2.5 WATER RESOURCES

2.5.1 INTRODUCTION

2.5.1.1 Background

Surface water is the water visible on the Earth's surface. It covers nearly 70 percent of the Earth's surface and includes oceans, lakes, rivers, streams, and wetlands. Surface water is critical to all life cycles; it houses resources, nutrients, minerals, and energy. It also provides a three-dimensional medium for flora and fauna.

Delaware has diverse surface-water resources, from faster-moving Piedmont streams to slow-moving coastal plain streams; the Delaware Bay and Inland Bays estuaries; and many tidal rivers containing fresh or brackish waters. Surface waters support uniquely diverse fish and wildlife populations, provide multiple recreational opportunities, and provide approximately 70 percent of the drinking-water supply for New Castle County.

The Chesapeake Basin generally consists of slow-moving coastal plain streams although the tidal Nanticoke River, the tidal Broad Creek, and the Chesapeake and Delaware Canal are exceptions.

2.5.1.2 Historical Perspective

The progress of mankind has taken its toll on surface-water quality. Recent improvements in environmental protection and awareness have helped, but pollution remains a major concern. As recently as 1975, Delaware routinely experienced serious water pollution and public health problems as a result of the discharge of untreated sewage and wastes. Since then, as a result of voluntary efforts, regulatory actions, and significant private and public investments in wastewater treatment facilities, localized improvements in water quality have been achieved.

The need for additional cleanup and pollution prevention continues. The focus of water-quality management has shifted from point source discharges (end-of-pipe) to decreased stream flows and nonpoint source problems, such as urban and agricultural runoff, erosion, and sedimentation. Unaddressed, these problems lead to poor habitat conditions for fish and other aquatic life, decreased enjoyment of our surface waters for recreation, and unhealthy conditions for those surface waters upon which we rely for drinking-water supply and other domestic uses.

As a result of water-quality protection programs that are in place in Delaware, surface-water quality has remained fairly stable in spite of increasing development and population growth. Impacts to waters are generally the result of past practices or contamination events, activities that are not regulated or otherwise managed,

CONTENTS

WATER RESOURCES

or changes/events that occur on a larger regional scale. For example, air pollutants from sources outside of Delaware may contaminate Delaware's surface waters via rainfall.

Improvements in water quality have been documented in localized areas where a discharge was eliminated or better treatment installed. Basin-wide water-quality improvements in waters that are being impacted by historical yet unquantified pollution sources are very difficult to detect over a short period of time. Targeted monitoring over long time periods (years) is necessary in order to detect changes.

Although Delaware's surface-water quality may not have changed significantly over the last several years, there have been many improvements made in watershed assessment approaches and methodologies. Additionally, many water-quality criteria are stricter as a result of amendments to the state's Water Quality Standards. Therefore, we have become more proficient at identifying water-quality problems and, at the same time, are calling for higher-quality waters.

The stability of Delaware's surface-water quality is likely the result of increased efforts to control both point and nonpoint sources of pollution. In addition to the significant investments in wastewater treatment technologies previously mentioned, many private business interests are investing in practical and cost-effective nonpoint source pollution control practices (Best Management Practices) on farms, residential developments, and commercial and industrial sites. Likewise, public agencies such as the Delaware Department of Transportation are investing revenues in improved storm-water management practices and wetlands creation to mitigate the impacts of maintenance and new highway construction activities.

The detailed assessment that follows indicates water quality in the majority of the Basin remains stable, but cautions that phosphorus and bacteria levels are relatively high, causing concern for nutrient over-enrichment and potential health risks to swimmers. In addition, localized increasing nitrogen trends were identified in the Nanticoke, Marshyhope, and Chesapeake drainage watersheds.

2.5.2 SURFACE WATER

2.5.2.1 Watershed Characteristics

The Chesapeake Basin has a long narrow drainage area in western Delaware *(see Map 1.2-1 Chesapeake Basin Watersheds)*. The Basin includes seven watersheds: Elk Creek, Chesapeake Drainage System, Choptank River, Marshyhope Creek, Wicomico River, Pocomoke River, and the Nanticoke River and its tributaries (Broad Creek, Gum Branch, Deep Creek, Gravelly Branch). Part of the Chesapeake and Delaware Canal, from south of Lums Pond to the Delaware and Maryland State Line, is also included in the study. Drainage areas in New Castle County and Kent County are much of the headwaters. Following is a description of each watershed's characteristics.

Upper Chesapeake Bay Drainage System

For the purpose of this portion of the assessment, the Elk River, Perch Creek, western segment of the Chesapeake and Delaware Canal, Bohemia River, Sassafras River, and the Chester River are referred to as the Upper Chesapeake Bay Drainage System. Minor portions of these watersheds are within Delaware and drain through Maryland's eastern shore to the Chesapeake Bay. The area within the segment is rural and the topography is flat, ranging between 50 and 100 feet above sea level. There are numerous small streams throughout the watersheds. The residential development in this area is dependent upon individual septic systems. The area is principally farms, which are scattered throughout.

Pathogens (as indicated by elevated *Enterococcus* levels), nutrients, physical habitat condition, and water supply are the main concerns for this watershed.

Choptank River Watershed

The Choptank River watershed is located in the west-central portion of Kent County. It is bounded on the west by the Maryland State Line, on the southeast by the Marshyhope Creek and Murderkill River watersheds, on the northeast by the St. Jones River watershed, and on the north by the Chester River watershed. Land area in this watershed is approximately 61,000 acres. The Choptank River is 2.7 miles long within Delaware. It is formed by the confluence of Culbreth Marsh Ditch (10.7 miles long) and Tappahanna Ditch (10.6 miles long). Cow Marsh Creek (17.4 miles long) is another watercourse. Major tributaries that merge with the Choptank River in Maryland include Heron Run, White Marsh Branch, and Sonston Prong, which combine to form Gravelly Branch. The major tributary of Cow March Creek is Meredith Branch. All streams generally flow in a westerly direction. There are no tidal areas located in this segment. The streams are rather slow and turbid. During dry periods, some segments are ephemeral. The watershed is level to gently sloping and is poorly drained.

Pathogens (as indicated by elevated *Enterococcus* levels), high bacteria counts, low dissolved oxygen levels, nutrients, physical habitat condition, and water supply are the main concerns for this watershed.

Marshyhope Creek Watershed

The Marshyhope Creek watershed is comprised of about 61,000 acres straddling the Kent and Sussex County borders near the Maryland State Line. The 15-mile long main stem of the creek rises west of Harrington and flows southwest into Maryland west of Bridgeville. Marshyhope Creek is a major tributary to the Nanticoke River Estuary in Maryland. The majority of land in this watershed is used for agricultural purposes, although forests cover a large area.

Pathogens (as indicated by elevated *Enterococcus* levels), high bacteria counts, low dissolved oxygen levels, nutrients, physical habitat condition, and water supply are the main concerns for this watershed.

Upper Nanticoke River System

The Upper Nanticoke River System (including the Gum Branch, Gravelly Branch, and Deep Creek watersheds) covers approximately 179,000 acres in western Sussex County. Generally, the topography of the area is flat to slightly undulating except for very short steep slopes along the major streams. Concentrations of population are not limited to the towns of the watershed, but extend along all highways connecting the towns. The rural non-farm population is rapidly expanding and is most noticeable in the areas of well-drained soils, particularly from Greenwood to Seaford. The major land use in this watershed is agriculture.

