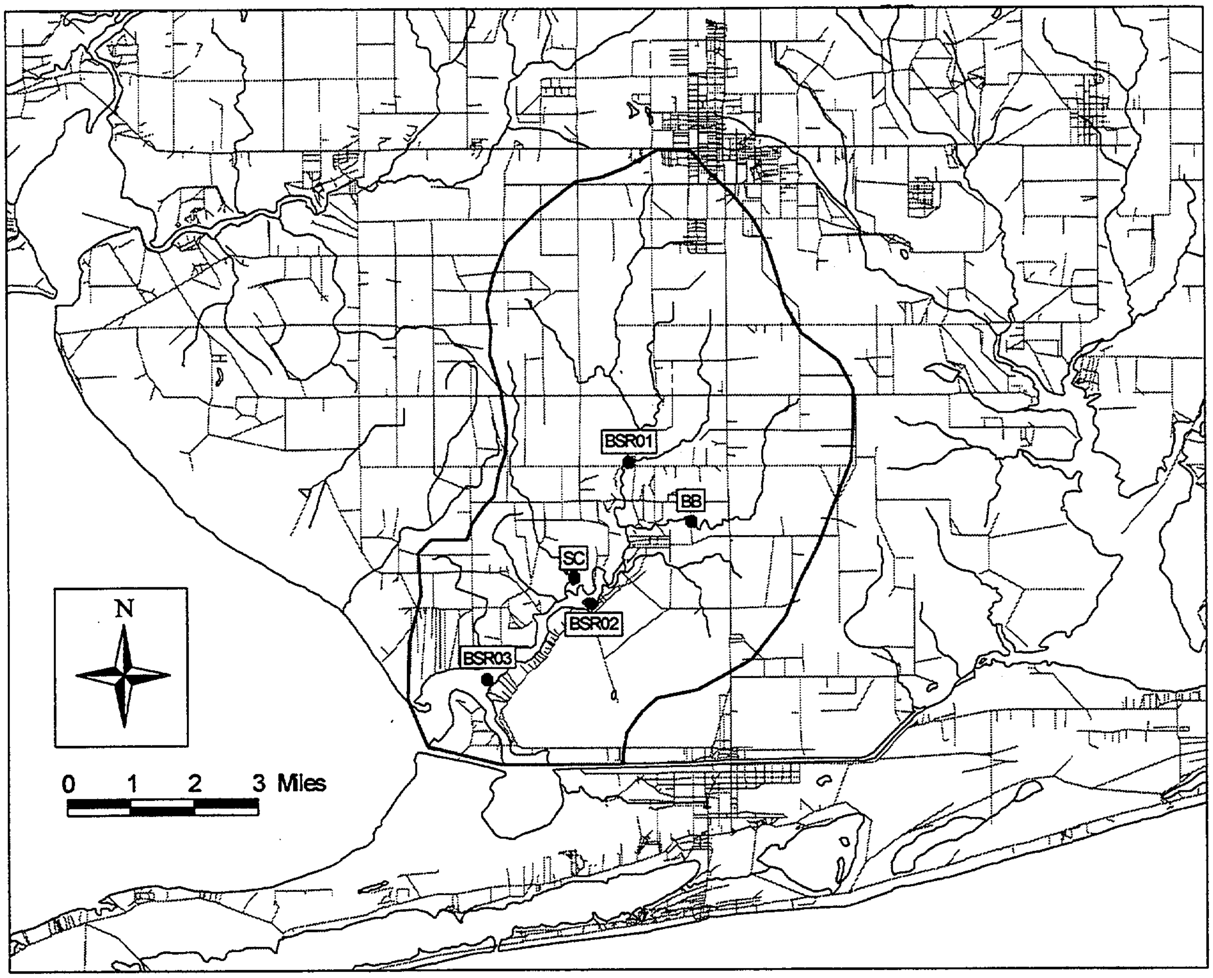


FIGURE 5

Sediment and Benthic Invertebrate Sampling Sites

Results

Results of sediment metal analyses are listed in Table 4. The concentrations of eight trace metals were compared to the concentration of aluminum as described in Schropp and Windom (1988) and ADEM (1991) for determining whether sediments of the watershed were enriched with trace metals. Graphical plots of these relationships are illustrated in Figures 5a-h. Superimposed on the data plots are regression lines and 95% confidence bands for each metal/aluminum relationship as would be expected to occur in uncontaminated sediments. The basis for determining these relationships are described by Schropp and Windom (1988) and ADEM (1990).

As might be seen from examination of the graphical plots, the concentrations of the metals from the sample sites are in ranges normally expected for coastal sediments. These results, together with the facts of the shipyard survey of 1991, indicate that, overall, the sediments of the Bon Secour River Watershed are still relatively clean compared to Dog River and Bayou LaBatre. The findings of the sediment chemistry survey are not conclusive proof that the BRW is absolutely free of any sediment contamination; rather, these results illustrate any such contamination is not widespread and, if present, would have to be very localized.

TABLE 4

BON SECOUR RIVER WATERSHED SEDIMENTS

STATION	Al	As	Ba	Cd	Cr	Cu	Mn	Hg	Ni	Pb	Sn	Zn
BB	6,370	<1.0	45	<0.10	8	<5	23	0.06	1.5	6	1.3	5
BSR01	6,985	1.1	45	<0.10	6	8	19	0.06	1.5	6	1.3	10
BSR02	16,175	2.3	51	0.12	14	8	96	0.05	2.8	3	<1.0	31
BSR03	53,050	7.5	137	0.23	38	16	340	0.08	18.5	4	1.7	80
SC	18,800	2.9	52	0.12	16	7	97	0.07	5.5	10	1.3	32
AVG	20,276	3.4	66	0.13	16	9	115	0.06	6.0	6	1.3	31
MAX	53,050	7.5	137	0.23	38	16	340	0.08	18.5	10	1.7	80
MIN	6,370	<1.0	45	<0.10	6	<5	19	0.05	1.5	3	<1.0	5

All values are expressed as mg/kg dry weight of sample.

All values are the average of duplicate samples

Those values preceeded by a less than sign "<" represent thr limit of detection for the method of analysis utilized.

