HYDROGRAPHIC SERVICES REVIEW PANEL (HSRP)

DATE: September __, 2020

TO: NOAA Administrator

SUBJECT: HSRP White Paper: Alaska Coastal Mapping Strategy (ACMS)

This white paper provides HSRP recommendations to the NOAA Administrator on implementing the ACMS. It was authored by HSRP members with direct experience in coastal mapping. For coastal mapping of Alaska, the HSRP recognizes the critical importance of:

1. establishing a consistent, authoritative vertical datum for Alaska
2. completing NOAA's Vertical Datum Transformation Tool (VDatum) to function in all of Alaska
3. completing GRAV-D data collection in Alaska, and
4. defining the official shoreline of Alaska, as explained at Appendix B.

BACKGROUND

In 2004, the Committee on National Needs for Coastal Mapping and Charting, Ocean Studies Board, Mapping Science Committee, Division of Earth and Life Studies of the National Research Council (NRC), published its report: *A Geospatial Framework for the Coastal Zone: National Needs for Coastal Mapping and Charting*[1]. That committee was chaired by Dr. Larry Mayer of the University of New Hampshire. The Hydrographic Services Review Panel (HSRP) considers the recommendations of that NRC committee (see Appendix A) to remain valid today for coastal mapping of Alaska – from the necessity for VDatum to easily transform data between reference systems to the need for new remote sensing technologies that have since been developed to fill critical gaps at the land-water interface. Topographic/bathymetric lidar, acoustic sonar improvements, unmanned surface vessels and the technical implementation of Gravity for the Redefinition of the American Vertical Datum (GRAV-D) are but some of these improvements.

In 2016, the Interagency Working Group on Ocean and Coastal Mapping released its draft guidance for the *National Coastal Mapping Strategy 1.0: Coastal Lidar Elevation for a 3D Nation*[2]. That coastal mapping strategy was finalized in 2018[3]. Table 1 of that strategy defines five bathymetric lidar Quality Levels and recommends bathymetric lidar be collected to at least $QL2_B$. These quality levels evolved from the partnership among USACE, NOAA, USGS and NAVO known as the Joint Airborne Lidar Bathymetric Technical Center of Expertise (JALBTCX), a partnership that continues today to inform standards and best practices for topobathymetric lidar acquisition and processing.

In November 2019, the Presidential Memorandum on *Ocean Mapping of the United States Exclusive Economic Zone and Shoreline and Nearshore of Alaska*[4] was issued. Section 2 called for an ocean mapping, exploration and characterization strategy. Section 3 of that memorandum directed the NOAA

[1] https://www.nap.edu/read/10947/chapter/1
[2] https://iocm.noaa.gov/reports/IWG-OCM-Natl-Coastal-Mapping-Strat-DRAFT-PUBLIC-COMMENT-4.29.16.pdf
[3] https://iocm.noaa.gov/about/documents/strategic-plans/IWG-OCM-Final-Coastal-Mapping-Strategy-2018-with-cover.pdf
[4] https://www.whitehouse.gov/presidential-actions/memorandum-ocean-mapping-united-states-exclusive-economic-zone-shoreline-nearshore-alaska/

Administrator, in coordination with the State of Alaska and the Alaska Mapping Executive Committee (AMEC) – co-chaired by NOAA and the U.S. Geological Survey (USGS) - to develop a proposed strategy within 180 days to map the shoreline and nearshore of Alaska and inform actions of the Ocean Policy Committee and relevant agencies. NOAA subsequently developed two strategies – one for the National Ocean Mapping, Exploration and Characterization (NOMEC) and another for the Alaska Coastal Mapping Strategy (ACMS).

In June of 2020, the White House released *Mapping the Coast of Alaska: A 10-Year Strategy in Support of the United States Economy, Security and Environment*[5] -- commonly referred to as the Alaska Coastal Mapping Strategy (ACMS). This strategy was written by the AMEC agencies, including NOAA, the State of Alaska, and the USGS. The Executive Summary of the ACMS affirms that Alaska's 66,000 miles of shorelines constitute a tremendous strategic economic and ecological resource to the Nation. It states: "Accurate and contemporary mapping of Alaska's coastal and nearshore regions are critical to informed use of these vast resources, maritime domain awareness, safeguarding of the health and security of coastal communities, and strengthening of the Blue Economy." The Executive Summary further states: "Subject to the availability of appropriations, implementing the Alaska Coastal Mapping Strategy would yield significant upgrades to Alaska's geospatial framework and mapping of the coastal zone by 2030. Products derived from topographic, nearshore bathymetric, and orthoimagery data, including the Alaska shoreline, would vastly improve life, safety, and economic opportunities for Alaska residents and the Nation."

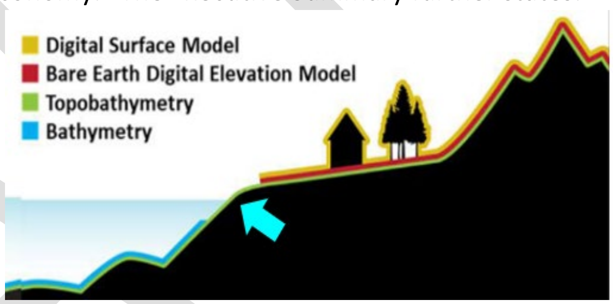

Figure 1. The aqua arrow points to the seamless topobathymetric 3-D surface that includes both underwater bathymetry (depths) and onshore topography (land elevations) with no data gaps at the land/water interface known as the coastal zone or intertidal zone.

HSRP RECOMMENDATIONS

The remainder of this white paper will provide HSRP recommendations for the Alaska Coastal Mapping Implementation Plan that address the four ACMS goals and eleven objectives.

ACMS Goal 1: Build on Existing Mapping Partnership to Meet Alaska's Coastal Mapping Needs.

<u>Objective 1.1. Establish a Team for Alaska Coastal Mapping Implementation</u>. The HSRP understands that NOAA and AMEC have already created a Coastal Mapping Subcommittee, co-chaired by representatives from NOAA and the AMEC, responsible for development of the ACMS Implementation Plan. HSRP recommends that NOAA and its Federal partners include representatives from academia and the geospatial industry to provide non-governmental insight to the strategy implementation. In addition, HSRP members are available to support that team in any way we can.

<u>Objective 1.2. Refine Stakeholder Mapping Priorities, Costs, and Data Standards</u>. The HSRP has specific recommendations on each of these topics:

[5] https://iocm.noaa.gov/about/documents/strategic-plans/alaska-mapping-strategy-june2020.pdf

Mapping Priorities: Where new tidal datums need to be established to fill major gaps in the NWLON in Alaska, those tidal datums should have highest priority because knowledge of high and low tide is essential for all data acquisitions to follow.

NOAA needs to consider the needs and applications of all stakeholders (Federal agencies, defense and national security, local government, academia, or private community) who will benefit from the Alaska Mapping Program. The strategy indicates that needs were surveyed during 2019 from over 40 representatives from federal, state and local agency liaisons, Native corporations and associations, non-profit and professional organizations, and academia. The outcome of the aforementioned survey should be used as the base for setting priorities. Local communities need to be given a higher priority especially if such mapping provides means to enhance their life and wellbeing. The HSRP recommends that the ACMS Implementation Plan gives highest priority to coastal villages for solutions to their mapping needs and supporting infrastructure. The uninhabited coastal areas should be of lower priority when appropriations are insufficient to address the entire Alaska coastal areas unless there is a national security priority dictates otherwise.