The waters of the Nanticoke River System are designated as having Exceptional Recreational or Ecological Significance (ERES) and, therefore, receive a higher level of protection. The watershed supports a variety of valued recreation opportunities including recreational and tournament fishing; boating, and water skiing; swimming; wildlife observation; and hunting. However, surface-water-quality data indicate stresses to the watershed including high nutrient loads, high bacteria counts, and occasional low dissolved oxygen levels.

Pathogens (as indicated by elevated *Enterococcus* levels), nutrients, physical habitat condition, and water supply are the main concerns for this watershed.

Broad Creek Watershed

The Broad Creek watershed is comprised of about 75,000 acres in southwestern Sussex County. The 20-mile long main watershed rises east of Delmar and flows toward the northwest through Trussum and Records ponds to the town of Laurel. The creek, which becomes tidal freshwater at this point, continues northwest to its confluence with the Nanticoke River southwest of Seaford. The major land use in the watershed is agriculture, although residential uses are important at Laurel. State-owned areas that provide access to water-based recreation include Horseys Pond, Records Pond, and Raccoon Pond.

The waters of the Basin are designated as having Exceptional Recreational or Ecological Significance (ERES) and, therefore, receive a higher level of protection. However, surface-water-quality data indicate stresses to the watershed, including high nutrient loads, high bacteria counts, and occasional low dissolved oxygen levels.

Pathogens (as indicated by elevated *Enterococcus* levels), nutrients, physical habitat condition, and water supply are the main concerns for this watershed.

Pocomoke River Watershed

The Pocomoke River watershed is comprised of roughly 16,000 acres in southern Sussex County. The 9-mile long main stem of the river in Delaware rises southwest of Millsboro and flows south to the Maryland border. The river eventually discharges to the lower Chesapeake Bay near Crisfield, Maryland. Basin land uses are split between agriculture and freshwater wetlands. Slopes are gentle.

Pathogens (as indicated by elevated *Enterococcus* levels), high bacteria counts, low dissolved oxygen levels, nutrients, physical habitat condition, and water supply are the main concerns in this watershed.

Wicomico River Watershed

At the time of this publication, there were insufficient data available to characterize this watershed.

2.5.2.2 Quality

The preliminary assessment of water-quality data for the Chesapeake Basin within Delaware has been done. The study used statistical methods to assess the chemical and physical water-quality data collected through the state's ambient surface water-quality monitoring program.

The assessment analyzed data from 106 sampling locations distributed along the Nanticoke River and its tributaries, Choptank River, Marshyhope Creek, Upper Chesapeake Drainage System, and Pocomoke River *(see Map 2.5-1 Surface Water Monitoring Locations)*. These data included general chemical and physical parameters, bacteria, and nutrients, and were retrieved mainly from the EPA's STORET (STOrage and RETrieval) system. As these data had censored values, outliers, multiple observations within a time interval, as well as the common problems when data are retrieved and converted from one type to another type, they were manipulated and treated before applying statistical methods on them.

Mean, median, standard deviation, maximum, and minimum statistical parameters were used to characterize the existing condition. In addition, excursion analysis applied to parameters that had applicable numerical limits stated in the State of Delaware Surface Water Quality Standards or the EPA Quality Criteria for Water. Trend analysis was used to characterize the changes of the water-quality condition. It used the Mann-Kendall and Seasonal Kendall nonparametric methods. The analysis applied these methods to the data to test the statistical significance of apparent changes in concentration over time and, at the same time, estimated the magnitudes of the changes.

Results from the analysis showed major concerns related to the following parameters, as their concentration levels were frequently found above acceptable water-quality criteria limits:

- *Enterococcus* bacteria: Concentrations frequently exceeded the fresh-water-quality standard of 100#/100 ml in a number of places, mainly, along the tributaries.
- Total phosphorus: Excessive concentrations (average above 0.1 mg/l, 0.05 mg/l, or 0.025 mg/l) support the concern of nutrient enrichment in the Basin.
- Dissolved oxygen: Concentration exceeded the standard (5.5 mg/l for June to September and 4.0 mg/l as a minimum) quite frequently in the Broad Creek, Choptank River, Marshyhope Creek, and Upper Chesapeake Drainage System.
- pH: With the exception of values measured for the Chesapeake and Delaware Canal, pH values consistently fell outside the acceptable range of 6.5 standard unit – 8.5 standard unit.

Trend analysis showed that, collectively, no parameter had an obvious change throughout the Basin. Although there were instances where changes were detected at several locations, the magnitude and spatial coverage of the changes were not large enough to indicate significant change in water quality. Therefore, the study indicates that water quality in the Chesapeake Basin has remained stable.

Eutrophication

With increasing concerns over eutrophication in the Basin, several nutrient species have been analyzed for status and trend. They are described below.

Phosphorus

Total Phosphorus. Concern about phosphorus content in streams is based primarily on the role of phosphorus in promoting eutrophication. Among the major nutrients, phosphorus is most likely to limit plant growth in freshwater streams. This is the case in the Chesapeake Basin as manifested by nitrogen/phosphorus (N/P) ratio analysis discussed later in this part. Despite the strong correlation that exists between total phosphorus concentrations and the degree of eutrophication, a water-quality standard for phosphorus in streams has yet to be developed. However, the EPA's "Quality Criteria for Water" suggests upper limits of total phosphorus for the prevention of nuisance growth. The criteria are 0.05 mg/l at the point where a stream enters a lake, 0.025 mg/l within a lake, and 0.1 mg/l in streams not flowing directly into lakes.

Excursion analysis of 1992–1996 records showed that total phosphorus exceeded the limits frequently (>25 percent of the time) throughout most of the Basin. The high exceedance suggests possible eutrophy existence in the Basin.

As discussed above, trend analysis suggests that total phosphorus has remained stable in the Basin. A few areas showed concentration changes, but the affected spatial coverage was too small to indicate a watershed-wide change in phosphorus level trends.

N/P ratios were calculated for each station to determine whether the limiting nutrient in the eutrophication process was phosphorus or nitrogen. Generally, a ratio above 10 indicates that phosphorus is the limiting nutrient, while a ratio below 10 indicates nitrogen as the limiting nutrient. N/P ratios throughout most the Basin were well above 10, thereby indicating that phosphorus is the limiting nutrient in the eutrophication process in the Basin. Only a few places in the Marshyhope Creek and the Upper Chesapeake Drainage System had N/P ratios of less than 10. *Map 2.5-2 Total Phosphorus Concentrations and Trends* shows the sampled locations and associated data.

Nitrogen

Total Nitrogen. Total nitrogen concentrations were calculated by adding up concentrations of Total Kjeldahl Nitrogen (TKN) and nitrate-nitrite nitrogen. Mean and median concentrations of total nitrogen were in the range of 1.13 mg/l – 6.72 mg/l. Trend analysis was not informative for this parameter.

Total Kjeldahl Nitrogen (TKN). Total Kjeldahl Nitrogen, which represents the combined concentrations of ammonia and organic nitrogen, is another water-quality indicator. A review of the current data showed that TKN concentrations were relatively uniform in the Basin. Between 1970 and 1996, decreasing trends were detected at several locations. Two locations, Tappahanna Ditch and Culbreth Marsh of Choptank River's tributaries, had increasing trends with the changing rates of 0.168 mg/l and 0.195 mg/l, respectively.

