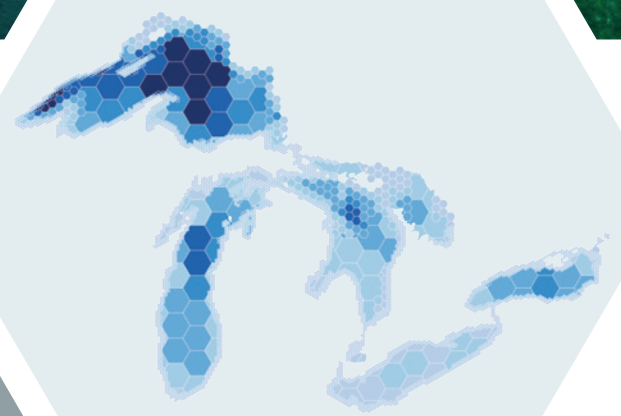
Costs and Approaches for Mapping the Great Lakes

LAKEBED 2030

AN INITIATIVE FOR HIGH-DENSITY MAPPING OF THE GREAT LAKES

Lakebed mapping supports decision-making and research via seamless, publicly accessible data discovery, analysis, and imaging.



great lakes observing system

GREAT LAKES BOTTOM MAPPING WORKING GROUP

The Great Lakes Observing System (GLOS) provides end-to-end data services that support science, policy, management, and industry in the Great Lakes. A nonprofit working in the U.S. and Canada, GLOS works to equip observers with high-quality, up-to-date lake information from the region's observing network.

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EXECUTIVE SUMMARY

The Great Lakes Region of North America holds critical, intrinsic value in its unique positioning, incredible biodiversity, vast recreational outlets, and historical significance. Monitoring and forecasting systems are necessary to track physical, chemical, and biological trends currently threatening the lakes' ecosystems and economies.

As trends like climate change accelerate these shifts, parallel technological advancements continue to yield more informative and more current models of lake dynamics, which are integral to decision-making and research in sectors like public health, maritime transport, and tourism. Bathymetry, the study of underwater depth, can provide a detailed picture of the lakebed and is foundational to such modeling efforts, with a broad spectrum of insight-based benefit to both natural and anthropogenic relationships within the Great Lakes Region.

The multinational, multi-agency network of Great Lakes management has resulted in a discontinuous patchwork of bathymetric modeling and policies, which provides sporadic imaging of the lakebed, with varying resolution, accessibility, and geographic concentration. However, emerging technologies in this field continue to improve our ability to map the Great Lakes at high resolution and can be combined to optimize efficiency, cost, and resolution. Ultimately, the present cost to produce a high resolution continuous lakebed surface in the Great Lakes is around $200 million. Once funded, the facilitation of map production will require centralizing key stakeholders and rights holders, coordinating technologies and data, and rendering bathymetry data to provide a seamless representation of the Great Lakes lakebed.

CONTENTS

INTRODUCTION AND BACKGROUND

$6T
Gross domestic profit (GDP) of the Great Lakes region[7]

$7B
Annual value of Great Lakes commercial, tribal, and recreational fisheries[4]

51M
Regional jobs supported by the Great Lakes[7]

200M
Annual tons of cargo shipped in the Great Lakes and tributaries[10]

$35B
In economic activity supported by maritime commerce[16]

107M
People live in the Great Lakes region[6]

40M
People get their drinking water from the Great Lakes[15]

Statistics refer to the U.S. and Canada together

PHYSICAL FEATURES

The Great Lakes of North America span 244,160 square kilometers and drain from lands over double their size.[1] The Great Lakes hold 84% of America's surface freshwater, and 21% of that of the entire planet.[2] If the lakes were spread over the 48 contiguous United States, the water would cover them nearly three meters deep. The lakes' ecological conditions support 3,500 unique plant and animal species, including 177 fish species, of which 61 are listed as threatened or endangered.[3,4]

The Great Lakes coastlines are also home to a diverse array of ecosystems and built environments, with fragile habitats, critical infrastructure, and opportunities for human activity dotted all along 17,017 kilometers of shoreline, when counting islands and connecting channels,[1] greater the distance from Detroit to Melbourne, Australia. Made up of dunes, bluffs, wetlands, and more, the lakeshores have the same diversity as ocean shores.[5] The basin is home to over 34 million residents, accounting for 8% of the U.S. population, and 32% of the Canadian population.[6]

Dollar amounts are in USD.

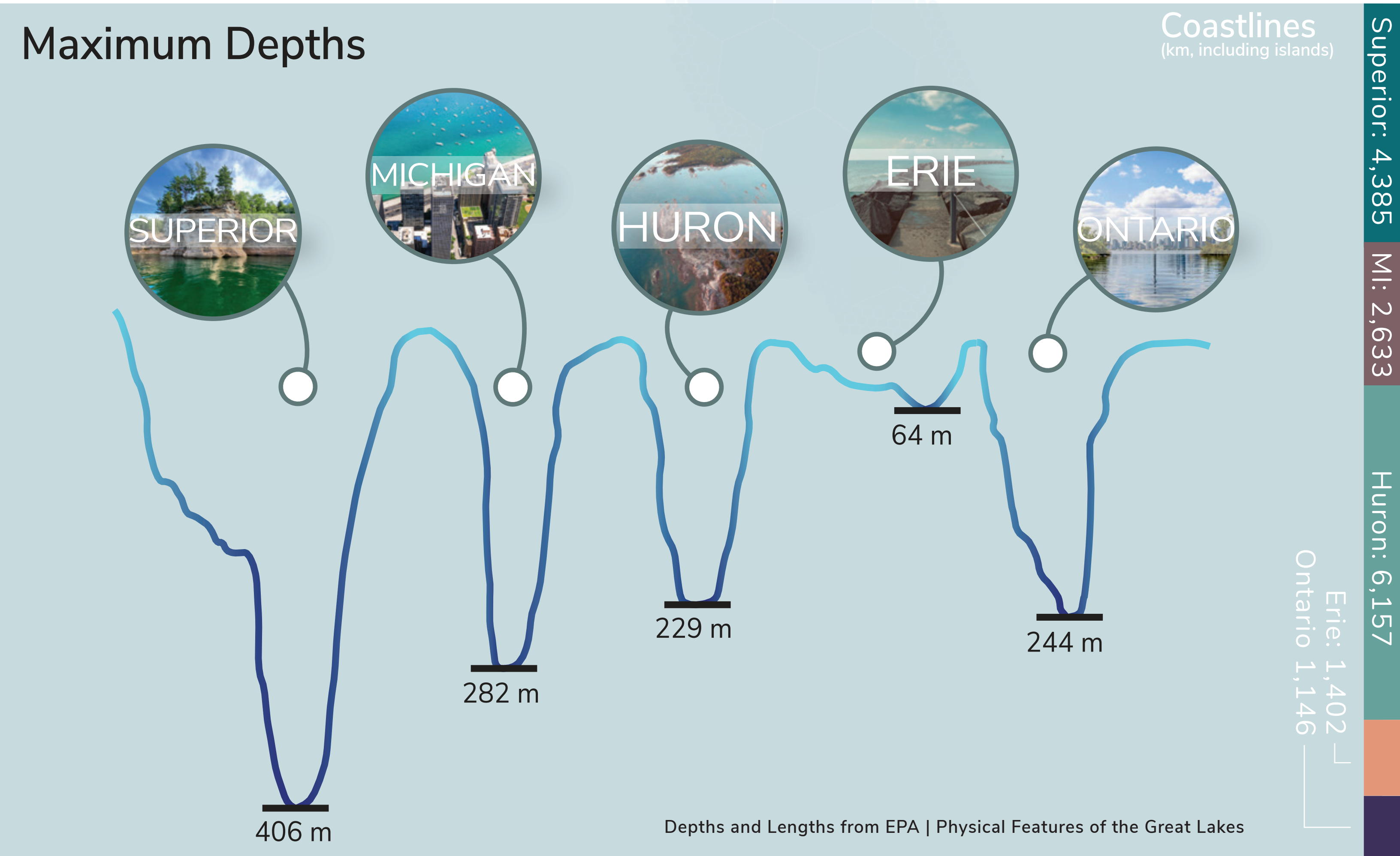
1. EPA | Physical Features of the Great Lakes
2. EPA | Facts and Figures about the Great Lakes
3. NOAA | Great Lakes Region Ecosystem-Based Management Activities
4. GLFC | The Great Lakes Fishery: A World-Class Resource!
5. USACE | Great Lakes Coasts
6. MI Sea Grant | Great Lakes Fast Facts
7. CGLR | The Great Lakes Economy: The Growth Engine of North America
8. MI Sea Grant | The Dynamic Great Lakes Economy: Employment Trends from 2009 to 2018
9. BLS | Charting the labor market: Data from the Current Population Survey (CPS)
10. Great Lakes St. Law. Seaway System | The St. Lawrence Seaway
11. University of Michigan Research Seminar in Quantitative Economics | Socioeconomic Impacts of the Great Lakes Restoration Initiative
12. OMAFRA | Agriculture in the Great Lakes Basin – Stewardship and Innovation
13. GLPF | Agriculture in the Great Lakes
14. Kadar, I | The International Supply Chain of the Great Lakes Region
15. IJC | Great Lakes Water Quality
16. The Great Lakes Seaway Partnership | Economic Impacts Study

