AGRONOMIST REPORT

Briar Chapel
Chatham County, North Carolina

Prepared for:

NEWLAND COMMUNITIES

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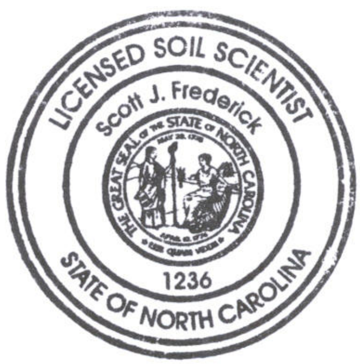

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Executive Summary

The objective of this report is to provide the Briar Chapel Reuse Water Facility with recommendations for the establishment and maintenance of a forage/ornamental and natural forest land application system in accordance with the North Carolina Division of Water Quality (NCDWQ) regulations Section .0200 – Waste Not Discharged to Surface Waters. In addition, recommendations are provided which are consistent with the recently adopted Chatham County Compact Community Ordinance (CCO). The forested land application system will utilize hardwood tree species capable of producing large amounts of biomass and providing favorable soil conditions to enhance adsorption and denitrification of phosphorous and nitrogen respectively. The forage/ornamental system will also provide treatment for the reuse water through the assimilation of large quantities of nutrients and water. The proposed Briar Chapel subdivision in Chatham County proposes to land apply tertiary treated reuse water to approximately 450 acres consisting of 167 individual receiver sites. The Soil Scientist/Hydrogeologic Reports recommend the application of reuse water to the receiver sites at a rate of 0.45 in/wk based off an annual average hydraulic loading. Given this rate of application and using a conservative estimate for the concentration of nutrients in the reuse water, the site is not limited by nutrient or other constituent loading.

The Briar Chapel facility will provide tertiary treatment of domestic effluent by using an activated sludge process with tertiary filter. A less intensive treatment process (secondary treatment, extended aeration) is used by several similar facilities in the region of Briar Chapel, and these numbers have been utilized to determine the anticipated maximum concentrations of nutrients (mg/L) in the reuse water (Table 1). It is anticipated that the nitrogen and phosphorus concentrations in the effluent leaving the Briar Chapel Facility and entering the storage lagoons will be <25 mg/L (TN) and < 5 mg/L (TP), respectively. This will supply approximately 132 lbs/ac/yr total nitrogen (TN) and assuming 75% availability, approximately 20 lbs/ac/yr plant available phosphorus (PAP). These anticipated total nitrogen concentrations are conservative estimates for the irrigation water and do not take into consideration denitrification occurring in the storage ponds or soil microbial interactions on the receiver site. Therefore actual plant available nitrogen (PAN) will be lower than the total nitrogen concentrations presented. In addition, these anticipated loadings are within acceptable agronomic loadings as indicated by state water quality agencies and demonstrated in other permitted natural forest/forage land application systems across the state.

Soil analyses of Wedowee soils, the predominant soil series at the proposed irrigation site, indicate there are potential nutrient deficiencies. The reuse water will provide supplemental nutrients and a consistent source of water to growing crops, in this case both natural forest and forage species. However, additional nutrient amendments to provide optimum growing conditions will be required initially, and may also be required on an annual basis as a supplement to the nutrients in the reuse water. Recommendations for nutrient amendments are provided in Table 3. Annual soil testing and monthly analysis of the reuse water needs to be accomplished to determine if there are continued nutrient deficiencies. This will help to insure proper management of the site. The proposed natural forest system and forage/ornamental system at the Briar Chapel treatment facility site will provide sufficient treatment of this reuse water. The forage/ornamental system will provide opportunities for recreational activities, add open space to the development, and reduce fertilizer application to the site. The mixed pine/hardwood forest system will provide the community valuable open space while effectively renovating the projected reuse water.

1.0 Introduction

Newland Communities/NNP-Briar Chapel, LLC (Newland), proposes to complete a reclaimed water project as part of Briar Chapel, a large-scale, mixed-use development within the Cape Fear River Basin in Chatham Co., NC. Under Section .0200 Rules – Waste Not Discharged to Surface Waters set forth by the North Carolina Division of Water Quality (NCDWQ), municipalities, and privately owned treatment works (POTWs) can divert their highly treated effluent to reuse sites. Many county governments, municipalities, and industries are facing similar situations with finding alternatives for reuse water treatment in nutrient sensitive regions. Reuse is a viable alternative for the Briar Chapel project and will provide an excellent source of water for growing crops.

1.1 Objectives

Soil, Water & Environment Group, LLC. (SWE), personnel completed a comprehensive Agronomist Report of potential reclaimed water irrigation areas on the Briar Chapel project property. Recommendations are provided in this report concerning hydraulic loadings, nutrient loadings, as well as site and irrigation system management on this tract. Also recommendations are provided for the establishment and maintenance of a reuse land application system on the selected site. Cropping scenarios, species/system selection, fertilizer recommendations, vegetation establishment and management, and vegetation harvesting regimes are provided. Specifically, the Agronomist Report satisfies permit requirements and conforms with all criteria outlined in 15A NCAC 2H .0205(d)(7)(D) and conforms to all criteria within the Draft Compact Community Ordinance of Chatham County, referenced here within as the CCO.

1.2 Methodology

Work completed was conducted according to Section .0200 Rules – Waste Not Discharged to Surface Waters. In addition, recommendations are provided which are consistent with the draft CCO for Chatham County. Field investigations were conducted to describe the potential reuse sites according to the soils, geologic features, hydrology, and wetlands. Reuse water to be irrigated was analyzed and recommendations are provided for the establishment and management of a reuse water irrigation system on the site. Recommendations are given according to site characteristics including soils, hydrology, vegetation, and any site limiting factors. Also recommendations concerning cover crops and their ability to accept the proposed rates of liquids, solids, minerals, and other reuse water constituents, and appropriate application months as well as maintenance are included in this report.

1.3 Site Description

The proposed reclaimed water irrigation system site is located west of US 15-501, north of Andrew's Store Road (SR 1528), and south and east of Mann's Chapel Road (SR 1532) in Chatham County, North Carolina. Chatham County is located in the Piedmont Plateau physiographic province. The soils present on the proposed receiver sites, according to the Chatham County Soil Survey (USDA, 1970), are mapped primarily as Wedowee sandy loam, with areas of Vance sandy loam, Helena sandy loam, and Chewacla/Wehadkee (loam and fine sandy loam respectively).

The Briar Chapel community proposes to land apply approximately 737,066 GPD of pretreated reuse water on receiver sites totaling approximately 450-acres. This site was historically used for farm and/or pasture land. A mixture of mature pine/hardwood forest and a major utility corridor exists currently on the site.

The proposed Briar Chapel site is located in the Cape Fear River Basin. There are several unnamed tributaries located on the site and associated wetlands. These areas have been delineated and buffers have been established around surface waters. The CCO requires that, 100-foot buffers be maintained on perennial streams, 50-foot buffers be maintained on intermittent streams, and 50- or 30-foot buffers be maintained on ephemeral streams, depending on the acreage they drain.

In light of these requirements, there will be a total of 236.7 acres of stream buffers preserved on the site. No reuse water will be applied within these buffers which will be protected in perpetuity, consistent with Section 9 of the CCO. These buffer protections exceed buffer requirements set forth in Section .0200 Rules – Waste Not Discharged to Surface Waters set forth by the North Carolina Division of Water Quality (NCDWQ), and exceed NCAC 2H .0219(k)(B-C) rules for wastewater reuse, which only provides 25-foot buffers around surface waters not classified SA and does not provide protections for ephemeral channels.

