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CORPS OF ENGINEERS

U. S. LAKE SURVEY

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DEPARTMENT OF THE ARMY
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FORWARD

The U.S. Lake Survey is the Corps of Engineers District having responsibility for charting, conducting hydraulic and hydrologic studies and "fresh-water" oceanographic investigations of the Great Lakes. These Bulletins, published semiannually, contain articles and short reports on selected, unique problems or certain phases of particular projects which are deemed of especial interest to the scientific and engineering community.

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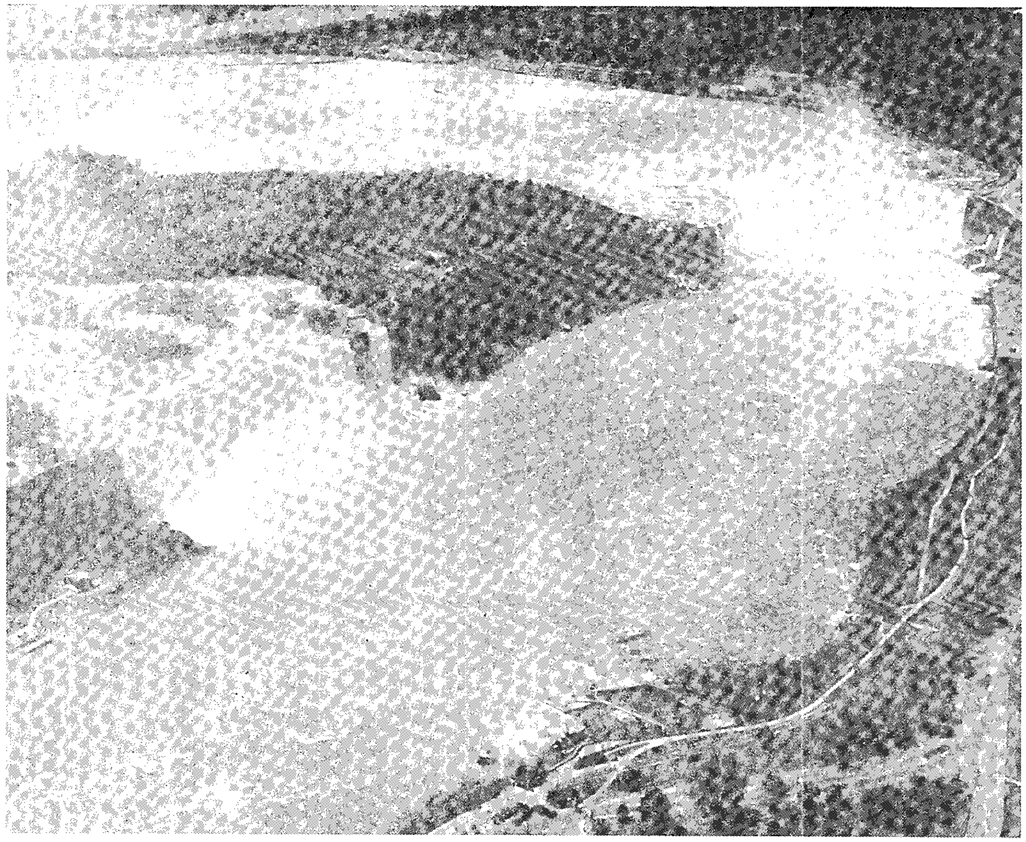


Figure 1. Niagara Falls

DETERMINATION OF FLOW OVER NIAGARA FALLS

BY

Leonard T. Schutze, Chief
International Coordination Section

World famous Niagara Falls are well known for their scenic beauty. Not as well known is the economic significance of the Falls to both the United States and Canada. There are six hydroelectric power plants which use Niagara River water for the generation of low-cost electricity. The various power diversions coupled with the minimum flows in the River required by the Treaty of February 27, 1950, respecting the uses of the waters of the Niagara River, complicate the already complex flow conditions making an accurate determination of flow over the Falls difficult.

The 36-mile long Niagara River, see Figure 2, flows northerly out of the northeast end of Lake Erie into southwest Lake Ontario. The difference in elevation between the two lakes approximates 326 feet; 185 feet at the falls and the remainder accounted for in the natural slope of the river and in the rapids sections above and below the falls. Proceeding north from its head the river separates, flowing around Grand Island into the Chippewa-Grass Island Pool which extends westerly from Grand Island to the rapids above the falls, thence through the rapids, over the falls, and into the Maid-of-the-Mist Pool, which is about two miles long. Beyond the Maid-of-the-Mist Pool the river traverses the three-mile long Whirlpool Rapids and thence to Lake Ontario.

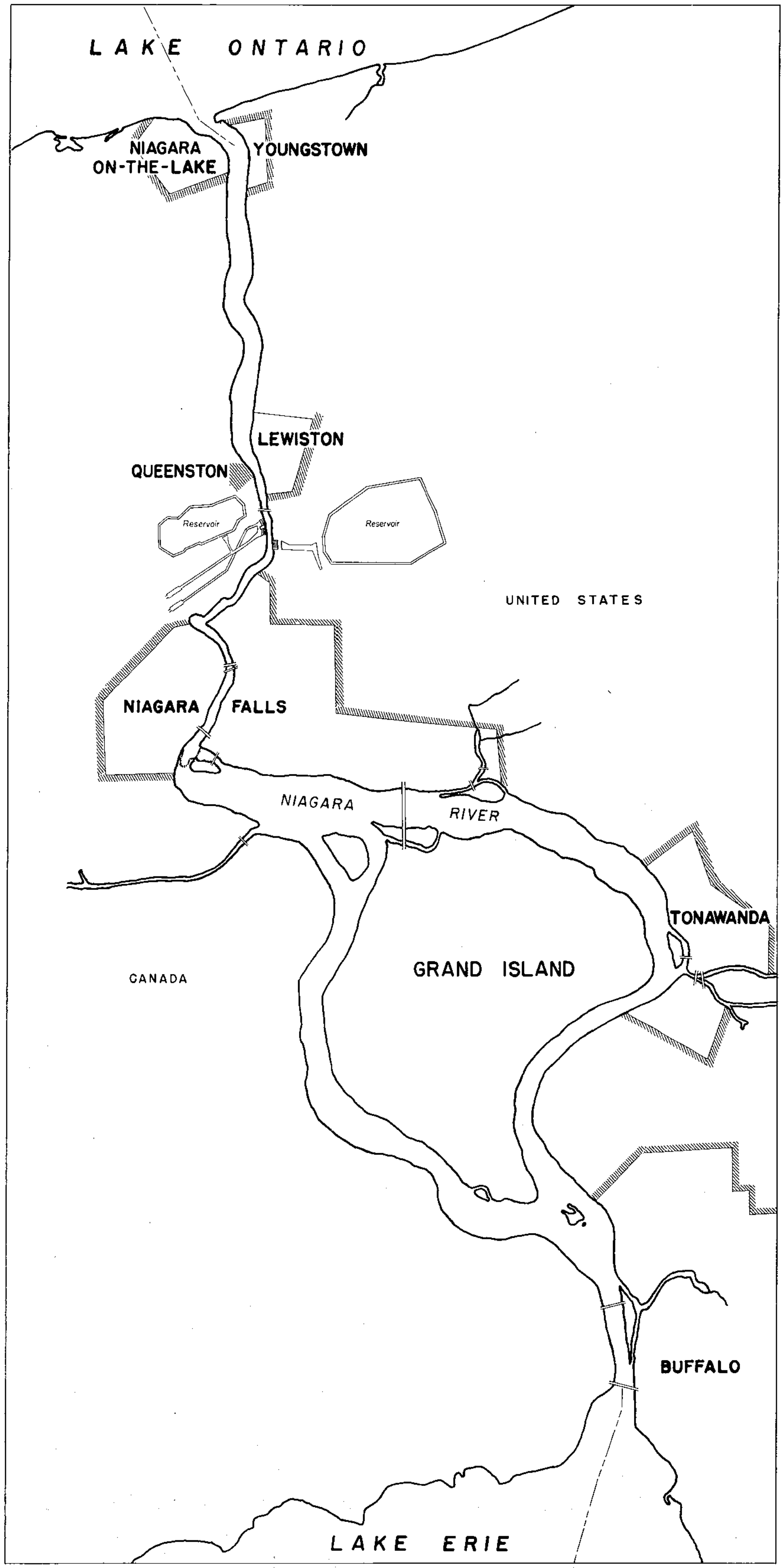


Figure 2. Niagara River

The Treaty of February 27, 1950 specifies that in order to insure the scenic beauty the flow over the Falls is not to be reduced to less than certain values. Table 1 shows the minimum flows established by the Treaty.

