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HYDROGRAPHIC SURVEYING IN THE GREAT LAKES DURING THE NINETEENTH CENTURY(*)

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ABSTRACT

This paper reviews the development of hydrographic surveys in the Great Lakes during the 19th century. It traces the work of the early Admiralty surveyors and of the U.S. Corps of Engineers through to the formation of the Canadian Hydrographic Service and describes some of the methods used and the hardships faced by the early surveyors.

INTRODUCTION

The immensity of the Great Lakes is often not appreciated by those outside the North American continent, but combined they are the largest freshwater body in the world, covering an area greater than the United Kingdom or Romania. By area, Lake Superior is the largest freshwater lake in the world with Lakes Huron and Michigan rating fourth and fifth respectively, Lake Erie as tenth and Lake Ontario, the smallest, rating thirteenth.

The great industrial heart of both Canada and the United States lies around the lakes and depends on the raw materials transported by water to its factories.

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Until the completion of railroads on either side of the lakes, all movement east and west was dependent on waterborne traffic.

At the beginning of the 19th century there were no widely published, proper charts. Cartographers had depicted the shoreline of the lakes with varying degrees of accuracy and with the limited travel on the lakes these sufficed for the crude navigation practised. But these were maps rather than charts, compiled from rough exploratory surveys from many sources and certainly showed no soundings and little information of specific use to the mariner.

The Revolutionary War of 1776 and the War of 1812 drew the attention of the British to the fact that Upper Canada had an open water border, one shore of which belonged to a potential enemy. The most efficacious and least expensive fortresses were those that floated – that is to say a fleet. Without such a force to oppose him an enemy could prepare and attack without molestation and could choose his point of invasion with impunity.

The actions during the War of 1812, the routine movements of the small British naval force and the safety of navigation generally in the post-war period emphasized the urgent need for accurate surveys of the border waters. The Treaty of Ghent (1814) included provisions for instituting a boundary commission.

By this time the dreams of a northwest passage via the lakes had been completely discredited, but water transportation was the key to opening up the interior of the American continent, as wagon haulage was difficult, slow and expensive.

The Louisiana Purchase of 1803 gave the United States control of the Mississippi River, opening the Midwest to water transport to Lake Michigan and the then small village of Chicago. Fourteen years later, New York State Governor de Witt Clinton dug the first spadeful of earth for the Erie Canal. When it was completed in 1825 it linked Albany with Buffalo via the Hudson River and the Mohawk Valley along 363 miles of waterway with 82 locks. This opened the Middle West to New York with its European shipping connections and gave that port its initial predominance over other Atlantic seaboard ports.

The lakes were open to the populated eastern seaboard, and to thousands of immigrants from Europe the riches of the Middle West offered a new life of freedom. Entrepreneurs on both sides of the border sought to exploit this traffic and cities and towns sprang up along the shores of the lakes. Charts were needed to ensure a safe navigational system of transportation once clear of the canals and rivers.

Admiral G.H. Richards, Hydrographer of the Royal Navy (1863-74) later commented that "the labours of the surveyor have always been and always must be the precursor of commerce". It was also in recent memory of the Admiralty that they had lost more ships to navigational hazards than to enemy action in the Napoleonic wars. The time for charting action had obviously arrived and the British Admiralty responded by sending Captain William Fitzwilliam Owen to Canada to take charge of the lake surveys.

BRITISH ADMIRALTY SURVEYS

OWEN

Owen was an extremely able officer in his early forties who had distinguished himself as a navigator and hydrographer in the Dutch East Indies. He was captured by the French in 1808 and detained at Mauritius (Ile de France) at the same time as the great surveyor Matthew Flinders of Australian fame. During their two years of mutual incarceration they undoubtedly discussed and refined the surveying methods of the day.

Owen had as his senior assistants Lieutenants A.T.E. Vidal and A.B. Becher and John Harris, Master, R.N. These officers had been on the lakes during the War of 1812 and were recruited to the hydrographic survey by Owen.

Originally the Admiralty intended setting up headquarters for the Great Lakes surveys at Quebec. However Kingston, nearer the scene of operations, became the base and there Mrs. Harris looked after the survey party, tending to their cooking, mending and other household chores. In 1815, Owen and his party were engaged in various surveys from the Gulf of St. Lawrence through to Georgian Bay and toward the end of the season were surveying the eastern shores of Lake Huron and Georgian Bay from the schooner *Huron*.

The proceedings of that year were not part of a connected plan and were merely intended to obtain information on points of particular interest to the naval authorities in Canada. They were considered as reconnaissance surveys only. For example, the Detroit River (Fig. 1), an area that was later to be contentious when drawing the boundary line, was surveyed [DELAFIELD, 1943].

During this first season Owen went to the naval establishment in Quebec City, to look for another assistant. There he met a young midshipman, Henry Wolsey Bayfield, who impressed him. It is recorded that Bayfield was reluctant to leave a career in General Service for the uncertainties of one as hydrographer with its low pay, hardships and isolation, not only from civilization but from the fleet and the eyes of senior officers who could accelerate the promotion of a bright young officer. Nevertheless, Owen persuaded him to take this step, which was a fortunate one for Bayfield, who ultimately became a full Admiral, and for the advancement of the science of hydrography in Canada.

Bayfield was promoted to Lieutenant shortly after accepting Owen's offer. He trained under Owen on H.M. Sloop *Star* on the surveys of Lake Ontario and the channels leading to the St. Lawrence River. Owen was extremely pleased at his progress and reported to the Secretary of the Admiralty that Bayfield's "services will ever be valuable in this branch of his profession" [McKENZIE, 1976].

The *Star* was paid off at the end of the 1816 season and Bayfield was due to return to Britain; however, Owen again interceded and persuaded him to remain on as his assistant surveyor. Advancement to charge surveyor came quickly and unexpectedly a few months later when, as a result of the Rush-Bagot agreement,

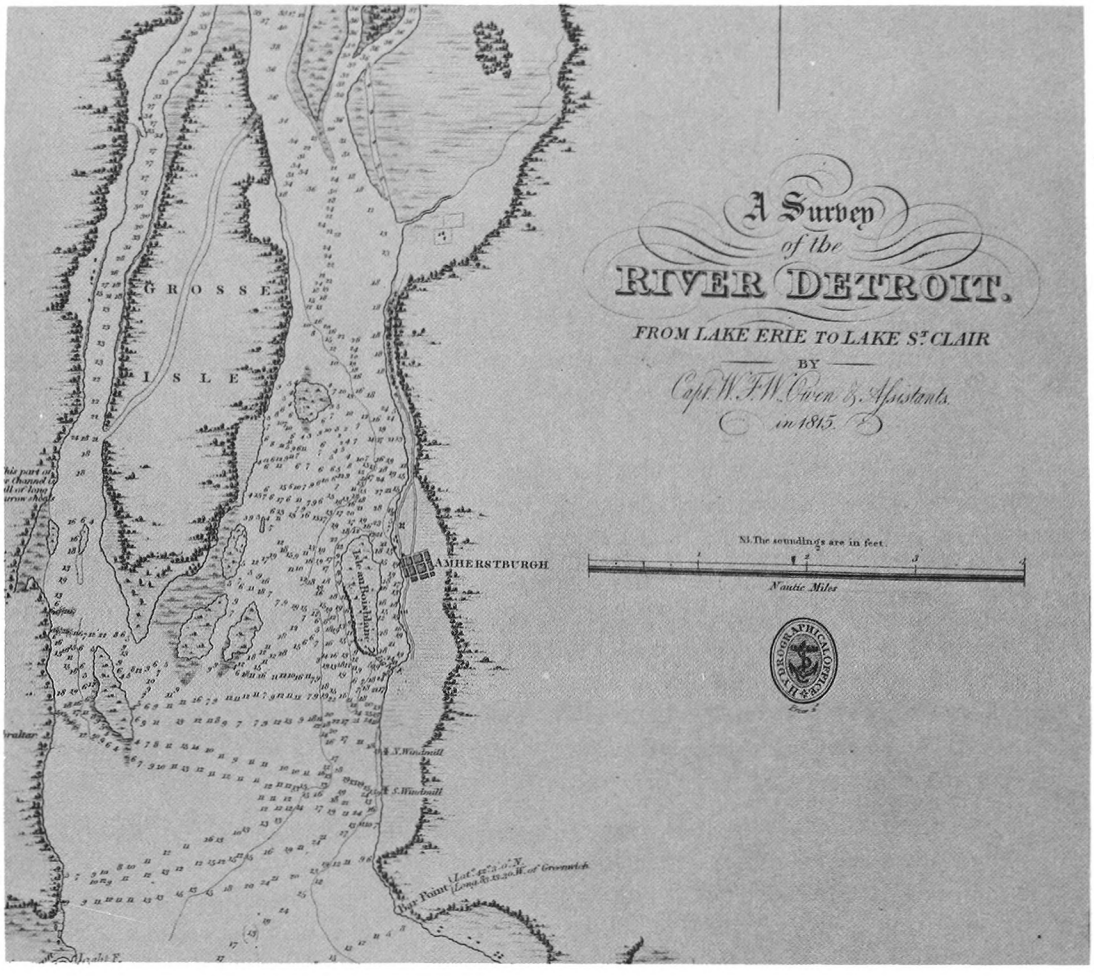

FIG. 1. – Admiralty, Chart 331. A Survey of the River Detroit from Lake Erie to Lake St. Clair. Captain W.F.W. Owen and assistants in 1815, London, 1828.

the fleets on the Lakes were scrapped, Owen's establishment was reduced and he was recalled to England (DAY, 1967). After a period at the Admiralty assisting in the formation of the Naval Surveying Service, Owen went on to make his name synonymous with hydrographic surveys of the African coast.

