JORDAN BROOK WATERSHED MANAGEMENT PLAN
FINAL REPORT

TOWN OF WATERFORD, CONNECTICUT

FEBRUARY 2000

#C-11-4
28 Industrial Drive
Public Hearing
Exhibit 35

Fuss & O'Neill Inc. *Consulting Engineers*

JORDAN BROOK WATERSHED MANAGEMENT PLAN
FINAL REPORT

TOWN OF WATERFORD, CONNECTICUT

FEBRUARY 2000

Prepared By:

Fuss & O'Neill, Inc.
146 Hartford Road
Manchester, CT 06040

In Conjunction With:

Marine and Freshwater Research Service
276 State Street
Guilford, CT 06437

Fuss & O'Neill Inc. *Consulting Engineers*

146 Hartford Road, Manchester, CT 06040-5921
TEL 860 646-2469 FAX 860 643-6313

78 Interstate Drive, West Springfield, MA 01089
TEL 413 452-0445 FAX 413 846-0497

140 Sherman Street, Fairfield, CT 06430-5822
TEL 203 256-1790 FAX 203 256-5742

410 North Broadway, East Providence, RI 02914
TEL 401 434-9760 FAX 401 434-9920

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EXECUTIVE SUMMARY

Jordan Brook drains from an 8.2 square-mile watershed located along the eastern edge of the Town of Waterford. This watershed includes several major developments, including the Crystal Mall, and is bisected by the I-395 and I-95 highway right-of-ways. While a significant percentage of the southern portion of the watershed has been developed, water quality in Jordan Brook generally meets State drinking water standards, and the watershed wetland systems remain in relatively good condition.

Large areas of the watershed remain undeveloped, especially in its northern reaches. Uncontrolled future residential, commercial, or industrial development in the watershed would increase pollutant loadings from stormwater runoff to receiving wetlands and watercourses, reduce groundwater base flows that are necessary to maintain dry weather flows in streams, increase peak flows and flooding, and continue to encroach on upland fringe areas that "screen" wetlands from development.

The purpose of this study was to evaluate existing watershed resources and develop a recommended plan to protect those resources from potential impacts as identified above. The following paragraphs summarize the major findings and recommendations of this study.

- **Wetland areas generally in good condition:**

  Wetland areas within the watershed remain in good condition and many have features that justify the wetlands as having special significance. Some wetlands appear to have been impacted by encroaching development and water quality impacts, and other wetlands would be sensitive to any future impacts to water quality.

- **Surface water quality generally fishable and drinkable:**

  Surface water quality in the watershed generally meets "fishable and drinkable" standards established for the State of Connecticut with the exception of total coliforms. Since the source of total coliform can include non-pollution sources such as plant matter, this finding is not conclusive evidence of sanitary contamination.

- **Development impacts water quality:**

  While surface water quality still meets standards, in-stream concentrations of pollutants increase downstream as development and impervious surfaces increase. Based on modeling of future pollutant loads, stormwater pollutant loadings could increase by more than 100% for zinc and between 30 and 50% for phosphorous, copper, and lead with future development. Copper, lead, and zinc can be toxic to aquatic life at certain concentrations in aqueous form. Phosphorous is a limiting nutrient for algal growth in surface water impoundments.

- **Water Quality Management Plan:**

  A surface water quality management plan has been developed that specifies the levels of controls that would be recommended to be implemented based on the level of risk

that a new development would pose to water quality. Three tiers of controls are recommended.

I. Base level controls would apply to developments with only small potential for impacts and would require controls to remove gross contaminants and minimize the risk of accidents such as spills causing major water quality impacts.

II. Secondary controls would apply to developments with greater risk for water quality impacts and would require a minimum of 80% removal of total suspended solids.

III. Tertiary controls would apply to developments with the greatest risk for water quality impacts and would require developers to demonstrate no net increase in pollutant loads from pre-development conditions.

- **Continue surface water quality monitoring:**

  Surface water quality should continue to be monitored to evaluate trends in water quality and confirm that new developments have appropriate controls.

- **No net increase in peak flows:**

  Evidence of flooding and channel scour was observed during watershed visits. It is recommended that future developments demonstrate no net increase in peak flows at downstream points-of-concern. The number of downstream points-of-concern to be evaluated is proposed to be dependant on the size of the development and its potential to increase flooding risk. A watershed-wide hydrologic model has been developed that should be incorporated into future evaluations.

- **Maintain pre-development groundwater base flows:**

  Pre-development groundwater base flows should also be maintained. At a minimum, "clean" roof runoff should be infiltrated into the ground. This approach does not require a complicated technical evaluation of current on-site infiltration to groundwater, would typically maintain or increase base flows, and would minimize the risk of groundwater pollution by infiltrating only clean runoff.

- **Designate upland areas as open space and implement Upland Protection Zone:**

  A number of upland areas in the watershed would provide value as open space by improving the value of watershed wetlands by screening developments, providing fringe habitat, maintaining wildlife access, and improving human access to wetlands of special significance. Upland areas that could provide value have been evaluated and ranked in terms of their importance. A 50-foot Upland Protection Zone is also recommended for all wetlands and a 100-foot Upland Protection Zone is recommended for perennial streams. Factors which should be considered in adjusting these widths are discussed.

1.0 INTRODUCTION

Jordan Brook drains from a watershed located along the eastern edge of the Town of Waterford. This watershed includes several major developments, including the Crystal Mall, and is bisected by the I-395 and I-95 highway right-of-ways. While a significant percentage of the southern portion of the watershed has been developed, water quality in Jordan Brook generally meets State fishing and drinking water standards, and watershed wetland systems remain in relatively good condition.

Large areas of the watershed remain undeveloped especially in its northern reaches. Uncontrolled future residential, commercial, or industrial development in the watershed would increase pollutant loadings from stormwater runoff to receiving wetlands and watercourses, reduce groundwater base flows that are necessary to maintain dry weather flows in streams, increase peak flows and flooding, and continue to encroach on upland fringe areas that "screen" wetlands from development.

The goal of this study was to evaluate existing wetland resources in the watershed and develop a plan to protect those resources from impacts related to future development. In order to conduct this study, the Town of Waterford retained Fuss & O'Neill, Inc. whose team included Dr. Priscilla Baillie of Marine and Freshwater Research Service. During this study several workshops were conducted with the project team and Fuss & O'Neill in order to develop a plan that best met the Town's needs and addressed specific issues in this watershed. Representatives from the Town of Waterford during these workshops included professional staff from the Waterford Planning Department as well as representatives from the Town's Conservation Commission and Department of Public Works.

This report outlines the results of the study. Current watershed conditions are evaluated, including wetlands, stream water quality, land use, and hydrologic conditions (Sections 2.0 and 3.0). A hydrologic model of the watershed was developed to address stormwater quantity management issues (Section 4.0). A stormwater quality control plan was developed for the Town to protect stormwater quality from future development in the Jordan Brook watershed (Section 5.0). Other watershed issues addressed as part of this project and incorporated into the watershed management plan include aquifer protection and open space planning (Section 6.0). The recommended watershed management plan is presented in Section 7.0. A Geographical Information System database has also been developed for this watershed that incorporates the results of this study. A user's guide and instructions for the database are attached as Appendix A of this report.

2.0 CURRENT WATERSHED CONDITIONS

2.1 Watershed Description

The Jordan Brook watershed is an 8.2 square-mile watershed located in southeastern Connecticut. A majority of the watershed (94%) is located in the Town of Waterford, with a small portion of the watershed (6%) located in the City of New London. This watershed is oriented in a north-south direction, extending approximately 5.5 miles from its headwaters near Waterford's northern border with Montville, south to Jordan Cove which discharges to the Long Island Sound.

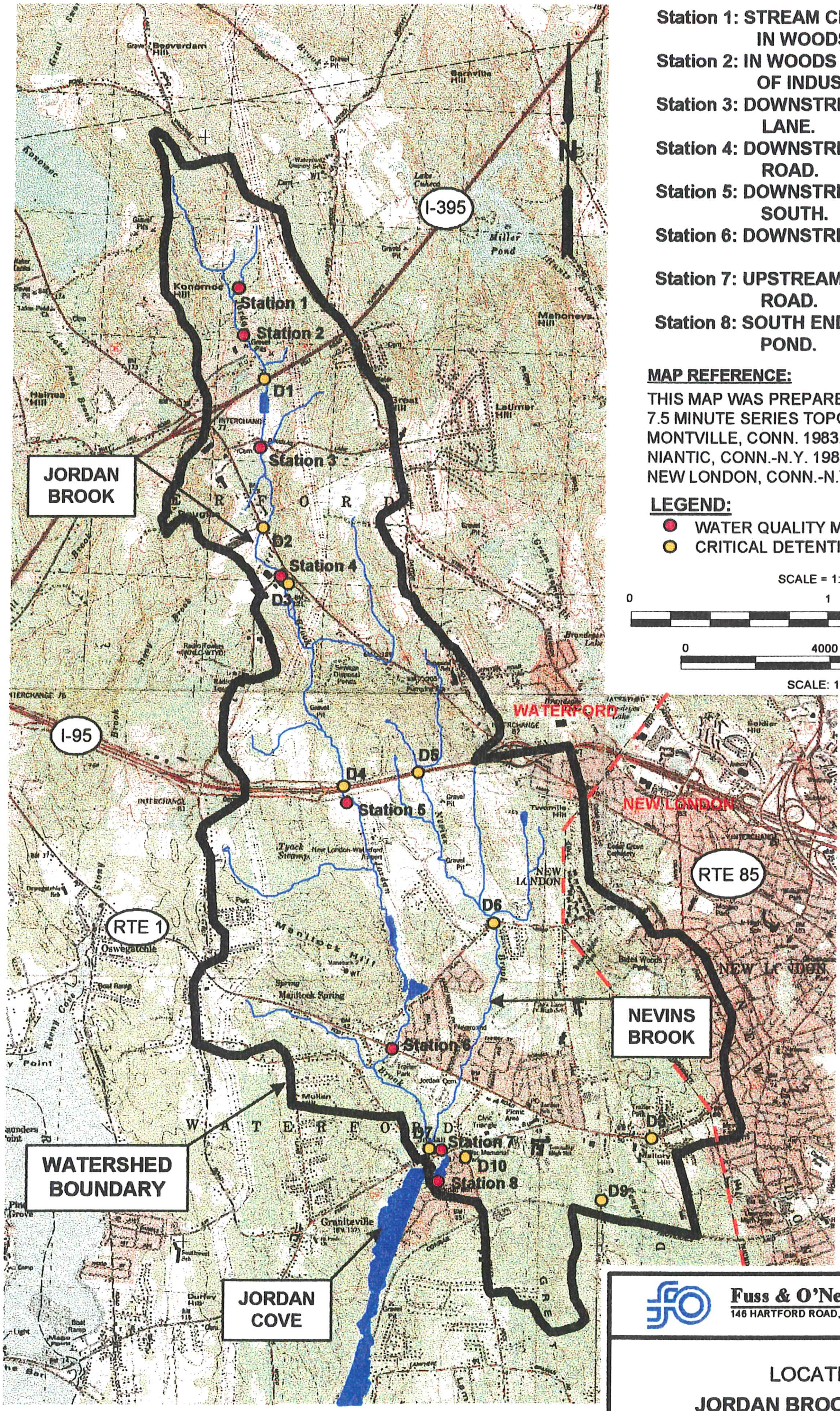
The upper reaches of the Jordan Brook watershed are largely undeveloped. Jordan Brook crosses several highways, including Interstate-95, Interstate-395, and State Route 85 through the central portion of the watershed. Development and corresponding impervious areas increase as the brook flows south. Jordan Brook reaches its confluence with Nevins Brook approximately 400 feet upstream of Jordan Cove. Nevins Brook drains the southeastern portion of the watershed. Several smaller tributaries oriented in an east-west direction feed the central and southern portions of Jordan Brook. Figure 1 is a location map of the Jordan Brook watershed.

The northern half of the watershed is hilly and predominantly wooded, with a maximum elevation of approximately 380 feet atop Konomoc Hill near the Jordan Brook headwaters. The watershed topography gradually flattens south of Interstate-95 in the more developed portions of the watershed. Several impoundments are located in the upper and lower reaches of Jordan Brook. Tyack Swamp is a large wetland situated between Interstate-95 and Manitock Hill on the western side of the watershed. Two interconnected wetland/marsh systems located east of Clark Lane and south of Post Road (U.S. Route 1) comprise the southeastern corner of the watershed adjacent to the City of New London.

2.2 Water Quality Classifications

The surface waters of Jordan Brook and most of Nevins Brook are classified by the Connecticut Department of Environmental Protection (CTDEP) as B/A (CTDEP, 1986) with some upstream reaches of Nevins Brook classified as A. Inland surface waters classified by the CTDEP as B/A are those that may not meet Class A water quality criteria or one or more designated uses for Class A waters. Class A water quality standards and designated uses are provided in Appendix B. The goal for B/A surface waters is achievement of Class A criteria and attainment of Class A designated uses. Class A waters are a potential drinking water supply and support designated uses such as fish and wildlife habitat, recreational use, agricultural/industrial supply, and navigation (CTDEP, 1997). For the purposes of this study, water quality standards for Class A surface waters are used to evaluate water quality impacts since this level of quality is the stated goal for these waters.

Groundwater throughout a majority of the watershed is classified by the CTDEP as GA, however several areas in the northern half of the watershed have been classified as "GA, GAA may not meet current standards" (CTDEP, 1986). Such groundwater may not meet the GA or



Station 1: STREAM CROSSING IN WOODS.
Station 2: IN WOODS NORTHEAST OF INDUSTRIAL DRIVE.
Station 3: DOWNSTREAM OF DOUGLAS LANE.
Station 4: DOWNSTREAM OF CROSS ROAD.
Station 5: DOWNSTREAM OF PARKWAY SOUTH.
Station 6: DOWNSTREAM OF POST ROAD.

Station 7: UPSTREAM OF ROPE FERRY ROAD.
Station 8: SOUTH END OF DAM AT MILL POND.

MAP REFERENCE:

THIS MAP WAS PREPARED FROM THE FOLLOWING 7.5 MINUTE SERIES TOPOGRAPHIC MAP:
MONTVILLE, CONN. 1983,
NIANTIC, CONN.-N.Y. 1983
NEW LONDON, CONN.-N.Y. 1984

LEGEND:

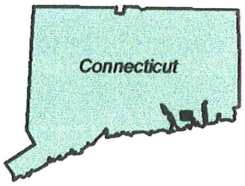
- WATER QUALITY MONITORING STATION
- CRITICAL DETENTION LOCATION

SCALE = 1: 48000

0 1 2 MILE

0 4000 8000

SCALE: 1"= 4000'



Quadrangle Location

FIGURE 1

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(860)646-2469

LOCATION MAP

JORDAN BROOK WATERSHED

JORDAN BROOK WATERSHED MANAGEMENT PLAN

WATERFORD CONNECTICUT

PROJ. NO. 93154A2 DATED : OCTOBER 1998 SCALE: 1"= 4000'

J:\DWG\P93\93154\A2\FIGURE1.PPT

GAA water quality standards, which require the groundwater to be suitable for drinking without treatment (CTDEP, 1997). This classification is typically assigned by CTDEP to groundwaters where there may be a source of pollution. Class GA water quality standards are provided in Appendix B.

2.3 Land Use

Watershed land use affects the quantity and quality of stormwater generated in the watershed. Factors such as impervious area, drainage system, development characteristics, traffic volume, air emissions, and exposure of other pollutant sources are dependent on land use. Land use mapping for the watershed was provided by the Town of Waterford. Several of the Town-defined land use categories were field-verified to determine the nature or level of development (e.g., undeveloped, commercial, residential, etc.) associated with these land uses.

Figure 2 depicts the land use categories within the Jordan Brook watershed. The percentages of each land use within the watershed are summarized in Table 1. As shown in the table, approximately 76 percent of the watershed consists of a combination of undeveloped, single family residential, and public facility land uses. Approximately 17 percent of the watershed consists of commercial, industrial and multi-family land uses. Highways and roads comprise approximately 7 percent of the watershed area.

In general, the level of development in the watershed increases proceeding from the headwaters to the lower reaches of the watershed. The northern portion of the watershed consists primarily of undeveloped woodland, with some residential areas along the eastern side of the watershed. Interstate 395 passes through the northern portion of the watershed. A combination of undeveloped woodland/meadows and residential land uses characterize the area between Interstate-395 and State Route 85. Commercial and industrial/manufacturing developments are located along the northern stretch of Route 85, which passes in a southeasterly direction through the northern half of the town. The area between Route 85 and Interstate 95, which passes in an east-west direction through the center of the watershed, includes several major commercial developments such as Crystal Mall, a large regional mall, and other high-traffic mall developments (i.e., Home Depot, Wal-Mart, Crossroads Centre).

The southern half of the watershed, roughly defined as the area south of Interstate-95, is characterized by a mixture of undeveloped land, open space, and residential and commercial land uses. The areas of highest intensity residential development are located north and south of Post Road (U.S. Route 1), which passes through the southern portion of the watershed in an east-west direction. Numerous commercial retail developments are located along Post Road, with several major shopping centers situated near the intersection of Post Road and State Route 156. A number of municipally-owned lands, including schools and parks, are also located in this area of the watershed. Additionally, the Northeast Rail Corridor traverses the watershed south of Route 1.

Land Use Classifications
Jordan Brook Watershed Management Study
Town of Waterford

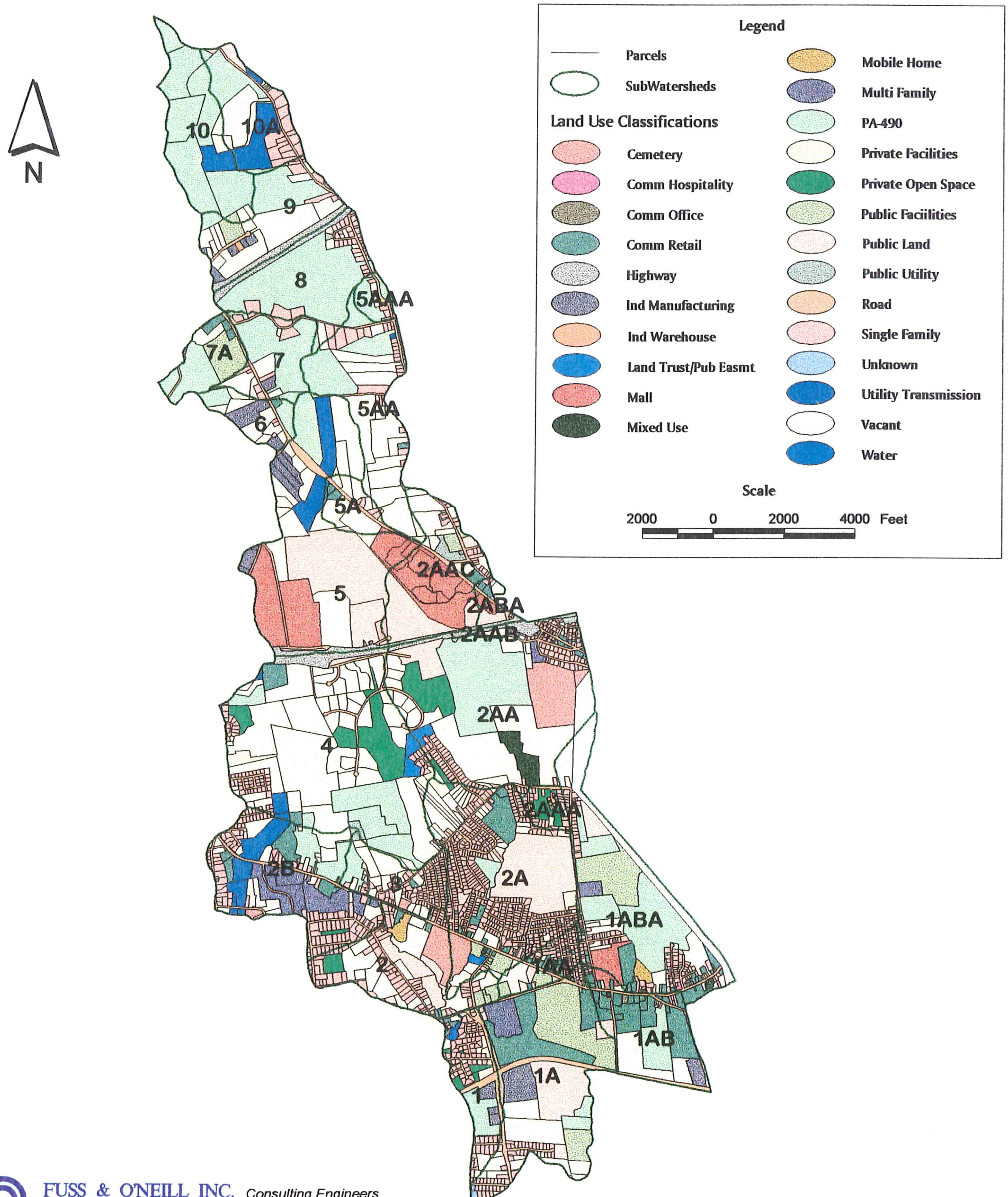

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FIGURE 2

TABLE 1
SUMMARY OF WATERSHED LAND USES
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Land Use Classification	Area (acres)	Percent of Watershed Area
Vacant	1358	27.7%
PA-490 (Undeveloped)	981	20.0%
Single Family	613	12.5%
Public Land	415	8.4%
Road (Public ROW)	250	5.1%
Commercial Retail	241	4.9%
Mall	194	4.0%
Public Facilities	188	3.8%
Utility Transmission	125	2.5%
Private Open Space	115	2.3%
Cemetery	87	1.8%
Interstate Highway	83	1.7%
Multi-Family	83	1.7%
Industrial Manufacturing	81	1.7%
Mixed Use	24	0.5%
Private Facilities	22	0.5%
Land Trust/Public Easement	16	0.3%
Public Utility	14	0.3%
Mobile Home	11	0.2%
Water	3	0.1%
Unknown	2	0.05%
Industrial Warehouse	1	0.02%
Commercial Hospitality	1	0.02%
Commercial Office	1	0.02%
Total (1)	4908	100.0%

Notes:
(1) Table Excludes area of watershed located in New London.

2.4 Aquifers

Groundwater aquifers are saturated permeable geologic units that can transmit significant quantities of water (Freeze and Cherry, 1979) for public drinking water supplies and other uses. Groundwater aquifers within the Jordan Brook watershed were delineated based upon surficial materials mapping for the State of Connecticut (Stone et al., 1992). Surficial materials are classified in terms of grain size distribution as well as areal and vertical extent. Glacial meltwater deposits such as gravel, sand, and silt and floodplain alluvium generally correspond to the major groundwater aquifers in Connecticut. As such, areas classified as glacial meltwater and floodplain alluvium deposits in the watershed were characterized as potential groundwater aquifer areas.

Figure 3 illustrates the distribution of potential groundwater aquifers across the Jordan Brook watershed. As shown in Figure 3, potential groundwater aquifers are generally concentrated along Jordan Brook, Nevins Brook, and their associated tributaries. In the northern portion of the watershed, sand and gravel deposits are confined to a relatively narrow corridor which follows the main stem of Jordan Brook. A more widespread area of potential groundwater aquifer deposits exists in the southern portion of the watershed. The potential groundwater aquifers in the southern half of the watershed are also located in some of the most highly developed areas in the watershed.

In its 1998 Plan of Preservation, Conservation & Development, the Town of Waterford identified potential public water supply well sites immediately north of the intersection of Jordan Brook and Interstate 95 and near the confluence of Jordan and Nevins Brook. These sites correspond to areas having some of the thickest stratified deposits in the watershed, which may provide significant yields for future public water supply (Town of Waterford, 1998).