TABLE 1

Required Flows Over Niagara Falls

Dates	Hours Daily	Minimum Flows (cubic feet per second)
1 Apr-15 Sep	0800-2200	100,000
16 Sep-31 Oct	0800-2000	100,000
At All Other Times		50,000

All Niagara River hydroelectric power plants divert water from above the Falls. The diverted water runs through the turbines and is returned to the River below the Falls. Local terminology divides the plants into high-head and low-head. The high-head plants located at Lewiston, New York, and Queenston, Ontario, use most of the diverted water and utilize nearly all of the difference in elevation between the lakes (almost 316 of the available 326 feet), returning water to the river below Whirlpool Rapids. The low-head plants discharge into the Maid-of-the-Mist Pool at the foot of the Falls where the water elevation is about 76 feet higher than below Whirlpool Rapids.

No adequate stage-discharge relationship has been derived for the flow over Niagara Falls because of the complexity of flow conditions in the Chippewa-Grass Island Pool and the rapids above the falls. Operation of the control works at the lower end of that pool, variations in the amounts of diversions through the various intakes, and the presence of ice results in innumerable changes in flow patterns and water levels. These changing water levels preclude the use of a simple stage discharge curve to compute the flow over the Falls.

However, there is a well-defined stage-discharge relationship for flow out of the Maid-of-the-Mist Pool which is located immediately below the Falls. This relationship between Pool level and flow through Whirlpool Rapids, shown in Figure 3, was derived from several years (dating back to 1907) of field measurements of the Niagara River flow. The water level at the Ashland Avenue gage near the lower end of the Pool is recorded each hour of the day. The official daily flow out of the pool is computed for each hour using the stage-discharge equation for the Ashland gage. The Niagara River flow at Queenston (below the Pool) is the sum of the flow from Maid-of-the-Mist Pool and the discharges from the high-head power plants.

The computed hourly flows out of the Pool are also used to determine flows over the Falls, since the inflow to the Pool is the sum of the discharge from the low-head power plants and the flow over the Falls. Except for a few hours following the twice-daily change in flow over the Falls from April through October, the level of the Maid-of-the-Mist Pool remains nearly constant, and the inflow equals outflow. Thus most of the time, the hourly flow over the Falls is obtained by subtracting the low-head plant discharge from the computed hourly Pool outflow.

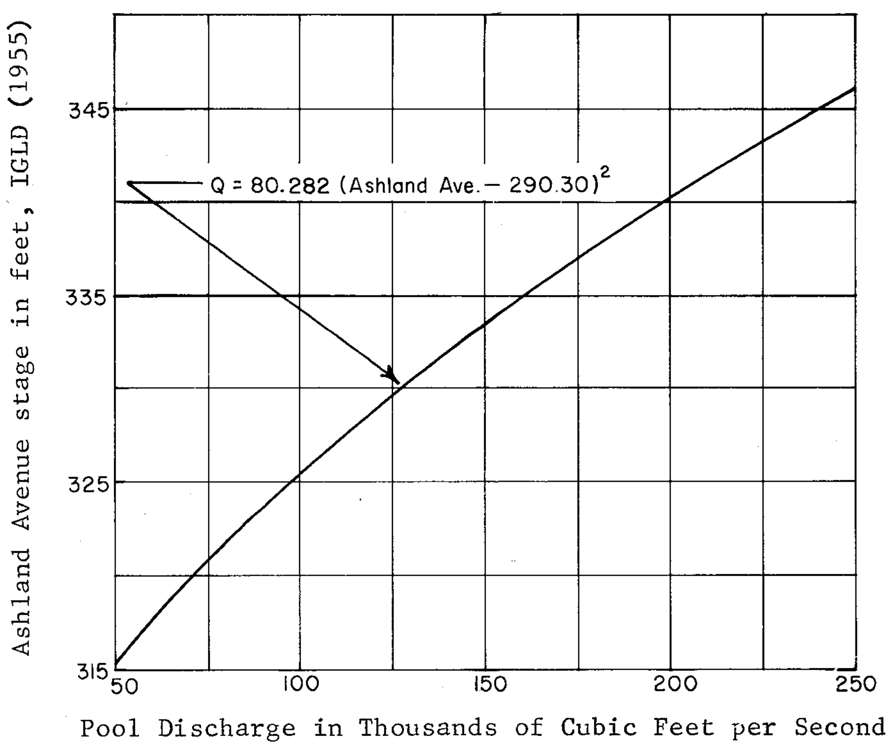


Figure 3. Maid-of-the-Mist Pool stage - discharge relationship

When the flow over the Falls is changed 50,000 cubic feet per second in order to comply with the Treaty, the level of the Pool suddenly changes more than ten feet and outflow no longer equals inflow during this period. A method of determining inflows during these periods of rapidly changing Pool stages and discharges was developed by investigating relationships between inflow, stages, and discharges resulting from various inflow changes.

The progressive changes in discharge due to changing inflow to the Pool from 50,000 to 100,000 cubic feet per second, and from 100,000 to 50,000 cubic feet per second are shown in Figure 4. These hydrographs were obtained by plotting the discharge at the end of successive five-minute periods following inflow change using a routing equation based on the volumetric principle:

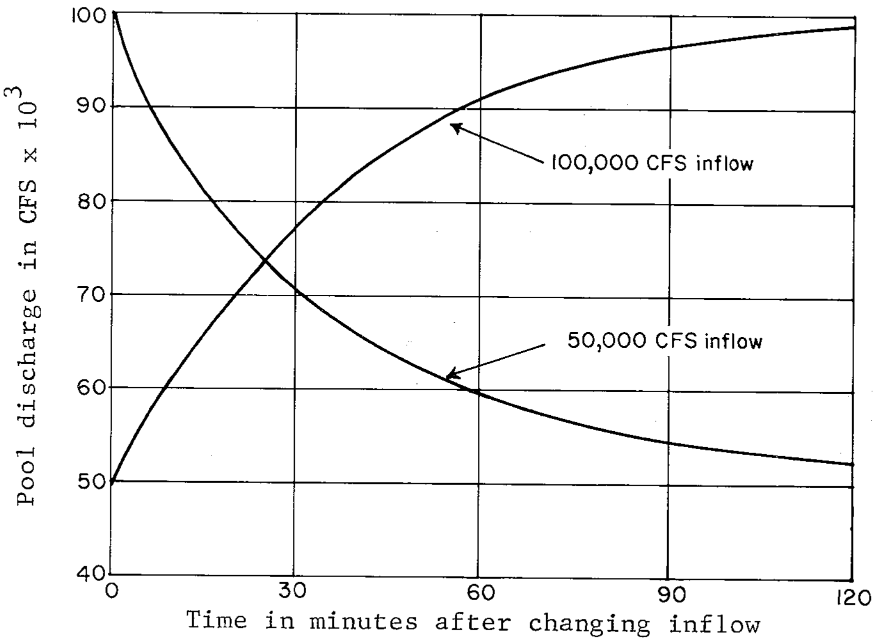


Figure 4. Hydrographs of routed discharges

$$\text{Storage Change} + \text{Outflow} = \text{Inflow} \qquad (1)$$

or $$S_1 - S_0 + 1/2k\,(Q_0 + Q_1) = kI$$

or $$S_1 + 1/2kQ_1 = S_0 - 1/2kQ_0 + kI \qquad (2)$$

where, S_0, S_1 = Ashland Avenue levels, in feet, at beginning and end of period, respectively.

