NOTICE OF OFFICE OF MANAGEMENT AND BUDGET ACTION

Date 05/21/2018

Department of Commerce
National Oceanic and Atmospheric Administration

FOR CERTIFYING OFFICIAL: Rod Turk
FOR CLEARANCE OFFICER: Jennifer Jessup

In accordance with the Paperwork Reduction Act, OMB has taken action on your request received 12/27/2017

ACTION REQUESTED: New collection (Request for a new OMB Control Number)
TYPE OF REVIEW REQUESTED: Regular
ICR REFERENCE NUMBER: 201712-0648-007
AGENCY ICR TRACKING NUMBER:
TITLE: 3D Nation National Enhanced Elevation Study 2018
LIST OF INFORMATION COLLECTIONS: See next page

OMB ACTION: Approved with change
OMB CONTROL NUMBER: 0648-0762
The agency is required to display the OMB Control Number and inform respondents of its legal significance in accordance with 5 CFR 1320.5(b).

EXPIRATION DATE: 05/31/2021 DISCONTINUE DATE:

BURDEN:	RESPONSES	HOURS	COSTS
Previous	0	0	0
New	800	2,400	0
Difference			
Change due to New Statute	0	0	0
Change due to Agency Discretion	800	2,400	0
Change due to Agency Adjustment	0	0	0
Change due to PRA Violation	0	0	0

TERMS OF CLEARANCE: This ICR is approved under section 3507 of the Paperwork Reduction Act. If NOAA continues this data collection in the future and chooses to resubmit this ICR, NOAA must submit the following information from this approval to OMB:

1. Overall cumulative response rate using one of the AAPOR definitions;
2. Item non-response rates for all questions;
3. Frequency of all responses from all questions.

OMB Authorizing Official: Dominic J. Mancini
Deputy and Acting Administrator,
Office Of Information And Regulatory Affairs

List of ICs			
IC Title	Form No.	Form Name	CFR Citation
3D questionnaire	NA	3D Nation Elevation Requirements and Benefits Study	

PAPERWORK REDUCTION ACT SUBMISSION

Please read the instructions before completing this form. For additional forms or assistance in completing this form, contact your agency's Paperwork Clearance Officer. Send two copies of this form, the collection instrument to be reviewed, the supporting statement, and any additional documentation to: Office of Information and Regulatory Affairs, Office of Management and Budget, Docket Library, Room 10102, 725 17th Street NW, Washington, DC 20503.

1. Agency/Subagency originating request
NOAA/National Ocean Service with DOI/USGS

2. OMB control number
a. 0648 - ______ b. [✔] None
Ref: OMB Control No. 1028-0099

3. Type of information collection (*check one*)
a. [✔] New Collection
b. [ ] Revision of a currently approved collection
c. [ ] Extension of a currently approved collection
d. [ ] Reinstatement, without change, of a previously approved collection for which approval has expired
e. [ ] Reinstatement, with change, of a previously approved collection for which approval has expired
f. [ ] Existing collection in use without an OMB control number
For b-f, note Item A2 of Supporting Statement instructions

4. Type of review requested (*check one*)
a. [✔] Regular submission
b. [ ] Emergency - Approval requested by ____/____/____
c. [ ] Delegated

5. Small entities
Will this information collection have a significant economic impact on a substantial number of small entities? [ ] Yes [✔] No

6. Requested expiration date
a. [✔] Three years from approval date b. [ ] Other Specify:______

7. Title 3D Nation National Enhanced Elevation Study 2018

8. Agency form number(s) (*if applicable*)

9. Keywords

10. Abstract

The NOAA Office of Coast Survey and the USGS National Geospatial Program are partnering to conduct a follow-on study to the National Enhanced Elevation Assessment (NEEA) conducted via survey in 2010-11 and finalized in 2012 (OMB Control No. 1028-0099, https://pubs.usgs.gov/fs/2012/3088). This follow-on study will incorporate coastal and ocean requirements for elevation data along with a revisit of the terrestrial elevation data needs assessed in 2010 to understand how those requirements and benefits dovetail in the nearshore coastal zone. The primary tool to gather information will be a questionnaire covering a wide range of business uses that depend on 3D elevation data to inform policy, regulation, scientific research, and management decisions. NOAA, USGS and partner mapping agencies are working to improve the technology systems, data, and services that provide information about 3D data and related applications within the United States. By learning more about business uses and associated benefits that would be realized from improved 3D data, the agencies will be able to prioritize and direct investments that will best serve user needs.

11. Affected public (*Mark primary with "P" and all others that apply with "x"*)
a. ___ Individuals or households
b. _x_ Business or other for-profit
c. _x_ Not-for-profit institutions
d. ___ Farms
e. _x_ Federal Government
f. _x_ State, Local or Tribal Government

12. Obligation to respond (*check one*)
a. [✔] Voluntary
b. [ ] Required to obtain or retain benefits
c. [ ] Mandatory

13. Annual recordkeeping and reporting burden
a. Number of respondents: 800
b. Total annual responses: 800
1. Percentage of these responses collected electronically: 95 %
c. Total annual hours requested: 800
d. Current OMB inventory: 0
e. Difference: 800
f. Explanation of difference
1. Program change ______
2. Adjustment ______

14. Annual reporting and recordkeeping cost burden *(in thousands of dollars)*
a. Total annualized capital/startup costs: 0
b. Total annual costs (O&M): 0
c. Total annualized cost requested: 0
d. Current OMB inventory: 0
e. Difference: 0
f. Explanation of difference
1. Program change ______
2. Adjustment ______

15. Purpose of information collection (*Mark primary with "P" and all others that apply with "X"*)
a. ___ Application for benefits
b. _x_ Program evaluation
c. ___ General purpose statistics
d. ___ Audit
e. _P_ Program planning or management
f. _x_ Research
g. ___ Regulatory or compliance

16. Frequency of recordkeeping or reporting *(check all that apply)*
a. [ ] Recordkeeping b. [ ] Third party disclosure
c. [✔] Reporting
1. [ ] On occasion 2. [ ] Weekly 3. [ ] Monthly
4. [ ] Quarterly 5. [ ] Semi-annually 6. [ ] Annually
7. [ ] Biennially 8. [ ] Other (describe) One time plus possible ir

17. Statistical methods
Does this information collection employ statistical methods
[✔] Yes [ ] No

18. Agency Contact (person who can best answer questions regarding the content of this submission)
Name: Ashley Chappell, ashley.chappell@noaa.gov
Phone: 240.429.0293

19. Certification for Paperwork Reduction Act Submissions

On behalf of this Federal Agency, I certify that the collection of information encompassed by this request complies with 5 CFR 1320.9

NOTE: The text of 5 CFR 1320.9, and the related provisions of 5 CFR 1320.8(b)(3), appear at the end of the instructions. *The certification is to be made with reference to those regulatory provisions as set forth in the instructions.*

The following is a summary of the topics, regarding the proposed collection of information, that the certification covers:

(a) It is necessary for the proper performance of agency functions;

(b) It avoids unnecessary duplication;

(c) It reduces burden on small entities;

(d) It used plain, coherent, and unambiguous terminology that is understandable to respondents;

(e) Its implementation will be consistent and compatible with current reporting and recordkeeping practices;

(f) It indicates the retention period for recordkeeping requirements;

(g) It informs respondents of the information called for under 5 CFR 1320.8(b)(3):

- (i) Why the information is being collected;
- (ii) Use of information;
- (iii) Burden estimate;
- (iv) Nature of response (voluntary, required for a benefit, mandatory);
- (v) Nature and extent of confidentiality; and
- (vi) Need to display currently valid OMB control number;

(h) It was developed by an office that has planned and allocated resources for the efficient and effective management and use of the information to be collected (see note in Item 19 of instructions);

(i) It uses effective and efficient statistical survey methodology; and

(j) It makes appropriate use of information technology.

If you are unable to certify compliance with any of the provisions, identify the item below and explain the reason in Item 18 of the Supporting Statement.

Signature of Senior Official or designee	Date

Agency Certification (signature of Assistant Administrator, Deputy Assistant Administrator, Line Office Chief Information Officer, head of MB staff for L.O.s, or of the Director of a Program or StaffOffice)	
Signature signed by Cheryl Marlin	Date 12/20/2017
Signature of NOAA Clearance Officer	
Signature BRABSON.SARAH.1365710488 Digitally signed by BRABSON.SARAH.1365710488 Date: 2018.06.29 14:48:11 -04'00'	Date

SUPPORTING STATEMENT
3D Nation Elevation Requirements and Benefits Study 2018

OMB CONTROL NO. 0648-xxxx

A. JUSTIFICATION

1. <u>Explain the circumstances that make the collection of information necessary.</u>

The National Oceanic and Atmospheric Administration (NOAA) Office of Coast Survey and the U.S. Geological Survey (USGS) National Geospatial Program (NGP) are partnering to conduct the *3D Nation Elevation Requirements and Benefits Study*. This study is designed to gather information from users of elevation data (both topography and bathymetry) about their requirements for the data they need to conduct their business, and the benefits they will derive if all of their requirements could be met by readily available elevation data. An important aspect of this study is the collection of coastal and ocean requirements for elevation data, which have never been comprehensively gathered before, and the merging of this information with data about terrestrial elevation requirements.

The goal of this study is not to gather customer satisfaction information about already available 3D elevation data, but to learn more about organization's business uses and the associated benefits that could be realized from improved 3D elevation data. The results of the study will help federal mapping agencies to develop and refine future program alternatives for better 3D elevation data to meet many federal, state, and other national business needs. Clarity on what users need will help inform program management options and decisions. The results of this study will help NOAA and partner agencies develop a required national coastal mapping strategy and help the USGS NGP evaluate its program direction now that approximately 50% of terrestrial elevation data have been collected under the interagency 3D Elevation Program (3DEP).