3.0 WATERSHED EVALUATION

Jordan Brook and its associated wetlands were field visited during the course of this study by members of the project team. Additionally, the Town of Waterford currently monitors water quality in Jordan Brook at selected sampling locations. Results of the field evaluations and water quality monitoring are described in this section.

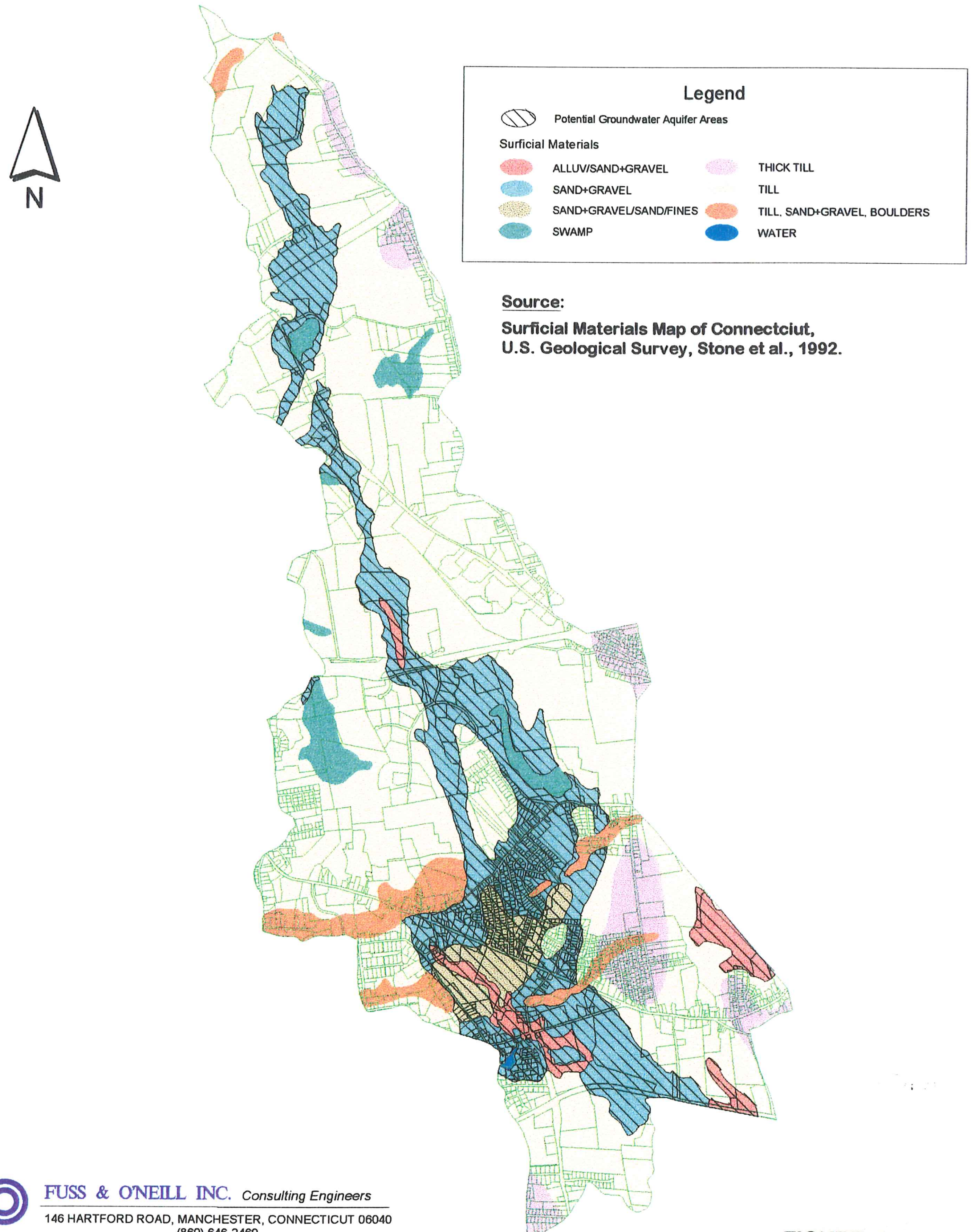
3.1 Jordan Brook

3.1.1 Field Observations

Fuss & O'Neill personnel conducted a site visit of the Jordan Brook watershed on March 12, 1998. The purpose of the site visit was to observe the general conditions of Jordan Brook and its surrounding watershed and to identify:

- Potential sources of stormwater pollution in the watershed (e.g., areas of erosion/sedimentation and areas of significant litter/debris), and

Potential Groundwater Aquifers
Jordan Brook Watershed Management Study
Town of Waterford



Source:

Surficial Materials Map of Connectciut, U.S. Geological Survey, Stone et al., 1992.

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FIGURE 3

- Restrictions where flooding may be a concern (e.g., bridges and culverts).

The site visit consisted of observing Jordan Brook and its major tributaries at selected road crossings, as well as observation of several major commercial developments. Observations from the site walkover and inspection are described in the following sections.

3.1.1.1 Areas of Erosion/Sedimentation

In general, the streambanks along Jordan Brook and its tributaries at the observed locations are either highly vegetated in undeveloped areas or lined with riprap or concrete in more developed areas. The site walkover was performed during dry weather, approximately 24 to 48 hours following a significant rainfall event. As a result, Jordan Brook and its tributaries were flowing nearly full at the time of the inspection.

Evidence of sediment input and erosion in Jordan Brook from adjacent upland areas was observed at several major road crossings. This evidence included in-stream sand bars, streambank gully erosion, and exposed (unvegetated) earthen areas adjacent to the brook that were observed at the following locations:

- Jordan Brook at Interstate-95
- Jordan Brook at Footbridge in Incomplete Subdivision near former Waterford Airport Property
- Jordan Brook at Route 1
- Jordan Brook at Route 156 (Rope Ferry Road)
- Jordan Brook Tributary (upper "Fenger Brook") at Route 1

The identified crossings are located in developed areas of the watershed south of Interstate-95. These observations are consistent with the relationship between sediment loading and level of development.

3.1.1.2 Areas of Significant Litter and Debris

Accumulated litter and debris was observed along the stream banks at several of the inspected stream crossings. The most significant quantities of litter and debris, which generally consisted of paper, styrofoam, plastic and other small, floatable materials, were noted at major road crossings and in the more developed areas of the watershed (i.e., south of Route 1). These locations included:

- Jordan Brook at Cross Road
- Jordan Brook at Route 85
- Jordan Brook Tributary at Ellen Ward Road
- Nevins Brook at Route 1
- Jordan Brook Tributary at Miner Lane
- Jordan Brook Tributary at Route 1

Larger materials such as tires, scrap metal, and discarded equipment were observed at the Interstate-95, Fog Plain Road, and Miner Lane crossings.

3.1.1.3 Evidence of Flooding

Although water surface elevations and flows were high at the time of the site inspection, evidence of significant historical or recent flooding was observed at only one location, Jordan Brook at Route 1 east of Reynolds Lane. Jordan Brook, the stormwater discharge from Route 1 or the adjacent cemetery, and the outlet of a wetland area converge immediately upstream of this culvert crossing. Several large uprooted trees, accumulated brush and organic debris, and matted overbank vegetation were observed, which are indicative of high-velocity flows and backwater associated with prior flooding. A stone retaining wall along the west bank of Jordan Brook immediately upstream of the crossing (single concrete box culvert) appears to restrict or channelize flood flows in this area.

3.1.2 Water Quality

The Town of Waterford currently conducts semiannual water quality monitoring of Jordan Brook. Surface water samples are collected at eight stations along Jordan Brook, which are shown on Figure 1. The sampling stations are located primarily at major road crossings and are approximately evenly spaced along Jordan Brook. The Jordan Brook sampling stations are listed (from upstream to downstream) in Table 2. Nine rounds of water samples have been collected since monitoring began in 1993. These samples were analyzed for the following parameters.

Total Phosphorous
Total Suspended Solids
Turbidity
Total Coliforms
Fecal Coliforms
Fecal Streptococci
Sodium
Iron
Manganese
Conductivity
pH
Chloride
Copper
Biochemical Oxygen Demand
Chemical Oxygen Demand
Nitrate
Dissolved Oxygen
Oxygen Saturation
Color
Odor
Temperature
Alkalinity
Hardness

In order to evaluate Jordan Brook water quality, seven critical parameters were analyzed. These parameters were selected as they have greater potential to impact uses of the stream and are more likely to be affected by development as opposed to natural sources. The parameters-of-concern that were analyzed are total phosphorous, turbidity, total coliforms, dissolved oxygen, conductivity, chloride, and copper.

TABLE 2
JORDAN BROOK SAMPLING STATIONS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Station Number	Description
1	Stream crossing in woods, east of Konomoc Hill
2	Stream crossing in woods northeast of Industrial Drive cul de sac
3	Downstream of Douglas Lane
4	Downstream of Cross Road
5	Downstream of Parkway South
6	Downstream of Post Road
7	Upstream of Rope Ferry Road
8	South end of dam at Mill Pond

3.1.2.1 Analysis of Parameters-of-Concern

The average concentration of each of the parameters-of-concern at each of the sampling stations are shown on Figures 4-10. Of the nine events monitored, three events (9/14/93, 9/12/95, 6/10/94) had no rainfall for at least 48 hours before the sampling event and were defined as dry weather events. Only one event (6/12/95) was clearly influenced by wet weather. The other five sampling events occurred on 9/29/94, 6/18/96, 9/24/96, 6/25/97, and 9/23/97 and could not be classified as either "wet" or "dry". For comparison purposes, the average concentrations from these three dry and one wet weather events were plotted against the average concentration of all nine events. It should be noted that the wet weather concentrations are based on only one event and, therefore, are not statistically valid compared to the other average concentrations.

- **Phosphorous:** Phosphorous is typically the limiting nutrient in freshwater systems. The State of Connecticut Water Quality Standards (effective April 12, 1996) classify surface waters with 0.03 to 0.05 mg/l of total phosphorous as eutrophic and highly enriched with nutrients. Higher levels of phosphorous are considered highly eutrophic. Eutrophic conditions lead to algal blooms and dissolved oxygen depletion in impoundments.

  In this watershed, average phosphorous concentrations are generally above 0.03 mg/l. A number of impoundments exist in the watershed where significantly increased phosphorous loads could lead to increased potential for eutrophication. However, these elevated levels are mostly due to high concentration results from two sampling events, 9/24/96 and 9/23/97. Phosphorous concentrations during other sampling events were generally below 0.03 mg/l.

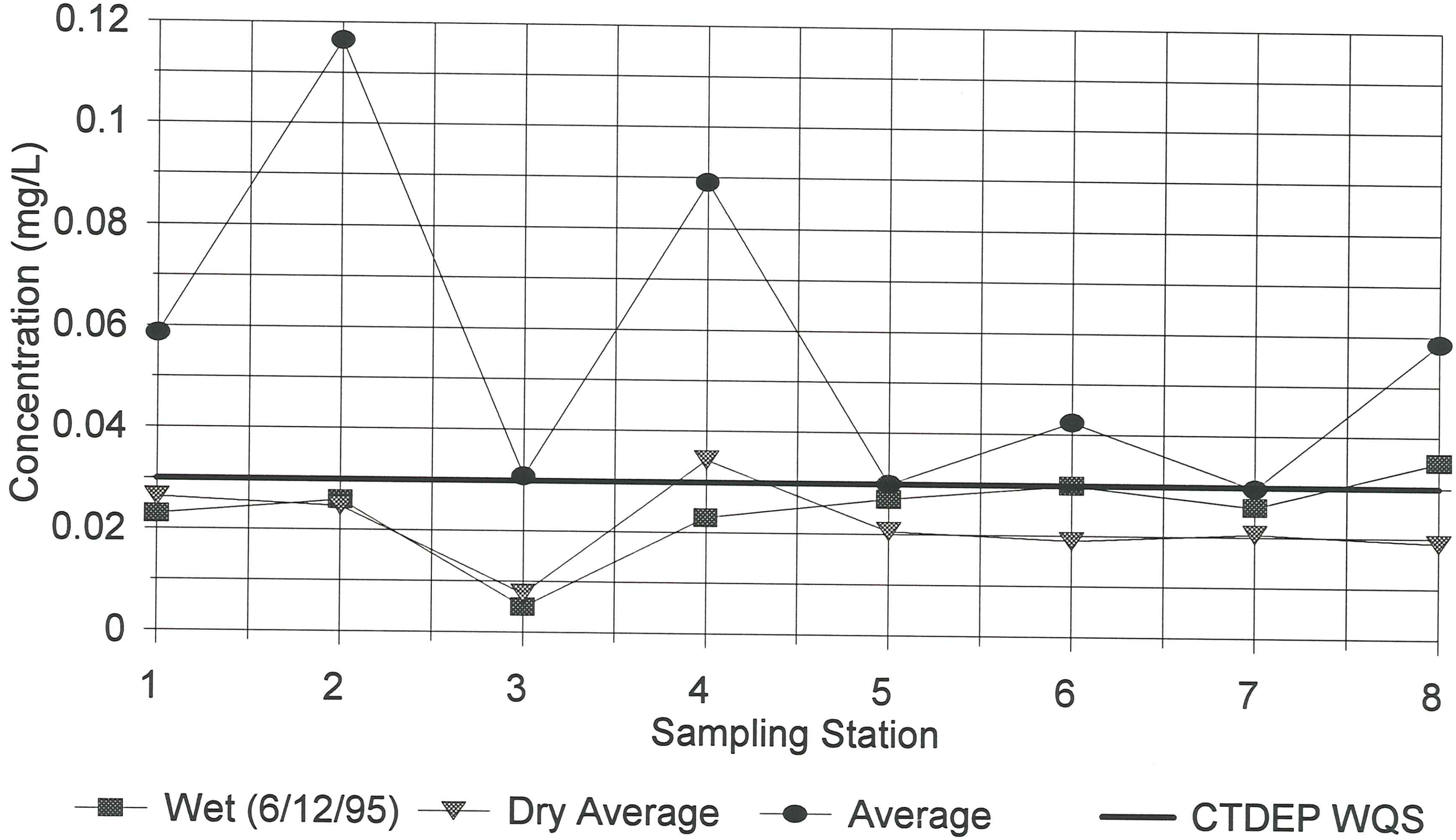
- **Turbidity:** Surface water criteria specified in the Connecticut Water Quality Standards establish a turbidity standard of 5 NTU over ambient levels. Average concentrations in Jordan Brook are below this level.

- **Total Coliforms:** The standard for total coliforms in Class A streams is 500 counts/100 ml based on the Connecticut Water Quality Standards. Average water quality in the stream exceeded this standard at most stations. Dry and wet weather concentrations increased in the more developed downstream reaches of the watershed.

- **Nitrate:** While no criteria have been established for nitrate in the Connecticut Water Quality Standards, nitrogen is a limiting nutrient in salt water systems. Nitrate levels were significantly higher during the one wet weather event measured. Nitrate levels also increase with development. Septage lagoons are also shown on USGS mapping as being near the reach of brook where nitrate levels increase (stations 4 and 5).

- **Dissolved Oxygen:** All dissolved oxygen concentrations were above 5 mg/l which is the minimum criteria per the Connecticut Water Quality Standards. Concentrations generally decreased through developed areas of the watershed. This is likely due to the water temperature increase that is typically found through developed areas.

Figure 4
Average Phosphorous Concentration
Jordan Brook Watershed



CTDEP WQS - Connecticut Dept. of Environmental Protection, Surface Water Quality Standards, effective April 8, 1997.

Figure 5

Average Turbidity and TSS

Jordan Brook Watershed

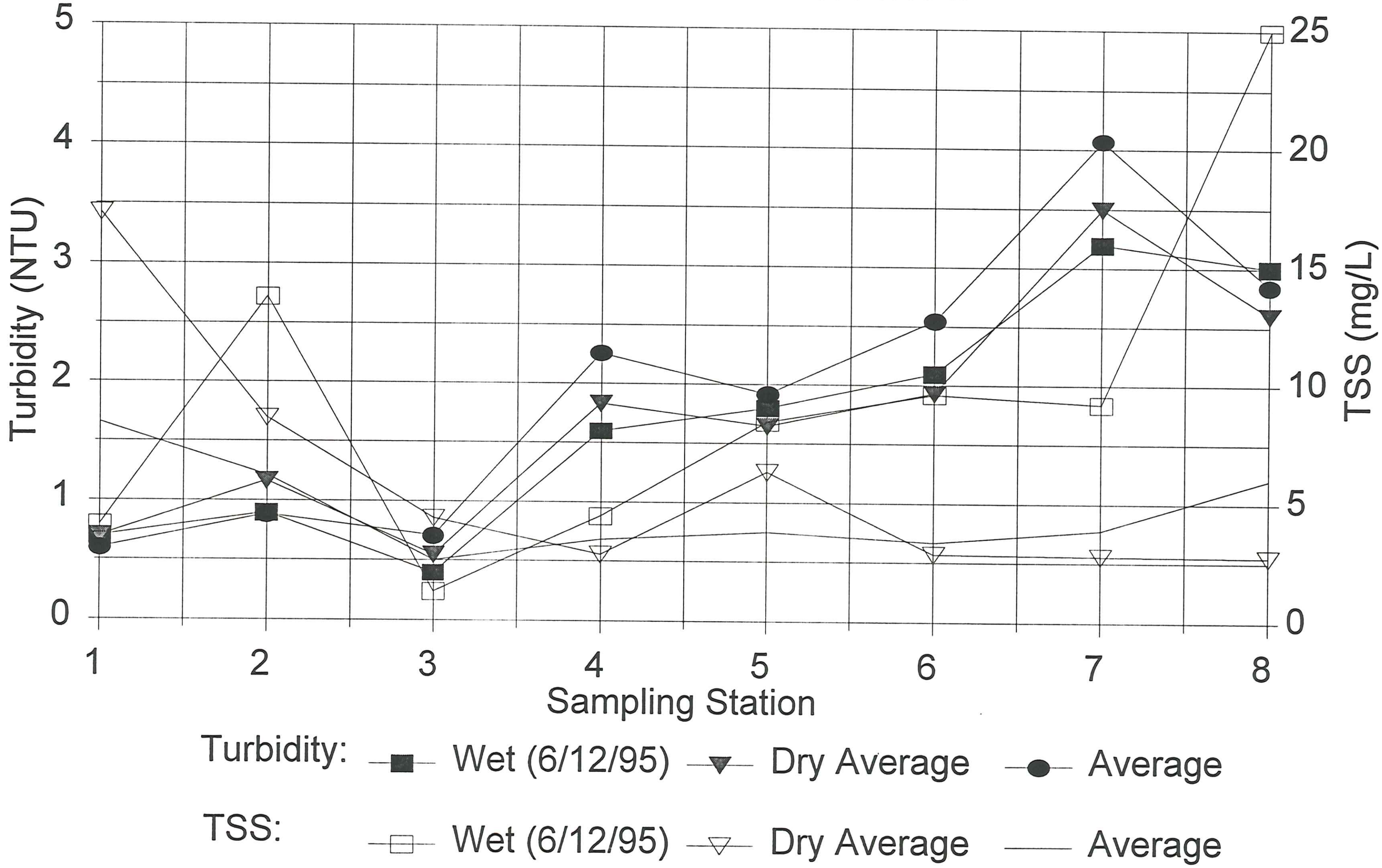
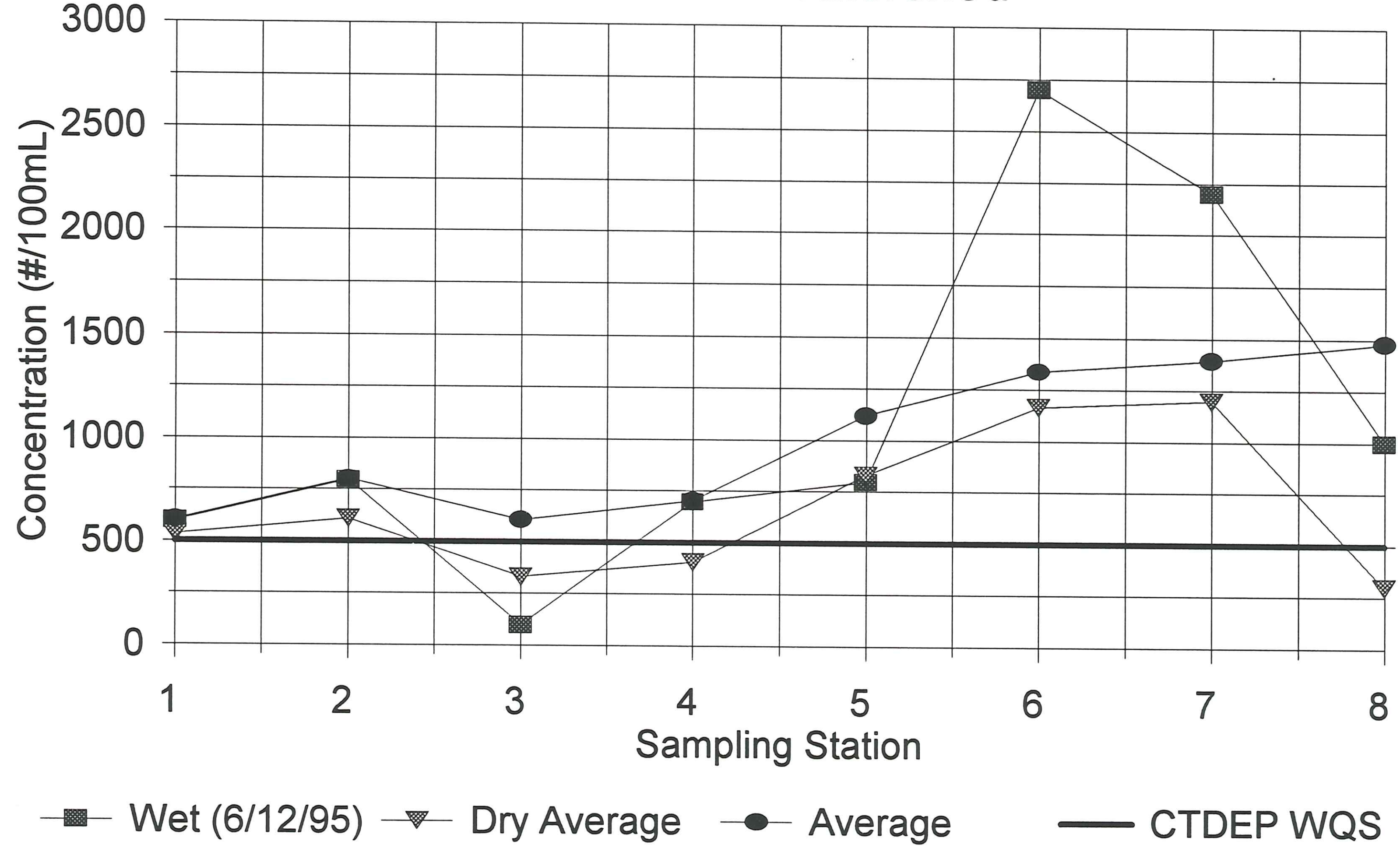


Figure 6

Average Total Coliforms
Jordan Brook Watershed



CTDEP WQS - Connecticut Dept. of Environmental Protection, Surface Water Quality Standards, effective April 8, 1997.

