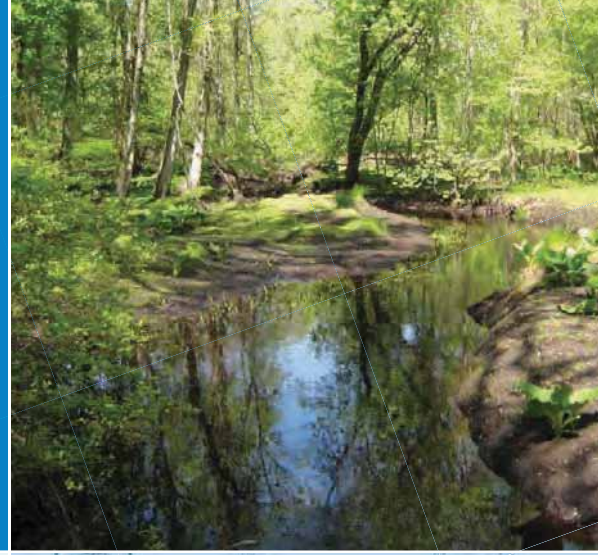
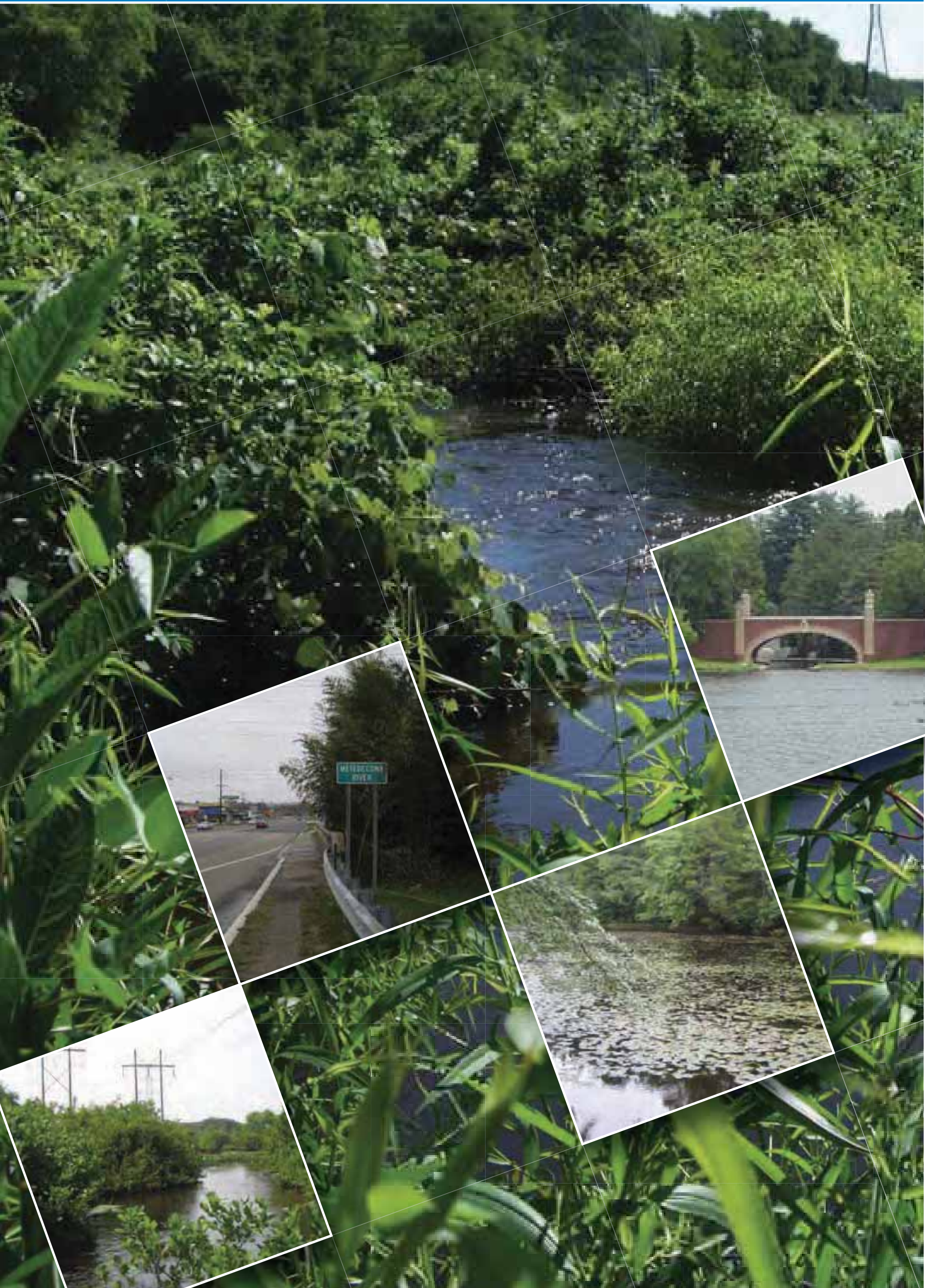
BRICK UTILITIES
THE BRICK TOWNSHIP MUNICIPAL UTILITIES AUTHORITY

Metedeconk River Watershed Protection and Restoration Plan

TASK 3, TECHNICAL ANALYSIS





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Executive Summary

The Metedeconk River is an important resource for Monmouth and Ocean Counties. It is the primary source of potable water for the Brick Township Municipal Utilities Authority (BTMUA) which serves more than 100,000 residents in both counties. Due to its “exceptional water supply significance”, NJDEP designated the river as Category One waterway, which protects it from any measureable degradation in water quality. The Metedeconk River is also northernmost river draining to the Barnegat Bay, one of 28 Congressionally-designated estuaries in the National Estuary Program. The river provides the second highest discharge of fresh water to the Barnegat Bay Estuary, second only to Toms River.

A Metedeconk River Watershed Protection and Restoration Plan is being developed which will ultimately result in a number of mitigation projects for future implementation. A technical analysis of all relevant data concerning the Metedeconk River watershed has been completed and is summarized in this report.

Developed in parallel to this report, BTMUA has completed a visual assessment program in which 83 individual steam segments were evaluated. Results from these visual assessments have also been reviewed and are integrated with water quality data and surrounding land use information, as appropriate. An analysis of the data will be used to identify potential areas for protection or restoration projects that could be implemented during the next phase of the project.

Other watershed studies and investigations conducted over the past 10 years center around a general set of conclusions and recommendations, most focusing on the potential impacts associated with increasing impervious cover within the watershed and excessive nutrient loading of nitrogen and phosphorus. Nitrogen loading to the Barnegat Bay is increasing, and most of the non-point source pollution to the bay is from stormwater runoff. Although the impervious cover is high, since the watershed contains a high percentage of wetlands, well drained soils, and is relatively flat, impacts to the river haven’t yet been significant. However, previous reports indicate that the watershed may be approaching an impervious cover threshold which could be detrimental to the water quality and hydraulics of the river.

The percent of impervious cover within the watershed continues to increase and has increased from 12% to 15% since 1995, using the watershed delineation as specified within this analysis. Since 1995, most of the development has occurred in Jackson, Howell and Lakewood Townships. The highest intensity of development is found in Lakewood, accounting for the largest relative increase in high density residential, commercial and industrial land uses. Lakewood is also projected to be the largest growing municipality within the watershed by far, in which 26,000 new residential units are projected within the next twenty years. Any potential impacts to the Metedeconk River will need to be properly managed. Future development should include Low Impact Development (LID) techniques to the fullest extent practical.

Impacts resulting from increases in impervious cover are beginning to be observed in both water quality (increasing trend in stream conductance and total dissolved solids) and stream flow data. Data collected from the USGS stream gage along the North Branch of the Metedeconk near Lakewood indicate that although there is no discernable change in average annual total flow, the baseflow component is declining. In addition, hydraulic impacts to the river such as increased "flashiness" are beginning to be observed in the data. Hydraulic impacts can only adequately be evaluated on the North Branch of the Metedeconk River. The USGS gage on the South Branch has not been active for more than 10 years. Although it has recently been restored, it should continue to be monitored and maintained so that a complete set of flow data from both branches can be evaluated into the future.

Water supply is a concern for the Metedeconk watershed. The New Jersey Statewide Water Supply Plan projects significant water supply deficits for the Metedeconk watershed based upon population growth and build-out projections. Much of the water use in the watershed is depletive in nature, as wastewater is collected, treated and discharged to the Atlantic Ocean. During summer 2010, numerous water utilities in the region, including BTMUA, experienced record water demands, and a Statewide drought watch was issued by NJDEP. Water conservation programs are recommended. Future water supply needs of Lakewood Township will be significant and a water supply plan for the build-out has not yet been developed.

Stormwater in much of the watershed is either discharged directly to the Metedeconk or its tributaries via stormwater outfalls or detained in basins prior to discharge. Both of these practices are antiquated by today's standards. There are many opportunities for the installation of stormwater BMPs and other restoration projects. In addition, maintenance of stormwater management infrastructure is a concern within all of the watershed municipalities, and a funding mechanism and maintenance tracking system would be helpful to ensure the long-term maintenance of these facilities.

BTMUA implements a robust water quality monitoring program throughout much of the watershed with water quality samples primarily collected along the main stem of the North and South Branches. This monitoring program should be maintained to the fullest extent practical. Additional water quality monitoring of smaller tributaries and groundwater within the watershed should be conducted to more adequately assess potential problem areas as well as the success of future mitigation projects. This expanded monitoring program would require a funding mechanism as well as an implementation strategy.

Total Maximum Daily Loads (TMDLs) for fecal coliform, total coliform and phosphorus are in place for the Metedeconk River, and significant load reductions are required. Many of the TMDL implementation strategies focus on stormwater management issues.

Although previous investigations have cited stormwater runoff as the major source of nitrogen and phosphorus loading, septic systems are also a significant source of nitrogen. The location of parcels on septic should be identified and a regional (watershed) GIS map be developed. In commercial, industrial and high density residential areas where it does not already exist, sanitary sewer service should be extended. Besides high density residential areas, sanitary sewer service may also be required in low and medium density areas, depending on the lot size and housing density. Extension of sanitary sewer will, however, reduce recharge to the aquifer system due to regional wastewater treatment and discharge offshore. This reduced return flow could potentially adversely impact baseflow to the Metedeconk. A more detailed analysis concerning this possible impact should be conducted as sewer service/septic maps were not available at the time of this analysis.

Although nitrogen concentrations at the BTMUA intake remain well below the drinking water standard of 10 mg/L-N, the increasing nitrogen load is potentially impacting Barnegat Bay. Total nitrogen concentrations at the BTMUA intake have recently exceeded 1.5 mg/L-N. Recent passage of the Statewide Fertilizer Bill will help reduce nitrogen loading, but additional mitigation measures should be evaluated.

The results of this technical analysis and the stream visual assessment report are to be evaluated by the Steering Committee and the Stakeholder Advisory Committee so that more refined objectives for the Metedeconk River Watershed Protection and Restoration Plan can be established. Once defined, these objectives will be the foundation for the development of the plan and the mitigation projects to be implemented throughout the watershed.

Section 1
Introduction

The Metedeconk River is an important resource to potable water supply as well as to the Barnegat Bay Estuary. It is considered by NJDEP as a waterway with "exceptional water supply significance" and as such was designated a Category One (C1) waterway in 2004. As a C1 waterway, it is protected from any measureable degradation in water quality (Surface Water Quality Standards rules at N.J.A.C. 7:9B).

The Metedeconk River is the primary water source to the Brick Township Municipal Utilities Authority (BTMUA) which serves more than 100,000 residents within Brick Township, the Ramtown section of Howell Township, Point Pleasant Borough and Point Pleasant Beach Borough. In addition to providing a drinking water source to more than one hundred thousand residents, the Metedeconk River provides the second highest discharge of fresh water to the Barnegat Bay Estuary, second to Toms River.

As the Metedeconk River is a vital resource for drinking water and ecological health, numerous studies have been developed for the Metedeconk River watershed over the past 15 years. These studies have characterized the water quality of the watershed as "good", but note that the buffering capability of the watershed's wetlands and coarse, sandy sediments, would be overwhelmed by continued development and increases in impervious cover. In addition, these studies have identified that water quality issues within the river are primarily due to impacts from stormwater runoff. Total Maximum Daily Loads (TMDLs) have been developed for several areas of the watershed which address fecal coliform, phosphorous, pathogens and total coliform. As the Metedeconk River watershed is already one of the most developed watersheds within the Barnegat Bay watershed, there are serious concerns that continued development and water quality degradation may negatively impact the Barnegat Bay.

The purpose of this report is to provide a technical analysis of all relevant data concerning the Metedeconk River watershed for the protection and restoration plan. Water quality and quantity analyses are included as well as an evaluation of land use and municipal plans and ordinances. Water quality and quantity issues were previously addressed in the Metedeconk River Watershed Management Plan Phase I: Watershed Characterization and Preliminary Analysis in 2000 (herein referred to as the Phase I Report; CDM, 2000) and therefore, many of the analyses evaluate the change in conditions from data that was used during that analysis. Results from the visual assessement project have also been reviewed and are coupled to water quality data and surrounding land use as appropriate. An analysis of the data will be used to identify potential areas for protection or restoration projects that could be implemented during the next phase of the project. The layout of this report is as follows:

Section 2 – Watershed characteristics and summary of previous investigations

Section 3 – Visual assessments

Section 4 – Water quality and water quantity

Section 5 – Regulations and municipal information

Section 6 – Preliminary problem analysis

Section 7 – Summary and preliminary recommendations

Section 8 - References

Section 2
Watershed Characteristics & Previous Investigations

2.1 Municipalities and Sub-Basins

The Metedeconk River watershed is located in southern Monmouth and northern Ocean counties in New Jersey and seven municipalities are included within its boundaries (**Figure 2-1; Table 2-1**). Almost the entire watershed is included within five municipalities, namely Brick, Freehold, Howell, Jackson and Lakewood Townships. Millstone and Wall Townships make up less than 1% of the watershed area. The topography of the Metedeconk River watershed is characterized by a general low relief with maximum elevation of 320 feet above mean sea level in Millstone.

The flow of the Metedeconk River is divided between the North and South Branches which are fed by dozens of tributaries within eleven sub-basins or HUC 14 watersheds (**Figure 2-2**). For the purposes of this study, the HUC14s will be referenced by the alternate ID as shown in **Figure 2-2** (e.g. NB1, SB1, etc). These alternate identifiers are similar to those introduced in the Phase I Report (CDM, 2000); although it should be noted that NB2 includes the formerly identified NB2 and NB3.

2.2 Summary of Previous Investigations

Numerous studies have been conducted within the Metedeconk River watershed over the past 10 years. A common theme throughout the various recommendations is land use management and stormwater control through both structural and non-structural means due to excessive nutrient and coliform loading. Development of a regional stormwater management plan was also recommended by several investigations, including the Preliminary Metedeconk Watershed Study for Brick Township Municipal Utilities Authority prepared by Owen, Little and Associates in 1988. In addition, the establishment of watershed committees involving stakeholders from all municipalities, including outreach and development of educational programs was also a consistent recommendation.

Major findings and recommendations of reports that have been prepared over the last 10 years are briefly summarized below.

2.2.1 Metedeconk River Watershed Management Plan – Phase I: Watershed Characterization and Preliminary Analysis, 2000

The 2000 assessment of watershed conditions suggests that while the health of the watershed is primarily of good quality, it is on the threshold of experiencing degradation as urbanization increases.

- Summary of water quality data – Water quality in the river was characterized as very good. The parameters of some concern are total organic carbon, dissolved phosphorus, lead, and cadmium. Phosphorous (P) loading was a concern, particularly since the river is P limited.

- Watershed Management Model (WMM) results – A screening level model was used to assess land use based pollutant loading rates from the townships. Total Suspended Solids (TSS) load is greatest in Lakewood (150-175 lb/ac-yr), Phosphorus (P) load is greatest in Brick and Lakewood from commercial and low and medium density residential areas (0.5-0.6 lb/ac-yr), Nitrate (NO_3) load is the greatest from the urbanized areas of Lakewood, and the medium and high density residential areas in the upstream portions of Lakewood and downstream portions of Jackson (3.0-3.2 lb/ac-yr), and Zinc loading is greatest from the industrial/commercial areas in Howell.

- Future land use concerns – There is high potential for the loss of open space throughout the watershed. At the time, the watershed was 60% open space, however, zoning would allow for only 18% open space at full build-out. Most of the existing open space was zoned for residential development. At full build-out, 63% of the watershed would be converted to medium or low density residential areas. This change in land use would likely result in significant changes in volume and peak runoff, and potential degradation of water quality and damage to the riparian habitat. Zoning at the time would also allow for significant development in the 100 ft riparian corridor.

- Impervious surface concerns – The watershed was 10.8% impervious cover in 1999 (using a different watershed boundary than used in this 2010 analysis), which is at the threshold of becoming a medium priority watershed for corrective measures to protect aquatic habitat and water quality. At this level of imperviousness, both fish and aquatic insect diversity are declining and wetlands and water quality are threatened. At full build-out, the percent impervious surface would increase to 16%, indicating that existing zoning is not sufficiently protective. For reference, the impervious surface cover as an indicator of stream health is listed below (from Schueler, 1995):

% Imp.	Channel Stability	Water Quality	Stream Biodiversity	Pollutants of Concern	Characteristic
0-10	Stable	Good to Excellent	Good to Excellent	Sediment & Temp only	Stable
11-25	Unstable	Fair to Good	Fair to Good	…& nutrients, metals	Unstable
26-100	Highly unstable	Fair to Poor	Poor	…& bacteria	Highly unstable

- Water quality recommendations – Jackson and Lakewood have the greatest potential to impact water quality at build-out, and measures to reduce the hydrologic and water quality impact of future development were recommended.

- Municipal issues – At the time of the report, none of the major upstream Townships had developed a stormwater management plan. Wetland protection could be enhanced in ordinances as development proceeded.

- Water supply – The report indicated that the need for backup groundwater supply and a storage reservoir for BTMUA would be required under extreme demand scenarios.

2.2.2 Metedeconk Watershed Source Water Stewardship Exchange Team Report, 2003

The Metedeconk Watershed was the focus of a USEPA-funded Source Water Stewardship Exchange pilot project designed by the Trust for Public Land in partnership with the University of Massachusetts and US Forest Service. In June of 2003 a panel of five experts known as the "Exchange Team" participated in a week long endeavor involving various meetings to assess the Metedeconk River watershed, identify impacts to water quality and quantity and develop strategies to address these potential impacts.

The Exchange Team had the following conclusions and recommendations:

- The Metedeconk River watershed is at a point in which additional impacts from development may result in an exponential increase in impacts. The percent of land cover in the watershed that is impervious exceeds the 10% threshold in which water quality impacts have been documented. Significantly degraded water quality has not been observed in the watershed due to the fact that much of the headwaters within the watershed are within wetlands, riparian forests remained intact, there is a mild topography, and the sandy nature of the soils promotes infiltration.

- Baseflow makes up a vast majority of the flow in the Metedeconk (60-80%). Therefore groundwater protection is critical and groundwater quality has a direct impact on the quality of the water within the Metedeconk.

- A lack of a coordinated approach to stormwater and resource management along with inconsistent municipal ordinances presents a significant threat to the health of the watershed.

- A "Metedeconk Watershed Forum" should be established consisting of elected officials and municipal utility authorities. An "Environmental Commission" should be created to handle water quality and land use protection.

- A Metedeconk Watershed Association should be developed or the existing Manasquan River Watershed Association could possibly be expanded to cover the Metedeconk. This non-profit organization could be responsible for community involvement and educational activities.
- A Regional Stormwater Management Plan should be developed.
- A unified watershed database should be developed to consolidate data from various agencies. In addition, parcel data should be converted into electronic format and placed into a unified GIS.
- Protect and restore critical natural land
- Utilize maps produced by UMass as the foundation, but additional data and GIS could be integrated to identify critical lands.
- Restore riparian forests on marginal land, defined as “small tracts of open space or abandoned land between commercial and residential development or urban infrastructure”
- Sustainable development with conservation should be implemented;
- Utilize low impact development and conservation development techniques with the lead from the established Metedeconk Watershed Forum.
- Encourage growth around existing infrastructure
- Identify lands that will have the least impact to water resources and encourage development in those areas – Stafford Township and Howell are examples.
- Update ordinances to allow for low impact development
- Implement low impact development demonstration projects
- Create funding sources:
- Create a “funding quilt” that combines funding sources
- Establish an open space tax in Lakewood and Wall Townships
- Establish a stormwater utility or have existing utilities charge a Watershed Protection Fee and have these utilities provide stormwater management.

2.2.3 Conservation, Restoration, and Stormwater Management Priorities for Source Water Protection in the Metedeconk River Watershed, 2003

As part of the USEPA-funded Trust for Public Land Source Water Stewardship Project, the University of Massachusetts (Barten et al, 2003) developed conservation, restoration, and stormwater management priority indices within the Metedeconk River watershed in order to evaluate where and what type of management technique would be most beneficial to the water quality of the Metedeconk River at the BTMUA intake. The study determined the following:

- Wetlands and riparian forests in the western portion of the watershed are largely intact and that conservation of these wetlands and riparian forests would be the ideal management measure. These lands play a crucial role to the overall water quality of the Metedeconk River, as they serve as the headwaters of the watershed. Due to the undeveloped nature of these areas, water quality from this area is high.

- Within the central region of the watershed, urban development is evident and there are various tributaries with one or more breaks in the riparian forest along the stream(s). Various segments have also been identified for restoration.

- Areas in the eastern portion of the watershed, upstream of the BTMUA intake, generally have continuous riparian forests, but there are particular areas, namely Lake Carasaljo, a portion of the north branch in Lakewood, downstream of Lake Shenandoah where stormwater management activities would be beneficial as riparian areas are depleted. Various segments have also been identified for restoration.

- An overall conclusion of the study was that the large percentage of impervious surface coverage, high percentage of developed land, and limited forest cover were a concern and would be detrimental in many other watersheds with different hydrogeologic characteristics than the Metedeconk. The reasons why the water quality within the Metedeconk may continue to be adequate are a generally flat topography, deep, sandy soils and the large percentage of wetlands. However, there exists a threat of overwhelming these sinks which is of concern.

- In addition, the results of the study show that protection of the riparian corridor is of critical importance for maintaining Metedeconk River water quality and hydrologic function.

2.2.4 Assessment of Land Use Change and Riparian Zone Status in the Barnegat Bay and Little Egg Harbor Watershed: 1995-2002-2006, 2007

The purpose of this Rutgers University study was to evaluate the condition of the riparian zones within the Barnegat Bay and Little Egg Harbor watersheds.

- The estuary is eutrophic due to excessive nutrient loading, particularly from nitrogen.

- The riparian zone in the Metedeconk River watershed continues to be developed and is "significantly compromised with > 20% of the zones in altered land use". Urban land use within the watershed has increased from 25.1% in 1995 to 29.8% in 2006.

