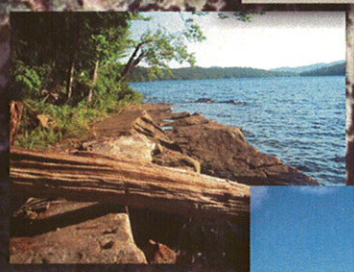
Greenwood Lake Commission
New Jersey/New York

Greenwood Lake Dredging Plan



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HydroQual

Environmental
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The Commission is a bi-state agency created by the state legislatures of New Jersey and New York with the goal of protecting the natural, recreational, scenic resources and economic vitality of Greenwood Lake and its watershed.

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HDR|HydroQual, in conjunction with Gahagan & Bryant Associates, Inc. and EcoLogic, L.L.C., developed the Greenwood Lake Dredging Plan for New Jersey in close coordination with the Greenwood Lake Commission. HDR|HydroQual is a full-service architecture and engineering services firm with offices in New York and New Jersey.

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EXECUTIVE SUMMARY

INTRODUCTION

Greenwood Lake is located in Passaic County, New Jersey and Orange County, New York. The lake is one of the largest lakes within the Highlands region of northern New Jersey. The lake is bounded to the north by the Town of Warwick and Village of Greenwood Lake in New York and to the south by the Township of West Milford in New Jersey. The lake is approximately nine miles long and has a maximum width of approximately 0.7 miles. The lake itself encompasses approximately 1,884 acres and consists of two uniquely different basins. The New York portion of the lake is much deeper than the New Jersey side of the lake with water depths up to approximately 60 feet and steeply sloped banks. In contrast, the southern portion of the lake has a maximum depth of approximately 10 feet and is characterized by gradually sloping banks. The watershed drainage area to the lake is approximately 16,036 acres and approximately 80% is forested with the balance consisting of primarily residential and commercial uses. Several streams also flow into the lake with the largest being Belcher Creek located in the southwestern portion of the lake. The eastern and western limits of the lake are characterized by steep mountain ridges which parallel the lake shoreline.

The lake provides a source of high quality raw water and is the headwaters of the Wanaque River which drains to the Monksville and Wanaque Reservoirs which represent a critical component of the public drinking water supply for a significant portion of northern New Jersey, approximately 3.5 million people. The Wanaque River drainage area, inclusive of Greenwood Lake, and the catchment area specific to the Monksville Reservoir are the primary inflows to this reservoir. As a result, maintenance and improvement of water quality within Greenwood Lake is important to these downstream public water supplies.

WATER QUALITY CHALLENGES

Greenwood Lake was originally a vacation destination, but over the past 50 or more years has evolved into a year-round community. These changes, in conjunction with increased development in the surrounding watershed, have impacted the water quality of the lake due to septic systems originally constructed for seasonal residents, increased runoff and the pollutant loadings associated with these.

Since the mid-1970's, several studies have characterized and quantified pollutant loads and water quality problems within Greenwood Lake. Several actions have been implemented over this period to directly address Greenwood Lake's water quality and resource value problems. Lake drawdowns, weed harvesting, stump reduction efforts, development of new ordinances to address septic system pollution and implementation of several stormwater management initiatives have been undertaken by the Greenwood Lake Commission and other committed stakeholders.

Greenwood Lake was also identified as impaired by the New Jersey Department of Environmental Protection (NJDEP) and New York State Department of Environmental Conservation (NYSDEC), primarily due to nutrients. A Total Maximum Daily Load (TMDL) for phosphorus was prepared by the NJDEP in 2004. The NJDEP indicated that Greenwood Lake

is impaired because it is becoming eutrophic, "as evidenced by elevated total phosphorus, elevated chlorophyll-a, and/or macrophyte (e.g., aquatic vegetation) density that impairs recreational use." As the lake has been listed as impaired for phosphorus, the TMDL was prepared to specify the phosphorus load reductions required to eliminate the impairment and thus restore the Lake's water uses. An integral component of the TMDL is implementation of actions that will reduce pollutant loads to the required levels.

CURRENT STUDY

As part of a larger plan for the improvement of Greenwood Lake originally presented within the Phase I Diagnostic Feasibility Study and Clean Lakes Study completed in the 1980s, several action items were established for future implementation. These were intended to reduce ongoing degradation of water quality within Greenwood Lake and included:

- Upgrade of existing sewage treatment plants (STP) with discharges to the lake or its tributaries;
- Development of septic management districts to monitor existing septic systems and establish improved design specifications for new systems;
- Development of a comprehensive stormwater management plan;
- Implementation of a site plan review committee to evaluate new development within the watershed;
- Increased public education;
- Periodic weed harvesting;
- Periodic lake drawdowns for the management of nuisance aquatic vegetation; and
- Dredging.

Dredging was identified as one of the action items, as it was understood that among the potential sources of nutrients to the lake, and in particular phosphorus, were existing, organic-rich sediments within the lake. The 2004 TMDL noted that recycling of nutrients from these sediments was one of the more significant sources of phosphorus. These nutrients have contributed to the growth of nuisance vegetation within the lake which has impacted recreational opportunities and contributes to the ongoing eutrophication of the lake.

The current study was prepared to develop a proposed conceptual dredging plan for the New Jersey portion of Greenwood Lake. This plan establishes the framework for future work efforts that the Commission may wish to undertake with regard to the dredging of one or more locations within Greenwood Lake. The proposed dredging plan encompasses the following components:

- Identification of potential dredging locations.
- Recommendation of a dredging method appropriate to these sites.

- Determine if post-dredging processing (e.g. dewatering, stabilization, etc.) may be required, if potential locations proximate to the lake are available, and if these possess sufficient acreage.

- Identification of potential disposal or beneficial use alternatives for the management of dredged material.

- Develop an order of magnitude estimate of proposed dredging and the cost for this based upon a proposed dredging depth.

GOALS OF DREDGING

Development of a dredging plan and subsequent dredging of Greenwood Lake would serve to meet several goals of the Greenwood Lake Commission and the surrounding communities, while addressing many of the action items identified within the Clean Lakes Study and recently reiterated in the 2005-2006 Greenwood Lake Commission Progress Report. These include the following:

Nuisance Aquatic Vegetation

Greenwood Lake has had ongoing problems with emergent macrophytes for many years. Nutrients that are already present within the lake or are still being discharged to the lake and its watershed from point (i.e. STPs) or non-point sources (e.g., failing septic systems, stormwater runoff) have contributed to this problem. Prior reports emphasized the preponderance of aquatic macrophytes in the lake's southern region. The abundance of aquatic plants and algae in the lake's southern basin is due to the lake's morphometry and the nature of the substrate. Subsequent monitoring and analysis have confirmed that this region is also close to major inputs of sediment and nutrients needed to support plant growth.

The lake is impacted by several species of aquatic vegetation that affect water quality, aesthetics, navigation and contribute to the ongoing accumulation of organic-rich sediments. Several areas of the lake that have limited water circulation, significant stormwater or other nutrient inputs and/or accumulated organic-rich sediments have ongoing problems with aquatic vegetation. This includes several coves along the shoreline of the lake, several arms or reaches within the northern portions of the lake in New York, and a large area at the southernmost end of the lake that is located in proximity to Belcher Creek. Primary nuisance species of concern within the lake based upon previous studies and discussions with the Commission include Eurasian water-milfoil, Carolina fanwort, Big-leaf pondweed, Fernleaf pondweed and Curly-leaf pondweed.

Dredging can be utilized as a potential method for the management of nuisance aquatic vegetation however there are limitations to this that are dependent upon the specific water body. Aquatic vegetation requires nutrients, but more importantly requires light penetration. Dredging will remove rooted aquatic plants along with sediments. Consequently, dredging can improve the recreational and aesthetic quality of Greenwood Lake. The effectiveness and longevity of dredging as a control measure for aquatic macrophytes, however, depends on several inter-related factors: the extent of dredging and the lake bottom bathymetry after dredging is completed, water clarity and light penetration, the texture and nutrient status of the lake bottom

after dredging is completed, and the nature of the macrophyte community. Implementation of dredging as part of an overall program for the management of aquatic vegetation was therefore one of the primary goals for the dredging.

Nutrient Control

Dredging areas of existing, organic-rich sediments in conjunction with the ongoing efforts of the Greenwood Lake Commission and surrounding communities to reduce pollutant inputs to the lake can serve to reduce potential sinks that contribute to ongoing water quality issues. Removal of these organic-rich sediments from specific areas within the lake was identified as another key goal for the implementation of dredging.

Water Supply and Flood Control

Greenwood Lake drains to the Wanaque River and the Monksville and Wanaque Reservoirs, significant public drinking water supplies for approximately 3.5 million people in northern New Jersey. Water flows from Greenwood Lake and the Wanaque River are the primary sources of inflow to the Monksville Reservoir with the exception of the catchment area of the reservoir itself. Maintenance and improvement of water quality within Greenwood Lake has a direct impact to these downstream reservoirs. Dredging within Greenwood Lake for the improvement of water quality would therefore provide a tangible benefit to these water supplies.

As a result of the largely undeveloped nature of Greenwood Lake's watershed, the lake has historically provided a significant source of high quality raw water that is an important resource to downstream reservoirs. Maintenance and improvement of water quality within Greenwood Lake is therefore of critical importance to these reservoirs. Implementation of dredging within the lake would serve to improve water quality by reducing organic-rich sediments that have been contributing to the ongoing degradation of water quality.

Dredging would also increase the overall storage capacity of Greenwood Lake. Ongoing sedimentation due to stormwater runoff, the accumulation of decaying organic materials (i.e. aquatic weeds) and from other sources have been slowly decreasing overall storage capacity of the lake. In addition to improving water quality, dredging would serve to restore or increase the overall storage capacity of Greenwood Lake. This would provide additional capacity for potential flood control and increase the potential supply of water that could be made available to downstream reservoirs

Likewise, an increase in the storage capacity of the lake would assist in potential flood control and would also result in a potential increase in the availability of high quality raw water for these reservoirs within northern New Jersey. As a result, benefits to existing public water supplies and for potential flood control were also identified as goals that would be achieved by dredging.

Navigation

Greenwood Lake is comprised of two very different subbasins. The New York portion of the lake in general has much deeper waters, while the New Jersey side of the lake is much shallower. In addition, substantial areas of the latter portion of the lake possess large submerged

stump fields that impact navigation. Stump fields and additional locations that have accumulated sediment over time combined with the generally shallower water depths within the New Jersey portion of the lake have presented navigation issues. These areas present challenges to recreational boaters and in some instances result in damage to vessels. In addition, many of these same areas are also impacted by nuisance vegetation which has also adversely affected navigation. The Commission previously was responsible for the reduction of 2,214 stumps in 2006/2007 under a $100,000 grant from the NJDEP. In addition, the federal government has awarded an additional $90,000 in funding for additional stump reduction efforts.

Lake Management

Lake management currently includes lake drawdown activities, but also the maintenance or improvement of recreational opportunities within the lake, such as swimming and improved habitats. The Greenwood Lake Commission and surrounding communities currently conduct periodic drawdowns (approximately every four years) of the lake for the management of aquatic macrophytes and to allow for the maintenance of waterfront structures. The current drawdown is five feet, although investigation of potential future drawdowns of seven feet is being considered. Additional drawdown would potentially result in a further reduction of nuisance aquatic vegetation. Potential obstacles to the efficient drawdown of the lake under current or future operational scenarios, was therefore taken into account as part of the dredging plan.

PROPOSED DREDGING PLAN

Introduction

Based upon a review of available information, an evaluation of potential alternatives, preliminary field investigations and hydrographic surveys, a proposed dredging plan was prepared for Greenwood Lake. The primary goals for the dredging plan were focused upon the reduction of existing nutrients within the lake, the management of nuisance aquatic vegetation, the potential increase in the capacity of the lake for water supply and flood control purposes, improvements in existing navigation and facilitation of ongoing lake management activities.

Dredging Plan Development

A total of six locations were identified and prioritized as candidate dredging sites. These sites were primarily identified based upon existing conditions (e.g., nuisance vegetation) and water depths. Sites were prioritized based upon the overall goal of improving water quality, which would be a benefit to the surrounding communities and would ensure that Greenwood Lake continues to represent a high quality source of raw water for downstream public water supplies. Reduction of organic-rich sediments and nuisance aquatic vegetation were therefore very important in this regard.