Q_0, Q_1 = Pool discharge, in cubic feet per second, corresponding to S_0 and S_1 respectively, from relationship in Figure 3.

I = Inflow in cubic feet per second.

k = Conversion factor to change cubic feet per second to feet on Pool per 5 minutes, and is equal to 300 seconds divided by 10,400,000 square feet, the Pool area.

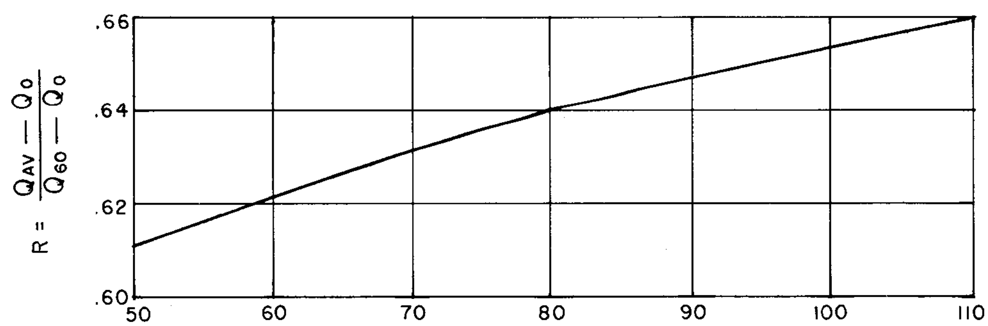
The levels and discharges computed for the hydrographs in Figure 4 were used to determine a relationship between outflow during an hour and Pool discharges at the beginning and end of the hour. The hourly periods considered extended from 0 through 60 minutes after changing inflow, 5 through 65 minutes, 10 through 70, and so on to include the hour from 60 through 120 minutes after changing inflow. The outflow during each of these hours was computed using equation (1) by subtracting the storage change from the inflow. It was found that the differences between the outflows and the corresponding discharges at the beginning of the hour varied between 61 and 65 per cent of the change in discharge during the hour. The ratios of differences, R, when plotted against corresponding beginning-of-hour discharges gave the outflow-discharge relationship shown in Figure 5. The ratio R may be expressed in symbols:

$$R = \frac{Q_{AV} - Q_0}{Q_{60} - Q_0}$$

or

$$Q_{AV} = Q_0 + R(Q_{60} - Q_0) \qquad (3)$$

where, Q_{AV} is outflow in cfs-hours, a volume equivalent to the average discharge in cubic feet per second flowing one hour; and Q_0, Q_{60} are discharges in cubic feet per second at the beginning and end of the hour.



Q_0 Initial discharge in CFS x 10^3

Figure 5. Outflow - discharge relationship

Substituting Q_{AV} from equation (3) for Outflow, and 2,890 $(S_{60} - S_0)$ for Storage Change, equation (1) may be written in cfs-hour units of volume as

$$\text{Inflow} = 2{,}890\ (S_{60} - S_0) + Q_0 + R(Q_{60} - Q_0) \qquad (4)$$

where S_0, S_{60} are Ashland Avenue levels of Pool, in feet, at beginning and end of hour, respectively.

Q_0, Q_{60} are Pool discharges, in cubic feet per second, corresponding to S_0 and S_{60}, respectively, from relationship in Figure 3.

R is ratio corresponding to Q_0 from relationship in Figure 5.

The flow over Niagara Falls is determined in the period following the 50,000 cubic feet per second change in flow by subtracting the recorded hourly discharge of the low-head power plants from the Inflow computed from equation (4). The level of the Pool generally returns to a stable condition about two hours after the change in flow indicating outflow and inflow are equal; the flow over the Falls then is determined by subtracting the low-head plant discharge from the outflow as previously indicated.

Tables have been prepared for the stage-discharge and outflow-discharge relationships. Using these tables, the flow over the Falls may be determined simply and accurately from the hourly Ashland Avenue gage records and the low-head power plant hourly records.

LAKE SURVEY CHARTS

by
Gilbert E. Ropes, Former Chief*
Hydrographic Branch
U. S. Lake Survey

INTRODUCTION

A major function of the U. S. Lake Survey is the preparation and publication of navigation charts of the Great Lakes. The Lake Survey, a District of the North Central Division, Corps of Engineers, had its beginning, 125 years ago, in 1841 when the Congress appropriated $15,000 for a "Survey of the Northern and Northwestern Lakes." The responsibility for the survey was placed on the Corps of Topographical Engineers (merged into the Corps of Engineers in 1863) and assigned to Capt. W. G. Williams. Headquarters were established in Buffalo, New York, but in 1845 they were moved to Detroit, Michigan, where they have remained.

AREAS COVERED

Lake Survey charts cover the Great Lakes and their connecting waters, the International Section of the St. Lawrence River, Lake Champlain, the New York State Barge Canal System, and the Minnesota-Ontario Border Lakes from Lake Superior to and including the southern portions of Rainy Lake and Lake of the Woods, see Figure 1. There are 143 different charts. They fall in the following categories:

a. Six General Charts, one for each of the five Great Lakes and one showing all the Lakes, at scales ranging from 1 to 400,000 down to 1 to 1,200,000.

b. Fifty-six Coast Charts, covering the coastal waters along from 30 to 150 miles of lake shoreline at scales from 1:80,000 down to 1:120,000. Many Coast Charts contain large-scale insets of important areas in the reach of shoreline covered.

c. Sixty-four Harbor, River and Area Charts at scales from 1:5,000 down to 1:60,000.

d. Five folios of charts designed for use by recreational and other small craft. The folios measure 11 by 17-1/2 inches and the charts are at scales of from 1:5,000 down to 1:15,000 with a few at smaller scales. Two more folios are in production.

e. Twelve maps of the Minnesota-Ontario Border Lakes that do not show water depths.

*Mr. Ropes retired from the Lake Survey on 29 December 1965.