ECONOMIC SIGNIFICANCE

The Great Lakes region of North America has economic, environmental, social, and strategic value. Home to a diverse array of sectors and industries, as well as unique ecological resources and habitats, the lakes are integral to the vitality of the entire region. If the region was a country, it would have the third largest GDP globally at over $6 trillion and support for over 51 million jobs.[7] With over 800,000 jobs in the U.S. as of 2018, manufacturing is the area's largest market, experiencing 8% job market growth between 2009-2018, about twice the U.S. national labor force growth rate.[8,9] Transportation and warehousing is another prominent Great Lakes sector, with over 200 million tons of cargo shipped along the waterway annually.[10] This maritime trade contributes to the total $278 billion in annual bilateral U.S.-Canadian trade, totaling more than regional trade with Mexico, China, United Kingdom, Germany, and Japan combined.[14]

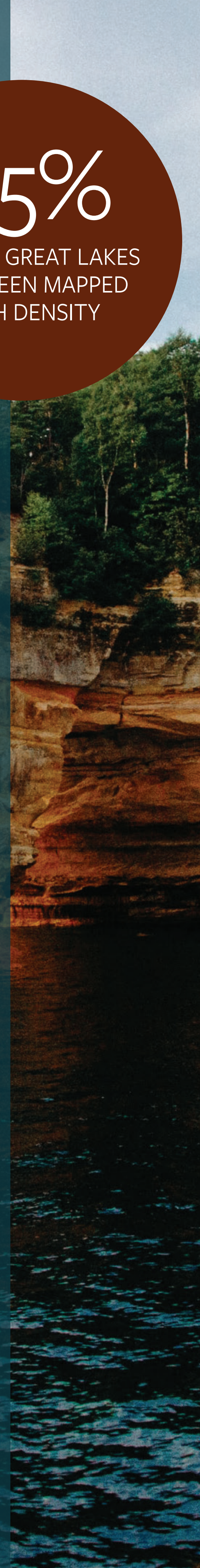
Great Lakes coasts, fisheries, and agricultural provide expansive avenues for tourism, recreation, food production, and drinking water. Because of this, investments in the ecosystem have large returns. Projections through 2036, based on the Great Lakes Restoration Initiative, estimate that every dollar spent on restoration generates "$3.35 of additional economic output."[11]

Great Lakes climate supports a highly productive agricultural sector that accounts for 25% of Canada's total food production and 7% for the U.S.[12,13] Besides agriculture, the lakes support a highly valuable fishery, loved by millions of recreational anglers and the source of 75,000 jobs in commercial fishing. This tightly integrated network of economic output, positioned along an international border, and with its unique climate and ecosystem, situates the region as strategically critical to the vitality of the U.S., Canada, and many key trade partners globally.



Depths and Lengths from EPA | Physical Features of the Great Lakes

THE CASE FOR MAPPING



<15%
OF THE GREAT LAKES HAVE BEEN MAPPED AT HIGH DENSITY

Despite the far-reaching social, environmental, and economic significance of the Great Lakes, we lack a thorough understanding of the underwater environment. Bathymetry, the study of underwater depth, is critically underutilized. In fact, a maximum of only 15% of the Great Lakes has been mapped at high density, compared to over 40% of total U.S. waters, and the large majority of this area is limited to coastlines.[17]

As the underwater equivalent to topography, bathymetry reveals otherwise invisible information about hydrodynamics, habitats, infrastructure safety and security, and more. Multiple recent Great Lakes needs assessments, information prioritizations, and discrete projects cite more detailed and higher density Great Lakes bathymetric data as integral to many aspects of both natural and anthropogenic prosperity. Benefits range broadly from ecosystem protection, fishery and recreation management, maritime industry safeguarding, public health, and exploration (there are over 6,000 shipwrecks in the Great Lakes, many of which are undiscovered). As awareness of the importance of bathymetric mapping builds in many diverse sectors and communities, there is an opportunity for governments at multiple levels and on both sides of the border to form cohesive strategies for collaborative mapping.

However, the strategy and milestones for a large bathymetric data campaign are only just emerging, with proposed goals such as increasing the regularity of nearshore mapping by 10% to better track hydrological changes, working at a federal level to secure funding and establish protocols, and increasing process transparency with more publicly available mapping data from external partners.[18]

All this occurs as climate change effects continue to worsen and threaten both human-made and natural ecosystems in widespread ways. As such, the need for high-density bathymetry for observations and analysis continues to mount, particularly because it provided insights about the ecosystem that satellites and other monitoring systems are unable to.[19]

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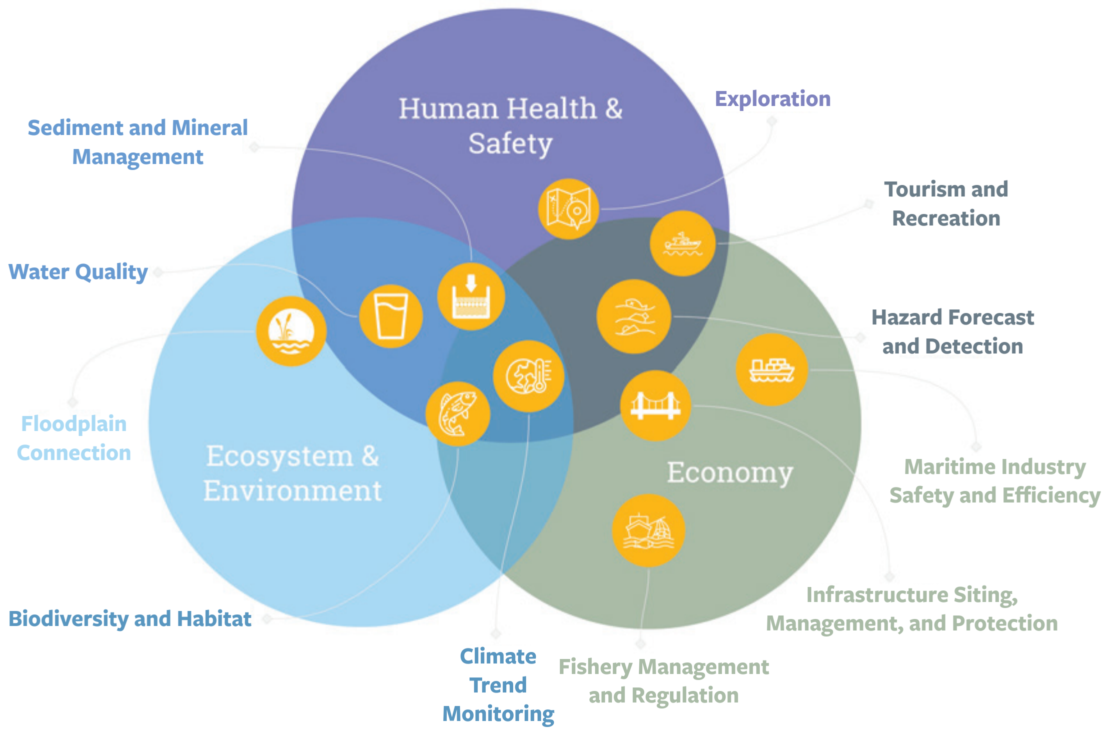
17. NOAA | US Bathymetry Coverage and Gap Analysis
18. NOAA Office of Coast Survey | Office of Coast Survey Contributions to a National Ocean Mapping Strategy
19. Zhong, Y., Notaro, M., & Vavrus, S.J. | Spatially variable warming of the Laurentian Great Lakes: an interaction of bathymetry and climate
20. Regional Data Platform Scoping Study: Federal Data Task Report | Dewberry for NOAA Office for Coastal Management

"Bathymetry data are collected and distributed in a patchwork form and are difficult to find and use at scales beyond individual surveys. **Additional high resolution / full bottom surveys are needed for complete coverage in priority areas of interest**...Seamless 'best available' products and more up to date bathymetry data products are needed."[20]

