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Application of the NWT Winter Water Withdrawal Protocol with Bathymetric Profiles of Select Small Lakes in the Mackenzie Delta Region

By

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Large volumes of water are required by industry in the Northwest Territories (NWT) to conduct activities such as hydrocarbon exploration and winter road construction. Fish living in small lakes are particularly sensitive in late winter due to limited oxygen supplies. These oxygen supplies can be further reduced to harmful levels through winter water withdrawals. In order to better assess the fish overwintering habitat potential of small lakes, the Department of Fisheries and Oceans - Western Arctic Area (DFO) requires industrial water users to submit volume estimates of potential water sources. These estimates are to be derived from bathymetric surveys conducted using the minimum standards outlined in the *DFO's Protocol for Winter Water Withdrawal in the NWT*. This report demonstrates the application of the protocol using an example of how the level of effort expended on bathymetric surveys directly affects the accuracy of the resulting lake volume estimates. Also presented are bathymetric data from 55 small lakes in the Mackenzie Delta and adjacent tundra areas, providing insight into the diversity of lake basin shapes in the area.

Key Words; Northwest Territories, NWT, bathymetry, bathymetric profiles, Mackenzie Delta, tundra lakes, oil and gas, seismic, winter road, water withdrawal

RÉSUMÉ

Cott P.A., Monita, D.M.A., Majewski A.R., Hanna B.W., and Bourassa K.J. 2005. Application of the NWT Winter Water Withdrawal Protocol with Bathymetric Profiles of Select Small Lakes in the Mackenzie Delta Region. Can. Manuscr. Rep. Fish. Aquat. Sci. 2731: vii +73 p.

Dans les Territoires du Nord-Ouest (T. N.-O.), les divers consommateurs d'eau dans le secteur industriel requièrent de grands volumes d'eau pour mener leurs activités, comme la prospection de gisements d'hydrocarbures et la construction de chemins d'hiver. Les poissons retrouvés dans les petits lacs sont particulièrement vulnérables à la fin de l'hiver à cause des faibles concentrations d'oxygène dans l'eau. Le prélèvement d'eau en hiver peut réduire davantage ces concentrations jusqu'à des niveaux dangereux. Afin de pouvoir mieux évaluer le potentiel des petits lacs comme habitat d'hivernage du poisson, le ministère des Pêches et des Océans – Secteur de l'Arctique de l'Ouest (MPO) exige que les consommateurs d'eau dans le secteur industriel présentent des estimations des volumes des sources d'eau potentielles. Ces estimations doivent reposer sur des levés bathymétriques effectués en regard des normes minimales établies dans le Protocole de prélèvement de l'eau en hiver dans les Territoires du Nord-Ouest, produit par le MPO. Nous appliquons le protocole en utilisant un exemple qui montre comment le niveau d'effort déployé lors des levés bathymétriques influe directement sur la précision des estimations résultantes du volume d'eau dans un lac. Sont aussi présentées des données bathymétriques sur 55 petits lacs du delta du Mackenzie et de régions avoisinantes de la toundra pour donner un aperçu de la diversité des formes de lac dans la région.

Mots clés: Territoires du Nord-Ouest, T. N.-O., bathymétrie, profils bathymétriques, delta du Mackenzie, lacs de la toundra, pétrole et gaz, séismique, chemin d'hiver, prélèvement d'eau

INTRODUCTION

In the Northwest Territories (NWT) large volumes of water are required by industry to undertake various activities such as winter road construction, exploratory drilling, ice crossing construction, hydrostatic testing of pipelines and camp use. Due to the remoteness and the limited extent of permanent roads in the NWT, projects are usually conducted during the winter when travel over frozen lakes, rivers and land is possible. Water is normally withdrawn from lakes or rivers adjacent to the access route or development being constructed.

In small shallow lakes, without any sources of water recharge during the winter, the available oxygen is fixed at the point of ice cover. Over the course of the ice covered season, available oxygen is slowly depleted in lakes through respiration and biological oxygen demand from decomposing organic material. Withdrawing water from small lakes during ice covered conditions can further exacerbate the effects of critical factors to fish such as; limited dissolved oxygen (Gaboury and Patalas 1984), shrinking winter habitat resulting in higher fish densities (Bégout Anras et al. 1999; Gaboury and Patalas 1984; Paller 1997), freezing littoral habitat killing benthos and macrophytes (Tarver 1980; Rørslett 1989; Hellsen et al. 1996; Rørslett and Johansen 1996; Paller 1997; Turner et al. 2004) and freezing of incubating eggs in littoral areas (Jansen 2000). The aforementioned factors can lead to physiological stress and winterkill (Wetzel 2001).

The Department of Fisheries and Oceans - Western Arctic Area (DFO) recognized that industrial winter water withdrawal from small lakes has the potential to cause negative impacts to over-wintering fish and fish habitat and implemented a winter water withdrawal protocol to address these concerns.

The purpose of this report is to demonstrate a practical application of DFO's *Protocol for Winter Water Withdrawal in the NWT* and to present bathymetric data on 55 small lakes in the Mackenzie Delta and adjacent tundra areas to be accessible for fisheries managers, industry and the general public.

Winter Water Withdrawal Protocol

In the past, water source information that was required to obtain water licences or land use permits was insufficient for DFO to assess potential impacts to fish and fish habitat, or to allow for adequate mitigation measures to be determined or developed. Accordingly, DFO, in conjunction with other regulators and representatives from the oil and gas industry, developed the *DFO Protocol for Water Withdrawal for Oil & Gas Activities in the Northwest Territories.* As a pilot initiative, this protocol was distributed to the oil and gas industry in August of 2002. The protocol was revised in January 2005 and renamed DFO's *Protocol for Winter Water Withdrawal in the NWT* (hereafter referred to as the protocol; Appendix A) as it now applies to all industrial water users within the NWT, not just the oil and gas industry. The revised document follows the same general format as the previous protocol but with added clarity and instruction. Also, the revision includes input from the Natural Resource Industry Association, a multi-industry group including organizations such as the Canadian Association of Petroleum Producers, Prospectors and Developers Association of Canada, Mining

Association of Canada, and the Government of Northwest Territories – Department of Transportation.

The intent of the protocol is to provide a standardized tool to assist industry in avoiding possible impacts to fish from winter water withdrawals while obtaining the water they require, as well as ensuring consistency among water users. The information outlined in the protocol, that is now required from industrial water users in project proposals, allows DFO to more effectively assess and recommend mitigation against potential impacts to fish and fish habitat.

The protocol outlines various water withdrawal limits for lakes depending on physical lake characteristics such as maximum depth and maximum expected ice cover. These limits were adapted from recommendations outlined in the Berger Inquiry (1977), regulators experiences on the Alaskan North Slope (W. Morris, Alaska Department of Natural Resources *pers. comm*. 2002) and through the use of the precautionary principle (DFO 2002). DFO designates a lake as providing overwintering fish habitat if the maximum water depth is greater than the maximum expected ice thickness, rather than relying on fish capture methods which can be unreliable at proving the absence of fish. Water withdrawal thresholds corresponding to the maximum expected ice thickness are outlined below.

1. If less than 100 m^3 is to be used from a given water body per ice covered season, the protocol does not apply, regardless of maximum expected ice cover.

2. If the maximum water depth is less than the maximum expected ice thickness, no threshold on water use is applied.

3. If the maximum water depth provides less than 1.5 m of free water beneath the maximum ice cover, no water withdrawal is allowed as fish in these waterbodies are considered to be particularly vulnerable to the effects of water withdrawal.

4. If the maximum water depth provides 1.5 m or greater of free water under the maximum expected ice thickness, withdrawals are not to exceed 5% of the available free water volume per ice covered season. This volume is calculated using the appropriate maximum expected ice thickness.

It is recognized that maximum expected ice thickness varies throughout the NWT; therefore, ice thickness data from lakes throughout the NWT and corresponding acceptable minimum water depths for a 5% withdrawal, were compiled using long term data from Environment Canada: Water Survey of Canada and Canadian Ice Services (Table 1).

Table 1. Maximum expected ice thicknesses and corresponding minimum water depths required for 5% water withdrawal in three distinct regions of the NWT as outlined in the *DFO Protocol for Winter Water Withdrawal in the NWT.*

Area	Maximum Expected Ice Thickness (m)	Minimum Waterbody depth Required for 5% Water Withdrawal (m)
Above the Tree Line	**2.0**	**≥3.5**
Below the Tree Line - North of Fort Simpson	**1.5**	**≥3.0**
Deh Cho –South of Fort Simpson	**1.0**	**≥2.5**

Accurate volumes are required to determine the threshold volumes outlined in the protocol, therefore DFO requires industrial water users to conduct bathymetric surveys on waterbodies proposed to be used as winter water withdrawal sources. A minimum standard for the bathymetric survey of lakes that are less than 1 km in length at the longest axis is outlined in Figure 1. The protocol requires additional transects be included in bathymetric surveys of lakes that are greater than 1 km in length, as outlined in the protocol (Appendix A).

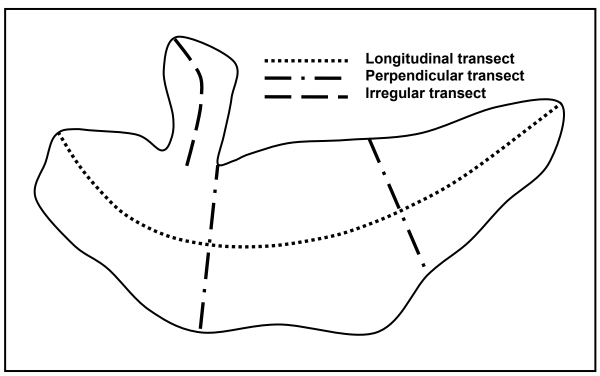

Figure 1. Minimum transect requirements, as outlined in the *DFO Protocol for Winter Water Withdrawal in the NWT,* for the bathymetric survey of a lake less than 1 km at its longest axis.

Based on the bathymetric survey, an estimation of the total available water volume under maximum expected ice cover can be calculated, as well as the maximum depth of the lake to determine if over-wintering habitat is present.

Bathymetry of 55 lakes on the Mackenzie Delta and surrounding area

Bathymetry of 55 lakes in the Mackenzie Delta area of the NWT is presented in this report. These lakes were surveyed in 2001 and 2003. Each lake was sampled with an effort beyond the minimum requirements outlined in the protocol and therefore represents a high standard of resolution.

These bathymetric profiles provide insight into the diversity of basin shape of lakes in the Mackenzie Delta and adjacent tundra areas. It has been generally assumed that within the study region, the majority of lakes have pan shaped bathymetry and thus lakes of similar size (determined from maps or aerial reconnaissance) would have similar volumes. The data presented in this report serves to illustrate the wide variability of morphology of lakes within the region. This report also demonstrates the application of the protocol by using bathymetric data to demonstrate the potential effects that changes in sampling effort during bathymetric surveys can have on lake volume estimates. The potentially critical impacts of winter water withdrawal from shallow waterbodies on fish and fish over-wintering habitat in the NWT are also discussed.

It should be recognized that the methodologies (e.g. data analysis techniques) used to collect and generate the bathymetric images contained within this report only represent potential methods of obtaining the information specified in the protocol. Other methodologies may be used to achieve the same end result while conforming to the recommendations outlined within the protocol.

MATERIALS AND METHODS

Location and Site Description

Bathymetric profiles were conducted on lakes in the Mackenzie Delta region, NWT. The lakes are located throughout the Mackenzie Delta and tundra east of the Mackenzie River, north of Inuvik and south of Tuktoyaktuk (7594500 mN to 7713000mN, 467500mE to 587000mE; Figure 2).

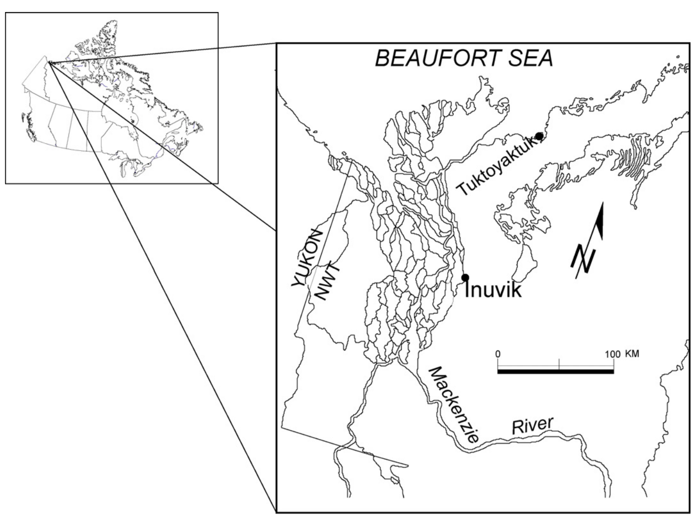

Figure 2. Location of bathymetric surveys conducted on 55 lakes in the Mackenzie Delta during 2001, 2002, and 2003.

Selection of Lakes

A total of 55 lakes were surveyed in the region; including six lakes in 2001; two lakes in 2002, and 47 lakes in 2003. The majority of these lakes were selected for their connection to oil and gas related activities. However, two lakes near Tuktoyaktuk, Kudlak Lake (Lake 25), and 3rd Lake (Lake 26) were surveyed to provide community planners with information on their potential to serve as water supply reservoirs. The bathymetric profiles of these lakes were used to attain estimates on the potential available water volume, and to select locations for intake sites.

Bathymetric System Overview

All lakes were surveyed using a single beam bathymetry system consisting of a transducer, echosounder, mobile computer, specialized hydrographic software, a global positioning system (GPS) unit, and a mobile power source.

Lake Access/Survey Vessel

The selection of survey vessels was based primarily on the ability to access the lakes. Most lakes were surveyed using an inflatable Zodiac™ boat that could be transported via floatplane or helicopter. Larger lakes that were accessible from the Mackenzie River or its channels were surveyed from a shallow draft jet boat. The complete bathymetric system was installed on each vessel and the exact position of the GPS antenna relative to the transducer, as well as the depth of the transducer in the water column, was established. These offsets were then incorporated into the hydrographic surveying software so that no post-processing of the sounding information for these parameters was required.

Echosounder & Transducer

A hydrographic survey quality echosounder and transducer were used to generate and process the acoustic information. A high frequency channel (200 kHz) was used for lakebed surface detection. The depth measurements were computed using the hardware manufacturer's proprietary software, then streamed to a hydrographic software package that combined the depth measurement with a position generated from a portable GPS unit at that time. Bar checks were conducted daily and calibrations made to ensure accuracy.

Position

Positional information was provided by a single frequency GPS receiver which streamed non-differentially corrected horizontal positional data. Although the elevation of the water surface varies during the season, all vertical elevations were measured relative to the water surface at the time of the survey.

Surveying Protocol

At the time when the bathymetric surveying was initiated, there was no standard protocol for bathymetric surveying. Nine lakes (lakes 1, 19, 20, 21, 22, 23, 24, 25 and 26 respectively) were surveyed prior to the development of the protocol, however they were sampled with the rigor required by the protocol and therefore are included within the report.

The protocol required at least one longitudinal transect be conducted from shore to the furthest opposite shore. For lakes less than 1 km in length (lake length = length of longest longitudinal transect), two evenly spaced transects, perpendicular to the longitudinal transect, were required. For lakes greater than 1 km in length, the perpendicular transects needed to be spaced at a minimum of 500 m intervals. Irregularities in the shoreline such as long, narrow bays or fingers were accounted for with extra transects.

Post-Processing

Data post-processing was conducted with hydrographic surveying software especially designed for this purpose. Post-processing of the soundings was conducted to remove any errant or erroneous data points usually associated with electronic noise or reflections off other particles in the water column which are not a part of the lake bottom.

Chart Production

During single beam bathymetric surveying, only depths along transects are recorded and the depth of the lake between these data points must be interpolated. The model chosen for the production of images of the bottom bathymetry of each of the lakes presented in this report was the Kriging model (Deutsch and Journel 1992). This model incorporates a geostatistical gridding method that is widely used in many fields for the interpolation of irregularly spaced data such as those generated from single beam bathymetric surveys.

Water Volume Estimates

The interpolated model of the lake was used to develop the grid files from which the imagery was produced. The grid files were also the basis for the generation of lake volume estimations. The trapezoidal rule was the chosen method of volume determination (Press *et al*. 1988) for each cell in the grid and the cumulative total of all cells equaled the total volume of the lake. Volume under ice was calculated after 'lowering' the surface corresponding to desired ice thickness then remodeling the lake.

RESULTS AND DISCUSSION

Bathymetric images for the 55 surveyed lakes can be found in Appendix B. Accompanying the images are volume estimates correlating to varying expected ice thicknesses. Lakes < 1.5 m in maximum depth are not delineated as these lakes were not a category outlined in the protocol during the survey period for the bathymetric images contained within this report. Lakes range from a maximum depth of 1.9 m (Lake 28) to 28 m (Lake 53) and from a maximum length of approximately 0.5 km (Lake 54) to approximately 6.5km (Lake 21). Lake size does not necessarily equate to lake depth, with a third of the lakes ≥ 1 km being ≤ 3.5 m in maximum depth (e.g. Lake 25 being 5.5 km long and only 2.5 m deep) and almost half of lakes <1 km having maximum depth >3.5 m (e.g. Lake 40 being only 0.9 km long yet almost 20 m deep). The bathymetric information compiled clearly indicates that lake depth cannot be assumed from lake surface area. Given the inherent variability of natural lakes, it is essential that bathymetry is gathered with rigor in order to adequately estimate volume.

Benefits

Obtaining accurate bathymetry of potential water source lakes will allow fisheries managers to more adequately assess the fish habitat in these waterbodies. A greater level of protection can be offered to over-wintering fish by identifying lakes that are vulnerable to water withdrawal and either avoiding them or stipulating withdrawal limits to minimize adverse effects. Also, accurate bathymetry enables the identification of non-fish bearing lakes (i.e. lakes likely to freeze to the bottom).

Inadequate sampling effort can result in inaccurate water volumes estimates. Accurate volume estimates are essential in order to ensure that the 5% threshold is adhered to, thereby protecting overwintering fish populations. The better the resolution in the bathymetric data, the easier it is to assess key habitat components such as adequate depth to provide overwintering habitat. Accurate lake volume estimates are also of great benefit from an industrial operations standpoint, as can be seen when comparing bathymetric images of various levels of effort on the same lake. Lake 55 was arbitrarily chosen for this demonstration with sampling effort ranging from one vertical transect (scenario A1; Figure 3), one horizontal transect (scenario A2; Figure 4), one vertical and one horizontal transect (scenario B; Figure 5), three vertical and one horizontal transects (the minimum level of effort recommended in the protocol; scenario C; Figure 6), six vertical and one horizontal transects (scenario D; Figure 7), fourteen vertical and three horizontal transects, plus infilling of bays (scenario E; Figure 8).

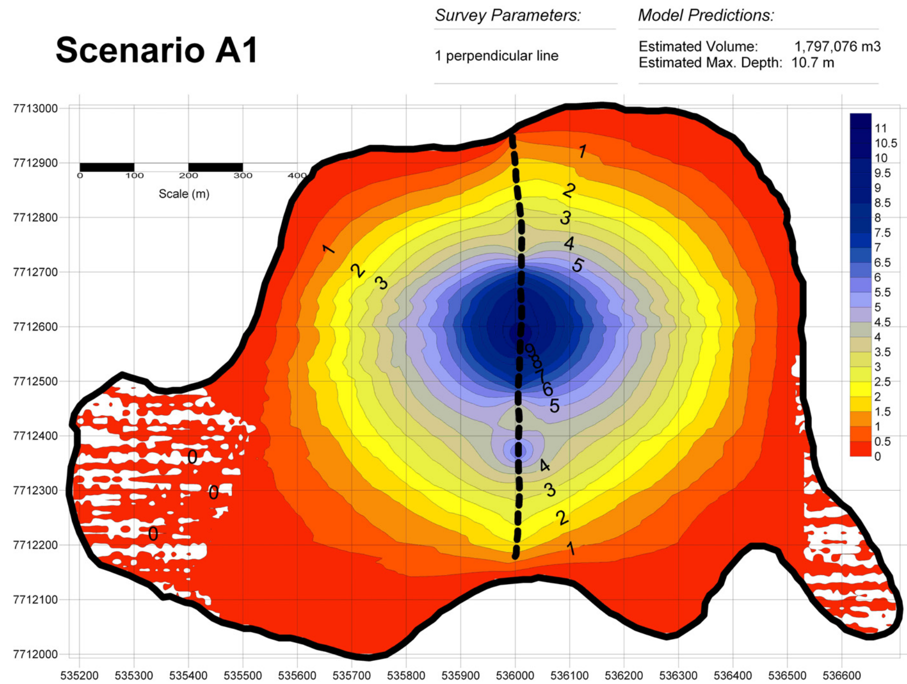

Figure 3. Scenario A1: Minimal sampling effort consisting of one vertical transect.

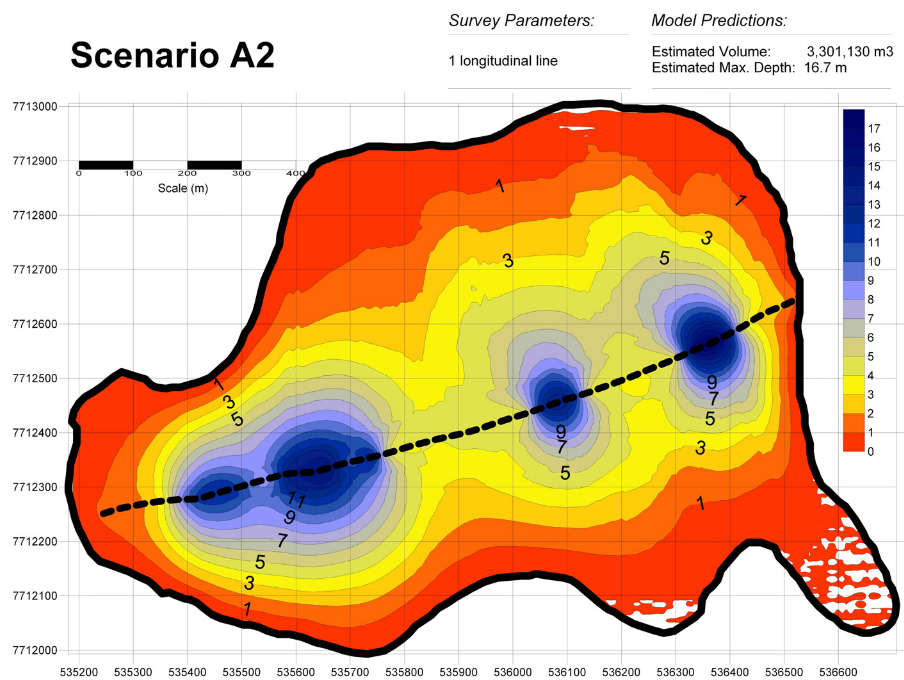

Figure 4. Scenario A2: Minimal sampling effort consisting of one horizontal transect.

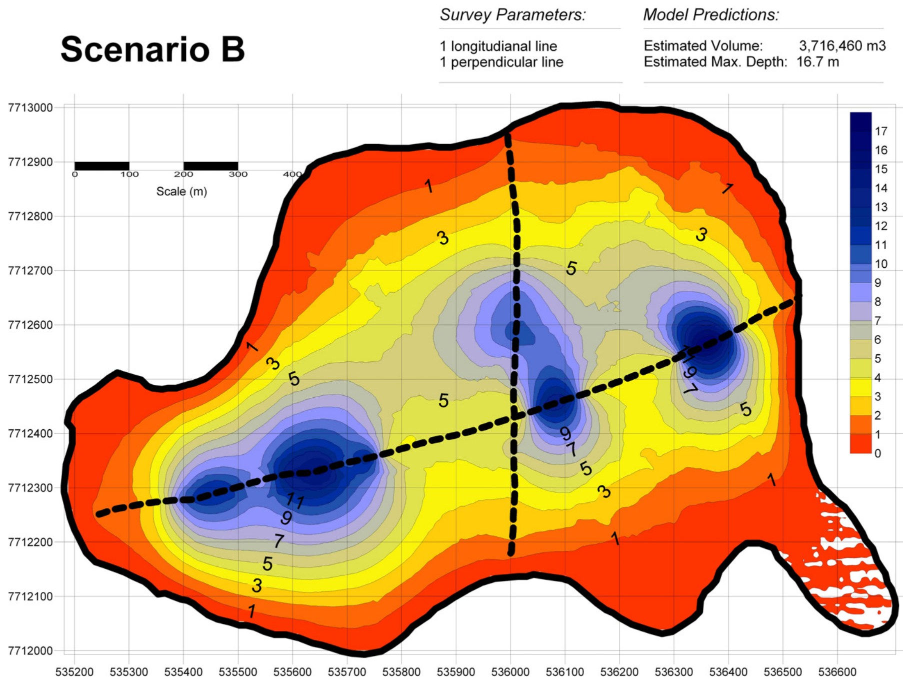

Figure 5. Scenario B: Limited sampling effort consisting of both a vertical and a horizontal transect.

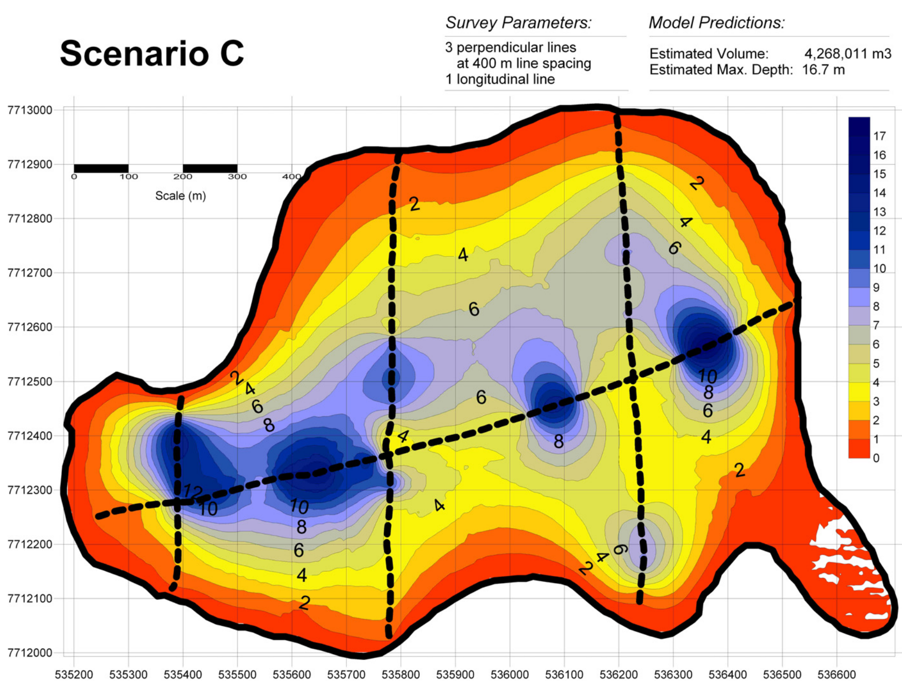

Figure 6. Scenario C: Sampling effort that is acceptable to the *DFO Protocol for Winter Water Withdrawal in the NWT*, providing enough resolution to adequately assess fish overwintering habitat while offering a conservative water volume estimate for withdrawal volume calculations.

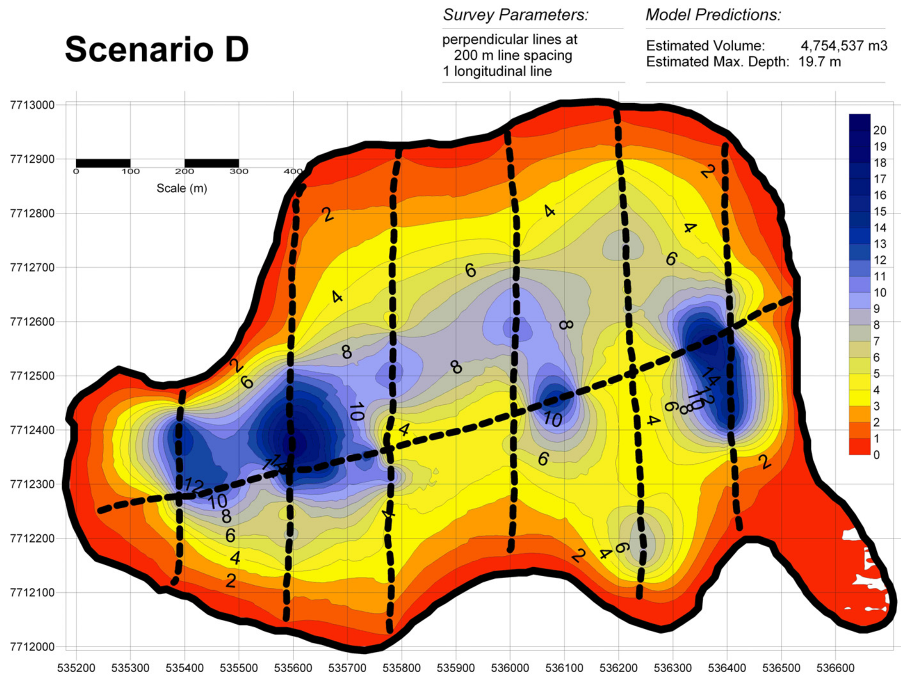

Figure 7. Scenario D: Depicts the effects of increasing the number of vertical transects conducted during a bathymetric survey (i.e. decreasing spacing to 200m), providing a higher level of resolution than depicted in Scenarios A1 – C.

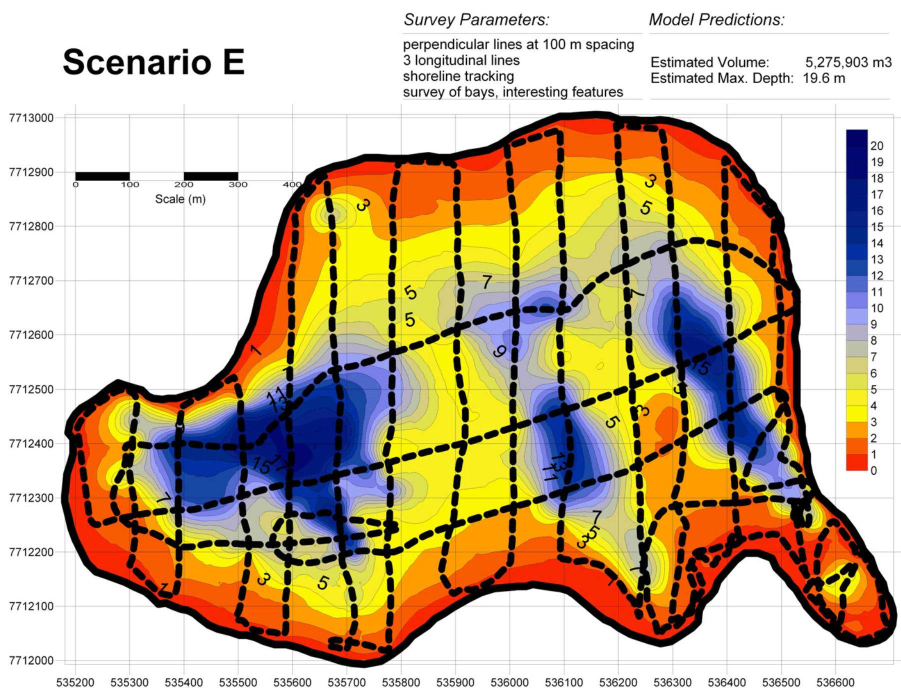

Figure 8. Scenario E: Depicts the gain in resolution, and correspondingly increased water volume estimate, achieved by decreasing the spacing of vertical transects to 100m, conducting 3 horizontal transects, incorporating shoreline tracking, and surveying bays and interesting features.

The estimated water volume was determined to be 1,797,076 m^3 in scenario A1 and by incrementally adding both horizontal (longitudinal along the longest axis) and vertical transects (perpendicular to the longitudinal transects) the volume estimate increased to 5,275,903 m^3 in Scenario E (Figure 8), nearly three times the original volume estimate. Figure 9 illustrates the incremental increase in estimated water volume corresponding to increases in sampling effort, demonstrating that the level of effort expended on the bathymetric survey is directly linked to the level of accuracy obtained regarding the actual volume contained in a given lake.

