SECTION 6

SEDIMENT SAMPLING REQUIREMENTS

6.1 INTRODUCTION

The proposed dredging of Greenwood Lake would require sampling and analyses of the materials to be dredged. This sampling is required to determine if the material is suitable for disposal or reuse at specific upland disposal or beneficial management locations. The ultimate sampling required would be determined based on consultations with regulatory personnel in New York and/or New Jersey. As the potential end use or disposal locations for removed materials have largely not been identified at this point in time, actual testing requirements would be determined for specific dredging locations and potential end use or disposal sites. Information provided within this section provides an overview of the potential testing required based upon our current understanding of the work efforts.

Sediment quality within Greenwood Lake would be anticipated to not contain significant contamination. This is based upon the nature of existing uses within the larger watershed which consist of primarily residential, some commercial and limited industrial uses. In addition, approximately 80 percent of the watershed area is currently forested. Previous, but limited sampling of sediments within the New York and New Jersey portions of the lake conducted in 1988 for the Corps of Engineers by IEP, Inc. and a single sample collected in 2008 near Rocky Cove in New Jersey did not indicate significant levels of contamination.

Sediment samples were collected in September 1988 from 15 stations located in Greenwood Lake, its tributaries and at other locations in the vicinity of the lake. No PCBs, dieldrin or DDT were detected in any of the samples. Metals were detected in each sample and exceeded the NYSDEC 6 NYCRR Part 375 Environmental Remediation Program Unrestricted Use Soil Cleanup Objectives in eight of the samples. These metals concentrations, however, were not unusually high and in certain instances were only slightly above the objectives. All metals concentrations were below the NJDEP Residential Direct Contact Soil Remediation Standards. The 2008 sample results were all less than the Part 375 Unrestricted Use Soil Cleanup Objectives, as well as the NJDEP Residential Direct Contact Soil Remediation Standards. These results are considered to be consistent with the characteristics of the watershed. It would be expected that additional sampling conducted in support of future dredging and materials managements efforts, as described within this Section, would have comparable results.

Based upon the limits of the current study, proposed dredging, as well as potential access, staging and processing areas, would be located within the boundaries of New Jersey. Various locations for the upland disposal or management of dredged materials, however, could be located in New Jersey or New York. The primary agency that would have jurisdiction over sampling requirements would therefore be the NJDEP since all proposed dredging under the current plan will occur within the State of New Jersey. However, if dredged materials were to be disposed of or used in a beneficial manner in New York, then the NYSDEC would also be involved in the sediment sampling process.

Within this section is a description of the sampling requirements for New York and New Jersey and the necessary analyses that may be required for the further evaluation of alternatives that may be considered by the Greenwood Lake Commission. The sediment sampling guidelines discussed within this section provide a description of the major processes that would be involved for the proposed action. However, exact sampling requirements are determined on a case by case basis and will be dependent upon the alternative disposal or management location(s) that may be selected by the Commission and further discussions that will take place with involved agencies from one or both states as the plan is advanced.

Presented below is a brief discussion of the process to determine sediment sampling requirements. For each involved state agency, the process for developing a sampling plan, sampling requirements, analyses and a discussion of the regulatory limits that the sampling results will be compared to in order to determine the suitability for the specific disposal or management location is provided.

6.2 SEDIMENT SAMPLING REQUIREMENTS

6.2.1 New Jersey Department of Environmental Protection

A pre-application meeting with the NJDEP Division of Land Use Regulation is required prior to the submittal of permit applications, to discuss the proposed project, required permits, sampling and testing protocols and other required information for the alternative(s) chosen. At the pre-application meeting, a project manager from the NJDEP Division of Land Use Regulation will be assigned to the project and will act as the NJDEP point of contact with the Commission. The purposes of the pre-application meeting are to preliminarily identify any potential project impacts and areas of concern, to identify the required permits, to identify the sampling plans needed to properly characterize the sediments to be dredged, to identify any additional information that the NJDEP may require as part of its review process and to develop a plan and tentative schedule for completing data gathering and review activities. Results from the sampling and analysis identified as a result of the pre-application meeting will be used as part of the Acceptable Use Determination (AUD) process, which will determine suitability for the use of the dredged materials at one of the alternative upland disposal locations within New Jersey that may be considered by the Commission. For dredged material that would be disposed of at a landfill, copies of the current facility permits which verify that the site is operating in accordance with applicable rules and regulations and can lawfully accept the dredged material must be provided. The landfill that would be accepting the dredged materials may also have their own sampling and testing requirements that would also have to be met prior to acceptance of the materials.

Prior to a pre-application meeting, the NJDEP Division of Land Use Regulation will require some basic information about the proposed action, including, but not limited to the location of the proposed dredging, a basic site plan containing information about the proposed dredging and a hydrographic survey. The more information that is provided to the NJDEP for review prior to the pre-application meeting, the more familiar the NJDEP will be with the project and the more useful the pre-application meeting will be. The following list provides a summary of the information that will be useful to provide to the NJDEP for review prior to the pre-application meeting:

- The proposed dredging method, project depth and areal extent of the project.
- The location of the proposed disposal or management area, photographs of the disposal or management site and method of transporting material to this area(s).
- For beneficial use options, a description of how the dredged material will be used.
- The estimated volume of dredged material.
- The length of time necessary to conduct the dredging.
- The past history of on-site and adjacent land uses.
- Documented spills – including type, volume and date – either on land or into Greenwood Lake.
- Any additional information about the project that may be useful.

It would also be recommended that a representative from the NJDEP Office of Dredging and Sediment Technology attend the pre-application meeting because of their involvement in the sampling and analysis process. Once the pre-application materials have been received by the NJDEP, they will require at least two to four weeks for review prior to the pre-application meeting.

Once the pre-application meeting has taken place, a sampling plan will be developed based upon the information discussed during the pre-application meeting. The sampling plan will include the number of samples to be collected, the sampling locations and the analyses to be conducted. Based upon the material management alternative selected, the number of samples collected, their locations and the analyses to be performed may vary according to the specifics of each project, however, in general, one core sample will be required for every 8,000 cy of dredged materials. Up to three (3) samples can be composited as long as grain size and composition are similar. Samples will be analyzed for grain size, total organic carbon, percentage moisture and bulk sediment chemistry parameters, which include volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs) and metals. Depending upon the project and/or the upland management alternative selected, the NJDEP may require the analysis of additional or fewer parameters in order to characterize the sediments. The results of the sampling analyses would be compared to the NJDEP Soil Remediation Standards found in N.J.A.C. 7:26D. If the sampling results exceed the Residential Direct Contact Soil Remediation Standards, fewer disposal or management options may be available for the dredged materials; however if the sampling results do not exceed the Residential Direct Contact Soil Remediation Standards, the reuse options available for the management of these materials may be broader.

All sampling would need to be conducted prior to the submission of any permits for the proposed dredging activities. Sampling results would be sent to the NJDEP Division of Land Use Regulation in support of required permit applications, as described in Section 5.

6.2.2 New York State Department of Environmental Conservation

If it is determined that dredged material originating from New Jersey will be placed at a location within New York State, the location accepting the dredged material for disposal or beneficial reuse must demonstrate to the NJDEP that this option has been approved by the NYSDEC. Approval could consist of a letter from the NYSDEC stating that the material is acceptable for beneficial reuse or in the case of disposal at a landfill, copies of the current facility permits which verify that the site is operating in accordance with applicable rules and regulations and can lawfully accept the dredged material must be provided. For dredged materials that would be disposed of at a landfill, the landfill that would be accepting the dredged materials may also have their own sampling and testing requirements that would also have to be met prior to acceptance of the materials.

If the dredged material will be beneficially used, as oppose to disposal, a Beneficial Use Determination (BUD) would be required from the NYSDEC. Prior to NYSDEC approval, sampling and analyses would have to be conducted as part of a BUD process. For the potential reuse of dredged materials, a sampling plan will need to be prepared and provided to the NYSDEC, Division of Solid Waste for approval. This sampling plan will need to include the following information:

- Volume of materials to be dredged;
- Number of proposed samples;
- Location of samples on a map; and
- What analyses will be conducted.

The number of samples required per cubic yard of dredged material is summarized in Table 6-1. At a minimum, each sample would need to be analyzed for the following parameters:

- Volatile organic compounds (VOCs) (EPA Method 8260B)
- Semi-volatile organic compounds (SVOCs) (EPA Method 8270C)
- Pesticides (EPA Method 8081A)
- PCBs (EPA Method 8082)
- Toxic metals (EPA Method 6010B): arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc.

Table 6-1. BUD Sampling Requirements

Number of Cubic Yards	Minimum Number of Samples
Under 5,000	1 for each 1,000 cubic yards
5,000 to 10,000	6
10,000 to 20,000	7
20,000 to 30,000	8
Over 30,000	Contact NYSDEC

The sampling plan would then be sent to the NYSDEC for review and comment. Upon approval of the sampling plan and completion of required sampling, the results would be compared by NYSDEC to the Part 375 Unrestricted Use Soil Cleanup Objectives to determine the suitability of the dredged materials for reuse. If the sampling results are below the Unrestricted Use Soil Cleanup Objectives, the dredged materials could be used for what the NYSDEC refers to as a "generic use" and would no longer be considered solid waste. The dredged material would be usable for a variety of potential material management alternatives. If results of the soil sampling analyses exceed the Unrestricted Use Soil Cleanup Objectives, the NYSDEC would need to be petitioned for the use of the dredged materials at a specific location(s). As part of this petition, a specific end use location would need to be identified. Information for the location that describes how, where and to what depth the dredged materials would be placed; the engineering controls that may be required to contain the contaminants; a description of what type of vegetative, asphalt or other cap would be placed on the dredged materials; and how any potential impacts of the contamination would be contained. The NYSDEC would then review the petition and determine whether the petitioned disposal location would be acceptable to human health standards and a determination would be made. Upon the approval of a site specific BUD, dredged material can be used for the beneficial reuse(s) identified.

6.2.3 Additional Sampling Requirements

In addition to testing requirements that would be required by the NJDEP and NYSDEC, additional analyses may be required by the disposal facility or end user as noted above. As an example, if materials will be disposed within a landfill, many disposal facilities will require the completion of additional testing such as Toxicity Characteristic Leaching Procedures (TCLP) or additional physical testing to demonstrate that the material is suitable for placement within these facilities. Likewise, potential beneficial reuse of these materials under an AUD or BUD may also result in a need for additional testing. Additional testing requirements would be determined based upon the identification of the anticipated disposal or materials management site.