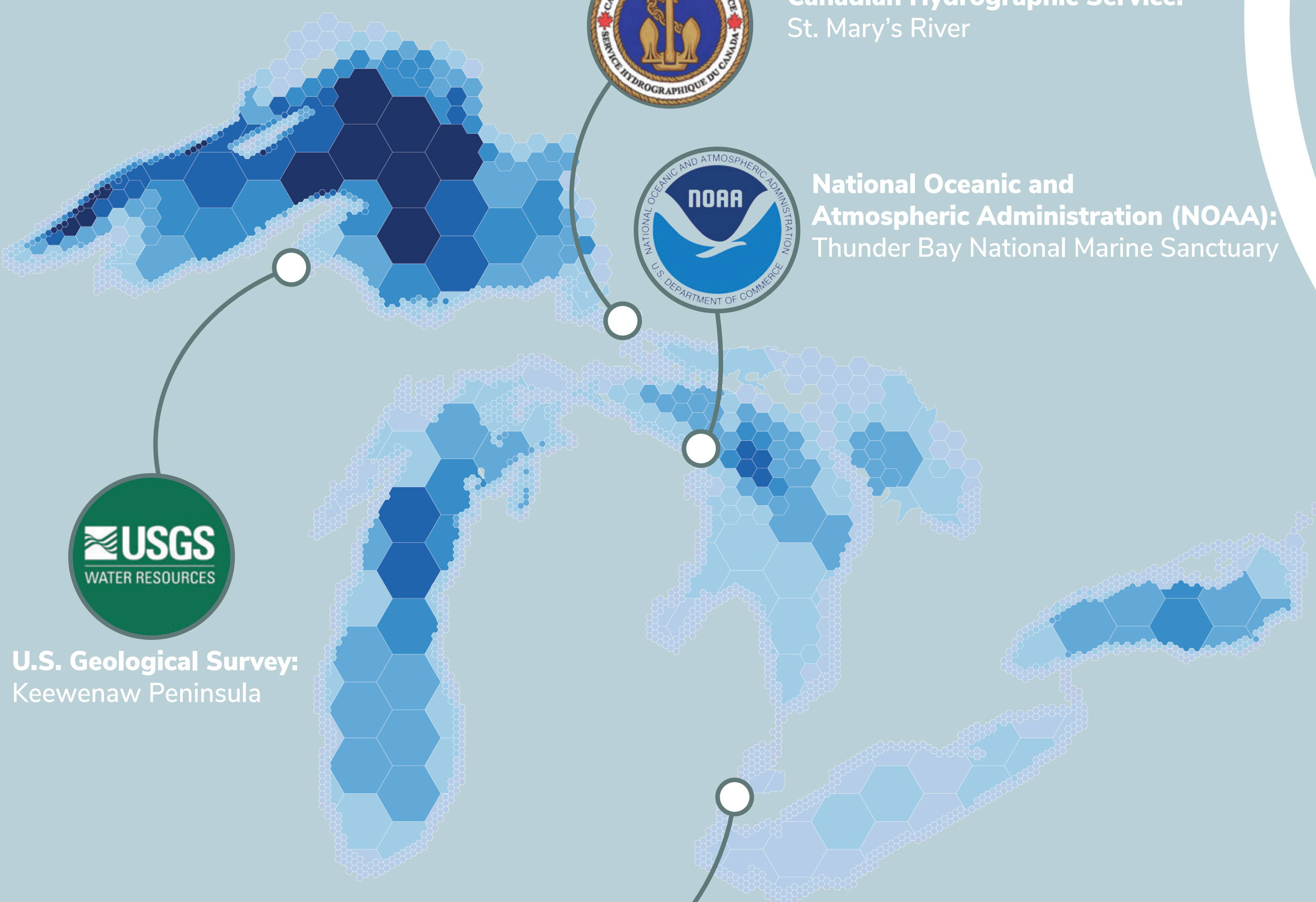


KEY POLICIES DRIVING MAPPING AND BATHYMETRY EFFORTS

YEAR	NAME	DIRECTIVE	KEY LANGUAGE
1972	Coastal Zone Management Act	US flag	"**Preserve, protect, develop,** and where possible, to restore or enhance the resources of the nation's coastal zone"
1996	Oceans Act	Canadian flag	"Ocean and coastal mapping program for the Great Lakes...that enhances ecosystem approaches in decision-making for **conservation and management of marine resources and habitats, establishes research and mapping priorities,** supports the siting of research and other platforms, and advances ocean and coastal science"
2009	Ocean and Coastal Mapping Integration Act	US flag	"**Improved public access to marine data and information,** efficient interagency coordination on ocean-related matters, and engagement with marine industries, the science and technology community, and other ocean stakeholders"
2014	World-Class Tanker Safety System	Canadian flag	Targeted Canadian Hydrographic Service surveying and product updates for key Canadian ports, including those on the Great Lakes "...measures demonstrate **the Government of Canada's ongoing commitment to strengthen marine safety measures to protect the public and the environment**"
2017	Ocean Protection Plan	Canadian flag	"**Fill important gaps in high-resolution coastline and bathymetry** in inter-tidal zones and near-shore areas to ensure the delivery of improved navigational charts and enhanced electronic navigational charts in near-shore areas, high-risk coastal and inland water zones"
2018	Executive Order 13840: Ocean Policy To Advance the Economic, Security, and Environmental Interests of the United States	US flag	"Collect data for the purpose of understanding oceans and their living resources and ecosystems; **prepare and publish data, reports, statistics, charts, maps, plans, sections and other documents"**
2020	Digital Coast Act	US flag	"**Filling data information gaps, including coastal elevation,** land use and land cover, critical infrastructure, socioeconomic and human use, structures, living resources and habitat, cadastral, and aerial imagery"

MAPPING EFFORTS

A SAMPLE OF GREAT LAKES BATHYMETRIC SURVEYING



Canadian Hydrographic Service:
St. Mary's River

National Oceanic and Atmospheric Administration (NOAA):
Thunder Bay National Marine Sanctuary

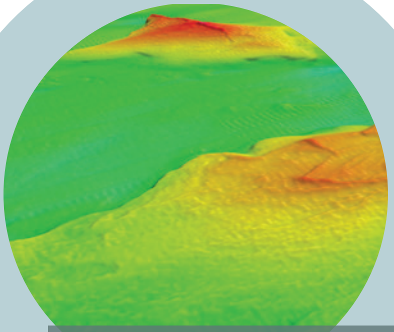
U.S. Geological Survey:
Keewenaw Peninsula

U.S. Army Corps of Engineers:
Coastline

Depth (meters)
<40
>200

Data Density
High
Medium
Low

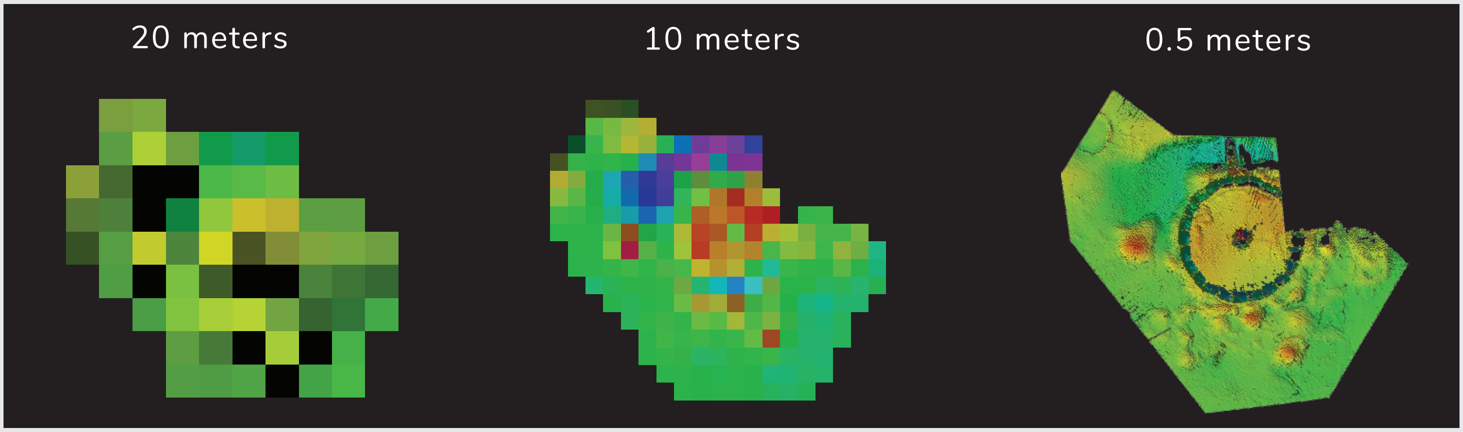
Autonomous Surface Vehicle BEN uses sonar and GPS to survey the lakebed and provide data for high-density maps. BEN's expedition in Thunder Bay served as a test case to continue improving the technology. (University of New Hampshire)



A processed bathymetric map of Lake Huron in Thunder Bay Marine Sanctuary. (Ocean Exploration Trust & University of New Hampshire Center for Coastal Ocean Mapping)

ON DENSITY & RESOLUTION

While satellite and other bathymetry technologies have existed for decades, data density is key when exploring areas such as sediment loads, benthic (lakebed) micro-organism habitats, and sinkholes. Data density refers to the amount of data points collected in a given area: the more points collected, the higher the density. With more advanced tools and processing capabilities, higher density data collection is increasingly feasible and cost-efficient. It is able to create much clearer, more granular images. Below, the Detroit water intake crib, a critical piece of drinking water infrastructure, is visible at increasing degrees of resolution.