- The Metedeconk River watershed was among the areas with the highest percentage of altered land in the riparian zone. The Metedeconk River had approximately 24% of land within the riparian zone as "altered land" and is a high priority sub-basin to the Barnegat Bay and Little Egg Harbor watershed.

- Intact riparian zones should be the focus of conservation efforts and open space preservation;

- Restoration efforts to reduce nitrogen loading should focus in riparian areas adjacent to agricultural areas and residential development, although educational programs would be required;

- Re-vegetation of large tracts of barren land should also be targeted.

2.2.5 Barnegat Bay 2020: A Vision for the Future of Conservation, 2008

The Trust for Public Land (TPL) summarized the Barnegat Bay watershed and identified open space preservation land acquisition needs throughout the watershed. Major conclusions and recommendations, as they relate to the Metedeconk River, are as follows:

- Throughout the Barnegat Bay watershed, the Toms River and Metedeconk River basins are the most heavily developed and have the highest concentrations of volatile organic compounds and heavy metals as compared with other basins in the watershed.

- Nutrient loading into Barnegat Bay from fertilizers contribute to eutrophic conditions within the bay;

- The report cites that approximately 29% of excess nutrient loading is due to organic nitrogen in residential and commercial fertilizer

- Stormwater runoff from industrial and urban land accounts for about 71% of non-point source pollution in the bay.

- Eutrophication in the bay is worse near the Metedeconk River than in the southern, less developed portions of the Barnegat Bay watershed.

- Low impact development techniques (LID) and stronger design standards are critical in the Metedeconk River watershed to protect the bay as development continues.

2.2.6 Phase I Diagnostic-Feasibility Study of Lake Carasaljo, 2005

In April of 2005, Birdsall Engineering (2005) conducted a study of Lake Carasaljo for Lakewood Township. The study evaluated the type and source of pollutants entering the lake as well as restoration and protection options.

The major conclusions of the study were:

- Primary pollutants to the lake were phosphorous and fecal coliform;
- Stormwater runoff is the primary source of pollutants to the lake;
- Waterfowl contribute a significant source of fecal coliform, but still less than stormwater;
- Turbidity is a problem and is likely due to stormwater runoff and excessive phytoplankton;
- The lake can be characterized as eutrophic due to its high nutrient concentration and excessive coverage of macrophytes, primarily fanwort.

The major recommendations of the study were as follows:

- Mitigation methods need to focus on stormwater runoff.
- Land use management for the densely developed area surrounding the lake as well as the lesser developed areas of the watershed is necessary in addition to stormwater management through both structural and non structural techniques and waterfowl management.
    - Primary watershed (more densely developed area within the immediate vicinity of the lake) – use of structural stormwater management techniques, particularly those that focus on phosphorous removal, was strongly recommended and identification of potential sites should be a priority.
    - Secondary watershed (outside immediate vicinity and upstream) – land use management including open space preservation and low impact development methods.
    - Establish a lake management committee and develop public education and outreach programs.

- In an attempt to control the abundance of fanwort, Lakewood should continue winter drawdown practices. In addition, chemical treatment using aquatic herbicides (AVAST!) could supplement the drawdowns and watershed management practices.

- Waterfowl management should be conducted including installation of a vegetative buffer around the lake.

- The development of a regional stormwater management plan was strongly recommended.

2.2.7 Contributions of Nitrogen to the Barnegat Bay-Little Egg Harbor Estuary: Updated Loading Estimates, USGS, 2009

- The assessment of the nitrogen loading to the Barnegat Bay-Little Egg Harbor Estuary (BBLEH) was updated by USGS and the Barnegat Bay National Estuary Program in 2009. The study indicates that the Toms River and Metedeconk River basins account for more than 60 percent of the nitrogen load to the estuary from surface water runoff. This is significant information, for as indicated in the report, the BBLEH is classified as highly eutrophic and the ecological health of the estuary is particularly susceptible to the effects of nutrient loading.

- Excess nitrogen can lead to toxic and nuisance algal blooms, changes in species populations, low dissolved oxygen, and an overall decline in water quality. Nitrogen can enter the estuary as a component of stormwater runoff, baseflow, atmospheric deposition, ocean water influxes, and through the release of nitrogen in bottom sediments. Nitrogen loads from the major river basins were calculated using a flow-weighted approach. Water quality data were compiled from NJDEP, the NJ Pinelands Commission, and USGS for the water years 1987 through 2008. The nitrogen load in surface water runoff was estimated using linear regressions developed by Baker and Hunchak-Kariouk and the percentage of urban development in the ground-water discharge area of the BBLEH.

- The updated load for the Metedeconk River basin incorporated streamflow and water-quality data collected at stations on both the North Branch and South Branch. This data was not available during the 2001 analysis. The previous analysis estimated a total nitrogen load of 77,000 kg/yr (19.7 percent of the overall surface water discharge load to the BBLEH). The 2009 estimate was increased to 86,000 kg/yr (21.2 percent of the surface water discharge load). The nitrate load was 50,000 kg/yr. The USGS attributes the increase in total nitrogen to possibly a more complete set of water quality data and/or increased development in the basin. The area weighted load for total nitrogen and nitrate were 434.8 kg/km^2/yr and 232.5 kg/ km^2/yr for the North Branch and 535.5 kg/ km^2/yr and 348.1 kg/ km^2/yr for the South Branch (1987-2008).

- The median concentration of total nitrogen and nitrate for the North Branch between 1987-2008 was 0.87mg/l and 0.49 mg/l, respectively. Likewise the median concentration of total nitrogen and nitrate for the South Branch was 0.86mg/l and 0.50 mg/l, respectively. The basins were divided into categories of greater than 10% urban land cover and less than 10% urban land cover (with the North and South Branches in the > 10% urban land cover). For comparison, the average nitrogen and nitrate concentrations for the basins with less than 10% urban land cover were 0.27 mg/l and 0.02 mg/l.

2.3 Land Use Patterns

Land use within the Metedeconk River watershed was provided by the New Jersey Department of Environmental Protection (NJDEP) Bureau of Geographic Information Systems. All data were analyzed using GIS and existing (2007) land use data were documented and compared with previous land use data (2002, 1995/1997) to evaluate changes in land use over time. NJDEP has identified over 70 different land use types in the 2007 land use database. For the purposes of this analysis, the land use types were consolidated into 12 separate categories as follows:

Agriculture
Commercial
Forest
High Density Residential
Medium Density Residential
Low Density Residential
Mixed Urban
Transportation/Communications/Utility
Industrial
Urban Open Space (which includes stormwater basins)
Water
Wetlands

Existing (2007) land use is shown on **Figure 2-3** and summarized by municipality in **Table 2-2.** Existing land use is shown for each Township on **Figures 2-3a-g. Table 2-3** documents the corresponding land use for the same categories in 1995/1997 and **Table 2-4** documents the change in land use by municipality. Existing land use, 1995/1997 and the change in land use by HUC 14 is shown in **Tables 2-5, 2-6, and 2-7**, respectively.

On a watershed scale, the largest changes are clearly the loss of forest to residential, commercial and industrial development. The increase in the water land use category is likely a function of wet or clogged retention basins being depicted as surface water from an aerial photograph and therefore being designated "water" by the NJDEP. The loss of almost 650 acres of wetlands is also likely a function of how the wetlands were delineated from aerial photographs by the NJDEP. Wetlands are identified by the aerials, but when field surveys are conducted, it is possible that the land use isn't actually a wetland or that the field designated area is different from the aerial analysis.

From a municipality and acreage basis, Jackson Township has realized the most residential development since 1995. However, more than 50% of the development that has occurred was low density residential, which in general, will pose a relatively low risk to the health of the watershed (as opposed to medium and high density residential or industrial land uses). Howell and Lakewood Townships have the next highest residential growth rate (from a land use acreage basis) with Lakewood showing the highest number of acres of high density residential developed since 1995 / 1997. Freehold and Brick Townships have shown relatively little additional development since 1995. Almost all of Freehold Township's residential development has been in low density residential whereas most of Brick's has been medium density residential.

Lakewood Township shows the highest development with regard to commercial and industrial land use followed by Howell and Jackson Townships.

From a HUC14 basis, the change in acreage by land use between the South Branch and North Branch is similar, although the South Branch has undergone more than five times the development of high density residential land uses.

Figure 2-4 shows generalized changes in land use in which the 13 categories above were simplified into Open or Developed (agriculture and water uses remained the same classification). In evaluating the changes in land use over time, the 2002 data were also evaluated. When the before and the after are the same it means there was a change in one of the original 70 land use categories but would be in the same consolidated land use category. For example, the change for an area that shows Developed / Developed might have been a Residential to a Mixed Urban. Or, an Open / Open might be a Coniferous Brushland to Coniferous Forest. In doing this analysis, there is some overlap that occurs which results in some non-intuitive classifications. Overlap areas represent areas that changed between 1995 and 2002 and then changed again between 2002 and 2007. For example, there may have been a large residential development built between 1995 and 2002 that show as a change from Agriculture to Developed. However, between 2002 and 2007 parts of the development, on the fringe or areas that may never have been developed, have started to revert to forest. These areas would show a change from 'Developed' to 'Open' in the 2002 to 2007 layer.

In addition, there may have been changes within a particular simplified land use (open or developed). For example, the change for an area that shows Developed / Developed might have been a Residential land use category in 1995, but was changed to a 'Mixed Urban' in 2007. An Open / Open change designation may be a change from 'Coniferous Brushland' to 'Coniferous Forest'. The purpose of Figure 4 is only to highlight where development occurred. Due to the many potential combinations of land uses from the 13 categories (originally more than 70), specific land use changes per parcel would not be easily identifiable.

Figures 2-3a-g also include the existing NJDEP approved sanitary sewer service area (as depicted by NJDEP). Discharge from septic systems to groundwater can have an adverse impact on water quality, particularly for nitrate as nitrogen. Within the past 10 years or so, a lot of focus has been given to nitrate in groundwater as it poses not only a threat to drinking water supplies (the NJDEP drinking water standard for nitrate as nitrogen is 10 mg/L-N), but can lead to excessive nitrogen loading into rivers which in turn provide an excessive load to coastal embayments, which are often nitrogen limiting. Therefore, excessive nitrogen loading may lead to eutrophic conditions.

Although New Jersey currently utilizes methods to limit residential development to lot sizes large enough to allow for nitrate dilution (Hoffman and Canace, 2001), many developments were constructed long before these methods were enforced and therefore lot sizes may not be appropriate for adequate nitrate dilution. Granted, many of these areas are connected to public sewer, although in older areas that were in place before sanitary sewers were made available may still be on septic. The NJDEP coverage map has been coupled with any readily available data from the towns (primarily sewer service maps generated from the NJDEP database), but there currently isn't a GIS database that is available for actual sewer connections. Having this database developed may aid in targeting particular areas for additional monitoring and perhaps mitigation.

In addition to land use designations, **Tables 2-2 through 2-7** also indicate the percentage of impervious cover within the watershed. Impervious cover estimates from previous studies using 1995/1997 land use land cover data (see below) have ranged from 10.8% (CDM, 2000) to 17% (Barten et al, 2003). However, each of these studies has used a different watershed boundary definition for the Metedeconk River. For example, the Phase I Report does not include CFL1 (HUC14 identifier 02040301040020) and therefore the total watershed area encompasses 44,077 acres. In contrast, the UMass study includes the Beaver Dam Creek HUC14 which is developed and approximately 5,177 acres in size. Although the Beaver Dam Creek is within the Metedeconk HUC11, it is separate from the other HUCs in that it discharges directly to the estuarine environment.

Using the latest watershed boundary for the Metedeconk, the overall impervious cover has increased from 12% in 1995/1997 to 15% in 2007 (**Figure 2-5**). On a municipal basis, the highest amount of impervious cover is in Lakewood Township with 2,460 impervious acres within the Metedeconk River watershed. The largest increase in impervious surface since 1995/1997 was in Jackson and Lakewood Townships, having increases of 487 and 438 acres, respectively. On a HUC 14 basis, the most impervious surface is found within NB2 and NB5, followed by SB4 and SB5. The lowest amount of impervious surface is found at the headwaters within NB1 and

SB1. The largest increase in impervious surface by HUC was in the South Branch, within SB3 and SB5 increasing by 261 and 190 impervious surface acres, respectively.

2.4 Zoning Patterns

Zoning patterns for each township were acquired from the individual townships for Brick, Freehold and Howell Townships. Zoning data for Jackson and Lakewood Townships was acquired through the Ocean County Planning Department.

Zoning maps for each township are shown on **Figures 2-6** through **2-10** for the five largest municipalities in the watershed. As shown on the maps, Freehold Township and Howell Township generally have low to very low residential density zoning along the main stem of the river, with the exception of the Route 9 corridor in Howell.

The vast majority of the southern portion of Freehold Township is zoned Rural Environmental (RE), which allows a minimum of 10 acres per each building lot. There are a few smaller areas of existing homes with a Rural Residential (RR) – 5 acre lot size and R-80 – 2 acre lot size scattered within the watershed. The RE zone is not served by public sewer and contains lands with a prevailing high water table, high recharge capability for the regional aquifer, and other environmentally sensitive areas such as wetlands and floodplains. The RE zone also allows for parks, golf courses and cluster subdivisions from 3 acre to 10 acre lot sizes in order to preserve and not disturb the remaining tract area.

Although a build-out analysis was beyond the scope of this task, “open” land use designations from the NJDEP 2007 land use / land cover database (urban open, vacant, forest, etc) were coupled with the zoning coverages to determine what could be developed within each town and HUC. This would be land that is currently classified as an open land use (open space, recreation, vacant, etc), that is currently zoned for development (residential, commercial, or industrial). A summary of “developable land” within each municipality is listed in **Table 2-8**. Most of the potential development is to residential land uses. As shown on the table, Howell and Jackson Townships have the most potential development, on an acreage basis. Most of the developable land in Howell, however, is zoned low density residential (2 – 6 acre zoning). In Jackson Township, much of the existing land use surrounding the Metedeconk River is wetlands and forests, although much of it is currently zoned residential, commercial, or industrial.

A fair amount of acreage of developable land is also available in Lakewood Township. Much of the “developable” land is currently zoned medium-high density residential or industrial. The current industrial area in CFL-1 is presently somewhat broken up by patches of forest. These forested areas are also zoned industrial and may allow for the impervious cover in this area to be more connected. Should this development move forward, best management practices should be utilized in an effort to maintain a connected network of open space corridors and preserve the ecological function of the existing buffers. With new more high-density development there is an opportunity to explore innovative LID techniques. The areas in NB5 and SB5 that are currently forest and urban open space are currently zoned as open space.

It's important to note that the developable land presented in **Table 2-8** is a somewhat crude analysis and its purpose is only to estimate a relative developable area for each of the townships. The developable acreage does not account for the number of units, setbacks, Metedeconk River riparian buffer width, etc. By no means do these data replace any more detailed evaluations that may have been conducted prior to this study nor should the acreage presented in **Table 2-8** be used for any detailed planning analyses without first consulting the planning departments of the individual municipalities.

2.5 Hydrogeology

Most of the flow within the river occurs as base flow discharging from the unconfined Kirkwood-Cohansey aquifer system. Because of the importance of baseflow to the Metedeconk River, changes in land use and rapid growth in Ocean and Monmouth counties are cause for concern because of the impact of groundwater withdrawal and groundwater quality, as well as changes to the pattern of groundwater recharge on the underlying aquifer system.

The Kirkwood-Cohansey aquifer system is characterized by a southeastward dipping wedge of unconsolidated deposits of sand and gravel with interbedded layers of silt and clay. The system is actually composed of two units, the Cohansey Sand and the upper part of the Kirkwood Formation, but as they are hydraulically well connected, they act as a single aquifer system. A representative cross-section is shown on **Figure 2-11**. The lower portion of the Kirkwood Formation is composed of primarily clay and acts as a thick confining bed which limits hydraulic connection to underlying aquifers and represents a regional confining unit. The sediments within the Kirkwood-Cohansey are generally transmissive having horizontal hydraulic conductivity ranges between 9 – 140 ft/day (CDM, 2000) and is a productive aquifer system. The water table ranges from over 150 feet above mean sea level in Millstone to sea level where it discharges to the Barnegat Bay (Watt et al, 1994).

As discussed later in Section 3 of this report, groundwater flow and water quality within the Kirkwood-Cohansey system is critical to the health of the Metedeconk River watershed as baseflow accounts for almost 70% of average annual total flow. During periods of low precipitation, baseflow makes up 100 percent of the flow, making maintenance of baseflow a high priority for watershed management.

Although the primary aquifer system is the Kirkwood-Cohansey, the Vincentown Aquifer outcrops in the northwestern portion of the watershed (**Figures 2-11 and 2-12**). This area represents a recharge area to the Vincentown, however, and since the Vincentown is mostly confined by the Kirkwood Formation, it will not contribute to baseflow to the Metedeconk. In addition, only a very small portion is within the Metedeconk River watershed (approximately 240 acres).

2.6 Annual Precipitation and Groundwater Recharge

Average annual precipitation over the watershed varies between 43 and 48 inches, and rainfall is fairly evenly distributed over the 12 months of the year (**Figure 2-13; Figure 2-14**). There may be a slightly higher amount of precipitation in the central and western portions of the watershed as suggested by data from Divisions 2 and 3 as specified by the Office of the New Jersey State Climatologist (ONJSC; **Figure 2-13**). Data from the ONJSC database are averaged over a large area, while the BTMUA data are collected from their facilities located within the watershed and may be more representative. Data from the BTMUA weather station are available from 1997 to present. Although older data are available from the ONJSC, they are not utilized in this analysis to maintain a consistent time period for comparison to BTMUA data as well as to use more current data which would be more representative of recent conditions.

Precipitation evaporates back to the atmosphere, infiltrates the groundwater system as recharge, or runs off directly to the river as stormwater runoff. Average annual evapotranspiration (ET) is about one-half the amount of precipitation, or about 23 inches (Watt, 1994; that study utilizes a weather station in Hightstown which indicated average annual precipitation of 1980-1989 was 45.9 inches).

The aquifer system receives recharge through infiltration of precipitation. Infiltration, unlike precipitation, is not evenly distributed throughout the year. During the winter months, most of the precipitation that falls eventually infiltrates and recharges the groundwater system. Some may be lost to pervious area runoff if the ground is frozen or may runoff in the form of snow melt. During the summer, ET is high, and little recharge occurs except during large storm events. Estimated annual average recharge to the Metedeconk River watershed is approximately 15 inches per year (Watt et al, 1994, Nicolson, 1997).

2.7 Metedeconk River Flow Characteristics

There are three USGS stream gages that have been used to collect flow data along the Metedeconk River, although only one of the gages is currently active (**Figure 2-1; Table 2-9**). Since gage 01408120 has continuous streamflow measurements for a significant period of time, this gage was used for flow analyses. This gage is also a "real-time" gage that can be accessed online (http://nj.usgs.gov). It should be noted, however, that this gage is representative of flow from the North Branch only. Although a baseflow separation analysis could be conducted on the South Branch, data would not be representative of any changes that have been occurring in the watershed over the past 11 years. Although there are some data for 1972 and 2010, in order to calculate annual averages, the calendar year was used and thus only data from 1973-2009 were utilized. At the time this report was prepared, the full 2010 data set was not available.

Because total stream flow is very dependent on changes in climatic and / or meteorological conditions (**Figure 2-15**), a baseflow separation analysis was conducted so that total flow could be divided into corresponding runoff and baseflow components. Baseflow is mostly comprised of groundwater discharge to the stream, while runoff results from overland discharge. Regarding potential development impacts to the Metedeconk River, increased impervious cover would generally increase runoff and decrease baseflow. Average annual total flow, however, may not necessarily be directly affected. Rather, the baseflow component of total flow would be reduced (and runoff increased). Other potential impacts may be observed through an increase in peak discharge rates, and the fraction of the year that daily mean discharge in a stream exceeds annual average discharge (CWP, 2003; Konrad and Booth, 2002).

2.7.1 Total Flow

Total stream flow statistics for the period of record (beginning in 1973 representing the start of a full calendar year of data) as well as from 1990 to 2009 (representing the period after which data were summarized in the Phase I Report) are summarized in **Table 2-10**. Average annual stream flow is shown on **Figure 2-15** and average monthly discharge is shown on **Figure 2-16** for the total period of record (1973-2009). As expected, on average, lowest flows occur during the summer months. A cumulative distribution frequency curve for USGS gage 01408120 is shown on **Figure 2-17** which illustrates that approximately 90% of the time, flow within the North Branch of the Metedeconk River (at the gage location) is less than 100 cfs. For comparative purposes to the South Branch, a second curve is shown for both 01408120 and 01408140 during the overlapping time periods (June 1992 through March 1999) on **Figure 2-18**. Although flow in the North Branch is greater for the higher flows (highest 18%), in general, flow within the South Branch is slightly higher for lower flows even though the drainage area is almost 27% smaller. This may potentially be attributed to the North Branch gage experiencing more groundwater withdrawals at the time which would reduce baseflow to the river. The former Parkway Water Company wells are upgradient of the North Branch USGS stream gage, whereas there are no community supply wells screened in the Kirkwood-Cohansey upgradient of the South Branch gage (see Section 3).

As development increases, the amount of impervious cover increases. This increase in impervious cover can result in changes in stream flow in that more discharge will be in the form of runoff as opposed to baseflow. Impervious cover has been correlated with changes in potential stream quality. In general, as mentioned above, watershed percent impervious cover between 10-25% is considered “impacted”; 25 – 60% is considered “non supporting” and > 60% is considered urban drainage (Schueler, 1995; CWP, 2003). Besides potential water quality issues, there are also potential hydrologic impacts from increased impervious cover (channel stability, stream biodiversity).

In order to evaluate if changes in the hydrology of the Metedeconk have been observed in the measured stream flow data from the North Branch USGS gage, four statistics were evaluated as conducted in Konrad and Booth (2002). These were annual mean discharge (Q_{mean}), the fraction of the year that the mean discharge was exceeded (T_{Qmean}), the 7-day low flow (Q_{min}) and the annual maximum discharge (Q_{max}). As mentioned above, another potential change in stream flow is an increase in runoff / decrease in baseflow over time, which is evaluated in the next section through baseflow separation techniques.

As described in Konrad and Booth (2002), changes in Q_{mean} are not necessarily reflective of urban development unless there are bulk changes in shallow groundwater withdrawal or interbasin transfers of stormwater are large. Although there has been a reduction in the amount of groundwater withdrawal for community potable supply over the past several years, there are no stormwater discharges that originate outside of the Metedeconk River watershed. Changes in Q_{mean} are generally reflective of a change in stream depth and wetted surface area which may have an impact on the biological community.