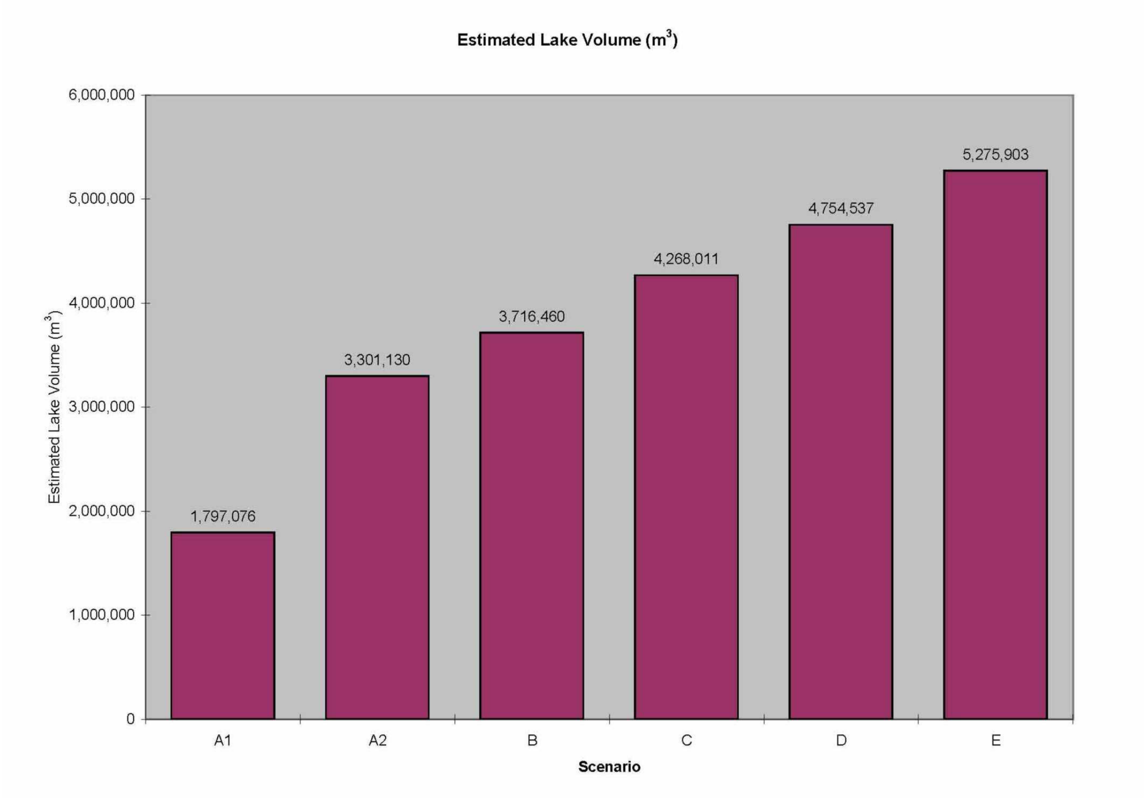

Figure 9. Water volume estimates calculated for Lake 55 (see Appendix 2) using bathymetric survey scenarios (Figures 3 – 8) that differ in sampling effort.

The larger the available volume in the lake is, the larger the volume available for withdrawal. If bathymetry is conducted in a way that provides little resolution, the overall volume will likely be under-estimated as deep areas of a lake may be missed altogether. Therefore, a lake may not appear to fall into a category that is suitable for water withdrawal under the protocol. Missing suitable water sources can cause increased costs due to project delays and increased water hauling distances. Since most of the cost associated with conducting bathymetric surveys in the NWT is mobilizing personnel and equipment to site, the additional cost of running extra transects is minimal while the corresponding benefits, including improving public perception, is substantial.

Accurate bathymetry can also assist in determining the likely extent of ground-fast ice. Knowing the extent of ground-fast ice can help in determining the safest winter ice-road routing. For seismic exploration, knowing the extent of ground-fast ice can identify areas where vibroseis units can be used safely and effectively from a data acquisition standpoint, possibly precluding the need for explosive infilling which can be expensive and harmful to fish (Cott and Hanna 2004). By understanding the basin morphology in small lakes, over-wintering habitat such as deep holes can be avoided.

Guidelines outlining a minimal acceptable sampling effort (i.e. the protocol) is a valuable tool for industry as it eliminates the guesswork associated with compiling project related environmental information while ensuring consistency between users. It also provides standardized information to DFO regulators that allows for more effective impact assessments, facilitating project review and reducing review time.

Next Steps

A database is being developed to act as a repository for incoming bathymetric information such as the images presented in Appendix B. This database will assist in coordinating water use within projects and between water users. Industry will benefit by having suitable water sources already identified which can be selected from. This will help to avoid duplication of effort thereby reducing costs and time.

A study has been implemented by DFO to investigate the effects of winter water withdrawal on fish in small northern lakes. Chemical parameters and fish population characteristics will be investigated on two small lakes where 10% and 20% of their under ice volume will be withdrawn respectively. These indices will be compared to the two lake's pre-treatment condition, as well as a reference lake. This study is modeled, in part, after the Lake 226 water withdrawal experiment conducted at the Experimental Lakes Area in Northwestern Ontario, where withdrawals of 30% and 45% were shown to have significant effects on fish populations (Jansen 2000). The resulting information will help reinforce or refine recommendations outlined in the protocol.

DFO is working with Environment Canada and Noetix Research to study the feasibility of using RADAR satellite imagery to assess the extent of bottom-fast ice. Lakes that are completely bottom fast during late winter do not have fish over-wintering habitat potential. This technique may enable water users to identify water sources that can be used without any impact to fish or fish habitat and enable fisheries managers to determine lakes that are not fish bearing during the winter.

DFO is open to considering other techniques that may have the potential to assess water volume in small northern lakes, for example the use of multispectral imagery (Steve Solomon, Natural Resources Canada, *pers. comm*. 2005).

CONCLUSIONS

With the economy of the NWT continuing to expand with developments such as the proposed Mackenzie Gas Project, new diamond mines, and associated winter road construction, the demand for water in the winter season is going to increase. The effective determination of sensitive over-wintering fish habitat, combined with the responsible and coordinated withdrawal of water, using precautionary threshold limits will help ensure the protection of northern fisheries resources while allowing industrial development to proceed. Although this report demonstrates the application of the protocol to lakes within Mackenzie Delta and adjacent tundra, the findings are potentially applicable to industrial activities that require water withdrawal in northern regions throughout the world.

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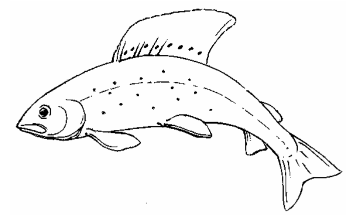
APPENDIX A

DFO PROTOCOL FOR WINTER WATER WITHDRAWAL IN THE NORTHWEST TERRITORIES

Fisheries and Oceans   Pêches et Océans



DFO Protocol for Winter Water Withdrawal
In the Northwest Territories

Rationale

In the Northwest Territories, winter activities such as access road construction, exploratory drilling and camp operations often require large amounts of water. Excessive amounts of water withdrawn from ice covered waterbodies or watercourses can lead to oxygen depletion, loss of over-wintering habitat and/or reductions in littoral habitat. The potential for such negative impacts to over-wintering fish and fish habitat has made winter water withdrawal a critical issue for the Department of Fisheries and Oceans (DFO) in the Northwest Territories. To address the issue of water withdrawal, and to provide standardized guidance to water users, including volume limits for certain water source types, DFO has developed this protocol in conjunction with industry and other regulators.

This protocol pertains to works and activities where a total water volume greater than or equal to (≥) $100m^3$ is required from any given waterbody or watercourse during one ice-covered period.

This protocol will **not** apply to the following:
- Winter water withdrawal from the Mackenzie River;
- Any other waterbody or watercourse that is exempted by DFO (i.e. Great Bear Lake, Great Slave Lake, Gordon Lake, and others as and when determined by DFO), and;
- Any waterbody (not including watercourses) from which less than $100m^3$ is to be withdrawn over the course of one ice-covered period.

Water Withdrawal from Waterbodies:
For the purposes of this protocol, a **waterbody** is defined as any water-filled basin that is potential fish habitat. A waterbody is defined by the ordinary high water mark of the basin, and excludes connecting **watercourses** (see definition in **Water Withdrawal from Watercourses** below). In order to establish a winter water withdrawal limit for a given waterbody, the following criteria must be adhered to:

1. In one ice-covered season, total water withdrawal from a single waterbody is not to exceed 5% of the available water volume calculated using the appropriate maximum expected ice thickness provided in Table 1.
2. **In cases where there are multiple users withdrawing water from a single waterbody, the total combined withdrawal volume is not to exceed 5% of the available water volume calculated using the appropriate maximum expected ice thickness provided in Table 1. Therefore, consistent and coordinated water source identification is essential.**
3. **Only waterbodies with maximum depths that are ≥1.5m deeper than their corresponding maximum expected ice thickness should be considered for water withdrawal (Table 1). Waterbodies with less than 1.5m of free water beneath the maximum ice are considered to be particularly vulnerable to the effects of water withdrawal.**
4. **Any waterbody with a maximum expected ice thickness (Table 1) that is greater than, or equal to, its maximum depth (as determined from a bathymetric survey) is exempt from the 5% maximum withdrawal limit.**

To further mitigate the impacts of water withdrawal, water is to be removed from deep areas of waterbodies (>2m below the ice surface) wherever feasible, to avoid the removal of oxygenated surface waters that are critical to over-wintering fish. The littoral zone should be

avoided as a water withdrawal location. Water intakes should also be properly screened with fine mesh of 2.54 mm (1/10") and have moderate intake velocities to prevent the entrainment of fish. Please refer to the *Freshwater Intake End-of-Pipe Fish Screen Guideline* (DFO, 1995) which is available upon request, or at the following internet address: www.dfo-mpo.gc.ca/Library/223669.pdf.

In order to determine the maximum water withdrawal volume from an ice-covered waterbody and thereby conform to this protocol, the following information must be provided to DFO for review and concurrence, prior to program commencement.

Water Source Identification

1. Proposed primary and secondary access routes for all project activities, with proposed water source and crossing locations clearly identified on a map, with geographical coordinates (latitude/longitude and/or UTMs) included.
2. Documented watercourse connectivity (permanently flowing and/or seasonal) between the proposed water source and any other waterbody or watercourse.
3. Aerial photos or satellite imagery of the water sources if available.
4. Estimated total water withdrawal requirement for work or activity and estimated total water withdrawal per water source (in m^3).

Bathymetric Survey Results

1. For all waterbodies: One longitudinal transect, connecting the two farthest shorelines, is to be conducted regardless of waterbody size. **Note: a longitudinal transect may be straight or curved in order to accommodate the shape of a lake (see Figure 1).**
2. **For waterbodies equal to or less than 1km in length: a minimum of one longitudinal transect and two perpendicular transects are to be conducted. Perpendicular transects should be evenly spaced on the longest longitudinal transect, dissecting the lake into thirds (Figure 1).**
3. **For lakes greater than 1km in length: a minimum of one longitudinal transect is to be conducted. Perpendicular transects (min. of 2) should be evenly spaced on the longest longitudinal transect at maximum intervals of 500m.**
4. Additional transects should be run as required to include irregularities in waterbody shape such as fingers or bays (Figure 1).
5. All longitudinal and perpendicular transects are to be conducted using an accurate, continuous depth sounding methodology, such as open water echo sounding, that provides a continuous depth recording from one shore to the farthest opposing shore (Figure 1). Any alternative technology should be reviewed by DFO prior to implementing for bathymetric surveys.

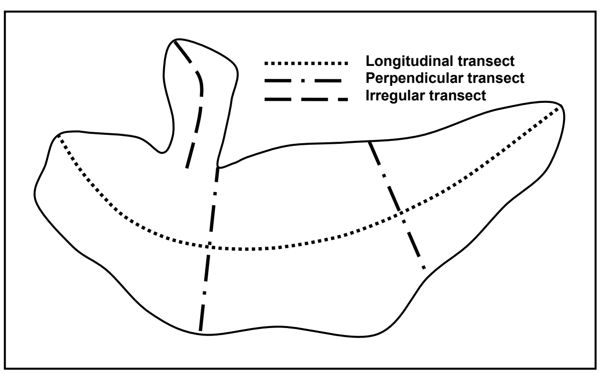


Figure 1. Minimum transect layout for a lake that is less than 1 km in length, with an irregularity.

Volume Calculations

1. Document the methods used to calculate surface area. If aerial photos or satellite imagery were used, provide the date (day/month/year) taken, as surface area may change depending on the time of year. If maps were used, provide the year that they were surveyed.
2. Detail the methods used to determine the total volume of free water, incorporating the relevant bathymetric information.

3. Calculate the available water volume under the ice using the appropriate maximum expected ice thickness, i.e. *Total Volume* $_{lake}$ – *Ice Volume* $_{max\ thickness}$ = *Available Water Volume* (see Table 1 for maximum ice thickness).
4. For programs where ice-chipping is used, the total ice volume to be removed from the waterbody should be converted to total liquid volume and incorporated into the estimate of total water withdrawal requirement per water source.

Table 1. Maximum expected ice thickness, and corresponding water depth requirements, for different regions in the Northwest Territories.

Area	Maximum Expected Ice Thickness (m)	Minimum Waterbody depth Required for 5% Water Withdrawal (m)
Above the Tree Line	**2.0**	**≥3.5**
Below the Tree Line - North of Fort Simpson	**1.5**	**≥3.0**
Deh Cho –South of Fort Simpson	**1.0**	**≥2.5**

Water Withdrawal from Watercourses:

For the purposes of this protocol, a **watercourse** is defined as a channel through which water flows and is potential fish habitat. A watercourse is defined by the ordinary high water mark of the channel, and excludes connecting waterbodies or watercourses. In order to establish a winter water withdrawal limit for a given watercourse, the following criteria must be adhered to:

1. **Total water withdrawal for all activities is not to exceed 5% of the instantaneous flow rate of a single watercourse at the time of withdrawal.**
2. **In cases where there are multiple users withdrawing water from a single watercourse, the total combined withdrawal rate is not to exceed 5% of the instantaneous flow rate at the time of withdrawal. Therefore, consistent and coordinated water source identification is essential.**

To further mitigate the impacts from water withdrawal, water intakes should be properly screened with fine mesh of **2.54 mm (1/10")** and have moderate intake velocities to prevent the entrainment of fish. Please refer to the *Freshwater Intake End-of-Pipe Fish Screen Guideline* (DFO, 1995) which is available upon request, or at the following internet address: www.dfo-mpo.gc.ca/Library/223669.pdf.

In order to determine the maximum water withdrawal rate from an ice-covered watercourse and thereby conform to this protocol, the following information must be provided to DFO for review and concurrence, prior to program commencement. DFO will only consider watercourses to be used as water sources if no suitable alternatives exist.

Water Source Identification

1. Proposed primary and secondary access routes for all project activities, with proposed water crossings and water source locations clearly identified on a map, with geographical coordinates (latitude/longitude and/or UTMs) included.
2. Aerial photos or satellite imagery of the water sources if available.
3. Estimated total water withdrawal requirement for work or activity, and estimated total water withdrawal per water source (in m^3).

Stream Survey Requirements

1. **Location and date of survey (day, month, and year).**
2. **Photos of the stream location where withdrawal is to occur.**
3. **An accurate measurement of flow rate (to be confirmed immediately prior to water withdrawal commencing).**
4. **Stream survey should include; profile (minimum of ten evenly spaced points), depth, width, and flow rate.**
5. **Survey effort should reflect channel width: <2m wide, three vertical stations; 2-10m, 10 vertical stations; >10m, 20 vertical stations.**

6. **Pump specifications (type, model, horsepower, and max discharge rate).**
7. **Information on substrate type, in-water vegetation, riparian vegetation, and bank description is also requested.**

A brief project summary report documenting and confirming total water volume used per water source, withdrawal rates, flow rates per source and corresponding dates should be submitted to DFO within 60 days of project completion. Information should be provided in the following format (this information would also be useful as part of the project description):

Lake ID	number and/or name
Coordinates	latitude and longitude and/or UTM coordinates
Surface area	in m^2
Total Lake Volume	in m^3
Under Ice Volume	in m^3 (based on max ice thickness for region)
Max expected ice thickness value used	in m
Calculated 5% Withdrawal volume	in m^3
Total required water volume extracted	in m^3
Photograph of waterbody	
Bathymetric Map(s) of waterbody	

Any requests deviating from the above must be submitted to DFO and will be addressed on a site-specific basis.

Please note that adherence to this protocol does not release the proponent of the responsibility for obtaining any permits, licenses or authorizations that may be required.

For more information contact DFO at (867) 669-4900.

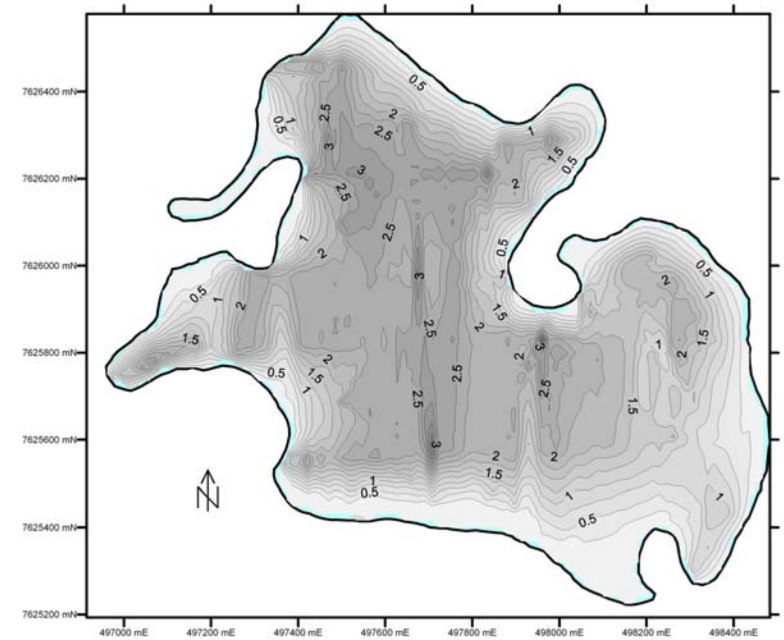
Canada **Current as of January 31, 2005/pc/am/bh/jd**

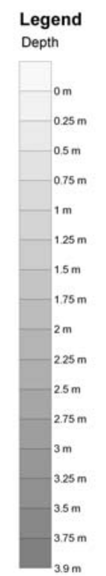
APPENDIX B

BATHYMETRIC IMAGES ON 55 LAKES IN THE MACKENZIE DELTA AND SURROUNDING AREA.

Lake 1

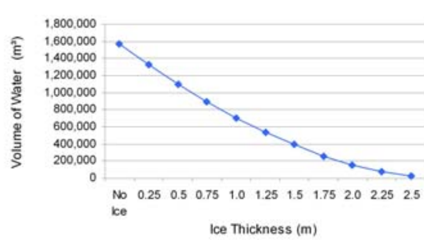
Contour Map





Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	1,571,297	100.0
0.25	1,323,784	84.2
0.5	1,098,620	69.9
0.75	892,562	56.8
1.0	705,641	44.9
1.25	537,454	34.2
1.5	390,020	24.8
1.75	261,690	16.7
2.0	154,648	9.8
2.25	73,460	4.7
2.5	24,323	1.5

Volume of Water (m³) vs. Ice Thickness (m)



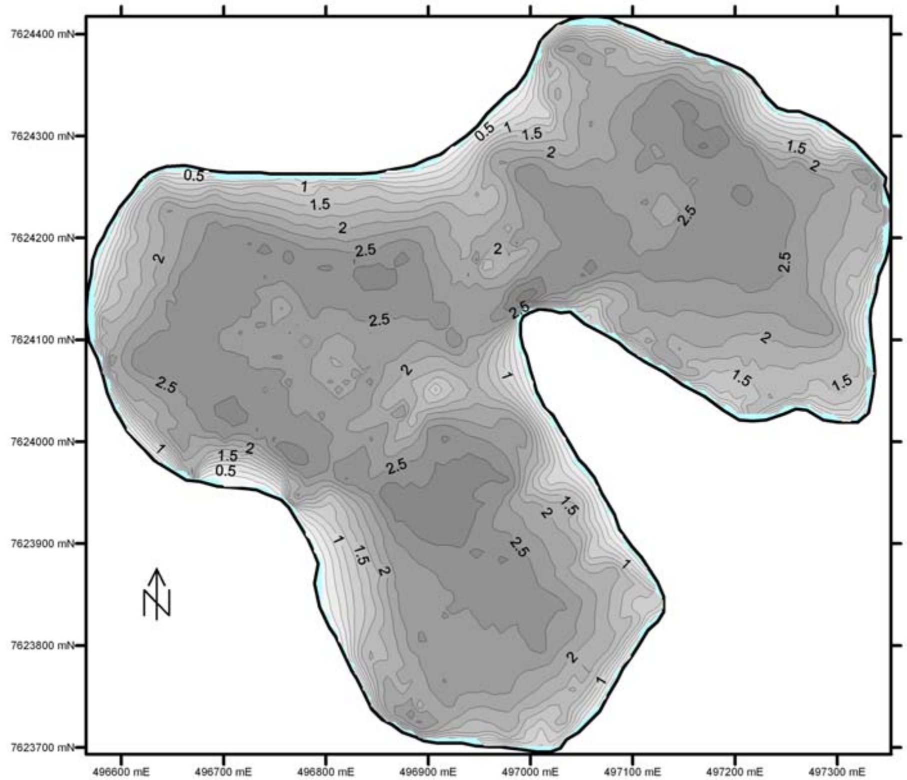
LAKE DETAILS

Average Depth: 1.4 meters
Maximum Depth: 3.9 meters
Lake Volume: 1,571,297 cubic meters
Top Lake Surface Area: 1,044,082 square meters

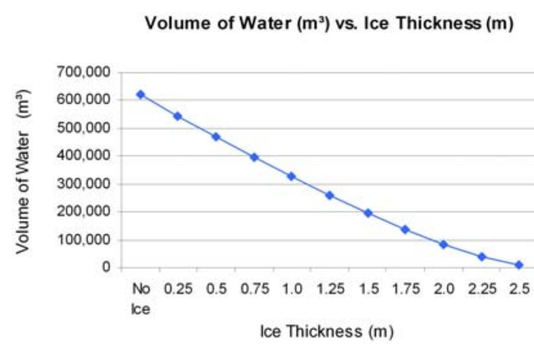
Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 2

Contour Map



Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	621,965	100.0
0.25	544,954	87.6
0.5	469,867	75.5
0.75	396,953	63.8
1	326,386	52.5
1.25	258,627	41.6
1.5	194,408	31.3
1.75	135,205	21.7
2	83,080	13.4
2.25	40,606	6.5
2.5	11,211	1.8



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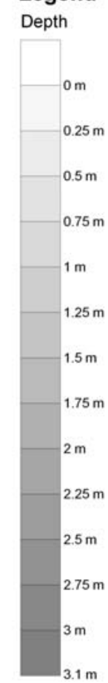
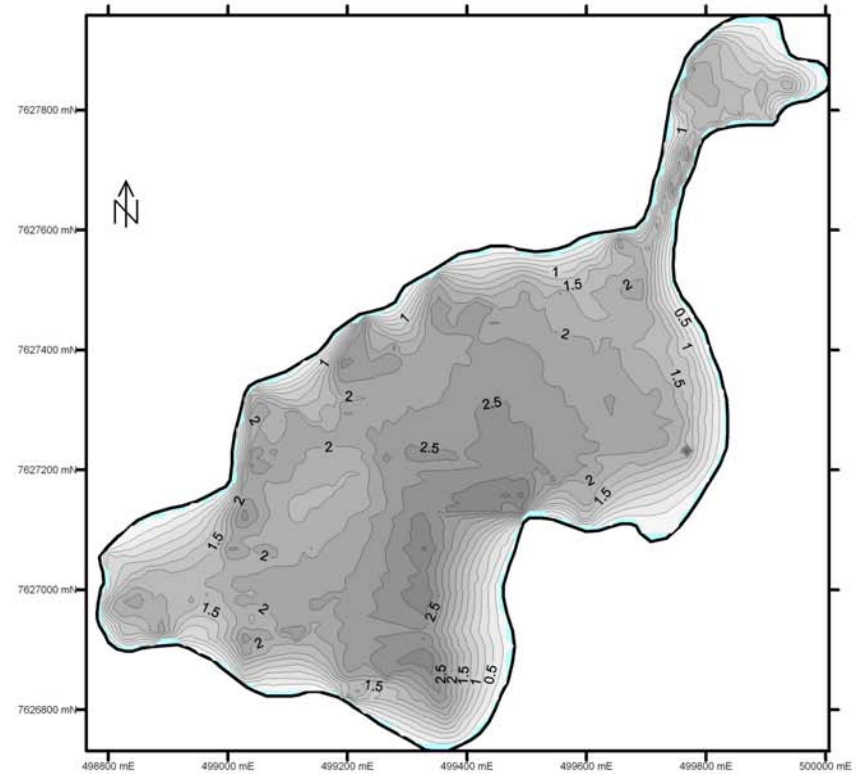


Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

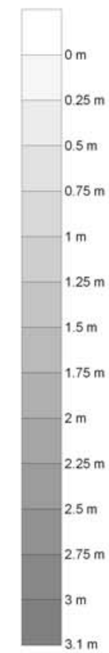
Lake 3

Contour Map



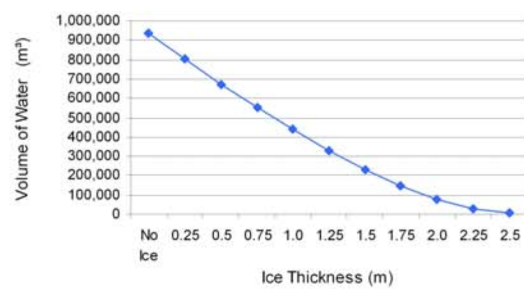
Legend

Depth



Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	938,582	100.0
0.25	801,801	85.4
0.5	673,362	71.7
0.75	552,057	58.8
1.0	437,842	46.6
1.25	331,130	35.3
1.5	232,814	24.8
1.75	145,419	15.5
2.0	75,540	8.0
2.25	29,303	3.1
2.5	7,918	0.8

Volume of Water (m³) vs. Ice Thickness (m)



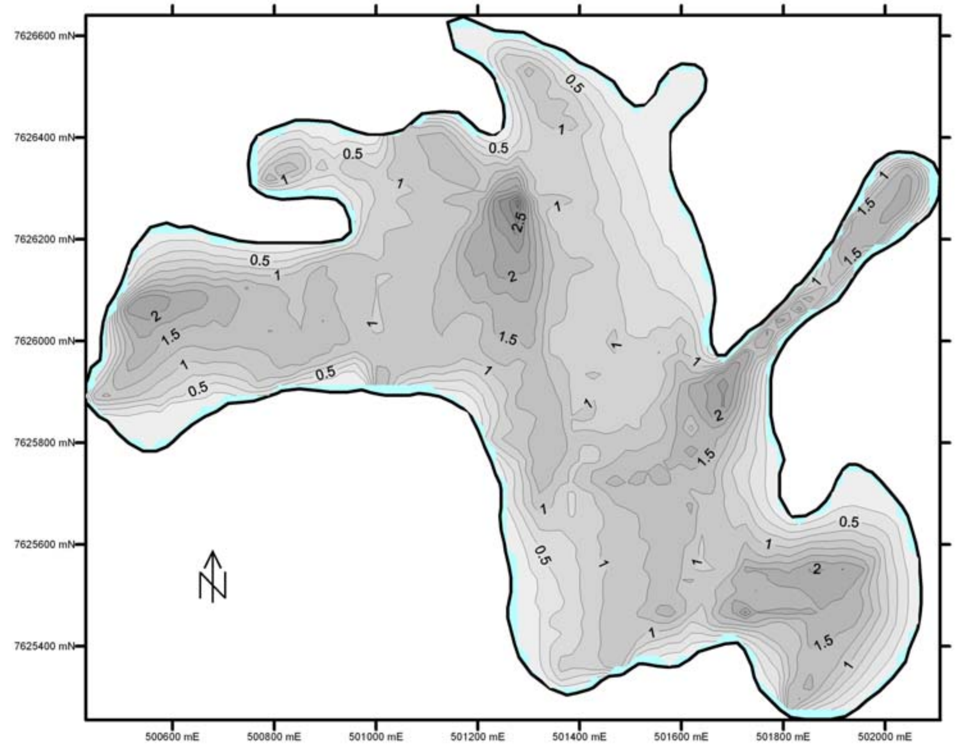
LAKE DETAILS

Average Depth: 1.7 meters
Maximum Depth: 3.1 meters
Lake Volume: 938,582 cubic meters
Top Lake Surface Area: 531,576 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 4

Contour Map



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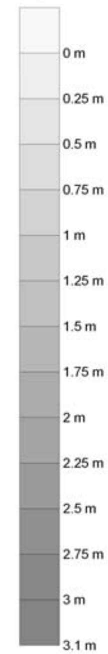
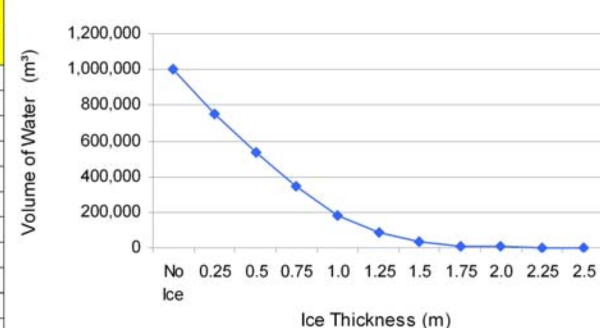
Depth



Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	1,000,637	100.0
0.25	752,914	75.2
0.5	534,101	53.4
0.75	342,422	34.2
1.0	185,261	18.5
1.25	85,305	8.5
1.5	35,334	3.5
1.75	12,689	1.3
2.0	4,340	0.4
2.25	1,468	0.1
2.5	465	0.0

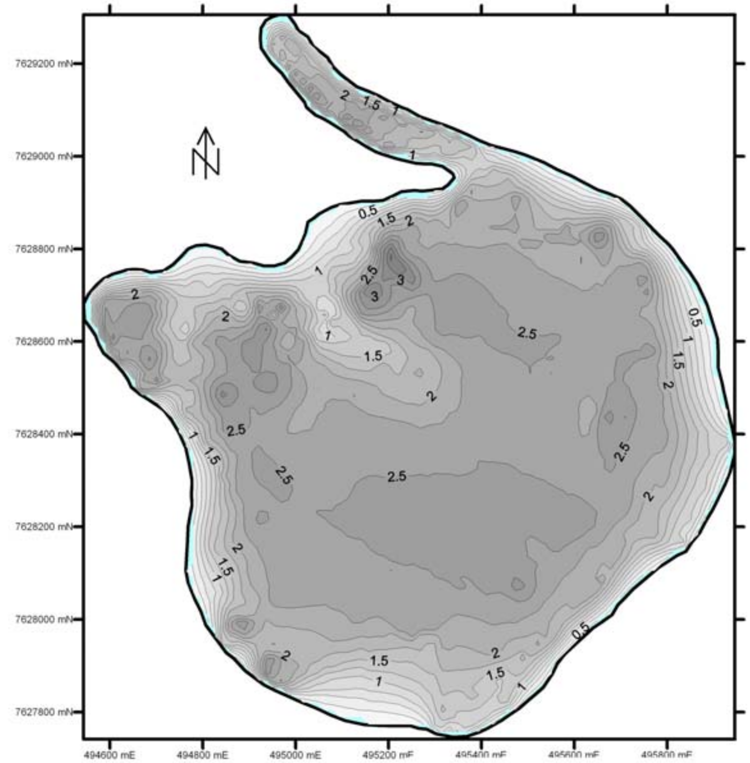
Volume of Water (m^3) vs. Ice Thickness (m)



Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

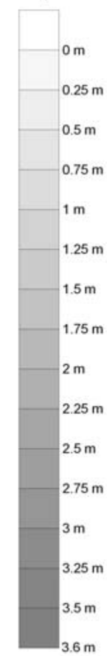
Lake 5

Contour Map



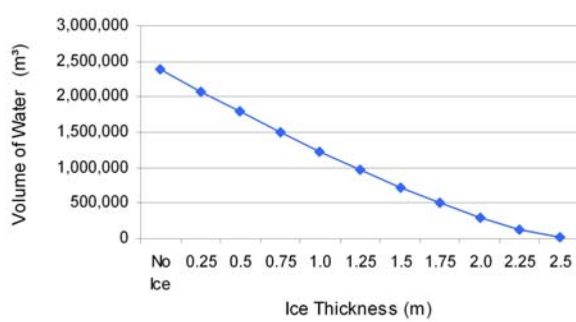
Legend

Depth



Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	2,383,667	100.0
0.25	2,079,130	87.2
0.5	1,785,421	74.9
0.75	1,502,283	63.0
1.0	1,229,850	51.6
1.25	970,534	40.7
1.5	726,966	30.5
1.75	501,538	21.0
2.0	298,313	12.5
2.25	127,177	5.3
2.5	21,668	0.9