Vidal served under Owen in various capacities and on completion of the African surveys he was engaged in surveys of the Cape Verde Islands and the Azores.

It is indicative of the regard the Admiralty had for the work of these two officers that they both had surveying ships of the Royal Navy named after them in the post-World War II era. Other ships of that period were H.M.S. *Dalrymple*, named after the first British Hydrographer of the Navy, and H.M. ships *Cook* and *Dampier*, named after the explorer hydrographers.

BAYFIELD

The departure of Owen left Bayfield (Fig. 2) in charge of the surveys of Lake Erie and Lake Huron, but the reduced establishment left him with only one inexperienced midshipman, Philip E. Collins, and two boats, the *Troughton* and the *Ramsden,* named for the famous British instrument makers. With this small force the survey of Lake Erie was completed by 1818. The scale was approximately six miles to the inch with soundings in feet. Larger scale plans of the Grand River, River Segnan, the south of the Cayanoga River, the village of Cleveland and Presqu'Isle Harbour were included on this original chart published as Admiralty Chart 332 (*).

From about 1750, masters of H.M. ships were required by the Admiralty to keep 'Remark Books' in which they recorded details of ports they visited and of the coasts they traversed. One of the seven standard headings was a description of

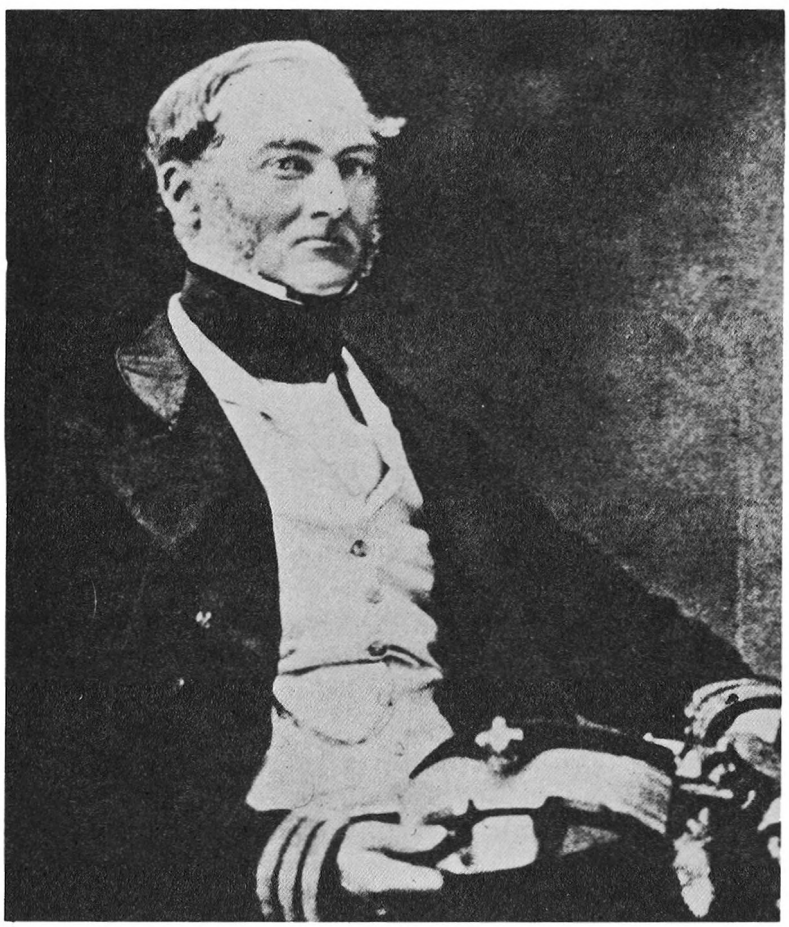

FIG. 2. – Admiral Henry W. Bayfield, R.N., Officer in Charge, Admiralty surveys of the Great Lakes, 1817-25. Credit Canadian Hydrographic Service (C.H.S.).

(*) In quotations and chart title references, spelling, aberrant capitalizations and place names of the day have been retained.

fortifications, and, in the inset of Presqu'Isle Harbour, which was a U.S. naval base, Bayfield inserted descriptions of the four blockhouses.

> No. 1 is 40 feet square at the base, of an Octagon shape; 8 guns (18 or 24 Pounders) mounted; it is strongly built of Oak. No. 2 A Block House, the strength of which could not be ascertained. No. 3 The remains of an old square bastioned Fort; this & No. 1 Block house stand 60 feet above the Lake. No. 4 A Naval Store, which, with several other buildings, stands on a ridge of low sand hills, enclosing an impassable marsh. On the small creek or run of water to the Westward of No. 1 Block house is a Grist Mill.

With Lake Erie surveyed, Bayfield and Collins moved to Penetanguishene to begin their work on Lake Huron. This proved to be a drawn out, time-consuming survey. To survey a 45-mile stretch of the north shore took ten weeks, for, as Bayfield described in his journals, "in that distance we have ascertained the Shape, size & situation of upwards of 6,000 Islands, flats, and Rocks; the main shore too is broken into deep Bays and Coves... ". Altogether, approximately 20 000 islands were surveyed in Lake Huron, ranging from the 100-mile long Manitoulin Island to small islands only large enough for one man to stand on.

There were no comfortable night quarters for the party, which had to be self-sufficient, carrying with them all their necessities for a period of up to six weeks. Bayfield noted :

> Two Boats, not larger than ships cutters, carried our whole stock of conveniences ... I had not room even for a matress, but slept, in all weathers, in the Boat, or on the shore upon a Buffaloe robe under the Boat's mainsail thrown over a few branches placed on the ground. Many a night have I slept out, in this way, when the Thermometer was down to near Zero, and sometimes even below it. Yet even this was not so wearing as trying to sleep, in vain, in the warm nights of summer ... in the smoke of a Fire to keep off the clouds of Moschettoes which literally darkened the air.

There was no medical aid and the survey crews were afflicted with fever and scurvy.

Despite these trials, Bayfield was able to report at the end of the 1822 season that he had completed the survey of Lake Huron as far as the entrance to Lake George.

The terrain and methods of transportation for the instruments brought more problems to the hydrographers, and by the end of the Huron survey Bayfield noted that "The Rocky shores of Lake Huron have so shook our Time Keepers, that in their present state they are useless" and before commencing work on Lake Superior he indented for a new or repaired time keeper, a boat sextant, a theodolite, and other small instruments.

In the spring of 1823 the party moved into Lake Superior. The Admiralty chartered a Hudson's Bay Company schooner, the *Recovery*, but Bayfield, having no experienced master for her, found that he could make better progress with the survey in his small boats and used *Recovery* only for supplying the party with stores and occasionally making runs with the chronometers. The party wintered at Fort William where they were almost completely isolated, receiving mail from England only once in six months. Bayfield and Collins circumnavigated Lake Superior during the three survey seasons of 1823-25, surveying the coastline from their boats. This was the loneliest of the lakes, known only to the Indians and fur traders, with the great harbors of Duluth and the Lakehead in Canada yet to be built.

The end of the 1825 season brought a welcome break and Bayfield and Collins returned to England to work up their field notes, sketches and plans into the charts that were to form the folios for lake navigation. This task was to employ Bayfield for yet another two years. He informed the Hydrographer of the Navy that "the Charts of the Lakes which I have just finished are as critically correct in all the details as to render any future Survey of them unnecessary for Nautical or general purposes", but also qualified his statement, "it is highly desirable that they should be filled up with Soundings, which except to a certain extent from the shore I could not obtain without a Vessel".

The Lake Huron Chart, Sheet III, depicting part of Georgian Bay (Fig. 3), is a typical example of Bayfield's work. One can see the thousands of offshore rocks and islets. Soundings are shown out to deep water. The nature of the bottom is noted. The coastline is described. An interesting feature of the Bayfield charts is the height of cliffs (*) and banks given in Roman numerals, a symbol which I have not found elsewhere on Admiralty charts.