Presently, only 14% of the Alaska coastline has been adequately mapped; the missing 86% is critically needed for coastal zone applications. Subject to the availability of funds, mapping should commence immediately in areas in which there is the necessary geospatial infrastructure, i.e., Continuously Operating Reference Stations (CORS) for accurate positioning by the GNSS, and tide stations needed for accurate predictions of high and low tides and for completion of NOAA's VDatum tool in Alaska. Unfortunately, the areas with necessary geospatial infrastructure are believed to closely align with the 14% of the Alaska coastline that has already been adequately mapped. For the remaining 86%, NOAA should be proactive and act boldly to address the highest priority areas in time for implementation of the National Geodetic Survey (NGS) North American-Pacific Geopotential Datum of 2022 (NAPGD2022), now scheduled for release in 2024 because of Covid-19 delays. "But what are the highest priority areas?" -- we asked. When the HSRP met in Alaska in 2018, our members were impressed by the complexities of supplying coastal villages that have no airstrips and no roads to the mainland. Their supplies are delivered by tug barges providing logistics over-the- shore (Figure 2). Coastal villages normally have no docks and often have large tidal ranges -- up to 25 feet per day. They lack tide predictions to forecast high and low tides when supply barges can best come ashore. They need seamless topobathymetric data of their coastal zone, but they don't have it. Because they lack needed data, tug barges currently use sounding skiffs and sounding sticks to determine water depths (Figure 3); some skiffs have consumer-grade depth sounders in addition to sounding sticks. Mark Smith of Vitus Energy said that all barge operators need seamless topobathymetric data from dry land out to at least the 4m depth at low tide. Coincidentally, the 4-meter depth contour normally defines the Navigable Area Limit Line (NALL) in NOAA's Hydrographic Surveys Specifications and Deliverables[6].

[6] https://nauticalcharts.noaa.gov/publications/docs/standards-and-requirements/specs/hssd-2017.pdf

Figure 2. Fuel barge from Vitus Energy that supplies coastal villages with fuel. They use sounding skiffs outfitted with a consumer depth sounder and a sounding pole for physical soundings of shallow water. This is archaic.

Figure 3. This shows a tug barge going up an Alaska inlet, preceded by the sounding skiff in the distance that determines safe depths for passage. They would be much more efficient with GPS/GNSS and known depth data.

<u>Costs</u>: *The National Coastal Mapping Strategy 1.0: Coastal LIDAR Elevation for a 3D Nation* states: "The purpose of the plan is to coordinate the collection of new data and eliminate redundancy, reduce costs, and support the widest possible range of coastal data." A similar statement should guide the ACMS Implementation Plan. Various agencies involved in mapping the coast of Alaska should join efforts and pool their resources to implement the strategy according to stakeholder priorities.

The HSRP recommends consideration of alternative technologies to reduce costs for development of needed tidal datums where there are huge gaps in the NWLON network. We also make recommendations for cost efficiencies in acquisition of topobathymetric lidar, imagery, and sonar data for nearshore bathymetry. For optimal cost effectiveness, it is important to recognize the need for tasks to be performed in the correct sequence:

1. CORS: NGS's home page for CORS[7] describes plans for the Foundation CORS Network in Alaska and elsewhere. Alaska will have two Foundation CORS from NOAA, two from the National Science Foundation (NSF), and one from the National Aeronautics and Space Administration (NASA), for a total of five. The HSRP recommends that NOAA work with the NSF to expedite the Foundation CORS Network serving coastal areas of Alaska. The planned NASA Foundation CORS in Fairbanks will have minimal impact on mapping of Alaska's coastal zone. However, the current lack of Foundation CORS should not be a "showstopper" because the existing CORS network in Alaska is still able to support Precise Point Positioning of mapping aircraft, UAVs, and marine vessels. The addition of the proposed foundation CORS will provide the backbone for the use of Online Positioning User Service (OPUS) in Alaska. OPUS is a tool that provides access to high-accuracy National Spatial Reference System (NSRS) coordinates using the NOAA CORS Network (NCN) and will be used to support survey tasks described in this document. A dense network of CORS will also support the suite of tools being developed for OPUS Projects which will support geodetic activities needed for mapping in Alaska.
2. Where topobathymetric lidar or imagery is used, this data should be tide-controlled to capture as much of the intertidal zone surface as possible during low tide (see Figure 4).

[7] https://geodesy.noaa.gov/CORS/foundation-cors.shtml

3. To minimize costs, acoustic (sonar) data requirements should not be determined until after topobathymetric lidar data have been acquired and evaluated for data voids. An example of topobathymetric lidar data voids is shown at Figure 5. Only then should NOAA and AMEC determine where sonar data are required and determine where multi-beam sonar data should be acquired for higher priority areas (coastal villages) and where less-expensive single-beam sonar data would be acceptable for lower priority areas. Sonar data should be collected as near as feasible to high tides when swaths cover a broader area of the intertidal zone and require fewer swaths.

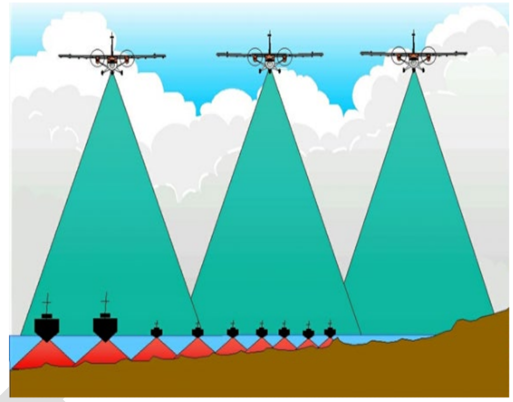

Figure 4. This figure shows why topobathy lidar is most efficient in shallow waters, where multibeam sonar is least efficient; topobathy lidar should be collected at low tide. But topobathy lidar may have data voids because of water turbidity; then sonar becomes the most efficient in deeper waters to fill those voids and is most efficient at high tide. This figure also shows why unmanned surface vessels are better suited for acoustic mapping in shallow waters, compared with larger vessels that are more likely to run aground in shallow waters.

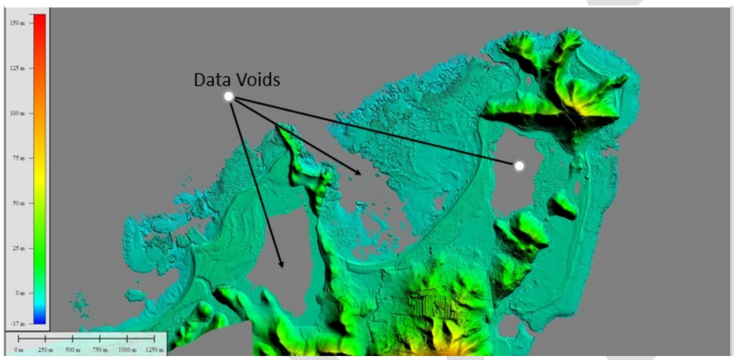

Figure 5. Example of bathymetric lidar data voids in areas where aquatic vegetation, bioluminescence or sediments in the water prevent penetration by the green laser. Other voids occur where the laser extinction depth is exceeded.

<u>Data Standards</u>:

While NOAA's 2020 Shoreline Mapping Project Instructions[8] agree with the Lidar quality levels specified in the National Coastal Mapping Strategy, we believe the instructions lack a few "buy-up options" that users from outside NOAA may expect from a coastal mapping program. HSRP recommendations on standards and specifications include:

1. Select quality level(s) for topography and bathymetry that suit the mapping priorities as derived from the survey mentioned in our response to Objective 1.2 above.
2. Select topographic and bathymetric quality levels as described in NOAA's Shoreline Mapping Project Instructions and the National Coastal Mapping Strategy but encourage and allow other stakeholders to contribute additional funding for a "buy-up option" if they need lidar data of higher point density or accuracy, for example.
3. NOAA's Shoreline Mapping Project Instructions call for 4-band imagery (R, G, B, NIR) with ground resolution of 25-cm. While this may be suitable for NOAA's use, higher resolution imagery and/or hyperspectral imagery may be needed for other applications including coastal analysis, near-shoreline water quality, and benthic habitat mapping, for example. NOAA should encourage and allow other stakeholders to contribute additional funding for imagery "buy-up options" to satisfy coastal mapping requirements that exceed the NOAA standard.

[8] https://www.ngs.noaa.gov/RSD/topobathy/STYYXX-TB-C_Project_Instructions_v3.0.2.pdf

4. The HSRP sees a good opportunity to develop a national standard for coastal mapping that focuses on defining the various uses and applications of products from the coastal mapping program and then align technologies and specifications to suit such applications.