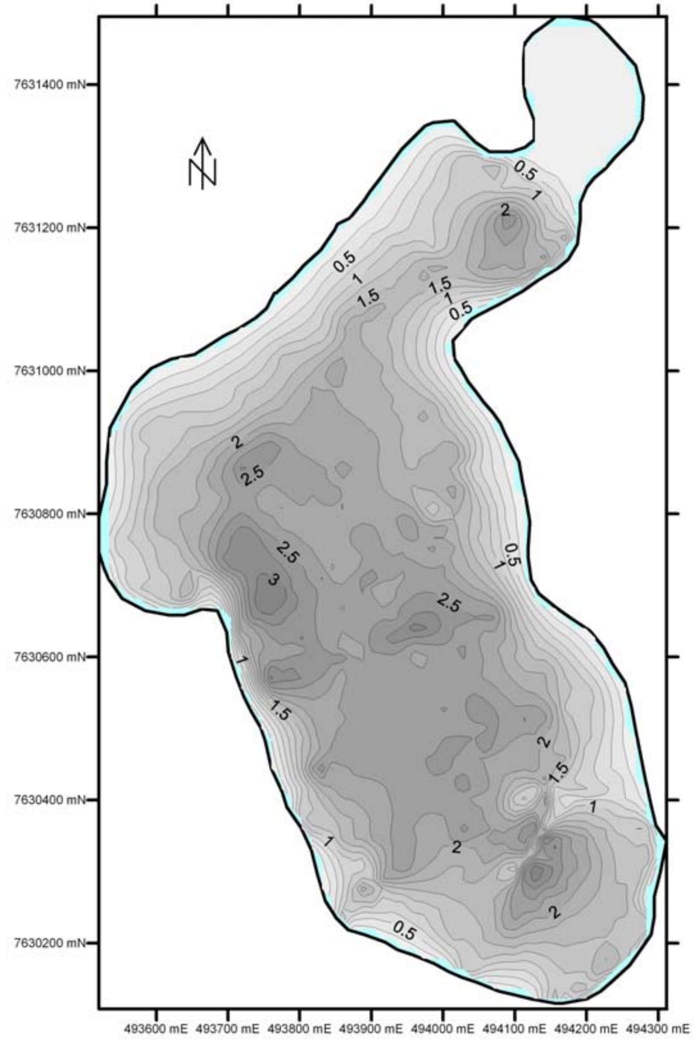
Volume of Water (m³) vs. Ice Thickness (m)



LAKE DETAILS

Average Depth: 1.9 meters
Maximum Depth: 3.6 meters
Lake Volume: 2,383,667 cubic meters
Top Lake Surface Area: 1,192,044 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

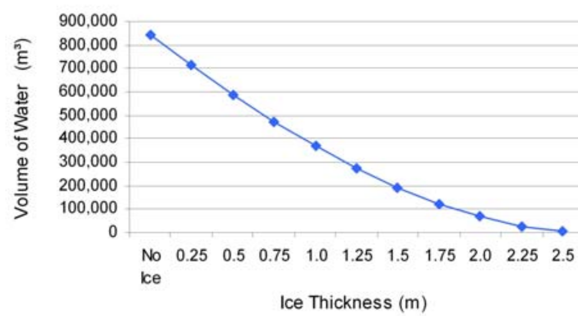


Lake 6

Contour Map

Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	845,098	100.0
0.25	713,022	84.4
0.5	590,039	69.8
0.75	475,312	56.2
1.0	369,682	43.7
1.25	275,234	32.6
1.5	192,757	22.8
1.75	123,351	14.6
2.0	67,972	8.0
2.25	26,452	3.1
2.5	7,240	0.9

Volume of Water (m³) vs. Ice Thickness (m)



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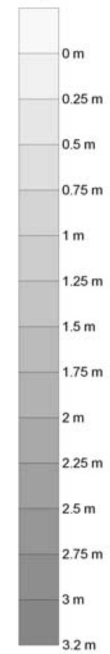
Depth



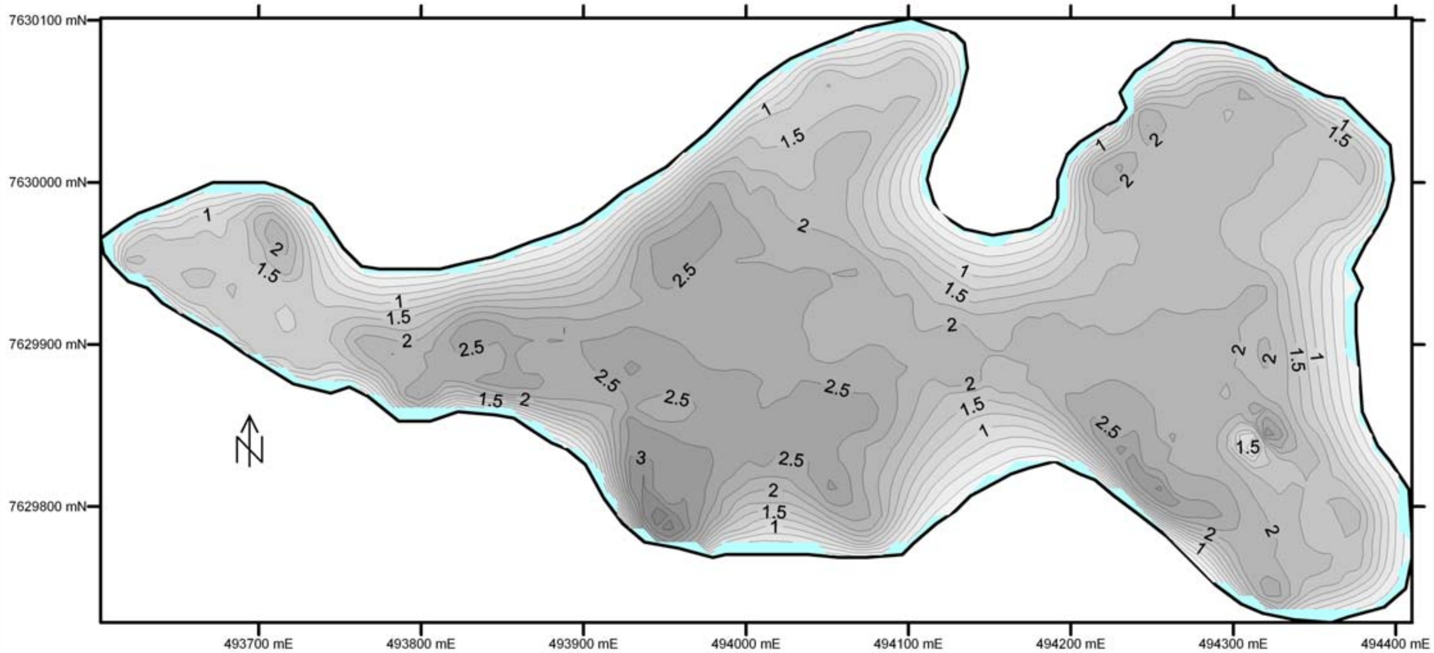
LAKE DETAILS

Average Depth: 1.5 meters
Maximum Depth: 3.2 meters
Lake Volume: 845,098 cubic meters
Top Lake Surface Area: 540,855 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 7

Contour Map



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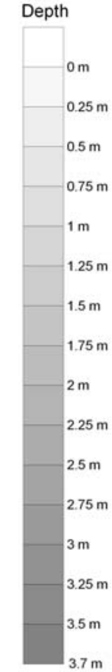
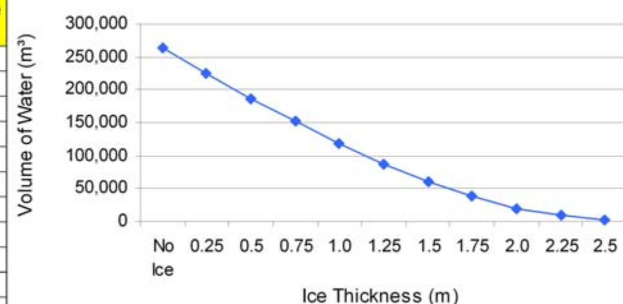


Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	263,238	100.0
0.25	224,144	85.1
0.5	186,851	71.0
0.75	151,723	57.6
1.0	118,734	45.1
1.25	87,983	33.4
1.5	60,670	23.0
1.75	37,652	14.3
2.0	20,252	7.7
2.25	8,933	3.4
2.5	2,726	1.0

Volume of Water (m³) vs. Ice Thickness (m)



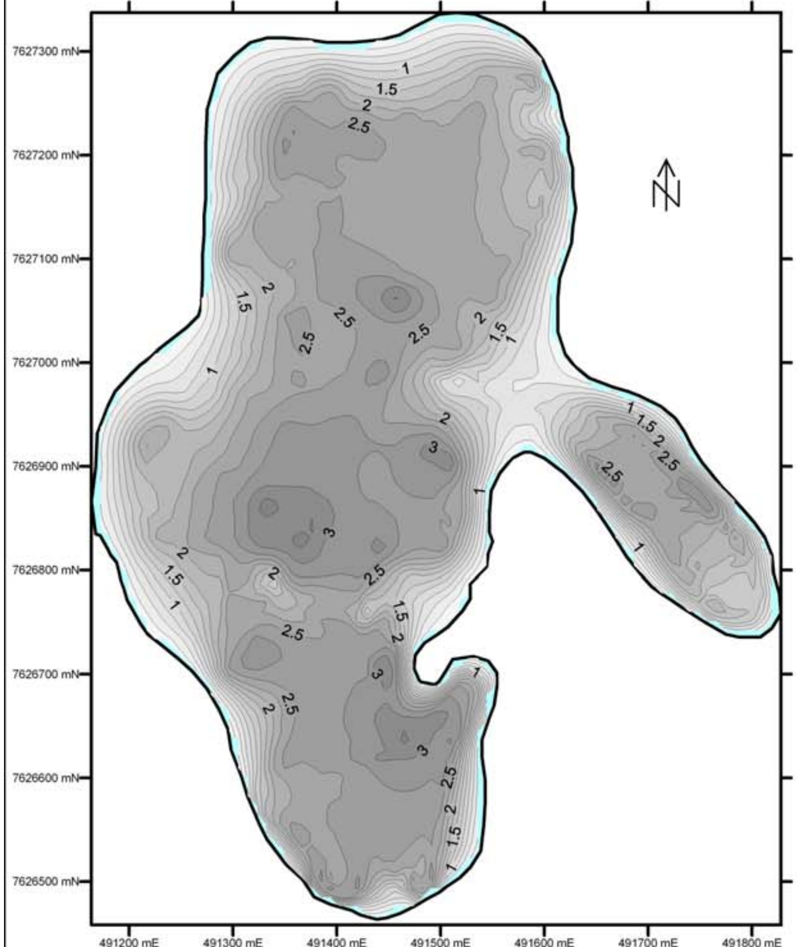
LAKE DETAILS

Average Depth: 1.7 meters
Maximum Depth: 3.7 meters
Lake Volume: 263,238 cubic meters
Top Lake Surface Area: 148,653 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 8

Contour Map



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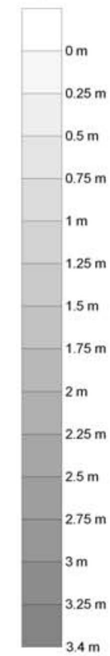
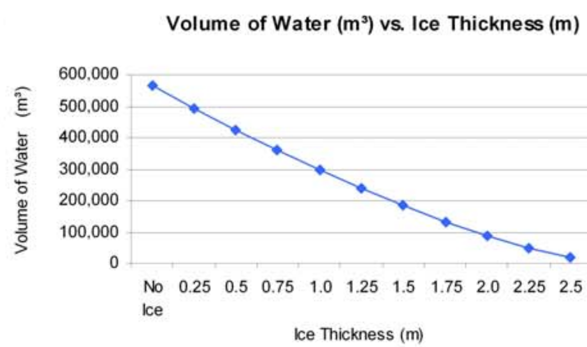


Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	567,508	100.0
0.25	494,213	87.1
0.5	424,645	74.8
0.75	359,194	63.3
1.0	297,526	52.4
1.25	239,380	42.2
1.5	184,756	32.6
1.75	134,052	23.6
2.0	88,487	15.6
2.25	49,349	8.7
2.5	20,106	3.5



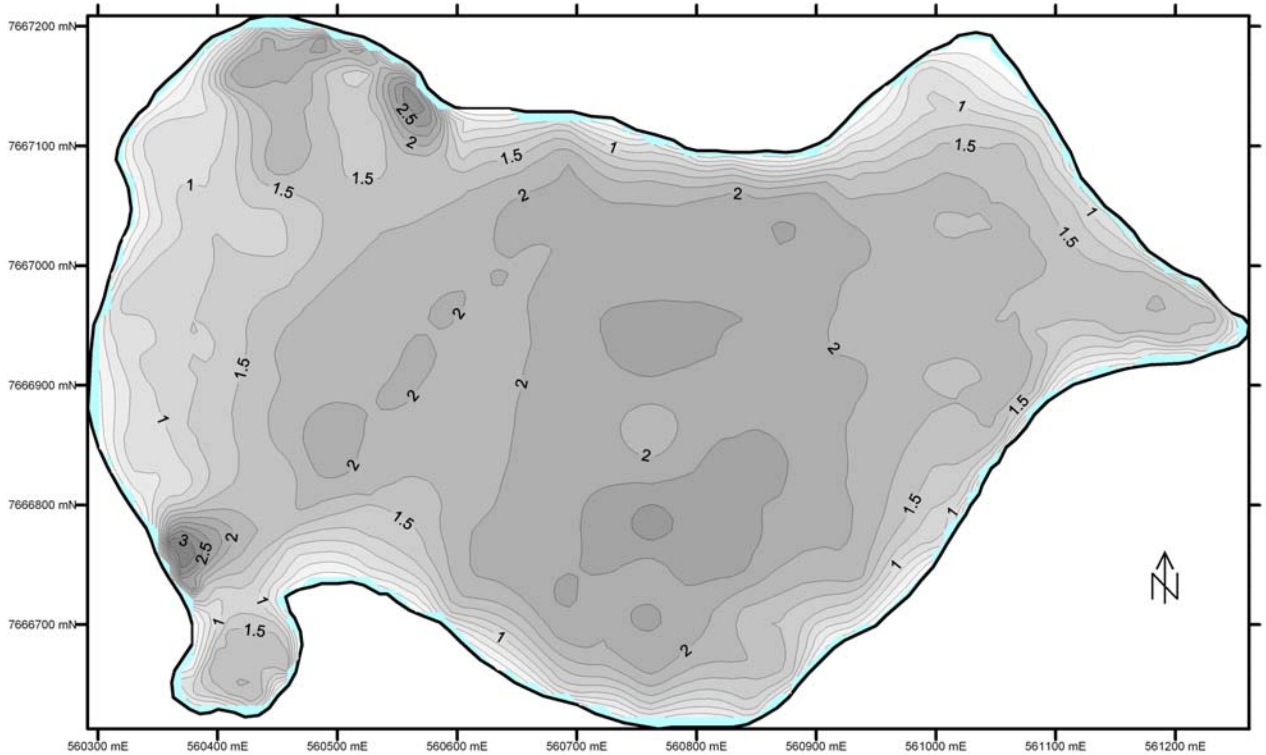
LAKE DETAILS

Average Depth: 1.9 meters
Maximum Depth: 3.4 meters
Lake Volume: 567,508 cubic meters
Top Lake Surface Area: 284,661 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 9

Contour Map



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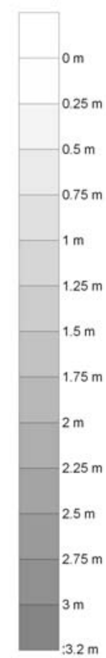
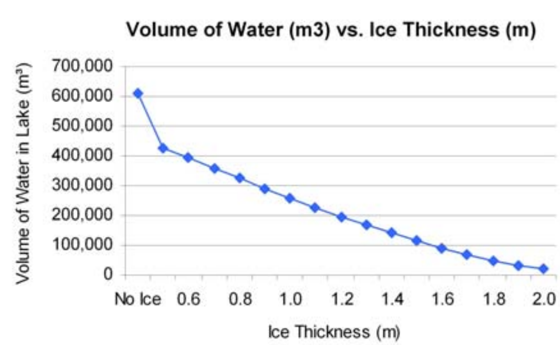


Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	612,159	100.0
0.5	428,660	70.0
0.6	393,368	64.3
0.7	358,621	58.6
0.8	324,509	53.0
0.9	291,200	47.6
1.1	258,901	42.3
1.2	197,301	32.2
1.3	168,376	27.5
1.4	140,815	23.0
1.5	114,690	18.7
1.6	90,217	14.7
1.7	67,937	11.1
1.8	48,268	7.9
1.9	32,347	5.3
2.0	19,967	3.3



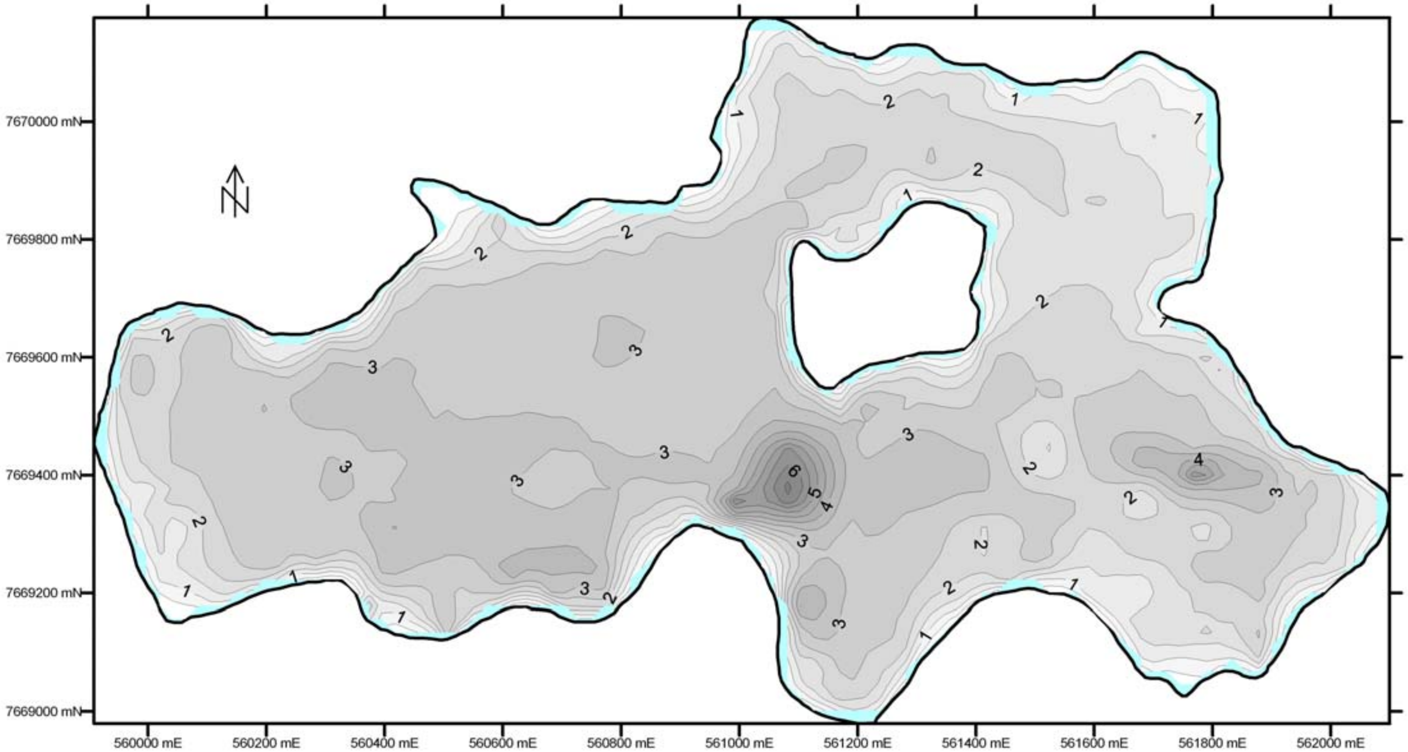
LAKE DETAILS

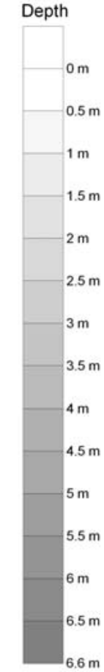
Average Depth: 1.6 meters
Maximum Depth: 3.2 meters
Lake Volume: 612,159 cubic meters
Top Lake Surface Area: 360,387 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 10

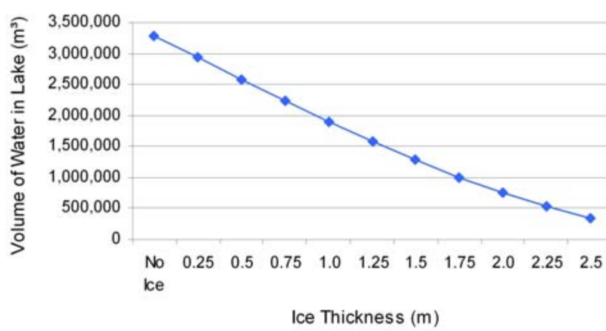
Contour Map





Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	3,289,435	100.0
0.25	2,932,035	89.1
0.5	2,581,442	78.5
0.75	2,239,008	68.1
1	1,906,307	58.0
1.25	1,586,369	48.2
1.5	1,283,253	39.0
1.75	1,002,164	30.5
2	747,790	22.7
2.25	524,066	15.9
2.5	335,024	10.2

Volume of Water (m^3) vs. Ice Thickness (m)



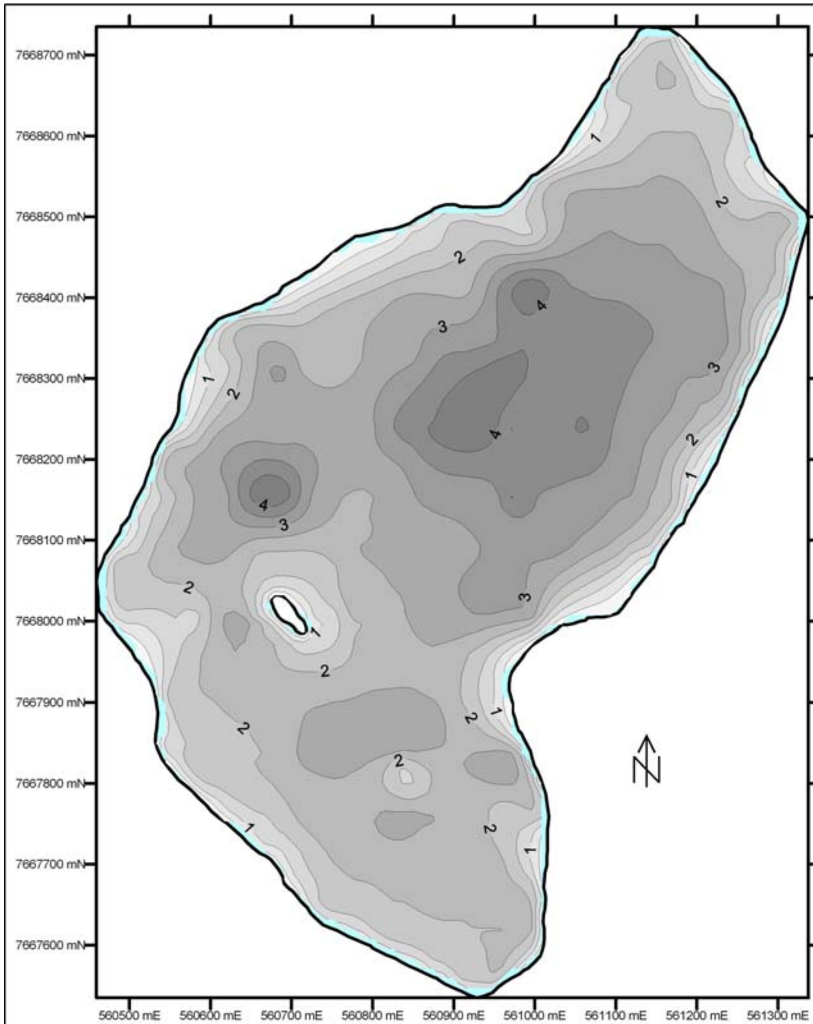
LAKE DETAILS

Average Depth: 2.3 meters
Maximum Depth: 6.6 meters
Lake Volume: 3,289,435 cubic meters
Top Lake Surface Area: 1,348,009 square meters

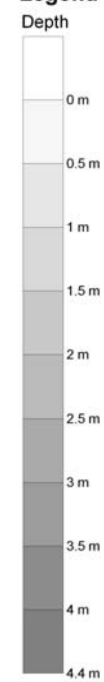
Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 11

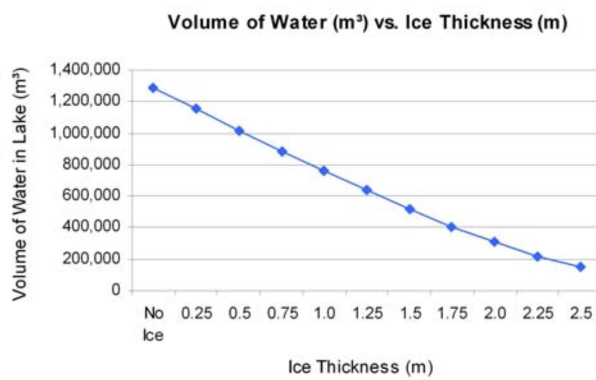
Contour Map



Legend



Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	1,289,354	20.3
0.25	1,152,898	18.1
0.5	1,018,456	16.0
0.75	886,791	13.9
1.0	758,472	11.9
1.25	634,572	10.0
1.5	516,247	8.1
1.75	405,881	6.4
2.0	306,596	4.8
2.25	220,379	3.5
2.5	151,551	2.4



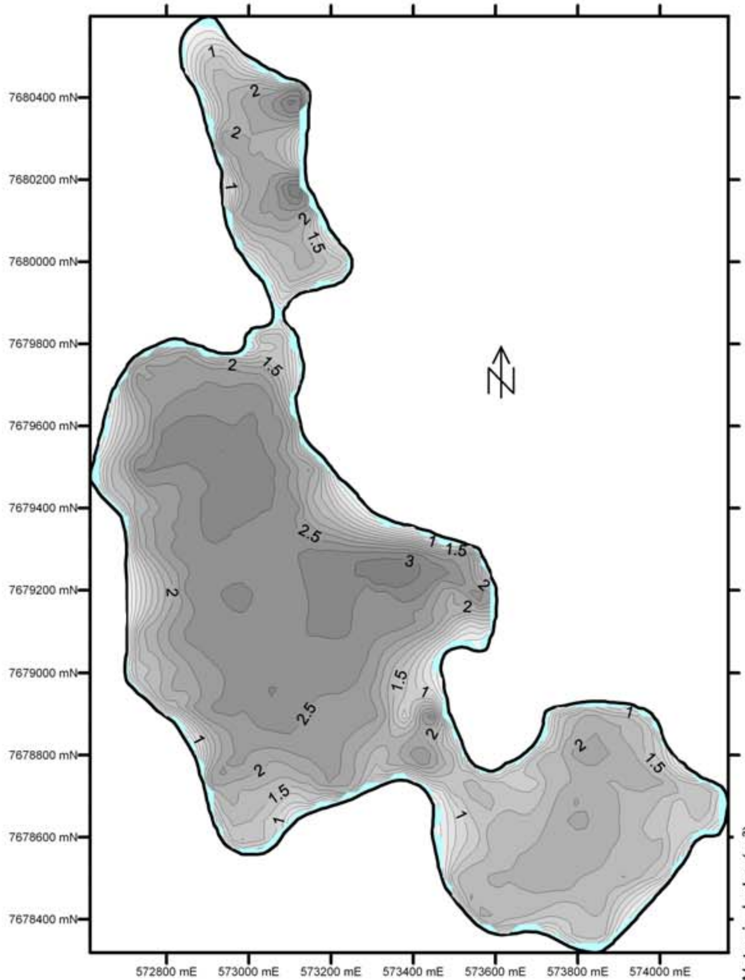
LAKE DETAILS

Average Depth: 2.4 meters
Maximum Depth: 4.4 meters
Lake Volume: 1,289,354 cubic meters
Top Lake Surface Area: 525,228 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

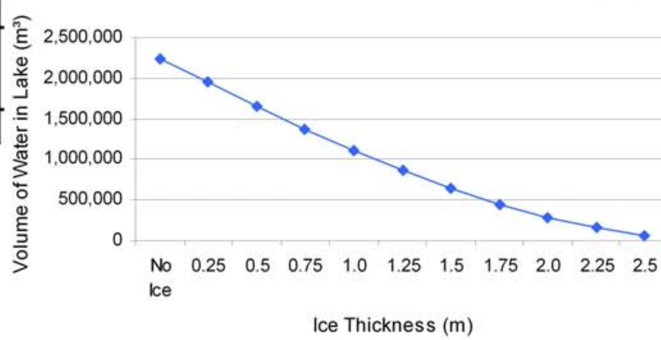
Lake 12

Contour Map



Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	2,246,198	100.0
0.25	1,948,465	86.7
0.5	1,659,437	73.9
0.75	1,380,815	61.5
1.0	1,114,670	49.6
1.25	864,169	38.5
1.5	636,786	28.3
1.75	442,066	19.7
2.0	287,160	12.8
2.25	163,716	7.3
2.5	66,755	3.0

Volume of Water (m^3) vs. Ice Thickness (m)



Legend

Depth

0 m
0.25 m
0.5 m
0.75 m
1 m
1.25 m
1.5 m
1.75 m
2 m
2.25 m
2.5 m
2.75 m
3 m
3.1 m

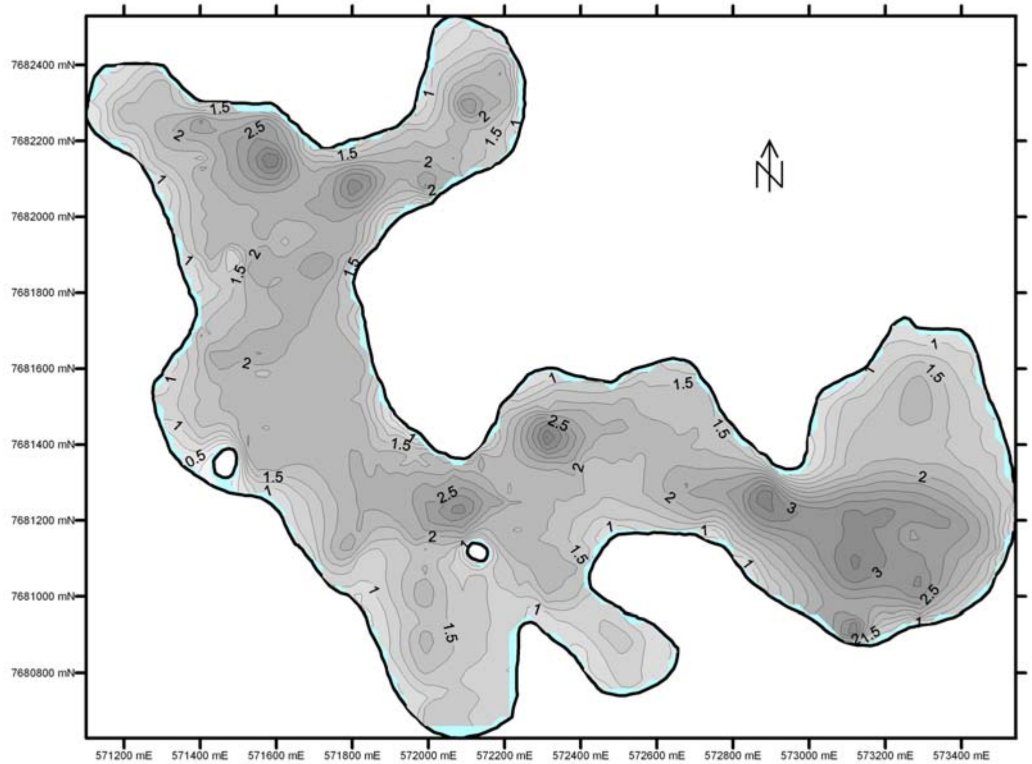
LAKE DETAILS

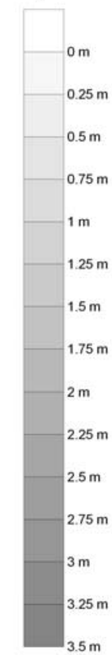
Average Depth: 1.9 meters
Maximum Depth: 3.1 meters
Lake Volume: 2,246,198 cubic meters
Top Lake Surface Area: 1,112,654 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

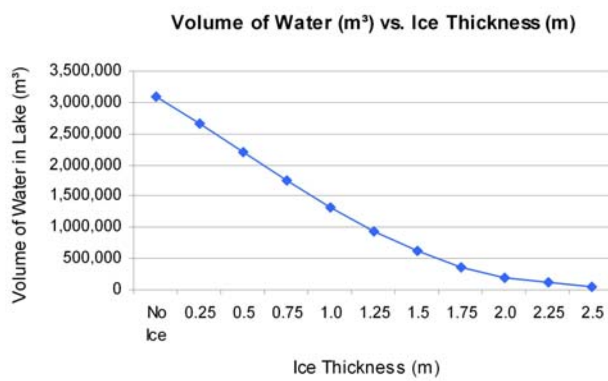
Lake 13

Contour Map





Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	3,100,134	100.0
0.25	2,648,994	85.4
0.5	2,199,014	70.9
0.75	1,751,536	56.5
1.0	1,324,268	42.7
1.25	941,008	30.4
1.5	618,300	19.9
1.75	362,906	11.7
2.0	198,977	6.4
2.25	110,476	3.6
2.5	56,124	1.8