Hydrographers also write *Sailing Directions*, or *Pilots* as they are sometimes called. These are narrative descriptions of the coastline, offlying dangers, harbor facilities, tidal streams, meteorological conditions, etc., and are complementary to a chart. Frequently the narrative descriptions they contain cannot be shown by symbols on a chart and they are separate publications. However, in Bayfield's day these books were not published and much of this information was printed as notes on the chart. Examples of this on Admiralty Chart 320 of Lake Huron are "Greenstone containing much iron which affects the needle", a warning of major importance to the mariner depending on his magnetic compass. Also "Small rivers shut or nearly so with sand, are all open in the spring". Again a matter of importance to small craft seeking shelter from spring gales but also a warning that the bars made the river mouths impassable after the spring runoffs.

The Admiralty recognized the value of the work of the lake hydrographers and the hardships they had endured in the Canadian wilderness by promoting Bayfield to Commander in 1826 and Collins to Lieutenant in 1827.

Bayfield saw the need to connect his lake surveys with a survey of the St. Lawrence River and Gulf as there was no chart of the river between Montreal and Quebec, and the only charts from Quebec east to Anticosti Island were over 60 years old and not too accurate. A safe navigational connection with Europe was essential for the expansion of Canadian trade and immigration, and accordingly he sought Admiralty permission to return to Canada to carry out these surveys. Arriving back in Canada at Quebec City on September 1, 1827, accompanied by the faithful Collins and an additional assistant, Midshipman Augustus Bowen, he commenced the task that was to be his lifework until his retirement in 1856.

(*) Since the original publication, Lieutenant Commander David, R.N., has suggested that Bayfield got the idea for this type of notation as to the height of cliffs from Beaufort, who on his Karamanian charts used Roman Numerals thus :

Cliffs 100 ft high 200 ft 300 ft 400 ft, etc.

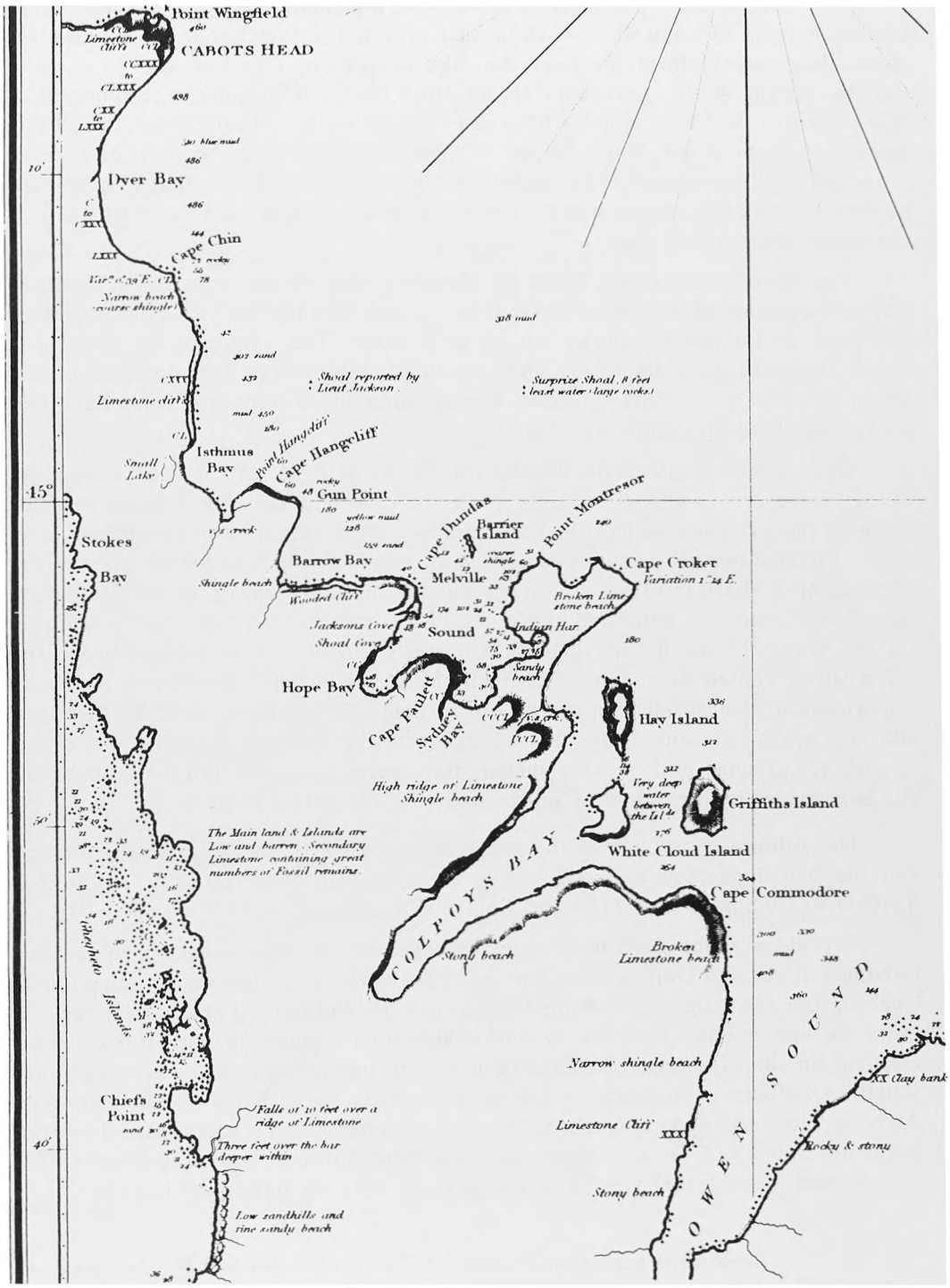

FIG. 3. – Portion, Admiralty Chart "Lake Huron, Sheet III", by Captain H.W. Bayfield, R.N., 1822. A full-scale facsimile of this chart has been published by the Association of Canadian Map Libraries. Copies may be obtained from the National Map Collection, Public Archives of Canada, 395 Wellington St., Ottawa, Ontario, K1A ON3. Price $ 3.00.

Bayfield lived many years after retirement, attaining the rank of Admiral [DAWSON, 1969]. He died in Charlottetown, Prince Edward Island, on February 10, 1885, at the fine old age of 90.

By modern standards the age of 90 may not be exceptional, but for hydrographers in the golden era of British Hydrography who served under Sir Francis Beaufort, Hydrographer of the Navy 1829-55, it was probably a record. They surveyed the world but at the price of an early death for many of them. Henry Foster drowned off Panama at 36; W.G. Skyring was murdered by natives off the west coast of Africa; Thomas Graves was assassinated in Malta; G.B. Lawrence and David Gordon died of fever; James Wood died on survey aged 47, and H.M.S. *Fairy* with William Hewett was lost at sea with all hands [FRIENDLY, 1977]. Collins died of apoplexy in 1835 while surveying the Magdalen Islands after 16 years of service as Bayfield's assistant.

Some 60 years after Bayfield's work on the lakes, Captain Boulton, of whom we shall hear more later, wrote (1908-1909):

> While making a survey of the Georgian Bay and North Channel of Lake Huron ... I had a good opportunity of witnessing the marvellous quantity and excellence of Admiral Bayfield's work. He had neither the time nor the means to find all the outlying rocks and shoals, nor was it necessary ... in that locality where his own open boats were probably the largest craft sailing thereon.

UNITED STATES LAKE SURVEY

ORGANIZATION

Excellent though they were in their day, Bayfield's charts of the Lakes had little real value to the mariner some 15 years later when larger ships in greater numbers were plying their waters. By this time the country bordering the lower lakes was well settled and works for improving or forming harbors on Lake Huron were under construction. Chicago was the only port of any significance on Lake Michigan. The settlers were pouring in, in increasing numbers, and with them came an expanding volume of trade, especially from Buffalo to Detroit to Chicago. Passage to Lake Superior was still by portage around Sault Ste. Marie and the shipping industry experienced high losses in life and property each year on these waters.

Storms on the lakes equal in violence those of the oceans but, unlike the open sea, there is little searoom for riding out a gale. Ships are never more than a few hours' run from the shore and a long continued blow can cast a ship ashore unless she can find a port or safe haven. For example, a vessel leaving Chicago had no shelter until she reached Manitou Island on northern Lake Michigan and once through the Straits of Mackinac, except in the vicinity of Presque Isle, had no refuge until reaching the head of the St. Clair River. Even there the channels were narrow and winding, and in seasons of low lake levels vessels frequently had to use lighters to discharge their cargoes [COMSTOCK, 1882]. The U.S. authorities recogniz-

ed these problems and on March 3, 1841, Congress appropriated $ 15 000 for a "Hydrographical Survey of the Northern and Northwestern Lakes". The dual objectives of the survey were to provide nautical charts and to determine what new engineering works were required. The task was assigned to the Corps of Topographical Engineers which in turn organized the U.S. Lake Survey for the purpose of making the survey. The officers were members of the Corps of Topographical Engineers until this corps was consolidated with the Corps of Engineers in March 1863, and the Lake Survey became a part of that organization. Initially the survey was based in Buffalo but during the 1845 field season the establishment moved to Detroit. This was to be its base until it ceased as an entity and came under the National Ocean Survey in Washington, D.C., in 1970 during a reorganization of government departments.