Konrad and Booth (2002) also defined T_{Qmean} as the fraction of the year that daily stream flow exceeds annual mean discharge for that given year. This term is also commonly referred to as "flashiness" (Henshaw and Booth, 2000). In general, there is in inverse correlation between runoff and T_{Qmean}, particularly for streams that exhibit a high percentage of their flow as groundwater baseflow. "Flashier" streams will have a lower value of T_{Qmean}. For example, if a stream is completely ambient, then stream flow would be higher than the average annual flow 50% of the time and lower than the average annual flow 50% of the time, or have a T_{Qmean} of 0.50. In the opposite extreme, if a stream was very flashy and had one large event every week that exceeded the average, then the T_{Qmean} would be (52 / 365), or 0.14. So, T_{Qmean} decreases as a stream becomes more flashy.

As with Q_{mean}, the relationship between Q_{min} and increases in development are not consistent, although a decreasing trend in Q_{min} may indicate that the biologic community is being threatened. The Q_{min} is not the same as the 7Q10, although the 7Q10 is calculated from Q_{min} (the consecutive 7-day low flow, or Q_{min}, that has a recurrence interval of once every 10 years is the 7Q10).

Trend plots for each of the four statistics are shown on **Figure 2-19** and are listed in **Table 2-11** for the period of record of the North Branch stream gage. Also shown in **Table 2-11** are the associated Mann-Kendall p values. The Mann-Kendall trend analysis was used to determine if there was statistical evidence that a trend existed. The null hypothesis, Ho, is that a trend does not exist. The Mann-Kendall analysis is based on the S-statistic, the variance of the S-statistic, and p, which is compared to alpha. More detailed information on the Mann-Kendall analysis can be found in the literature (Gilbert, 1987; Gibbons, 1994; Helsel and Hirsh, 2002; Neislen, 2006). For a 90% confidence, alpha = 0.10 and 0.05 for 95% confidence. If p is less than a given alpha, then a trend exists at that particular confidence interval.

An important point is made in Neislen (2006), "Failing to reject Ho does not mean that it was "proven" that there is no trend. Rather, it is a statement that the evidence available is not sufficient to conclude that there is a trend at the specified confidence level." Therefore, a trend may exist, but just not at that particular confidence level. For example, Q_{max} may have a weak upward trend (positive S-statistic), but it is not statistically supported at the 90% confidence interval. Similarly, declining trends in T_{Qmean} and Q_{min} are not statistically supported at the 95% or 99% confidence interval.

2.7.2 Baseflow and Runoff

As mentioned above, previous investigations have indicated that most of the total flow within the Metedeconk River is from baseflow. The Phase I Report (CDM, 2000) indicated that between the period of 1973 to 1989, baseflow accounted for between 63-79% of total flow, averaging 71%. As increases in development and impervious cover may reduce baseflow and increase runoff, baseflow separation analyses were conducted. Baseflow reduction from impervious cover isn't the only mechanism through which development can reduce baseflow. The installation of sanitary sewers can also have a significant impact on baseflow as recharge to the aquifer in the form of septic return is removed, and sewage is treated and discharged offshore. However, total flow declines as well. A good example of this is observed in Nassau County, New York, where sanitary sewers were installed throughout the county from the 1950s through the 1980s due to elevated nitrogen in groundwater from septic system discharge. Total flow to Bellmore Creek has declined from a pre-sewering annual average that often exceeded 10 cfs to an average annual discharge that has exceeded 5 cfs only 6 times since 1985.

Baseflow separation analyses were conducted on the USGS gage 01408120 for the period of record. The data obtained from the discharge monitoring station provided daily readings of total flow. These data were separated into baseflow and surface runoff using the "sliding interval" technique described by White and Sloto (1990). The sliding interval technique assigns the baseflow for a particular day as the minimum daily flow experienced over a range of days beginning before and ending after the particular day. The time period interval is based upon the time of concentration and is determined by the drainage area. The baseflow value is subtracted from the total flow (as recorded by the USGS gage) to calculate direct runoff at that particular day.

For extended precipitation events, the sliding interval technique may over-estimate baseflow for time steps associated with wet-weather events. Therefore, a hydrograph analysis was also conducted using digital filter methods. Digital filter algorithms take into account flow duration as opposed to local minimum methods used in manual baseflow separation analyses, which allow for better estimations of baseflow associated with wet-weather events. For this analysis, the Web based Hydrograph Analysis Tool (WHAT; Lim et al, 2005) was used. WHAT is a web-based baseflow separation model that uses USGS stream flow gage data as input. The tool has two digital filter algorithms available to calculate baseflow values: the BFLOW and Eckhardt digital filters. As discussed in Lim et al (2005), the Eckhardt digital filter should match base flow from measured values and was utilized for the Metedeconk analysis.

The Eckhardt digital filter is applied as follows (from Lim et al, 2005):

$$b_t = \frac{(1 - BFI_{\max}) x\alpha + b_{t-1} + (1-\alpha) x BFI_{\max} x Q_t}{(1-\alpha) BFI_{\max}}$$

Where b_t is filtered baseflow at time, t; b_{t-1} is the filtered baseflow at the t-1 time step; BFI_{max} is the maximum value of the long term ratio of baseflow to total flow; α is the filter parameter and Q_t is total stream flow at time step, t. Based on previous investigations, it is recommended that values of BFImax for perennial streams in porous aquifers (like the Metedeconk) of 0.80. A filter parameter of 0.98 was used as the default in WHAT. Lim et al (2005) indicates that a previous investigation found that a filter parameter of 0.925 was reasonable, as compared to manual separation results. In addition, it was also discussed that Eckhardt (2005) found that the results are not very sensitive to the filter parameter, but more so to BFI_{max}.

Hydrograph analysis results for the sliding interval and digital filter technique using the WHAT program are shown on **Figure 2-20**. On an average annual basis, differences between the sliding interval technique and the digital filter technique are minor. As a percentage of total flow, baseflow has declined steadily since 1973 (declining trend is supported by Mann-Kendall analyses for a negative trend at a 99% confidence interval). Although as shown in Section 2.3.1, average annual discharge is generally stable (no trend in either direction), the baseflow component of average annual flow is declining. Since 1990, average annual baseflow as a percentage of total flow averages just below 68% (using sliding interval techniques; as compared to 71% for the period evaluated for the North Branch in the Phase I Report, also calculated using sliding interval techniques). Since 2000, average annual baseflow as a percentage of total flow is approximately 67% (using sliding interval techniques).

Over the period of record, at the North Branch stream gage, monthly average baseflow ranges from a low of 10 cubic feet per second (cfs) in August 2002 to a high of approximately 103 cfs in April 1984. Maximum monthly average baseflow since 1990 was approximately 100 cfs in March 1993 using the sliding interval technique. However, using digital filters, maximum monthly average baseflow was approximately 95 cfs in May 1998. Comparing to March 1993, baseflow using digital filters is approximately 90 cfs (somewhat expected in that it is lower than the sliding interval technique). In May 1998, the sliding interval technique calculates baseflow at 96.5 cfs, higher than that calculated using digital filters.

Using WHAT and the Eckhardt filter, the average monthly baseflow at the South Branch USGS gage (014008150) between 1992 and 1999 was 37.8 cfs, or approximately 65 percent of total flow.

2.7.3 Summary

Average annual total flow within the Metedeconk has remained somewhat consistent in which flow is primarily controlled by climatic factors. However, the baseflow percentage of the total flow has declined over the period of record for the North Branch of the Metedeconk. Although data exist for two gages located on the South Branch, data only exist for a limited time period and long-term trends cannot be evaluated.

In addition to a decline in baseflow (and subsequent increase in runoff) over time, stream flashiness has also increased in the North Branch, likely in response to an increase in development and impervious cover. There were no statistically significant trends observed in mean discharge and maximum discharge also shows some increase over time, although the trend is not statistically significant at a 90% confidence level. These parameters were not calculated for the South Branch as data sets under 10 years may not be robust enough for a thorough analysis (Konrad and Booth, 2002).

Hydrograph analyses using sliding interval and digital filter techniques (WHAT) yield similar results when evaluating annual averages, with only minor differences. However, the difference in technique was evident on an average monthly basis. Although the digital filters (WHAT) technique accounts for longer duration of wet periods, results vary with changes in user defined constants (alpha and BFImax), which are not specifically known for the Metedeconk River and therefore introduces some additional uncertainty in the analysis.

Section 3
Visual Assessments

Conditions throughout the Metedeconk Watershed were visually assessed along 83 stream reaches. Field crews assessed the physical characteristics of the reaches in accordance with the Visual Assessment Project Plan (VAPP), which was adopted from the USDA Stream Visual Assessment Protocol (SVAP) and other sources. Various attributes along the stream reaches were scored on a scale of 1-10 based on visual observations. The attributes included a number of parameters which included characteristics that describe the hydraulic, habitat, or water quality conditions of the sites. The average of the scores determines the overall score of the reach. The reaches are then ranked by overall score into the categories of excellent (≥ 9.0), good (7.5-8.9), fair (6.1-7.4), and poor (≤6.0). These rankings are important in comparing sites throughout the watershed, determining sites in need of protection or restoration, and evaluating the effectiveness of BMPs or completed restoration projects in the future. The rankings also provide a general idea of the health of the watershed at the tributary level. A full description of the stream visual assessments (SVA) and results can be found in the Metedeconk River Stream Visual Assessments Report.

The stream reaches were selected by BTMUA to represent the range of riparian conditions throughout the project area. Reaches were selected based on BTMUA watershed monitoring program information, staff experience, accessibility, and GIS information, such as NJDEP Land Use/Land Cover 2002. Stream reaches were defined as a minimum of twelve times the active channel width and a maximum of 200 yards, depending on site and access constraints. The assessments were recorded on field data sheets and the sites were documented with photographs and the GPS locations. In addition to the physical attribute scores and GPS location, information such as weather conditions, width of riparian area, the presence and condition of utilities such as sanitary sewer lines, stormwater outfalls, and other stormwater infrastructure, adjacent land use, signs of nonpoint source pollution such as algae, litter, and any other notable observations are recorded on the SVA forms. The information collected through the visual assessments is valuable not only in that it provides a numerical assessment of the overall watershed health, but it also identifies specific issues or problem sites that may have been otherwise overlooked, and serves as a snap-shot of current conditions to use as a reference for future restoration projects.

While the overall water quality of the Metedeconk River is generally considered to be good, the SVA results reveal that there are some issues within the watershed since greater than half, approximately 58%, of the sites received an overall score in the poor to fair category. The overall break down of scores is: 1 excellent (1%), 33 good (40%), 30 fair (36%), and 19 poor (23%). Although the assessments are qualitative in nature and based on the judgment of the observer, the results of the study are characteristic of an urbanizing watershed. For the most part, the sites in the less developed western headwaters of the North and South Branch had higher scores (good – fair) than those in the more urbanized eastern tributaries (**Figure 3-1**). As can be seen in the figure, sites with poor or fair scores are characterized by reaches with steep channel banks (TR13-1) and sediment deposits (SE-P) or absent buffers (CP-3), while the good and excellent sites have adequate buffers (SL), less visible impairments to water quality (POND6), and the stream has access to the floodplain (NM). An interesting observation in the eastern area is that while many of the reaches along the tributaries have an overall score in the poor to fair range, the main stems of the North and South Branch into which they discharge have higher scores, in the fair to good range. This may be due to the fact that there is a more intact riparian area along the main stem of the North and South Branch which tends to be absent in the upstream tributaries.

Many of the upstream tributaries in the eastern portion of the watershed are fed by stormwater. For example the tributary at site SPC1, Sparrow Creek, begins as a stormwater outfall that receives runoff from the upstream residential development. The overall condition of this reach is poor with a score of 3.2. Riparian vegetation is almost entirely absent, there is little habitat for fish or macro-invertebrates, there is abundant algae, and there is evidence of stream channelization. While the assessment describes the banks as stable, all the other indicators suggest that the stream reach is in poor condition and water quality may be impaired. However, the background information collected during the visual assessment at this site also indicates that this site may be an excellent site for BMP implementation or restoration. Although this is a heavily developed headwater, there is an elementary school nearby that may be an excellent opportunity for a BMP that would reduce and treat stormwater runoff and also serve as a public outreach and education tool.

Sites SA-DEN, NM, and POND6 are examples of sites with the highest scores and have excellent or good rankings. SA-DEN near Derby Ave and Ocean Ave in Lakewood is the only site that scored an excellent ranking at 9.5. This site is along the main stem of the South Branch approximately one mile upstream from the confluence of the North and South Branch. There is an abundant riparian buffer (greater than 300 ft) along this reach and no stormwater outfalls, which may be a factor in the excellent condition of the reach. This site could be considered a reference site for other sites throughout the watershed. It is interesting that although there are some upstream reaches that are ranked as poor, this downstream reach scores so high.

The physical characteristics of the stream and surrounding area were scored, including channel condition, hydrologic alteration, riparian zone, bank stability, water appearance, nutrient enrichment, barriers to fish movement, in-stream fish cover, pools, invertebrate habitat, canopy cover, and riffle embeddedness (only scored if riffles are present). While many of these parameters are interrelated, they represent features that describe the hydraulic stability of the stream reach, the condition of the in-stream and riparian habitat, and the condition of the water quality of the stream. The barriers to fish movement score was the lowest score in many of the reaches in the western portion of the watershed. This value had the tendency to pull the overall score slightly lower than would be expected in a less densely developed area.

However, the ‘barriers to fish movement’ parameter is an important indicator because it identifies dams, spillways, and culverts that would hinder the migration of fish and other species that are important for a healthy ecosystem. There are a number of ponds, dams, and spillways along the tributaries of the western portion of the watershed that were identified in the SVA. The assessment parameters were divided into categories that describe the hydraulic condition of the channel and the condition of the overall in-stream and riparian habitat. The channel category included channel condition, hydrologic alteration, and bank stability, while the habitat category included riparian zone, in-stream fish cover, pools, invertebrate habitat, canopy cover, and riffle embeddedness. An average score was calculated for each category. Overall, the average channel condition scores were higher than the habitat condition scores. While many of the sites scored low in habitat categories, such as pools or canopy cover, the channels were generally of good condition. While most channels showed signs of past channelization and some showed evidence of high stormwater flows, few were severely eroded. Sediment was observed in channels that receive stormwater runoff. Stormwater was conveyed to most reaches by outfalls at road crossings with no treatment. A number of the reaches were in areas that were cleared for power lines. Since the native riparian vegetation was not intact, these areas had lower scores in the habitat categories. Few stormwater BMPs were observed in the SVA survey. Numerous detention and retention basins were observed and identified as possible sites for restoration.

The scores that describe the hydraulic channel condition are higher than the ecosystem scores in the headwaters of the watershed. This may be because habitat condition is more sensitive to changes in watershed land use and can show signs of degradation before the channels respond. The lower habitat scores may suggest that there may be further degradation of the channels in the future, and steps should be taken to protect the stream channels from increases in stormwater flows to maintain the integrity of the stream channels and the overall health of the watershed. Sites that were identified in the SVA as possible candidates for restoration are summarized in **Table 3-1**. These sites will be cross-checked and coordinated with ongoing and planned restoration work being conducted by State, County and local governments and re-visited during Task 5, Identification of Watershed Management Strategies, of the Metedeconk River Watershed Protection & Restoration Plan.

Section 4
Water Quantity & Water Quality

There are several water supply-related concerns for the Metedeconk River watershed. The most recent New Jersey Statewide Water Supply Plan (August 1996) projects significant water supply deficits for the area through 2040. Among the water supply challenges described in the plan are high peak water demands during the summer months, periodic droughts, stream baseflow depletion from shallow groundwater withdrawals, vulnerability of shallow aquifers to contamination due to the permeable soils, localized salt water intrusion in the Point Pleasant area, and the large-scale depletive water use from regional wastewater treatment discharges to the Atlantic Ocean. All of these concerns, with the exception of salt-water intrusion in Point Pleasant, are applicable to the Metedeconk River watershed. Further, the watershed falls entirely within Water Supply Critical Area #1, where confined aquifers have been depleted and their availability for water supply is severely limited.

Options offered in the Water Supply Plan (1996) to help alleviate these concerns include managing the use of surface and groundwater water supplies to maximize availability (conjunctive use), aggressive water conservation programs, development of reservoir storage, and development of aquifer storage and recovery (ASR) well facilities to store water underground during low demand periods for later recovery during high demand periods. Since the 1996 Water Supply Plan was released, several water purveyors in the watershed have developed ASR facilities, and the Brick Township Municipal Utilities Authority completed construction of the 860 million gallon Brick Reservoir in 2004. The NJDEP is currently working on an updated statewide water supply plan.

The purpose of this section is not to project water supply use and quality within the watershed into the future through some type of build-out analysis, but rather document its current state and identify any concerns that may become a more serious issue in the future.

4.1 Water Quantity

The 7Q10 (also referred to as the MA7CD10 by NJDEP, or the minimum average seven consecutive day flow with a statistical recurrence interval of 10 years) for the Metedeconk River has been calculated by the USGS (Watt, 1994) by using low-flow correlation methods to stream flow data measured at the Toms River near Toms River, NJ stream flow gaging station (USGS gage 01408500). This correlation technique was utilized due to the relatively short time period for which stream flow data were available for the North Branch (at the time 1972-1989 for gage 01408120) and South Branch (1972-1976 for 01408140). Correlation equations were derived and stream flows recorded at the Toms River station (data available since 1929) were used to calculate corresponding flows in the Metedeconk River. The calculated 7Q10 was 14.7 and 13 cfs for the North and South Branches, respectively.

Since more than 20 years of data have been made available from the USGS gage for the North Branch of the Metedeconk River near Lakewood (01408120), the 7Q10 was calculated in a different fashion, by simply calculating the running 7-day average, using the minimum 7-day average for each year and determining the flow rate that has a probability of occurring once every 10 years. Using this simplified approach, the 7Q10 for was calculated to be approximately 11.5 cfs, or 7.4 million gallons per day (mgd) for the North Branch. Although flow data are very limited for the South Branch, from available data, the 7Q10 is approximately 13 cfs, or 8.4 mgd. Total flow downstream of the confluence would be approximately 24.5 cfs, or 15.8 mgd downstream of the confluence.

4.1.1 Water Use

Water users that withdraw or have the potential to withdraw more than 100,000 gallons per day are regulated by the NJDEP. Non-agricultural users are regulated with Water Allocation permits or Temporary Dewatering permits. Agricultural users are regulated with Agricultural Water Use Certifications (if the user diverts more than 100,000 gallons per day) or Agricultural Water Use Registrations (divert less than 100,000 gallons per day, but have the potential to). Similarly, Water Use Registrations are issued to non-agricultural users who also do not typically withdraw or divert more than 100,000 gallons per day but have the potential to (combined installed pump capacity of 70 gpm).

There are currently four primary water purveyors within the Metedeconk River watershed: Brick Township Municipal Utilities Authority (BTMUA; which has taken over Parkway Water Company), Lakewood Township Municipal Utilities Authority, Jackson Township Municipal Utilities Authority, and New Jersey American Water Company. All of these purveyors utilize groundwater for potable supply although most of the BTMUA potable supply is from an intake upstream of the mouth of the Metedeconk River. Although there are a total of 51 community supply wells within the watershed, there are only 18 that are screened into the Kirkwood-Cohansey aquifer system (**Figure 4-1**). Since the baseflow to the Metedeconk is derived from the Kirkwood-Cohansey aquifer, and hydraulic connection between the upper Kirkwood-Cohansey and lower aquifers is limited due to the confining unit present in the lower Kirkwood, withdrawals from that aquifer will have a direct impact on baseflow to the Metedeconk. However, it should be noted that increased withdrawals from deeper aquifers may indirectly impact the Metedeconk as the higher pumping rates will result in larger recharge areas and may result in less recharge to baseflow to the Metedeconk. A more detailed evaluation into the recharge areas of the deeper supply wells is required to make an accurate assessment of their impact on the Metedeconk.

Within the watershed, there are 23 community supply wells that are screened within the Kirkwood-Cohansey aquifer system that are either within or immediately adjacent to the watershed (**Figure 4-1; Table 4-1**). The five wells that are outside the boundary of the watershed have their wellhead protection areas (or recharge areas) overlap within the watershed and therefore a fraction of the water that the supply well pumps recharges within the Metedeconk River watershed (and therefore does not enter the river as baseflow). In addition to community public supply use, there are four golf courses within the Metedeconk River watershed: Metedeconk National, Lakewood Country Club, Woodlake Country Club and Forge Pond Country Club. All four golf courses utilize surface water (irrigation ponds and intakes along the Metedeconk) for irrigation, although Forge Pond Country Club also has three wells for domestic supply.

Monthly groundwater withdrawals from the community supply wells screened into the Kirkwood-Cohansey aquifer system are shown on **Figure 4-2**. As shown on the figure, total withdrawals from the system have declined since 2003, due to the shut-down of the Parkway system wells and the general cessation of shallow groundwater use by BTMUA between 2006-2010. Note, however, that groundwater use increases during the summer drought of 2010 in response to record demand. Average annual withdrawals are shown on **Figure 4-3** for 2003 through 2009 indicating the general decline in groundwater use for potable supply from the Kirkwood-Cohansey.

BTMUA directly withdraws surface water for potable use from its Metedeconk River intake which is treated and sent to its distribution system. BTMUA also owns and operates a 1-billion gallon reservoir located outside of the watershed on Herbertsville Road in the northwest portion of Brick near the border of Wall Township (**see Figure 4-1**). This pumped raw water storage reservoir is also supplied with water drawn from the Metedeconk River intake. BTMUA's diversion is governed by a water allocation permit issued by NJDEP and includes minimum passing flow requirements and flood-skimming provisions to ensure withdrawals do not negatively impact downstream areas or nearby freshwater habitat. In addition, BTMUA owns and operates an aquifer storage and recovery (ASR) well system where treated water is stored underground during low demand periods for later use during high demand periods. The ASR system hasn't been in operation since October 2009 due to problems with the existing ASR Well 10. As of the date of this report, BTMUA is undertaking an ASR well replacement project with a new ASR Well 15A expected to be completed during 2011.

Surface water withdrawals for non-agricultural users are summarized on **Figure 4-4** for the Metedeconk River (BTMUA and golf course irrigation). From 2003-2009, the average monthly surface water withdrawal was approximately 6.8 mgd.

There are only three farms within the watershed are registered with NJDEP, two of which use surface water for irrigation. The other farm uses groundwater, but the well is screened within the upper Potomac-Raritan-Magothy (PRM) aquifer and groundwater withdrawals are not likely to impact the flow within the Metedeconk River. A summary of reported water use is shown on **Figure 4-4**. Note that total withdrawal is only a small fraction of the withdrawals for potable supply. However, there are more than 400 agricultural parcels within the watershed comprising almost 1,700 acres. It is likely that there are a number of agricultural users that withdraw water, but less than 100,000 gallons per day or 70 gpm. The cumulative impact of agricultural irrigation pumping from these sites could be significant.