Figure 7

Average Nitrate Concentration
Jordan Brook Watershed

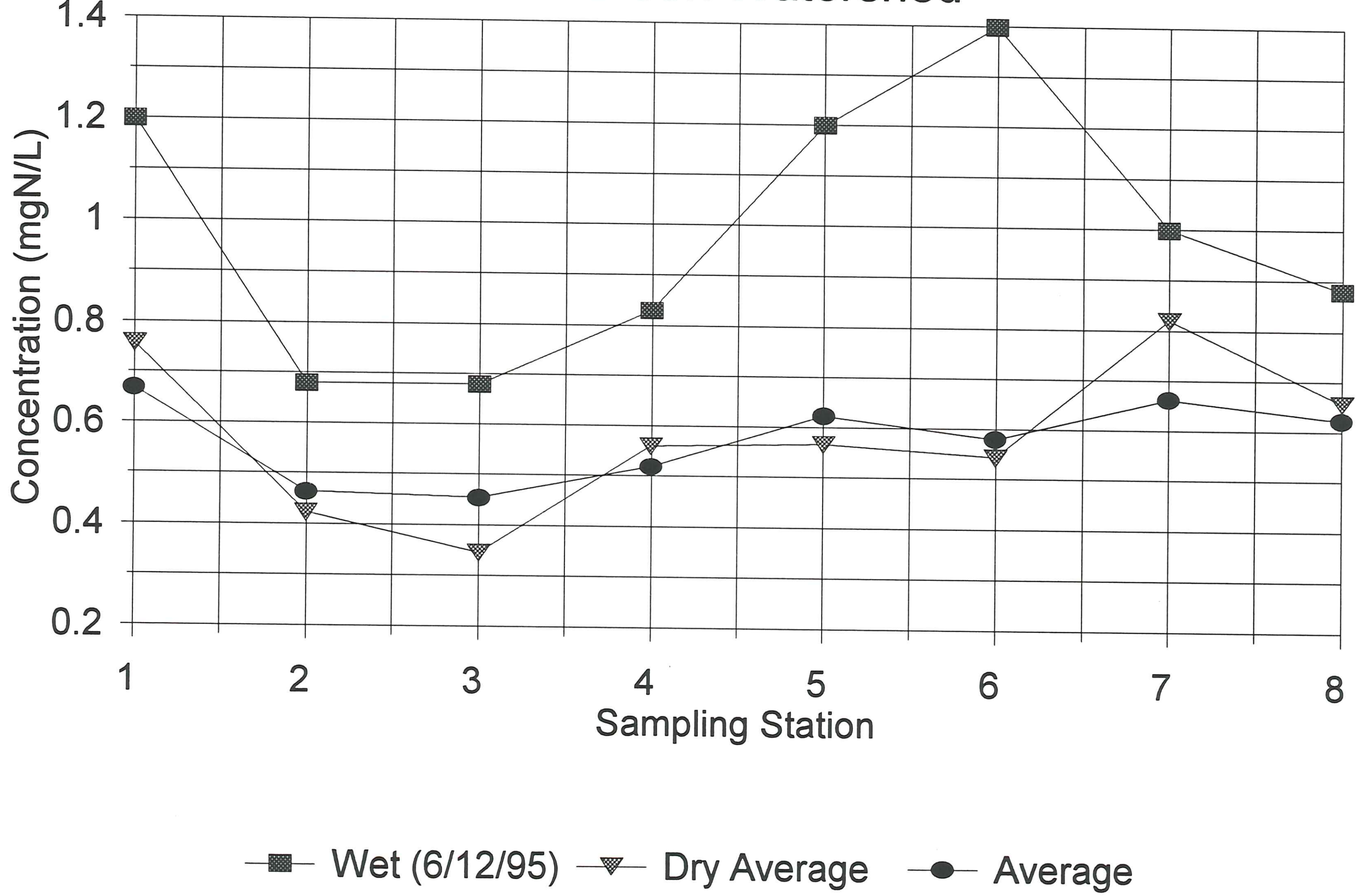


Figure 8

Average DO and BOD Concentrations
Jordan Brook Watershed

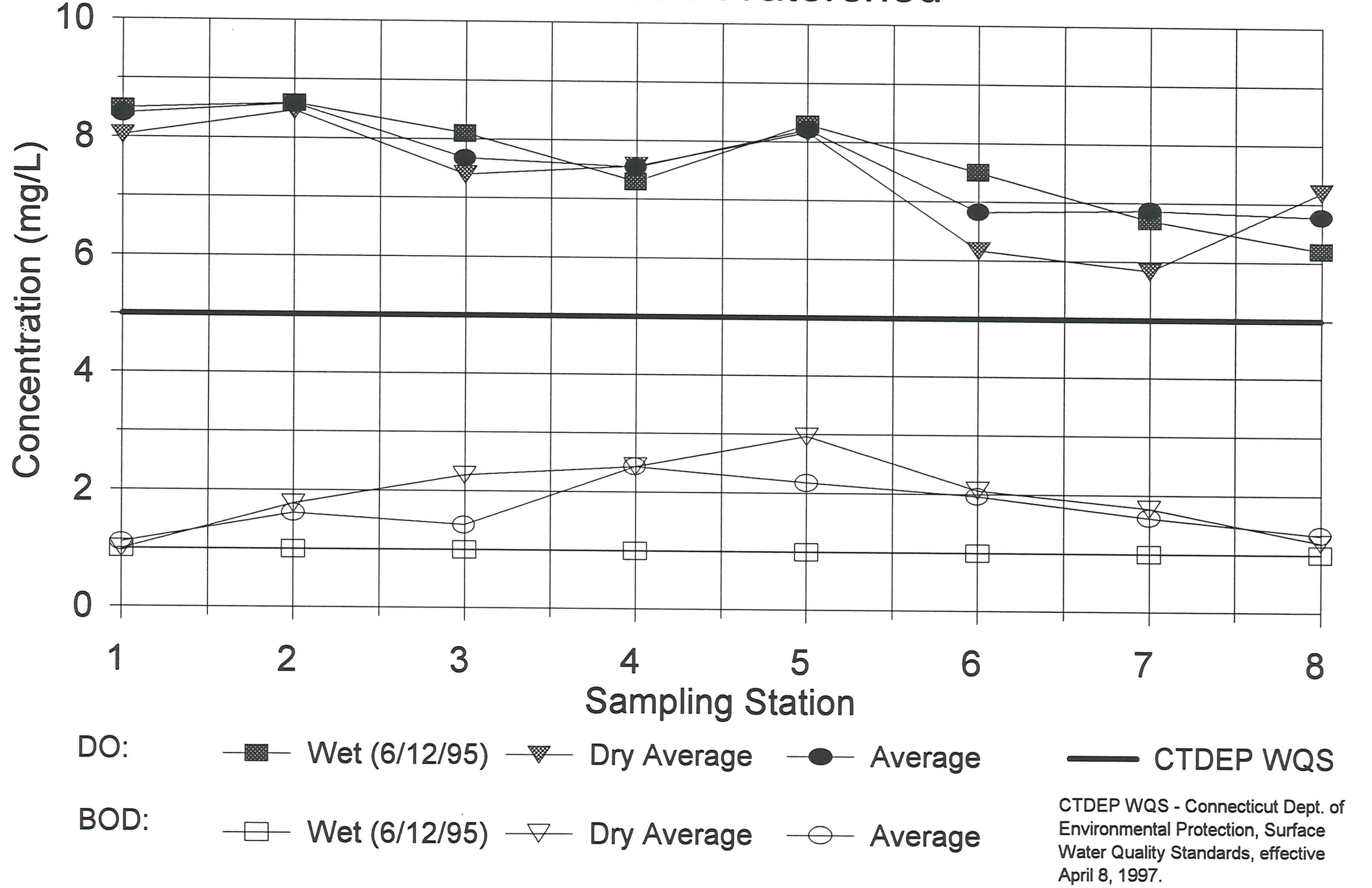


Figure 9

Average Conductivity

Jordan Brook Watershed

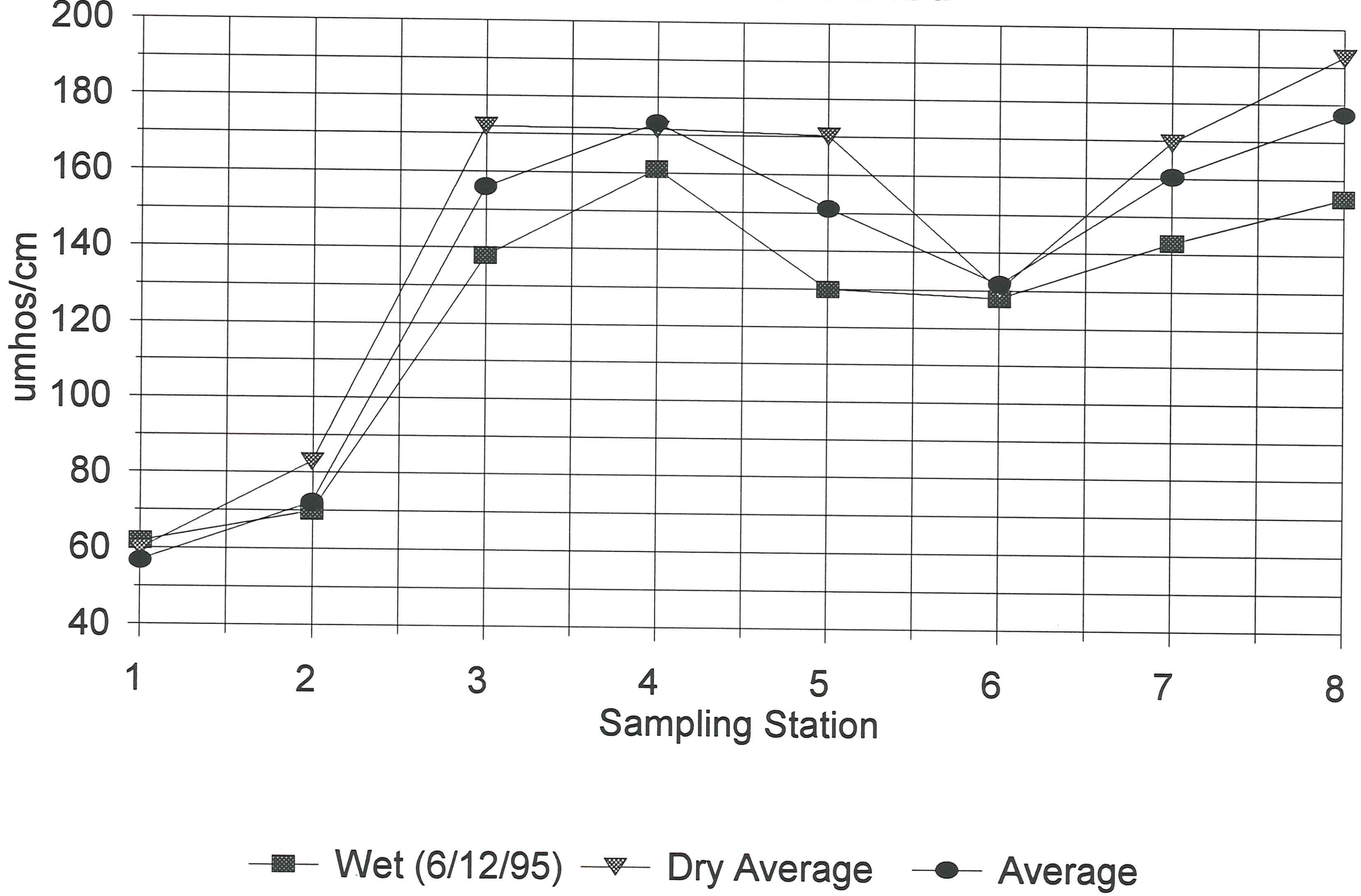
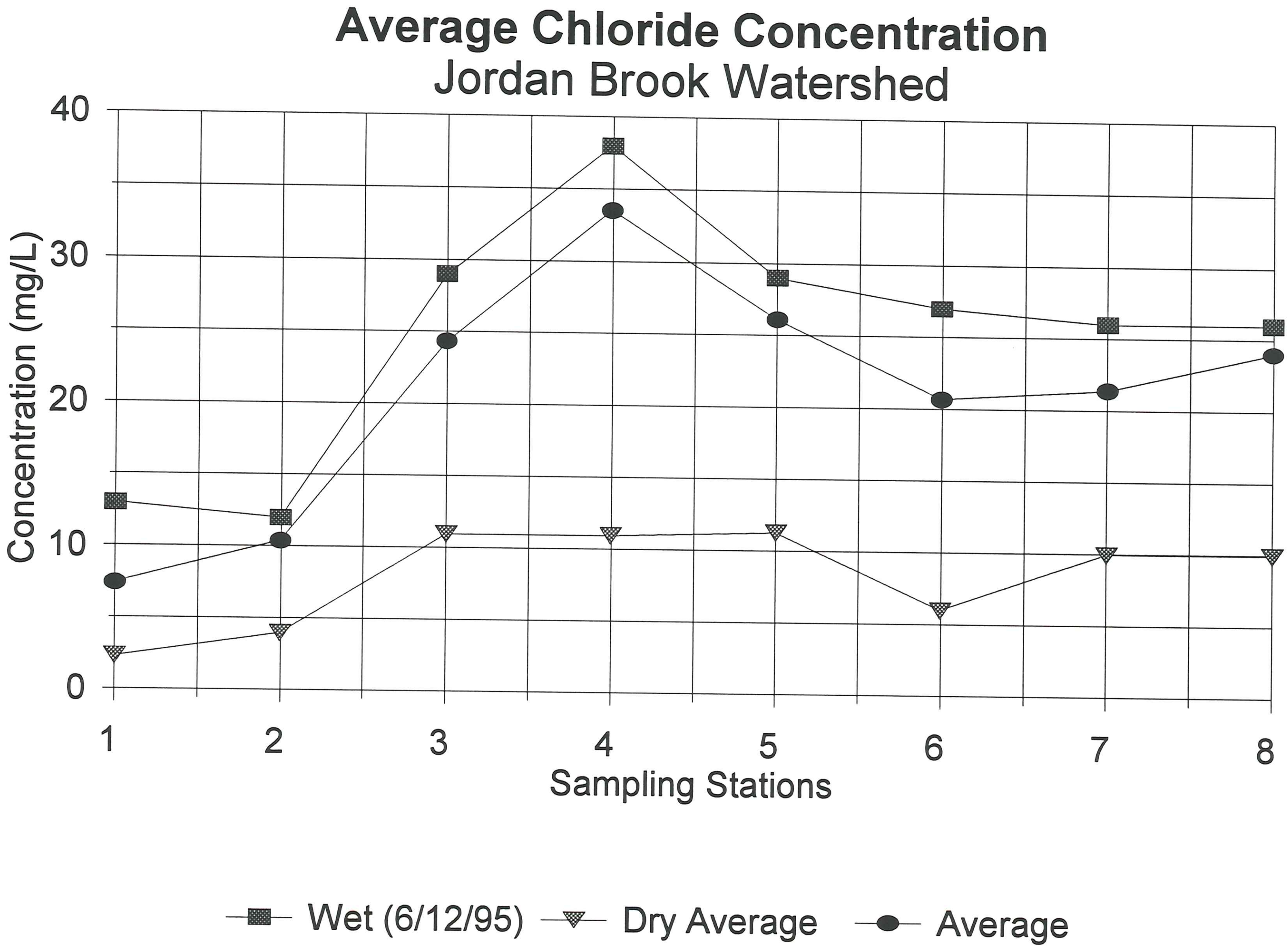


Figure 10


Average Chloride Concentration
Jordan Brook Watershed
Concentration (mg/L)
40
30
20
10
0
1
2
3
4
5
6
7
8
Sampling Stations
Wet (6/12/95)
Dry Average
Average

- **Conductivity:** Conductivity is a measurement of inorganic salts in the water. Based on this monitoring, conductivity concentrations increase significantly immediately downstream of I-395. This is likely the result of the use of deicing salts on this highway.

- **Chloride:** Chloride concentrations also significantly increase immediately downstream of I-395 which is likely the result of the use of deicing salts on the highway. Concentrations generally decreased at downstream stations.

- **Copper:** Copper levels detected in the brook were either not detected or were detected just at detection limits. Detection limits used by the laboratory were equivalent to CTDEP chronic water quality criteria (0.0048 mg/l). No figure is provided for copper since levels of copper were never measured above detection limits.

In summary, with the exception of some elevated levels of phosphorous and coliforms, stream water quality appears to be within CTDEP Class A surface water quality criteria. However, current watershed development has increased levels of some of these parameters.

The data available to determine wet and dry weather impacts is limited. Future sampling should be conducted in a manner that would better determine wet and dry weather impacts.

While total coliform levels exceed Class A surface water quality criteria, these levels may not be attributable to a man-made source of pollution. Total coliform sources include degrading plant matter, as well as sewage and other man-made sources. In addition, since the elevated phosphorous levels are caused by only two of the nine sampling events, the elevated phosphorous levels may not be representative of actual stream conditions.

Some modifications to the monitoring program are recommended to better determine wet weather impacts and bacteria and phosphorous impacts in this surface water. The recommended water quality monitoring program is described in Section 7.1.

3.1.2.2 Effects of Imperviousness on Surface Water Quality

Research has found a strong correlation between impervious surfaces in a watershed and water quality in downgradient water resources. Literature reports that when 10 to 30% of the watershed consists of impervious surfaces, downgradient water resources are typically found to be impacted. When more than 30% of the watershed consists of impervious surfaces, downgradient water resources have been found to be degraded.

The average amount of impervious surface (i.e., roof and paved areas) associated with each watershed land use was determined using GIS land use and impervious surface data provided by the Town. Table 3 summarizes the percentage of the watershed that is impervious above each existing sampling station. For the purposes of this study, impervious areas are defined as roof and paved areas. The percent impervious represents the total impervious area in the watershed above the sampling station. The percent impervious is computed by dividing the impervious areas above the sampling station by the total watershed area above that station.

TABLE 3
SUMMARY OF IMPERVIOUS AREAS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Station	Total Area (Sq-ft)	Impervious Area (Sq-ft)	% Impervious (%)
1	5,820,000	186,000	3%
2	13,639,000	212,000	2%
3	29,216,000	1,340,000	5%
4	39,871,000	2,441,000	6%
5	72,550,000	5,008,000	7%
6	101,870,000	6,658,000	7%
7	172,093,000	16,568,000	10%
8	214,599,000	24,825,000	12%

Based on stream sampling, no significant water quality impacts were observed with the exception of total coliform levels that were consistently above desired levels for Class A waters through the watershed. Since most of the watershed is less than 10% impervious, this observation is consistent with the above research.

The only parameters that exhibited clear impacts with increased imperviousness during stream sampling were turbidity, conductivity and dissolved oxygen. Water quality standards for Class A streams only exist for turbidity and dissolved oxygen levels. The levels for both of these parameters in the stream are within standards.

3.1.2.3 Land Use Evaluation

The total amount of impervious area within each land use across the entire watershed was also computed. Results of the evaluation are summarized in Table 4, which includes the total area, impervious area, and percent imperviousness of each land use. The total area shown in Table 4 is the total land use area that is currently shown on the Town's electronic land use mapping. This total area does not correspond to zoning.

As shown in the table, the average level of imperviousness varies significantly with land use. Commercial, industrial, mall, and highway land uses generally contain the highest percentage of impervious surfaces (approximately 40 to 75 percent), while largely undeveloped land uses such as vacant land, open space, utility transmission, and land trust/public easements contain less than 3 percent impervious surfaces. Multi and single family residential land uses, public and private facility, and commercial retail land uses contain intermediate levels of imperviousness (approximately 18 to 30 percent).

3.1.2.4 Subwatershed Evaluation

For the purposes of this study, the Jordan Brook watershed was subdivided into 26 subwatersheds as shown in Figure 11. These subwatersheds were delineated from topographic mapping provided by the Town for Jordan Brook tributaries, at major road crossings, and at locations selected for hydrologic evaluation.

An evaluation was performed to determine the amount of impervious surface coverage within each subwatershed using GIS data on impervious surfaces and the subwatershed boundaries delineated for this project. The percent imperviousness of each subwatershed was calculated by dividing the impervious area within a subwatershed by the total subwatershed area. Results of the evaluation are summarized in Table 5. The impervious area values in Table 5 do not reflect future land use conditions since it is not possible to accurately determine the amount of impervious area that will be associated with future development.

The percentage of impervious area for individual subwatersheds ranges from approximately 20 to 30 percent in the most highly developed subwatersheds (1, 1AA, 1AB, 1ABA, 2AAB, 2AAC, and 2ABA) to less than 3 percent in subwatersheds 10 and 10A, which are located in a forested area near the Jordan Brook headwaters. In general, subwatersheds with the highest percentage

TABLE 4
CURRENT IMPERVIOUSNESS OF WATERSHED LAND USES
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Land Use	Total Area (sq-ft)	Impervious Area (sq-ft)	Percent Impervious
Cemetery	3,791,000	230,000	6%
Commercial Hospitality	42,000	20,000	48%
Commercial Office	42,000	17,000	40%
Commercial Retail	10,514,000	2,548,000	24%
Highway	3,633,000	1,396,000	38%
Industrial Manufacturing	3,537,000	1,294,000	37%
Industrial Warehouse	44,000	32,000	73%
Land Trust/Public Easement	686,000	19,000	3%
Mall	8,452,000	3,683,000	44%
Mixed Use	1,058,000	217,000	21%
Mobile Home	491,000	124,000	25%
Multi Family	3,597,000	713,000	20%
PA-490	42,713,000	327,000	<1%
Private Facilities	965,000	203,000	21%
Private Open Space	4,992,000	46,000	<1%
Public Facilities	8,176,000	2,094,000	26%
Public Land	18,057,000	271,000	2%
Public Utility	622,000	33,000	5%
Single Family	26,684,000	4,751,000	18%
Unknown	104,000	3,000	3%
Utility Transmission	5,425,000	50,000	<1%
Vacant	59,143,000	1,316,000	2%

Jordan Brook Subwatersheds
Jordan Brook Watershed Management Study
Town of Waterford

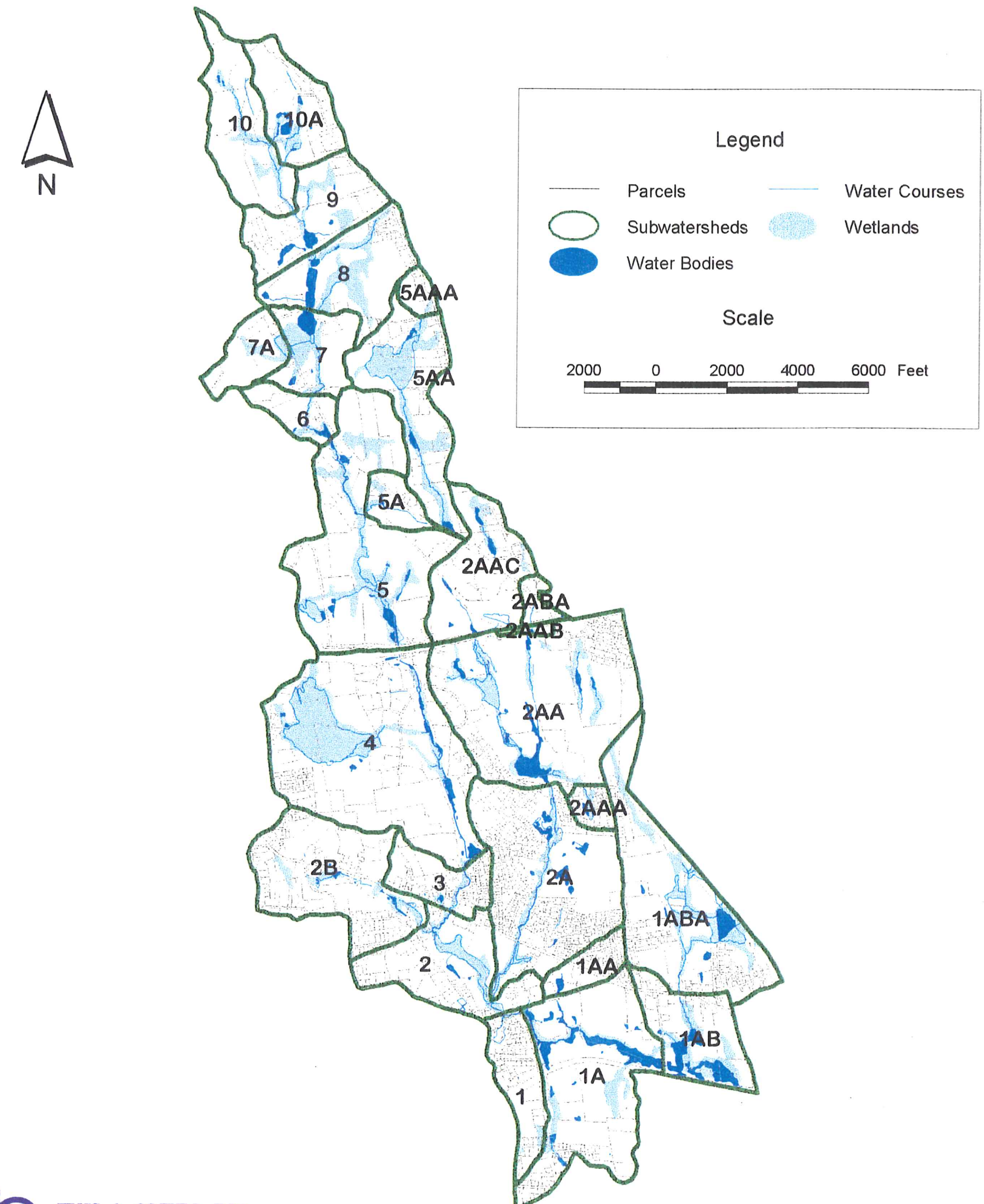


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FIGURE 11

TABLE 5
CURRENT IMPERVIOUSNESS OF JORDAN BROOK SUBWATERSHEDS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Subwatershed	Total Area (sq-ft)	Impervious Area (sq-ft)	Percent Impervious
1	3,761,000	969,000	26%
1A	14,643,000	2,052,000	14%
1AA	1,981,000	659,000	33%
1AB	6,237,000	1,862,000	30%
1ABA	13,044,000	3,026,000	23%
2	8,679,000	981,000	11%
2A	15,605,000	2,837,000	18%
2AA	20,907,000	1,856,000	9%
2AAA	1,173,000	186,000	16%
2AAB	305,000	117,000	38%
2AAC	7,987,000	2,465,000	31%
2ABA	926,000	262,000	28%
2B	11,258,000	1,466,000	13%
3	3,645,000	608,000	17%
4	24,721,000	930,000	4%
5	19,307,000	1,902,000	10%
5A	2,093,000	282,000	13%
5AA	9,706,000	245,000	3%
5AAA	1,003,000	90,000	9%
6	2,542,000	380,000	15%
7	4,556,000	255,000	6%
7A	3,130,000	422,000	13%
8	8,113,000	468,000	6%
9	7,178,000	660,000	9%
10	7,987,000	26,000	<1%
10A	5,719,000	186,000	3%

Note:
1. Table excludes area of watershed located in New London

of impervious coverage are located in the southern and central portions of the Jordan Brook watershed.

