

Workplan for Cycle II NAWQA Activities in the North Atlantic Coastal Plain Aquifer System

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Summary

The North Atlantic Coastal Plain aquifer system (NACPAS) is one of 16 principle aquifers selected for investigation during cycle II of the NAWQA program. The NACPAS planning team was tasked with 1) producing a written plan of study for the regional synthesis of major ground-water-quality issues across the NACP during cycle II, 2) critically reviewing cycle I accomplishments and the NIT cycle II plan of study, and 3) recommending and prioritizing ground-water studies for cycle II.

Aquifers and geographical areas not fully assessed during pilot and cycle I activities in the NACP include 1) the Severn – Magothy aquifer system on Long Island, 2) the Severn – Magothy and Potomac aquifers which serve as one aquifer system where they outcrop along the Fall Line from New Jersey to Virginia, and 3) the Castle Hayne aquifer in southeastern North Carolina.

The NACPAS planning team believes cycle II activities should address water-quality assessments in the abovementioned aquifers and geographical locations while continuing to assess trends and process-oriented studies in other areas of the NACP. The following recommendations and prioritizations either reiterate or augment NIT plans and ensure the goal of regional synthesis of water-quality issues following cycle II. The recommendations are presented in *general* order of priority:

1. Separate the Severn – Magothy and Potomac aquifer systems into the following two areas for assessment: 1) Long Island where these aquifers are mantled with 250+ ft of glacial deposits, and 2) their outcrop/subcrop belt which extends along the Fall Line from New Jersey southward to Virginia,
2. Conduct a NMAS for the Castle Hayne aquifer in southeastern North Carolina,
3. Conduct NMAS, SWA, and (or) TANC studies to compliment the planned new urban LUS on Long Island,
4. Resample the ALBE agricultural FPS network,
5. Conduct a SWA and (or) TANC study to compliment the NMAS and NLUSs planned for the outcrop/subcrop belt of the Severn – Magothy and Potomac aquifer systems,
6. Resample two prototype SWA networks (linjfpsot3 and dlmvspcg10) to provide information on trends in water quality from these important public-supply-well networks,
7. Incorporate the NLUS in the Severn – Magothy and Potomac aquifer systems (to be conducted by DELR) into the Trends network,
8. Conduct a SWA and (or) TANC study to compliment the Castle Hayne aquifer NMAS, and
9. Conduct an agricultural LUS in eastern Long Island.

Introduction

In 2001 the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) program entered its second decade of study unit investigations (cycle II). The overall goals of the program in cycle II remain the same as in cycle I: 1) *status* – provide a nationally consistent description of current water-quality conditions for a large, representative part of the Nation's water resources, 2) *trends* – define long-term trends (or the lack thereof) in water quality, and 3) *understanding* – identify, describe, and explain (to the extent possible) the major processes governing observed water-quality conditions and trends. In recognition of the programs advances in assessing the status of water-quality conditions during cycle I and to ensure the programs continuing relevance and success, cycle II will place an increasing emphasis on understanding trends in and identifying processes governing water quality, while continuing to assess status in critical areas not addressed during cycle I. Furthermore, as NAWQA enters cycle II, there will be an increasing need to maintain a balance between 1) directly assessing the Nation's most important water resources, 2) synthesizing results from multiple study units into regional assessments of priority water-quality issues, and 3) increasing the programs capability to extrapolate these assessments to areas with similar climatic and hydrogeologic settings which have not been assessed as part of the NAWQA program. Towards this goal, the NAWQA Implementation Team (NIT), which is charged with the design and implementation strategy for cycle II investigations, selected 16 principle aquifer systems for study during cycle II (Gilliom and others, 2000). These 16 aquifer systems were selected based on overall withdrawals for drinking-water supplies while ensuring that all major aquifer lithologies across the country were represented (Gilliom and others, 2000).

The North Atlantic Coastal Plain aquifer system (NACPAS) was selected as one of the 16 principle aquifer systems for investigation during cycle II. The NIT defined the geographical extent of NACPAS and has proposed a strategy of investigations that would address the Programs 3 primary goals of status, trends, and understanding during the course of cycle II (Gilliom and others, 2000). Additionally, representatives from NLT and each of the 4 study units that overlie the NACPAS (ALBE, PODL, DELR, and LINJ) (fig. 1) were assembled to independently 1) assess accomplishments in NACPAS during cycle I, 2) identify areas of high priority for cycle II investigations, and 3) develop a work plan for cycle II investigations in NACPAS. This document provides background information on NACPAS, summarizes work accomplished in NACPAS during cycle I, prioritizes areas and water-quality issues for cycle II investigations, and provides an assessment of whether or not the NIT proposed investigations in NACPAS will adequately address these areas and water-quality issues.

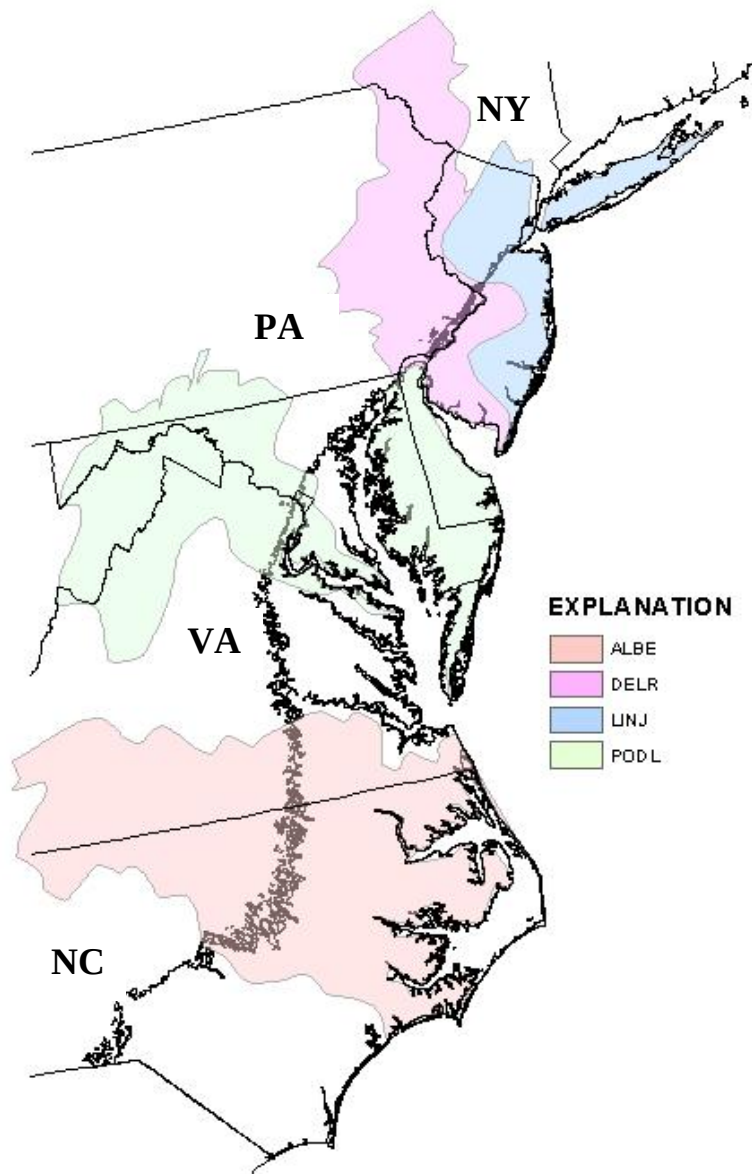


Figure 1. Location of study units overlying the North Atlantic Coastal Plain.

Objectives and Planning Steps

The overall objective of the NACPAS planning team was to produce a written plan of study for the regional synthesis of major water-quality issues across the NACP during cycle II. The primary planning steps include:

- 1) Developing a regional stratification scheme of the NACP to identify major aquifers and hydrogeologic settings,
- 2) Compiling available water-use information to identify the most important drinking-water resources,
- 3) Reviewing cycle I NAWQA accomplishments in NACP to identify aquifers and hydrogeologic settings that have been adequately addressed and those for which there is a relative lack of water-quality data,
- 4) Recommending and prioritizing cycle II activities to meet program goals in NACPAS, and
- 5) Comparing and contrasting recommendations with most recent NIT guidance.

Scope of Workplan

A large amount of water withdrawn from the NACPAS for drinking water supplies is withdrawn from surficial aquifer systems or where confined aquifers outcrop or subcrop along the Fall Line near large metropolitan areas. Furthermore, many of the confined aquifer systems are affected by saltwater intrusion in down-dip portions of their extent and are thus not utilized as sources of potable water. For these reasons, the focus of this workplan is on the upper several 100 feet of section because this is where most regional drinking-water supplies are obtained and the part of the aquifer system that is most vulnerable to anthropogenic contamination.

Study Area

The NACPAS covers about 50,000 square miles extending from the North Carolina – South Carolina State border northward to Long Island, New York (Trapp and Horn, 1997a and 1997b) (fig. 2). The aquifer system grades southward into the South Eastern Coastal Plain Aquifer System and is bounded on the west by the Fall Line, which separates the Piedmont and Coastal Plain Physiographic Provinces, and on the east by the Atlantic Ocean (Trapp and Horn, 1997a) (fig. 2). On Long Island, which is part of the Coastal Plain physiographic province, deposits of glacial origin mantle NACPAS sediments. NACPAS sediments that underlie Long Island are the sole source of potable water for nearly 3 million residents and these sediments are in hydraulic connection with the overlying glacial deposits that also provide potable water for Long Island residents. For these reasons, Long Island is an area that is of interest to participants of both the NACP and the glacial deposits principle aquifer study groups.

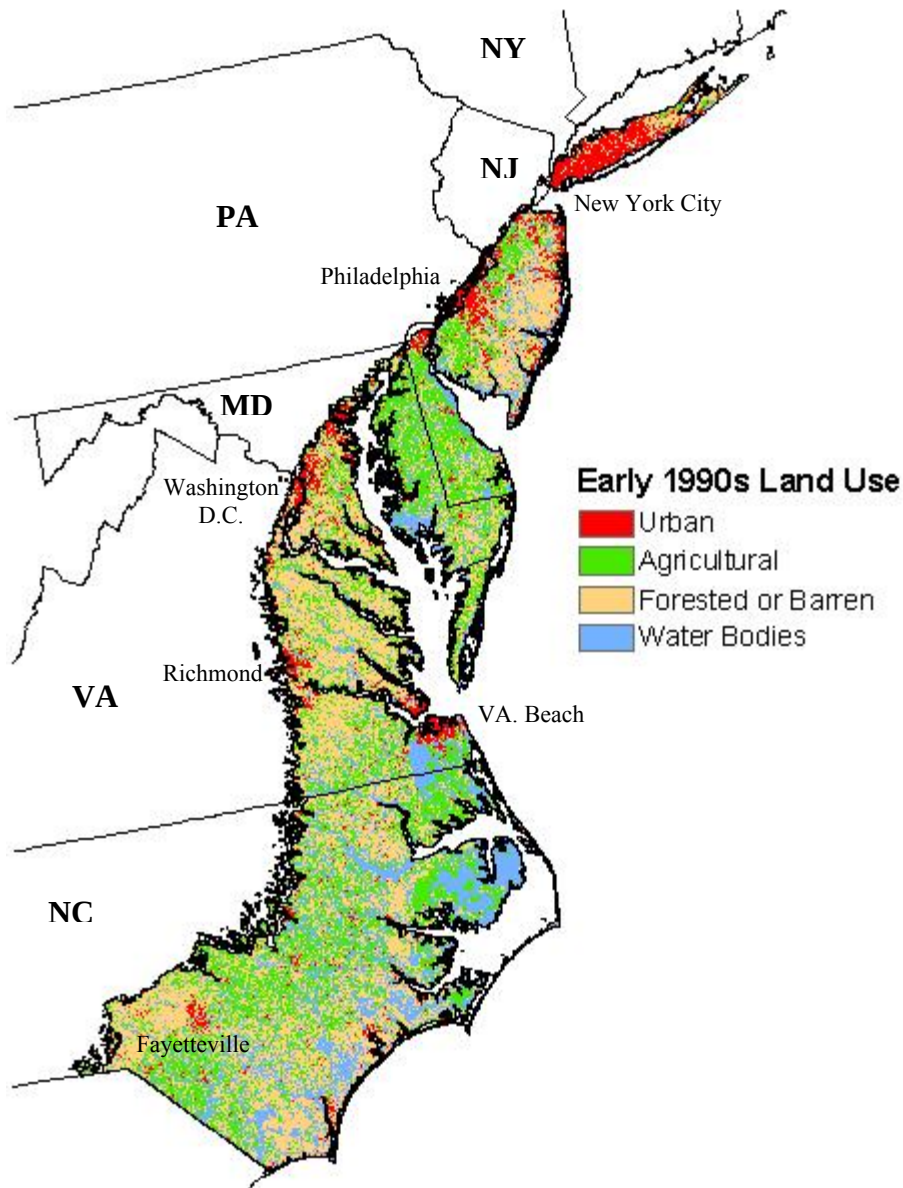


Figure 2. Land use in the North Atlantic Coastal Plain.

Vertical Sequence of Aquifers

The NACPAS consists of 6 regional aquifer systems in sedimentary deposits that range in age from Cretaceous to Holocene (Trapp and Horn, 1997a, Zapecza, 1989). These mostly unconsolidated sediments were deposited in a range of environments from fluvial to marine during a series of transgressions and regressions of the sea. Coastal Plain sediments vary texturally both laterally and vertically and form aquifers of varying extent that are composed of sand, gravel, and limestone and that are separated by confining units of silt and clay. These sediments form a wedge-shaped mass that thickens seaward and obtains a thickness of as much as 10,000 feet along the North Carolina coastline (Trapp and Horn, 1997a). The distribution and extent of the regional aquifers is illustrated on figures 3A and B. It is important to note that the

hydrogeologic framework of the NACP is much more complex on a local scale than is depicted in figs. 3A and B, however, these figures serve to provide a regional perspective on the NACPAS.

The **surficial aquifer** is the uppermost aquifer in the NACP. It is generally unconfined but is of limited extent occurring primarily in the coastal plain of North Carolina, the Delmarva Peninsula, and on Long Island (Trapp and Horn, 1997a). The average saturated thickness of the surficial aquifer is about 50 feet except on Long Island and buried channels on Delmarva Peninsula where its average saturated thickness is 250 feet or more.

Surficial sediments in the NACPAS are underlain by the **Chesapeake aquifer** with a clayey confining unit separating the two (Trapp and Horn, 1997a) (fig. 3A and B). Where the surficial aquifer is not present, units of the Chesapeake aquifer may serve as the surficial aquifer system (for example, the Kirkwood-Cohansey aquifer system in southern New Jersey).