SECTION 7

HYDROGRAPHIC SURVEYS

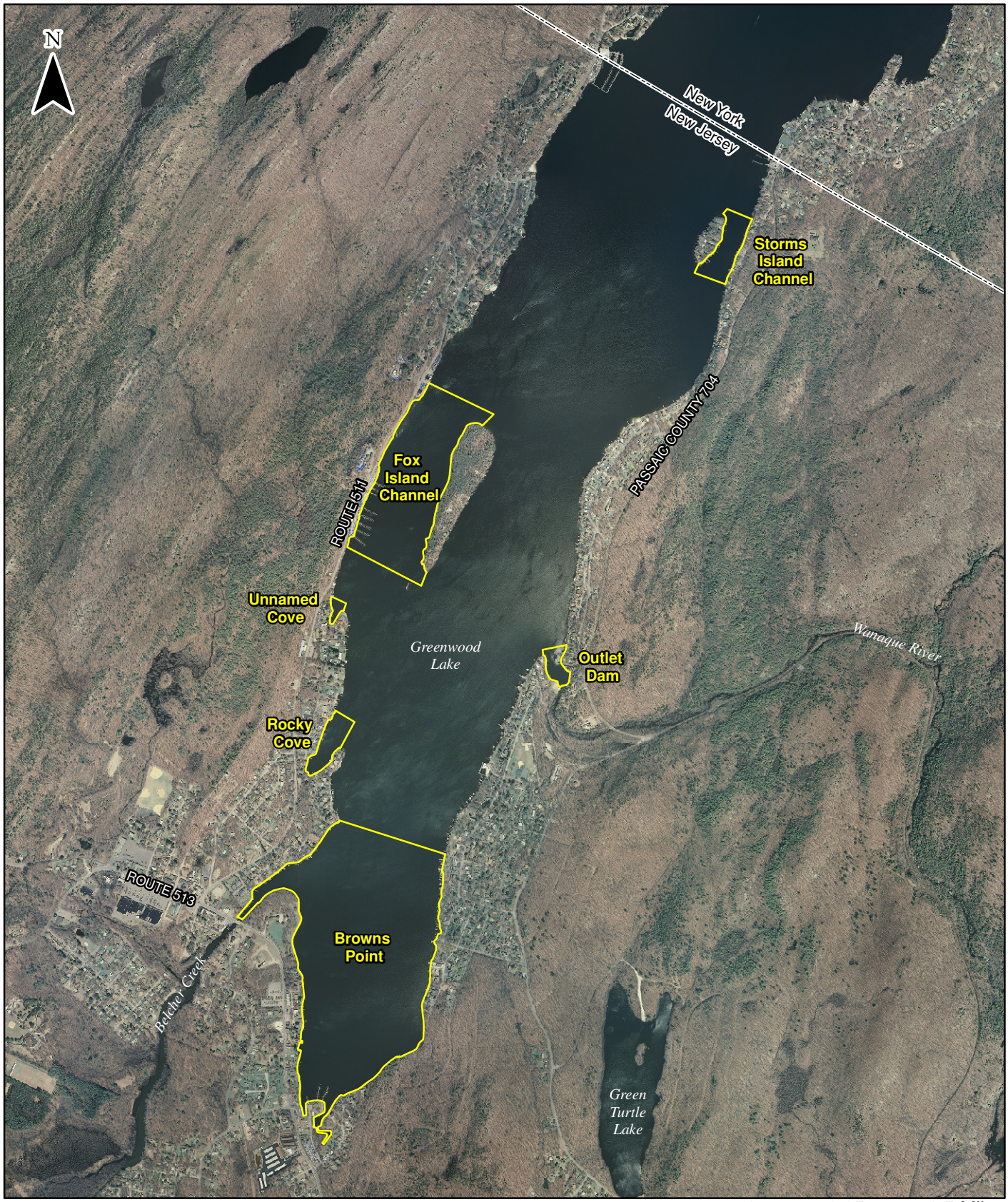
7.1 INTRODUCTION

In order to develop additional information for the development of a dredging plan for Greenwood Lake, limited hydrographic surveys were conducted to develop an understanding of existing water depths and the potential need for dredging at candidate locations. Presented within this section is an overview of the work that was conducted and the results of these surveys. Proposed survey lines are included within Appendix A. Full surveys are provided within Appendix B.

7.2 AREAS OF STUDY

One of the first tasks in developing the dredging plan was to collect, review and evaluate available historical information. This data acquisition effort included searches of existing data and previous site surveys. In addition, time and more site specific efforts were primarily focused on certain candidate areas where the dredging was deemed most likely to occur based upon discussions with the Greenwood Lake Commission and the discussions presented within Section 2. As a result, hydrographic survey efforts were focused upon six general areas which are shown on Figure 7-1 and a more detailed drawing is provided within Appendix A, which illustrates the specific areas that were surveyed. It should be noted that the surveys conducted did not exclude areas that would not be dredged due to sensitive resources (e.g., stump fields) or other reasons. This was primarily due to the method of survey data collection that used a series of fixed survey lines across the areas of interest.

Surveys in these areas were performed at a density (i.e. line spacing) that provided design quality data and would serve as the basis for volume computations. Construction grade surveys are typically spaced at 25 to 50-foot intervals perpendicular to the channel and/or the shoreline depending on the extent of the dredge area. A larger spacing was used for these surveys to cover more area with the limited funds that were available for the surveys. However, this spacing was used to accurately define the thickness of proposed dredging and was used to develop a dredging template (depth/elevation). The dredge template can be developed as a flat (continuous elevation) dredge surface. When the existing mudline elevation is compared to the proposed dredging template, a thickness can be developed. The dredge material thickness multiplied by the areal extent of dredging determines the dredge volume (i.e. 30,000 cy of dredging). These calculations were performed in software where Digital Terrain Models (DTMs) are developed from 3D points/elevations and/or depths. A DTM is a digital representation of ground surface topography. Figure 7-2 represents an example of a DTM image.



Base Map Source: New Jersey Geographic Information Network, 2007

0 0.25 0.5 Miles

HydroQual
1200 MacArthur Boulevard
Mahwah, New Jersey 07430
(201) 529-5151 f:(201) 529-5728

Figure 7-1 Location of Bathymetric Surveys

Greenwood Lake Dredging Plan
Greenwood Lake Commission

GREENWOOD LAKE COMMISSION N.Y. N.J.

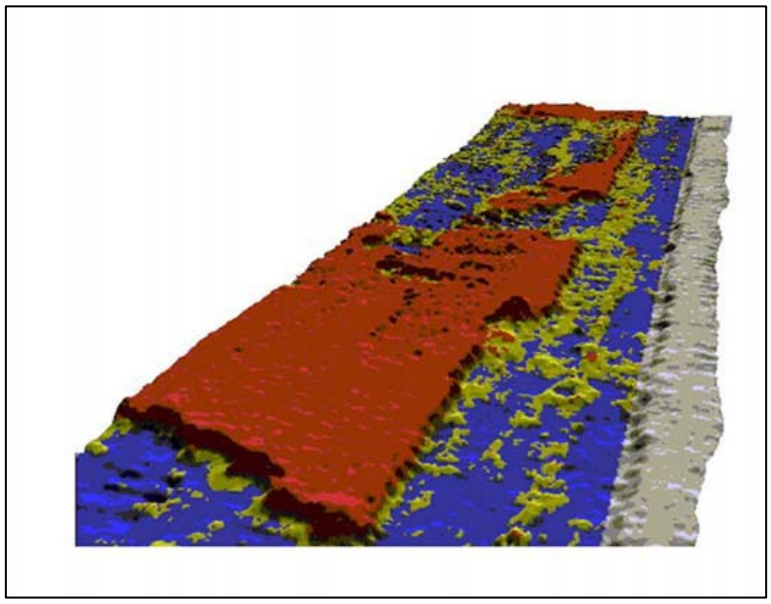


Figure 7-2. Digital Terrain Model (DTM) of Ground Surface Topography.

7.3 METHODS

Hydrographic surveys were conducted by Gahagan & Bryant Associates. These surveys used a single beam hydrographic survey system to determine water depths. Surveys to determine the volume of material were accomplished with the use of a survey vessel equipped with an automated acquisition system. Horizontal location of survey lines and depth sounding points were determined by the use of an automated Real Time Kinematic (RTK) positioning system. The survey was accomplished by the utilization of RTK receivers using a shore based reference station (base station) with known coordinates and elevations. Corrections from the base station were transmitted to the survey vessel RTK receiver where they were collected via data collection software (i.e. Hypack) to provide an accurate vertical/horizontal position of the discrete sounding locations. All hydrographic surveys conducted were consistent with the guidelines as referenced in the USACE Hydrographic Survey Manual EM 1110-2- 1003, dated 01 January 2002, for Navigation and Dredging Support Surveys, for soft bottom material. Field surveys were conducted on May 5, 2010 and included in water hydrographic surveys and limited upland surveys to collect additional data points which were conducted on May 6, 2010. In addition, a survey of the crest of the outlet dam was conducted on June 18, 2010 in order to establish a baseline elevation to measure all water depths from as a defined pool elevation for Greenwood Lake was not available. Copies of completed surveys are provided in a digital format in Appendix B.

7.4 RESULTS OF SURVEY EFFORTS

Surveys were completed by Gahagan & Bryant Associates for six (6) areas of Greenwood Lake within New Jersey. These areas consisted of the Browns Point and Belcher Creek area, Rocky Cove, an unnamed cove, the outlet dam area, Storms Island Channel and Fox Island Channel. The largest area that was studied was the Browns Point area, which is the main area comprising the southern portion of the lake. The average water depth found in this area ranged between five and six feet, and three feet around the water's edge. Just south and east of Browns Point is South Shore Marina. The average water depth at the marina is four feet deep with a deep spot off the westernmost pier at 6.5 feet. Northwest of the Browns Point area on the western shore is Belcher Creek. The entrance to the creek is about 3.5 feet deep and deepens to six feet in the center of the creek. On the edges of Belcher Creek the water depth is about two feet.