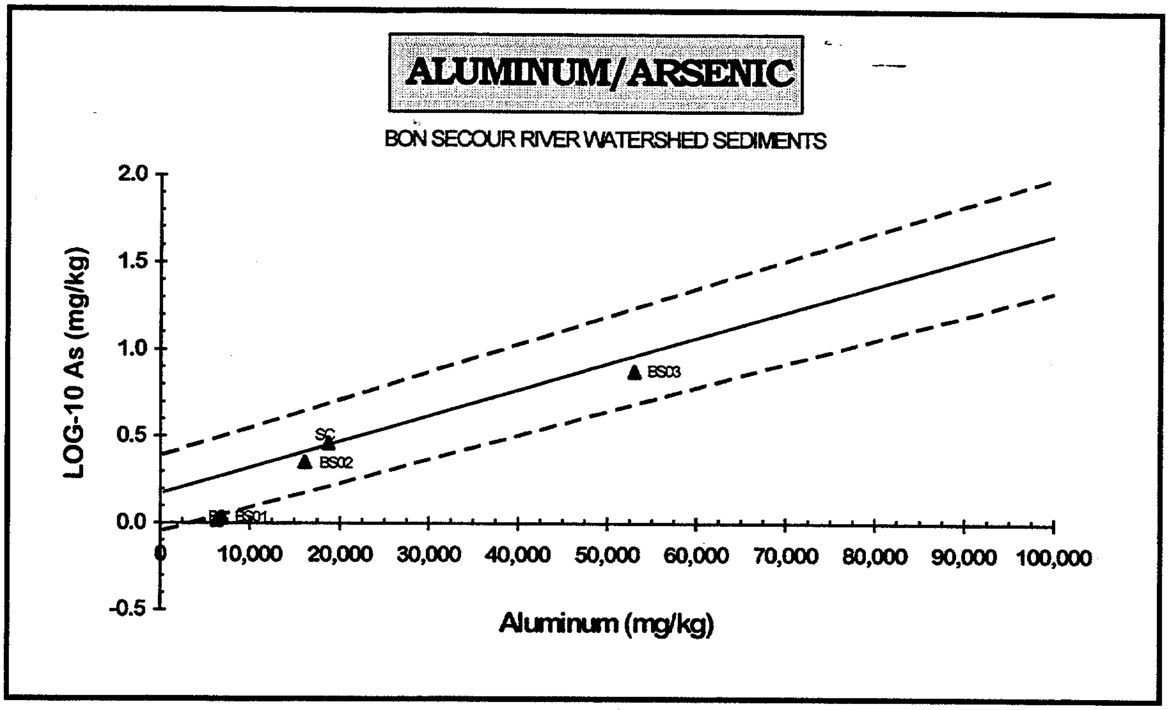


Figure 6a

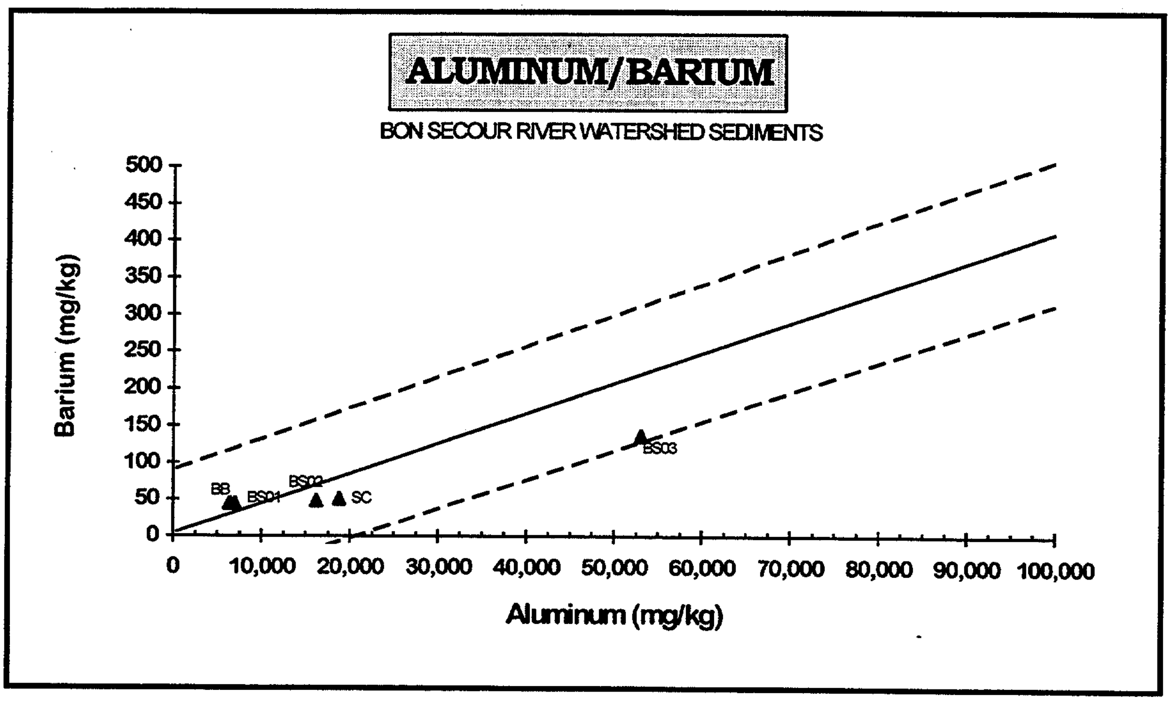


Figure 6b

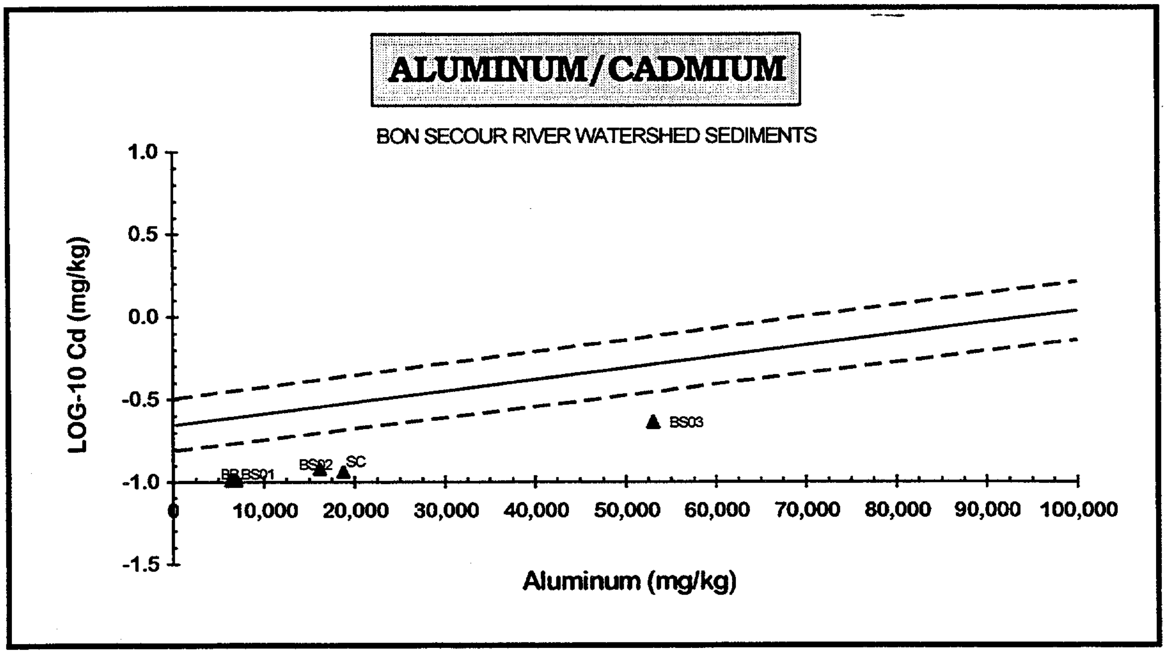


Figure 6c