3.2 Inland Wetlands

A survey of watershed wetlands and watercourses has been completed. The purpose of this survey was to develop a description and biological evaluation of significant surface water and wetland ecosystems within the Jordan Brook watershed. During this survey, available information on watershed wetland systems was reviewed which included CTDEP aerial photographs, town wetlands mapping, US Geological Survey (USGS) maps, and other CTDEP maps and reports. In addition, watershed wetlands and watercourses were evaluated visually at a number of stations. Based on this data, wetland functional values were estimated using CTDEP Bulletin No. 9 as a guide. Note that although this evaluation provides a baseline assessment of wetland resources throughout the watershed, it is not intended to supplant requirements that developers provide additional detailed information about on-site wetlands as required for a specific project.

3.2.1 Wetland Resources

For the purposes of this study, the long streams and wetland corridors within the watershed were divided into five major segments and a name was assigned to each segment. The mainstem of Jordan Brook was divided into three segments: Lower Jordan Brook (JL) from the dam at Jordan Mill Park north to Route I-95; Central Jordan Brook (JC) from Routes I-95 to I-395; and Upper Jordan Brook (JU) from Route I-395 north to the vicinity of Lake Konomoc. Nevins Brook (N) and an unnamed brook, hereafter designated East Brook (E), formed the fourth and fifth segments. Each of the five segments was further subdivided into sections of mainstem stream (M), tributaries (T), large swamps (S), or ponds (P). For example, a pond in the central section of Jordan Brook would be designated JCP2 (J for Jordan Brook, C for central section, P for pond and 2 as the pond number in the segment). A total of 41 wetlands within the watershed, varying in size from 2 to 94 acres, were so numbered for the purposes of evaluation during this study. The number of individual wetlands within the five main segments is shown below. The location of these areas are shown in Appendix C.

NUMBER AND TYPE OF WETLANDS

Segment	Mainstem Sections	Tributaries	Swamps	Ponds	Total
Jordan Lower	3	1	1	3	8
Jordan Center	2	6	2	1	11
Jordan Upper	1	1	1	2	5
Nevins Brook	2	3	2	2	9
East Brook	3	1	2	2	8
Total	11	12	8	10	**41**

The wetlands were visited between April 8 and April 28, 1998. A brief description of each of the wetlands is given in Appendix C.

3.2.2 Evaluation of Resources

Wetlands within the Jordan Brook watershed were evaluated using an adaptation of the method developed by the CTDEP (Ammann, et al., 1991). This method was designed for use by municipalities as a planning tool. It consists of a scientifically defensible numerical scoring system which can be used to compare the relative value of all wetlands within the same watershed. It is not intended to be used for the approval or rejection of specific development proposals. However, the scores can be used to establish wetland policy, to identify particularly high value wetlands, and to determine which wetlands may require special levels of protection or warrant detailed study.

The CTDEP method identifies thirteen functional values of wetlands. Because of the large number of individual wetlands in the Jordan Brook watershed, study resources were focused on the four major functional values most important to the ecology of wetlands: *Ecological Integrity, Wildlife Habitat, Finfish Habitat and Visual/Esthetic Quality.*

- *Ecological Integrity* is a measure of the overall health of a wetland and is based on such factors as the quality of the inflow water, the type of wetland soils, the degree of disturbance of soils and vegetation within and near the wetland, and the level of human activity in the vicinity.

- The suitability of the wetland as *Wildlife Habitat* is based on size of the wetland, the amount of open water, the number of different vegetation communities present, and the percentage of wetland edge bordered by undisturbed upland habitat.

- The value of the wetland as *Finfish Habitat* is considered separately for streams and ponds. Water quality is important, together with the size of the water body, the type of aquatic and wetland vegetation, the characteristics of the bottom and the abundance of cover available to fish.

- The *Visual/Esthetic Quality* of a wetland is based on the nature of the vegetation, the degree of noise and odors present, the amount of visible open water, and the appearance and use of the surrounding land. Although the visual quality of a wetland is not strictly an ecological function, it is an important factor to residents in the area, and to people using the wetland for such passive ecology-oriented recreation as hiking or bird watching.

Functional values not included in the study were: *Educational Potential, Water Based Recreation, Flood Control, Groundwater Use Potential, Nutrient Retention/Sediment Trapping, Shoreline Anchoring, Forestry Potential, Archaeological Potential, Urban Wetland Quality and Noteworthiness.*

Educational Potential is based primarily on such sociological factors as the proximity of the site to schools, the amount of parking, student safety issues, public access, the presence of trails, and the accessibility of open water. *Water Based Recreation* depends on whether fish are stocked and hunting is permitted. Parking is again important, together with access to other boating areas. Such issues are not relevant to the ecology of wetlands, and therefore these functions were not selected.

The CTDEP method of evaluating the *Flood Control* function is based on the area of watershed above a wetland compared to the area of watershed downstream at a potential flood damage location. The *Groundwater Potential* of a wetland depends on whether the wetland is upstream from a stratified drift aquifer and whether there are existing public or private wells. The quality of the groundwater is also taken into account. Thus *Flood Control* and *Groundwater Potential* are essentially based on the topography and hydrogeology of the area rather than on the ecology of the wetlands, and these functions were not included in this evaluation. *Flood Control* issues were considered, however, as part of the hydrologic evaluation of the watershed (Section 4.0), and *Groundwater Potential* was considered as part of the aquifer evaluation (Section 6.1).

To evaluate the *Nutrient Retention/Sediment Trapping* function, the CTDEP method relies on the average slope of the watershed above the wetland, the dominant land use, and potential sources of nutrients or sediments within the watershed (i.e., cropland, pasture, livestock, septic problems, areas of soil erosion, etc.). Consequently, the method does not consider the actual ability of the wetland to remove pollutants, but rather considers the contribution of pollutants from adjacent land uses. The *Shoreline Anchoring* function is based on the presence or absence of banks and shorelines, on the width of adjoining wetlands, and on the density of vegetation bordering the watercourse. The detailed field examination of the watershed and most of the forty one wetlands required to complete the evaluation of these functions was beyond the scope of this study.

The remaining four functional values were deemed not applicable to most of the Jordan Brook watershed wetlands. Including such functions in the study would tend to reduce the mean scores of otherwise valuable ecosystems, and to lower their evaluation. *Forestry Potential* is usually limited to wetlands on large privately owned tracts of agricultural or wooded land. The evaluation of *Urban Water Quality* requires that wetlands fall within a ½ mile radius of 90% commercial, industrial, or transportation land use. Very few of the wetlands meet these criteria. Criteria for *Noteworthiness* include the use of the wetland as a scientific research site, inclusion in the Federal list of Natural Landmarks, and the presence of unique biological or geological features. The Jordan Brook wetlands do not meet these criteria. Another criterion for *Noteworthiness* is the presence of rare species habitats. The Connecticut Natural Diversity Data Base was contacted to determine whether or not any Endangered, Threatened or Special Concern Species are known to occur within the watershed. Their reply of April 26, 1998 indicated that one plant and one bird species have been reported somewhere in the area, but no information was given concerning the exact location of these species (Appendix E). Information was also requested from the Connecticut State Archaeologist regarding possible archaeological sites within the wetlands. The Public Archaeology Survey Team is responsible for the development of *Archaeological Potential* information (Appendix E).

3.2.2.1 Evaluation Procedures

For each of the four functional values, a series of six to twelve questions are posed which are given a score of 1.0, 0.5 or 0.1, with the score of 1.0 representing the highest value. Some of the questions are designed to be answered in the office using maps, aerial photographs, reports, or reference books. Other questions are answered in the field by direct observation of conditions in and around the wetlands. Conductivity, a measure of the ionic content of the water which is frequently used to indicate pollution, was measured in the larger streams and ponds using a YSI Conductivity meter. A brief description of each wetland is given in Appendix C.

One of the limitations of the evaluation method is the problem of scale. Questions answered from maps and photographs in the office are very broad and are based on characteristics of the entire wetland and the watershed. On the other hand, questions answered by observations in the field are very specific, and are based on conditions at the individual viewing locations. This difference in scale is a disadvantage of the CTDEP method.

A total of thirty nine questions were answered for streams, thirty six questions for ponds, and thirty questions for wooded or shrub swamps. The average of the scores, designated the Functional Value Index (FVI), was calculated for each wetland. This index, the value of which is always less than or equal to 1.0, can be used to compare the relative values of different wetlands within the watershed. In addition, since larger wetlands are generally considered of greater value than smaller systems, each FVI was multiplied by the acreage of its wetland to yield a second index known as Wetland Value Units (WVU).

Because of the number of wetlands within the watershed, a total of over one thousand, six hundred and fifty questions were answered to develop the wetland values. Specific methods used to answer the questions are summarized in Appendix D. The individual scores for each question and the average scores for each of the four functional values are also presented in Appendix D.

3.2.3 Significant Resources

The results of the survey are summarized in Table 6. The table lists the wetlands and shows for each wetland the area and conductivity, together with the average FVI and WVU scores. Where a wetland was evaluated at two or more locations, the average value for all viewing locations is shown. Mean FVI and WVU scores for the various wetlands can be compared using the graphs in Appendix D.

In addition to the scores developed by the DEP method, Subjective Opinion scores are given for each wetland. These scores, ranging from 1 to 4, are predicated on years of experience and reflect the opinion of the biologist regarding the overall value of the wetland. The scores are formed in response to such characteristics as vegetation diversity, the density of the shrub layer and canopy, the presence or absence of invasive species, the prevalence of saturated soils or standing water, etc. The purpose of the Subjective Opinion scores was to complement the more schematic CTDEP method.

TABLE 6
INLAND WETLANDS SUMMARY
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Wetland	Area (acres)	Mean Conductivity (umhos/cm)	Mean FVI (Score)	Mean WVU (Score)	Subjective Opinion (Score)	Final Wetland Value	Water Quality Sensitive	Special Signif.
Lower Jordan Brook								
JLM1	37.4	80	0.66	24.67	3	High	I	X
JLM2	2.0	72	0.68	1.35	4	Very High	P	X
JLM3	17.1	60	0.66	11.25	2	High	P	
JLT1	18.9	94	0.50	9.51	2	Average	I	
JLS1	93.9		0.62	58.61	3	High		X
JLP1	3.0	98	0.49	1.48	2	Average	I	
JLP2	2.1	71	0.64	1.34	3	High		
JLP3	3.4	74	0.69	2.35	4	Very High	P	X
Central Jordan Brook								
JCM1	60.1	82	0.75	44.78	3	Very High	P	X
JCM2	31.4	83	0.57	17.99	2	Average	I	
JCT1	16.3	51	0.46	7.48	2	Low		
JCT2	47.0	56	0.68	31.86	3	High	P	X
JCT3	22.7		0.48	10.97	2	Low		
JCT4	7.0		0.49	3.43	2	Low		
JCT5	12.4		0.55	6.85	1	Low		
JCT6	40.4	154	0.62	25.24	4	High	P	X
JCS1	27.1		0.74	20.17	4	Very High		X
JCS2	26.6		0.47	12.53	2	Low	I	
JCP1	6.0		0.56	3.34	2	Average	I	
Upper Jordan Brook								
JUM1	45.5	38	0.72	32.96	4	Very High	P	X
JUT1	9.5		0.59	5.56	2	Average		
JUS1	3.6		0.48	1.73	1	Low		
JUP1	2.2		0.50	1.11	2	Average	I	
JUP2	2.8	56	0.59	1.65	3	High		
Nevins Brook								
NM1	30.3	97	0.56	16.99	2	Average	I	
NM2	16.3	102	0.71	11.56	3	Very High	P	X
NT1	26.8	110	0.74	19.82	4	Very High	P	X
NT2	6.5	253	0.50	3.25	3	High	I	
NT3	7.1	84	0.65	4.64	3	High		
NS1	13.9		0.60	8.35	4	High		
NS2	14.4	62	0.58	8.34	2	Average	I	
NP1	2.5	33	0.67	1.67	4	Very High	P	X
NP2	3.7	102	0.57	2.09	2	Average	I	

TABLE 6 (CONTINUED)
INLAND WETLANDS SUMMARY
JORDAN BROOK WATERSHED MANAGEMENT STUDY
TOWN OF WATERFORD
FEBRUARY 2000

Wetland	Area (acres)	Mean Conductivity (umhos/cm)	Mean FVI (Score)	Mean WVU (Score)	Subjective Opinion (Score)	Final Wetland Value	Improve Water Quality	Special Signif.
East Brook								
EM1	47.3	171	0.43	20.52	1	Low	I	
EM2	17.8	178	0.39	6.85	2	Low	I	
EM3	39.9	195	0.71	28.37	3	High	P	X
ET1	14.3	87	0.49	7.07	1	Low	I	
ES1	27.5		0.46	12.60	3	Average		
ES2	34.9		0.76	26.53	4	Very High		X
EP1	0.8		0.33	0.26	1	Low	I	
EP2	1.2	80	0.33	0.40	2	Low	I	

Notes:
Mean FVI represents average score assigned to each of the four functional values.
Mean WVU represents mean FVI multiplitied by the acreage of the wetland.
I = Improve Water Quality
P = Preserve Water Quality

Each wetland was ranked in the Final Wetland Value column as Low, Average, High or Very High. To develop these rankings, mean FVI scores were first sorted into four categories: less than 0.50 (Low), from 0.50 to 0.60 (Average), from 0.60 to 0.70 (High) and over 0.70 (Very High). When mean WVU scores were also taken into consideration, it was found that most of the larger wetlands had already been rated as either High or Very High based on the FVI scores. Finally, the rankings were checked against the Subjective Opinion scores; seven wetlands were adjusted upwards and two were adjusted downwards.

It is important to note that the rankings reflect the comparative value of various wetlands within the watershed. One wetland may be considered more valuable than another for a variety of reasons, but all wetlands are important ecosystems which deserve protection. Therefore, a Low or Average ranking should never be construed as justification for lax development practices.

Some of the wetlands within the watershed would benefit greatly by improvements in the quality of stormwater flowing into them. These wetlands are designated "P" (preserve current water quality) or "I" (improve current water quality) in Table 6. Wetlands marked "P" are located primarily in undeveloped areas. They would be significantly impacted by degraded stormwater from road runoff or construction related sedimentation. Wetlands marked "I" are generally surface waters which flow through developed areas somewhere along their course. They are already adversely affected by urban drainage, and would be significantly enhanced by water quality improvements.

Those wetlands deemed especially sensitive and meriting all possible measures of protection or preservation are indicated in the last column of Table 6. All of the Very High value wetlands are considered to be of special significance, together with large High value wetlands (WVU's greater than 20). Protection or preservation measures should include detailed consideration of all development proposals impinging on Upland Review Areas and Upland Protection Zones (see below). Developers should be required to provide specific descriptions and evaluations of on-site and neighboring wetlands. Special efforts should be made to prevent erosion and sedimentation, and engineered stormwater controls should be required.

The Town of Waterford Inland Wetlands Regulations are currently being revised to include Upland Review Areas bordering all wetlands. Upland Review Areas are upland areas in which certain activities, such as grading, excavating or filling, are regulated by the Inland Wetlands Commission. The purpose of an Upland Review Area is to control long-term and short-term impacts from the development of uplands in close proximity to wetlands.Specific elements of each development site plan must be reviewed on a case by case basis. Upland Protection Zone recommendations are outlined in Section 7.6.1 of this report. A copy of the CTDEP Guidelines for Upland Review Area Regulations is provided in Appendix F.

4.0 HYDROLOGIC EVALUATION OF JORDAN BROOK

4.1 TR-20 Model Input Data

A hydrologic model has been developed for the existing watershed conditions. The TR-20 model, developed by the Soil Conservation Service (1983), was used to simulate the hydrology of the watershed. Model inputs for this watershed were developed based on electronic data and previous approved TR-20 runs provided by the Town of Waterford. The watershed's Geographic Information System has also been programmed to compute curve numbers for each subwatershed. As indicated in Section 2.1, the Jordan Brook watershed was subdivided into 26 subwatersheds, which correspond to locations where estimates of peak flows are desired. In general, these locations include major road crossings and the outlets of critical detention areas such as wetlands and ponds.

TR-20 simulates the hydrologic response of a watershed based on factors such as land use cover type, soil characteristics, rainfall depth, drainage area, watershed topography, channel characteristics, and detention effects. TR-20 model input data for the Jordan Brook watershed were developed from various sources, including published data and electronic GIS data coverages provided by the Town. The following paragraphs summarize the model inputs and data sources for the TR-20 model of the Jordan Brook watershed:

- **Rainfall:** Flood flows were simulated for the 10, 25, and 100 year frequency storms using a 24-hour Type III storm, which is the standard utilized for Connecticut. Rainfall depths for each of these storms were obtained from published rainfall records for New London County, Connecticut (U.S. Department of Commerce, 1961).

- **Watershed Drainage Areas:** Subwatersheds were delineated based upon topographic mapping provided by the Town. Subwatershed drainage areas were calculated using the ArcView® GIS.

- **Curve Numbers:** TR-20 curve numbers, which account for the combined effects of surface depressions, vegetation interception, evapotranspiration, and infiltration, were developed based upon soil mapping provided by the Town and estimates of cover type and hydrologic condition. A customized ArcView® GIS application was developed to calculate area-weighted curve numbers for each of the subwatersheds.

- **Time of Concentration:** Time of concentration, which is the time required for the most upstream point in a watershed to contribute flow at the watershed outlet, is affected by surface roughness, flow patterns, and land slope. Time of concentration was estimated for each watershed based on sheet flow, shallow concentrated flow, and open channel flow paths using topographic and watershed mapping provided by the Town.

- **Critical Detention Structures:** Structures or areas that could provide significant detention and attenuation of watershed flood flows were identified, as shown on Figure 1. Storage-elevation-discharge curves were developed for the identified culvert crossings using survey information provided by the Town, as well as data developed by previous studies (Buck and Buck, 1989; Fugro, 1995). Table 7 summarizes the locations and identified wetland areas corresponding to the critical detention structures.

- **Channel Routing:** TR-20 simulates hydrograph attenuation resulting from channel reach length by performing stream channel routing. Channel reach lengths were estimated from mapping provided by the Town, and routing coefficients were calculated using nomographs developed by the Soil Conservation Service (1983) for a trapezoidal channel.

As indicated in Section 2.1, a portion of the Jordan Brook watershed is located within the City of New London, which was delineated as its own subwatershed. TR-20 model inputs for this subwatershed were developed from standard USGS topographic and Soil Conservation Service soils mapping, using the techniques described above. Backup calculations for this subwatershed are included in Appendix G.

Values of the TR-20 model input parameters (drainage area, curve number, and time of concentration) for each subwatershed are summarized in Table 8. The relationships of subwatersheds, detention structures, and reaches were defined within the model to accurately reflect the existing conditions within the Jordan Brook watershed. A schematic drawing showing these relationships is included in Appendix G. TR-20 model input data, supporting calculations, and model input/output files are also provided in Appendix G.

4.2 TR-20 Model Results

Table 9 summarizes the TR-20 model results at the downstream locations within each subwatershed along Jordan Brook and its major tributaries. The table includes predicted peak flows in cubic feet per second for the 10, 25, and 100-year frequency storms.

Modeled peak flows for the 10-year storm range from approximately 100 cfs in the upstream reaches of Jordan Brook to 1300 cfs near the watershed outlet upstream of Jordan Cove. Modeled peak flows are generally 10 to 20 percent higher and 40 to 90 percent higher for the 25-year and 100-year frequency storms, respectively compared to the 10-year storm, at each location. Peak flows generally increase proceeding downstream in the watershed, except at locations of significant detention where peak flows are attenuated. The highest peak flows along Jordan Brook are predicted to occur downstream of the confluence with the tributary associated with subwatershed 2B. Significant detention provided by the Route 156 crossing and the wetlands in the southernmost subwatersheds result in reduced peak flows south of Route 156.

Peak flows predicted by the model were compared to peak flows calculated from previous TR-20 studies of Jordan Brook (Buck and Buck, 1989), as well as peak flows derived by the Federal Emergency Management Agency using standard flood flow formulas for ungaged streams (FEMA, 1990). Table 10 presents a comparison of 100-year peak flows predicted by each study.