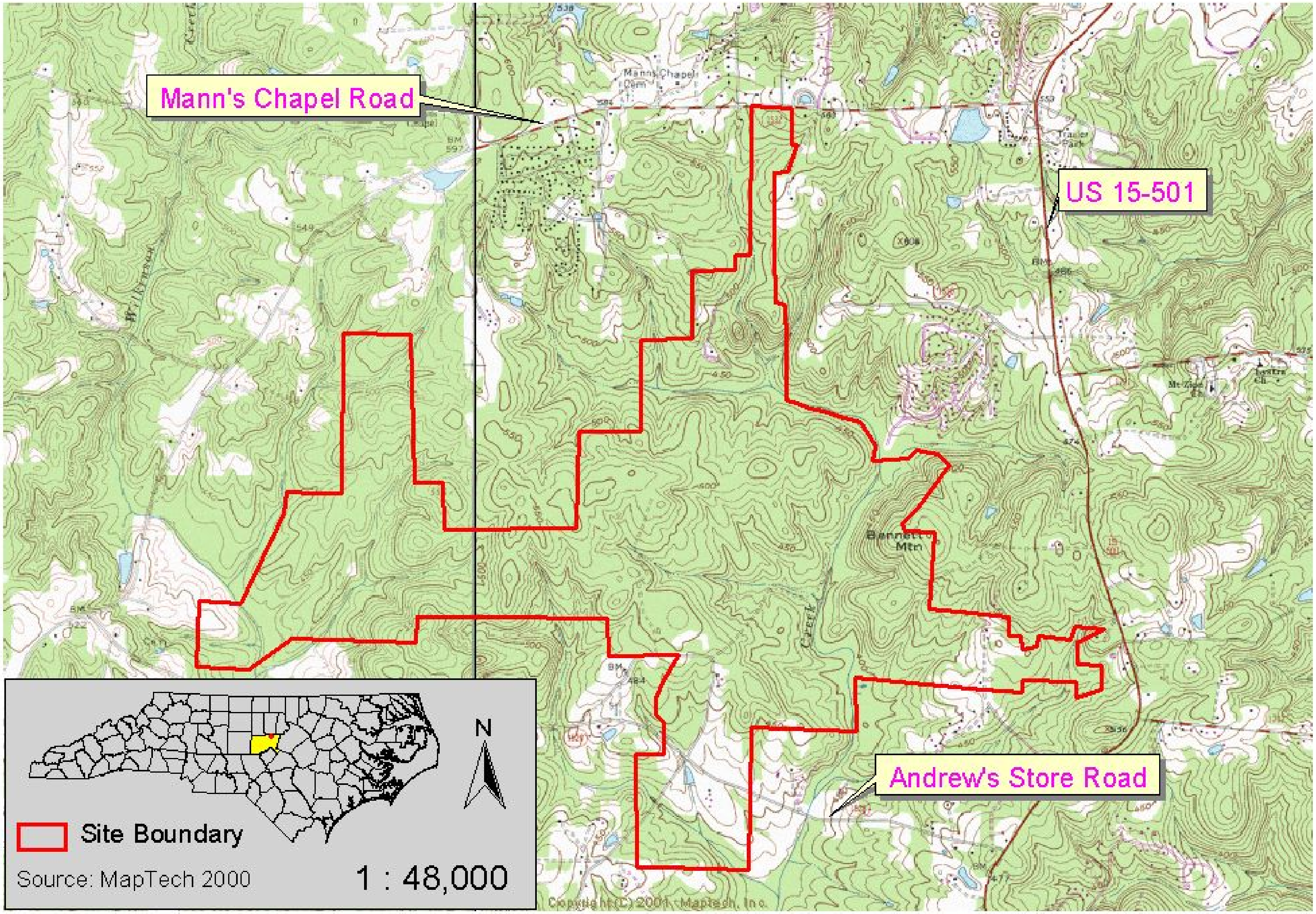

Figure 1: Proposed Briar Chapel Site Location Map, Chatham County, NC

2.0 Reuse Water Remediation/Application

Treated reuse water applied to the receiver sites will be utilized in several ways. Water will be lost through transpiration by vegetation, evaporation from the vegetation and soils surface, and percolation through the soil profile. Any excess nutrients in the reuse water will be treated through microbial processes, plant uptake, adsorption to soil solids, and biologically mediated chemical transformations (i.e. denitrification).

The primary objective of establishing a reuse water receiver site using mixed pine/hardwood trees and forage/ornamental species is to effectively renovate the water through the plant-soil system to prevent nutrients, biological oxygen demand (BOD) and other unwanted constituents from entering groundwater and nearby surface waters.

Mixed pine/hardwood tree and forage/ornamental systems under reuse water irrigation create a soil/plant system that effectively renovates reuse water through nutrient use and concentration, adsorption, and fixation. This has been demonstrated at facilities such as Edenton, Woodland, and Garner, NC, and Clayton Co. GA, and numerous other locations throughout the southeastern United States.

Nutrients promote plant growth and microbiological activity in the soil. Reuse water is basically a fertilizer to these organisms and they respond by increasing metabolism and growth. Because there will be a decreasing need to use machinery on the site for competition control and mowing in the natural forest system, soil structure will be maintained or improved while at the same time soil microbiological activity will increase due to litter accumulation. This will result in a gradual improvement in soil condition for reuse water absorption, infiltration, and renovation.

The estimated average annual nitrogen uptake of forested ecosystems for southern forests is 250 lbs/ac/yr for 40-60 year old mixed hardwood species, 200 lbs/ac/yr for 20-year old loblolly pine with no understory, and 250 lbs/ac/yr for 20-year old loblolly pine with understory (Crites et al, 2000). According to other publications (Rubin, 1994, EPA, 1981), the maximum total nitrogen that can be applied to forested sites is 200-400 lb/ac/yr. Other research indicates that forest plantations with canopy closure can assimilate nitrogen levels in excess of the 200 lbs/ac/yr (Rubin and Frederick, 1994).
In a study near Helen, Georgia, a southern mixed hardwood forest on a 30% slope was given a loading rate of 3.0 in/wk. The nitrogen loading rate was 608 lb/acre and the percolate nitrate concentration was 3.7 mg/L (Nutter et al, 1978).

Trees transpire large quantities of water from much deeper soil depths compared to grass cover. Trees also support much larger leaf areas for transpiration. Even in the winter, photosynthesis and transpiration continue to remove water and nutrients from the site, albeit at a reduced rate. Reuse water should not be applied to the site whenever icing of trees could cause physical damage. Such conditions may predispose the trees to disease and insect damage.

The highest uptake of nitrogen, phosphorus and potassium can generally be achieved by perennial grasses and legumes (Crites et al., 2000). Coastal Bermuda grass systems are capable of sequestering 300 lbs N/ac/yr or higher with good management practices. Good management practices include weed control, efficient harvesting/growing crop, and minimizing equipment trafficking on the site especially following rainfall or irrigation events. Overseeding with a winter annual can extend the nutrient capacity of the site and increase nitrogen utilization. Careful management during the winter months is important to reduce impacts from equipment trafficking and soil loss through erosion.

2.1 Reuse Water Characterization

The anticipated effluent will meet reuse water quality standards. Levels of BOD and total suspended solids (TSS) must be ≤ 10 mg/L and 5 mg/L respectively and meet the federal shellfish standard for coliform of < 14 counts/100mL.

The reuse water will be from domestic sources and will be treated using an activated sludge process with subsequent tertiary filtration. Facilities with less intense secondary treatment, extended aeration processes, with the exception of one facility, are located near Briar Chapel, including the Governors Club WWTP, Barclay Downs WWTP, Briarwood Farms WWTP, and Mallards Crossing. Anticipated maximum concentrations of nutrients (mg/L) in the reuse water at Briar Chapel were determined from these facilities' data. The results, which are presented in Table 1, are averages taken from monthly monitoring data for each facility during 2003.

Table 1: Annual Average Reclaimed Water Nutrient (mg/L) Data Obtained from Regional Wastewater Treatment Facilities [1.] (2003).

	Total Nitrogen	**NH_3**	**Total Phosphorus**	**TSS**	**BOD**
Governors Club [2.]	17.9	0.7	N/A	2.8	2.0
Barclay Downs	11.7	0.3	4.4	2.2	2.3
Briarwoods Farms	20.0	1.7	4.2	4.2	2.2
Mallards Crossings	22.4	0.1	1.6	3.4	2.0
AVERAGE	**18.0**	**0.7**	**3.4**	**3.1**	**2.1**

1.] Treatment consists of secondary, extended aeration. Note: Proposed Briar Chapel System will consist of tertiary, extended aeration, with filtration, and nutrient reduction, further decreasing nutrients in the effluent.
2.] Governors Club treatment process consists of tertiary treatment with extended aeration.