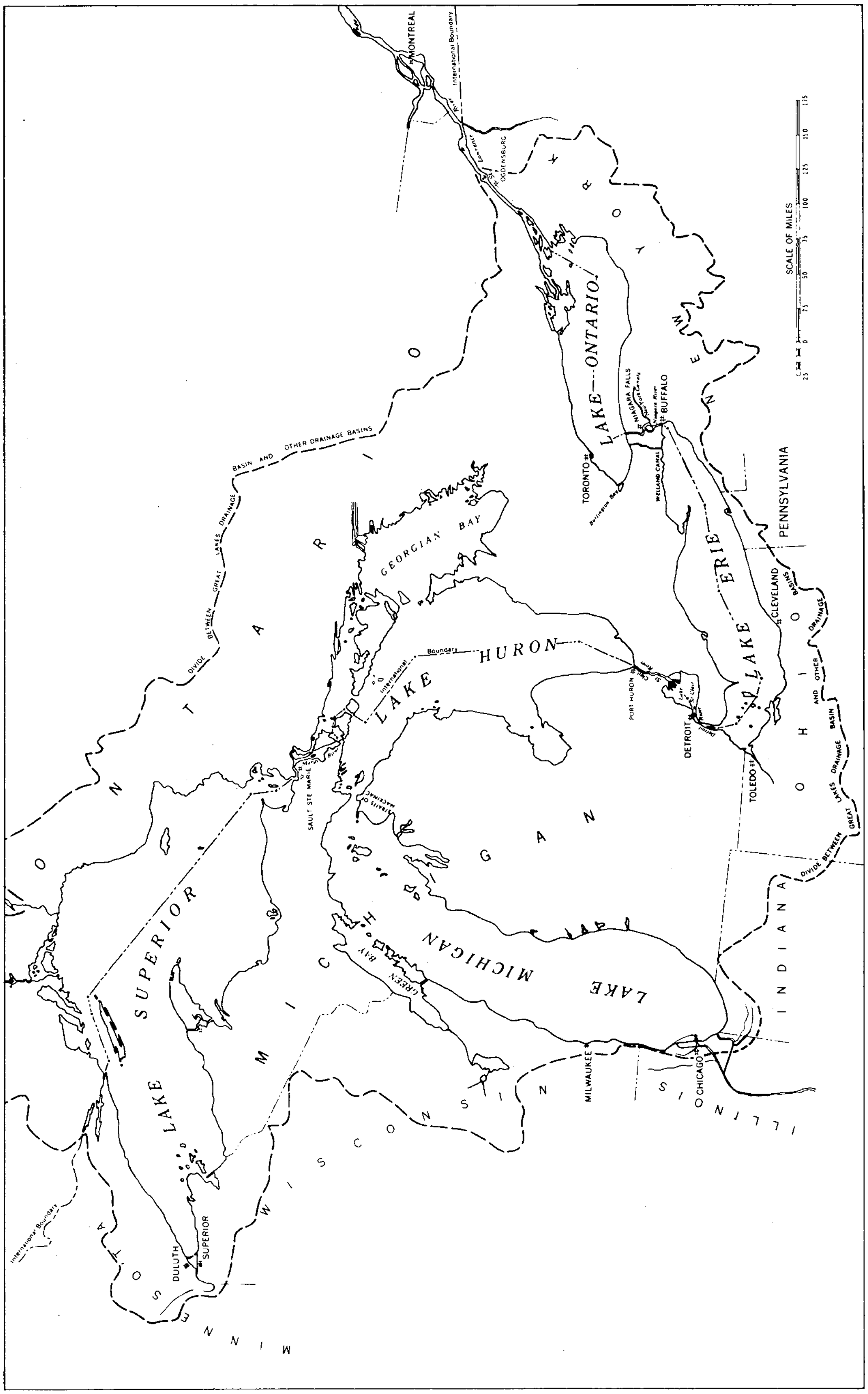


Figure 1. The Great Lakes

CURRENT CHARTING PROGRAM

Once a chart of an area is made, it could be reprinted indefinitely if the charted features did not change. However, changes, especially man-made ones, do take place, and past experience has shown that on the average most charts need updating once every three years.

The ideal program for publishing new editions of Great Lakes charts would be to update each chart to be published during the year at the close of the navigation season and have all new editions published prior to the opening of navigation the next year; this, however, is impracticable. Therefore, field surveys to inspect and determine necessary revisions to the charts are made from 1 May through mid-October, with the more important industrial harbors being scheduled first. As soon as it is updated in the field, the revised chart is processed through compilation, engraving and reproduction on a schedule that will provide about one-fourth of the new charts prior to 1 February, the remainder following at intervals during the next nine months. The compilation and engraving steps are shown in Figures 2 and 3.

The stock of printed charts is kept up to date by hand correction during the next three years to revise aids to navigation and add important new features.

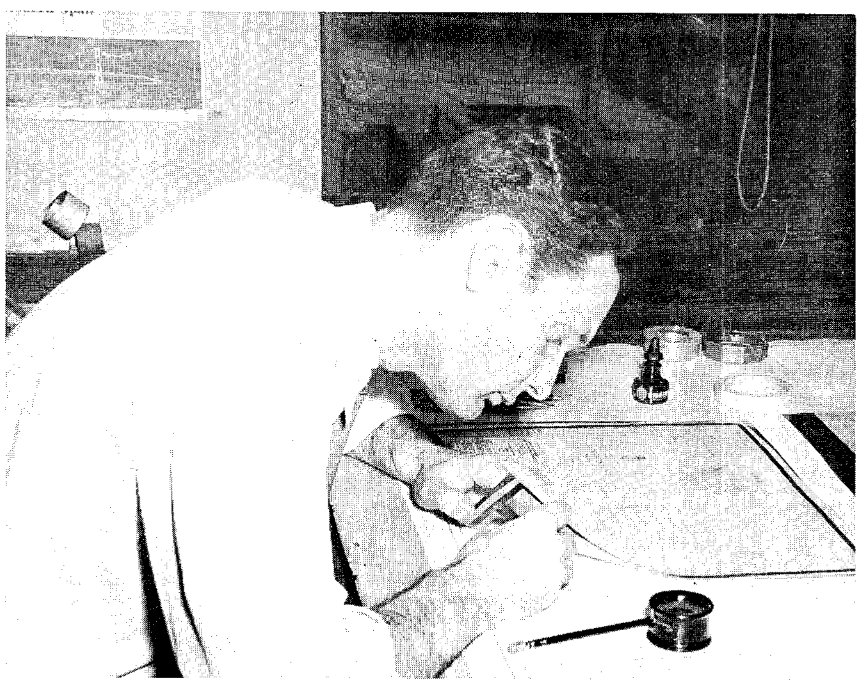


Figure 2. Compilation of chart

Figure 3. Engraving of chart

CHART PRINTING

Depending on when and for what purpose charts are printed determines what that particular printing is called, Figure 4 shows one of Lake Survey's printing presses. Lake Survey terminology breaks down the various printings into the following five categories: (1) new editions; (2) reprint editions; (3) additional printing; (4) overprinting; and (5) correction sheets.

New Editions. New editions are preceded by field reconnaissance in which all charted features are inspected and the necessary topographic and hydrographic surveys made to revise the chart. New editions of nearly all Lake Survey charts are printed once every three years. Some are printed more frequently and others less, depending usually on the number of changes occurring in the charted area. If, at the time a chart goes to press, it is known that major changes are planned within the next few years in the area covered, the chart schedule is modified to fit the construction schedule.

Reprint Editions. A reprint edition is one where a major revision is made to only a small but important area of the chart. In this case, the edition date noted on the chart is not changed, but a new date is added, preceded by the word "reprint."

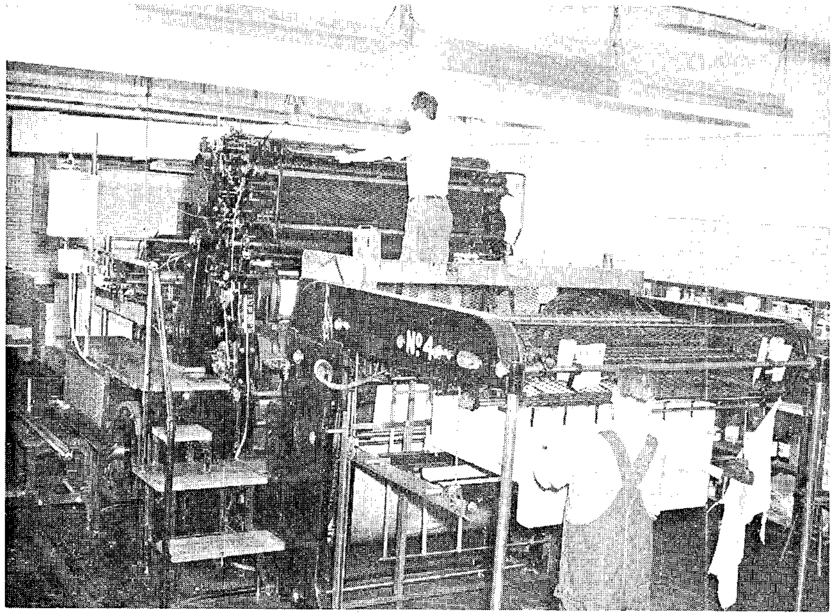


Figure 4. Lake Survey printing press

Additional Printing. As the name implies, an additional printing may be made between regular printings. Aids to navigation and other important features are updated on an additional printing. Such printings are made for one of three reasons: (1) stock depletion through unexpected sales; (2) increase in hand corrections, see Figure 5 to the point where it becomes more economical to print additional charts than to correct the existing stock; and (3) where annual sales are of such volume that more frequent printings are warranted because of handling and storage costs.

