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# Cruise Report:
# Great Lakes Benthic Mapping Cruise GL-23-02, August 21–September 15, 2023






**December 2024**

**National Centers for Coastal Ocean Science**
**NOAA National Ocean Service**
**U.S. Department of Commerce**

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## Corresponding Author

Mabrouk, Ayman. CSS, Inc., under contract to NOAA, National Ocean Service, National Centers for Coastal Ocean Science. ayman.mabrouk@noaa.gov

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Cover image credits: A. Mabrouk/CSS, Inc./NOAA (left three photos); K. Staley/MTU (top right); NOAA & MTU (lower right).

## Disclaimer

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# Great Lakes Benthic Mapping Cruise GL-23-02, August 21–September 15, 2023


## Authors

Ayman Mabrouk[2], Charles Menza[1], Tonya Hoevet[2], Chandra Goetsch[2], Rabiya Dar[2], Chris Taylor[1], Dennis Donahue[3], Ossian Foley[3], Jamey Anderson[4], and Hayden Henderson[4]

*[1] NOAA, National Ocean Service, National Centers for Coastal Ocean Science*

*[2] CSS, Inc., under contract to NOAA, National Ocean Service, National Centers for Coastal Ocean Science*

*[3] NOAA, Oceanic and Atmospheric Research, Great Lakes Environmental Research Laboratory*

*[4] Michigan Technological University; Great Lakes Research Center*



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# Executive Summary

The National Oceanic and Atmospheric Administration (NOAA), National Centers for Coastal Ocean Science (NCCOS), Great Lakes Environmental Research Laboratory (GLERL), and Michigan Technological University (MTU) completed a 26-day benthic mapping cruise (GL-23-02) between August 21 and September 15, 2023. The goal of the cruise mission was to characterize lakebed habitats in northwestern Lake Michigan offshore Washington Island and provide ground-truthing observation data for predictive substrate and biological community models.

The study area was 512 km², but the cruise covered only 219 km². The surveyed area encompassed depths between 3 and 30 m, extending from Washington Island and its surroundings south to Rowleys Bay. The cruise collected underwater video imagery with a Seaviewer drop camera at 171 sites and an Outland 1000 remotely operated vehicle (ROV) at 52 sites. A Ponar dredge was used to characterize fine unconsolidated sediments at nine sites. All data acquisition occurred from the NOAA Vessel *R2601 Cyclops* stationed temporarily at the Shoreline Resort Marina in Gills Rock, Wisconsin.

Sampling sites were selected to ground-truth lakebed features and habitats identifiable from several existing nearshore topographic-bathymetry lidar (light detection and ranging) surveys. Additional multibeam echosounder (MBES) data were concurrently collected in 2023 and are planned for collection in 2024 as part of the larger project goals, but they could not be used to plan the sampling sites for this mission. A stratified random sampling design was employed to select the sampling sites to capture a wide spectrum of depths and habitats within the study area.

A separate cruise, led by the United States Geological Survey (USGS), provided complementary ground-truthing data using an IVER3 autonomous underwater vehicle (AUV). Similar to the ROV and drop camera, the AUV collected high-resolution, downward-pointing imagery of the lakebed. Data from GL-23-02 and the USGS cruise are intended to be complementary and will be annotated with similar workflows to provide seamless ground-truthing coverage and used to develop benthic maps. These maps will offer spatial insights into lakebed geomorphology, substrates, habitats, anthropogenic impacts, and species distributions.

This report accounts for survey operations, equipment, methodologies, results, and findings from cruise GL-23-02.

# Background

In 2020, NOAA, in collaboration with the National Park Service and the United States Geological Survey (USGS) and in partnership with state resource management agencies, initiated a benthic habitat mapping project to address littoral management issues in the Great Lakes. The primary project objectives are to identify, delineate, and assess nearshore spawning reefs, nursery habitats, and other ecologically significant areas. Additionally, it aims to identify the potential threats to these critical locations. To achieve these objectives, the project team set out to compile existing physical surveys and biological collections, as well as collect new data to fill data gaps. These collected data will be analyzed to understand various habitats and emergent management issues. Complementing this data-driven approach is the development of intuitive mapping and modeling tools designed to facilitate user-friendly engagement. These tools will empower decision-makers locally and lakewide, guiding informed choices related to fisheries and the restoration of nearshore, shoreline, and upland areas. Crucially, this collaborative benthic habitat mapping project is made possible through funding from the Great Lakes Restoration Initiative.

# Objectives

The mission aimed to gather comprehensive imagery and physical data on the lakebed within the study area. Specifically, the objectives were:

1. Collect imagery data for the lakebed using a remotely operated vehicle (ROV) and drop camera
2. Characterize sediment samples
3. Collect precise navigation data for ROV, drop camera, and Ponar sampler.

These objectives were achieved through the following methodologies:

- **ROV Transects**:
    - Collect videos and images at target sites using ROV transects, validating remotely sensed lidar data contributed to habitat characterization.
- **Drop Camera Surveys**:
    - Capture videos at target sites using a drop camera to ground-truth remotely sensed data and contribute to habitat characterization.
- **Sediment Sampling**:
    - Collect and evaluate sediment samples from the lakebed using a Ponar sediment grabber, providing detailed information about the lakebed's fine unconsolidated sediment composition and characteristics.
- **Navigating with USBL**:
    - Increase spatial precision by using the ultra-short baseline (USBL) acoustic positioning system as a navigation source on the sensors (ROV, drop camera, and Ponar grabber).

# Team

The cruise field team comprised nine personnel from the Great Lakes Environmental Research Laboratory (GLERL), National Centers for Coastal Ocean Science (NCCOS), and Michigan Technological University (MTU) (Table 1). The team was typically divided into groups of 3–4 individuals for each of the four cruise legs. The groups changed across cruise legs to best accommodate staff schedules while meeting cruise objectives.

Table 1. GL-23-02 crew list. GLER = Great Lakes Environmental Research Laboratory; NCCOS = National Centers for Coastal Ocean Science; MTU = Michigan Technological University; GIS = geographic information system.

| Name | Affiliation | Title | Assigned Legs |
|---|---|---|---|
| Ossian Foley | CPC, Inc., under contract to NOAA GLERL | Captain | 1, 2, 3, and 4 |
| Tonya Hoevet | CSS, Inc., under contract to NOAA/NCCOS | Marine GIS Analyst | 1 |
| Rabiya Dar | CSS, Inc., under contract to NOAA/NCCOS | GIS Analyst | 2 |
| Ayman Mabrouk | CSS, Inc., under contract to NOAA/NCCOS | Marine Ecologist | 3 and 4 |
| Chandra Goetsch | CSS, Inc., under contract to NOAA/NCCOS | Modeler | 3 |
| Chris Taylor | NOAA/NCCOS | Marine Ecologist | 4 |
| Jamey Anderson | MTU | Head of Marine Operations at Great Lakes Research Center | 1, 2 |
| Hayden Henderson | MTU | Research Engineer | 1, 2, and 4 (partial) |
| Kaden Staley | MTU | Camera and Drone Operation Communication Office | 4 (partial) |

# Operations

Between August 21 and September 15, 2023, NCCOS, GLERL, and MTU completed a 4-week cruise, GL-23-02, to characterize the lakebed in northwest Lake Michigan. The study area encompassed 516 km² of lakebed offshore Washington Island and its surrounding islands south to Rowleys Bay, with depths ranging from 3 m to 80 m (Figure 1). However, this cruise focused on shallow depths ranging from 3 m to 30 m, an area of 219 km² from the total study area where remotely sensed data from lidar were available. The Interagency Working Group on Ocean and Coastal Mapping identified this region as a high-priority of lakebed mapping through a series of organized workshops that documented regional needs for the Great Lakes (Gouws et al., 2022). The study area included several significant shoals, such as Four Foot Shoal, Nine Foot Shoal, and Fisherman Shoal, which are crucial spawning grounds for Lake Whitefish and Lake Trout (Coberly and Horrall, 1980). Additionally, it covered bays like Rowley Bay and Detroit Harbor, which are known for their importance in lake herring spawning (Coberly and Horrall, 1980).

All cruise operations were accomplished using the *R2601 Cyclops,* based at the Shoreline Resort Marina in Gills Rock, WI. The cruise operated during daylight hours, generally between 0800 and 1700 CDT (1300 and 2200 UTC). The *R2601 Cyclops* is a 26-ft SeaArk aluminum-hull vessel operated by GLERL and used primarily for nearshore missions (Figure 2). The vessel is a versatile platform with an open back deck, a stern A-frame, a centerline hydraulic winch with a weight limit of 200 lb, and cabin space for computers and dry scientific equipment.

The objectives for legs 1 (August 21–25, 2023) and 2 (August 28–September 1, 2023) were to acquire benthic ground-truthing videos and images using the MTU Outland 1000 ROV. For legs 3 (September 4–8, 2023) and 4 (September 11–15, 2023), the primary goal was to collect benthic ground-truthing videos using the NCCOS drop camera. All four legs aimed to sample and describe fine sediment collected by the Ponar dredge opportunistically. Additionally, on leg 4, September 13, a half day was spent documenting the ground-truthing data collection effort (autonomous underwater vehicle [AUV], ROV, drop camera, and Ponar dredge collection methods) using a drone camera operated by a professional photographer from MTU (see Tables 1 and 2 for the participant list and cruise itinerary, respectively).

Environmental compliance and permit requests were addressed prior to the cruise. A National Environmental Policy Act categorical exclusion and associated annual confirmation of consistency with the existing Categorical Exclusion Memorandum were filed and approved by the acting NCCOS Director, Margo Schulze-Haugen.

**Table 2.** Itinerary for cruise GL-23-02. ROV = remotely operated vehicle.

| Leg | Date | Operations | Comment |
|---|---|---|---|
| 1 | August 21–25, 2023 | ROV, Ponar | Outland 1000 ROV, Ponar Dredge, Micro Ranger2 |
| 2 | August 28–September 1, 2023 | ROV, Ponar | Outland 1000 ROV, Ponar Dredge, Micro Ranger2 |
| 3 | September 4–8, 2023 | Drop Camera, Ponar | Seaviewer, Ponar Dredge, Micro Ranger2 |
| 4 | September 11–15, 2023 | Drop Camera, Ponar | Seaviewer, Ponar Dredge, Micro Ranger2 |