Authorizing statutes supporting the *3D Nation Elevation Requirements and Benefits Study* include the Ocean and Coastal Mapping Integration Act (33 USC 3501), which tells federal mapping agencies to better coordinate their activities and the Coast and Geodetic Survey Act (33 USC 883a et seq), which authorizes NOAA to collect elevation data for nautical charts and safe navigation.

This study builds on the National Enhanced Elevation Assessment (NEEA) white paper finalized in 2012 (NEEA overview at https://pubs.usgs.gov/fs/2012/3088/), which assessed terrestrial elevation data needs assessed via a similar survey in 2010 (OMB Control No. 1028-0099). The original NEEA, and its original survey methodology, serve as a model to follow for proven utility in effective program management, as its results have guided management of 3DEP since 2012. Refreshing the NEEA with this 3D Nation study will allow 3DEP to make necessary course corrections five years into the program. With the addition of ocean and coastal requirements and benefits, federal ocean and coastal mapping agencies will be able to coalesce around informed strategies to collectively improve their service delivery as well.

The primary tool to gather information will be a voluntary online questionnaire sent to a carefully curated list of elevation data users. The questionnaire covers a wide range of business uses that depend on 3D elevation data to inform policy, regulation, scientific research, and management decisions. Voluntary in-person interviews to clarify questionnaire results may also be arranged. The online survey instrument can be accessed here:

https://3dnation.checkboxonline.com/Survey.aspx?s=6f7513975ba340818246380e20e88650&u=1b7f7800-e21d-489a-aa74-00e59517923b&forceNew=true&test=true.

For purposes of this questionnaire, 3D elevation data refers to topographic data (precise three-dimensional measurements on land) and bathymetric data (precise three-dimensional measurements in the water). Questions will be asked about how elevation data relates to specific Mission Critical Activities (activities that are indispensable for mission accomplishment and/or essential for effective/efficient operations in accomplishing the core mission of the organization). The questionnaire also explores where stakeholders need elevation data (geographic extent), the accuracy and update frequencies required, and assessments of how organizations would benefit from better elevation data.

This questionnaire includes questions about the technical requirements for 3D elevation data as well as questions about the benefits of 3D elevation data to participant organizations. The technical requirements may best be answered by an elevation data user who has experience working with the data. The questions on benefits including potential revenue increase, cost savings and other operational improvements may best be answered by a stakeholder or person who makes management or business decisions. If applicable, the questionnaire may be jointly completed by an elevation data user and stakeholder in order to capture both perspectives for a Mission Critical Activity.

We have also established a process whereby the questionnaire responses will be validated and confirmed with each organization or state. This same process worked to great effect with NEEA and the USGS *Hydrography Requirements and Benefits Study* (HRBS) (OMB Control Number Control Number 1028-0112), allowing higher level managers and stakeholders to validate benefits information provided by their organization's respondents.

2. Explain how, by whom, how frequently, and for what purpose the information will be used. If the information collected will be disseminated to the public or used to support information that will be disseminated to the public, then explain how the collection complies with all applicable Information Quality Guidelines.

NOAA, USGS and partner mapping agencies are working to improve the technology systems, data, and services that provide information about 3D elevation data and related applications within the United States. This 3D Nation questionnaire will help federal agencies evaluate future program alternatives that would provide enhanced 3D data to meet many Federal, State, and other national business needs. By learning more about business uses and associated benefits that would be realized from improved 3D data, the agencies will be able to prioritize and direct investments that will best serve user needs over the course of the next few years.

The 3D Nation study information will be analyzed by NOAA, USGS and the contractor doing the study to help determine requirements and benefits of elevation data. Post-survey analyses will project out the costs for data acquisition, processing, QA/QC, life-cycle data management, data distribution, as well as benefits over the geographies and the number of years needed to deliver the program scenario being evaluated. The ROI analyses can be used to identify geographies where more-frequent or less-frequent updates would yield higher or lower ROIs for those areas so decision-makers can identify where more-frequent updates are warranted. The ROI analyses will also be able to highlight different geographies in which different data accuracies might yield higher ROIs.

Collected responses will be aggregated at the agency and national levels in subsequent reports and assessments following Information Quality Guidelines for quality, integrity, utility and objectivity. Responses associated with individuals will not be distributed, but the information collected will be used to support publicly disseminated information. The information collection process will be guided by an interagency management team led by NOAA and USGS with contracted support from Dewberry Consultants LLC. Dewberry was the contractor on the original NEEA study, as well as the HRBS. The information collection will be conducted using a standardized template. Responses are one-time and voluntary.

The sections of the questionnaire include:

- Respondent Information – name, contact information, organization type, etc. (all users asked to respond)
- Mission Critical Activity, Business Use, Program Name (all respond)
- Elevation Data Requirements and Benefits (subsections only required if a user indicates a need for that type of data)
  - Inland topography
  - Inland bathymetry
  - Nearshore bathymetry/topobathymetry
  - Offshore bathymetry
- Information Access Methods and Final Comments (all respond)

The online tool will direct respondents to only the sections of the survey applicable to them. Frequently Asked Questions and Benefits Examples will be hyperlinked from relevant questions for ease of access, and also visible in total.

NOAA Coast Survey and USGS NGP will retain control over the information and safeguard it from improper access, modification, and destruction, consistent with NOAA standards for confidentiality, privacy, and electronic information. See response to Question 10 of this Supporting Statement for more information on confidentiality and privacy. The information collection is designed to yield data that meet all applicable information quality guidelines. Prior to dissemination, the information will be subjected to quality control measures and a pre-dissemination review pursuant to Section 515 of Public Law 106-554.

The practical utility of this updated information collection has been well demonstrated by how integral the original NEEA was/is to effective USGS 3D Elevation program management.

NOAA and USGS anticipate similar benefits to both terrestrial and ocean/coastal federal mapping programs with this follow-on 3D Nation study. The work will culminate in a final report along the lines of the original NEEA study (available at http://www.dewberry.com/services/geospatial/national-enhanced-elevation-assessment) and summary white paper (https://pubs.usgs.gov/fs/2012/3088). These analyses will inform federal agency mapping coordination and planning to meet more stakeholder needs with mapping dollars, increase efficiencies and avoid redundant collections.

3. <u>Describe whether, and to what extent, the collection of information involves the use of automated, electronic, mechanical, or other technological techniques or other forms of information technology</u>.

The 3D Nation questionnaire will be conducted via an online survey tool located on NOAA's Office of Coast Survey site for ease of access, data collection and recording. (URL: XXX). The online tool will direct respondents to only the sections of the survey applicable to them. Frequently Asked Questions and Benefits Examples will be hyperlinked from relevant questions for ease of access, and also visible in total. Alternatives (e.g. accessible electronic PDF, printable PDF, paper survey mailed to respondent, verbal) will be provided to any respondents who seek to provide input via other methods. The direct results of the information collection will not be made available to the public at all. However, any aggregated analyses and reports will be made available to the public over the Internet.

If voluntary in-person interviews are conducted to clarify questionnaire results, the interviewers will use laptops to directly enter the answers being provided. This will help the contractor and NOAA/USGS keep all acquired information in a single database.

4. <u>Describe efforts to identify duplication</u>.

Based upon a scan of federal mapping agency and partner activities, we do not believe there is currently any national effort since the original NEEA study to collect elevation requirements and/or re-examine the queries asked in 2010. Even more importantly, there has not been a national study that incorporates ocean/coastal into an assessment of 3D elevation data needs.

In April 2017, the state of Florida undertook a study of state elevation data needs for its own purposes; organizers of that study requested NOAA/USGS input on the questions to ask of Florida state agency representatives. Lessons learned from both the original NEEA and the Florida study have helped to improve the approach that NOAA/USGS are taking to this national 3D elevation study. If Florida respondents indicate unwillingness to respond to the 3D Nation questionnaire because they feel it duplicates their earlier efforts, NOAA/USGS and contractor will follow up with the Florida study organizers to request that input and fill in any gaps with in-person interviews.

A process is also included within the study design to validate the survey information collected through interviews or workshops. These will be conducted with each participating Federal agency, state, and non-governmental or private organization. This validation process is intended to identify questionnaire responses that may describe the same or similar Mission Critical Activities in order to consolidate responses that may be duplicative.

5. If the collection of information involves small businesses or other small entities, describe the methods used to minimize burden.

The questionnaire is not anticipated to have a significant impact on small entities such as small businesses, organizations, or government bodies. The short duration of the survey will likely not impose a significant economic impact on a respondent.

6. Describe the consequences to the Federal program or policy activities if the collection is not conducted or is conducted less frequently.

If the collection is not conducted, NOAA/USGS and federal mapping partners will not have current data upon which to base elevation mapping program management decisions. We will only be able to rely on the 2010 NEEA results, which do not include ocean/coastal mapping data requirements, and do not provide the USGS an effective means to gauge the results/impact of its 3D Elevation Program to date. NOAA, USGS and partner mapping agencies are working to improve the technology systems, data, and services that provide information about 3D elevation data and related applications within the United States. By learning more about business uses and associated benefits that would be realized from improved 3D data, the agencies will be more informed and able to prioritize and direct investments that will best serve user needs over the course of the next few years.

7. Explain any special circumstances that require the collection to be conducted in a manner inconsistent with OMB guidelines.

There are no special circumstances related to the 3D Nation study inconsistent with OMB guidelines.