Nitrate-Nitrogen (NO_3 – N). Nitrate-nitrogen and nitrite-nitrogen are the two highly bioavailable sources of nitrogen for phytoplankton growth. Generally, nitrate-nitrogen concentrations are much higher than nitrite-nitrogen, thus, contributing more to phytoplankton growth.

(Many stations did not provide separate measures of nitrate-nitrogen and nitrite-nitrogen, but, rather, combined the two. See the discussion on Nitrite-Nitrate Nitrogen.)

Nitrite-Nitrogen (NO_2 – N). See discussion in Nitrate-Nitrite Nitrogen.

Nitrite-Nitrate Nitrogen (NO_2 + NO_3 - N). Average concentrations of nitrite-nitrate nitrogen in the Basin ranged from 0.25 mg/l to 5.96 mg/l. Trend analysis showed that the following reaches had increases in nitrate-nitrite nitrogen concentrations:

1. Lower reach of Nanticoke mainstem near and downstream of Woodland Ferry;
2. Upper reach of Nanticoke main stem, from upstream of Seaford to northeast of Bridgeville;
3. Records Pond on Broad Creek;
4. Main stem of Marshyhope Creek near Adamsville; and
5. Gravelly Run of the Upper Chesapeake Drainage System.

These locations are shown on *Map 2.5-3 Total Nitrogen Concentrations and Trends*.

Total Ammonia Nitrogen. Ammonia nitrogen, which exists in waters as ammonia (NH_3) or as ammonium-ion (NH_4^+), is an indicator of organic pollution. The ammonia (NH_3) form is toxic to fish, and toxicity varies with the pH of stream water. The EPA recommends 0.02 mg/l of NH_3 as a criterion to protect freshwater aquatic life.

Average concentration of ammonia nitrogen ranged from 0.019 mg/l to 0.563 mg/l. Decreasing trends were detected at several locations.

<u>*Dissolved Oxygen (DO)*</u>

Dissolved oxygen is the most essential measure of stream water quality. The Delaware Surface Water Quality Standards indicates that daily average concentration of DO should not be less than 5.5 mg/l in June – September, and minimum concentration of DO should not be less than 4.0 mg/l for supporting aquatic life.

Overall, DO levels were acceptable during 1992 – 1996. The mean and median concentrations of DO were generally above 5.5 mg/l. Excursion analysis showed water quality met the standards throughout most of the Basin. Only a few spots had data values that exceeded standards more than 25 percent of the time. During the same time, mean and/or median concentrations at these locations were below 5.5 mg/l. The occurrences of the exceedance were frequent enough to indicate that dissolved oxygen was not adequate to support aquatic life at these few locations. These locations were Trussum Pond and Raccoon Pond of the Broad Creek watershed; White Marsh Branch of the Choptank River; the upper stream of Marshyhope Creek; and Cypress Branch of the Upper Chesapeake Drainage System.

Trend analysis indicated that the concentrations of DO were quite stable in the Basin. The occasionally detected changes were not significant enough to suggest a Basin-wide change in level trends. *Map 2.5-4 Dissolved Oxygen Concentrations and Trends* shows the sampled locations.

<u>*Chlorophyll-a*</u>

Chlorophyll-*a* concentrations were high (>38 μg/l) along the lower reach of the Nanticoke main course from Sharptown up to Seaford, and in its tributaries of Hearns Pond and the lower reach of Broad Creek. No trend has been detected over time.

Bacteria

The state water-quality standard for primary contact recreation in fresh water is based on the geometric average of *enterococcus* bacteria. This average shall not exceed 100 colonies per 100 ml under conditions characterized by the absence of rainfall-induced runoff. As no such rainfall data were available along with water-quality data, the analyses were performed without considering the rainfall-induced situation. Primary contact recreation is the designated use for all streams in the Basin except for the Chesapeake and Delaware Canal.

Evaluation of historical data demonstrated that *enterococcus* bacteria concentrations violated the standard in a number of places. The following locations had geometric means that exceeded 100-colonies/100 ml:

A. Nanticoke River Watershed
   (1) Lower reach of Gum Branch;
   (2) Chapel Branch;
   (3) Clear Brook; and
   (4) Bucks Branch.

B. Broad Creek Watershed
   (1) Tussock Branch;
   (2) Meadow Branch;
   (3) Pepper Branch;
   (4) Saunders Branch;
   (5) Thompson Branch;
   (6) Elliot Pond Branch; and
   (7) Wiley's Pond.

C. Choptank River Watershed
   (1) Culbreth Marsh;
   (2) Tappahanna Ditch; and
   (3) White Marsh Branch.

D. Marshyhope Creek Watershed
   (1) Main stem of Marshyhope Creek.

E. Upper Chesapeake Drainage System
   (1) Cypress Branch;
   (2) Sewell Branch; and
   (3) Gravelly Run.

Trend analysis indicated that concentrations of *enterococcus* bacteria in the Basin were remaining stable, except at two locations. Tappahanna Ditch and Culbreth Marsh of Choptank River's tributaries had increase trends with rates 156 #/100 ml/year and 92 #/100 ml/year, respectively.

Other

<u>*Total Suspended Solids*</u>

Total suspended solids measures the impurities that may cause murkiness, turbidity, odor, color, and even disease. High solids content may also indicate high phosphorus concentrations that, in turn, promote eutrophic conditions.

Examination of historical data showed that total suspended solids concentrations in lower reaches of streams were three to four times higher than in upper reaches and their tributaries. In the Nanticoke watershed, the mean and median concentrations were around 20 mg/l in the lower reach of the main stem of the Nanticoke River (from Sharptown Station 304011 up to Seaford Station 304031), while the mean and median were around 5 mg/l in the upper reach of the main stem (from Middleford Station 304041 to Northeast Bridgeville Station 304291) and the tributaries.

Overall concentrations were stable throughout the Basin. No significant changes were noticed in the main streams of the watersheds. Only two tributaries in the Choptank watershed had significant concentration increases: Culbreth Marsh with a rate of 7.0 mg/l/year, and Tappahanna Ditch with a rate of 5.8 mg/l/year.

Total Hardness

Total hardness is an important parameter for drinking water. Water supplies are classified as soft, moderately hard, hard, or very hard based on the following total hardness values:

Total Hardness (as $CaCO_3$ in mg/l)	**Classification**
0 – 75	soft
75 – 150	moderately hard
150 – 300	hard
300 and up	very hard

Historical data showed that water in the Basin is soft. Total hardness concentrations were all below 75 mg/l, except one station at Summit Bridge on the Chesapeake and Delaware Canal, where total hardness had a mean 500 mg/l and median 264 mg/l. No significant trends were noticed in the Basin, except at Chesapeake City on the Chesapeake and Delaware Canal, which showed an increase of 40 mg/l/year.

pH

The state's surface-water-quality standard requires that freshwater pHs be in the range of 6.5 to 8.5 standard unit (su). Although the mean and median were within this range for most of the Basin, the excursion analysis indicated that data points fell outside the range (below 6.5 su in most cases) quite frequently over wide areas of the Basin. Over time, no significant changes in pH trends (in water-quality perspective) have been identified.

Water Temperature

Water temperatures were relatively uniformly distributed throughout the Basin (i.e., around 13°C, but with noticeable variability between seasons). The lowest temperatures were 0°C recorded during the winter, while the highest was 31.5° C recorded in the summer. Over time, no changes have been identified for this trend.