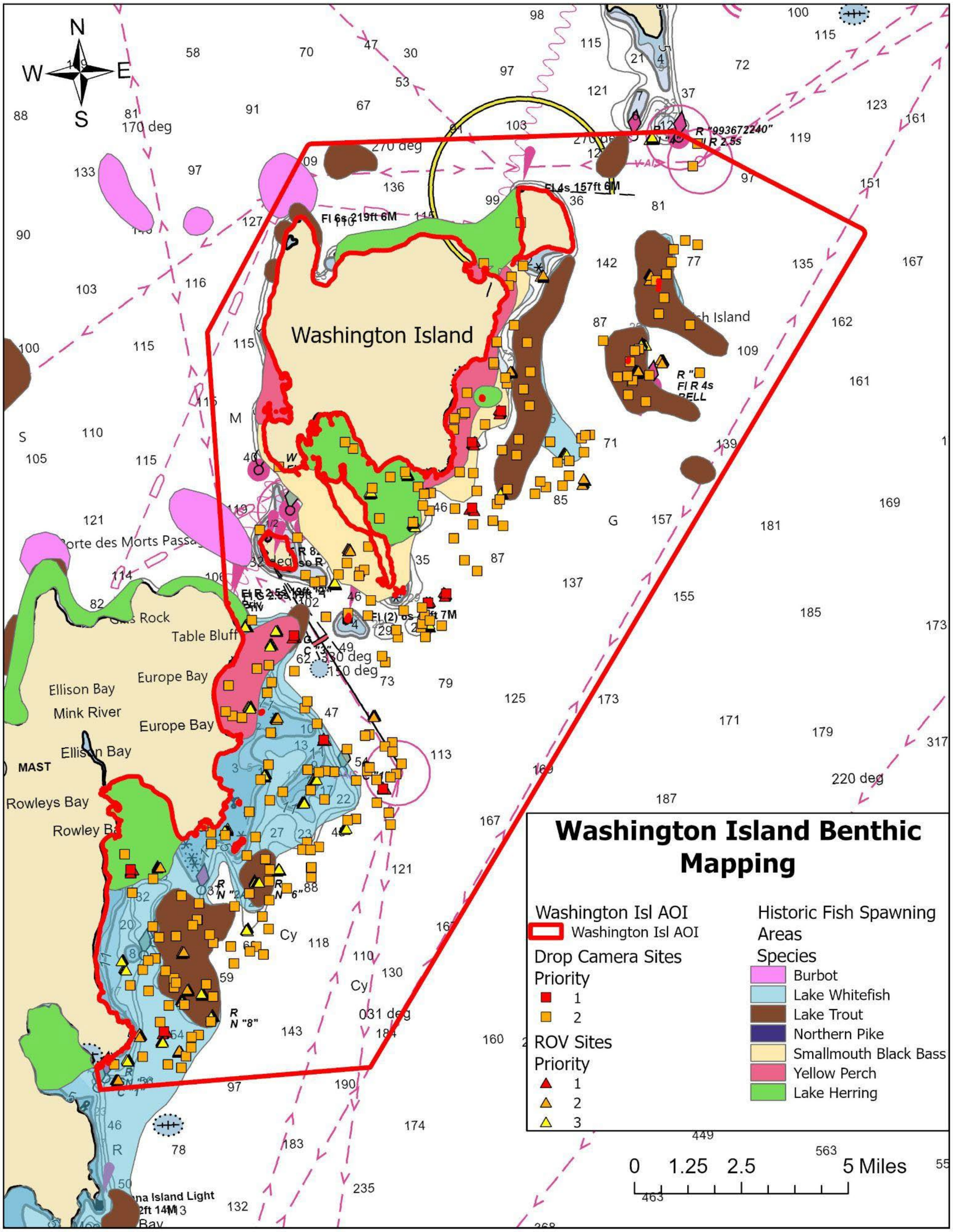


Figure 1. Map for the ground-truthing operations conducted by the NOAA Vessel *R2601 Cyclops* shows the study area, drop camera, and remotely operated vehicle (ROV) sites, as well as the historic fish spawning areas extracted from Coberly and Horrall (1980). AOI = area of interest.


Figure 2. NOAA Vessel *R2601 Cyclops* (26-ft SeaArk) used by NCCOS for the ground-truthing missions for the study area at Gills Rock Boat Ramp, Gills Rock, Wisconsin. Credit: A. Mabrouk/CSS, under contract to NOAA.

# Sampling Equipment and Methods

Ground-truthing data were collected within a survey domain defined by areas with existing lidar data. Lidar data originated from two sources: a 2022 aerial collection completed by Dewberry under contract with NOAA, and a 2012 collection by the Joint Airborne Lidar Bathymetry Technical Center of Expertise. Both datasets provide elevation data at 1-m resolution from shorelines down to approximately 30-m depth within the study area. The 2022 collection additionally included lidar reflectance at a 1-m resolution.

While ground-truthing operations were underway, multibeam echosounder (MBES) data were also collected by GLERL using NOAA Vessel *R4001*, which is outfitted with a hull-mounted Kongsberg 2040C. However, MBES data were not used to inform the selection of 2023 ground-truthing sampling sites due to the considerable post-processing required before the data are ready for analysis.

Sampling sites were chosen within the joint footprint of lidar datasets using a five-stage process:

1. **Blended DEM Generation:** Lidar data were combined to generate a blended 4-m resolution digital elevation model (DEM). The DEM resolution was aggregated to 4 m from 1-m source layers, to reduce the visibility of survey artifacts and small gaps.

2. **Terrain Metrics Calculation:** Terrain metrics were derived from the blended DEM using the 3 × 3 cell neighborhood, including the standard deviation of elevation, bottom aspect, bottom slope, and the bathymetric position index (Lundblad et al., 2006). The DEM and its derivatives, along with the backscatter intensity surface generated from lidar surveys, formed the environmental variables used to stratify sampling site selection.

3. **Stratified Random Site Selection:** Sampling sites were selected using a stratified random design employing the conditioned Latin hypercube sampling (cLHS) method (Minasny and McBratney, 2006). This sampling strategy provided an efficient way to sample the full coverage of values within the DEM, terrain variables, and backscatter intensity surfaces. A total of 852 sites were selected by the cLHS method based on the anticipated field time and the spatial density of sites used to generate high-accuracy benthic maps in other areas (Menza and Kendall, 2019).

4. **Targeted ROV Sampling:** Unique lakebed features identified in the remote data but not captured by the stratified random design were purposefully chosen for ROV sampling. These features often include isolated structures or sharp transitions discernible in DEMs or the backscatter surface, as well as morphological features with dimensions that exceeded the 3 × 3 cell neighborhood used to derive terrain metrics.

5. **Platform Allocation:** Sampling sites were assigned to different platforms based on platform efficiencies, depth, and logistic feasibility as follows:

    a. ROV sites (398 sites) were chosen to collect information at targeted features identified in stage 4, particularly discrete benthic features where it would be logistically difficult to use a drop camera and/or where more imagery data were needed to characterize feature edges and substrate gradients accurately.

    b. Drop camera sites (222 sites) were selected from sites chosen by the cLHS method that were shallower than 10 m.

    c. AUV sites (232 sites) were selected from sites chosen by the cLHS method that were deeper than 10 m. However, some of these deeper sites were reassigned to drop camera surveys due to time constraints on the USGS team.

    d. Ponar sites were chosen at a subset of sites where data were gathered by the ROV, drop camera, or AUV, and more information was needed to identify fine substrates.

    e. The first ten sites selected by the cLHS method were selected to serve as calibration sites, where all platforms were planned to deploy.

# Micro-Ranger 2 Ultra-Short Baseline System

A Sonardyne Micro-Ranger 2 USBL system was used for precise underwater acoustic positioning of the ROV, drop camera, and Ponar dredge. The system consisted of a mounted global navigation satellite system (GNSS) antenna vertically co-located with a transceiver (Figure 3), transponders attached to each data collection platform (i.e., ROV, drop camera, and Ponar), and a topside controller with a laptop. The transceiver was attached to the bottom of an aluminum pole, mounted to the port-side gunnel using a tension clamp. The clamp allowed the pole to rotate from an out-of-water horizontal position, parallel to the gunnel facilitating travel between sites, to a vertical position, submerging the transceiver in the water during data collection activities.

The transponder locations were tracked in real-time using Ranger software installed on the laptop located in the cabin of the *R2601*. The Micro-Ranger 2 system calculated the range (distance), bearing (heading), and depth from acoustic signals and showed the results on a radar-style software display (Figure 3). These measurements were combined with geographic coordinates referencing the ship and received from the external GNSS antenna to derive the geographic coordinates of the underwater transponder. Based on the GNSS and Micro-Ranger 2 equipment specifications, horizontal spatial accuracy (horizontal error) was expected to be less than 10 m in water depths down to 80 m and closer to 4 m in water depths less than 10 m.

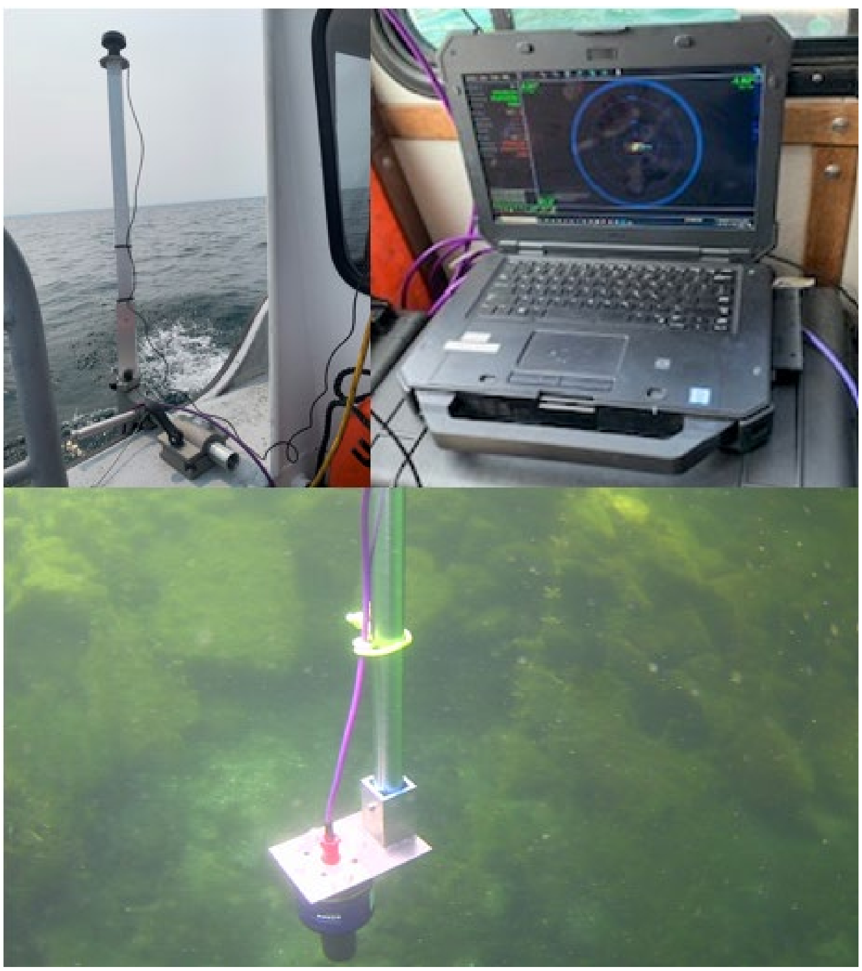

Figure 3. Top left, Micro-Ranger 2 pole with the GPS antenna. Top right, Micro-Ranger 2 application on a laptop showing the transponder distance, heading, and depth. Bottom, Micro-Ranger 2 transceiver underwater on the USBL pole. Credit: A. Mabrouk/CSS, under contract to NOAA.

# ROV

MTU operated an Outland 1000 ROV, a relatively small and light (17.7 kg) vehicle with four ⅓ horsepower thrusters and a depth rating of 300 m (Figure 3). The ROV contains a 360°-rotating, forward standard definition (SD) color camera and a downward-pointing Arctic Rays Thresher compact, deep sea 4K ultra-high-definition (UHD) camera with green lasers (4.5-cm distance between dots), as well as battery-powered green lasers (25.6-cm distance between dotes), added for scaling. Two light-emitting diode lights provided 500 lumens each, and spatial positioning was provided by a mounted Sonardyne Micro-Ranger 2 transponder. The topside control unit provided real-time video from the SD color camera onto a 15-in. LCD monitor, and videos from both SD and UHD cameras were recorded on a DVR (Figure 4). The system required 110 volts alternating current (VAC) of power, which was provided by a portable generator or Goal Zero Yeti power station.