8. Provide information on the PRA Federal Register Notice that solicited public comments on the information collection prior to this submission. Summarize the public comments received in response to that notice and describe the actions taken by the agency in response to those comments. Describe the efforts to consult with persons outside the agency to obtain their views on the availability of data, frequency of collection, the clarity of instructions and recordkeeping, disclosure, or reporting format (if any), and on the data elements to be recorded, disclosed, or reported.

A Federal Register Notice was published on February 24, 2017 (82 FR 11558), soliciting public comments on the study. It included a link to a draft of the questionnaire in case any respondents wanted to review the actual questionnaire. The comment period was open until April 25, 2017, but no comments were received. In an effort to ensure broad awareness of the planned study and any opposing views or constructive feedback, NOAA and USGS subsequently sent the draft questionnaire out to stakeholders, associations and other groups who might care to review and comment on it (e.g. the American Society for Photogrammetry and Remote Sensing and Association of American State Geologists).

NOAA and USGS also developed an outreach plan to inform stakeholders at related conferences and workshops about the study. The plan was implemented via a number of conferences and association meetings, where we offered to make the questionnaire available to anyone who cared to review it. These opportunities included the 2017 national MAPPS meeting of firms in the surveying, spatial data and geographic information systems fields; the Joint Airborne Lidar Bathymetry Technical Center of Expertise Summer 2017 Workshop; the National States Geographic Information Council (NSGIC) 2017 Spring meeting; and the American Shore and Beach Preservation Association (ASBPA) 2017 Fall meeting. Reaction was very positive, as many of those in the briefs had participated or knew of the NEEA study; coastal states at the NSGIC and ASBPA meetings were especially pleased that ocean/coastal elevation data was being added to the study. Questions during these sessions included when the survey would start, how will participants be identified, could anyone take the survey, and could they answer for more than three mission critical activities.

NOAA and USGS also received comments in the document from a few 3D Elevation Program Working Group and Interagency Working Group on Ocean and Coastal Mapping members. Responses from non-feds were mainly informal, ranging from emails to verbal comments and questions during presentations. All responses were positive; no negative feedback was received on the intent and planned process for the 3D Nation Study. Examples of text comments and the few emailed comments include:

- This is superb.
- My only suggestion is to consider "Question 2. Which type of organization do you represent?" as one-third of all state geological surveys are state-government-mandated more-or-less, and university-based. So university-based state geological surveys, like me, would wonder whether to say they are state government, or academic.
- The questionnaire looks good.
- Should be "Commonwealth of the Northern Mariana Islands."
- Is there going to be a glossary that defines all the technical terms in the document?
- Will there be a map (s) which shows the huc-2 or -4?
- A respondent could be interrupted while completing the survey or need to check on some information. Can they pause and then resume?
- On approximate size of features: While the sizes make sense here, the descriptions of those sizes (e.g. survey-level features) are a bit odd. Also, you say "size of the features" but half your descriptions reference scales, not features. Maybe ask the size of the smallest features that need to be resolved and just give the choices in meters.
- On horizontal accuracy needed: Accuracy measure? 95%? 90% circular error? All points within? RMSE?

Comments like the last two above helped NOAA and USGS to refine and improve the questions to be more clear.

9. <u>Explain any decisions to provide payments or gifts to respondents, other than remuneration of contractors or grantees</u>.

N/A.

10. <u>Describe any assurance of confidentiality provided to respondents and the basis for assurance in statute, regulation, or agency policy</u>.

There is no assurance of confidentiality provided. However, the information will be stored on the NOAA Coast Survey Nautical Charting system, which has an approved Privacy Impact Assessment (NOAA6501, with valid Authority to Operate). Results will be downloaded to Coast Survey resources. The applicable System of Records Notice is Commerce/NOAA-11, Contact Information for Members of the Public Requesting or Providing Information Related to NOAA's Mission (82 FR 3721, amended notice published January 12, 2017).

11. <u>Provide additional justification for any questions of a sensitive nature, such as sexual behavior and attitudes, religious beliefs, and other matters that are commonly considered private</u>.

N/A.

12. <u>Provide an estimate in hours of the burden of the collection of information</u>.

Because this will be an attentive, knowledgeable, and highly motivated sample, we anticipate a response rate of approximately 80% for the online survey (yielding 800 actual respondents of the invited 1000).

We have performed user testing of the questionnaire as coded within the survey software and have found that the time spent to answer the questions and review the Frequently Asked Questions as needed within the questionnaire was approximately 60-90 minutes without taking time out to consult others within the organization. We estimate that the average respondent may take between 30 and 60 minutes to consult within their organization as needed.

Note that most survey participants will not be responding to the entire questionnaire, but a subset, depending on the focus of their activity. The majority of respondents will have one Mission Critical Activity and one geographic area they are interested in which results in 42 questions being asked. For example, participants from the 20 non-coastal states will never see questions 36-61; participants whose focus is on offshore activities will only see questions 1-10 and 49-68.

Therefore, we believe that 2.5 hours per respondent should be sufficient to complete the questionnaire and consult within an organization for input, but to err on the conservative side, we will round up to 3 hours.

13. Provide an estimate of the total annual cost burden to the respondents or record-keepers resulting from the collection (excluding the value of the burden hours in Question 12 above).

$0, no additional record-keeping required.

14. Provide estimates of annualized cost to the Federal government.

The costs incurred by the Federal government include the contract to design and administer the questionnaire, conduct analyses and deliver reports over an 18 month period, at an estimated $1.1M total, $875K in year 1, $300K in year 2. There will be no additional costs beyond the normal labor costs for staff. Anticipated staff tasks include 3D Nation study project management, outreach (emails/calls/briefs/webinars) to potential respondents to encourage voluntary input, and a subset of follow-up interviews using regional agency representatives to clarify questionnaire responses.

3D Nation Study Federal Agency Annual Labor Costs (using $60 average staff hourly rate)		
Activity/Hours	# of employees	Cost
3D Nation study project management/ 200 hours	2 (NOAA/USGS)	$24,000
Pre-survey outreach to stakeholders/ 3 hours	20 (various fed'l mapping agency reps)	$3,600
Post-survey follow-ups/20 hours	10 (regional liaisons)	$12,000
	Total:	$39,600

15. Explain the reasons for any program changes or adjustments.

This is a new information collection.

16. For collections whose results will be published, outline the plans for tabulation and publication.

Once all of the *3D Nation Elevation Requirements and Benefits Study* data have been collected, consolidated and verified, and concurrence received from the Federal and state agency points of contact, analysis of the data can be performed. Follow-on analyses will project out the costs for data acquisition, processing, QA/QC, life-cycle data management, data distribution, as well as benefits over the geographies and the number of years needed to deliver the program scenario being evaluated. These analyses can be used to identify geographies where more-frequent or less-frequent updates would yield higher or lower ROIs for those areas so decision-makers can identify where more-frequent updates are warranted. The ROI analysis will also be able to highlight different geographies in which different data accuracies might yield higher ROIs.

The *3D Nation Elevation Requirements and Benefits Study* final report will fully document the study. This would include an overview of the study goals and project scope; documentation of the study process; a summary of the data that was gathered during the study, to include the full details of the consolidated and validated stakeholder input (with no attribution to individual respondents); the results of the analysis of the gathered data; and recommendations and conclusions. The results will be available through NOAA and USGS webpages.

17. If seeking approval to not display the expiration date for OMB approval of the information collection, explain the reasons why display would be inappropriate.

N/A.

18. Explain each exception to the certification statement.

N/A.

SUPPORTING STATEMENT
3D Nation Elevation Requirements and Benefits Study 2018

OMB CONTROL NO. 0648-xxxx

B. COLLECTIONS OF INFORMATION EMPLOYING STATISTICAL METHODS

1. Describe (including a numerical estimate) the potential respondent universe and any sampling or other respondent selection method used. Provide data on the number of entities (e.g., establishments, State and local governmental units, households, or persons) in the universe and the corresponding sample in tabular form. The tabulation must also include expected response rates for the collection as a whole. If the collection has been conducted before, provide the actual response rate achieved.

The sample for this collection will largely consist of day-to-day professional users of elevation data (topographic, bathymetric) and activities/industries that rely on elevation data. The survey data will be collected electronically through an online questionnaire.

Respondent Universe

The respondent population for the online survey will be selected from a pre-defined list of federal, state, local, and tribal governmental agencies, academia, industry and non-governmental entities known to use elevation data. NOAA and USGS geospatial liaisons will work with their state, local, and tribal counterparts to provide a list of individuals using elevation data. For purposes of this study, up to 1000 people will be chosen to complete the online survey (see Table 1 below). Each respondent will be contacted via email (or other means as needed) and given the instructions for completing the survey.

We anticipate a response rate of at least 80% for the online survey (yielding 800 actual respondents).

Table 1. Organizations in respondent universe for Survey and Interviews

Surveys			
Organization	**Number of Organizations**	**Average Expected Survey respondents per Organization**	**Total Respondents**
Federal agencies	60	5	300
U.S. States	50	8	400
U.S. Territories	5	2	10
Tribal Governments	10	2	20
Academia	25	3	75
Private Sector/Industry	75	1	75
Not-Governmental	60	2	120
		Total	1000

2. Describe the procedures for the collection, including: the statistical methodology for stratification and sample selection; the estimation procedure; the degree of accuracy needed for the purpose described in the justification; any unusual problems requiring specialized sampling procedures; and any use of periodic (less frequent than annual) data collection cycles to reduce burden.

The respondent sample will be comprised of a known population of elevation data users based upon a confirmed list (n=1000). Representatives from federal, state, local, and tribal government organizations, academia, industry and non-governmental entities will be contacted and asked to participate in this study. The sample will not be stratified because the population is known by NOAA and USGS as contacts and through working relationships.