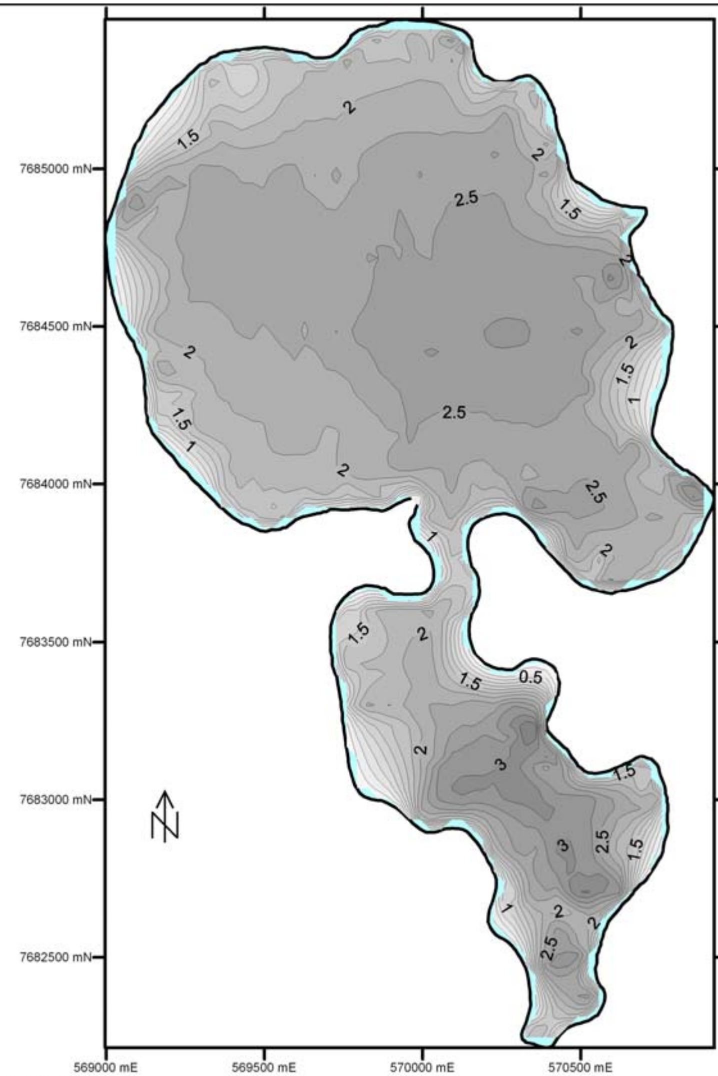
LAKE DETAILS

Average Depth: 1.7 meters
Maximum Depth: 3.5 meters
Lake Volume: 3,100,134 cubic meters
Top Lake Surface Area: 1,676,252 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 14

Contour Map

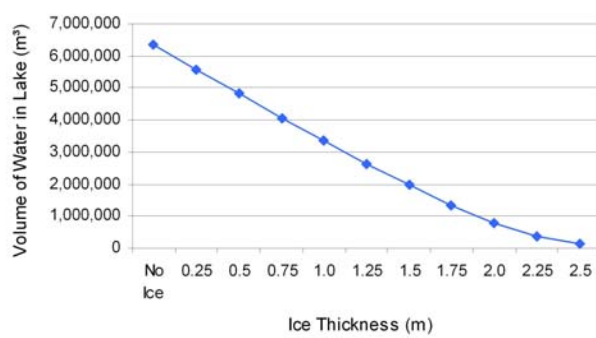


LAKE DETAILS

Average Depth: 2.0 meters
Maximum Depth: 3.5 meters
Lake Volume: 6,360,440 cubic meters
Top Lake Surface Area: 2,949,923 square meters

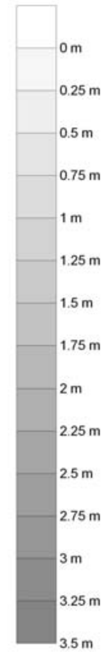
Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	6,360,440	100.0
0.25	5,580,629	87.7
0.5	4,817,080	75.7
0.75	4,070,888	64.0
1.0	3,344,481	52.6
1.25	2,642,840	41.6
1.5	1,974,413	31.0
1.75	1,352,424	21.3
2.0	803,084	12.6
2.25	376,070	5.9
2.5	125,363	2.0

Volume of Water (m^3) vs. Ice Thickness (m)



Legend

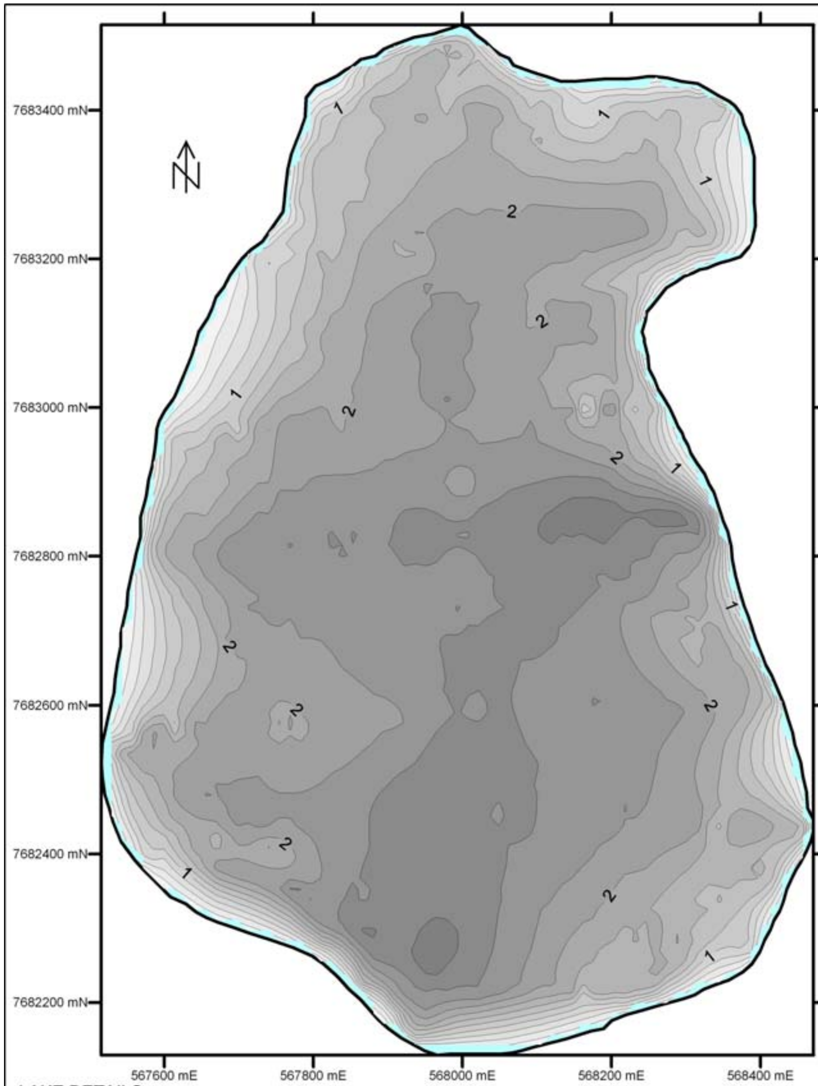
Depth



Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 15

Contour Map

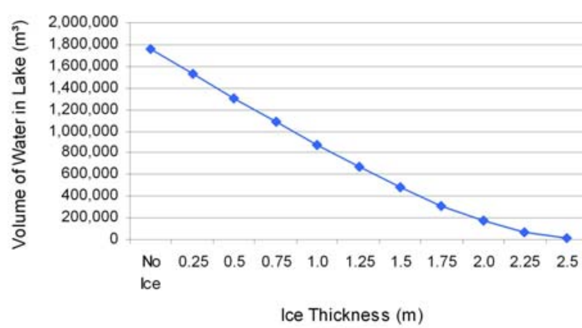


LAKE DETAILS

Average Depth: 1.9 meters
Maximum Depth: 3.0 meters
Lake Volume: 1,763,876 cubic meters
Top Lake Surface Area: 913,892 square meters

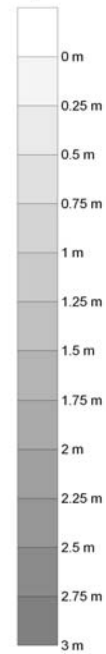
Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	1,763,876	100.0
0.25	1,529,959	86.7
0.5	1,302,215	73.8
0.75	1,081,623	61.3
1.0	869,178	49.3
1.25	667,168	37.8
1.5	479,145	27.2
1.75	311,516	17.7
2.0	171,929	9.7
2.25	69,397	3.9
2.5	13,413	0.8

Volume of Water (m^3) vs. Ice Thickness (m)



Legend

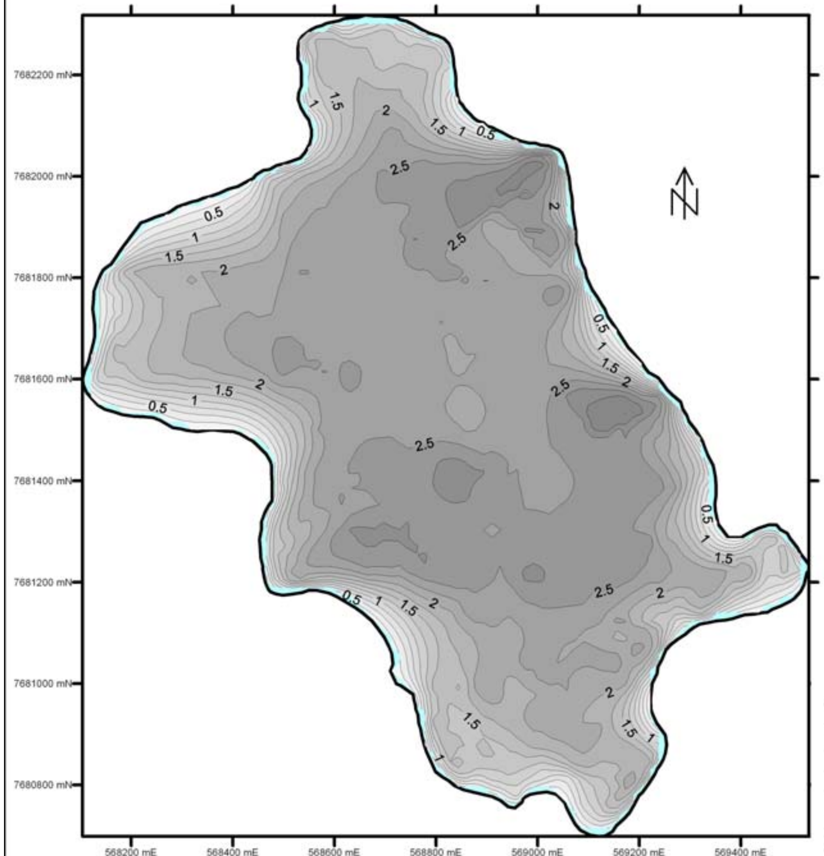
Depth



Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

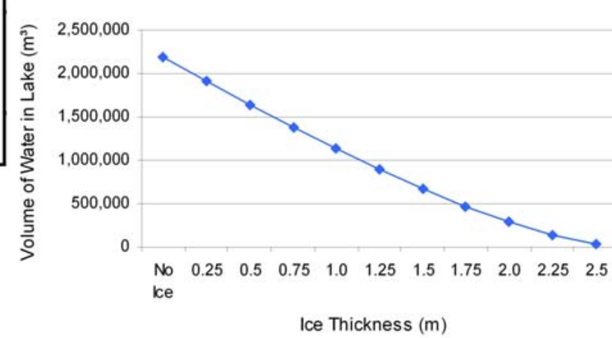
Lake 16

Contour Map



Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	2,188,830	100.0
0.25	1,911,901	87.3
0.5	1,643,094	75.1
0.75	1,382,990	63.2
1.0	1,132,658	51.7
1.25	893,867	40.8
1.5	670,182	30.6
1.75	466,563	21.3
2.0	285,801	13.1
2.25	134,059	6.1
2.5	35,726	1.6

Volume of Water (m³) vs. Ice Thickness (m)

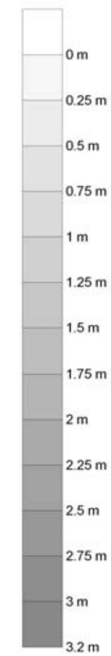


LAKE DETAILS

Average Depth: 2.0 meters
Maximum Depth: 3.2 meters
Lake Volume: 2,188,830 cubic meters
Top Lake Surface Area: 1,076,391 square meters

Legend

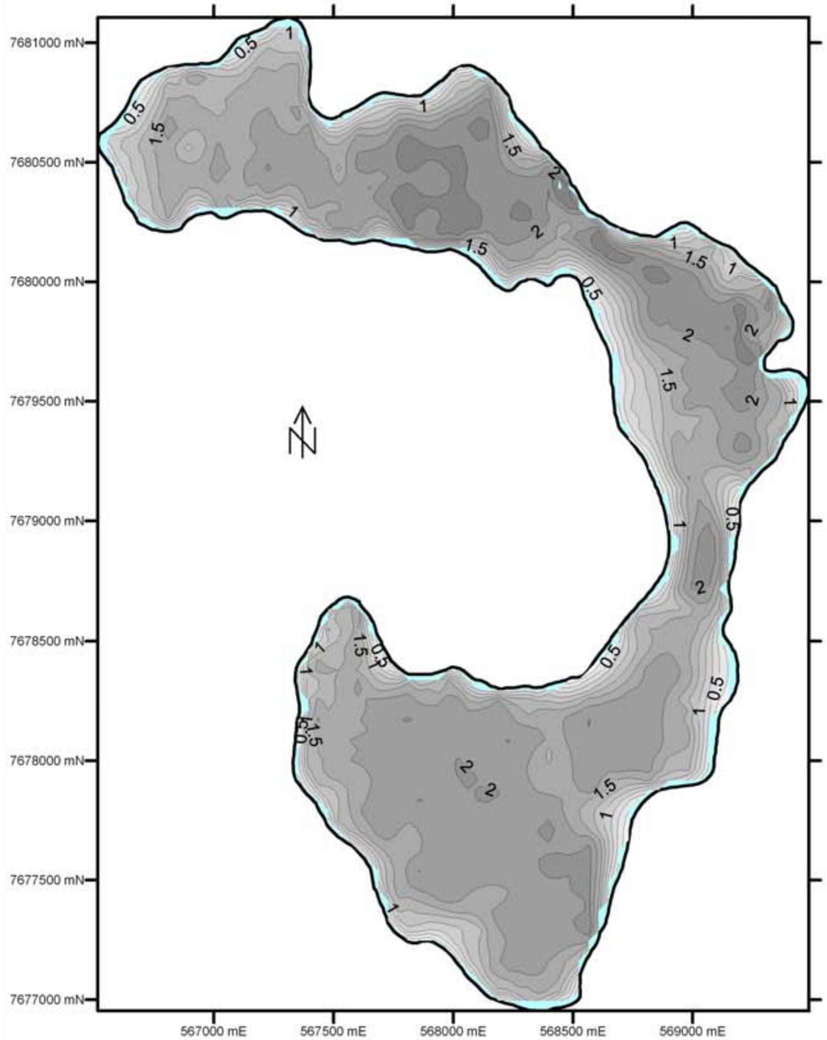
Depth



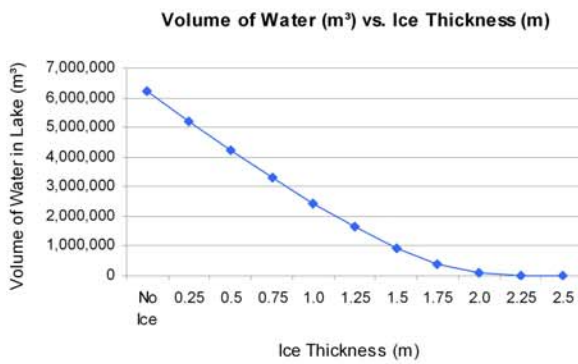
Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 17

Contour Map

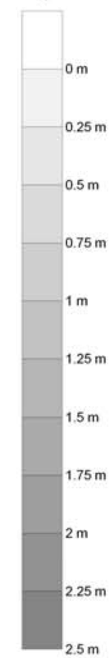


Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	6,227,219	100.0
0.25	5,212,120	83.7
0.5	4,236,587	68.0
0.75	3,308,061	53.1
1.0	2,436,353	39.1
1.25	1,636,330	26.3
1.5	930,025	14.9
1.75	381,672	6.1
2.0	87,884	1.4
2.25	8,387	0.1
2.5	10	0.0



Legend

Depth



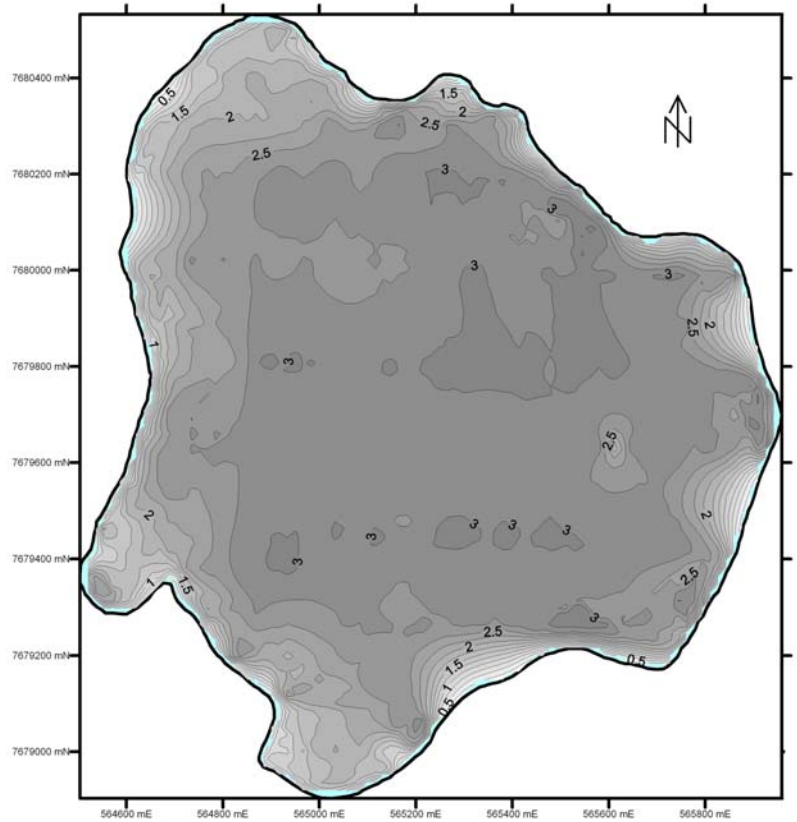
LAKE DETAILS

Average Depth: 1.5 meters
Maximum Depth: 2.5 meters
Lake Volume: 6,227,219 cubic meters
Top Lake Surface Area: 3,765,805 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

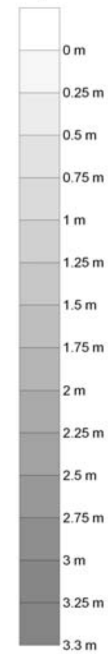
Lake 18

Contour Map



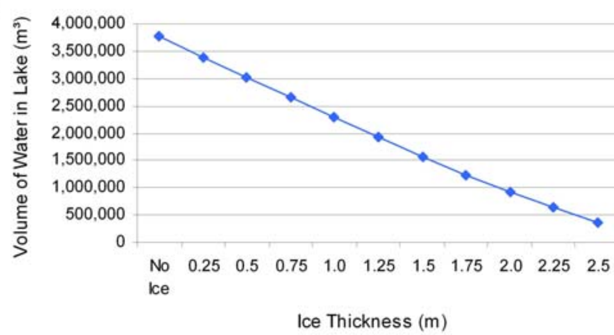
Legend

Depth



Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	3,770,461	100.0
0.25	3,391,159	89.9
0.5	3,016,164	80.0
0.75	2,646,465	70.2
1.0	2,282,756	60.5
1.25	1,926,116	51.1
1.5	1,578,454	41.9
1.75	1,243,993	33.0
2.0	926,068	24.6
2.25	630,132	16.7
2.5	357,346	9.5

Volume of Water (m³) vs. Ice Thickness (m)



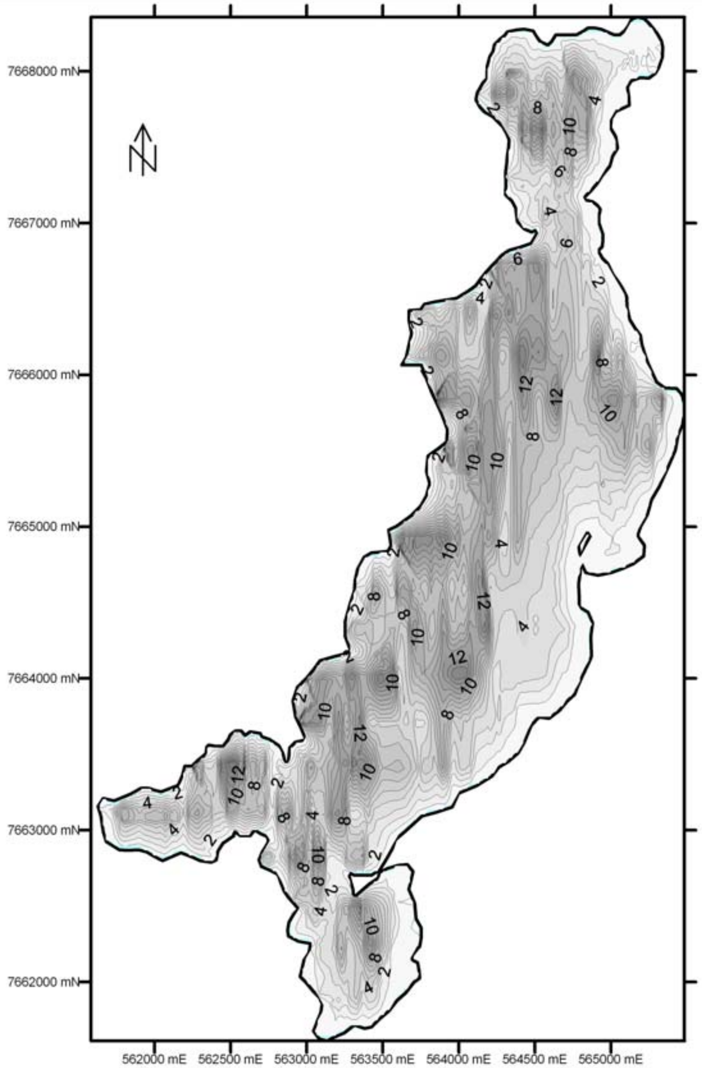
LAKE DETAILS

Average Depth: 2.5 meters
Maximum Depth: 3.3 meters
Lake Volume: 3,770,461 cubic meters
Top Lake Surface Area: 1,475,925 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

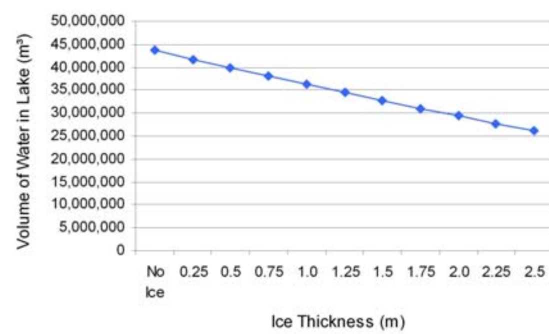
Lake 19

Contour Map

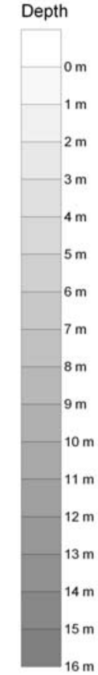


Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	43,868,500	100.0
0.25	41,810,289	95.3
0.5	39,865,012	90.9
0.75	37,992,425	86.6
1.0	36,179,056	82.5
1.25	34,416,415	78.5
1.5	32,699,344	74.5
1.75	31,024,445	70.7
2.0	29,389,307	67.0
2.25	27,792,427	63.4
2.5	26,232,741	59.8

Volume of Water (m^3) vs. Ice Thickness (m)



Legend



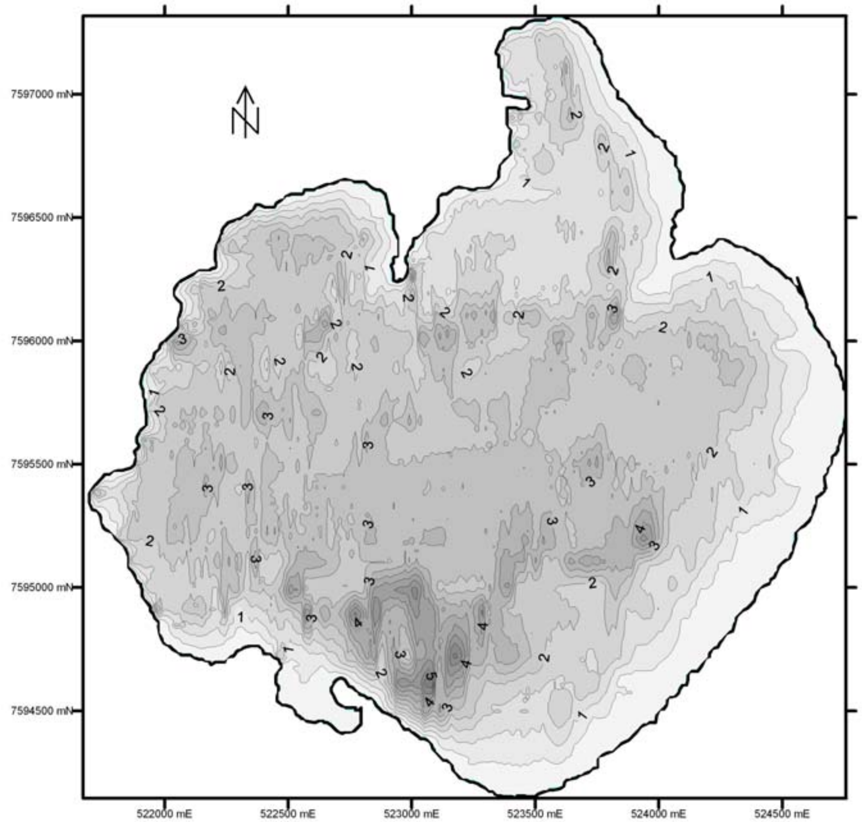
LAKE DETAILS

Average Depth: 5.3 meters
Maximum Depth: 16.0 meters
Lake Volume: 43,868,500 cubic meters
Top Lake Surface Area: 26,326,225 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

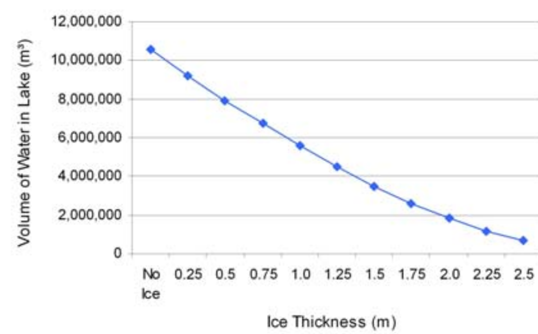
Lake 20

Contour Map

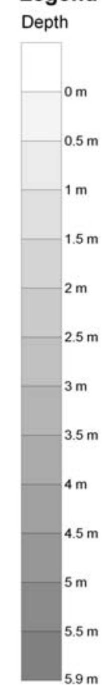


Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	10,589,209	100.0
0.25	9,213,672	87.0
0.5	7,932,933	74.9
0.75	6,720,190	63.5
1.0	5,563,684	52.5
1.25	4,473,302	42.2
1.5	3,488,499	32.9
1.75	2,607,837	24.6
2.0	1,819,225	17.2
2.25	1,147,344	10.8
2.5	665,231	6.3

Volume of Water (m³) vs. Ice Thickness (m)



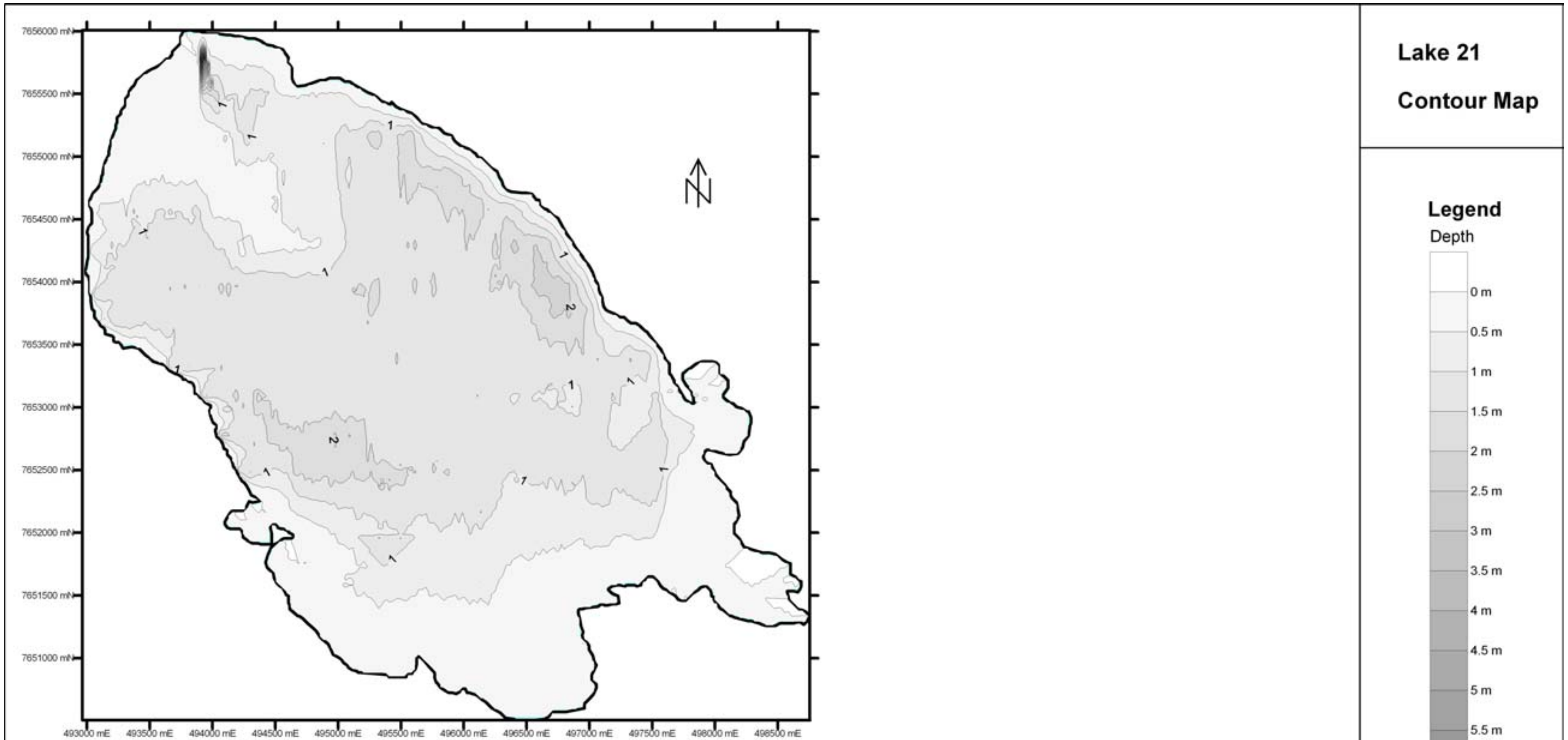
Legend



LAKE DETAILS

Average Depth: 1.9 meters
Maximum Depth: 5.9 meters
Lake Volume: 10,589,209 cubic meters
Top Lake Surface Area: 9,793,064 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

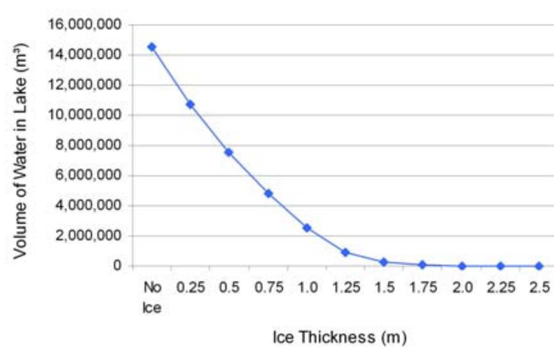


LAKE DETAILS

Average Depth: 0.8 meters
Maximum Depth: 7.0 meters
Lake Volume: 14,520,537 cubic meters
Top Lake Surface Area: 31,864,335 square meters