Total Alkalinity

The Quality Criteria for Water has recommended 20 mg/l or more as $CaCO_3$ for freshwater aquatic life, except where natural concentrations are less. In the Basin, the mean and median concentrations of alkalinity were around 20 mg/l. Only a few places had lower concentrations of roughly 10 mg/l. These data indicate that Basin water has sufficient buffering capacity. No obvious change to this trend was observed over time for most of the Basin, although Sewell Branch in the Upper Chesa-peake Drainage System had a decrease of 5.5 mg/l/yr.

Biological Assessment of Nontidal Streams

Biological and physical habitat data have been collected in Delaware since 1990 and have been used in the Section 305(b) reports in 1992, 1994, 1996, and 1998. These data are currently being compiled for the Chesapeake Basin Preliminary Assessment. The biological assessments are based upon aquatic macroinvertebrates, including the aquatic forms of insects, crayfish, worms, and snails. Physical habitat assessments are based upon visual measurements of the stream channel, banks, shade, and the riparian zone.

Total Maximum Daily Load

Federal Clean Water Act Requirements

Section 303(d) of the 1972 Federal Clean Water Act (CWA), as amended, requires states to develop a list of water bodies that need additional pollution reduction beyond that provided by the application of existing conventional controls. These waters are referred to as "Water Quality Limited" and must be periodically identified by the Department or the federal Environmental Protection Agency (EPA).

Water Quality Limited waters requiring the application of Total Maximum Daily Loads (TMDL) are identified in a document commonly referred to as the "303(d) list." A TMDL is the level of pollution or pollutant load below which a water body will meet water-quality standards and thereby allow use goals such as drinking-water supply, swimming and fishing, or shellfish harvesting to be achieved. A state's 303(d) list must be reviewed and approved by EPA by April 1st of every even-numbered year.

A full TMDL process determines the pollutants causing water-quality impairments, identifies maximum permissible loading capacities for the water body in question, and, for each relevant pollutant, assigns load allocations — Total Maximum Daily Loads — to each of the different sources, point and nonpoint, in the watershed.

The full TMDL process is an effective and important tool for achieving water-quality standards, but is time-consuming and labor-intensive. For this reason, TMDLs are currently pursued for high-priority waters with the most severe water-quality problems including the Inland Bays, Nanticoke River, and the Appoquinimink River. These waters are typically impacted by both point sources (e.g., sewage treatment plants, industrial facilities) and nonpoint sources (e.g., storm-water runoff from urban and agricultural lands).

The CWA mandates that EPA perform all of the responsibilities not adequately addressed by a state. To date, scores of Section 303 lawsuits across the county have been filed against EPA. Plaintiffs have prevailed in most of those cases resulting in court-ordered TMDL development schedules as short as five years.

Citizen Groups Sue EPA Over Delaware Water Quality

In August 1996, James R. May, Esq., Director of the Environmental Law Clinic at Widener University School of Law, on behalf of the American Littoral Society (and its affiliate, Delaware River Keeper Network) and the Sierra Club, filed a federal complaint. This complaint charged the EPA with "the failure to perform its mandatory duties to identify and then to improve the water quality of hundreds of miles of rivers, streams, and Atlantic coastline, and thousands of acres of lakes, reservoirs, ponds, bays, estuaries, and wetlands in the State of Delaware which fail to meet the fishable and swimmable water-quality standard as required by the Federal Water Pollution Control Act, 33 U.S.C. §1251 et seq. (1988) commonly known as the Clean Water Act." (*American Littoral Society, et al. v. United States Environmental Protection Agency, et al.;* Civil Action No. 96-5920)

The Complaint asks the Court to order EPA to:

- Comply with CWA requirements for TMDLs in Delaware on a short time line.
- Commit to updating Delaware's Continuing Planning Process, which serves as the overall framework for water resources management in the state.
- Not issue or approve any new or renewed National Pollutant Discharge Elimination System (NPDES) permits discharging into impaired waters for which TMDLs or TMDTLs (Total Maximum Daily Temperature Loads) have not been established.
- Cease any additional grant funding to Delaware to administer the 303(d) program until the state's 303(d) list meets the requirements of the CWA.
- Administer the NPDES program for Delaware until the state has an EPA-approved CPP in place.

The Department agreed to be present during a federally funded mediation process and assist EPA with program and technical issues. A settlement was reached and the Department's Secretary and EPA's Regional Administrator signed an interagency Memorandum of Understanding (MOU) dated July 25, 1997.

Delaware's Total Maximum Daily Load Program

Since the early 1990s, EPA has urged states to adopt a watershed approach to water-quality management. EPA issued a new TMDL guidance document in 1991 encouraging the development of TMDLs on a watershed basis. Delaware has implemented a watershed approach that includes the integration of the TMDL monitoring and assessment program for each watershed in accordance with DNREC's Whole Basin Management Program schedule.

Settlement Negotiations. Plaintiffs demanded an accelerated schedule to ensure that TMDLs for all 1996-listed waters will be established by 2006. DNREC and EPA agreed to a schedule for completion of the TMDLs on a 10-year schedule.

Included in the settlement with EPA, and in addition to the commitment to a 10-year schedule for TMDL development in Delaware, are commitments to prepare a supplement to Delaware's 1996 List of Impaired Waters to include waters impacted by habitat degradation from agricultural and urban activities, develop guidance documents regarding the use of biological and habitat data for listing waters in 1998, and develop protocols for assessing wetlands in Delaware. The MOU between EPA and DNREC sets forth the duties of EPA and DNREC that will serve as the framework for administering the TMDL program in Delaware.

Current TMDL Activities in the Chesapeake Bay Basin. The Nanticoke River and Broad Creek have been identified as water-quality-limited waters, included in Delaware's 1996 and 1998 303(d) list, and were targeted for development of TMDLs by December 15, 1998. The major environmental problems in these waters are nutrient overenrichment and low dissolved oxygen levels caused by point source discharges and nonpoint sources.

By Secretary's Order No. 98-W-0045, the Department has adopted the Total Maximum Daily Loads (TMDLs) Regulation for nitrogen and for phosphorus for the Nanticoke River and Broad Creek. The effective date of the final regulations was December 10, 1998, meeting the December 15, 1998 deadline.

Future Pollution Management Activities. Once a TMDL is promulgated, a Pollution Control Strategy (PCS) will be developed. A PCS will specify the necessary pollutant load reductions that need to occur such that loadings will be less than or equal to the TMDL. Plans are for reductions to be achieved through voluntary (for those activities that are voluntary now) and regulatory (for those activities that are regulated now) actions. However, TMDLs will provide watershed-wide pollution reduction targets which the Department (and EPA) will be legally obligated to meet. This obligation will require new approaches for addressing point and nonpoint sources of pollution. Concepts such as "pollution trading" between different sources of pollution, geographic targeting, and pollution prevention will all be considered as part of the PCS. Meeting these targets may require regulation under existing law.

2.5.2.3 Quantity

Streams in the Chesapeake Basin receive most of their water as base flow from ground water. This ground water, along with normal precipitation, provides an abundant water supply during all but the most severe droughts. However, localized water-quantity problems can arise if the resource is not properly managed. For instance, many of the small streams in the Basin are used as sources of irrigation water. As long as stream flow is normal or above, this use does not create a problem. If stream flow drops substantially below normal (due to over-utilization upstream or severe drought) then these small streams may suffer habitat degradation or loss, and the water is not available for other users downstream.