The assignment was onerous, as the U.S. shoreline from Saint Regis, New York, to Duluth, Minnesota, is about 5 500 miles and the water area of the U.S. portion of the lakes is about 61 000 square miles. Colonel J.J. Abert, Chief of Topographical Engineers, directed Captain W.G. Williams to take charge of the survey of the northern and northwestern lakes. At that time Williams was general superintendent of harbor improvements on Lake Erie, based at Buffalo and naturally established the Lake Survey office there. Williams was instructed to commence his surveys at the entrance to Green Bay and also to make surveys of other areas of difficult navigation in the vicinity of the Straits of Mackinac. This starting point was chosen not only because of the importance to navigation of the area but also as a favorable point from which to extend survey control out to the Beaver and Manitou Islands and thence to the east shore of Lake Michigan. The work for the first three years was mainly establishing and measuring bases, clearing lines of sight and observing triangulation.

The first survey vessel used was the *Ark* and, according to W.C. Hearding, who described her to the Houghton Historical Society in 1867, was "a sort of barge which could operate in the shallow water such as in Sandusky Bay marshes".

MEN AND METHODS

A shore based survey party would consist of a chief of party, three or four assistants, and the requisite number of chainmen, leadsmen, and boatmen to furnish the necessary assistance to the surveyors and crews of the six-oared cutters used for sounding. They had complete camp equipment and established their tents on shore. After surveying six or seven miles on either side of the camp they moved location further along the shore. Second- or third-order trigonometric control was developed from surveyed bases over their field of work. Frequent observations for azimuth and variation of the compass were made, usually on Polaris. The shoreline and the important features of topography were determined by theodolite and chain. Where the shores were densely wooded or marshy, the topography back from the shore was, as a rule, simply sketched, detailed surveys only being made when there were settlements or towns.

The inshore hydrography usually covered out as far as the three- or four-fathom contour, but included the development of shoals and dangers within

several miles offshore. Soundings were taken at regular intervals of time, the surveyor fixing the position of the boat, the leadsmen heaving their sounding leads as they were rowed backward and forward, inshore and out again, at courses right angled to the shore, thus cutting the depth contours at an angle giving maximum definition for subsequent delineation of the contour lines. As these were spot soundings the skill of the hydrographer lay in interpreting these contours, appreciating where extra lines of sounding would give better definition of shoal areas.

The working conditions were hard to imagine : long hours of pulling at an oar or heaving a lead; the numbing cold in the early spring and late fall; the chilling spray from the splash of the lead – a curse at most times but bringing a momentary cooling in the heat of summer, and the blackflies and mosquitoes that followed the boat every time she reached the shore ends of the sounding lines, adding to the surveyors' discomfort. Hearding described a typical day in his journal as having sounded 29 lines and made 510 heaves of the lead, plus sketching in a stretch of a river shoreline. And at the end of the day a meal, the amount and quality depending on the length of time away from the supply base or the skill of a marksman on the survey party. The length of the season was governed by the weather but usually lasted from May to October, the other seven months being spent in the office working up the past season's surveys.

Captain Williams soon appreciated the requirement for a major vessel and submitted an estimate for an iron-hulled steamer in 1842. She was built at Buffalo and launched as the *Abert,* after Colonel Abert, on December 21, 1843, making her first sea trials the following month. She later became the *Surveyor.*

Abert commenced her U.S. Lake Surveys career surveying harbors on Lake Erie and by 1845 Colonel Abert was able to state in his Annual Report that all the lake harbors, except those upon Lake Superior, had been surveyed, and that he was prepared, if authorized by Congress, to compile and publish a portfolio of them.

Captain Williams left the survey in the fall of 1845 and served in Mexico, where he was killed the following year at the Battle of Monterrey.

Lieutenant Colonel James Kearney assumed charge of the survey in the fall of 1845 and remained in command until 1851. These were lean years for the survey as there was no financial allotment in 1847 and in 1849 only $ 10 000 was allotted of the standard $ 25 000 which was established in 1846, and which remained at that level until 1852 with the exceptions mentioned. These were lean years also in staff and equipment as there was a lack of officers because they were required for military duties in Mexico, and Kearney reported in 1849 that he was nearly destitute of any topographical or hydrographical instruments that were fit to be taken into the field. Despite these obstacles the compilation of a chart of the whole of Lake Erie on a scale of 1:400 000 was completed in 1849 and forwarded to Washington, although its systematic distribution to mariners was not begun until 1852.

The opening of the Soo Locks in 1855 naturally had a bearing on the work of the Lake Survey. As early as 1853 the appropriations contained clauses requiring surveys of navigational hazards in the St. Marys River. In the season of 1854 surveys were completed from Lake Huron to the Soo. The following year, just

before the opening of the canal for navigation, the work was completed from the Soo to Point Iroquois, at the east end of Lake Superior.

An event had taken place on May 24, 1844, news of which undoubtedly took some time to reach the surveyors in the field, but one which was to allow them new levels of precision in their determination of position. That day Samuel Morse transmitted his first message over a telegraph from Washington, D.C., to Baltimore [KEMP, 1976]. Some 16 years later the lake surveyors had use of the Montreal Telegraph Company's wires for signals between Detroit and Goderich for no charge and the Mayor of Goderich arranged for a site for an observatory in his town. This eliminated the need for chronometers which had always been troublesome instruments to carry around the lakes. In 1859 Meade had complained that the commercial passenger steamers onboard which he was obliged to transport his chronometers had too powerful engines, put into slightly built hulls carrying too high a pressure in their boilers, which caused undue vibration and tremor and affected their chronometers as they carried them from various ports for astronomical observations.

Captain J.N. Macomb, who had been an assistant to Captain Williams in the initial surveys of the lakes, relieved Kearney in April 1851 and under his guidance the Lake Survey proper can be said to have begun. Larger appropriations became available. During Macomb's tenure they jumped from $ 25 000 in 1851 to $ 50 000 in 1856. With the additional funds he was able to obtain better instruments, to employ a larger staff and to prosecute the work more systematically. In 1851 a lieutenant in charge of a party is recorded as receiving $ 1.00 a day whereas the carpenter was paid $ 1.50, a wheelsman or a leadsman 80 cents, the cook 83 cents, and seamen and coalheavers 60 cents [*National Ocean Survey*].

Captain Macomb would personally take charge of the major party onboard *Surveyor* and, in addition to the triangulation and offshore work, would make frequent inspections of the shore parties, bring in their supplies and occasionally move them from camp to camp.

> The methods used in offshore surveys at that time were described.
>
> The general method of running the lines of off-shore soundings was to anchor a buoy at each extremity of the line in water sufficiently deep for the steamer to pass round it, and to take the soundings at regular intervals of time as the steamer passed over the line between the buoys, running at a speed of about 4 miles an hour. The position of the steamer at the time of taking a sounding was also frequently determined by reading sextant angles between stations or other objects on shore. The positions of shoals and reefs were indicated by placing upon them tripod stations, which were located by intersections from the stations on shore. These tripods were made of such a height as to stand two-thirds out of water when placed in position, and were secured by piling stones on a platform built between the legs of the tripod above the water. They not only answered the purpose for which they were mainly intended, but also served in the absence of buoys, which of late years have been placed in such positions by the Light-house Establishment as beacons to warn navigators of the positions of dangerous places, and were much appreciated by the masters of vessels. On several occasions, before proceeding to his field of operations in the Straits of Mackinac, Captain Macomb went to the west end of Lake Erie to place these tripods on shoals already known, and to locate and mark others which had been discovered since the original surveys.