From these numbers, it is anticipated that maximum TN levels with the Briar Chapel facility will be less than 25 mg/L, without nutrient removal mechanisms in place, and with the majority of the nitrogen in the effluent in the inorganic, NO_2-N and NO_3-N fractions due to the tertiary treatment process. The proposed treatment facility design will consist of a tertiary, extended aeration with filtration **and** nutrient removal for phosphorus. Nutrient removal mechanisms will provide additional treatment to remove phosphorus and subsequently meet non-discharge agronomic requirements at a **minimum**. Total phosphorus concentrations are anticipated to be less than 5 mg/L by means of this treatment design and nutrient removal mechanisms.

In the activated sludge process, biological nitrogen removal is accomplished by the conversion of nitrogen in the reuse water from organic nitrogen and ammonia to nitrate, followed by reduction of the nitrate to nitrogen gas. Nitrate production occurs in an aerobic activated sludge treatment zone during a process called nitrification. The nitrate is then converted through a series of intermediate steps to nitrogen gas in an anoxic zone (an anaerobic condition with nitrate present) during a process called denitrification, effectively removing the nitrogen from the reuse water. However, not all of the nitrogen is removed. Since the anticipated ammonia levels in the reuse water exiting the treatment facility is small (< 1 mg/L), it is estimated that the majority of the nitrogen remaining will be in the plant available, nitrate form.

2.2 Micronutrients and Trace Metals in Soils / Reuse water

Once the reuse water irrigation system is established, annual soil testing must be instituted. The soil test results will provide recommendations that will enable proper maintenance. Once soil testing begins, tests must be accomplished annually to determine trace metals, particularly zinc and copper, as well as Exchangeable Sodium Percentage (ESP) and concentrations of macro and micro nutrients in the soil.

2.2.1 Salt Loadings

Imbalances with nutrients such as sodium, calcium, and magnesium may occur in a spray irrigation system and cause degradation in soil structure, lower soil permeability, lower soil water infiltration, and lower uptake of nutrients in plants. One way to evaluate the potential soil problems that may occur on a site receiving irrigation water is to calculate the sodium adsorption ratio (SAR) for the irrigation water.

The SAR of any irrigation water must be determined and monitored. The SAR is calculated as the ratio of sodium (Na) to one half the square root of calcium (Ca) and magnesium (Mg) with all concentrations expressed as equivalents. The SAR calculation is:

$SAR = Na/(Ca/2 + Mg/2)^{½}$ (units in meq/L)

Generally an SAR in excess of 10 is considered to be a hazard on most soils for irrigation purposes and system operators must take special precautions to monitor salt levels of sodium in both irrigation water and soil. In a sandy soil, however, the SAR of irrigation waters is less of a concern because of the limited exchange capacity of the receiver soils. An SAR in excess of 7.5 is considered to be a mild hazard to irrigation and system operators should consider establishing a similar monitoring program. If the level of sodium in the soil exchange complex increases to a level over 10, then corrective measures such as gypsum addition should be implemented.

Continuing operations with high levels of sodium can result in problems with soil infiltration and nutrient imbalances. Nutrient imbalances can be controlled through gypsum application. The sodium in the reuse water and soil should be closely monitored to prevent future problems with the land application receiver site.

The second concern regarding the SAR is potential adverse impact to plant materials. Irrigation water with high SAR values may change the osmotic potential in the soil solution and this often results in adverse impact to plant materials. For these reasons, the SAR must be monitored closely. For example, irrigation with liquid containing an SAR of 20 is permissible, provided system monitoring indicates no long-term adverse consequence to the soil and the plant material (A. R. Rubin, 2003).

2.2.2 Soil Sodium:

Another measure of sodium, completed for the soil, to determine potential problems with irrigation systems, is called the exchangeable sodium percentage (ESP). ESP is calculated as follows:

ESP = Na/CEC * 100

Where: Na is an index value for sodium (North Carolina Agronomic Division – Soil Testing Indices)

This calculation should result in data no greater than 10-15%. Soils with ESP values > 10-15% can be remediated through under draining and adding soluble sources of Ca such as gypsum ($CaSO_4$), being careful of Mg deficiencies in plants. Ca/Mg ratios should be kept in balance. The Ca/Mg ratio should not exceed 10/1 to 15/1 based on routine soil testing. If ESP values exceed 15% then amendments such as gypsum or another calcium substitute should be added to correct the situation. A prescription of 1 ton/2units ESP is recommended to address this problem.

Excessive sodium in the soil system can lead to management problems in the future and affect the overall capacity of the site.

2.2.3 Trace Metals

The USEPA regulates the levels to which selected metals can accumulate on a waste receiver site. Regulated metals have not been tested in the reuse water at Briar Chapel. We recommend that zinc (Zn) and copper (Cu) be tested in the reuse water and during annual soil sampling to make sure that these constituents do not limit the capacity of the site for reuse water treatment. The maximum cumulative levels permitted for the life of the land application site are 1,338 lb./ac Cu and 2,498 lb./ac Zn (USEPA, 1981).

3.0 Site Specific Soils/Nutrients

3.1 Existing Soil and Site Conditions

According to the soils mapped by NRCS at Briar Chapel, the soil resources are well suited for this reuse activity. Soil conditions should not limit or preclude the use of the reclaimed water throughout the designated receiver site sites and promote a good environment to establish both forest and forage systems.

The soils present on the receiver site sites according to the Chatham County Soil Survey mostly consist of Wedowee sandy loam. These are very deep, well drained, moderately permeable soils that formed in residuum from weathered crystalline rock of the Piedmont Plateau. The texture of these soils is sandy loam, slopes range from 0-35% but are mainly 6-15%, and approximately 1/4 of the soils are classified as bouldery. The bouldery classification will not hinder the development of growing crops because the larger stones will be located in the substratum and not in the rooting depth.

Vance sandy loam, Helena sandy loam, and Chewacla/Wehadkee (loam and fine sandy loam, respectively) soils were also present in smaller quantities. Slopes on these soils ranged from 2-10%. The Vance series is well drained, slowly permeable that formed in residuum weathered from acid crystalline rocks in the Piedmont. The Vance series is moderately deep to saprolite and very deep to bedrock, located predominantly on ridges and side slopes. The Helena series consists of very deep, moderately well drained, slowly permeable soils that formed in residuum weathered from a mixture of felsic, intermediate, or mafic igneous or high-grade metamorphic rocks. These soils are on broad ridges and toeslopes of the piedmont uplands. The NRCS maps also indicate that a small portion of Chewacla/Wehadkee soils are present on the site.

Table 2: Soil Analysis of Upland Soils at the Briar Chapel Reuse Water Receiver Sites, Chatham County, NC.

Depth	pH	Phosphorus (ppm)	Potassium (ppm)	Calcium (ppm)	Magnesium (ppm)	CEC [1]	BS% [2]
Uplands							
0-6 in.	4.6	3.0	56.7	82.8	50.3	2.4	42.0
6-12 in.	4.8	2.1	68.4	17.7	37.9	2.3	26.0

[1] Cation Exchange Capacity (meq/100g) – defined as the amount of cations adsorbed on soil-particle surfaces per unit mass of the soil under chemically neutral conditions.
[2] Base Saturation – defined as the percentage of the CEC occupied by base cations.

Soil analyses of the proposed irrigation site indicate there are some nutrient deficiencies (Table 2). The recommended nutrient and lime additions for the forage/ornamental system are presented in Table 3. These results are presented as recommended loadings in pounds per acre or tons per acre. The recommended nutrient additions should be supplied prior to the planting of the forage/ornamental system. Regardless of the vegetation program, soil fertility values must be corrected prior to establishment of the crop.

Table 3: Supplemental Nutrient and Lime Recommendations as lbs/ac or tons/ac for Lime, for the Briar Chapel Reuse Water Land Application System, Chatham County, NC[1.].