The **Castle Hayne – Aquia aquifer** underlies the Chesapeake aquifer with a clayey confining unit separating the two aquifers except in North Carolina where the unit is hydraulically connected to land surface (Trapp and Horn, 1997a) (fig. 3A and B). In North Carolina, this aquifer system is represented by limestones of the Castle Hayne formation, which produce large volumes of water. Further north, the aquifer is mostly glauconitic sand and, in some locations, is absent where the glauconitic sands grade into clayey sediments.

Although shown in figures 3A and B as separate aquifers, on a regional scale the Severn-Magothy and Potomac aquifers form the Potomac-Raritan-Magothy (PRM) aquifer system that extends from Long Island southward to Virginia. The **Severn-Magothy aquifer** underlies the Castle Hayne – Aquia aquifer from Long Island southward to the Delmarva Peninsula (Trapp and Horn, 1997a) (fig 3A and B). On Long Island, this aquifer system is represented by the Magothy aquifer, which subcrops beneath the surficial Upper Glacial aquifer. In New Jersey, Delaware, and Maryland, the Severn-Magothy is represented by the upper Potomac-Raritan-Magothy aquifer system, which outcrops or subcrops along the Fall Line; elsewhere it is confined. The **Peedee-upper Cape Fear aquifer**, which is the southern equivalent of the Severn-Magothy aquifer, is present from southeastern Virginia to the North Carolina – South Carolina border and is generally confined throughout its extent.

The **Potomac aquifer** is the lowermost and most widespread aquifer of the NACPAS and is separated from overlying aquifers everywhere by a confining unit (Trapp and Horn, 1997a) (fig. 3a and b). On Long Island, the Potomac is represented by the Lloyd aquifer. In New Jersey, Delaware, and Maryland, the Potomac is represented by the middle and lower Potomac-Raritan-Magothy aquifer system which outcrops or subcrops along the Fall Line. In North Carolina, the Potomac aquifer is relatively thin and is a less important source of drinking-water supplies.

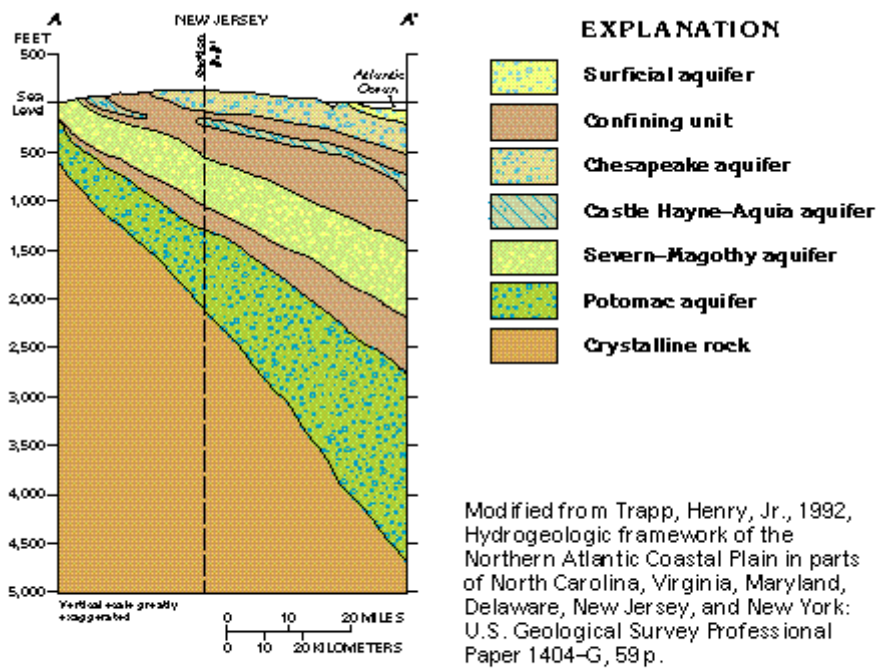


Figure 3A. West to east cross-section of the North Atlantic Coastal Plain Aquifer System in central New Jersey.

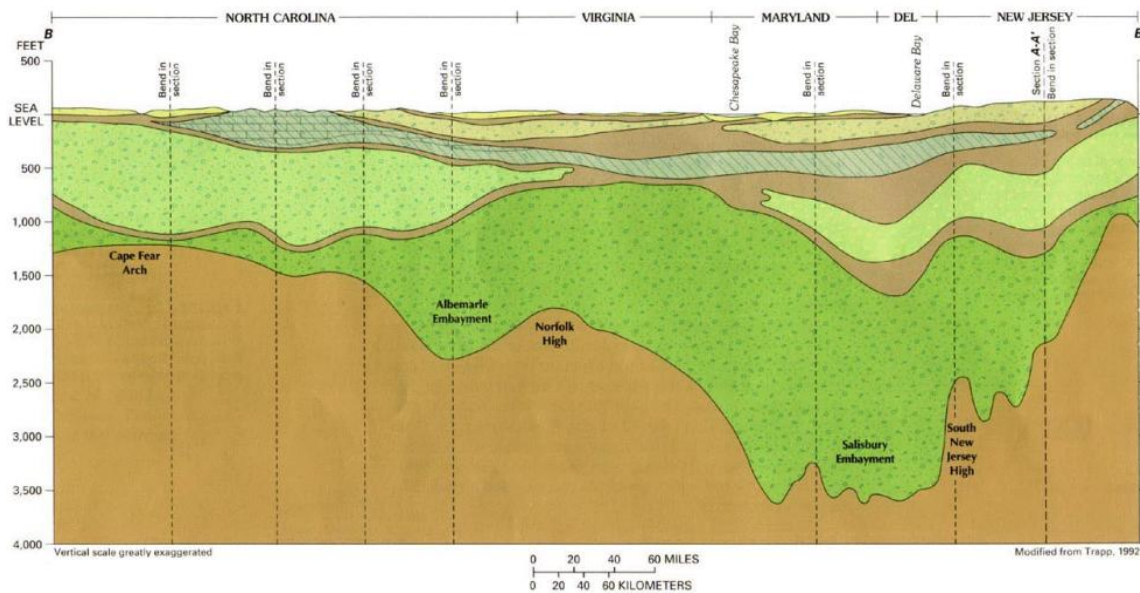


Figure 3B. South to north cross-section of the North Atlantic Coastal Plain Aquifer System (from Trapp and Horn, 1997a).

Surficial Hydrogeologic Framework

In addition to the framework of the primary aquifers of the NACPAS, a framework for the surficial hydrogeology of the NACP has been developed based on a regionally consistent map of the depositional history and texture of surficial sediments (Ator and others, 2000). The surficial hydrogeologic framework defines 7 distinct subregions (fig. 4) in which the natural physical factors that govern the occurrence and transport of contaminants to shallow ground water and streams are relatively consistent (Ator and others, 2000). The seven hydrogeologic subregions were delineated primarily from physiography and the bulk texture (average grain size) of surficial sediments. Because ground-water surveys of the NAWQA program have generally focused on unconfined aquifer systems that are susceptible to anthropogenic contamination, the surficial hydrogeologic framework is an important component for regional stratification purposes. The 7 surficial hydrogeologic regions are defined as follows:

1. *Coastal lowlands* – Low-relief platform of the Outer Coastal Plain and margins of the major estuaries. Area is very flat and low lying, with poorly developed stream drainage and numerous tidal wetlands and pocosins with perched water tables. Streams are low gradient and largely tidal. Sediments were deposited primarily in estuarine and near-shore marine environments during the Holocene and Pleistocene, and are primarily fine grained, except for linear ridges of sand associated with ancient shorelines. Soils of swamps and marshes contain abundant organic matter. Soil types reflect chronic poor drainage and poor oxidation.
2. *Middle Coastal Plain, mixed sediment texture* – Broad platform of the Middle Coastal Plain created by Pleistocene sea level high stands. Borders are typically scarps or other time-indicator elevation breaks, such as the Suffolk and Princess Anne Scarps and equivalent scarps in Delaware that were formed during sea level high stands during the Pleistocene. Land surface is moderately dissected by streams; local relief generally ranges from 25 to 30 feet. Sediments were deposited in near-shore marine and estuarine environments. Sediment texture varies laterally and vertically with changes in depositional systems from marine littoral to deltaic. Sediment grain sizes are mixed, and range from coarse sands associated with shorelines to clays and silts deposited in back-barrier lagoons and estuaries.
3. *Middle Coastal Plain, fine sediments* – Dissected inner portion of the Middle Coastal Plain with predominantly fine-grained sediments at land surface. Local relief ranges from 45 to 150 feet. This unit is associated with Pliocene and Miocene-age estuarine deposits of the Bacons Castle Formation and fine-grained Miocene-age marine sediments of the Chesapeake Group (primarily of the Calvert Formation).
4. *Middle Coastal Plain, sands with overlying gravels* – outcrop belt of marine inner-shelf sands of the inner Middle Coastal Plain, overlain by upper delta plains of fluvial sands and gravels in New Jersey and on the Delmarva Peninsula. Sediments are Pliocene and Miocene age and largely include units of the Chesapeake Group. The original broad flat upland surface has not been completely dissected by developing stream networks. Local relief is less than 100 feet. Greater incision occurs near major tributaries that cut across the Middle Coastal Plain.
5. *Inner Coastal Plain, upland sands and gravels* – Deeply dissected innermost Coastal Plain adjacent to Fall Line, including sand and gravel caps on adjacent Piedmont hills. Local relief ranges from 100 to 150 feet. Sediments, which range in age from Miocene to Pliocene, are dominated by coarse fluvial sands and gravels overlying marine sands or saprolite of crystalline rocks. Surficial units are completely incised and there is no connectivity between upland surfaces on adjacent interfluves.
6. *Inner Coastal Plain, dissected outcrop belt* – outcrop and subcrop belt of lower Tertiary and Cretaceous formations with 250 to 300 feet of relief. Locally, older units may be covered with younger sands and gravels, particularly in the northern Delmarva Peninsula. Tertiary and Cretaceous units are generally deeply weathered where exposed. Some units are leached and oxidized to depths of tens of feet. There is widely contrasting variability in the permeability and geochemistry of units. These contrasts affect aquifer recharge and water-quality characteristics. The landscape is deeply dissected and streams typically cut into underlying units.

7. Alluvial and Estuarine Valleys – Incised valleys of major rivers that cut across the Coastal Plain, commonly perpendicular to regional strike. Scarps along the river valleys are connected to regional coastal scarps. Sediments range in age from Pliocene to Holocene, most are Pleistocene. Coarse-grained alluvial sediments fill deeper parts of the valleys. Upper portion of sequence is typically composed of fine-grained, organic-rich sediments deposited in alluvial flood plains or estuarine environments. In larger rivers there is a rich suite of minerals where sediment originates in the Piedmont and Appalachian Physiographic Provinces. Valleys in North Carolina are broader with greater volumes of alluvial fill than are valleys to the north that drain to the Chesapeake and Delaware bays, which are more deeply incised. Weathering is dominated by physical processes to the north and chemical processes to the south.

A preliminary evaluation of the surficial hydrogeologic framework is provided by comparison to available regional ground-water-quality data (Ator and others, 2000). As predicted by the framework, concentrations of major ions and nutrients typically differ significantly between Subregions I and IV. For example, phosphorus and ammonia plus organic nitrogen concentrations are higher in Subregion I, while nitrate concentrations are higher in subregion 4. Water quality in Subregions II, VI, and VII is typically more variable and intermediate between those in Subregions I and VI. Limited data were available from Subregions III and V.

Major-ion and nutrient chemistry in samples collected from randomly selected first-order streams in each subregion during base-flow conditions in the late winter and spring of 2000 (Pitchford and others, 1998, Ator and others, 2000) provides further insight into variable chemical transport and transformation among the seven surficial hydrogeologic subregions. Dominant sources of major ions and nutrients to shallow ground water and small streams are apparently anthropogenic in each subregion, as might be expected considering the siliciclastic surficial and shallow-subsurface sediments typical of the NACP. Although concentrations of most major ions increase with increasing non-forested land use in all subregions, this effect is significantly greater in Subregion VI than in Subregions I, III, or VII. The topographic relief and predominantly well-weathered, permeable sediments typical of Subregion VI apparently facilitate the movement of soluble anthropogenic chemicals through ground water to streams. Conversely, Subregions I and VII are generally flat and poorly drained, and surficial sediments in Subregion III contain abundant silt and clay. Nutrient concentrations increase with increasing watershed agriculture throughout the NACP, although seasonal trends vary among some Subregions. Nutrients decrease in base flow from February through May in Subregions IV, VI, and VII. This seasonal pattern suggests typical slow, diffuse ground-water flow; the seasonal trend may be related to increasing biotic uptake through the spring and/or decreasing relative discharge from shallower ground water as the water table drops. Concentrations increase with time in Subregion I, however, suggesting that the abundant artificial ditching typical of the Coastal Lowlands effectively short-circuits ground-water flowpaths, and nutrients measured in stream base flow in 2000 were actually applied in that same year. Redox conditions in streams are also related to land use throughout the NACP, but only relate to soil drainage in the most hydrogeologically variable Subregions (II, VI, and VII). With improved soil drainage, base flow in first-order streams is

generally more oxic in Subregions II and VI, but more reducing in Subregion VII (S.W. Ator, USGS, written communication).