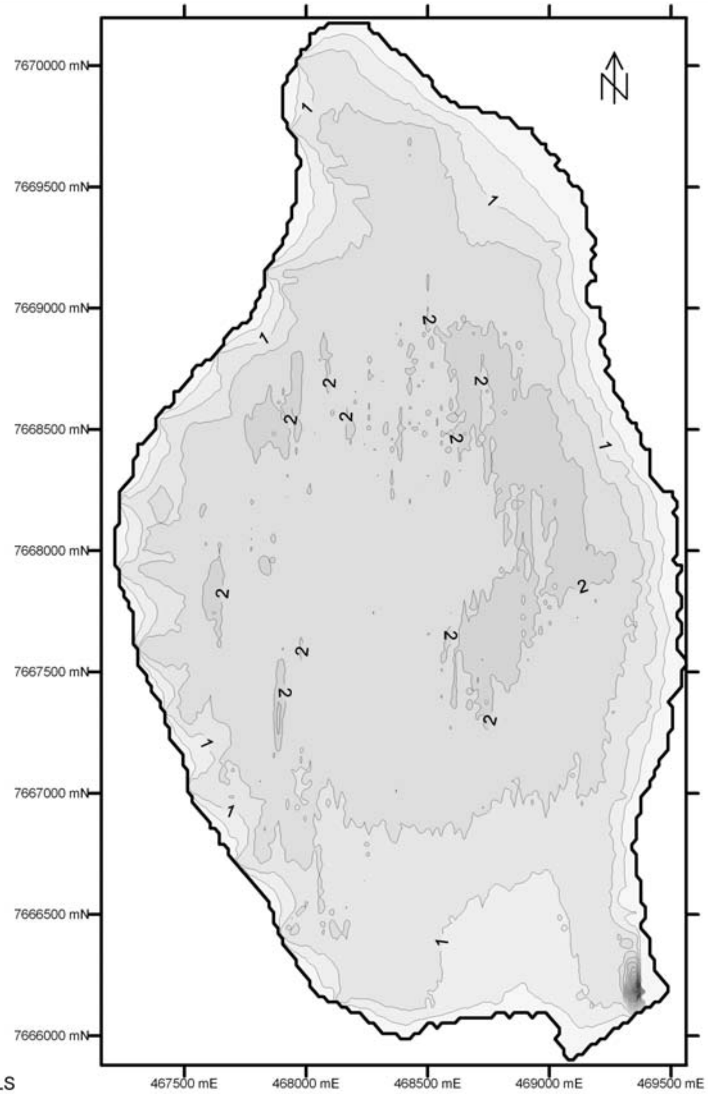
Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	14,520,537	100.0
0.25	10,732,041	73.9
0.5	7,551,993	52.0
0.75	4,842,884	33.4
1.0	2,553,953	17.6
1.25	880,114	6.1
1.5	248,495	1.7
1.75	90,931	0.6
2.0	39,554	0.3
2.25	24,248	0.2
2.5	19,689	0.1

Volume of Water (m^3) vs. Ice Thickness (m)



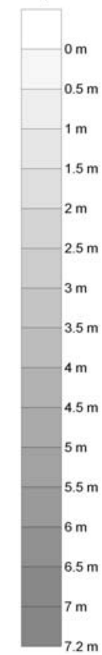
Lake 22

Contour Map



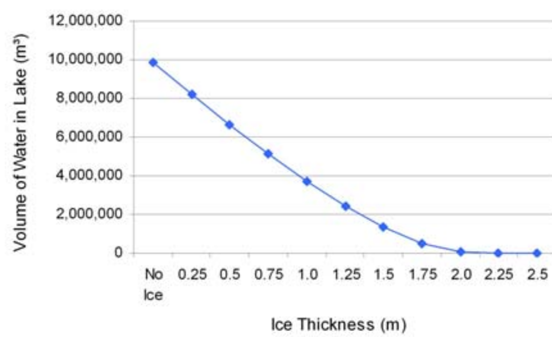
Legend

Depth



Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	9,856,299	100.0
0.25	8,191,003	83.1
0.5	6,610,390	67.1
0.75	5,110,063	51.8
1.0	3,705,470	37.6
1.25	2,429,376	24.6
1.5	1,337,924	13.6
1.75	470,578	4.8
2.0	52,530	0.5
2.25	15,294	0.2
2.5	12,093	0.1

Volume of Water (m³) vs. Ice Thickness (m)



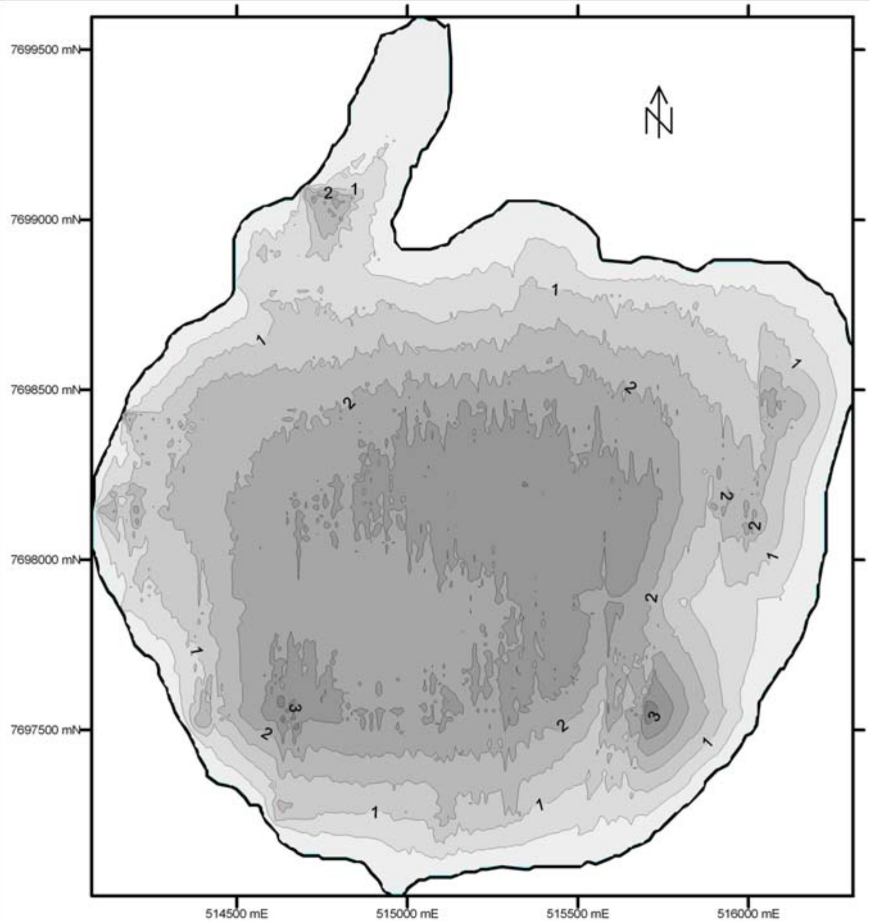
LAKE DETAILS

Average Depth: 1.4 meters
Maximum Depth: 7.2 meters
Lake Volume: 9,856,299 cubic meters
Top Lake Surface Area: 10,383,256 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

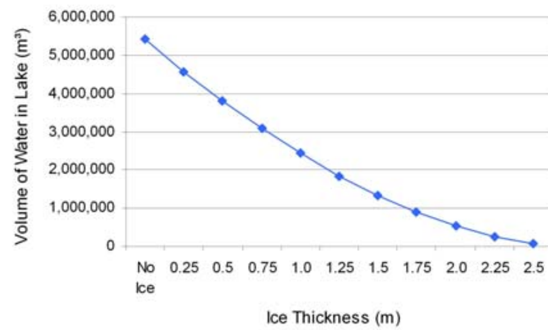
Lake 23

Contour Map



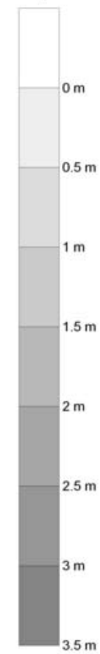
Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	5,426,767	100.0
0.25	4,577,751	84.4
0.5	3,798,029	70.0
0.75	3,078,053	56.7
1.0	2,426,682	44.7
1.25	1,846,592	34.0
1.5	1,340,117	24.7
1.75	911,742	16.8
2.0	556,354	10.3
2.25	263,971	4.9
2.5	63,544	1.2

Volume of Water (m³) vs. Ice Thickness (m)



Legend

Depth



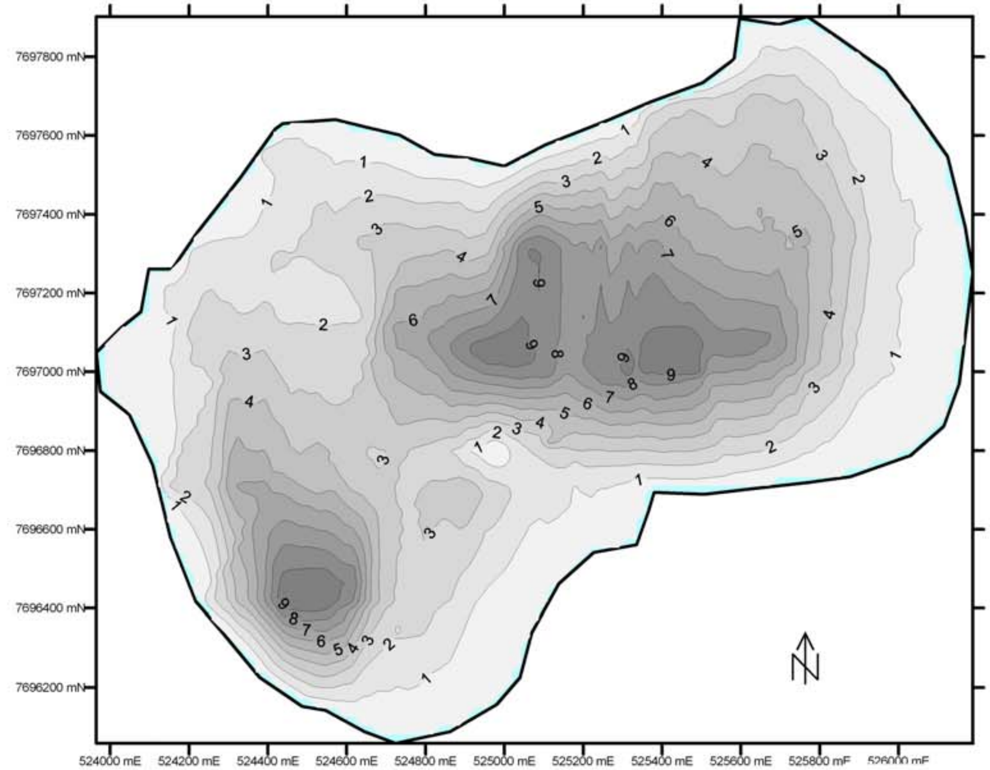
LAKE DETAILS

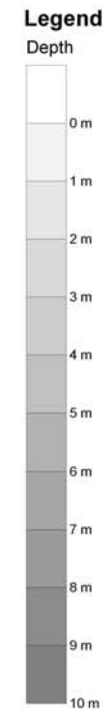
Average Depth: 1.5 meters
Maximum Depth: 3.5 meters
Lake Volume: 5,426,767 cubic meters
Top Lake Surface Area: 5,769,203 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

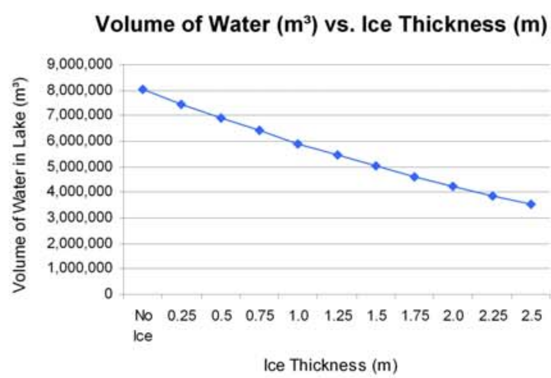
Lake 24

Contour Map





Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	8,061,505	100.0
0.25	7,468,333	92.6
0.5	6,920,145	85.8
0.75	6,402,826	79.4
1.0	5,911,779	73.3
1.25	5,446,610	67.6
1.5	5,009,997	62.1
1.75	4,600,403	57.1
2.0	4,216,204	52.3
2.25	3,856,271	47.8
2.5	3,519,238	43.7



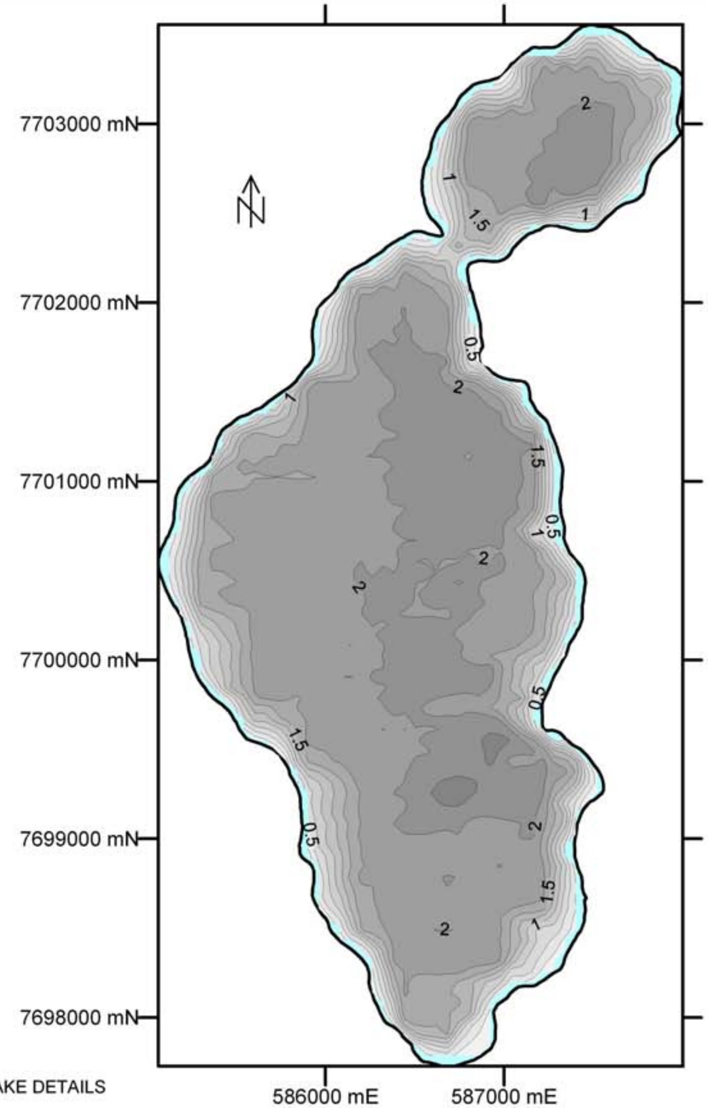
LAKE DETAILS

Average Depth: 3.3 meters
Maximum Depth: 10.0 meters
Lake Volume: 8,061,505 cubic meters
Top Lake Surface Area: 4,101,841 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 25

Contour Map

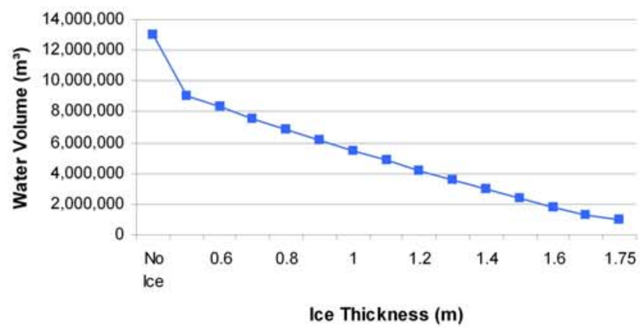


LAKE DETAILS

Average Depth: 1.54 meters
Maximum Depth: 2.9 meters
Lake Volume: 13,008,359 cubic meters
Top Lake Surface Area: 7,724,101 square meters

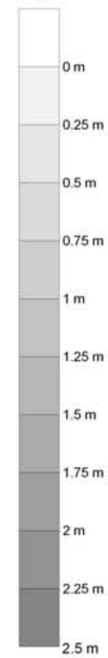
Ice Thickness (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	13,008,359	100.0
0.5	9,057,622	69.6
0.6	8,315,672	63.9
0.7	7,589,937	58.3
0.8	6,880,239	52.9
0.9	6,186,136	47.6
1	5,508,018	42.3
1.1	4,845,980	37.3
1.2	4,200,401	32.3
1.3	3,572,287	27.5
1.4	2,962,748	22.8
1.5	2,373,931	18.2
1.6	1,809,336	13.9
1.7	1,273,819	9.8
1.75	1,019,368	7.8

Volume of Water (m^3) vs. Ice Thickness (m)

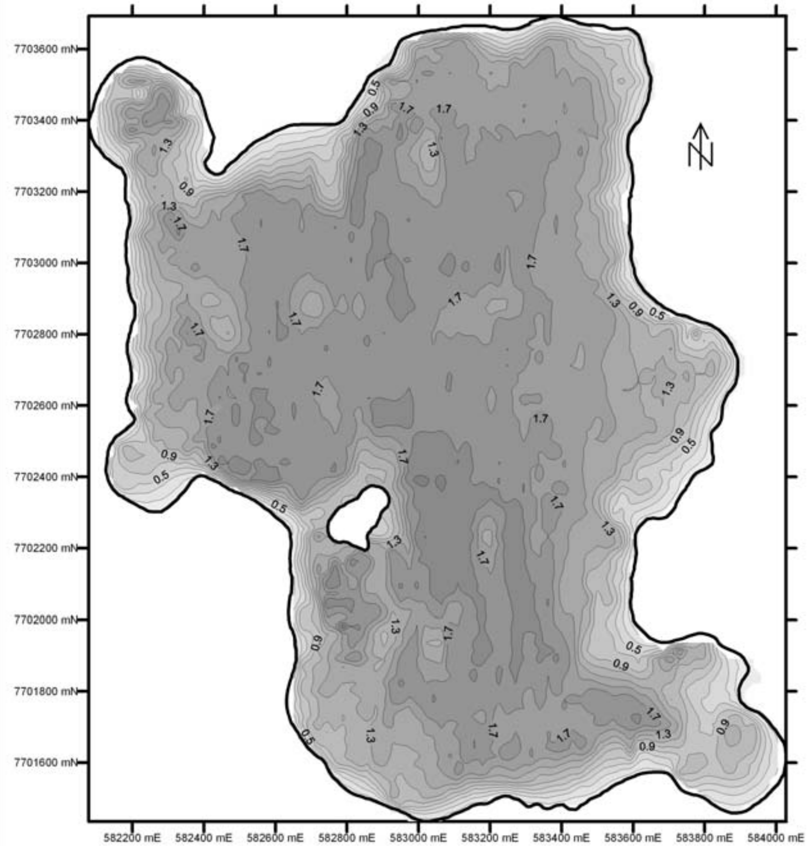


Legend

Depth



Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

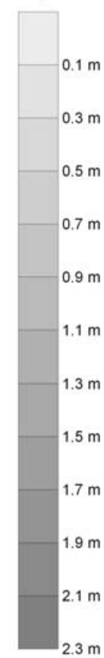


Lake 26

Contour Map

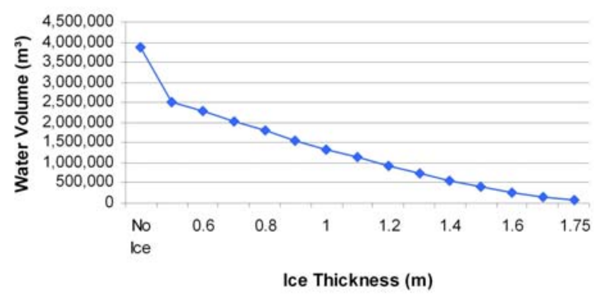
Legend

Depth



Ice Thickness (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	3,854,968	100.0
0.5	2,521,922	65.4
0.6	2,272,597	59.0
0.7	2,029,417	52.6
0.8	1,792,973	46.5
0.9	1,564,148	40.6
1	1,343,508	34.9
1.1	1,130,973	29.3
1.2	927,676	24.1
1.3	734,875	19.1
1.4	555,556	14.4
1.5	391,383	10.2
1.6	247,206	6.4
1.7	130,896	3.4
1.75	85,103	2.2

Volume of Water (m³) vs. Ice Thickness (m)



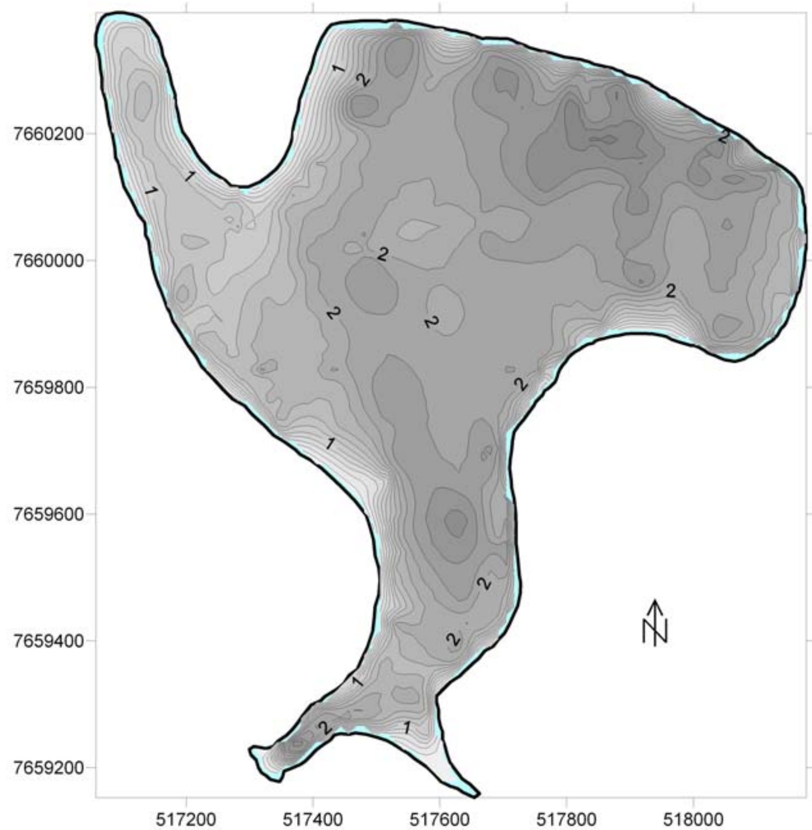
LAKE DETAILS

Average Depth: 1.4 meters
Maximum Depth: 2.2 meters
Lake Volume: 3,854,968 cubic meters
Top Lake Surface Area: 2,753,584 square meters

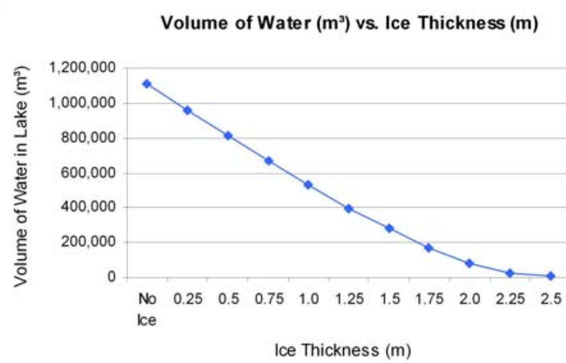
Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

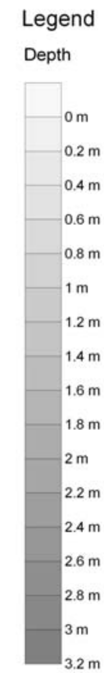
Lake 27

Contour Map



Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	1,112,403	100.0
0.25	958,914	86.2
0.5	810,188	72.8
0.75	666,468	59.9
1.0	527,962	47.5
1.25	396,987	35.7
1.5	278,232	25.0
1.75	171,946	15.5
2.0	82,339	7.4
2.25	27,490	2.5
2.5	7,022	0.6





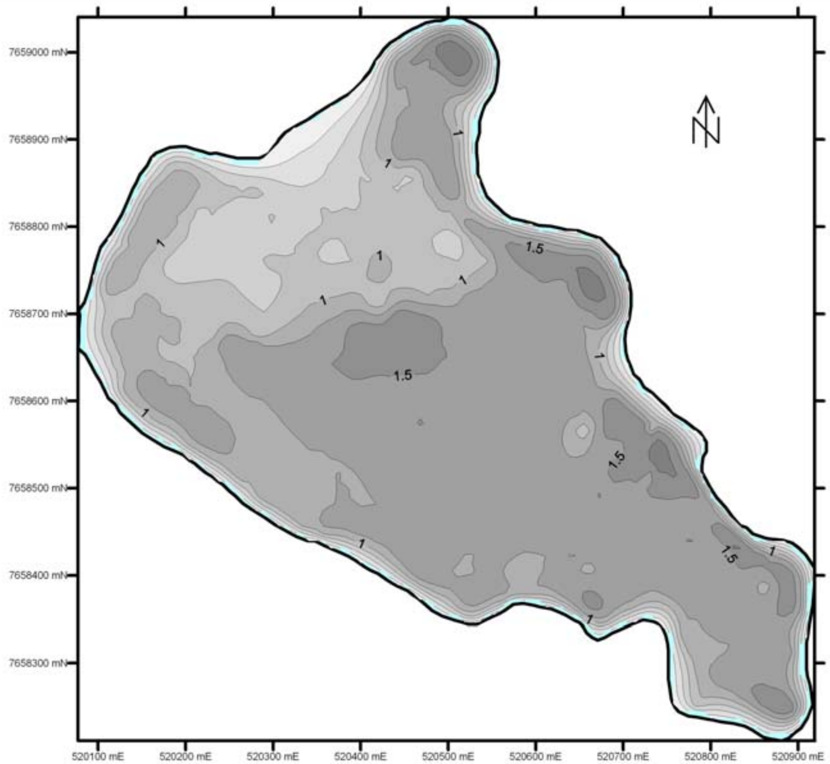
LAKE DETAILS

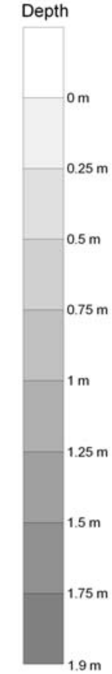
Average Depth: 1.8 meters
Maximum Depth: 3.1 meters
Lake Volume: 1,112,403 cubic meters
Top Lake Surface Area: 591,192 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

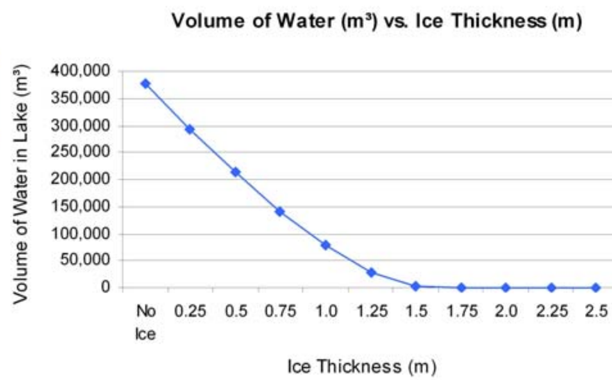
Lake 28

Contour Map





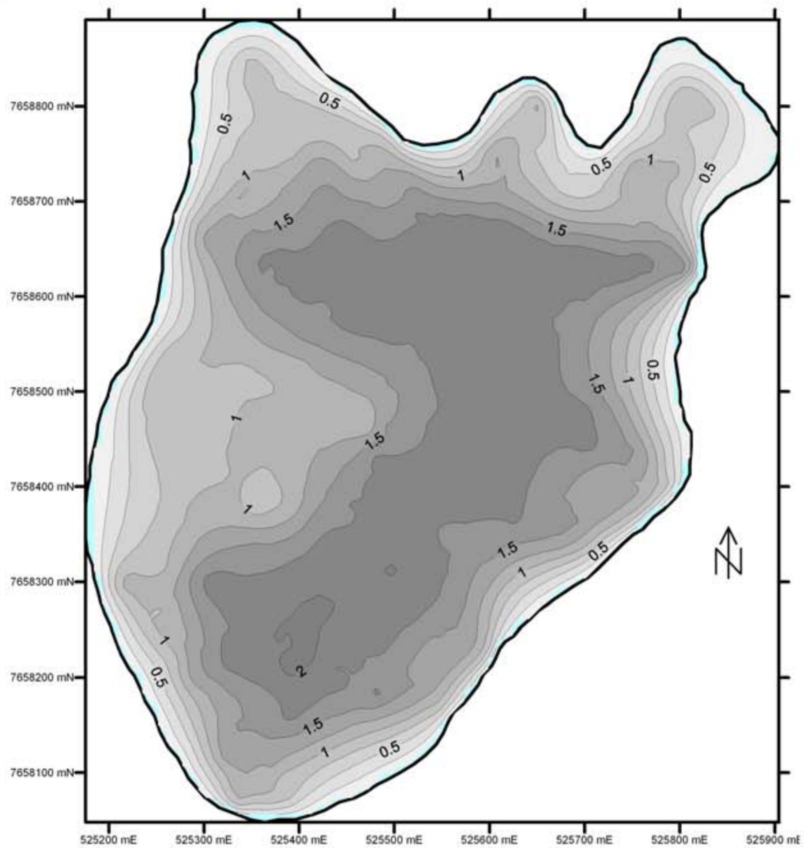
Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	376,606	100.0
0.25	293,747	78.0
0.5	214,671	57.0
0.75	140,479	37.3
1	78,197	20.8
1.25	27,648	7.3
1.5	2,994	0.8
1.75	155	0.04
2	0	0.0



LAKE DETAILS

Average Depth: 1.0 meters
Maximum Depth: 1.9 meters
Lake Volume: 376,606 cubic meters
Top Lake Surface Area: 324,674 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

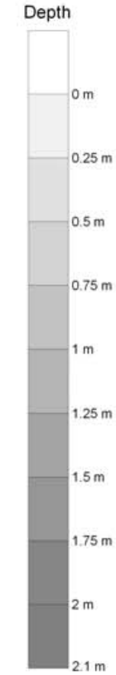


Lake 29

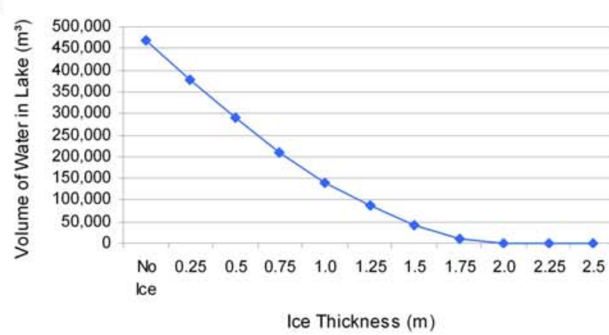
Contour Map

Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	469,133	100.0
0.25	375,899	80.1
0.5	289,936	61.8
0.75	210,886	45.0
1	141,565	30.2
1.25	86,179	18.4
1.5	41,895	8.9
1.75	9,722	2.1
2	67	0.01
2.25	0	0.0

Legend



Volume of Water (m^3) vs. Ice Thickness (m)



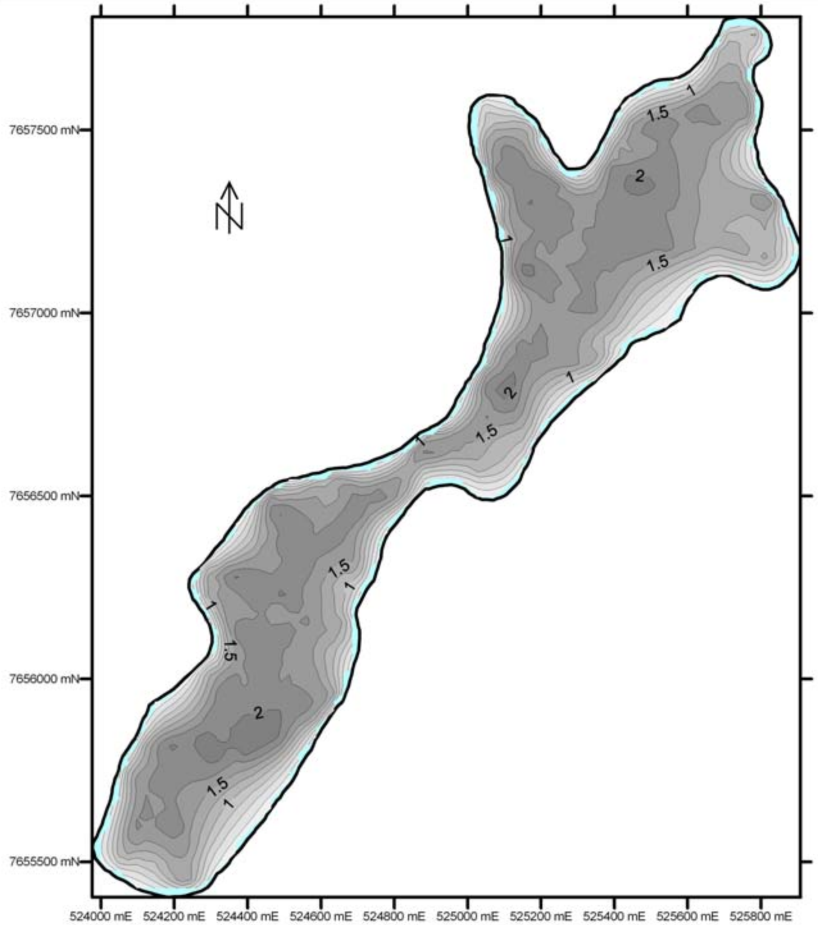
LAKE DETAILS

Average Depth: 1.2 meters
Maximum Depth: 2.1 meters
Lake Volume: 469,133 cubic meters
Top Lake Surface Area: 374,200 square meters