Slightly northeast of the entrance to Belcher Creek, but still on the western shore is Rocky Cove. Rocky Cove is deeper than Belcher Creek for the most part as the average water depth ranges from five to six feet and ranges from three to four feet on the edge of the cove. The entrance to Rocky Cove has an average water depth of six feet. Directly north of Rocky Cove is an unnamed cove. The entrance to this cove ranges from five to six feet and 2.5 to three feet near the shore.

North of the unnamed cove is the second largest area that was surveyed; this area being Fox Island Channel. The water depth in this channel ranges from six to eight feet with the average water depth near the shore about five feet. There is also a deep hole located mid-way between the two marinas in the center of the channel, where the water depth ranges from 10 to 14 feet. Across the lake on the eastern shore and slightly south is the location of the existing outlet dam to the Wanaque River. Just before the entrance to the dam the water depth ranges from 8.5 to 11.5 with an average depth around 9.5 feet.

The final and most northern area studied, which is north of the dam on the eastern shore is Storms Island Channel. The entrance and center of the channel have a water depth that ranges from six to seven feet and nears two to three feet on the edge of the island and shore. Figures detailing the water depths and the lake bottom elevations are provided in Appendix B.

All water depths are based on a flat pool elevation of 618.18 feet (NAVD88). This elevation is the controlling elevation of the dam crest.

SECTION 8

PROPOSED DREDGING PLAN

8.1 INTRODUCTION

Based upon a review of available information, an evaluation of potential alternatives and preliminary field investigations, a proposed dredging plan has been prepared for Greenwood Lake. The plan presented within this section was developed based upon the most currently available information and it should be noted that additional investigations of potential dredging methods, site-specific conditions and other factors will likely need to be considered in more detail as a formal dredging plan is implemented for one or more of the proposed locations.

The plan presented within this section has been developed with the goals of the Greenwood Lake Commission and prior studies as the key driver. The primary goals associated with the implementation of a dredging plan for Greenwood Lake were focused upon a 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 (e.g., lake drawdowns)

8.2 PROPOSED AREAS FOR DREDGING AND PRIORITIZATION

A total of six locations were identified as candidate dredging sites. These sites were primarily identified based upon existing conditions (e.g., nuisance vegetation) and water depths. The six locations that were identified are as follows:

- Browns Point/Belcher Creek
- Outlet Dam
- Rocky Cove
- Unnamed Cove
- Fox Island Channel
- Storms Island Channel

Based upon a review of these locations, in conjunction with the goals for the proposed dredging and the results of hydrographic surveys completed as part of the current study, a ranking of the proposed locations was prepared. This prioritization of sites was based upon addressing the ultimate goals of the overall dredging plan with improvement in water quality as an overall goal as this would be a benefit to the surrounding communities and would also 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 a potential reduction in nuisance aquatic vegetation were therefore very important in this regard. The potential volume of materials that would need to be removed and the associated cost for dredging and the management of the dredged material were not taken into account as part of the ranking of candidate sites.

- As a result of this assessment it is recommended that the Browns Point/Belcher Creek area be the primary candidate for dredging. 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. Likewise, this is the largest candidate area and the dredging of this location would result in a significant increase in the capacity of the lake.

- The outlet dam was ranked second. 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 affect upon these drawdown activities. Results of hydrographic surveys generally showed water depths of 6 to 10 feet with some shallower areas closer to the dam that are two to four feet deep. However, the use of the dam to manage water levels and additional information that boat activity in proximity to the dam is likely greater than the smaller coves along the western shore, resulted in a higher ranking for this location. In addition, the benefits associated with the dam, such as for periodic lake drawdowns, benefit the entire lake community.

- Rocky Cove and the Unnamed Cove south of Greenwood Small Craft Marina would represent the next highest ranked sites. 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 and Storms Island 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. Results of the hydrographic surveys indicated that these locations generally had current water depths between six to seven feet, more than many of the other locations evaluated. Other major goals for the overall dredging plan with the exception of increased lake capacity would generally not be applicable for these two locations.

8.3 PROPOSED DREDGING DEPTH

An existing and maintained baseline water depth does not currently exist for Greenwood Lake. In addition as discussed in greater detail below, there is not necessarily a fixed dredging depth that would result in the complete elimination of aquatic nuisance vegetation. As a result, a baseline depth for the completion of proposed dredging within Greenwood Lake needed to be established as part of the current plan. Based upon the results of hydrographic surveys that were completed within the lake, which 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 corresponds to a dredge elevation of 608 feet NAVD88. As the dredging plan is refined or specific components of the plan are advanced, it is anticipated that a refinement of the project depths for individual locations may be warranted.

As noted previously, a fixed dredging depth that would permanently address aquatic nuisance vegetation does not exist and/or would be cost prohibitive due to the depths required. Light penetration is a key factor affecting macrophyte distribution, and is important in predicting the potential effectiveness and longevity of a dredging project to reduce macrophyte abundance. Emergent, free-floating and floating-leaved plants require bright, atmospheric sunlight, whereas submergent species are much more tolerant of shade. The *light compensation point* (the point at which the photosynthetic rate is equal to the respiration rate) for some submergent species is as low as 0.5% of full sun.[1] Dredging increases the water depth, which results in decreased light transmission to the substrate or lake bed. This inhibits the growth of aquatic plants that require more light.

The quality and quantity of light depends on the quantity of dissolved materials and suspended particulate matter in the water column and on water depth. There is a strong correlation between Secchi disk transparency and the maximum depth of macrophyte growth, as summarized in Table 8-1. There are Secchi disk transparency data for Greenwood Lake, which can be used to support an analysis of how the macrophyte community might respond to a deeper littoral habitat, post-dredging. As displayed in Figure 8-1, the lake's Secchi disk transparency has varied over time and location, with lower values (corresponding to diminished water clarity) in recent years. Water clarity (and Secchi disk transparency) is lower in the southern region.

Table 8-1. Regression Equations of Secchi Depth vs. Maximum Depth of Plant Growth

Equation	Region	Reference
$MD = 0.83 + 1.22\ SD$	Wisconsin	Dunst, 1982
$MD^{0.5} = 1.51 + 0.53\ \ln SD$	Various	Duarte & Kalf, 1987
$MD = 0.61 \log SD + 0.26$	Finland; Florida; Wisconsin	Canfield et al., 1985
$MD = 2.12 + 0.62\ SD$	Wisconsin	Nichols, 1992
$MD^{0.5} = 1.33 \log SD + 1.40$	Quebec; World	Chambers & Kalf, 1985
Source: Restoration & Mgmt Lakes-Reservoirs (3rd edition 2005) Macrophyte Ecology/Mgmt (pg 282) MD = maximum depth of plant growth (meters); SD = Secchi depth (meters)		

A review of the light requirements of Greenwood Lake's macrophyte community (Table 8-2) confirms that some of the nuisance species have the lowest light compensation points; as a consequence, these species are able to thrive in deeper waters than more desirable species. In two case studies of New York lakes – Collins Lake and Ann Lee Pond – dredging resulted in a community shift to plants less limited by greater water depth[2]. In Collins Lake, dredging was employed to control the exotic species Curly-leaf pondweed; however, the long-term effect was to shift the population from Curly-leaf pondweed to Eurasian water-milfoil, which was better adapted for growth in low light conditions.

[1] Restoration & Mgmt Lakes-Reservoirs (3rd edition 2005) Macrophyte Ecology/Mgmt (pg 281).

[2] Diet for a Small Lake, pg. 138-140.

Table 8-2. Depth and Light Requirements of Macrophytes Identified in Greenwood Lake

Macrophytes	Presence Observed	Optimal Depth	Light Requirements	Citation
Emergent				
Arrowhead *Sagittaria* species Perennial	1981	6-12 inches	Full sun	http://plants.usda.gov/factsheet/pdf/fs_sala2.pdf
Pickerelweed *Pontedaria* species Perennial	1981	up to 40 inches	Sun/part shade Shade-intolerant	http://wisplants.uwsp.edu/scripts/detail.asp?SpCode=PONCOR http://www.wildflower.org/plants/result.php?id_plant=POCO14 http://plants.usda.gov/java/charProfile?symbol=POCO14
Floating-leaved				
Yellow pond lily (*Nuphar advena*) Perennial	1981 1992-1995	less than 7 ft deep up to 16 inches deep	Sun or shade Sun	http://wisplants.uwsp.edu/scripts/detail.asp?SpCode=NUPADV http://www.wildflower.org/plants/result.php?id_plant=NULUA
Water lily *Nymphaea* species Perennial	1992-1995	less than 7 ft deep	Sun, part-shade, shade	http://www.wildflower.org/plants/result.php?id_plant=NYOD http://wisplants.uwsp.edu/scripts/detail.asp?SpCode=NYMODO
Duckweed *Lemna* species Perennial	1981	not rooted, free-floating, depth irrelevant Needs quiet waters	Shade-intolerant Sun	http://plants.usda.gov/java/charProfile?symbol=LEMI3 http://www.wildflower.org/plants/result.php?id_plant=LEMI3

Table 8-2. Depth and Light Requirements of Macrophytes Identified in Greenwood Lake

Macrophytes	Presence Observed	Optimal Depth	Light Requirements	Citation
Submergent				
Eurasian Water-milfoil (*Myriophyllum spicatum*) Perennial **Invasive**	1981 1992-1995	Typically 3.3 ft to 13 ft, but have been found as deep as 33 ft (Aiken *et al*., 1979)	Light is not considered a limiting factor (Hartleb *et al.*, 1993).	http://nyis.info/plants/EurasianWatermilfoil.aspx
Large-leaved pondweed (*Potamogeton amplifolius*) Perennial	1981 1992-1995	greater than 3 ft Usually less than 9 ft, but found as deep as 18 ft. (Fernald (1970); and Voss (1972))	Sun Shade-intolerant	http://wisplants.uwsp.edu/scripts/detail.asp?SpCode=POTAMP http://www.npwrc.usgs.gov/resource/plants/mnplant/poam.htm http://www.wildflower.org/plants/result.php?id_plant=POAM5 http://plants.usda.gov/java/charProfile?symbol=POAM5
American eelgrass (*Vallisneria americana*) Perennial	1981 1992-1995	1 ft to 7 ft	Shade-intolerant Sun/part-shade	http://plants.usda.gov/java/charProfile?symbol=VAAM3 http://www.wildflower.org/plants/result.php?id_plant=VAAM3 http://wisplants.uwsp.edu/scripts/detail.asp?SpCode=VALAME
Coon's tail (*Ceratophyllum demersum*) Perennial	1981 1992-1995	to more than 7 ft	Intermediate shade tolerance Part-shade	http://plants.usda.gov/java/charProfile?symbol=CEDE4 http://www.wildflower.org/plants/result.php?id_plant=CEDE4
Southern naiad (*Najas guadalupensis*) Annual	1981 1992-1995	3 ft or more	Sun Shade-intolerant	http://plants.usda.gov/java/stateSearch?searchTxt=Najas+guadalupensis&searchType=Sciname&stateSelect=US36&searchOrder=1&imageField.x=55&imageField.y=6 http://wisplants.uwsp.edu/scripts/detail.asp?SpCode=NAJGUA http://www.wildflower.org/plants/result.php?id_plant=NAGU