	Forage System	**Natural Forest System**
Lime[2.]	1.5	1.5
N [3.]	100-150	100-150
P[4.]	50-100	70 – 90
K [5.]	80 – 100	10 – 30
Cu [6.]	5	5
Zn	5	5

1. Nutrient and lime recommendations are average values provided by NCDA, recommendations for Bermuda grass and/or mixed pine/hardwood forests.
2. Calcium carbonate ($CaCO_3$)
3. Ammoniacal (NH^4+ salt) and urea ($(NH_2)_2CO$ forms.
4. Additional phosphorus should be added as phosphorus oxide (P_2O_5).
5. Potassium should be added as KCl or K_2O (potash).
6. Copper sulfate ($CuSO_4$)

Maintenance of soil fertility is an important component of any land treatment operation. Without vegetation, the effectiveness of any land application operation is compromised.

In general the soil materials mapped by the NRCS at the Briar Chapel reuse water application sites are well suited for the reuse project proposed. The topsoil depth is sufficient to allow irrigation of significant volumes of liquid. The subsoil in these soils contains a sufficient volume of clay material. Clay materials typically exhibit a very high CEC and will assist with storage of plant nutrients such as phosphorus on the sites and with the protection of shallow groundwater and adjacent surface waters.

The irrigation water applied will provide supplemental nutrients and a consistent source of water to growing crops. Supplemental nutrients may need to be applied to the site in addition to the irrigation water. Soil testing should be done on an annual basis, and additional nutrient applications should be consistent with the recommendations.

4.0 Hydraulic Loadings

Briar Chapel proposes to spray reuse water on approximately 450-acres of forage/ornamental and natural forest areas near the proposed reuse water treatment facility. The Soil Scientist Evaluation and Hydrogeologist Report recommend a hydraulic loading capacity of 0.45 in/wk, which equates to 23.4 in/yr.

The effluent to be applied will provide supplemental nutrients and a consistent source of water to growing crops, in this case forage grasses and trees.

5.0 Nutrient Loadings

In North Carolina, most soils are naturally acidic and low in nutrients. While the supplemental nutrients in the proposed irrigation water will enhance these soils, both lime and fertilizer may still be required to support optimal plant growth. Soil testing provides site specific lime and fertilizer recommendations for specific crops and field conditions.

The management of soil fertility without soil testing is not recommended since soil nutrient and pH relationships are complex. Acid soils, for example, can limit root growth and cause certain nutrients to be unavailable for plants. Unless soil acidity and pH are corrected through liming, applying fertilizer may not correct the problem.

Soil testing measures the soil's nutrient-holding capacity and provides a sound basis for land management decisions. Fertilizer recommendations based on soil test information optimize crop yield, save money, and protect the environment from excess fertilizer runoff. Following recommendations for lime application can produce similar benefits.

It is recommended to test the soils on an annual basis in order to fine-tune irrigation events on the receiver sites. Sampling should be done during the same time of the year and samples need to be analyzed by a lab certified for the testing of soil, such as the NC Department of Agriculture – Soil Testing Section (NCDA, 2004).

5.1 Nitrogen Loadings

The nitrogen content of a reclaimed water source and the anticipated volume irrigated are utilized to determine the amount of plant available nitrogen applied to a site. The total nitrogen level in a reuse water source is determined by measuring the levels of total Kjeldahl Nitrogen (TKN), ammonia nitrogen (NH_3), and nitrate/nitrite nitrogen ($N0_3/N0_2$) in the irrigation water. $N0_3/N0_2$ and NH_3 are the inorganic forms of nitrogen and total Kjeldahl Nitrogen (TKN) is the organic form of nitrogen. In most domestic reuse water facilities, including the proposed facility at Briar Chapel which will utilize a form of activated sludge with tertiary filtration, the biological activity will break down the organic matter releasing and or consuming the nitrogen as energy in the process. It is estimated that the nitrogen in the reclaimed water will primarily be in the inorganic fraction, and of this amount, almost all will occur in the $N0_3/N0_2$ form. Therefore total nitrogen, which is anticipated to be less than 25 mg/L, based off an annual average, will be used to determine an approximation of nitrogen loadings.

Using total nitrogen instead of PAN to calculate the nitrogen loading does not account for the microbiological transformations in the soil such as mineralization and immobilization or ammonium volatilization. When accounted, plant available nitrogen loadings will be less than total nitrogen loadings.

Liquid irrigated onto the site will contain TN calculated as:

TN (0.45 in/wk liquid loading: 25.0 mg TN/L annual avg.)
25.0 mg/L TN * (286,759,382 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 450 ac = **132.8 lbs TN/ac/yr**

Volume of reclaimed water applied on an annual basis is calculated by using the recommended maximum soil loading rate (0.45 in/wk). The calculation is as follows:

0.45 in/wk * 27,158 gal/acre-in * 450 acres = 5,499,495 gal/wk

5,499,495 (gal/wk) * (356 days/yr) * (1 wk/7 days) = 286,759,382 gallons/year = **785,642 gallons/day**

This annual nitrogen loading rate was calculated by multiplying the amount of nitrogen in the reclaimed water by the gallons of reclaimed water applied. This number was then converted to pounds of nitrogen being applied on the entire site and subsequently divided by the total acreage to yield pounds of nitrogen per acre per year. The final numbers show that the maximum annual average hydraulic loadings anticipated by the proposed design will result in a maximum annual average application of less than **132 lbs TN/ac/yr**. This number is most likely higher than actual plant available nitrogen loadings because as previously stated it does not account for soil microbiological interactions and potential denitrification processes occurring in the storage ponds prior to application. These numbers were used to provide a conservative estimate of total nitrogen to meet the agronomic needs of the receiver crops and to protect adjacent streams and groundwater from nutrient enrichment. The anticipated loadings are within acceptable loadings for the proposed land application systems as indicated by state water quality agencies and demonstrated in other permitted natural forest/forage land application systems across the state.

It should be noted that in the past year, SWE personnel, faculty from NC State, and other consultants met with the NCDENR, Construction Grants and Loans (CGL) section, to discuss nutrient loading rates for forest systems. As a result of that meeting, CGL agreed to increased rates for plant available nitrogen to 150 lbs/ac/yr on a case-by-case basis. Historically, CGL has accepted 40-60 lb/ac/yr for pine forests and 70-100 lb/ac/yr for hardwood forests. These accepted, higher loading rates are consistent with past and current research by NCSU faculty (personal communication with Drs. Lee Allen, Doug Frederick, & Bob Rubin, 2004).

In addition, another state agency, NCDWQ, Non-Discharge Section examines each proposed treatment system on a case-by-case basis. This agency will be reviewing the Briar Chapel project. Several North Carolina municipal wastewater systems similar to the one proposed by Briar Chapel have been permitted by the state to accept total nitrogen loadings that exceed historical agronomic data used for determining nutrient loadings on these systems from USDA-NRCS.

5.2 Phosphorus Loadings

Domestic reuse water contains low levels of phosphorus as total phosphorus (TP), phosphate (PO_4) or phosphorus oxide ($P2O_5$). Each of these forms of phosphorus can be essential as nutrients for plants. Plants generally require phosphorus at a rate of 25% to 50% of the nitrogen application rate.

The anticipated phosphorus (TP) concentration in the Briar Chapel effluent will be less than 5.0 mg/L. Since nitrogen will not be limiting in this land application system, all available phosphorus should be utilized by the growing crops and forest system biological complex.

<u>TP (< 5 mg TP/L annual avg.)</u>

5.0 mg/L TP * (286,759,382 gal/yr) * 8.34 (lb/10^6 gal/mg/L) / 450 ac = **26.5 lb/ac/yr**

Because most North Carolina soils, including the soil at Briar Chapel, are acidic, phosphorus fixation will be dominated by Al and Fe compounds. A regular soil testing regime, and liming program, should be followed to allow maximum agronomic availability of both native and fertilizer applied phosphorus. The efficiency of phosphate uptake by plants will be higher if lime is applied to fields prior to application. Assuming 75% availability, plant available phosphorus (PAP) will be less than **19.8 lbs/ac/yr**. These phosphorus loadings can be assimilated by the cover crops and soils specified.

The assimilative capacity for phosphorus is below that for nitrogen and the anticipated levels of phosphorus can be assimilated by the forest or forage crops and soils specified provided an effective sedimentation and erosion control program is in place. The sedimentation and erosion program is necessary to reduce the loss of phosphorus, which exits a site adsorbed to fine soil particles lost with runoff during storm events. Riparian buffers are also important sinks for phosphorus transported in overland flow during periods of unusually high precipitation. These buffers will be maintained along the borders of receiver sites and streams in accordance with the CCO.