Stream-Flow Gauging

Eleven USGS stream-flow gauging stations are located in the Chesapeake Basin, two of which are still in operation *(Table 2.5-1 USGS Stream Flow Gauging Stations* and *Map 2.5-1 Surface Water Monitoring Locations)*. The two active stations are Station 01487000 on the Nanticoke

Figure 2.5-1

STREAM FLOW AT NANTICOKE GAUGING STATION (01487000)

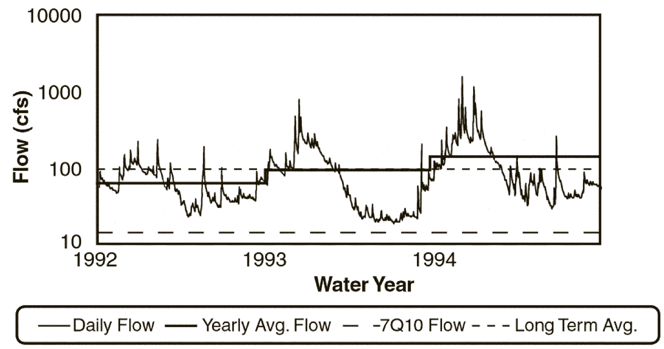


Table 2.5-1

USGS STREAM-FLOW GAUGING STATION

STATION ID	LOCATION	WATERSHED	DRAINAGE AREA (MILE^2)	PERIOD OF RECORD	LATITUDE/ LONGITUDE
01487000	Nanticoke River, Near Bridgeville	Nanticoke	75.4	4/1/43- Present	38° 43' 45" 075° 33' 41"
01488500	Marshyhope Creek, Near Adamsville	Nanticoke	43.9	4/1/43- Present	38° 50' 59" 075° 40' 24"
01488000	Holly Dr., Near Laurel	Nanticoke	2.2	3/20/51- 3/19/75	38° 32' 20" 075° 33' 55"
01487900	Meadow Branch, Near Delmar	Nanticoke	3.9	8/25/67- 3/19/75	38° 29' 05" 075° 35' 16"
01486980	Toms Dam Branch, Near Greenwood	Nanticoke	6.4	5/21/66- 3/19/75	38° 48' 04" 075° 33' 28"
01487500	Trap Pond Outlet, Near Laurel	Nanticoke	16.7	7/1/51- 9/30/71	38° 31' 40" 075° 28' 58"
01488600	Marshyhope Creek, At Adamsville	Nanticoke	60.4	4/1/69- 9/30/71	38° 49' 52" 075° 41' 12"
01490500	Culbreth Marsh Ditch, Near Chapeltown	Choptank	11.6	2/1/51- 9/30/56	39° 04' 45" 075° 41' 05"
01490470	Tappahanna Ditch, Near Hartly	Choptank	5.9	11/08/51- 2/3/73	39° 08' 07" 075° 41' 30"
01490490	Beachy Neidig Ditch, Near Willow Grove	Choptank	2.3	2/13/66- 7/13/75	39° 04' 57" 075° 39' 27"
01490600	Meredith Branch, Near Sandtown	Choptank	8.4	2/13/66- 7/13/75	39° 02' 23" 075° 41' 52"
01491010	Sangston Prong, Near Whiteleysburg	Choptank	1.9	9/21/66- 7/13/75	38° 58' 25" 075° 43' 32"

River near Bridgeville, and Station 01488500 on the Marshyhope Creek near Adamsville. *Figure 2.5-1* shows daily flows at Station 0148700 for the three-year period from 1992 through 1994. This figure shows that the yearly average flows at this station for the years 1992, 1993, and 1994 are 65.26 cubic feet per second (cfs), 88.62 cfs, and 133.49 cfs, respectively. Furthermore, the long-term average flow and the 7Q10 flow at this station are 90 cfs and 14.92 cfs, respectively. The 7Q10 flow is considered by water-quality managers as the critical low-flow condition for the stream, and represents the lowest seven-day average flow that occurs once in every ten years.

Figure 2.5-2

TIDAL ELEVATIONS OF NANTICOKE RIVER AT SEAFORD (RTE. 13 BRIDGE)

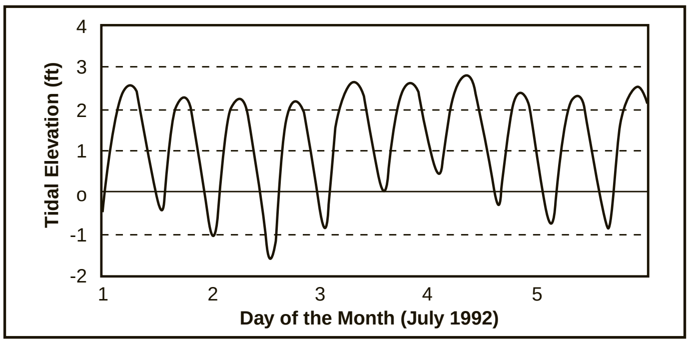


Figure 2.5-3a

CROSS-SECTIONAL PROFILE OF THE NANTICOKE RIVER AT SHARPTOWN, MD

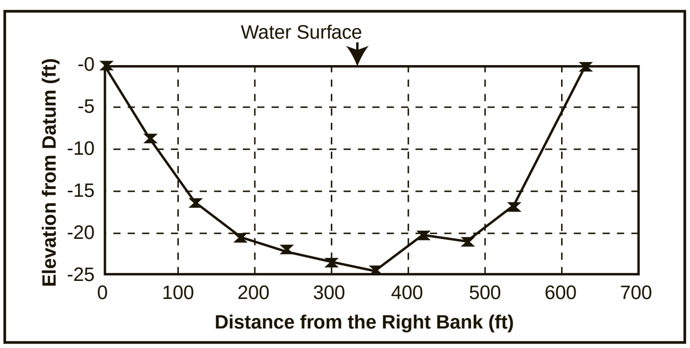
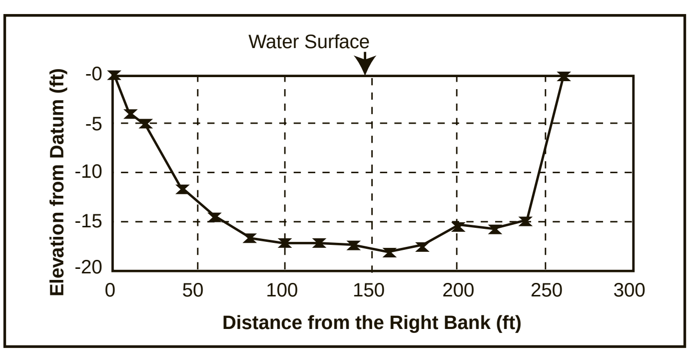


Figure 2.5-3b

CROSS-SECTIONAL PROFILE OF THE NANTICOKE RIVER AT SEAFORD, DE



Tidal Characteristic and Elevations

The Nanticoke River, from its mouth at the Chesapeake Bay up to the Rd. 545 Bridge north of Seaford, and the Chesapeake and Delaware Canal are the only two tidal systems in the Chesapeake Basin.