Figure 4. The remotely operated vehicle Outland 1000 (left), and the topside control unit and ultra-short baseline system (right). Credit: A. Mabrouk/CSS, under contract to NOAA

The Outland 1000 ROV was deployed along predetermined transects typically ranging between 50 m and 150 m in length. Any transects greater than 150 m were subset into 150-m segments and collected separately on different dives. Transects were positioned using bathymetry and backscatter to locate features of interest. Since local wind and currents can affect the choice of the best direction for ROV transects, two perpendicular transects were planned to cover each feature of interest, and only one was surveyed based on the site conditions. The ROV traversed transects along the lakebed at a speed of 0.25–0.5 knots and at an altitude of 1–1.5 m.

The ROV was deployed with the vessel in one of two distinct configurations: 1) When weather conditions were calm, the ROV was deployed while the boat engine was neutral. In this configuration, the vessel was placed in gear as needed to slowly maneuver to keep the ROV umbilical taut and secure. 2) When weather conditions were less than ideal, the vessel was anchored, and the ROV was deployed off the stern to operate the ROV safely.

During ROV dives, the USBL system tracked the ROV location while it collected videos and photos across the transect. The transect was occasionally paused to inspect and/or take more detailed videos of specific features. ROV imagery collection was accomplished by a four-person team consisting of a boat captain, ROV operator, ROV deck hand, and data manager. The ROV deck hand manually deployed and recovered the ROV on the back deck with guidance from the boat captain and ROV operator (Figure 5). A data manager collected deployment information as well as important events encountered on the lakebed. Key data requirements and protocols are derived from Mabrouk et al. (2022).

Figure 5. Michigan Technology University staff recovering the ROV at the back deck of the vessel. Credit: A. Mabrouk/CSS, under contract to NOAA. ROV = remotely operated vehicle.

# Drop Camera

NCCOS scientists utilized a high-definition (HD) drop camera system to capture underwater videos. The core component of this system was the Seaviewer 6000 HD camera, capable of operating at depths of up to 300 m. The camera was outfitted with two 900-lumen dive lights, two green lasers positioned 25 cm apart for precise field-of-view measurements, a stabilization fin, and a 2.27-kg dive weight tethered to the bottom hole of the camera housing by a 50-cm-long cord (Figure 6). Additionally, a USBL transponder (Sonardyne Micro-Ranger 2) was affixed to a 100-m durable braided handline tether extending from the top hole of the camera housing for camera spatial positioning. A camera power/video cable extended from the rear of the housing, connecting to the topside console, which included a 13-in. LCD monitor, a Seaviewer DVR with GPS overlay, and a Blackmagic Design Video Assist DVR (Figure 6). The camera system operated on 110–240 VAC of power, and when necessary, an external 12-volt battery provided 4–6 hr of operation. The lasers and dive lights are powered by AA and 18650 lithium rechargeable batteries, respectively.

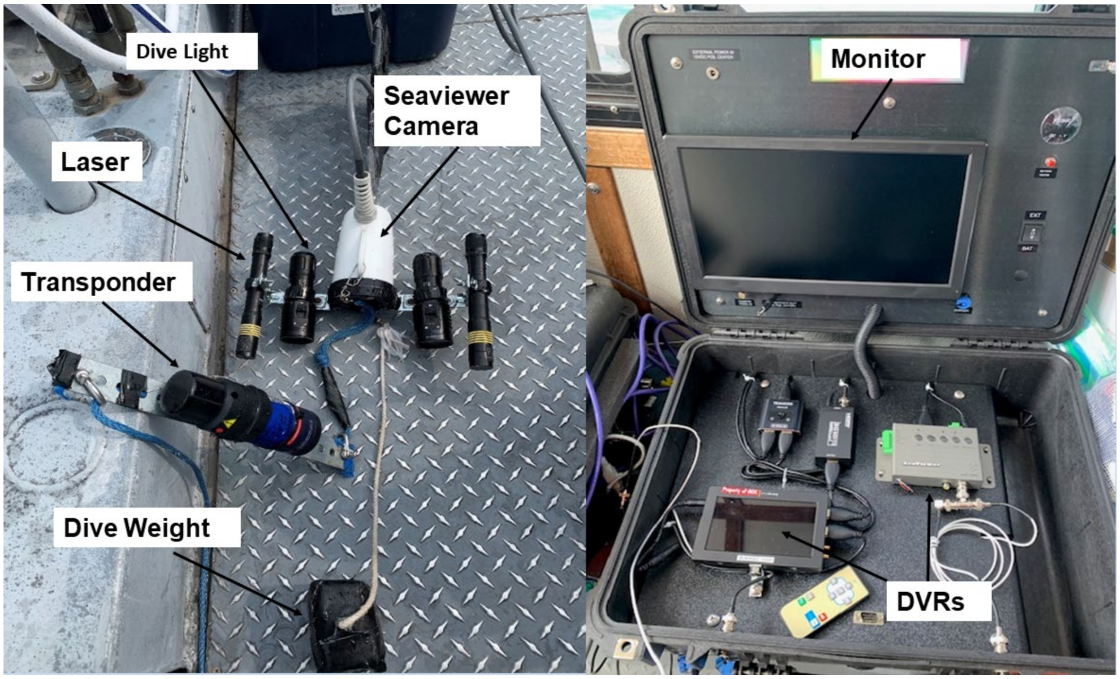

Figure 6. The drop camera Seaviewer 6000 HD with accessories (left), and the topside unit with the monitor and DVRs (right). Credit: A. Mabrouk/CSS, under contract to NOAA.

Whenever possible, the camera was deployed within 5 m of the target site off the vessel's starboard and slightly upwind so that the camera would descend as close as possible to the site as the boat drifted (Figure 7). Throughout the dive, the camera was positioned approximately 1 m above the lakebed, primarily facing downward. However, at the beginning and end of a dive, the camera orientation was adjusted, using the tether and cable to capture oblique perspectives of the bottom. When there was no risk to the camera, it was lowered closer to the bottom to inspect the substrate and biological cover. Additionally, the dive weight was used to check the substrate type, especially at sites with fine sediments.

Drop camera video collection was executed by a three-person team composed of a boat captain, a data manager, and a camera operator, who manually deployed and recovered the camera. The USBL system tracked the drop camera subsurface location throughout the dive. Additionally, a handheld Trimble GPS with an external antenna was used to track the drop camera location, especially at shallow sites, and its data were compared post-mission with the USBL system’s location data. The typical duration of drop camera video recordings was generally 3 min. Key data requirements and protocols are derived from Mabrouk et al. (2022).


Figure 7. NCCOS staff deploying the Seaviewer drop camera off the vessel starboard. Credit: K. Staley/ MTU

# Ponar Sediment Dredge

A standard 23 × 23 cm (9 × 9 in.) Ponar dredge was used to opportunistically collect sediment surface samples from unconsolidated fine substrates, including sand, mud, or clay. These samples provided additional non-visual information for these fine substrates and supplemented sediment identification from imagery data collected by the ROV and drop camera.

The dredge was deployed off the stern of the R2601 *Cyclops* using the stern A-frame and a twisted cable fed through an overhead block. A motorized cable reel positioned in the middle of the back deck was used to deploy and retrieve the dredge.

The dredge had two arms attached to two opposing semicircular jaws that close to grab an 8.2-L sample up to 89 mm depth. It had a dry weight of 23 kg, increasing to 34 kg when loaded with a sample. A weight was attached to each jaw, allowing easier penetration of the sediment. The dredge had a spring trigger mechanism, which was released upon contact with the bottom, closing the jaws on the sediment sample. A safety pin was inserted when the dredge was not in use, preventing the jaws from closing unexpectedly and safeguarding users from injury. A 500-µm AISI 316 stainless steel mesh with a rubber flap at the top of each jaw kept the sediment sample in the dredge while being recovered to the vessel. The USBL transponder was kept in a custom mount linking the dredge to the winch wire (Figure 8).

At each sampling site, the dredge was lowered slowly until within approximately 3 m of the lakebed and then was allowed to free-fall to the bottom. This strategy improved depth penetration and reduced the propensity of the Ponar jaws to close prematurely. If a Ponar dredge did not acquire sufficient sediment, the dredge was redeployed until an adequate sample was obtained.

Figure 8. Ponar dredge with attached ultra-short baseline transponder, camera, and lights. Credit: A. Mabrouk/CSS, under contract to NOAA.

When the Ponar dredge was retrieved, the stainless steel mesh was removed, and a photograph was taken to capture a placard with site metadata and to document the sediment sample’s color and texture information (Figure 9). The sediment was then assessed using the sediment data collection form (Appendix B) to record the presence of grain sizes according to the Wentworth grain size scale (Wentworth, 1922), the dominant grain size class, the presence of benthos, sediment stiffness, and sediment color. A waterproof geotechnical gauge card was used to facilitate consistent characterizations. The sample was dumped into the water after it was characterized.


Figure 9. Standard Ponar dredge with the window opened, capturing a sandy sediment and a placard with the site information. Credit: A. Mabrouk/CSS, under contract to NOAA.

# Results and Discussion

The GL-23-02 cruise accomplished all the primary mission objectives, and the resulting ground-truthing data are expected to meet the requirements to create benthic habitat maps. The cruise completed 52 ROV transects, 171 drop camera sites, and nine Ponar dredge samples (Table 3) across 20 days. Of these, 8 days were lost to bad weather, preventing the vessel from safely leaving the marina. As a result, the number of Ponar sites sampled was reduced, as ROV and drop camera data collection were prioritized during the remaining fair-weather days. Detailed information on the ROV transects, drop camera sites, and dredge samples, including deployment times and coordinates, are presented in Tables A1, A2, and A3 (Appendix A).

Imagery data and sediment sample collection followed standard operating procedures developed before the cruise, with adjustments made based on the lessons learned from the previous GL-23-01 cruise (Menza et al., 2023). Between February 2024 and September 2024, data collected from GL-23-02 will be processed, undergo quality assessment and control, and be annotated to characterize the lakebed. The cloud-based Tator image annotation platform (CVision AI, Inc.) will be used to coordinate and standardize benthic annotations. Despite the decreased Ponar samples, the GL-23-02 cruise met project requirements, and the collected data are expected to provide sufficient ground-truthing information required for generating benthic habitat maps of the study area.

A separate cruise led by USGS from May 6 to June 5, 2023, provided complementary ground-truthing data using an AUV. The AUV collected high-resolution downward-pointing still photos of the lakebed and will be annotated in concert with images and videos collected by GL-23-02. The combination of ROV transects, camera sites, dredge samples, and AUV missions will provide a full view of lakebed habitats in the operation areas.

Ground-truthing data collection was limited to shallow waters (<30 m), covering an area of 219 $km^2$ of the total study area due to the limited depth penetration of lidar-based remote sensing (Figure 10). A follow-up ground-truthing cruise is planned for 2025 and will cover the deeper waters (>30 m) that constitute the remainder of the study area. This cruise will occur after the ongoing MBES survey is complete and the final remotely sensed data are processed and available for ground-truthing mission planning.