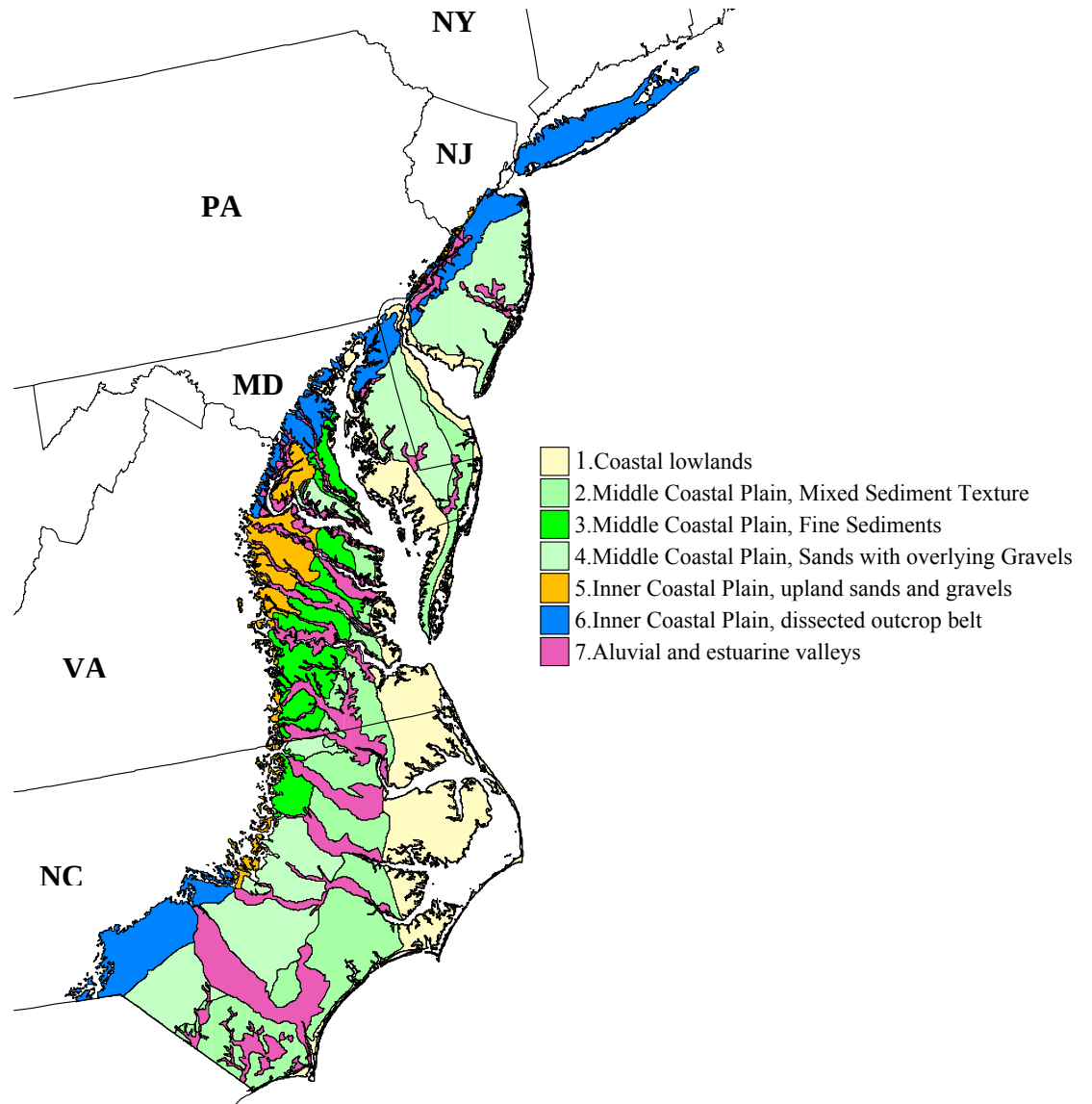


Figure 4. Surficial hydrogeologic framework for the North Atlantic Coastal Plain.

Population and Land Use

Land use in the NACP consists of intensely developed and populated urban centers, rural agricultural settings, and undeveloped areas. Because of the intensity and diversity of land use across the NACP, this area is ideal for investigating relations between shallow ground-water quality and natural and anthropogenic factors.

Although only about 8 percent of the NACP is urbanized, in 1995 over 55 million people lived throughout the NACP. The more heavily urbanized and populated parts of the NACP include Long Island, NY, southern New Jersey (in the vicinity of New York City), urban areas located along the Fall line (such as Philadelphia, PA., Wilmington, DE., Baltimore, MD., Washington, D.C., and Richmond, VA.), Virginia Beach, VA., and Fayetteville, NC (fig. 2). In addition to major metropolitan areas, about 28 percent of the NACP consists of agricultural land. These areas include much of the North Carolina Coastal Plain, the Delmarva Peninsula, and localized areas in southern New Jersey and eastern Long Island (fig. 2). The remainder of the NACP consists of rural and undeveloped lands including wetlands and forests (fig. 2).

Water-Use

Water-use data for the NACPAS is available from several sources, however, no one source 1) is up-to-date (compiled within the last 5 years), 2) distinguishes between purpose of withdrawal (domestic supply, public supply, industrial, etc.), 3) identifies the aquifer from which withdrawals occurred, and 4) provides locational information (lat/long of withdrawal, county from which withdrawal occurred, etc.). The lack of a single source of information compromises the task of assessing water use across the entire NACP in a consistent manner. Nonetheless, water-use data that is available provides insight into the distribution and type of withdrawals that occur in the NACP.

In 1995, over 1,900 Mgal/d of freshwater was withdrawn from the NACPAS for public and domestic supplies (J. Denis and others, USGS, written comm., 2001). Many of the large urban areas located along the Fall Line, (such as Philadelphia, PA., Wilmington, DE., Baltimore, MD., Washington, D.C., and Richmond, VA.), are primarily reliant on surface-water sources in the Piedmont Physiographic province because the NACPAS is thinly saturated near the Fall Line. Also, New York City, which includes Kings and Queens Counties on Long Island, obtains almost all of its drinking-water supplies from reservoirs located in upstate New York. Substantial withdrawals of surface water for public supply in the NACP occur primarily in the vicinity of Virginia Beach, VA., where ground-water pumping has caused movement of salt water into

freshwater aquifers and in Monmouth County in southern New Jersey where surface water is used to supplement ground-water supplies to meet large water-use demands (fig. 5).

East of the Fall Line, ground water sources become increasingly important for both domestic and public supply (fig. 5). However, the relative importance of the primary aquifers as a source of drinking-water supplies differs considerably across the NACP (fig. 6). In 1995, about 8 million people in the NACP relied on public supply obtained from ground-water sources for potable water (J. Denis and others, USGS, written comm., 2001). About 700 Mgal/d are withdrawn to meet this demand. Large volumes of water are obtained from confined aquifers including the Potomac, Peedee-Upper Cape Fear, Severn-Magothy, and Castle Hayne-Aquia (Trapp and Horn, 1997a). Aquifers that are under semi-confined or unconfined conditions, however, are also heavily used for public supply. For instance, nearly 3 million people are reliant on the sole-source aquifer system on Long Island, which is hydraulically connected to land surface (fig. 6). Over 260 Mgal/d are withdrawn from the Severn-Magothy aquifer on Long Island making this the single largest withdrawal for drinking-water supplies across the entire NACP (fig. 6). Large volumes of water are also withdrawn from surficial aquifer systems in southern New Jersey and on the Delmarva Peninsula to meet growing water demands and a large amount of water withdrawn from confined aquifers of the Severn-Magothy aquifer system in New Jersey, Delaware, and Maryland is derived from areas where these aquifers outcrop or subcrop beneath unconfined aquifers (fig. 6).

In 1995, over 2.5 million people in the NACP relied on domestic wells for drinking-water supplies. Domestic supply is an important source of drinking water throughout the NACP including some of the more heavily populated areas such as southern New Jersey and Suffolk County, Long Island, New York (fig 5). Domestic supply in the NACP is typically derived from surficial, unconfined aquifers, which yield the volumes of water necessary to meet household needs (Trapp and Horn, 1997).

The three aquifer systems that provide the largest volumes of water for public and domestic supply in the NACP are the Severn-Magothy (about 450 Mgal/d), the Potomac (about 240 Mgal/d), and the Chesapeake (about 140 Mgal/d) (Ground-water Atlas 730-L & 730-M).

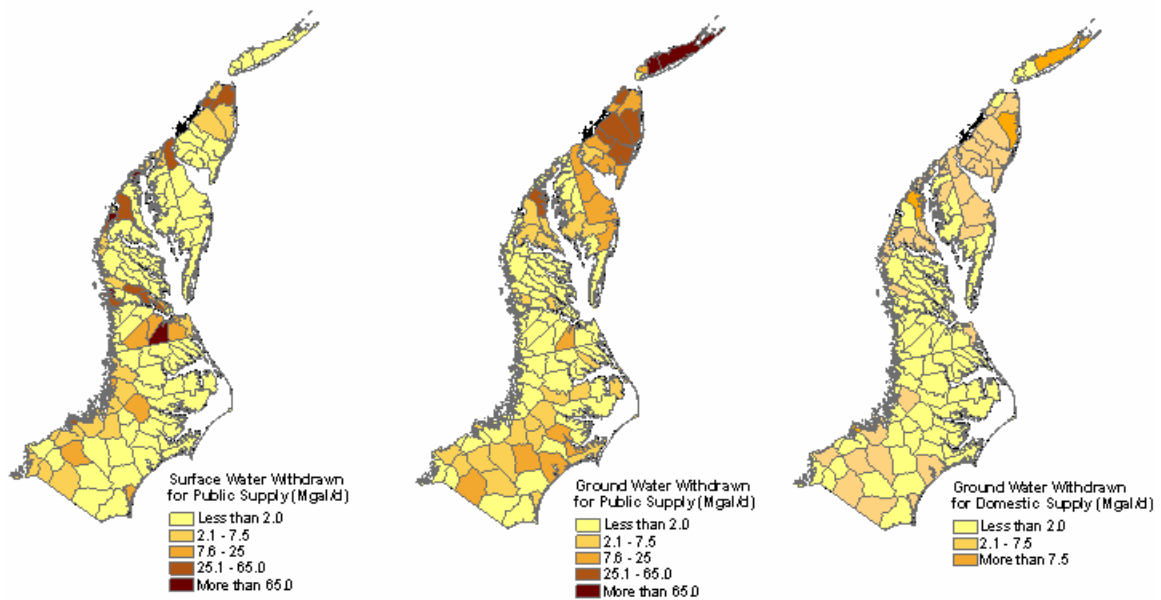


Figure 5. Distribution of ground-water withdrawals from the North Atlantic Coastal Plain, 1995. (data from J. Denis and others, USGS, written comm..)

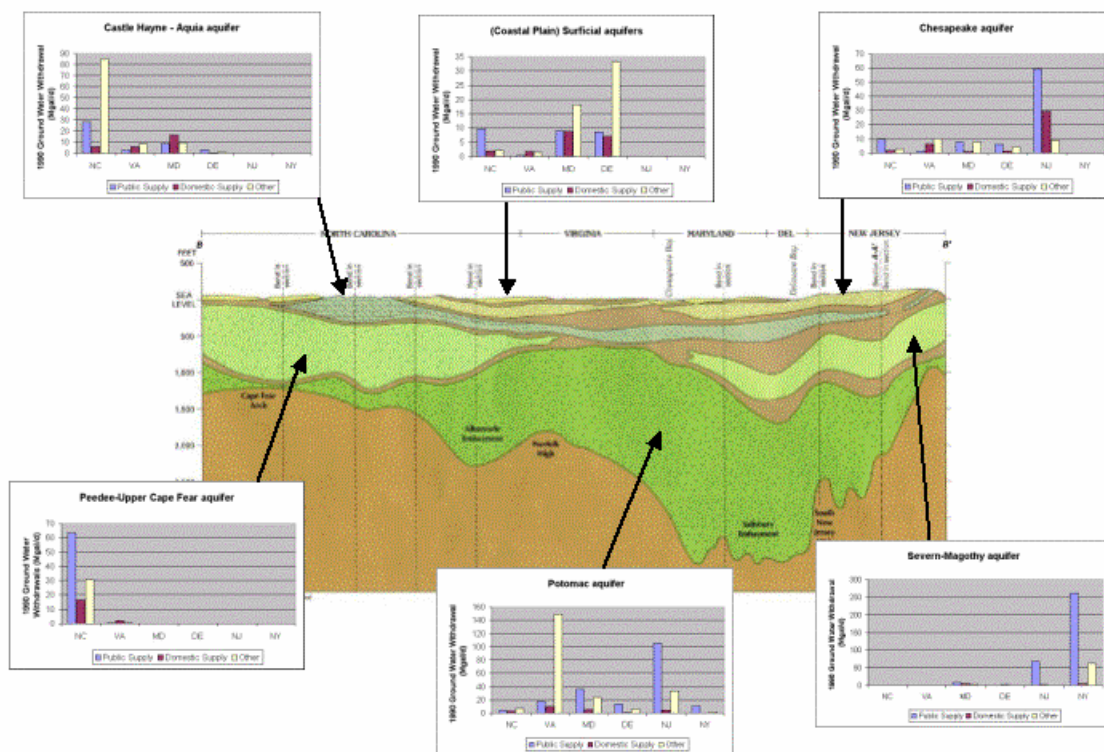


Figure 6. Amount of water withdrawn in 1990 from the primary aquifers of the North Atlantic Coastal Plain Aquifer System by use and by State. (data from M. Horn, USGS)

Water-Quality Issues

Because the NACPAS is used extensively as a source of potable water supplies, and, in some areas, is a sole-source, the chemical quality of ground water is a major concern for those who use the water and for water managers and health officials responsible for ensuring a safe drinking-water supply. Contamination in the NACPAS was documented as early as the 1940s when fertilizers and detergent compounds were detected in samples of shallow ground water underlying the heavily developed areas of Long Island (Flynn and others, 1958; Perlmutter and Koch, 1964). VOCs and pesticides were detected in samples of ground water from Long Island and New Jersey in the early to mid 1970s as analytical methods to detect these compounds were developed (Koppleman, 1978). Since this time, numerous water-quality investigations have documented the occurrence of nutrients, VOCs, pesticides, and trace elements in ground-water samples from the NACPAS. Although it is beyond the scope of this workplan to provide a thorough review of the numerous water-quality investigations that have been undertaken in the NACP, a review of the most prominent water-quality issues based on results from more recent water-quality investigations is provided below. These more recent water-quality investigations have focused on 1) assessing the vulnerability of aquifers in the NACP to contaminants introduced at or near land surface, 2) improving the understanding of contaminant sources and the fate and transport of contaminants as they migrate throughout an aquifer system, and 3) identifying and assessing newly emerging water-quality issues.

Water-quality studies conducted in the 1980s and 1990s indicate that the concentration of nitrate in samples of shallow ground water underlying agricultural areas across much of the NACP and agricultural and urban areas on Long Island frequently exceed drinking-water guidelines (Ayers and others, 2000; Shedlock and others, 1999; Spruill and others, 1998; Eckhardt and Stackelberg, 1995). Pesticide compounds are frequently detected in shallow ground water underlying agricultural and urban areas, and VOCs in shallow ground water underlying urban areas, throughout much of the NACP (Ayers and others, 2000; Shedlock and others, 1999; Spruill and others, 1998). Concentrations of pesticides and VOCs in shallow ground water are generally low; however, and rarely exceed drinking-water guidelines. Nonetheless, elevated nitrate concentrations and the frequent detection of pesticides and VOCs in water samples from unconfined aquifers throughout much of the NACP indicate that these aquifers are vulnerable to chemicals used in agricultural and urban areas. The use of (1) pesticides, nitrogen-based fertilizers, and manure to support crop production, 2) septic systems for disposal of domestic wastewaters, and 3) common products such as fuels and solvents that contain VOCs, combined with the presence of well-drained and well-aerated soils across much of the NACP, favor the formation of nitrate and the movement of nitrate and organic contaminants such as pesticides and VOCs to ground water.