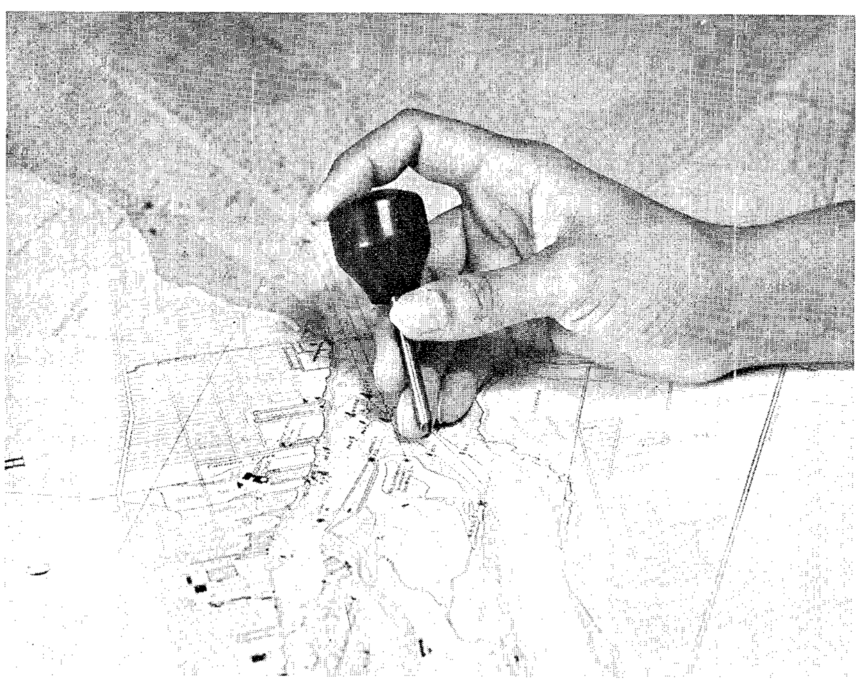


Figure 5. Hand correcting chart

Overprints. On occasion, a reprint edition can be avoided by overprinting, usually in red on existing stock. Overprinting is best suited to revise numbers for aids to navigation or to add a construction area or danger zone.

Correction Sheets. These are small, one-color sheets showing a revised portion of the chart. They are attached to each chart at the time of sale.

FIELD SURVEYS

To keep charting data as current as possible, the Lake Survey Hydrographic Branch has four field sections which operate on the Great Lakes each season. Three are assigned to hydrographic survey missions, and the fourth, the Control Section, furnishes the primary horizontal and first-order vertical control for the other three.

Two of the sections, "Inshore A" and "Inshore B", make new surveys of selected inshore areas. Such surveys are used to replace old surveys which in many cases are the original surveys. Today's needs are for greater detail and more accuracy, particularly in the area from shore out to about the 40-foot depth contour. Modern equipment and methods used by these Sections are meeting these needs.

The Revisory Section, see Figure 6, is responsible for checking and verifying all topographic and hydrographic features shown on the charts. Revisory surveys are made as close to the new edition printing date as possible to insure that charts contain the latest possible information.

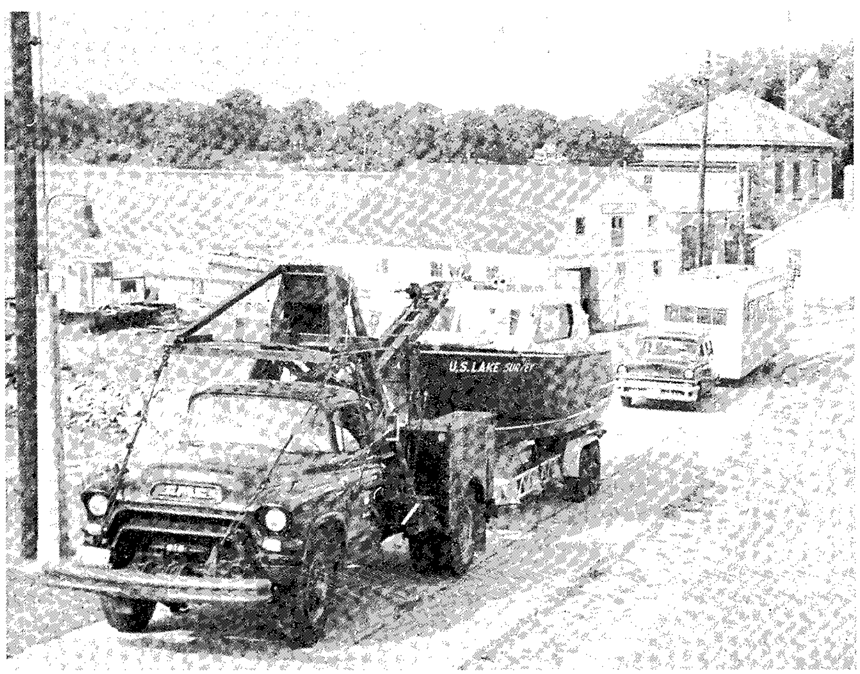


Figure 6. Revisory survey party

OTHER SOURCES OF DATA

Corps of Engineers District Offices. Information on available depths in project areas, as well as additions or changes to piers and breakwaters, is furnished by the responsible Corps of Engineers District Office. Final proofs of each chart are sent to the appropriate District Office for last minute revisions.

U. S. Coast Guard and Canadian Department of Transport. Buoys, lights, fog signals and radio beacons, all of which are generally referred to as aids to navigation, are the responsibility of the U. S. Coast Guard for United States waters and the Department of Transport for the Canadian waters. Because of the great importance of such aids, the stock of charts is hand corrected whenever a change is made by either of these two agencies. To hold hand corrections to a minimum, close coordination is maintained between the Lake Survey and both agencies. The Coast Guard is informed of new editions of Lake Survey charts six months in advance, and it attempts to schedule contemplated revisions to the aids in that area prior to the new edition. Proofs are also furnished just prior to printing. On occasion, a major change in the buoyage on a particular chart cannot be scheduled to take place prior to the new edition, therefore, a short edition is printed and an additional printing is scheduled to coincide with the Coast Guard schedule.

Other Charting Agencies. Close coordination is also maintained with the other two United States charting agencies, the U. S. Coast and Geodetic Survey and the Navy Oceanographic Office. In these cases, it is methods and equipment that are coordinated rather than chart information.

In addition, very close coordination is maintained with the Canadian Hydrographic Service, Lake Survey's counterpart on the Great Lakes. An example of such international cooperation took place during the re-survey of the St. Lawrence River from Ogdensburg to Cornwall after construction of the Power and Seaway projects. Each office furnished a hydrographic party to accomplish the field work. The Lake Survey party started at Ogdensburg, New York, and worked downstream, and the Canadian party started at Cornwall, Ontario, and worked upstream until they met. The results of the surveys were exchanged.