Study participants are being identified as follows:

- Each Federal agency has a Point of Contact (POC) that was nominated by their agency as someone with broad understanding of agency programs and their use(s) of elevation data. The POCs are identifying participants within their agency to respond to the questionnaire and participate in the validation process. They are also recommending participants from non-governmental and private organizations. The Federal POCs will also review the agency's initial responses to the questionnaire and sign off on the final validated agency study input.
- Each state has a State Champion that was selected in consultation with regional experts as someone with broad knowledge of elevation activities within their state. Similar to the Federal POCs, the State Champions are identifying study participants within their state to respond to the questionnaire and participate in the validation process. The State Champions will also review the state's initial responses to the questionnaire and sign off on the final validated statewide study input.
- The 3D Nation Elevation Requirements and Benefits Study has identified tribal needs as an important stakeholder group for improving our understanding 3D elevation data requirements for the nation. State Champions are best positioned to help identify tribes that are active in the elevation data community and have the background needed to assess their tribe's elevation data needs. Additionally, the 3D Nation Study will have a representative from the Bureau of Indian Affairs responding to the study. We will also ask BIA to recommend tribal associations and groups that might respond from the collective perspective, such as the National Congress of American Indians and the National Tribal Land Association.

The data collected during the online survey study will be coded directly into an on-premises computerized database using Checkbox Survey software. Data analysis will consist of descriptive summary statistics – sum, maximum, minimum, mean, median. Descriptive statistics will be used to describe current uses within the programs of the organizations represented within the sample. Because NOAA and USGS are interested in determining ways to improve the availability of elevation data, it is important to gather baseline information concerning current requirements and to determine any information gaps or unmet needs.

The monetary benefits being collected in this study will be attributable to a given Mission Critical Activity and the geographic Area of Interest and requirements for 3D elevation data needed to accomplish the activity. It should be noted that study participants are free to answer any of the benefits questions as "Unknown" or "Unable to provide." The benefits questions also include a place to describe the benefits in narrative form as well as how the value was derived. During the validation process, organization stakeholders will be asked to verify that the benefits they provided are reasonable.

In the follow-on analyses of the questionnaire results, the benefits dollars will be apportioned spatially across the Mission Critical Activity Area of interest (e.g. dollars per square mile) and compared to costs per square mile for data collection. If a study participant identifies requirements that will not be met by a program scenario that is being evaluated, the benefits dollars will be reduced to account for the program not meeting all of the requirements for an activity. For example, if a participant identified $1 million in benefits for having Quality Level 2 data updated annually and the program scenario is for Quality Level 2 data delivered every five years, then the benefits would be assumed to be reduced proportionally.

In the study report(s), data aggregation will be done by groupings that are defined in the study questionnaire, such as by Business Use (e.g. Water Supply and Quality), organization type (e.g. Federal, State, etc.), geographic area type (e.g. inland, nearshore, offshore), or data type (e.g. topography, bathymetry). No extrapolation will be made from one type of study participant to a larger group. One organization type's responses (e.g., state, county, Tribe, agency, etc.) will not be assumed to apply to any other similar organization type.

3. Describe the methods used to maximize response rates and to deal with nonresponse. The accuracy and reliability of the information collected must be shown to be adequate for the intended uses. For collections based on sampling, a special justification must be provided if they will not yield "reliable" data that can be generalized to the universe studied.

Several steps will be taken to maximize response rate and ensure an accurate and reliable sample. We predict that the response rate of at least 80% will be met due to the highly technical nature of the respondents, support of the NOAA and USGS geospatial liaisons, and contractor follow-up.

We are using this web-based survey as a strategy to decrease costs, increase the speed of data collection, increase response rates by providing additional modes for response, and decrease the amount of non-response error. The Tailored Design Method for mail and internet surveys will be followed to help ensure a high response rate and representative sample. As a part of this process we will:

1. request participation in advance.

2. use the questionnaire introduction to share:
- the purpose of the survey
- the reason for participation
- the terms of anonymity and how the results will be used.

3. allow enough time to complete the survey. With Checkbox Survey, we will be able to allow the respondent to begin the survey and return at a later time if needed.

4. provide clear survey instructions for each section, explaining how to navigate through and submit the survey.

5. provide a survey that is easy to follow with clear and direct questions/instructions:

6. send reminders during the survey period for those that have not completed the survey.

4. Describe any tests of procedures or methods to be undertaken. Tests are encouraged as effective means to refine collections, but if ten or more test respondents are involved, OMB must give prior approval.

NOAA and USGS asked nine federal agency colleagues to complete the questionnaire, in order to troubleshoot issues in advance of broader dissemination. Their feedback was extremely helpful to improve the survey instrument.

As detailed in Section A8 of this statement, the questions for this collection were subject to extensive internal NOAA and USGS review, as well as reviews by external partners, including the 3DEP Working Group, the Interagency Working Group on Ocean and Coastal Mapping, representatives from associations such as the American Society for Photogrammetry and Remote Sensing, the National States Geographic Information Council and the Association of American State Geologists. The review and pre-testing of the questionnaire were performed to gather comments concerning the overall structure, sequence and clarity of questions. Individuals were also asked to estimate the time burden of the survey. Comments and suggestions provided by reviewers and pre-test participants were evaluated and used to revise the survey instrument where appropriate. Comments that improved clarity and comprehension of content were also incorporated.

5. Provide the name and telephone number of individuals consulted on the statistical aspects of the design, and the name of the agency unit, contractor(s), grantee(s), or other person(s) who will actually collect and/or analyze the information for the agency.

Ashley Chappell, Ashley.chappell@noaa.gov, 240.429.0293
Allyson Jason, ajason@usgs.gov, 703.648.4572
Sue Hoegberg, shoegberg@dewberry.com, 703.849.0419
Dave Maune, dmaune@dewberry.com, 703.849.0396

Frequently Asked Questions (FAQs)

It is important for respondents to the questionnaire to understand the answers to the 31 FAQs explained, with graphic examples, below. The terms explained herein must be understood in order to provide valid responses to questions pertaining to 3D elevation data requirements and benefits. The individual FAQs will be repeated as you come to the relevant questions in the questionnaire.

FAQ #1: What is a Program, a Business Use (BU) and a Mission Critical Activity (MCA)?

A program is a major component of an organization that has a well-defined mission and goals and which is supported by one or more Mission Critical Activities (MCAs). For the purpose of this study, an MCA is an activity or process that uses some form of elevation data, including derivative products, to accomplish a Business Use (BU) for which we specify 30 pre-selected BUs for use in this study. For example, within an emergency management program, hydrologic and hydraulic (H&H) modeling could be an MCA that supports BU #15 (Flood Risk Management) that requires elevation data for effective H&H modeling. *Mission Critical* is defined as "indispensable for mission accomplishment and/or essential for effective/efficient operations in accomplishing the core mission of the organization."

Table 1 shows the list of 30 BUs used in the questionnaire, along with examples of MCAs that fit within each BU. Questionnaire respondents will be asked to name their own MCA(s) using their own words and to also identify one of the pre-selected BUs as primary that best fits your MCA. You may also select a secondary and tertiary BU, if any, that also fit your MCA.

Table 1. Business Uses and Examples of Mission Critical Activities.

Business Uses	Examples of Mission Critical Activities
BU 01 - Water Supply and Quality	Fate and transport of contaminants. Pollution risk mitigation. Runoff and sedimentation analyses. Point- or non-point source pollution modeling. Management of contaminants and marine debris - point, non-point, vessel, and atmospheric pollution; spills; trash.
BU 02 – Riverine Ecosystem Management	Stream channel analysis and mapping. Stream bank erosion analysis. Aquatic and terrestrial species habitat management. Environmental management.
BU 03 - Coastal Zone Management	Analysis of coastal erosion and inundation. Hurricane storm surge and wind damage modeling and assessment. Coastal hazard modeling and mapping. Coastal hazard mitigation. Tsunami modeling. Land use and environmental planning. Coastal resiliency. Oil spill modeling. Littoral zone management including dunes and beaches.

BU 04 – Forest Resources Management	Forest health assessment. Determination of standing inventory of forest resources. Prescribed burn planning. Analysis of carbon stocks for trade. Harvest systems planning.
BU 05 – Rangeland Management	Assessment of rangeland health. Mapping for soil erosion potential due to grazing.
BU 06 - Natural Resources Conservation	Conservation engineering. Soils and wetlands mapping and characterization. Modeling of biological and ecological systems. Erosion control. Rainfall penetration studies, impervious surfaces. Assessment of blue carbon stocks.
BU 07 – Wildlife and Habitat Management	Conservation planning for wildlife refuges and marine sanctuaries. Conservation of critical habitats. Management of diverse migratory bird habitats, coral reef and coral communities, marine mammals, protected fish species, and trust resources.
BU 08 – Agriculture and Precision Farming	Farm pond design. Irrigation system design. Detailed site analysis to support precision farming. Analysis of farm sedimentation and runoff. Calibration of fertilizer application, fertilizer management, and irrigation planning. Optimized terraforming.
BU 09 – Fisheries Management and Aquaculture	Management of fisheries. Sustainable aquaculture.
BU 10 – Geologic Assessment and Hazard Mitigation	Geologic mapping and analysis. Sinkhole and steephead mapping, monitoring, and analysis. Identification of geomorphologic units. Landslide hazard mapping and assessment. Karst mapping, including springs and caves. Aquifer recharge.
BU 11 – Geologic Resource Mining and Extraction	Onshore or offshore mineral extraction. Monitoring sand as a local resource. Seabed resources. Open mine volume computations. Stockpile analysis. Environmental impact assessment and site restoration.
BU 12 – Renewable Energy Resources	Alternate energy development – solar, tidal, wind, wave, and ocean current. Assessment of rooftops for solar energy potential. Analysis of wind energy potential and turbine placement. Low head power potential for hydropower.
BU 13 – Oil and Gas Resources	Oil and gas exploration and production. Pipeline and route selection. Facility siting to mitigate geologic hazards. Construction planning. Environmental impact assessment and mitigation. Regulatory compliance.
BU 14 - Cultural Resources Preservation and Management	Discovery and analysis of underwater archaeological and historical cultural sites. Site protection and preservation planning. Discovery and analysis of Native American and other historical cultural sites and subsistence activities.
BU 15 – Flood Risk Management	Flood risk modeling and mapping of riverine and coastal areas. Dam/dike/levee safety analysis. Emergency management. Flood forecasts.