Tidal characteristics of the Nanticoke River were studied during a three-year period from 1991 through 1994. This monitoring, conducted through a cooperative agreement between the Department and the USGS, was initiated to help develop a hydrodynamic and water-quality model of the Nanticoke River and its main tributary, Broad Creek. *Figure 2.5-2* shows tidal elevation of the Nanticoke River at the Rte. 13 Bridge, near Seaford during the first five days of July 1992. The results of this and other similar studies indicate that within tidal portions of the Nanticoke River, average tidal range is about 2.5 feet, and maximum tidal velocity is less than 1.0 feet per second.

For the Chesapeake and Delaware Canal, the average tidal elevation at Summit Bridge is about 3.5 feet, and the maximum tidal velocity is roughly 2.0 feet per second.

Stream Bathymetry

The Department conducted a stream bathymetry survey of the Nanticoke River in 1991. During this survey, which was also coordinated with the USGS, cross-sectional profiles of the Nanticoke River at Sharptown, Maryland, and at Seaford, Delaware, were determined *(see Figures 2.5-3a and 2.5-3b)*. The information gathered during this survey was used for developing and calibrating a hydrodynamic and water-quality model of the Nanticoke River and its main tributary, Broad Creek. The model development effort was completed in 1995.

2.5.3 GROUND WATER

Ground water is defined as the subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated. Ground-water studies, however, must include recognition of subsurface water found above the water table, termed the unsaturated (or vadose) zone, and of surface-water bodies. All three are tightly interrelated as part of the entire hydrologic cycle.

2.5.3.1 Use

Ground water is both an important environmental and economic resource throughout the Chesapeake Basin because of its role in providing base flow to streams and wetlands (particularly important during times of low rainfall and drought), and as a source of water supply for domestic, public, industrial, and agricultural users. In all portions of the

Chesapeake Basin, ground water provides a vital supply of base flow to all streams and rivers. In the upper portion of the Chesapeake Basin, base flow contributes between 60 to 70 percent of the total stream flow (Baxter and Talley, 1997) and in the lower Chesapeake drainage to contribution is almost 80 percent (Johnston, 1976). Furthermore, except for the area above the Chesapeake and Delaware Canal, ground water is the sole source of drinking water and provides the majority of water for all other uses in the Chesapeake Basin.

2.5.3.2 Characteristics

As discussed in Section 2.1.2 (Geology), the entire Chesapeake Basin is in the Atlantic Coastal Plain physiographic province. Delaware's Coastal Plain is a layer cake of interbedded sand, silt, and clay that thickens as it dips to the southeast. The reader is directed to Section 2.1.2 for a more detailed description of the geology. This geology and the relatively high local precipitation of over 40 inches per year create an environment where ground water occurs at relatively shallow depths beneath the land surface throughout the Basin *(see Map 2.5-5 Water Table Elevation)*. And, as detailed in the Geology Section, useable ground water can also be found at significant depths beneath the Basin.

The same factors that make the Chesapeake Basin's ground water easily accessible and plentiful can also lead to easier contamination from numerous land-use practices. Most of the soils in the Basin are very permeable, which enables the rapid transfer of surface contaminants into the unconfined (water table) aquifer. *Map 2.5-6 Water Resource Protection Areas* shows the extent of the areas with high ground-water recharge potential where rain and surface water can very rapidly enter the water table. In addition, many of the subsurface sediments are also quite permeable and can facilitate further migration of contaminants through the aquifer toward discharge locations (wells, streams, etc.).

For the purposes of ground-water-quality analysis, the resource must be further divided into unconfined and confined aquifers. In general, the unconfined, or water table, aquifer is more susceptible to anthropogenic contamination than are the deeper confined aquifers. This means that surface and near-surface land-use practices can more easily and more rapidly impact water quality in the unconfined aquifer. Contamination of the deeper aquifers is usually slower and, in most cases, is caused by localized, site-specific problems or practices. Although the water-table aquifer is more vulnerable to contamination, its accessibility, relatively high yield, and useable thickness make it the most highly utilized aquifer in the Basin for both potable and non-potable water. Sections 2.3.2 and 2.3.3 detail known and potential contaminant sources that can impact ground-water quality and, consequently, ground-water availability.

In this section, ground-water quality and quantity data are reviewed, and general conclusions about the resource are made. It is important to note that, in most cases, ground-water data by its very nature is a biased dataset. The water is extracted from wells that were often installed for specific purposes (domestic water use, contaminant monitoring, etc.) and is only a snapshot of the resource as a whole. *Map 2.5-7 Ground-Water Monitoring Locations* shows the locations from which the Department receives or collects ground-water-quality data. These data are collected for a number of purposes and represent the best currently available assemblage. The data and conclusions presented are, most often, well specific, and variables like well depth, aquifer, pumping rate, and well use should be understood before the data are used for other purposes.

2.5.3.3 Quality

Nutrients

As discussed in Section 2.3.2, many different land-use practices can introduce nutrients as a contaminant into the subsurface. The following is a brief summary of the nutrient-related findings associated with the data collection for this assessment.

<u>*Nitrate*</u>

Map 2.5-8 Nitrate Concentrations in Selected Wells shows the wells for which the Department has nitrate-nitrogen data. Because of resource constraints, most of this information comes from wells that were installed for reasons other than ambient water-quality measurements. The map ranks average nitrate concentration (as dot color) and shows the average and maximum concentrations along with the total number of samples for each well. These data come from numerous sources as indicated in the map legend.

An analysis of the map shows that nitrate levels near major towns are elevated when compared with levels observed for the same types of wells in the less developed portions of the Basin. The areas near Bridgeville, Laurel, and Seaford have the highest average and maximum concentrations. There are seven locations near Bridgeville (three Public Water Supply (PWS) wells, two Ground Water Discharge (GWD) Monitoring sites, and two United States Geological Survey (USGS) wells) and three locations near Laurel (two PWS wells, and one GWD site) with average concentrations exceeding the 10 mg/l maximum contaminant level (MCL) drinking water standard. This condition does not necessarily mean that consumers are drinking water that exceeds this standard, as water is often diluted to below these levels in the water supply systems.

Very little information is known about the average water quality of the numerous domestic wells in the more rural areas throughout the Basin. Although Andres (1994) estimates that almost 20 percent of the population of southern Kent and Sussex counties have domestic well water with nitrate concentrations exceeding 10 mg/l, location-specific water quality is not well defined. During the 1993 National Water Quality Assessment (NAWQA) investigation, the USGS found average nitrate concentration to be 6.7 mg/l for wells in the Nanticoke watershed. Work done for the Department's 1996 Watershed Assessment Report (305(b)) showed that the average nitrate concentrations for Public Water Supply wells in the Nanticoke watershed was 4.15 mg/l. These PWS wells are generally deeper than common domestic wells, and since nitrate concentrations, in general, decrease with depth, the potential for higher average concentration in shallow wells exists.

Lack of data for the middle and upper portions of the Basin is evident *(refer to Map 2.5-8 Nitrate Concentrations in Selected Wells)*. This shortcoming is due to the relative bias of the various data sets to areas of greater development. Individual private wells are used in most of the upper Chesapeake Basin and all of the middle Chesapeake Basin. Because of this abundance of private wells and the lack of compliance-monitored sites, there is very little routinely collected ground-water data in these regions. The lack of shallow well data from the more rural areas throughout the Basin is almost certainly biasing the data presentation by not showing the impacts of septic systems and agricultural practices on ground water in those areas.