MAPPING THE GREAT LAKES

CREWED VESSELS

As the need for high-density Great Lakes bathymetric data mounts across a diverse spectrum of sectors and interests, the technological abilities of surveying tools improves as well. In large part, the appropriate tool depends on the depth of water, but certain methods can also supplement others to minimize cost while simultaneously ensuring accuracy. The prevailing method, particularly for greater depths, uses a type of vessel-mounted sonar called a multibeam echosounder (MBES) that analyzes the time it takes for acoustic waves, or "pings," to reflect off of the lakebed and return to the receiver to measure depth. MBES is unique from other sonars in that it detects directional information from the returning sound waves, which results in several measurements from a single ping. MBES systems are relatively cheap, but the vessels that deploy them are not. For nearshore areas, smaller vessels are safer and cheaper options, but larger vessels for deep lake areas cost upwards of $1,100 per hour to operate.

UNCREWED VESSELS

Additionally, the development of cost, hazard, and time-saving uncrewed surface vessels (USVs) and autonomous underwater vehicles (AUVs) is well underway. AUVs in particular are already widely used in certain ocean applications such as pipeline surveying, but remain relatively expensive, with steadily high operational costs. However, as the demand for surveying capabilities on these vessels grows during the span of Lakebed 2030, more uncrewed and autonomous devices will enter commercial production. The current cost of these technologies, whether used alone or in tandem with a larger vessel, is $439 to $655 per hour, projecting a cost savings of 40% to 60% over purely vessel-based surveying, depending largely on ongoing servicing and maintenance costs. Similarly, satellite-derived bathymetry (SDB) can derive water depths of up to 15 meters, and has an estimated cost savings of 65% over multibeam technologies for shallow depths. However, SDB can only be applied in water with optimal water column conditions. In the end, it has not evolved enough yet to meet the needs of Lakebed 2030.

NOAA Ship Thomas Jefferson

NOAA white ships have not conducted survey missions in the Great Lakes since 1984, but there are plans for them to return in 2022.

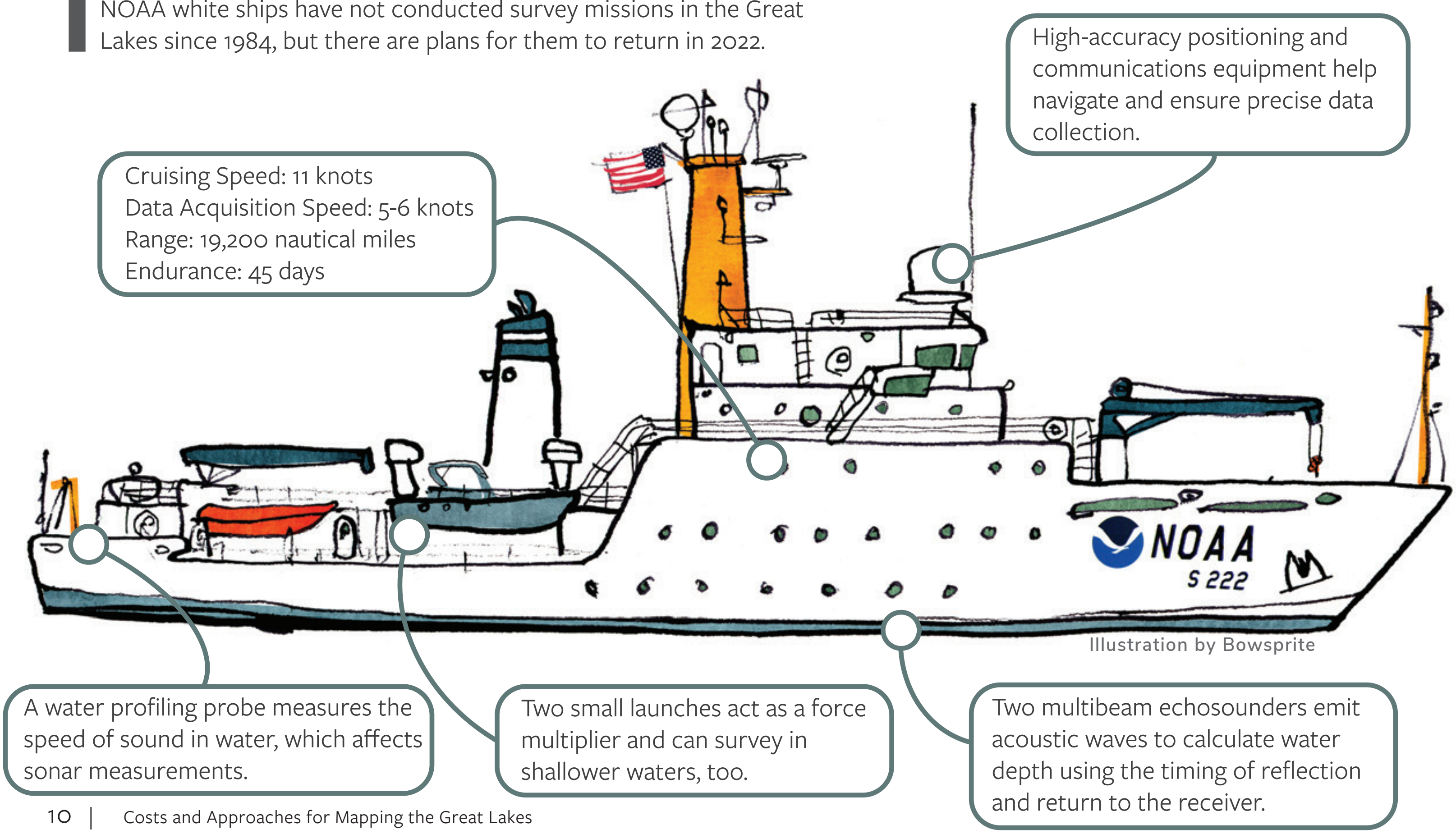
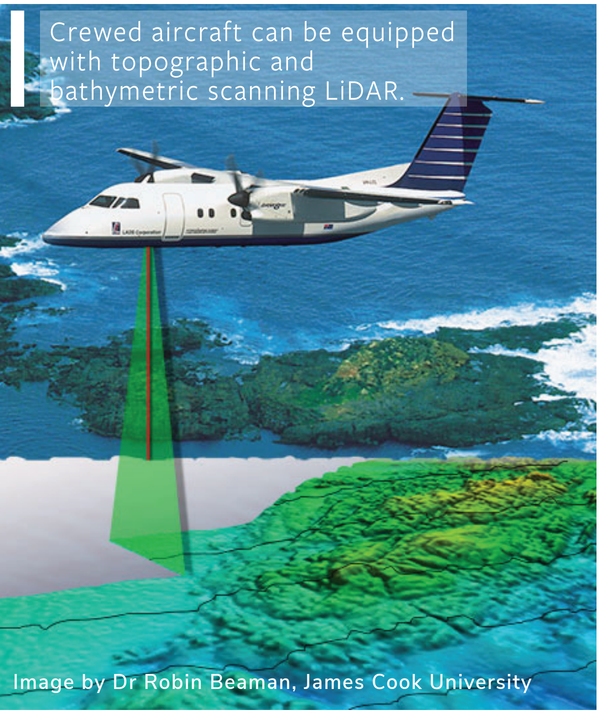


Illustration by Bowsprite

An uncrewed aerial vehicle (UAV) can be equipped with topographic and bathymetric scanning LiDAR.



Crewed aircraft can be equipped with topographic and bathymetric scanning LiDAR.