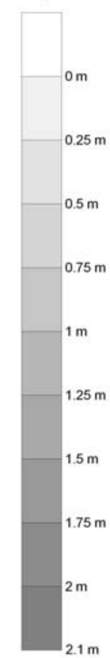
Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 30

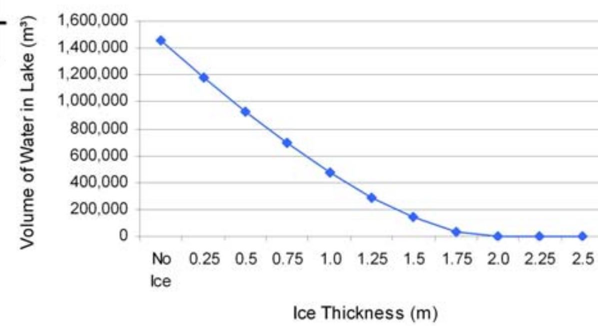
Contour Map



Legend



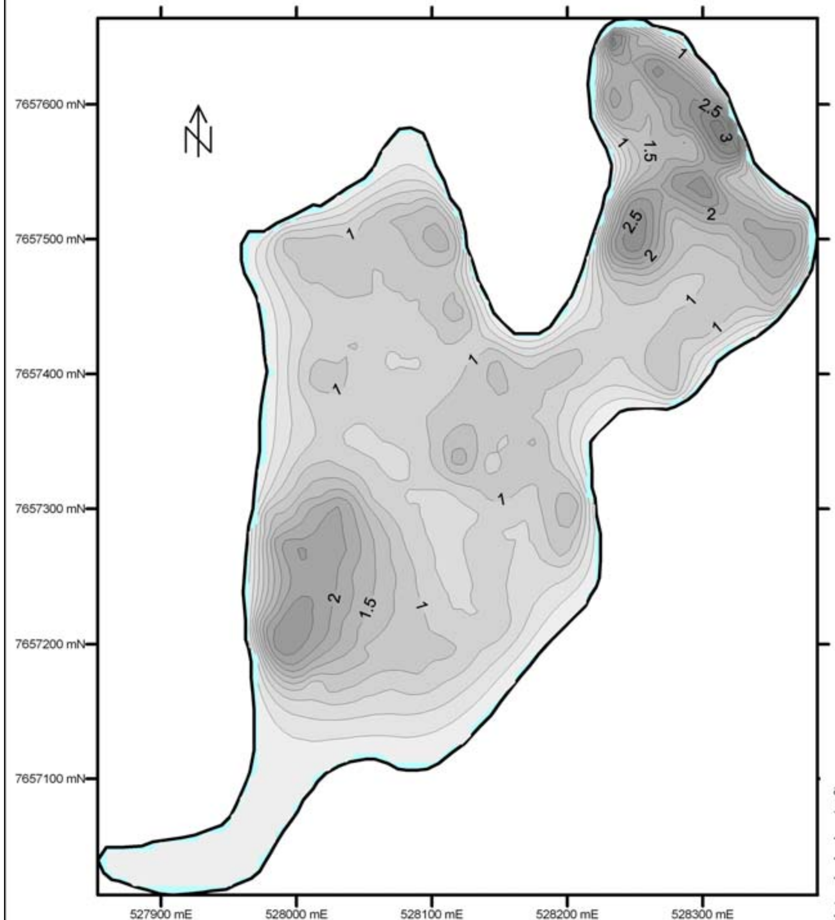
Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	1,458,472	100.0
0.25	1,182,708	81.1
0.5	925,990	63.5
0.75	691,483	47.4
1	479,275	32.9
1.25	292,189	20.0
1.5	138,811	9.5
1.75	30,341	2.1
2	1,303	0.1
2.25	0	0.0



Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

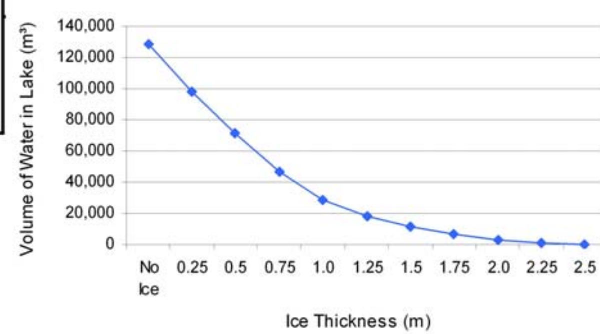
Lake 31

Contour Map

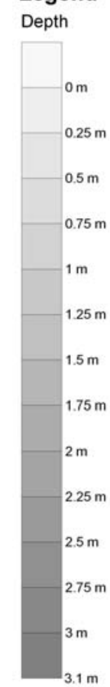


Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	128,732	100.0
0.25	98,557	76.6
0.5	71,362	55.4
0.75	47,048	36.5
1.0	28,980	22.5
1.25	18,232	14.2
1.5	11,324	8.8
1.75	6,299	4.9
2.0	2,876	2.2
2.25	1,059	0.8
2.5	317	0.2

Volume of Water (m^3) vs. Ice Thickness (m)



Legend



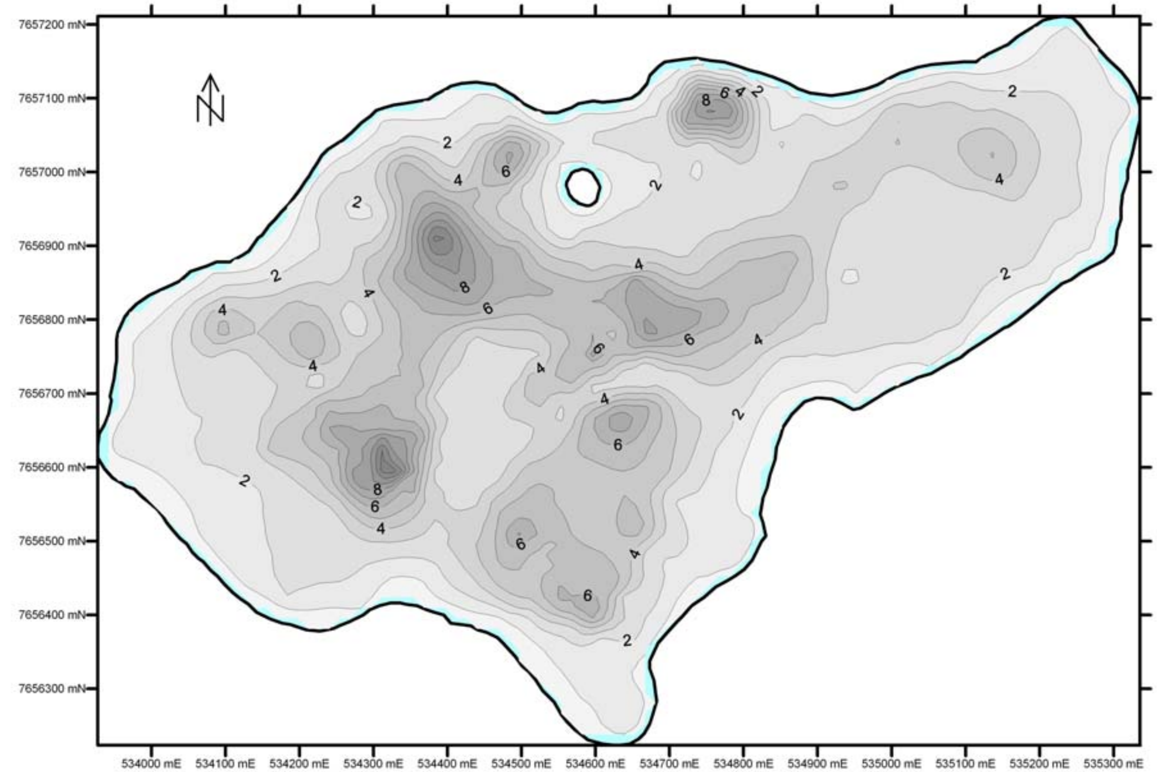
LAKE DETAILS

Average Depth: 1.0 meters
Maximum Depth: 3.1 meters
Lake Volume: 128,732 cubic meters
Top Lake Surface Area: 125,341 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

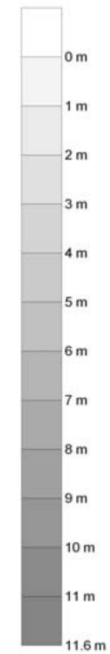
Lake 32

Contour Map



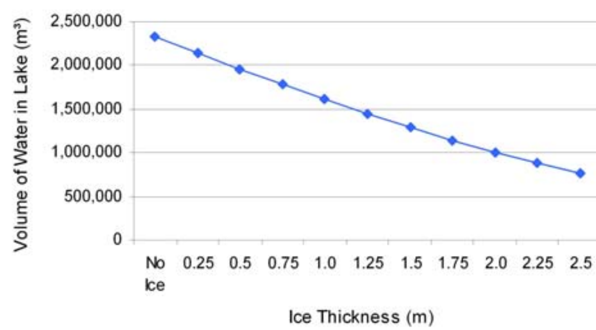
Legend

Depth



Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	2,331,337	100.0
0.25	2,143,663	91.9
0.5	1,960,575	84.1
0.75	1,783,181	76.5
1.0	1,611,897	69.1
1.25	1,447,542	62.1
1.5	1,291,705	55.4
1.75	1,144,732	49.1
2.0	1,007,443	43.2
2.25	881,556	37.8
2.5	768,641	33.0

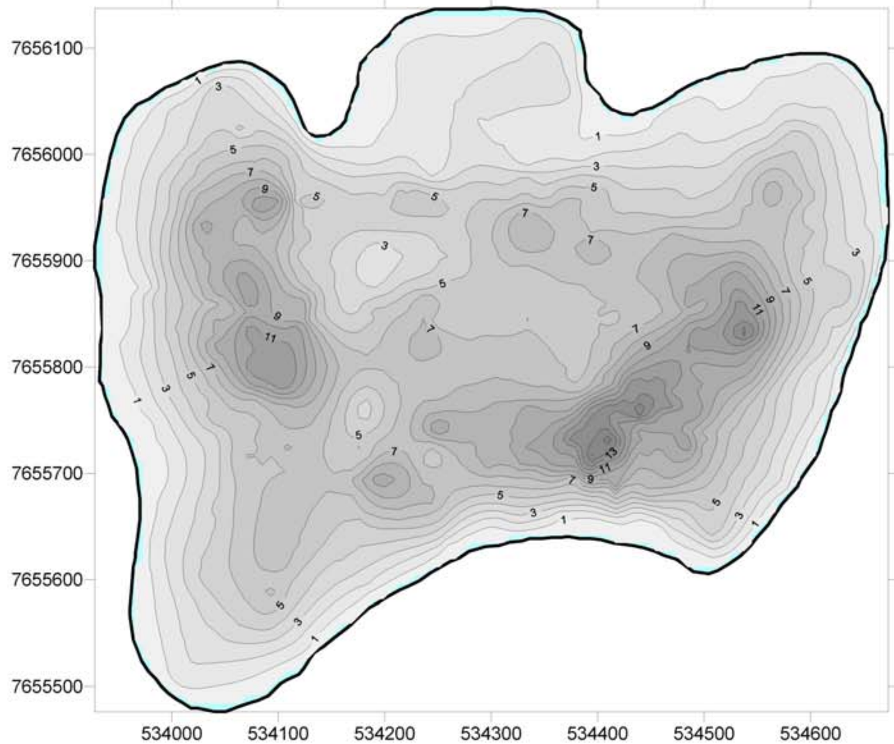
Volume of Water (m³) vs. Ice Thickness (m)

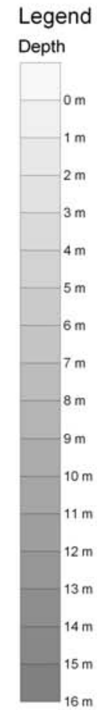


Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

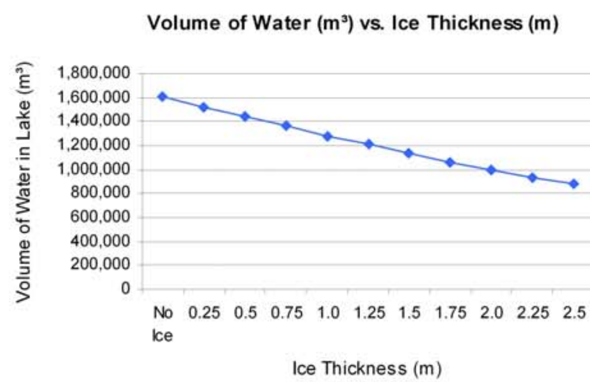
Lake 33

Contour Map





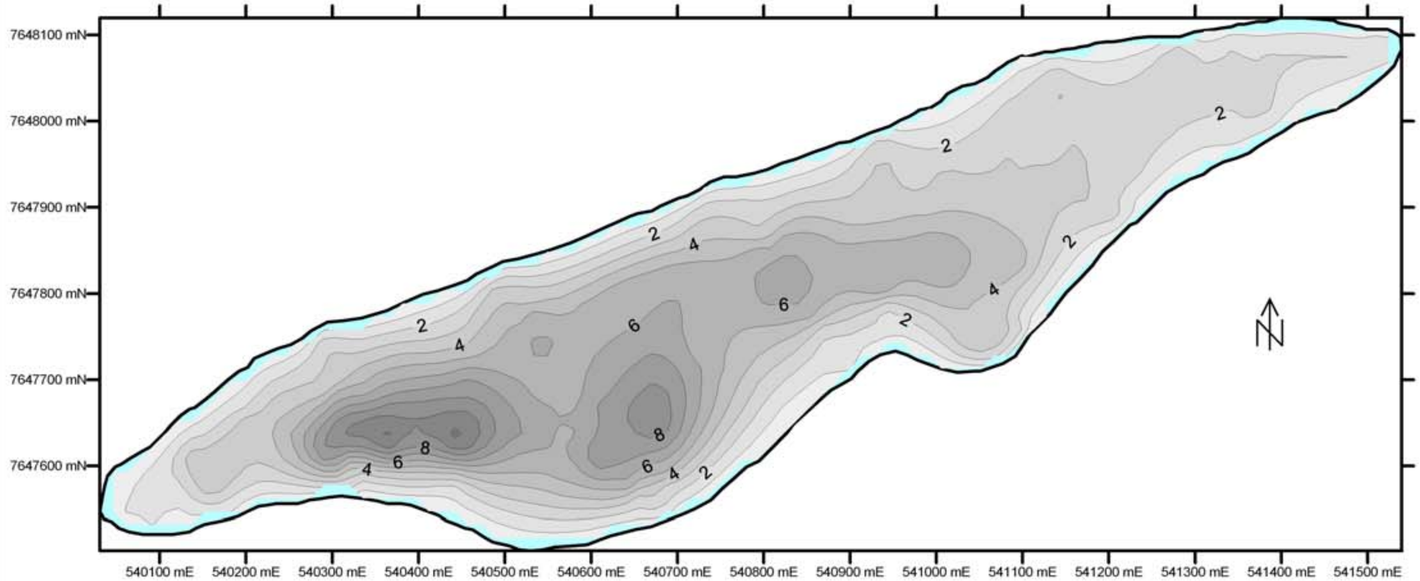
Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	1,608,010	100.0
0.25	1,522,677	94.7
0.5	1,439,943	89.5
0.75	1,359,779	84.6
1.0	1,282,121	79.7
1.25	1,207,040	75.1
1.5	1,134,657	70.6
1.75	1,065,137	66.2
2.0	998,681	62.1
2.25	935,343	58.2
2.5	874,475	54.4



Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

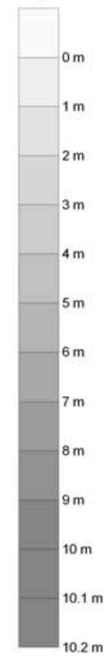
Lake 34

Contour Map

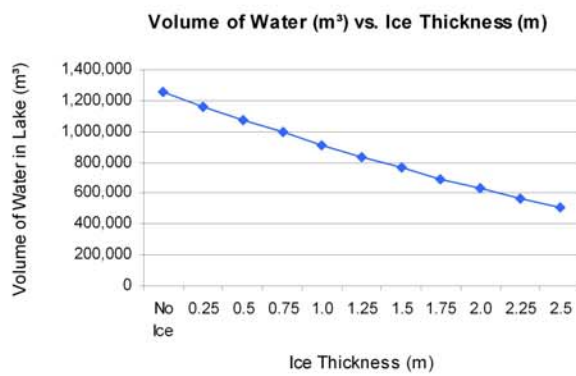


Legend

Depth



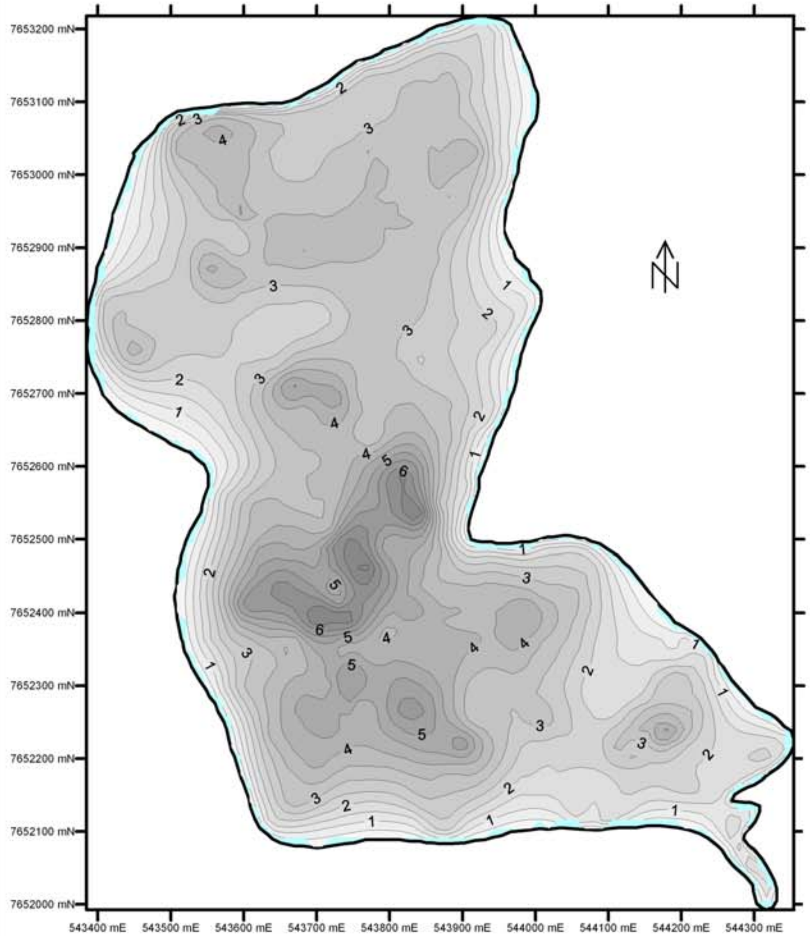
Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	1,253,972	100.0
0.25	1,164,383	92.9
0.5	1,077,179	85.9
0.75	993,366	79.2
1.0	913,317	72.8
1.25	836,913	66.7
1.5	764,042	60.9
1.75	694,767	55.4
2.0	629,437	50.2
2.25	568,271	45.3
2.5	511,393	40.8



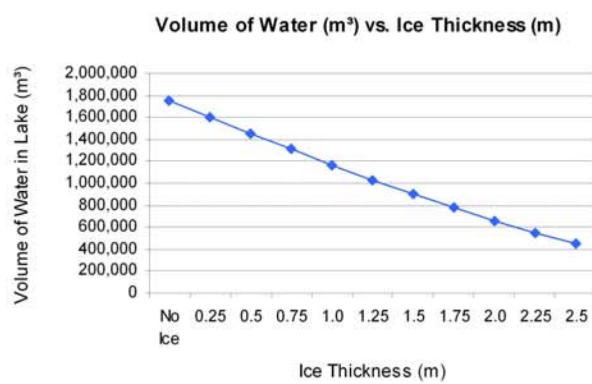
Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 35

Contour Map

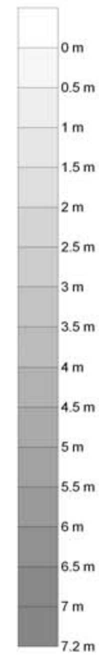


Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	1,756,925	100.0
0.25	1,603,374	91.3
0.5	1,453,752	82.7
0.75	1,308,439	74.5
1.0	1,167,518	66.5
1.25	1,031,399	58.7
1.5	900,484	51.3
1.75	775,877	44.2
2.0	658,665	37.5
2.25	549,449	31.3
2.5	448,895	25.6



Legend

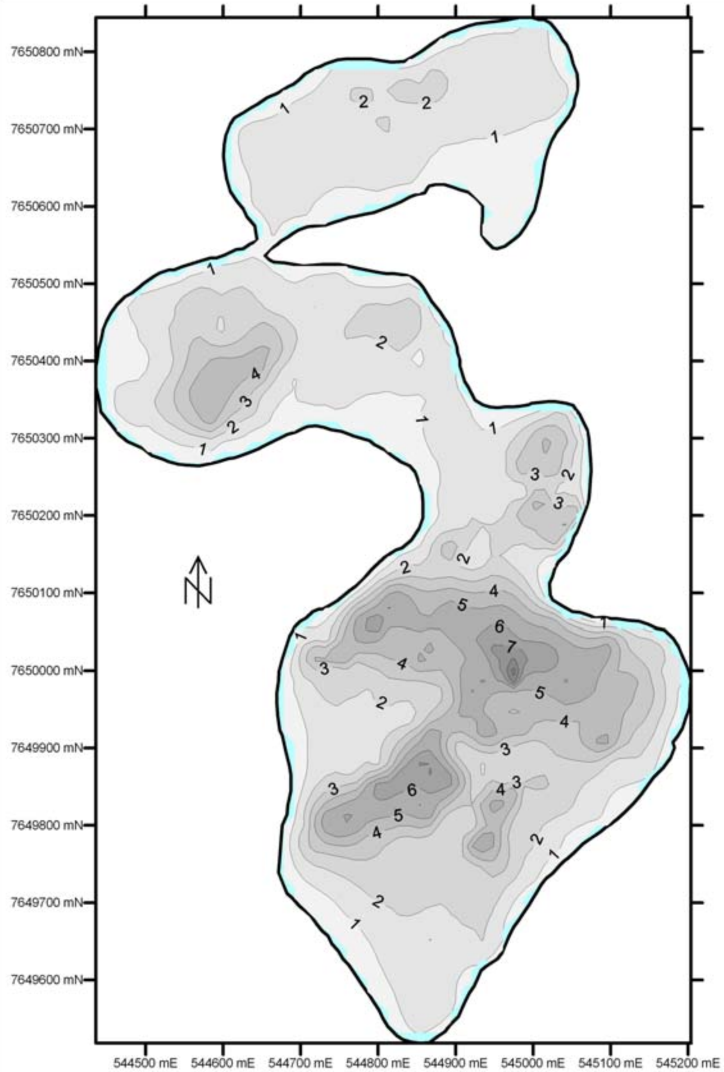
Depth



Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 36

Contour Map

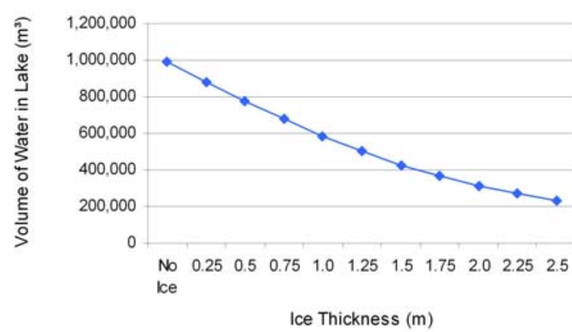


LAKE DETAILS

Average Depth: 2.2 meters
Maximum Depth: 9.4 meters
Lake Volume: 993,729 cubic meters
Top Lake Surface Area: 417,487 square meters

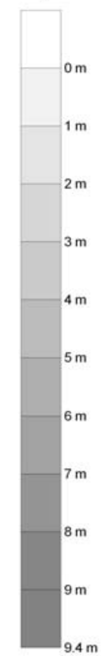
Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	993,728	100.0
0.25	883,228	88.9
0.5	778,130	78.3
0.75	678,885	68.3
1.0	585,832	59.0
1.25	500,537	50.4
1.5	426,425	42.9
1.75	365,103	36.7
2.0	313,767	31.6
2.25	269,222	27.1
2.5	230,652	23.2

Volume of Water (m³) vs. Ice Thickness (m)



Legend

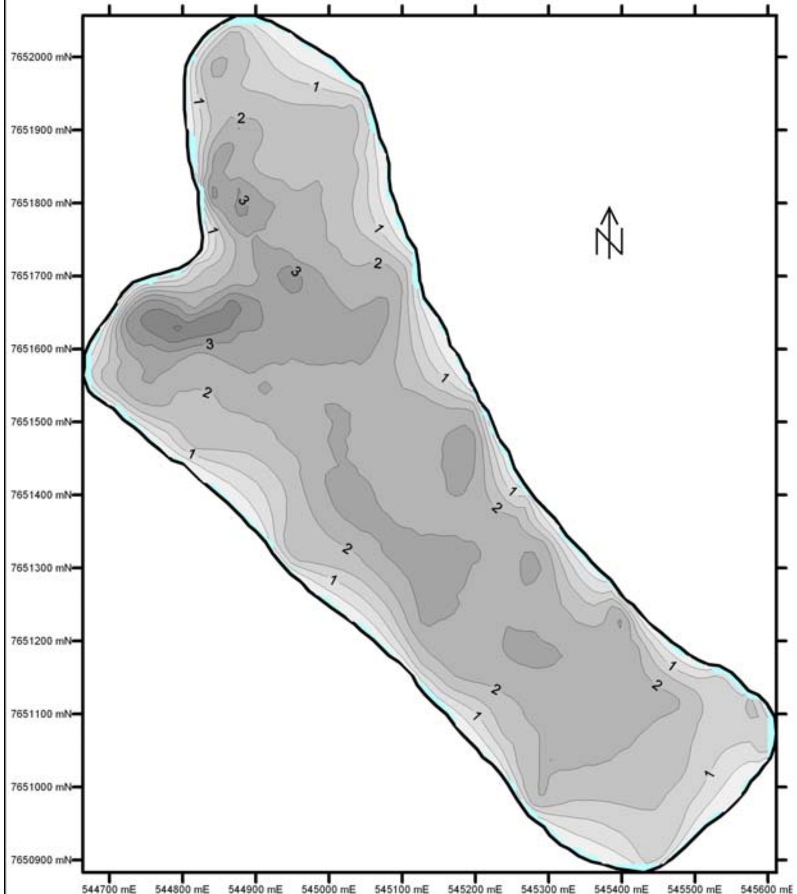
Depth



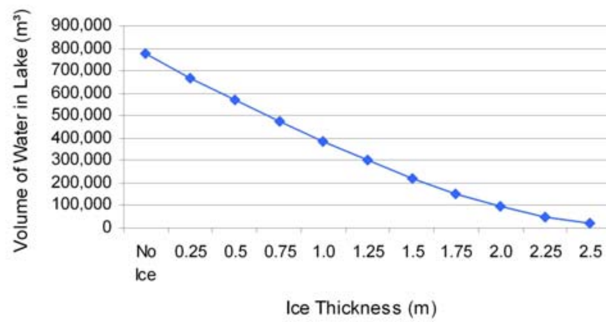
Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 37

Contour Map

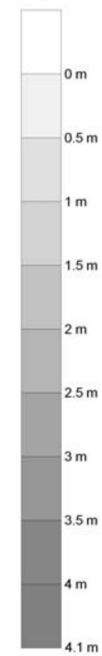


Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	773,017	100.0
0.25	669,448	86.6
0.5	570,227	73.8
0.75	475,395	61.5
1.0	385,244	49.8
1.25	300,348	38.9
1.5	222,178	28.7
1.75	152,193	19.7
2.0	93,314	12.1
2.25	47,681	6.2
2.5	18,378	2.4

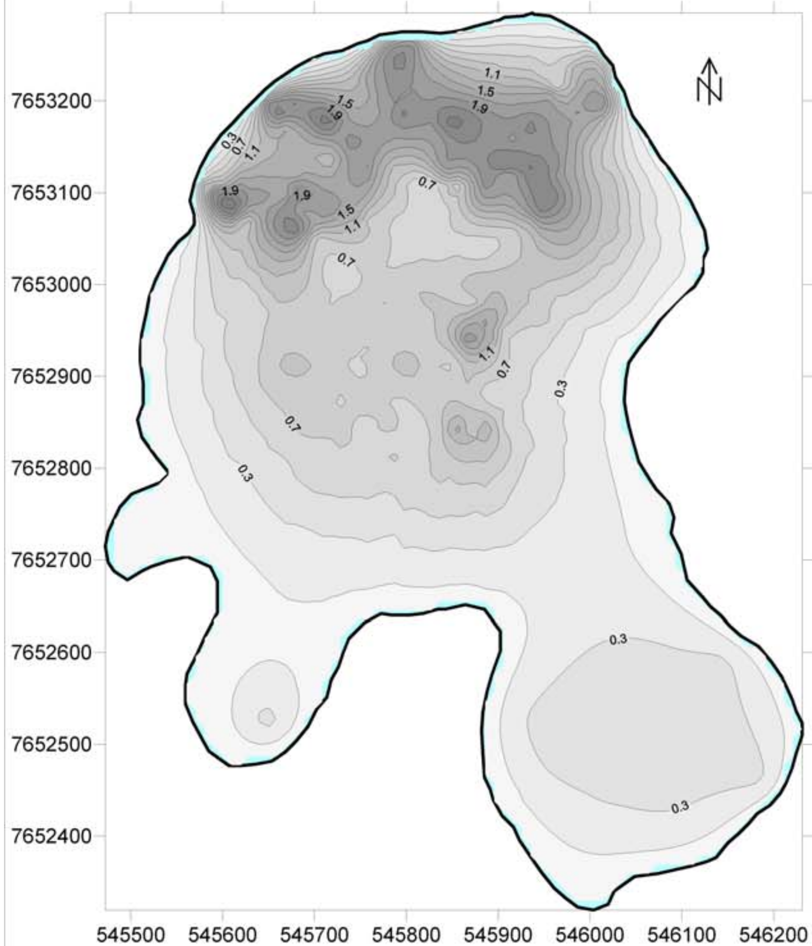


Legend

Depth

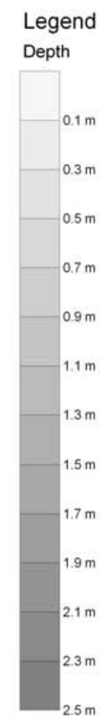


Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27



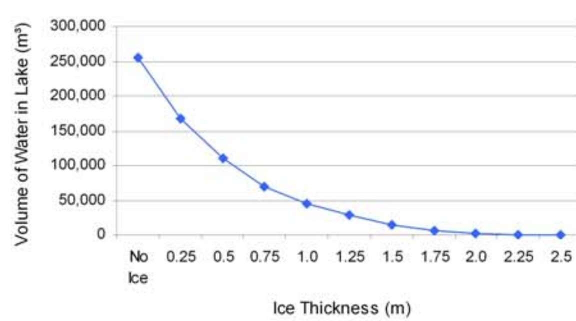
Lake 38

Contour Map



Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	254,603	100.0
0.25	168,150	66.0
0.5	110,389	43.4
0.75	70,097	27.5
1.0	45,527	17.9
1.25	28,347	11.1
1.5	15,210	6.0
1.75	6,022	2.4
2.0	1,291	0.5
2.25	56	0.0
2.5	0	0.0

Volume of Water (m³) vs. Ice Thickness (m)