Although human activities associated with agricultural and urban land uses are the principle sources of contaminants in ground water, factors other than land use can affect ground-water quality. These factors include hydrogeologic conditions, chemical degradation, naturally-occurring contaminants, and the time period when ground water recharge occurred. For example, in agricultural areas of the outer Coastal Plain (surficial hydrogeologic region I), nitrate concentrations in shallow ground water are significantly lower than in similar settings of the middle and inner Coastal Plain. Low nitrate concentrations in shallow ground water of the outer Coastal Plain are due to denitrification and nitrate-reduction processes resulting from the large amounts of organic carbon in these poorly drained soils and sediments (Spruill and others, 1998; Ator and others, 2000). Additionally, some extensively used pesticides are not detected in ground water because they degrade readily or are not mobile (Ayers and others, 2000). Some constituents, such as radium and phosphorous, were detected in ground water where surficial sediments or aquifer materials are known to contain these elements (Ayers and others, 2000; Spruill and others, 1998). Finally, samples of water from confined aquifer systems generally are not affected by agricultural and urban activities at land surface because most water in these confined aquifer systems predates urban and agricultural activities (Shedlock and others, 1999).

Several water-quality issues of emerging concern in the NACPAS have only recently been identified including the occurrence of pesticide metabolites, select radionuclides, and organic contaminants associated with wastewater effluent. The occurrence of pesticides in ground water underlying agricultural and urban settings across the NACP is well documented, however, the occurrence of metabolite compounds has only recently been identified as an important water-quality concern. When analyzed for, metabolites of heavily used pesticides such as metolachlor, alachlor, and atrazine are commonly found at concentrations an order of magnitude or more than the parent compounds (Kalkhoff and others, 1998; Ferrari, 2001); thus, to fully assess the fate of pesticides and their influence on drinking-water resources pesticide metabolites must also be considered.

Recent National and Statewide reconnaissance surveys of selected radionuclides in public ground-water supplies (Focazio and others, 2001; Szabo and others, 2002) indicate that concentrations of Ra-224 are significantly elevated in water from parts of the Coastal Plain aquifer systems. Preliminary interpretations indicate that the combination of aquifer characteristics (permeable, coarse grained, quartzose), geochemistry (acidic), and land use (agricultural with nitrogen bearing leachate that increases acidification) affects the concentration of radium isotopes such as Ra-224 in unconfined Coastal Plain aquifers in New Jersey (Szabo and others, 2002). To fully assess the chemical quality of ground-water drinking supplies in the NACP, the occurrence, concentration, and source of these naturally occurring radionuclides must also be assessed.

Organic compounds that are likely derived from domestic, industrial, and (or) agricultural wastewaters including antibiotics and other prescription drugs, nonprescription drugs, fragrances, flame-retardants, plasticizers, plant and animal steroids, detergent metabolites, byproducts of oil use and combustion, and other extensively used chemicals have recently been found to occur extensively in surface- and ground-water resources and drinking-water supplies (Kolpin and others, 2002; Buser and others, 1998a, 1998b, and 1999; Herberer and Stan, 1997; Halling-Sorensen and others, 1998). These compounds form an important, yet previously under-evaluated, class of contaminants that should be considered when fully assessing the chemical quality of drinking-water supplies.

Regional Stratification

Regional stratification consists of consideration of 3 primary factors: (1) the geographic extent of each primary aquifer, (2) anthropogenic susceptibility which is the set of natural factors that govern the likelihood that anthropogenic contaminants will leach to the ground-water system, and (3) vulnerability which refers to the degree to which sources of contamination are present in the recharge area of a susceptible system. Susceptible systems in which no sources of contamination exist would be assigned low vulnerability, whereas, susceptible systems that have sources of contamination in their recharge areas would be considered vulnerable to contamination.

The first step in regional stratification is to determine the geographic extent of where each primary aquifer is hydraulically connected to land surface (unconfined vs. confined) (fig. 7). In those areas where an aquifer is confined, the system is considered less susceptible to contaminants introduced by anthropogenic activities than in those areas where the aquifer is unconfined. If these confined systems were not assessed in cycle I then they are candidates for new status studies (MASSs), but will generally be of lower priority than unconfined systems. If these confined systems were assessed in cycle I they would be candidates for trends assessments (fig 7).

The second step in regional stratification involves determining the relative degree of susceptibility for systems that are more susceptible (unconfined) to anthropogenic contamination (fig. 7) as defined by overlaying the surficial hydrogeologic framework. Surficial hydrogeologic subregions define areas in which the natural physical factors that govern the transport of contaminants to shallow ground water are relatively consistent (table 1). The 7 hydrogeologic subregions represent areas of similar geology and form a continuum of natural physical factors (Ator and others, 2000). In a general sense, Subregions I and IV represent end members of this continuum. Subregion I consists of flat lying, poorly drained soils that are low in DO and rich in organic matter content. These conditions generally result in low nitrate concentrations and are not conducive to the transport of pesticides and other organic compounds. Subregion IV consists of

well-drained sands and gravels that are well oxygenated and low in organic matter content. These conditions favor the formation of nitrate and the movement of nitrate and pesticides and other organic compounds from land surface to shallow ground water. For the purpose of this stratification, subregions V and VI are grouped with subregion IV because of the sandy, well-weathered nature of the surficial sediments. Subregions II, III, and VII exhibit mixed surficial sediment characteristics and are also grouped together.

The third step in regional stratification is to determine aquifer vulnerability (fig. 7). Where each aquifer system is unconfined the distribution of land use within each surficial hydrogeologic subregion is determined. Land use is a surrogate variable representing the type and amount of contaminant applied at land surface. Numerous investigations in the NACPAS have documented that contaminant occurrence and distribution is significantly related to land-use setting (Ayers and others, 2000; Shedlock and others, 1999; Spruill and others, 1998.). Where agricultural or urban land is not present the shallow ground water system is identified as susceptible but less vulnerable (fig 7). If these systems were not assessed in cycle I then they are candidates for new status studies (MASs) but would be of lower priority than more vulnerable systems (fig. 7). If these systems were assessed in cycle I then they are candidates for trends assessment (fig. 7). Where agricultural or urban land is present the shallow ground-water system is identified as susceptible and vulnerable to anthropogenic contamination due to the presence of contaminant sources in the aquifers recharge area. If these systems were not assessed in cycle I then they are high priorities for new status studies (MASs or LUSs) (fig. 7). If these systems were assessed in cycle I then they are candidates for trends assessment (fig. 7).

The NACPAS was stratified based on the hydrogeologic framework, surficial hydrogeologic subregions, and distribution of land use. Results of this stratification are shown in figure 8. For the purpose of stratification, the Cretaceous Severn – Magothy and Potomac aquifers are combined (fig. 8). These aquifers are further subdivided to distinguish between where they are mantled with sediments of glacial origin (on Long Island), where they outcrop and subcrop along the Fall Line from New Jersey to Virginia, and where they are generally confined (fig. 8).

Table 1. Surficial hydrogeologic framework hypotheses for chemical transport.

Surficial hydrogeologic region	Conditions Affecting Ground-Water and Surface-Water	Hypothesized Speciation and Concentration of Nitrogen	Hypothesized Potential for Pesticide Mobility
I	Predominantly reducing conditions in poorly drained, organic sediments; oxidizing conditions in sandy beach ridges. Organic matter affects water chemistry. High water table limits infiltration. Runoff potential is low, except to unbuffered drainage ditches in fields.	Ammonia and organic nitrogen dominant in poorly drained organic sediments; nitrates present in water from predominantly sandy sediments. Water will generally contain relatively low nitrate and relatively high ammonia and organic nitrogen concentrations. Nitrogen may be present from natural and anthropogenic sources.	High potential for pesticides to be bound by fine-grained sediments and organic matter in soils of poorly drained areas. There may be some transport of pesticides through sandy surficial sediments into ground and surface waters in areas where pesticides are applied. Pesticides may runoff into drainage ditches.
II	Wide range of chemical environments associated with variations in sediments from coarse sands to clays, silts, and organic matter. This area has a variable depth to the water table and variable potential for infiltration.	Occurrence and concentrations of nitrogen species will vary widely in association with variations in sediment-type distribution, land use, and oxidation-reduction conditions.	Occurrence and concentrations of pesticides will vary widely in association with variations in sediment-type and land use distribution.
III	Fine-textured surficial sediments will promote over land runoff and limit infiltration. The presence of an unconfined aquifer will be limited. Most ground water will be confined and under reducing conditions.	Concentrations of nitrogen species in shallow ground water will be very low because of confined conditions. Nitrogen species could be present and transported to surface water in runoff; concentrations will depend on land use.	The potential for pesticides to infiltrate into ground water is low because of confined conditions. Pesticides may be transported to surface water in overland runoff from areas where they are applied.
IV	Sandy surficial sediments promote oxidizing conditions and infiltration of water into the surficial aquifer. Overland runoff is limited, but possible, in areas with higher slope. Stream channels are generally sandy, but can contain significant organic matter.	Nitrate dominates nitrogen speciation. Concentrations vary with land use and can be quite high in ground water and surface water of areas with nitrogen application because of the predominance of sandy sediments. Nitrate concentrations in surface water may be affected by denitrification in stream channels with organic sediments.	The potential for pesticides to be transported into ground water is relatively high. Pesticide transport will be affected by variability in land use and soil characteristics. The presence of organic matter in stream beds may limit transport from ground water to surface water in some areas.
V	Sandy surficial sediments promote oxidizing conditions and infiltration of water into the surficial aquifer. Runoff potential is high in areas with steep slopes. Stream incision extends into confining beds and confined aquifers where reducing conditions affect water chemistry.	Nitrate dominates nitrogen speciation. Concentrations will vary with land use. Nitrate concentrations in surface water may be affected by denitrification in areas where streams incise into aquifers and confining beds under reducing conditions. Nitrogen in surface water will be mostly associated with runoff.	The potential for pesticides to be transported into ground water is relatively high. Pesticide transport will be affected by variability in land use, and soil characteristics. Most pesticide occurrence in surface water will be associated with runoff because of stream incision into confined aquifers and confining beds.
VI	Water chemistry is affected by variability in the permeability and lithology of different geologic units that subcrop and outcrop in this area. Oxidizing conditions occur in surface and near surface sand units and in the highly weathered soils. Reducing conditions occur where aquifers are confined and in confining beds.	Nitrate dominates nitrogen speciation in sediments under oxidizing conditions. Concentrations will vary with land use. Nitrate will be denitrified to form nitrogen gas under confined conditions. Runoff will be an important nitrogen transport mechanism in areas with limited infiltration and high slope.	The potential for pesticides to be transported into ground water is moderate in areas with sandy surficial sediments because of loamy soils. Pesticide transport will be affected by variability in land use. Most pesticide occurrence in surface water will be associated with runoff because of stream incision into confined aquifers and confining beds.
VII	The predominantly fine-grained nature, relatively high organic-matter content of shallow sediments, and shallow water table may result in reducing conditions in shallow ground water. Areas with sandy surficial sediments may have oxidizing conditions. Topography is locally relatively flat, promoting infiltration and reducing runoff.	Transport, speciation, and concentrations of nitrogen will depend on local conditions and be variable. In flat areas with fine-grained near-surface sediments, ammonia and organic nitrogen could be the dominant nitrogen species. Overland transport of nitrogen should be limited because of locally flat topography.	The presence of fine-grained sediments, organic matter and shallow water table on valley terraces will limit pesticide mobility. In areas with sandy surficial sediments, pesticides may be present in ground water. Overland transport to surface water will be limited by flat topography.

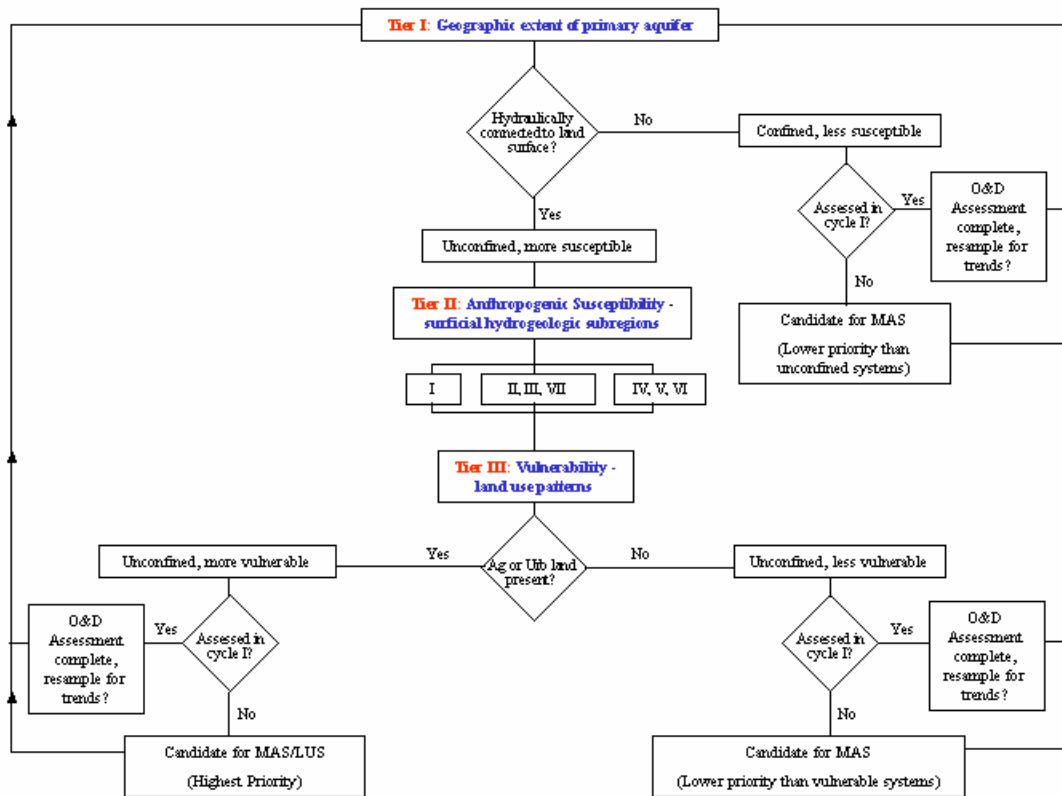


Figure 7. Flow diagram illustrating the stratification and prioritization process.