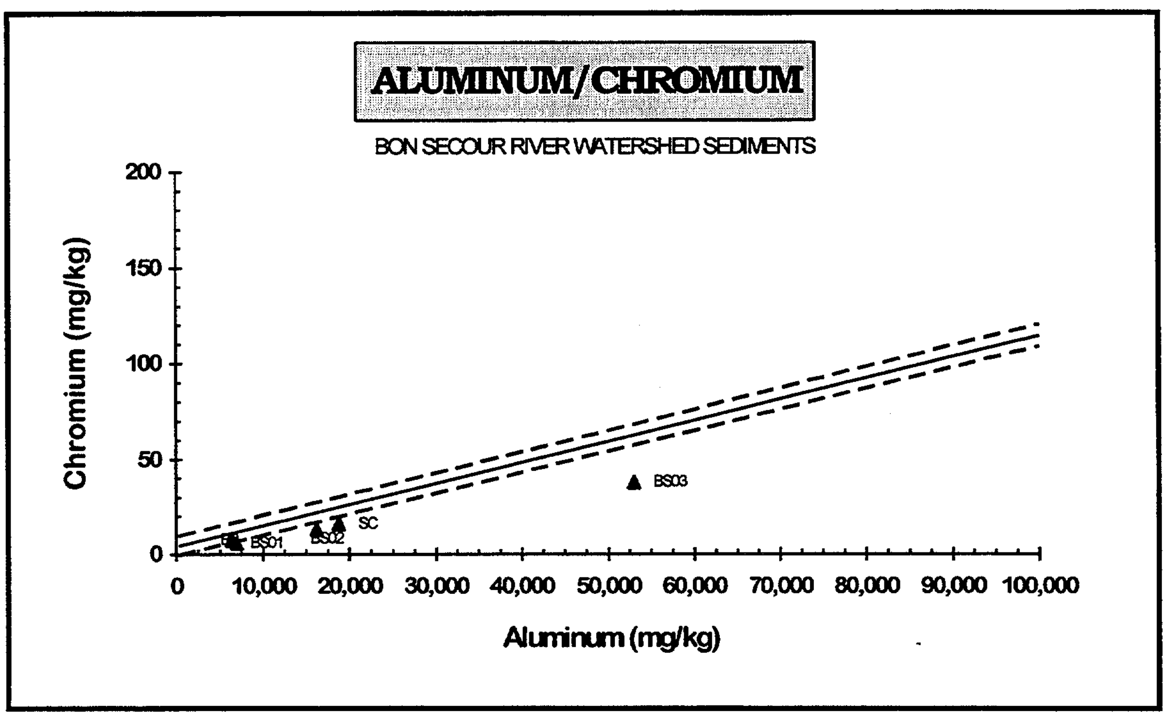
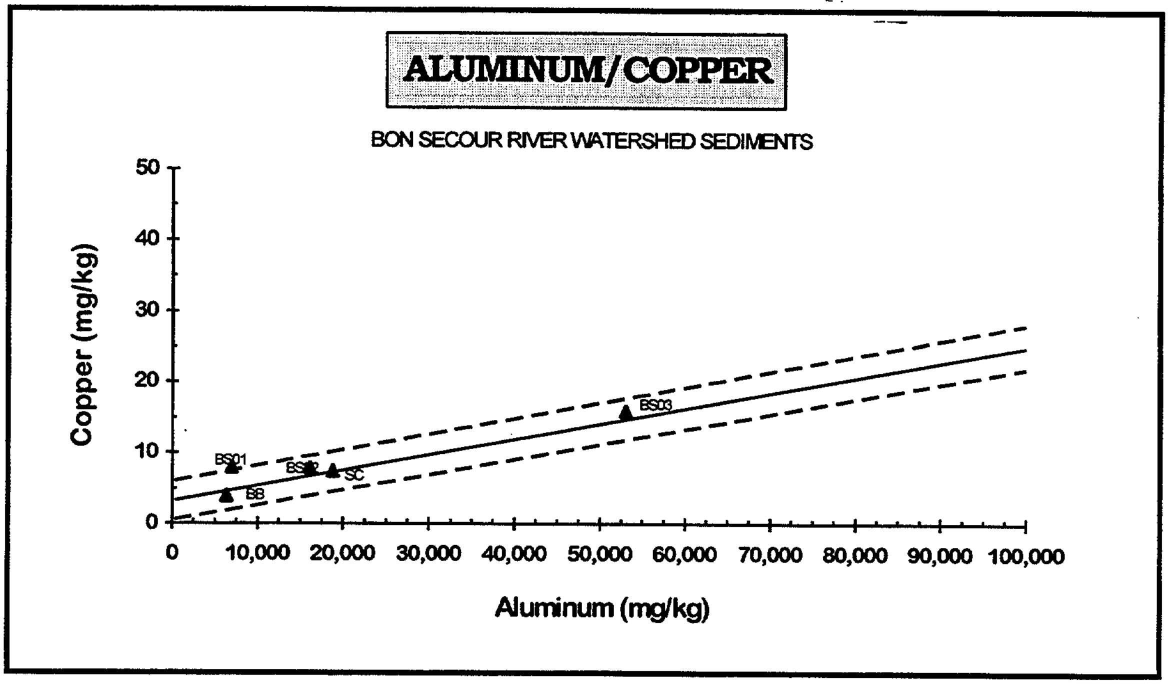


Figure 6d



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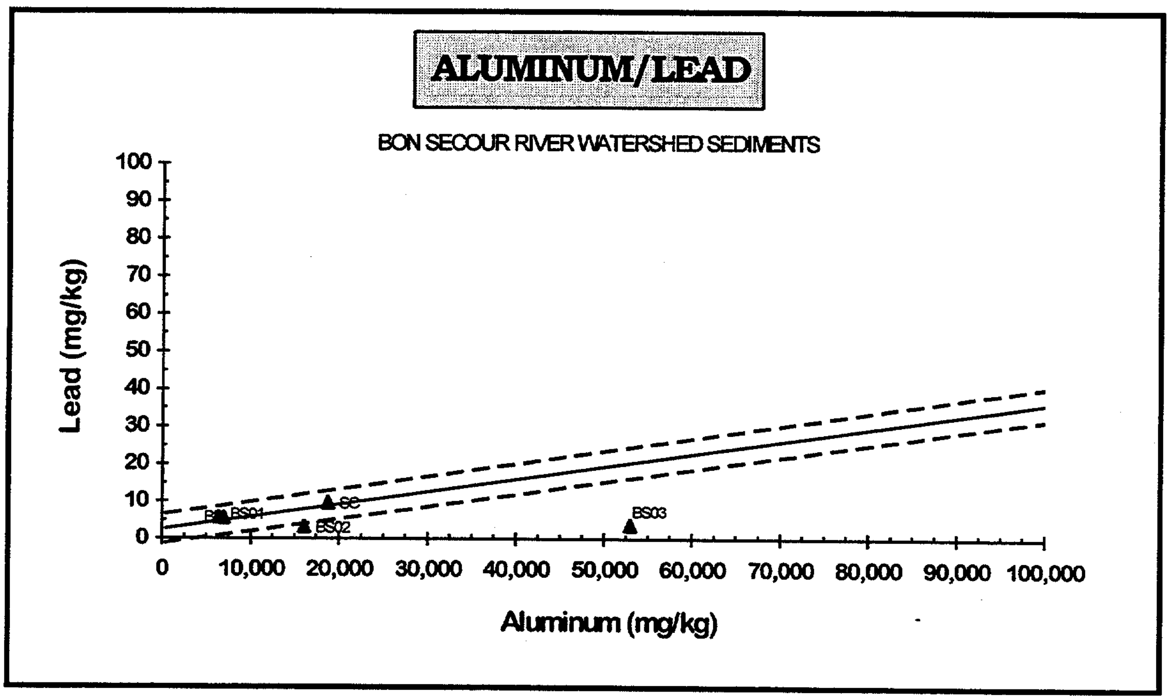