Another method used was to run the ship offshore on a compass course at right angles to the shoreline and to position the ship by simultaneous theodolite

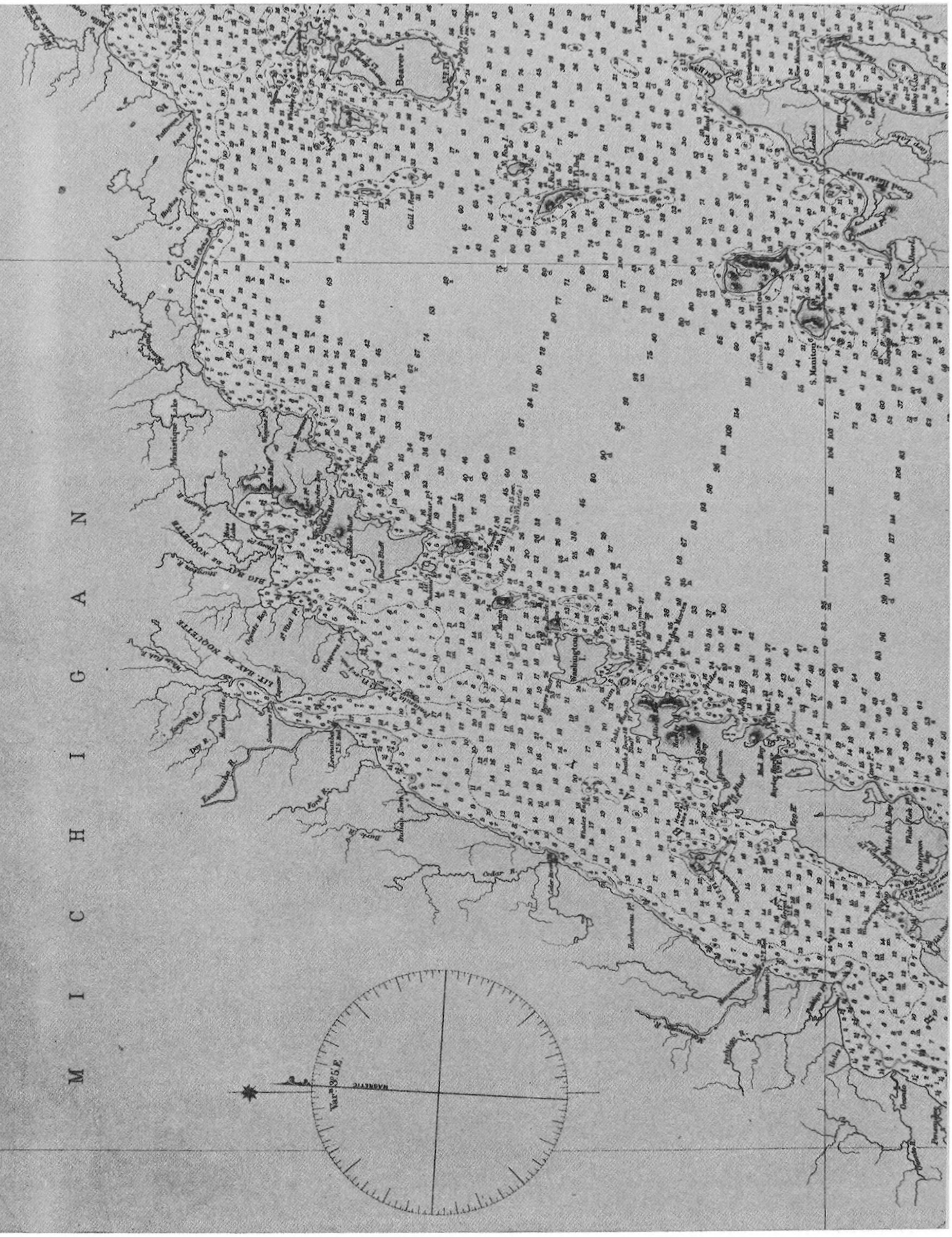

FIG. 4. – Admiralty Chart 301. North American Lakes, Lake Michigan, from the United States Government Surveys to 1876 with corrections and additions to 1890. London, 1864.

readings to her from known stations ashore. Offshore lines were run about one mile apart and extended about eight to ten miles offshore and right across the lake at intervals of ten to fifteen miles to determine the general character of the lake bottom (Fig. 4).

In 1854 Macomb submitted an estimate of $ 50 000 for an additional major vessel and two years later an iron-hulled side-wheel steamer joined the survey. When built, she was named *Jefferson Davis* after the then Secretary of War but her name was changed to *Search* on her arrival in Detroit. This name, according to records was "a name appropriate to one of her most important uses, that of seeking out and exposing hidden dangers".

Captain Meade (Fig. 5) assumed charge of the surveys in 1857 and the principal work completed during his tenure of office was the survey of Lake Huron, nearly all of his resources being employed there during the seasons of 1857-59. By 1861 there was published a general chart of Lake Huron at 1:400 000, charts of Saginaw Bay and the south end, Lake Huron at 1:120 000 and two 1:40 000 charts of Thunder Bay and Presque Isle and Middle Island to add to the Lake Huron chart folio which until then had consisted of only two large-scale harbor and river charts.

The schooner *Coquette* was hired for $ 200 a month in 1859 and she remained in service until she was wrecked in 1864. She was the only schooner ever used for

FIG. 5. – Major General George H. Meade, U.S. Army, Officer in Charge of the Survey of Northern and Northwestern Lakes, 1857-61. Credit U.S. Military Academy.

U.S. Lake Survey work. Frequently she was towed over larger distances by one of the steamers and when the wind was favorable she would make sail, under tow. Meade also had the *Search* modified from side wheel to the more efficient screw type propeller.

The annual budget took a big jump in 1858 when it was increased to $ 75 000 from the $ 50 000 of Macomb's years. In 1862, it topped $ 100 000 and reached a high of $ 125 000 in 1865. However, the 1862 appropriation was not made available until too late in the season for productive work in Lake Superior.

In 1860 the survey of the northeast end of Lake Michigan was extended southward to include Fox Island and Manitou Island and Grand and Little Traverse Bays, thus providing data for a chart of the dangerous part of the lake for vessels making passage between the Straits of Mackinac and Chicago. A general reconnaissance survey of Lake Superior was made in 1859 by Captain Meade on the *Search* and the general survey was commenced in the spring of 1861, the parties starting at the west end of the lake. However, just prior to the start of the field season the Civil War broke out and all the officers other than a superintendent were withdrawn, leaving only civilians to carry on the work of the survey.

Colonel J.D. Graham succeeded Meade at the end of the 1861 season and introduced one major innovation which was brought into general practice where telegraph facilities were not available : the use of small gunpowder flashes while observing at night. The difference in longitude was determined by means of a series of powder flashes made about one minute apart. The times of the flashes were prearranged according to a program. The instant of each flash was recorded at all observing stations by chronometers whose rate was determined nightly by star observations. The difference of local time of each flash as recorded was the difference in longitude between the stations.

Lieutenant Colonel W.F. Raynolds had charge of the survey from 1864-70 and the survey of Lake Superior was the main work during his term of office. The seasons there were shorter due to the weather, and before and after the Superior season the parties were employed on the other lakes making special surveys of harbors and localities where improvements were being made.

Raynolds obtained an addition to his fleet in 1865 when the screw propeller steamer *Ada* was purchased from the U.S. Navy. She had been built on the Clyde in Scotland as a blockade runner during the Civil War and was captured by the Navy. After extensive alterations she was ready for the 1866 season.

FIELD SURVEYING CONDITIONS

As Bayfield had found before him, Superior was a lonely lake and the coastline difficult for surveying. In his 1866 report Raynolds records :

> It is the exception to find anything but a dense forest ... Parties within easy hearing distance cannot see each other. And last, though but by no means least, during the summer season, which is the only one in which work can be done at all, the forests are so full of venomous insects that it is next to impossible for an instrument to be used.

Despite these harsh conditions the surveyors made the most of their odd days of rest as an entry from the steamer *Surveyor*'s log for July 4, 1867, shows.

> The event of the day was a boat race between the *Surveyor*'s first cutter and a boat from each party. The distance run was about 4 miles and 800 feet, from a line across the harbour at Greene's camp around a buoy and back again. The boats and their oarsmen were started at 11 and a half a.m. The *Surveyor*'s first cutter, as was to be expected, turned the buoy and reached home followed by Lieutenant Greene's and Lampson's boat at quarter mile intervals respectively. The first prize of $ 25 was therefore awarded to the *Surveyor* boat, the second of $ 10 to Greene's, whilst Lampson's crew had the satisfaction of going home beaten. The latter boat was badly steered which perhaps prevented a closer contest between the two boats. After the race we toasted "The day we celebrate" and so ended *our* celebration of the 4th of July.

Fevers and other sicknesses were endemic. An entry for August 1867 in the *Surveyor*'s log shows that George the cook was fired for being drunk, this happening when several officers had been invited onboard *Surveyor* for breakfast. A cook was borrowed from the *Search* and his first query was whether he would receive George's pay if he did the work. He followed this with a statement that he couldn't make tomato soup. Obviously they were lucky to have tomatoes, as in the following season a log extract notes : "In the afternoon 17 chipmunks were trapped. Porcupine boullion for dinner, no pepper, thus enhancing full porcupine flavor. We found a few potatoes which were duly incorporated in the Boullion. Second course was bread hardtack, for tea fricassied chipmunk with the usual etceteras". However the following day "A supply of fresh trout put an end to fancy cookery".

The weather too played its part in frustrating the hydrographers. In 1871 the forest fires on the west shore of Lake Michigan were so extensive that base camps had to be removed because the fires were getting uncomfortably close. The village of Peshtigo, Wisconsin, was destroyed by fire with considerable loss of life and the great Chicago fire occurred at the same time. Two years later the problem was too much moisture, and, of the 105 days one party was in the field, 62 days had rain or fog to impede the progress of the survey. At no time during the season were there two consecutive days without stormy weather.