<u>Objective 1.3. Cost-Effectively Resource the Alaska Coastal Mapping Implementation Plan</u>. The HSRP has no specific recommendations for this objective beyond proposed cost efficiencies documented herein and the importance of the private-sector involvement in addition to other federal and state agencies and universities. A good example to follow is what the AMEC did for IFSAR mapping of Alaska through extensive funding partnerships. Note: for the Alaska IFSAR mapping program, the USGS had primary responsibility for topographic mapping of Alaska; yet 46% of the funding came from other funding partners and stakeholders.

<u>Objective 1.4. Integration with Complementary AMEC Mapping Priorities</u>. The HSRP has no specific recommendations for this objective because the Coastal Mapping Subcommittee is already taking complementary AMEC mapping priority acquisition plans into consideration.

ACMS Goal 2: Expand Coastal Data Collection to Deliver the Priority Geospatial Products Stakeholders Require.

<u>Objective 2.1. Execute a Flexible Alaska Coastal Mapping Campaign</u>. The HSRP assumes that the Alaska Coastal Mapping Implementation Plan will prioritize diverse requirements and attempt to best satisfy specific requirements each year between 2020 and 2030. The HSRP agrees that the Alaska Coastal Mapping Implementation Plan needs to be flexible to accommodate a myriad of competing priorities and funding variables, especially when cooperative funding is received for a specific purpose that may not have been among NOAA's highest priorities in its initial plan.

<u>Objective 2.2. Upgrade Alaska National Spatial Reference System Components to Support Mapping Data Acquisition</u>. The HSRP has previously recommended the sequence in which data should be acquired by priority area, i.e., with establishment of Foundation CORS and tidal datums being highest priorities. The Alaska Water Level Watch (AWLW) Collaborative Working Group 2020-2025 draft Guidance Plan includes Figure 6, with 32 large gaps in NWLON coverage along Alaska's coasts including the Aleutian Islands. For Objective 3.2 below, the HSRP recommends that NOAA consider three alternative means for establishment of additional tidal datums in Alaska to fill these gaps.

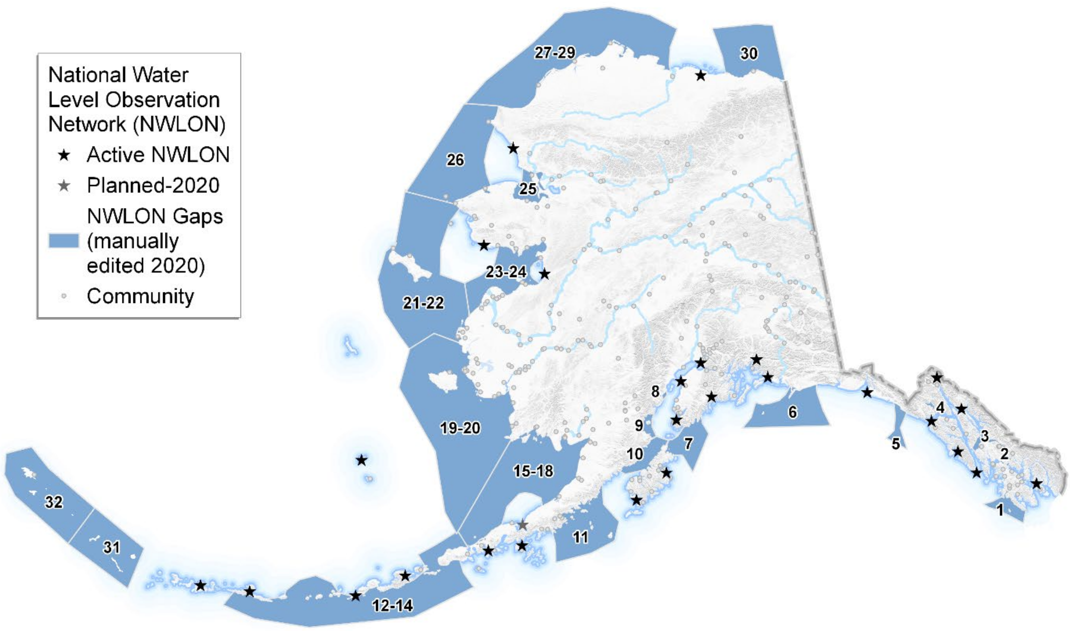

Figure 6. The blue areas show the major gaps in NWLON stations in Alaska, overlaid with small circles showing the location of Alaska communities, both coastal and inland. These gaps need to be filled either by NWLON or by more-affordable, temporary tide gauges in order to execute the Alaska Coastal Mapping Strategy.

Objective 2.3. Produce and Disseminate Key Datasets and Products from Alaska Coastal Mapping Data. The HSRP fully concurs with the approach to Objective 2.3 in the ACMS.

Goal 3: Leverage Innovation in Mapping Technology Development

Objective 3.1. Upgrade Alaska Climatology Tool for Smart Application of Satellite and Airborne Lidar Bathymetry. Satellite Derived Bathymetry (SDB) and Airborne Lidar Bathymetry (ALB) both require data to be acquired at the times and locations when waters are clearest. NOAA has developed a water clarity climatology tool[9], based on satellite image records, to identify patterns in time and space to maximize Alaska's potential for topobathy lidar for shoreline mapping. This tool is also relevant to SDB. Figure 7 shows a climatology tool map of

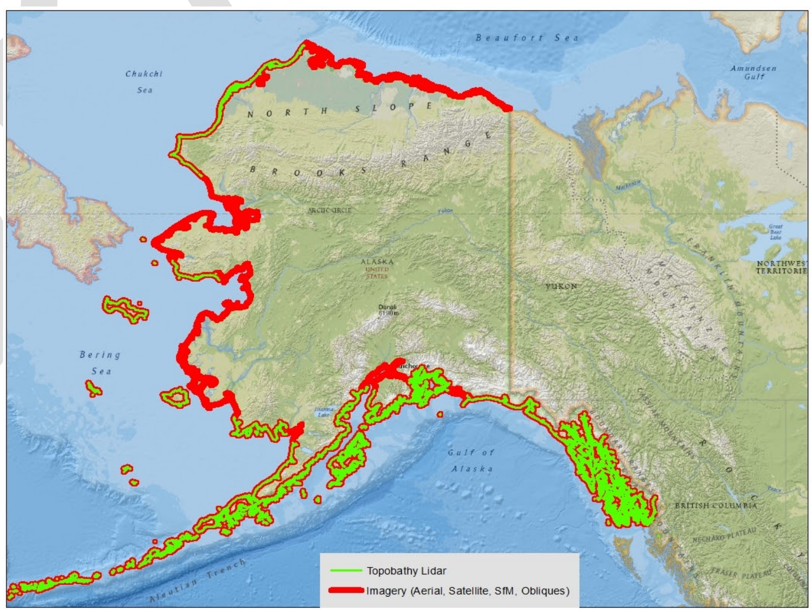

Figure 7. NOAA's Water Clarity Climatology Tool for predicting times and locations when waters are clearest for ALB or SDB. The SfM acronym stands for Structure from Motion, a stereo photogrammetric technique commonly used to produce orthoimagery from Unmanned Aerial Systems (UAS).

[9] https://www.ngs.noaa.gov/RSD/topobathy_wc.shtml

Alaska where topobathy lidar and SDB are most likely to work. HSRP members concur that this climatology tool should be upgraded with lessons learned from actual projects in Alaska.

Objective 3.2. Monitor and Test New Technologies for Acquisition Efficiencies.