- ***Browns Point/Belcher Creek*** area is the primary candidate sites for dredging (Figure ES-1). These areas are known to contain organic-rich sediments, are located within a region of the lake that has previously been identified as a significant source of nutrients, has ongoing aquatic vegetation impacts and navigation issues related to shallow water depths and vegetation. This is also the largest candidate area and dredging would result in a

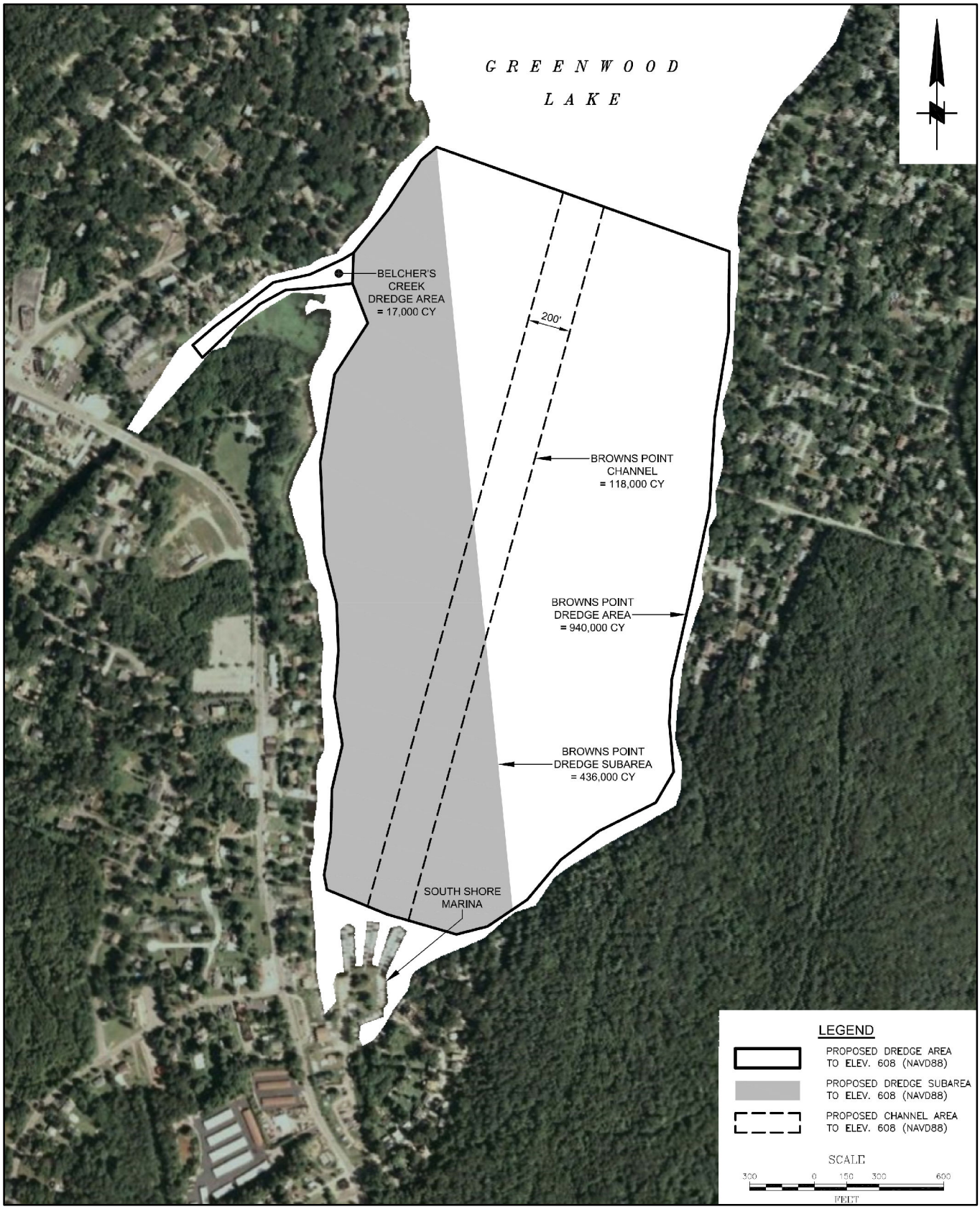

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Figure ES-1 Proposed Dredging Areas
Browns Point and Belcher Creek

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significant increase in the capacity of the lake of up to 193 million gallons (see Table ES-1).

- The ***Outlet Dam*** was ranked second (Figure ES-2). The dam is critical for the control of lake levels during drawdowns and as a result the maintenance of sufficient depths in this area is important. Concerns related to shallow water depths in proximity to the outlet dam were identified due to their potential adverse impact upon drawdown activities. Results of hydrographic surveys generally showed water depths of 6 to 10 feet with some shallower areas closer to the dam that were two to four feet deep. The use of the dam to manage water levels and additional information that boat activity in proximity to the dam is likely higher than the smaller coves along the western shore, resulted in a higher ranking for this location. In addition, benefits associated with the dam, such as lake drawdowns, also benefit the entire lake community. Dredging at this location would also increase lake capacity.

- ***Rocky Cove*** and the ***Unnamed Cove*** south of Greenwood Small Craft Marina represent the next highest ranked sites (Figure ES-2). These locations are also impacted by aquatic vegetation and it is anticipated that this problem has contributed to sediment accumulation and an increase in organic material within these locations from annual weed die offs.

- Dredging of the channels adjacent to ***Fox Island*** (Figure ES-2) and ***Storms Island*** (Figure ES-3) were determined to be the lowest priority of the six candidate areas. Dredging within these areas would primarily be directed towards an improvement in existing navigation depths. Hydrographic surveys generally indicated water depths between six to seven feet. Dredging of these locations would also result in an increase in lake capacity.

Proposed Dredging Depth

An existing and maintained baseline water depth does not currently exist for Greenwood Lake. There is also not necessarily a fixed dredging depth that would result in the complete elimination of aquatic nuisance vegetation. Based upon the results of hydrographic surveys that generally showed water depths that ranged from four to seven feet within the six candidate dredging locations, a depth of 10 feet (as measured from the crest of the outlet dam) was initially identified as the proposed project depth. The 10-foot elevation would correspond to a dredge elevation of 608 feet NAVD88. Refinement of the project depth for individual locations may be warranted as the plan is implemented.

Proposed Dredging

Three dredging methods were evaluated for Greenwood Lake and ***mechanical dredging*** with the use of a clamshell bucket is recommended. This method allows dredging to occur where access may be limited due to water depth or environmental concerns. Mechanical dredging also allows for multiple transportation and rehandling options. Equipment for mechanical dredging would be transported to the sites through the use of a Flexifloat work platform system. Dredged material would be placed into 20-30 cubic yard scows. A conservative estimate for dredged

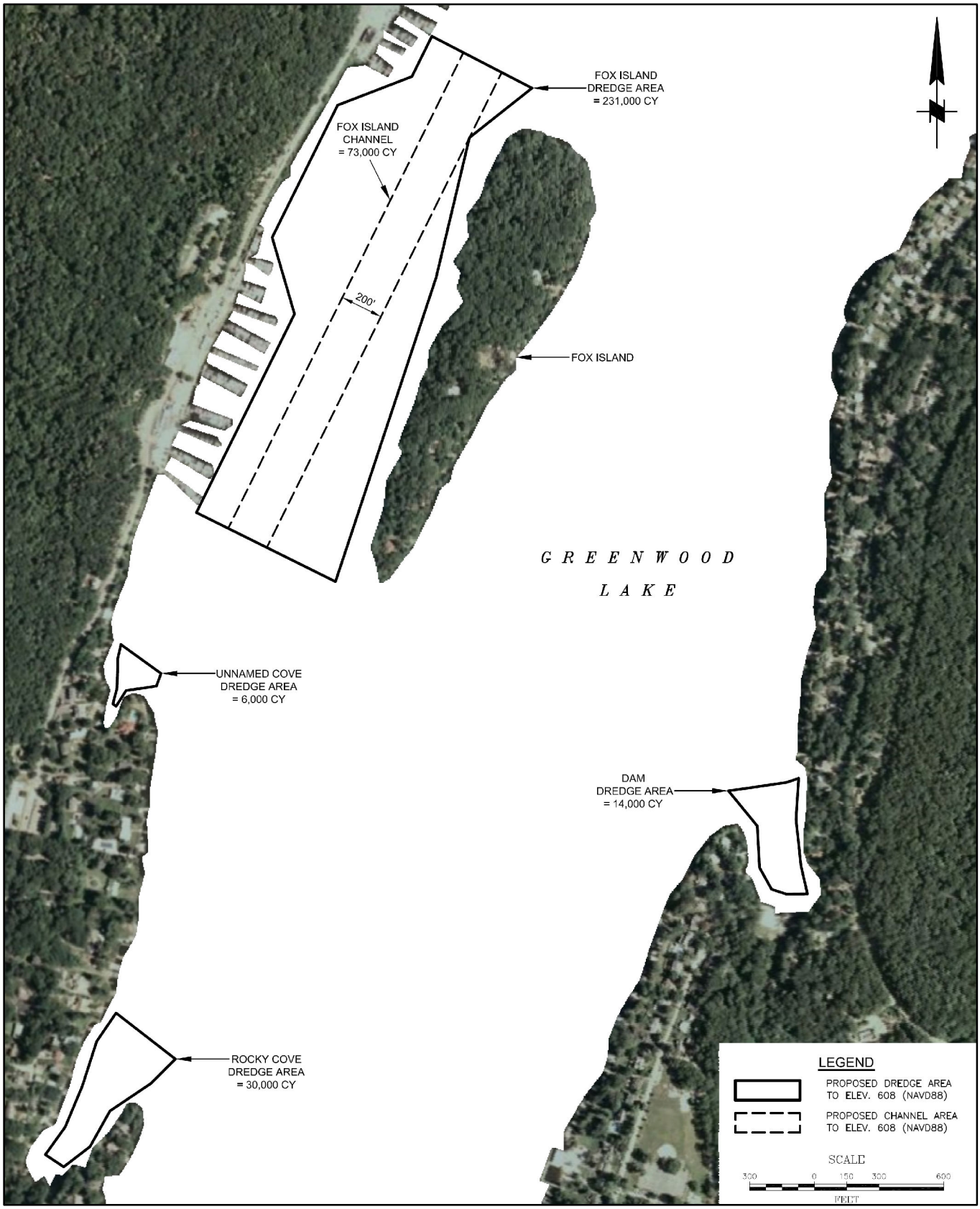

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Figure ES-2 Proposed Dredging Areas
Rocky Cove, Fox Island Channel, Outlet Dam, and Unnamed Cove

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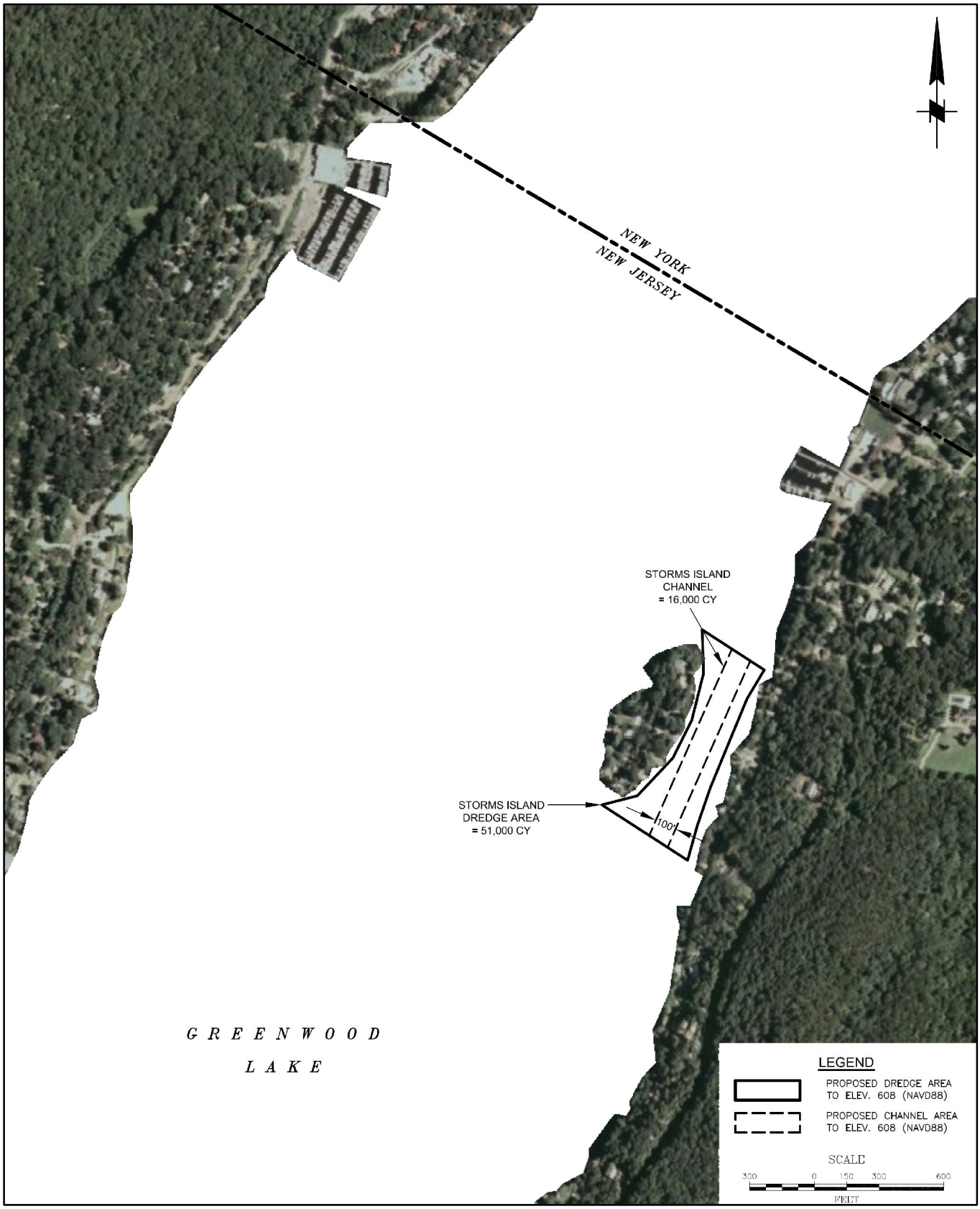

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Figure ES-3 Proposed Dredging Area
Storms Island Channel

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material transloading on a daily basis would be on the order of 500-2,000 cy with an estimate of 1,000 cy considered conservative.

Hydraulic dredging was generally ruled out due to the required transport distances from the point of dredging to a potentially suitable near shore facility. No suitable near shore facility was available. Pipeline handling issues and the costs associated with processing of slurry make-up water would also be prohibitive. The one potential exception to this would be the use of the Tilcon Ringwood Quarry as a near shore location for the placement of dredged materials from the Browns Point and Belcher Creek areas.

Direct transport of material to a location like the quarry would require access to a pipeline route. Safety concerns from pipe breakage in residential or other areas and the potential for lines plugging could result in down time for a contractor. This could potentially put the Commission at risk for claims from the general public or from the contractor. Placement of a pipeline from the Browns Point and Belcher Creek areas could exit the lake at the South Shore Marina and would then travel along the north side of Greenwood Lake Turnpike. A road crossing would be required at Awosting Road and also at Greenwood Lake Turnpike at Burnt Meadow Road where the pipeline would then enter the quarry. The total distance would be approximately three miles. Crossing of six private driveways or roads would also be required along the pipeline route and there is at least one significant change in elevation that would require the use of multiple booster pumps along the route. As a result, although mechanical dredging is recommended, further assessment of hydraulic dredging may be warranted if access to the quarry for the placement of material is arranged and the quantity of material would justify the mobilization costs for a hydraulic dredge and multiple booster pumps.