During summer 2010, numerous water utilities in the region, including BTMUA, experienced record water demands, and a Statewide drought watch was issued by NJDEP. Meeting water demands with future population growth will only become more challenging. Lakewood Township, in particular, is expecting significant population growth in the coming decades, and the water supply plan for the build-out of Lakewood has not been established and is only briefly addressed in the Lakewood Smart Growth Plan as not being an issue (T&M, 2009). Much of the water use in the watershed is depletive in nature, as wastewater is collected, treated and discharged to the Atlantic Ocean. Water conservation and reuse programs are recommended. Details of water supply issues for future and / or build-out conditions are expected to be addressed by NJDEP in an updated New Jersey Statewide Water Supply Plan. This document should aid in determining the potential impacts of future water supply demands to the Metedeconk River.

In addition to water supply, extension of sanitary sewer may pose adverse impacts with regard to baseflow. Replacement of septic systems which recharge the aquifer with sanitary sewers which carry sanitary flow out of the watershed will reduce baseflow to the Metedeconk River. Baseflow to streams within Nassau County, NY were significantly reduced following large scale installation of sanitary sewers (Reilly et al, 1983; CDM, 1998); however, groundwater quality with respect to nitrogen was improved (CDM, 1998).

4.2 Water Quality

BTMUA has an extensive water quality monitoring program that includes 68 sampling stations that extend upstream for both the north and south branches of the Metedeconk (**Figure 4-5**). Many of these stations are sampled routinely for a full suite of drinking water parameters and several sites (the BTMUA intake, NA and SA) are sampled daily. Some of the stations are sampled for particular compounds (VOCs, for example).

As the watershed of the Metedeconk River is urbanized, water quality to the river is threatened by pollutants within groundwater that ultimately discharge to the Metedeconk River as baseflow (including nitrogen from septic systems, chemical leaks from underground storage tanks and various chemical spills, etc) as well as from urban runoff from impervious surfaces such as untreated parking lots. Runoff from pervious areas is a threat as well, particularly from nutrient loading from fertilization as well as coliform from pet and waterfowl waste.

Using the parameters outlined in the Phase I Report as a baseline, an evaluation was conducted to update the previous analysis as well as determine if there are any observed trends in the available data. In addition to BTMUA data, recent (2000-present) water quality data was collected by the USGS at six stations and have been incorporated into this analysis. Although there are more stations that the USGS has collected water quality data from within the watershed, the samples were collected prior to 2000 and are therefore not relevant to updates to the water quality analysis conducted in the Phase I Report.

Either nitrogen or phosphorus may be the limiting nutrient in a particular surface water body. Phosphorus is typically the limiting nutrient for algal growth and productivity in fresh water systems, and nitrogen is usually the limiting nutrient in marine water bodies. Like nitrogen, phosphorus may be introduced to the aquifer system by sanitary wastewater or by fertilization. Unlike nitrogen, dissolved phosphorus is more likely to sorb onto sediments, and is not as mobile. A total maximum daily load (TMDL) has been established for phosphorus for a section of the North Branch of the Metedeconk River. Although a TMDL for nitrogen does not currently exist, nitrogen loading to the Barnegat Bay is important as it is the limiting nutrient to that water body.

Available water quality data from the USEPA's modernized STORET (data since January 1, 1999) have also been compiled and reviewed. Much of the data within the STORET database only contains one or two sample dates and was therefore not included in any trend analyses.

4.2.1 Groundwater Quality

Groundwater quality data for the Kirkwood-Cohansey are much more limited than surface water quality data. Although there are numerous USGS groundwater monitoring wells in the watershed, water quality data are limited for wells within the Kirkwood-Cohansey. In fact, only one monitoring well, USGS 400346074081701 291417-- MW64, has water quality data available post-2000. For the purposes of the groundwater quality summary, available data from BTMUA and New Jersey American water supply wells were used. However, the NJ American wells are localized and represent only a small portion of the watershed. In addition, the wells are located near the southern boundary of the watershed and water quality collected from these wells may not be representative of water quality within the watershed.

In addition, no groundwater data were available within the modernized STORET database.

The Phase I Report also noted a lack of groundwater quality data within the watershed. The following summary was given, as summarized from Watt et al (1994).

Chloride	5 to 10 mg/l
Sulfate	10 mg/l
Total Phosphorus as phosphate	0.1 mg/l
Alkalinity as calcium carbonate	1 to 2 mg/l
pH	4.5 to 5.5
Dissolved Ammonia	0.1 to 0.2 mg/l

Dissolved Nitrate/Nitrite	0.5 mg/l
Lead	0.005 mg/l
Manganese	0.04 mg/l
Nickel	0.002 mg/l
Zinc	0.02 mg/l

A summary of groundwater quality can also be found in Nicholson et al (2003), although only data from 1980-2001 from a very limited number of wells within the Metedeconk River watershed are summarized as the analysis also included Toms River and Kettle Creek watersheds in Ocean County.

Based on the limited data that were available from the BTMUA and New Jersey American supply wells, a summary of detected parameters is listed in **Table 4-2**. In addition to the parameters shown on the table, both systems have had volatile organic compounds (VOCs) detected in raw water. Both systems have had detections of methyl-tert-butyl-ether (MTBE), naphthalene and toluene. In addition, the BTMUA wells have had low level detections of 1,1,2-trichloroethane (TCA), dibromomethane, trichlorobenzenes, tetrachloroethene (PCE), trichloroethene (TCE), and xylene. It is important to note that raw well water samples are collected prior to any treatment and these results do not indicate that contaminants were present in the finished water. Both systems deliver drinking water that meets or exceeds NJDEP's Safe Drinking Water Standards.

As mentioned in the Phase I Report, the quality of the groundwater feeding the Metedeconk River is not uniform, due to the relatively short flow paths from the recharge areas to discharge to the river. Because of the short flow paths, local impacts to the groundwater quality can be significant, and must be considered in examining the vulnerability of the river to local sources of groundwater pollution.

Due to the limited available data, the groundwater quality summary presented here is not necessarily indicative of the groundwater quality of the Metedeconk River watershed. At present, the best indicator of groundwater quality in the watershed is baseflow samples collected primarily by BTMUA. However, there are transformations that occur through the sediment water interface within the river through the hyporheic zone (Dubrovsky et al, 2010). Although the water quality of the Metedeconk is generally good, particularly when evaluating against drinking water standards, there are particular areas within the Metedeconk that experience contaminant loading that may be able to be more closely monitored with a groundwater quality monitoring program.

4.2.2 Surface Water Quality

The Phase I Report concluded that the surface water quality of the Metedeconk River was good, but identified some parameters of concern, namely total organic carbon, dissolved phosphorous, lead and cadmium. Since the Phase I Report, total maximum daily loads (TMDLs) have been established for total coliform, fecal coliform, lake pathogens and phosphorus. A TMDL is simply the maximum amount of a pollutant that a water body can sustain while meeting its water quality standards.

The Metedeconk River is classified as a class FW2 waterway, most of which is classified as a “non-trout” status (FW2-NT; except a stretch of the North Branch from Aldrich Road to Lanes Mills is classified as “trout maintenance”, or FW2-TM). In addition and as indicated earlier in this memorandum, the Metedeconk River is classified as a Category One (C1) waterway due to its exceptional water supply significance. The C1 designation covers the entire watershed eastward to Forge Pond at State Hwy 70 and includes both the North and South Branches and all freshwater tributaries. According to State regulations, C1 waters are to be protected from any measurable changes (including calculable or predicted changes) to the existing water quality. The purpose of this water quality analysis is to determine if a measurable decline in water quality has been observed and identify potential problem areas for restoration, particularly those areas that will address TMDLs or existing water quality impairments.

The North Branch Metedeconk River at Lakewood (site ID 01408100) and the South Branch Metedeconk River near Laurelton (site ID 01408152) as well as Lake Carasaljo and Ocean County Park Lake are identified as impaired by pathogens, as indicated by the presence of fecal coliform in excess of the Surface Water Quality Standards (SWQS). The North Branch Metedeconk (site ID 6 – Jackson Mills Rd; HUC NB1 on **Figure 2-2**) is also impaired for phosphorus and a TMDL has been established for that HUC14. TMDLs have been established for the North and South Branches of the Metedeconk River for fecal coliform and total coliform. Fecal coliform TMDLs have also been established for Lake Carasaljo and Ocean County Park Lake. Various other water quality impairments have also been identified on the New Jersey 2008 303(d) list of water quality limited waters.

Parameters addressed by the Phase I Report are updated here as well as a brief overview of the TMDLs that have been established and the load reductions that have been identified to achieve them.

Surface water quality was primarily evaluated using BTMUA’s water quality database, supplemented with data collected from the USGS and NJDEP (STORET) at various stations along the north and south branches. The parameters evaluated for the Phase I Report were also evaluated here and average annual water quality data from 2008 were plotted for each water quality station so that average annual conditions could be evaluated downstream. The year 2008 was chosen as that was the latest year for which a full year of sample data was included for most of the sample stations. In addition, annual precipitation in 2008 (49.45 inches) was close to the average annual precipitation over the period of record at the BTMUA station (48.30 inches).

Average annual (2008) concentrations for the various water quality parameters summarized in the Phase I Report are shown on **Figure 4-6**. In addition to average annual water quality data, trend plots were developed and mapped to evaluate any increasing trends over time. As BTMUA collects samples on a daily basis from the intake as well as the closest upstream water quality stations, NA and SA, it should be noted that averages reported for those stations are based on significantly more data.

Specific Conductance (uS/cm)

Conductivity is a field reading that measures the ability of water to conduct an electric current. It is directly related to the concentration of dissolved solids in the water. High conductivity is an indicator of high levels of dissolved solids. The presence of road salts such as sodium chloride and calcium chloride, septic systems, or other anthropogenic sources can increase conductivity. The average conductivity for the North Branch is approximately 167 uS/cm, an increase from 150 uS/cm as reported in the Phase I Report, while the average for the South Branch is approximately 136 uS/cm, which is more than double the Phase I Report average of about 65 uS/cm. Although these conductivity averages are generally low, and indicative of relatively unpolluted surface water, there is an increasing trend as the sampling locations move further downstream on both branches in addition to an increasing trend over time (**Figure 4-7**). This increase is most likely due to the higher level of urbanization downstream and the increase of pollutants in both stormwater runoff and groundwater in more urbanized areas. The Metedeconk River temporarily exhibits very high conductance levels following road de-icing operations during the winter. The increasing trend in conductivity may also represent long-term increases in groundwater conductivity resulting from percolation of road salts into the shallow aquifer. Water quality trend plots shown on **Figure 4-7** are monthly average data due to the amount of specific conductance data collected.

Highest conductivity values are found at sampling stations SO and TR12-1. Although much of the surrounding land use is forest and wetlands, there are some commercial and industrial parcels adjacent and/or upstream of the sampling station which may explain the increased conductance values.

Total Dissolved Solids (mg/l)

Total dissolved solids (TDS) are a measure of the total solutes in water. It can be calculated from the sum of the concentrations of dissolved major ions or measured by determining the mass of residue left after evaporation. TDS can vary greatly among samples since it is influenced by both storm water events and groundwater and generally mimics the specific conductance. As with specific conductance, average values are generally increasing downstream as well as over time (**Figure 4-8**). The North and South Branch average TDS values are approximately 20 to 30 mg/l higher than the averages included in the Phase I report. The SWQC for total dissolved solids is either 500 mg/L, or any increase in background concentrations which may affect aquatic biota. TDS exceeds 500 mg/L at only a few isolated sampling events at several stations and are primarily during winter months and potentially associated with an influx of road salt in runoff following snow events (see **Figure 4-8**).

There is a general downstream trend of increasing conductivity and TDS on both the North and South Branch. This pattern corresponds with the general decreasing trend of VAPP scores on the reaches tributary to the sampling stations. Similar to nitrate, the conductivity and concentration of TDS on the North Branch starts to increase downstream of station NK. The conductivity steadily increases downstream through stations NJ and NI, and is nearly double that of NK at station NG. The VAPP scores of the tributaries between NK and NG reflect a degraded watershed condition, which seems to be fairly consistent with the observed increase in total dissolved solids.

The conductivity at the most upstream site NP is interesting because it indicates a steady increase over time. The VAPP scores at this site describe a reach that is relatively healthy from a hydraulic perspective, but has undergone some recent changes to habitat, more likely from new development or other land use alterations. However, the conductivity at the next downstream sites (NN through NK) remains at a lower value and does not show such a drastic increase over time. The high VAPP scores through this reach represent streams that have not been degraded and are of good condition. The land use through this reach is mostly wetland and some forest area with small pockets of residential area or agriculture. Conductivity and TDS on the North Branch remain elevated from station NG downstream to the BTMUA intake. Conductivity levels on the upstream tributaries tend to be higher at stations directly downstream from residential areas and in the vicinity of sites with low VAPP scores. This is the case at stations MF1, SHB-2 and SHB-1. Stations HS4 and HS5 have elevated conductivity levels. While these stations are along a relatively undeveloped reach of Haystack Brook, they are downstream of site HS6, which receives runoff from a residential area and has a poor VAPP score.

Conductivity and TDS on the South Branch show a similar trend and relationship to VAPP scores as along the North Branch. Conductivity remains low until station SI (with the exception of station SO which is a tributary receiving runoff from an industrial area) where the levels of total dissolved solids quickly increase and remain elevated downstream to station SA. While reach SI has a VAPP score of “good”, all but one of the six reaches tributary to SI have VAPP scores of “fair”. The highest conductivity was observed at stations TR12-2 and TR12-1, which is almost four times that of baseline conditions. High TDS concentration was also observed at these stations. The VAPP reaches in the vicinity of these stations both have overall VAPP scores of “fair” and “poor” in stream habitat scores. TR13-3 also has similarly high conductivity and is directly downstream of a residential area. The conductivity is slightly lower at the next downstream station TR13-2, which is more remote from residential areas. Both sites have VAPP scores of “fair”. The reaches described are a few of the several reaches where sampling data was taken along a tributary to the main stem. The elevated levels of total dissolved solids may indicate that the tributaries are more sensitive to changes in upstream land use and respond more quickly to alterations than the main branches. This trend is also observed in the VAPP results.

Dissolved Oxygen (mg/l)

Dissolved oxygen is often used as an indicator of the biological health of surface waters, and can be indicative of the degree of nutrient loading to surface waters. Since shallow moving river water tends to reoxygenate, DO is less of an indicator for fast flowing rivers than it would be for quiescent water bodies such as lakes and ponds. Also, colder water is capable of holding more dissolved oxygen than warmer water, which results in seasonal variations in DO. Average DO for both branches is about 8 to 10 mg/l, which is relatively high and close to the saturation concentration at temperatures of around 50 to 60 degrees Fahrenheit. These values are similar to those reported in the Phase I report.

As shown on **Figure 4-6**, dissolved oxygen varies throughout the year, ranging from between 6 – 8 mg/L during the summer months to 12-14 mg/L during the winter months.

The Surface Water Quality Criteria for dissolved oxygen for FW2-TM waters is 'not less than 5.0 mg/L at any time' and 'not less than 4.0 at any time for FW2-NT waters'. As dissolved oxygen does not drop below 5.0 at one time (in 2008) along the FW2-TM stretch, the SWQC is being maintained for that reach. However, as shown on **Figure 4-6**, dissolved oxygen drops below 4.0 at upstream stations along the North Branch (NM through NP) and along the South Branch at SK and SO. This is potentially due to the amount of wetlands present in the headwaters area which can be a reducing environment (and can also provide a means for denitrification). Another potential is that excessive phosphorus loading in this area is causing some eutrophication. This HUC 14 has a TMDL for phosphorus and VAPP scores are low for nutrient enrichment and water appearance (also see phosphorus discussion below). The New Jersey 2008 303(d) list, as well as the draft 2010 303(d) list, includes the North Branch as impaired from Route 9 to above I-195 for dissolved oxygen. The source of this impairment should be further investigated.

Fecal Coliform (counts per 100ml)

The data for fecal coliform is very variable. This is due to the fact that fecal coliform is primarily transported in wet weather runoff. Counts tend to spike after rainfall events as runoff impacts the river and drop to zero during longer dry periods. Groundwater generally does not contribute any fecal coliform to the river. From a groundwater perspective, only those sites that are unsewered and close enough to the river (or tributaries) to allow groundwater to discharge within a very short travel time would have the potential to contribute fecal coliform.

Average counts of fecal coliform have increased from those reported in the Phase I Report, particularly along the North Branch. The average readings at the North Branch varied from 280 to over 2000 counts per 100 ml, and from 80 to over 8000 counts per 100 ml for the South Branch, although the very high average concentration at SF includes a single sampling event of 212,000 counts/100 mL (isolated incident of a sewer main break and spill into Lake Manetta on 9/30/2008). Without that data point, the average fecal coliform at Station SF is 546 counts per 100 mL. The increased counts of fecal coliform suggest that, while the waters of the Metedeconk are suitable as a drinking water source, particularly after disinfection, storm water runoff is impacting the water quality within the watershed.

The average fecal coliform counts provided in the Phase I report varied from 0 to over 500 counts per thousand ml at the North Branch, and from 0 to over 300 counts per thousand ml for the South Branch. However, it would be difficult to compare the averages over time due to the affect of storm events on the sampling data. There are fecal coliform TMDLs in place for the Metedeconk River which are discussed below.

pH

The pH of samples taken from the Metedeconk River is fairly consistent from the headwaters to the intake, with a slightly lower pH found in samples taken from the headwaters of both branches and is very consistent with pH reported in the Phase I Report. Both branches have an average pH of about 5 in the headwaters areas, and about 6 in the downstream portions. This represents slightly acidic water. The river water pH is primarily affected by the naturally occurring low pH of the ambient groundwater (4.5 to 5.5) and is not indicative of any problems in the watershed.

SWQC for pH is 4.5 to 7.5. The surface water pH has dropped below 4.5 at several water quality stations along the Metedeconk River (**Figure 4-9**). Water quality trend plots shown on **Figure 4-9** are monthly average data due to the amount of pH data collected. Although there are some declining trends evident (2001 – 2003), the pH recovers and there is no apparent long term trend observed in the data. As the trends are observed at most stations, it is possibly a regional trend in the groundwater system as opposed to a watershed issue. However, as groundwater data are generally not available, these trends cannot be confirmed.

Total Organic Carbon (mg/l)

Total organic carbon (TOC) is a measure of the amount of organic material in the source water. TOC is of particular importance to treatment processes that involve chlorination because of the concern about the formation of disinfection byproducts such as THMs. Higher TOC levels increase the demand for treatment oxidants and result in higher disinfection byproducts that are regulated under the Safe Drinking Water Act. The average TOC values range from 4 to about 16 mg/l, which are moderate levels for a surface water source. Both the North Branch and the South Branch have similar levels of about 6 mg/l on average near the intake. Levels are pretty stable along the length of the stream, with TOC concentration somewhat higher near the headwaters. These values are consistent with the TOC values in the Phase I Report and the presence of extensive wetlands within the headwaters region.

Water Temperature (degrees Fahrenheit)

The temperature profile along the river shows a clear rising trend from the headwaters area to the intake. Average temperatures are approximately 52 degrees Fahrenheit (11.1 degrees Celsius) near the headwaters for both branches, to approximately 56 degrees Fahrenheit (13.3 degrees Celsius) at the intake. The rise in temperature could potentially be due to a reduced vegetative cover moving downstream. The increasing trend moving downstream as well as the average water temperatures are consistent with those reported in the Phase I Report.

The SWQC for temperature for the stretch of the North Branch classified as FW2-TM is to not exceed a daily maximum of 25 degrees Celsius or a rolling seven day average of 23 degrees Celsius, unless these increases are due to natural conditions (groundwater). For all other reaches of the Metedeconk, the SWQC is to not exceed a daily maximum of 31 degrees Celsius or a seven day average of 28 degrees Celsius. Both of these criteria are met, based on 2008 data. The New Jersey 2008 303(d) list and the draft 2010 303(d) list includes the length of the North Branch from the confluence to I-195 as impaired for water temperature, though it should be noted that the 2008 list is based upon data from previous years. Based on BTMUA water quality data, the criteria are met in 2008, but are not always met in previous years and are therefore in agreement with the 2008 303(d) list.

Total Suspended Solids (mg/L)

Total suspended solids (TSS) are used as one of the primary indicators of poor watershed management of soils. TSS is often associated with agricultural runoff, runoff from construction sites, highways, and highly urbanized areas. Average TSS data in 2008 were available for only the intake, NA and SA. Average TSS concentrations were about 2.7 mg/L at NA and approximately 1 mg/L at the intake and at SA. While these are very low TSS concentrations, TSS is extremely variable, and can rise by several orders of magnitude during storm events. For example, maximum TSS has been measured at 118 mg/L at station NH over the period of record. On the South Branch, a maximum TSS of 68 mg/L was measured at SG. Both of these maximum values occurred on 12/8/1999.

SWQC for TSS is 25 mg/L for the FW2-TM reach and 40 mg/L everywhere else.

Biological Oxygen Demand (mg/L)

Biological Oxygen Demand (BOD) is a measure of the oxygen consumed by biological activity. It is considered an indicator of watershed health because oxygen levels can be greatly depleted if there is a higher than normal level of biological activity involved in consuming excess organic material. BOD data are limited in 2008, but average BOD data between 2007 to 2009 indicate that average BOD in the North Branch was between 3 and 5 mg/l, while average BOD in the South Branch was generally 2 to 5 mg/l. Station SK on the South Branch is an outlier in which average BOD concentration was 19 mg/L in 2007. However, there is an outlier in this dataset as BOD was 47 mg/L in May 2007. Concentrations were 6.03 mg/L in November 2007. These are relatively low BOD values and do not differ much from the averages in the Phase I report.

Chemical Oxygen Demand (mg/L)

Chemical Oxygen Demand (COD) is a measure of the oxygen necessary to chemically oxidize all the organic material in the water, and can be used to indicate a presence of organic pollutants in surface water. COD also includes the biologically available oxygen. COD generally centers around 20 mg/L for both branches, moving downstream, similar to what was reported in the Phase I Report. For the North Branch, COD exceeded 50 mg/L at Station NP. As reported in the Phase I Report, COD concentrations indicate that a significant portion of the oxygen demand is not available for biological activity.

Nitrogen (mg/L)

Nitrogen load to the Metedeconk River is in the form of ammonia, nitrate and nitrite. There are several anthropogenic sources of nitrate to the river, but the most prominent are from stormwater runoff of fertilized landscapes and groundwater discharge which receives nitrogen loading from septic systems in unsewered areas, as well as from fertilization practices from residential, commercial and agricultural land uses. A more detailed evaluation of nitrate/nitrite as nitrogen is described below.

Ammonia (mg/L)

There are two analyses for ammonia within the BTMUA database, one from data collected in the field (using a probe) and a second from the BTMUA lab analysis. Ammonia concentrations reported by the lab are consistent with ammonia concentrations reported by the USGS for ammonia (filtered) in which concentrations are generally below 0.10 mg/L as nitrogen.