**Table 3.** Number of ground-truthing sites/transects accomplished by sensory type during GL-23-02. ROV = remotely operated vehicle.

| Date | No. of Drop Camera Sites | No. of Ponar Sites | No. of ROV Transects |
|---|---|---|---|
| Leg 1 | 0 | 3 | 30 |
| Leg 2 | 0 | 0 | 22 |
| Leg 3 | 67 | 3 | 0 |
| Leg 4 | 104 | 3 | 0 |
| **Total** | **171** | **9** | **52** |

# ROV

Fifty-two ROV dives were completed during GL-23-02 at sites between 3-m and 22-m water depth (Figure 10). ROV transects were spread across major geomorphological features, providing high-resolution imagery across key target sites, including Fish Island, Fishermen Shoal, Waverly Shoal, Nine Shoal, Four Foot Shoal, and other complex habitats. The presence of both a forward/oblique-oriented tilt camera (pilot camera) and a stationary downward-looking camera was useful for distinct purposes. The pilot camera provided a real-time view of the ROV's forward path and served as the primary visual tool for the operator, allowing them to navigate underwater, avoid obstacles, and position the ROV in the water column for ideal footage (Figure 11). It provided a broader view of the lakebed, offering a contextual understanding of the underwater environment and its benthic habitats. This is crucial for reaching specific locations and conducting detailed surveys. The downward camera provided a close-up view of the lakebed essential for annotation with standard measures of percent cover and standardized perspectives of benthic habitats, which are expected to improve future annotation workflows using artificial intelligence.

Preliminary assessments of the video and USBL datasets indicated that the Outland 1000 ROV and Micro-Ranger 2 were likely synchronized, providing spatially explicit video data that met project requirements. Work in the field and preliminary data assessments also identified the following issues, which will be investigated in the continued effort to improve data management and annotation accuracy.

**Thresher Camera Video Quality and Size:** While the video met the mission requirements, several issues were identified that will need to be addressed in post-processing. The video imagery had a color imbalance, creating a green hue on frames, and a barrel/fisheye distortion, causing a spherical aberration along frame edges. The color imbalance was probably caused by insufficient light, suggesting the need for a brighter light source in future missions. The barrel/fisheye distortion can be corrected post-processing with a calibration board and will not impact annotation efforts. However, in the last two days of leg 2, the distortion was corrected by changing the camera lens type setting and will no longer be an issue.

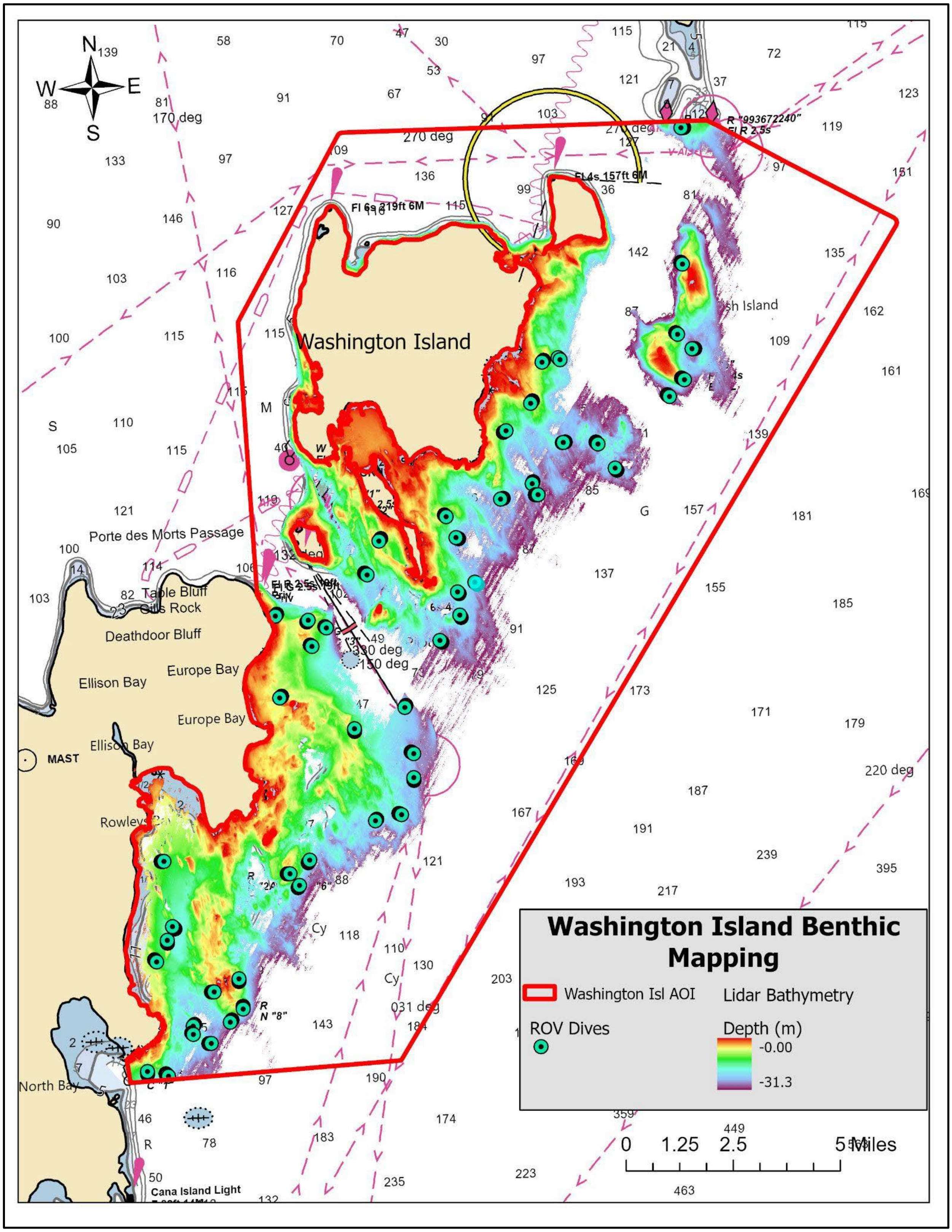


Figure 10. Map of the 52 ROV dive sites surveyed by cruise GL-23-02 and the lidar bathymetry data coverage area in the study area. AOI = area of interest; ROV = remotely operated vehicle.


Figure 11. ROV's Pilot camera still images of smallmouth bass (*Micropterus dolomieu*) on the left and freshwater drum (*Aplodinotus grunniens*) on the right. Credit: NOAA & MTU. ROV = remotely operated vehicle.

# Drop Camera

The drop camera was successfully deployed at 171 sites across the study area (Figure 12). A preliminary evaluation of the collected videos and USBL data indicates that the data align with the project's objectives. USBL coordinates display concise, well-defined lines, suggesting that the data will be straightforward to process and integrate with the drop camera videos. The camera's adjustable orientation underwater proved advantageous, functioning similarly to the dual-camera setup of the ROV. The forward-facing orientation allowed for better identification of large-scale structures, while downward orientation provided more accurate assessments of benthic cover. The drop camera's efficiency was notable in shallow areas, enabling data collection from up to 44 sites per day.

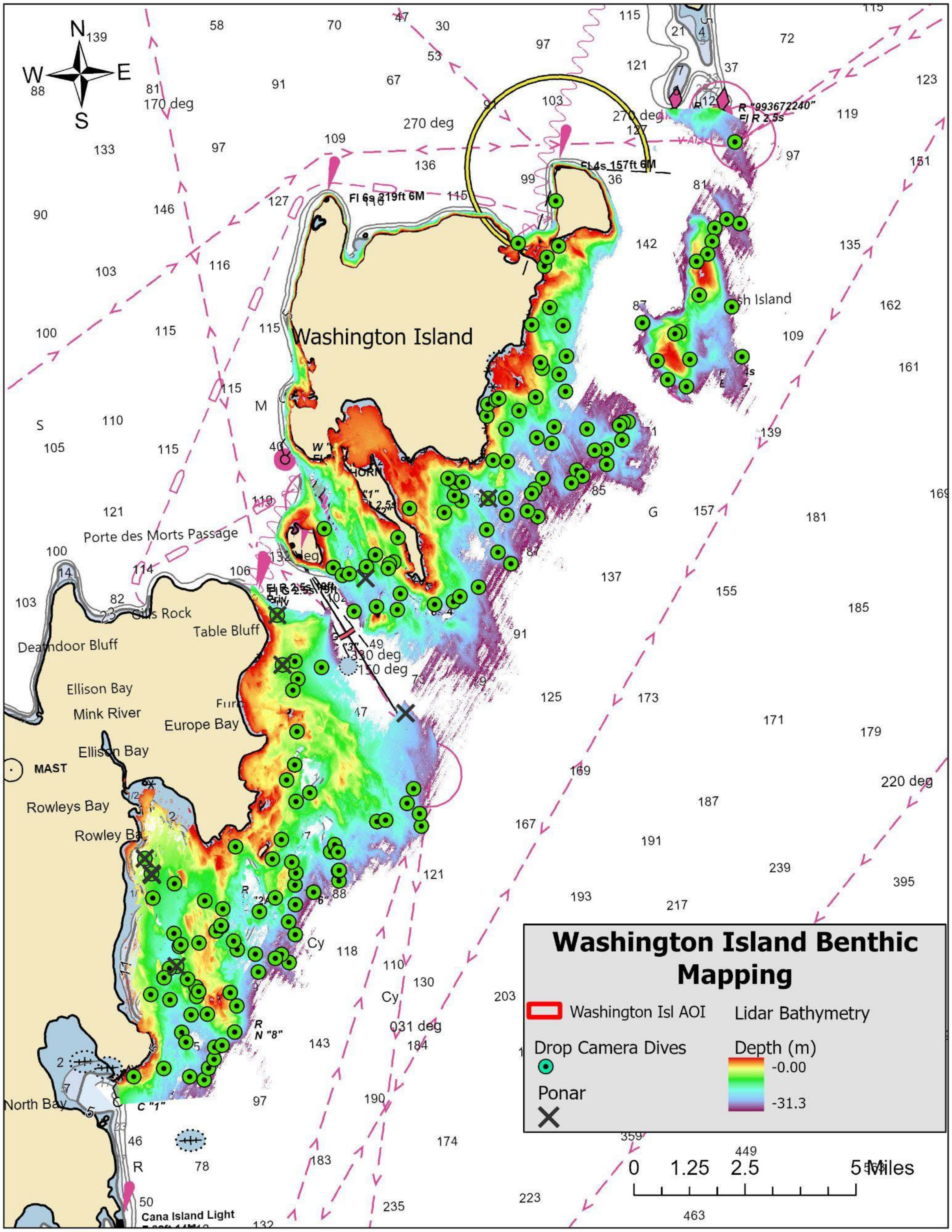


Figure 12. Map of the 171 drop camera dives and nine Ponar sites surveyed by cruise GL-23-02.

## Ponar

The Ponar dredge was used to collect samples at nine sites (Figure 12), primarily located in the southern and central areas of the study region. These samples were classified as follows: five were composed of sand, two consisted of silt/clay, and one contained a mix of sand and pebbles. Poor weather was not the only factor that limited the number of Ponar samples; it was also noted that many of the shallow sites surveyed were dominated by boulders and cobbles, making them unsuitable for Ponar dredge collection.