Table 8-2. Depth and Light Requirements of Macrophytes Identified in Greenwood Lake

Macrophytes	Presence Observed	Optimal Depth	Light Requirements	Citation
Waterweed *Elodea* species Perennial	1981 1992-1995	Recorded deeper than 25 ft (Fernald (1970); and Voss (1972)).	Sun	http://www.wildflower.org/plants/result.php?id_plant=ELCA7 http://www.npwrc.usgs.gov/resource/plants/mnplant/elca.htm
Robbins' Pondweed (*Potamogeton robbinsii*) Perennial **NJ endangered**	1981	5 ft to 11 ft 6.6 – 9.8 m (1983 Phase I Rpt Greenwood Lake)	Shade-intolerant Sun	http://plants.usda.gov/java/charProfile?symbol=PORO2 http://www.wildflower.org/plants/result.php?id_plant=PORO2 http://dnr.wi.gov/fish/reports/final/chippewahallielakeapm1998-2005.pdf
Variable-leaf Pondweed (*Potamogeton gramineus*) Perennial	1981	about 3 ft deep	Shade-intolerant	http://plants.usda.gov/java/charProfile?symbol=POGR8 http://wisplants.uwsp.edu/scripts/detail.asp?SpCode=POTGRA
Carolina fanwort (*Cabomba caroliniana*) Perennial	1981	less than 9.8 ft, but up to 33 ft deep (Australian Department of the Environment and Heritage 2003)	Intermediate shade tolerance	http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=231 http://plants.usda.gov/java/charProfile?symbol=CACA
Nodding water nymph (*Najas flexis*)	1981	3 ft or more	Part-shade Intermediate shade tolerance	http://wisplants.uwsp.edu/scripts/detail.asp?SpCode=NAJFLE http://www.wildflower.org/plants/result.php?id_plant=NAFL http://plants.usda.gov/java/charProfile?symbol=NAFL
Curly-leaf pondweed (*Potamogeton crispus*) Perennial **Invasive**	1992-1995	3 to 10 ft deep	Shade-intolerant	http://wisplants.uwsp.edu/scripts/detail.asp?SpCode=POTCRI http://plants.usda.gov/java/charProfile?symbol=POCR3

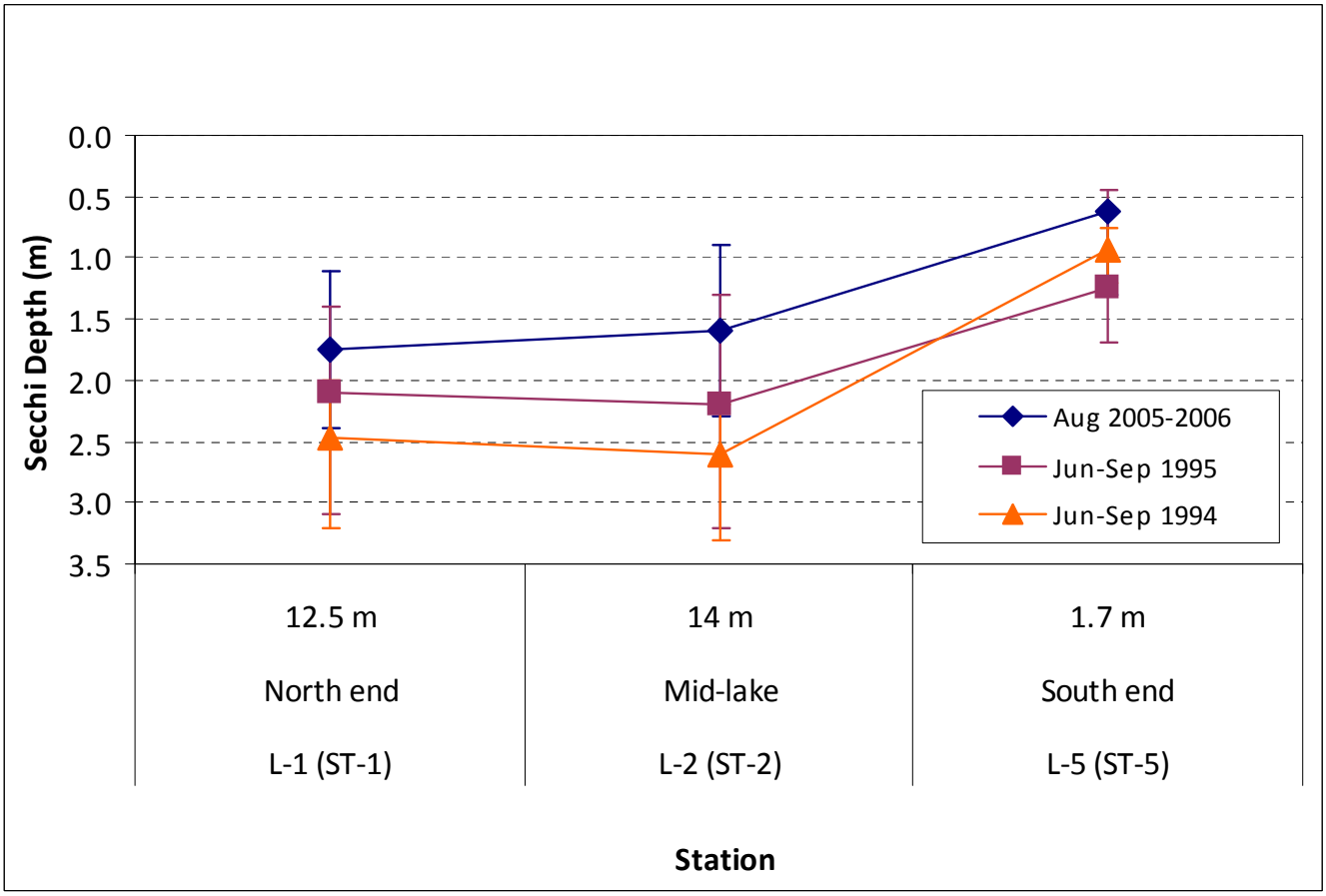


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Figure 8-1 Greenwood Lake Summer Average Secchi Depth over time with Minimum and Maximum

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Greenwood Lake Commission

In summary, macrophyte growth in Greenwood Lake tends to be limited to water depths of 5 meters (approximately 16 feet) or less under current conditions of water clarity and substrate composition. Removal of sediments rich in nutrients and organic material by dredging will reduce the pool of nutrients available to support plant growth. However, additional characterization of the substrate that would be exposed after dredging would be necessary to evaluate the extent to which nutrient availability may be altered.

Considering the optimal light conditions for the lake's current macrophyte community, how individual species may respond to sediment removal of various depths due to dredging can be predicted. This analysis is illustrated in Figure 8-2; note how the emergent and floating-leaved plants are essentially absent from the littoral zone at water depths above 8 feet (2.4 meters). In contrast, the Eurasian water-milfoil and fanwort, two nuisance species within Greenwood Lake, have been observed in far deeper waters.

Physical removal of macrophytes by dredging will result in reduced biomass, but the effect will be temporary. Recolonization of the dredged areas can be expected to occur within a few growing seasons, based on experience in other lakes. For a recently completed dredging project on Lake Algonquin, a small impoundment of the Sacandaga River in Hamilton County New York, the littoral zone was dredged to a depth of 2 meters. Macrophyte recolonization was very rapid within this clear lake, with comparable biomass present within one to two years. The species composition of the macrophyte community did however shift. As expected, plants adapted to grow in deeper waters were most successful in the dredged areas. However, the Lake Algonquin dredging project was designed to leave areas of the littoral zone untouched, in order to protect habitat and insure that there would be a reservoir of organisms, macroinvertebrates, as well as macrophytes, to recolonize the dredged areas.

8.4 PROPOSED DREDGING

8.4.1 Dredging Method

The proposed dredging method for Greenwood Lake would be mechanical dredging. This method allows for digging to occur where access to areas may be limited due to water depth or environmental concerns. The use of a clamshell bucket allows the operator to have precise control over where the dredging occurs and the bucket can be fitted with RTK GPS to provide a more precise dredging operation. Mechanical dredging also allows for multiple transportation and rehandling options. Equipment for mechanical dredging would be transported to the site and a Flexifloat system would be used as a floating work platform. Dredged material would be placed into 20-30 cy scows. A conservative estimate for dredged 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 because of the required transport distances from the point of dredging to a potentially suitable near shore facility. No near shore facility was identified during the site reconnaissance study and conversations with members of the Commission, indicated that a near shore facility was not practical, Pipeline handling issues and the costs associated with processing of slurry make-up water would also be prohibitive. The one