Continuously Operating Reference Stations (CORS):

- Consider adding CORS stations collocated with CO-OPS tide stations where practical
- Extend CORS network to offshore platforms, islands, etc., to support ellipsoid reference surveying and Online Positioning User Service (OPUS)
- For new installations, select coastal sites suitable for both positioning and measuring water levels via GNSS reflectometry
- Support and perform GNSS Reflectometry research to enable more use of this technology

National Water Level Observation Network (NWLON):

- Consider expanding the network using GNSS Reflectometry, especially in challenging coastal environments like Alaska. Consider extending offshore observations (buoys, platforms, bottom mount gauges, etc.)
- Improve the GNSS ties at the NWLON stations through leveling ties between NWLON stations and nearby CORS and a more robust GNSS observation campaign (NOAA Technical Memorandum NOS NGS-58)
- Consider using a Modified 5-yr Epoch for all tide stations. This would provide more consistency between the tidal datums and ensure the tidal datums are more current.
- Publish relationship of NAVD88 and/or the new NAPGD2022 on tidal datums page for all published stations.

Vertical Datums Transformation (VDatum):

- Extend coverage throughout Alaska, especially the major ports and coastal communities
- The current National Tidal Datum Epoch (NTDE) is 1983 to 2001. This will be updated to a new 19-year period soon. Some tidal datums reference a modified 5-year epoch. Incorporating transformations between different tidal datum epochs would be useful.
- Perform more robust GNSS ties at temporary tide stations. The current SOW is a single 4-hour observation of a single tidal benchmark. Increasing this to two marks and following NOAA Technical Memorandum NOS NGS-58 guidelines would significantly improve the tie between the tidal datums and a global reference frame.
- The tidal datum and ellipsoid height info for many of the tidal benchmarks used in the development of the VDatum grids reference different epochs. The reference epoch for the current NSRS is 2011. The center of the current NTDE is 1992. Combining tidal datum and ellipsoid heights referencing different epochs introduces errors especially in regions with significant vertical land motion.

Alternative Sensors for Tidal Datums. To fill gaps in the NWLON network, the HSRP recommends that NOAA consider alternative lower-cost sensors for acquiring tidal data and establishing tidal datums in Alaska. NOAA's training module: "Using the NOAA Tidal Analysis Datums Calculator"[10] enables partners to compute tidal datums themselves using CO-OPS methodologies and their data which may not be collected to NOAA NWLON standards:

- Non-Vented Pressure Sensors: These systems have been used statewide in Alaska over the years because of their versatility over vented pressure sensors (Figure 8). For establishing authoritative tidal datums, non-vented pressure sensors have typically been secured to oceanographic anchors and deployed offshore with a vessel due to their size (Figure 9). This approach is not only expensive because of the vessel time but the anchors typically move which introduces measurement error that regularly exceeds the requirements in the NOAA tide station installation specifications. There are now low cost non-vented pressure sensors on the market with the power duration, sensor accuracy, sampling frequency, memory and size suitable for securing to natural coastal features. Figure 10 shows a picture of a non-vented pressure tide gauge installed in St. Michael Alaska to validate GNSS-Reflectometry water level measurements from UNAVCO station AT01. Figure 8 shows a vented pressure tide gauge being installed near the community of Gambell on St. Lawrence Island in the Bering Sea. The cost of the equipment, materials and labor to install the tide gauge in Figure 10 is significantly less than for the tide gauges in Figure 8 and 9.

Figure 8. Picture of a vented pressure tide gauge installed for tidal datum determination on St. Lawrence Island, Alaska. Field crew is securing air hose that runs from below MLLW to the electronics enclosure on top of the hill in the background.

Figure 9. Non-vented pressure, conductivity and temperature sensors secured to an oceanographic anchor prior to deployment south of the Alaska Peninsula.

Figure 10. RBR Solo Depth Logger installed at St. Michael, Alaska. This is a non-vented pressure sensor that was intentionally installed above MLLW to measure a portion of the tide range.

Photos courtesy of JOA Surveys

[10] https://www.meted.ucar.edu/training_module.php?id=10036#.X1-lXGhKgdU

- GNSS Tide Buoy: These systems consist of a GNSS receiver and antenna secured to a buoy hull. The buoy is deployed in the ocean and directs signals from GNSS constellations, used to precisely determine the 3D position of the antenna. These positions are then reduced to the water line. The two primary advantages of these systems are 1) measurements are referenced to a stable global reference frame, and 2) they do not require fixed coastal structures for deployment. Typically, measurements from pressure, microwave and acoustic tide gauges are referenced to the sensor. Movement of the sensor mounting structure (i.e. dock, seawall, bedrock, piling) introduces error, if the movement is not quantified and timestamped. Because GNSS Tide Buoys use direct signals from positioning satellites the buoy (i.e. sensor) movement is continuously quantified and timestamped thus eliminating mounting structure movement as an error source. Figure 11 is a picture of a GNSS Tide Buoy deployed in Shotgun Cove of Alaska's Prince William Sound.

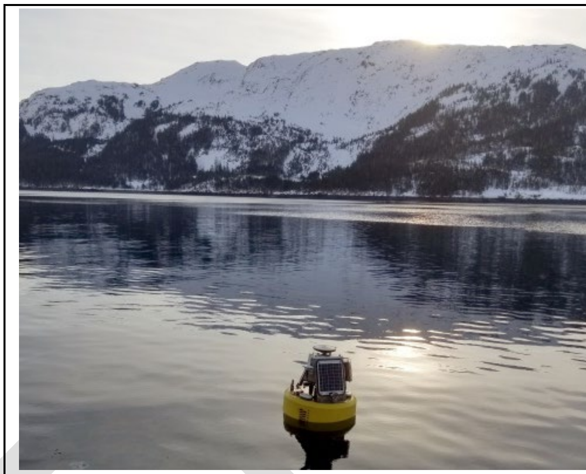

Figure 11. A GNSS Tide Buoy deployed in Alaska's Prince William Sound. Photo courtesy of JOA Surveys, LLC.

  The two predominant processing methods for GNSS Tide Buoy data are Differential GNSS (DGNSS) and Precise Point Positioning (PPP). DGNSS tends to provide more accurate results; however, this processing is relative and requires data from base stations such as CORS. There currently are not enough CORS along Alaska's coast to provide statewide coverage. In regions without CORS coverage a temporary base station must be installed. PPP does not require base stations which reduces operational costs by eliminating the need to install temporary base stations when CORS are not available.

- GNSS-Reflectometry (GNSS-R): The system shown at Figure 12 is essentially a GNSS base station (CORS or temporary CORS) that uses direct signals from GNSS constellations to precisely position the base station antenna and indirect signals (i.e. multipath) to determine the height of the antenna above a reflective surface. When the base station is placed close enough to the water this system can be used to measure the tidal variations. The two main advantages of this approach are: 1) it is a non-contact approach of measuring water levels at an oblique angle, and 2) movement of the sensor

Figure 12. GNSS-Reflectometry water level system installed in Koyuk, AK by JOA Surveys, LLC in support of the NOAA Office of Coast Survey Project OPR-R385-KR-20. TerraSond Ltd. was the prime contractor. Photo courtesy of JOA Surveys.

(i.e. GNSS antenna) can be monitored on a continuous basis. The main disadvantage of the system is that the measurements have more error than those from pressure, acoustic and microwave tide gauges, thus making them unsuitable for NWLON stations. However, much of the error is filtered out in the tidal datum computation process, making the measurements suitable for tidal datum determination especially along coastlines that are remote and unprotected. In 2019, *GPS World* published a relevant GNSS-R article entitled: Innovation: Monitoring sea level in the Arctic using GNSS.[11]

The HSRP recommends NOAA support additional research for consideration of technical and cost proposals of these or other alternative sensors at temporary tide stations in Alaska to establish the tidal datums necessary to achieve VDatum coverage statewide.

Unmanned Systems. For collection of topobathy lidar, HSRP members conclude that unmanned aerial systems would be of no benefit in Alaska as the depths, bottom types, and turbidity are extremely challenging to manned aircraft systems that have far superior capabilities. Instead, a combination of manned aerial topobathy lidar systems (Figure 13) and unmanned surface vessels collecting single-beam or multi-beam sonar would be the most efficient way to collect nearshore bathymetry to depths where manned and unmanned hydrographic assets are effective. Furthermore, unmanned aerial systems (UAS) can play a role in collecting imagery in remote areas to specifications that will support Structure from Motion (SfM) photogrammetry for production of orthoimagery. NOAA has tested current UAS camera systems that have provided imagery that meet the same specifications as manned large format camera systems.