## AUV

The USGS AUV collected imagery at seven sites throughout the study area collected October 3–6, 2023 (Figure 13). Unlike other platforms, it also collected imagery between sites along transects. Each transect was generated prior to the field season, based on a traveling-salesman algorithm to minimize the distance traveled by the AUV. Currently, the plan is to focus on annotating images within only a short (i.e., 10-m) buffer around each site to correspond with the other datasets, but there is the potential to extend annotations to the rest of the imagery collection if needed. Preliminary reviews of the AUV imagery indicate they will complement the imagery collected during GL-23-02 by the ROV and drop camera.

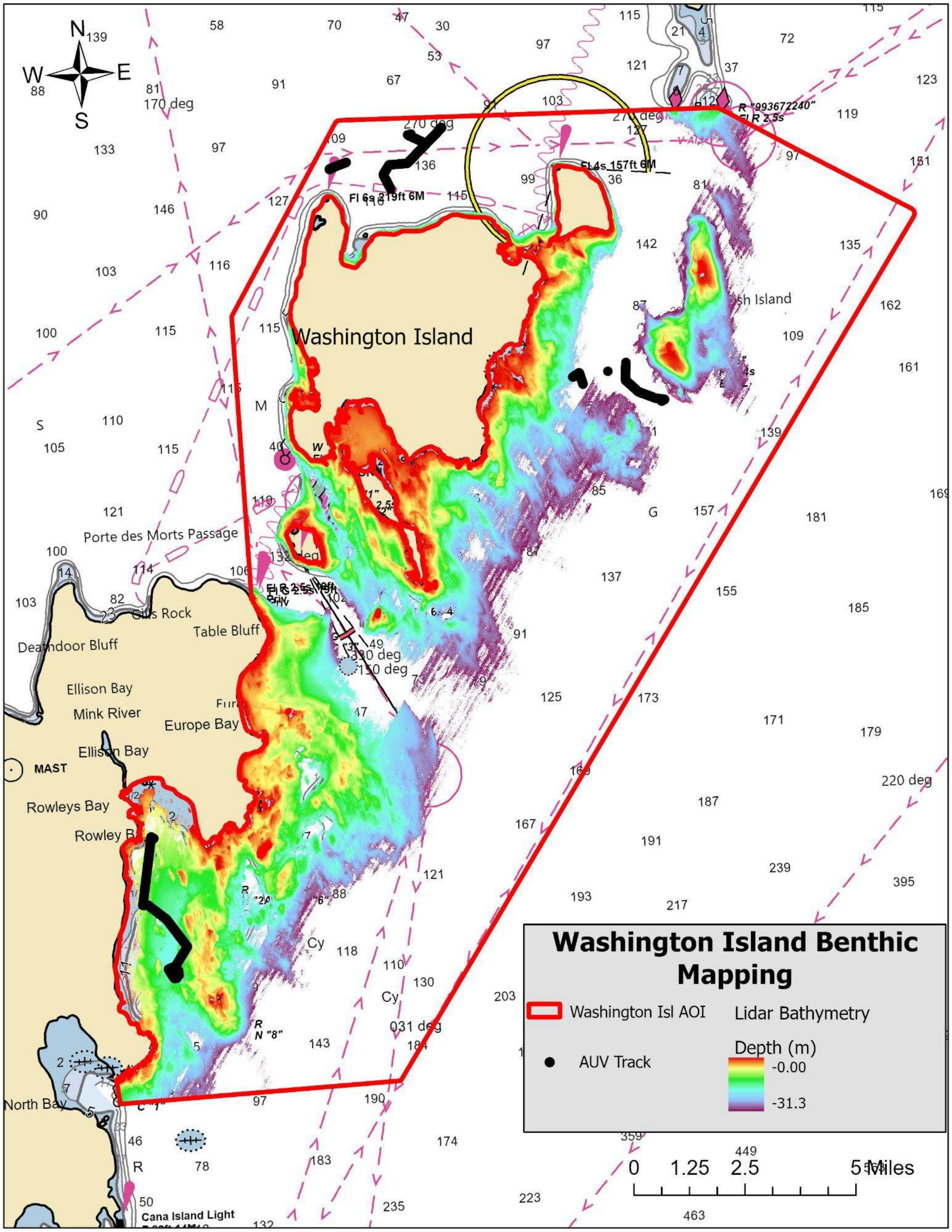


Figure 13. Map of the autonomous underwater vehicle (AUV) dive tracks completed by the U.S. Geological Survey Great Lakes Science Center and lidar bathymetry data coverage area in the study area.

# Data Accessibility

The video data from this cruise and video annotations of lakebed characteristics will be archived at the NOAA National Centers for Environmental Information (NCEI) within 1 year of completing quality assurance procedures. Data will be made publicly available through the NCEI data dissemination portal at that time.

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# Appendix A: Site Information

Table A1. Remotely operated vehicle (ROV) dive list for cruise GL-23-02. Deployment IDs are consecutive. Coordinates belong to ROV launch locations, and depth values are the on-bottom depths at the time of ROV landing. Dates and times are in Coordinated Universal Time (UTC).

| Deployment ID | Transect ID | Target Site ID | Launch Date | Launch Time (hr:min:s) | Latitude (DD) | Longitude (DD) | Depth (m) | Bottom Time (hr:min:s) |
|---|---|---|---|---|---|---|---|---|
| GL2302_L1_R001 | T01a | 1 | 8/21/2023 | 17:06:20 | 45.291673 | −86.871995 | 16.9 | 0:29:22 |
| GL2302_L1_R002 | T37a | 449 | 8/21/2023 | 18:24:03 | 45.296876 | −86.925818 | 3.2 | 0:11:54 |
| GL2302_L1_R003 | T38a | 507 | 8/21/2023 | 19:28:47 | 45.308320 | −86.917462 | 7.6 | 0:15:16 |
| GL2302_L1_R004 | T07a | 7 | 8/21/2023 | 20:30:25 | 45.288766 | −86.880838 | 12.0 | 0:10:23 |
| GL2302_L1_R005 | T39a | 515 | 8/21/2023 | 21:03:09 | 45.280692 | −86.880331 | 12.8 | 0:08:15 |
| GL2302_L1_R006 | T35a | 483 | 8/23/2023 | 16:55:54 | 45.284030 | −86.968585 | 5.3 | 0:10:56 |
| GL2302_L1_R007 | T36a | 491 | 8/23/2023 | 17:33:07 | 45.281055 | −86.954309 | 6.0 | 0:08:52 |
| GL2302_L1_R008 | T10a | 10 | 8/23/2023 | 18:03:45 | 45.279256 | −86.945768 | 9.1 | 0:08:34 |
| GL2302_L1_R009 | T32a | 459 | 8/24/2023 | 14:24:34 | 45.256295 | −86.967601 | 4.6 | 0:10:43 |
| GL2302_L1_R010 | T4a | 4 | 8/24/2023 | 14:58:14 | 45.243523 | −86.933264 | 5.9 | 0:16:04 |
| GL2302_L1_R011 | T33b | 471 | 8/24/2023 | 15:39:50 | 45.251708 | −86.908290 | 16.2 | 0:09:09 |
| GL2302_L1_R012 | T03a | 247 | 8/24/2023 | 16:23:48 | 45.227222 | −86.905752 | 16.3 | 0:08:59 |
| GL2302_L1_R013 | T27a | 420 | 8/24/2023 | 16:49:49 | 45.213626 | −86.924221 | 14.1 | 0:07:08 |
| GL2302_L1_R014 | T25b | 411 | 8/24/2023 | 17:16:11 | 45.200628 | −86.956921 | 12.7 | 0:09:41 |
| GL2302_L1_R015 | T24b | 403 | 8/24/2023 | 17:39:55 | 45.196271 | −86.966608 | 5.6 | 0:12:27 |
| GL2302_L1_R016 | T05a | 259 | 8/24/2023 | 19:09:53 | 45.201922 | −87.026675 | 7.9 | 0:08:39 |
| GL2302_L1_R017 | T20a | 367 | 8/24/2023 | 19:48:32 | 45.168078 | −87.031813 | 7.6 | 0:09:11 |
| GL2302_L1_R018 | T17a | 343 | 8/24/2023 | 20:18:51 | 45.157290 | −87.004794 | 5.1 | 0:09:11 |
| GL2302_L1_R019 | T16a | 332 | 8/24/2023 | 20:47:51 | 45.152108 | −86.991275 | 7.7 | 0:09:43 |
| GL2302_L1_R020 | T40a | 526 | 8/25/2023 | 13:51:37 | 45.314900 | −86.885758 | 5.4 | 0:08:32 |
| GL2302_L1_R021 | T09a | 9 | 8/25/2023 | 14:16:03 | 45.320389 | −86.858074 | 13.4 | 0:09:48 |
| GL2302_L1_R022 | T43a | 547 | 8/25/2023 | 14:39:08 | 45.325586 | −86.843489 | 18.5 | 0:09:41 |
| GL2302_L1_R023 | T06a | 265 | 8/25/2023 | 15:02:16 | 45.343171 | −86.855565 | 12.1 | 0:11:57 |
| GL2302_L1_R024 | T08a | 8 | 8/25/2023 | 15:30:25 | 45.352936 | −86.842404 | 6.1 | 0:08:43 |
| GL2302_L1_R025 | T46a | 571 | 8/25/2023 | 15:50:12 | 45.366477 | −86.836333 | 4.8 | 0:07:30 |