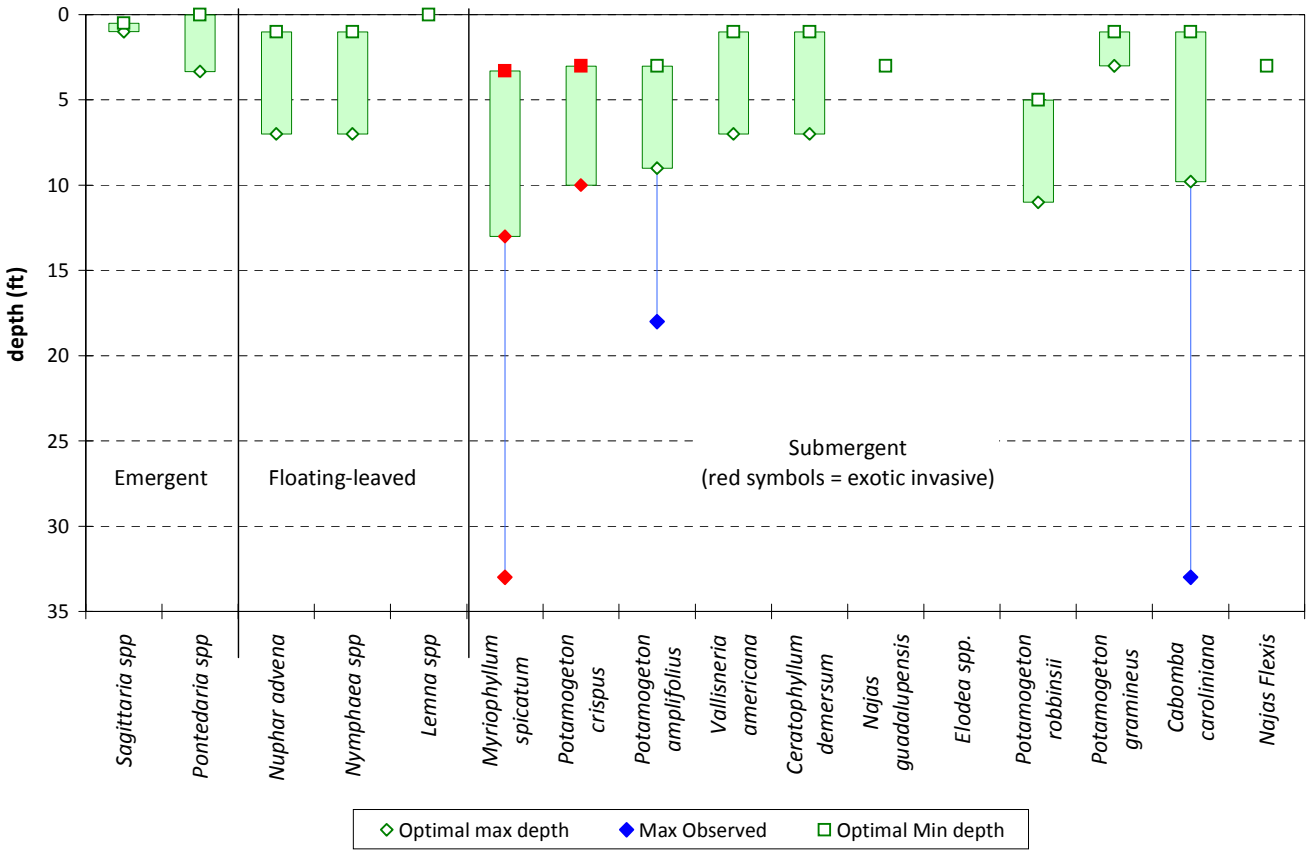

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Figure 2 Optimal Growth Depth of Macrophtye Species

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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. In addition, 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 area could exit the lake at the South Shore Marina and would then travel along the north side of Greenwood Lake Turnpike where a road crossing of Awosting Road and then Greenwood Lake Turnpike at Burnt Meadow Road where the pipeline would then enter the quarry would be required. The total distance would be approximately three miles. Six crossings of private driveways would also be required along the pipeline route and there is at least one significant change in elevation that would need to be overcome with multiple booster pumps required along the route. As a result, although mechanical dredging has been recommended as the approach for Greenwood Lake, 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 mobilization of 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. This method has been used in past projects at the lake, however during such operations the contractor has been required to develop geotechnical reinforcement "fingers" of clean fill in order to operate over soft sediment. There are also 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 have been deemed unreachable by this excavation method and would remain undredged. In addition, several dredging sites would not be affected by the drawdown and at Belcher Creek it is anticipated that flow into the lake would continue during a drawdown.

Geotechnical reinforcement fingers at the site would be required due to past experience and due to the lack of geotechnical data to accurately define substrate conditions. The process of building and removing geotechnical reinforcement 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 would be a significant additional justified cost.

Contracting dredging operations using this method on such a large scale will cause significant additional justified cost due to the unknown site conditions, i.e. contractors will incorporate the cost of this potential risk into their bids. 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 are not required the contractor would still run the risk of embedding equipment in the sediment which will ultimately lead to persistent equipment delays (i.e. longer project duration), and additional justified costs which would also open the contract to change of condition claims.

Working during winter months with temperatures below freezing could potentially work assuming all materials are frozen and can be driven on. Predicting the temperatures during the contracting period however is not possible. This contracting approach still poses 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.

8.4.2 Processing Methods

The dredged material at Greenwood Lake 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 waterfront 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 the site reconnaissance and further review of potential waterfront locations, there does not appear to be adequate space for staging and drying material at any of the locations that were 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 going to be 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 used 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 for this project. 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 present problems for processing dredge material.

As a result material processing would not be a component of the current dredging plan.

8.4.3 Staging Area

Several staging locations are available for the Greenwood Lake dredging plan. These include Browns Point Park and all of the major New Jersey marinas with the exception of Greenwood Small Craft Marina. Potential issues associated with the use of marinas includes seasonal issues 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.

South Shore Marina and Browns Point Park have been selected as the primary staging/transloading locations for the Greenwood Lake project. The South Shore Marina location is close to the proposed primary dredge sites several potential end use sites 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 is how much space at the marina could be allocated to the project. This will have a direct correlation 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 not interfere with the ongoing operations of the marina. 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 candidate 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.

8.5 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 the existing horse farm near Pinecliff Lake also have potential for the placement of dredged materials as these sites are also 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 the these materials be maintained as part of any overall dredged material management plan.

8.6 PLANNING LEVEL COSTS

To develop an accurate cost estimate, dredge volumes need to be calculated. Dredge volumes were calculated based on a dredge elevation of 608 feet NAVD88. Different scenarios were examined to give a range of magnitude of dredging volumes and associated costs. Figures 8-3 through 8-5 show several suggested dredge footprints and the volumes associated with each scenario. As noted previously for the purposes of developing planning level costs, the dredge footprints shown in Figures 8-3 to 8-5 did not exclude areas where dredging would not be allowed, such as Big Rock Cove and several stump field locations (see Figure 2-2). Table 8-3 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 8-3. 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				

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.

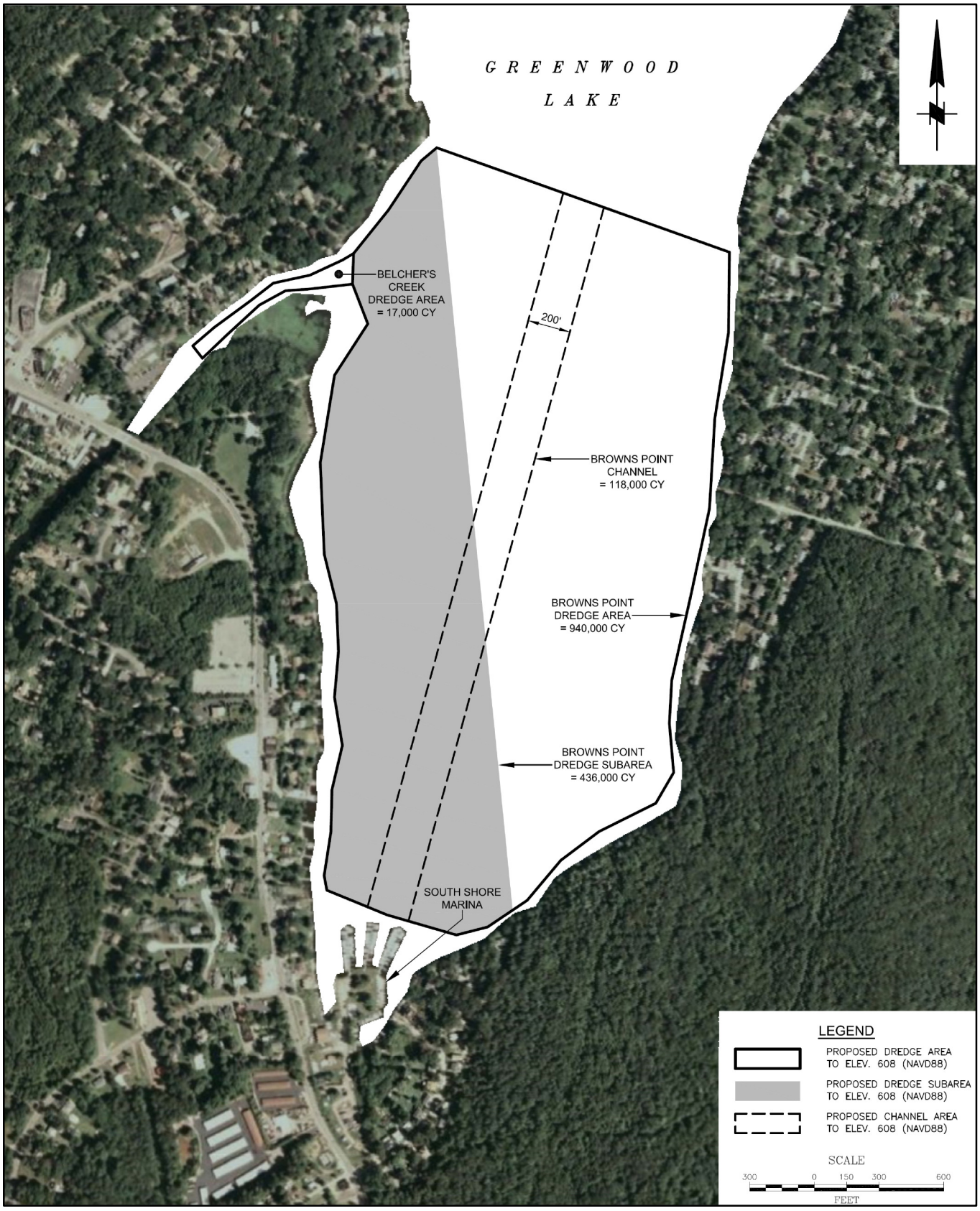

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Figure 8-3 Proposed Dredging Areas
Browns Point and Belcher Creek