"Dredging in the dry" was ruled out to due to various concerns and challenges. For "dry dredging" to be successful, the dredging would have to commence during the winter months when the lake's drawdown is greatest and the soft sediments would need to be frozen. There are several site conditions which make dredging in the dry difficult to contract. The bathymetry of the proposed dredging areas shows several deep holes which would make complete dewatering impossible. These areas would be unreachable by this excavation method and would remain undredged. Several dredging sites would also not be expected to be fully exposed during a drawdown and inflows from Belcher Creek would be expected to continue.

Geotechnical reinforcement fingers may also be required based on past experience and the lack of geotechnical data to accurately define substrate conditions. The process of building and removing these fingers would require large amounts of clean fill materials to be moved to the dredging area, stockpiled, moved to additional dredging areas and eventually removed to form these fingers. The additional earthwork required by this methodology could be a significant additional justified cost.

Contracting dredging operations using this method on such a large scale will also cause significant additional justified cost due to the unknown site conditions. It is difficult to provide a contractor with detailed plans and specifications when little is known of the geotechnical properties of the material to be dredged and the substrate. Additional geotechnical investigations could be completed, but may not prove to be cost effective as they cannot guarantee contractor confidence. If geotechnical reinforcement fingers were not required, the contractor would still run the risk of embedding equipment in the sediment which will ultimately lead to equipment

delays (i.e. longer project duration), additional justified costs due to the potential increased risk and a higher potential for change of condition claims.

Working during the winter months with temperatures below freezing could potentially work at some locations assuming all materials are frozen and can be driven on. Predicting the temperatures during the contracting period however is not possible. This contracting approach would still pose risk to the Commission due to the assumed viability of the underlying sediments. Warm temperatures could cause materials to become mobile and driving trucks on the materials would pump sediments and liquefy them making traversing them difficult.

Processing Methods

Based upon preliminary and limited sediment quality data it is assumed that no processing of dredged materials is proposed as part of the plan. Sediments will be mechanically dredged and placed into a scow. When the scow is full, a tug boat will take the scow to a nearby marina or other lakefront location for offloading of the dredged material. Material will be dug out of the scow and transferred to waiting dump trucks, or into roll off containers for temporary material staging. The roll offs can be loaded onto flatbed hauling trucks for transfer or the material can be dug out of the boxes and placed into trucks. This approach minimizes the on-site area requirements for handling of the material.

Based on site reconnaissance and further review of potential waterfront locations, there does not appear to be adequate space for staging or the drying of material at any of the locations considered. Use of the marinas without completely shutting them down for a season and having all boats, docks, and equipment moved would be unacceptable to marina owners. All material will need to be hauled off-site on a daily basis. If materials were allowed to dry naturally, these would need to sit for approximately one year.

Similar to the problems presented above with near shore drying cells, Geotubes would also not be a viable option. The use of Geotubes requires a significant area for storage (approximately two to five acres depending on the quantity of material dredged) and based on site reconnaissance areas of this size will not be available. The lack of storage space and the inability for filled Geotubes to fully dry during winter months when space might be available at a marina facility would also present problems for processing dredge material.

As a result no material processing is recommended as part of the proposed dredging plan.

Staging Area

Several staging locations are available. These include Browns Point Park and all of the major New Jersey marinas with the exception of Greenwood Small Craft Marina. Potential concerns associated with the use of marinas include seasonal issues, the need to temporarily relocate waterfront operations and issues related to truck traffic and safety. As mechanical dredging has been recommended, use of one or more marinas would need to occur during the off-season, probably October to December and/or April to May.

The South Shore Marina and Browns Point Park were selected as the primary staging/transloading locations. South Shore Marina is located close to the proposed primary

dredge sites, several potential end use locations and local roads. The marina provides a location that is easy to access, has deep water launching areas, and a large area where supplies can be stored. One main concern would be how much space at the marina could be allocated to the project. This will be directly related to what season of the year the dredging can occur in. The Commission and the selected contractor would need to work with the marina owner to determine areas available for transloading operations and to determine the best time of year to begin and end the project to limit interference with ongoing marina operations. A conservative estimate is that approximately 1,000 cy of material could be removed per day. If more that 30-60,000 cy of material was to be dredged, dredging may need to occur over more than one season which could result in multiple mobilization/demobilization costs.

Browns Point Park was also identified as a potential staging/transloading site. This location is immediately adjacent to the Belcher Creek and Browns Point areas and Greenwood Lake Turnpike. The site would provide excellent access to the lake for the staging of equipment particularly for dredging equipment and/or the offloading of materials to trucks, although there is only an unimproved road to the waterfront. This road leads to an area of existing waterfront access where the Commission currently launches its weed harvester serving this portion of the lake.

While this location has very good access to Greenwood Lake and in particular the Browns Point and Belcher Creek areas which are considered high priority sites for dredging, the location has several issues that would need to be considered for its use. A portion of Browns Point Park that borders Belcher Creek is mapped as freshwater wetlands by the NJDEP and as a result potential permitting issues or additional restrictions (e.g., transition area requirements) could potentially impact proposed use of the park. Use of the park would also require approval from NJDEP for the temporary use of a Green Acres site. Nevertheless the park would represent a good location for the staging and offloading of dredged materials.

Dredged Material Management

The recommended alternative for dredged material management is direct transfer to truck with materials transported to the Tilcon Ringwood Quarry. This approach provides the most flexibility and ability to manage materials. The quarry is located in close proximity to Greenwood Lake and the major proposed dredging locations and preliminary evaluations of the quarry indicate that it would probably have more than enough capacity for the placement of dredged materials. Potential future use of the quarry, negotiations with the present owner and other factors would need to be considered to advance the site as part of the overall dredging plan.

In addition to the quarry site, the Wallisch Estates site would also be a desirable location for the placement of dredged materials. Use of this site would require the development of a diked/bermed area for the placement of dredged material which may increase the overall cost of dredging. However, this site is very large and is currently under public ownership.

Other locations such as Evergreen Farms and an existing horse farm near Pinecliff Lake also have potential for the placement of dredged materials as these sites are relatively large. As with all potential end use sites, additional site-specific investigations would be required to further evaluate the utility of these locations for the placement of dredged materials. In addition, these

locations are privately-owned and it is likely that both would require some level of clearing to facilitate efficient material placement.

It is also recommended that additional smaller management sites for dredged material and/or potential end users that may only require small portions of these materials be maintained as part of any dredged material management plan.

PLANNING LEVEL COSTS

Dredge volumes were calculated based on a dredge elevation of 608 feet NAVD88 in order to develop an accurate cost. Different scenarios were prepared to provide a range of dredging volumes and associated costs. Table ES-1 provides an estimate of the dredge removal volumes for each suggested footprint and also shows an estimate of the potential increase in water storage capacity in million gallons (MG) that would be gained as part of these efforts.

Table ES-1. Summary of Estimated Dredge Volumes and Potential Additional Lake Storage Capacity Created

Area	Channel Volume (CY)	Capacity Created (MG)	Mass Removal Volume (CY)	Capacity Created (MG)
Browns Point	118,000	23.86	940,000	190.07
Browns Point Subarea*			436,000	88.16
Belcher Creek	17,000	3.44		
Dam Area			14,000	2.83
Rocky Cove			30,000	6.07
Unnamed Cove			6,000	1.21
Fox Island	73,000	14.76	231,000	46.71
Storm Island	16,000	3.24	51,000	10.31
Total	224,000	45.29	1,272,000*	257.20
* Browns Point Subarea not included in total as it is included within Browns Point mass removal estimate				

Dredge volumes were based on achieving a water depth of approximately 10 feet at a normal pool elevation, which was assumed to be at the dam crest elevation. The additional water storage capacity that would be created by dredging represents a conservative estimate. This additional storage would potentially enhance the raw water that could be available to water supply reservoirs downstream of Greenwood Lake.

Costs associated with mechanical dredging, transport, offloading, and placement at the Tilcon Ringwood Quarry are summarized in Table ES-2 below. Only two order of magnitude cost estimates are presented within Table ES-2 for the dredging of a channel and/or mass removal for each candidate site as applicable. In addition, the dredging of a subarea of the Browns Point site is shown in Table ES-3 and Figure ES-1. This location only includes approximately half of the larger Browns Point area (see Table ES-1). This subarea would only encompass a roughly triangular area that would extend from just south of Rocky Cove, to the

South Shore Marina to the mouth of Belcher Creek. This area is a location of known aquatic vegetation and other issues.

Table ES-2. Summary of Estimated Dredging Capital Costs
Candidate Sites

Area	Channel Estimated Cost	Mass Removal Estimated Cost
Browns Point	$ 5,900,000	$ 47,000,000
Belcher Creek	$ 850,000	$ -
Rocky Cove	$ -	$ 1,500,000
Unnamed Cove	$ -	$ 300,000
Dam Area	$ -	$ 700,000
Fox Island	$ 3,650,000	$ 11,550,000
Storm Island	$ 800,000	$ 2,550,000
Total	$ 11,200,000	$ 63,600,000

Table ES-3. Estimated Dredge Volume and Dredging Capital Cost
Browns Point Subarea

Area	Mass Removal Volume (CY)	Estimated Cost
Browns Point Subarea	436,000	$ 21,800,000

Costs estimates were based on $50/cy for mobilization, dredging, transport, placement and a minimum dredging quantity of 20,000 cy. Costs will vary based on market conditions and the size of the project(s). Costs will generally range from $40/cy to $55/cy (including mobilization and demobilization fees). Engineering design, construction management, permitting and sediment testing costs can be expected to range from six to eight percent of the capital costs shown in Table 8-4 for each alternative(s) that was advanced. These costs would be in addition to the capital costs shown in Table ES-2 and Table ES-3.

Implementation of all or portions of the dredging plan could be advanced in stages if this is desirable from a budgeting or scheduling perspective. Capital costs however, would be affected if multiple mobilizations/demobilizations are required, if the Commission decides to dredge all areas or if multi-season dredging may be required for a variety of reasons.

Likewise dependent upon the physical and chemical characteristics of the dredged material, some material may be suitable for sale as a soil amendment or similar beneficial use. The sale of this material to public or commercial users would provide a source of funds that would serve to defray the overall cost of dredging. It is however, unlikely that these funds would substantially impact the overall cost of the dredging plan.

PROPOSED DREDGING PLAN SUMMARY

In summary, the proposed dredging plan for Greenwood Lake would involve the dredging of up to six initial candidate sites. Browns Point and Belcher Creek would be recommended for initial action and in particular the Browns Point subarea (Figure ES-1). These

areas would meet several objectives for proposed dredging. These include the dredging of an area that is adjacent to a portion of the lake that has been shown to contribute the highest levels of phosphorus input from stormwater. In addition, dredging within this area would remove nutrient-rich sediments and would occur within an area known to have recurring issues with nuisance aquatic vegetation. Dredging of this area would therefore improve water quality which would be a benefit to the lake community, but also to downstream water supply reservoirs that have historically relied upon Greenwood Lake as a source of high quality raw water. These areas also represent the largest areas of dredging proposed within the New Jersey portion of the lake. This would therefore result in a potential increase of up to 193 million gallons (MG) of water storage capacity which would also represent another benefit to the Monksville and Wanaque Reservoirs. Finally, initial dredging of this area would also serve to improve navigation through an increase in water depths and the near term removal of nuisance vegetation.

It is recommended that proposed dredging be accomplished through the use of mechanical dredging. Excavators on Flexifloat platforms would be the recommended approach. Ease of access to all areas of the lake with limited impacts to existing lake uses and waterfront businesses would be the primary benefit of this approach. Dredged material would be placed in scows and then transported to a lakefront offloading area for direct transfer to trucks or roll off containers. While the use of hydraulic dredging may be possible for the Browns Point and Belcher Creek areas of the lake if a nearby placement site is identified, this is not the currently recommended approach. Likewise, dredging in the dry was also not recommended due to the significant uncertainty associated with subsurface conditions within the lake, the need for significant freezing of these sediments during lake drawdown activities which cannot be assured and the potential need and cost associated with temporary fills that may be required to make this alterative more viable. All of these represent significant risks that contractors would incorporate into their costs for the proposed work and/or would potentially expose the Commission to contractor claims.

It is recommended that dredged materials be offloaded directly to trucks or roll off containers at either the South Shore Marina and/or Browns Point Park. No processing of these materials is recommended. Both of these locations are located in immediate proximity to the largest candidate dredge locations (Browns Point and Belcher Creek) and are also closest to the two recommended dredge management locations, the Tilcon Ringwood Quarry and Wallisch Estates. Materials would be transported directly to one or both of these sites as part of the plan

FUTURE ACTIONS

Implementation of a dredging plan for Greenwood Lake would only represent one component of the overall plan for the continued improvement of water quality. The continuation of prior programs and initiatives implemented over the past 20 years by the Commission and other lake stakeholders, as well as the implementation of current and future proposed actions must be continued as part of an overall integrative management plan for the lake.

Existing programs that should be implemented, continued and/or expanded, as applicable, include the following:

- Continued weed harvesting;

- Periodic lake drawdown for weed management and maintenance activities;
- Continued wastewater treatment plant improvements;
- Stormwater management and retrofit programs;
- Completion of the stump reduction program;
- Septic management plans and ordinances;
- Ongoing and future enforcement of current and future ordinances; and
- Ongoing education and outreach programs.

The continued implementation of these programs and initiatives in conjunction with the dredging of selected portions of the lake to improve water quality, remove nutrient-rich sediment, reduce aquatic nuisance vegetation and increase overall storage capacity will continue the improvement of Greenwood Lake. Improved water quality will benefit the surrounding communities, increase the attractiveness of the lake as a destination for water-based recreation, increase economic activity within the surrounding villages and towns, and ensure that Greenwood Lake continues to represent a high quality source of raw water for downstream public water supply systems.

SECTION 1

INTRODUCTION

1.1 OVERVIEW OF GREENWOOD LAKE

1.1.1 Lake History

Greenwood Lake (Figure 1-1) was originally known as Long Pond and was acquired from the Minsis subtribe of the Lenni-Lenape Indians in 1707. Agriculture was the primary activity during the 18th and early 19th century, however, iron mining and forging were also increasingly important with the exploitation of iron ore deposits within the surrounding areas. During the Revolutionary War, the Greenwood Lake valley was considered an important industrial center with the Towns of Warwick and Pompton Plains serving as the major population centers. A dam was constructed as early as 1765 to support the sawmills, forges and grist mills within the region, but in 1836 a more substantial dam was constructed near the Wanaque River on the southeastern portion of the lake. This dam was initially developed in order to provide water to the Morris and Essex Canal. Construction of the dam resulted in an increase in the elevation of the lake by 12 feet to the elevation that largely exists today. Construction of the dam also resulted in the flooding of previous upland areas within this area and this is the primary source for many of the tree stump fields that are currently located within the New Jersey portion of the lake south of Storms Island.