TABLE 7
CRITICAL DETENTION LOCATIONS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Location ID	Location Description	Subwatershed	Wetland Area
D1	I-395	9	JUM1
D2	Route 85	7	JCM2
D3	Cross Road	6	JCM2
D4	I-95	5	JCM1
D5	I-95 Nevins Brook	2AAC	NM2
D6	Fog Plain Road (Nevins Brook)	2AA	NS1
D7	Rope Ferry Road	2	JLM1
D8	Post Road (Unnamed East Brook)	1ABA	EM3
D9	Miner Lane (Unnamed East Brook)	1AB	EM2/ES1
D10	Great Neck Road (Unnamed East Brook)	1A	EM1

TABLE 8
TR-20 MODEL INPUT PARAMETERS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Subwatershed	Area (sq. mi.)	Area (acres)	Curve Number	Time of Concentration (hours)
1	0.165	105.7	74	1.00
1A	0.565	361.3	78	1.55
1AA	0.082	52.4	79	0.35
1AB	0.239	153.0	78	0.54
1ABA	0.474	303.4	78	0.83
2	0.318	203.7	67	0.64
2A	0.616	394.2	72	0.90
2AA	0.756	483.8	72	0.77
2AAA	0.048	30.4	71	0.29
2AAB	0.013	8.2	84	0.24
2AAC	0.301	192.9	80	0.71
2ABA	0.038	24.0	81	0.38
2B	0.430	274.9	73	0.60
3	0.146	93.1	67	0.47
4	0.906	580.0	61	1.01
5	0.708	453.1	72	0.85
5A	0.079	50.3	68	0.45
5AA	0.346	221.5	68	1.18
5AAA	0.040	25.3	76	0.40
6	0.095	61.1	75	0.44
7	0.169	108.4	70	0.58
7A	0.117	75.1	78	0.56
8	0.297	190.0	71	0.73
9	0.262	167.6	75	0.43
10	0.280	179.5	66	1.01
10A	0.209	133.6	69	0.80
New London	0.51	326.4	70	1.26
Subtotal	7.6978	4926.592		
Total	8.2078	5252.992		

TABLE 9
SUMMARY OF COMPUTED EXISTING PEAK FLOWS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Point of Concern (TR20 Section)	Description	TR-20 Peak Flow (cfs)		
		10-Year Storm	25-Year Storm	100-Year Storm
1 (003)	Outlet of subwatershed 10 Jordan Brook	264	342	510
2 (D1)	Outlet of subwatershed 9 (post-detention) Jordan Brook at I-395	122	140	171
3 (007)	Outlet of subwatershed 8 Jordan Brook at Douglas Lane	290	363	511
4 (D2)	Outlet of subwatershed 7 (post-detention) Jordan Brook at Route 85	460	567	792
5 (D3)	Outlet of subwatershed 6 (post-detention) Jordan Brook at Cross Road	193	211	955
6 (D4)	Outlet of subwatershed 5 (post-detention) Jordan Brook at I-95	820	951	1089
7 (023)	Outlet of subwatershed 4 Jordan Brook at Fog Plain Road	1100	1357	1711
8 (025)	Outlet of subwatershed 3 Jordan Brook at Route 1	1140	1416	1805

TABLE 9 (Continued)
SUMMARY OF COMPUTED EXISTING PEAK FLOWS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Point of Concern (TR20 Section)	Description	TR-20 Peak Flow (cfs)		
		10-Year Storm	25-Year Storm	100-Year Storm
9 (026)	Outlet of subwatershed 2B Jordan Brook tributary at Ellen Ward Rd.	380	477	676
10 (027)	Confluence of Jordan Brook and tributary associated with subwatershed 2B	1348	1722	2336
11 (D6)	Outlet of subwatershed 2AA (post-detention) Nevins Brook at Fog Plain Road	362	505	1126
12 (D7)	Outlet of subwatershed 2 (post-detention) Jordan Brook at Route 156	1049	1299	1919
13 (D8)	Outlet of subwatershed 1ABA (post-deten.) Jordan Brook tributary at Route 1	418	460	558
14 (D9)	Outlet of subwatershed 1AB (post-detention) Jordan Brook tributary at Miner Lane	314	366	461
15 (D10)	Outlet of subwatershed 1A (post-detention) Jordan Brook tributary at Great Neck Road	204	242	318
16 (053)	Outlet of subwatershed 1 Jordan Brook at entrance to Jordan Cove	1231	1505	2188

TABLE 10
COMPARISON OF PREDICTED PEAK FLOWS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Location	100-Year Peak Flows (cfs)		
	TR-20 Fuss & O'Neill (1998)	TR-20 Buck & Buck (1989)	FEMA (1990)
Jordan Brook at I-395	171	200	344
Jordan Brook at Douglas Lane	511	503	NA
Jordan Brook at Route 85	792	759	NA
Jordan Brook at Cross Road	955	949	NA
Jordan Brook at I-95	1089	904	588
Jordan Brook at Route 1	1805	1097	695
Jordan Brook at entrance to Jordan Cove	2188	NA	1923

Notes: 1) For comparison purposes only, FEMA reported flows were adjusted by the ratio of watershed areas used in the Fuss & O'Neill (1998) and FEMA (1990) studies.

N/A Flows not reported at these locations.

The results of this study are consistent with the TR-20 model results of Buck and Buck (1989). Peak flows predicted by both studies at most locations are within 15 percent, with the exception of flows in the lower portion of the watershed (i.e., south of Route 1), which may be attributable to differences in watershed delineations in these areas. Peak flows from this study are consistently higher than peak flows estimated by FEMA, which were adjusted by a ratio of drainage areas for comparison purposes. The exception was at the entrance to Jordan Cove where peak flows computed by TR-20 were consistent with FEMA reported peak flows. The discrepancy between the TR-20 and FEMA flows may be due to differences in the methods used in each study (i.e., physical modeling versus statistical regression).

4.3 Stormwater Quantity Control Evaluation

Development alters a watershed's runoff characteristics, causing higher peak flows, increases in runoff volume, and shorter travel times with increasing impervious surfaces. Without appropriate controls, future development could potentially aggravate flooding at critical downstream locations and cause erosion and scour of natural watercourses and wetlands. An evaluation was performed to identify areas in the watershed where additional stormwater detention could be recommended. The approach and outcome of this evaluation are described below.

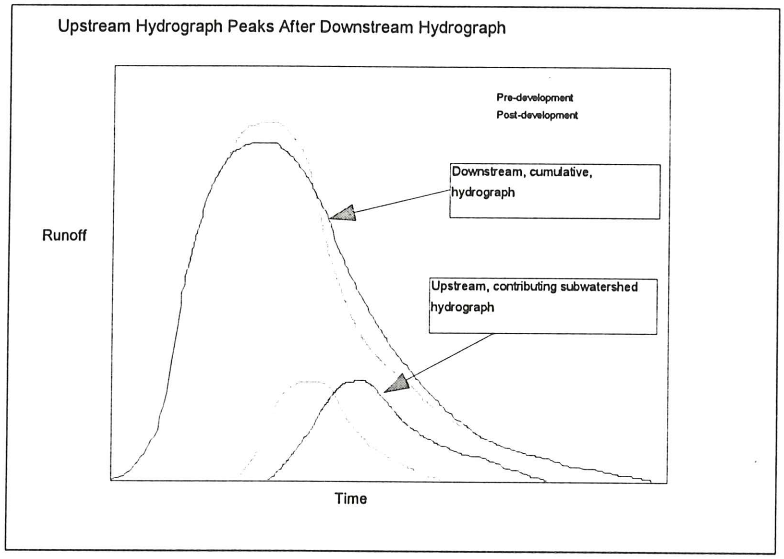
4.3.1 Methodology

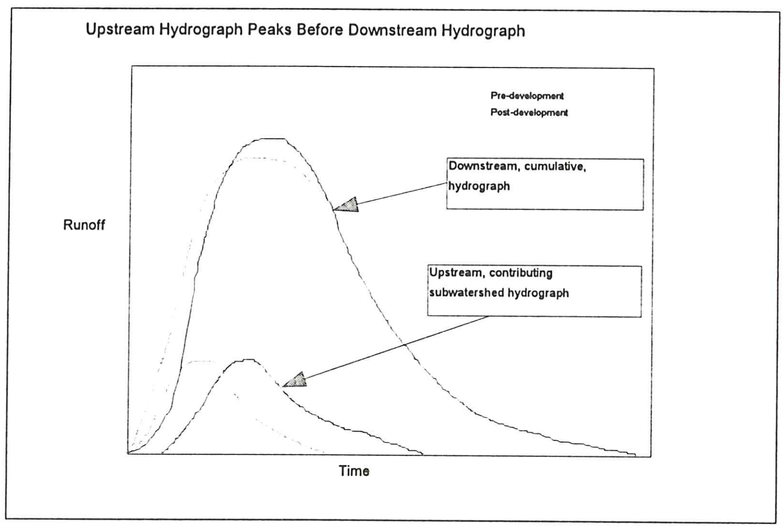
Output from the TR-20 model developed for existing watershed conditions was evaluated in an effort to identify areas where stormwater detention should be provided. The modeled runoff hydrographs at potential points-of concern such as major road crossings and the outlets of existing detention areas (i.e., wetlands and ponds) were examined.

Specifically, the time to peak for upstream contributing subwatersheds was compared to the time to peak for cumulative hydrographs at downstream points-of-concern. Recognizing that future development will cause existing runoff hydrographs to peak earlier (i.e., shift to the left on the time scale), development in subwatersheds with runoff hydrographs that currently peak before the downstream cumulative hydrograph would not tend to increase peak flows at the downstream location. Similarly, development in subwatersheds with runoff hydrographs that currently peak after the downstream cumulative hydrograph would tend to increase peak flows at the downstream location since the upstream flows will reach the downstream location closer to the time of the peak at that location. This relationship is illustrated graphically in Figure 12.

An attempt was made to develop a generalized rule for identifying subwatersheds where detention should be provided based upon a comparison of the hydrograph time to peak for individual subwatersheds and downstream points-of-concern, as described above. However, this comparison is complicated by the attenuation provided by existing detention areas such as wetlands and major road crossings where flooding occurs. Actual runoff travel times are influenced by the amount of detention associated with these areas, which is a function of flow rate and available storage volume. Therefore, a generalized detention rule for future development is not possible due to the influence of existing detention.

FIGURE 12
EFFECT OF DEVELOPMENT ON RUNOFF HYDROGRAPHS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000





4.3.2 Conclusions

Based on our evaluation of existing hydrologic conditions in this watershed, the following has been concluded:

- Evidence of channel scour and erosion was observed in watershed watercourses during the course of this study. In addition, a number of culvert crossings exist in the watershed where high stormwater flows could potentially overtop the culvert crossing and cause flooding.

- In order to not increase channel erosion in watershed watercourses and to not exacerbate existing flooding conditions, future developments should demonstrate that their project would result in no net increase in peak flows at watershed points-of-concern. This may require controls that attenuate peak flows such as detention basins.

- Detention should not be automatically required for all developments since retaining peak flows in some subwatersheds could actually increase peak flows at downstream points-of-concern. Stormwater detention requirements should be determined on a case-by-case basis using the watershed's TR-20 model for proposed developments that have potential for downstream impacts. Developments that could be exempted from this evaluation are single family residences, subdivisions with four or less parcels and no new roads, or any other project that generates less than 5,000 square feet of new impervious surfaces that is not infiltrated. These developments would be expected to generate less than 1 cubic feet per second of peak stormwater flows during significant storm events.

- The volume of stormwater runoff may also need to be attenuated depending on the size and location of the site. Increased runoff volumes will prolong peak velocities in watercourses and consume flood storage capacity that is needed to attenuate existing peak flows.

5.0 STORMWATER QUALITY EVALUATION

5.1 Future Watershed Land Use

Future land use in the Jordan Brook watershed is based on zoning classifications and mapping associated with the "Town of Waterford Zoning Regulations" (1993), which regulates future development in the Town of Waterford. Figure 13 depicts the zoning classifications within the watershed as defined by the Town zoning regulations. Zoning classifications for parcels within the Jordan Brook watershed are summarized in Table 11.

The central and northern portions of the Jordan Brook watershed are the least developed areas in the watershed and are subject to the most significant changes in future land uses according to the Town's zoning classifications. Largely forested areas north and south of Interstate-395 are zoned for residential development, which includes single and multi-family residences,

Zoning Classifications
Jordan Brook Watershed Management Study
Town of Waterford

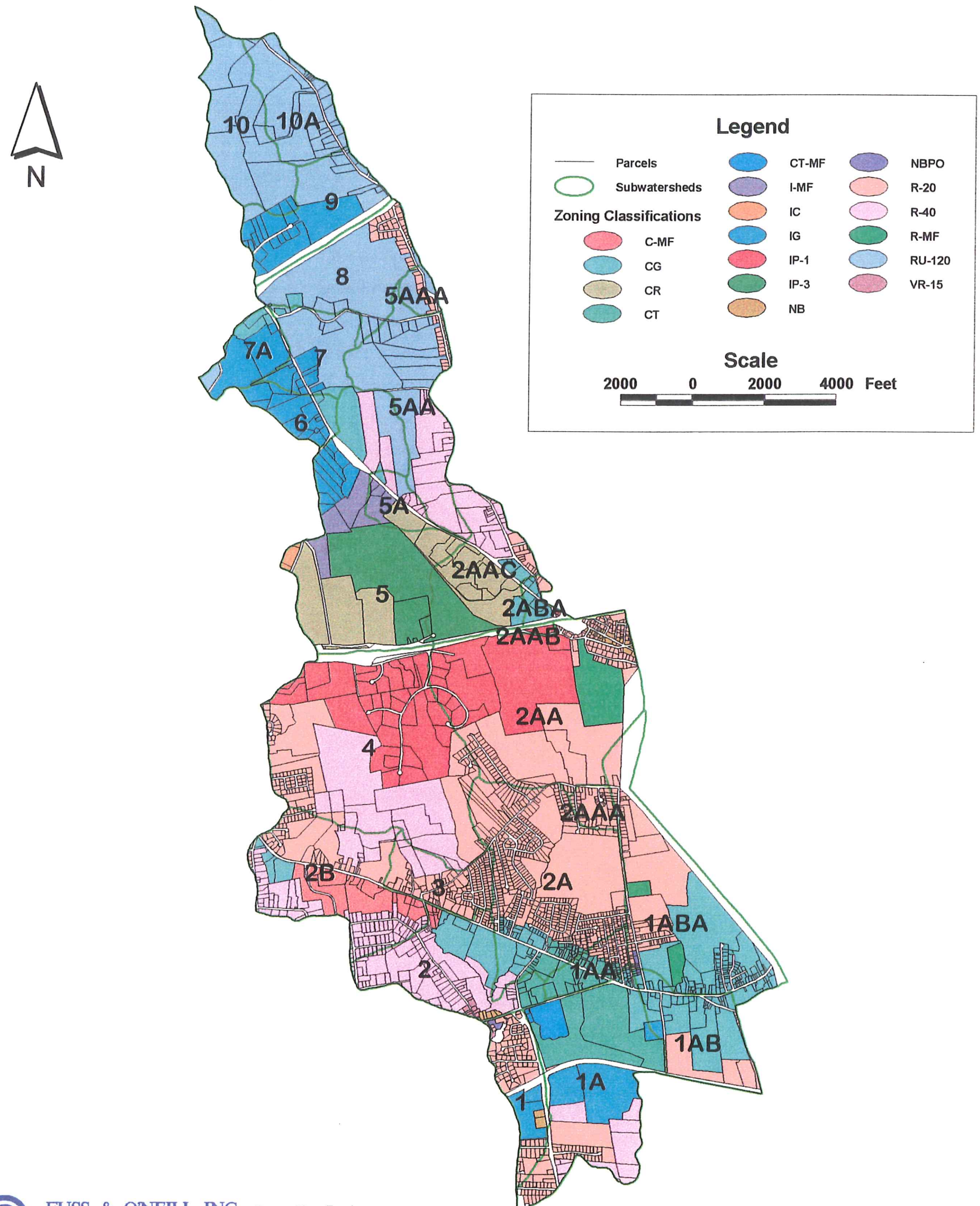


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FIGURE **13**

TABLE 11
WATERFORD ZONING CLASSIFICATIONS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Zoning District	Description
C-MF	Commercial Multi-Family
CG	General Commercial
CR	Regional Commercial
CT	Civic Triangle
CT-MF	Civic Triangle Multi-Family
I-MF	Industrial Multi-Family
IC	Industrial Commercial
IG	General Industrial
IP-1	General Industrial Park
IP-3	Special Aquifer Industrial Park
NB	Neighborhood Business
NBPO	Neighborhood Business Professional Office
R-20	Medium Density Residential
R-40	Low Density Residential
R-MF	Residential Multi-Family
RU-120	Rural Residential
VR-15	Village Residential

farming, and certain public facilities such as libraries, schools, parks, and playgrounds. Undeveloped parcels located south of Interstate-395 along the Route 85 corridor are zoned for commercial, industrial, and residential development. A Special Aquifer Industrial Park District located immediately north of Interstate-95 consists of several large parcels currently occupied by single family residences. Vacant and open space parcels immediately south of Interstate-95 are located within an Industrial Park zoning district. Undeveloped parcels scattered throughout the lower portion of the watershed are zoned for residential and commercial development. However, much of the lower Jordan Brook watershed is nearly fully developed and, therefore, land uses in the lower portions of the watershed are not expected to change significantly in the future.

5.2 Land Use Pollutants-of-Concern

Potential pollutants-of-concern associated with existing and potential future land uses within the watershed were identified for the stormwater quality evaluation. These pollutants were selected for the evaluation based upon the following factors:

1) their levels in stormwater are more heavily influenced by land use rather than natural sources, and

2) quantitative, land use-based loading factors for these pollutants are available from literature sources.

The land use pollutants-of-concern selected for the stormwater quality evaluation include total suspended solids (TSS), biochemical oxygen demand (BOD), nitrogen, phosphorous, copper, lead, and zinc. The following paragraphs summarize sources of these pollutants in stormwater runoff.

In general, there are two primary sources of suspended solids in stormwater runoff. Soil erosion is a potentially significant contributor of solids, especially at sites with unstabilized soils and inadequate erosion protection. To a lesser degree, some soil erosion also occurs on stabilized land during more severe storm events. In addition to soil erosion, stormwater runoff also sweeps other solids which accumulate on the land surface. Solids which are "washed off" include pet droppings, vegetative matter (i.e. leaves, grass clippings), litter, street sand, solids from atmospheric deposition and other debris.

Biochemical oxygen demand is a measure of how much oxygen is consumed by bacteria while they decompose organic matter in water and is therefore a measurement of the strength of organic matter in water (i.e., pollution). Sources of BOD in stormwater include organic material such as leaves, lawn clippings, sewage, manure, and food processing wastewaters.

Nitrogen and phosphorous are algal nutrients that are needed for algal growth. Excessive amounts of these nutrients leads to algal blooms and eutrophication in surface water impoundments. Phosphorous is typically the limiting nutrient in freshwater systems and nitrogen is typically the limiting nutrient in marine systems. The primary sources for these nutrients include lawn and crop fertilizers, sewage, manure, detergents and atmospheric deposition.

The primary source of metals in stormwater runoff is exposure and dissolution of metals during precipitation. "Exposed" sources include galvanized pipes, roof gutters, downspouts, roofing materials, outdoor metal plating, paints, wood preservatives, catalytic converters, brake linings, and tires. Rainfall, which is acidic in the northeastern United States, mobilizes trace metals from surfaces. Atmospheric deposition is also a documented source of metals.

5.3 Pollutant Loading Evaluation

Stormwater pollutant loadings to surface water resources within the watershed were evaluated using a GIS pollutant loading model. The GIS pollutant loading model was applied to existing and future watershed conditions in order to evaluate potential stormwater impacts of future development. A description of the model and the results of the pollutant loading evaluation are presented below.

5.3.1 Model Description

The GIS pollutant loading model, which was developed for the ArcView® GIS system, calculates annual mass loadings of pollutants-of-concern for each of the Jordan Brook subwatersheds. The model integrates GIS database coverages of parcels, land use, subwatershed boundaries, and land use-based pollutant loading and reduction factors.

The following pollutants-of-concern are included in the GIS pollutant loading model:

- Biochemical Oxygen Demand (BOD)
- Total Suspended Solids (TSS)
- Total Nitrogen
- Total Phosphorous
- Copper, Lead, Zinc

Annual stormwater pollutant loading factors were selected based on a literature review of non-point source pollutant loadings associated with various land uses. Pollutant loading factors were assigned by matching the Town land use with the most closely related land use reported in the literature. The model includes a range of loading factors for each pollutant-of-concern, which reflects the range of values reported in the literature as well as variability in watershed conditions that affect stormwater quality. Table 12 lists the pollutant loading factors that were selected for the watershed land uses. Literature sources of the loading factor values are provided as a footnote to Table 12. Loading factors are expressed in units of mass per area per year (kilograms/hectare/year).

Stormwater pollutant loading reduction factors were developed to account for existing treatment measures or practices within the watershed that reduce pollutant loadings. Street sweeping and major structural stormwater controls for specific large developments were considered in

TABLE 12
LAND USE POLLUTANT LOADING FACTORS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Land Use	Pollutant Loading Factors (kg/ha-yr)													
	BOD		TSS		Nitrogen		Phosphorous		Copper		Lead		Zinc	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Cemetery	14.00	36.00	157.00	600.00	5.00	12.00	0.50	2.20	0.03	0.15	0.06	0.27	0.10	0.57
Commercial Hospitality	40.00	98.00	800.00	1300.00	5.00	16.30	1.20	2.20	0.07	0.35	0.30	1.00	1.63	3.24
Commercial Office	40.00	98.00	800.00	1300.00	5.00	16.30	1.20	2.20	0.07	0.35	0.30	1.00	1.63	3.24
Commercial Retail	40.00	98.00	800.00	1300.00	5.00	16.30	1.20	2.20	0.07	0.35	0.30	1.00	1.63	3.24
Highway	90.00	170.00	120.00	6300.00	17.00	25.00	1.40	2.40	2.80	5.60	1.10	1.40	4.10	5.10
Industrial Manufacturing	10.00	17.70	400.00	2000.00	3.00	14.00	0.35	6.00	0.29	1.30	0.37	0.50	0.98	12.00
Industrial Warehouse	10.00	17.70	400.00	2000.00	3.00	14.00	0.35	6.00	0.29	1.30	0.27	0.50	0.98	12.00
Land Trust/Public Easement	5.00	40.00	2.00	900.00	1.00	8.00	0.01	0.70	0.02	0.03	0.01	0.05	0.01	0.03
Mixed Use	10.00	17.70	400.00	2000.00	3.00	14.00	0.35	6.00	0.29	1.30	0.27	0.50	0.98	12.00
Mobile Home	30.00	90.00	300.00	1750.00	6.70	11.20	0.50	3.40	0.05	0.15	0.14	0.87	0.30	0.73
Multi Family	30.00	90.00	300.00	1750.00	6.70	11.20	0.50	3.40	0.05	0.15	0.14	0.87	0.30	0.73
PA-490	5.00	40.00	2.00	900.00	1.00	8.00	0.01	0.70	0.02	0.03	0.01	0.05	0.01	0.03
Private Facilities	30.00	90.00	300.00	1750.00	6.70	11.20	0.50	3.40	0.05	0.15	0.14	0.87	0.30	0.73
Private Open Space	5.00	40.00	2.00	900.00	1.00	8.00	0.01	0.70	0.02	0.03	0.01	0.05	0.01	0.03
Public Facilities	10.00	17.70	400.00	2000.00	3.00	14.00	0.35	6.00	0.29	1.30	0.27	0.50	0.98	12.00
Public Land	5.00	40.00	2.00	900.00	1.00	8.00	0.01	0.70	0.02	0.03	0.01	0.05	0.01	0.03
Public Utility	10.00	17.70	400.00	2000.00	3.00	14.00	0.35	6.00	0.29	1.30	0.27	0.50	0.98	12.00
Mall	76.00	186.00	800.00	1300.00	29.00	31.00	2.0	2.20	0.09	0.66	1.30	1.40	3.10	3.30
Single Family	14.00	36.00	157.00	600.00	5.00	12.00	0.50	2.20	0.03	0.15	0.06	0.27	0.10	0.57
Utility Transmission	5.00	40.00	2.00	900.00	1.00	8.00	0.01	0.70	0.02	0.03	0.01	0.05	0.01	0.03
Vacant	5.00	40.00	2.00	900.00	1.00	8.00	0.01	0.70	0.02	0.03	0.01	0.05	0.01	0.03
Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 12 (Continued)
LAND USE POLLUTANT LOADING FACTORS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

SOURCES:

1. Novotny, V., Unit Pollutant Loads - Their Fit in Abatement Strategies, Water Environment & Technology, January, 1992.
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determining appropriate pollutant loading reduction factors for each of the watershed land uses. It should be noted that controls associated with smaller developments were not considered in this model as those controls have not been widely implemented through the watershed and thereby would not significantly change the watershed loadings that would be computed by this model.