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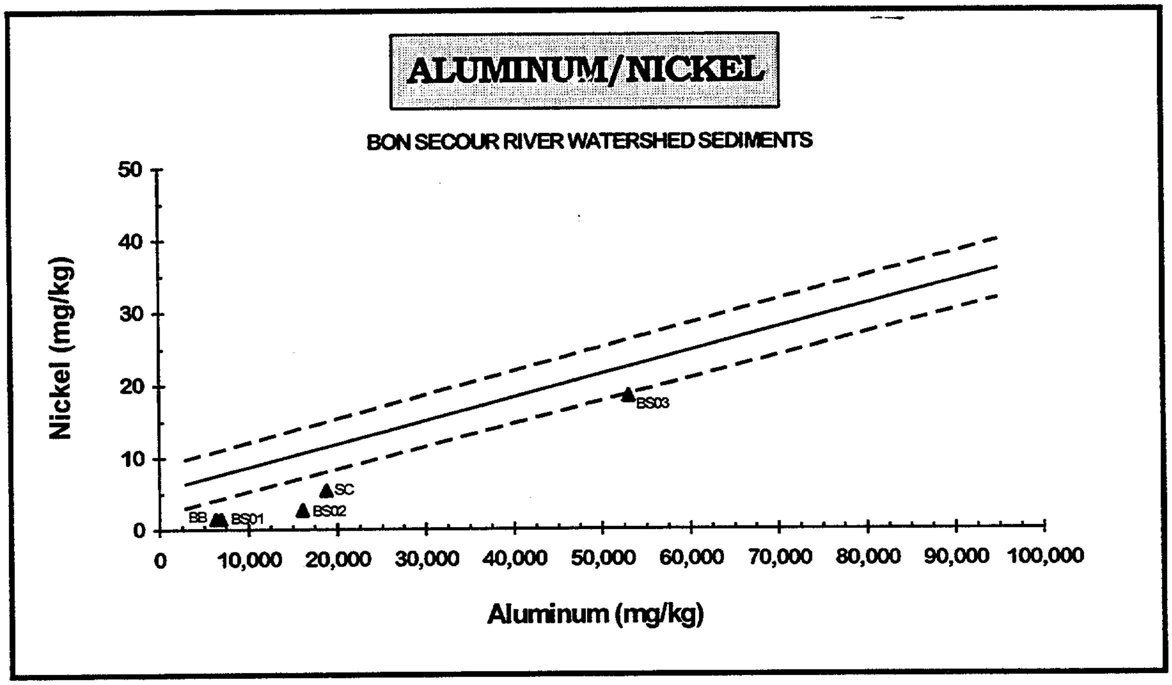

Figure 6g

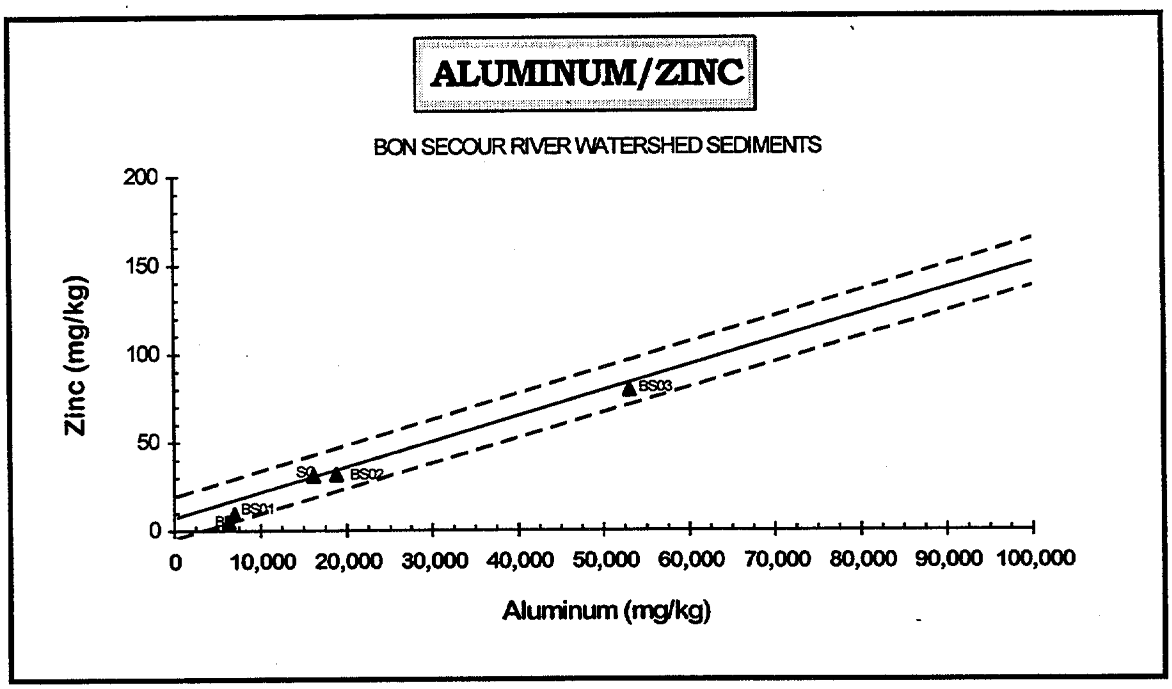

Figure 6h

BENTHIC BIOLOGY

INTRODUCTION

Plant and animals inhabiting streambeds, living on bay bottoms and in the ocean depths are referred to as benthic organisms. The word benthic originates from the Greek word *benthos,* referring to the bottom of the sea or those organisms living on the bottom. The collection of plants and animals living on the bottom and in the sediments of a body of water is referred to as a benthic community.

The structure of a benthic community in streams and estuarine waters is governed by numerous factors including dissolved oxygen, salinity, nutrient concentrations, siltation and sediment characteristics. The study of benthic communities has become a valuable component of monitoring strategies providing information above and beyond that which is obtained through projects focusing only on physical and chemical parameters (Hart and Fuller eds., 1974; Hynes, 1971 and 1972; Mason et al., 1971; Mackenthun, 1969; Pennack, 1989; Pratt and Coler, 1976 and Wilhm, 1972). Information about the benthic community of a watershed combined with knowledge of the watershed's geology, hydrology, water quality and land-use practices permits the development of more effective management plans affording a greater degree of resource protection.