Ammonia concentrations collected from stations SI and SH on the South Branch are approximately twice the annual average concentration of the other stations. Based on the 2008 laboratory data, in general, the ammonia concentrations are the same from the headwaters to the intake, and no clear source beyond that of the groundwater baseflow can be identified. As identified in the Phase I Report, the South Branch has slightly higher concentrations than does the North Branch.

Surface water quality criteria for ammonia are based on the following formulas (as specified in N.J.A.C. 7:9B, for pH < 8.30):

Acute: $0.179\left(10^{0.026(Temp-20)+0.41(pH-7.80}\right)$ for FW2-TM

$0.201\left(10^{0.026(Temp-20)+0.41(pH-7.80}\right)$ for FW2-NT (March through Oct)

$0.232\left(10^{0.026(Temp-20)+0.41(pH-7.80}\right)$ for FW2-NT (November through Feb)

Chronic: $0.046\left(10^{0.026(Temp-20)+0.41(pH-7.80}\right)$ for FW2-TM

$0.054\left(10^{0.026(Temp-20)+0.41(pH-7.80}\right)$ for FW2-NT (March through Oct)

$0.060\left(10^{0.026(Temp-20)+0.41(pH-7.80}\right)$ for FW2-NT (November through Feb)

Based on the above equations, the BTMUA temperature and pH data were evaluated (most sample points) to determine the average SWQC for the Metedeconk. For the FW2-TM reach, the average SWQC is 0.01 mg/L for chronic and 0.04 mg/L for acute. For the FW2-NT portions of the stream, the ammonia criteria are:

Season	Acute (mg/L)	Chronic (mg/L)
March through October	0.051	0.014
November through February	0.032	0.008

As shown on **Figure 4-6**, on an annual average basis, the ammonia is exceeded. Evaluating a trend plot of the ammonia concentrations at the intake and moving upstream to Station SI along the South Branch, the standard is not violated at all times, but frequently exceeds 0.05 mg/L. Concentrations are consistent with those collected by the USGS. In addition, it's evident that the annual average ammonia concentration at SH and SI is not necessarily representative as only one data point in 2008 is available.

Nitrite/Nitrate (as N; mg/L)

Nitrate is the major component of nitrogen load, and indicates agricultural and lawn fertilizer pollution in runoff, as well as groundwater transport of septic system discharges to the river. While the nitrate concentrations are well below drinking water standards (the drinking water standards for nitrite and nitrate are 1 and 10 mg/L, respectively), there may be downstream water quality and eutrophication concerns as the concentration approaches 1 mg/l. Nitrogen is a pollutant of concern because it can lead to eutrophication in downstream lakes and estuaries and therefore is of particular concern to the Barnegat Bay. Nitrite is a very small component of total nitrogen as average nitrite concentrations ranged from 0.002 to 0.14 mg/l in the North

Branch, while the average nitrite concentrations were in the range of 0.002 to 0.05 mg/l in the South Branch.

Average annual nitrate concentrations range from near zero in the headwaters to more than 1 mg/L downstream (**Figure 4-10**). Although there does not appear to be a significant trend over time, concentrations at the intake have exceeded 1 mg/L. Nitrate loading appears to be more significant on the North Branch, elevated downstream of site NK and beginning to approach 1 mg/L at station NG.

While the visual assessment scores on the main stem of the North Branch tend to be in the fair to good range, the visual assessment scores on the upstream tributaries downstream of NK tend to be in the fair to poor range. The average in stream nitrogen concentrations almost doubles between site NK and the next downstream sampling site NG. The intensity of residential land use also increases along this reach and its tributaries. Nitrate levels at MF1, which is near the mouth of Muddy Ford Brook, are approximately the same level as those along the main stem of the North Branch. This is interesting because the total area draining to Muddy Ford Brook is small in comparison to the entire area draining to the North Branch. The drainage area upstream of MF1 is a mixture of agriculture and residential development. Residential areas are predominantly at the headwaters of the tributaries to Muddy Ford Brook, and the streams are fed by stormwater. The VAPP scores in the drainage area to Muddy Ford Brook are relatively low. Nitrate is also elevated along the Cabinfield Branch, which discharges to the North Branch just above the confluence of the North and South Branches. The stream originates as stormwater runoff from downtown Lakewood, and runs through the Woodlake Golf and Country Club. The Schoolhouse Branch tributary to the south originates in Ocean County Park receives runoff from residential and commercial areas and the Woodlake Country Club before it discharges to the Cabinfield Branch. VAPP scores along these reaches are in the poor to fair range.

Nitrate concentrations increase somewhat along the South Branch between sites SK and SI. The density of residential development increases in the areas that drain to this segment on the South Branch. The upstream tributaries in this area tend to have VAPP scores in the fair range.

Total nitrogen load from the Metedeconk River was calculated by the USGS to be 86,000 kg/yr (Weiben and Baker, 2009), 50,000 kg/yr being composed of nitrate, 32,000 kg/yr being composed of total ammonia plus organic nitrogen, and the remaining 7,600 kg/yr being ammonia. HUC NB2 exhibits the highest nitrogen load (Nicholson, 2010).

Total Phosphorus (mg/L)

Total Phosphorus (TP) is an important indicator of the presence of agricultural and lawn fertilizers in runoff and of increased nutrient loads to a river. Phosphorus will tend to sorb onto soils and unlike nitrogen, does not migrate well through groundwater. Phosphorous issues are generally associated with stormwater runoff from fertilized areas. The surface water quality standard for the river is 0.1 mg/l and for ponds and lakes the standard is 0.05 mg/l. As mentioned in the Phase I Report, in general, eutrophication in lakes begins to become a problem at concentrations of approximately 0.02 mg/L (Thomann and Mueller, 1987).

Phosphorus concentrations tend to decrease at the sampling sites further downstream, but tend to remain relatively constant throughout the watershed. Average annual total phosphorus concentrations are below 0.1 mg/L for all stations, although time history plots show several stations that have exceeded 0.1 mg/L for total phosphorus (**Figure 4-11**) and most stations have exceeded 0.05 mg/L at one time. There is no evident trend in the phosphorus data, although in general, concentrations are higher within the North Branch than the South Branch. Note that the North Branch has more than twice the amount of agricultural acreage within its watershed (see **Table 2-5**), which may explain the increased phosphorus concentrations.

Phosphorus concentrations are the highest at the most upstream station NP on the North Branch and remain elevated at the next downstream station NK. There is a TMDL for phosphorus on the North Branch for this HUC14, which is based on the surface water quality standard of 0.1 mg/l. The average phosphorus concentration at site NK is below the surface water quality standard; however, some of the samples exceed the standard concentration. While the VAPP scores along the reaches upstream from site NK do not indicate an impaired watershed condition, the scores for nutrient enrichment and water appearance are low at site NK, which would warrant further investigation. In addition, the elevated phosphorus observed within NB1 is interesting as more than 75% of the land use is forest and wetlands. Additional detail regarding the phosphorus TMDL is discussed below.

The watershed area between sites NO and NL is predominantly undeveloped wetlands and some forest. There are scattered small areas of agriculture and residential land use. The most upstream headwaters of the North Branch include some localized areas of large lot residential land use. There is a pond just upstream of the most upstream site, NQ, which was indicated in the VAPP as a possible source of nutrients. The amount of urban residential and agricultural land use intensifies between sites NL and NK. Except for a few outliers, the phosphorus concentrations are below the surface water quality standards from stations NG downstream to the BTMUA intake. The phosphorus concentrations at most stations along the South Branch are below the surface water quality standard with the exception of a few outlier samples. The average phosphorus concentration at each site remains relatively constant.

Lead (mg/L)

Heavy metals such as lead can be associated with industrial areas and transportation corridors as they accumulate particles from automobile exhaust, tire and break wear, motor oil additives, and rust from vehicles.

Average lead values for the North Branch are generally around 0.003 mg/l. There is an unusually high value of 12.0 mg/l at station NP which skews the station average. The average annual concentrations within the South Branch are higher with an overall average of 0.005 mg/L and a maximum average annual concentration of approximately 0.013 mg/L, which approaches the drinking water action level of 0.015 mg/L. This elevated concentration occurs at Station SD where the site is bounded by commercial and industrial land use.

Copper (mg/L)

Average copper values for the North Branch was generally around 0.004 mg/l, while average values for the South Branch were in the range of 0.005 mg/l. The average annual concentration at the intake was approximately 0.006 mg/l, well below the EPA drinking water maximum contaminant level goal of 1.3 mg/l.

As with lead, the station showing the highest annual average copper concentration is SD.

Zinc (mg/L)

Average zinc values for the North Branch and South Branch are approximately 0.019 mg/l, consistent with Phase I Report concentrations. There is no apparent spatial trend with the data and concentrations are similar for the North and South Branches.

Cadmium (mg/L)

As data are limited for cadmium in 2008, average concentrations were calculated between 2002-2009. Average cadmium concentrations for the North Branch are about 0.0002 mg/l. Average concentrations on the South Branch are approximately 0.00016 mg/l, and no spatial trend is evident. Average cadmium concentrations for both branches are below the USEPA MCLG of 0.005 mg/l (with the exception of NL as indicated above).

Arsenic (mg/L)

The North and South Branches of the Metedeconk River are listed on the New Jersey 2008 303(d) list as being impaired for arsenic. The lowest SWQC for arsenic for FW2 waters is 0.017 ug/L, although the New Jersey drinking water standard for arsenic is 5 ug/L. Average annual arsenic concentrations in 2008 are shown on **Figure 27**. As shown on the figure, concentrations at the intake and upstream are well below the drinking water standard. Concentrations at NO and NP may not be representative due to limited data in 2008. Arsenic concentrations for NO are 1.76 ug/L and 0.725 ug/L in 2009 and 2010, respectively.

Volatile Organic Compounds (ug/L)

The use of VOCs as solvents and degreasers became widespread beginning in the mid-1940s. VOCs are also present in products such as paint, cleaning agents, deodorants, adhesives, and polishing products that were commonly used by industries, commercial establishments, and homeowners without disposal restrictions until the mid-1970s, when VOCs began to be detected in groundwater. VOCs can be both mobile and persistent in the natural environment and many are known carcinogens.

As almost 70% of the total flow in the Metedeconk River is composed of baseflow, it is not surprising that VOCs within the groundwater system would be detected in baseflow samples. However, as VOCs volatilize, they are not stable in a surface water environment and concentrations are expected to be below those typically found in groundwater. Therefore, since VOCs are volatile, other than direct spills, the likely source of the VOC contamination is through groundwater. NJDEP drinking water standards are as low as 1 ug/L for many commonly detected VOCs (benzene, trichloroethene (TCE), tetrachloroethene (PCE), etc), although SWQC is lower in some cases (0.15 ug/L for benzene, for example).

Within the coastal plain, it is not uncommon to detect low concentrations (below the drinking water MCL) of VOCs within streams (Nicholson et al, 2003). Nicholson et al (2003) discuss that in general, the most frequently detected VOCs in surface waters in this region are MTBE, chloroform, TCE, PCE, and 1,1,1-trichloroethane (TCA), which have also been detected in streams on Long Island (CDM, 2006).

Volatile organic compounds have been monitored by BTMUA for several years. Total VOC concentrations from the BTMUA water quality sampling stations since 2000 are shown on **Figure 4-12**. Non-detects are represented as "zero" in this analysis. In addition, some data had reported concentrations in trip blanks (as also identified by Nicholson et al, 2003). These data were removed. Lastly, if duplicate samples were analyzed, the maximum value was used. There is no temporal trend that is identifiable, although there is some correlation geographically in that the stations within the vicinity of the Route 9 corridor seem to show elevated TVOC concentrations relative to other stations.

The "Clover-3" and "POND-6" stations are routinely monitored for VOCs by BTMUA as they are known sites of VOC contamination. Clover-3 is located adjacent a former coal gas plant in Lakewood Township and POND-6 is located adjacent an asphalt plant in Brick Township (both were sites for stream visual assessments). Other known contaminated sites (as identified by NJDEP) are shown on **Figure 4-12**. These may help explain some of the additional sites that are relatively high in TVOC concentrations (TR13-2, SE-1). Relatively high concentrations at station NO are somewhat interesting as the surrounding land use is wetlands. However, the source may be some commercial or industrial parcels located upgradient. It appears that there is a decreasing trend in TR13-1 and TR13-2, which may indicate that the source of the contamination is not continuous and the tail end of the plume is discharging into the river.

Unusually high concentrations of VOCs have been detected at Station NO at the headwaters of the North Branch. The primary contaminant is naphthalene, and may be a result of uncertainty within the lab data (naphthalene has been detected in various trip blanks). The nearby sites do not have similar trends, and the surrounding land use is mostly wetlands. There are a few observations of relatively high VOC concentrations at station NA, however, the concentrations are diminished by the time the water reaches the BTMUA intake. In summary, while there are some VOCs detected throughout the watershed, the concentrations do not persist and are not generally observed at BTMUA's intake, and therefore do not seem to be impacting the quality of the Barnegat Bay. However, there are some isolated instances of elevated VOCs that are an indication of the urbanization of the watershed as described above.

The most frequently detected VOCs within the Metedeconk River watershed are shown in **Table 4-3**. These are similar to compounds identified by the USGS (Nicholson et al, 2003).

4.2.3 Total Maximum Daily Loads (TMDLs)

The Metedeconk River is currently listed on the New Jersey 2008 303(d) list of water quality limited waters. Total Maximum Daily Loads (TMDLs) are developed to address impaired waterbodies listed by NJDEP on Sublist 5 of the *Integrated List of Waterbodies.* TMDLs exist for fecal coliform, total coliform and phosphorous.

4.2.3.1 In-Stream Fecal Coliform TMDL

A fecal coliform TMDL was established for the Metedeconk River because both the North Branch and the South Branch are listed on Sublist 5 of the *2002 Integrated List of Waterbodies* as impaired for pathogens, as indicated by fecal coliform. The fecal coliform SWQS are defined in N.J.A.C 7:9B-1.14(c), which states that fecal coliform levels should not exceed a geometric average of 200 cfu/100 ml nor should more than 10 percent of the total sample taken during a 30 day period exceed 400 cfu/100 ml in FW2 waters. **The TMDL for both the North Branch and South Branch Metedeconk River is a 90% load reduction of fecal coliform.**

4.2.3.2 Lakes Fecal Coliform TMDL

Fecal coliform TMDLs were also established for two lakes within the Metedeconk River Watershed. Lake Carasaljo and Ocean County Park Lake are listed as High Priority on the *2004 Integrated List of Waterbodies* and Sublist 5 of the *2006 Integrated List of Waterbodies* for fecal coliform impairment. The TMDLs for Lake Carasaljo and Ocean County Park Lake were calculated using a similar method as the stream

TMDLs. However, the lake TMDLs are based on the Health Department standard of 200 cfu / 100 ml, which is more stringent than the SWQS. The less stringent SWQS is a geometric mean of 126 cfu / 100 ml or a single sample of 235 cfu / 100 ml for primary contact recreation in FW2 and Pinelands waters. The TMDL was based on monitoring data available from the Ocean County Health Department as well as the NJ Department of Health, which collects data for bathing beaches during May to September. The TMDL reductions were based on the single sample maximum concentration identified in the record of observed data. Since the TMDL loads are presented as average annual loads, the summer critical condition period (May – September) and the average load contributed during the other seasons are included. A 5% margin of safety was calculated for each lake. **The TMDL for Lake Carasaljo is an overall watershed load reduction of 99% to 15,300 million fecal coliform colonies per year, and the TMDL for Ocean County Park Lake is an overall watershed load reduction of 96% to 691 million fecal coliform colonies per year.**

4.2.3.3 Total Coliform TMDL

The Metedeconk River discharges into Barnegat Bay, which is also impaired for total coliform. The SWQS in New Jersey specify that shellfish waters shall meet National Shellfish Sanitation Program (NSSP) guidelines. Waterbodies are listed as impaired if they do not fully support shellfish harvest in accordance with National Shellfish Sanitation Program (NSSP) criteria. TMDLs were developed to meet the NSSP 90th percentile (330 cfu / 100 ml) and geometric mean (70 cfu / 100 ml) criteria for total coliform. Source assessments were also conducted to identify and characterize potential pathogens sources that may be impacting water quality and shellfish growing areas in the listed waters. Shoreline surveys, an analysis of land use, point source information, literature sources, and other available data were used in the source assessment. The Metedeconk River estuary was included in the Local Area Report (LAR) completed for the BB-1 shoreline survey area. The BB-1 shoreline survey area is defined as Barnegat Bay North, areas from Bayhead to Bay Shore. LARs provide information on local shellfish growing areas with a characterization on the growing area, surrounding land use, and potential pollution sources in the watershed. These reports helped to develop the TMDL for the Metedeconk River by identifying potential pathogen sources that may be impacting shellfish harvest areas.

The TMDL for the Metedeconk River Estuary is an 87% reduction in total coliform load. The loads contributed by forest lands and barren lands were not reduced in the TMDL allocation, therefore the load reduction is to be applied to urban areas, agricultural lands, and marinas. Since the Metedeconk River empties into Subarea D of the Barnegat Bay, the TMDL for this area of the Barnegat Bay was calculated using a nested approach to account for proposed reductions in upstream tributaries. By using this approach it was determined that by meeting the TMDL of an 87% total coliform reduction in the Metedeconk River and a 41% reduction in the neighboring Beaverdam Creek Estuary, Subarea D of the Barnegat Bay would require no further action to support designated uses.

4.2.3.4 Phosphorus TMDL

The Phosphorus TMDL has been established for the North Branch Metedeconk River's westernmost HUC14 subwatershed (NB1) and is based upon impairment listed on Sublist 5 of the *2004 Integrated List of Waterbodies*. The in stream New Jersey SWQS for phosphorus states that total phosphorus shall not exceed 0.1 mg/l in any stream, unless it can be demonstrated that total P is not a limiting nutrient and will not otherwise render the water unsuitable for the designated uses in FW2 streams. The nutrient policy also includes that, except as due to natural conditions, nutrients are not to be allowed in concentrations that would promote an over-abundance of algae, nuisance aquatic vegetation, abnormal fluctuations in dissolved oxygen or pH, changes to the composition of aquatic ecosystems, or otherwise render the waters unsuitable for the designated uses. Total phosphorus source loads were estimated using the Unit Areal Load (UAL) methodology, which applies pollutant loading coefficients (otherwise known as "export coefficients) to available land use data. Data from seventeen water quality samples taken at Jackson Mills Rd in Freehold were used in the TMDL analysis. The average value of the samples was 0.13 mg/l, with 47% of the samples exceeding the 0.1 mg/l SWQS.

The TMDL for the North Branch Metedeconk River's westernmost HUC14 is an overall reduction of 49.8% of the phosphorus load, which can be achieved through an 84.9% reduction in total phosphorus load from residential, commercial, industrial, mixed/other urban and agricultural land uses.

Although the use of watershed models is beyond the scope of this task analysis, the export coefficients utilized by NJDEP to develop the phosphorus TMDL (**Table 4-4**) were used with the updated 2007 land use / land cover database (NJDEP, 2010; **Table 2-2**) and an updated phosphorus load for each HUC14 along the North Branch was calculated (**Table 4-5; Figure 4-13**). On a HUC14 scale, NB2 shows the highest phosphorus load, likely due to its size and amount of commercial land use. The only phosphorus data within that HUC is for station NG, which has generally had lower phosphorus concentrations than NK and NP, although it contains considerably more residential land use.

4.2.3.5 Summary of TMDL Implementation Strategies

A summary of the four TMDLs in the Metedeconk River watershed is included in **Table 4-6**. Implementation strategies that are recommended to achieve the bacteria and phosphorus TMDLs (as specified by the TMDLs) include agricultural BMPs, urban stormwater BMPs and retrofits, geese management plans, pest waste ordinances, riparian buffer restoration, the identification and elimination of sewage conveyance facilities failures, and addressing inadequate on-site sewage disposal.

Low phosphorus fertilizer ordinances are strongly encouraged by the phosphorus TMDL implementation plan, and are required in predominantly urban watersheds in accordance with Phase II NJPDES stormwater rules. A statewide fertilizer ordinance has recently been passed as part of an overall Barnegat Bay protection strategy which would not allow fertilizers containing phosphorus to be sold and used by professional landscapers unless a need can be established. Also, fertilizers will no longer contain more than 0.75 lbs of total nitrogen and 30% of the total nitrogen would be slow-release nitrogen. In addition, application restrictions will be enforced and an education outreach program would be established regarding the environmental and water resource impacts of over-fertilization.

Under the Phase II NJPDES stormwater rules for the Municipal Stormwater Regulation Program, municipalities with separate storm sewer systems are required to implement various control measures that should reduce bacteria and nutrient loadings. These requirements also include measures to eliminate "illicit connections" of domestic sewage and other waste to the stormwater conveyance system, adopt and enforce pet waste ordinances, prohibit feeding of unconfined wildlife on public property, clean catch basins, perform good housekeeping at maintenance yards, and provide related public education and employee training. These strategies will help to achieve the percent reductions to meet the TMDL targets.

The North Branch Metedeconk River is predominantly urban, and the loads from this source will be addressed by the recommendations stated above that fall under the Phase II Stormwater Program. There are some agricultural properties in the watershed, many of which house livestock, and a number of horse farms. Agricultural BMPs are recommended to address fecal coliform and phosphorus loadings from these areas. Local community-based goose management plans are also suggested to address the large population of geese that resides around Lake Aldrich. Similar recommendations are made for the South Branch Metedeconk River, which encompasses a large percent of urban area, livestock, and three lakes (Lake Carasaljo, Ocean County Park Lake, and Lake Eno) with significant geese populations.

The fecal coliform TMDL implementation plan also identifies microbial source tracking (MST), which can be used to determine sources of fecal contamination. The presence of coliphages in defined contaminant areas can help to determine the sources of fecal contamination, whether they be point human, non-point human, point animal (livestock), or non point animal such as pet waste, or wildlife. A TMDL source tracking project was completed as a result of the stream fecal coliform TMDL. Lake Carasaljo was one of the sampling sites included in the study, and the results of this study, and future studies, can help to pinpoint other implementation strategies to reach the target TMDLs for the Metedeconk River.

Section 5
Municipal Management Information

This section reviews municipal regulations of the five largest upstream townships within the Metedeconk River watershed: Brick, Freehold, Howell, Jackson, and Lakewood as they pertain to water resources management. The Phase I Report (CDM, 2000) identified various stormwater / riparian protection gaps in the Township ordinances at that time. As part of this current analysis, various meetings were held with the township engineers and / or various government officials in order to obtain the available ordinances and mappings to determine any potential stormwater, development, or sanitary concerns that the township may have. The current township ordinances where gaps previously existed were evaluated in order to determine any changes in status of a specific regulation. A brief summary of potential issues or any continued gaps is presented.