Pollutant removal efficiencies associated with street sweeping were assigned based on a range of values reported in a street sweeping study prepared by the Southeastern Wisconsin Regional Planning Commission (dated 1991). The Waterford Department of Public Works sweeps public roads and municipal parking lots in the watershed twice per year. Therefore, pollutant removal due to street sweeping was considered for all "developed" land uses. Additionally, the major commercial developments in the watershed (i.e., Crystal Mall, Home Depot, Wal-Mart, etc.) are equipped with structural stormwater controls such as detention ponds and constructed wetlands, which are designed to provide significant removal of stormwater pollutants for these large developments. The pollutant removal effectiveness of these controls was considered for parcels having a "Mall" land use designation. Reduction factors for these parcels were determined based on literature-based pollutant removal efficiencies for detention basins. Table 13 summarizes the pollutant reduction factors used in the model.

The GIS pollutant loading model calculates stormwater pollutant loadings based on parcel area, land use pollutant loading rates, and pollutant reduction factors. It should be noted that pollutant loadings are the total mass of pollutants generated from an area and are not equivalent to pollutant concentrations which are a measure of the quantity of pollutants in a fixed volume of water. Stormwater pollutant loadings for individual parcels within the watershed are calculated by the following equation:

$$PL = Area \times [(1-RF_{max})(LF_{min}) + (1-RF_{min})(LF_{max})]/2$$

where:

PL	=	average pollutant load in kilograms per year (kg/yr)
Area	=	parcel area in hectares (ha)
$LF_{min,max}$	=	minimum and maximum pollutant loading rates in kg per hectare per year (kg/ha-yr)
$RF_{min,max}$	=	minimum and maximum pollutant reduction factors (expressed as decimal values)

The model calculates average pollutant loadings for each land parcel based on a range of pollutant loading rates and reduction factors as shown in the above equation. Loadings from individual parcels within a subwatershed are summed to obtain a pollutant loading value for the entire subwatershed.

TABLE 13
LAND USE POLLUTANT REDUCTION FACTORS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Land Use	Pollutant Reduction Factors (decimal values)													
	BOD		TSS		Nitrogen		Phosphorous		Copper		Lead		Zinc	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Cemetery	0.000	0.000	0.029	0.029	0.015	0.015	0.022	0.022	0.047	0.047	0.047	0.047	0.047	0.047
Commercial Hospitality	0.000	0.000	0.029	0.029	0.015	0.015	0.022	0.022	0.047	0.047	0.047	0.047	0.047	0.047
Commercial Office	0.000	0.000	0.029	0.029	0.015	0.015	0.022	0.022	0.047	0.047	0.047	0.047	0.047	0.047
Commercial Retail	0.000	0.000	0.029	0.029	0.015	0.015	0.022	0.022	0.047	0.047	0.047	0.047	0.047	0.047
Highway	0.000	0.000	0.029	0.029	0.015	0.015	0.022	0.022	0.047	0.047	0.047	0.047	0.047	0.047
Industrial Manufacturing	0.000	0.000	0.029	0.029	0.015	0.015	0.022	0.022	0.047	0.047	0.047	0.047	0.047	0.047
Industrial Warehouse	0.000	0.000	0.029	0.029	0.015	0.015	0.022	0.022	0.047	0.047	0.047	0.047	0.047	0.047
Land Trust/Public Easement	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mixed Use	0.000	0.000	0.029	0.029	0.015	0.015	0.022	0.022	0.047	0.047	0.047	0.047	0.047	0.047
Mobile Home	0.000	0.000	0.029	0.029	0.015	0.015	0.022	0.022	0.047	0.047	0.047	0.047	0.047	0.047
Multi Family	0.000	0.000	0.029	0.029	0.015	0.015	0.022	0.022	0.047	0.047	0.047	0.047	0.047	0.047
PA-490	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Private Facilities	0.000	0.000	0.029	0.029	0.015	0.015	0.022	0.022	0.047	0.047	0.047	0.047	0.047	0.047
Private Open Space	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Public Facilities	0.000	0.000	0.029	0.029	0.015	0.015	0.022	0.022	0.047	0.047	0.047	0.047	0.047	0.047
Public Land	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Public Utility	0.000	0.000	0.029	0.029	0.015	0.015	0.022	0.022	0.047	0.047	0.047	0.047	0.047	0.047
Mall	0.000	0.000	0.709	0.903	0.212	0.606	0.120	0.609	0.238	0.619	0.238	0.619	0.238	0.619
Single Family	0.000	0.000	0.029	0.029	0.015	0.015	0.022	0.022	0.047	0.047	0.047	0.047	0.047	0.047
Utility Transmission	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Vacant	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Water	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

NOTES:

Pollutant Removal Efficiencies:

Street Sweeping: BOD = 0% TSS = 2.9% Nitrogen = 1.5% Phosphorous = 2.2% Metals = 4.7%

Detention Basin: BOD = 0% TSS = 70-90% Nitrogen = 20-60% Phosphorous = 10-60% Metals = 20-60%

Overall pollutant removal efficiency for landuses having both street sweeping and detention basins are calculated assuming treatment in series.

SOURCES:

1. U.S. EPA, Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters, USEPA, Office of Water, 840-B-92-002, 1993.
2. ASCE, Design of Urban Runoff Quality Controls, Proceedings of an Engineering Foundation Conference on Current Practice and Design Criteria for Urban Quality Control, July 10-15, 1988.
3. Design of Stormwater Wetland Systems, Anacostia Restoration Team, Department of Environmental Programs, Metropolitan Washington Council of Governments.
4. Current Assessment of Urban Best Management Practices, Metropolitan Washington Council of Governments.
5. Schueler, T.R., Controlling Urban Runoff, July, 1987.
6. Costs of Urban Nonpoint Source Water Pollution Control Measures, Tech. Report 31, Southeastern Wisconsin Regional Planning Commission, June, 1991.

5.3.2 Current Pollutant Loadings

A GIS pollutant loading model was developed for existing watershed conditions. The results of the pollutant loading evaluation are summarized in Table 14, which includes computed annual pollutant loadings (kg/yr) in each of the Jordan Brook subwatersheds. As shown, estimated pollutant loadings generally correlate with the level of development in the watershed with the highest modeled pollutant loadings occur in areas of the watershed with substantial commercial, industrial, and residential development (i.e., subwatersheds 1A, 1ABA, 2A, 2AA, 4, and 5). In general, larger subwatersheds also contribute higher pollutant loadings, as the current pollutant loading values were not converted to areal loading rates by dividing by subwatershed area.

While the modeled pollutant loadings represent the impacts of existing land use conditions in the watershed, it should be noted that the loadings are intended to be used for comparative purposes and are not appropriate for estimating contaminant concentrations or comparison to water quality monitoring data at individual sampling locations.

5.3.3 Future Pollutant Loadings

The GIS pollutant loading model was applied to "full-build" conditions in the watershed to evaluate the worst-case water quality impacts of future development. The goal of this exercise was to identify those subwatersheds which have the potential for significant water quality degradation as a result of future development by comparing pollutant loadings under existing and future conditions.

Full-build conditions were modeled based upon the Town zoning map and zoning classifications, which represent the potential maximum level of development allowed by the Town. Land uses were assigned to each of the Town's zoning classifications, as shown in Table 15. Existing undeveloped parcels of land not designated as open space were then changed to reflect the land uses associated with the parcels' zoning. For example, the land use designation of an existing vacant parcel which is zoned for medium density residential development (R-20) was changed from "vacant" to "single family", with corresponding changes in pollutant loading and reduction factors. The land uses of undeveloped parcels containing wetlands, steep slopes (>15%), or that are currently public land or designated as PA-490 land were held fixed under the full-build scenarios to accurately reflect future development in the watershed. The GIS pollutant loading model was run with the updated pollutant loading and reduction factors associated with the "future" land uses, resulting in annual pollutant loadings representative of full-build conditions.

Table 16 summarizes modeled pollutant loadings under full-build conditions. The percent change in future pollutant loadings as compared to current pollutant loadings is shown in bold text. The results indicate that loadings of all of the parameters of concern under a full-build scenario will increase on average across the watershed as compared to existing conditions. On average, loadings of phosphorous and metals are predicted to experience the largest percentage increase, greater than 30 percent, whereas nitrogen, BOD, and TSS loadings are predicted to

TABLE 14
SUMMARY OF CURRENT POLLUTANT LOADINGS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

		Annual Pollutant Loadings (kg/yr)						
Subwatershed	Area (acres)	BOD	TSS	Nitrogen	Phosphorous	Copper	Lead	Zinc
10	183	1700	34000	340	30	0	0	10
10A	131	1200	23000	280	30	0	0	10
9	165	2200	53000	450	60	40	10	110
8	186	2400	49000	470	40	30	10	40
5AAA	23	200	4100	50	10	0	0	0
5AA	223	2100	40000	450	40	0	0	10
7	105	1000	20000	210	20	0	0	20
7A	72	700	19000	170	30	10	10	80
6	58	500	15000	130	20	10	0	60
5	443	8100	89000	1360	120	30	40	150
5A	48	500	8900	100	10	0	0	0
2AAC	183	5000	35000	780	70	20	30	90
2ABA	21	600	7700	90	10	10	0	10
2AA	480	5100	110000	1140	140	30	20	140
2AAB	7	200	5600	40	0	10	0	10
4	568	6200	130000	1220	110	40	20	70
1ABA	299	3900	72000	830	130	20	20	230
2A	358	3900	70000	950	130	10	20	110
2AAA	27	300	4500	70	10	0	0	0
2B	258	3500	60000	710	110	10	20	60
3	84	800	15000	210	30	0	0	10
2	199	2000	38000	500	70	10	10	60
1AA	45	500	12000	140	30	0	0	60
1AB	143	2400	39000	430	60	10	20	100
1A	336	3900	100000	920	190	30	30	460
1	86	800	17000	220	30	0	0	50

TABLE 15
ZONING-BASED LAND USES
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Zoning District	Description	Land Use Classifications
C-MF	Commercial Multi-Family	Multi-Family
CG	General Commercial	Commercial Office
CR	Regional Commercial	Mall
CT	Civic Triangle	Commercial Office
CT-MF	Civic Triangle Multi-Family	Multi-Family
I-MF	Industrial Multi-Family	Multi-Family
IC	Industrial Commercial	Industrial Manufacturing
IG	General Industrial	Industrial Manufacturing
IP-1	General Industrial Park	Industrial Manufacturing
IP-3	Special Aquifer Industrial Park	Industrial Manufacturing
NB	Neighborhood Business	Commercial Retail
NBPO	Neighborhood Business Professional Office	Commercial Office
R-20	Medium Density Residential	Single Family
R-40	Low Density Residential	Single Family
R-MF	Residential Multi-Family	Multi-Family
RU-120	Rural Residential	Single Family
OS	Open Space	Private Open Space
VR-15	Village Residential	Multi-Family

TABLE 16
SUMMARY OF FUTURE POLLUTANT LOADINGS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Subwatershed	Area (ha)	Annual Pollutant Loadings (kg/yr) / Percent Change from Current Loadings						
		BOD	TSS	Nitrogen	Phosphorous	Copper	Lead	Zinc
10	74	kr 1,757 5.7%	kr 36,434 7.1%	kr 365 8.3%	kr 34 21.4%	kr 3 50.0%	kr 3 50.0%	kr 21 90.9%
10A	53	kr 1,302 6.4%	kr 23,475 2.0%	kr 326 15.2%	kr 39 30.0%	kr 3 50.0%	kr 4 33.3%	kr 12 71.4%
9	67	kr 2,078 -6.3%	kr 68,941 29.5%	kr 561 23.6%	kr 119 116.4%	kr 51 45.7%	kr 21 61.5%	kr 358 222.5%
8	75	kr 2,356 0.1%	kr 49,011 -0.1%	kr 472 0.4%	kr 45 2.3%	kr 26 0.0%	kr 10 0.0%	kr 37 2.8%
5AAA	9	kr 216 0.0%	kr 4,043 -2.4%	kr 50 6.4%	kr 5 0.0%	kr 0 N/A	kr 1 N/A	kr 1 0.0%
5AA	90	kr 2,153 4.4%	kr 38,433 -3.8%	kr 548 23.1%	kr 66 57.1%	kr 4 33.3%	kr 7 75.0%	kr 21 162.5%
7	42	kr 979 2.1%	kr 23,613 21.0%	kr 233 9.9%	kr 32 45.5%	kr 5 150.0%	kr 3 50.0%	kr 60 275.0%
7A	29	kr 712 -0.4%	kr 16,703 -12.6%	kr 156 -8.8%	kr 22 -29.0%	kr 4 -33.3%	kr 3 -40.0%	kr 46 -43.9%
6	24	kr 452 -10.7%	kr 19,231 30.3%	kr 155 18.3%	kr 41 70.8%	kr 9 80.0%	kr 5 66.7%	kr 136 112.5%
5	179	kr 9,198 13.1%	kr 88,839 0.2%	kr 1,548 13.6%	kr 155 25.0%	kr 38 11.8%	kr 48 26.3%	kr 183 25.3%
5A	19	kr 1,125 124.1%	kr 8,789 -1.1%	kr 190 90.0%	kr 21 133.3%	kr 2 100.0%	kr 7 600.0%	kr 14 366.7%
2AAC	74	kr 5,072 2.1%	kr 36,729 5.9%	kr 827 6.4%	kr 82 13.9%	kr 19 0.0%	kr 29 3.6%	kr 97 6.6%
2ABA	9	kr 539 -9.9%	kr 7,814 1.0%	kr 90 -4.3%	kr 9 0.0%	kr 6 0.0%	kr 4 0.0%	kr 13 0.0%
2AA	194	kr 5,036 -1.2%	kr 123,008 15.7%	kr 1,375 20.8%	kr 236 74.8%	kr 55 61.8%	kr 33 57.1%	kr 444 212.7%
2AAB	3	kr 228 -3.8%	kr 6,223 12.0%	kr 43 10.3%	kr 6 100.0%	kr 7 16.7%	kr 2 0.0%	kr 19 137.5%
4	230	kr 5,719 -7.6%	kr 171,102 36.7%	kr 1,676 37.5%	kr 351 207.9%	kr 88 151.4%	kr 49 145.0%	kr 888 1187.0%
1ABA	121	kr 4,216 7.5%	kr 74,404 4.0%	kr 895 8.2%	kr 142 11.8%	kr 20 5.3%	kr 28 21.7%	kr 252 8.6%
2A	145	kr 4,145 7.3%	kr 72,312 3.7%	kr 1,035 8.9%	kr 151 13.5%	kr 13 8.3%	kr 23 21.1%	kr 124 18.1%
2AAA	11	kr 262 1.2%	kr 4,357 -2.5%	kr 76 8.6%	kr 11 22.2%	kr 1 0.0%	kr 1 0.0%	kr 4 33.3%
2B	105	kr 3,049 -12.8%	kr 53,632 -10.6%	kr 665 -6.2%	kr 91 -13.3%	kr 6 -14.3%	kr 15 -25.0%	kr 44 -26.7%
3	34	kr 811 0.9%	kr 14,456 -1.7%	kr 218 5.8%	kr 29 11.5%	kr 2 0.0%	kr 3 0.0%	kr 16 14.3%
2	81	kr 2,283 15.4%	kr 40,162 5.9%	kr 583 17.5%	kr 89 30.9%	kr 8 33.3%	kr 14 75.0%	kr 80 42.9%
1AA	18	kr 691 35.8%	kr 14,096 18.6%	kr 161 17.5%	kr 32 23.1%	kr 5 25.0%	kr 6 50.0%	kr 67 21.8%
1AB	58	kr 2,483 1.5%	kr 39,164 -0.2%	kr 446 4.7%	kr 63 8.6%	kr 8 0.0%	kr 17 6.3%	kr 102 4.1%
1A	136	kr 3,934 0.3%	kr 96,577 -2.6%	kr 1,002 8.4%	kr 206 10.8%	kr 34 3.0%	kr 33 6.5%	kr 463 1.3%
1	35	kr 825 2.5%	kr 16,179 -4.0%	kr 252 14.0%	kr 42 23.5%	kr 5 25.0%	kr 5 25.0%	kr 50 8.7%
Average		6.8%	5.8%	13.8%	38.9%	32.1%	50.3%	113.7%

Notes:
N/A - not applicable due to zero loading under current conditions

increase by less than 15 percent under a full-build development scenario. Negative percent change values in Table 16 suggest that pollutant loadings will decrease in a few subwatersheds under full-build conditions. These negative values are the result of future, zoning-based land uses which have slightly lower pollutant loading values than existing land uses. These loadings are not from existing non-conforming uses but rather from existing undeveloped land that has greater potential to contribute solids and organic matter than the zoned land uses. In actuality, pollutant loadings under full-build conditions in these watersheds will be similar to current pollutant loadings.

Several subwatersheds stand out as major potential future contributors of pollutant loadings. Subwatersheds 4, 5A, 6, 7, and 9 showed the largest percent increases in future loadings of nearly all of the modeled pollutants. Other subwatersheds, including 1AA, 2, 2AA, 2AAB, 5, and 5AA resulted in significant percent increases in future loadings of some, although fewer, pollutants. These areas are located within the central and northern portions of the Jordan Brook watershed, where the potential for development of currently undeveloped land or increased intensity of development is the highest.

The modeled pollutant loadings for each subwatershed were converted to unit area pollutant loadings (kg/acre-yr) by dividing by the area of each subwatershed. Unit area pollutant loadings represent average pollutant loading rates per unit area of the subwatershed, thereby allowing direct comparison of pollutant loadings from subwatersheds of different sizes. Predicted future unit area pollutant loadings for each subwatershed are summarized in Table 17. As shown in the table, subwatersheds 2AAB, 2ABA, 2AAC, 6, and 9 have the highest future areal pollutant loading rates for most of the pollutants considered. These subwatersheds are relatively small in size and, consistent with the pollutant mass loadings, are located in the central and northern portions of the Jordan Brook watershed which have a high potential for development of currently undeveloped land or increased intensity of development.

5.4 Conclusions

Based on our evaluation of current water quality and modeled pollutant loadings in the Jordan Brook watershed, the following conclusions have been made.

- While current water quality in the watershed generally meets Class A (fishable, drinkable) standards with the exception of total coliform, water quality in the watershed has been impacted by existing development.

- Future development in the watershed with no controls could increase current pollutant loadings by more than 100% for zinc and between 30 and 50% for phosphorous, copper and lead. Nitrogen, solids and organic loadings are also projected to increase by between 5 and 15%. Copper, lead and zinc are all metals that can be toxic to aquatic life at certain concentrations in aqueous form. Phosphorous is a limiting nutrient for algal growth in surface water impoundments.

TABLE 17
SUMMARY OF FUTURE UNIT AREA LOADINGS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Subwatershed	Area (acres)	Annual Unit Area Pollutant Loadings (kg/acre-yr)						
		BOD	TSS	Nitrogen	Phosphorous	Copper	Lead	Zinc
10	183	10	200	2.0	0.2	0.02	0.02	0.11
10A	131	10	180	2.5	0.3	0.02	0.03	0.09
9	165	13	420	3.4	0.7	0.31	0.13	2.17
8	186	13	260	2.5	0.2	0.14	0.05	0.20
5AAA	23	9	180	2.2	0.2	0.00	0.04	0.04
5AA	223	10	170	2.5	0.3	0.02	0.03	0.09
7	105	10	230	2.2	0.3	0.05	0.03	0.57
7A	72	10	230	2.2	0.3	0.06	0.04	0.64
6	58	9	330	2.7	0.7	0.15	0.09	2.33
5	443	20	200	3.5	0.3	0.09	0.11	0.41
5A	48	23	180	4.0	0.4	0.04	0.15	0.29
2AAC	183	28	200	4.5	0.4	0.10	0.16	0.53
2ABA	21	24	370	4.2	0.4	0.28	0.19	0.61
2AA	480	10	260	2.9	0.5	0.11	0.07	0.93
2AAB	7	29	890	6.1	0.9	1.00	0.29	2.72
4	568	10	300	3.0	0.6	0.16	0.09	1.56
1ABA	299	14	250	3.0	0.5	0.07	0.09	0.84
2A	358	11	200	2.9	0.4	0.04	0.06	0.35
2AAA	27	11	160	2.8	0.4	0.04	0.04	0.15
2B	258	12	210	2.6	0.4	0.02	0.06	0.17
3	84	10	170	2.6	0.3	0.02	0.04	0.19
2	199	12	200	2.9	0.4	0.04	0.07	0.40
1AA	45	15	310	3.5	0.7	0.11	0.13	1.47
1AB	143	17	270	3.1	0.4	0.06	0.12	0.71
1A	336	12	290	3.0	0.6	0.10	0.10	1.38
1	86	9	190	2.9	0.5	0.06	0.06	0.58

- Appropriate controls should be implemented as part of new developments to control water quality impacts from stormwater runoff. Some developments that have little potential to impact water quality should be exempt from applying water quality controls. These developments include single family homes and residential subdivisions with less than four lots and no new roads.

6.0 OTHER WATERSHED ISSUES

6.1 Aquifer Protection

A significant portion of the Jordan Brook watershed is underlain by stratified drift deposits which are potential groundwater aquifer areas. A large percentage of these aquifer areas are located in areas of potential future development according to current zoning regulations. Land use activities within groundwater aquifer areas should be regulated in order to minimize the potential for contamination of future groundwater supplies.

6.1.1 Land Uses of Concern

Potential groundwater aquifer areas in the watershed were identified based upon surficial materials mapping (Figure 3), as described in Section 2.4. Zoning-based land uses within these areas were reviewed to identify those uses that have significant potential to impact aquifer water quality. These "land uses of concern" (Table 18) were selected consistent with the State of Connecticut's draft aquifer protection regulations (C.G.S. 22a-354i-1 through 10), which rank regulated activities or land uses based on relative severity of impacts to groundwater quality. A copy of the draft regulations is provided in Appendix K. In general, regulated activities include businesses that use hazardous materials which are RCRA hazardous wastes and hazardous materials under CERCLA, as well as other substances which have significant potential to impact groundwater supplies as a result of outdoor exposure. It should be noted that the draft regulations have been developed to apply to well fields that supply water to water distribution systems serving more than 1000 people.

The land uses listed in Table 18 were selected as follows:

1) Land uses listed in the Town of Waterford zoning classifications which are located within potential aquifer areas (defined according to surficial deposits in the watershed) were identified.

2) The identified land uses which are listed as "land uses of concern" in the State of Connecticut draft aquifer protection regulations were included in Table 18.

6.1.2 Groundwater Recharge

Aquifer yield is dependent on the volume of water that infiltrates into the aquifer. In addition, groundwater recharge is critical to maintain stream base flows during dry periods which maintain aquatic life as well as maintain the moisture levels of wetland areas.