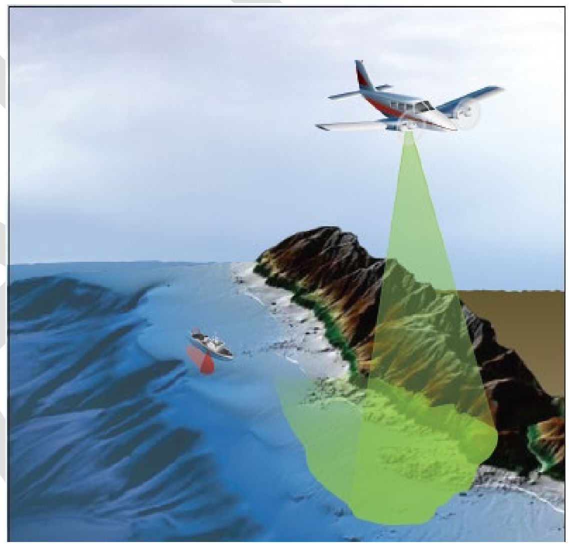

Figure 13. Dependent on water clarity, aerial topobathy lidar, collected at low tide, is the best way to map seamless topobathymetric surfaces in the intertidal zone; but tide-controlled aerial photography and unmanned surface vessels with single- or multibeam sonar, collected at high tide, can map the intertidal zone where waters are too turbid for topobathy lidar.

Unmanned Surface Vessels (USVs). To achieve 100% bathymetric bottom coverage from multibeam sonar, there are many USV options to choose from. The University of New Hampshire Center for Coastal and Ocean Mapping (CCOM) and Joint Hydrographic Center (JHC) has already evaluated many of these.[12] [13]

[11] https://www.gpsworld.com/a-tidal-shift-monitoring-sea-level-in-the-arctic-using-gnss/

[12] https://coastalscience.noaa.gov/news/noaa-evaluates-capabilities-unmanned-surface-vessel/

[13] https://www.nauticalcharts.noaa.gov/updates/noaa-ship-thomas-jefferson-tests-innovative-drix-autonomous-surface-vehicle/

Figure 14. The Z-boat, with multibeam sonar, is one of many options to choose from on surveying shallow waters for NOAA's coastal mapping program and to fill voids from topobathy lidar where waters are too turbid for full bottom coverage.

[14] The fixed angle of the sonar causes the width of the swath across the seafloor to vary with depth; therefore, in order to achieve complete bottom coverage, neighboring survey lines must be spaced more closely in shallow water than in deep water. The Z-boat, with multi-beam sonar at Figure 14, is just one of many options designed for ocean surveying with waves that impact speed and bearing. Such USVs include data transmission and automated swath survey path planning. With input from the CCOM, NOAA should evaluate available technologies to determine which systems best satisfy requirements.

Hydroball Buoy: The Alaska Ocean Observing System (AOOS) has been working closely with the Alaska Water Level Watch regarding alternative tide sensors. One such sensor now under evaluation is the Hydroball (Figure 15), a small (28 pound) fully autonomous buoy that includes a single beam echosounder, GNSS receiver, and a digital compass and can be moored, towed or drifted. Based on its usage in Canada, the AOOS is optimistic that it holds promise for meeting needs of nearshore bathymetry, especially at the mouths of frequently-changing rivers, while also leveraging the capacity of local workforces in Alaska.

Figure 15. Hydroball buoy.

Autonomous Surface Vessels (ASVs). The 2020 Arctic Mapping mission[15] is a single-beam sonar mission supporting NOAA's effort to provide modern, accurate mapping data of the Bering Sea and Alaska's North Slope. Using a fleet of Saildrones (Figure 16), the goal is to identify the 20-meter and 50-meter depth contours delineating a virtual lane to be mapped for safe passage of commercial vessels (Figure 17). Saildrones operate autonomously, but they are remotely monitored by Saildrone Mission Control 24/7. Missions can be adapted or adjusted on the fly. NOAA is working to integrate single-beam and multi-beam technology for shallow-water and coastal bathymetric missions. The HSRP recommends that CCOM investigate the feasibility and practicality of using Saildrones or other ASVs to survey shallow water coastal areas of Alaska for NOAA's Coastal Mapping Program where topobathymetric lidar may be unable to penetrate turbid waters.

[14] https://www.nauticalcharts.noaa.gov/updates/unmanned-surface-vehicles-evaluated-for-hydrographic-survey/

[15] https://www.saildrone.com/news/national-ocean-service-arctic-bathymetry-mission

Figure 16. Although the Saildrones operating in the Arctic are equipped with single-beam sonar, options are available also for multi-beam sonar.

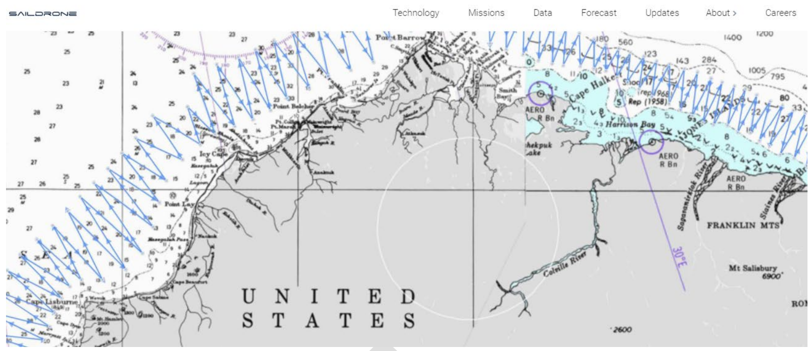

Figure 17. For the Arctic, the fleet of Saildrones perform a zig-zag pattern with a spacing of no more than five nautical miles between passes to delineate a corridor between the 20-meter and 50-meter contours for safe navigation of commercial vessels.

Goal 4: Conduct Strategic Communications to Promote Widespread Stakeholder Engagement.

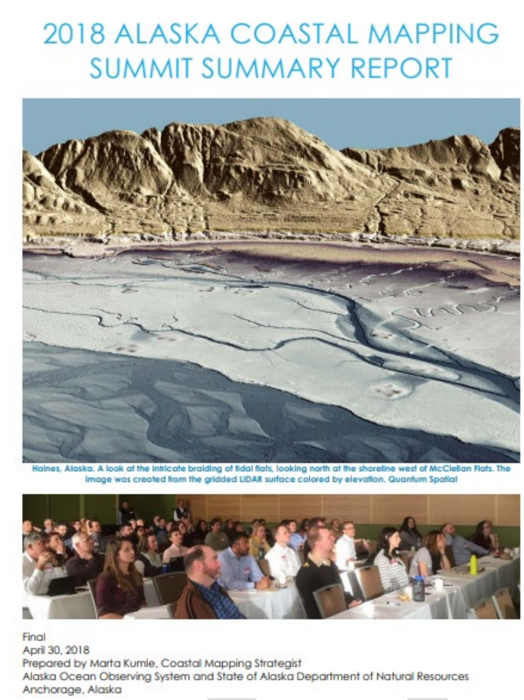

Figure 18. NOAA's Coastal Mapping Summits and Reports are ideal ways to improve private sector involvement with NOAA and the AMEC.

Objective 4.1: Strengthen Stakeholder Communications to Grow Participation in the Alaska Coastal Mapping Campaign. HSRP specific recommendations for improving stakeholder communication and participation include:
(1) develop an outreach and public engagement strategy that communicates the importance and value of mapping the coast and shoreline of Alaska; the Alaska Coastal Mapping Summits and Reports (Figure 17) have been outstanding in this regard.
(2) develop mechanisms that ensure the participation of non-government sectors in the development and execution of the Alaska coastal strategy and Implementation Plan;
(3) develop mechanisms that support the demonstration of innovative technologies/solutions from all sectors that would accelerate mapping the coast of Alaska with emphasis on autonomous solutions where warranted;
(4) increase the profile and improve the transparency of the AMEC, e.g., as a minimum publish minutes that can be shared with the public;
(5) develop a database (or some coordinated/integrated source) for all data required (existing and future) to map the shoreline of Alaska; develop a gap analysis in line with the work generated by NOAA for the USA EEZ;
(6) develop a series of standards and protocols to ensure consistency of coastal mapping data acquired by many sources across all sectors, related to the broader standards above, and
(7) engage stakeholders as early as possible in the process, and focus on getting their input early, rather than their feedback near the end.