U. S. Power Squadrons. The Lake Survey has recently established with the U. S. Power Squadrons a program of cooperative charting. The Power Squadrons is a private organization of recreational boatmen whose principle aim is safe boating through education and training. The Lake Survey - Power Squadrons cooperative charting program is similar to one previously established by the U. S. Coast and Geodetic Survey and the Power Squadrons for United States coastal waters. Both programs provide for Power Squadrons members to check the charts of the area they are cruising in and make notations of changes. Marked up copies of charts showing changes are then submitted to the charting agency involved.

CONCLUSION

To properly serve both commercial and recreational navigation, the Lake Survey continually strives to develop and publish the best, most up-to-date charts possible. New charts are being made to cover some of the areas already charted at larger scales to show more detail where the need for such is indicated and others are being produced to show areas never before covered. Conversely, when a chart is no longer needed, it is discontinued. As each chart is scheduled for reprint or new edition, a careful study is made to determine whether or not the chart is needed and, if so, how to improve it. Careful planning and controlled expansion of services to meet the ever-changing and increasing needs of the Great Lakes community have been, and will continue to be, the Lake Survey's policy.

CONSTRUCTION AND OPERATION OF SOUTH MANITOU ISLAND RESEARCH STATION

by

Donald J. Leonard, Chief
Data Collection Branch
Lake Survey District, Corps of Engineers

INTRODUCTION

The Lake Survey District has established a data collection station on an island in northern Lake Michigan to gather scientific data needed for a study of evaporation rates on Lake Michigan. A more precise understanding of lake evaporation and its causes would assist in forecasting lake levels and in devising lake regulation plans. The details of the construction and operation of this data collection station located at South Manitou Island is of possible interest to governmental and educational agencies who may have a need to establish instrumented stations at isolated locations.

South Manitou Island, see Figure 1, about 2-1/2 miles wide and 3-1/2 miles long, is located off the eastern shore of northern Lake Michigan, 17 miles west of Leland, Michigan, and about 8 miles northwest of Glen Arbor, Michigan. The eastern half of the Island is partially level at an elevation of about 600 feet above mean sea level. The shore line at the bay in the eastern portion is gently sloping; the remainder is characterized by a beach about 100 feet wide with sharply rising banks or bluffs. The western half of the Island is hilly. At one point the shore line rises from the beach to about 430 feet above the lake surface. Most of the Island is heavily wooded, with few areas cleared over 50 acres. A natural deep harbor exists in the sheltered bay on the southeast side of the Island. Transportation to and from the Island is provided by scheduled mailboat service from Leland, Michigan, which operates daily in the summer and weekly in the winter except when extreme ice conditions shut down operations. Telephone service is provided to the Island, so communications are always available.

CONSTRUCTION OF THE STATION

Land Installation. The south shore of the Island was selected as the location for the data station since this shore is exposed to the prevailing winds. The unobstructed 200-mile fetch leading to the south shore provides an opportunity to study meteorological factors

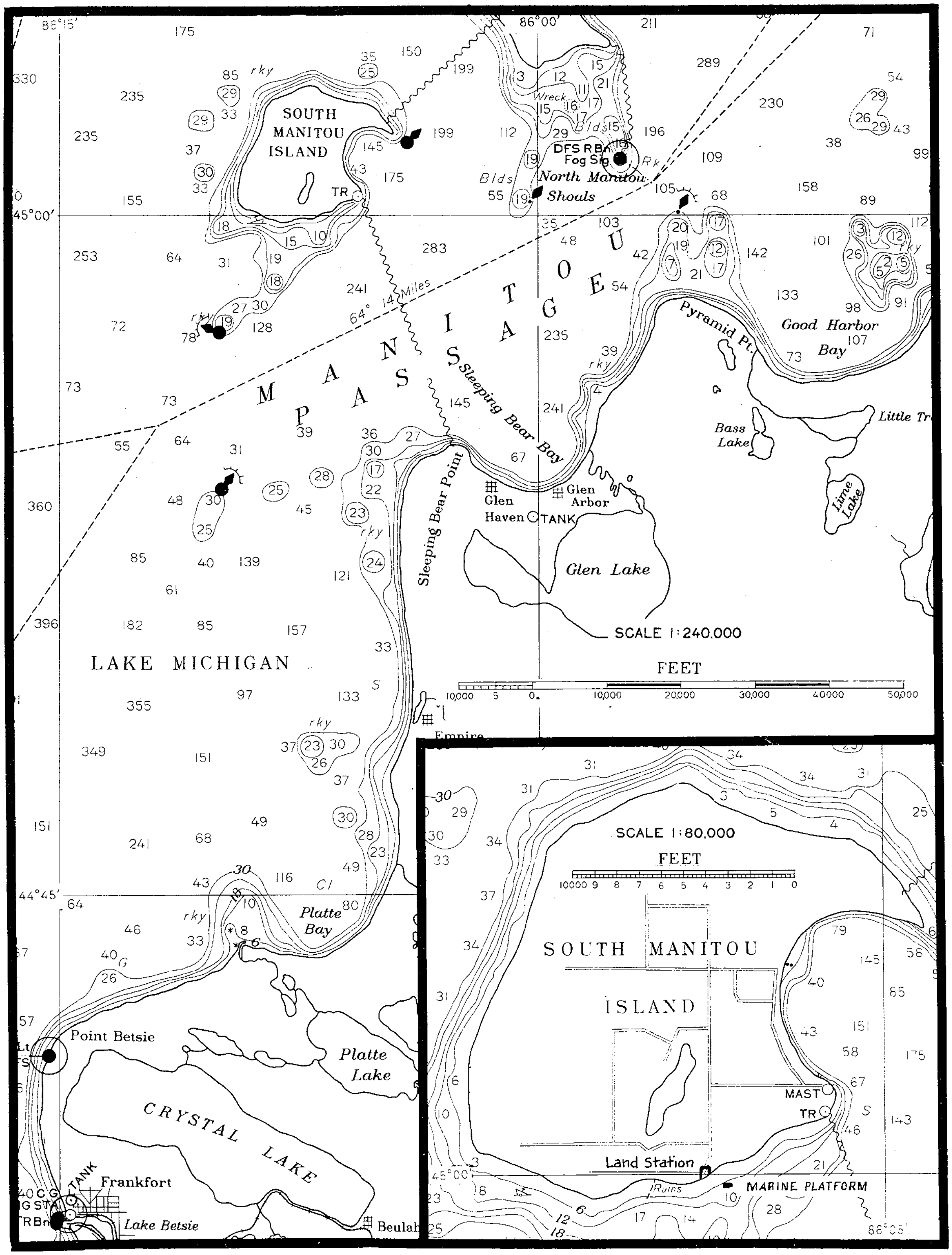


Figure 1. Location of South Manitou Island

relatively unaffected by land features. The desired land was leased in August 1963 with the initial construction bids being requested in September 1963. Construction of two shore buildings and related support facilities by a local contractor began in October 1963 and was ready for use by early November.

The two buildings were required for the generator installation and the instrument recording equipment. The generator building, 8 by 10 feet in size, has a poured concrete floor with permanent generator mountings. The generators were shipped to the Island and installed by late November 1963. The 8 by 12-foot instrument building, located 10 feet away, provides an insulated instrument closet 31 inches deep by 55 inches wide, with a minimum height of over 8 feet. Figure 2 is a photograph of these buildings. A small oil heater was provided to heat the instrument building when required. The addition of a heating element in the insulated instrument closet was found to be sufficient to maintain an adequate temperature in the building even during severely cold weather. Support structures include concrete foundations for the wind tower and radiometer and wooden platforms for the two precipitation gages located at the land station. The land based instrument package, a joint effort of the Lake Survey and the Weather Bureau, was completed in December 1963. The completed installation is shown in Figure 3.