TABLE 18
AQUIFER PROTECTION AREAS - LAND USES OF CONCERN
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Land Use/Activity of Concern	
Cemetery, Crematory, Embalming Services	Construction Equipment Rental
Fossil Fuel Power Plants and Other Utility Plants	Chemical Manufacturing
Municipal, State, or Federal Garages	Primary Metal Industry and Electronics Manufacturing
Company Fleet Maintenance Garages and Storage Facilities	Photo Finishing Labs, Furniture Stripping/Finishing
Trucking and Motor Freight Terminals	Recycling Facilities (waste oil, spent antifreeze, spent lead-acid batteries)
Gas Stations, Vehicle Service Stations	Solid Waste Facilities (as regulated under CGS 22a-207, 208a, & 260)
Auto Body/Paint Shops	Rubber and Plastic Manufacturing
New and Used Car Dealers	Production of Stone, Clay, or Glass Products
Boat, Recreational Vehicle, and Motorcycle Dealers	Textile Mills, Tanneries, or Apparel Production Facilities
Boat Yards (storage, repair, or servicing)	Lumber and Wood Production
Laboratories (biological, chemical, clinical, educational, R&D)	Pulp and Paper Manufacturing
Temporary Outdoor Storage Facilities	Printing and Publishing
Golf Courses	Public Airports
Fuel Oil Dealers (wholesale or retail)	Salt Storage Facilities
Wholesale Trade (coal, minerals and ores, salvage auto parts, chemicals)	Hazardous Waste Treatment, Storage, or Disposal Facilities (TSDF)
Lawn Care Services, Commercial Greenhouses and Nurseries	Publicly Owned Treatment Works (POTW)
Dry Cleaners	Underground Petroleum or Hazardous Materials Storage/Transmission Equipment

Future development can reduce the volume of water that infiltrates into the ground by placing an impervious surface over the ground and forcing that water to runoff instead of allowing some portion of that water to infiltrate. The Minnesota Pollution Control Agency's best management practices manual, entitled "Protecting Water Quality in Urban Areas" (dated July 1991), estimates that approximately 50% of precipitation infiltrates into the ground with natural cover (i.e. leaf litter, meadow). In comparison, only 15% of precipitation infiltrates into the ground where 75 to 100% of the site consists of impervious surfaces.

The United States Geological Survey has estimated the amount of groundwater recharge in this watershed in Connecticut Water Resources Bulletin No. 15, "Water Resources Inventory of Connecticut, Part 3, Lower Thames and Southeastern Coastal River Basins," dated 1968. Table 3 of that report (see Appendix H) indicates that an average of 15.48 inches per year of precipitation infiltrates into the ground in the Jordan Brook watershed, with 20% of the watershed overlying stratified drift deposits. Figure 40 of that report (see Appendix H) shows that groundwater recharge varies with the surficial geology. For sites overlying stratified drift deposits, average groundwater infiltration is approximately 23.2 inches per year. For sites overlying glacial till deposits, average groundwater infiltration is approximately 8 inches per year.

6.2 Open Space Evaluation

6.2.1 Existing Conditions

In the Jordan Brook watershed, several tracts of potentially developable land have been preserved as "open space." Figure 2 identifies these current open space areas in the watershed. In general, these open space areas include deeded open space that is privately owned, parcels owned by land trusts, land owned by the State of Connecticut as well as parks owned by the Town of Waterford including Stenger Farm, Cohanzie Park and North Road Park. This open space land is protected against future development and is generally located in the southern, more developed, half of the watershed. These parcels are typically unconnected and often are isolated by developed land.

In addition, approximately 20% of the watershed is designated under Public Act 490. While development is not prohibited on this land, this program reduces the tax burden on this land, thereby relieving some pressure to develop the land and allows it to continue to serve as "open space." Much of the undeveloped headwaters of Jordan Brook is currently designated PA-490 land.

The 1998 Waterford Plan of Preservation, Conservation, and Development included recommendations to preserve additional open space/greenways including the following:

- strive to increase the amount of preserved open space,
- pursue public ownership of open space,
- strive to set aside funds on the annual budget to acquire open space,
- encourage private ownership of open space,

- establish a coordinated open space and greenbelt system,
- acquire or preserve parcels that contribute the most to the Town's open space and greenbelt system,
- establish a comprehensive trail system in Waterford, and
- continue to encourage the use assessment (PA-490) program.

6.2.2 Watershed Evaluation

The purpose of this evaluation is to identify developable areas of land that would provide value as open space with the goal of protecting "important natural scenic or other resources and improve wildlife habitat and wildlife 'corridors,' especially stream corridors or riparian areas along watercourses" as stated in the 1998 Waterford Plan of Preservation, Conservation and Development. It should be noted that this evaluation did not include land already controlled by the Town. Since the Town already owns or controls this land via regulations, the Town could prevent development of this land. This includes both publicly-owned land as well as wetlands.

The following criteria were considered to identify parcels that could provide value as open space:

- Significant Wetlands: Parcels adjacent to wetlands identified as having special significance during this study could provide open space value by minimizing the encroachment of development into the wetlands and preserving the upland riparian zone adjacent to the wetlands.

- Flood Control: Areas that provide storage for watershed flood control were considered.

- Existing Open Space Areas: Opportunity to connect individual open space parcels were considered as providing value to create larger individual open space tracts and minimize isolated parcels.

- Wetland Access: Improving access to wetlands could increase their value by increasing their educational potential. New greenways can be created through secured open space areas to improve public access to wetlands of special significance in the watershed. Potential greenway locations are shown on Figure 14. These greenways were conceived as loops or segments from existing greenways (as identified in the 1998 Waterford Plan of Preservation, Conservation, and Development) in the watershed that can be added individually, as a group, or any combination thereof. The layout of the greenways was chosen to obtain the maximum benefit from a given wetland, considering its size and shape. Greenway configurations also were selected by considering other factors such as access to public facilities and scenic views. In one instance a proposed greenway skirts the perimeter of the junior high school property. The area of the greenway immediately across from the junior high school is noted for its scenic view in the westerly direction. For the two northern special significance wetlands, the greenways are proposed for the uphill sides of the wetlands to provide a panoramic view of the wetlands. In addition, one of the greenways follows along the Crystal Mall to provide access to and from the mall.

- Erosion Hazards: Parcels that, if developed, would have greater erosion potential were also considered. In general these parcels have long, steep slopes that drain directly into wetlands.

- Aquifer areas: Securing open space in aquifer areas both maintains current infiltration and protects against future pollution.

6.2.3 Conclusions

Parcels that met one or more of these criteria are listed on Table 19. This table ranks the relative strengths of each of these parcels against each of these criteria. A score of 1 to 3 is assigned for each criteria. Higher scores are assigned for parcels which best meet the criteria. As a result, the highest total scores are assigned to parcels that appear to offer the greatest possible open space benefits. As numbered on Figure 14, the five parcels that provide the greatest potential as open space (i.e., parcels with the highest score) are parcels 6, 7, 19, 21 and 26. It should be noted that these recommendations are in addition to open space acquisitions that the Town is already considering for greenways and trails as identified in the 1998 Waterford Plan of Preservation, Conservation, and Development.

PA-490 parcels were considered in this evaluation. While the tax burden on these parcels has been reduced to alleviate the pressure to develop the parcel on its owner, this act does not prevent development. PA-490 parcels are indicated on the rating matrix.

7.0 RECOMMENDED PLAN

The following paragraphs outline a recommended plan to control wetland impacts that may be caused by new development or changed land use activities in the Jordan Brook watershed. The goal of these recommendations is to maintain or improve existing ecological conditions in watershed wetlands and watercourses while not unreasonably restricting future development.

In general, this plan controls several types of potential impacts associated with development. These potential impacts include:

- Degradation of surface water quality which would impair both human uses as well as aquatic life.

- Reduction of groundwater base flows which would lower water tables and potentially affect wetland moisture levels and stream flows that are necessary to support aquatic life during dry periods.

- Degradation of wetland habitat which would reduce capability to support existing flora and fauna in the wetlands.

TABLE 19
RATING MATRIX OF POTENTIAL OPEN SPACE AREAS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Parcel Number	Protect Wetlands of Special Significance	Flood Control	Connect Open Space/Wetland Areas	Improve Access	Erosion Hazard	Development Potential	Aquifer Areas	Size	Total
1	2	2	0	1	1	1	1	2	10
2	2	2	2	1	2	1	1	2	13
3	2	2	2	1	1	3	3	2	16
4	3	2	2	1	1	2	2	3	16
5	3	3	1	1	2	2	2	2	16
6	3	1	0	3	3	2	3	3	18
7	3	1	3	3	3	1	2	3	19
8	1	1	0	1	1	1	1	1	7
9	2	1	0	1	1	2	1	1	9
10	2	1	0	1	1	2	1	1	9
11	2	1	0	1	1	2	1	1	9
12	3	1	1	3	1	2	1	3	15
13	3	1	0	1	2	3	1	1	12
14	3	1	0	1	1	1	1	1	9
15	3	1	0	2	2	2	1	1	12
16	3	1	0	2	2	2	1	1	12
17	3	1	0	2	2	2	1	1	12
18	3	1	0	2	2	2	1	1	12
19	3	3	2	2	2	2	2	3	19
20	3	1	0	1	2	3	2	1	13
21	3	1	3	1	2	3	2	3	18
22	3	1	3	1	3	2	1	3	17
23	3	1	1	1	1	2	1	3	13
24	3	1	0	1	1	3	1	1	11
25	1	1	0	1	3	1	1	2	10
26	2	3	3	1	1	2	3	3	18
27	1	3	1	1	1	3	3	1	14
28	3	1	3	1	2	1	2	1	14
29	1	3	2	1	1	1	3	2	14
30	3	1	3	1	1	2	3	3	17

Key:

State Owned Property

Property Included in Public Act 490

Notes:

A score of 1 to 3 was assigned for each criteria in accordance with the following: A score of 0 which was assigned to parcels where criteria does not apply. A higher score was assigned for those parcels that best met the criteria.

Proposed Greenway Corridors & Open Space Parcels
Jordan Brook Watershed Management Study
Town of Waterford

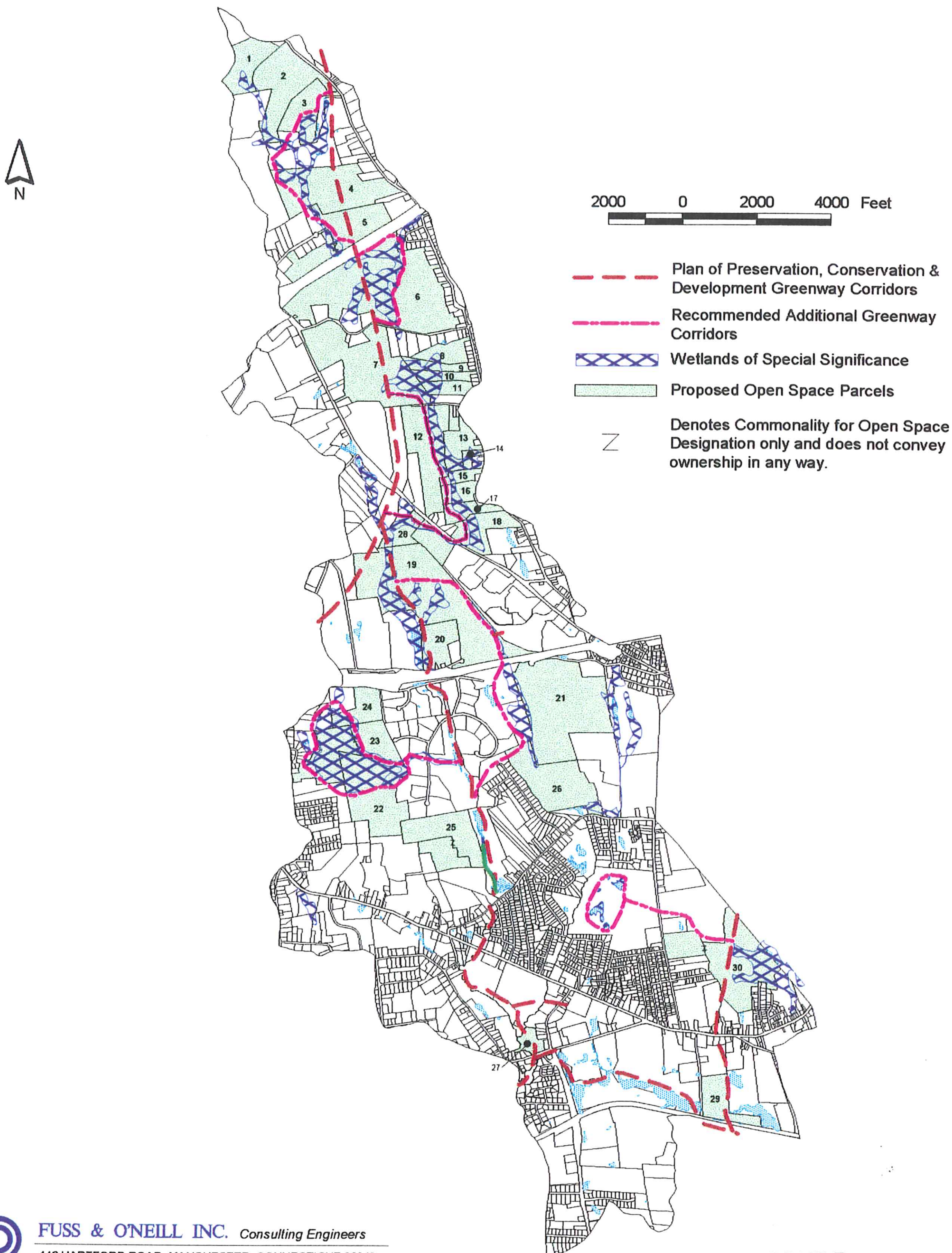

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FIGURE 14

- Increase in stream flood flows which would increase scour of stream channels and reduce vegetative habitat along channel banks.

The implementation of this recommended plan is solely dependent on the Town of Waterford. No further study is recommended before implementation. All of these recommendations can be implemented upon approval by the Town.

The following paragraphs outline the recommended watershed plan.

7.1 Continue to Monitor Water Quality

Water quality in the Jordan Brook watershed should continue to be monitored to evaluate changes in future water quality as the watershed continues to be developed. If any statistically significant degradation of water quality is observed, the Conservation Commission should consider modifying this plan to further protect water quality.

The recommended monitoring program has been developed to be consistent with the scope of the existing program. The following paragraphs outline this proposed program and the modifications to the existing program.

- Continue to monitor Stations 2, 3, 4, 5, 6, 7 and 8 on Jordan Brook. Move Station 1 to the Nevins Brook crossing with Post Road to better define impacts from the Nevins Brook subwatershed. In the future, if additional funding becomes available, sampling stations could be added upstream of Station 1 to better define sources of impacts and effects of existing natural features to attenuate pollutants on Nevins Brook if it is determined to be a significant source of pollutant loadings.

- If funding would allow another sampling station to be added, the station should be located at Great Neck Road. This unnamed stream is not currently monitored and has a large drainage area that extends into New London. Depending on future sampling results, sampling stations could also be added upstream of this station to better define sources of impacts.

- Samples should continue to be collected at least twice annually. Samples should be collected during early spring (April) and late summer (August) which are the two periods of the year with the highest potential for water quality impacts. Early spring samples will better quantify impacts from winter sanding and deicing. Late summer will better quantify impacts during low flow conditions when there is little dilution available.

- Samples should be collected to attempt to better define dry and wet weather impacts. A minimum of one dry weather and one wet weather round of samples should be collected each year. Dry and wet weather sampling should alternate between April and August from year to year. The following criteria should be used to define wet and dry weather conditions:

Wet Weather: Wet weather samples should be collected during or immediately following storms with more than 0.5 inches of rainfall and that occur at least 72 hours after any previous storm event of 0.1 inch or greater. Samples should be collected during the first 30 minutes of a storm event discharge.

Dry Weather: Dry weather samples should be collected only after at least 72 hours of dry weather.

- The following parameters should be monitored:

Total Suspended Solids	pH
Turbidity	Conductivity
Total Phosphorous	Total Coliform
Ammonia (new)	Enterococcus (new)
Biochemical Oxygen Demand	Lead (new)
Dissolved Oxygen	Copper
Color	Zinc (new)
Chloride	Flow
Total Organic Nitrogen (new)	Temperature
Nitrate (new)	

Lead and zinc are proposed to be monitored as the concentrations of these metals can be significantly influenced by stormwater. Enterococcus is also proposed to be monitored, instead of fecal coliform or streptococcus, as it is a better indicator of sewage contamination. Also, ammonia has been added to better define nitrogen impacts. Total organic nitrogen and nitrate should be monitored as excessive nitrogen loads could impact surface water impoundments and the Long Island Sound. Nitrite is not typically present at significant levels in the environment and would not have to be monitored.

- Several parameters are not recommended for continued monitoring. The following parameters are recommended for elimination from the current monitoring program:

Fecal Coliforms and Fecal Streptococci: The Connecticut Water Quality Standards provide criteria for total coliform and enterococcus organisms, but provide no criteria for fecal coliform and fecal streptococci organisms in Class A waters. As a result, we recommend that the Town focus on total coliforms and enterococcus as indicators of sanitary contamination.

Iron, Manganese, Alkalinity, and Hardness: These parameters are significantly influenced by natural sources and are not good indicators of manmade impacts.

Sodium: Chlorides are being used as a measure of deicing impacts.

Chemical Oxygen Demand: Biochemical oxygen demand will be monitored and is typically used to measure the presence of oxygen demanding organics in natural waters.

Oxygen Saturation: This parameter is dependent on dissolved oxygen levels which will continue to be monitored. Dissolved oxygen standards are also specified by the State of Connecticut.

Odor: Odor is a qualitative assessment and could be caused by both natural and manmade conditions.

- Land development projects that rely on water quality controls should monitor both pre- and post-treatment stormwater discharges to confirm the adequacy of the design and operation of the controls. Influent and effluent grab samples should be collected from storm events that generate between 0.5 and 1.0 inch of rainfall during a 24-hour period. Before sampling, there should be at least a 72-hour period of no rainfall, and pre-treatment (influent) samples should be collected during the first flush of the storm. Runoff generated by the first half-inch or first inch of precipitation is typically considered the first flush. Post-treatment (effluent) samples should be collected after pre-treatment samples are collected with a delay in time equal to the time the water is detained in the treatment system during that storm. Initial and long-term post-construction monitoring of water quality controls is recommended.

  Initial Monitoring: Initial monitoring should be performed within one year following installation and initial startup of the control system to assess the system's design and short-term pollutant removal efficiency. Sampling of five separate storm events is recommended in order to make a statistically-valid conclusion as to the effectiveness of the treatment system. The samples should be collected during early spring (April) and late summer (August) in order to examine seasonal variation of treatment performance. At least two storm events should be sampled during each season.

  Long-Term Monitoring: Biennial (i.e., once every two years) monitoring should be performed to provide information on the long-term pollutant removal efficiency and operation and maintenance of water quality controls for developments requiring secondary or tertiary controls. Biennial monitoring should be initiated following completion of the initial, first-year monitoring program.

  The table below lists the parameters that are recommended for initial and long-term monitoring. Discharge quality goals are also listed for each parameter. The ultimate goal would be for discharge quality to not be acutely toxic to aquatic life, however, this sampling does not account for stream dilution that would affect actual toxicity. At a minimum, it is recommended that stormwater discharges achieve CTDEP stormwater goals which, based on CTDEP's statistical analysis, is readily achievable in Connecticut with proper controls.

STORMWATER DISCHARGE QUALITY GOALS

Monitoring Parameter	Discharge Quality Goals
Total Oil and Grease	5 mg/l
Chemical Oxygen Demand	75 mg/l
Total Suspended Solids	100 mg/l
Total Phosphorous	0.5 mg/l
Total Kjeldahl Nitrogen	2.5 mg/l
Nitrate as Nitrogen	1.5 mg/l
Total Copper	0.100 mg/l
Total Lead	0.050 mg/l
Total Zinc	0.500 mg/l
Aquatic Toxicity	$LC_{50} \geq 50\%$

A more thorough monitoring approach would be to use automatic samplers to collect grab influent and effluent samples of discrete time intervals during a storm event. Influent and effluent flow meters should also be used to measure flows throughout the sampling period. This data would allow the Town to compute a pollutagraph and resulting influent and effluent pollutant loadings. In addition to computing removal efficiencies, this data could be used to evaluate the controls' response throughout a storm event. Data should also be collected during periods that could affect performance (e.g. freezing weather, structure flooded from previous storms).

7.2 Control Stormwater Quality

A stormwater quality control plan is recommended for future developments to protect watershed water quality. This recommended plan utilizes a tiered approach to define the appropriate level of stormwater controls that would be necessary to protect downstream resources based on the type and size of development and its potential water quality impacts. The stormwater control plan consists of base level controls as well as two additional levels of controls which are triggered based on development characteristics such as level of imperviousness, size of the development, land use, and receiving water/wetland resources. The framework and elements of this plan are described below. The approach is summarized in Table 20.

7.2.1 Base Level Controls

Base level controls are intended to provide baseline protection against degradation of downstream resources across the entire watershed. Base level controls provide gross contaminant and sediment reduction and serve to dissipate the potential erosive energy of stormwater runoff. A base level of stormwater quality controls would be required for all new developments. Redevelopments that result in land use changes or modifications to the storm

TABLE 20
STORMWATER QUALITY CONTROL SELECTION CRITERIA
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
FEBRUARY 2000

Selection Criteria	Stormwater Quality Control Level		
	Base Level Controls	Secondary Controls	Tertiary Controls
Receiving Water Resource	All other wetlands/watercourses	All other wetlands/watercourses	Discharge to wetland/ watercourse sensitive to water quality
Land Use	All other land uses	All other land uses	Facilities with potential for extremely high pollutant loadings
Percent Impervious	0 to 10 percent	Greater than 10 percent	—
Size of Development	0 to 5 acres	Greater than 5 acres	—

drainage system should also be required to implement these controls as an opportunity to improve current watershed water quality. Base level controls should not be required for single-family houses or residential subdivisions with four or fewer lots that have no new roads, provided that any discharge from the subdivision would not affect a wetland or watercourse which is sensitive to water quality. Development that is part of a phased development project should not be exempt from base level controls.

The intent of these controls is to treat all runoff from developed portions of a site. Diffuse controls would be required for sheet flow off of developed portions of a site and point controls would be required for discrete point discharges. Base level controls will consist of, at a minimum, one or a combination of the following stormwater Best Management Practices (BMPs):

1) Diffuse Stormwater Discharges: For stormwater which discharges off-site in a uniform, diffuse manner (i.e., sheet flow runoff), one or more of the following BMPs should be required:

   - Vegetated buffer strip
   - Level spreader
   - Infiltration basin
   - Vegetated drainage swale

   These measures provide a minimum level of stormwater treatment by promoting infiltration and filtration of stormwater pollutants by vegetation.

2) Point Stormwater Discharges: Stormwater treatment using a gross particle separator or similar technology designed to remove gross solids and floatables would be required for all point stormwater discharges to storm drains, receiving waters, or wetlands. Appropriate treatment technologies include:

   - Oil/particle separator,
   - Sediment basin (with floatables trap),
   - Vegetated drainage swale (would require additional measures to trap floatables),
   - Infiltration basin.

3) Uncontaminated Runoff: Uncontaminated runoff such as rooftop runoff, except from metal roofs which can leach metals or roofs with industrial process venting, is recommended to be infiltrated directly into the ground using infiltration basins, trenches, or chambers.

A numeric pollutant reduction goal is not recommended for base level controls. Since developments that qualify for base level controls have a low potential for water quality impacts, the intent with this level of controls is to protect against gross contaminants that can be readily removed and emergency conditions such as spills.

7.2.2 Additional Stormwater Quality Controls

In addition to the base level controls required for all future development, more stringent stormwater quality controls would be required for developments which have the potential to generate higher pollutant loadings. Similarly, stormwater discharges to wetlands or watercourses identified as being sensitive to water quality (Section 3.2.3) would also require an additional level of protection to limit pollutant impacts to these resources. Under this stormwater quality control plan, two levels of additional controls may be required for stormwater discharges which meet these criteria.