For monitoring the affects of urban development and runoff in the BRW it was decided to concentrate resources on surveying the benthic macroinvertebrate community. Benthic macroinvertebrates in tidally influenced watersheds are typified by crustaceans (crabs, crawfish and shrimp), mollusks (clams and snails) and polychaetes (bristleworms and clamworms). Benthic macroinvertebrates commonly respond to specific degradation in water quality and bottom habitats; therefore, they are good "indicators" of environmental quality (Hynes, 1971 and 1972; Wilhm and Dorris, 1968).

OBJECTIVE

The objective of the benthic biology portion of the survey was to characterize the benthic macroinvertebrate community of the BRW relative to stream segments and tributaries, and evaluate the water quality and sediment chemistry for chemical and physical factors influencing the distribution of species and diversity of the community. More specifically the effort sought to quantify abundance of individuals and species; determine diversity and evenness at different sites in the basin and compare biological data with water quality data, sediment chemistry data and land-use practices for possible associations between dissolved oxygen, nutrients, siltation and enriched concentrations of metals.

Considering the broad nature of the watershed study it was the intention of the survey team to demonstrate benthic biology as a watershed assessment tool and not to conduct an in-depth study of the taxonomy of the basin. Therefore it was decided to limit the benthic biology program to one set of samples to be gathered in a brief period of time (preferably one day) during moderate flow. Additional detail about the aquatic biology of the BRW (i.e. submersed grassbeds, marshland acreage, fish stocks etc.) are far beyond the scope of this study and would have to be provided through a comprehensive biological survey accounting for seasonal and other factors.

BENTHIC INVERTEBRATE SURVEY

Materials and Methods

Three sites in the Bon Secour River were visited on September 28,1995 for collecting benthic invertebrate specimens (Figure 4). These locations are the same as those sampled for sediment metals. Sites of similar stream morphology, depth and bottom habitat were selected so as to minimize natural variability as much as was practical.

At each station three replicate benthic samples were taken with a 0.023 m^2 (6"x 6") stainless steel petite Ponar grab for a total area sampled of 0.069 m^2 (0.75 ft^2) at each station. The contents of each sample were washed through a 0.5 mm sieve (US #35 mesh) and all material, debris and organisms, retained on the sieve was preserved in a solution of 10% formaldehyde stained with rose bengal.

Each replicate was sieved a second time in the lab to further clean the sample of sediment. The washed samples were then placed in a white enamel pan and the organisms picked from debris using needle-nose forceps and lighted magnifiers. Organisms were then placed in labeled capped vials containing 95% ethanol for temporary storage until they were identified.

Specimens were sorted and identified to the lowest possible identification level (LPIL) using optical light microscopes. Identified and counted specimens were preserved in 95% ethanol in vials labeled with the taxonomic name of the organism, location of sample site and date collected. The following references were consulted when identifying macroinvertebrate specimens: Abele and Kim (1986); Brigham, Brigham and Gnilka (1982); Fauchald (1977); Heard (1982); Holsinger (1976); Pennack (1989); Stimpson, Klemm and Hiltunen (1982); Hopkins, Valentine and Lutz (1989); Simpson and Bode (1980); Uebelacker and Johnson (1984); Williams, A. (1984) and Williams, W. (1976).

Names and abundances of species collected were entered into Microsoft Excel™ spreadsheets for calculation of population statistics. Population statistics employed for the benthic biology survey included the indices of community diversity, species evenness and species richness.

These population statistics provide numerical indices which, in conjunction with information on the types and numbers of species collected and water quality data, allow for determination of the health of aquatic environments (Shannon and Weaver, 1963; Lloyd, *et al.*, 1968; Margelef, 1958 and 1968; Pielou, 1975; Wilhm and Dorris, 1968).

Community diversity was calculated using the Shannon-Wiener information measure or the Shannon index of general diversity (H') (Shannon and Weaver, 1963; Margelef, 1968 and Pielou, 1975). The Shannon index was utilized because it incorporates both richness and evenness. The index is calculated by the equation:

$$H' = -\Sigma p_i \log p_i$$

H' = the symbol for diversity in a community

p_i = the proportion of the community made up by a particular species (*i*)

$\log p_i$ = the logarithm of p_i; it may be base 2, *e* or 10, in this study base 2 is utilized.

Species evenness was determined by Pielou's evenness index (J') (Pielou, 1966) as calculated from:

$$J' = H'/\log s$$

where s = the number of species per site

H' = the Shannon-Wiener index.

Margelef's richness index (d) (Margelef 1958) was utilized as another measure of health of the benthic community. This is determined by the formula:

$$d = s\text{-}1/\log N$$

where s = the number of species

N = the number of individuals per site.

Results

A total of 10 species representing 6 taxonomic classes were collected from the six stations. The most abundant organisms were oligochaetes (Family Tubificidae), and polychaetes (Families Capitellidae and Spionidae). Overall, the numbers of individuals and species collected were surprisingly low considering the apparently clean sediments at these sites and the apparent absence of hypoxia. The low number of individuals from the Bon Secour River sites, given the accompanying conditions is considered by aquatic biologists to be an indication of a disturbance, such as siltation, with broad effects to the entire infaunal community (Hynes, 1971 and Pennack, 1989). For this study such responses by the benthic community are best typified by the collection from station BSR01. The river at this site was so severely affected by siltation that the bottom was entirely covered with shifting and unconsolidated silty-sand; furthermore, no specimens were collected at this site. A summary of benthic community statistics may be found in Table 5, species collected are listed in Table 6 and site specific information may be found in Table 7.

Table 5
Summary Statistics for Benthic Invertebrate
Communities of the Bon Secour River Watershed

Station	Number of Specimens	Number of Species	Density per Square Meter	Shannon-Weiner Diversity Index	Margelef's Richness	Pielou's Evenness
BSR01	0	0	0	N/A	N/A	N/A
BSR02	40	2	571	0.17	0.62	0.56
BSR03	99	8	1414	1.16	3.51	1.28

Table 6

Species Collected from the Bon Secour River Watershed

NEMERTEA
- *Tubulanus sp* (LPIL)

OLIGOCHAETA
- Tubificidae (LPIL)

POLYCHAETA
- Capitellidae
  - *Mediomastus ambeseta*
- Spionidae
  - *Streblospio benedicti*
- Pilargidae
  - *Parandalia americana*
  - *Sigambra bassi*
- Goniadidae
  - *Glycinde solitaria*

CRUSTACEA
- Mysidacea
  - *Mysidopsis sp* (LPIL)
- Isopoda
  - Idoteidae
    - *Edotea montosa*
- Decapoda
  - Portunidae
    - *Callinectes sapidus*

Table7

Benthic Invertebrates Collected Listed by Station

Station BSR01

No specimens collected at this station

Station BSR02	Species	Number Collected
	Tubificidae (LPIL)	39
	Polychaeta-*Parandalia americana*	1
	TOTAL	40

Station BSR03	Species	Number Collected
	Nemertea-*Tubulanus sp.* (LPIL)	6
	Polychaeta-*Mediomastus ambeseta*	80
	Streblospio benedicti	6
	Glycinde solitaria	3
	Sigambra bassi	1
	Mysidacea-*Mysidopsis sp* (LPIL)	1
	Isopoda-*Edotea montosa*	1
	Decapoda-*Callinectes sapidus*	1
	TOTAL	99

REVIEW AND CONCLUSIONS

The results of this survey bring to light the distinctly evident impacts of land use patterns and associated non-point sources on the waters of the BRW. This watershed receives minimal amounts of treated wastewater from point sources; however, turbidity values and fecal coliform counts were observed to be considerably elevated at times. The effects of erosion and siltation have become conspicuous as was indicated by the severe bar and shoal formation observed in the middle basin. This was further indicated by the low numbers of benthic infaunal organisms collected, especially at station BSR01.