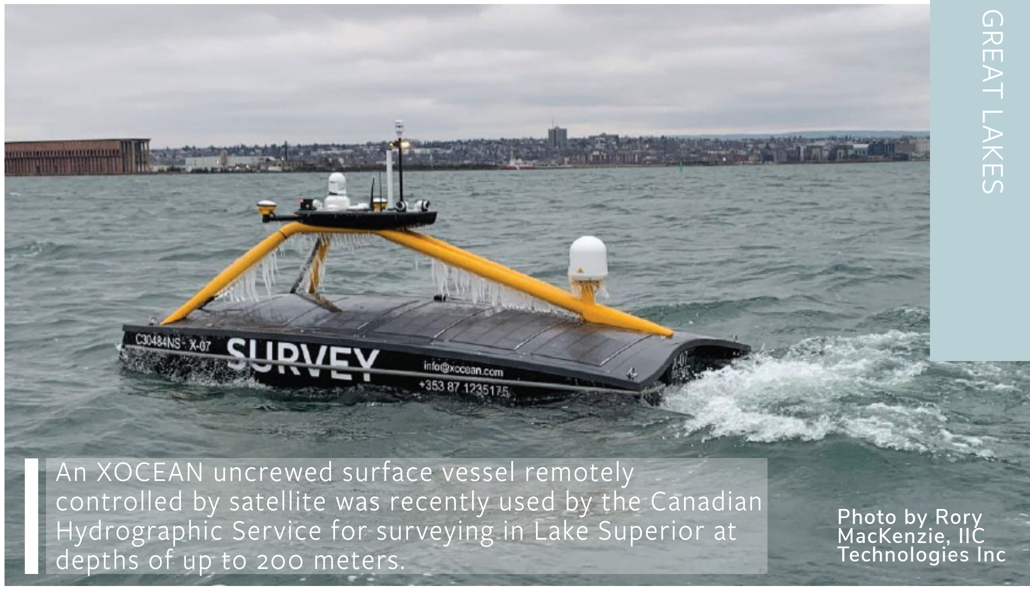
Image by Dr Robin Beaman, James Cook University

The Sounder Unmanned Surface Vehicle is capable of both supervised and autonomous operation.

Photo by Kongsberg Marine

Blue Ocean Monitoring's Iver3 is capable of operation at depths up to 200 meters and single-user deployment directly from shore.

Photo by Blue Ocean Marine Services blue-ocean.com.au



An XOCEAN uncrewed surface vessel remotely controlled by satellite was recently used by the Canadian Hydrographic Service for surveying in Lake Superior at depths of up to 200 meters.

Photo by Rory MacKenzie, IIC Technologies Inc

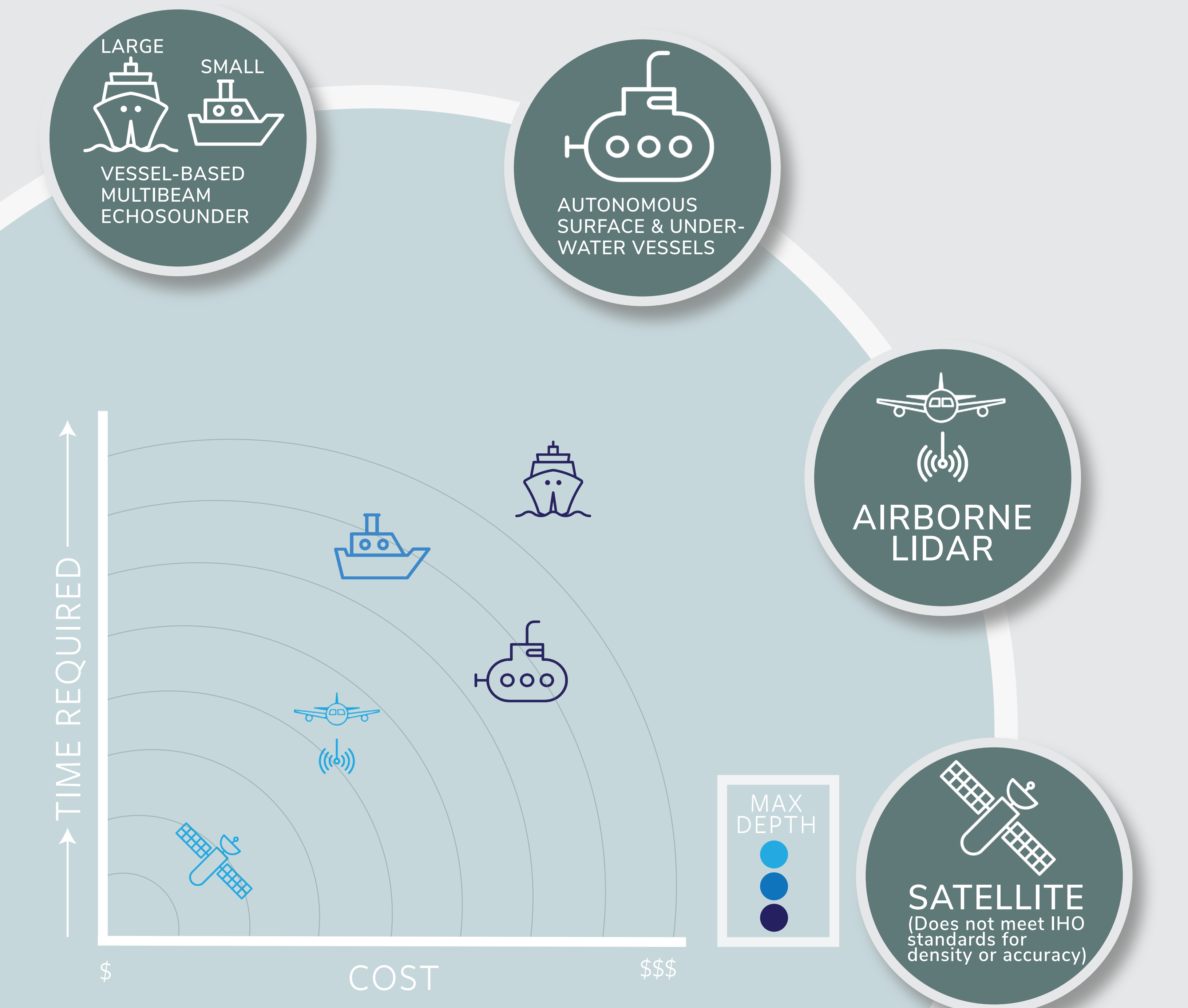
CCGS Hudson is a hydrographic survey vessel operated by the Canadian Coast Guard for the Canadian Oceanographic Service since 1964. *Hudson* has performed numerous surveys for scientific endeavors involving continental drift, ocean circulation, marine life, and more.

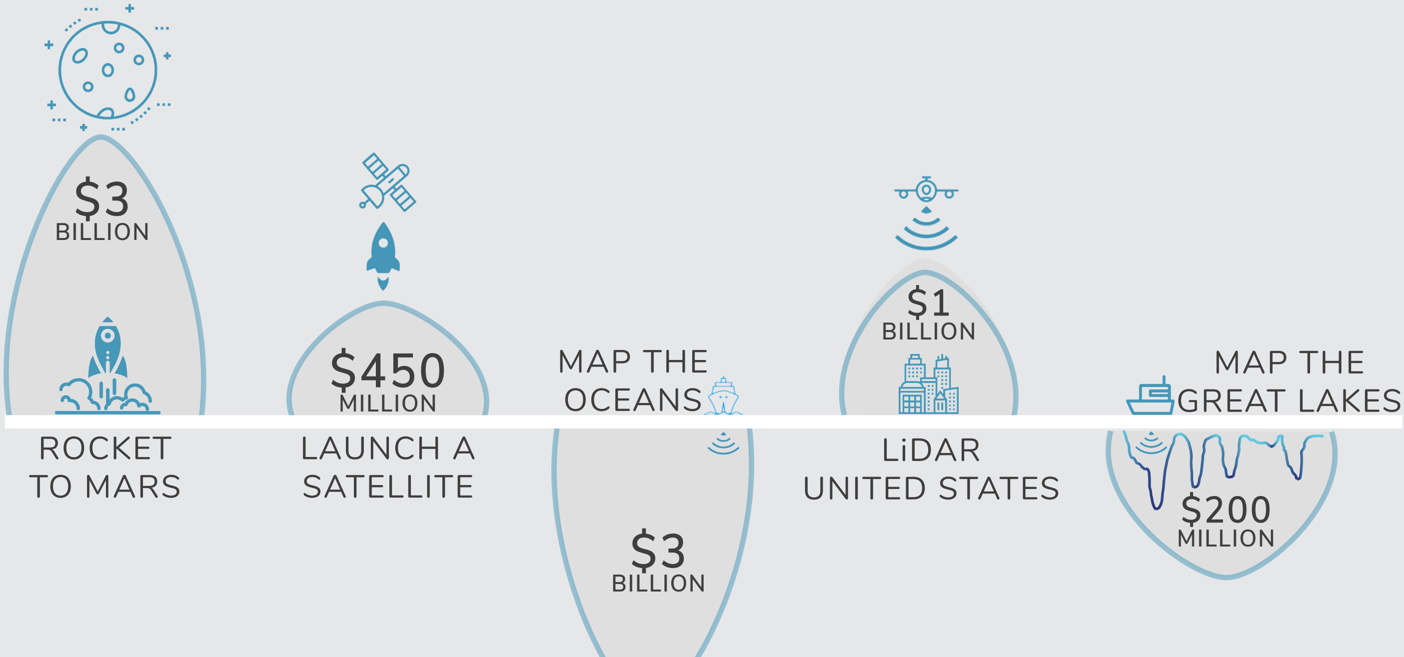
Photo by noaateacheratsea.blog

MAPPING THE EFFORT

Estimates to survey and collect high-density bathymetric data for the entire lakebed of the Great Lakes range from $130 million to $187 million, although additional processing, production, and hosting of the data adds to the total cost. The lower estimates incorporate the use of LiDAR and small vessel surveying at depths up to 20 meters, but, besides Erie, the lakes have depths beyond this scope (up to 406 meters in Lake Superior) and require large or uncrewed vessels for the bulk of the area. The table below represents the various technology options, their relative cost, and the time required to complete data collection, ranging from less than eight years to over 80 years. Note that satellite data does not achieve density of accuracy standards, but is included for comparison.