7.2.2.1 Secondary Stormwater Quality Controls

This level of control would require implementation of stormwater quality control technologies which remove at least 80 percent of the total suspended solids (TSS) load. The 80 percent TSS removal requirement applies to post-development conditions after a site is stabilized. Examples of BMPs which have been shown to achieve 80 percent TSS removal on average include:

- Extended detention pond (equipped with sediment forebay)
- Wet pond (equipped with sediment forebay)
- Constructed wetland
- Sand or organic filter
- Devices using swirl/vortex technology
- Other proprietary technologies demonstrated to provide 80 percent TSS removal

Floatables such as oil and grease could be removed using a base level control such as an oil/water separator in combination or in addition to the above measures.

7.2.2.2 Tertiary Stormwater Quality Controls

This level of additional stormwater quality control has the goal of "no net increase" in future pollutant loadings as compared to existing conditions, considering maximum attainable reductions in stormwater pollutant loadings. This level of controls would require at least 80 percent removal of TSS, removal of floatables, and demonstration of no net increase in loadings of other pollutants suspected of being present in the stormwater (e.g., nutrients, metals, coliform bacteria). Required stormwater controls would likely consist of one or a series of state-of-the-art stormwater BMPs. This level of control would be required only for those developments with the greatest potential for significant pollutant loadings or potential impacts to wetlands or watercourses which are sensitive to water quality.

Tertiary stormwater quality controls would require developers to evaluate current and future pollutant loadings in order to demonstrate that the new discharge would not increase pollutant loadings as compared to existing conditions. This would require the use of a stormwater pollutant loading model to evaluate the stormwater quality impacts of the development and proposed Best Management Practices (BMPs). A watershed pollutant loading model with an intermediate level of complexity such as the P8 Urban Catchment Model (P8), for example, would be appropriate for this application. Other models are available for this analysis.

7.2.3 Stormwater Quality Control Technologies

A list of commonly used stormwater quality controls and associated pollutant removal efficiencies is provided in Table 21. The BMPs shown in the table include generic categories of control technologies (e.g., wet ponds, sand filters, and swirl concentrators) as well as proprietary technologies such as Stormceptor™, Stormtreat™, and Vortechnics™ products. The range of pollutant removal efficiencies were obtained from published studies and vendor information and, therefore, do not necessarily have a common basis for comparison. However, they are provided as a guide to their potential application. The BMPs shown in Table 21 could potentially function as base level, secondary, tertiary stormwater quality controls, depending on the pollutant removal efficiency of a particular control technology.

The removal efficiencies listed in Table 21 are typical values reported by a variety of studies and BMP applications. Data collected from one type of control at one site cannot be assumed to apply to similar controls at other sites. A number of design conditions would affect actual efficiencies including peak flows at time of measurement, flow patterns through the structure and form of pollutant (e.g. aqueous or particulate form) in the site's stormwater. The literature data used in the model is a generalized average for these types of controls. Actual pollutant removal efficiencies would vary depending on site-specific pollutant loading and flow conditions. Monitoring is recommended to verify actual removal efficiencies for structural controls. Additionally, structural stormwater BMPs should be regularly inspected and maintained to ensure their proper operation. Recommended stormwater BMP operation and maintenance practices are summarized in Appendix I.

7.2.4 Selection Criteria for Level of Controls

Selection of the appropriate level of stormwater quality controls (base level or additional controls) for a particular development will be based on consideration of the following criteria:

- Receiving water resource
- Land use of proposed development
- Level of imperviousness
- Size of development

Selection criteria for each of these development characteristics are described below and are summarized in the matrix presented as Table 20. The most stringent of the applicable control levels will dictate the required level of controls for a particular development.

7.2.4.1 Receiving Water Resources

The quality of the water body or wetland receiving the stormwater discharge from a site is an important factor in determining the appropriate level of stormwater quality controls for a

TABLE 21
COMMON STORMWATER QUALITY CONTROLS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
JANUARY 2000

PRODUCT NAME	REMOVABLE MATERIALS - % removed							
	Floating Oil/Grease	Solids	Nitrogen	Phosphorous	Fecal Coliform	Hydrocarbons	Metals	BOD5
CPS - 2000 Coalescing Phase Separator	99%	99%	-------	-------	-------	-------	-------	-------
CSF Stormwater Treatment System	X	X	-------	-------	-------	-------	X	-------
Sedimentation Trap	-------	-------	-------	-------	-------	-------	-------	-------
Downstream Defender	X	X	-------	-------	-------	-------	-------	-------
NRCS Nutrient & Sediment Control System	-------	90-100%	80-90%	85-100%	-------	-------	-------	90-100%
Stormceptor	90%	60-80%	-------	-------	-------	-------	50-80%	-------
Stormtreat	X	99%	77%	90%	97%	-------	77%	-------
Streamguard Catch Basin Inserts	88%	X	-------	-------	-------	-------	-------	-------
Streamguard Passive Skimmer	-------	-------	-------	-------	-------	X	-------	-------
Vortechs	X	80%	-------	-------	-------	X	X	-------
Deep Sump (Modified) Catch Basin	-------	-------	-------	-------	-------	-------	-------	-------
Siltsack	X	X	-------	-------	-------	-------	-------	-------
Drainage Channel	-------	-------	-------	-------	-------	-------	-------	-------
Shallow Marsh	-------	80%	30%	45%	-------	-------	-------	-------
ED Shallow Wetland	-------	60%	20%	40%	-------	-------	-------	-------
Submerged Gravel Wetland	-------	90%	60%	70%	-------	-------	-------	-------
Pond/Wetland System	-------	85%	35%	60%	-------	-------	-------	-------
Pocket Marsh	-------	55%	60%	35%	-------	-------	-------	-------
Micropool ED pond	-------	50%	30%	30%	-------	-------	-------	-------
Wet Pond	-------	80%	40%	50%	-------	-------	-------	-------
Wet Extended Detention Pond	-------	75%	40%	65%	-------	-------	-------	-------
Multiple Pond System	-------	80%	45%	65%	-------	-------	-------	-------
Pocket Pond	-------	70%	30%	50%	-------	-------	-------	-------
Extended Detention Pond	-------	70-90%	20-60%	10-60%	-------	-------	20-60%	-------
Level Spreader/Vegetated Strip	-------	80-100%	40-60%	30-80%	-------	-------	20-80%	-------
Infiltration Trench	-------	90%	50%	65%	-------	-------	-------	-------
Infiltration Basin	-------	90%	50%	65%	-------	-------	-------	-------
Porous Pavement	-------	90%	85%	65%	-------	-------	-------	-------
Sand Filter	-------	70-90%	30-45%	40-60%	-------	-------	40-80%	-------
Surface Sand Filter	-------	85%	40%	50%	-------	-------	-------	-------
Underground Sand Filter	-------	80%	35%	50%	-------	-------	-------	-------
Perimeter Sand Filter	-------	80%	45%	45%	-------	-------	-------	-------
Organic Filter	-------	80%	50%	45%	-------	-------	-------	-------
Pocket Sand Filter	-------	80%	35%	40%	-------	-------	-------	-------
Bioretention	-------	80%	50%	50%	-------	-------	-------	-------
Dry Swale	-------	90%	90%	75%	-------	-------	-------	-------
Wet Swale	-------	80%	40%	25%	-------	-------	-------	-------
Grassed Biofilter Swale	-------	-------	-------	-------	-------	-------	-------	-------
Off-line Bioretention Cell	-------	80%	40%	50%	-------	-------	-------	-------
Dry Wells	-------	-------	-------	-------	-------	-------	-------	-------
Water Quality Inlets	-------	-------	-------	-------	-------	-------	-------	-------
Oil/Grit Separator	-------	10-25%	5-10%	5-10%	-------	-------	5-25%	-------
Swirl Concentrator	-------	15-40%	10-15%	10-15%	-------	-------	10-30%	-------

NOTES:
BOD5 - Biochemical Oxygen Demand
X - affirmative, but removal not quantified
----- - information not available

TABLE 21
COMMON STORMWATER QUALITY CONTROLS
JORDAN BROOK WATERSHED MANAGEMENT PLAN
TOWN OF WATERFORD
JANUARY 2000

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4) Schueler, T.R., Kumble, P.A., and M.A. Heraty, A Current Assessment of Urban Best Management Practices: Techniques for reducing Non-Point Source Pollution in the Coastal Zone, Department of Environmental Programs, Metropolitan Washington Council of Governments, 1992.
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6) U.S. Department of Agriculture, Natural Resources Conservation Service, Community Assistance Partnership, Innovative Stormwater Treatment Products and Services Guide, prepared for the November 17 & 19, 1997 Stormwater Technologies Trade Shows.
7) U.S. Environmental Protection Agency, Environmental Impacts of Stormwater Discharges, EPA 841-R-920-001, USEPA, Office of Water, June, 1992.
8) U.S. Environmental Protection Agency, Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters, EPA 840-B-92-002, USEPA, Office of Water, 1993.
9) U.S. Environmental Protection Agency, Sand Filter Design for Water Quality Treatment, USEPA, Watershed Management Unit, April, 1992.

development. Wetlands or watercourses which are sensitive to water quality should be protected by providing the maximum attainable (i.e., tertiary) level of stormwater controls. Tertiary stormwater quality controls would be required for all developments which discharge to such wetlands or watercourses as a point source, either directly or via a storm drainage system, or as uniform, diffuse flow. Stormwater discharges to all other wetlands or watercourses would require base level or secondary controls, depending on the other selection criteria.

7.2.4.2 Land Use

As described in the pollutant loading evaluation presented in Section 5.4, research indicates that stormwater pollutant loadings are directly related to land use. Certain land uses generate higher concentrations of pollutants than found in typical runoff. In general, industrial, commercial, highway, and multi-family land uses generate the highest pollutant loads, as demonstrated by the pollutant loading evaluation. In contrast, single family residential, office, and institutional land uses normally yield smaller potential pollutant loads. Therefore, developments would require varying levels of stormwater quality controls depending on the proposed land use for the site.

Developments with the following land uses would require tertiary stormwater quality controls:

1) Industrial facilities subject to the U.S. EPA's National Pollution Discharge Elimination System (NPDES) Stormwater Permit Program

2) Auto salvage yards (auto recycling facilities)

3) Auto fueling facilities (gas stations)

4) Fleet storage areas (cars, buses, trucks, public works)

5) Vehicle service and maintenance facilities

6) Commercial parking lots with high intensity use (Shopping malls, fast food restaurants, convenience stores, supermarkets, etc.)

7) Road salt storage facilities (if exposed to rainfall)

8) Commercial nurseries

9) Flat metal rooftops of industrial facilities

10) Facilities with outdoor storage and hazardous substances loading/unloading areas, regardless of the primary land use of the facility or development

11) Facilities subject to chemical inventory reporting under Section 312 of the Superfund Amendments and Reauthorization Act of 1986 (SARA), if materials or containers are exposed to rainfall

12) Marinas (applicable to coastal areas)

As described previously, developments having the above land uses would be required to demonstrate, through the use of a pollutant loading model, that loadings of all potential pollutants of concern would not increase as compared to existing conditions. All other land uses would require either base level or secondary controls, depending on the results of other selection criteria.

7.2.4.3 Level of Imperviousness

Research has shown a strong correlation between the amount of impervious area in a watershed and water quality impacts to downstream water resources. Water quality of downgradient water resources is generally protected when less than 10 percent of the watershed consists of impervious surfaces. However, when 10 to 30 percent of the watershed consists of impervious surfaces, downgradient water resources typically show signs of impacts. When more than 30 percent of the watershed consists of impervious surfaces, downgradient water resources have been found to be degraded.

The level of stormwater controls required for a proposed development is recommended to be partially dependent on the level of imperviousness of the development. Greater impervious area would require more extensive controls. For the purposes of this plan, impervious area includes any surfaces which prevent infiltration of water into the subsurface such as pavement and structures. Such areas should be determined based on final project site plans. Developments with less than 10 percent impervious area would require base level controls. Developments with more than 10 percent impervious area would require secondary stormwater quality controls.

7.2.4.4 Size of Development

The size of a development is a gross indicator of the potential for stormwater pollutant loadings from a site. Developments with less than five acres of disturbed area would require base level controls. Developments with greater than five acres of disturbed area would require secondary stormwater quality controls. This criterion is consistent with the CTDEP's existing stormwater general permit that requires projects that result in more than five acres of disturbance to install controls with a goal of at least 80% TSS reduction. For the purpose of this plan, disturbed area means the total area on a site that will be exposed or susceptible to erosion during the entire construction period.

7.3 Maintain Groundwater Base Flows

It is recommended that new developments maintain pre-development groundwater base flows. One means of potentially accomplishing this recommendation would be for new developments to infiltrate "clean" roof runoff. The only exception to this recommendation is that runoff from metallic roofs should not be infiltrated. Galvanized roof drains should also not be used. Alternatively, new developments can be allowed to infiltrate less water if they can demonstrate through an engineering evaluation of actual site conditions that less water can be infiltrated and still maintain groundwater base flows.

The advantage of this approach is that it minimizes risk of groundwater pollution by only infiltrating clean runoff. Since surface runoff can convey pollutants swept from surfaces, infiltration of this runoff will increase risk of groundwater pollution. Stormwater pollutants that pose the greatest risk to groundwater include leaked oils/greases and aqueous metals. While particulate pollutants would not reach groundwater, they could become trapped in the infiltration device and result in future maintenance problems. In addition, groundwater pollution is difficult to detect without careful monitoring and is also difficult to remediate. If runoff from paved surfaces is infiltrated, pretreatment should be provided in accordance with <u>Section 7.4</u>.

Infiltration structures should be designed by one of two methods:

i. Provide adequate storage volume within the infiltration structure and stone backfill to store all of the runoff for a 10-year frequency storm.

ii. Size the structure such that 10-year frequency storm peak discharge into the structure is equal to the following equation.

$$Q = (0.2)(k)(I)(H)$$

where:
Q = infiltration rate per foot perpendicular to flow net
k = hydraulic conductivity, as measured by a certified soils laboratory for the soils directly below the bottom elevation of the infiltration structure (ft/sec)
I = hydraulic gradient, as estimated by constructing a two-dimensional flow net and dividing the number of stream tubes by the number of equipotential lines
H = difference in elevation between the top of the infiltration structure and high groundwater (ft)

Only 20% effectiveness should be assumed because of long-term clogging by fines.

If the difference between groundwater and the bottom of the infiltration structure is more than five feet, it is recommended that a detailed engineering analysis be performed to confirm that hydraulic gradients do not vary in the strata below the structure.

7.4 Maintain Pre-Development Peak Discharge Rates

Increased development could result in increased impervious surfaces and, without adequately sized stormwater controls, will increase peak stormwater flows and increase the volume and rate at which runoff will drain from the site. In order to control this potential impact from new development, we recommend that developers include detention/retention devices such that pre-development peak discharge rates from the site are maintained. Some developments that have little potential to significantly impact off-site peak discharge rates could be exempted from this requirement. The developments that could be exempted are small projects that would generate a net increase of peak stormwater flows of less than 1 cubic foot per second and where this level of control may be overly burdensome and include:

- Single family residences,
- Subdivisions with four lots or less with no new public/private roads,
- A project with a net increase of less than 5,000 square feet of impervious surfaces.

In order to minimize peak flow impacts, we recommend that new developments conduct the following evaluation to determine whether adequate detention/retention devices have been proposed.

1. Demonstrate no net increase in pre-development peak flows from the site for proposed conditions.

    - Demonstration should be made at each point where runoff from newly developed areas drains from the site.

    - Acceptable methods to compute pre and post development peak flows are TR-20, TR-55 and Rational Method.

    - Peak flows should be evaluated for 2, 10, 25 and 100-year frequency storms.

2. Compare total proposed peak discharge from the site to existing peak flows at each downstream points-of-concern for the 10-year frequency storm. Points-of-concern and associated peak flows are provided on Table 9.

    - For multiple discharges from a site, applicant must sum the peak flows from all of the discharges from newly developed areas to compare to peak flows at downstream points-of-concern. Flows from multiple discharges can either be directly added or hydrographs can be summed reflecting the difference in the timing of the peaks.

3. If the total proposed peak discharge from the site exceeds 10% of the existing peak flow at a point-of-concern; demonstrate no net increase in pre-development peak flows at each point-of-concern between the site and the downstream most point-of-concern

where the proposed peak discharge from the site exceeds 10% of the existing peak flow at the point-of-concern.

- Peak flows should be evaluated for the 10, 25 and 100-year frequency storms.
- Acceptable method to compute post-development peak flows is TR-20.
- The watershed TR-20 model should be utilized as the base model to evaluate proposed impacts.

This evaluation of downstream points-of-concern may require additional infiltration of stormwater runoff from paved surfaces in order to reduce runoff volumes that may impact downstream detention systems that attenuate existing peak flows. In order to minimize the potential for groundwater pollution at a site due to infiltration of stormwater runoff from paved surfaces, we recommend that runoff from paved surfaces be pretreated before it is infiltrated into the ground. Pretreatment should include the following:

- **Oil/water Separation:** Oil/water separators should be designed and maintained in accordance with current CTDEP regulations. A copy of these regulations is attached as Appendix J.
- **Remove 80% of Total Suspended Solids:** A structure sized and designed to remove at least 80% of total suspended solids shall be used to pretreat runoff prior to infiltration.

7.5 Acquire Additional Open Space

While encroachment of new development into wetland areas can be prevented through existing regulations, upland areas can be developed, within limitations, unless that land is controlled/or owned by an entity (public or private) that prevents its development. The intent and benefit of maintaining adjacent upland areas is maintenance of wetland hydrology and ecological setting. Some upland areas significantly improve the value of wetlands by screening wetlands from development, providing fringe habitat and providing wildlife access to wetlands. In addition, upland areas can be used to improve human access to wetlands, thereby improving their educational value.

It is recommended that the Town continue to acquire upland open space that would improve the value of wetlands in this watershed. Instead of allowing developers to donate small isolated parts of a development as open space, we recommend the following:

- If a developer does not control land that has significant open space values, a monetary contribution can be made to a fund set aside to acquire open space with value elsewhere in the Town. This "fee in-lieu-of open space" practice is currently allowed under Section 8-25b of the Connecticut General Statutes, which provides mechanisms to establish and utilize the fund.

- If upland areas are to be purchased by the Town as open space, the Town should consider the value that they provide in this watershed. Table 19 identifies those parcels that would improve wetlands value and ranks their selective importance.

The State of Connecticut provides financial assistance to municipalities and non-profit land conservation organizations to acquire land for open space through its Open Space and Watershed Land Acquisition Grant Program (Public Act No. 98-157), administered through the CTDEP's Division of Land Acquisition & Management. Grants may be for the purchase of land that is:

- Valuable for recreation, forestry, fishing, conservation of wildlife or natural resources;
- A prime natural feature of the State's landscape;
- Habitat for listed threatened, endangered, or special concern species;
- Relatively undisturbed outstanding example of a native ecological community;
- Important for enhancing and conserving water quality;
- Valuable for preserving local agricultural heritage; or
- Eligible to be classified as Class I or Class II watershed land.

Other criteria considered in evaluating grant proposals include protection of land adjacent to and complementary to existing open space, closer proximity to urban areas, land vulnerable to development, and consistency with State and local plans of conservation and development. Land acquired under this program would be preserved in perpetuity, and a permanent conservation easement would be provided to the State to ensure that the property remains in a natural and open condition. The easement would include a requirement that the property be made available to the general public for recreational purposes, unless the municipality elects to purchase the development rights to the property.

Land owners may donate or sell land directly to the State under Connecticut's Recreation and Natural Heritage Trust Program (CGS 23-74 through 23-80), which is also administered through the Land Acquisition and Management Division of the CTDEP. Similar to the goals of the Watershed Land Acquisition Grant Program described above, the purpose of the Recreation and Natural Heritage Trust Program is to allow the State to acquire and thereby ensure the preservation and conservation of land having ecological diversity, unusual natural interest, or habitat for endangered or threatened species. Additional evaluation criteria for this program include consistency with the State plan of conservation and development, whether a parcel is threatened with conversion to incompatible land uses, and closer proximity to population centers for parcels identified as having a high priority recreation value.

7.6 Other Wetland Protection Techniques

7.6.1 Upland Protection Zones

One of the most effective ways to protect wetlands of special significance is to designate an Upland Protection Zone of undisturbed vegetation along the wetland boundary within the Upland Review Area. Natural vegetation stabilizes transitional soils between uplands and wetlands, thereby preventing erosion and sedimentation. The ability to anchor soils on steep slopes is especially important. The vegetation slows the passage of stormwater, allowing infiltration into the soil, thereby removing nutrients and other pollution. Edge habitats in uplands bordering wetlands are also heavily utilized by wildlife, especially birds. An Upland Protection Zone 50 feet in width is recommended for all wetlands, and a 100-foot width is recommended adjacent to perennial streams. This width should be adequate to prevent soil erosion on sloping land and to provide upland nesting sites for birds. Also, 50 to 100 feet of undisturbed vegetation will offer an unbroken travel corridor for mammals, reptiles and amphibians.

Factors which should be considered in adjusting the width of an upland protection zone are as follows:

- **Significance of Wetland Resources:** While all wetlands provide some value, the relative significance of individual wetlands should be considered. More significant wetlands typically have greater utilization by wildlife and additional undisturbed upland area would minimize their disturbance.

- **Slopes:** As slopes increase, erosion potential on those slopes also increase. Increasing, the width of upland protection zones in areas where steep slopes exist would provide an area stabilized by natural vegetation that could filter sediment before entering wetlands or water courses, both during and after construction.

- **Soil Types:** As with slopes, soil types are also a factor in erosion potential. Erosion potential of soils is a function of soil texture, cohesiveness and organic content. Lists of highly erodible soils are provided on the soil surveys prepared by the Natural Resources Conservation Service. Once again, increasing the width of the upland protection zone in areas with highly erodible soils would provide a strip of natural vegetation that could filter sediment before entering wetlands both during and after construction.

- **Flood Plain Limits:** Establishing an upland protection zone of the landward boundary of established flood plains would both preserve flood storage and carrying capacity of watercourses.

Maintenance of an Upland Protection Zone is minimal since the area is left as natural as possible. However, developers should be required to remove any trash which has accumulated within the Zone and in the wetland. Areas of the Zone which are damaged should be restored with plantings of high wildlife value. Hiking trails or picnic areas are allowable but the use of motorized recreational vehicles such as dirt bikes, all terrain vehicles or snow mobiles should be prevented. No structures, other than bridge supports, culvert abutments, stormwater control devices, or utility lines could be allowed in the Upland Protection Zone. Stormwater controls should include energy dissipaters, such as plunge pools, rip-rap pads, level spreaders or multiple outlets, to slow the rate of flow and disperse points of entry into the wetlands.

7.6.2 Biological Inventories

An alternative or supplementary means of evaluating water quality would be to conduct periodic biological inventories of the organisms that exist in watershed watercourses. This assessment consists of "counting" insects, amphibians and other organisms that may exist at a sample site. Organisms sensitive to water quality as well as diversity would decrease with increased water quality impacts. As a result, this approach would provide data on actual water quality impacts to fauna in a watercourse and would reflect long-term water quality trends. Conventional water quality monitoring only provides a snapshot of water quality at the time of sampling and data can only be compared to standards to estimate what impacts are occurring.

One approach to implement a biological inventory would be to establish four sample sites in undeveloped portions of the watershed. Three could be located on Jordan Brook, one below I-95 above developed areas, one between I-95 and I-395, and one above I-395 as background The fourth sampling site could be located near Great Neck Road for the watercourse draining from New London. Exact locations of sampling sites should be determined by the scientist conducting the evaluation and would generally be riffles in the watercourse. In accordance with DEP recommendations, sampling should be done annually in the fall.

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