BU 16 – Sea Level Rise and Subsidence	Modeling and mapping the effects of sea level rise or subsidence. Population and economic vulnerability assessments. Coastal inundation and infrastructure assessment.
BU 17 – Wildfire Management, Planning and Response	Determination of forest fuel and fire susceptibility. Fire behavior modeling to support wildfire suppression activities. Wildland/urban interface building identification. Post fire analysis to determine landslide prone areas.
BU 18 – Homeland Security, Law Enforcement, Disaster Response, and Emergency Management	Infrastructure and border protection. Coastal search and rescue. Population dynamics. Emergency fuel supply and movement. Line of sight analysis in urban areas. Disaster response. Flood risk analysis resulting from acts of terrorism.
BU 19 – Land Navigation and Safety	Road and railroad route selection and maintenance. Slope analysis for autonomous cars. GPS navigation visualization.
BU 20 – Marine and Riverine Navigation and Safety	Nautical charting. Bathymetric measurements of near-shore submerged coastal topography. Identification of hazards to navigation. Sediment management at coastal navigation projects. Precision marine navigation. Movement of goods and fishing vessels.
BU 21 – Aviation Navigation and Safety	Determination of in-flight hazards and path obstructions. Aeronautical charting. Runway construction and repair.
BU 22 – Infrastructure and Construction Management	Marine construction. Bridge design and construction. Engineering and construction of dams, levees, dikes, reservoirs, and coastal structures. Shipyard and port construction. Water, sewer, or power line planning and vegetation analysis. Pump, drain, and well placement. Stormwater modeling. Cut and fill analysis for earth-moving. Building site analysis. Road infrastructure. Infrastructure hardening or mitigation for climate change effects, e.g. sea level change.
BU 23 – Urban and Regional Planning	Land development and zoning. Municipal mapping of building footprints and elevations. Port resilience planning. Parks and transportation planning. Virtual city creation. Urban ecology planning.
BU 24 – Health and Human Services	Health emergency response. Habitat modeling and disease prevention. Defining boundaries for health advisories for swimming and fishing. Marine-based bioproducts and pharmaceuticals. Public health and safety. Prevention of waterborne diseases.
BU 25 – Real Estate, Banking, Mortgage, and Insurance	Assessment of risk for natural hazards (e.g., sinkholes, flooding) to inform insurance policy rates and the determination of mandatory insurance. Building permit compliance.

BU 26 – Education K-12 and Beyond, Basic Research	Development of 3-D visualizations to help students understand the Earth they live on. Understanding of continental-scale climate change impacts. Ocean science. Ocean education. Scientific research. Data dissemination. Development of training simulators.
BU 27 – Recreation	Planning and development of recreational facilities such as rafting, boating, swimming, diving, and fishing areas; ski slopes; and golf courses. Location-based products and services such as maps and guides. Tourism. Trail and vista site planning. Orienteering.
BU 28 - Telecommunications	Telecommunication tower site selection. Design of radio and radar systems. Interference analysis. Path profiles. Undersea telecommunication route selection and deployment.
BU 29 - Military	Tactical military operations. Strategic defense. Amphibious landings and logistics over-the-shore. Operation of ships and submarines. Weapons system testing. Management of flight facilities and offshore launch or target areas.
BU 30 – Maritime and Land Boundary Management	Delimitation of legal and other coastal boundaries, inland boundaries, and ordinary high water lines (OHWL).

FAQ #2: What are NOAA's and USGS's mapping and coordinating mandates?

NOAA and USGS are authorized to conduct their mapping programs through the Coast and Geodetic Survey Act of 1947 (33 USC 883a et seq) and the Organic Act of March 3, 1879 (20 Stat. 394; 43 U.S.C. 31), respectively. NOAA, USGS, and their federal partners are also directed to improve coordination and collaboration through the Ocean and Coastal Mapping Integration Act of 2009 (OCMIA, P.L. 111-11, Title XII, Subtitle B).

FAQ #3: Who is being asked to participate in the study?

Because 3D elevation data are collected and used to meet a wide range of mission critical needs, the study is seeking input from managers and data users from a variety of government entities (e.g., Federal, State, local, Tribal) as well as not-for-profit, academic, private, and commercial entities. By learning more about your business uses and associated benefits that would be realized from improved 3D elevation data, we will be able to prioritize and direct investments that will best serve the user community needs. The findings are expected to establish national business needs and associated benefits for 3D elevation data and associated technologies. This information will enhance the responsiveness of NOAA, USGS, and other Federal agency programs to meet stakeholder needs, and inform the design of directed future programs that balance requirements, benefits, and costs at a national scale.

FAQ #4: What is meant by inland topography, inland bathymetry, nearshore bathymetry, and offshore bathymetry?

As depicted in Figure 1, the intertidal zone, also known as the littoral zone, is the area exposed to the air at low tide and submerged at high tide; this zone is bounded by the Mean High Water (MHW) and Mean Lower Low

Water (MLLW) boundaries which are used differently by coastal states to define official baseline boundaries between state-owned and privately-owned lands. A state's exclusive economic zone (EEZ) extends seaward to a distance of no more than 200 nautical miles out from its coastal baseline.

The Interagency Working Group on Ocean and Coastal Mapping (IWG-OCM) represents the bathymetric mapping community that maps bathymetric surfaces to include offshore and nearshore areas, the intertidal zone, beaches, and submerged objects that pose a threat to marine navigation. The U.S. Geological Survey (USGS) 3D Mapping Program (3DEP) represents the topographic mapping community that maps the tops of structures/vegetation and the bare earth terrain to include the beach and intertidal zone. Thus both mapping communities share interest in mapping the intertidal zone and beach areas shown. USGS, USACE and FEMA, are interested in mapping inland bathymetry (rivers and lakes).

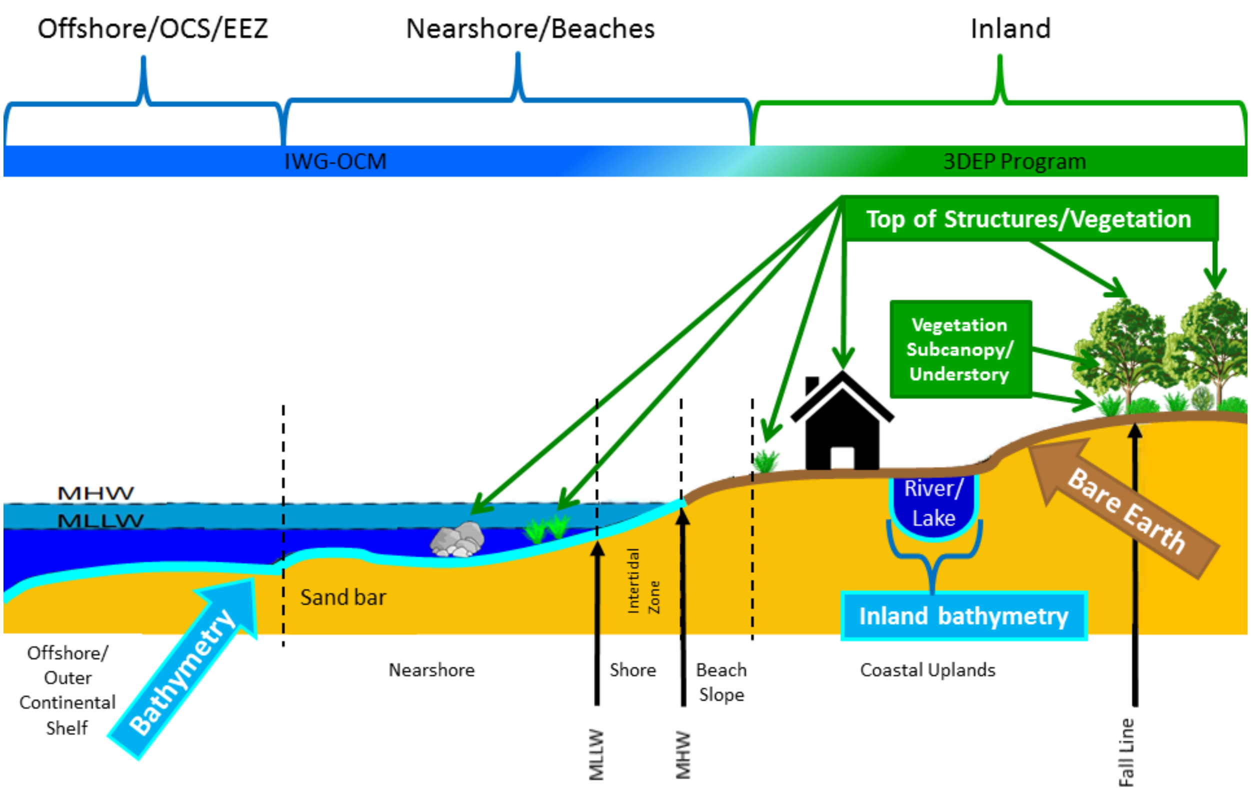


Figure 1. Examples of bare-earth inland topography, inland bathymetry, nearshore bathymetry and offshore bathymetry.