$130-200M
COST TO MAP THE GREAT LAKES AT HIGH-DENSITY





LIDAR

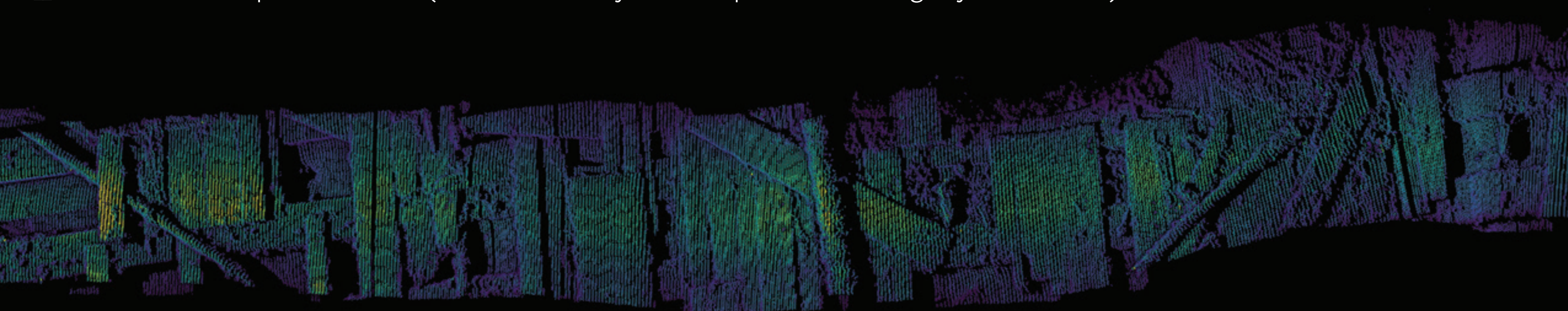
The cost of surveying can also be cut drastically by combining ship-based sonar with another form of reflection-based sensing known as light detection and ranging (LiDAR). Unlike multibeam echosounders which use acoustics, LiDAR uses a pulsed laser to compute distance and sculpt a 3D representation of the bathymetry. LiDAR is deployed by aircraft, but has significant limitations in applicability. Accuracy can only be achieved up to depths of about 25 meters, depending on water clarity conditions. High turbidity (water cloudiness) or algae cover can obscure the light beams and make LiDAR highly inaccurate. It should also be noted that LiDAR, regardless of whether the aircraft is crewed or autonomous, costs around a quarter of vessel-based MBES surveying at $233 to $250 per hour.

COMBINING TECHNOLOGIES

In parallel, differing combinations of technologies for bathymetric surveying offer markedly different time projections for completion. Relying on vessels alone to map the entirety of the Great Lakes is projected to take over 40 years at current average vessel speeds. However, the introduction of LiDAR for shallow depths, as well as AUV or USV solo missions and vessel accompaniment can drastically reduce these projections to 12-14 years with the same levels of accuracy, even taking into account factors like climate, technology maintenance, vessel transit time, and vessel traffic. As markets for uncrewed technology and survey capabilities (e.g. cheaper devices and wider swath widths of MBES systems) continue to expand, a coordinated effort to facilitate the necessary funding, technologies, crews, data management, processing, and production will propel the goals of Lakebed 2030 forward.

MAPPING A SHIPWRECK

A processed image of a shipwreck from a single pass with a remotely-operated vehicle (ROV) equipped with a UL5-500 scanner from 2G Robotics. Mapping the entire lakebed at this resolution takes millions of passes in total. (Data collected by ASI Group for GLOS. Image by 2G Robotics)



WHY GLOS?

The Great Lakes Observing System (GLOS), a 501(c)(3) based in Ann Arbor, MI, has served as the IOOS Regional Association for the Great Lakes since 2008 with a mission to provide end-to-end data services that support science, policy, management, and industry. In 2021, GLOS was successfully re-certified as a Regional Information Coordination Entities (RICE) under the authority of the Integrated Coastal and Ocean Observation System Act of 2009 (ICOOS Act) and was approved to submit data as a "trusted node" to the International Hydrographic Organization Data Center for Digital Bathymetry (IHO DCDB). The network of trusted nodes serve as data liaisons between data collectors and the DCDB.

>230K
Data users served annually by GLOS

NETWORK

The network of partners engaged with GLOS has evolved and grown over time to a system currently supporting over 40 institutional data providers, 250 observing assets, and serving an average of over 250,000 data users per year throughout the region's eight U.S. states and two Canadian provinces. Through a project funded by the Great Lakes Restoration Initiative and administered through the U.S. Geological Survey, GLOS helped to lead the Bottom Mapping Working Group (BMWG). The BMWG consists of a region-wide network of partners with goals of promoting lakebed mapping efforts, creation of a data inventory categorizing available high-density data, and the development, deployment, and analysis of a spatial prioritization survey among interested constituents.

As a result of the diverse nature of priorities in the Great Lakes, a wide array of networked stakeholders has emerged to oversee, protect, and explore the region. GLOS functions to equip shareholders within this array with the data, tools, information, and insight to function efficiently and effectively within the scope of their agency. As such, GLOS is uniquely positioned at a critical intersection of the Great Lakes management and research web, with working relationships in a variety of arenas of lake health and vitality. The breadth of administrative capacity in this role situates GLOS well to help lead the Lakebed 2030 effort towards mapping the Great Lakes at high-density by 2030.

FINANCIAL

As a 501(c)(3), GLOS is well positioned as a financial facilitator for Lakebed 2030. Ultimately, Lakebed 2030 will be a collaborative effort requiring investment in technology innovation, education and training, mission planning, coordination and execution, data processing, and outreach. Additional funds will be required for these activities. This report only details the costs associated with mobilization, planning and executing the mapping of the Great Lakes.

The development of a strategic plan could help reveal approaches and estimated costs of these other activities. Some potential methods for raising operating capital for Lakebed 2030 include a shared pool of resources contributed by partnering organizations and solicitation of donor funds from high-net-worth individuals, philanthropic organizations, and foundations. National, state, and provincial governments may also wish to directly contribute funds. Community members around the Great Lakes may also be in a position to contribute to the pool of resources required for this effort through crowdfunding, giving individual donations, contributing crowdsourced bathymetry, by registering vessels, and more.

GLOS has a long history of being the IOOS Regional Association and working with principal investigators on a variety of grant-based programs. This experience would serve the community well by dispersing donor funds to grantees for a variety of Lakebed 2030 activities. As an independent nonprofit organization, GLOS has no commercial bias and can work across the spectrum of government, academia, industry and other nonprofits.

CAPACITY

In 2019, GLOS helped to launch the Smart Great Lakes Initiative with the goal of advancing technology applications to improve understanding, use, conservation, and management of the lakes. Since then, the initiative has grown to include a network of more than 70 pioneering members spanning government, academic, for profit and nonprofit sectors. In 2021, members released the Common Strategy for Smart Great Lakes, which charts a course for future collaboration. The initiative could easily serve as a model for the Lakebed 2030 initiative and development of a Lakebed 2030 Coalition.