Objective 4.2: Use Online Tools and Technologies to Communicate Plans and Performance. The HSRP concurs with NOAA's approach to this objective.

Appendix A

Recommendations from the National Research Council, 2004

A Seamless Bathymetric/Topographic Dataset for All U.S. Coastal Regions

One of the most serious impediments to coastal zone management is the inability to produce accurate maps and charts so that objects and processes can be seamlessly tracked across the land-water interface. Differences between agency missions, onshore topographic versus offshore bathymetric mapping techniques, differing vertical reference frames, and the inherent difficulty of collecting source data in the surf and intertidal zones have combined to produce this fundamental incompatibility. It will be impossible to properly understand processes, undertake planning, and establish boundaries in the coastal zone while two sets of disparate and non-convergent maps and charts are being separately maintained.

The barrier to the production of continuous integrated mapping products across the land-sea interface is the inherent difference in the horizontal and vertical reference surfaces (datums) and projections used for maps and charts. Horizontal datum and projection issues can be readily resolved with existing transformation tools, although these tools must be made more readily available to the user community. However, vertical datum issues present a serious challenge. In order to seamlessly combine offshore and onshore data, vertical datum transformation models must be developed. These models depend on the establishment and maintenance of a series of real-time tidal measuring stations, the development of hydrodynamic models for coastal areas around the nation, and the development of protocols and tools for merging bathymetric and topographic datasets.

The Tampa Bay Bathy/Topo/Shoreline Demonstration Project, a collaborative effort between NOAA and the USGS, has developed a suite of such tools (called Vdatum) and has demonstrated the feasibility of generating a seamless bathymetric/topographic dataset for the Tampa Bay area. This project has also demonstrated both the inherent complexity of such an undertaking and the substantial benefits that arise from interagency collaboration and coordination.

> **Recommendation 1: In order to combine onshore and offshore data in a seamless geodetic framework, a national project to apply Vdatum tools should be initiated. This will involve the collection of real-time tide data and the development of more sophisticated hydrodynamic models for the entire U.S. coastline, as well as the establishment of protocols and tools for merging bathymetric and topographic datasets.**

This dataset must be documented and disseminated in such a way that it can become the base for a wide range of applications, including the definition of local, regional, or national shorelines. As a result of this effort, it will be possible to merge data collected either on land or offshore into a common geodetic reference frame, while at the same time allowing application-specific maps and charts to be generated that maintain traditional tidal-based datums (e.g., for navigational charts) or orthometrically based datums (e.g., for topographical maps).

Shoreline Definition Protocols

Numerous agencies have identified the lack of a consistently defined national shoreline as a major barrier to informed decision making in the coastal zone. While a consistent shoreline is certainly desirable, many different definitions of the shoreline remain embedded in local, state, and federal laws, making it impractical to call for a single "National Shoreline." Rather, the key to achieving a consistent shoreline is the seamless geodetic framework referred to in Recommendation 1. With a seamless bathymetric/topographic dataset across the land-water interface, appropriate difference or tidal models, and consistent horizontal and vertical reference frames, any shoreline definition can be transformed and integrated within the common framework. The Vdatum tool kit and associated Web sites will be the key to establishing internally consistent shorelines between and among disparate surveys and studies.

Recommendation 2: To achieve national consistency, all parties should define their shorelines in terms of a tidal datum, allowing vertical shifts to be calculated between and among the various shoreline definitions, while at the same time permitting different agencies and users to maintain their existing legal shoreline definitions. In situations where legislation or usage does not preclude it, the committee recommends that the internationally recognized shoreline established by NOAA's National Geodetic Survey be adopted.

The committee encourages the Federal Geographic Data Committee's (FGDC) Marine and Coastal Spatial Data Subcommittee to pursue implementation of this recommendation.

Easy Access to Timely Data

Easy access to timely data is an essential component of effective coastal zone management. Many agencies have created Web sites that offer access to data in a variety of forms as well as data manipulation tools. However, these sites still represent only a small percentage of existing coastal zone data.

Recommendation 3: A single Web portal should be established to facilitate access to all coastal mapping and charting data and derived products. The site should be well advertised within federal and state agencies, state and local governments, academic institutions, nongovernmental organizations and conservation groups, and to other potential users. The portal should work well with all Web browsers and on all computer platforms, to make it easily accessible to all users.

The single portal is not intended to host all coastal data. Rather, it should serve as a focal point that links to many distributed databases maintained by individual agencies or organizations. This site would represent the one place where users, particularly new users, could begin their search for coastal data and derived products. A single, easily accessible data portal with appropriate data manipulation tools should also promote the timely entry and retrieval of data. Coordination of such a site logically falls under the purview of the FGDC and is fully consistent with the Geospatial One-Stop concept.

Data Integration, Interchangeability, and Accuracy

Providing easy access to data through a single Web portal is a critical starting point for addressing the needs of the coastal zone community. However, users must also be able to combine and integrate data collected by different agencies using a range of sensors and often based on different datums or projections. Users must also be able to assess the attributes and accuracy of the data provided. Integration of data and assessment of data quality are made possible by the establishment of data and metadata standards and the application of tools for data transformation.

Recommendation 4: All thematic data and other value-added products should adhere to predetermined standards to make them universally accessible and transferable through a central Web portal. All sources should supply digital data accompanied by appropriate metadata.

The FGDC is in the process of establishing a series of standards for the National Spatial Data Infrastructure (NSDI) that will be applicable to all coastal zone data. Unfortunately, implementation of the NSDI continues to be problematic for the coastal/marine community due to highly variable levels of commitment by different agencies and insufficient incentives to fully implement its principles. This may, in part, be due to the structural and budgetary barriers discussed in Chapter 6, the inability of a single set of standards to serve all applications and disconnects between those developing the standards and the user community. One approach to addressing this issue is for additional involvement by the private sector.

> **Recommendation 5: The private sector should be more involved in developing and applying data standards and products. Agency procurement requirements can be used to encourage the private sector to deliver needed products in a timely fashion.**

The committee is aware of numerous examples where private-sector initiatives established well-accepted and easily used data protocols—in effect de facto standards—that significantly enhance the effectiveness of data products. The private sector is often capable of greater speed and efficiency in the adoption of standards and tools than its government agency counterparts. Access to data, metadata, and data standards must be complemented by readily available tools to easily convert between and among different data formats, scales, and projections.

> **Recommendation 6: Government agencies and the private sector should continue to develop tool kits for coastal data transformation and integration. This will facilitate data analyses and the production of a range of value-added products. The tools should be accessible through the Web portal.**

Documentation of the tools and techniques used to process data must also be provided to help the user community understand the limitations and appropriate uses of various datasets. A variety of training courses and workshops will be essential to provide end-users with the knowledge and tools necessary for intelligent application of the available data.

Improved Coordination and Collaboration

Any activity that involves multiple federal, state, and local agencies, academic researchers, and the private sector has the potential for redundancy and overlap of effort. This is amplified when the activity requires expensive platforms, technologies, and sensors. In the area of coastal zone mapping and charting, the large number of agencies involved, their differing histories, the breadth of their mandates, and the complexity of the task offer ample opportunities for redundancy and inefficiency. Because data acquisition is unquestionably the most expensive aspect of coastal zone mapping, elimination of redundancy and overlap in this area is likely to yield large savings. Ensuring that all relevant agencies are aware of one another's activities will be an important first step toward improved coordination.