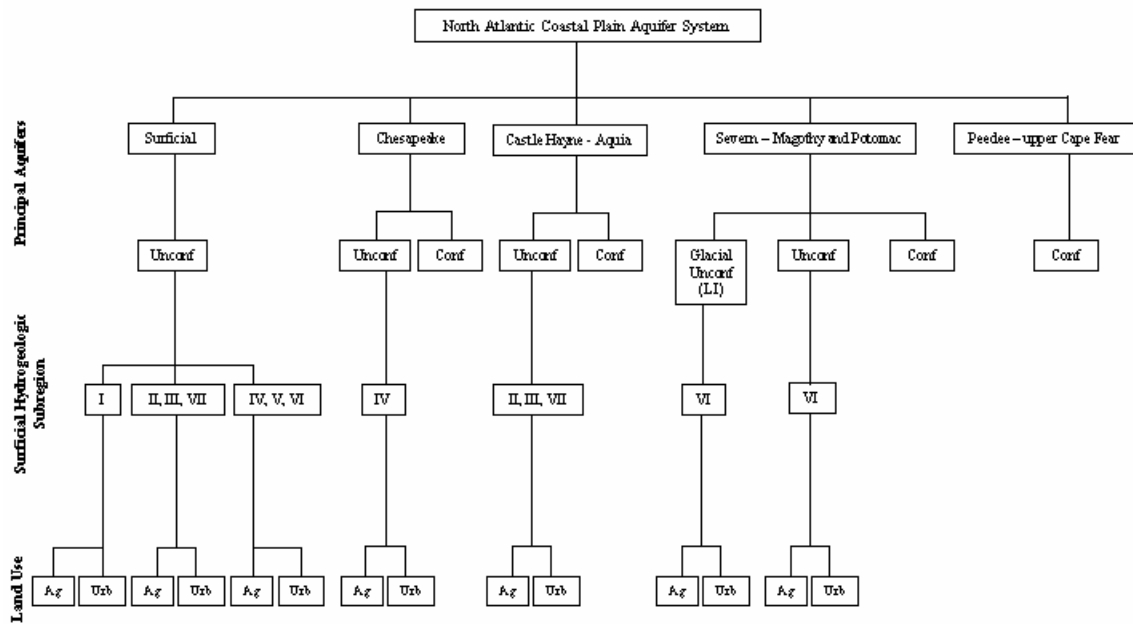


Figure 8. Regional stratification of the North Atlantic Coastal Plain Aquifer System.

Pilot and Cycle I NACPAS NAWQA Studies

Studies conducted in the NACP during cycle I are described in table 2, illustrated on figures 9 and 10 and summarized in table 3. MASs, LUSs, and FPSs were conducted in the Surficial and Chesapeake aquifers reflecting the need to provide a broad baseline assessment of water-quality conditions in these important drinking-water sources and the need to assess agricultural and urban lands as potential nonpoint sources for select contaminants (fig. 10; table 3). In the ALBE, where alternative supplies do not exist, the Surficial aquifer provides a critical source for domestic supply. On the Delmarva Peninsula, the Surficial aquifer is an important source for domestic and public supply (fig. 6). Furthermore, in both the ALBE and DLMV, the Surficial aquifer provides baseflow to local streams where the chemical quality of stream water is of the utmost importance due to water-quality concerns associated with Pamlico Sound and Chesapeake Bay. The Chesapeake aquifer in southern New Jersey is increasingly used to meet growing demands for domestic and public supply. Two surveys of water-quality conditions in water from public supply wells were conducted during cycle I – one in the Surficial aquifer (dlmvspcg10) and one in the Chesapeake aquifer system (linjfpsot03) (table 2; fig.10).

Examination of figures 9 and 10 and table 3 indicates geographical areas that were (and were not) assessed during pilot and cycle I activities. Primary geographical areas not fully assessed during pilot and cycle I include 1) Long Island, New York where sediments of glacial origin mantle the Severn – Magothy aquifer system, 2) the outcrop belt of the Severn-Magothy and Potomac aquifer systems which runs parallel to the Fall Line from New Jersey southward into Virginia, 3) eastern Maryland and Virginia (excluding the Delmarva peninsula), and 4) southeastern North Carolina.

Three primary aquifers that have hydraulic connection to land surface were not fully assessed during pilot and cycle I activities - the Castle Hayne, Severn-Magothy, and Potomac aquifers (fig. 10; table 3). Each of these aquifers provides locally important sources for public and (or) domestic supply (fig. 6) and represent gaps in cycle I assessments of water-quality conditions across the NACPAS. The Peedee – upper Cape Fear was also not fully assessed in cycle I, however, it is generally confined throughout its extent and is considered to be less susceptible to anthropogenic contamination than the other primary aquifer systems and, thus, of lower priority for assessment in the NAWQA program.

Table 2. Completed or planned cycle I and II studies in the NACP. [SM & P: Severn - Magothy and Potomac aquifers]

SUID	Netcode	Aquifer Sampled	Number of Sites	Cycle	Description
albe	sus1	Surficial	11	I	MAS in Surficial aquifer, Inner Coastal Plain
albe	sus2	Surficial	16	I	MAS in Surficial aquifer, Outer Coastal Plain
albe	sus7	Castle Hayne	30	II	MAS in Castle Hayne aquifer, Coastal Plain
albe	lusag1	Surficial	26	I & II	cycle I Ag LUS (corn, soybean) in Inner and Outer Coastal Plain resampled for trends in cycle II
albe	lusag2	Surficial	15	I	Cycle I Ag LUS (corn, soybean) of domestic wells in Inner and Outer Coastal Plain
albe	lusur1	Surficial	15	I	Urban LUS in VA Beach area
albe	fpsag1	Surficial	22	I & II	Agricultural FPS in surficial aquifer resampled for trends in cycle II
dilmv	sus1	Surficial	29	I & II	Cycle I MAS, deeper wells, sampled during Delmarva Pilot, resampled under Cycle II during Cycle I for trends
dilmv	sus	Mixed	36	I	Cycle I MAS in unconfined and confined portions of 10 aquifers in Chesapeake and Severn-Magothy systems
dilmv	luscr1	Surficial	30	I & II	Pilot Ag LUS, shallow wells, sampled during Delmarva Pilot, resampled under Cycle II during Cycle I for trends. Well locations coordinated with dlmvsus1
dilmv	fpsag1	Surficial	13	I	Cycle I Ag FPS, Locust Grove, wooded buffer, Coastal Plain
dilmv	fpsag2	Surficial	22	I	Cycle I Ag FPS, Fairmount, some wooded buffer, Coastal Plain
dilmv	fpsag3	Surficial	9	I	Cycle I Ag FPS, Willards, poorly-drained, ditched, Coastal Plain
dilmv	fpsag4	Surficial	10	I	Cycle I Ag FPS, Townsend, Coastal Plain
dilmv	spcg10	Surficial	30	I	Cycle I MAS of public-supply wells in Delaware in unconfined aquifer (SWAP)
podl	sus2	SM & P	30	II	Cycle II MAS in Severn – Magothy and Potomac aquifers for new status
delr	lusur	SM & P	30	II	Cycle II urban LUS in vicinity of Camden, NJ where Severn – Magothy and Potomac aquifers outcrop and subcrop for new status
linj	sus2	Chesapeake	30	I & II	Cycle I MAS in Chesapeake aquifer system resampled in cycle II for trends
linj	lusrc1	Chesapeake	30	I & II	Cycle I new urban LUS in Chesapeake aquifer resampled in cycle II for trends
linj	lusur1	Chesapeake	20	I	Cycle I old urban LUS in Chesapeake aquifer
linj	luscr1	Chesapeake	15	I	Cycle I Ag LUS in Chesapeake aquifer
linj	lusfo1	Chesapeake	13	I	Cycle I Forested LUS in Chesapeake aquifer
linj	lusot2	Chesapeake	30	I	Cycle I urban FPS in Chesapeake aquifer – 30 deeper monitoring wells co-located with lusrc1
linj	lusot3	Chesapeake	30	I	Cycle I urban FPS in Chesapeake aquifer – 30 public-supply wells
linj	lusur	Surficial (glacial)	30	II	Cycle II urban LUS in glacial sediments that mantle Severn – Magothy aquifer on Long Island

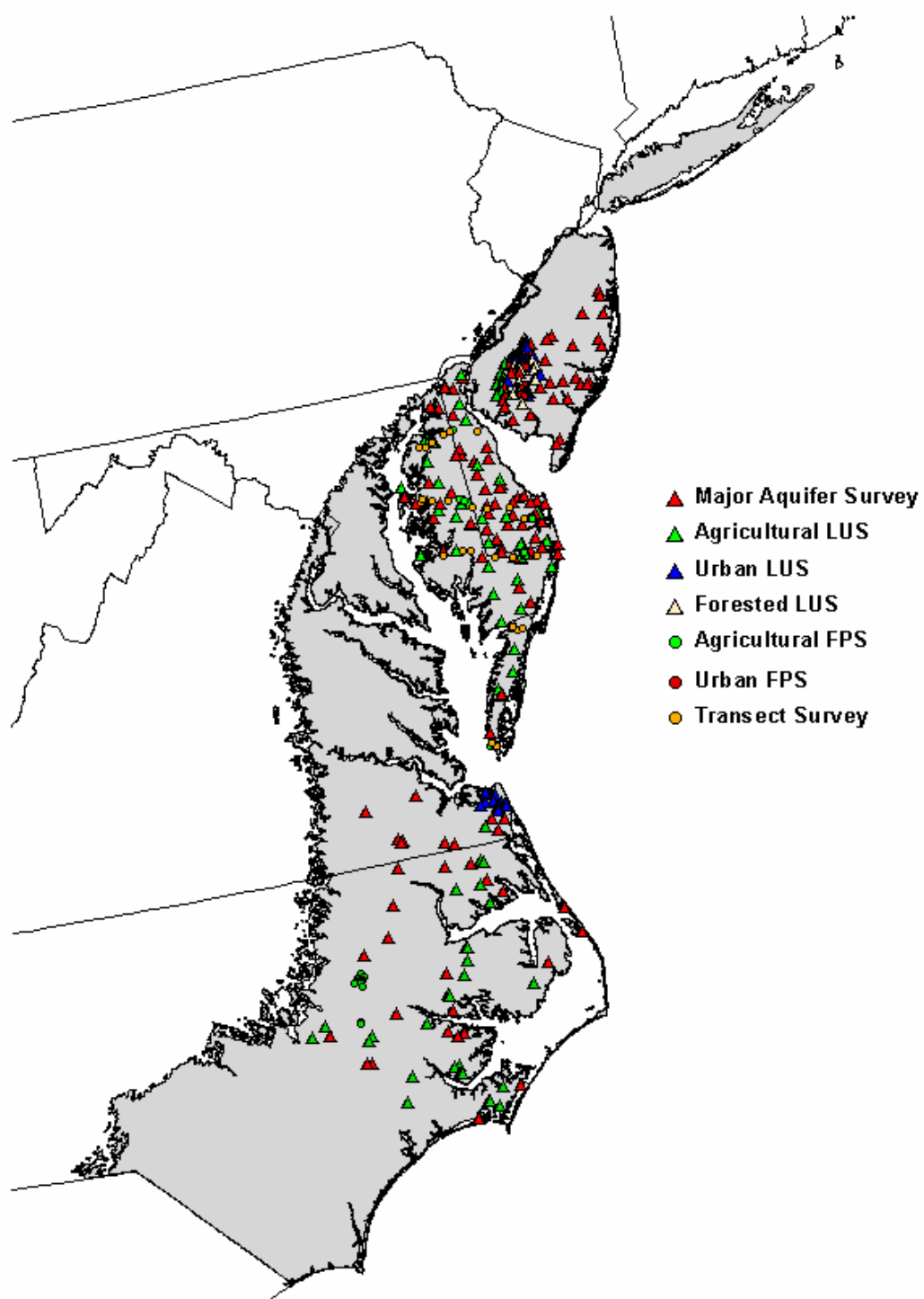


Figure 9. Location of wells sampled in the NACP during pilot and cycle I activities.

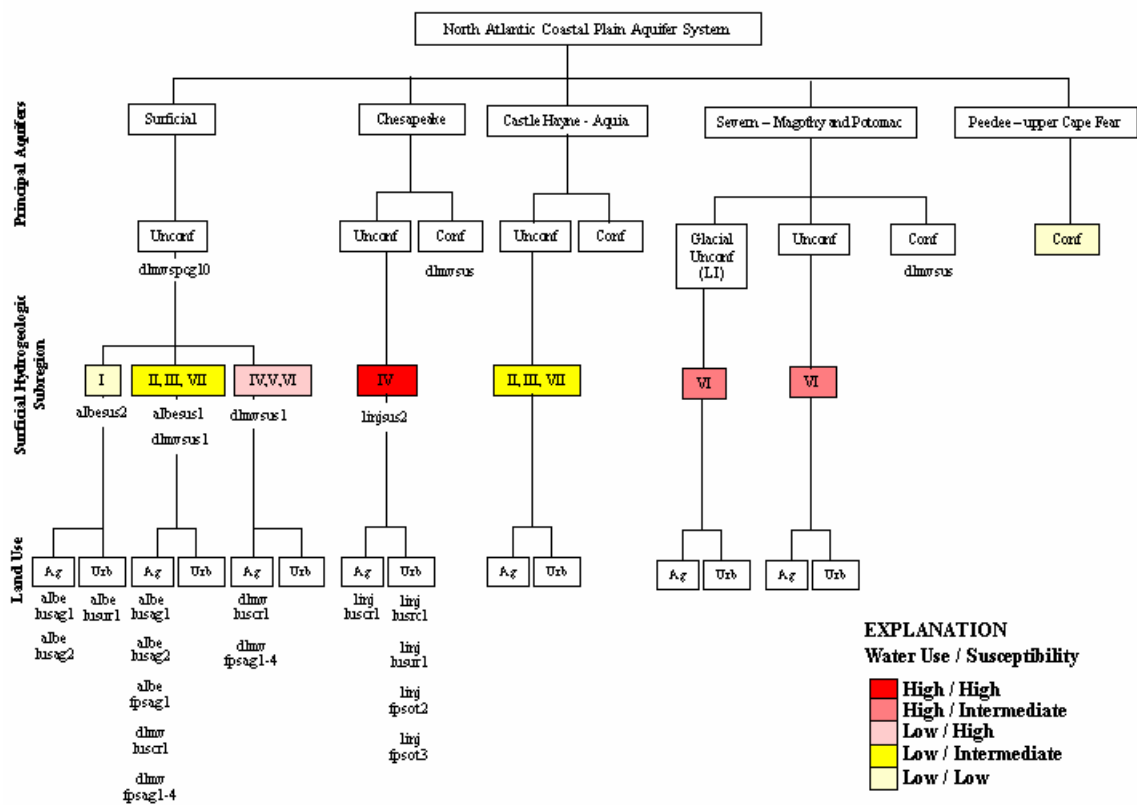


Figure 10. Regional stratification overlain with cycle I accomplishments. The stratification is color coded to identify those strata with highest drinking-water use and that are most susceptible to contamination from anthropogenic sources.

Planned Cycle II NACPAS NAWQA Studies

Studies planned in the NACP during cycle II are described on table 2, illustrated on figures 11 and 12, and summarized in table 3. This section describes these studies by primary aquifer in the NACPAS. More detailed descriptions of select ground water studies discussed in this section are provided in appendix 1.

Surficial aquifer

New status surveys are not planned for the Surficial aquifer in cycle II because this aquifer system was adequately assessed in cycle I (table 3; fig. 10). Several networks, however, will be resampled for trends in cycle II including a MAS and agricultural LUSs and FPSs in ALBE and DLMV (table 3; fig. 11). An ACT study is being conducted by the PODL study unit and currently is the only topical study that has been identified for the NACPAS for cycle II (table 3).

Chesapeake aquifer

New status surveys are not planned for the Surficial aquifer in cycle II because this aquifer system was adequately assessed in cycle I (table 3; fig. 10). Several networks, however, will be resampled for trends in cycle II including a MAS and an urban LUS (table 3; fig. 11).