These findings have shown, as was the case with the Dog River Watershed, a clear need for controlling stormwater runoff and erosion at construction sites. Adherence to construction site Best Management Practices (BMPs) as standard operating proceedures needs to be emphasized to all contractors. The permit requirements and BMP guidelines of the NPDES General Permit Program for construction and other land clearing activities, if properly followed, should produce a significant reduction in the suspended solids loads and turbidity of area streams. These improvements will, in turn, provide a chance for restoration of more productive aquatic habitats and better quality water.

These changes are not a matter of technical obstacles to be overcome; rather the issue is one of implementation.

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APPENDIX

TABLE A-1 STATE OF ALABAMA WATER QUALITY CRITERIA

TABLE A-2 MANUFACTURING AND PROCESSING FACILITIES PERMITTED TO DISCHARGE WASTEWATER

TABLE A-3 A SUMMARY OF WATER QUALITY DATA

TABLE A 1

STATE OF ALABAMA
SPECIFIC WATER QUALITY CRITERIA
APPLICABLE TO THE WATER USE CLASSIFICATIONS
OF THE BON SECOUR RIVER WATERSHED

Classification: Swimming and other whole body water contact sports..

Best usage of waters: Swimming and other whole body water contact sports

Conditions related to best usage: The waters under proper sanitary supervision by the controlling health authorities, will meet accepted standards of water quality for outdoor swimming places and will be considered satisfactory for swimming and other whole body water contact sports. The quality of waters will also be suitable for the propagation of fish, wildlife and aquatic life. The quality of salt waters and estuarine waters to which this classification is assinged will be suitable for the propagation and harvesting of shrimps and crabs.

Specific criteria:

Sewage, industrial wastes, or other wastes:
None which are not effectively treated or controlled in accordance with ADEM Administrative Rule 335-6-10-.08

pH:
Sewage, industrial wastes or other wastes shall not cause the pH to deviate more than one unit from the normal or natural pH, nor be less than 6.0, nor greater than 8.5. For estuarine waters and salt waters to which this classification is assinged, wastes as described herein shall not cause the pH to deviate more than one unit from the normal or natural pH, nor be less than 6.5, nor more than 8.5.

Temperature:
The maximum temperature in streams, lakes and reservoirs shall not exceed 90 degrees Fahrenheit.

The maximum in-stream temperature rise above ambient water temperature due to the addition of artifical heat by a discharger shall not exceed 4 degrees F in coastal or estuarine waters waters during the period October through May, nor shall the rise exceed 1.5 degrees F during the period June through September.

In lakes and reservoirs there shall be no withdrawal from, nor discharge of heated waters to, the hypolimnion unless it can be shown that such discharge or withdrawal will be beneficial to water quality.

In all waters the normal daily and seasonal temperature variations that were present before the addition of artificial heat shall be maintained, and there shall be no thermal block to the migration of aquatic organisms.

Thermal permit limitations in NPDES permits may be less stringent than those required above when a showing by the discharger has been made pursuant to Section 316 of the Federal Water Pollution Control Act (FWPCA), 33 U.S.C. Section 1251 et seq. or pursuant to a study of an equal or more stringent nature required by the State of Alabama authorized by Title 22, Section 22-22-9(c), Code of Alabama 1975, that such limitations will assure the protection and propogation of a balanced, indigenous population of shellfish, fish and wildlife, in and on the body of water to which the discharge is made. Any such demonstration shall take into account the interaction of the thermal discharge component with other pollutants discharged.

Dissolved Oxygen:

For a diversified warm water biota, including game fish, daily dissolved oxygen values shall not be less than 5 mg/l at all times; except under extreme conditions due to natural causes, it may range between 5 mg/l and 4 mg/l, provided that the water quality is favorable in all other parameters. The normal seasonal and daily fluctuations shall be maintained above these levels. In no event shall the dissolved oxygen level be less than 4 mg/l due to discharges from existing hydroelectric generation impoundments. All new hydroelectric generation impoundments, including addition of new hydroelectric generation units to existing impoundments, shall be designed so that the discharge will contain at least 5 mg/l dissolved oxygen where practicable and technologically possible.

In coastal waters, surface dissolved oxygen concentrations shall not be less than 5 mg/l, except where natural phenomena cause the value to be depressed.

In estuaries and tidal tributaries, dissolved oxygen concentrations shall not be less than 5 mg/l, except in dystrophic waters or where natural conditions cause the value to be depressed.

In the application of dissolved oxygen criteria referred to above, dissolved oxygen oxygen shall be measured at a depth of 5 feet in waters 10 feet or greater in depth; and for those waters less than 10 feet in depth, dissolved oxygen criteria will be applied at mid-depth.

Toxic substances; color producing substances; odor producing substances; or other deleterious substances attributable to sewage, industrial wastes, or other wastes:

Only such amounts, whether alone or in combination with other substances, and only such temperatures as will not render the waters unsafe or unsuitable as a source of water supply for drinking and food-processing purposes, or exhibit acute toxicity or chronic toxicity, as demonstrated by effluent toxicity testing or by application of numeric criteria given in ADEM Administrative Rule 335-6-10-.07, to fish,wildlife and aquatic life, or where applicable, shrimp and crabs; impair the waters for any other usage established for this classification or unreasonably affect the aesthetic value of waters for any use under this classification.

Bacteria:

Waters in the immediate vicinity of discharges of sewage or other wastes likely to contain bacteria harmful to humans, regardless of the degree of treatment afforded these wastes, are not acceptable for swimming or other whole body water-contact sports.

In all other areas, the bacterial quality of water is acceptable when a sanitary survey by the controlling health authorities reveals no source of dangerous pollution and when the geometric mean fecal coliform organism density does not exceed 100/100 ml in coastal waters and 200/100 ml in other waters. When the geometric mean fecal coliform organism density exceeds these levels, the bacterial water quality shall be considered acceptable only if a second detailed sanitary survey and evaluation discloses no significant public health risk in the use of the waters

The policy of nondegradation of high quality waters shall be stringently applied to bacterial quality of recreational waters.

Radioactivity:

The concentrations of radioactive materials present shall not exceed the requirements of the State Department of Public Health.

Turbidity:

There shall be no turbidity of other than natural origin that will cause substantial visible contrast with the natural appearance of waters or interfere with any beneficial uses which they serve. Furthermore, in no case shall turbidity exceed 50 Nephelometric units above backround. Backround will be interpreted as the natural condition of the receiving waters, without the influence of man-made or man-induced causes. Turbidity levels caused by natural runoff will be included in establishing backround levels.