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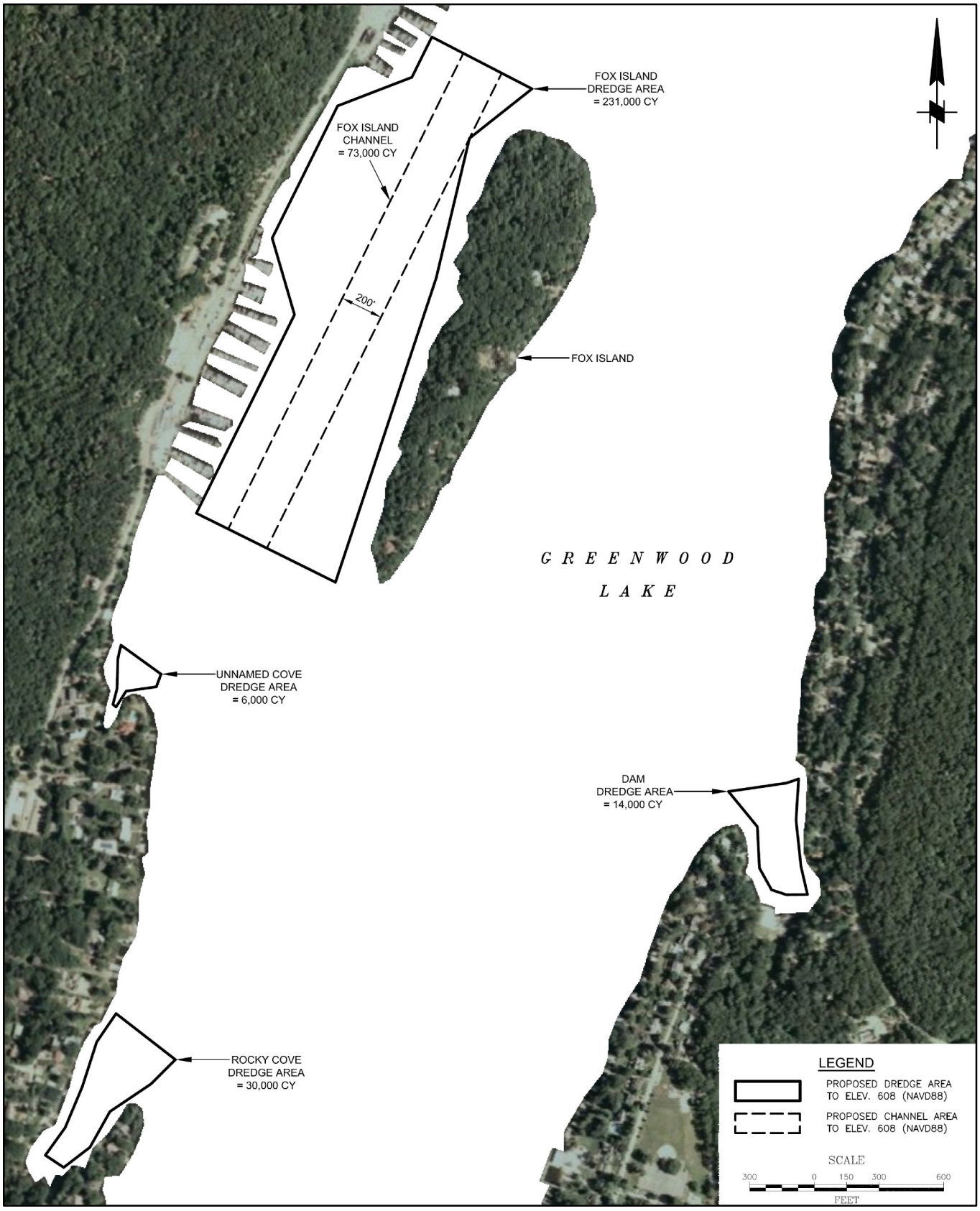

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Figure 8-4 Proposed Dredging Areas
Rocky Cove, Fox Island Channel, Outlet Dam, and Unnamed Cove

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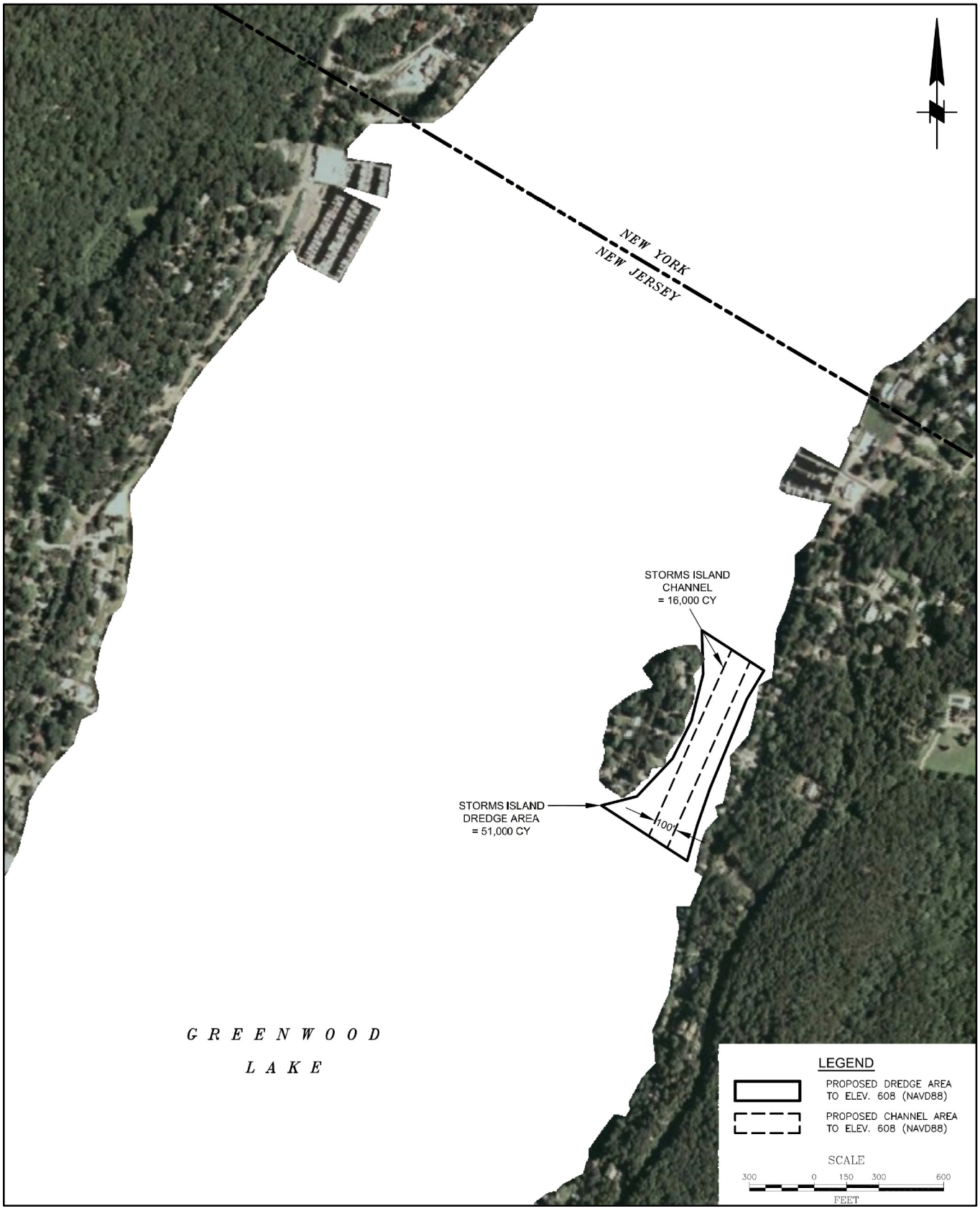

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Figure 8-5 Proposed Dredging Area
Storms Island Channel

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Costs associated with mechanical dredging, transport, offloading, and placement at the Tilcon Ringwood Quarry are summarized in Table 8-4 below. Only two order of magnitude cost estimates are presented below. These included the costs associated with digging a channel and/or mass removal as noted for each candidate site as applicable and illustrated in Figures 8-3 to 8-5. The Browns Point Subarea (Figure 8-3) would only include approximately half of the larger Browns Point area. This subarea would 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.

Table 8-4. Summary of Estimated Dredging Capital Cost

Area	Channel Volume (CY)	Mass Removal Volume (CY)
Browns Point	$ 5,900,000	$ 47,000,000
Browns Point Subarea	$ -	$ 21,800,000
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*
* Browns Point Subarea not included in total		

Costs were estimated based on $50 per cy for mobilization, dredging, transport, placement and a minimum dredging quantity of 20,000 cy. These costs will vary based on market competition and the actual size of the project. Generally, costs will range from $40/cy to $55/cy (including mobilization and demobilization). Depending on the amount of money available for dredging, different scenarios could be developed to fit the Commission's budget. Actual costs will also vary based on the actual dredging quantity and space available for use at the waterfront marina or park. 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 were advanced. These costs would be in addition to the capital costs shown in Table 8-4.

It should be noted that the implementation of all or portions of the dredging plan could be advanced in stages if that is deemed 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 materials available or if multi-season dredging may be required for a variety of reasons (e.g., budgetary limitations, staging site availability, etc.). This would be based on the limited production of equipment that could be used in the Lake and transported over the roadway.

It should also be noted that 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. Dredged materials could also be stockpiled or stored for future use if a site were

available, such as the Tilcon Ringwood Quarry. 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. Additional physical and/or chemical testing may be required. It is however, unlikely that the collection of these funds, if the characteristics of the materials were acceptable, would substantially impact the overall cost of the dredging plan.

8.7 SUMMARY OF PROPOSED DREDGING PLAN AND FUTURE ACTIONS

8.7.1 Proposed Dredging Plan

The proposed dredging plan for Greenwood Lake as presented within this section would involve the dredging of up to six initial candidate sites. Browns Point and Belcher Creek would be recommended for initial action and as discussed within this Section the dredging of Browns Point could be phased with the initial area of focus the Browns Point subarea (see Figure 8-3). This area 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 previously 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 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.

Proposed dredging would 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 use 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 signifcant 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 a contractor would incorporate into his 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 offs at either South Shore Marina and/or Browns Point Park. 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 to these sites as part of the plan

8.7.2 Future Actions

The Greenwood Lake Commission and other lake stakeholders have implemented a variety of actions over the past 20 years directed at improving water quality within Greenwood Lake. Implementation of a dredging plan for Greenwood Lake would represent only one component of an overall plan for the continued improvement of water quality. The continuation of prior programs and initiatives, as well as the implementation of current and proposed actions by the Commission and its community partners 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 harvesting of weeds within the lake;
- Periodic lake drawdown for weed management and maintenance activities;
- Continued improvement of wastewater treatment plants, particularly for phosphorus;
- 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.