5.1 State Regulations

With the exception of construction in streams, floodways or wetlands, land use regulation in New Jersey is delegated to the municipalities under the Municipal Land Use Law. Each municipality must have a Land Development Ordinance and a Development Plan which integrates land use and infrastructure planning. Development cannot occur without a Site Plan Approval by the Municipal Planning Board and / or the Zoning Board of Adjustment. Included in the site plan review process is compliance with the local Stormwater Management Ordinance, County Stormwater Management Regulations, Soil Erosion and Sediment Control Standards as well as any additional development restrictions (within the riparian corridor, wetland setbacks, etc.).

In 2004, new stormwater regulations were adopted in New Jersey that specifically address water quality issues associated with stormwater. One set of regulations were the Phase II New Jersey Pollutant Discharge Elimination System (NJPDES) Stormwater Regulation Program Rules (N.J.A.C. 7:14a), which established Statewide Basic Requirements (SBRs) that were to be implemented in an effort to reduce nonpoint source pollutant loads in stormwater (NJDEP, 2010; Obropta, 2009). These apply to all municipalities that have municipal separate storm sewer systems (MS4s) as well as to public complexes (universities, etc) and highway agencies. The municipalities are grouped by population into Tier A (larger and more densely populated) and Tier B municipalities. All of the Metedeconk River watershed municipalities fall into the Tier A category and municipalities must establish a stormwater pollution prevention plan as well as apply with SBRs.

Stormwater Management Rules (N.J.A.C. 7:8) were also established which develop requirements for stormwater management plans and ordinances and establish stormwater design standards for proposed developments, including compliance with Category One buffers. Procedures for implementing stormwater management plans under the Municipal Land Use Law are also included in the Stormwater Management Rules.

Every municipality in the state is required to prepare a Stormwater Management Plan and a Stormwater Control Ordinance or Ordinances to implement said plan. The goals of the stormwater management plan are as follows (N.J.A.C. 7:8-2.2):

- Reduce flood damage, including damage to life and property;
- Minimize, to the extent practical, any increase in stormwater runoff from any new development;
- Reduce soil erosion from any development or construction project;
- Assure the adequacy of existing and proposed culverts and bridges, and other in-stream structures;
- Maintain groundwater recharge;
- Prevent, to the greatest extent feasible, an increase in nonpoint pollution;
- Maintain the integrity of stream channels for their biological functions, as well as for drainage;
- Minimize pollutants in stormwater runoff from new and existing development to restore, enhance, and maintain the chemical, physical, and biological integrity of the waters of the state, to protect public health, to safeguard fish and aquatic life and scenic and ecological values, and to enhance the domestic, municipal, recreational, industrial and other uses of water;
- Protect public safety through the proper design and operation of stormwater management measures;

The stormwater management plans must incorporate nonstructural management strategies into design standards that focus on the following (as summarized by Howell Township Stormwater Management Plan):

1. “Protect areas that provide water quality benefits or areas particularly susceptible to erosion and sediment loss;” (N.J.A.C. 7:8-5.3(b)1.).

    i.e., preserve forested areas, riparian corridors and high groundwater or aquifer recharge capabilities and any other natural area with significant hydrologic function, specific legal and / or procedural measures to ensure areas remain preserved in the future and, re-establish wooded and forested areas that were disturbed.

2. “Minimize impervious surfaces and break up or disconnect the flow of runoff over impervious surfaces;” (N.J.A.C. 7:8-5.3(b)2.).

i.e., use vegetative filters and buffers, promote sheet flow over vegetated areas, use level and / or curb cuts at appropriate locations, utilize the minimum pavement widths, vegetate landscape islands, utilize pervious materials at appropriate locations and locate parking underground or beneath buildings.

3. "Maximize the protection of natural drainage features and vegetation;" (N.J.A.C. 7:8-5.3(b)3.).

   i.e., preserve forested areas, riparian corridors and high groundwater or aquifer recharge capabilities and any other natural area with significant hydrologic function and take specific legal and / or procedural measures to ensure areas remain preserved in the future.

4. "Minimize the decrease in the pre-construction "time of concentration;" (N.J.A.C. 7:8-5.3(b)4.)

   i.e., increase sheet flow, disconnect impervious areas, use vegetative stormwater conveyance systems and dense vegetation at appropriate locations, utilize natural features and reduce slopes.

5. "Minimize land disturbance including clearing and grading'" (N.J.A.C. 7:8-5.3(b)5.)

   i.e., preserve forested areas, riparian corridors and high groundwater or aquifer recharge capabilities and any other natural area with significant hydrologic function and reduce lawn areas.

6. "Minimize soil compaction;" (N.J.A.C. 7:8-5.3(b)6.)

   i.e., use light weight equipment during construction and minimize disturbed land areas.

7. "Provide low maintenance landscaping that encourages retention and planting of native vegetation and minimizes the use of lawns., fertilizers and pesticides;" (N.J.A.C. 7:8-5.3(b)7.)

   i.e., use native plants that will result in lower fertilizer and water needs, will promote infiltration characteristics similar to those of natural area and can attract native wildlife and provide better habitats.

8. "Provide vegetated open-channel conveyance systems discharge into and through stable vegetated areas;" (N.J.A.C. 7:8-5.3(b)8.)

i.e., use vegetated channels and swales at appropriate locations to increase surface roughness and decrease flow velocities and ensure vegetative conveyance systems are tolerant to higher frequency storms.

9. "Provide other source controls to prevent or minimize the use or exposure of pollutants at the site in order to prevent or minimize the release of those pollutants into stormwater runoff." (N.J.A.C. 7:8-5.3(b)9.)

   i.e., provide trash receptacles litter fences, require regular sweepings, provide "pet waste stations," provide storm drain inlets and trash racks, and utilize berms and secondary containment systems (this section is more specifically geared toward commercial and industrial areas or areas with high residential population densities).

All major developments, similar to all municipalities, must also adhere to maintaining groundwater recharge by either maintaining 100% of the average annual pre-construction groundwater recharge volume for the entire site or infiltrating the increase in the stormwater runoff volume from pre-construction to post-construction of the two-year storm.

Furthermore, stormwater quality (N.J.A.C. 7:8-5.5) standards must be adhered to so that each project reduces the total suspended solids (TSS) to an 80% reduction of the water quality design storm event. However, since the Metedeconk River is a Category One waterway and requires a 300 foot riparian buffer area (special water resource area), any development within the buffer must achieve a 95% TSS post-construction removal rate. Furthermore, additional NJDEP stormwater management measures to address discharge temperatures on the C-l waterway must also be studied. It should be noted that only in rare instances is any development within the C-1 buffer area permitted.

Regarding stormwater quantity, one of the following three design standards must be met (N.J.A.C. 7:8-5.4 3):

- Demonstrate at no point in time that the post-construction runoff hydrograph exceeds the pre-construction runoff hydrograph;

- Demonstrate there is no increase, as compared to the pre-construction condition, in the peak runoff rates of stormwater leaving the site for the 2, 10 and 100-year storm event, and that the increased volume or change in timing of stormwater runoff will not increase flood damage at or downstream of the site; or

- Demonstrate the post-construction peak runoff rates for the 2, 10 and 100-year storm events are 50, 75 and 80 percent, respectively, of the pre-construction runoff rates. However, for stormwater runoff quantity requirement, stream encroachment standards (N.J.A.C. 7:13-2.8) will require a 100-year storm event, 75 percent of the pre-construction peak runoff rates.

Over the past ten years the Townships have undertaken many revisions to the Master Plans and/or ordinances. At the time of the Phase I Report, none of the major upstream townships had developed Stormwater Management Plans or associated ordinances to implement the plans. Since that time, all of the townships reviewed have Stormwater Management Plans and/or Ordinances in place. The Stormwater Management Plan becomes an integral part of the Master Plan prepared by that municipality pursuant to Section 19 of P.L. 1975,c.291 (C. 40:55D-28). Each municipality is also required to coordinate the plan with the appropriate Soil Conservation District established pursuant to Chapter 24 of Title 4 of the revised statutes and with any stormwater management plans prepared by any other municipality or any county, area wide agency or the state relating to the river basins located in that municipality.

A brief summary of major plans and ordinances for each of the five largest townships within the Metedeconk River watershed is provided below. Although the availability of individual ordinances may vary for each township, the following primary plans and ordinances are summarized for each:

- Stormwater management plan;
- Stormwater control ordinances;
- Relevance of the township's Master Plan to water resources (zoning/land use);
- Other pertinent codes and/or plans

5.2 Municipal Plans/Ordinances

5.2.1 Brick Township

Approximately 25% of Brick Township is included in the Metedeconk River watershed and essentially includes the area downstream of the confluence of the two branches. Much of Brick Township is already built out and was more than 95% built out by the Census 2000 (Brick Stormwater Management Plan, 2007). Brick Township is unique in the Metedeconk River watershed as it is entirely served by public water and sewer through the Brick Township Municipal Utilities Authority (BTMUA). The BTMUA has a service contract with the Ocean County Utilities Authority (OCUA) to treat all sewage within the township.

5.2.1.1 Stormwater Management Plan

Brick has adopted a stormwater management plan in 2005 which is thorough and very protective of the watershed. The plan is in compliance with the Stormwater Management Rules and identifies various township ordinances that were developed in accordance with N.J.A.C 7:14a and N.J.A.C. 7:8. The management plan also outlines the Open Space Preservation and Recreation Plan which targets acquisition and preservation of floodplains and wetlands throughout the township.

The stormwater management plan also indicates that a survey of all stormwater facilities will be conducted and repair and / or maintenance of the stormwater facilities will be performed. This survey analysis is on-going at this time.

5.2.1.2 Stormwater Control Ordinance

Chapter 396 of the Brick Township code specifies the stormwater control ordinance and is in compliance with Stormwater Management Rules. Maintenance and repair of stormwater basins is addressed through requirements to submit a maintenance plan for the basins. Annual evaluations of the maintenance plan are required. Violations of design standards, compliance and repair of facilities are subject to a fine of $500 per day until the facility in question is repaired or restored.

5.2.1.3 Land Use/Zoning (Master Plan)

The Brick Township Master Plan was modified in June 2007 as an update to the 1997 Master Plan. The objectives of the Master Plan that concern water resource protection are as follows:

- To implement the Open Space & Recreation Plan.
- To encourage the continued Municipal acquisition and recreational development of vacant waterfront property for public access & use.
- To implement the Conservation & Open Space Plan Element.
- To implement the conservation plan by protecting the environmentally sensitive lands as delineated on the Master Plan
- To provide for additional open space and recreational areas and to provide incentives for dedication to the Township of lands for those purposes.
- To implement the Municipal Stormwater Management Plan Element.
- To improve surface & groundwater quality through the completion of the Sewerage Infrastructure Improvement Act requirements by adhering to the NJDEP Water Quality Standards and Municipal Stormwater Regulations Program.
- To discourage direct discharge of storm water into bodies of water, to discourage the off-site flow of stormwater and to require on-site retention in underground facilities whenever feasible.
- To protect environmentally critical areas and preserve woodlands and open space and to encourage the beautification of the Township through landscaped areas.
- To encourage energy conservation policies through techniques as applied in Site Plan and Subdivision Review and other governmental action.

- To improve the quantity and quality of landscaping and buffer plantings.
- To protect riparian buffers from encroachment from new development through low density residential zoning (minimum lot size of 40,000 square feet).

The Master Plan also identifies other ordinances which target water resource protection such as pet waste, litter control, containerized yard waste, improper disposal of waste, wildlife feeding and a yard waste collection program. All of these ordinances have been updated to include requirements outlined in the Stormwater Management Rules.

The master plan also discusses geese management strategies as part of the implementation of the fecal coliform TMDL.

One of the major development objectives of the Brick Township Master Plan is to encourage the re-planning and rehabilitation of all major commercial areas and neighborhood business districts in general, and in particular, the Brick Town Center. As these areas are upgraded and redeveloped, there is the opportunity for improving the existing stormwater infrastructure to limit the nonpoint source pollution loads to the Metedeconk River and its tributaries. These areas represent good candidates for implementation of low impact development (LID) techniques.

The Master Plan also identifies the upgrading of existing residential neighborhoods through housing rehabilitation, increased code enforcement, landscape improvements, and infrastructure maintenance as a development objective. Since the stormwater runoff from older residential developments is discharged directly to the receiving waterways without treatment, there is an opportunity to retrofit these areas with BMPs, LID or improved management strategies during rehabilitation.

A unique opportunity lies in the rehabilitation of the Brick Town Center. The targeted area is a 1.12 square mile district within the Metedeconk watershed near the confluence of the North and South branches and Forge Pond, between Chambers Bridge Rd and the Garden State Parkway, and is served by Rt. 88 and Rt. 70. The area is a fairly compact and highly impervious mix of uses including public, commercial, and residential uses, and there are some undeveloped parcels of land. The future plan for the Brick Town Center emphasizes the incorporation of mixed uses and utilizes smart growth principles such as connectivity, public spaces, shared infrastructure, streetscaping, and the protection of natural resources. Since stormwater generated from this area directly impacts the Metedeconk River, there is an opportunity to improve the quality of the watershed with future rehabilitation efforts.

Overall, there were no clearly identifiable gaps in municipal ordinances for water resource protection in Brick Township based upon applicable regulations. However, more progressive LID practices can be incorporated and design standards for retention / detention basins can be strengthened to require evaluations for groundwater mounding as proposed by the USGS (Carleton, 2010). In addition, the status of the stormwater facility survey should be evaluated.

5.2.2 Freehold Township

Freehold Township is within the upper limits of both the north and south branches of the Metedeconk River. Approximately 25% of the total land area is within the Metedeconk River watershed. It should be further noted that approximately 50% of this area is restricted by wetlands. This same area is also preserved by several large public and quasi public parks.

Population growth rate projections according to the NJTPA report from 2000 to 2010 was estimated at 12% or 31,564 to 35,430 residents. It is anticipated to slow to 6% for the next 10 years, putting less demand on housing construction and on the watershed.

Freehold Township has been proactive over the years and has set goals in order to mitigate stormwater impacts throughout the watershed from existing and proposed developments and to provide long term maintenance strategies.

5.2.2.1 Stormwater Management Plan

This document prepared by the Freehold Township Engineering Department sets forth the typical strategies that are required to address N.J.A.C. 7:14A-25 Municipal Stormwater Regulations and N.J.A.C. 7:8 Stormwater Management Rules. The management plan was adopted March 3, 2005 and revised in August 2006.

The goals of this plan are similar to the ones outlined in N.J.A.C. 7:8 and contains all of the required elements, such as minimizing stormwater runoff, reducing soil erosion, maintaining groundwater recharge and minimizing pollutants.

As per the date of the Stormwater Management Plan, the Township was conducting an inventory of all streams within the town and to evaluate which streams need to be restored. The status of that inventory as it relates to the Metedeconk River watershed should be reviewed and compared to nearby sites evaluated as part of the Visual Assessment Project Plan.

5.2.2.2 Stormwater Management Ordinance

This ordinance adopted February 28, 2006 provides similar requirements as the other municipalities within the watershed for low impact techniques and structural BMP’s that need to be implemented for any new development. The same restrictions and guidelines apply for the special resource protection areas of the Township designated as Category One, such as the 300 foot buffers, limited encroachments, soil erosion control, temperature control and water quality. Ground water recharge standards and rates shall also be calculated utilizing the NJDEP formulas. As shown on **Figure 2-6**, approximately 90% of the Freehold portion of the watershed is in the R-E zone, which requires a minimum 10 acre lot size and a maximum impervious cover of 5%.

Whenever an applicant submits a site plan or subdivision plan to the Township for approval, they shall demonstrate that the project complies with all the required stormwater components listed within a "check list for the site development stormwater plan".

A maintenance and repair plan for the stormwater infrastructure system is also required by the applicant's engineer setting forth proper schedules and responsible parties. What is unclear in the ordinance is whether the Township requires a fee to accept responsibility of future maintenance.

Since the southern portion of the Township does not provide for public sewer to the areas zoned for 10 acre lots, this area will need to be developed on individual septic systems and comply with the restrictions outlined in the Township Stormwater Management Ordinance.

This ordinance does permit development or construction upon lands with delicate hydrology, subject to certain restrictions of septic regulations, and it limits mounded systems with ejector pumps as a means of septic disposal upon such lands. It recognizes that activity in this area could result in substantial impairment to the water resources of the watershed and the region, cause pollution from septic wastes and/or create consequential difficulties to structures constructed thereon. The ordinance allows construction and development, provided the water table is not such as to disqualify such activity, pursuant to the standards and regulations of the chapter.

Prior to approving a subdivision or site plan in this area of the Township, it will need to determine that there will be no substantial detriment to the water resources.

Each application shall provide detailed information of the soil's capability for treatment of the septic system effluents containing nitrogen and phosphates. Since this portion of the Township has a high aquifer recharge rate, percolation rates also need to be addressed when reviewing an application for a septic approval.

5.2.2.3 Land Use/Zoning (Master Plan)

Many of the goals of the Master Plan are applicable to stormwater management such as:

- To promote the establishment of appropriate population densities in locations that will contribute to the well being of persons, neighborhoods and preservation of the environment.

- To promote a desirable visual environment through creative development techniques which respect the environmental qualities and constraints of the Township and of particular sites.

- To encourage the preservation and restoration of historic buildings and sites within the Township in order to maintain the heritage of Freehold Township for the enjoyment of future generations.
- Protection of natural and environmental resources including floodplains, wetlands, marsh, and aquifer recharge areas, and areas suitable for public and quasi-public recreation activities.
- To protect and enhance the environmental quality of the Township.

To help achieve these goals, a number of ordinances have been reviewed and altered to allow for nonstructural stormwater management techniques as well as low impact design including the allowance for curb cuts and cluster development.

5.2.2.4 Other Relevant Ordinances

5.2.2.4.1 Land Use Regulations – Flood Damage Prevention and Watercourses – August 25, 2009

This ordinance regulates flood hazard areas related to public health and safety. It also regulates the stream and watercourses in order to prevent siltation, erosion of the banks, and degradation of water quality caused by encroachment.

The ordinance further restricts depositing or dumping of any material uses, pesticides, erection of structures, rates of runoff, channel modification, etc.

5.2.24.2 Land Use Regulations – Riparian Zone Ordinance – Chapter XIII – June 29, 2010

The purpose of this recent ordinance was to designate riparian zones and provide regulation for these zones in compliance with N.J.A.C. 7:15-5.25(g), which requires all municipalities to adhere to these regulations. All new disturbances or activities in the riparian zone, which are 300 feet wide along both sides of any Category One waterway, and all upstream tributaries must comply with these new regulations.

5.2.3 Howell Township

Howell Township is the second largest municipality within the Metedeconk River watershed comprising more than 20 square miles (**Table 2-1**). Howell Township has been very proactive in its watershed and natural resource protection and has a considerable amount of documentation related to its protection and to containing the growth or land development within the township.

5.2.3.1 Stormwater Management Plan

The Stormwater Management Plan for Howell Township was updated in March 2005 and was formally adopted in May 2007. The Stormwater Management Plan follows requirements specified in N.J.A.C 7:8.

In addition to the stormwater management plan goals described above, some of the key components and goals of this document for Howell Township are as follows:

- Encourage the preservation of agriculture and farmland within the township (Howell Township Master Plan, Land Use Plan Goals, 1994);

- Limit the intensity of development, in areas relying on groundwater supplies and on-site sewage disposal, based on conservation estimates of available water resources and the ability of the soil and groundwater to sustain on-lot disposal systems without degrading or impairing the water quality (2006 Land Use Plan Element, Goals and Objectives, Natural Resources, 2006);

The Municipal Stormwater Management Plan (MSWMP) also made recommendations to address or upgrade various Municipal Regulations that were previously adopted in order to make sure they were consistent with N.J.A.C. 7:8 Stormwater Management Regulations and N.J.A.C. 7:8-5.3 and Chapter 2 of the NJ Stormwater BMP Manual for non-structural management strategies and low impact techniques. This detailed document further explains the ways to achieve these goals by means of adopting the nonstructural or structural performance design standards as specified in N.J.A.C. 7:8 and/or the New Jersey Best Management Practices (BMP) manual that will be required of each development. Every site plan or subdivision must comply with these new Municipal Ordinances.

Howell Township also has identified mitigation projects where proposed developments that do not meet the aforementioned requirements and may need variances or waivers from strict compliance of the performance standards. Pursuant to a meeting held with William Nunziato, P.E., Township Engineer, there are several sites located throughout the township where groundwater recharge, water quality, or water quantity improvements could be provided by a developer as an alternative for satisfying the requirements and meeting the intent of the ordinance.

5.2.3.2 Stormwater Management Control Ordinance

The Phase I Report identified Howell as having a fairly weak ordinance requiring the “slowing down” of the rate and volume of storm runoff. The stormwater management control ordinance has been updated as of August 12, 2008 to reflect the Stormwater Management Rules.

The purpose of this ordinance was to implement the goals of the MSWMP. All site developments must follow the requirements within a detailed checklist that sets forth the design and performance standards for erosion control, groundwater recharging, stormwater quality, and quantity reduction to the maximum extent practical. These standards shall be met by incorporating non-structural practices. One of the largest components of this ordinance is the section regarding a maintenance plan.

The Howell Land Use Ordinances also require a floodplain permit issued by the Planning Board after an applicant has demonstrated to the board that there will be no significant advance impacts on downstream flooding. This ordinance is somewhat outdated since it makes reference to providing a 50 foot wide stream buffer which has now become a 300 foot wide requirement by the NJDEP.

The required maintenance plan shall be integrated into the design of all commercial and residential projects. When a stormwater management facility is required for a single-family detached development and the applicant enters into an agreement with the Township to maintain the basin, the applicant must contribute all replacement and operating costs, pursuant to a detailed "annual cost calculation spreadsheet, over a 10-year life span". This spreadsheet includes a cost breakdown for every component of the basin, which is then incorporated into an equation to calculate the contribution fee required by the municipality.

5.2.3.3 Land Use/Zoning (Master Plan)

The Master Plans and their individual land use components within Howell Township have been continually revised and amended in order to address various topics, such as stream corridors, utilities, housing density, and undeveloped lands, watershed areas and environmentally sensitive areas.

The Master Plan recommended the removal of the cluster option in zones not served by public sanitary sewer and potable water facilities. The Master Plan made recommendations to implement the stormwater management plan and Statewide Basic Requirements from N.J.A.C. 7:14A that aim to reduce non-point pollution related to litter, pet waste, wildlife feeding, street sweeping, catch basin cleaning, public education, maintenance of residential yards, etc. These recommendations have since been adopted by the Township Land Use Ordinances.

One of the goals of the Township is to establish development densities and intensities at levels which do not exceed the capacity of the natural resources and the available limitation of the soils for on-site sewerage disposal without degrading or impairing the water quality.

Howell has established Agricultural Rural Estates Zoning districts (ARE) that address the fragile resources and limit the previous permitted densities. These plans recommend larger lots of 2, 3, 4 and 6 acres in size within the southern portions of the Township, which are within the Metedeconk River watershed (see **Figure 2-7).** It further recommends open land subdivision clustering and lot averaging concepts in order to provide techniques that aid in preserving critical resources such as the watershed.