| Deployment ID | Transect ID | Target Site ID | Launch Date | Launch Time (hr:min:s) | Latitude (DD) | Longitude (DD) | Depth (m) | Bottom Time (hr:min:s) |
|---|---|---|---|---|---|---|---|---|
| GL2302_L1_R026 | T51b | 615 | 8/25/2023 | 16:20:46 | 45.397787 | −86.819729 | 4.8 | 0:07:43 |
| GL2302_L1_R027 | T52b | 619 | 8/25/2023 | 18:04:22 | 45.443252 | −86.764897 | 12.5 | 0:07:54 |
| GL2302_L1_R028 | T50b | 607 | 8/25/2023 | 18:38:05 | 45.397846 | −86.768793 | 13.0 | 0:09:06 |
| GL2302_L1_R029 | T49a | 595 | 8/25/2023 | 19:07:01 | 45.374118 | −86.772467 | 7.7 | 0:10:10 |
| GL2302_L1_R030 | T48a | 590 | 8/25/2023 | 19:41:05 | 45.368510 | −86.764930 | 21.2 | 0:11:01 |
| GL2302_L2_R001 | T45b | 570 | 8/28/2023 | 16:20:48 | 45.337543 | −86.811709 | 13.9 | 0:08:59 |
| GL2302_L2_R002 | T44b | 559 | 8/28/2023 | 16:58:06 | 45.328461 | −86.803096 | 15.0 | 0:09:15 |
| GL2302_L2_R003 | T57a | 659 | 8/30/2023 | 18:52:37 | 45.179014 | −87.022506 | 12.3 | 0:14:49 |
| GL2302_L2_R004 | T56a | 654 | 8/30/2023 | 19:35:02 | 45.175247 | −87.026364 | 12.9 | 0:16:17 |
| GL2302_L2_R005 | T02b | 2 | 8/30/2023 | 20:22:14 | 45.146540 | −87.014737 | 10.9 | 0:10:50 |
| GL2302_L2_R006 | T14b | 320 | 8/30/2023 | 20:48:50 | 45.143670 | −87.016210 | 11.9 | 0:07:36 |
| GL2302_L2_R007 | T10a | 290 | 8/30/2023 | 21:19:43 | 45.131196 | −87.037999 | 8.5 | 0:12:32 |
| GL2302_L2_R008 | T53a | 630 | 8/30/2023 | 21:52:27 | 45.129362 | −87.028014 | 14.5 | 0:14:29 |
| GL2302_L2_R009 | T15a | 324 | 8/30/2023 | 22:33:12 | 45.139941 | −87.008268 | 16.4 | 0:08:36 |
| GL2302_L2_R010 | T54a | 635 | 8/30/2023 | 23:03:58 | 45.147617 | −86.996771 | 12.8 | 0:08:08 |
| GL2302_L2_R011 | T55b | 650 | 8/30/2023 | 23:31:59 | 45.161432 | −86.992754 | 7.4 | 0:09:45 |
| GL2302_L2_R012 | T58b | 671 | 8/30/2023 | 0:02:06 | 45.191469 | −86.962952 | 14.1 | 0:08:32 |
| GL2302_L2_R013 | T61b | 695 | 8/31/2023 | 13:47:51 | 45.273222 | −86.953087 | 7.6 | 0:15:05 |
| GL2302_L2_R014 | T59a | 678 | 8/31/2023 | 14:27:10 | 45.214870 | −86.912235 | 12.5 | 0:10:52 |
| GL2302_L2_R015 | T60b | 690 | 8/31/2023 | 14:56:42 | 45.235326 | −86.905368 | 18.5 | 0:09:50 |
| GL2302_L2_R016 | T62b | 703 | 8/31/2023 | 15:31:08 | 45.272591 | −86.889932 | 20.3 | 0:08:54 |
| GL2302_L2_R017 | T63b | 711 | 8/31/2023 | 16:02:41 | 45.307307 | −86.880171 | 16.4 | 0:10:31 |
| GL2302_L2_R018 | T64b | 719 | 8/31/2023 | 17:10:56 | 45.321189 | −86.842681 | 20.6 | 0:06:29 |
| GL2302_L2_R019 | T65a | 725 | 8/31/2023 | 17:40:27 | 45.338437 | −86.828780 | 17.2 | 0:09:00 |
| GL2302_L2_R020 | T67b | 743 | 8/31/2023 | 18:09:38 | 45.353324 | −86.777629 | 20.8 | 0:10:25 |
| GL2302_L2_R021 | T68b | 754 | 8/31/2023 | 18:35:21 | 45.358150 | −86.769123 | 15.8 | 0:12:18 |
| GL2302_L2_R022 | T66b | 738 | 8/31/2023 | 19:09:50 | 45.366466 | −86.828399 | 12.0 | 0:08:54 |

Table A2. Drop camera dive list for NOAA Vessel *R2601* cruise GL-23-02. Deployment IDs are consecutive. Coordinates belong to drop camera launch locations, and depth values are the on-bottom depths at the time of drop camera landing. Dates and times are in Coordinated Universal Time (UTC).

| Deployment ID | Target Site ID | Launch Date | Launch Time (hr:min:s) | Latitude (DD) | Longitude (DD) | Depth (m) | Bottom Time (hr:min:s) |
|---|---|---|---|---|---|---|---|
| GL2302_L3_D001 | 198 | 9/8/2023 | 15:49:32 | 45.198497 | −87.017386 | 9.1 | 0:03:31 |
| GL2302_L3_D002 | 146 | 9/8/2023 | 16:02:38 | 45.207136 | −87.030645 | 6.3 | 0:02:52 |
| GL2302_L3_D003 | 5 | 9/8/2023 | 16:36:23 | 45.201924 | −87.028044 | 7.6 | 0:02:33 |
| GL2302_L3_D004 | 38 | 9/8/2023 | 17:03:33 | 45.193958 | −87.027620 | 8.5 | 0:02:20 |
| GL2302_L3_D005 | 86 | 9/8/2023 | 17:16:29 | 45.182294 | −87.018412 | 12.1 | 0:02:15 |
| GL2302_L3_D007 | 155 | 9/8/2023 | 17:32:28 | 45.178567 | −87.015585 | 10.4 | 0:01:38 |
| GL2302_L3_D008 | 27 | 9/8/2023 | 17:42:15 | 45.171438 | −87.017721 | 10.9 | 0:02:00 |
| GL2302_L3_D009 | 106 | 9/8/2023 | 17:58:30 | 45.170843 | −87.021119 | 12.4 | 0:01:53 |
| GL2302_L3_D010 | 81 | 9/8/2023 | 18:05:57 | 45.167764 | −87.023866 | 10.6 | 0:01:41 |
| GL2302_L3_D011 | 204 | 9/8/2023 | 18:44:57 | 45.162605 | −87.030124 | 5.8 | 0:02:05 |
| GL2302_L3_D012 | 160 | 9/8/2023 | 18:53:30 | 45.160500 | −87.021459 | 11.5 | 0:01:49 |
| GL2302_L3_D013 | 217 | 9/8/2023 | 19:02:04 | 45.155344 | −87.011991 | 12.7 | 0:02:32 |
| GL2302_L3_D014 | 191 | 9/8/2023 | 19:11:03 | 45.149807 | −87.016455 | 11.8 | 0:01:42 |
| GL2302_L3_D015 | 2 | 9/8/2023 | 19:23:32 | 45.146540 | −87.014737 | 10.9 | 0:02:12 |
| GL2302_L3_D016 | 36 | 9/8/2023 | 19:35:32 | 45.138274 | −87.025380 | 12.2 | 0:01:34 |
| GL2302_L3_D017 | 121 | 9/8/2023 | 19:49:50 | 45.135975 | −87.039153 | 3.5 | 0:03:19 |
| GL2302_L3_D018 | 158 | 9/8/2023 | 20:05:44 | 45.135360 | −87.013437 | 17.4 | 0:03:43 |
| GL2302_L3_D019 | 114 | 9/8/2023 | 20:20:53 | 45.134064 | −87.007027 | 21.1 | 0:02:04 |
| GL2302_L3_D020 | 35 | 9/8/2023 | 20:28:57 | 45.137926 | −87.004624 | 20.7 | 0:01:50 |
| GL2302_L3_D021 | 232 | 9/8/2023 | 20:38:08 | 45.140842 | −87.001991 | 22.5 | 0:01:41 |
| GL2302_L3_D022 | 124 | 9/8/2023 | 20:49:39 | 45.149376 | −86.992145 | 11.1 | 0:02:01 |
| GL2302_L3_D023 | 208 | 9/8/2023 | 21:02:19 | 45.157828 | −86.990694 | 8.4 | 0:01:48 |
| GL2302_L3_D024 | 51 | 9/8/2023 | 21:18:01 | 45.161366 | −87.009168 | 5.9 | 0:02:00 |
| GL2302_L3_D025 | 71 | 9/8/2023 | 21:28:02 | 45.164472 | −87.009092 | 5.8 | 0:02:20 |
| GL2302_L3_D026 | 162 | 9/8/2023 | 21:35:07 | 45.167145 | −87.013024 | 8.5 | 0:02:12 |
| GL2302_L3_D027 | 144 | 9/8/2023 | 21:52:25 | 45.168818 | −86.980079 | 21.1 | 0:02:00 |
| GL2302_L3_D028 | 220 | 9/8/2023 | 22:04:14 | 45.171488 | −86.965838 | 18.7 | 0:01:49 |

| Deployment ID | Target Site ID | Launch Date | Launch Time (hr:min:s) | Latitude (DD) | Longitude (DD) | Depth (m) | Bottom Time (hr:min:s) |
|---|---|---|---|---|---|---|---|
| GL2302_L3_D029 | 102 | 9/8/2023 | 22:11:37 | 45.174244 | −86.969158 | 20.4 | 0:03:42 |
| GL2302_L3_D030 | 172 | 9/8/2023 | 22:22:12 | 45.174597 | −86.981337 | 12.3 | 0:01:45 |
| GL2302_L3_D032 | 174 | 9/9/2023 | 14:34:06 | 45.347214 | −86.865512 | 1.4 | 0:01:59 |
| GL2302_L3_D033 | 201 | 9/9/2023 | 14:49:01 | 45.350994 | −86.865006 | 0.0 | 0:01:18 |
| GL2302_L3_D034 | 142 | 9/9/2023 | 14:57:33 | 45.352339 | −86.861173 | 1.5 | 0:01:13 |
| GL2302_L3_D035 | 186 | 9/9/2023 | 15:02:15 | 45.352770 | −86.859793 | 2.8 | 0:01:09 |
| GL2302_L3_D036 | 42 | 9/9/2023 | 15:10:02 | 45.348518 | −86.850382 | 9.4 | 0:01:21 |
| GL2302_L3_D037 | 6 | 9/9/2023 | 15:17:07 | 45.342667 | −86.856907 | 8.0 | 0:01:17 |
| GL2302_L3_D038 | 8 | 9/9/2023 | 15:26:23 | 45.352936 | −86.842404 | 6.1 | 0:02:58 |
| GL2302_L3_D039 | 73 | 9/9/2023 | 15:38:01 | 45.354320 | −86.828689 | 16.4 | 0:01:51 |
| GL2302_L3_D040 | 156 | 9/9/2023 | 15:46:03 | 45.359995 | −86.831238 | 13.1 | 0:01:33 |
| GL2302_L3_D041 | 141 | 9/9/2023 | 15:53:34 | 45.362140 | −86.839123 | 5.6 | 0:01:24 |
| GL2302_L3_D042 | 224 | 9/9/2023 | 15:58:32 | 45.364139 | −86.839768 | 5.4 | 0:02:16 |
| GL2302_L3_D043 | 193 | 9/9/2023 | 16:07:02 | 45.365796 | −86.827697 | 12.7 | 0:01:40 |
| GL2302_L3_D044 | 55 | 9/9/2023 | 16:15:56 | 45.375762 | −86.828662 | 12.0 | 0:01:50 |
| GL2302_L3_D045 | 53 | 9/9/2023 | 16:26:42 | 45.376404 | −86.843297 | 3.7 | 0:01:35 |
| GL2302_L3_D046 | 150 | 9/9/2023 | 16:34:33 | 45.381819 | −86.834660 | 7.8 | 0:01:41 |
| GL2302_L3_D047 | 214 | 9/9/2023 | 16:48:31 | 45.395324 | −86.836537 | 1.0 | 0:01:27 |
| GL2302_L3_D048 | 123 | 9/9/2023 | 16:54:35 | 45.398238 | −86.834996 | 3.0 | 0:01:31 |
| GL2302_L3_D049 | 215 | 9/9/2023 | 17:03:27 | 45.401794 | −86.829350 | 2.4 | 0:01:32 |
| GL2302_L3_D050 | 13 | 9/9/2023 | 17:26:08 | 45.403144 | −86.848130 | 5.1 | 0:01:39 |
| GL2302_L3_D051 | 120 | 9/9/2023 | 17:40:00 | 45.416539 | −86.829651 | 1.2 | 0:03:48 |
| GL2302_L3_D052 | 145 | 9/9/2023 | 19:00:39 | 45.441059 | −86.743231 | 19.2 | 0:01:27 |
| GL2302_L3_D053 | 18 | 9/9/2023 | 19:09:26 | 45.433477 | −86.745835 | 19.4 | 0:01:42 |
| GL2302_L3_D054 | 181 | 9/9/2023 | 19:20:00 | 45.406768 | −86.744997 | 21.6 | 0:01:56 |
| GL2302_L3_D055 | 95 | 9/9/2023 | 19:28:57 | 45.408374 | −86.750855 | 19.6 | 0:01:53 |
| GL2302_L3_D056 | 109 | 9/9/2023 | 19:36:27 | 45.405497 | −86.756579 | 24.2 | 0:02:57 |
| GL2302_L3_D057 | 14 | 9/9/2023 | 19:45:15 | 45.401233 | −86.757863 | 17.8 | 0:03:53 |