Figure 1-1. Greenwood Lake around 1845 by Cropsey.

With the increased elevation and extent of the lake, the surrounding area became much more attractive as a tourist destination for people from the more urban areas to the south and southeast. During the 19th century, Greenwood Lake became recognized as an attractive vacation spot, particularly for residents of New York City. With this increasing popularity, many hotels and seasonal cottages were developed in close proximity to the lake starting in the 1870s. In addition, steamboat and rail transport to the lake was also available. In the 20th century, winter recreation, in addition to the existing summer recreational opportunities at the lake, were common and the area became a year round resort area. As a result of this, the Village of Greenwood Lake in New York eventually incorporated in 1924. The popularity of this area as

a recreational destination continued until about the 1940s when the tourist trade began to decline. Although it had occurred prior to this, it was about this time that much of the previously seasonal housing stock, particularly along the New York side of the lake, were converted into year round residences. These conversions also occurred within the New Jersey portion of the lake, although more year round residences had already historically existed within this area.

Recreation and tourism, however, has continued to be the most important industry for Greenwood Lake and the surrounding area with boating, swimming, water skiing and fishing as ongoing activities. This typically occurs between April and October, but the lake is also utilized during the winter months for ice fishing, snowmobiling and other uses.

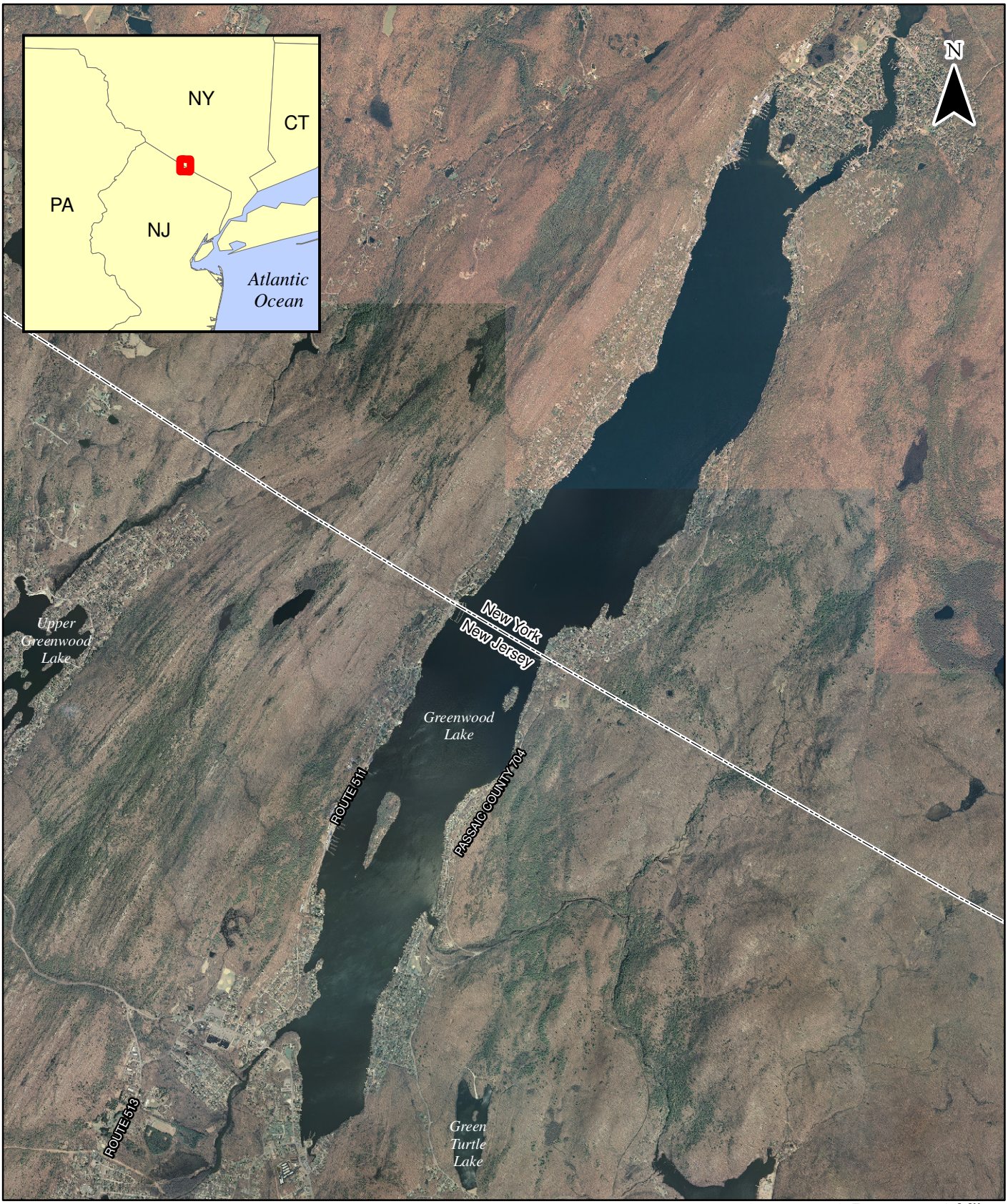
Land uses within the immediate areas surrounding the lake and the larger drainage area today are almost exclusively comprised of residential and park uses. The latter are comprised of several state parks within New Jersey, as well as the Appalachian Trail which is located west of the lake. Additional commercial uses are largely focused within the Village of Greenwood Lake to the north and the Township of West Milford to the south. Approximately 80% of the watershed area is forested.

1.1.2 Physical Characteristics

Greenwood Lake is located in Passaic County, New Jersey and Orange County, New York. The lake is one of the largest lakes within the Highlands region of northern New Jersey (Figure 1-2). The lake is bounded to the north by the Town of Warwick and Village of Greenwood Lake in New York and to the south by the Township of West Milford in New Jersey. The lake is the headwaters of the Wanaque River which drains to the Monksville and Wanaque Reservoirs which make up part of the drinking water supply for a significant portion of northern New Jersey, approximately 3.5 million people. The Wanaque River drainage area, inclusive of Greenwood Lake, and the catchment area specific to the Monksville Reservoir are the primary inflows to this reservoir. As a result, maintenance of the water quality within Greenwood Lake is important to the downstream public water supplies.

The lake is approximately nine miles long and has a maximum width of approximately 0.7 miles. The lake itself encompasses approximately 1,884 acres and consists of two uniquely different basins. The New York portion of the lake is much deeper than the New Jersey side of the lake with water depths up to approximately 60 feet and steeply sloped banks. In contrast, the southern portion of the lake only has a maximum depth of approximately 10 feet and is characterized by gradually sloping banks. The significant difference in characteristics between the two basins can largely be attributed to the fact that the New York portion of the lake is comprised of the original naturally occurring portions of Greenwood Lake, while the New Jersey end of the lake was largely man-made when the dam was constructed in 1836 near the Wanaque River flooding those portions of the lake that were largely located within New Jersey.

The watershed drainage area to the lake is approximately 16,036 acres and as noted previously is comprised of primarily residential and park uses and large forested areas. Several streams also flow into the lake with the largest being Belcher Creek located in the southwestern portion of the lake. The eastern and western boundaries of the lake are characterized by steep mountain ridges which parallel the shoreline of the lake. These have served to largely limit



Base Map Source: New Jersey Geographic Information Network, 2007

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Figure 1-2 Site Location Map

Greenwood Lake Dredging Plan
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development along these shorelines to the areas in close proximity to the lake. Several smaller lakes including Pinecliff Lake, West Milford Lake, Reflection Lake and Capri Lake are also located within the drainage area of the lake and represent the headwaters of Belcher Creek.

1.2 WATER QUALITY CHALLENGES

As stated in the draft Restoration and Protection of the Resources of the Greenwood Lake Watershed in New Jersey report (September 2009) prepared by the Greenwood Lake Commission – "*Historically, Greenwood Lake provided its shoreline and surrounding municipalities with recreational opportunities and economic benefits. Residents and tourists enjoyed swimming, boating, hiking, and the beautiful scenery centering on the Lake. Marinas, restaurants and local beaches routinely attracted sightseers, vacationers and local patrons. The Lake was originally a vacation destination, but over the past 50 years has evolved into a year-round community, this has subsequently impacted the water quality of the Lake as septic systems originally constructed for seasonal residents have had difficulty addressing the constant needs of the community as it currently exists. Likewise, increased development within the immediately surrounding area and the larger watershed that feeds the Lake have imposed additional stresses (e.g., increased runoff and the pollutant loadings associated with this). These pressures have subsequently taken a toll on Greenwood Lake and its water quality.*"

As noted above, the most significant challenges to water quality within Greenwood Lake have been the development of year round communities and the increase in development within the overall drainage area to Greenwood Lake over the past several decades. Very few areas within the immediate drainage area have dedicated and separate sewage collection and wastewater treatment systems. Septic systems represent the overwhelming method for wastewater treatment within the watershed.

Since the mid-1970's, several studies have been completed that have characterized Greenwood Lake and quantified pollutant loads and water quality problems. These studies are summarized in the draft restoration and protection report. In addition, actions have been implemented over this period to directly address Greenwood Lake's water quality and resource value problems. Lake drawdowns, weed harvesting, stump reduction efforts, development of new ordinances to address septic system pollution and implementation of several stormwater management initiatives have been undertaken by the Greenwood Lake Commission and other committed stakeholders.

In addition, the States of New York and New Jersey also created the Greenwood Lake Commission. The Commission was established in 2001 "to help ensure that the natural, scenic, and recreational resources of Greenwood Lake and its watershed are protected from despoliation due to environmental and other threats, so that the pristine beauty of the area will be preserved and maintained for the enjoyment and recreation of present and future generations". The Commission has also served as an official vehicle to do comprehensive planning, to be responsible for projects, and receive funds from public and private sources for the improvement of Greenwood Lake.

In addition, Greenwood Lake has also been identified as impaired by the New Jersey Department of Environmental Protection (NJDEP) and New York State Department of Environmental Conservation (NYSDEC), primarily due to nutrients. A Total Maximum Daily Load (TMDL) for phosphorus was prepared by the NJDEP in 2004. The NJDEP has indicated that Greenwood Lake is impaired because it is becoming eutrophic, "as evidenced by elevated total phosphorus, elevated chlorophyll-a, and/or macrophyte (e.g., aquatic vegetation) density that impairs recreational use." As the lake has been listed as impaired for phosphorus, the TMDL was prepared to specify the phosphorus load reductions required to eliminate the impairment and thus restore the Lake's water uses. An integral component of the TMDL is implementation of actions that will reduce pollutant loads to the required level.

With the establishment of the TMDL, the NJDEP and NYSDEC will be seeking to limit or reduce discharges of phosphorus into Greenwood Lake. This will result in the inclusion of more stringent limits on the discharge of phosphorus to Greenwood Lake from existing or future point sources. Recent draft permits for the renewal of the West Milford Shopping Center STP and the Crescent Park STP operated by the West Milford Municipal Utilities Authority have included requirements for a reduction in the discharge of phosphorus through the implementation of lower permit limits. This, combined with other initiatives that have been put in place or are being actively evaluated, will serve to improve water quality in the future.

1.3 GOALS FOR CURRENT STUDY AND PLAN

As part of the original Request for Proposals for this project, the Greenwood Lake Commission set forth the goals for the current study. Overall it is the intent of this study to advance one of the initiatives set forth within the Clean Lakes Study conducted in the 1980s which recommended dredging as one of several actions intended to address ongoing degradation of water quality within Greenwood Lake. Among the benefits that would be associated with the implementation of dredging would be the removal of organic-rich sediments, an improvement in existing water depths, an increase in the volume of water within the lake and the near-term control of existing emergent macrophyte problems.

The goals of the current study are to develop a proposed conceptual dredging plan for Greenwood Lake. This plan would establish the framework for future work efforts that the Commission may wish to undertake with regard to the dredging of one or more locations within Greenwood Lake. The proposed dredging plan encompasses the following components:

- Identify candidate sites for potential dredging.
- Evaluate and recommend a dredging method appropriate to these sites and/or Greenwood Lake in particular.
- Determine if post-dredging processing (e.g. dewatering, stabilization, etc.) may be required, if potential locations proximate to the lake are available, and if these possess sufficient acreage.
- Identify potential disposal or beneficial use alternatives for the management of dredged material.

- Develop an order of magnitude cost for the dredging of one or more of these areas based upon a proposed dredging depth(s).

These are discussed in greater detail within this report. In addition, other sites and technologies that were evaluated as part of the overall study and the basis for the inclusion or exclusion of these from the recommended plan are also provided within the following sections.

SECTION 2

ASSESSMENT OF POTENTIAL DREDGING SITES

2.1 INTRODUCTION

One of the initial efforts as part of the development of a dredging plan for Greenwood Lake was the identification of potential candidate locations. An assessment of potential sites was focused upon a review of available information pertinent to dredging including site visits and a review of prior studies; the development of general criteria or goals for the identification of sites; and the identification of potential sites for further consideration, as well as areas that would not be evaluated further.