<u>Inland Topography</u>

In Figure 1, "Inland topography" does not end at the top of the beach slope but typically includes the beach area, sometimes as far out as the MLLW line, if tidal conditions permit, to map all land areas that are not submerged.

Inland topography refers to data collected on land, and may include the land surface, features and objects on land such as building structures and vegetation, as well as bare earth topography under vegetation.

Inland Bathymetry

Inland bathymetry refers to data collected on the bottoms of lakes, reservoirs, and rivers and may include submerged features such as structures, objects, or vegetation.

Nearshore Bathymetry

The nearshore includes coastal waters seaward from the MLLW line well beyond the surf zone and includes the area influenced by coastal currents; but there is no clear boundary between nearshore and offshore. For the purpose of this questionnaire, nearshore bathymetry will pertain to coastal areas to a depth of 10 meters (20 meters in the Florida Keys where waters are exceptionally clear)

Offshore Bathymetry

For the purpose of this questionnaire, offshore bathymetry will pertain to areas between 10 and 60 meters deep where waters are clear and waters deeper than 60 meter.

FAQ #5: What topographic/bathymetric features can be mapped in 3D?

Various features can be mapped in 3D. Several factors will influence the ultimate method used to collect topographic/bathymetric features. These factors include the desired spatial and temporal resolution, and environmental conditions in addition to a few others. Descriptions of the various topographic/bathymetric features along with some example uses for these features are:

Bare earth ground: This refers to the topographic surface of the terrain, free from vegetation, buildings and other man-made structures.

Tops of buildings, structures, objects: This refers to the tops of manmade features, the first surface seen when mapped from an aerial sensor flying above and looking downward.

Tops of vegetation: This refers to tree canopies and tops of other vegetation, typically mapped from an aerial sensor flying above and looking downward.

Tops of submerged structures, objects: This refers to the tops of submerged features or objects, normally pertaining to features that could represent a hazard to marine navigation.

Tops of submerged vegetation: This refers to the tops of submerged vegetation, typically mapped to determine the location, height and/or classification of such vegetation.

Subcanopy of vegetation/understory: This refers to vegetation that is below the top tree canopy.

River/lake bottom: This refers to rocky, sandy or muddy bottom of a river or lake, excluding submerged aquatic vegetation.

Nearshore elevation (<10 m deep): This refers to the rocky, sandy or muddy bottom of the nearshore bathymetric surface, including coral reefs but excluding submerged aquatic vegetation, out to a depth of 10 meters.

Sea Surface: This refers to the elevation of the surface of the body of water, as opposed to the elevation of any submerged land or objects. This may sometimes be referred to as altimetry data when in reference to measurements for a body of water.

Ocean/sea bottom (>10 m deep): This refers to the rocky, sandy or muddy bottom of the offshore bathymetric surface, including coral reefs but excluding submerged aquatic vegetation, at depths in excess of 10 meters.

Other: This refers to any other feature or surface to be mapped, not clearly included in the other categories listed.

FAQ #6: How do I enter unique geographic area requirements for the 3D Nation Requirements and Benefits Study that are not covered by standard pick lists in the questionnaire?

Email your shapefile, KML, or geodatabase to iwgocm.staff@noaa.gov. Please use a unique filename that includes your Mission Critical Activity and organization, or abbreviations thereof. The projection and datum (.prj file) information must also be included.

For information about how to create a shapefile or KML file without having GIS software on your computer, go to: https://cms.geoplatform.gov/elevation/3DEP/AOIGenerationDirections.

FAQ #7: What is Total Horizontal Uncertainty (THU) at the 95% confidence level, and how does it correlate with topographic data Quality Levels?

The Total Propagated Uncertainty (TPU) is the result of uncertainty propagation in 3D when all contributing measurement uncertainties, both random and systematic, have been included. Total Horizontal Uncertainty (THU) is the horizontal component of the TPU. The International Hydrographic Organization (IHO), American Society for Photogrammetry and Remote Sensing (ASPRS), and the Federal Geographic Data Committee (FGDC) all specify that uncertainties be expressed at the 95% confidence level, meaning there is a 95% probability that horizontal (radial) errors are ≤ the stated value. THU at the 95% confidence level = 1.7308 x RMSEr, where RMSEr = the square root of [$RMSEx^2$ + $RMSEy^2$]. ASPRS also uses the term "Horizontal Accuracy Class" to specify how accurate geospatial data should be in terms of RMSEx and RMSEy, depicted as RMSExy.

Table 2 correlates topographic data Quality Levels with Aggregate Nominal Pulse Density (ANPD), RMSEx, RMSEy, RMSEr, RMSEz and THU. QL0 through QL3 generally pertain to standard aerial lidar or photogrammetry, QL4 pertains to higher altitude photogrammetry, and QL5 pertains specifically to high altitude aerial IfSAR. Horizontal accuracy from photogrammetry is derived from the Aerial Triangulation solution, and horizontal accuracy from lidar and IfSAR is a function of positional error derived from the GPS or Global Navigation Satellite System (GNSS), attitude (angular orientation) error as derived from the Inertial Navigation System (INS), and the flying altitude of the sensor.

Table 2. Horizontal and vertical accuracies achievable for standard aerial topographic data Quality Levels

Topographic Data Quality Level	RMSEz	Aggregate Nominal Pulse Density (ANPD)	ASPRS Horizontal Accuracy Class = RMSExy	RMSEr	Total Horizontal Uncertainty (THU) at 95% confidence level
QL0 UAV *	≤5 cm	≥20 pts/m^2	24.5 cm	34.7 cm	≤30 cm (~1 ft.)

QL0 HD	≤5 cm	≥20 pts/m^2	24.5 cm	34.7 cm	≤60 cm (~2 ft.)
QL0	≤5 cm	≥8 pts/m^2	24.5 cm	34.7 cm	≤60 cm (~2 ft.)
QL1 HD	≤10 cm	≥20 pts/m^2	32.7 cm	46.2 cm	≤80 cm
QL1	≤10 cm	≥8 pts/m^2	32.7 cm	46.2 cm	≤80 cm
QL2 **	≤10 cm	≥2 pts m^2	40.9 cm	57.8 cm	≤1 m
QL3	≤20 cm	≥1 pt m^2	81.7 cm	1.16 m	≤2 m
QL4	≤50 cm	≥0.04 pts/m^2	2.0 m	2.9 m	≤5 m
QL5 IfSAR	≤100 cm	≥0.04 pts/m^2	5.7 m	8.1 m	≤14.0 m

* Although QL0 UAV is not currently a standard topographic data Quality Level, it is included here to show that a smaller THU for small areas or roads could be achieved by flying at a much lower altitude with an Unmanned Aerial Vehicle (UAV) or with a Mobile Mapping System (MMS) on the ground.

** QL2 is the current minimum standard for nationwide topographic lidar, recognizing that legacy QL3 topographic lidar datasets remain

FAQ #8: What is Total Vertical Uncertainty (TVU) at the 95% confidence level, and how does it correlate with topographic data Quality Levels?

The Total Propagated Uncertainty (TPU) is the result of uncertainty propagation in 3D when all contributing measurement uncertainties, both random and systematic, have been included. Total Vertical Uncertainty (TVU) is the vertical component of the TPU. The IHO, ASPRS, and FGDC all specify that vertical uncertainties be expressed at the 95% confidence level, meaning there is a 95% probability that vertical (elevation) errors are ≤ the stated value. TVU at the 95% confidence level = 1.9600 x RMSEz. ASPRS also uses the term “Vertical Accuracy Class” to specify how accurate geospatial data should be in terms of RMSEz, and (although discouraged) some users still think of vertical accuracy in terms of “equivalent contour accuracy” which is generally accepted to be 3 x RMSEz.

Table 3, below, translates the latest ASPRS standard in terms of the topographic data Quality Levels used for this study.

Table 3. Vertical Accuracy Classes relative to standard topographic data Quality Levels

Topographic Data Quality Level	RMSEz	Aggregate Nominal Pulse Density (ANPD)	Vertical Accuracy Class = RMSEz	Total Vertical Uncertainty (TVU) at 95% confidence level	Equivalent Contour Accuracy
QL0 HD	≤5 cm	≥20 pts/m^2	5 cm	9.8 cm	15 cm, ~6 inch
QL0	≤5 cm	≥8 pts/m^2	5 cm	9.8 cm	15 cm, ~6 inch
QL1 HD	≤10 cm	≥20 pts/m^2	10 cm	19.6 cm	30 cm, ~1 foot
QL1	≤10 cm	≥8 pts/m^2	10 cm	19.6 cm	30 cm, ~1 foot
QL2	≤10 cm	≥2 pts m^2	10 cm	19.6 cm	30 cm, ~1 foot
QL3	≤20 cm	≥1 pt m^2	20 cm	39.2 cm	60 cm, ~2 foot

QL4	≤50 cm	≥0.04 pts/m^2	50 cm	98.0 cm	150 cm, ~5 foot
QL5 IfSAR	≤100 cm	≥0.04 pts/m^2	1 meter	1.96 meters	300 cm, ~10 foot

FAQ #9: What is the significance of MLLW, MHW and MHHW?

Some organizations choose to pay extra for tide-coordinated elevation data acquisition, for example, by specifying that topographic data be acquired with water levels at or below Mean Lower Low Water (MLLW) to expose more land that is not submerged, and/or by specifying that topobathymetric data be acquired with water levels at or above Mean High Water (MHW) or Mean Higher High Water (MHHW) to map more water depths that are submerged. This combination enables the tidelands to be mapped both ways, making it easier to seamlessly merge topographic and bathymetric data across the tidelands by establishing seamlines where the two datasets agree on common elevations after NOAA’s Vertical Datum Transformation Tool (VDatum) is used to transform bathymetric data from a tidal datum to NAVD88.