5.3 Organic Loadings

Average monthly BOD and TSS for the reuse water leaving the treatment facility is estimated to be ≤ 3 mg/L and ≤ 4mg/L respectively. These estimates were obtained from wastewater treatment facilities using secondary and tertiary treatment with extended aeration in the region. These values provide a conservative estimate of anticipated loadings for proposed Briar Chapel facility.

The water will be reuse quality, and organic loadings will be insignificant. Reuse quality standards state that BOD and TSS must have monthly concentrations less than 10 mg/L and 5 mg/L respectively. Given that a site with moderately drained soils can accommodate up to 10,000 lb/ac/yr organic loadings (Carlile et al., 1974 Crites et al., 2000, EPA, 1981, Rubin, 2002), the organic loadings at the proposed receiver sites will be inconsequential.

5.4 Recommendations

A composite reuse water sampling program should be instituted to address the various inputs to the natural forest and forage/ornamental systems irrigated through this proposed program. The reuse water parameters to be monitored include as a minimum the following: total nitrogen and plant available nitrogen (Kjeldahl-N (organic) and NH_3-N and nitrate (inorganic)), total phosphorus, potassium, sodium, calcium, magnesium, copper, and zinc. These are all critical parameters in a natural forest or forage/ornamental land application system. The sodium adsorption ratio (SAR) of the liquid irrigated should be less than 10.

6.0 Reuse Receiver Site and Species Selection

Natural forest and forage/ornamental systems are recommended for the Briar Chapel reuse water irrigation project. The forage/ornamental system will utilize a combination of forage grasses and ornamental species. These areas will be managed for nutrient assimilation, recreation, and aesthetics. The natural forest system will utilize existing mature, hardwood and pine forest. These areas will be managed for nutrient assimilation, open space, and timber production.

Selection of these systems was determined by the master site plan, existing site conditions, and approximate location to residential areas within the community. Figure 3 (Appendix A) details the proposed receiver site areas and recommended land use. Detailed recommendations for the establishment, maintenance, management, and harvesting of vegetation on both of these systems are provided in Section 7. In addition, the natural forest systems will meet criteria set forth for open space requirements in Section 10 of the draft CCO.

6.1 Forage/Ornamental System

A forage/ornamental system is recommended for areas outlined in the master site plan for road medians, recreational fields, common areas, and utility corridors.

Forage/ornamental systems can be established on a variety of soils and exhibit characteristics to effectively treat reuse water and assimilate nutrients in growing vegetation. These characteristics include:

1. Forage crops tolerate a wide range of soil moisture levels.
2. Forage crops utilize significant levels of nutrients.
3. Forage crops develop perennial root systems and consume nutrients throughout the growing season.

4. Forage crops may be perennial and remain productive for several years without replanting.

6.1.1 Site Selection

Site selection is critical when establishing a forage/ornamental reuse water application system. Existing published data (i.e. soil surveys, hydraulic conductivities, etc.) are useful to determine general site characteristics, but detailed site specific information may be necessary for proper design of the system. Detailed field study provides data regarding microsite variation, existing soil fertility, in-situ soil texture and morphology, and water table depth. Site specific data is essential to establish proper loading rates, species recommendations, and maintenance recommendations. This report utilizes site specific data as well as existing soil and land use data.

6.1.2 Species Selection

Forage species will be utilized for approximately less than one quarter of the reuse water application system. A variety of forage species are compatible with the proposed reuse system including coastal Bermuda grass (*Cynodon* sp.), fescue (*Fetescue* sp.), eastern gamma grass (*Tripsicum* sp.) and dallisgrass (*Paspalum dilatatum*). In addition, utility corridors that typically consist of a variety of forbs, grasses, and herbaceous material are compatible with anticipate hydraulic and nutrient loadings for the proposed reuse system. All forage species and ornamental plantings will be established and managed to meet the nutrient and hydraulic demands of the growing crop.

6.2 Natural Forest System

Forest systems have a variety of attributes favorable for treatment of reuse water including: 1.) Most natural forest stands sites are nutrient deficient and capable of assimilating large amounts of nutrients through biotic conversion and soil adsorption, and 2.) Trees have perennial root systems, which allow year round uptake of nutrients and enhance infiltration.

Detailed knowledge of site history and soil characteristics is necessary for proper design and maintenance recommendations of reuse water application systems. Ideal reuse water application sites will have deep (>1m) soils with loam to sandy loam surface horizons over silt loam to sandy clay loam subsurface horizons. Soils well suited for high nutrient and hydraulic loading rates will be well drained (water table >1m deep) with pH values between 5.5 and 7.0 (Frederick et al., 1994). Soils that are very clayey or very sandy are somewhat limited for reuse water applications, although waste characteristics and application rate are important mitigating factors. The proposed forested irrigation sites are excellent with respect to these criteria.

Mature mixed pine/hardwood natural forest systems are capable of assimilating large quantities of nutrients and water through biological and biochemical pathways and are tolerant of periodically saturated soil conditions.

6.2.1 Natural Forest System Site Selection

Site selection is critical when establishing a reuse water application system. Existing published data (i.e. soil surveys, hydraulic conductivities, etc.) are useful to determine general site characteristics, but detailed information may be necessary for proper design of the system. Detailed field study provides data regarding microsite variation, existing soil fertility, in-situ soil texture and morphology, and water table depth. These site specific data are essential to establish proper loading rates, species recommendations, and maintenance recommendations. The proposed receiver sites at Briar Chapel exemplify ideal reclaimed water irrigation areas. Site specific soils and hydraulic conductivity data show that the receiver sites can accept additional water and nutrient loadings in accordance with existing topography and vegetation, soil fertility and other soil characteristics, as well as water table depth.

6.2.2 Natural Forest System Species Selection

Existing natural forest stands will be utilized for approximately three quarters of the reuse water application system. The forest cover consists of a mixture of mature, 40-60 year-old pine/hardwood stands, 100+ year-old oak ridges and hill tops, as well as predominantly mature pine stands 40-60 years-old (Appendix A – Figure 4). Characteristics of these tree species are presented in Table 4.

Table 4: Characteristics of Common Tree Species Proposed for the Briar Chapel Reuse Water Land Application Systems.

Species	Flooding tolerance [1,2,3,5]	Preferred soil texture [4,6]	Preferred soil pH range [4,6,7,8,9]
Liquidambar styraciflua (sweetgum)	tolerant	silt-clay loam (fine)	5.50-7.50
Quercus sp. (oaks)	v. tolerant – mod. tolerant	moderate to fine	4.50-5.50
Pinus taeda (loblolly pine)	intolerant – mod. tolerant	sand-clay	4.50-6.50 (moderately acid)

[1] Baker, 1977; [2] Hook, 1984; [3] Gill, 1970; [4] Willett and Bilan, 1993; [5] Gardiner et al., 1993;
[6] Burns and Honkala, 1990; [7] Harrington, 1991; [8] Baker and Broadfoot, 1979; [9] Broadfoot, 1976

Table 5: Recommended Vegetation Crop for Forage/Ornamental and Natural Forest Areas at the Proposed Briar Chapel Reuse Water Receiver Sites, Chatham County, NC.

Receiver site Designated Land Use	**Crop**	**Comments**
Forage/Ornamental	Coastal Bermuda grass and other perennial grasses, ornamental species	- managed for nutrient assimilation, recreation, and

		aesthetics.
Natural Forest	Mixed pine/hardwood trees	- managed for nutrient assimilation, open space, and timber production.

7.0 Receiver Crop Establishment, Management, and Harvesting

Data obtained from the investigation of the soils and site characteristics at the Briar Chapel Reuse water Facility receiver site were utilized to determine the best suitable receiver crop or combination of crops for the master site plan. Recommendations are provided for vegetation establishment, management, and harvesting on the proposed reuse water receiver site.

7.1 Fertility

Based on soil fertility samples, fertilizer recommendations for the forage/ornamental receiver crops are provided in Table 3. Fertilizers should be applied to the site at the recommended rates prior to vegetation establishment and management. This is essential to the success of the vegetation and the overall success of the land application reuse water system. Supplemental nutrients, provided below, will be required prior to establishment, and following system establishment and should be continually determined through annual soil testing.