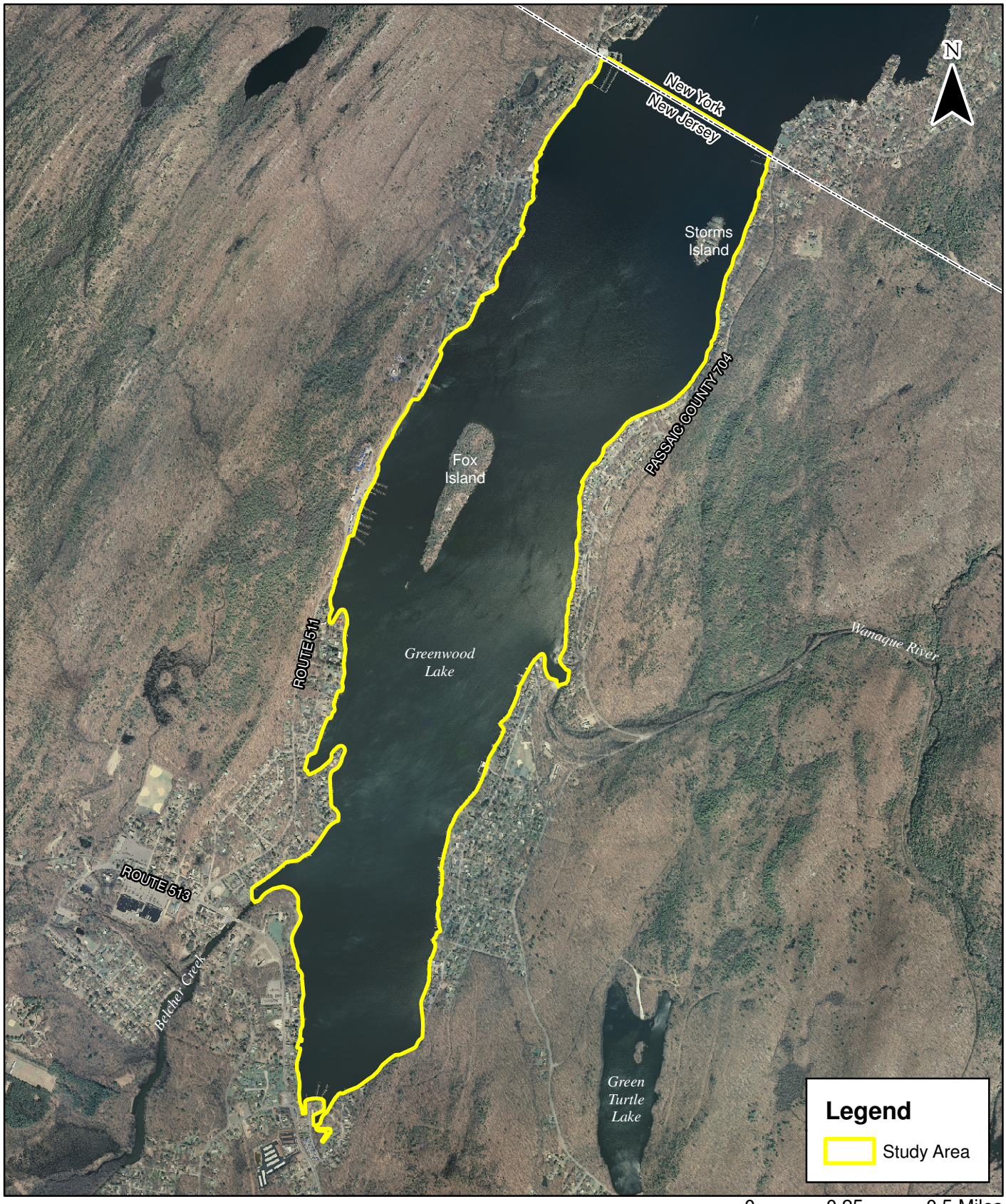
Presented within this section is a discussion of the goals to be addressed by dredging and some of the potential limitations or issues that may be associated with these, those areas of the lake that were excluded from further consideration, and a discussion of those sites that were selected as potential candidates for future dredging and the basis for this selection. In accordance with the requirements of the overall project, the limits of the current study only evaluated potential dredging locations within the New Jersey portions of the lake (Figure 2-1).

2.2 GOALS OF DREDGING

As part of a larger plan for the improvement of Greenwood Lake originally set forth within the Phase I Diagnostic Feasibility Study and Clean Lakes Study completed in the 1980s, several action items were established for future implementation. The action items were intended to reduce ongoing degradation of water quality within Greenwood Lake and/or improve water quality. These included, but were not limited to:

- Upgrade of several existing sewage treatment plants (STP) with discharges to the lake or its tributaries;
- Development of septic management districts to monitor existing septic systems and establish improved design specifications for new systems;
- Development of a comprehensive stormwater management plan;
- Implementation of a site plan review committee to evaluate all new development within the watershed;
- Public education;
- Periodic weed harvesting;
- Periodic lake drawdowns for the management of nuisance aquatic vegetation; and
- Dredging.

Dredging was identified as one of the action items, as it was understood that among the potential sources of nutrients to the lake, and in particular phosphorus, were existing, organic-rich sediments within the lake. As noted within the 2004 TMDL prepared by the NJDEP, recycling of nutrients from these sediments was identified as one of the more significant sources



Base Map Source: New Jersey Geographic Information Network, 2007

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Figure 2-1 Limits of Study Area

Greenwood Lake Dredging Plan
Greenwood Lake Commission

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of phosphorus. These nutrients contribute significantly to the growth of nuisance vegetation within the lake which has impacted recreational opportunities and is also contributing to the ongoing eutrophication of the lake.

In addition, the development of a dredging plan and the subsequent implementation of dredging within Greenwood Lake would serve to meet several goals of the Greenwood Lake Commission and the surrounding communities, while addressing many of the action items identified within the Clean Lakes Study and recently reiterated in the 2005-2006 Greenwood Lake Commission Progress Report. These included the following:

- Control of nuisance vegetation
- Nutrient control or reduction
- Water supply and flood control
- Navigation
- Lake management

A further discussion of these goals is provided within the following subsections.

2.2.1 Nuisance Aquatic Vegetation

Greenwood Lake has had ongoing problems with emergent macrophytes for many years. Nutrients that are already present within the lake or are still being discharged to the lake and its watershed, either from point sources (i.e. STPs) or non-point source (e.g., failing septic systems, stormwater runoff) have contributed to this problem.

Surveys of Greenwood Lake's macrophyte community indicate that the community is composed of emergent, floating-leaved and submergent species. Data from two survey efforts, completed in 1981 and 1992-1995, documented the presence of the invasive *Myriophyllum spicatum* (Eurasian water-milfoil), indicating that this plant has long been present in the lake (Table 2-1). However, its relative abundance has increased; the 1981 survey estimated that Eurasian water-milfoil comprised less than one percent of the biomass, while it was cited as the most abundant plant in the 1990s. The macrophyte *Elodea* was also cited as present in nuisance amounts in the 1990s.

Both the Phase 1 and Phase 2 Diagnostic Feasibility reports for Greenwood Lake emphasized the preponderance of aquatic macrophytes in the lake's southern region. The abundance of aquatic plants and algae in the lake's southern basin is due to the lake's morphometry and the nature of the substrate. Water depth in the southern basin ranges from 1.5 – 2.5 m, while the central and northern basins have only limited areas shallower than 5 m. The maximum depth of macrophyte growth in Greenwood Lake is approximately 5 m. The substrate in the southern basin of Greenwood Lake was characterized as "mucky" in the Phase 1 investigation in the 1980s. Subsequent monitoring and analysis have confirmed that this region is also close to the major inputs of sediment and nutrients needed to support plant growth.

Table 2-1. Comparison of Macrophyte Species Lists for Greenwood Lake 1981 and 1992-1995

List of species (1981 survey)	***List of species (1992-1995 surveys)***
• Abundant: - *Lyngbya latissima* (algae) - *Myriophyllum spicatum* - *Potamogeton robbinsii* - *Potamogeton amplifolius* - *Cabomba caroliniana* • Common: - *Vallisneria americana* - *Ceratophyllum demersum* - *Najas guadalupensis* • Sparse: - *Potamogeton gramineus* - *Sagittaria spp.* - *Elodea spp.* • Present: - *Nuphar advena* - *Najas flexilis* - *Lemna spp.* - *Nitella spp.* (stonewort) - *Pontederia spp.*	• High densities - *Myriophyllum spicatum* - *Potamogeton amplifolius* - *Nymphaea spp.* - *Nuphar advena* - *Cabomba caroliniana* • Some - *Elodea* - *Vallisneria americana* - *Najas flexilis* • Minor/fragments - *Potamogeton crispus* - *Ceratophyllum spp.* - *Spirogyra (green algae)*

The lake is impacted by several species of aquatic vegetation that affect water quality, aesthetics, boat navigation and contribute to the ongoing accumulation of organic-rich sediments. Primary nuisance species of concern within the lake based upon a review of previous documentation (Greenwood Lake Commission Report, August 2006 and Reconnaissance Report – Greenwood Lake and Belcher Creek, New Jersey & New York Clean Lake Study, December 1989) and discussions with the Commission include Eurasian water-milfoil (*Myriophyllum spicatum*), Carolina fanwort (*Cabomba caroliniana*), Big-leaf pondweed (*Potamogeton amplifolius),* Fernleaf pondweed (*Potamogeton robbinsii*) and Curly-leaf pondweed (*Potamogeton crispus*).

Several known areas of the lake that have limited water circulation, significant stormwater or other nutrient inputs and/or have accumulated organic-rich sediments have ongoing problems with aquatic vegetation. This includes several existing coves along the shorelines of the lake, several arms or reaches of the lake within the northern portions of the lake in New York and a large area at the southernmost end of the lake that is located in proximity to Belcher Creek, which has historically been a source of nutrient inputs to the lake from multiple STPs, stormwater and other sources. Implementation of dredging as part of an overall program for the management of aquatic vegetation was therefore one of the primary criteria for the identification of candidate sites.

Dredging can be utilized as a potential method for the management of nuisance aquatic vegetation, however there are limitations to this that are dependent upon the specific water body. Aquatic vegetation requires nutrients, but more importantly requires light penetration. Dredging will remove rooted aquatic plants (macrophytes) along with sediments. Consequently, dredging can improve the recreational and aesthetic quality of Greenwood Lake. The effectiveness and longevity of dredging as a control measure for aquatic macrophytes, however, depends on several inter-related factors: the extent of dredging and the lake bottom bathymetry after dredging is completed, water clarity and light penetration, the texture and nutrient status of the lake bottom after dredging is completed, and the nature of the macrophyte community.

In Greenwood Lake, macrophytes cover most of the littoral zone, defined as the area of the lake where sunlight reaches the lake bottom. Aquatic macrophytes are an important component of lake ecology; rooted plants and algae influence the lake's productivity and biogeochemical cycles. Macrophytes produce food for other organisms and provide habitat areas for insects and fish, and help to stabilize sediments. The productivity, distribution, and species composition of submerged macrophyte communities are affected by a variety of environmental factors such as light, temperature, sediment composition, nutrient status and wave energy.

2.2.2 Nutrient Control

The primary nutrient of concern within Greenwood Lake that has been contributing to the continued degradation of water quality and the eutrophication of the lake is phosphorus. The NJDEP and NYSDEC have recognized the impact of this nutrient to the lake and a TMDL for phosphorus was established in 2004 with the goal of reducing overall total phosphorus discharges to the lake from a variety of sources.

Implementation of a dredging program within selected portions of Greenwood Lake cannot selectively remove areas of phosphorus as this nutrient is ubiquitous within the sediments of the lake or is dissolved within the water column. Dredging areas of existing, organic-rich sediments in conjunction with the ongoing efforts of the Greenwood Lake Commission and surrounding communities to reduce pollutant inputs to the lake, however can serve to reduce potential sinks that contribute to ongoing water quality issues. Removal of these organic-rich sediments from specific areas within the lake was identified as another key goal for the implementation of dredging and the selection of specific locations.

2.2.3 Water Supply and Flood Control

As discussed within Section 1, Greenwood Lake drains to the Wanaque River which subsequently drains to the Monksville and Wanaque Reservoirs, significant drinking water supplies for approximately 3.5 million people in northern New Jersey. Water flows from Greenwood Lake and the Wanaque River are the primary sources of inflow to the Monksville Reservoir with the exception of the catchment of the reservoir area itself. As a direct result the maintenance and improvement of water quality within Greenwood Lake has direct impact to these downstream reservoirs. Dredging of one or more locations within Greenwood Lake for the improvement of water quality would therefore provide a tangible benefit to these water supplies.

The proposed dredging of Greenwood Lake would be a component of the overall plan to improve water quality within the lake. As a result of the largely undeveloped nature of Greenwood Lake's watershed, the lake has historically provided a significant source of high quality raw water that is an important contributor and resource to downstream reservoirs. Maintenance and improvement of water quality within Greenwood Lake is therefore of critical importance to these reservoirs. Implementation of dredging within the lake would serve to improve water quality by reducing organic-rich sediments that have been contributing to the ongoing degradation of water quality within Greenwood Lake.

In addition, the dredging of selected portions of the lake would also increase the overall storage capacity of Greenwood Lake. Ongoing sedimentation due to stormwater runoff, the accumulation of decaying organic materials (i.e. aquatic weeds) and other sources have been slowly decreasing the overall storage capacity of Greenwood Lake. In addition to serving to improve water quality, implementation of dredging would serve to restore or increase the overall storage capacity of Greenwood Lake. This would serve to provide additional capacity for potential flood control and increase supply that could be made available to downstream reservoirs

Likewise, an increase in the storage capacity of the lake would assist in potential flood control and would also result in a potential increase in the availability of high quality raw water for the Monksville and Wanaque Reservoirs that serve a significant population within northern New Jersey. As a result, benefits to existing public water supplies and for potential flood control were also identified as goals that would be achieved by the implementation of dredging within the New Jersey portion of Greenwood Lake.

2.2.4 Navigation

Greenwood Lake is comprised of two very different subbasins. The New York portion of the lake in general has much deeper waters, is characterized by steeply sloped shores and has a bed that is largely comprised of rock, boulder and stone or sand. A substantial portion of the New Jersey side of the lake is much shallower, with more gentle banks and a more silty or muck-like bottom. In addition, there are substantial areas of this portion of the lake that possess large submerged stump fields that impact navigation. The primary reason for the differences between the New Jersey and New York portions of lake is related to creation of the current lake with the construction of a dam in 1836 within the southeastern corner of the lake that resulted in the flooding of formerly upland areas within New Jersey.

Stump fields and additional locations that have accumulated sediment over time combined with the generally shallower water depths within the New Jersey portion of the lake have presented navigation issues within several locations. These areas present challenges to recreational boaters and in some instances result in damage to vessels. In addition, many of these same areas are also impacted by nuisance vegetation which has also adversely affected navigation.