Figure 2 shows why MHHW, MHW, and MLLW are especially relevant to coastal states. The boundary line between privately owned and state-owned lands is based on these boundary lines and differs between states. Mean Lower Low Water (MLLW) defines the chart datum, which is the level of water from which charted depths displayed on a nautical chart are measured.

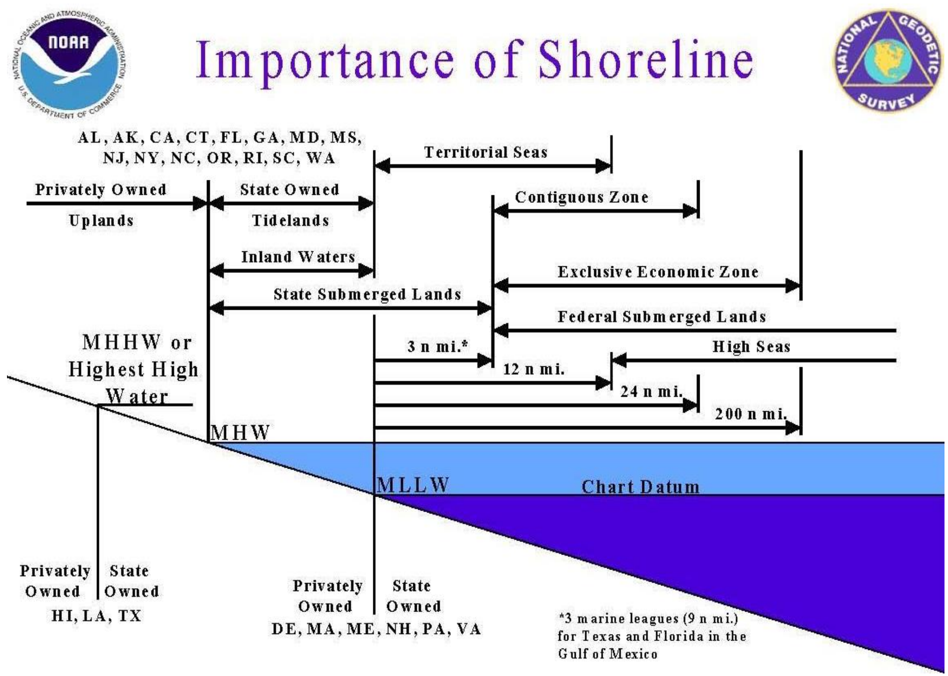


Figure 2. In a number of states, MHW defines the official shoreline that separates privately owned uplands from state-owned tidelands, inland waters and state submerged lands. In other states, MLLW or MHHW defines the official shoreline. The MLLW not only establishes the chart datum for U.S. waters, but MLLW establishes territorial seas and distances to the beginning of the Exclusive Economic Zone and Federal Submerged Lands, for example.

Mean Higher High Water (MHHW): MHHW is defined as the arithmetic mean of the higher high water heights of the tide observed over a specific 19-year Metonic cycle denoted as the National Tidal Datum Epoch (NTDE). Only the higher high water of each pair of high waters of a tidal day is included in the mean.

Mean High Water (MHW): MHW is defined as the arithmetic mean of the high water heights observed over a specific 19-year Metonic cycle.

Mean Sea Level (MSL): MSL is defined as the arithmetic mean of hourly heights observed over a specific 19-year Metonic cycle.

Mean Low Water (MLW): MLW is defined as the arithmetic mean of the low water heights observed over a specific 19-year Metonic cycle.

Mean Lower Low Water (MLLW): MLLW is defined as the arithmetic mean of the lower low water heights of the tide observed over a specific 19-year Metonic cycle. Only the lower low water of each pair of low waters of a tidal day is included in the mean.

FAQ #10: What are cross-sections and transects and how do they differ?

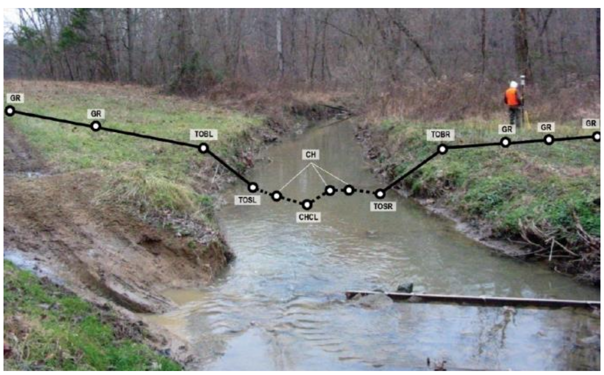


Figure 3. Cross section surveyed across a stream.

Cross-sections are spot elevations surveyed across stream channels for riverine flood studies to determine the shapes and slopes of stream banks and the underwater topography. For such flood studies, cross-sections are typically surveyed immediately downstream from bridges and at selected intervals between bridges for hydraulic modeling of rivers and streams. See Figure 3.

Figure 4. Transect surveyed across beach, dune, and inland.

Transects are spot elevations surveyed perpendicular to shorelines to determine the shapes and slopes of beaches and sand dunes for wave runup models and similar applications. For coastal flood studies, transects are surveyed at selected locations along lengthy shorelines for

Figure 5. Transect survey points with 3D coordinates.

hydraulic modeling of coastal wave action. See Figures 4 and 5.

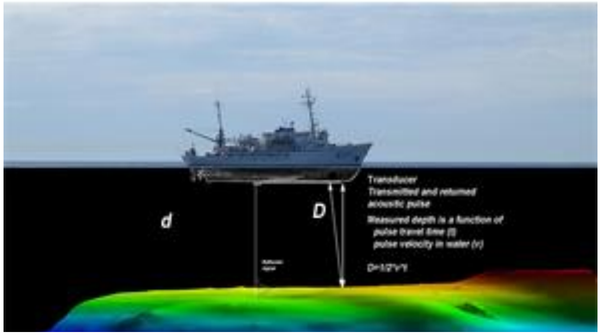


Figure 6. Track of a single beam echo sounder (vertical beam sonar).

Single beam echo sounders (SBES), also known as vertical beam sonar, produce a line of elevation points, directly below the vessel's track, on the floor of a bathymetric surface, as shown in Figure 6. This is similar to cross sections and transects surveyed on land.

With a single line of elevation points, the SBES differs from the multibeam echo sounder (MBES) which produces a wide swath of elevation points on the bathymetric surface, similar to a swath of aerial lidar.

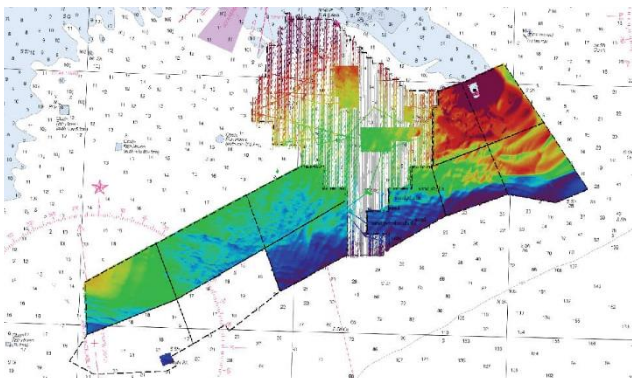


Figure 7. Set line spacing performed on multibeam sonar alongside areas of complete coverages.

MBES can also produce transect data when acquisition is based on a set line spacing rather than a goal of complete coverage. This is often utilized in areas of flat or static sea floors. Figure 7 shows a project where complete coverage and set line spacing was used in different areas.

Often times, MBES or SBES and a sidescan sonar can be run concurrently. When the extents of a sidescan sonar exceed the outer reaches of the MBES, it creates a similar result to set line spacing, as seen in Figure 8.

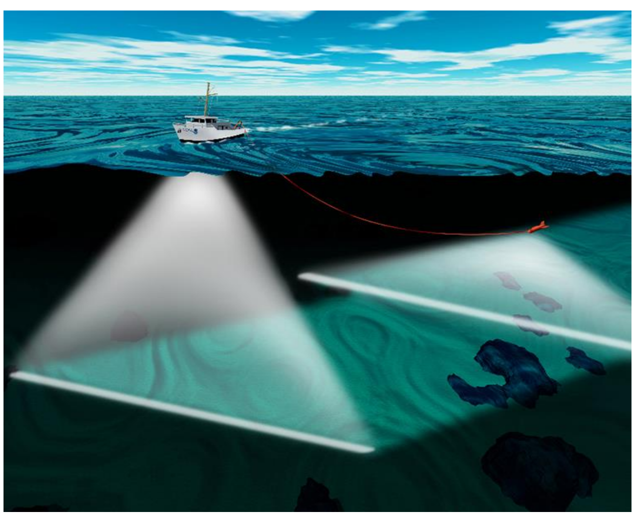


Figure 8. Sidescan sonar swath exceeding multibeam swath. If coverage is designed so that only sidescan data will overlap, it will create set line spacing for multibeam data.

FAQ #11: How are topographic data produced and how are their Quality Levels (QLs) defined?

Topographic Technologies

For topographic mapping, traditional *photogrammetry* uses stereo imagery from two different perspectives to map topographic surfaces, and *IfSAR* uses radar to map topographic surfaces through clouds; but both technologies are best for mapping the tops of reflective surfaces rather than the bare-earth terrain beneath a forest canopy. Airborne *lidar* can provide highly-accurate, high density data for vegetation, bare earth and features under vegetation, and man-made structures simultaneously. All lidars use laser pulses to measure the distance to an object by determining the time of flight for an emitted laser beam. A scanning mechanism (such as an oscillating mirror) is typically employed to steer a series of laser pulses (typically over 100 KHz) over a wide area from an airborne platform. All airborne lidar systems use enabling technologies such as Global Positioning System (GPS) and Inertial Measurement Unit (IMU) to determine the location and orientation of the remote sensor located on the airborne platform.