Castle Hayne aquifer

The Castle Hayne aquifer was not assessed during cycle I, thus, a new MAS (albesus7) is scheduled for cycle II that will address a major gap identified in cycle I assessments (table 3; fig. 11). This new MAS will also be incorporated into the trends network upon completion (table 3).

Severn – Magothy and Potomac aquifers

The Severn – Magothy and Potomac aquifers were not assessed during cycle I. During cycle II, a new MAS is planned for the outcrop belt as it extends along the Fall Line from New Jersey to Virginia (podlsus2) addressing a major gap identified from cycle I assessments (table 3; fig. 10). In addition, two urban LUSs are planned – one in the glacial sediments that overlie the Severn – Magothy on Long Island (linjlusur) and one in the outcrop belt in the vicinity of Camden, New Jersey (delrlusur) (table 3). The new urban LUS on Long Island will also be incorporated into the trends network (table 3).

Peedee – upper Cape Fear aquifer

The Peedee – upper Cape Fear aquifer was not assessed during cycle I, however, because it is generally confined throughout its extent it is considered to be less susceptible to anthropogenic

contamination than the other primary aquifer systems and, thus, of lower priority for assessment in the NAWQA program. There are no plans to assess the Peedee – upper Cape Fear aquifer during cycle II (table 3).

Table 3. Pilot and cycle I accomplishments, cycle II plans, and NACPAS planning team recommendations. [Recommendations in bold type. Cycle II studies numbered by priority in each category. New Status networks that are to be incorporated into Trends network are not prioritized in Trends category]

Aquifer System	Pilot and Cycle I			Cycle II								
	Occurrence and Distribution			New Status			Trends				TANC	ACT
	MAS	LUS	FPS	NMAS	NLUS	SWA	RMAS	RLUS	RFPS	RSWA		
Surficial	albesus1 albesus2 dlmvsus1	albelusur1 albelusag1 albelusag2 dlmvluser1	albefpsag1 dlmvfpsag1 dlmvfpsag2 dlmvfpsag3 dlmvfpsag4 podldwgs1		3. linjlusag [@]		1. dlmvsus1	1. albelusag1 2. dlmvluser1	1. albefpsag1	2. dlmvspcg10 [*]		1. podl
Chesapeake	linjsus2 dlmvsus	linjlusrc1 linjlusur1 linjluser1 linjlusfo1	linjfpsot2 linjfpsot3				2. linjsus2	3. linjlusrc1		1. linjfpsot3 ^{**}		
Castle Hayne				1. albesus ⁷		3. albe [#]	albesus7				3. albe ^{!!}	
Severn – Magothy (glaciated on LI)				2. linjsus [!]	1. linjlusur	1. linj ^{\$}		linjlusur			1. linj ^{!!!}	
Severn – Magothy and Potomac	dlmvsus			3. podlsus2	2. delrlusur	2. delr [^]		delrlusur ^{&}			2. delr ^{!!!!}	
Peedee – upper Cape Fear												

[!] conduct new MAS on Long Island in coordination with new urban LUS, SWA, and TANC studies.

[@] new LUS of agricultural setting in eastern Long Island.

[#] conduct SWA study in Castle Hayne aquifer system if water-quality results from albesus7 warrant.

^{\$} conduct SWA study on Long Island in coordination with NMAS, new urban LUS, and TANC studies.

[^] conduct SWA study in vicinity of Camden, New Jersey in coordination with NMAS, NLUS, and TANC studies.

[&] include delrlusur in trends network to provide some representation for Severn – Magothy and Potomac aquifer system.

^{*} resample podldwgs1 as a SWA trend network.

^{**} resample linjfpsot3 as a SWA trend network.

^{!!} conduct TANC study in Castle Hayne aquifer system if water-quality results from albesus7 warrant.

^{!!!} conduct TANC study on Long Island in coordination with new urban LUS, new MAS, and SWA studies.

^{!!!!} conduct TANC study in vicinity of Camden, New Jersey in coordination with new urban LUS, new MAS, and SWA studies.

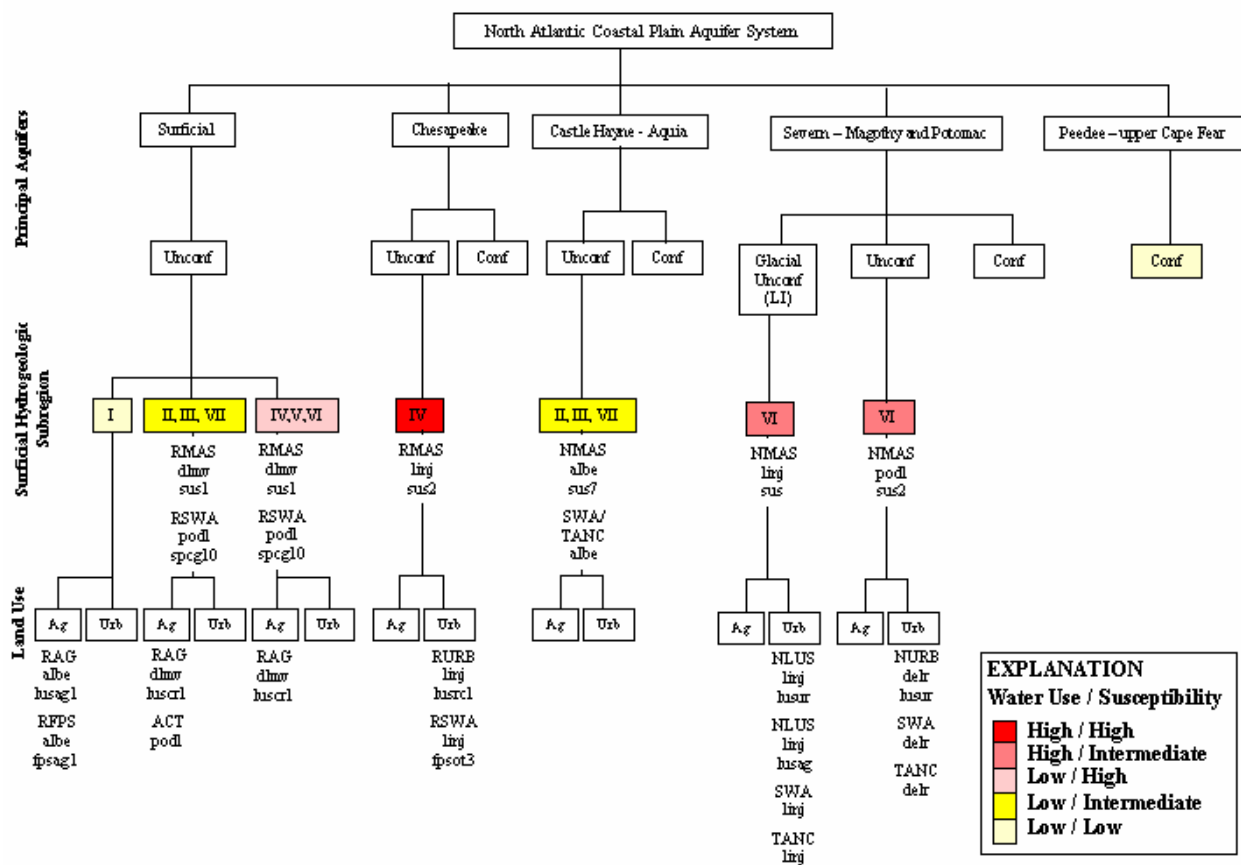


Figure 11. Proposed and recommended studies for cycle II overlain on regional stratification. The stratification is color coded to identify those strata with highest drinking-water use and that are most susceptible to contamination from anthropogenic sources.

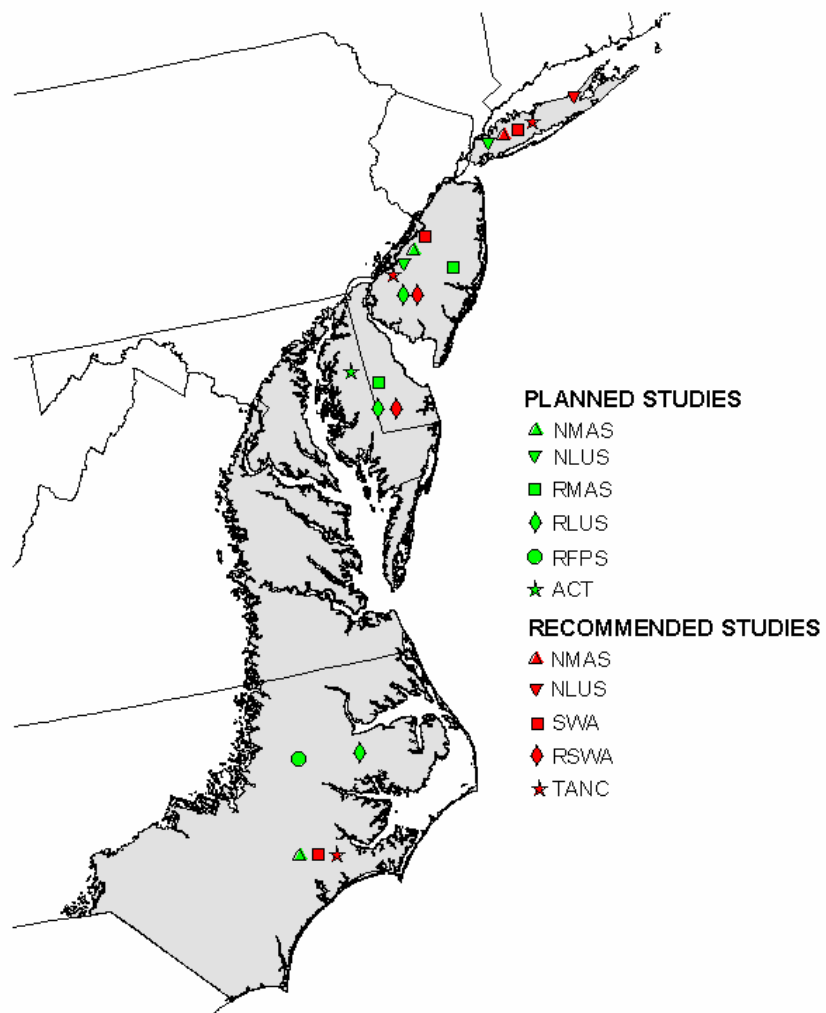


Figure 12. Location of planned and recommended cycle II studies.

Recommendations for Cycle II Studies

The NACPAS team recommends that all planned studies presented in the previous section be undertaken. In addition, the NACPAS team would recommend several studies in addition to planned studies to ensure the goal of regional water-quality assessment following cycle II. These recommendations are presented on table 3 and illustrated on figures 11 and 12. This section presents these recommendations by aquifer system including source-water assessments and ground-water topical studies. Prioritization of planned and recommended studies is provided in the following section “Prioritization of Cycle II Studies”.

Surficial Aquifer

The current NIT plan does not include new agricultural LUSs for the NACPAS in cycle II. One important agricultural setting in the NACP left unassessed by current NIT plans includes the surficial aquifer in eastern Long Island. The agricultural setting of eastern Long Island is important because it represents a somewhat unique scenario in which traditional row-crop vegetables are rapidly being replaced by vineyards and because residents of eastern Long Island are reliant on domestic supply from the surficial aquifer (fig. 5). The occurrence of pesticide compounds in shallow ground water and water from supply wells is currently being addressed by a cooperative study between the USGS, Suffolk County, and NYSDEC (J. Eimers, personal communication). **The NACPAS planning team recommends consideration of a new Agricultural LUS on eastern Long Island** pending assessment of the coverage provided by the cooperative study.

During cycle I, a network of public supply wells in the surficial aquifer on Delmarva Peninsula (dlmvspcg10) was sampled representing a prototype SWA study. **The NACPAS planning team recommends that dlmvspcg10 be resampled** as part of the trends network to provide data on changes in water-quality for this important set of public-supply wells.

Chesapeake Aquifer

During cycle I, a network of public supply wells in the Chesapeake aquifer in southern New Jersey (linjfpsot3) was sampled representing a prototype SWA study. **The NACPAS planning team recommends that linjfpsot3 be resampled** as part of the trends network to provide data on changes in water-quality for this important set of public-supply wells.

Castle-Hayne Aquifer

A NMAS of the Castle-Hayne aquifer system is currently being conducted in the ALBE (albesus7) and this network will subsequently be included in the trends network (table 3). If water-quality findings from

albesus7 warrant, **the NACPAS planning team recommends that the Castle Hayne aquifer system be considered for a SWA and (or) TANC study.** This aquifer system is increasingly used as a source for public supply in the rapidly growing southeastern portion of North Carolina and consisting of limestone is the only aquifer in the NACP that is not comprised on unconsolidated sediments.

Severn – Magothy and Potomac Aquifers

The NACPAS planning team recommends that the Severn-Magothy and Potomac aquifer systems be separated into 2 areas for assessment. The Severn – Magothy aquifer extends from Long Island southward to Virginia and the Potomac is present throughout the entire NACP forming an area too large to effectively cover with 1 MAS or LUS. Furthermore, on Long Island the Severn - Magothy is overlain by 250+ ft of saturated glacial sediments whereas south of Long Island it outcrops or subcrops near land surface. Because it is mantled with glacial deposits, the inorganic chemistry of the Severn-Magothy aquifer on Long Island differs from the remainder of the Severn-Magothy aquifer system. Due to the presence of the thick, saturated glacial sediments on Long Island, the physical, chemical, and biological processes that govern the transport of contaminants to ground water likely differ between Long Island and the remainder of the Severn – Magothy aquifer system in the NACP.

The NACPAS planning group recommends that a NMAS be conducted in the Surficial and Severn - Magothy aquifer systems on Long Island in coordination with the planned new urban LUS and that these surveys be coordinated with a SWA and TANC study to fully address water quality issues on Long Island. An urban LUS is planned for Long Island during cycle II (table 3). Nesting this new urban LUS with a NMAS, SWA, and TANC study would provide information on the source strength of select contaminants, their occurrence and concentration throughout the aquifer system including water discharging from major public-supply wells, and the primary processes that govern the transport of contaminants to the supply wells thereby following the **source-transport-receptor model**. These nested water-quality surveys would be linked with a 3D ground-water flow model that has been developed for Long Island and that can be used to 1) describe the rate and patterns of ground-water flow through the aquifer system, 2) delineate areas contributing recharge to wells, and 3) predict future trends and distributions of contaminants throughout the aquifer system.