Classification: Fish and Wildlife.

Best usage of waters: Fishing, propogation of fish, aquatic life and wildlife, and any other usage except for swimming and water-contact sports or as a source of water supply for drinking or food-processing purposes.

Conditions related to best usage: The waters will be suitable for fish, aquatic life and wildlife propogation. The quality of salt and estuarine waters to which this classification is assigned will also be suitable for the propogation of shrimp and crabs.

Other usage of waters: It is recognized that the waters may be used for incidental water contact and recreation during June through September, except that water contact is strongly discouraged in the vicinity of discharges or other conditions beyond the control of the Department or the Alabama Department of Public Health.

Conditions related to other usage: The waters, under proper sanitary supervision by the controlling health authorities, will meet accepted standards of water quality for outdoor swimming places and will be considered satisfactory for swimming and other whole body water-contact sports.

Specific Criteria:

Sewage, industrial wastes, or other wastes:

None which are not effectively treated or controlled in accordance with ADEM Administrative Rule 335-6-10-.08

pH:

Sewage, industrial wastes or other wastes shall not cause the pH to deviate more than one unit from the normal or natural pH, nor be less than 6.0, nor greater than 8.5. For estuarine waters and salt waters to which this classification is assinged, wastes as described herein shall not cause the pH to deviate more than one unit from the normal or natural pH, nor be less than 6.5, nor more than 8.5.

Temperature:

The maximum temperature in streams, lakes and reservoirs shall not exceed 90 degrees Fahrenheit.

The maximum in-stream temperature rise above ambient water temperature due to the addition of artifical heat by a discharger shall not exceed 4 degrees F in coastal or estuarine waters waters during the period October through May, nor shall the rise exceed 1.5 degrees F during the period June through September.

In lakes and reservoirs there shall be no withdrawal from, nor discharge of heated waters to, the hypolimnion unless it can be shown that such discharge or withdrawal will be beneficial to water quality.

In all waters the normal daily and seasonal temperature variations that were present before the addition of artificial heat shall be maintained, and there shall be no thermal block to the migration of aquatic organisms.

Thermal permit limitations in NPDES permits may be less stringent than those required above when a showing by the discharger has been made pursuant to Section 316 of the Federal Water Pollution Control Act (FWPCA), 33 U.S.C. Section 1251 et seq. or pursuant to a study of an equal or more stringent nature required by the State of Alabama authorized by Title 22, Section 22-22-9(c), Code of Alabama 1975, that such limitations will assure the protection and propogation of a balanced, indigenous population of shellfish, fish and wildlife, in and on the body of water to which the discharge is made. Any such demonstration shall take into account the interaction of the thermal discharge component with other pollutants discharged.

Dissolved Oxygen:

For a diversified warm water biota, including game fish, daily dissolved oxygen values shall not be less than 5 mg/l at all times; except under extreme conditions due to natural causes, it may range between 5 mg/l and 4 mg/l, provided that the water quality is favorable in all other parameters. The normal seasonal and daily fluctuations shall be maintained above these levels. In no event shall the dissolved oxygen level be less than 4 mg/l due to discharges from existing hydroelectric generation impoundments. All new hydroelectric generation impoundments, including addition of new hydroelectric generation units to existing impoundments, shall be designed so that the discharge will contain at least 5 mg/l dissolved oxygen where practicable and technologically possible.

In coastal waters, surface dissolved oxygen concentrations shall not be less than 5 mg/l, except where natural phenomena cause the value to be depressed.

In estuaries and tidal tributaries, dissolved oxygen concentrations shall not be less than 5 mg/l, except in dystrophic waters or where natural conditions cause the value to be depressed.

In the application of dissolved oxygen criteria referred to above, dissolved oxygen oxygen shall be measured at a depth of 5 feet in waters 10 feet or greater in depth; and for those waters less than 10 feet in depth, dissolved oxygen criteria will be applied at mid-depth.

Toxic substances attributable to sewage, industrial wastes, or other wastes:

Only such amounts, whether alone or in combination with other substances, and only such temperatures as will not render the waters unsafe or unsuitable as a source of water supply for drinking and food-processing purposes, or exhibit acute toxicity or chronic toxicity, as demonstrated by effluent toxicity testing or by application of numeric criteria given in ADEM Administrative Rule 335-6-10-.07, to fish and aquatic life, including shrimp and crabs in estuarine and salt waters or the propogation thereof.

Taste, odor and color-producing substances attributable to sewage, industrial wastes, or other wastes:

Only such amounts, whether alone or in combination with other substances, and only such temperatures as will not render the waters unsafe or unsuitable as a source of water supply for drinking and food-processing purposes, or exhibit acute toxicity or chronic toxicity, as demonstrated by effluent toxicity testing or by application of numeric criteria given in ADEM Administrative Rule 335-6-10-.07, to fish and aquatic life, including shrimp and crabs in estuarine and salt waters or adversely affect the propagation thereof; impair the palatability or marketability of fish and wildlife or shrimp and crabs in estuarine and salt waters; or unreasonably affect the aesthetic value of waters for any use under this classification.

Bacteria:

Bacteria of the fecal coliform group shall not exceed a geometric mean of 1,000/100 ml on a monthly average value; nor exceed a maximum of 2,000/100 ml in any sample.

For incidential water contact and recreation during June through September, the bacterial quality of water is acceptable when a sanitary survey by the controlling health authorities reveals no source of dangerous pollution and when the geometric mean fecal coliform organism density does not exceed 100/100 ml in coastal waters and 200/100 ml in other waters. When the geometric mean fecal coliform density exceeds these levels, the bacterial water quality shall be considered acceptable only if a second detailed sanitary survey and evaluation discloses no significant public health risk in the use of the waters. Waters in the immediate vicinity of discharges of sewage or other wastes likely to contain bacteria harmful to humans, regardless of the degree of the treatment afforded these wastes, are not acceptable for swimming or other whole body water-contact sports.

Radioactivity:

The concentrations of radioactive materials present shall not exceed the requirements of the State Department of Public Health.

Turbidity:

There shall be no turbidity of other than natural origin that will cause substantial visible contrast with the natural appearance of waters or interfere with any beneficial uses which they serve. Furthermore, in no case shall turbidity exceed 50 Nephelometric units above backround. Backround will be interpreted as the natural condition of the receiving waters without the influence of man-made or man-induced causes. Turbidity levels caused by natural runoff will be included in establishing backround levels.

TABLE A 2

MANUFACTURING & PROCESSING FACILITIES IN THE WATERSHED PERMITTED TO DISCHARGE TREATED WASTEWATER

Facility:	Aquila Seafood.
Location:	17309 River Road Bon Secour, Alabama
NPDES Permit No.	AL 0002321
Receiving waters:	Bon Secour River
Nature of wastewater:	Screened washwater from seafood packing and freezing operations. Cooler water and drainage from unloading and loading areas.
Monitored parameters:	Flow, pH, Total Suspended Solids, Settleable Solids, Oil & Grease, 5-Day Biochemical Oxygen Demand, Residual Chlorine.