5.2.3.4 Other Relevant Ordinances

5.2.3.4.1 Riparian Buffer Regulations and Stream Corridor Preservation

This Ordinance dated March 18, 2010 updated the September 2, 2004 regulations and allows Howell Township to strictly enforce not only the C-1 waterways, but all waterways within the Township. These new regulations address the goals and objectives of the Township to protect the stream corridors and drinking water supply and comply with the associated NJDEP regulations and a court settlement.

The Township will also require an applicant to rehabilitate and/or re-establish the vegetation buffer of the stream corridor, if it has been previously disturbed. A detailed plant list is provided of acceptable native plant material that should be used to stabilize the disturbed areas within the 300 foot buffer and enhance pollutant uptake.

5.2.3.4.2 Fertilizer Ordinance:

It should also be noted that Howell has ordinances limiting the amount of phosphorous in outdoor fertilizer to zero with the exception of commercial farms and initial establishment of growth. This will aid in the possible reductions in phosphorus concentrations downstream.

5.2.4 Jackson Township

Jackson Township comprises the largest portion of the Metedeconk River watershed at almost 21.5 square miles.

5.2.4.1 Stormwater Management Plan

The Township is currently updating all the documents for consistency with the NJDEP regulations. At this time, the updated Stormwater Management Plan has not been finalized.

5.2.4.2 Stormwater Control Ordinance

The Phase I Report identified that Jackson Township previously contained some weak terminology in that the code “encourages” recharge areas and water quality enhancement measures (detention basins). As the Stormwater Management Plan has yet to be completed, the stormwater control ordinance has not been reviewed.

5.2.4.3 Land Use/Zoning (Master Plan)

Jackson Township is similar to other municipalities within the region having experienced substantial increases in residential and commercial growth. A 30% increase in growth has occurred since 2000 to the current population of 55,000 residents. Approximately 4,775 new housing units have been constructed since 2000, added to the 14,640 units that were present in 2000.

In review of the township Land Use Code, it appears that it contains substantial language to protect the watershed. The Land Use Code provides a requirement for a stormwater management system maintenance schedule of all detention or retention basins or infiltration systems to be dedicated to the Township, subject to a maintenance fee that is calculated at the rate of $1,025/acre of basin size, multiplied by a 25 year maintenance period. Subsurface infiltration systems are calculated at the rate of $1.00/linear foot multiplied by 25 years plus other components of the system.

The design standards for stream corridors (109-402) mirror the regulations of the State and Federal agencies and where in conflict, the Township's rules will not supersede. It is the goal of the Township to protect and maintain the native buffers up to 300 feet in width and to reestablish plantings in areas less than 300 feet. The ordinance states that the Township recognizes the value of protecting the corridor.

The other typical regulation for non-structural, low impact techniques, recharge, water quality and quantity reductions adopted by the other townships are also adopted here.

The Land Use Code also contains a detailed checklist for an Environmental Impact Statement (109-169) which is required for construction of more than seven (7) lots or more than 20,000 SF of commercial development. The site plan or subdivision approval is required to discuss the potential impacts on the watershed and what strategies will be undertaken to minimize them.

The Master Plan analysis estimates that under existing zoning, 7,565 more residential units could be constructed for full build out of the Township along with 4.9 million square feet (ft^2) of commercial space and 9.7 million ft^2 of industrial development. The proposed Land Use Plan (updated July 2009) and ordinances (if approved) would reduce the total residential units to approximately 5,650 and increase the commercial and industrial square footage to 9.5 and 14.3 million ft^2.

In review of the Metedeconk River watershed development potential, it was interesting to note that a majority of the 2,417± acre area within the watershed to the North Branch is already developed (81.3% of the available land). The North Branch of the Metedeconk River only has approximately 176 acres of developable land left and 83 acres of "underdeveloped" land. Therefore, the area contributing to the North Branch is somewhat close to build out conditions. At the current zoning, this land area will only generate 38 units and 50,094 ft^2 of commercial space.

The proposed zoning changes for the land located within the North Branch watershed will not alter the future residential build-out numbers.

The South Branch of the river has substantially more land area (11,305 acres) with approximately 1,700 acres (15%) of land area that can still be developed resulting in approximately 2,150 new residential units under current zoning. The commercial and industrial component is fairly substantial at approximately 6 million ft^2 under the proposed Land Use Plan for the Metedeconk River watershed. The proposed zoning changes for the land located within the South Branch will reduce the residential units by ½ to approximately 1,100 units still to be developed.

The commercial and industrial uses are anticipated to increase in both the North and South Branch watersheds to 8.7 million ft^2 or a 45% increase as the Township shifts direction away from residential zoning.

In the review of the Township mappings, existing sewer service is accommodated in approximately 68% of the area within the Metedeconk watershed (**Figure 5-1**). The proposed plan for public sewer service is similar to the existing plan. Some small areas have been removed, possibly due to environmental constraints and/or critical habitats. This detailed process is ongoing and Township ordinances will need to be modified to address existing and proposed developments and where future growth is going to be directed based upon the proposed Township land use plan and future land use ordinances.

There are many areas within the Township where land development has occurred on small ½ to ¼ acre lots that should be connected to the sewer system. From discussions with Township Engineer, the neighborhood constructed around Lake Eno has been identified as in need of public sewer service.

The regulation also states "that single-family residential properties (including home-based businesses) served by properly functioning septic systems shall be "exempt" from the mandatory connection requirements upon execution of an acknowledgement and release form by those individuals and/or entities as set forth in Resolution 2001-128 of the Jackson Township M.U.A. Any and all exemptions terminate immediately upon the failure of the property owner's private septic system".

The recently adopted NJDEP Wastewater Management Regulations require either the County or Municipality or both to undertake an inventory of existing septic systems and implement a routine maintenance schedule for inspections and pump outs and possible penalty measures for non-compliance. These options are also being studied; however, due to the cost of these programs for mandatory hook-up and/or maintenance of the existing systems, and the economic burden on financially stressed homeowners, there is some political resistance to adopting new regulations. Without some form of funding from either the County or State mandatory hookup will be difficult.

5.2.4.4 Other Relevant Ordinances

5.2.4.4.1 Fertilizer Ordinance:

Jackson Township has adopted a fertilizer ordinance (October 2010) which limits outdoor fertilizer application (outside of commercial farms). Fertilizer application is prohibited during or before precipitation events and on impervious surfaces. In addition, fertilizer application is prohibited during a 15 day time period prior to the growing season (identified as March 1 – November 15th of each year). In addition, the ordinance prohibits the outdoor application of fertilizers containing phosphorus with some exceptions (demonstrated need, initial vegetative establishment, residential container plantings or fertilizer that is delivered directly to the root zone).

5.2.5 Lakewood Township

The North Branch of the Metedeconk River serves as the northern boundary line between Lakewood and Howell Townships, and a small section of Brick Township and the northeast corner of Lakewood. The South Branch crosses the center portion of Lakewood connecting Lake Carasaljo, Lake Manetta and Lake Shenandoah. The drainage areas to these two branches of the Metedeconk River comprise approximately 2/3 of the Township area.

Population growth in Lakewood continues and is expected to increase by 130,000 persons by 2030. With new development to accommodate this population growth, potential problems may arise for the watershed from non-point source pollution.

The eastern three fourths (¾) of the Township is located within the CAFRA zone, making it subject to more detailed development review by NJDEP for stormwater management and environmental impacts.

Lakewood Township is primarily considered a Suburban Planning Area (PA2) on the State Master Plan Policy Map. A small Fringe Planning Area (PA3) is located in the western portion of the Township along the headwaters of the South Branch of the Metedeconk River. Small areas of Environmentally Sensitive Planning Area (PA5) are located at the northern boundary of the Township with Howell Township along the Metedeconk River. Critical Environmental Site Mapping (CES) identifies area along both branches.

Lakewood is seeking to have the entire Township designated PA2 with the exception of the PA5 and CES areas.

5.2.5.1 Stormwater Management Plan

The stormwater management plan and control requirements are specified within the Lakewood Township Unified Development Ordinance, which contains language from the Stormwater Management Rules.

5.2.5.2 Stormwater Control Ordinance

As indicated above, stormwater is addressed with the Unified Development Ordinance (see below).

5.2.5.3 Re-Examination Report of the Master Plan

The Lakewood Master Plan, adopted March 13, 2007 by the Lakewood Planning Board, stated that at the time of the 2000 U.S. census the Township had a population of 60,352 residents, or a 34% increase from 1990. The North Jersey Transportation Planning Association (NJTPA) projected a 12.5% increase by the year 2005 to 67,910 and a projected growth to 70,869 by 2010, 77,320 by 2020, and 87,690 by 2030.

These population projections are substantially lower than the growth projections established by the 2007 American Community Survey as published in the Lakewood

Smart Growth Plan of 2009 (T&M Associates, 2009). While this plan concurs with the 60,352 population numbers for 2000, it states that the 2007 population is actually 86,770 and that it is anticipated that the resident population will increase between 2010 and 2020 by 50,000, and yet another 80,000 between 2020 and 2030 for a total increase of 130,000 persons; or a total of 230,000 residents.

The Lakewood Smart Growth Plan projections estimate that approximately 26,000 new housing units will be required to meet the population demands of the township. The significant discrepancies between the Smart Growth Plan and the NJTPA documents will need to be reviewed once the 2010 Census data is finalized and released.

Significant changes in land use have occurred over the past ten years throughout the entire Township with the construction of medium density single family residential homes in the northern Metedeconk River watershed, industrial and commercial uses in the central section, and high density multi-family uses located outside the Metedeconk River watershed toward the south.

The Master Plan Reexamination Report (March 13, 2007) recognizes the anticipated growth and that careful planning is required to provide the proposed housing and economic needs of the Township, while not over burdening the ecosystem. It further recognizes that the Metedeconk River receives most of its flow (60-80%) from the groundwater recharge from the Kirkwood-Cohansey aquifer. However, no other specific discussions are noted in the document, nor are any recommendations made on how to preserve the recharge rates.

The Master Community vision or goal is to encourage new development and re-development, not only in the downtown areas, but also throughout the entire Township. The Land Use Plan within the reexamination report does not contain a build out analysis similar to Howell or Jackson Townships. Therefore, it is unknown what the total population, commercial density, or impervious coverage will be on the watershed at the time, other than the approximate total of 26,000 new residential units.

The documents state that where new development is proposed on raw, undeveloped land, an effort should be made to preserve mature specimen trees and other significant on-site vegetation. Where on-site vegetation cannot reasonably be preserved, developers will be required to replace vegetation on-site or at an alternative location in the Township to be determined and agreed upon by the Board (Planning or Zoning) granting the development approval. This type of approval option may allow for over clearing and an increase in impervious coverage on a project site.

The 2007 Master Plan Re-examination Report seeks to maximize the use of existing utility systems and encourage expansion to areas identified for future growth and development. It also seeks the following:

- Encourage development in areas presently serviced by public utilities in accordance with the existing development and the character of the neighborhood and proximate parcels.
- Through public and private partnerships, extend public utilities into developable areas.
- Upgrade existing infrastructure, including retention / detention basins and underground systems in the older, established areas of town.
- Prepare new stormwater management ordinances pursuant to NJDEP rules, regulations and standards.
- Explore and investigate the possibilities for a surface water reservoir in the Township.
- Through public and private endeavors, preserve environmentally sensitive areas including stream corridors, wetland areas, woodlands, and other environmentally sensitive lands and waters.
- Protect and preserve existing green space and parkland.
- Preserve the Little League area as parkland in the downtown area.
- Encourage the development of additional parkland in both the downtown area and more remote residential neighborhoods.
- Establish a comprehensive greenway system linking public open spaces and recreational sites with community facilities (i.e. libraries and schools).
- Institute and encourage creative methods for financing the acquisition and preservation of open spaces.
- Limit the permitted disturbance of natural features, including tree clearance, during land development.
- Promote awareness of businesses that may produce environmental concern such as water quality and pollution impacts.
- Encourage the establishment of a waterway protection system and the protection of endangered wildlife species.
- To preserve the supply of clean water for Lakewood and surrounding municipalities by encouraging compliance with State buffer requirements.
- Prepare and adopt a Wellhead Protection Plan.

- Increase open space inventory to meet community growth by investigating open space acquisition funding sources.
- Complete the acquisition of Crystal Lake with the Ocean County Natural Lands Trust.
- Consider Passive Open Space Zone for environmentally sensitive areas such as Lake Carasaljo or designation as a Critical Environmental Site (Cross Acceptance) or an Environmentally Sensitive Planning Area (State Plan).
- Continue to maintain open space networks, critical habitat, and contiguous tracts of land for habitat. Prepare and adopt a habitat protection plan for the Township.

5.2.5.4 Other Relevant Ordinances

5.2.5.4.1 Township of Lakewood Unified Development Ordinance (UDO)

On July 12, 2005, the Township adopted the UDO and reviewed it again after one year. The Land Use Ordinances certified typical sections on Environmental Impact Studies, site grading and erosion, stormwater management policies and basic construction and maintenance. The following highlights and / or concerns are noted:

a. Environmental Impact Statement (18-820) – EIS:

An EIS is required for every major subdivision that involves ten or more lots or more than 5,000 square feet of commercial space. However, the reviewing board may waive all or a portion of the requirements if the applicant can provide sufficient evidence that the proposed development will only have slight or negligible impacts to the environment. The ordinance is unclear on how the board determines which checklist item can be waived and if there are no environmental impacts.

b. Soil Removal and Grading (18-822):

This ordinance states that more than 425 cubic yards of soil disturbance or relocation within the township will require Township approval. Furthermore, any site disturbance exceeding 1,275 SF shall include a site plan that addresses soil erosion, drainage, run-off, dust, etc. The 1,275 SF limit is substantially more restrictive than the 5,000 SF requirements of the Ocean County Soil Conservation Service.

c. Golf Courses (18-1003):

This section of the ordinance addresses construction of golf courses and requires stormwater management, turf management plans, and water resource management plans designed to minimize water impacts. The plans need to provide for surface and ground water quality monitoring for nutrients, pesticides, etc., and control non-point source pollutants. The results of the monitoring are required to be submitted quarterly to the Township Engineer. The ordinance further requires a 100 foot wide forested buffer between turf areas and the 100 year flood plain, or any intermittent stream channel.

d. Stormwater Management / RSIS (18-815):

The Stormwater Management measures are similar in form to the other municipalities and address groundwater recharge and run-off quantity standards. Non-structural strategies as found in the New Jersey Stormwater Best Management Practices Manual are recommended to the maximum extent practicable. When an applicant states that they cannot comply with these strategies, based upon engineering, environmental or a safety reason, they must be able to provide a basis for that contention to the Board. However, it should be noted that when an applicant cannot comply, no impact fees or reconstruction of an alternative site is required, unlike other municipalities in the watershed.

The typical NJDEP recommended Category One special water resource protection area standards are listed within the Ordinances and apply to all projects within the Metedeconk River watershed. An applicant must follow the requirements set forth in a detailed checklist and provide drainage and basin maps, drainage calculations, environmental site analysis, groundwater recharge calculations, and a maintenance and repair plan.

Regarding the maintenance of stormwater management measures, the Ordinance states that "the responsibility of maintenance **shall not** be assigned or transferred to the municipality in a residential development or project." All commercial or industrial uses shall be by the owner of the site after posting a two (2) year maintenance guarantee in accordance to NJSA 40:55D-53 and following typical maintenance standards found in other municipalities.

However, it should be noted that further in these ordinances it states that: "For all proposed drainage and basins serving a residential community, the Township shall be responsible for all maintenance (both annual and perpetual). The following one-time maintenance fees shall be assessed per unit and put into a separate and dedicated fund, which shall be used by the Township exclusively for maintenance and repair of such stormwater management facilities within the Township:

Single-family detached dwellings:	$750.00
Single-family attached dwellings:	$500.00
Multi-family dwellings:	$300.00

Funds shall be posted as a condition of the release of this performance guarantee."

Since these basins are stormwater control measures, there is a discrepancy regarding the Township accepting ownership of residential projects.

Within 18-815.1.2(3) of the Unified Development Ordinance, it is specified that it is the policy of the Lakewood Planning Board and Zoning Board of Adjustment to minimize the number of stormwater basins by encouraging joint use of the basins between various developments and minimizing the number of basins within a development (Ordinance number 2006-22, section 815.1.2). However, the basin needs to be large enough to handle the combined flow. A water table mounding evaluation should be conducted on these larger basins as groundwater table mounding could pose a problem and limit infiltration rates (Carleton, 2010).

5.2.5.5 Lakewood Smart Growth Plan, 2009

The Smart Growth Plan is similar in nature to the 2007 Master Plan Reexamination Report and incorporated its goals and visions for center-based development areas in the Township.

It further serves as a framework for future sustainable growth in appropriate locations that are consistent with the existing land uses of the Township and to provide a balance in preserving open space and providing environmental protection.

One of the interesting strategies of the plan is a non-contiguous clustering option ordinance that once adopted will allow for the preservation of certain key critical natural resource areas and direct growth towards appropriate areas of the Township. The plan aims to promote growth through the adoption of additional environmental ordinances and conservation practices and its goal is to create design criteria where site plan applications within CAFRA jurisdiction of the Township can be reviewed by the Planning Board that will address the open space and tree save components of CAFRA on non-contiguous parcels. This will allow developers to preserve other lands outside their subject parcel and preserve approximately 1,000 acres of watersheds, headwaters, stream corridors, and properties adjoining other environmentally sensitive areas along with parks and active recreation areas. This report states that in order to accomplish this, the Township will need to adopt the following additional plans and ordinances:

- Open space and recreation plan.

- Riparian corridor protection plan and ordinances.
- Water conservation plan
- Wellhead protection plan.

The Smart Growth Plan does not include a water supply plan for the additional population. The plan references that the two water purveyors located within Lakewood Township, Lakewood Township Municipal Utilities Authority and New Jersey American Water Company, indicated that potable water supply would not be a limitation to the build-out population projections. At this time, it is not clear which aquifer the additional water would be withdrawn from or if the additional supply would originate within the Metedeconk River watershed.

5.2.5.6 Sanitary and Sewer Services

Almost the entire Township is located within the County approved service area, with the exception of two small areas in the western section of the Township near the boundary line with Jackson Township. The two areas are located along both branches of the Metedeconk River watershed. It is proposed that sewer service be available throughout the entire Township, with the exception of environmentally sensitive lands and wetlands. The Township's goals are to encourage extending and upgrading the existing infrastructure into developable areas.

Sanitary sewer service is provided by both Lakewood Township M.U.A. and New Jersey American Water Company. Despite the availability of sewer service and adequate capacity, there are no mandatory hook-up requirements for existing residential and commercial facilities. As mentioned above, due to the economic burden on financially stressed homeowners, without some form of funding from either the County or State, mandatory hookup will be difficult. Additional outreach should be implemented to homeowners that are currently on septic and where sanitary service is available to outline the benefits of connecting to the sewer service and the comparative costs between connection to sewer and installation and maintenance of a septic system.

The Route 88 corridor east of Hew Hampshire Avenue stands out as one area where sanitary sewer service would be particularly beneficial. This area is characterized by numerous automobile sales and service facilities. Commercial operations of this nature relying on septic systems in such close proximity to the Brick Township MUA's drinking water intake raise water quality concerns.

Where public sewer service is not available, the Township Ordinance (18-811) will permit septic systems, with the Board of Health approval, on a temporary basis. The Ordinance is unclear when a homeowner is required to hook-up (if at all) to the public system if/or when it becomes available. In addition, lots proposing septic systems are only required to meet separation distances between the leach field and property line, house or wells. There are no requirements for minimum lot size as it relates to nitrate dilution or evaluating subsurface soil conditions.

5.3 Summary of Potential Issues

5.3.1 General

The review of the municipal management information as it pertains to water resources and the Metedeconk River watershed has revealed that since the Phase I Report was completed in 2000, the five largest upstream townships within the Metedeconk River watershed: Brick, Freehold, Howell, Jackson, and Lakewood have made significant progress in development of plans and ordinances focused on the maintenance and protection of the water resources within the watershed. There are a few potential issues, however, which have been identified. The following are applicable to all five municipalities:

- A detailed survey of existing sanitary septic systems should be conducted involving a maintenance schedule for inspections, as per NJDEP Wastewater Management Regulations. A funding mechanism for this inventory should be identified.
- Extension of sanitary sewer systems should be conducted where appropriate.
- Although each township has identified initial maintenance responsibilities for stormwater control measures, the long-term responsibility of maintenance should be clarified , as should the funding mechanisms to provide inspections and maintenance. Currently, the duration of maintenance cost varies between municipalities.

5.3.2 Brick Township

As indicated earlier in this section, overall, there were no clearly identifiable gaps in municipal ordinances for water resource protection in Brick Township based upon applicable regulations. However, some changes can be incorporated (in addition to the above general potential issues):

- More progressive LID practices can be incorporated and design standards for retention / detention basins can be strengthened. The Brick Town Center represents a unique opportunity to implement LID and BMP techniques.
- The status of the stormwater facility survey should be evaluated.

5.3.3 Freehold Township

As with Brick Township, overall, there were no clearly identifiable gaps in municipal ordinances for water resource protection based upon applicable regulations. Similarly, more progressive LID practices can be incorporated and design standards for retention / detention basins can be strengthened.

The status of the stream inventory referenced in the Stormwater Management Plan, as it relates to the Metedeconk River watershed, should be reviewed and compared to nearby sites evaluated as part of the Visual Assessment Project Plan.

5.3.4 Howell Township

In addition to the general potential issues discussed above in Section 5.3.1, Howell Township has indicated that there are several sites located throughout the Township where groundwater recharge, water quality, or water quantity improvements could be made to potential developments. These should also incorporate LID and BMP techniques whenever possible.

5.3.5 Jackson Township

In addition to potential items addressed in Section 5.3.1, as of the date of this report, the Stormwater Management Plan and stormwater control ordinance has not been completed. These should be completed as soon as possible to meet all requirements of the Stormwater Management Rules (N.J.A.C. 7:8). Following completion, they should be reviewed to identify any regulatory gaps or potential issues as they may relate to the Metedeconk River watershed.

In addition, the neighborhood constructed around Lake Eno has been identified as in need of public sewer service.

5.3.6 Lakewood Township

In addition to the general potential issues described in 5.3.1, the following have been identified as potential issues which may impact the Metedeconk River watershed:

- Within the Master Plan, where on-site vegetation cannot reasonably be preserved, developers will be required to replace vegetation on-site or at an alternative location in the Township to be determined and agreed upon by the Board (Planning or Zoning) granting the development approval. This type of approval option may allow for over clearing and an increase in impervious coverage on a project site.

- An EIS is required for every major subdivision that involves ten or more lots or more than 5,000 square feet of commercial space. However, the reviewing board may waive all or a portion of the requirements if the applicant can provide sufficient evidence that the proposed development will only have slight or negligible impacts to the environment. This ordinance should be expanded to be specific as to how the board determines which checklist item can be waived and if there are no environmental impacts.