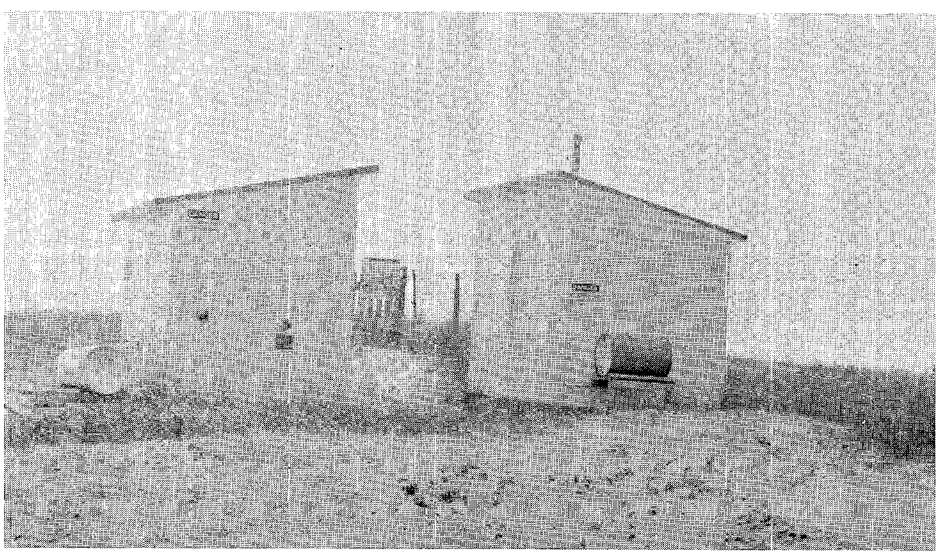


Figure 2. Generator and Instrument buildings

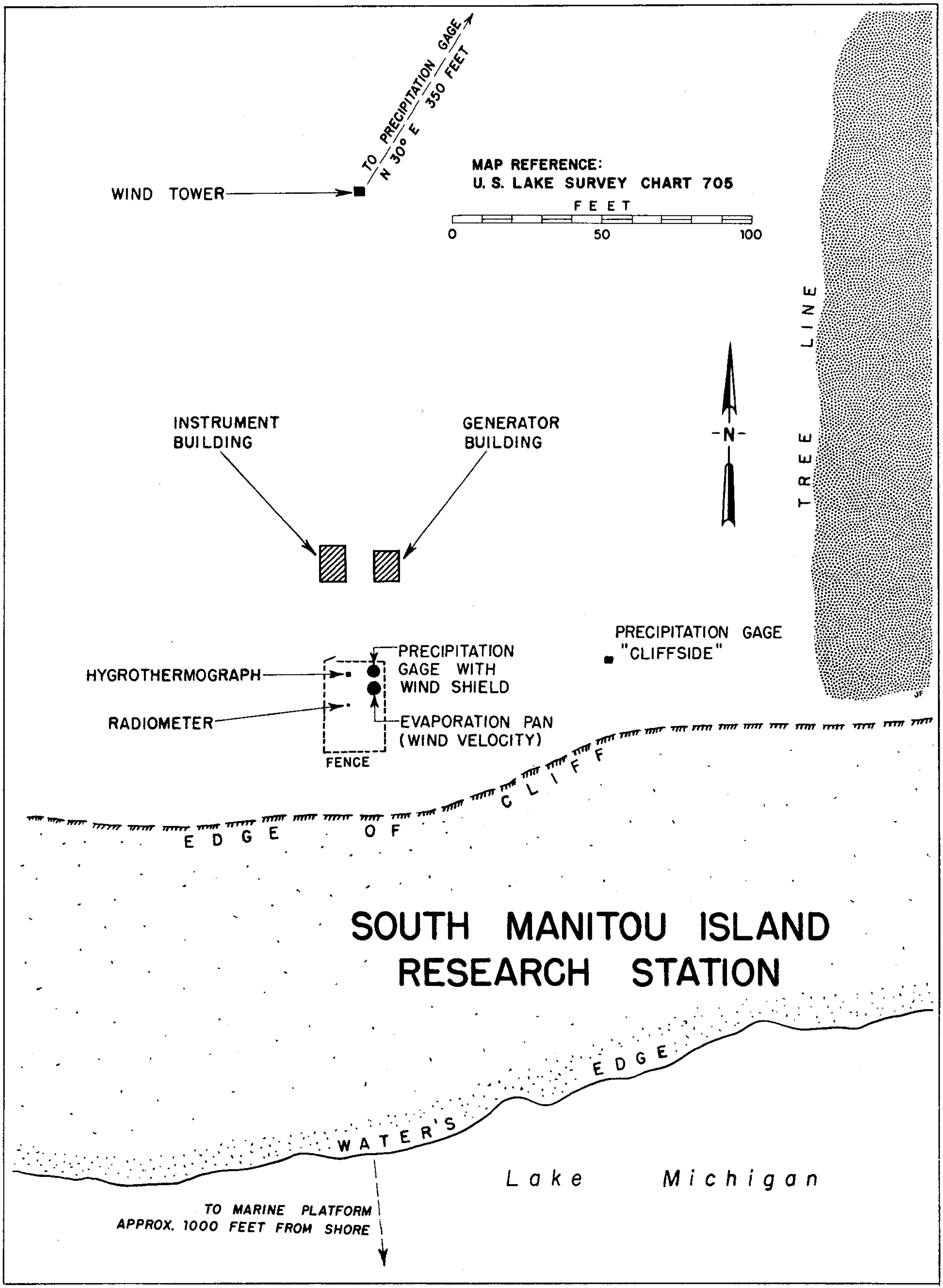


Figure 3. Land Station Installation

Marine Platform. A small over water instrument platform was needed to house instruments used to measure parameters in and above the lake. The Lake Survey engineers designed and hired a local contractor to build a five-timber pile cluster to support the marine platform. The piles were driven into the sandy lake bottom from 7 to 10 feet using the water jetting method. The pile cluster was secured with a wire rope band and the piles evenly topped to provide a level surface 7 feet above the water. Adverse weather conditions delayed the installation of the marine platform until May 1964, but by 1 June 1964 the entire installation was fully operational. However, extreme lake ice conditions during the 1964-65 winter sheared the piles and displaced the instrument platform 300 feet to the east. The structure was rebuilt in April 1965 using a new arrangement consisting of four corner piles and a center pile. Diagonal timber members and wire rope were used to join the piles which provided a more stable foundation than the previous one. This structure has withstood the present (1965-66) winter; however, the platform instruments were removed in November 1965 when the operational season was curtailed. Figure 4 shows the marine platform.