Facility:	Billy's Seafood.
Location:	16780 River Road Bon Secour, Alabama
NPDES Permit No.	AL 0068497
Receiving waters:	Bon Secour River
Nature of wastewater:	Screened washwater from seafood packing and freezing operations. Cooler water and drainage from unloading and loading areas.
Monitored parameters:	Flow, pH, Total Suspended Solids, Settleable Solids, Oil & Grease, 5-Day Biochemical Oxygen Demand, Residual Chlorine.

Facility:	Bon Secour Fisheries.
Location:	16780 River Road Bon Secour, Alabama
NPDES Permit No.	AL 0003298
Receiving waters:	Bon Secour River
Nature of wastewater:	Screened floor wash down water and process wastewater from peeling and deveining shrimp, shucking and washing oysters, and preparing fish.
Monitored parameters:	Flow, pH, Total Suspended Solids, Settleable Solids, Oil & Grease, 5-Day Biochemical Oxygen Demand, Total Kjeldahl Nitrogen, Total Phosphorus, Ammonia as Nitrogen, Dissolved Oxygen of Effluent, Dissolved Oxygen of Receiving Waters-upstream and downstream of discharge.

Facility:	Carson & Company.
Location:	County Road 10 Bon Secour, Alabama
NPDES Permit No.	AL 00
Receiving waters:	Bon Secour River
Nature of wastewater:	Screened wastewaters resulting from the handling and processing of shrimp and stormwater runoff associated with areas of industrial activity.
Monitored parameters:	Flow, pH, Total Suspended Solids, Settleable Solids, Oil & Grease, 5-Day Biochemical Oxygen Demand, Total Residual Chlorine Total Kjeldahl Nitrogen, Total Phosphorus, Ammonia as Nitrogen, Dissolved Oxygen of Effluent, Dissolved Oxygen of Receiving Waters-upstream and downstream of discharge.

Facility:	Plash's Seafood Inc.
Location:	16615 Floyd Plash Ln. Gulf Shores, Alabama
NPDES Permit No.	AL 0000833
Receiving waters:	Bon Secour River
Nature of wastewater:	Screened washwater from crab processing operations. Washdown water from packing and freezing operations. Cooler water and drainage from unloading and loading areas.
Monitored parameters:	Flow, pH, Total Suspended Solids, Settleable Solids, Oil & Grease, 5-Day Biochemical Oxygen Demand, Residual Chlorine.

Facility:	Shutt's Safe Harbor Seafood.
Location:	5832 Heritage Circle. Bon Secour, Alabama
NPDES Permit No.	AL 0049638
Receiving waters:	Bon Secour River

Nature of wastewater: Screened washdown water from from packing and freezing operations. Cooler water and drainage from unloading and loading areas.

Monitored parameters:	Flow, pH, Total Suspended Solids, Settleable Solids, Oil & Grease, 5-Day Biochemical Oxygen Demand, Residual Chlorine.

TABLE A 3
SUMMARY OF SURFACE WATER ANALYSES

LOCATION		WATER TEMP. (DEG C)	pH (S.U.)	D.O. (mg/L)	SPECIFIC CONDUCTIVITY (µmhos/cm)	TURBIDITY (NTUs)	NITRATE NITROGEN (mg/L)	AMMONIA NITROGEN (mg/L)	TOTAL KJELDAHL NITROGEN (mg/L)	PHOSPHATE (mg/L)	[3] FECAL COLIFORM (mg/L)
STATION BS01	AVERAGE	21	6.1	6.6	79	55	1.861	0.060	0.48	0.142	473
	MAXIMUM	25	6.5	7.5	101	135	3.350	0.229	1.60	0.384	12,400
	MINIMUM	17	5.7	5.5	49	2.2	0.021	<0.01	<0.01	0.036	5
STATION UTNW	AVERAGE	21	5.9	3.8	110	63	2.514	0.155	0.93	0.189	11,732
	MAXIMUM	24	6.5	8.0	135	171	3.970	0.254	1.60	0.642	32,500
	MINIMUM	18	5.5	0.9	80	12.4	0.769	0.105	0.1	0.051	2,000
[1] STATION UTF	AVERAGE					32	0.067	0.029	1.66	0.054	1,574
	MAXIMUM					58	0.137	0.077	3.60	0.133	6,000
	MINIMUM					18.4	0.013	<0.01	0.68	0.003	500
STATION NEBS	AVERAGE	20	6.4	7.7	51	35	0.947	0.039	0.50	0.044	586
	MAXIMUM	26	8.7	9.3	68	78	1.810	0.073	1.60	0.212	5,600
	MINIMUM	14	5.2	6.6	40	4.1	0.032	<0.01	0.09	0.003	156
[2] STATION SC	AVERAGE	16	6.5	7.4	74	58	1.709	0.316	1.03	0.231	4,414
	MAXIMUM	18	7.4	9.8	86	92	3.780	1.945	2.90	0.606	15,000
	MINIMUM	14	6.0	5.3	66	11.5	0.209	<0.01	0.13	0.022	1,440
[2] STATION SHC	AVERAGE	18	6.0	6.9	112	22	1.530	0.046	0.60	0.092	4,687
	MAXIMUM	20	6.4	8.1	225	59	2.230	0.162	1.50	0.405	20,250
	MINIMUM	14	5.8	5.2	58	6.4	0.472	<0.01	0.13	0.013	1,260
STATION BB01	AVERAGE	21	6.1	5.9	73	9.3	1.210	0.017	0.51	0.033	90
	MAXIMUM	26	6.8	7.7	93	16.8	2.415	0.067	0.83	0.075	272
	MINIMUM	10	5.6	4.4	49	1.8	0.006	<0.01	0.09	0.003	32
STATION BB02	AVERAGE	24	6.4	7.5	13,018	2.2	0.541	0.060	0.90	0.046	0
	MAXIMUM	27	7.1	9.5	17,900	2.3	1.240	0.163	1.60	0.084	0
	MINIMUM	19	6.0	3.2	4,670	2	0.243	<0.01	0.22	0.01	0
STATION BS02	AVERAGE	22	7.4	9.0	15,150	14.6	0.403	0.03	0.86	0.091	15
	MAXIMUM	33	8.3	11.4	24,280	36	2.150	0.14	2.20	0.306	88
	MINIMUM	13	6.1	5.6	1,510	2.7	<0.005	<0.01	0.15	0.017	0

1: DUE TO ITS INTERMITTANT FLOW CHARACTERISTICS, STATION UTF WAS SAMPLED ONLY FOLLOWING STORM EVENTS. PREVAILING CONDITIONS PREVENTED MEASUREMENT OF TEMP., DO, pH & COND.

2: STATIONS SC & SHC WERE NOT FLOWING JULY-SEPTEMBER. DATA REPRESENTS SAMPLES COLLECTED DURING TIMES OF FLOW, JANUARY-JUNE

3: AVERAGE VALUES GIVEN FOR FECAL COLIFORM REPRESENT THE GEOMETRIC MEAN GM $X_N = (X_1 * X_2 .. X_N)^{1/N}$