A. 1.5 tons lime/ac - Soil pH is very low. This low pH influences the availability of essential plant nutrients. The lime recommended is required to facilitate the uptake of essential plant nutrients.

B. 100-150 lbs nitrogen/ac – This is generally supplied in the form of urea, ammoniacal nitrogen, or nitrate nitrogen in inorganic fertilizers.

C. 60 to 90 lbs phosphorus/ac - This is generally supplied as a phosphate compound. The phosphorus recommended is essential for root development.

D. 80 to 100 lbs potassium/ac - Generally this is supplied as a salt of potassium such as potassium chloride. Potassium is essential for development of root, stem, and leaf tissue.

E. 5 lbs copper/ac - Both the Bermuda grass or the eastern gamma grass crops require trace minerals to prosper. The copper levels in the soil are very low and supplemental copper must be supplied. Generally this is supplied through the addition of copper sulfate.

F. <u>5 lbs zinc/ac</u> - Both the Bermuda grass or the eastern gamma grass require this trace mineral to grow and prosper. This is usually added in the form of chelated zinc.

7.2 Forage/Ornamental System Establishment, Management, and Harvesting

7.2.1 <u>Forage/Ornamental System Establishment</u>

Coastal Bermuda grass can be established on most median areas and recreational fields using live sprigs at a sprigging rate of 40 bushels per acre. Sprigs should be placed 2 to 3 inches apart with 24 to 30 inch rows during the months of early March through April. Sprigging can be completed later in the growing season provided **irrigation is available** to the newly established plants. Establishment of the forage system species should proceed as follows:

1. Disk and subsoil to a depth of 12-18 inches, remove existing vegetation and incorporate chemical controls for existing vegetation for establishment only.
2. Adjust soil fertility with lime and nutrients.
3. Disk and pulverize soil in seedbed.
4. Incorporate seed or sprigs at rates recommended.
5. Irrigate to assure crop germination or sprig development.

Eastern gamma grass and dallisgrass should be established on areas with higher slopes using pure lives seeds at 15 lbs/ac. Seeds should be placed between 0.75 and 1.0 inches apart during the months of **April through mid June**. Fescue can be established in recreational field areas as well. This can be accomplished by disking in a cover crop of fescue in the fall **(Oct.-Nov.)** (broadcast 10-15 lb/ac or drilled at 6 lb/ac). Establishment of a fescue crop is possible in the early spring as well **(Mar.-Apr.)**.

Ornamental species can be planted throughout the site accordingly. Mulch or protective barriers should be placed around the outside the plant to avoid damage from mowing equipment.

7.2.2 <u>Forage/Ornamental System Management</u>

Forage/ornamental system management recommendations for Briar Chapel reuse water receiver site include:

- Follow up monitoring of forage plantings within one year after planting.
- Regular cutting of the receiver sites with low ground pressure equipment following adequate drainage/dry down of the spray zone.
- Grass clippings should be bagged or removed from the receiver sites following cutting for aesthetics and additional nutrient removal.
- Sprinkler inspection to ensure adequate coverage.

Irrigation operations on the forage/ornamental areas should be limited to times from the very early morning, say 0400 hours to late afternoon or early evening say no later than 2000 hours. This assures that the crop is irrigated during or near daytime hours and this minimizes the potential for plant diseases to impact the turf crop. Turf and other grass crops are susceptible to fungal infections if irrigated extensively during nighttime hours. The irrigation operations must be scheduled primarily during daytime or near daytime hours. Irrigation in the late evening followed by long periods of dark is not a recommended reuse practice.

7.2.3 Forage/Ornamental Harvesting

The forage system (all species) should produce a yield of 3 to 8 tons/ac/yr provided nutrient loadings, fertilization, and irrigation are provided. The grass can be harvested and baled into either square or round bales or mowed and bagged on a more regular basis. All species should be harvested prior to seed head development. If the grass is baled, multiple cuttings of all species are possible during a typical growing season. If the grass is mowed on a more periodic basis, clippings should be bagged and removed. Mowing on the fields should be done with low ground pressure equipment when the soil is dry or cannot be compacted. No harvesting of ornamental species is required for aesthetic reasons and since they comprise a small portion of the forage/ornamental system. If desired and allowable, ornamentals can be grown within the existing power utility right of way and designated as a nursery for supplying stock to the grounds of the development when necessary.

7.3 Natural Forest System Establishment, Management, and Harvesting

7.3.1 Natural Forest System Establishment

Existing natural forest stands will be utilized for approximately three quarters of the reuse water application system. The existing cover consists of a mixture of mature, 40-60 year-old pine/hardwood stands, 100+ year-old oak ridges and hill tops, as well as predominantly mature pine stands 40-60 years-old (Appendix A – Figure 3) .

7.3.2 Natural Forest System Management

Forest systems used for reuse water application require little maintenance as compared with forage systems. However, periodic inspection for disease and impacts from natural disasters is important to ensure the success of natural forest systems. Early identification of these problems is important to minimize the effects on the system and maximize forest yield.

Periodic maintenance of the irrigation infrastructure is needed for a forested land application system. It should be noted that any equipment trafficking during this maintenance should **only** take place when the irrigation site is **adequately drained**.

Equipment traffic on saturated soils may cause rutting, increase surface ponding, and alter hydraulic conductivity of the soil.

Irrigation equipment and infrastructure should also be maintained to ensure proper application of reuse water. Sprinklers should be inspected to ensure adequate coverage and adjusted for areas where ponding and/or surface runoff may occur. Herbaceous plants and vines grow rapidly with reuse water applications and may interfere with stationary sprinkler operation. Sprinklers should be routinely inspected and herbaceous/vine growth should be removed.

7.3.3 Natural Forest Harvesting Recommendations

Predominantly Hardwood Stands

It is recommended that no forestry activities such as precommercial thinning be done on these areas for the next 25-50 years. Trees will be competing among themselves in the understory and there is no point in doing any stocking reduction. These areas are valuable open space areas for the proposed project and harvesting activities should be minimized. The dominant oak tress (*Quercus alba*) are long-lived and will provide long-term, consistent, nutrient and hydraulic assimilation capacity for the reuse land application system.

As the mature oak/mixed hardwood stand begins to deteriorate in the next 25-50 years, the forest can be thinned to allow younger stands to take over the canopy. At year 25, following this thinning, it is recommended another thinning be completed to improve quality, species composition and spacing (access). This thinning could be followed by another thinning at about 35 years. This later thinning is optional but would improve the species composition, quality, and value of the stand. The forest stand could then be clearcut at age 50 or it could be carried on to an older age 60 - 80 years.

Predominantly Pine Stands

Pine stands on these sites should be thinned prior to reuse water application and irrigation infrastructure installation. Depending on the initial spacing (trees/acre) and age class, the initial thinning should be a selective thinning leaving about 150-350 trees/acre as the final crop. These trees can be left until 50 or 60 years to produce large-diameter sawtimber and higher value trees. Hardwoods will regenerate in the understory after the thinning and thus maintain effective water and nutrient assimilation.

Both natural stands and plantations irrigated with reuse water exhibit accelerated growth. Since the primary objective of this land application system is nutrient and water uptake, forest stands should be harvested near growth peak to maximize the nutrient removal capacity and evapotranspiration (ET) of the system.

Hardwood stands are regenerated by coppicing (stump sprouts), so there is no need to replant following initial harvest and site disturbance is minimal. Multiple sprouts will quickly arise from the cut stumps and continue to assimilate nutrients from the reuse water. These multiple sprouts will naturally thin themselves as 1 to 3 stems become dominant from each stump.

Harvesting can be accomplished using standard mechanized equipment such as feller-bunchers and skidders. In some areas, rock outcroppings limit access for equipment. Hand equipment, such as chain saws will be necessary in these areas. Harvesting contractors should be instructed to operate equipment with caution when working around permanent irrigation systems. It is recommended that the irrigation system designer install removable heads and risers to facilitate harvesting operations. Site operators should also allow sufficient time for the reuse water site to dry out prior to trafficking by heavy logging equipment. Soil rutting and soil compaction can occur when the site is not dry. Physical damage to irrigation equipment and soil quality is expensive to repair and easily avoidable.