METHODS

In present day surveys, communication between ship and shore using radiotelephone is taken for granted, however, in 19th-century hydrography on the lakes, a system of signaling using balloons was employed when doing offshore surveys. As previously described, the position of the ship was fixed by theodolite angles taken on shore. These readings were taken simultaneously with a sounding and the operations synchronized by a balloon. This method was first mentioned in 1867 and is described.

> The steamer, at starting, whistles, drops the balloon, and a sounding is taken at the same time, and in running out and in the balloon is dropped and a sounding is taken every ten minutes. At the instant the balloon drops, the observers on shore take readings to the steamer and note the time. On the steamer the time of dropping the balloon is noted, and a sextant-angle is read, if possible, between two points located on

shore by the triangulation. The watches used by the observers on shore are compared with the watch used on the steamer, before and after the day's work. In water less than 20 fathoms deep, soundings are taken every five minutes. The lead-line is compared with the standard measure every day when in use. The notes are plotted every evening, to make sure that the soundings are properly distributed. Lines of soundings are also run entirely across the lakes, 15 miles apart.

REDUCTION OF ACTIVITIES

By 1882 the field work was completed insofar as any hydrographic survey is ever completed, and the agency was disbanded with the small exception of a chart reproduction section. However, hydrographic charting standards never remain static for long and continuing reproduction of the same charts does not adequately provide the tools for safe navigation in areas of increasing traffic. These early surveys considered 18 feet as being the danger line since the deepest draft ships on the lakes at that time were only drawing up to about 12 feet. But new ships were built with deeper drafts and so previously safe areas became marginal and required more rigorous examination for the new generation of shipping. There are improvements in navigational precision and it is of little use for the navigator of a ship to know precisely where he is unless the dangers he wishes to avoid are marked with equal precision on the chart.

To illustrate how quickly the charts became outdated, the 1891 report of the U.S. Lake Survey stated :

> Many of the charts now issued are based upon surveys made 30 and 35 years ago ... Many new towns of considerable importance are not shown on the charts ... The Commerce of the Latter (Lake Superior) has increased from the small volume of 1855 to over 9 million tons in 1890... Moreover with the improvement of channels the draft of vessels has increased, first from 9 1/2 feet to 12 feet and then from 12 to 16 feet. Improvements now in progress will before many years secure a draft of 20 feet and every season the larger vessels are discovering dangers previously unknown.

By 1899 the picture was even blacker and in a plea for greater funding the comment was made :

> It has not been possible with the limited appropriations made during the last ten years to keep our lakes surveys up to the same standard of excellence that they possessed fifteen years ago. They do not correctly show the conditions now existing and are by no means so satisfactory to the navigator as they were fifteen years ago.

Between the years 1841 and 1904 the lake survey appropriations for all purposes were $ 3.8 million, but it was found then, as it is being found now, that without continuing sustaining funds and manpower the product of a charting agency and the high standards of its publications are soon eroded by the passing of time and the ever increasing demands of the shipping industry.

There were 76 charts in the original U.S. lake series, all of which were printed from copperplates. The general charts of the lakes were produced at a scale of 1:400 000 with a coastal series of 1:80 000 and harbor charts in varying scales. The annual issue of charts in 1857 was 1675 and had risen to 13 439 in 1903 by which time there were 99 charts, 59 of which were in color.

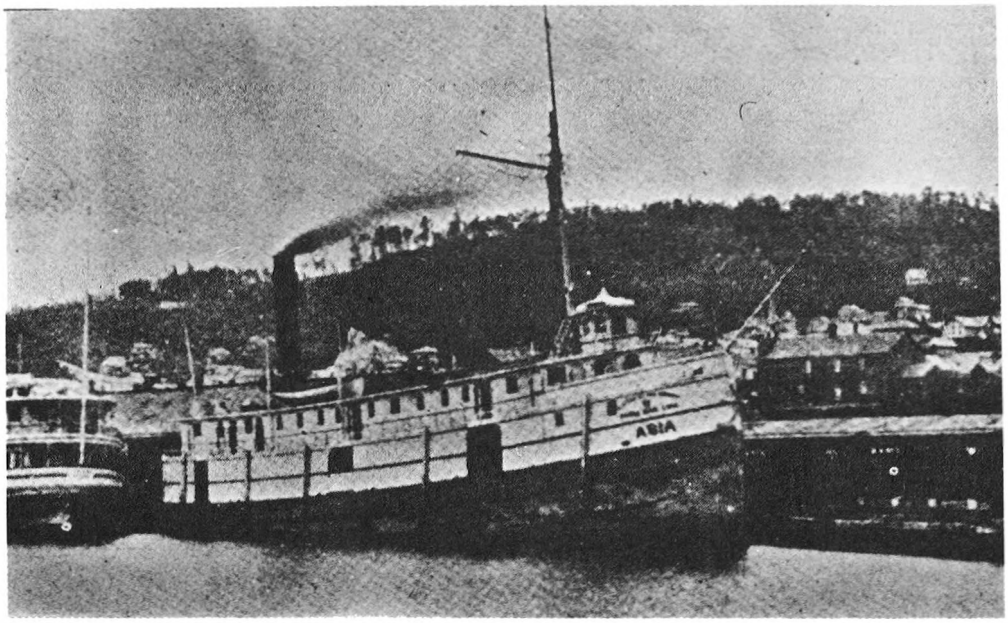

FIG. 6. – S.S. *Asia*. National Archives, Ottawa.

Up to February 20, 1890, one full set of charts was issued free to each U.S. registered vessel but a decision handed down by the Judge Advocate General amended the interpretation and thereafter charts were sold at a rate of from five to thirty cents, the price being set to cover the costs of paper and printing.

THE TRANSITION : BRITISH TO CANADIAN SURVEYS

Shipping losses were still high on the lakes when the Lake Survey completed its first series of surveys and it was this factor, focused on one particular loss, that stirred the Canadian government, which had been virtually inactive in hydrographic surveys on the lakes since Bayfield, to enter the lakes again. The *Asia*, a steamer of 347 tons, was a passenger and cargo carrier on Lake Huron (Fig. 6). She was not designed for the lake trade, being of a class known as 'Old Canal Propellers', and was employed on a triweekly service from Collingwood, where a connection was made with an express train from Toronto, to Meaford, Owen Sound, and Sault Ste. Marie. On September 14, 1882, she was lost during a storm of hurricane proportions. The exact loss of life was never known but it was certainly over 120, and there were only two survivors. There was considerable speculation about the cause. The owners, fearful of legal action if it were proven that the ship was unseaworthy, in a letter to the *Toronto Globe* brought forth a theory of the ship hitting an uncharted shoal. The official inquiry came to a different conclusion. Captain P.A. Scott, R.N., who conducted the investigation, stated in his summary that the vessel was not in good ballast trim ... that she was

of a class of vessels not intended to run on the Great Lakes and that she had not sufficient cargo in her hold to enable a vessel of her description, with lofty upperworks, to stand up against a gale [*Canada*, 1883].

Although it was proven at the inquiry that the presence of shoals, actual or suspected, in the area had nothing to do with the disaster, public opinion was such that Ottawa was stirred to action, and the prime requirement was a full-scale charting program.

Being unable to find a qualified hydrographer in Canada, the government, through official channels, approached Admiral Sir Frederick Evans, Hydrographer of the British Navy 1874-84, who instructed the officer in charge of the Newfoundland survey to proceed to Ottawa, there to confer with the Canadian ministers. This trip was the first expense incurred against a sum of $ 5 000 voted by Parliament for surveys of Lakes Superior and Huron. The amount of $ 77.81 was well spent as Staff Commander W.F. Maxwell, the officer concerned, succeeded in having Staff Commander John G. Boulton, R.N., appointed, on loan, to take charge of the surveys, known at that time as the Georgian Bay Survey.

BOULTON SETS UP THE SURVEY ORGANIZATION

Boulton was a highly experienced hydrographer, having seen service "additional for surveying duties" in Australia, South Africa and under Maxwell for nine years in Newfoundland and Labrador (Fig. 7). On July 11, 1883, he was seconded to the Dominion government to take charge of the Georgian Bay Survey with full pay and allowances as in the Royal Navy.

FIG. 7. – Staff Commander J.G. Boulton, R.N., Staff Officer in Charge, Georgian Bay Survey, 1883-93. Credit C.H.S.

It was further understood that the Canadian government would supply all vessels, equipment and support and assumed that suitable Canadians would be trained as hydrographers and thus eventually effect the complete domestic takeover of hydrographic responsibility in Canadian waters.