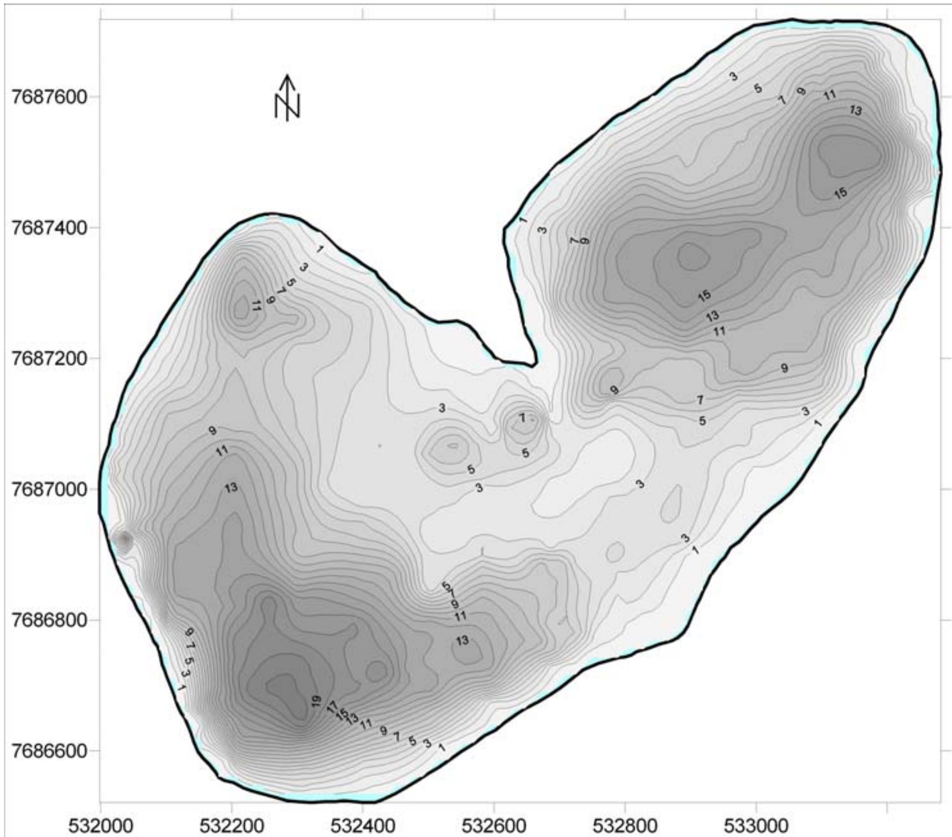
LAKE DETAILS

Average Depth: 0.5 meters
Maximum Depth: 2.5 meters
Lake Volume: 230,302 cubic meters
Top Lake Surface Area: 418,355 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

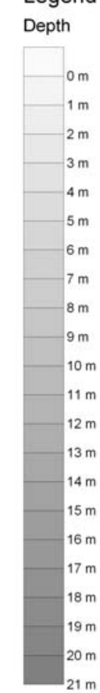
Lake 39

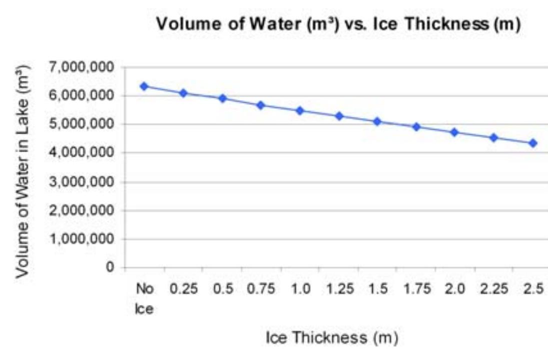
Contour Map



Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	6,339,253	100.0
0.25	6,118,851	96.5
0.5	5,903,498	93.1
0.75	5,693,137	89.8
1.0	5,487,567	86.6
1.25	5,286,540	83.4
1.5	5,089,924	80.3
1.75	4,897,608	77.3
2.0	4,709,854	74.3
2.25	4,526,735	71.4
2.5	4,348,702	68.6

Legend

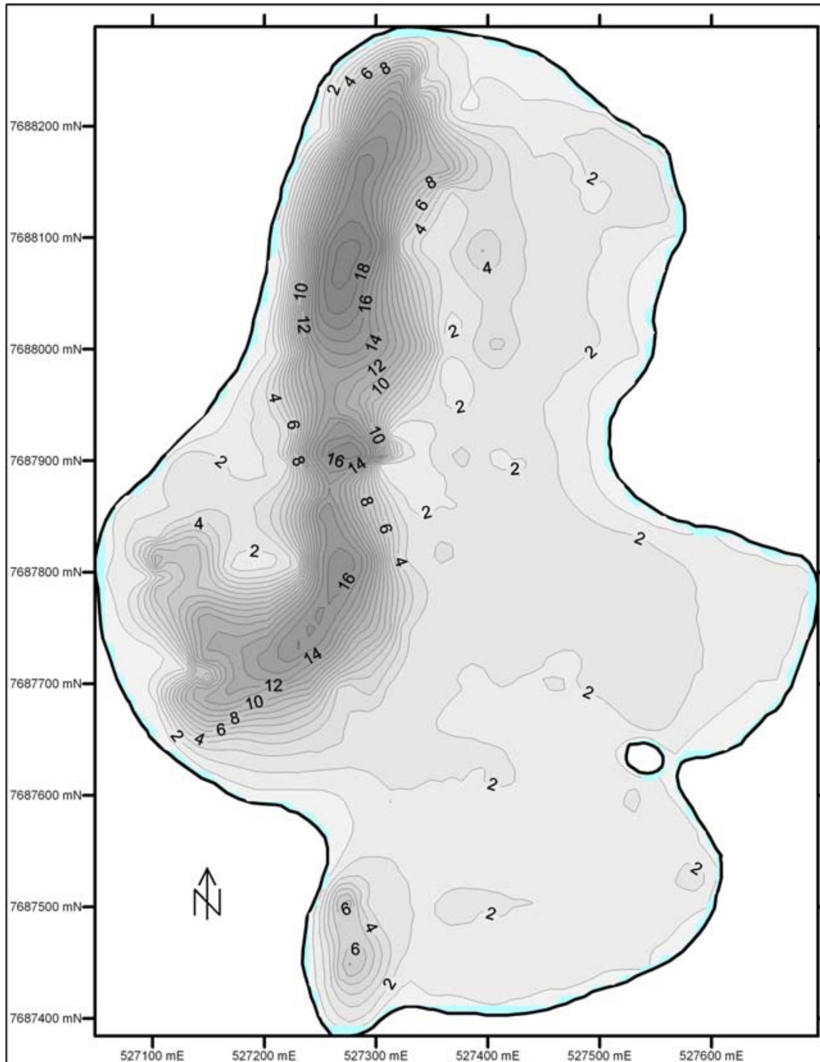




Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

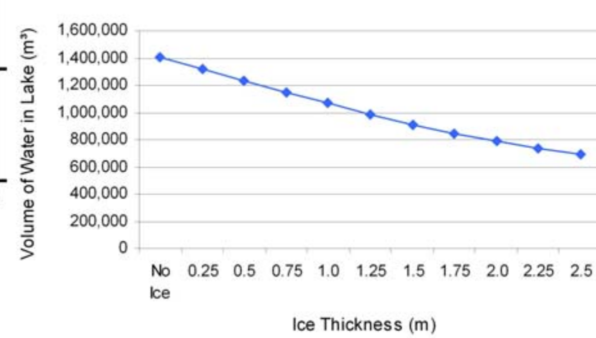
Lake 40

Contour Map



Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	1,405,218	100.0
0.25	1,316,875	93.7
0.5	1,230,570	87.6
0.75	1,146,555	81.6
1.0	1,064,972	75.8
1.25	986,215	70.2
1.5	910,986	64.8
1.75	842,280	59.9
2.0	783,981	55.8
2.25	736,175	52.4
2.5	696,297	49.6

Volume of Water (m³) vs. Ice Thickness (m)



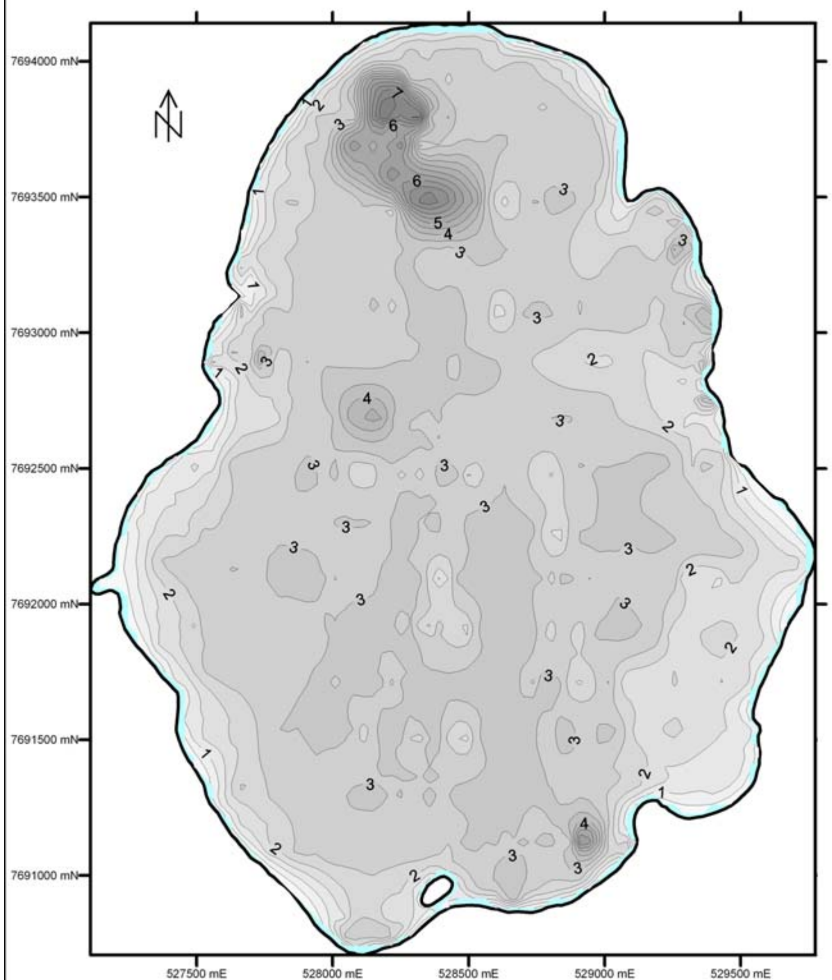
Legend

Depth

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 41

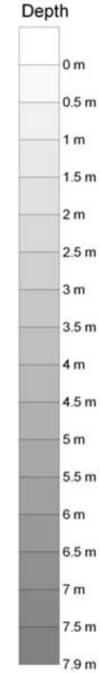
Contour Map



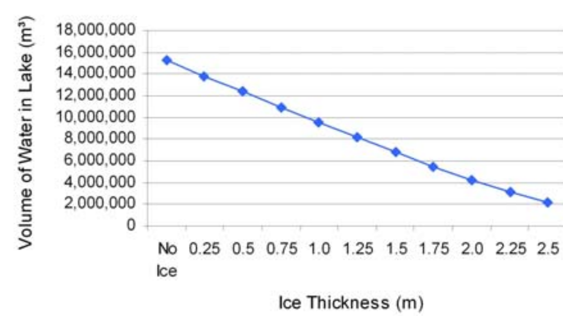
Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	15,312,725	100.0
0.25	13,835,975	90.4
0.5	12,376,503	80.8
0.75	10,937,382	71.4
1.0	9,522,672	62.2
1.25	8,139,701	53.2
1.5	6,795,613	44.4
1.75	5,501,247	35.9
2.0	4,284,112	28.0
2.25	3,149,062	20.6
2.5	2,115,270	13.8

Legend

Depth



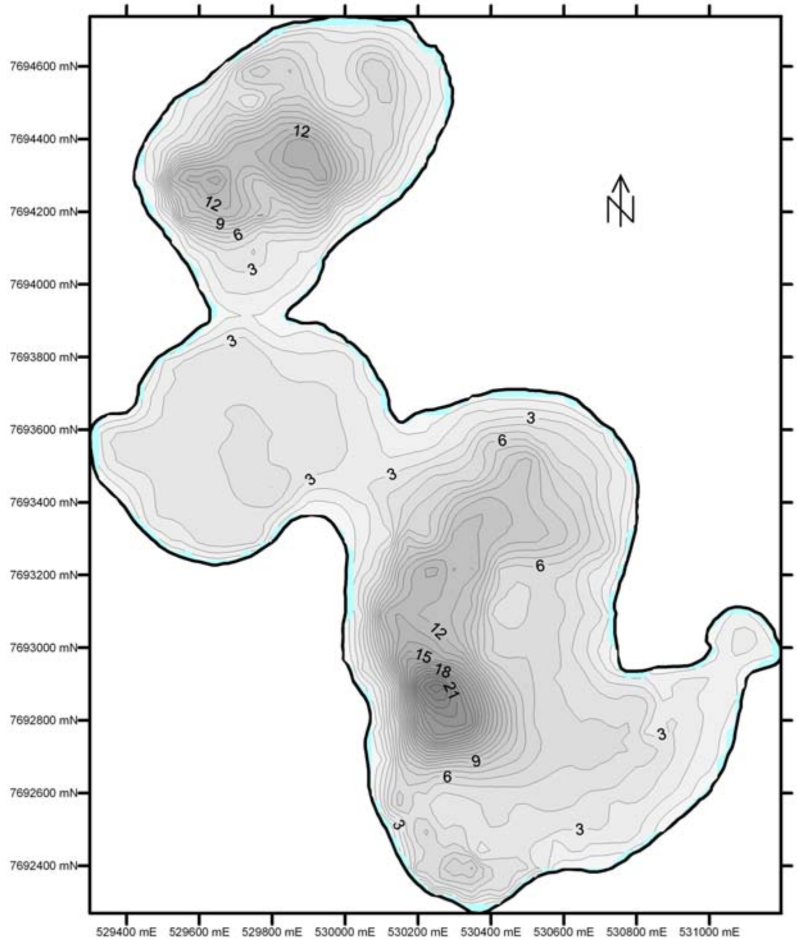
Volume of Water (m^3) vs. Ice Thickness (m)



Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 42

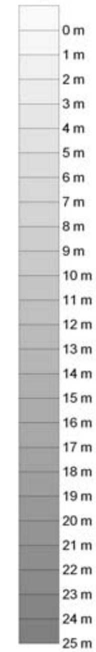
Contour Map

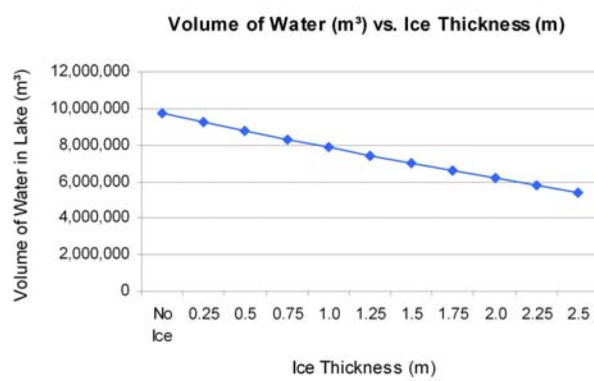


Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	9,766,287	100.0
0.25	9,276,018	95.0
0.5	8,794,247	90.0
0.75	8,323,145	85.2
1.0	7,864,082	80.5
1.25	7,417,928	76.0
1.5	6,985,918	71.5
1.75	6,568,826	67.3
2.0	6,167,426	63.2
2.25	5,782,723	59.2
2.5	5,414,222	55.4

Legend

Depth

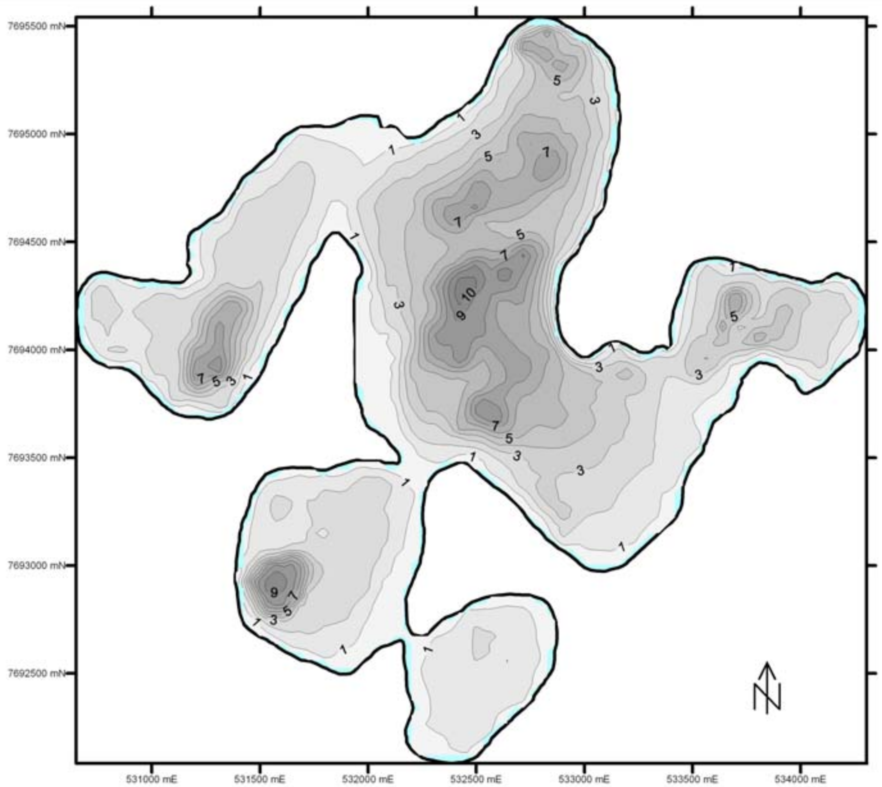




Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

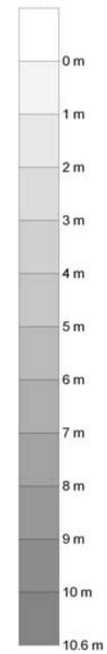
Lake 43

Contour Map

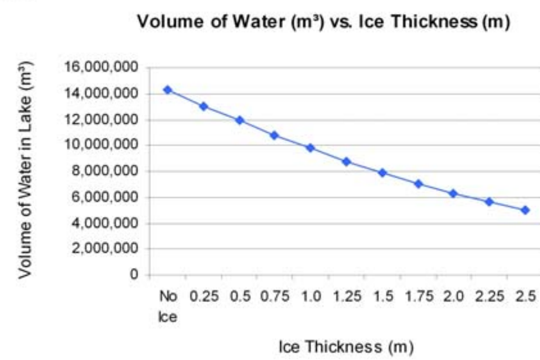


Legend

Depth



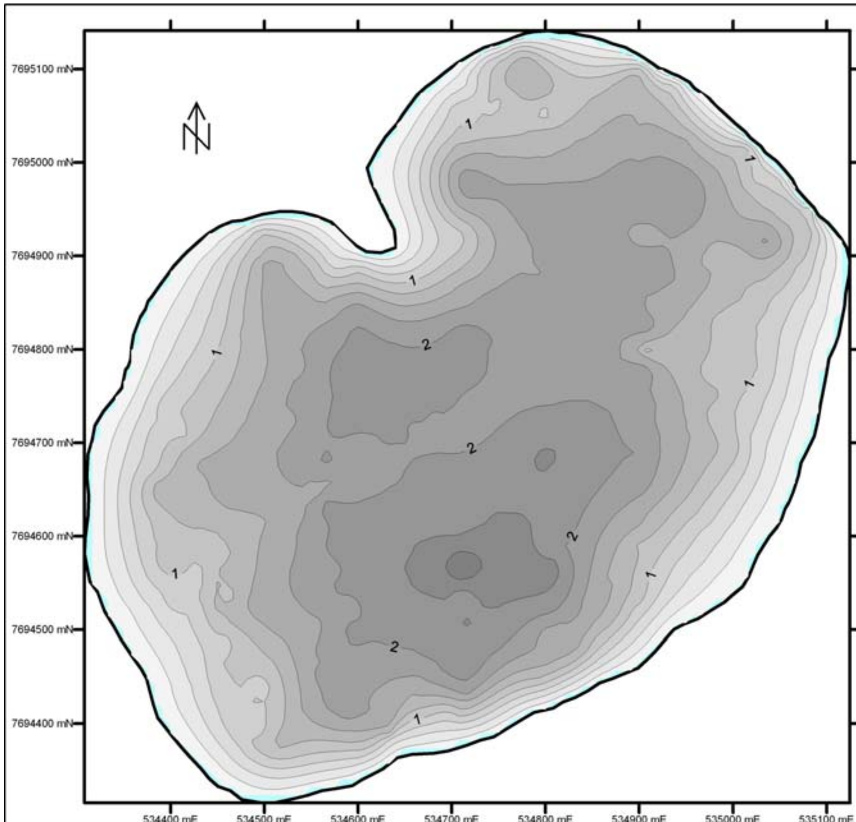
Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	14,248,636	100.0
0.25	13,047,775	91.6
0.5	11,902,381	83.5
0.75	10,810,825	75.9
1.0	9,772,389	68.6
1.25	8,787,543	61.7
1.5	7,866,478	55.2
1.75	7,021,122	49.3
2.0	6,262,847	44.0
2.25	5,603,921	39.3
2.5	5,031,508	35.3



Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

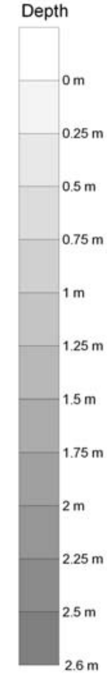
Lake 44

Contour Map

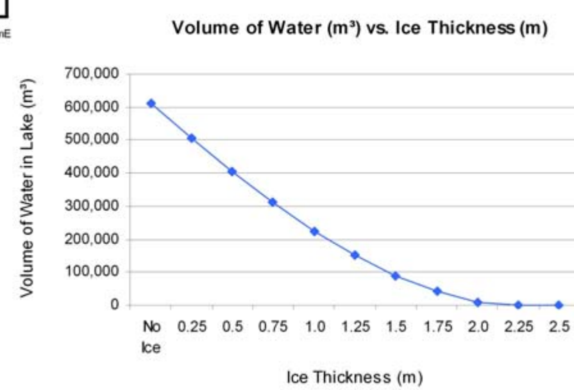


Legend

Depth



Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	613,239	100.0
0.25	504,055	82.2
0.5	403,504	65.8
0.75	310,505	50.6
1.0	225,447	36.8
1.25	150,964	24.6
1.5	88,589	14.4
1.75	40,530	6.6
2.0	10,486	1.7
2.25	1,133	0.2
2.5	49	0.0



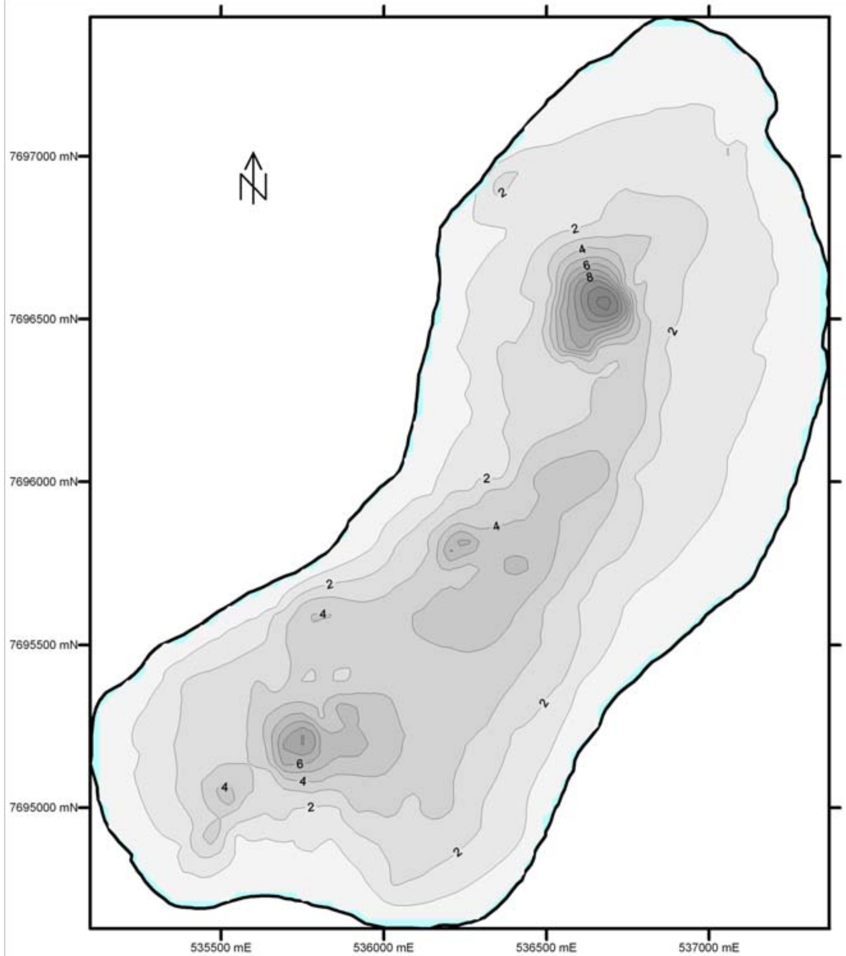
LAKE DETAILS

Average Depth: 1.4 meters
Maximum Depth: 2.6 meters
Lake Volume: 613,239 cubic meters
Top Lake Surface Area: 441,881 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

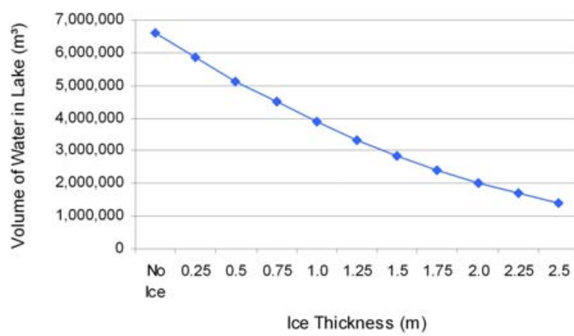
Lake 45

Contour Map



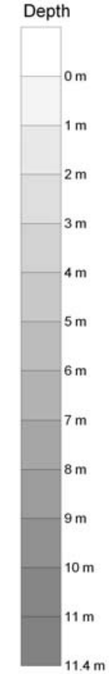
Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	6,627,750	100.0
0.25	5,846,502	88.2
0.5	5,136,509	77.5
0.75	4,484,498	67.7
1.0	3,884,954	58.6
1.25	3,332,120	50.3
1.5	2,827,642	42.7
1.75	2,390,394	36.1
2.0	2,017,134	30.4
2.25	1,689,322	25.5
2.5	1,399,733	21.1

Volume of Water (m³) vs. Ice Thickness (m)

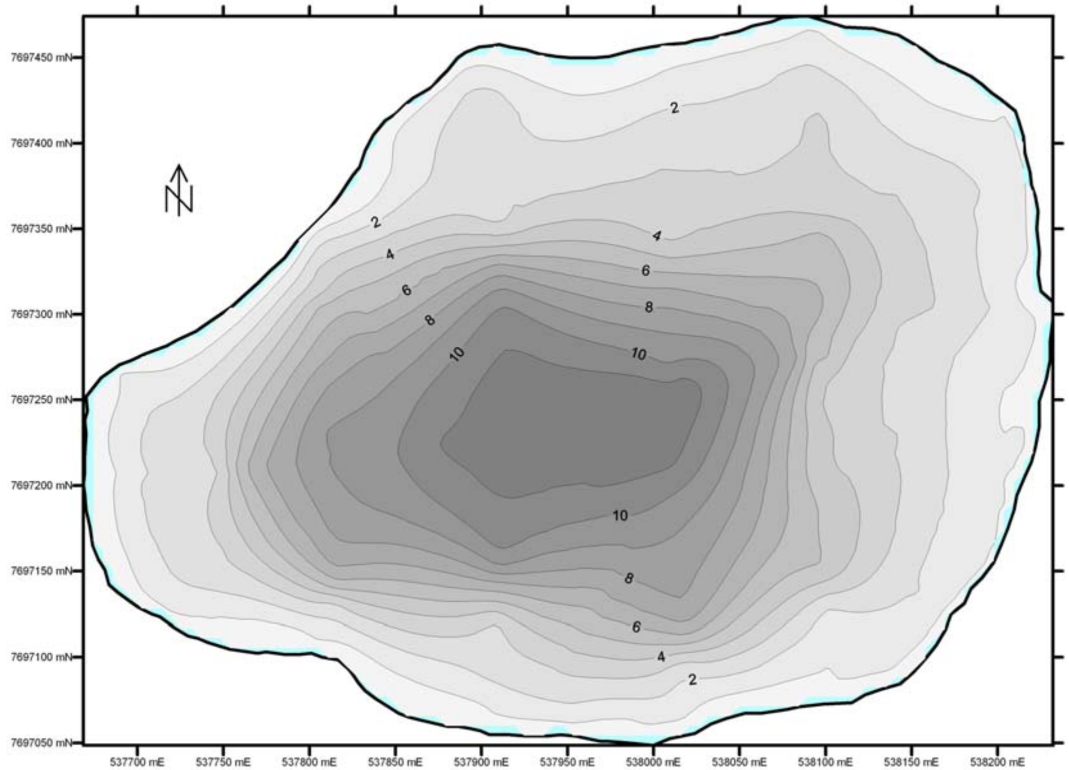


Legend

Depth

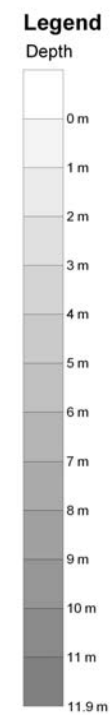


Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

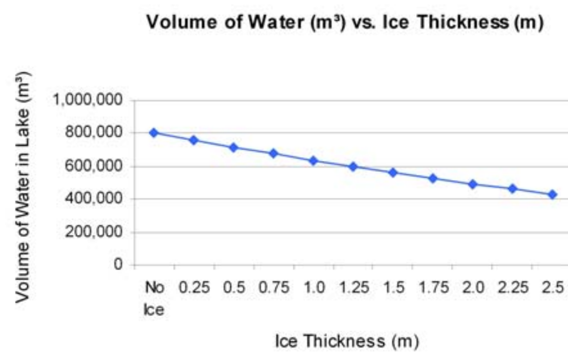


Lake 46

Contour Map



Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	805,121	100.0
0.25	761,092	94.5
0.5	718,208	89.2
0.75	676,589	84.0
1.0	636,297	79.0
1.25	597,640	74.2
1.5	560,778	69.7
1.75	525,772	65.3
2.0	492,714	61.2
2.25	461,703	57.3
2.5	432,880	53.8



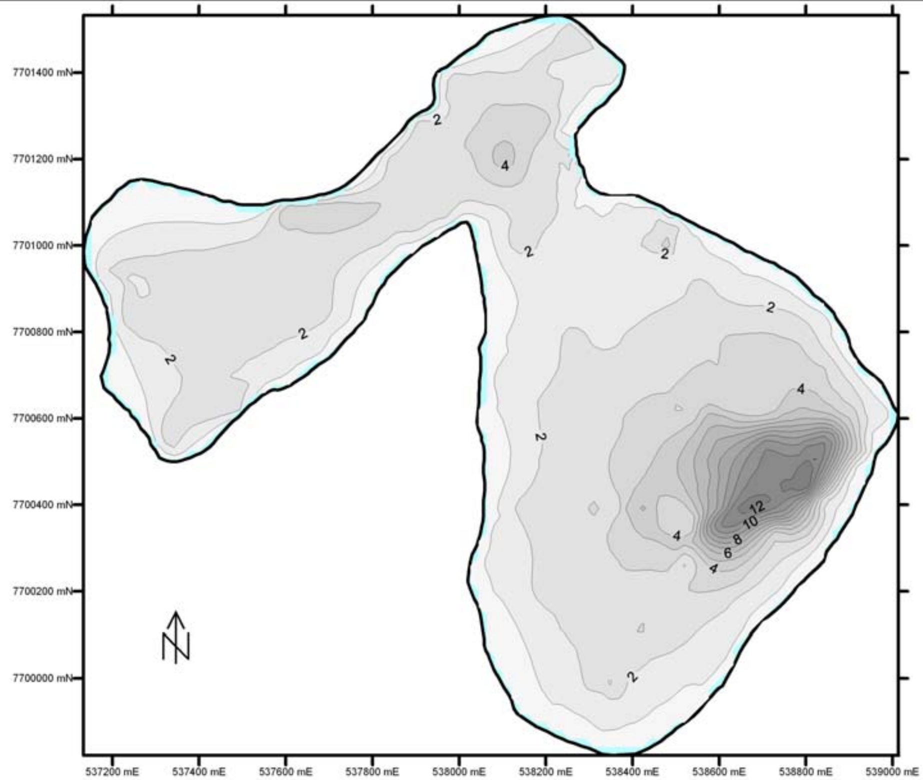
LAKE DETAILS

Average Depth: 4.5 meters
Maximum Depth: 11.9 meters
Lake Volume: 805,121 cubic meters
Top Lake Surface Area: 172,543 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