A NMAS of the Severn – Magothy and Potomac aquifer systems is planned for the PODL study unit (podlsus2) and will be conducted across the outcrop and subcrop belt from New Jersey to Virginia providing water-quality data for this important drinking-water resource. Furthermore, an urban LUS is planned for the DELR in the Camden, New Jersey area (delrlusur) and will be nested within podlsus2 (table 3). **The NACPAS planning team recommends further nesting these water-quality networks**

with a SWA and TANC study in the Camden, New Jersey area. Nesting these water-quality studies will allow for an assessment of the aquifer system following the **source-transport-receptor model**. As with Long Island, a 3D ground-water flow model of this area has been developed and would be linked with these water-quality surveys to 1) further assess the transport of contaminants to supply wells, 2) predict future trends and distributions of contaminants throughout the aquifer system including discharge to supply wells, and 3) compare and contrast transport processes where the aquifer is mantled with 250+ ft. of glacial sediments (Long Island) and where the aquifer outcrops or subcrops near land surface.

None of the water-quality networks in the Severn – Magothy and Potomac aquifers, which provide the largest amounts of water for public and domestic supply in the NACP (fig. 6), are scheduled for inclusion in the trends network. The urban LUS planned for Long Island (linjlusur) is scheduled to be included in the trends network; however, this network would be located in the surficial (glacial) sediments (which are in hydraulic connection with the underlying Severn – Magothy aquifer system). **The NACPAS planning team recommends that the urban LUS that is planned for the Severn – Magothy and Potomac aquifer systems (delrlusur) be incorporated into the trends network** because of the importance of these aquifers as sources of drinking water. The preference of the NACPAS Planning team is to include delrlusur rather than podlsus2 in the trends network because it will be easier to identify factors governing observed trends in a shallow ground-water network in a relatively homogenous land-use setting than from a network of domestic supply wells from a mix of land uses.

Peedee – upper Cape Fear Aquifer

The Peedee – upper Cape Fear aquifer was not assessed during cycle I and there are no plans for assessment during cycle II. The NACPAS planning team concurs with this as this aquifer is considered to be less susceptible to anthropogenic contamination than the other primary aquifer systems in the NACP.

Prioritization of Planned and Recommended Cycle II Studies

This section presents rationale for prioritization of cycle II studies by network category. The prioritization of these studies is illustrated on table 3.

New Status Studies

NMAS – NMAS studies are planned for the Castle Hayne (albesus7) and Severn – Magothy and Potomac aquifer systems where they outcrop along the Fall Line (podlsus2) (table 3). Historically, a larger number of water-quality investigations have been conducted in the Severn – Magothy and Potomac aquifers than the Castle Hayne; thus, the Castle Hayne receives highest priority for new MASs (table 3). Both the planned (podlsus2) and recommended (linjsus) NMASs in the Severn – Magothy aquifer systems are high priorities based on water use. The largest withdrawal for public and domestic supply in the NACPAS (over 260 Mgal/d) occurs from the Severn – Magothy aquifer system on Long Island where it provides a sole-source for a population of about 3 million (fig. 6); thus, the linjsus receives 2nd priority (table 3). Along the Fall Line where the Severn – Magothy and Potomac aquifers outcrop and subcrop, large withdrawals for public and domestic supply also occur (fig.6); thus, although 3rd in priority for NMASs, podlsus2 is an overall high priority study for the NACP in cycle II.

NLUS – NLUS studies are planned for the Severn – Magothy and Potomac aquifers (linjlusur and delrlusur) (table 3). Because the aquifer system on Long Island represents the single greatest source of drinking water in the NACP, linjlusur receives highest priority and delrlusur 2nd priority. A third NLUS is recommended (linjlusag) but receives lowest priority for NLUSs because a cooperative study between USGS, Suffolk County, and NYSDEC is currently addressing the occurrence of pesticides in this hydrogeologic setting (J. Eimers, personal communication).

Source-water assessments - SWAs will be conducted during cycle II to characterize water-quality in samples from public-supply wells in high priority aquifers in select metropolitan areas based on water use and population served. Because public-supply wells were not typically assessed in cycle I these studies are placed in the new status category. The number and location of SWAs that will be conducted in the NACPAS during cycle II has yet to be determined, however, in the interest of planning, the NACPAS planning team has recommended several areas that would be high priority for SWAs in the NACP (table 3). These studies are further prioritized based on water use and population served from each aquifer system and metropolitan area (table 3).

Trend Studies

Cycle II New Status networks that are planned or recommended for inclusion in the Trends network (albesus7, linjlusur, and delrlusur) are not prioritized for Trends, as they will be accomplished in cycle II under New Status.

RMAS – Resampling of two MASs is planned for cycle II (dlmvsus1 and linjsus2) (table 3). These studies are essentially of equal priority but because PODL has initiated work on dlmvsus1 it receives higher priority than linjsus2.

RLUS – Resampling of three LUSs is planned for cycle II (albelusag1, dlmvlusr1, and linjlusr1) (table 3). These studies are essentially of equal priority but because ALBE and PODL have initiated work on albelusag1 and dlmvlusr1 these studies receive priority over linjlusr1.

RFPS – Resampling of one FPS is planned for cycle II (albefpsag1) (table 3). This study represents the FPS network to be resampled in the NACP during cycle II; thus, this study becomes an overall high priority towards our goal of better understanding processes that govern the transport of contaminants along ground-water flowpaths.

RSWA – The NACPAS planning team is recommending that two prototype SWAs (dlmvspcg10 and linjfpsot3) be resampled in cycle II to provide information on trends in water-quality from these important networks of public-supply wells. The linjfpsot3 study is given 1st priority because it represents higher water use and population served (table 3).

Topical Studies

Currently, only one topical study is underway in the NACP (PODL ACT). FY04 and FY07 study units will likely accomplish additional ground-water topical studies, however, these studies have yet to be identified. In the interest of planning, the NACPAS Planning Team has recommended and prioritized several areas that would be high priority for additional topical studies in the NACP.

TANC – Three TANC studies are recommended for the NACP (table 3). These studies are prioritized based on water use and population served (table 3). The 3rd priority TANC study (albe) is recommended only if water-quality data from albesus7 warrants further investigation.

ACT – Only one ACT study is planned or recommended for cycle II (table 3) – prioritization is not necessary.

Report Products

TBD

Appendix 1.

New Status Studies

I. MAJOR AQUIFER SURVEY – Castle Hayne Aquifer (ALBESUS7)

Objective:

Determine the quality and age of ground water in the Castle Hayne-Aquia Aquifer in areas where it is most susceptible to contamination by surface sources.

Proposed Location:

Portions of the Castle Hayne-Aquia aquifer in the Inner Coastal Plain of southeastern North Carolina.

Background/Water Quality Issues Addressed:

The Castle Hayne-Aquia Aquifer consists of limestone, sand, and minor amounts of clay deposited under marine conditions. While the Castle Hayne-Aquia aquifer extends from New Jersey to North Carolina, the most transmissive aquifers and greatest water use occur in North Carolina (Trapp and Horn, 1997). In North Carolina, the regional Castle Hayne-Aquia Aquifer is dominated by the local Castle Hayne aquifer that is present throughout the Outer Coastal Plain and in the eastern portion of the Inner Coastal Plain. The Castle Hayne aquifer is buried throughout most of its extent and does not receive direct recharge from precipitation. However, where the Castle Hayne aquifer is close to the surface, much of the ground water in this aquifer has moved through local flow systems through leakage (Trapp and Horn, 1997). In the Outer Coastal Plain the Castle Hayne aquifer is typically overlain by the Castle Hayne, Pungo River, and Yorktown Confining Units (Winner and Coble, 1996) and is likely to contain old ground water that contains little or no anthropogenic contamination. In the Inner Coastal Plain, the Castle Hayne Aquifer is closer to the surface (< 25 m) and is typically overlain only by the Castle Hayne confining unit and a surficial aquifer. Furthermore, groundwater withdrawals have caused cones of depression in this area and have increased the likelihood that leakage from overlying aquifers may compromise the quality of water in this aquifer. Due to its greater susceptibility, this study will focus on this portion of the Castle Hayne aquifer. This area includes the cities of Jacksonville, Wilmington, and New Bern and surrounding rural areas that are dependent on this aquifer for their drinking water supply. Furthermore, no comprehensive assessments of this portion of the Castle Hayne aquifer have been conducted.

Approach:

Wells will be randomly selected from the area of the Inner Coastal Plain where the Castle Hayne aquifer is overlain by only the confining unit and the surficial aquifer as defined by Winner and Coble (1996). One existing domestic or public supply well per 80 km² will be selected for approximately 30 wells total. It is anticipated that a sufficient number of samples will fall along regional flow paths to characterize the quality of water as a function of ground water travel time. Samples taken from the Castle Hayne aquifer will be analyzed for major ions, nutrients, pesticides, volatile organic compounds and any additional constituents required for NAWQA Major Aquifer Studies. Samples will also be collected from a subset of wells for the purposes of age-dating (e.g., CFCs, tritium-helium). Water chemistry and age-dating will be used to establish the present condition of the aquifer as well as assess future risks. Comparisons of water chemistry and age between the Castle Hayne and studies conducted in the overlying surficial aquifer in

Cycle 1 will help to establish the geochemical evolution of natural and anthropogenic constituents found in the Castle Hayne aquifer.

II. MAJOR AQUIFER SURVEY – Severn – Magothy and Potomac Aquifers (PODLSUS2)

Objective: Document the spatial variability in unconfined ground-water quality in the outcrop and subcrop areas of the Lower Tertiary and Cretaceous aquifers along the Fall Line in areas where they are currently used for public supply.

Location: The Inner Coastal Plain in the Mid-Atlantic Region, from northern Virginia through Long Island, New York.

Background: Permeable sands and gravels of the Inner Coastal Plain (primarily of the Potomac Group and Raritan and Magothy Formations and equivalents) are important regional aquifers in the Mid-Atlantic Region, both where confined and unconfined. These units are exposed or subcrop beneath surficial sand units in places along the Fall Line from northern Virginia through Long Island, New York and are confined beneath less permeable younger Coastal Plain sediments to the south and east (Trapp, 1992). The outcrop area is heavily urbanized (16 percent, Vogelmann and others, 1998), and includes parts of the Washington, DC, Baltimore, Philadelphia, and New York City metropolitan areas. *Discuss recharge rate to these aquifers? – see Leahy and Martin, 1993?*

Inner Coastal Plain aquifers provide a critical regional water supply, particularly where confined. Nearly half (49 percent) of estimated ground-water withdrawals from 1978-80 in the entire Coastal Plain were from the Potomac and Magothy Aquifer systems. About 40 percent of this total was used in New Jersey; another 25 percent was used on Long Island (Leahy and Martin, 1993). In 1985, 251 million gallons of water per day were withdrawn from these systems (excluding Long Island), most (63 percent) of which was used for public, domestic, or commercial supply (Trapp and Horn, 1997). *Discuss possible evolution of this over the past 20 years...*

Limited available data suggest that shallow ground water in the unconfined part of the Inner Coastal Plain (excluding Long Island, New York) is affected by human influences. Major ion and nutrient concentrations in shallow Inner Coastal Plain ground water are highly variable, reflecting the variable geology and land use. Concentrations of atrazine, desethylatrazine, metolachlor, and simazine are higher in shallow ground water of this area than in other areas of the Coastal Plain. Geologic units of the Inner Coastal Plain are typically deeply weathered where exposed and can be quite permeable. The movement of pesticides from the land surface to ground water is likely to be significantly impeded only in areas of very fine sediments of loamy soils (Ator and others, 2000). *Add more info from NJ?*

How 'bout water quality in the confined area?

Water-Quality Issues Addressed: Network wells will be sampled for a broad suite of major ions, nutrients, pesticides, pesticide metabolites, trace metals, VOCs, and bacteria. Collected data will be useful for assessing the distribution of a wide range of natural and anthropogenic compounds that may affect the usefulness of the ground-water resource for human consumption in the aquifer recharge areas and may indicate the likelihood for contamination of these aquifers where they become confined to the south and east.

Approach: Wells will be randomly selected for sampling (Scott, 1990) within the Inner Coastal Plain as delineated on available geologic maps. This will include some parts of Maryland that are currently not included within the NAWQA program. Sampling will be conducted by DELR, LINJ, and PODL staff during 2003. Collected data will form a foundation for possible in-depth topical studies of contamination to public supply wells in the area during the cycle 2 HIP of the DELR and/or LINJ.

III. URBAN LAND-USE SURVEY – LINJ – location TBA

Trends Studies

1. MAJOR AQUIFER SURVEY – Surficial Aquifer (DLMVSUS1)

Objective: Document the spatial variability in unconfined ground-water quality in the Delmarva Peninsula and any trends that are apparent in that resource over the past decade.

Location: Delmarva Peninsula

Background: The Delmarva Peninsula includes approximately 6,000 mi² in Delaware, Maryland, and Virginia between the Chesapeake Bay in the west and Delaware Bay and the Atlantic Ocean in the east. The Peninsula is underlain by unconsolidated siliciclastic deposits of the Coastal Plain that thicken from a feather edge at the Fall Line to nearly 8,000 feet at Ocean City, Maryland (Vroblesky and Fleck, 1991); unconfined surficial aquifer is typically less than 100 feet thick. Climate on the Peninsula is humid and temperate. Precipitation averages approximately 45 inches per year and temperatures vary from about 2 degrees Celcius in January and February to 25 degrees C in July and August. Although small towns are common throughout the Peninsula, agriculture is the dominant land use in the study area (about 48 percent). Most cultivated land is used for corn and soybeans; large poultry farms are common, particularly to the south (Shedlock and others, 1999). Sussex County, Delaware is the leading poultry-producing county in the Nation (USDA, 1998).

The Delmarva MAS network was established and sampled in 1988 as part of the areal network of the NAWQA pilot program. This network included pairs of wells screened in the deeper part of the surficial aquifer (which are considered the MAS network for PODL Cycle II), and in the shallow part (which are considered a LUS network for DLMV Cycle I). Shallow ground water at that time was typically dilute (low dissolved constituent concentrations) and slightly acidic. Ground water in areas of residential or (especially) agricultural land use and sandy soils typically contained elevated nitrate concentrations (greater than 5 mg/L) and detectable pesticides. Median nitrate concentrations were 7.1 mg/L in ground water beneath residential areas and 8.2 mg/L beneath agricultural areas. Although pesticides were most commonly detected in the shallowest part of the surficial aquifer, nitrate concentrations were elevated throughout the aquifer. Nitrate concentrations were related to redox conditions as well as depth. Although the highest concentrations of nitrate were measured in shallower wells, overall, there was no trend of decreasing nitrate with depth. Pesticide detections only in shallower parts of the surficial aquifer were related to pesticide use (since the early 1970's) and the age of aquifer recharge (Koterba and others, 1993). Trace metals and volatile organic compounds (VOCs) were infrequently detected in shallow ground water (Shedlock and others, 1999).

Water-Quality Issues Addressed: Network wells will be sampled for a broad suite of major ions, nutrients, pesticides, pesticide metabolites, trace metals, VOCs, and bacteria. Collected data will be useful for assessing the distribution of a wide range of natural and anthropogenic compounds that may affect the usefulness of the ground-water resource for human consumption. Trends related to the movement of agricultural chemicals from shallow to deep parts of the surficial aquifer system will be evaluated.