> **Recommendation 7: All federally funded coastal zone mapping and charting activities should be registered at a common, publicly available Web site. This combined registry should be accessible through the single Web portal for coastal zone information.**

Each entry in the registry should include a description of the mapping activity, its location and purpose, the agency collecting the data, the tools to be used, the scales at which data will be collected, and other relevant details. Non-federally funded agencies conducting coastal mapping activities should be encouraged to register their activities at the same site. A section of the registry should be dedicated to descriptions of planned but unfunded coastal mapping activities, as well as a prioritized compilation of coastal areas where surveying would be particularly helpful to state or local agencies. Technically, components of such registration may already be required under Office of Management and Budget (OMB) Exhibit 300, but Recommendation 7 suggests a considerably expanded effort focused on making all federally funded coastal zone mapping efforts more widely known.

Once implemented, this registry could serve as the focal point for national coordination of geospatial data collection and analysis efforts. Individual agencies would continue to set their own priorities, but through the registry process any overlapping efforts could be quickly identified and avoided. The registry would also facilitate increased efficiency by highlighting opportunities for "incremental" surveys, where one agency takes advantage of the mapping activities of another agency in a region of common interest by providing a small amount of additional funding to achieve an additional objective. Such “piggyback” collaborative efforts would allow additional agencies to acquire data that meet their needs at minimal incremental cost.

> **Recommendation 8: To be effective, coordination should be carried out among all the primary agencies involved in coastal zone mapping; it should be mediated by a body that has the authority and means to monitor and ensure compliance; and it should involve people who are knowledgeable enough to identify the most critical issues.**

Structurally, the FGDC appears to be an appropriate body to oversee such coordination, but many concerns remain about its effectiveness. Some restructuring of FGDC, and perhaps an empowered Marine and Coastal Spatial Data Subcommittee, will be required to allay these concerns. In this light the committee endorses the recommendations of a recent design study team that calls for major structural and management changes for the FGDC (FGDC, 2000). A less appealing alternative might be either a new government office or an extra-governmental body charged with establishing oversight of all national coastal mapping and charting activities.

> **Recommendation 9: Whichever body is charged to carry out the needed coordination activities, dedicated staff personnel should be assigned to maintain the Web portal (Recommendation 3), the activities registry (Recommendation 7), and associated Web sites, and to proactively search for areas where efforts can be coordinated, supplemented, or combined to increase efficiency.**

Specific areas where better coordination among federal agencies is urgently needed (with the agencies likely to be involved listed in parentheses) include the following:

- High-resolution topographic and bathymetric data acquisition at the land-water interface, including aerial and satellite imagery, Light Detection and Ranging (LIDAR) surveys, and bathymetric surveys (Federal Emergency Management Agency [FEMA], National Aeronautics and Space Administration [NASA], NOAA, U.S. Army Corps of Engineers [USACE] and USGS.
- National seamless topographic/bathymetric Digital Elevation Models/Digital Depth Models (National Geospatial-Intelligence Agency [NGA], NOAA, and USGS).
- Derived products for mapping *shoreline change* (Bureau of Land Management [BLM], FEMA, NOAA, USACE, and USGS), *habitat change* (EPA, FWS, NOAA Fisheries, NOAA-National Ocean Service, and USGS), *hazard vulnerability* (FEMA, NOAA, and USGS), and *coastal inundation and erosion hazards* (FEMA, NOAA, USACE, and USGS).

Increased Data Collection

There is a widespread need for more and better data to be collected in the coastal zone. Growing pressure from a variety of constituencies (e.g., fisheries, shipping and navigation, Law of the Sea implementers, resource managers) will lead to ever-greater demands for useful information. The single most consistently cited need among the agencies and the user community is for enhanced bathymetric data, particularly in very shallow coastal waters. These data provide the basic geospatial framework for almost all other studies and are a key component for derived products such as offshore habitat maps.

> **Recommendation 10: The fundamental reference frame data for the entire coastal zone should be collected, processed, and made available. The dynamic nature of the coastal zone requires that there should be specific plans for repeat surveys over time. The important role of qualified private survey contractors in coastal zone mapping and charting should also be acknowledged. Much of the work done by this sector is contracted by government agencies, and accordingly the**

prioritization and tracking of surveys can be coordinated by the body called for in Recommendation 8.

Given the number of agencies and private-sector companies involved in coastal mapping, and their disparate missions and budget directives, it is unrealistic to expect agreement on a single, unified and prioritized national mapping initiative. While each agency has responsibility for its own mapping priorities, a strong and enforceable mechanism for tracking and coordinating existing, ongoing, and planned mapping efforts (as out-lined in Recommendation 7) would increase efficiency to the point where considerably more survey work could be carried out for each dollar spent. Inconsistencies in scale and resolution for new data collection efforts could be resolved by the coastal zone coordinating body called for in Recommendation 8. After surveying agency needs, the coordinating body could determine whether the incremental value of collecting data over a larger area or in a slightly different form (e.g., at higher resolution) warrants modification of a planned surveying effort.

Severe challenges remain for those attempting to map the coastal zone. As well as the fundamental conceptual problem of reconciling terrestrial and tidal datums, there are also a number of logistical challenges, including shallow depths, waves, turbid waters, and longshore currents, that make it difficult to operate survey vessels and other equipment safely, accurately, and efficiently.

Recommendation 11: New remote sensing and in situ technologies and techniques should be developed to help fill critical data gaps at the land-water interface.

There are a number of promising new technologies and techniques:

- Integrated bathymetric/topographic LIDAR, multispectral, hyperspectral, and photographic imaging systems;
- Sensors deployed on autonomous underwater vehicles;
- “Opportunistic” mapping using volunteer recreational boats equipped with specialized mapping sensors approved by issuing agencies;
- Autonomous bottom-crawling vehicles;
- Improved satellite imaging capabilities; and
- Data fusion capabilities.

Continued support from funding agencies for development of coastal remote sensing tools, combined with an increased emphasis on coastal needs, will greatly accelerate the development and implementation of these critically needed technologies. The private sector can play a major role in addressing this recommendation.

Underestimation of the importance of the coastal zone threatens the well-being of the nation, and those charged with management and maintenance of this critical environment carry tremendous demands and responsibilities. In order to understand and address the effects of complex natural and anthropogenic forces in the coastal zone, a holistic multidisciplinary framework must be developed to account for the interconnectivity of processes within the system. At the base of this framework is accurate geospatial information about the locations of important features and processes, both onshore and offshore. The recommendations and strategies outlined above call for the establishment of a consistent geospatial framework and the application of innovative new acquisition, integration, and data management technologies that should allow coastal zone scientists, engineers, and managers to efficiently produce easily accessible, fully interchangeable, accurate, timely, and useful geospatial data and mapping products that seamlessly extend across the coastal zone. The recommendations also suggest simple mechanisms to enhance collaboration and cooperation among those charged with acquiring data in this complex region. These mechanisms should facilitate efficiency gains that will allow most of the nation’s coastal zone to be mapped in a timely manner. While simple in concept, implementation of the suggested strategies will require a focused effort on the part of the coastal zone community. If implemented, however, the committee believes that a major step will have been taken toward assuring the long-term well-being of the coastal zone.

Note: Subsequent to the publication of this NRC study in 2004, the FGDC published multiple drafts of its National Shoreline Data Content Standard[16] referenced in Recommendation 4 above.