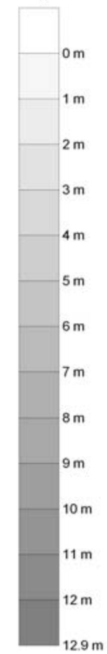
Lake 47

Contour Map



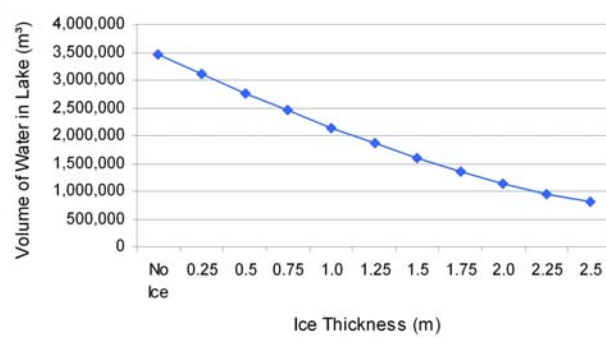
Legend

Depth



Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	3,452,380	100.0
0.25	3,103,815	89.9
0.5	2,769,868	80.2
0.75	2,450,967	71.0
1.0	2,147,183	62.2
1.25	1,859,459	53.9
1.5	1,591,635	46.1
1.75	1,350,917	39.1
2.0	1,138,706	33.0
2.25	959,083	27.8
2.5	822,630	23.8

Volume of Water (m^3) vs. Ice Thickness (m)



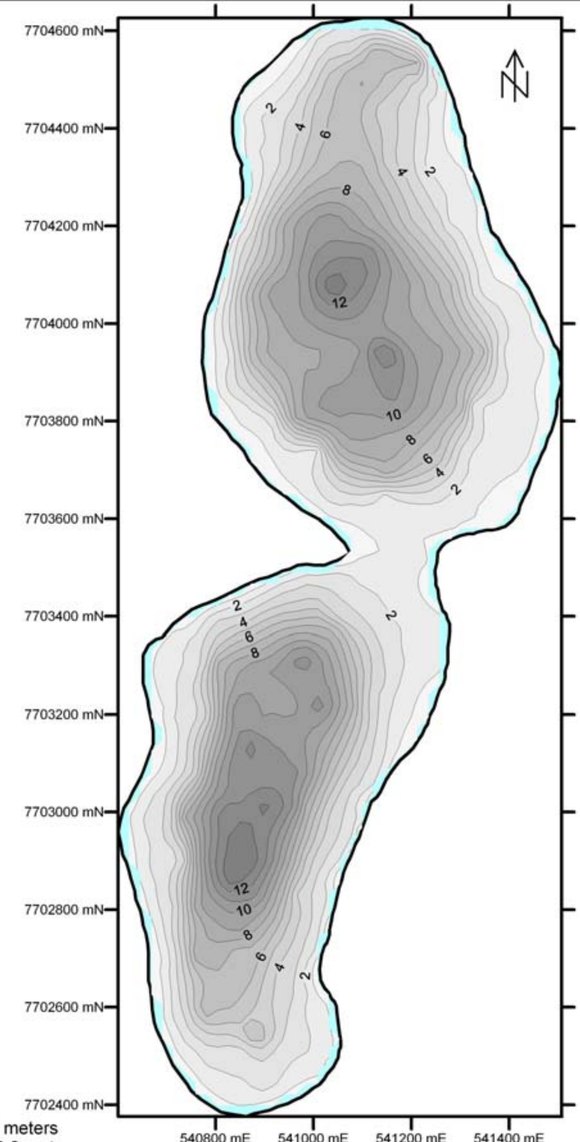
LAKE DETAILS

Average Depth: 2.4 meters
Maximum Depth: 12.9 meters
Lake Volume: 3,452,380 cubic meters
Top Lake Surface Area: 1,343,999 square meters

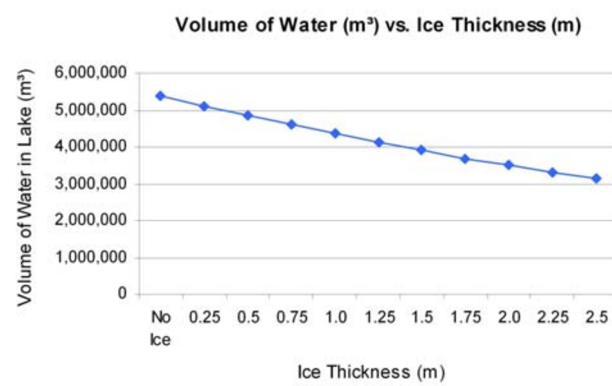
Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 48

Contour Map

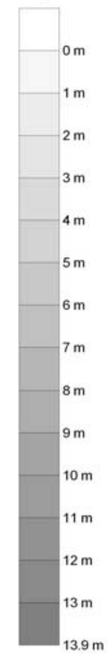


Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	5,380,515	100.0
0.25	5,113,517	95.0
0.5	4,852,910	90.2
0.75	4,600,130	85.5
1.0	4,355,912	81.0
1.25	4,121,440	76.6
1.5	3,898,854	72.5
1.75	3,690,201	68.6
2.0	3,494,485	64.9
2.25	3,309,057	61.5
2.5	3,132,272	58.2



Legend

Depth



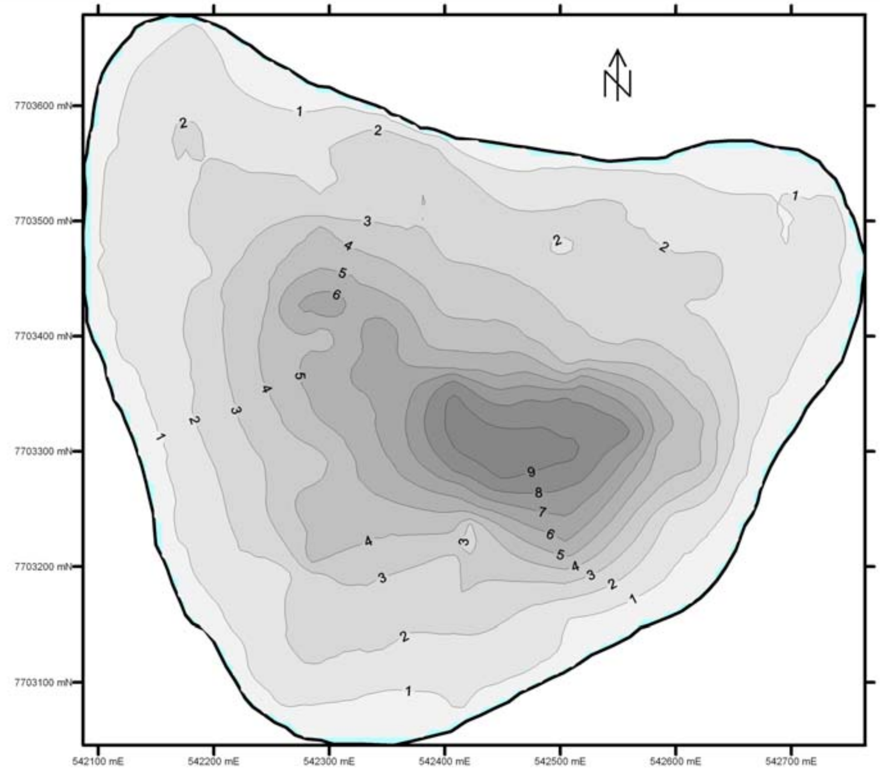
LAKE DETAILS

Average Depth: 5.0 meters
Maximum Depth: 13.9 meters
Lake Volume: 5,380,515 cubic meters
Top Lake Surface Area: 1,005,366 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

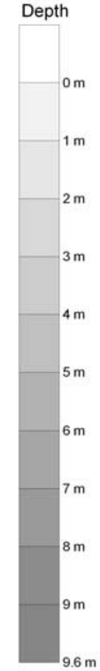
Lake 49

Contour Map

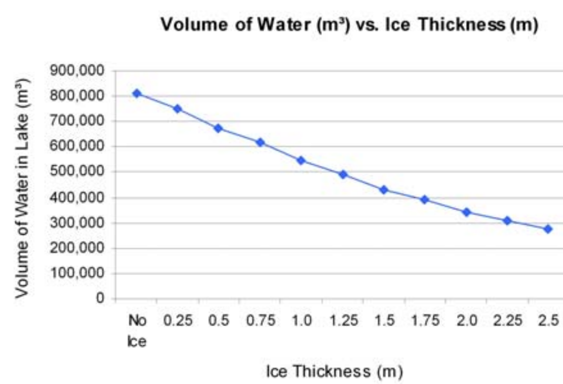


Legend

Depth



Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	814,227	100.0
0.25	750,519	92.2
0.5	673,910	82.8
0.75	615,914	75.6
1.0	545,113	66.9
1.25	494,138	60.7
1.5	432,937	53.2
1.75	391,727	48.1
2.0	341,849	42.0
2.25	310,705	38.2
2.5	277,287	34.1



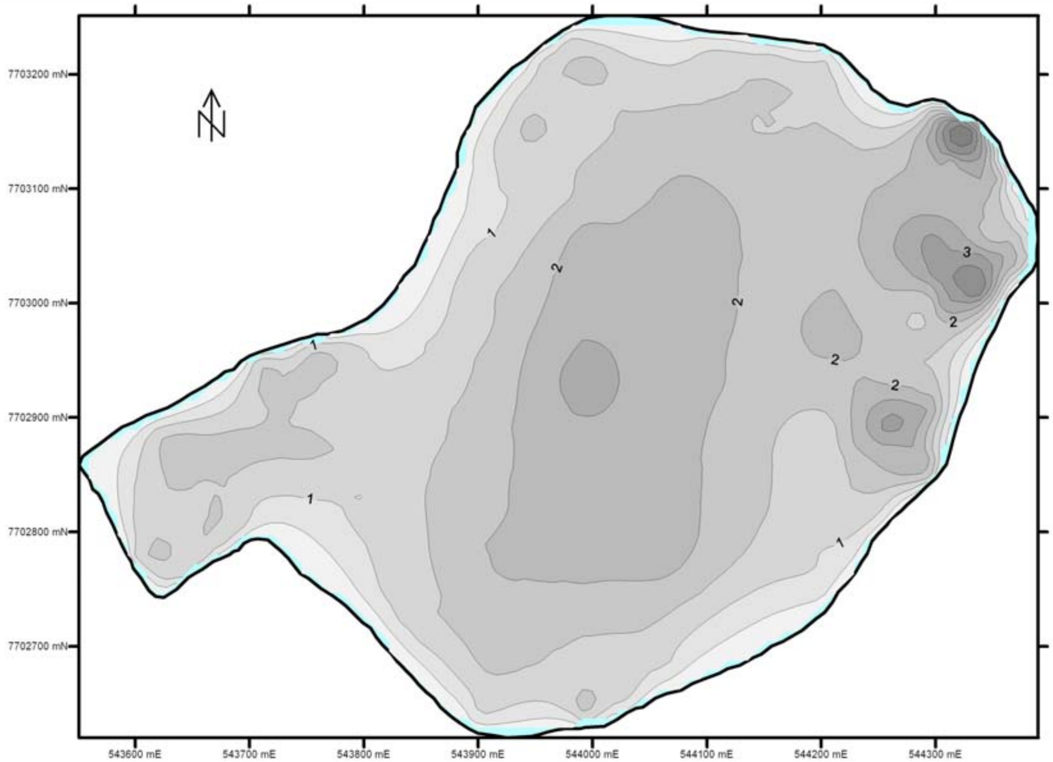
LAKE DETAILS

Average Depth: 2.8 meters
Maximum Depth: 9.6 meters
Lake Volume: 814,227 cubic meters
Top Lake Surface Area: 283,121 square meters

Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

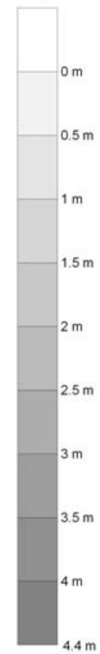
Lake 50

Contour Map



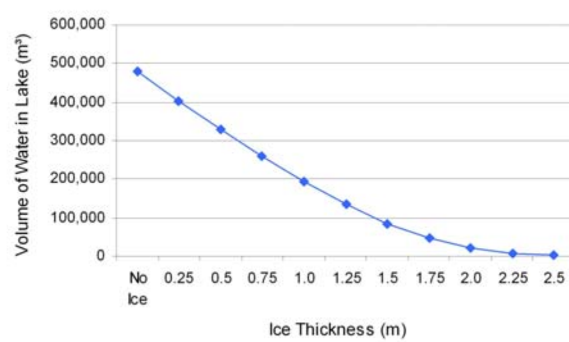
Legend

Depth



Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	478,512	100.0
0.25	402,603	84.1
0.5	329,789	68.9
0.75	260,193	54.4
1.0	194,286	40.6
1.25	134,263	28.1
1.5	84,456	17.6
1.75	47,566	9.9
2.0	21,998	4.6
2.25	9,069	1.9
2.5	4,738	1.0

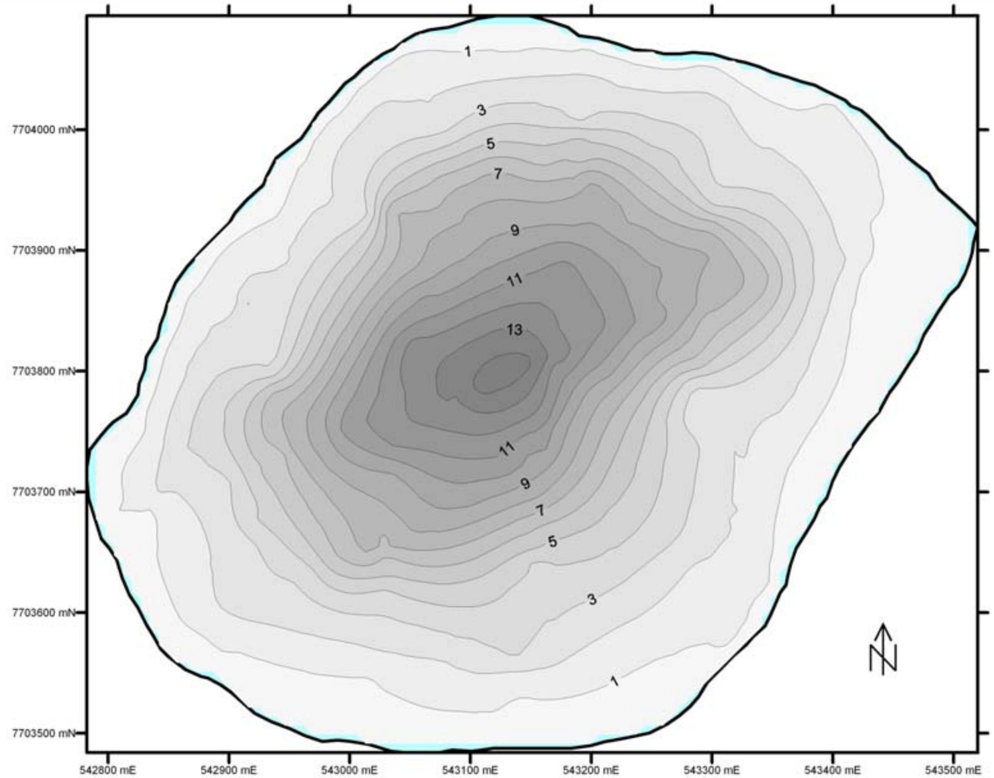
Volume of Water (m³) vs. Ice Thickness (m)

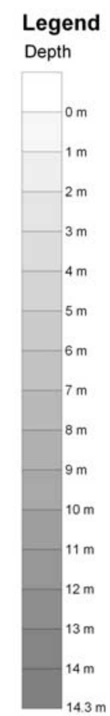


Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

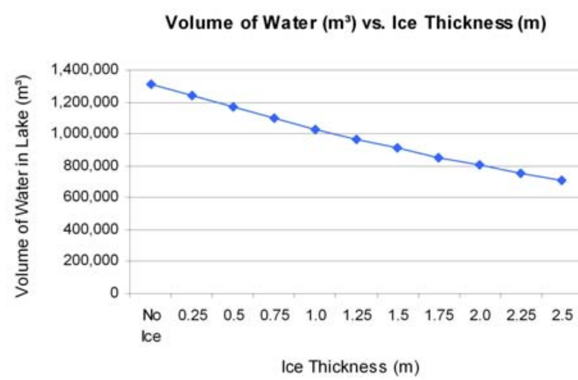
Lake 51

Contour Map





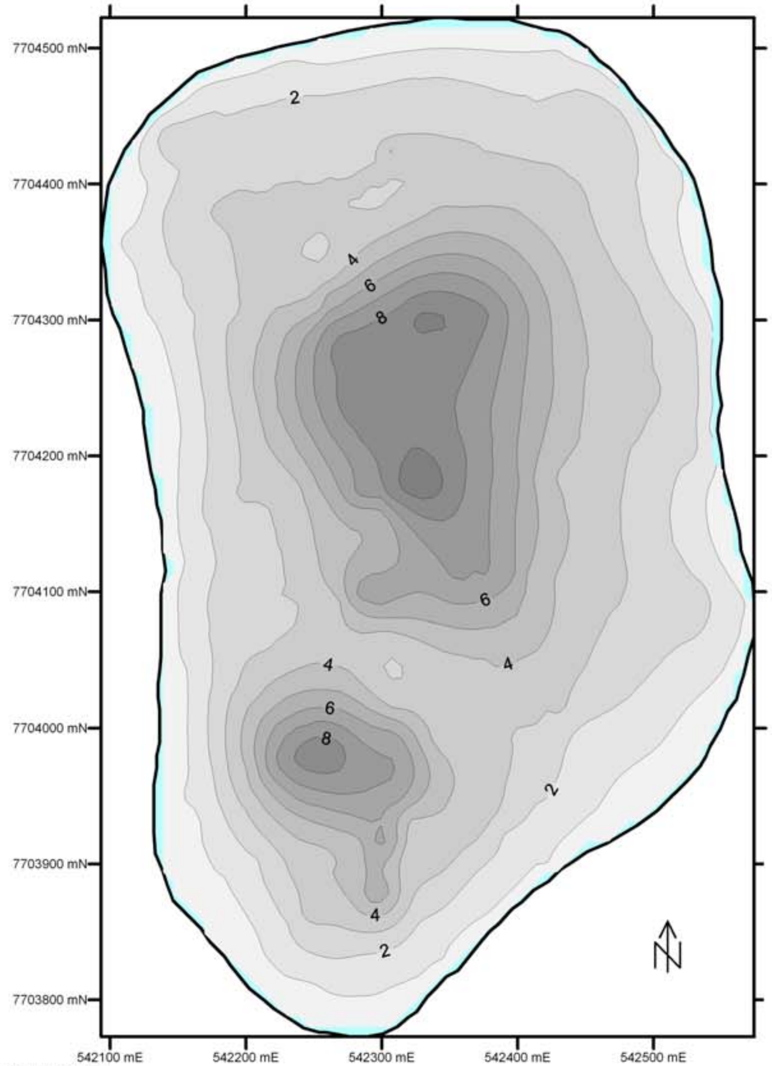
Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	1,314,881	100.0
0.25	1,238,104	94.2
0.5	1,165,352	88.6
0.75	1,096,142	83.4
1.0	1,030,392	78.4
1.25	968,163	73.6
1.5	909,538	69.2
1.75	854,482	65.0
2.0	802,771	61.1
2.25	754,611	57.4
2.5	709,829	54.0

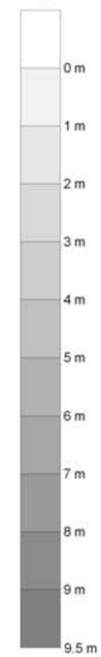


Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 52

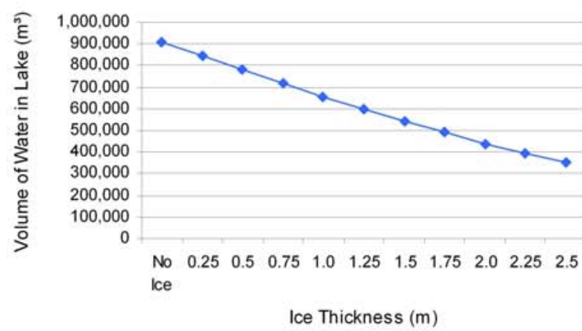
Contour Map





Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	910,830	100.0
0.25	843,456	92.6
0.5	778,473	85.5
0.75	715,802	78.6
1.0	655,428	72.0
1.25	597,480	65.6
1.5	542,116	59.5
1.75	489,513	53.7
2.0	439,751	48.3
2.25	393,106	43.2
2.5	349,983	38.4

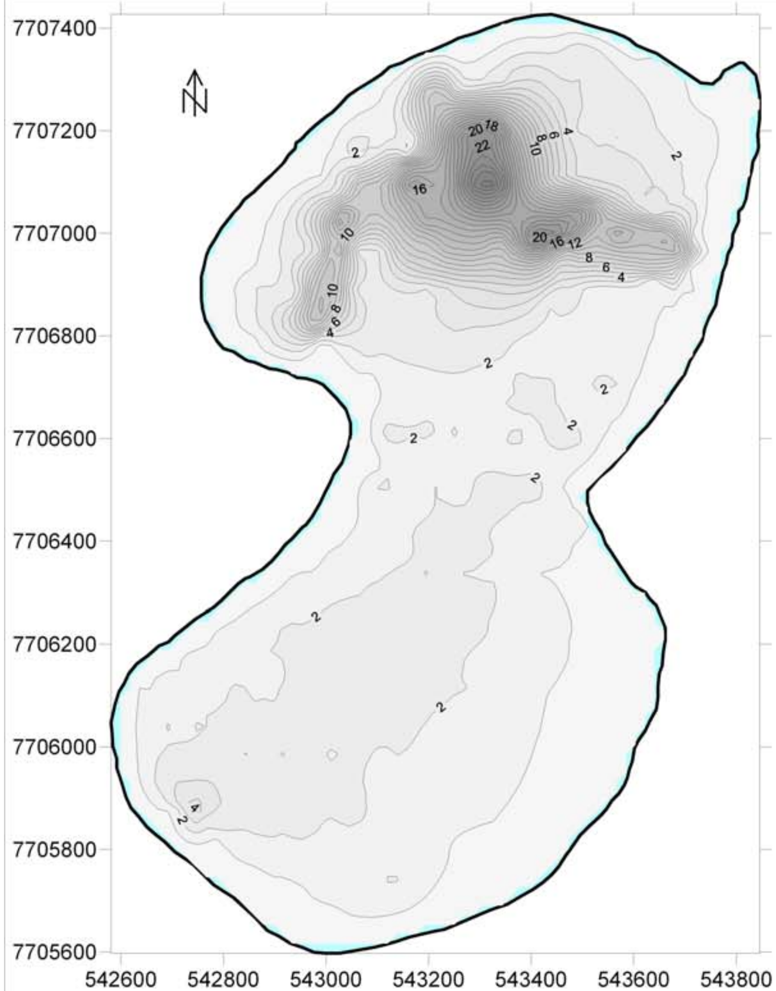
Volume of Water (m³) vs. Ice Thickness (m)



LAKE DETAILS

Average Depth: 3.3 meters
Maximum Depth: 9.5 meters
Lake Volume: 910,830 cubic meters
Top Lake Surface Area: 264,305 square meters

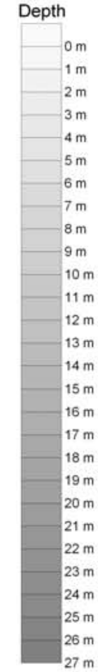
Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27



Lake 53

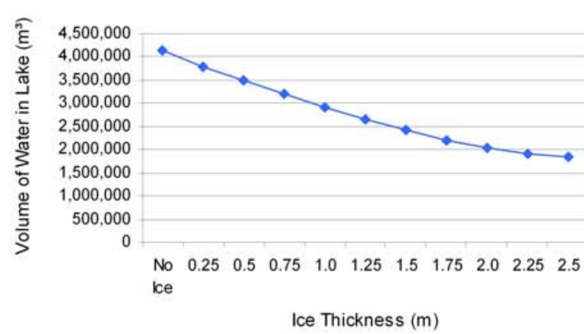
Contour Map

Legend

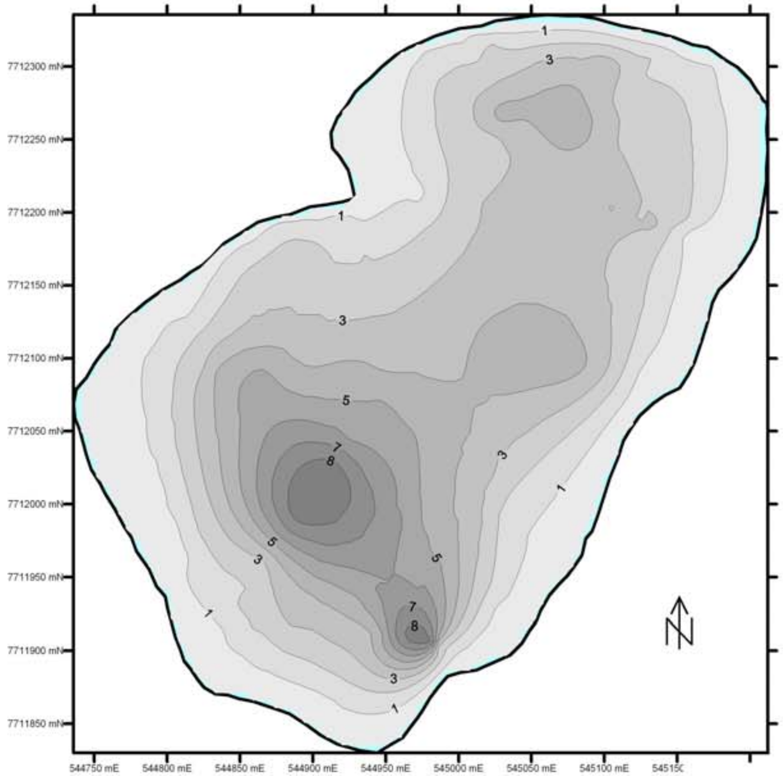


Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	4,144,687	100.0
0.25	3,802,208	91.7
0.5	3,487,251	84.1
0.75	3,194,317	77.1
1.0	2,920,429	70.5
1.25	2,664,305	64.3
1.5	2,426,813	58.6
1.75	2,214,095	53.4
2.0	2,042,567	49.3
2.25	1,921,889	46.4
2.5	1,831,830	44.2

Volume of Water (m^3) vs. Ice Thickness (m)



Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

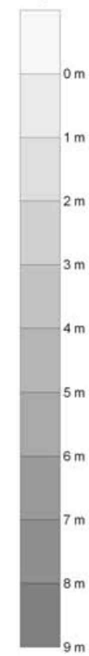


Lake 54

Contour Map

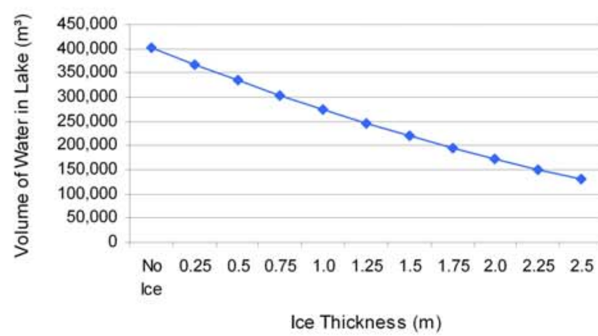
Legend

Depth



Ice Depth (m)	Volume of Water (m³)	Water Volume Remaining in the Lake (%)
No Ice	402,504	100.0
0.25	366,985	91.2
0.5	333,933	83.0
0.75	302,917	75.3
1.0	273,662	68.0
1.25	245,966	61.1
1.5	219,693	54.6
1.75	194,840	48.4
2.0	171,478	42.6
2.25	149,668	37.2
2.5	129,474	32.2

Volume of Water (m^3) vs. Ice Thickness (m)



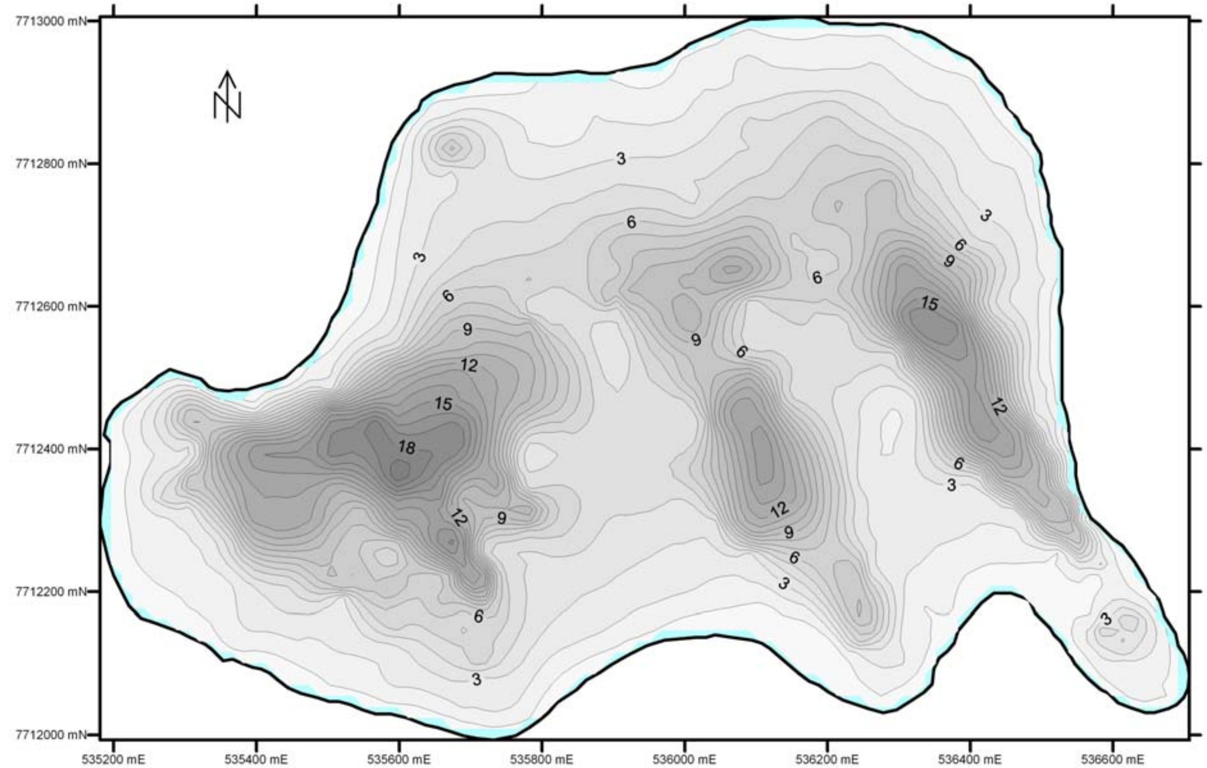
LAKE DETAILS

Average Depth: 2.7 meters
Maximum Depth: 9.0 meters
Lake Volume: 402,504 cubic meters
Top Lake Surface Area: 142,544 square meters

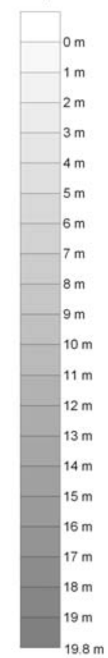
Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27

Lake 55

Contour Map

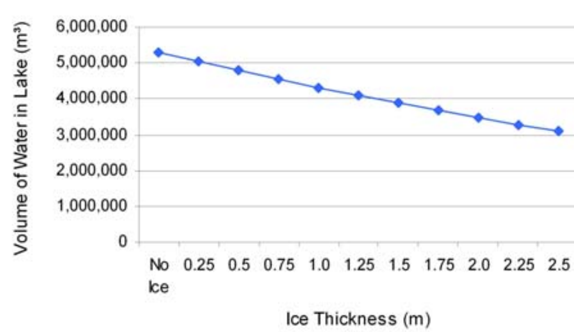


Legend



Ice Depth (m)	Volume of Water (m^3)	Water Volume Remaining in the Lake (%)
No Ice	5,279,903	100.0
0.25	5,029,114	95.3
0.5	4,784,233	90.6
0.75	4,546,156	86.1
1.0	4,315,149	81.7
1.25	4,091,503	77.5
1.5	3,875,801	73.4
1.75	3,668,201	69.5
2.0	3,470,139	65.7
2.25	3,282,691	62.2
2.5	3,105,217	58.8

Volume of Water (m^3) vs. Ice Thickness (m)



Projection: UTM
Zone 8
Spheroid: Clarke 1866
Datum: NAD 27