Approach: Wells were randomly selected for the MAS network to provide a relatively even spatial coverage of the Delmarva Peninsula. Sites were selected randomly within each of 32 relatively equal-sized, contiguous cells and an appropriate well tapping the surficial aquifer was located near each site. Selected wells are typically used for domestic supply and are screened at least 5 to 10 meters below the water table (Koterba and others, 1991). Each well sampled as part of the pilot network will be revisited and evaluated for continual usefulness by the NAWQA program. Where necessary, alternate wells will be

selected or installed as nearly as possible (in location and depth) to inaccessible or otherwise unusable network wells. Each well (in both the Cycle II MAS and Cycle I LUS networks) will be resampled during the late spring or summer of 2001.

II. MAJOR AQUIFER SURVEY – Chesapeake Aquifer (LINJSUS2)

Objective:

Document the occurrence and distribution of chemical constituents in the Kirkwood-Cohansey aquifer system and assess trends in the occurrence and concentration of these constituents over the last 10 years.

Location:

Kirkwood-Cohansey aquifer system, southern New Jersey

Background/Water-Quality Issues:

The chemical quality of ground water in the surficial Kirkwood-Cohansey aquifer system is of concern because of the increasing reliance on this aquifer system for public and domestic supply and its vulnerability to contamination from land surface. Historically, southern New Jersey has relied heavily on the confined Potomac-Raritan-Magothy (PRM) aquifer system for public supply. More recently, the NJDEP has restricted withdrawals from the PRM aquifer system as a result of severe water-level declines. Increased withdrawal from the surficial Kirkwood-Cohansey aquifer system is one alternative to meet current and future water-supply demands and withdrawals from this aquifer system for public and domestic supplies have risen steadily since the early 1980s. Furthermore, the highly permeable, unconsolidated sands and gravels that comprise the Kirkwood-Cohansey aquifer system are overlain by extensive urban and agricultural lands making the aquifer system vulnerable to contamination introduced at or near land surface. The vulnerability of this aquifer system to contaminants introduced at or near land surface has been confirmed by numerous water-quality investigations that demonstrate the occurrence of elevated concentrations of nitrate and the frequent low-level detection of pesticides and VOCs (Ayers and others, 2000; Stackelberg and others, 1997; other refs). Select trace elements (for example, radium and mercury) are also frequently detected in samples of water from the Kirkwood-Cohansey aquifer system (Szabo and others, 1997). The leaching and nitrification of applied fertilizers, which increase the dissolved-solids content and acidity of ground water, are likely mechanisms by which radium is mobilized from surficial sediments and transported to ground water. The source of mercury is thought to be linked to past use of mercury-based pesticides.

Approach:

Domestic wells that were randomly selected and sampled during cycle I will be resampled for this survey. If any of the cycle I wells are no longer accessible, an alternate well that is located as closely as possible to the inaccessible well will be sampled for a total of 30 wells. Each well will be sampled for a full suite of major ions, nutrients, trace metals, pesticides and their metabolites, and VOCs.

III. AGRICULTURAL LAND USE SURVEY – Surficial Aquifer – (ALBELUSAG1)

Objective:

Evaluate trends in water quality constituents in an intensive agricultural area containing primarily corn, soybean, and cotton.

Proposed Location:

Shallow aquifers (Surficial and Yorktown Aquifers) overlain by agricultural activities in the Coastal Plain of the ALBE Study-unit.

Background/Water Quality Issues Addressed:

The Coastal Plain of North Carolina is the most intensive agricultural area in the ALBE study unit (McMahon and Lloyd, 1995). The shallow water table throughout much of the Coastal Plain creates an environment that is susceptible to contamination from agricultural activities. Pesticides (e.g., alachlor, metolochlor, atrazine) and their transformation products (e.g., desethylatrazine, 2,6-diethylaniline) were detected in groundwater sampled during Cycle 1 (Spruill et al., 1998). Thin unsaturated zones, like those present in the Outer Coastal Plain, may limit the rate of degradation of alachlor (Potter and Carpenter, 1995) and may explain why alachlor and its degradation product 2,6-diethylaniline were only found in groundwater in this setting. While nitrate concentrations are typically low, levels are elevated and may exceed drinking water standards in aerobic portions of the aquifer.

Approach:

Wells sampled as a part of the Agricultural Land Use Study in Cycle 1 will be resampled once during this HIP for the purpose of assessing trends in ground water quality. Analytes will include nutrients, major ions and pesticides. If practical, pesticide degradates for constituents found during Cycle 1 (e.g., atrazine, metolochlor, alachlor) will be included as analytes.

IV. URBAN LAND USE SURVEY – Chesapeake Aquifer – (LINJLUSRC1)**Objective:**

Document the occurrence of chemical constituents in shallow ground water from the Kirkwood-Cohansey aquifer system underlying urban areas and assess trends in the occurrence and concentration of these constituents over the last 10 years.

Location:

Kirkwood-Cohansey aquifer system, Glassboro study area

Background/Water-Quality Issues:

The chemical quality of ground water is of particular concern in the Glassboro study area in southern New Jersey because ground water provides most of the public and domestic supply. This is one of the fastest growing regions in New Jersey. Its population was more than 250,000 in 1990 and is expected to increase as suburban development continues. Residential and commercial developments built within the last three decades occupy large tracts of land that previously were undeveloped or used for agricultural purposes. The NJDEP has identified serious water-supply problems in the Glassboro study area. Historically, this region has relied heavily on the confined Potomac-Raritan-Magothy (PRM) aquifer system for public-water supply. More recently, the NJDEP has restricted withdrawals from this aquifer system as a result of severe water-level declines. Increased withdrawal from the surficial Kirkwood-Cohansey aquifer system is one alternative to meet current and future water-supply demands. The aquifer system is vulnerable to contamination introduced at or near land surface because it consists of highly permeable unconsolidated sands and gravels. Previous water-quality investigations in this area documented elevated nitrate concentrations and the frequent low-level occurrence of pesticides and VOCs (Stackelberg and others, 1997).

Approach:

Shallow monitoring wells that were randomly located, installed, and sampled during cycle I will be resampled for this survey. If any of the monitoring wells are no longer accessible, a new well that is located as closely as possible to the inaccessible well will be installed and sampled for a total of 30 wells. Each well will be sampled for a full suite of major ions, nutrients, trace metals, pesticides and their metabolites, and VOCs.

UNDERSTANDING STUDIES

I. FLOW-PATH SURVEY – (ALBEFPS?)

Objectives:

Ground water flow path and surface water quality study in an agricultural watershed in the Inner Coastal Plain. Determine the changes in water quality along flow paths from a recharge area near a hog farm to discharge to either a first or second order stream. Determine the influence of ground water discharge on surface water quality with a particular focus on its implications for nutrient enrichment.

Proposed Location:

Sandy Run watershed (near Farmville, NC) of the Neuse River basin, Inner Coastal Plain.

Background/Water Quality Issues Addressed:

The geochemical evolution of ground water along flow paths will provide much needed information to better evaluate the risk agricultural activities pose for drinking water quality and nutrient loading to streams. The importance of nitrate removal and phosphorus release into solution in riparian zones is dependent on the hydrogeologic setting (e.g., Hill, 1996; Carlyle and Hill, 2001) with greater amounts of nitrate reduction and phosphorus release in systems dominated by shallow lateral flow as is found in much of the Coastal Plain. Nutrient loading to streams and ultimately to the estuaries is perhaps the most significant environmental problem facing this region. Increased nutrient loads have been linked to more frequent occurrences of nuisance algal blooms, hypoxia and fish kills in the Neuse River Estuary (e.g., Pinckney et al., 2000). The study area selected contains agricultural sources of nitrogen and natural sources of phosphorus. In this study, the fate of these and other important constituents regarding nutrient enrichment and drinking water issues will be determined.

Approach:

This project is proposed to complement an ongoing USGS/USEPA project that began as a NAWQA spinoff project during Cycle 1. In the USGS/USEPA project, surface water quality and discharge measurements are made in a nested design. This surface water component is combined with an intensive ground water monitoring effort to provide information on both the hydrology and nutrient chemistry of the Contentnea Creek basin, an important contributor of nutrients to the Neuse Estuary. Ground water samples are being collected along multiple flow paths to determine the change in water chemistry prior to discharge. Ground water ages have been estimated using CFCs and tritium.

While an intensive ground water monitoring effort exists at this site, there are significant gaps in the available data that must be filled in order to better understand changes in water chemistry. To assess the change in water chemistry over time, the concentration of each constituent of interest and its transformation product (e.g., excess N_2 , nitrate, etc) will be determined for ground water samples of varying age. Existing data are being interpreted to determine where additional samples and age-dating measurements are needed. To assess nutrient loading to streams from ground water discharge, additional ground water samples are needed in the riparian zones adjacent to both the first and second order streams to determine if upgradient sources of nitrate are being denitrified prior to discharge and if phosphorus is being mobilized in this zone. Also, the response of the ground water system to storm events is a critical piece of data needed to understand the hydrology and chemistry of these watersheds. Isotopic (δD , $\delta^{18}O$ of water) and other water quality measurements of precipitation, ground and surface water during a fall and spring storm are proposed to determine the amount of ground, soil and storm water in comprises stream flow during the course of a storm. Ultimately, results from the ground water portion of the flow path study,

chemical and isotopic analyses in surface water and hydrograph separation calculations will be interpreted to determine the influence ground water discharge has on surface water chemistry, particularly as it affects nutrient enrichment.

II. SWA (PODL)

III. ACT (PODL)

References Cited

- Ator, S.W., Denver, J.M., and Hancock, T.C., 2000, Relating shallow ground-water quality to surficial hydrogeology in the Mid-Atlantic Coastal Plain. National Water Quality Monitoring Council National Monitoring Conference, April 25-27, 2000, Austin, TX. Conference Proceedings, pp. 409-423.
- Carlyle, G.C. and A.R. Hill. 2001. Groundwater phosphate dynamics in a river riparian zone: effects of hydrologic flowpaths, lithology, and redox chemistry. *J. of Hydrology*, v. 247, 151-168.
- Ferrari, M.J., 2001, Occurrence and distribution of selected contaminants in public drinking-water supplies in the surficial aquifer in Delaware: U.S. Geological Survey Open-File Report 01-327, 62 p.
- Gilliom, and others –NIT plan
- Hill, A.R. 1996. Nitrate removal in stream riparian zones. *J. Environ. Quality*, v. 25, 743-755.
- Kalkhoff, S.J., Kolpin, D.W., Thurman, E.M., Ferrer, I., and Barcelo, D., 1998, Degradation of chloroacetanilide herbicides: The prevalence of sulfonic and oxanilic acid metabolites in Iowa ground water and surface water: *Environmental Science and Technology*, v. 32 no. 11, p. 1738-1740.
- Koterba, M.T., Banks, W.S.L., and Shedlock, R.J., 1993, Pesticides in shallow groundwater in the Delmarva Peninsula: *Journal of Environmental Quality*, Vol. 22, No. 3, pp. 500-518.
- Koterba, M.T., Shedlock, R.J., Bachman, L.J., and Phillips, P.J., 1991, Regional and targeted ground-water quality networks on the Delmarva Peninsula: Chapter 6 in Nash, R.G., and Leslie, A.R., eds., *Groundwater residue sampling*: American Chemical Society, Washington, D.C.
- Leahy, P.P. and Martin, Mary, 1993, Geohydrology and simulation of ground-water flow in the Northern Atlantic Coastal Plain Aquifer System: U.S. Geological Survey Professional Paper 1404-K, 81 p.
- McMahon, G. and O.B. Lloyd. 1995, Water-quality assessment of the Albemarle-Pamlico drainage basin, North Carolina and Virginia -- Environmental setting and water-quality issues: U.S. Geological Survey Open-File Report 95-136, 72 pp.
- Pinkney, J.L., H.W. Paerl, E. Haugen, and P.A. Tester. 2000. Responses of phytoplankton and *Pfiesteria*-like dinoflagellate zoospores to nutrient enrichment in the Neuse river estuary, North Carolina, USA. *Marine Ecology Progress Series*, v. 192, 65-78.
- Potter, T.L. and T.L. Carpenter. 1995. Occurrence of alachlor environmental degradation products in groundwater. *Environ. Sci. and Technol.*, v. 29, 1557-1563.
- Scott, J.C., 1990, Computerized stratified random site-selection approaches for design of a ground-water quality sampling network: U.S. Geological Survey Water-resources Investigations Report 90-4101, 109 p.
- Shedlock, R.J., Denver, J.M., Hayes, M.A., Hamilton, P.A., Koterba, M.T., Bachman, L.J., Phillips, P.J., and Banks, W.S.L., 1999, Water-quality assessment of the Delmarva Peninsula, Delaware, Maryland, and Virginia – Results of investigations, 1987-91: U.S. Geological Survey Water-supply Paper 2355-A, 41 p.
- Spruill, T.B., D.A. Harned, P.M. Ruhl, J.L. Eimers, G. McMahon, K.E. Smith, D.R. Galeone and M.D. Woodside. 1998. Water quality in the Albemarle-Pamlico drainage basin, North Carolina and Virginia, 1992-1995. U.S. Geological Survey Circular 1157, 36 pp.
- Trapp H., Jr., and Horn M.A., 1997a, Ground Water Atlas of the United States, Segment 11, Delaware, Maryland, New Jersey, North Carolina, Pennsylvania, Virginia, West Virginia. U.S. Geological Survey Hydrologic Investigations Atlas 730-L.

- Trapp H., Jr., and Horn M.A., 1997b, Ground Water Atlas of the United States, Segment 12, Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont. U.S. Geological Survey Hydrologic Investigations Atlas 730-M.
- Trapp, Henry, Jr., 1992, Hydrogeologic framework of the Northern Atlantic Coastal Plain Aquifer System in parts of North Carolina, Virginia, Maryland, Delaware, New Jersey, and New York: U.S. Geological Survey Professional Paper 1404-G, 59 p.
- Trapp H. and M.A. Horn. 1997. Ground Water Atlas of the United States, Segment 11. U.S. Geological Survey Hydrologic Investigations Atlas 730-L, 24 pp.
- USDA, 1998: 1997 Census of Agriculture, blah blah blah
- Vogelmann, J.E., Sohl, T.L., Campbell, P.V., and Shaw, D.M., 1998, Regional land cover characterization using Landsat and ancillary sources: Environmental Monitoring and Assessment, vol. 51, pp.415-428.
- Vrobesky, D.A., and Fleck.W.B., 1991, Hydrogeologic framework of the Coastal Plain of Maryland, Delaware, and the District of Columbia: U.S. Geological Survey Professional Paper 1404-E, 45 p.
- Winner, M.D. and R.W. Coble. 1996. Hydrogeologic framework of the North Carolina Coastal Plain. U.S. Geological Survey Professional Paper 1404-I, 106 pp.