- Within 18-815.1.2(3) of the Unified Development Ordinance, it is specified that it is the policy of the Lakewood Planning Board and Zoning Board of Adjustment to minimize the number of stormwater basins by encouraging joint use of the basins between various developments and minimizing the number of basins within a development (Ordinance number 2006-22, section 815.1.2). However, the basin needs to be large enough to handle the combined flow. A water table mounding evaluation should be conducted on these larger basins as groundwater table mounding could pose a problem and limit infiltration rates (Carleton, 2010).

- The Route 88 corridor east of Hew Hampshire Avenue stands out as one area where sanitary sewer service would be particularly beneficial.
- Where public sewer service is not available, the Township Ordinance (18-811) will permit septic systems, with the Board of Health approval, on a temporary basis. The Ordinance is unclear when a homeowner is required to hook-up (if at all) to the public system if/or when it becomes available. This ordinance should be revised to include this requirement.
- There are no requirements for minimum lot size as it relates to nitrate dilution or evaluating subsurface soil conditions. In addition, lots proposing septic systems are only required to meet separation distances between the leach field and property line, house or wells.

Section 6
Preliminary Problem Analysis

The purpose of this section is to highlight and summarize some of the concerns that have been identified throughout this technical analysis.

6.1 Previous Investigations

Previous investigations conducted over the past 10 years center around a general set of conclusions and recommendations, most focusing on increasing impervious cover within the watershed and excessive nutrient loading of nitrogen and phosphorus. Nitrogen loading to the Barnegat Bay is increasing and most of the non-point source pollution to the bay is from stormwater runoff. Although the impervious cover is high, the fact that the watershed contains a high percentage of wetlands, has well drained soils, and is relatively flat, impacts to the river haven't been significant. However, reports all indicate that a threshold may be approaching in which water quality impacts will be significant.

Other common recommendations indicated that conservation measures should focus on riparian forests and restoration sites should focus on areas where the riparian forest is missing. A coordinated effort should be made to protect and restore the watershed by the watershed municipalities, counties and other stakeholders. In addition, it was recommended by several studies that a regional stormwater management plan be developed, which has not been implemented.

6.2 Land Use/Land Cover

In general all the municipalities within the watershed have implemented the required stormwater plans and land use ordinances setting forth the established design standards. The percent of impervious cover within the watershed, however, continues to increase and has increased from 12% to 15% since 1995, using the watershed delineation as specified within this analysis. Since 1995, most of the development has occurred in Jackson, Howell and Lakewood Townships. Highest intensity development is found in Lakewood, accounting for the largest relative increase in high density residential, commercial and industrial land uses. Currently there are significant discrepancies between two different population projection studies for Lakewood that will need to be reviewed in detail once the 2010 Census data is made available. A projected growth rate of 26,000 new residential units in the next twenty years could have adverse impacts to the watershed if not properly managed.

As indicated throughout this memorandum, previous investigations have identified degraded stream health with increased impervious cover (**Table 6-1**). Moving forward, of the five largest municipalities in the watershed, most of the development will occur in Lakewood and Jackson Townships. Brick Township is near build-out and current zoning in Howell and Freehold Townships is for low-density residential or includes wetlands and should have a relatively minimal impact on the Metedeconk River.

Existing ordinances in Jackson Township in general are protective of the watershed although the stormwater management plan has not been finalized and there are many areas where development has occurred on small lots (½ to ¼ acre) that are currently served by septic systems, despite sewer service being available. Both Lakewood and Jackson do not have mandatory hookup requirements even though public sewer maybe available in the area. However, in Jackson Township, existing single family home exemptions terminate immediately upon the failure of the property owner's system. Although sewer service maps are available, a database that contains parcels that are connected to the existing sewer system should be developed so that areas on septic that have the capability to connect to sewer can be identified in all municipalities. This will also allow the local sewer Authority to implement an outreach maintenance education program for a homeowner or commercial users of a septic system.

The areas within the Metedeconk River watershed that are going to remain on septic will need to comply with the recently proposed nitrate dilution regulations with a target unit of 2 mg/l (throughout the HUC11). Based upon the prevailing soil types in Jackson for example, analysis results suggest a 5 acre lot size requirement for constructing a septic system. Large portions of the watershed are, however, zoned for 3 acre lot sizes. These areas are still being studied and the actual numbers are subject to modifications.

Lakewood Township has some gaps in existing municipal ordinances that are of concern, mainly regarding stormwater basins. The Lakewood Planning Board and Zoning Board of Adjustment aim to reduce the number of stormwater basins between adjoining developments. While this may in fact be fine in some instances, some stipulations should be included regarding the basin size, water quality and infiltration rate so that new developments cannot use older, pre-existing basins that may be sized for a much lower flow and are not capable of meeting current stormwater management standards. In addition, groundwater mounding may be a problem that could limit infiltration and result in flooding.

Maintenance of stormwater management infrastructure is somewhat of a concern, not just with Lakewood, but within all municipalities. From the ordinances evaluated in this study, Brick seems to have the most protective in that transfer or assignment of ownership must be agreed to in writing that maintenance will continue. While Howell and Jackson specify costs that must be paid to the township by the developer for basin maintenance, these costs cover only a brief period of time, 10 years for Howell and 25 years for Jackson. Once those funds are depleted, a funding mechanism is not identified (nor is a funding mechanism identified for Brick for that matter). Lakewood ordinances indicate that a one time fee ranging between $300-$750 per unit is all that is required for stormwater infrastructure maintenance. In meeting with Lakewood Township, maintenance of stormwater facilities was identified as a key concern, particularly since significant growth is occurring. A standard maintenance costing analysis should be developed for all towns so that each municipality knows what its actual cost will be and to insure that there will be adequate funds in the future to properly maintain the system. These newly generated funds should be placed within a designated stormwater account. A certain percentage from these generated funds could also aid in the maintenance of any existing facility located within the regional watershed. A maintenance tracking system or something similar as a component to any regional stormwater management plan should also be considered.

There are a number of stormwater basins of various sizes and ages throughout the Metedeconk River watershed (**Figure 6-1**). The Center for Remote Sensing and Spatial Analysis (CRSSA) at Rutgers University has developed a Stormwater Management and Planning Tool for the Barnegat Bay Watershed (SWMPT; see http://www.crssa.rutgers.edu/projects/coastal/stormwater/) that can be used in conjunction with **Figure 6-1** to provide an update and identify priority basins in Ocean County for maintenance/restoration.

6.3 Hydrology

Data collected from the USGS stream gage along the North Branch of the Metedeconk near Lakewood indicate that although there is no discernable change in average annual total flow, the baseflow component of total flow is declining, accounting for approximately 68% of the total flow, down from 71% as discussed in the Phase I Report (CDM, 2000).

- Groundwater withdrawals from the Kirkwood-Cohansey aquifer for public supply have declined over the last several years, which would result in an overall increase in baseflow to the river. Therefore, declines in the baseflow component to total flow within the Metedeconk may be somewhat masked by the increase in baseflow from a decline in shallow groundwater withdrawals although it is not clear if the lack of withdrawals have yet to be realized by the river. In addition, smaller, non-regulated, agricultural withdrawals could be causing a cumulative baseflow impact on the river. A better understanding of existing crop types at the agricultural parcels may help quantify that potential impact.

- Currently, streamflow data only are routinely monitored at one USGS gage on the North Branch. As the South Branch is not routinely monitored nor is the confluence, changes in hydraulic measures (Qmin, Qmax, TQmean, baseflow separations, etc) cannot be measured from the South Branch.

6.4 Water Quantity and Water Quality

Water supply is a concern for the Metedeconk watershed. The New Jersey Statewide Water Supply Plan (1996) projects significant water supply deficits for the Metedeconk watershed based upon population growth and build-out projections. Much of the water use in the watershed is depletive in nature, as wastewater is collected, treated and discharged to the Atlantic Ocean. During summer 2010, numerous water utilities in the region, including BTMUA, experienced record water demands, and a Statewide drought watch was issued by NJDEP. Future water supply needs of Lakewood Township will be significant and a water supply plan for the build-out has not yet been developed.

Water quality data indicate that there is a slow increasing trend in total dissolved solids and specific conductance concentrations which are likely indicative of increased urban development within the watershed over time. While water quality remains generally good, the increasing trends in these parameters and to some extent total nitrogen may indicate that impacts are being realized. Continued development and impervious cover without proper management practices could result in a continuance of the water quality degradation.

TMDLs for fecal coliform, total coliform and phosphorus are in place for the Metedeconk River, and significant load reductions are required. In order to meet the TMDL for phosphorus, an 85% load reduction from the agricultural and residential land uses within the HUC14 may be required. Many of the TMDL implementation strategies focus on stormwater management issues.

Although nitrogen concentrations at the BTMUA intake remain well below the drinking water standard of 10 mg/L-N, the increasing nitrogen load is potentially impacting Barnegat Bay. Although there are scattered sites with significant VOC concentrations (relative to other sites), the VOC issue seems to be localized as the concentrations decrease rapidly downstream (for example, elevated concentrations at POND6 are not observed at BTMUA's intake).

Although the BTMUA implements an extensive water quality monitoring program, most of the stations are focused along the main stems of the North and South Branches. Additional water quality data collection efforts along the tributaries would be helpful to identify and further refine problem areas within the watershed. Water quality monitoring efforts should be expanded particularly along the South Branch where additional development is anticipated.

Dissolved oxygen data are consistent with the New Jersey 2008 303(d) list which includes the North Branch as impaired from Route 9 to above I-195, particularly upstream of Stations NM and SK.

6.5 Visual Assessments

The results from the visual assessments of the 83 sites indicate the following:

- 19 sites are classified as "Poor" (23%)
- 30 sites are classified as "Fair" (36%)
- 33 sites are classified as "Good" (40%)
- 1 site is classified as "Excellent" (<1%)

Previous investigations have identified various parcels of land within the Metedeconk River watershed that are a priority for restoration, conservation and/or stormwater management. The 32 visual assessment sites identified in this memorandum as potential candidates for further analysis in later tasks correlate well with sites that have been identified as stormwater management priorities (Barten et al, 2003) and one of the VAPP sites is associated with a restoration priority area as identified by the Trust for Public Land (Barnegat Bay 2020; **Figure 6-2**).

Correlations with visual assessment scores and water quality are apparent in the watershed with respect to nitrogen. Within HUC NB2, between NJ to NF, nitrogen increases from 0.08 to 0.41 mg/L which is also associated with lower visual assessment scores on the tributaries moving downstream. In addition, HUCs NB3 and NB4 also have lower visual assessment scores and higher nitrogen concentrations (0.66 mg/L). There appears to be a similar trend in HUCs SB3, SB4, and SB5 on the South Branch.

Section 7
Summary & Preliminary Recommendations

- An increase in impervious cover over the last several years is likely impacting the watershed as evident by:
    - Increasing concentrations of specific conductance, TDS, and nitrogen;
    - Reduced baseflow and a corresponding increase in runoff;
        - Baseflow maintenance is critical and the fact that the baseflow component of total flow appears to be declining despite the decline in shallow groundwater pumping (potable supply) could be indicative of an increased impact resulting from impervious cover.
    - Hydraulic impacts such as increased “flashiness”.
- Future development should include Low Impact Development (LID) techniques to the fullest extent practical.
    - Green infrastructure/LID demonstrations and Urban Education Projects should be implemented for Lakewood.
- VAPP sites to be further evaluated in future tasks as potential sites for mitigation projects.
- Bacteria and phosphorus TMDL implementation strategies including agricultural BMPs, urban stormwater BMPs and retrofits, geese management plans, pest waste ordinances, riparian buffer restoration, the identification and elimination of sewage conveyance facilities failures, and addressing inadequate on-site sewage disposal should be employed.
- Water conservation programs should be identified and implemented to help offset peak demands. A water supply plan for build-out population projections should also be developed so that potential impacts to the watershed can be quantified (e.g. an updated New Jersey Statewide Water Supply Plan).
- Nitrate concentrations at the BTMUA intake have recently exceeded 1.5 mg/L-N and annual average concentrations indicate that nitrogen loading to the Barnegat Bay is increasing.
    - A recent bill was proposed (S2341) which would set a TMDL for the Barnegat Bay and streams within its watershed.
    - A Statewide Fertilizer Bill (S1411) was recently passed which would limit the amount of nitrogen in fertilizer as well as set restrictions on the amount, timing, and location of application. The proposed bill also prohibits phosphorous in fertilizer under most applications.

- Limiting fertilizer application and fertilizer content (e.g., no phosphorus) would reduce both nitrogen and phosphorus loads to the river thereby reducing nitrogen load to Barnegat Bay.

- There are current concerns regarding the lack of maintenance for stormwater management infrastructure, particularly due to a lack of available funds.
  - Funding mechanisms need to be identified and established so that maintenance of stormwater facilities can be conducted.
    - A regional stormwater utility authority could be created to oversee the design and installation of these facilities as well as provide maintenance.
      - Although there are no current stormwater utility authorities in New Jersey, a recent bill was proposed (S-2275) which would create a stormwater utility for Ocean County. This utility would essentially serve as the model for the State.
    - A maintenance tracking system, or something similar, should be developed.
    - Further evaluate the potential for shared services opportunities for stormwater management, regardless of a creation of a stormwater utility authority.
      - Evaluate the potential for corporate contributions.
- There is currently a lack of groundwater data for the Kirkwood-Cohansey aquifer system within the watershed. This makes it difficult to quantify some surface water quality characteristics from regional trends in groundwater quality.
  - A groundwater monitoring program should be implemented, perhaps utilizing many of the existing USGS monitoring wells.
  - A groundwater study on the potential impacts of road salting on the baseflow water quality of the Metedeconk River should be considered.
- Currently, flow data are only available for the North Branch at USGS gage 01408120. Flow data for the South Branch haven't been collected since 1999.
  - As of the date of this report, a USGS gage has been restored on the South Branch. This gage should be maintained into the future so that the hydrology of the South Branch can be monitored and potential impacts with additional development can be identified.
- There is currently no regional stormwater management plan, despite being recommended in a number of previous studies. There is a current TMDL for most

of the watershed for coliform and more consistent stormwater management between the various towns would be beneficial and allow for consistency regarding the development of waterfowl management programs and set forth a consistent and detailed set of design standards for stormwater controls for new and existing development. These design standards could include both non-structural (for low-density development) and structural mitigation solutions (for Lake Carasaljo and other high density areas). Design standards for stormwater infiltration basins should be updated to evaluate for the potential for excessive mounding beneath the basins as per recent USGS study.

- Potential issues regarding municipal ordinances as they relate to the protection of the water resources within the Metedeconk River watershed should be resolved (see Section 5).

- Although previous investigations have cited stormwater runoff as the major source of nitrate (and phosphorus), septic systems are also a significant source. The location of parcels on septic should be identified and a regional (watershed) GIS map be developed. This map can aid in the determination of where water quality issues may be located as well as help identify areas where sewer expansion should be prioritized.

- Where it does not currently exist, sanitary sewer service should be extended throughout the study area in high density residential areas and in commercial/industrial areas such as the Route 88 corridor in Lakewood east of New Hampshire Ave. Sanitary sewer service should also be extended in other medium or low density residential areas with the potential to contribute significant nitrogen loading (relatively low lot sizes, high housing density, failing septic systems, etc).

    - Connection to sanitary sewer, where available, should be conducted, particularly for older septic systems that may be failing. Properties that are currently served by older septic systems where sanitary sewer service exists should be identified and provided information about connecting to the sanitary sewer service.

- Visual assessment data has documented some issues with various larger lakes within the watershed, particularly regarding nuisance vegetation. Some of these lakes include: Lake Eno, Jackson Mills Lake, Aldrich Lake and Lake Shenandoah. These lakes, and other lakes with similar issues, should be evaluated for restoration/management.

- Education and outreach programs should be developed and implemented.

Section 8
References

Barnegat Bay National Estuary Program Strategic Plan: June 2008 – May 2001.

P.K. Barten, de la Cretaz, A.L. and Zhang, Y. 2003. **Conservation, Restoration, and Stormwater Management Priorities for Source Water Protection in the Metedeconk River Watershed, New Jersey**. University of Massachusetts – Amherst.

Birdsall Engineering, Inc. 2005. **Phase I Diagnostic – Feasibility Study of Lake Carasaljo**. Township of Lakewood, Ocean County, New Jersey.

CDM. 1998. **Nassau County 1998 Groundwater Study**.

CDM. 2000. **Metedeconk River Watershed Management Plan, Phase I: Watershed Characterization and Preliminary Analysis**, Brick Township Municipal Utilities Authority.

CDM. 2006. **Suffolk County Comprehensive Water Resources Management Plan Task 6.1 – Freshwater Streams, Ponds, and Wetlands**. Suffolk County Department of Health Services.

G.B. Carleton. 2010. **Simulation of Groundwater Mounding Beneath Hypothetical Stormwater Infiltration Basins**. United States Geological Survey (USGS) Scientific Investigations Report 2010-5102.

Center for Watershed Protection (CWP). 2003. **Impacts of Impervious Cover on Aquatic Systems**. Watershed Protection Research Monograph No. 1, March 2003.

Dubrovsky, N.M., Burow, K.R., Clark, G.M., Gronberg, J.M., Hamilton P.A., Hitt, K.J., Mueller, D.K., Munn, M.D., Nolan, B.T., Puckett, L.J., Rupert, M.G., Short, T.M., Spahr, N.E., Sprague, L.A., and Wilber, W.G. 2010. **The quality of our Nation's waters—Nutrients in the Nation's streams and groundwater, 1992–2004: U.S. Geological Survey Circular 1350**, 174 p.

Eckhardt, K. 2005. How to Construct Recursive Digital Filters for Baseflow Separation. Hydrological Processes 19 (2): 507-515.

Gibbons, R.D. 1994. **Statistical Methods for Groundwater Monitoring**. Wiley-IEEE. 286 p.

Gilbert, R.O. 1987. **Statistical Methods for Environmental Pollution Monitoring**. Van Nostrand Reinhold. New York. 320 p.

Helsel, D.R. and R. M. Hirsch, 2002. **Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3**. U.S. Geological Survey. 522 pages

P. C. Henshaw and Booth, D.B. 2000. **Natural Restabilization of Stream Channels in Urban Watersheds. Journal of the American Water Resources Association**. 36(6): 1219-1236.

R.E. Hickman. 1997. **Streamflow, tidal-water-level, and water-quality data for the tidal embayments of the Metedeconk and Toms Rivers, New Jersey, water years 1993-94.** United States Geological Survey (USGS) Open-File Report 96-368.

C.P. Konrad and Booth, D.B. 2002. **Hydrologic Trends Associated with Urban Development for Selected Streams in the Puget Sound Basin, Western Washington.** United States Geological Survey (USGS) Water-Resources Investigations Report 02-4040.

Lathrop, R.G. and S.M. Haag. 2007. **Assessment of Land Use Change and Riparian Zone Status in the Barnegat Bay and Little Egg Harbor Watershed: 1995-2002-2006**.

K.J. Lim, Engel, B.A., Tang, Z., Choi, J., Kim, K., Muthukrishnan, S., and Tripathy, D. 2005. **Web GIS-based Hydrograph Analysis Tool, WHAT**. JAWRA, 41(6): 1407-1416.

Monmouth County Wastewater Management Plan (WMP). 2010. **Wastewater Facilities and Proposed Service Area Map**. Draft for Public Meeting (v. 1.0). http://co.monmouth.nj.us/page.aspx?ID=3766

NOAA. 2010. Historical Palmer Drought Indices. Data accessed online at: http://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers.php.

R.S. Nicholson and Watt, M.K. 1997. **Simulation of Ground-Water Flow in the Unconfined Aquifer System of the Toms River, Metedeconk River, and Kettle Creek Basins, New Jersey**. United States Geological Survey (USGS) Water-Resources Investigations Report 97-4066.

R.S. Nicholson, Hunchak-Kariouk, K. and Cauller, S.J. 2003. **Review of Selected References and Data sets on Ambient Ground- and Surface-Water Quality in the Metedeconk River, Toms River, and Kettle Creek Basins, New Jersey, 1980-2001.** United States Geological Survey (USGS) Water-Resources Investigations Report 2003-4259.

R. Nicholson. 2010. **USGS Hydrologic Monitoring and Research in the Barnegat Bay Watershed**. New Jersey Department of Environmental Protection Technical Seminar for In-House Staff: The Science of Barnegat Bay. July 14, 2010. Accessed online at: http://www.state.nj.us/dep/dsr/barnegat-seminar/bb-nicholson.pdf

Nielsen, D. 2006. **Practical Handbook of Environmental Site Characterization and Ground-water Monitoring. 2nd Ed**. CRC Press, 2006. New York. 1318 p.

C.C. Obropta. 2009. **New Jersey's Stormwater Regulations**. NJ Agricultural Experiment Station, Rutgers Cooperative Research and Extension Fact Sheet FS556. Accessed online at: http://www.water.rutgers.edu/Fact_Sheets/fs556.pdf.

Office of the New Jersey State Climatologist. 2010. New Jersey Monthly Climate Tables. http://climate.rutgers.edu/stateclim_v1/data/

T.E. Reilly, Buxton, H.T., Franke, O.L. and Wait, R.L. 1983. **Effects of Sanitary Sewers on Ground-Water Levels and Streams in Nassau and Suffolk Counties, New York. Part 1: Geohydrology, Modeling Strategy, and Regional Evaluation.** United States Geological Survey (USGS) Water-Resources Investigations Report 82-4045.

T. Schueler. 1995. **Environmental Land Planning Series: Site Planning for Urban Stream Protection, for Metropolitan Washington Council of Governments, Washington, D.C.**, December 1995. Publication Number 95708.

T&M Associates. 2009. **Lakewood Smart Growth Plan**. Township of Lakewood. Ocean County, New Jersey. November 2009.

The Trust for Public Land. 2008. **Barnegat Bay 2020: A Vision for the Future of Conservation**. July 2008.

M.K. Watt, Johnson, M.L and Lacombe, P.J. 1994. **Hydrology of the unconfined aquifer system, Toms River, Metedeconk River, and Kettle Creek Basins, New Jersey, 1987-90.** United States Geological Survey (USGS) Water-Resources Investigations Report 93-4110.

Weiben, C., and Baker, R., 2009, **Contributions of Nitrogen to the Barnegat Bay-Little Egg Harbor Estuary: Updated Loading Estimates** , Barnegat Bay Partnership, http://www.bbep.org/studies.html

K.E. White and Sloto, R.A. 1990. **Base-Flow Frequency Characteristics of Selected Pennsylvania Streams.** United States Geological Survey (USGS) Water-Resources Investigations Report 90-4161.

O. Zapecza. 1989. **Hydrogeologic Framework of the New Jersey Coastal Plain**. United States Geological Survey (USGS) Professional Paper 1404-B.