Ground-water nitrate concentrations in the Chesapeake Basin demonstrate that much of the area has been impacted by human activity. Furthermore, the lack of data for much of the more rural areas does not mean that there is no concern, but rather shows the limitation of the Depart-ment's ability to assess the ground water in those areas with existing resources. To get an idea of the potential impact, compare *Map 2.5-8 Nitrate Concentrations in Selected Wells* to *Map 2.5-9 Domestic Well Densities* to identify areas where there is significant ground-water use with little information about water quality. For instance, east of Seaford, northwest of Laurel, and much of Kent County west of Dover show relatively high domestic well densities in areas with little or no ground-water-quality data.

Further information is required to truly understand Basinwide nitrate contamination trends. The lack of water-quality data for large portions of the Basin shows the need to incorporate all possible water-quality analyses into our "ambient" monitoring network. More effort should be made by the various programs and agencies to cooperate on future data collection and distribution.

Phosphorus

There are very few locations in the Chesapeake Basin where phosphorus data have been collected for ground water. The reason for the lack of data is that most of the ground-water monitoring locations shown on *Map 2.5-7 Ground-Water Monitoring Locations* have not been sampled for phosphorus. Phosphorus is not regulated under the Safe Drinking Water Act and therefore is not a required analyte in the PWS wells. Furthermore, phosphorus is often bound in the soil matrix and is usually not a major concern in ground water. Much more work and monitoring needs to be done if more information is to be obtained on phosphorus levels in ground water.

Chemicals

Section 2.3.3 discusses the many different chemical sources that can introduce contaminants into the subsurface. This problem occurs as a result of spills, leaks, land use practices, and permitted discharges. The following is a brief summary of specific chemical related findings associated with the data collection for this assessment.

Chloride

Map 2.5-10 Chloride Concentrations in Selected Wells shows wells for which the Department has chloride data. Chloride contamination comes primarily from three sources: road salt application, direct discharge, and natural salt-water intrusion. The first two sources are anthropogenic while the third is completely natural. However, natural salt-water intrusion can be exacerbated by human practices (e.g., dredging, channeling, over-pumped wells, etc.). Because of resource constraints, most of this information comes from wells that were installed for reasons other than ambient water-quality measurements. The map ranks average chloride concentration (as dot color) and shows the average and maximum concentrations along with the total number of samples for each well. These data come from numerous sources as indicated in the map legend.

A review of *Map 2.5-10 Chloride Concentrations in Selected Wells* shows that, even though the data are sparse, chlorides in ground water are not a major concern in the Basin. There are isolated areas where elevated chloride concentrations have been detected, but most of the data show levels near background. With the exception of the public well north of Middletown and the USGS well northwest of Greenwood, the other elevated chloride levels are located in monitoring wells at sites that discharge saline wastewater.

Although the wells do not adequately cover the entire Basin, a general conclusion can be made at this point. Average chloride concentrations did not exceed the secondary MCL at any of the sites.

The lack of data for the middle and upper portions of the Basin is obvious from the map. Again, this shortcoming is due to the relative bias of the various data sets to areas of greater development. Individual private wells are used in most of the upper Chesapeake Basin and all of the middle Chesapeake Basin. This fact, coupled with the lack of compliance monitored sites, leads to very little routinely collected ground-water data in these regions. The lack of shallow-well data from the more rural areas throughout the Basin may bias the data presentation by not showing impacts of septic systems and road salting on ground water in those areas.

Iron

Map 2.5-11 Iron Concentrations in Selected Wells shows the wells for which the Department has iron data. Iron contamination can come from human sources like salvage yards and industrial facilities, but is also a commonly occurring natural contaminant. As discussed in Section 2.1.2, many of Delaware's aquifers have significant levels of iron in the formation and, therefore, in the water. Iron contamination is mainly an aesthetic concern with regard to taste and water color, but the EPA has also established a secondary MCL of 0.3 mg/l for human consumption. Because of resource constraints, most of this information comes from wells that were installed for reasons other than ambient water-quality measurements. The map ranks average iron concentration (as dot color) and shows the average and maximum concentrations along with the total number of samples for each well. These data come from numerous sources as indicated in the map legend.

Map 2.5-11 Iron Concentrations in Selected Wells shows that numerous wells in the Chesapeake Basin have average iron concentration in exceedance of the 0.3 mg/l secondary MCL. Samples were collected from USGS wells and 20 PWS wells. No shallow monitoring wells from the GWD Monitoring sites are sampled for iron. The water from the PWS wells may be diluted to levels below the drinking-water standard prior to consumption, but the Safe Drinking Water Act does not require water suppliers to do so.

Once again, the lack of data for the middle and upper portions of the Basin is obvious from the map, again due to relative bias of the various data sets to areas of greater development. Individual private wells are used in most of the upper Chesapeake Basin and all of the middle Chesapeake Basin. This fact, coupled with the lack of iron analysis at compliance monitored sites, leads to very little available ground-water data in these regions.

Pesticides

Because a large portion of Delaware is devoted to agriculture, there is a significant chance of agricultural chemicals and by-products entering the subsurface as contaminants. Fertilizers contribute vital nutrients to the state's many crops, but, when not used wisely, can also contribute to ground-water pollution. In order to compete in the global economy, many of Delaware's farmers also use pesticides (herbicides, insecticides, fungicides, etc.) for better crop management. Such use can lead to these compounds contaminating various resources, like ground water.

Currently, the Delaware Geological Survey (DGS) has established an ambient ground-water-monitoring network in southern New Castle County *(Pluses on Map 2.5-7 Ground-Water Monitoring Locations)*. At the time of this assessment, the only pesticide MCL exceedance detected by this network in the Chesapeake Basin occurred at a well located southwest of Middletown (Baxter and Talley, 1997).

The Delaware Department of Agriculture (DDA) has developed a statewide pesticide-monitoring network to test for these chemicals in ground water. The network consists of over 100 shallow wells, selected somewhat randomly, throughout the state. *Map 2.5-7 Ground-Water Monitoring Locations* shows the approximate location of these wells in the Chesapeake Basin (green arrows). The DDA and DGS are currently working on a joint investigation to report their findings. Those data will be available once that report is released. Until the results of the DDA and DGS report are available further conclusions about overall pesticide concentrations are limited.

Ground-Water Quality Conclusions

Besides naturally occurring iron, nitrate is the main contaminant of concern in ground water throughout the Basin. Serious concerns for other contaminants may exist on a localized, site-specific basis. Overall, the Chesapeake Basin is impacted by elevated nitrate levels more than by any other contaminant.

2.5.3.4 Quantity

Well Density

Maps

A series of maps, generated for this assessment, depicts various categories of water-supply wells found throughout the Chesapeake Basin. Categories include Domestic *(Map 2.5-9 Domestic Well Densities)*, Public *(Map 2.5-12 Public Water Supply Well Locations)*, Industrial *(Map 2.5-13 Industrial Well Densities)*, and Irrigation wells *(Map 2.5-14 Irrigation Well Densities)*, and are based on well-permitting data. With the exception of *Map 2.5-12 Public Water Supply Well Locations,* which shows the exact well locations, each of the other categories of wells is depicted on separate maps as "densities" using a graduated chromatic-scale corresponding to numbers of wells of specific types existing within modified-grid area polygons. Some limited well attributes are included on the maps, such as the well counts for modified-grids, and DNREC well-permit identification numbers as depicted on the public well map.