Forage/Ornamental Land Application System Establishment Summary

Following are recommendations for establishment of a hardwood receiver site plantation at **Briar Chapel**:

- Delineate access corridors for sprinkler system and anticipated maintenance areas.

- Lime and fertilize receiver site to improve early growth and survival of groundcover according to recommendations provided in Table 3 of this report.

- Rip planting areas and disk to improve infiltration and incorporate any surficial organic material, lime, and fertilizer.

- Seed the receiver site with a groundcover consisting of Bermuda grass, tall fescue, gamma grass, dallisgrass and/or annual ryegrass.

- Band-apply a preemergent herbicide to planting areas if necessary to control herbaceous weeds.

- Plant forage species within proposed planting areas shortly after site preparation has been completed in early spring or fall.

- All planting areas should be irrigated immediately following planting and regularly throughout the first two growing seasons (i.e. March 1 through November 30) to ensure initial survival and growth.

Follow up inspection and replanting as necessary (within one year following planting).

Natural Forest **Land Application System Establishment Summary**

Following are recommendations for establishment of a hardwood receiver site plantation at **Briar Chapel**:

- Identify & delineate forested buffer zones vs. irrigated areas.

- Delineate access corridors for sprinkler system and anticipated maintenance areas.

- Clear understory and overstory vegetation from irrigation corridors, chip material, and broadcast mulch within these corridors.

- Maintain a minimum of 10 ft. separation between spray heads and trees/understory vegetation. Spray pressures < 80 psi will not harm or debark trees.

- In select dominant pine stands, thin trees to approximately 150-350 trees/ac. depending on stand size and age.

8.0 Conclusions

Overall, the proposed reuse water receiver site provides a viable option for reuse water remediation on-site at Briar Chapel. The proposed reuse water receiver site is adequate for a combination of forage and tree species systems. Developing both forage and managed, natural pine/hardwood forest land application systems will meet permit requirements for assimilating hydraulic and nutrient loadings from the treatment facility. These systems are also compatible with achieving water quality standards set forth by NCDWQ for Cape Fear River Basin. This combination system will result in the most effective reuse water treatment and assimilation system based on the existing site conditions, hydraulic loading rates, reuse water characteristics, and soil characteristics.

The forested system to be used on the majority of the site will require less maintenance than a forage system. The long term presence of forest cover and reduced vehicle traffic with forest systems will enhance infiltration and other soil characteristics important for renovation of reuse water and recharge of groundwater.

When implemented, the forested land application system will utilize hardwood tree species capable of producing large amounts of biomass and providing favorable soil conditions to enhance adsorption and denitrification of phosphorous and nitrogen respectively. The forage systems will also provide treatment for the reuse water, assimilating nutrients, and providing recreational areas for residents.

As the treated reuse water is irrigated, the trees and vegetation take up the available nutrients contained within the irrigated water. Specifically, these nutrients are nitrogen and phosphorous, which are two of the three basic components in a commercial fertilizer. After the plants use these nutrients for growth, the soil then acts as a filtering device for the remaining nutrients.

The overall success of either tree or forage system depends on the routine operation, maintenance, and optimal performance of the irrigation system. Tree and grass establishment, management, and harvesting should be accomplished by qualified professionals. Routine maintenance should be performed by the certified system operator.

With proper site management, hydraulic and nutrient loading management, the site will serve as a means to treat reuse water and protect surface waters. Site, soil, vegetation, and water quality all combine to support the reuse project proposed. Continuous monitoring of the quality of the reuse water applied to these sites as well as annual soil testing must be performed as an ongoing part of this project. The results of the water quality monitoring must be communicated to the customers involved in this reuse effort as well as regulatory agency personnel responsible for assuring compliance with environmental mandates.

9.0 Environmental Effects

There will be no adverse environmental effects from the implementation of this reuse water system. Site, soil, vegetation, and water quality all combine to support the reuse project proposed. The irrigation water will be high quality and will meet reuse standards. Continuous monitoring of the quality of the reuse water applied as well as annual soil testing combined with adherence to the recommendations in this report will insure these sites are successful.

The use of this reclaimed water will ultimately increase soil fertility and productivity at Briar Chapel and will enhance adjacent wetlands and low lying areas with increased base flow. There will be no adverse impacts to groundwater supplies or surface water supplies.

Based on the anticipated wastewater characteristics, anticipated hydraulic loading rates, and proposed development plans, the forage/ornamental and natural forested systems will provide a long-term solution to the wastewater management system for this project.

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APPENDIX

APPENDIX A

Reuse Water Receiver Site Maps

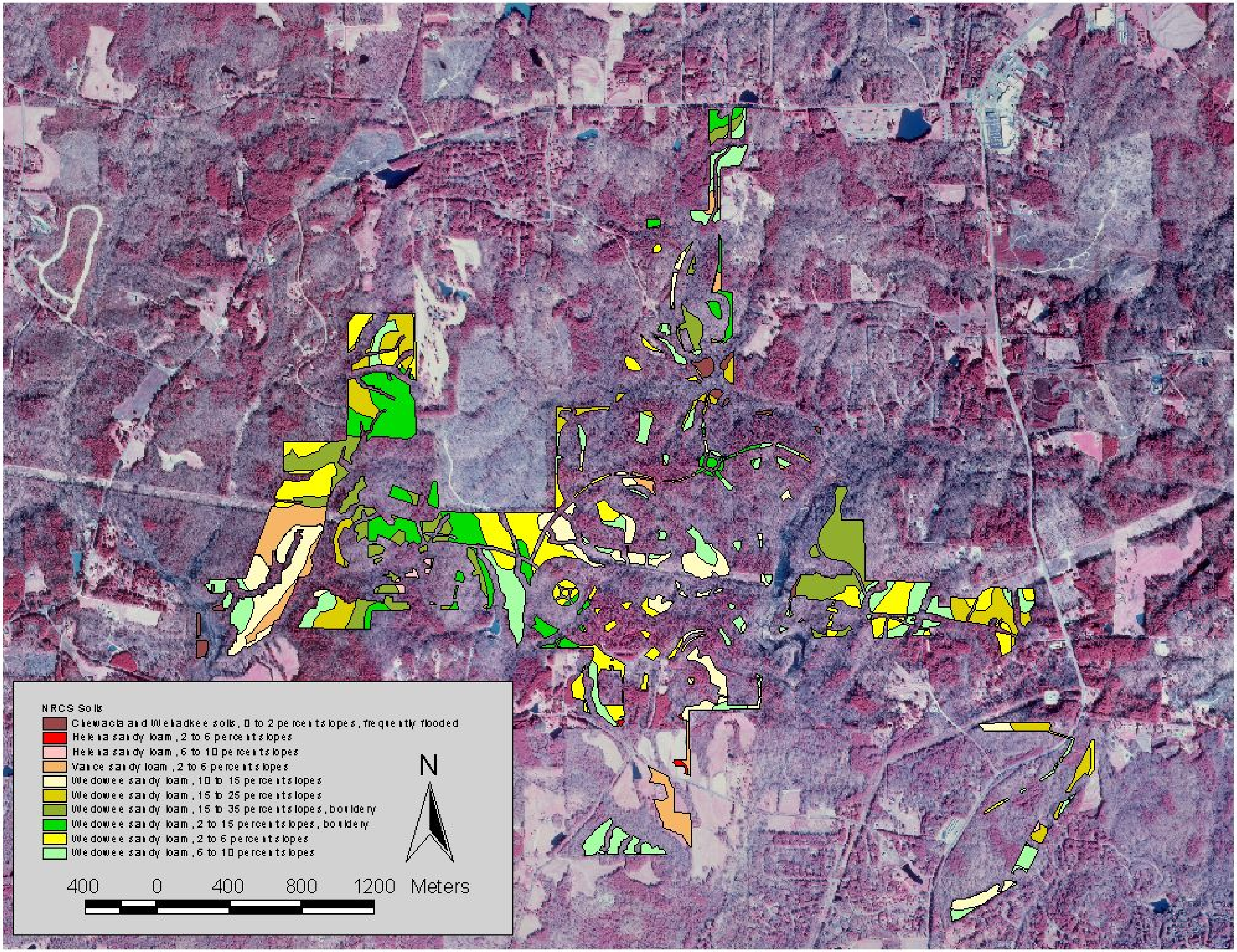

Figure 2: NRCS Soils Mapped at the Briar Chapel Reuse Water Irrigation Receiver sites, Chatham County, NC (USDA, 2003).