| Deployment ID | Target Site ID | Launch Date | Launch Time (hr:min:s) | Latitude (DD) | Longitude (DD) | Depth (m) | Bottom Time (hr:min:s) |
|---|---|---|---|---|---|---|---|
| GL2302_L3_D058 | 218 | 9/9/2023 | 19:54:50 | 45.397215 | −86.760486 | 3.6 | 0:01:48 |
| GL2302_L3_D059 | 133 | 9/9/2023 | na | 45.395173 | −86.765593 | 0.8 | NA |
| GL2302_L3_D060 | 180 | 9/9/2023 | 20:18:25 | 45.383858 | −86.764950 | 5.3 | 0:03:05 |
| GL2302_L3_D061 | 178 | 9/9/2023 | 20:31:12 | 45.379694 | −86.750138 | 23.3 | 0:01:45 |
| GL2302_L3_D062 | 19 | 9/9/2023 | 20:45:42 | 45.372185 | −86.775036 | 5.7 | 0:01:53 |
| GL2302_L3_D063 | 168 | 9/9/2023 | 20:51:37 | 45.371676 | −86.777068 | 4.7 | 0:01:56 |
| GL2302_L3_D065 | 30 | 9/9/2023 | 21:07:38 | 45.375431 | −86.792111 | 24.2 | 0:02:26 |
| GL2302_L3_D066 | 66 | 9/9/2023 | 21:20:14 | 45.362998 | −86.785875 | 9.5 | 0:01:45 |
| GL2302_L3_D067 | 59 | 9/9/2023 | 21:29:38 | 45.356750 | −86.781072 | 21.4 | 0:01:33 |
| GL2302_L3_D068 | 112 | 9/9/2023 | 21:38:16 | 45.354250 | −86.772732 | 19.4 | 0:01:35 |
| GL2302_L3_D069 | 152 | 9/9/2023 | 21:47:15 | 45.363130 | −86.770590 | 12.7 | 0:01:58 |
| GL2302_L3_D070 | 101 | 9/9/2023 | 21:58:15 | 45.363322 | −86.746303 | 23.1 | 0:01:49 |
| GL2302_L4_D002 | 77 | 9/11/2023 | 14:37:51 | 45.299641 | −86.939168 | 8.4 | 0:01:40 |
| GL2302_L4_D003 | 207 | 9/11/2023 | 14:45:12 | 45.297154 | −86.934885 | 7.4 | 0:02:28 |
| GL2302_L4_D004 | 143 | 9/11/2023 | 14:53:47 | 45.297450 | −86.931862 | 9.4 | 0:02:03 |
| GL2302_L4_D005 | 222 | 9/11/2023 | 15:03:51 | 45.285243 | −86.930117 | 25.3 | 0:02:27 |
| GL2302_L4_D006 | 10 | 9/11/2023 | 15:15:20 | 45.279256 | −86.945768 | 9.1 | 0:01:59 |
| GL2302_L4_D007 | 70 | 9/11/2023 | 15:27:41 | 45.267212 | −86.946162 | 12.7 | 0:01:07 |
| GL2302_L4_D008 | 179 | 9/11/2023 | 15:36:30 | 45.269567 | −86.958322 | 6.6 | 0:01:48 |
| GL2302_L4_D009 | 138 | 9/11/2023 | 15:43:38 | 45.268516 | −86.964135 | 7.6 | 0:01:44 |
| GL2302_L4_D010 | 130 | 9/11/2023 | 16:06:16 | 45.263706 | −86.957293 | 7.2 | 0:01:19 |
| GL2302_L4_D011 | 216 | 9/11/2023 | 16:34:08 | 45.260197 | −86.959590 | 7.3 | 0:02:10 |
| GL2302_L4_D012 | 153 | 9/11/2023 | 17:39:01 | 45.312443 | −86.942445 | 6.2 | 0:02:27 |
| GL2302_L4_D013 | 175 | 9/11/2023 | 17:53:33 | 45.299443 | −86.923403 | 11.8 | 0:03:38 |
| GL2302_L4_D014 | 41 | 9/11/2023 | 18:04:46 | 45.303220 | −86.919112 | 4.6 | 0:01:44 |
| GL2302_L4_D015 | 90 | 9/11/2023 | 18:22:53 | 45.308559 | −86.908542 | 3.0 | 0:02:14 |
| GL2302_L4_D016 | 154 | 9/11/2023 | 18:31:56 | 45.300703 | −86.910966 | 3.9 | 0:01:24 |
| GL2302_L4_D017 | 74 | 9/11/2023 | 18:36:20 | 45.300056 | −86.913033 | 4.2 | 0:01:50 |

| Deployment ID | Target Site ID | Launch Date | Launch Time (hr:min:s) | Latitude (DD) | Longitude (DD) | Depth (m) | Bottom Time (hr:min:s) |
|---|---|---|---|---|---|---|---|
| GL2302_L4_D018 | 161 | 9/11/2023 | 18:42:31 | 45.298733 | −86.913532 | 7.6 | 0:01:40 |
| GL2302_L4_D019 | 167 | 9/11/2023 | 18:54:48 | 45.286208 | −86.919481 | 2.9 | 0:02:10 |
| GL2302_L4_D020 | 184 | 9/11/2023 | 19:04:54 | 45.285175 | −86.909995 | 14.6 | 0:01:28 |
| GL2302_L4_D021 | 75 | 9/11/2023 | 19:13:12 | 45.290277 | −86.908304 | 11.3 | 0:02:32 |
| GL2302_L4_D022 | 115 | 9/11/2023 | 19:26:23 | 45.286429 | −86.892741 | 15.3 | 0:01:42 |
| GL2302_L4_D023 | 122 | 9/11/2023 | 19:37:01 | 45.287230 | −86.883826 | 15.1 | 0:01:50 |
| GL2302_L4_D024 | 7 | 9/11/2023 | 19:45:31 | 45.288766 | −86.880838 | 12.0 | 0:02:10 |
| GL2302_L4_D025 | 1 | 9/11/2023 | 19:55:33 | 45.291673 | −86.871995 | 16.9 | 0:01:52 |
| GL2302_L4_D026 | 182 | 9/11/2023 | 20:12:29 | 45.316290 | −86.886675 | 4.2 | 0:01:34 |
| GL2302_L4_D027 | 49 | 9/11/2023 | 20:28:11 | 45.317979 | −86.902748 | 4.4 | 0:01:46 |
| GL2302_L4_D028 | 60 | 9/11/2023 | 20:44:33 | 45.319954 | −86.878591 | 10.1 | 0:01:42 |
| GL2302_L4_D029 | 210 | 9/11/2023 | 20:50:59 | 45.321821 | −86.881688 | 12.4 | 0:02:20 |
| GL2302_L4_D030 | 203 | 9/11/2023 | 21:00:02 | 45.325762 | −86.880837 | 12.7 | 0:02:21 |
| GL2302_L4_D031 | 111 | 9/11/2023 | 21:07:10 | 45.325975 | −86.877698 | 12.9 | 0:01:19 |
| GL2302_L4_D032 | 52 | 9/11/2023 | 21:13:37 | 45.328196 | −86.883665 | 9.9 | 0:01:23 |
| GL2302_L4_D033 | 68 | 9/13/2023 | 17:42:53 | 45.285016 | −86.965731 | 9.6 | 0:02:12 |
| GL2302_L4_D034 | 194 | 9/13/2023 | 19:19:57 | 45.343689 | −86.800231 | 9.8 | 0:01:40 |
| GL2302_L4_D035 | 226 | 9/13/2023 | 19:24:41 | 45.343584 | −86.802414 | 18.2 | 0:02:38 |
| GL2302_L4_D036 | 83 | 9/13/2023 | 19:31:06 | 45.342615 | −86.804255 | 20.8 | 0:01:47 |
| GL2302_L4_D037 | 23 | 9/13/2023 | 19:39:46 | 45.337861 | −86.803353 | 12.0 | 0:01:39 |
| GL2302_L4_D038 | 132 | 9/13/2023 | 19:47:10 | 45.335119 | −86.810599 | 13.5 | 0:03:15 |
| GL2302_L4_D039 | 67 | 9/13/2023 | 19:55:31 | 45.334777 | −86.816190 | 20.0 | 0:01:41 |
| GL2302_L4_D040 | 117 | 9/13/2023 | 20:04:37 | 45.341830 | −86.819460 | 12.3 | 0:01:59 |
| GL2302_L4_D041 | 62 | 9/13/2023 | 20:13:49 | 45.343068 | −86.834505 | 18.0 | 0:01:49 |
| GL2302_L4_D042 | 80 | 9/13/2023 | 20:22:29 | 45.339623 | −86.842671 | 16.1 | 0:01:39 |
| GL2302_L4_D043 | 185 | 9/13/2023 | 20:31:21 | 45.337723 | −86.835784 | 15.3 | 0:01:19 |
| GL2302_L4_D044 | 187 | 9/13/2023 | 20:40:30 | 45.328472 | −86.824862 | 22.7 | 0:02:04 |
| GL2302_L4_D045 | 91 | 9/13/2023 | 20:51:30 | 45.330070 | −86.810960 | 18.1 | 0:02:14 |