A composite map *(Map 2.5-15 Combined Well Densities)* shows the above categories of wells, in addition to monitoring wells, in point-coverage format. Except for public wells and industrial wells that are used for potable purposes, the point-coverage well locations are not the exact locations. Rather, the locations are roughly evenly distributed within the modified-grid area. This method of geographic location was used in the absence of longitude and latitude data for those wells. However, the public wells are plotted using corrected Global Positioning System (GPS) longitude and latitude data to the Department's accuracy standard for GIS, and have been referenced for correct identification and ownership.

The monitoring wells plotted on the composite map are also in roughly even distribution within modified-grids and were included to indicate locations where ground-water quality is under investigation. Typical monitoring well installations are for evaluating underground storage tanks, community wastewater disposal systems, landfills, and even Superfund sites. Thus, areas with monitoring wells could be indicators of potential sources of contamination to water supply wells. This assessment technique is very generic, and site-specific information must be obtained for an area of interest to determine the existence or extent of any contamination problems. Refer to section 2.3 for a discussion on the known and potential contaminant sources found within the Basin.

Completing the map series is a map representing ground-water usage as a maximum-daily withdrawal rate within each modified-grid (also in a graduated chromatic scale). This map is based on the "Maximum Daily Use" as estimated at the time the original well construction permit was applied for, and, therefore, does not represent actual usage *(Map 2.5-16 Maximum Daily Ground-Water Use).*

Interpretation

Some observations can be made on the occurrence and distribution of the various wells. As seen in the composite density map, most wells are concentrated in and around municipalities, corresponding to traditional development and land-use patterns. Throughout the Basin, domestic supply wells are, in general, fairly evenly distributed in the rural areas, with industrial wells located near and within towns. A divergence from this pattern is seen in the middle of the Chesapeake Basin (Choptank River Watershed) and in the upper Chesapeake Basin west of Dover, where there is a predominance of domestic wells. This area lacks central public water systems as well as any major industrial or irrigation activity. There is also a relatively high concentration of domestic wells east of Seaford, also reflecting suburbanization in the vicinity proximal to a city. Although public water is available in Seaford, it is apparent that public water service has not been extended to the east side of Route 13, and a proliferation of domestic wells has been the result.

Irrigation wells are generally associated with major farming operations, which widely employ irrigation systems, and to a lesser extent with privately-owned farms. It is evident that very intensive agricultural activity exists in the Nanticoke River, Deep Creek, Broad Creek, Gum Branch, and Gravelly Branch watersheds. The predominance of agricultural land use in these areas may result in most of the private and public wells being installed closer to more urban areas (as compared to the portion of the Basin west of Dover, where residential development is concentrated but much less dense).

Some clusters of monitoring wells can be easily connected to known ground-water contamination sites, such as the Sussex County Landfill southeast of Georgetown along Route 9. Other sites include the Dupont-Seaford nylon plant landfill, and the Harvey and Knotts landfill in the extreme northern end of the Basin along Old County Road.

Areas of large ground-water withdrawals (as shown on *Map 2.5-16 Maximum Daily Ground-Water Use)* correspond most closely with the presence of irrigation wells. There is less of a relationship between numbers of irrigation wells within a modified grid and the intensity of irrigation withdrawals, as only a minority of the areas with the highest number of irrigation wells also have the highest rate of usage. This relationship may indicate geologic variation that affects ground-water availability, as well as, other factors related to actual farming operations.

Water Use

Most ground water is produced from the unconfined aquifer system named the Columbia Group. The Columbia is comprised primarily of well-sorted, fine-to-medium grained quartz sand and gravel. All potable water is provided by ground water. In the middle portion of the Basin, some limited use of the minor sand units in the confined Miocene-age formations occurs for domestic and small public wells. Deeper aquifers in the northern part of the Basin are tapped by several large public wells.

The Columbia Group aquifer in the southern portion of the Basin is especially productive, with possible yields from individual wells in excess of 3 million gallons per day. High yields are indicated by the concentration of high withdrawals associated primarily with irrigation in the Seaford and Laurel areas. The Columbia Group aquifer is also the source for most public and domestic supply. Throughout the entire Basin, approximately 80 modified-grids have combined well yields of greater than 1 million gallons per day.

Again, the ground-water usage map is based on estimated rates of use at the time of well construction. Actual rates of water usage are known for all industrial and municipal suppliers, who are required to submit production reports as a condition of their water allocation permit. Usage data are available for all permitted systems.

Data are limited on actual production rates for the majority of irrigation systems in the Basin. Several irrigation systems in the Basin do, however, hold water allocation permits, and historical records for those systems show that irrigation withdrawals constitute the majority of water usage during the irrigation season. Also, water usage for agriculture varies widely from season to season, depending on weather and cropping patterns.

Based on historical records, there are numerous surface-water intakes of various capacities throughout the Basin. Surface water is often used for irrigation in many parts of the Basin. These facilities cannot be accurately mapped at this time due to data availability issues. While records exist for surface-water irrigation systems, they were created in the early 1980s and have only been sporadically updated since. Few of these systems have been issued water allocation permits. A single industrial surface-water diversion exists in the Basin, and that is located on the Nanticoke River at the DuPont Seaford plant. This water is used for once-through cooling at the power generating station with a permitted maximum withdrawal rate of 64 million gallons per day.

2.5.4 DATA GAPS AND RECOMMENDATIONS

1. Because of the nature of the sampled media, it is often quite difficult to adequately sample ground water to characterize overall water quality in a large area. However, many programs and agencies are already collecting water samples for various reasons. Therefore, a combined strategy needs to be developed to coordinate, at least within the Department, these various ground-water sampling efforts. This coordination may include programs paying for the analysis of "new" parameters in another programs' wells, or merely developing a more efficient means of storing and exchanging ground-water-quality data. With the exception of the lower New Castle County monitoring network, all of the data used in this assessment were collected for other purposes. There is much useful data just within the Department, let alone other agencies that could help greatly with overall analysis.
2. Due to the large gap in reliable data for irrigation systems, a recommended step is to locate all operating irrigation wells and surface intakes via GPS, and compile updated information on the facilities including verification of identification numbers, and other essential attributes.
3. The location of all facilities with water allocations should be updated and a coverage created in the Department GIS similar to that created for public supply wells.
4. Analyze up-gradient well data from monitored sites to see if there are any regional trends in ground-water quality.
5. Determine more accurate base-flow loading for impacted streams; compare ground-water and surface-water data for interactions.
6. Delineation of all source-water protection areas, such as wellhead areas and excellent recharge potential area.
7. Establish wellhead protection ordinances, Best Management Practices, and/or regulations.
8. Identify intensive ground-water extractive use in areas that may have water availability issues.
9. Accurately define all sub-cropping aquifer areas to help protect the deeper portions of these aquifers.
10. Develop depth to ground-water maps for the entire state that highlight areas with an extremely shallow water table.
11. Review irrigation well water quality for nutrient loading. Incorporate in management plans.
12. Refine regional ground-water flow data with information from all possible sites.
13. Determine ground-water system lag time in various sites throughout the state. This could be very helpful in establishing timetables to see results of Pollution Control Strategies.
14. Future recommendations may emerge on permitting irrigation systems on a priority basis for stressed watersheds in order to properly allocate and manage water resources.

2.5.5 REFERENCES

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