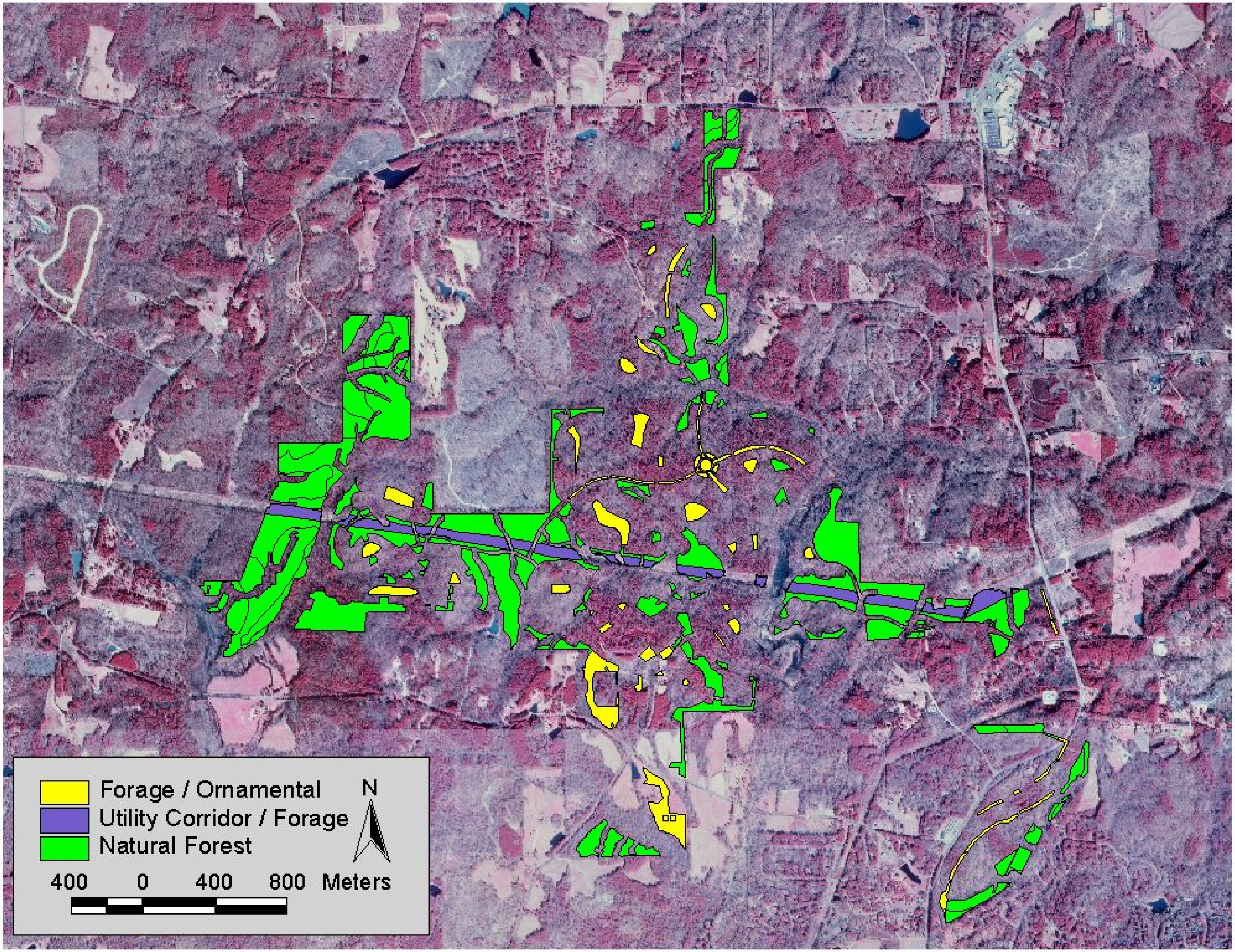

Figure 3: Briar Chapel Reuse Water Facility Receiver Sites Vegetation Plan, Chatham County, NC

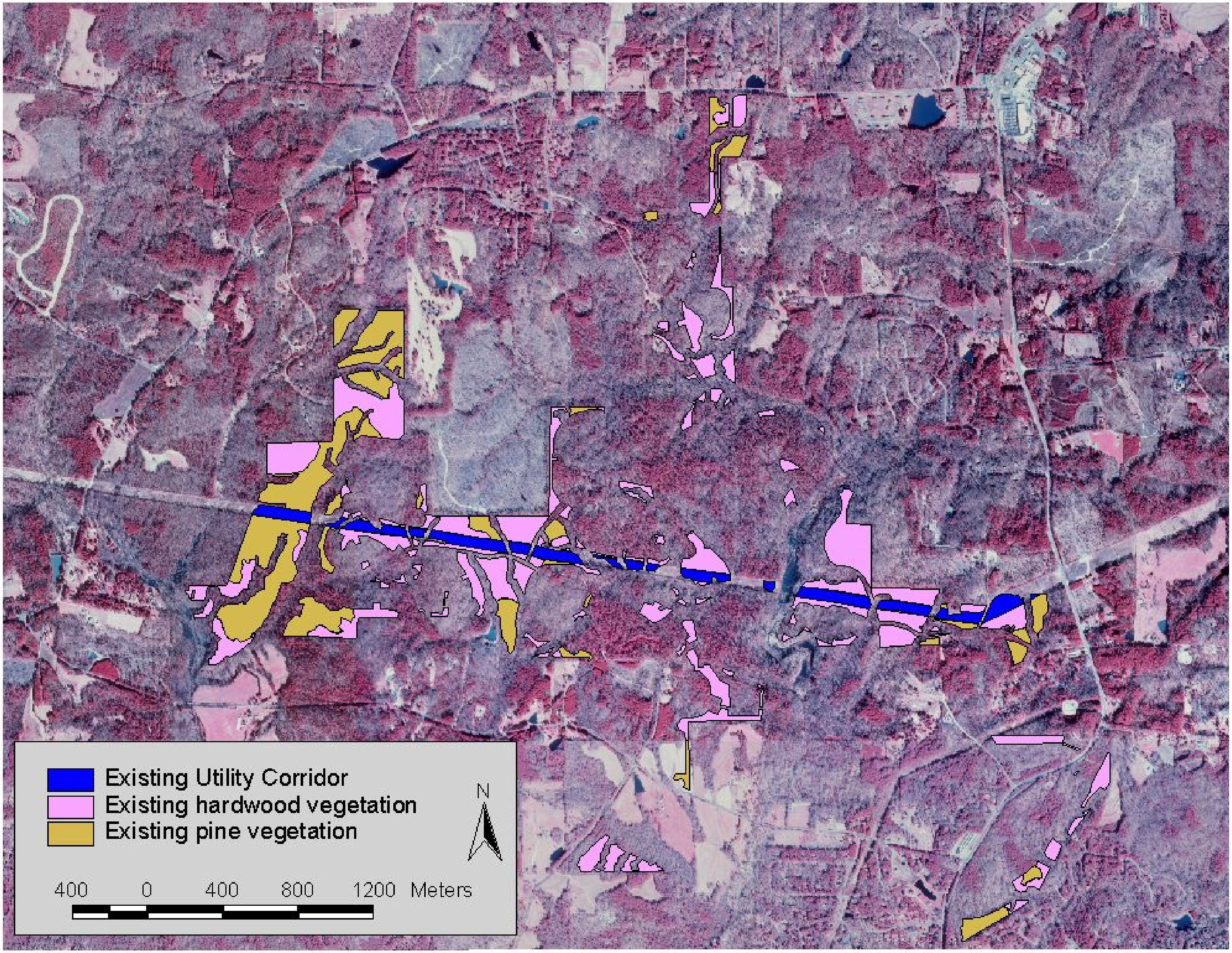

Figure 4: Briar Chapel Reuse Water Facility Receiver Sites Existing Natural Forest Cover Types, Chatham County, NC