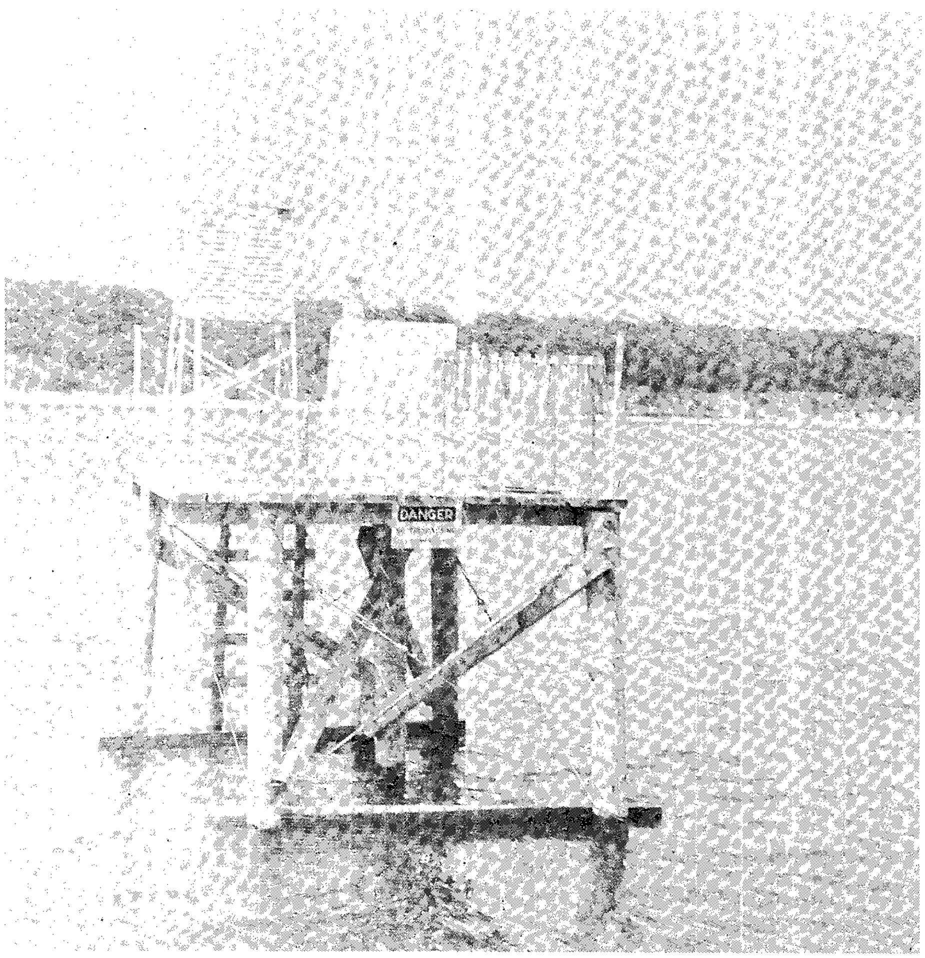


Figure 4. Marine Platform - 1965

DATA COLLECTION

Recording-type instruments have been installed where feasible to obtain continuous data. The Weather Bureau assisted in this portion of the project by procuring instruments and providing installation and maintenance on a reimbursable basis. Table 1 shows the recordings and observations taken from the land and marine stations.

TABLE 1

Recordings and Observations

Land Station	Marine Platform
Precipitation	Water temperature
Wind speed and direction	Precipitation
Incoming radiation	Air temperature
Air temperature	Humidity
Humidity	
Evaporation	
Cloud cover	
Extent of ice cover	

In addition to the shore and marine instrument stations, a water level recorder was installed and operated at the U.S. Government dock located on the southeast end of the Island. A pressure-cell type wave gage is positioned approximately 4,000 feet off Point Betsie (on the mainland) located 22 miles southwest of the land station in 50 feet of water, with pressure cell located at the 30-foot depth. A cable connects the pressure cell with a recorder housed in the U.S. Coast Guard Point Betsie Light Station.

The Lake Survey hired a resident of the Island as attendant-observer to operate the station on a year-round basis. He is required to make four inspection trips per week to the land station. When in operation, the platform is visited twice each week, using a small boat and outboard motor. The operational season of the platform is limited to the period when reasonable weather exists for safe boat travel. Servicing and routine maintenance of the generators are additional duties of the observer. Visual observations made by the observer during each inspection trip include:

a. Temperature - Maximum, minimum, dry bulb, and wet bulb.

b. General Observations - Descriptive remarks on general weather conditions.

c. Clouds - Estimate of cloud cover.

d. Visibility - Estimate of the visibility from the station over the water.

e. Snow on Ground - Obtain depth for the average snow cover.

f. Evaporation Pan - Evaporation in inches, precipitation which has occurred, maximum and minimum water temperature.

g. Ice Observations - Estimate of extent of ice cover and type of ice.

A log book is maintained on all inspection trips and information pertaining to the station's operation is recorded.

Chart records for each parameter are reduced to obtain values of hourly intervals and also instantaneous maximum-minimum readings for each day. The reduction of these climatological records from the original recorder charts to usable data is accomplished in compliance with standard methods of reduction.

Instrument charts are replaced every Monday. At two-week intervals the observer mails the collected data to Lake Survey, together with a written note pertaining to the operation of the station. When shipment of data is not possible during the winter, it is stored and shipped at the earliest opportunity. The observer is responsible for the proper operation of the instruments and for obtaining valid data from all sensors. He makes written notes of checks on the actual chart record as well as replacing charts, replenishing ink supplies, etc.

The U.S. Weather Bureau provides an annual maintenance-calibration inspection of instruments and an on-call or emergency maintenance, if required. Due to the services of a very competent observer, however, in over two years of operation of the station, no emergency maintenance service by the Weather Bureau technical staff has been necessary.

POWER PLANT OPERATIONS

The two 3-KW diesel-driven air-cooled generating units providing electric power for the station merit special mention because the power supply has been more reliable than anticipated.

Installation features include duct adapters to exhaust hot air outside the generator building in summer while in cold weather the hot air is exhausted inside the building to provide heat. A 140-gallon diesel fuel tank supplies the operating generator, which uses an average of 8 gallons of fuel per day. A transfer pump is used to replenish the supply tank from a 650-gallon storage tank. Additional fuel is stocked for the winter season in 55-gallon drums stored at the site. The storage tank serves the additional purpose of settling out debris and water which accumulate when fuel is stored for an extensive period in the drums.

One generator operated almost 8,000 hours before requiring an overhaul in October 1965. Upon dismantling, this generator showed surprisingly little wear considering the length of time it had operated.

Just one complete failure of the power plant has occurred in over two years of operation. This happened during the first month of operation and resulted from a dead battery bank and the subsequent failure of the alternating generator to function when it was switched on automatically. Only 8 hours of record were lost.

A number of difficulties in the servicing and operating of the power plant have occurred. However, the outstanding ability of the observer has solved these problems time and time again and enabled successful continuation of operation of the station. Continuous adjustment of the governor on the operating generator is required to keep the current produced within a close tolerance, so as to provide proper chart speed on the radiometer and wind recorders. Oil seals, fuel injectors, along with other items, have been installed by the observer as needed. Not only has this preventative maintenance resulted in eliminating operation delays, but substantial savings have resulted by eliminating repair costs.

PROBLEMS OF INSTRUMENTATION ENCOUNTERED

The speed of the electric-drive recorders was found to fluctuate up to ± one hour per day. In the reduction of these chart records, time adjustments had to be made, which increased the manual reduction time. The generators were found to be operating within their designed frequency range. A frequency standard was installed on the wind and radiometer recorders on 17 March 1965 that corrected for inconsistent time obtained because of the varying frequency of power delivered by the operating generator. With this modification, the problem has been completely eliminated.

The maintenance effort required for the outdoor instrumentation is extensive due to windblown sand which destroys exterior finishes and enters interior instrument component parts. Additional care is taken to clean and maintain these devices in good operating order.

FUTURE PLANS

A meteorological data recording system is being designed and built to replace the various separate recorders presently used at the station. Data from the instruments and certain other correlative information will then be recorded sequentially, every six minutes, on punch tape output. This new system will eliminate most of the manual data reduction work since the punched tape output can be fed directly into a computer. It is estimated that the new system will be installed in May 1966 and will serve until the South Manitou project is completed.

CONCLUSION

Lake Survey will study individual parameters and their relationships. In these studies data from all sources, such as Public Health Service, University of Michigan, and others, will be used. Other agencies are encouraged to make use of the data gathered by this research station.

The construction of this entire Research Station was accomplished within a low budget limitation. Its operation and maintenance on a year-round basis was accomplished very economically. Data have been received with only a negligible amount of loss due to breakdown or failures, a result which is due both to successful planning of the station and the availability of a competent instrument observer.