Initially Boulton was instructed to adopt Bayfield's coastline and to confine his activities to surveying the main steamer routes between Owen Sound through Georgian Bay to Sault Ste. Marie. However, as we have already noted, hydrographic surveys age as greater precision is required in charts, and, after due examination of the surveys on hand, Boulton strongly recommended complete new surveys. It is to the credit of the government ministers of the day, faced with large demands for transportation facilities in a young, growing country and having only a small budget, that, albeit reluctantly, they acceded to Boulton's recommendations.

By mid-August Boulton had reached Collingwood and immediately set about interviewing pilots, sailing masters and shipping authorities. He listened to their reports of uncharted rocks and shoals, he thoroughly familiarized himself with their routes between ports, heard their evaluations of weather conditions and, after taking all these factors into consideration, he decided to commence his survey at the entrance to Georgian Bay from Lake Huron and the North Channel. Not only was this a good starting point from a navigational point of view, being the entrance to the hazardous Georgian Bay, but also from a surveying aspect he had a good geodetic base from the U.S. surveys in the vicinity of Cove Island Lighthouse and so was saved the time-consuming task of bringing his own triangulation network many miles along the coast.

Because no government ship was available, Boulton chartered the fishing tug *Ann Long* for a period of 45 days at $ 30 a day and, on his shoestring budget, went to work. He later wrote of the *Ann Long* that with sacrifice to his comfort he was able to do as much work as with a larger and more expensive vessel.

At the end of the 1883 season he set up office on Parliament Hill, Ottawa, and got down to preparing his field sheets and layouts for future surveys, specifications for a ship and choosing an assistant. His choice was William J. Stewart, Gold Medalist of 1883 from the Royal Military College in Kingston, whom he hired at an annual salary of $ 550.

In early spring of 1884 the government purchased the former American tug *Edsall* (*) for $ 15 000 and after a $ 4 000 refit and modification she went into service as the *Bayfield*, a fitting reminder of the sterling work of Admiral Bayfield some 60 years earlier.

As sailing master and pilot, Boulton hired a Captain McGregor, who had been one of the first to pick up wreckage of the ill-fated *Asia* and who had lost a son in the sinking. Such a coastwise pilot was a valuable asset to the party.

Boulton soon found that progress was to be slow in his surveys and at the end of his first season noted that the peculiarly irregular character of the bottom necessitated very close sounding, and his statistics recorded 4 120 linear miles of soundings to cover 790 square miles. The *Bayfield* wintered at Owen Sound and for

(*) Built in 1864 in Buffalo, N.Y. 94 tons register, 110 ft. in length; 18.5 ft. beam; 9.3 ft. draft. Speed 8 knots; complement 22. Registry No. 61153.

FIG. 8. – First *Bayfield* sounding crew – 1884. Credit C.H.S.

many years this was traditionally home port when surveys were completed for the year and the lakes became ice fast.

Either his estimating was extremely good or else he spent to the hilt, but in his first year, out of a vote of $ 25 000, including purchase and refit of the *Bayfield,* he was only underspent by $ 254.46. Very few project managers today come within one percent of estimate.

The first gleanings from Boulton's surveys were published before the opening of the 1885 navigation season on the lakes, when he produced the first chapter of the *Georgian Bay and North Channel Pilot.* That year he also took another step toward the transition to a Canadian hydrographic service with Canadian hydrographers when he added a second graduate of the Royal Military College at Kingston onto his staff. This gave him greater flexibility in his field surveys as he was able to detach Stewart and a shore party from his ship operation. Eventually a third assistant was added and this complement of three hydrographers was to be the regular field staff through to 1904. He was also a pragmatist and knew that it would be some time before there would be sufficient well trained domestic hydrographers available and therefore based his survey program on the immediate and pressing needs of the day. Writing to Rear Admiral Wharton, Hydrographer of the Navy 1884-1904, (*Great Britain,* 1886) he noted "I do not feel justified putting the country to the expense of going beyond the *present trade routes,* especially if some of the parts omitted are so studded with rocks that they would take an interminable time to do properly, and when surveyed could scarcely be navigated by the best chart without local knowledge".

In a report to Ottawa, he further noted, "Should minerals be discovered, or any industries spring up, it will be an easy matter to extend the survey over the particular locality" [MEEHAN, 1967].

With this in mind he permanently marked his main triangulation stations for future surveyors to pick up when the necessity arose. This philosophy of initial route surveys which could eventually be built upon to reach new ports is to a certain degree one that has been employed in modern days in the Arctic by the Canadian Hydrographic Service.

A further chapter of the *Georgian Bay and North Channel Pilot* was on the bridges of ships by the beginning of the 1886 season and, even more significant to the safety of ships, they had the first new coast chart, covering Lake Huron from Cabot Head to Cape Smith and Entrance to Georgian Bay, published as Admiralty Chart number 906 and showing soundings in fathoms with a scale of approximately one and one-quarter miles to the inch. The Admiralty selling price was two shillings but by the time it was imported and distributed, the duty of 20 percent and the agent's markup brought the price to $ 1.25 which, considering the free issue of U.S. charts, caused considerable annoyance to Canadian shipping companies.

METHODS

Boulton (1890) described his methods of carrying out a hydrographic survey in the *Proceedings of the 7th Annual Meeting of the Association of Dominion Land Surveyors*.

> Having measured our small base, we proceed to throw as good a triangulation over our projected season's work as the natural features of the coast will permit.
>
> While the triangulation is being carried on, principally by the chief, his assistants are sketching in the coastline in the boats.
>
> This consists in pulling from point to point with a patent log towing astern, the index on the rail of the boat, and offsetting by estimation the indentations when they do not exceed a distance of 100 yards. Over that amount a patent log distance is run from the original line.
>
> Beacons made from the driftwood on the beach are erected about every half mile, and fixed by the main triangulation stations.
>
> These small stations also serve to fix the boat's soundings, and the inshore ends of the ship's lines, as well as the outlying dangers.
>
> The boat soundings are run out to a depth of seven fathoms, or, if the shore is very steep, to a distance of 400 yards.
>
> The officer takes away in his boat a small sheet of the points on the portion of the shore he is to sound.
>
> He also takes a sextant, station pointer, protracter, tracing paper and pencils, not forgetting his pipe and baccy, if a smoker.
>
> Two, or perhaps three, boats sounding together also adds cheerfulness to what sometimes would be a desolate scene, encourages a spirit of emulation among the crews, and in case of accident to one boat there is assistance at hand.

He also commented on the excellent hydrographic work done by the United States surveyors but in this context he noted :

> The boat sounding of a piece of coast by the American Surveyors would entail the services of three officers, perhaps four, two in the boat and two with theodolites at the shore beacons to fix the boat by intersecting lines at preconcerted signals. With us the one officer steers his boat, fixes his position, records his soundings, unassisted.

In April 1893 Boulton relinquished his command to Stewart who had been his assistant since 1884.

STEWART

Hansard of April 1, 1893, records the appreciation of the House of Commons for the work of Boulton, but there were some dissenting voices over the appointment of Stewart who was a surveyor but not a navigator. Although the U.S. Lake Surveys had been carried out by army engineers who were surveyors first and seamen by later experience, the appointment of a surveyor to head the Canadian surveys was a break with the British tradition of a seaman/surveyor and had been the subject of some correspondence between Canada and the British Hydrographer [*Canada*, 1893].

Stewart (Fig. 9) probably recognized the validity of the argument that the masters of a ship placed greater faith in a chart surveyed by a fellow navigator but silenced the argument by obtaining his Master's Certificate, Inland Waters, in 1897, though he never commanded his own survey ship.

The Georgian Bay survey was completed under Stewart in 1894, with the exception of an area in the middle where no shoals had ever been reported, and Stewart recommended that "it be left till more important work is done in other lakes". In fact this area waited some 70 years until electronic positioning equipment became available.

During Boulton's eleven years of surveying in Canada, the Admiralty published thirteen general, coast and harbor charts for the Great Lakes, eight of Georgian Bay and five for the North Channel. More significant was the technical experience that Boulton passed on to the young Canadian recruits that were to take charge on his departure. These men were the nucleus of the present-day Canadian Hydrographic Service. In the years to follow they in turn passed on their expertise to the new recruits in the time-honored tradition of hydrographers learning their profession from men who had acquired their knowledge in the hard school of practical experience.

Though some work was commenced in Lake Huron in 1894 it was discontinued in favor of surveys of Lake Erie because the volume of shipping in that lake was considerable and the completion of that survey was necessary for a correct definition of the International Boundary Line. This year the name of the organization was changed to the Great Lakes Survey.