| Deployment ID | Target Site ID | Launch Date | Launch Time (hr:min:s) | Latitude (DD) | Longitude (DD) | Depth (m) | Bottom Time (hr:min:s) |
|---|---|---|---|---|---|---|---|
| GL2302_L4_D046 | 108 | 9/13/2023 | 20:58:28 | 45.326808 | −86.814225 | 22.5 | 0:01:35 |
| GL2302_L4_D047 | 20 | 9/13/2023 | 21:14:39 | 45.326523 | −86.822265 | 23.6 | 0:01:41 |
| GL2302_L4_D048 | 183 | 9/13/2023 | 21:21:17 | 45.324371 | −86.827631 | 18.1 | 0:01:27 |
| GL2302_L4_D049 | 134 | 9/13/2023 | 21:28:53 | 45.326281 | −86.840717 | 19.3 | 0:01:57 |
| GL2302_L4_D050 | 113 | 9/13/2023 | 21:37:28 | 45.326084 | −86.855494 | 14.0 | 0:02:01 |
| GL2302_L4_D051 | 89 | 9/13/2023 | 21:45:04 | 45.332189 | −86.856857 | 9.8 | 0:02:01 |
| GL2302_L4_D052 | 188 | 9/13/2023 | 21:51:03 | 45.332710 | −86.863403 | 8.0 | 0:01:37 |
| GL2302_L4_D053 | 84 | 9/13/2023 | 21:58:59 | 45.320345 | −86.866303 | 18.5 | 0:01:37 |
| GL2302_L4_D054 | 9 | 9/13/2023 | 22:12:46 | 45.320389 | −86.858074 | 13.4 | 0:03:18 |
| GL2302_L4_D055 | 128 | 9/13/2023 | 22:22:37 | 45.322856 | −86.844593 | 17.8 | 0:01:29 |
| GL2302_L4_D056 | 48 | 9/13/2023 | 22:27:26 | 45.321400 | −86.846052 | 16.6 | 0:01:44 |
| GL2302_L4_D057 | 15 | 9/13/2023 | 22:34:48 | 45.313916 | −86.843508 | 22.9 | 0:03:18 |
| GL2302_L4_D058 | 140 | 9/13/2023 | 22:42:46 | 45.315813 | −86.848287 | 21.7 | 0:01:06 |
| GL2302_L4_D059 | 126 | 9/13/2023 | 22:49:27 | 45.314799 | −86.857934 | 18.0 | 0:02:01 |
| GL2302_L4_D060 | 165 | 9/13/2023 | 22:57:20 | 45.310301 | −86.867399 | 16.5 | 0:03:47 |
| GL2302_L4_D061 | 97 | 9/13/2023 | 23:06:20 | 45.302734 | −86.862671 | 16.4 | 0:01:47 |
| GL2302_L4_D062 | 100 | 9/13/2023 | 23:13:31 | 45.298919 | −86.856788 | 22.1 | 0:02:29 |
| GL2302_L4_D063 | 16 | 9/14/2023 | 14:01:46 | 45.246613 | −86.958606 | 2.9 | 0:01:42 |
| GL2302_L4_D064 | 12 | 9/14/2023 | 14:12:29 | 45.235812 | −86.960181 | 7.1 | 0:01:46 |
| GL2302_L4_D065 | 61 | 9/14/2023 | 14:21:14 | 45.230844 | −86.964235 | 5.4 | 0:02:04 |
| GL2302_L4_D066 | 225 | 9/14/2023 | 14:28:29 | 45.226439 | −86.953806 | 11.2 | 0:01:40 |
| GL2302_L4_D067 | 103 | 9/14/2023 | 14:35:17 | 45.223714 | −86.960151 | 8.2 | 0:01:27 |
| GL2302_L4_D068 | 219 | 9/14/2023 | 14:44:18 | 45.211429 | −86.967610 | 7.3 | 0:01:26 |
| GL2302_L4_D069 | 136 | 9/14/2023 | 14:51:08 | 45.205273 | −86.972121 | 6.8 | 0:02:08 |
| GL2302_L4_D070 | 166 | 9/14/2023 | 15:01:33 | 45.209624 | −86.988928 | 5.1 | 0:01:43 |
| GL2302_L4_D071 | 33 | 9/14/2023 | 15:11:50 | 45.189586 | −86.995806 | 7.5 | 0:01:51 |
| GL2302_L4_D072 | 170 | 9/14/2023 | 15:18:52 | 45.192395 | −87.004093 | 8.0 | 0:01:28 |
| GL2302_L4_D073 | 118 | 9/14/2023 | 15:29:30 | 45.178757 | −87.007376 | 5.4 | 0:01:49 |

| Deployment ID | Target Site ID | Launch Date | Launch Time (hr:min:s) | Latitude (DD) | Longitude (DD) | Depth (m) | Bottom Time (hr:min:s) |
|---|---|---|---|---|---|---|---|
| GL2302_L4_D074 | 157 | 9/14/2023 | 15:42:15 | 45.162986 | −87.008138 | 4.6 | 0:01:37 |
| GL2302_L4_D075 | 151 | 9/14/2023 | 15:50:50 | 45.155398 | −87.004549 | 9.1 | 0:01:52 |
| GL2302_L4_D076 | 147 | 9/14/2023 | 16:02:25 | 45.144380 | −87.001686 | 19.6 | 0:02:18 |
| GL2302_L4_D077 | 47 | 9/14/2023 | 16:09:07 | 45.144974 | −86.998213 | 20.4 | 0:01:38 |
| GL2302_L4_D079 | 107 | 9/14/2023 | 16:22:12 | 45.162068 | −86.993709 | 6.2 | 0:01:40 |
| GL2302_L4_D080 | 231 | 9/14/2023 | 16:29:29 | 45.172705 | −86.972251 | 19.5 | 0:01:57 |
| GL2302_L4_D081 | 26 | 9/14/2023 | 16:36:46 | 45.176030 | −86.989736 | 12.3 | 0:01:41 |
| GL2302_L4_D082 | 39 | 9/14/2023 | 16:42:16 | 45.178865 | −86.991263 | 9.0 | 0:01:33 |
| GL2302_L4_D083 | 131 | 9/14/2023 | 16:49:30 | 45.182268 | −86.999205 | 7.5 | 0:02:08 |
| GL2302_L4_D084 | 44 | 9/14/2023 | 16:55:28 | 45.183942 | −86.996761 | 7.1 | 0:01:24 |
| GL2302_L4_D085 | 69 | 9/14/2023 | 16:58:55 | 45.184077 | −86.996990 | 6.9 | 0:02:10 |
| GL2302_L4_D086 | 76 | 9/14/2023 | 17:08:32 | 45.180102 | −86.962931 | 21.1 | 0:02:01 |
| GL2302_L4_D087 | 43 | 9/14/2023 | 17:16:48 | 45.184396 | −86.965716 | 18.8 | 0:01:48 |
| GL2302_L4_D088 | 169 | 9/14/2023 | 17:27:23 | 45.188153 | −86.978850 | 10.4 | 0:01:31 |
| GL2302_L4_D089 | 72 | 9/14/2023 | 17:34:15 | 45.192337 | −86.971554 | 9.5 | 0:01:39 |
| GL2302_L4_D090 | 105 | 9/14/2023 | 17:42:03 | 45.189850 | −86.962122 | 16.8 | 0:02:20 |
| GL2302_L4_D091 | 104 | 9/14/2023 | 17:50:20 | 45.193655 | −86.953565 | 21.5 | 0:02:04 |
| GL2302_L4_D092 | 93 | 9/14/2023 | 18:00:07 | 45.197025 | −86.941607 | 20.9 | 0:01:35 |
| GL2302_L4_D093 | 56 | 9/14/2023 | 18:06:13 | 45.200320 | −86.941604 | 15.0 | 0:01:32 |
| GL2302_L4_D094 | 195 | 9/14/2023 | 18:11:20 | 45.200481 | −86.941374 | 14.3 | 0:01:27 |
| GL2302_L4_D095 | 197 | 9/14/2023 | 18:29:17 | 45.196331 | −86.961889 | 9.0 | 0:01:25 |
| GL2302_L4_D096 | 25 | 9/14/2023 | 18:35:20 | 45.200220 | −86.961352 | 9.8 | 0:01:44 |
| GL2302_L4_D097 | 63 | 9/14/2023 | 18:42:02 | 45.203812 | −86.963297 | 5.9 | 0:01:52 |
| GL2302_L4_D098 | 148 | 9/14/2023 | 18:53:25 | 45.206586 | −86.945341 | 19.5 | 0:02:38 |
| GL2302_L4_D099 | 21 | 9/14/2023 | 19:00:23 | 45.208989 | −86.943008 | 13.3 | 0:01:10 |
| GL2302_L4_D100 | 212 | 9/14/2023 | 19:08:02 | 45.206396 | −86.941521 | 18.5 | 0:01:54 |
| GL2302_L4_D101 | 119 | 9/14/2023 | 19:19:05 | 45.215998 | −86.923210 | 10.9 | 0:01:25 |
| GL2302_L4_D102 | 192 | 9/14/2023 | 19:25:03 | 45.271235 | −86.903860 | 15.8 | 0:01:19 |

| Deployment ID | Target Site ID | Launch Date | Launch Time (hr:min:s) | Latitude (DD) | Longitude (DD) | Depth (m) | Bottom Time (hr:min:s) |
|---|---|---|---|---|---|---|---|
| GL2302_L4_D103 | 98 | 9/14/2023 | 19:35:41 | 45.214011 | −86.902696 | 19.4 | 0:01:21 |
| GL2302_L4_D104 | 88 | 9/14/2023 | 19:41:55 | 45.218090 | −86.903377 | 19.1 | 0:01:31 |
| GL2302_L4_D105 | 209 | 9/14/2023 | 19:51:10 | 45.221605 | −86.908911 | 16.4 | 0:01:32 |
| GL2302_L4_D106 | 3 | 9/14/2023 | 19:58:04 | 45.226274 | −86.905732 | 14.2 | 0:01:20 |

Table A3. Ponar deployments during GL-23-02. Coordinates belong to Ponar launch locations, and depth values are the on-bottom depths. Dates and times are in Coordinated Universal Time (UTC).

| Deployment ID | Target Site ID | Launch Date | Launch Time (hr:min:s) | Latitude (DD) | Longitude (DD) | Depth (m) |
|---|---|---|---|---|---|---|
| GL2302_L1_P001 | 502 | 8/21/2023 | 19:05:40 | 45.296211 | −86.924615 | 14.0 |
| GL2302_L1_P002 | 471 | 8/24/2023 | NA | 45.251708 | −86.90829 | 16.2 |
| GL2302_L1_P003 | 5 | 8/24/2023 | NA | 45.201924 | −87.028044 | 7.6 |
| GL2302_L3_P001 | 146 | 9/8/2023 | 16:20:29 | 45.207136 | −87.030645 | 6.3 |
| GL2302_L3_P002 | 5* | 9/8/2023 | 16:49:20 | 45.201924 | −87.028044 | 7.6 |
| GL2302_L3_P003 | 27 | 9/8/2023 | 17:50:18 | 45.171438 | −87.017721 | 10.9 |
| GL2302_L4_P002 | 138 | 9/11/2023 | 15:55:18 | 45.268516 | −86.964135 | 7.6 |
| GL2302_L4_P003 | 68 | 9/13/2023 | 17:51:27 | 45.285016 | −86.965731 | 9.6 |
| GL2302_L4_P004 | 84 | 9/13/2023 | 22:04:35 | 45.320345 | −86.866303 | 18.5 |

* Site 5 was resampled to check algae and oxidation

# Appendix B: Sediment Data Collection Form

Figure B1. Example of the Ponar sample digital data sheet collected in the field.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Cruise ID** | GL2301_L4 | | | | | **Recorder:** | |
| **Site Code** | | | | **Date (mm/dd/yyyy)** | | **Time (UTC)** | **Deployment ID** |
| | | | | | | | |
| **Grab # 1 SEDIMENT DESCRIPTION (Check)** | | | | | | Depth: | Photo ID: |
| Grain Size | | | | Benthos | | | Color |
| | Present/Absent | Dominance | Comments | | Present/Absent | Comments | |
| Clay | | | | Wood | | | Clay Description |
| Silt | | | | Shell | | | |
| Sand | | | | Molluscs | | | Sand Description |
| Granule | | | | Live Veg | | | |
| Pebble | | | | Algae | | | H2 Sulfide |
| Cobble | | | | Anthro | | | |
| | | | | Other | | | Oxidized |
| Comments: | | | | | | | |
| | | | | | | | Stratification |
| | | | | | | | |

U.S. Department of Commerce

**Gina M. Raimondo**, Secretary

National Oceanic and Atmospheric Administration

**Richard Spinrad,** Under Secretary for Oceans and Atmosphere

National Ocean Service

**Nicole LeBoeuf,** Assistant Administrator for National Ocean Service

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