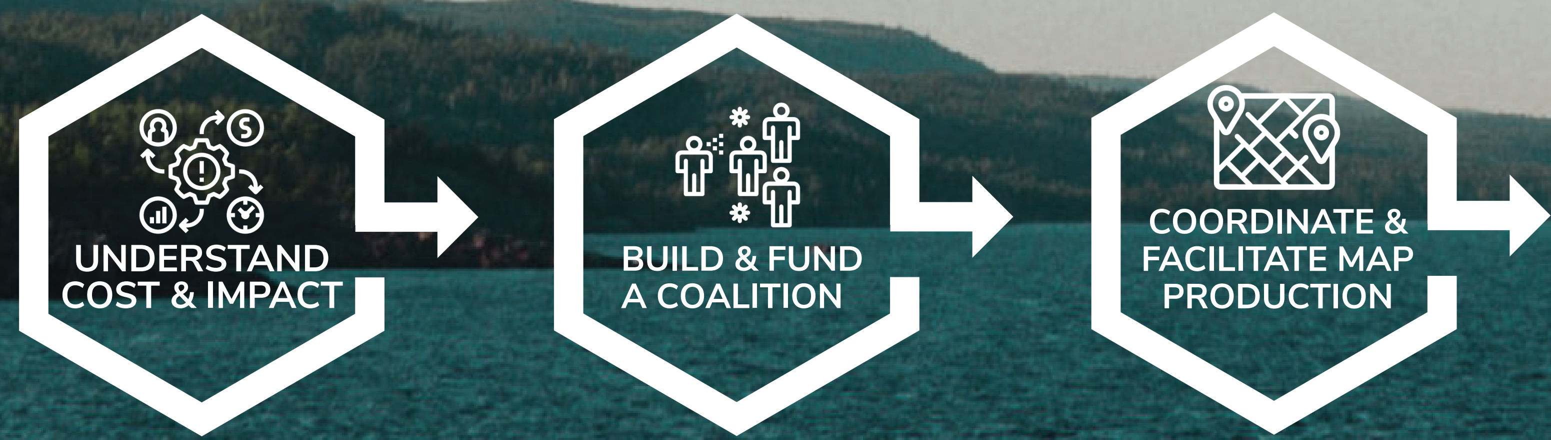
As part of the IOOS program funding cycle, GLOS has prepared a five-year data management and cyberinfrastructure plan including the development of a new information technology platform. The platform, called Seagull, will underpin the entire data collection, processing and dissemination process for a wide range of GLOS partners, data contributors and information consumers. This includes core GLOS real-time lake condition observations, bathymetry, benthic habitat, infrastructure, features of interest, and more. A part of this five-year plan includes the human resources required to foster relationships with mapping partners around the Great Lakes and the development of resources to support bathymetry data, metadata, discoverability and availability in Seagull, an open and freely accessible system. In addition, alongside Northwestern Michigan College, GLOS co-hosts a conference series that focuses on Great Lakes bathymetry efforts. In the end, besides being a neutral and natural leader in the Great Lakes for open data, metadata, and access, GLOS is also already closely aligned with regional mapping stakeholders.

TECHNOLOGY

The new GLOS information technology platform, Seagull, will provide a window into existing, new, and planned high-density bathymetry datasets in the Great Lakes. Seagull will leverage existing technologies with multibeam and LiDAR hardware and data processing and GIS software partners to better enable data contributors and information consumers rapid access to bathymetry data. Spatial footprints displayed on a rich, visual map will assist people in understanding where data already exists, complete with metadata.

One of the primary goals of Seagull is to deliver a continuous, high-density surface of the bathymetry of the Great Lakes from a variety of sources, via a web mapping application. Users will be able to visualize where high-density data exists, discover relevant metadata and access available datasets in gridded and source formats, if available. As more bathymetry data is collected as part of Lakebed 2030, the high-density surface will slowly be filled in, enabling visualization of a continuous surface depicting the lakebed from shore to shore. Seagull can serve as a conduit for smaller organizations or individuals with datasets that are not currently discoverable and available. Not only would others be able to send data to GLOS, Seagull can make metadata, data, and surfaces available via application programming interfaces (APIs) and web and map services. As part of the technology development to support a continuous model of the lakebed, GLOS will also develop workflows that can be shared with a wide network of data collection organizations and community scientists. GLOS has already worked with Orange Force Marine to develop a small device that community scientists can add to their vessels to transmit depth data from their fish finder or other existing hardware directly to the GLOS cloud for inclusion in Seagull. Because GLOS is a “trusted node” for crowdsourced bathymetry, GLOS can then send this data to NOAA’s data repository for inclusion in the IHO’s Crowdsourced Bathymetry initiative.

LAKEBED 2030 NEXT STEPS



COST REPORT SUMMARIES

In an effort to gather interest around Lakebed 2030 and contribute to a pragmatic strategy, in 2020, GLOS commissioned three surveying organizations to estimate the total cost of mapping the Great Lakes at high-density.

These three reports are preliminary estimates of costs and proposed tactics as compiled by three experienced companies: Orange Force Marine, XOCEAN, and Fugro. Any plan for comprehensive mapping by 2030 will require broad collaboration and feature a combination of tactics described by these reports.

ORANGE FORCE MARINE

Orange Force Marine (OFM) is a company local to the Great Lakes region. Their calculations featured the most diverse set of mapping methods, including a combination of large and small vessels used in conjunction with LiDAR collection, resulting in the least expensive of the three estimates. OFM says that the lakes are mappable by 2030, with Lake Erie taking the longest to complete based on shallower depths and reduce swath width areas covered.

$130 million

Total Cost

XOCEAN

XOCEAN is a medium-sized company that specializes in using remotely piloted vessels. Due to mapping one lake at a time, the speed of these smaller vessels, and allowances made for infill time, they estimate that total mapping would take a single vessel many decades. Using 10 vessels simultaneously, XOCEAN calculates the survey would be complete in eight years. Because their mapping vessels can be piloted remotely, XOCEAN's strategy saves money on travel and crew expenses. Multiple vessels would also deliver an additional cost reduction of 20%.

$151 million

Total Cost

FUGRO

Fugro is a large company with decades of mapping experience. Their estimate was based largely on traditional methods that featured one crewed mothership and two accompanying smaller ships. It avoided shallow water, assuming LiDAR coverage for these areas. The most expensive of the three estimates, Fugro says that the lakes are mappable by 2030.

$187 million

Total Cost

Though different in their approaches, all reports agree that mapping the Great Lakes at high-density is within grasp, given the proper funding. With continued innovation and a collaborative approach, a continuous, open, and highly detailed map is achievable.

The benefits of this map would be far-reaching and have impacts on management, infrastructure, research, and exploration for decades to come.

To read the full reports and become a part of this effort, visit **lakebed2030.org.**

COST REPORT SUMMARY

ORANGE FORCE MARINE

$130 million

✓ Small, highly motivated company
✓ Local to the Great Lakes region
✓ Services include bathymetry, marine data collection, first responder support, transportation, and marine training

"**Orange Force Marine** is a capable marine service company that provides flexible, reliable, efficient vessels and equipment, combining professional crew, highly experienced management and excellent service delivery, resulting in our ability to safely, efficiently and cost effectively deliver on our client's marine requirements." (From orangeforcemarine.com)

COST INFLUENCING FACTORS

High Quality Data (IHO Order 1A)
Multi-platform approach based on depth

- Large for 25-450 meters
- Small or uncrewed for 5-25 meters
- Airborne LiDAR for 0-10 meters

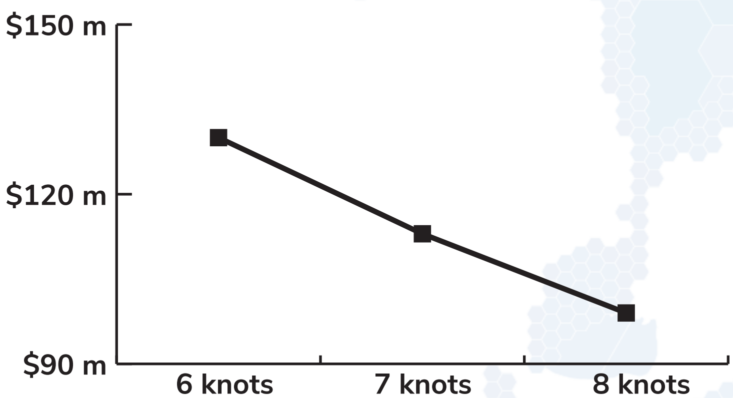
Superior	Michigan	Huron	Erie	Ontario
$31 m	$30 m	$36 m	$22 m	$10 m
24%*	23%*	28%*	17%*	8%*
4.8 yrs**	5.6 yrs**	7.1 yrs**	5.0 yrs**	1.8 yrs**

*Percentage based on overall cost.
**Years estimated based 180-200 survey days per year.

The mapping technology marketplace continues to see dramatic advances in game-changing technologies such as swarm robotics, edge processing, and semi-autonomous vehicles.

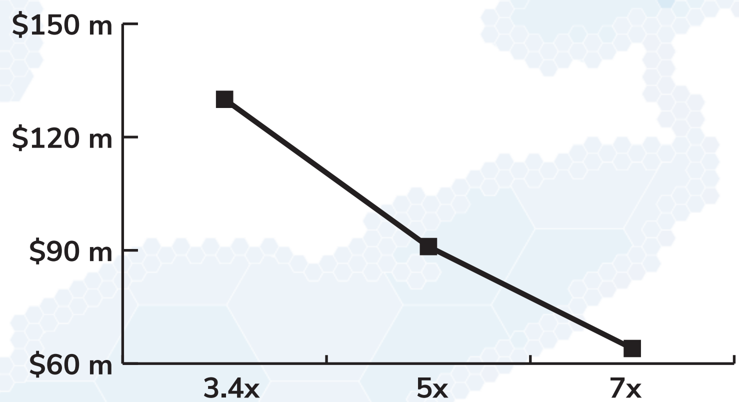
All these advances will serve as force multipliers, exponentially reducing cost and shortening the overall time required to map the Great Lakes.