2.2.5 Lake Management

An additional goal for the dredging of Greenwood Lake that was also considered was for overall lake management. Lake management includes lake drawdown activities, but also the maintenance or improvement of recreational opportunities within the lake, such as swimming and improved habitats. The Greenwood Lake Commission and surrounding communities currently conduct periodic drawdowns of the lake for the management of aquatic macrophytes and to also allow for the maintenance of waterfront structures. The current drawdown is five feet, although the stakeholders to the lake have been investigating the potential for future drawdowns of seven feet. Additional drawdown would potentially increase the potential killing of nuisance aquatic vegetation as part of the overall program for the management of vegetation within the lake. Potential obstacles to the efficient drawdown of the lake under current or future operational scenarios, was therefore taken into account as part of the overall effort to identify potential candidate sites for dredging.

2.3 AREAS EXCLUDED FROM FURTHER STUDY

The scope of the current study is limited to an investigation of potential dredging within the New Jersey portion of Greenwood Lake (Figure 2-1). One of the first efforts in evaluating and identifying potential candidate areas for dredging was to identify those locations which for various reasons would not be assessed further. This included an assessment of areas that currently have significant water depths, are not known areas of prior or recent nuisance vegetation and/or are considered sensitive resource areas (e.g., wetlands, fish spawning areas, etc.). Based upon limited field investigations and a review of existing data and maps, little or no wetland areas are located within the New Jersey portion of the lake.

In addition as part of the development of the plan, discussions with the Commission and additional meetings and discussions with the NJDEP occurred to assist in the identification of those areas that would not be considered further for potential dredging.

2.3.1 Sensitive Resource Areas

Stump Fields

As part of previous stump removal efforts within Greenwood Lake that were completed in 2006 and 2007 by the Greenwood Lake Commission, the NJDEP had indicated a concern with the removal of entire stumps due to the habitat value of these areas for fish. As a result, these prior efforts were focused upon stump reduction as opposed to stump removal during the 2006/2007 lake drawdown in order to limit potential impacts to existing fish habitat.

Based upon these prior efforts, discussions with the New Jersey Division of Fish, Game & Wildlife were initiated early in the study to identify potential areas of concern. A meeting with personnel from the Division of Fish, Game & Wildlife occurred on January 27, 2010. Based upon this meeting, no major sensitive areas were identified by Division personnel within Greenwood Lake with the exception of the existing stump fields that are located within the New Jersey portion of the lake, primarily those areas south of Storms Island and in the area of Fox Island. Several stump areas are located within the New Jersey portion of the lake, as well as

additional areas that were addressed as part of the 2006/2007 stump reduction program. A total of 2,214 stumps were reduced under a grant from the NJDEP. These areas represent fish habitat and it was indicated that no dredging activities should occur in proximity to these areas as part of any proposed dredging plan for the lake.

Four main locations of existing stump fields are located within the lake as generally shown on Figure 2-2. Stump fields are located immediately north of Fox Island and also west of Fox Island within Turners Strait. This latter area is located within an area south of Sportsman's Marina and north of Moosehead Marina to the west of the northern half of Fox Island. An additional stump field is located at the southern terminus of Storms Island near the eastern shore of the lake. A final field is located immediately south of Storms Island along the eastern shore of the lake. These four locations are currently scheduled for stump reduction efforts in the future by the Commission. In addition, several areas that were addressed as part of the completed stump reduction program may also need to be discussed further with Division personnel if it is decided that dredging is recommended within these locations. These are located in the areas west and south of Fox Island and in proximity to Browns Point Park.

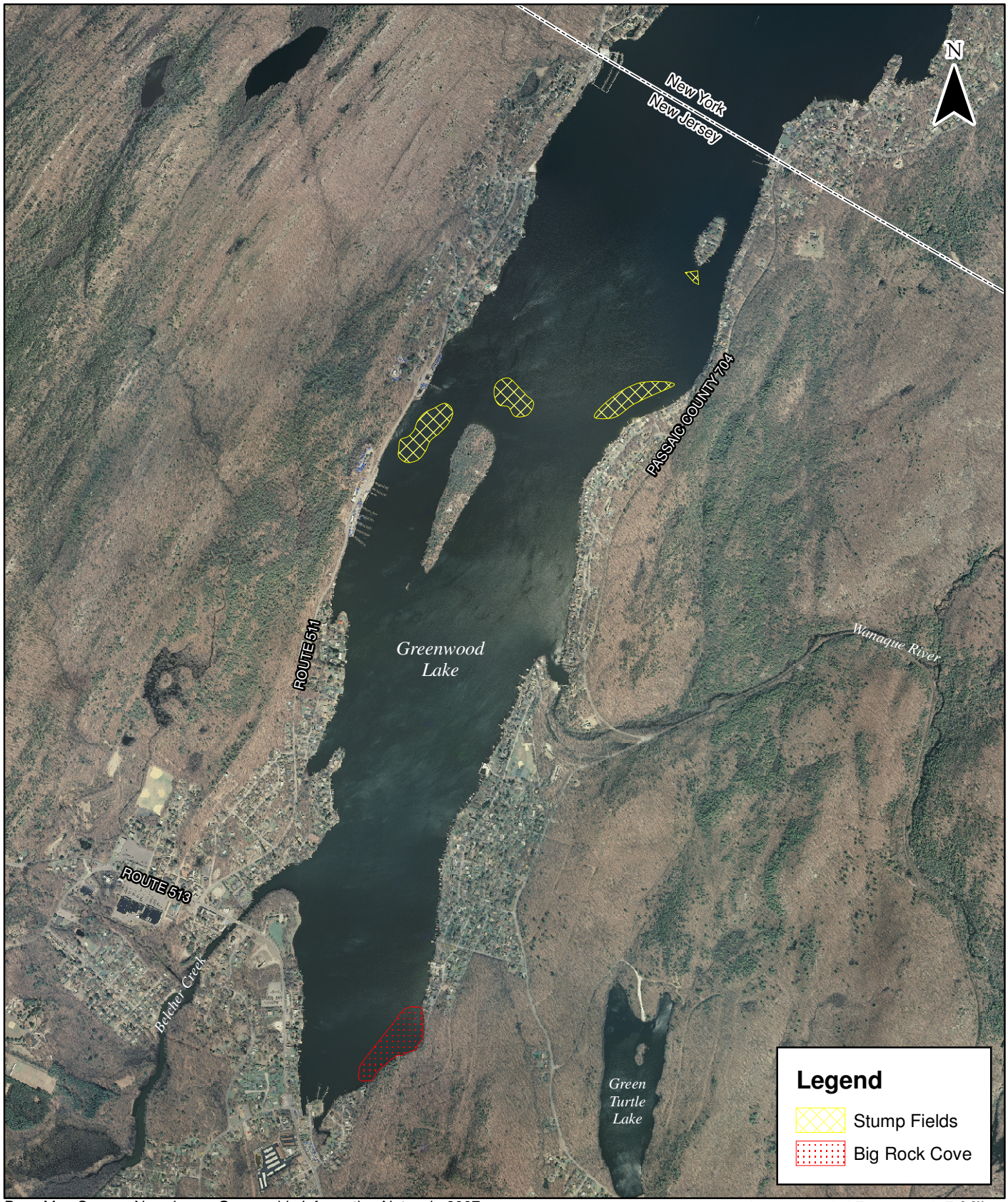
Big Rock Cove

An additional sensitive resource was identified by the Commission, specifically Big Rock Cove (Figure 2-2), which is located adjacent to state land. Big Rock Cove is a small embayment located immediately adjacent to the eastern shore of Greenwood Lake within the southwestern corner of the lake, north of South Shore Marina. This area was identified as a significant fish spawning and/or nursery area of particular importance to recreational fishermen. No further evaluation of this location for potential dredging was therefore conducted.

2.3.2 Other Areas

In addition to those areas that were identified as significant natural resources, several additional areas were eliminated from further consideration for potential dredging as part of the current study effort. As the primary goal of the dredging is to assist in the improvement of water quality through the removal of enriched sediments and the physical removal of nuisance macrophytes, dredging of the entire New Jersey portion of the lake was eliminated. On the one hand the estimated cost for the completion of such an effort would be substantial and would not focus upon the primary goals of the current dredging efforts. In addition, dredging of near shore areas with a few exceptions for known areas of significant nuisance macrophytes and dredging from "shore to shore" was also not advanced further. Potential cost associated with this, as well as potential liability for the Commission related to existing private waterfront structures (e.g., docks, bulkheads, etc.) were considerations that eliminated these areas at this point in time. The future dredging of areas excluded from the current study however, would not preclude the consideration of additional locations in the future.

Likewise a review of the limited existing hydrographic mapping of the lake undertaken by the Corps of Engineers as part of the Reconnaissance Report for Greenwood Lake and Belcher Creek, New York & New Jersey, Clean Lake Study (December 1989) and a soundings map prepared by Boat U.S. Foundation indicated several areas within the New Jersey portion of Greenwood Lake that had more significant water depths than the candidate locations that were



Base Map Source: New Jersey Geographic Information Network, 2007
All locations are approximate.

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Figure 2-2 Sensitive Resource Areas

Greenwood Lake Dredging Plan
Greenwood Lake Commission

ultimately selected. These areas were primarily located south of Storms Island and north of the Awosting Boat House along the eastern shore of the lake, which have existing water depths of approximately eight to nine feet or more, additional areas south of Fox Island and north of Rocky Cove which have depths of six to seven feet, and finally the area north of Fox Island extending from the western shore to approximately the mid-point of the lake that had existing depths of eight feet or more with some areas having depths of 13 to 25 feet.

2.4 CANDIDATE SITES AND RATIONALE

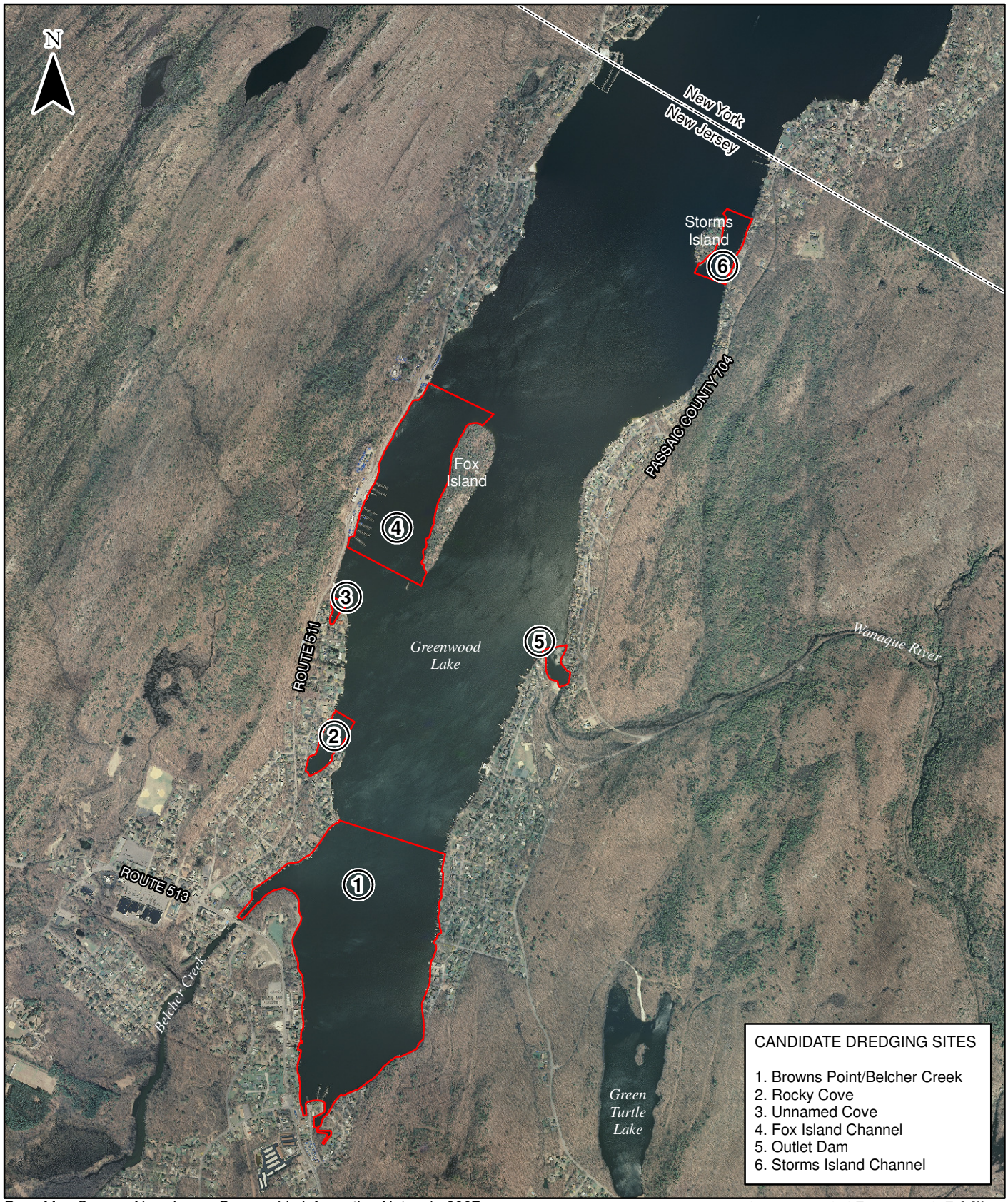
2.4.1 Introduction

Subsequent to the exclusion of specific areas of the study area within Greenwood Lake as previously discussed, the identification of potential locations for consideration was primarily driven by a historic knowledge of the sites and their characteristics. This information was derived from members of the Greenwood Lake Commission and others and a review of selected previous documentation prepared over the past 20 years. Primary issues of concern that were used to identify potential locations were areas with known nuisance vegetation issues, existing shallow water areas with the potential for organic-rich sediments and areas of existing navigation concerns. In addition, a "windshield" survey of these and other locations was also undertaken and hydrographic surveys of the selected locations were subsequently conducted to determine existing water depths. A total of six candidate sites were identified for future consideration and potential dredging. A brief summary of these is presented below and additional hydrographic survey data collected for each location is discussed in Section 7 and survey drawings are provided within Appendix B.