8.8 RECOMMENDED FUTURE STUDIES

The currently proposed dredging plan represents a conceptual plan. Advancement of the overall plan or specific components of the plan will require additional refinement and the completion of additional studies, analyses and engineering efforts in order to fully develop these. Presented within this section is a brief summary of the major additional studies that would be recommended. Implementation of these studies would be site-specific and what may be required for one site or alternative may not necessarily be required for all other scenarios.

8.8.1 Site Specific Studies

Further assessment of several locations for the staging or placement of dredged materials will require the completion of additional site-specific investigations. These could entail wetland studies, threatened and endangered species studies, topographic and bathymetric surveys, engineering analyses and others. As potential sites are formally identified for the advancement and implementation of specific components of the proposed dredging plan, these would need to be completed

8.8.2 Sediment Testing

More detailed and expansive physical and chemical testing of sediments is recommended in order to determine the level of potential contamination, if any. This information will also assist in the identification of potential end use or placement alternatives for the dredged materials. Physical analyses would assist in refining the dredging methods and approach and would also allow for an assessment of the potential use of the dredged material for different applications including possible beneficial reuse.

8.8.3 Additional Bathymetry

The Commission had considered the completion of a full survey of the lake as part of this current effort. The cost and time required to complete this task exceeded the funding available and therefore could not be undertaken for the current dredging project. In addition for selected dredge areas more detailed surveys could be done at a later date. It would also be recommended to document overall lake sedimentation rates if possible. This would require a bank to bank survey every five years. This would allow the Commission to track material movement around the lake, sediment accumulation rates and material movement into the lake.

8.8.4 Refinement of Plan and Costs

As six areas of Greenwood Lake were evaluated for dredging and the proposed staging (South Shore Marina and Browns Point Park) and material placement locations (Tilcon Ringwood Quarry and Wallisch Estates) have been recommended, further near shore and detailed mapping is suggested at these locations. Investigation of the shoreline location, pier structures, bulkheads, etc. is recommended to develop a more comprehensive knowledge of these areas. This would allow all parties to identify the issues and concerns that may be present at these areas.

8.8.5 Material Characterization

Due to the varied and potentially rocky nature of the lake bottom, material characterization is likely the most significant overall cost driver to the project. It will determine the dredging and transportation methods, as well as the disposal location, channel design and quantity of material to be removed. Before finalizing dredging templates and disposal or placement locations, a detailed classification of the material to be dredged must be completed. Several methods can be used to classify the material including standard penetration test (SPT) borings, vibracores and/or jet probes. SPT boring method is described in full detail in ASTM

D1586-99 and BS1377:Part9. The boring test requires a 140 pound hammer to drop 30 inches per blow to drive the sampling device into the sediment. The number of blows is counted per foot and is an indication of the cohesion of the material. The samples are taken at one foot intervals. The material is visually classified, bottled and capped for lab testing. The characterization continues with lab tests such as sieve analysis, Atterberg limits and moisture content for each sample. Characteristics which determine the "dredgeability" of the material are in situ shear strength, overall grain size distribution, angularity of coarse grain material, presence of rock or cobbles, and plasticity of fine grain material. The number of borings required depends on the proposed alignment and depth. Borings should reach a depth five feet below the required dredging depth.

Jet probing is often used in concert with vibracores. Jet probing is completed by forcing a probe with water jetting from the end into the sediment until refusal is reached. This depth is recorded with the corresponding horizontal positioning creating a surface of material which is likely to be difficult to dredge. This surface will aid in finalizing the dredging areas and depths with minimal cost.

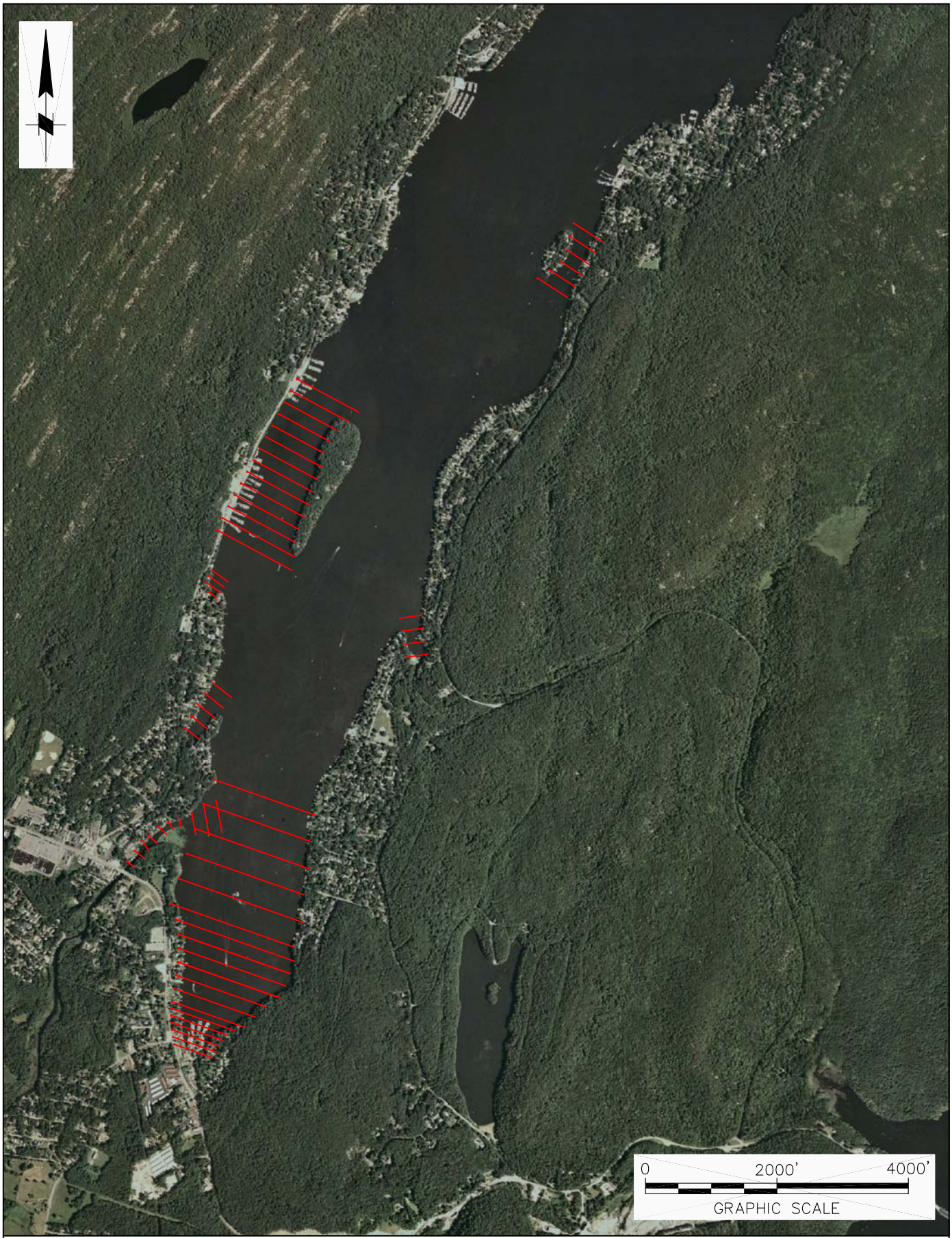
Vibracores are a quick way to determine material types. A vibrating mechanism is attached to a 20-foot hollow tube and lowered into the lake bottom from a survey boat/barge. The tube is extracted with the lake sediment inside the tube. The tube is cut open to reveal the material types of the lake bottom. The materials are tested in a lab to determine the characterization of them (i.e. silt, sand, gravel, etc).

The approach to sampling and testing of materials will be dependent on the quantity of material that will need to be dredged (i.e. cubic yards), depth of dredging below the mud line, and funds available for sampling and testing. The Greenwood Lake design team would recommend, at a minimum, performing vibracoring to confirm material types that need to be dredged. If funds are available for SPT borings, a drilling program could be developed for each of the dredge areas.

The importance of characterizing the dredged material will result in contract documents that reflect to a greater degree the actual conditions that the contractor will encounter. This in turn will result in more accurate bids and fewer change orders.

APPENDIX A

GREENWOOD LAKE
PROPOSED SURVEY LINES



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NEW JERSEY

PROPOSED SURVEY LINES

Drawing Date:	April 2010
Drawn By:	E. Cook
Checked By:	C. Roche
Drawing Name:	Greenwood_Lake
Drawing Scale:	1"=2000'

APPENDIX B

HYDROGRAPHIC PLAN SHEETS

SOUTH SHORE MARINA

CONTROL POINT
Z=619.23

BELCHERS CREEK

ROCKY COVE

BROWN POINT AREA

GREENWOOD LAKE

0 200' 400'
GRAPHIC SCALE

BATHYMETRY NOTES:

1. VERTICAL DATUM IS REFERENCED TO FEET BELOW THE DAM ELEV. (618.18 FT NAVD88).
2. BATHYMETRIC DATA IS EXPRESSED IN FEET BELOW DAM ELEV. AND WAS COLLECTED ON MAY 5, 2010 BY GAHAGAN & BRYANT ASSOCIATES.
3. WATER LEVEL WAS RECORDED AT SOUTH SHORE MARINA AND GREENWOOD SMALL CRAFT MARINA. WATER LEVEL WAS RECORDED AS 618.40 FT NAVD 88, .22 FT ABOVE THE DAM ELEV.
4. THE INFORMATION DEPICTED ON THIS MAP REPRESENTS RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME.
5. EQUIPMENT USED:
   VESSEL: "SKIFF"
   ECHO SOUNDER: ODOM ECHOTRAC MKII FATHOMETER (200kHz)
   HORIZONTAL POSITIONING: TRIMBLE DSM212 WITH DIFFERENTIAL CORRECTIONS
6. THE HORIZONTAL DATUM IS THE NEW JERSEY STATE PLANE NORTH AMERICAN DATUM 1983.
7. BACKGROUND IMAGE WAS OBTAINED FROM BING MAPS.

Mark	Description	Date	Appr.

Mark	Description	Date	Appr.