Stewart found that Lake Erie was unlike Georgian Bay in that there were no islands and only small indentations in the coastline. He therefore had to adopt new procedures to cope with the many dangerous reefs offshore, some as far as four miles from shore. However, with his practical training and background and the experience of the Americans on their similar coastline to draw on, he soon adapted and the Lake Erie survey was completed in 1897. The total cost of the survey of the Canadian shore of Lake Erie was just under $ 39 000. The last section of this survey was Port Colborne to Long Point, and two copies of this fair sheet were drawn, one going to the Admiralty in London for engraving and the other to Washington. This was one of the earliest records of the type of cooperation that has become standard practice today, although the Admiralty, as early as 1879 had instituted an exchange of new charts, on publication, with the U.S. authorities. Data from the U.S. surveys were incorporated in revisions and new editions of Admiralty charts.

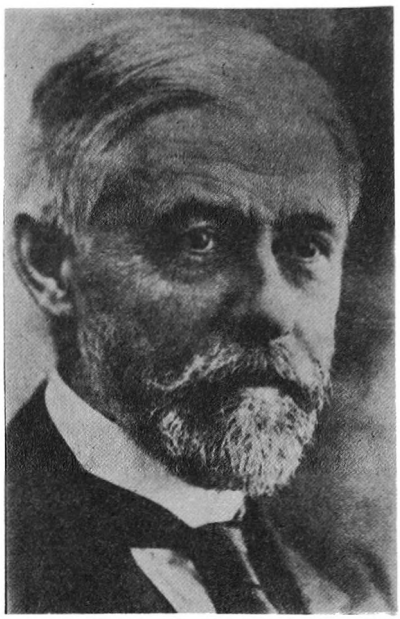

FIG. 9. – Mr. W.J. Stewart, Officer in Charge, Georgian Bay Survey 1893-1903. Great Lakes Surveys Chief Hydrographer, 1904-25. Credit C.H.S.

The survey of Lake Huron recommenced in August 1897 and that year the field season lasted until October 25, making it the longest field operation of the Service to date. The following winter, 1898-99 saw the first field sheet of Lake Huron, covering from Drummond Island (Michigan) to the Duck Islands, including False Detour Channel and Mississagi Strait, being forwarded to the British Admiralty for engraving and publication. In 1889 Stewart extended Boulton's 1884 surveys of Cape Hurd to Stokes Bay carrying the offshore sounding to depths of 40 to 60 fathoms. Because of the great pressure of work at the hydrographic office in London, the Lake Huron charts were not published until April 1901 when Admiralty Charts 1701, Cove Island to Great Duck Island, and 3014, Great Duck Island to Detour Passage, went on sale. These were at a scale of approximately one and one quarter nautical miles to the inch and in conjunction with the Georgian Bay charts gave coverage for mariners for the two direct routes from Owen Sound to the industrial shipping center of Sault Ste. Marie. The survey of Lake Huron was completed in 1901 when Stewart turned his attention to Lake Superior.

As early as 1899, Stewart, in anticipation of the survey of Lake Superior,had been recommending a replacement for the *Bayfield*. She had been built in 1863 and by 1893 was condemned but was still pressed into service for summer weather only. She could only make seven knots and the distance between harbors and the exposed shores and heavier seas encountered in the larger lake area made her a doubtful asset for the surveys planned.

It was not until the end of 1901 that a replacement, the *Lord Stanley* (*) (Fig. 10), was purchased for $ 50 000. However, she sustained heavy damage while

(*) Built in 1889 on the River Clyde, Scotland. 114 tons register; 140 ft. in length; 24.1 ft. beam; 10.5 ft. draft. Speed 10 knots; complement 20. Registry No. 96049.

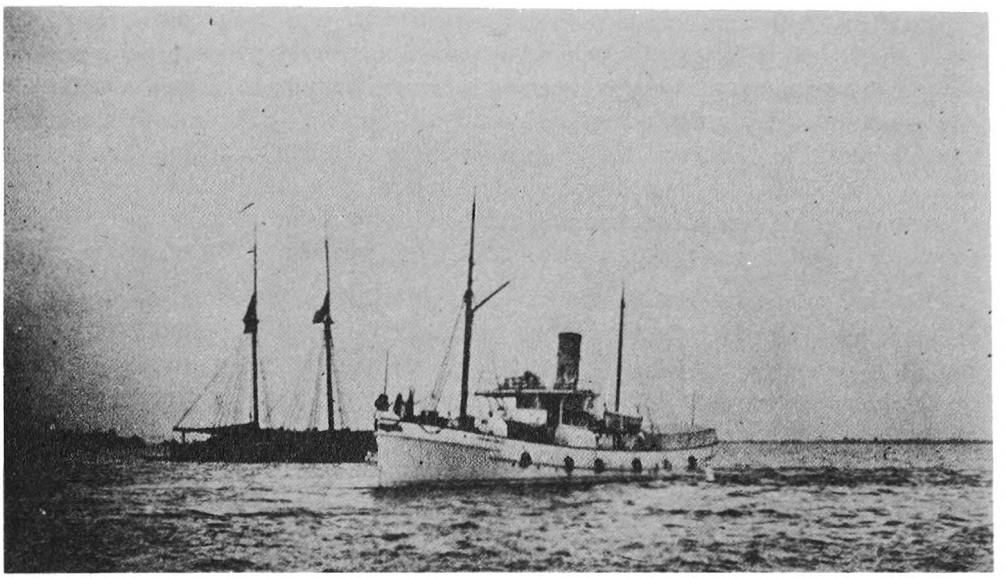

FIG. 10. – S.S. *Lord Stanley*, before conversion. Credit C.H.S.

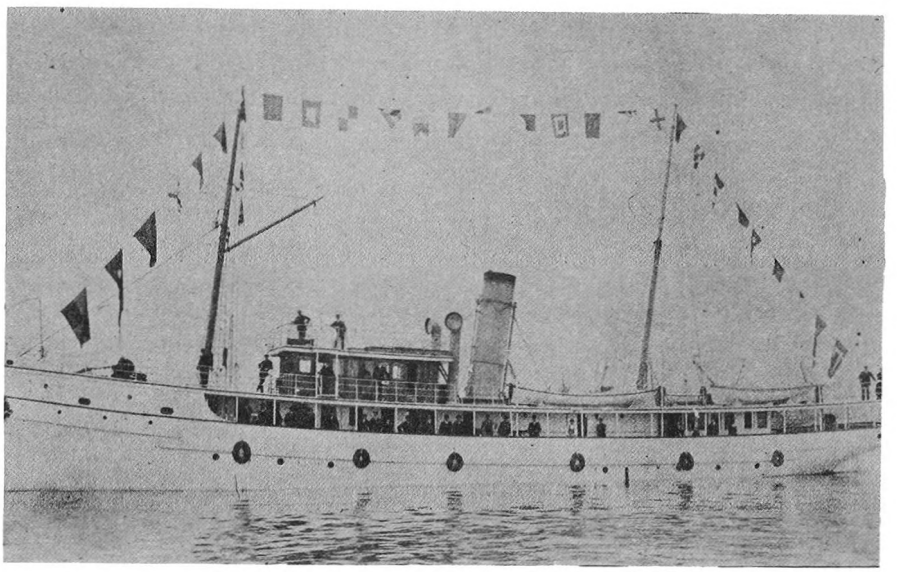

FIG. 11. – H.M. Dominion Surveying Steamer *Bayfield* (2) after conversion. Credit C.H.S.

leaving a wharf in Toronto and did not go into service in Lake Superior until 1903, by which time she had been renamed *Bayfield* (Fig. 11), becoming the second of the four ships of that name that have been in the Canadian Hydrographic Service.

As a consequence of this delay, the survey of Lake Superior had to be started using the aging *Bayfield*. She thus became the first Canadian survey vessel to see service in all the lakes. Little was achieved this first season as Stewart had detached his assistants to commence surveys of Lake Winnipeg.

Like his American predecessors, Stewart, too, had crew problems. After several sailors had deserted the *Bayfield* in Lake Superior, he wrote "It is a mistake engaging these young farmers who enjoy steamer life till the novelty wears off, then they want to go home to mother". As usual the ship's cook was temperamental and Stewart did not spare his feelings when he wrote of him that "the present holder of the position ... had not one redeeming quality. He cannot cook, is dirty and untidy..." This being brought about by the cook, who, when asked to bake bread replied that it was not part of a chef's work to bake.

The end of the 1903 season in Lake Superior also saw the end of an era and the beginning of a new chapter in hydrographic history. Before the 1904 season commenced, an Order-in-Council dated March 11, 1904, brought the Canadian Hydrographic Survey into being, combining the hydrographic efforts of several branches of government into the one service under the Department of Marine and Fisheries.

As we have shown, by the end of the 19th century the lakes held few mysteries for the mariner. Their coastlines and shoals were charted, or at least safe routes had been established on them, sufficient for the needs of navigation and drafts prevailing at that time. Main survey control had been established and the hydrographers who followed achieved greater accuracy with ever more modern instruments.

Data from surveys carried out by hydrographers on either side of the border were being used in charts of either nationality, and both Canada and the United States had permanent organizations set up to continue the work of their pioneer hydrographers.

Acknowledgements

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