2.4.2 Browns Point/Belcher Creek

Browns Point and Belcher Creek are located at the southernmost portion of Greenwood Lake (Figure 2-3). Surrounding land uses within this area are a mix of residential, commercial (e.g., marina, restaurants, professional offices) and open space (Browns Point Park and state-owned parkland or forest). Based upon discussions with the Commission this is an area that routinely is adversely impacted by nuisance aquatic vegetation during the spring and summer recreational season. Historic water depths within this area are relatively shallow generally less than five feet and recent bathymetry has indicated that current water depths range from five to six feet with shallower depths of approximately three feet along the edges of this area and an average water depth of approximately four feet in proximity to the South Shore Marina. Prior physical testing of sediment samples from this area presented within the Greenwood Lake Water and Sediment Quality Survey prepared for the Corps of Engineers (1988) indicated that samples could not be evaluated for grain size due to amount of organic material present within these sediments.

Belcher Creek is located immediately west of Browns Point Park and extends further south beyond the Greenwood Lake Turnpike overpass. Water depths within Belcher Creek based upon recently completed hydrographic surveys range from 3.5 to 6 feet with depths as shallow as two feet along the edges of the creek. Belcher Creek and the surrounding area have previously been identified as a significant source of total phosphorus to stormwater as noted in



Base Map Source: New Jersey Geographic Information Network, 2007
All locations are approximate.

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Figure 2-3 Areas of Potential Dredging

Greenwood Lake Dredging Plan
Greenwood Lake Commission

GREENWOOD LAKE N.Y. N.J. COMMISSION

the Stormwater Implementation Plan for Greenwood Lake (2006). In addition, prevailing winds at the lake also likely direct sediment within the lake to the southern portion of the lake encompassed by the Browns Point/Belcher Creek area. Based upon the known historic occurrence of significant nuisance vegetation growth within this area and prior observations from the Corps of Engineers, it is expected that the sediments within this area are likely organic-rich due to decaying vegetation within bottom sediments.

As a result an area extending from the southern terminus of the lake to an area generally demarcated by Rocky Cove to the north and approximately Pompton Avenue to the east was identified as a priority site for future dredging. Dredging of this location would remove organic-rich sediments, would increase water depths within the area thereby improving navigation by recreational vessels and would physically remove nuisance vegetation within this location. Based upon a review of water depths, new hydrographic survey data and discussions with the Greenwood Lake Commission, this candidate location would encompass an area of approximately 150 acres of the lake.

2.4.3 Unnamed Cove

A small, unnamed cove is located approximately 0.2 miles south of the Greenwood Small Craft Marina and 0.4 miles north of Rocky Cove (Figure 2-3). It is located along the western shore of Greenwood Lake and encompasses an area of approximately one acre. This area encounters recurring water quality and aesthetic issues associated with nuisance vegetation. Its physical orientation could likewise affect the ability of the cove to flush or circulate, which can result in a net increase in sediment accumulation over time. Due to the recurring nuisance vegetation issues, this location was identified as a candidate site.

2.4.4 Rocky Cove

Rocky Cove is a larger cove located along the western shore of Greenwood Lake south of the unnamed cove discussed above (Figure 2-3). The immediately surrounding area is exclusively residential and the area has also encountered nuisance vegetation on a recurring basis. Based upon the physical orientation of the cove, it is likely that limited circulation of water within the cove occurs which may contribute to these problems. The cove is approximately six acres in size. As nuisance vegetation is a continuing concern within this area, the location was identified as a potential site for future dredging.

2.4.5 Outlet Dam

An existing outlet dam is located along the eastern shore of Greenwood Lake (Figure 2-3). This is the location where Greenwood Lake discharges to the Wanaque River that subsequently drains into the Monksville Reservoir. The area immediately adjacent and south of the dam is a boat access area that is currently used for the launching of small watercraft such as kayaks. Surrounding land uses are primarily residential, although there is an area of undeveloped forest located south of the site along the access road to the dam. Based upon discussions with the Greenwood Lake Commission and a review of the hydrographic surveys conducted as part of this study, an existing shoal or shallow area is located north or west of the dam outlet location.

Water depths in the vicinity of the dam are between 8.5 to 11.5 feet with an average depth of approximately 9.5 feet based upon surveys conducted in May 2010 with some shallower areas closer to the dam that were two to four feet deep.

During lake drawdown efforts that are undertaken to control nuisance vegetation and to allow residents to repair or maintain their waterfront structures, the outlet dam is utilized to control the drawdown process. The current lake drawdown is five feet however, the Commission has been actively investigating a potential increase of the drawdown to seven feet. In order to facilitate existing and future drawdowns, water depths in close proximity to the dam must be maintained at or below these depths. As a result this location was identified as a potential candidate site for dredging. The total area currently under consideration is approximately three acres.

2.4.6 Fox Island Channel

Fox Island Channel is located immediately west of Fox Island, an approximately 17.2 acre island (Figure 2-3). It is within an area that was part of the 500 foot navigation channel proposed by the Corps of Engineers in the 1989 Clean Lakes Study Reconnaissance Report. The primary goal of dredging in this area would be to improve existing navigation. Four active and existing marinas are located either immediately west of this site or in close proximity, specifically the Greenwood Lake, Sportsman's, Moosehead and Greenwood Small Craft marinas. This site is also located within areas that were part of the 2006/2007 stump reduction program that was undertaken. Additional stump fields that were not addressed as part of that effort are also located in close proximity to the channel. The proposed candidate site would encompass the improvement of an existing channel that runs parallel to the island. The entire area west of Fox Island, extending to the existing shoreline and along the entire length of the island would be approximately 56 acres. It is anticipated that the areas of potential dredging would involve a channel in closer proximity to Fox Island. Existing water depths within this area are on the order of six to eight feet based upon recent hydrographic surveys with water depths closer to five feet near the shoreline. Dredging within this area would primarily be focused upon improved navigation and would need to be coordinated with the NJDEP due to existing stump fields.

2.4.7 Storms Island Channel

Storms Island is a small island, approximately 3.6 acres in size that is located along the eastern shore of the lake near the New York and New Jersey border (Figure 2-3). A narrow channel exists between the eastern shore and the island. In addition, floating islands have historically occurred in close proximity to the island and an existing stump field is located immediately south of the island. Floating islands are associated with summer algal blooms and gases from lake sediments that accumulate beneath matted sediment, vegetation and root systems and then float to the surface presenting a potential navigation hazard. Discussions with the Greenwood Lake Commission indicated that shallow water depths within this area were a concern. Field observations did indicate areas of significant erosion from the shoreline areas in the vicinity of the Storms Island Landing. Waters immediately adjacent to the shore were visibly shallow. Surveys conducted in 2010 indicated that water depths within this area ranged from six to seven feet within the channel area to as little as two to three feet along the shoreline. As a

result of the existing shallow waters at this location, an area of approximately eight acres was included as one of the potential dredging areas. This channel would parallel the length of island. Dredging at this location would primarily be to improve navigation and potentially address issues associated with floating islands that have occurred in proximity to the island.

SECTION 3

DREDGING EQUIPMENT AND METHODS

3.1 DREDGING METHODS

Typically once information such as location, access, and depth are known; the dredging equipment as well as the transportation and rehandling methods can be identified. The methods for removal, after careful evaluation of the sediment characterization, and site specific transportation and rehandling of sediments can vary and several different combinations of methods could be used. As proposed dredging at Greenwood Lake would entail the removal of sediment from the lake bottom, there are essentially two types of dredges, which could be used; mechanical and hydraulic, or a combination of the two.

3.1.1 Mechanical Dredging

Mechanical dredging includes clamshell buckets suspended from a crane and/or excavator-type machines with clamshell buckets mounted to a fixed arm. Clamshell buckets suspended from a crane can be used when water access and draft are concerns. They can be used in aquatic areas and wetlands, as well as upland locations. There are a wide variety of crane/clamshell dredges available. The cranes can be separate or directly attached to the hull of a barge. The main feature driving the size of the crane needed is the bucket capacity (i.e. cubic yards (cy)). The capacity for clamshell buckets can range from as small as a few cy to over 35 cy. For the dredging of Greenwood Lake, an excavator or crane would most likely not have a bucket size larger than 2-3 cy. The crane can "walk" onto a Flexifloat barge, which can be placed in the water by a small crane. Flexifloat barges are individual barges than can be assembled on-site to form a barge of the required size.

Similar to crane dredges (i.e. lattice boom), excavator dredges can also be used in areas with limited access and in a wide variety of environments (Figure 3-1). The flexibility of an excavator dredge is limited by the overall size and the length of the hydraulic arm (i.e. boom and stick). Mechanical dredges can also be outfitted with differential or real-time kinematic (RTK) positioning systems to assist with the precision removal of material. Excavators, small cranes and barges can be trucked to a dredge location where water access and draft are limited. The excavator can also be "walked" onto a Flexifloat barge, as discussed above. For the Greenwood Lake project, a Flexifloat assembly of barges might measure 40 feet by 60 feet to support an excavator that weighs approximately 120,000 pounds.

Either dredge system described above would be moved about the lake using a small push boat or tug boat. Typically the small tugs will have a draft of three to four feet.

Dredge material would be placed in small "scows" that would contain the dredged sediment and any water that collects in the bucket during the dredging operations. These small scows would most likely contain no more than 20 or 30 cy of material. Several of these barges would be required to make the dredging operation an efficient operation. The barges would be pushed to a near shore location and offloaded using a crane or an excavator. The offloading

process would involve moving the crane, digging materials from inside the scow and placing the material into a truck, near shore containment area or into roll off containers (similar to large trash bins).

Figure 3-1. Excavator-Mounted Clamshell Bucket.

3.1.2 Hydraulic Dredging

Hydraulic dredging can be used in restricted areas where overhead clearance or site access would limit the use of a traditional crane and scow combination. A small truckable hydraulic dredge can be lifted into an area (Figure 3-2). Hydraulic dredging involves "vacuuming" material from the waterbody bottom and transporting the material as a slurry to the desired processing, treatment, or management location. A hydraulic dredging approach for Greenwood Lake would involve pumping materials to Geotubes staged at a near shore area for dewatering. Slurry transport water may, however, need to be treated prior to discharge back into the lake. Placement within a sewer for treatment, as is done on many similar projects would not be an option for Greenwood Lake due to the lack of available sewers.

Another option for hydraulic dredging would involve pumping slurry material to a temporary tank also at a near shore location, adding polymers to promote dewatering and then pressing the water out of the material. Material would be dewatered using belt filter presses or plate and frame presses.

The main impediments to the use of hydraulic dredging are when debris and underwater growth may be present within the sediment and the need to treat all of the slurry transport water. Hydraulic dredging will many times require treatment of slurry transport water. Hydraulic dredging can result in a need to treat up to five times more water than the volume of material dredged.

Figure 3-2. Hydraulic Dredge Being Lifted into Water.

3.1.3 Dredging "In the Dry"

Discussions with the Greenwood Lake Commission also indicated that past projects have been performed in the dry during lake drawdowns (i.e. winter months). Lake drawdowns occur during the winter months on a periodic basis (typically every four years) and currently involve a five foot drawdown, although the Commission is currently seeking to increase this to seven feet in the future. Past operations during drawdowns have involved stump reduction efforts, waterfront repairs and some limited dredging for marinas and residential areas. Dredging "in the dry" is similar to mechanical dredging, however the lake water level is significantly reduced or even totally removed. "Dry dredging" differs from the two methods mentioned above where digging occurs under the water. In this case, the water level at Greenwood Lake would be significantly lowered by opening a section of the dam to allow water to flow more freely. This

would be followed by an excavator mechanically dredging one or more areas, use of a bulldozer and hauling materials by truck, which is similar to modern day earth removal. The benefits of "dry dredging" are that usually a more complete removal of the desired sediments occurs since the operator of the excavator is able to see the material to be removed since the area is not underwater.

Dredging in the dry however, can create challenges. Based upon discussions with the Commission, past projects at the lake have required the contractor to develop "fingers" of clean fill to track out onto the soft sediment similar to Figure 3-3. This process would require large amounts of materials to be moved around to create the fingers, which would subsequently need to be removed. Placement and removal of temporary fill would add additional time and cost to proposed dredging. If the contractor were to conduct dredging without these fingers, the contractor would run the risk of crossing into soft sediments or materials that are not fully frozen. This approach would run the risk of getting equipment stuck. As subsurface conditions are typically not uniform and the physical nature of these areas would be dependent upon the extent of any freeze, dredging in the dry can present significant challenges and an increased potential for contractor claims.

Figure 3-3. Representative Lake Drawdown Showing Staging on Temporary Fill.

3.2 PROCESSING/DRYING/STABILIZATION

Several different alternatives for the processing of dredged material were examined to determine their suitability for transport to appropriate off-site locations for beneficial reuse. The

technologies were reviewed without regard to their potential cost and the potential presence of contaminants was also not considered. Technologies and processing approaches that were reviewed and evaluated for their potential applicability to dredging within Greenwood Lake included:

- Geotubes
- Near Shore Drying Beds
- Pug Mill Stabilization
- Direct Transfer to off-site Location

A brief summary of these technologies is discussed below:

Geotubes

Geotubes (Figure 3-4) have been used successfully to dewater dredged material for various projects across the country. Geotubes are commonly filled hydraulically (directly from a hydraulic dredge or from a hydraulic unloader). For the Greenwood Lake project, a near shore site would need to be graded to promote drainage toward a sump area (a low point). Geotubes would be laid out side by side. A piping and valve system would need to be laid out to allow the inflow operator to fill the tubes at select locations simultaneously. Once the tubes have been filled and are near a dewatered state (approximately 10 to 20 days), additional Geotubes can be placed on top of the first layer. The stack height depends on the drying time of each tube, as well as the type of fabric used (i.e. the tensile strength of the sewn edge of the fabric) and the mesh size (i.e. the size of openings) of the fabric.

Figure 3-4. Geotubes Being Filled with Dredged Material.