[16] https://www.fgdc.gov/standards/projects/shoreline-data-content/index_html

Appendix B

The Importance of Vertical Datums, the VDatum Tool, and Shoreline Mapping

Vertical Datums[17]. Whether mapping on land, sea or from the air, the Global Positioning System (GPS) and Global Navigation Satellite System (GNSS) provide ellipsoid coordinates relative to the center of the earth. Those coordinates need to be translated into horizontal coordinates (e.g., latitude/longitude, UTM or State Plane Coordinates) and vertical coordinates need to be translated relative to a vertical datum, i.e., *a surface representing zero height*. There are several types of vertical datums relevant to Alaska coastal mapping:

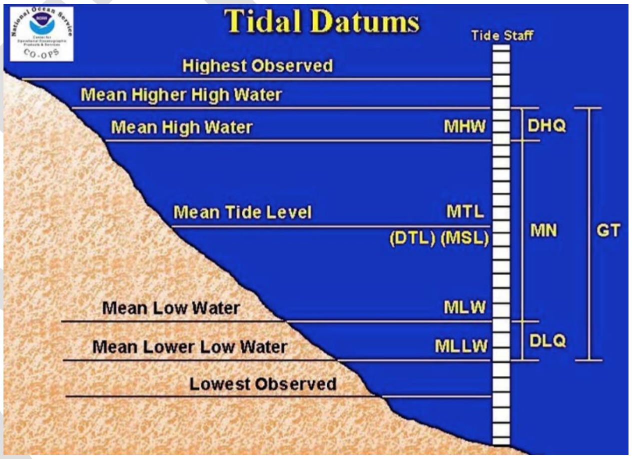

Figure 19. The relationship between various tidal surfaces.

- Tidal Datums[18]. For mapping wet areas, NOAA typically uses tidal datums as shown in Figure 18. A tidal datum is established by a tide gauge, a component of a modern water level monitoring station, fitted with sensors that record the height of the surrounding water levels. The "gold standard" for tide gauging is the National Water Level Observation Network (NWLON)[19] which operates continuously to the most rigorous standards. Figure 6, shown previously, provided by the Alaska Water Level Watch[20], shows major gaps in the NWLON network in Alaska, currently making it impossible to perform accurate coastal mapping for the major portions of Alaska's coasts currently unmapped. NOAA's Gaps Analysis Report[21] was used to identify these NWLON gaps. Geospatial changes in time and range of tide are used to delineate how much control a NWLON station can provide, and where there are geographic gaps between the control reach of adjacent NWLONs, there may be multiple gaps. Where there are multiple numbers in a gap, that means NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) believes there are several gaps within that area but does not have enough information to individually delineate those gaps. The HSRP was pleased to learn that CO-OPS is very supportive of and participates in the Alaska Water Level Watch (which includes the Alaska Ocean Observing System – AOOS) and their Build Out Plan. The Alaska Water Level Watch has a Build Out Plan[22] for filling these gaps with additional NWLON stations and/or less-expensive alternatives to NWLON stations for which NOAA's CO-OPS has provided additional

[17] https://www.ngs.noaa.gov/datums/vertical/
[18] https://geodesy.noaa.gov/INFO/facts/datum.shtml
[19] https://tidesandcurrents.noaa.gov/nwlon.html
[20] https://www.aoos.org/alaska-water-level-watch/
[21] https://tidesandcurrents.noaa.gov/publications/Technical_Memorandum_NOS_COOPS_0048_Updt.pdf
[22] http://arcg.is/0qqjDm

guidance[23] for tide gauges that do not need to operate continuously. This Build Out Plan includes an excellent video on the NWLON backbone. To help fill the major gaps in the NWLON stations in Alaska, NOAA should ensure adequate vertical control via short term gauges (90 days) operated to support completion of the VDatum models statewide. Comparison of long term NWLON data with short term gauges significantly reduces the uncertainty of those datums. It is imperative that the gaps shown in Figure 6 are filled by some affordable alternative to NWLON stations. In Goal 3, Objective 3.2, the HSRP introduced three innovative alternative methods for expedient tide gauging.

- Orthometric Datums. For mapping dry areas, USGS currently uses the North American Vertical Datum of 1988 (NAVD 88) for which *zero elevation* is based on mean sea level at a single point (Father Point/Rimouski) in Quebec. Then a level surface of equal gravity potential (the geoid) is extended throughout the U.S. to map *zero elevations* elsewhere. The geoid is an undulating surface that varies locally by changes in gravity mostly caused by local variables in the geophysical properties of the earth. NAVD 88 results in mean sea levels at other U.S. locations varying between -34 cm in Florida and +1.25 m in Washington, for example. NOAA's Gravity for the Redefinition of the American Vertical Datum (GRAV-D) program is in process of collecting gravity for all the U.S. and expects to complete the GRAV-D initiative by 2024. In the next few years (current target date is 2024), all vertical datums in the National Spatial Reference System (NSRS), including NAVD 88, will be replaced with the North American-Pacific Geopotential Datum of 2022 (NAPGD2022).

Vertical Datum Transformation Tool (VDatum)[24]. NOAA developed VDatum to address the inconsistent datum problem, primarily the major differences between tidal and orthometric datums, the primary reference levels to which geospatial data are gathered.

VDatum translates geospatial data between 36 different vertical reference systems and removes the most serious impediments to data sharing, allowing for the easy transformation of elevation data from one vertical datum to another. Geospatial data can be seamlessly integrated for the benefit of the U.S. public for applications such as Homeland Security and natural disaster preparedness. VDatum also allows NOAA to make full use of recent technological advancements such as integration of depth data from an aircraft using topobathymetric lidar that will greatly improve the efficiency with which it acquires new and more accurate data for NOAA's nautical, navigational, and geospatial products and services. VDatum will also improve the efficiency and accuracy of hydrographic surveys for nautical charts by eliminating the need for time-consuming water level corrections and post processing.

However, because of the large gaps in the NWLON network, VDatum in Alaska only exists in the Southeast Alaska regional model, added in 2019. Future development of coverage for the remainder of Alaska will commence once foundational geodetic and tidal data are established to allow for valid model construction. This is extremely urgent because of the pending introduction of the new North American-Pacific Geopotential Datum of 2022 (NAPGD2022).

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23 http://www.ioosassociation.org/sites/nfra/files/documents/boardmaterials/meetingmaterials/springmeeting2016/External_Source_Policy_22December2015.pdf

24 https://vdatum.noaa.gov/about.html

When the VDatum tool is complete for all of Alaska, advancements in the awareness of electronic charting systems and Electronic Chart Display and Information Systems (ECDIS) for the Electronic Navigational Chart (ENC) will be possible. A vessel's exact orientation in the water can be accurately determined using Differential GPS. This information can then be incorporated into the charting system along with real-time display of water depths corrected for tides for the entire body of water. Danger areas can be displayed automatically that will adjust depending on the vessels draft and water level as a vessel transits through areas of concern. This is especially important for tug barges that provide critical logistical support to coastal villages in Alaska. VDatum will also provide a tool for coastal restoration projects that require high-resolution wetland, bathymetric, and water level inundation maps.

Alaska's Shoreline. The NOAA Shoreline Website[25] provides the history and applications of shoreline mapping, e.g., boundary determination, shoreline change analysis, cartographic representation, and nautical chart production. Figure 19 shows how the Mean High Water (MHW) line divides privately-owned uplands from state-owned lands (or federal lands in Alaska), whereas Mean Lower Low Water (MLLW) is used as the chart datum for safety of navigation and establishes boundaries for territorial seas and the Exclusive Economic Zone (EEZ).

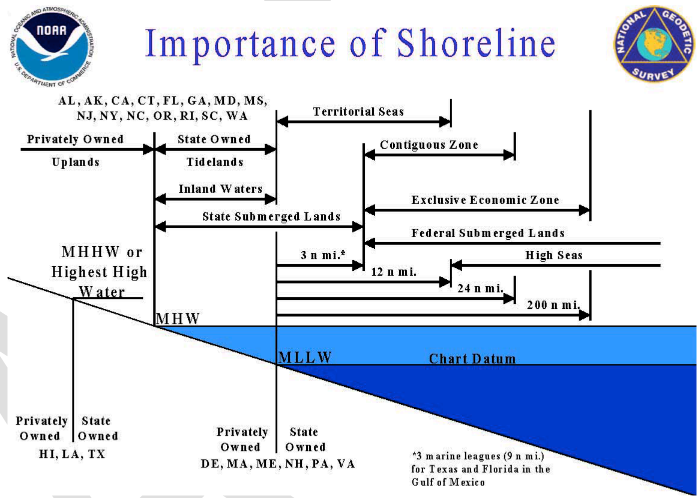

Figure 20. This graphic shows the importance of the MHW and MLLW lines in Alaska.

[25] https://shoreline.noaa.gov/