Speed (1 knot) Impact on Project Cost



Every one knot increase in speed reduces the overall cost by 13%.

Swath Width Impact on Project Cost



Doubling the swath width reduces cost by 30%.

COST REPORT SUMMARY

XOCEAN

$151
million

✓ Specializes in remotely piloted, uncrewed vessels
✓ Has experience mapping the Great Lakes
✓ Encourages an innovative approach to mapping
✓ Significant environmental benefits with low carbon emissions

"Using Uncrewed Surface Vessels (USVs), XOCEAN provides turnkey data collection services to surveyors, companies and agencies. From mapping the seabed to environmental monitoring, our platform offers a safe, economic and carbon neutral solution to collecting ocean data." (From xocean.com)

COST INFLUENCING FACTORS

Single survey vessel approach with the potential of operating dozens in parallel. Cost estimates also model:

- Weather delays
- Transit times
- Infill data collection.

Superior	Michigan	Huron	Erie	Ontario
$24 m	$29 m	$51 m	$37 m	$10 m
16%*	19%*	34%*	25%*	7%*
13.6 yrs**	15.9 yrs**	7.1 yrs**	20.3 yrs**	5.7 yrs**

*Percentage based on overall cost.
**Years estimated based 180-200 survey days per year.

XOCEAN's uncrewed survey vessels are more versatile, safer, and often less expensive due to being remotely controlled by onshore pilots. They also offer significant environmental benefits, producing 1,000 times less carbon than traditional survey vessels. XOCEAN is quickly ramping up production of their vehicles and driving down costs. Multi-vessel "swarm" missions are becoming more possible, potentially leading to a dramatically shortened timeline for mapping the Great Lakes.

Photo by XOCEAN

COST REPORT SUMMARY

$187 million

- ✓ Large, international company
- ✓ Decades of experience
- ✓ Can collect diverse marine data including bathymetry, environmental information, and terrestrial data

"**Fugro** is the world's leading Geo-data specialist, collecting and analysing comprehensive information about the Earth and the structures built upon it. Adopting an integrated approach that incorporates acquisition and analysis of Geo-data and related advice, Fugro provides solutions." (From fugro.com)

COST INFLUENCING FACTORS

Follows a traditional approach of a mothership and two "launches" or smaller vessels.
Assuming that 0-10 meters is already mapped by LiDAR.
Covers areas deeper than 10 meters to IHO Order 1A.

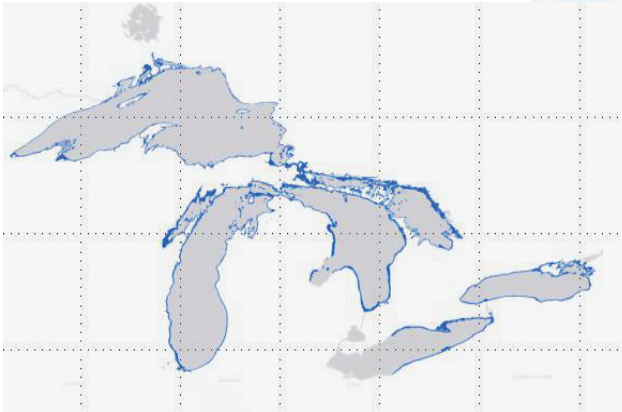
Superior	Michigan	Huron	Erie	Ontario
$38 m	$41 m	$52 m	$40 m	$15 m
16%*	19%*	34%*	25%*	7%*
4.8 yrs**	5.6 yrs**	7.1 yrs**	5 yrs**	1.8 yrs**

*Percentage based on overall cost.
**Years estimated based 180-200 survey days per year.

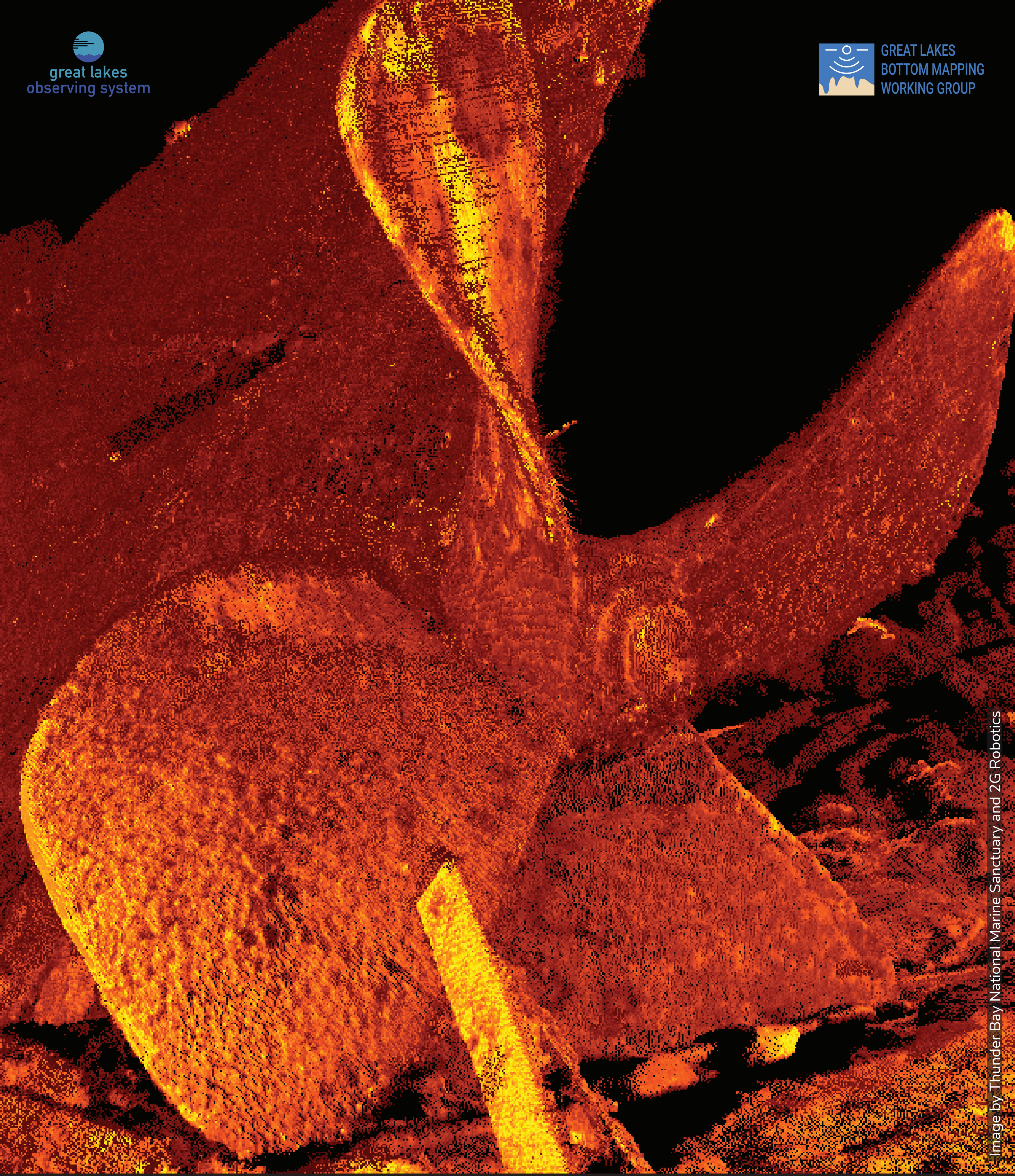
Though not up to IHO Order 1A standards and excluded from their calculations, Fugro highlighted several possible cost reduction methods including satellite derived bathymetry (SDB) and crowdsourced bathymetry (CSB).

SDB provides a safer, quicker method to map the shallow water depths. Very large areas can be processed at a fraction of regular MBES surveys. The estimated area possible to map with SDB is between 12,000 to 15,000 km^2, representing about 5% of the Great Lakes surface.

CSB data collected by standard navigation instruments on regular vessels during routine operations or recreational boating can help build the map in high-traffic areas. Though onboard equipment does not result in a high-density image, repeated passes on shipping routes or popular recreational areas can fill out the dataset over time.



Mapping all possible area using SDB at 2 meter resolution would cost between $1 and $1.9 million, and at 10 meter resolution would cost between $200,000 and $300,000.



LAKEBED 2030

An initiative to map the Great Lakes at high-density.

Lakebed2030.org