Additional materials/equipment that may be required beyond a typical inflow operation would be extra piping, valves, Geotubes (geotextile fabric), a metering system for polymer injection to promote rapid settlement of solids from water, and labor for valve operations. Once

the Geotubes have been filled and reach maximum percent solids (typical 50 percent solids), they can be cut open and the material excavated and transported. It was assumed that the final destination would accept the geotextile fabric and material as a mixture. Separation of the geotextile from the material would require significant effort to capture each piece. Working in cold temperatures with Geotubes can also cause problems. The problem will be that the material will freeze and not adequately dry out. Figure 3-5 provides a sample sketch of how the Geotubes could be stacked at a nearby shore area at Greenwood Lake. The 15 Geotubes shown can accommodate approximately 30,000 cy of dredged material and would require a space approximately 300 feet by 600 feet (approximately four acres). Figure 3-4 shows the Geotubes being filled with dredged material at a project site.

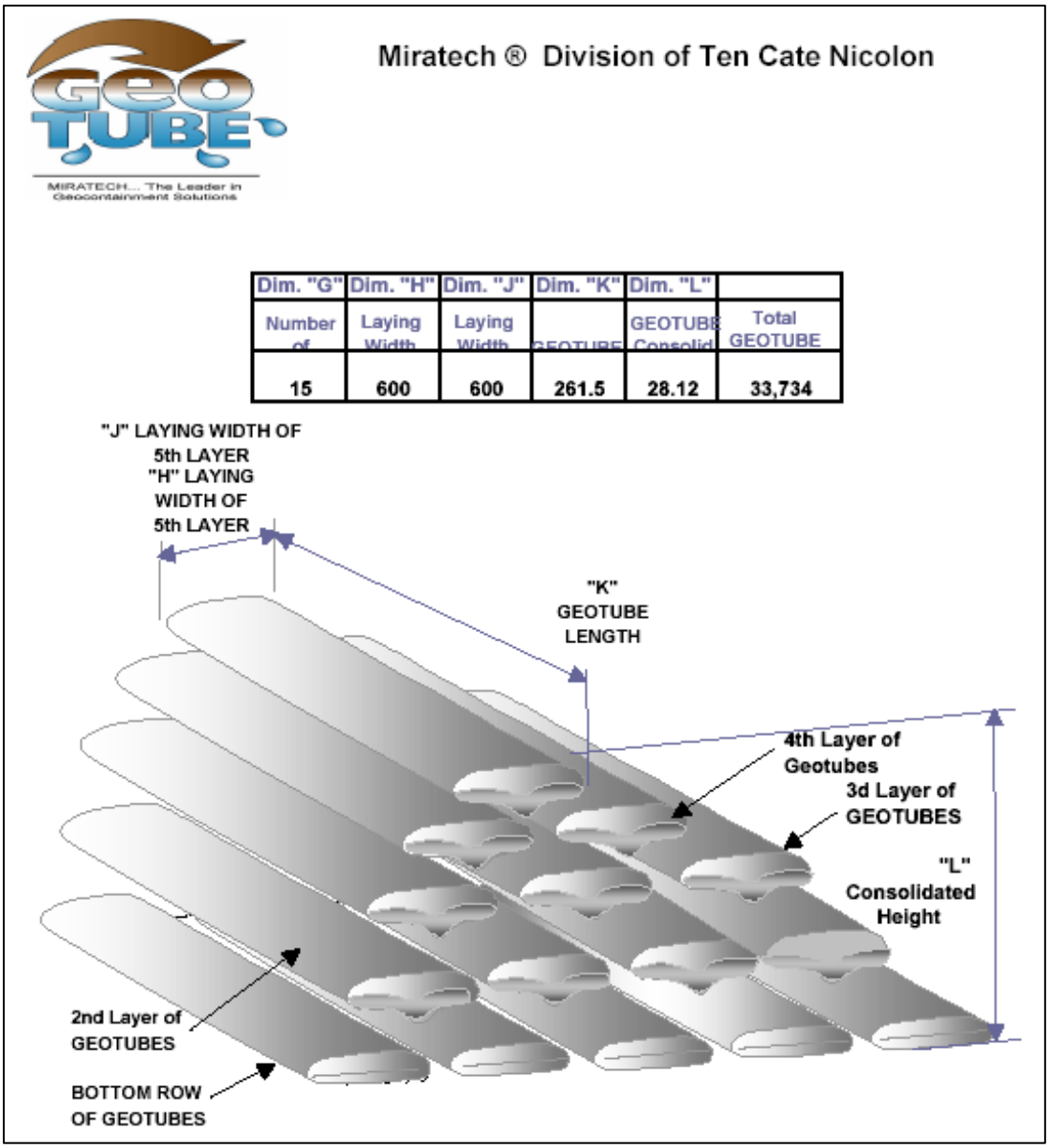

Figure 3-5. Geotube Stacking Diagram.

Near Shore Drying Beds

Development of a near-shore containment facility would be another potential alternative if a location was available. Material would be pumped or loaded into the containment area, allowed to naturally dewater and dry out. Once the material reached a state (i.e. less moisture in the material) where it could be rehandled, the material would be excavated out of the containment area and transported to an off-site location. If feasible, the materials could be left in place and excavated at a later date when more capacity is needed for the next dredging cycle. Based on a review of existing literature and prior experience, it is reasonable to assume that a two-foot lift thickness is the maximum thickness that may be dried in one 12-month season. This alternative, however, would require a significant area that may not be available in close proximity to Greenwood Lake, but perhaps a nearby off-site location could be utilized.

Pug Mill Stabilization

A pug mill operation (Figure 3-6) involves the removal of material mechanically from a barge with an excavator; the material is blended in a hopper on the shore, which is fed dredged material at a continuous rate (from a conveyor or a hopper being fed by a crane). An automatic metering system weighs the dredged material prior to entering the mixing hopper; reagent is added to the material at a pre-determined dosage rate (i.e. 10 percent by weight with lime or Portland cement). Paddles in the mixing hopper blend the material consistently. Processed material is then conveyed to a stockpile where dump trucks are loaded and the material hauled to a final location. These stabilized materials could then be used for construction fill. The addition of cement adds strength to the material. The process however, requires the continuous delivery of the selected reagent that is used to "dry up" or bind the water and strengthen the material. This approach is often used for small volume contaminated sediments. This method may be cost prohibitive for the Greenwood Lake project and the process requires multiple handlings of the material which also adds to the overall cost.

Figure 3-6. Pub Mill Processing Unit.

Direct Transfer to Off-site Location

For this scenario, dredged materials would be barged to a near shore offloading area. The material would be excavated from the barge and directly transferred to trucks or roll off

containers (Figure 3-7). The trucks would be lined or have rubber seals to prevent leakage of soft sediment and water onto roadways. Materials would be placed at the final "holding" location without any intended dewatering processing occurring. One example would be direct offloading to dump trucks and then truck delivery of the materials to the Tilcon Ringwood Quarry or other off-site location for final placement.

Figure 3-7. Material Being Loaded into Dump Truck for Offsite Disposal.

3.3 MATERIAL MANAGEMENT ALTERNATIVES

After any required dewatering or other processing of dredged material has been completed, appropriate disposal, management or beneficial use of dredged materials needs to be considered. Regional disposal alternatives and dredged material management facilities that may be available to accept materials were evaluated as part of the current study. However, it was anticipated that the majority of these facilities would not be in close proximity to Greenwood Lake and as a result the transportation costs would be prohibitive. As a result the Project Team worked with the Commission and other stakeholders to identify potential locations that may be suitable for the management or reuse of these materials. Based upon our current understanding of the proposed project, the review of limited sediment quality data and the nature of the watershed for Greenwood Lake, it is anticipated that much of the material that may be removed would not be contaminated and may therefore be suitable for clean fill, landfill cover, land reclamation purposes and other potential uses. These potential opportunities have been looked into and potential testing (physical or chemical) would need to be completed (See Section 6). Refinement

and selection of potential disposal or end use locations, however, may ultimately require the completion of additional testing or studies that were not anticipated as part of the current study.

3.3.1 Upland Disposal

This approach to material disposal involves the placement of materials at a location beyond the limits of the lake. The ideal location would be a near shore location with several acres (perhaps as much 10 acres) that could be cleared, containment berms developed, and material offloaded into this near shore containment facility (Figure 3-8). This is commonly practiced by the U.S. Army Corps of Engineers (USACE) all over the country. These facilities however, often require lengthy permitting processes and require discharge permits to place runoff back into the surrounding waterbodies. Several potential sites however are located in reasonable proximity to Greenwood Lake and are discussed within Section 4 including Wallisch Estates, a large horse farm located east of Union Valley Road (State Road 513), and Evergreen Farms also located along Union Valley Road.

Another option for upland disposal would involve the transport of dredged material to the existing Tilcon Ringwood Quarry. Minimal site preparation would be required assuming that the existing rock pits were not going to be mined further. Material would be trucked in and dumped. Water in the material would naturally evaporate or percolate into the surrounding soils. Based on initial visual observations, the quarry would likely be able to handle just about any volume of dredge material that would be removed from the lake.

Figure 3-8. Excavator Working at an Upland Disposal Site.

3.3.2 Beneficial Reuse

Beneficial reuse of dredged material typically involves using the material for an environmental enhancement or turning the material into a product that can be marketed and sold. Initial options that were considered for Greenwood Lake included:

- Blending the material with yard compost to develop a material suitable for use by the municipality or residents.

- Hauling material to neighboring farms located in Sussex County, New Jersey and Orange County, New York for use as a soil amendment.

- Use of material by surrounding municipalities, such as the prior use of dredged material from the New York portion of the lake for fill to create new athletic fields.

- Use of the materials for daily cover at local landfills.

All of the proposed options are viable however any one of these would only involve small quantities of dredged material over long durations. Small farms, composting facilities, and landfills will most likely not be able to handle the volume of material that would be dredged from the lake or during a small season (i.e. period of six months). This would limit the end use of the materials. Materials could potentially be staged at a location like the quarry and then retrieved at a later date if it proved to be economical to rehandle the material multiple times.

Beneficial reuse also depends on the material types that would be dredged. Fine-grained materials would be better suited for composting and applications on farm lands, while sand and rock material might be better suited for construction projects. Material types within the lake bed in those locations proposed for dredging would need to be further evaluated at a later date to determine the composition of the material and the suitability of this material to a specific beneficial use.

3.3.3 Land Reclamation

Land reclamation would involve the drying or pug mill processing of dredged materials and transport to a construction site. Dredged material would need to have a large component of sand and gravel content that would support construction load requirements of houses, buildings, highways, etc. Many airports, highways, building sites, and golf courses around the country have been built using dredge materials. Initial review of limited physical data of sediments within the New Jersey portion of the lake have indicated that the dredge material could be expected to contain significant amounts of silts and clays, however a more robust set of data would be required. If it was determined that the bed materials are fine grained (i.e. small particle size and composed of silts, clays, and organic leafy material), these probably would not be suitable for land reclamation/construction projects.

3.3.4 Habitat Creation

Once dewatered, sediment removed from the lake can potentially be used for projects designed to restore or enhance habitat in the Greenwood Lake watershed. The nutrient content, percent organic matter and texture (particle size distribution) will affect how the dredged material can be used. Sediment can be used in riparian areas, along segments of tributary streams and portions of the Greenwood Lake shoreline. Stabilizing eroding stream banks within the watershed, if the physical characteristics of the sediments are suitable (i.e., not fine-grained material), will help reduce the overall transport of sediment and its associated nutrients into the lake. Shoreline stabilization and restoration with plantings of native species can improve riparian habitat conditions, reduce shoreline erosion, and improve overall aesthetic quality. Based upon preliminary field reconnaissance conducted in March 2010, some shoreline areas might be suitable for restoration, such as the access area to Fox Island, were identified.

Upland areas could also benefit from the placement of sediment to meet various stakeholder needs. For example, development of the former Jungle Habitat site into a recreational complex, as cited in the Open Space Greenway and Prioritization Plan (2003), will conceivably require materials for grading and topographic enhancement.

Using dredged material for wetland creation is another alternative to consider. Creating wetlands is a complex endeavor, due to the need to provide a consistent hydrologic regime able to support the wetland vegetation and its associated functions. The dredged material from Greenwood Lake is likely to be favorable for wetland creation, due to its anticipated elevated levels of nutrients and organic matter. In addition, the dredged material will contain seeds and tubers of aquatic vegetation. Creating wetlands or artificial islands within the lake, near the confluence of streams contributing significant loads of nutrients and sediment, may serve as a filter to help trap materials and restore water quality. An engineered system that would allow periodic access for removal of accumulated sediment would help extend the effective period of the overall dredging operation.

For any of these potential habitat enhancement opportunities, additional investigations of the physical and chemical nature of the materials to be dredged would be required and additional investigations of potential sites within or adjacent to the lake and its tributaries or other off-site areas would also be required.

3.4 SUMMARY

Based upon a review of available dredging technologies discussed within this section, the use of mechanical dredging would be most appropriate for application within Greenwood Lake. Mechanical dredging from a barge with the use of scows is recommended. Although hydraulic dredging may be suitable for some areas of the lake where the dredged material can be transported by pipeline, continued challenges related to road crossings and other related issues would need to be addressed. Similarly dredging in the dry would also not be recommended as the preferred approach due to risks associated with the physical characteristics of the sediments during periods of drawdown (i.e. not solid), the potential need for temporary fills, the need for sufficient freezing of subsurface sediments and the higher potential for contractor claims. Discussions with Commission members have indicated previous problems with the use of

excavators within the lake during drawdowns and/or the need for the creation of temporary fills. In addition, recent hydrographic surveys also indicated the presence of deeper pockets within candidate dredging areas which would continue to be under water during a lake drawdown.

Based upon preliminary and limited sediment quality data, it is assumed that the processing of dredged materials would also likely not be recommended primarily due to the lack of suitable near shore areas of sufficient size for site dewatering and other processing technologies. Additional handling of the material as part of the application of these technologies would also be required resulting in increased costs, whereas direct offloading to trucks or roll off containers would allow transport to one or more of the potential end use sites that are in close proximity to the lake.

Direct placement of dredged materials in one or more potential end use sites as discussed within Section 4 would be the preferred approach for the management of dredged materials. This would represent the most cost effective approach for the management of these materials. This in conjunction with the potential use of dredged material for a host of other beneficial uses such as an admixture for yard waste compost, use by local farms or municipalities and habitat creation would be the recommended program for the management of dredged material.