Designed by: CMR | Date: JUNE 2010 | Rev.
Dwn. by: DCM | Ckd by: TMD | Drawing name: 20100505_Green
Reviewed by: TMD | Scale: AS SHOWN
Submitted by: — | Plot scale: 1 = 1

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GBA
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GREENWOOD LAKE
NEW YORK AND NEW JERSEY

JUNE 2010 SURVEY
WATER DEPTH SOUNDINGS, SHEET 1 OF 3

SEAL

WD-01

P:\Miscellaneous\2010_Greenwood_Lake_Hydrogra\20100505_Greenwood_Lake_BathyPlan(Depths).dwg

UNNAMED COVE

GREENWOOD SMALL CRAFT MARINA

CONTROL POINT
Z=619.28

MOOSEHEAD MARINA

FOX ISLAND CHANNEL

SPORTSMANS MARINA

GREENWOOD LAKE

DAM

0 200' 400'
GRAPHIC SCALE

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Submitted by: –
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Scale: AS SHOWN
Plot scale: 1 = 1
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JUNE 2010 SURVEY
WATER DEPTH SOUNDINGS, SHEET 2 OF 3

SEAL

WD-02

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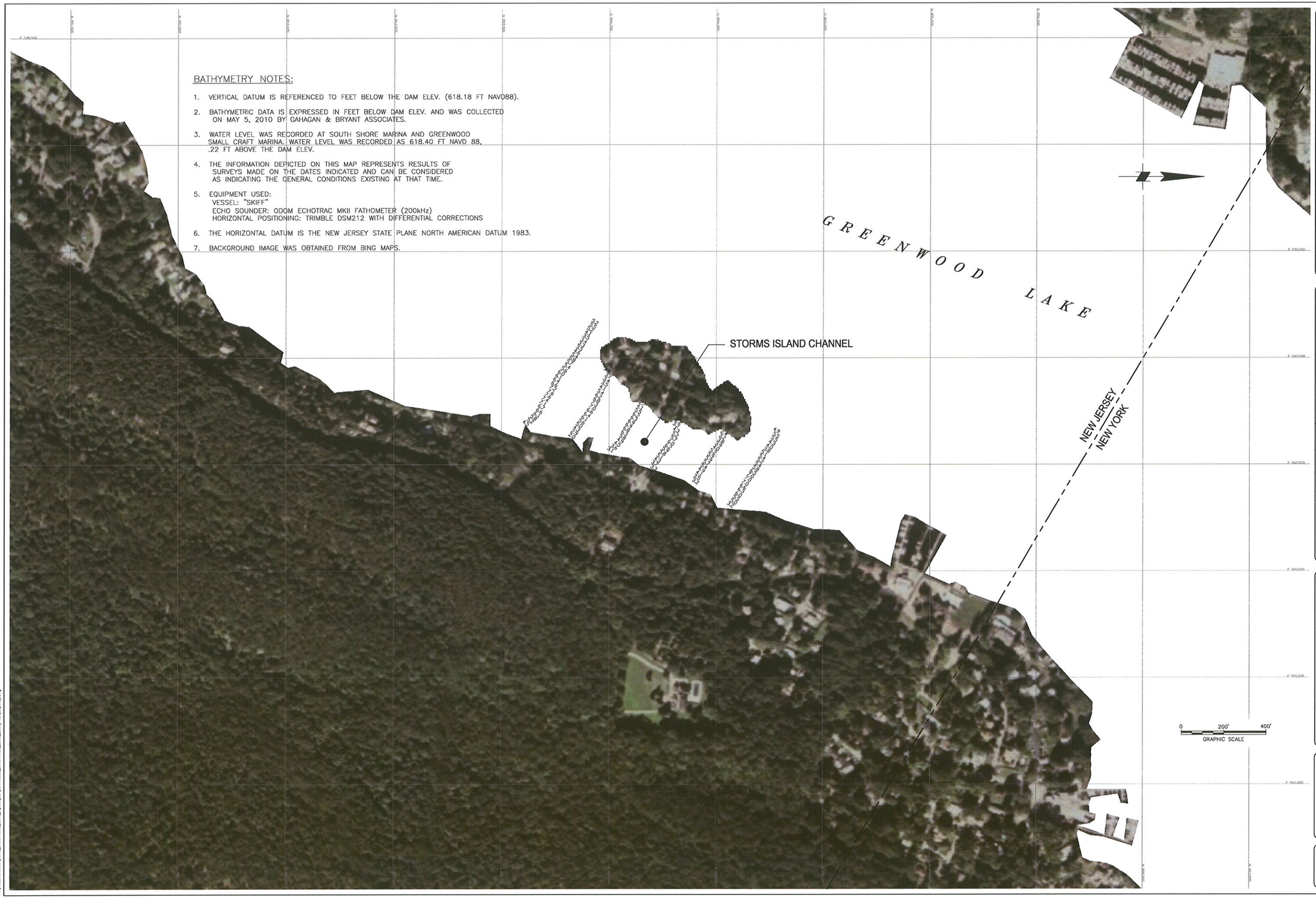

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Scale: AS SHOWN
Plot scale: 1 = 1
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JUNE 2010 SURVEY
WATER DEPTH SOUNDINGS, SHEET 3 OF 3

SEAL

WD-03

P:\Miscellaneous\2010_Greenwood_Lake_Hydrosurv\20100505_Greenwood_Lake_BathyPlan(Depths).dwg

SOUTH SHORE MARINA

CONTROL POINT
Z=619.23

BELCHERS CREEK

ROCKY COVE

BROWN POINT AREA

GREENWOOD LAKE

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0 200' 400'
GRAPHIC SCALE

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NEW JERSEY

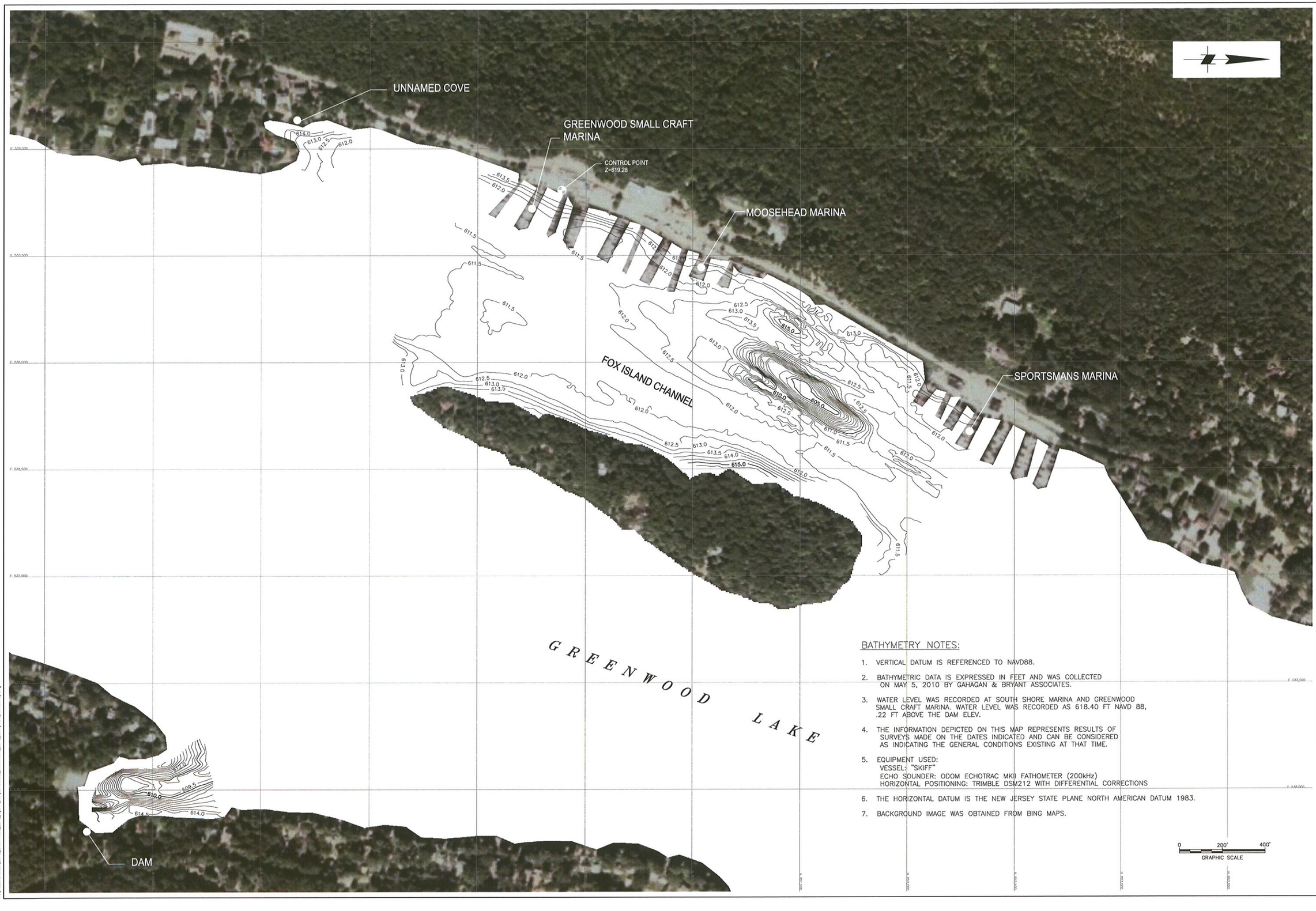
JUNE 2010 SURVEY

LAKE BOTTOM ELEVATIONS(NAVD88), SHEET 1 OF 3

SEAL

CM-01

P:\Miscellaneous\2010_Greenwood_Lake_Hydrosurv\2010050S_Greenwood_Lake_BathyPlan(Exercise).dwg



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0 200' 400'
GRAPHIC SCALE

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NEW JERSEY

JUNE 2010 SURVEY

LAKE BOTTOM ELEVATIONS(NAVD88), SHEET 2 OF 3

SEAL

CM-02

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GREENWOOD LAKE

STORMS ISLAND CHANNEL

NEW JERSEY / NEW YORK

614.0 612.0 611.5 614.5 612.5 613.5 615.0

0 200' 400'
GRAPHIC SCALE

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JUNE 2010 SURVEY
LAKE BOTTOM ELEVATIONS(NAVD88), SHEET 3 OF 3

SEAL

CM-03

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