Topographic lidar systems typically use a near infrared laser pulse to measure topography of the land surface, features and objects on land such as building structures and vegetation, as well as bare earth topography under vegetation (Figure 9).

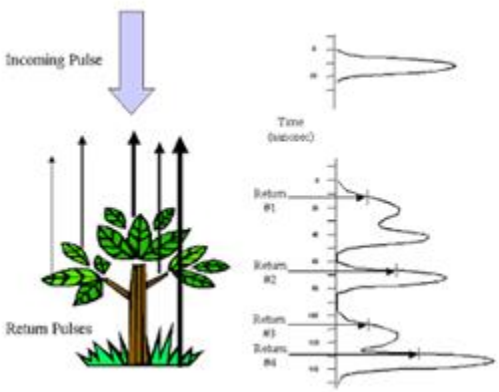


Figure 9. Topographic lidar, with near infrared laser, maps ground topographic features, vegetation and manmade features; unreliable for water surface and below.

Topographic Lidar Advantages

Topographic lidar routinely penetrates foliage where photogrammetry, which relies on aerial photography, cannot see the ground in stereo to map the bare-earth ground beneath.

Lidar uses up to 500,000 laser pulses per second to map 3-D coordinates from first, last, and intermediate returns from each laser pulse. The first return can be used to map the top reflective surface (DSM). Intermediate returns provide additional information about vegetation. The last return is used to map the bare-earth terrain (DTM); however, because last returns include elevations on rooftops and vegetation too dense to be penetrated, lidar last returns still require automated filtering and some manual filtering of lidar "point clouds" to produce the bare-earth surface. Figure 10 shows how it takes only a single lidar pulse to penetrate vegetation. Figures 11 and 12 show how lidar penetrates dense vegetation that normally could not be mapped by other technologies such as photogrammetric stereo compilation.

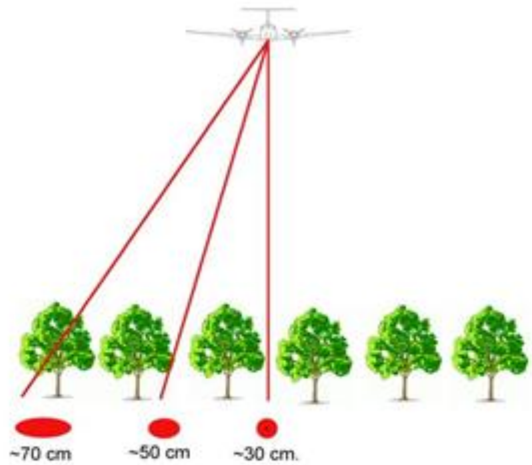


Figure 10. Lidar can map the bare-earth terrain in forests by single pulses that penetrate *between* trees and even *through* trees in some instances. The footprint size of each laser pulse varies by the angle of the scan, as shown here. Normally acquired in zig-zag patterns, lidar scans are so dense that scan lines are nearly parallel. Flying higher with a high pulse rate and narrow left-right scan angle allows a high point density and increased ability to penetrate dense vegetation by having near-vertical laser pulses that can better penetrate between trees.

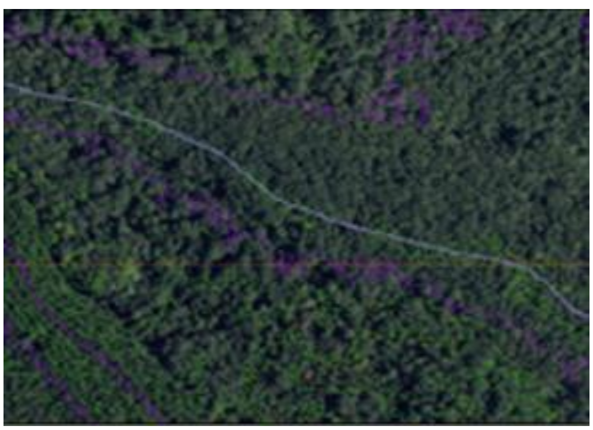


Figure 11. In spite of dense vegetation shown on this orthophoto in Florida, lidar data collected at a point density of 4 points/m^2 was still able to establish a hydro flow line for the dry drainage feature beneath.

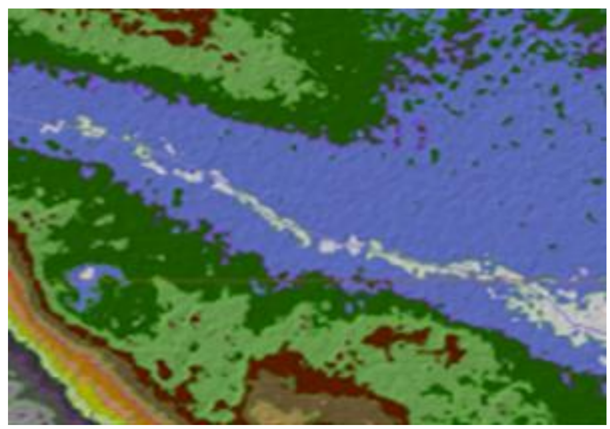


Figure 12. Color-coded by 1-foot contour elevation bands, the white polygons define depression contours that show dry *puddles* that should not normally be hydro-enforced (defined below). This does not necessarily work in mangrove and sawgrass.

Topographic Lidar Limitations

The major limitation of topographic lidar is that it cannot penetrate to the bare earth if the vegetation is too dense that pulses of laser light cannot penetrate through gaps in the canopy to reach the ground. As a rule of thumb, on a bright sunny day, if sunlight is "seen" on the ground, then it is possible to map that ground with lidar. Sometimes, increasing the point density can improve the probability of the laser pulse to find a gap in the canopy to reflect off the ground. As a result, a QL1 lidar dataset may produce a better ground model than a QL2 lidar dataset, due to the increased point density, and the new high density (HD) Quality Levels were specifically designed for mapping through dense vegetation.

A second limitation of topographic lidar is that there are sometimes void areas in urban canyons and areas with tall buildings that block non-vertical lidar pulses from reaching the ground. These void areas are immediately adjacent to tall buildings. This problem is minimized by flying higher with higher point density and/or by flying east-west flight lines in addition to north-south flight lines, for example.

Topographic Data Quality Levels

The USGS 3DEP is the elevation layer of The National Map, comprised of new 3DEP-quality data and integrating the data holdings of the National Elevation Dataset (NED), which has been retired. The 3DEP is currently acquiring QL5 IFSAR of Alaska and QL2 or better topographic lidar for the remaining 49 states and U.S. territories based on the USGS Base Lidar Specification V1.2 with major density and accuracy parameters as shown in Table 2. (Note that QL0 HD and QL1 HD are new and were added to specifically accommodate very high density datasets from Geiger-mode and single photon lidar.) The goal of the 3DEP is to acquire QL2 or better elevation data nationwide, updated on an 8-year cycle, with cost sharing between numerous partners.

The 3D Nation is a concept for acquiring consistent and seamless high-accuracy, high-resolution elevation data from the tops of the mountains to the depths of the seas, primarily through a combination of topographic data (from the 3DEP specifications in Table 4), as well as bathymetric data produced to topobathymetric lidar specifications explained in FAQ #23 and sonar specifications explained in FAQ #30.

Table 4. Topographic Data Density and Absolute Vertical Accuracy

Quality Level (QL)	Aggregate Nominal Pulse Spacing (ANPS)	Aggregate Nominal Pulse Density (ANPD)	$RMSE_Z$ (non-vegetated)	TVU at 95% confidence level	VVA at 95th percentile	Equivalent Contour Accuracy
QL0 HD	≤0.22 m	≥20 points/m^2	≤5 cm	≤9.8 cm	≤14.7 cm	~ 6 inch
QL0	≤0.35 m	≥8 points/m^2	≤5 cm	≤9.8 cm	≤14.7 cm	~ 6 inch
QL1 HD	≤0.22 m	≥20 points/m^2	≤10 cm	≤19.6 cm	≤29.4 cm	~ 1 foot
QL1	≤0.35 m	≥8 points/m^2	≤10 cm	≤19.6 cm	≤29.4 cm	~ 1 foot
QL2	≤0.71 m	≥2 points/m^2	≤10 cm	≤19.6 cm	≤29.4 cm	~ 1 foot
QL5*	≤5 m	≥0.04 points/m^2	≤100 cm	≤196 cm	≤294 cm	~10 feet

*Only applicable for IfSAR in Alaska

For the purpose of this questionnaire, Non-vegetated Vertical Accuracy (NVA) at the 95% confidence level is the same as Total Vertical Uncertainty (TVU) at the 95% confidence level. Vegetated Vertical Accuracy (VVA) at the 95^{th} percentile is evaluated separately.

The following definitions are relevant to the terminology used in Table 4.

Root Mean Square Error (RMSE) — The square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points. The RMSE is used to estimate the absolute accuracy of both horizontal and vertical coordinates when standard or accepted values are known, as with GPS-surveyed check points of higher accuracy than the data being tested. In the United States, the independent source of higher accuracy is expected to be at least three times more accurate than the dataset being tested.

RMSEz — The vertical RMSE ($RMSE_z$) is calculated as the square root of $\sum(Z_n - Z'_n)^2/N$, where:

- Z_n is the set of N z-values (elevations) being evaluated, normally interpolated (for TINs and DEMs) from dataset elevations of points surrounding the x/y coordinates of checkpoints
- Z'_n is the corresponding set of checkpoint elevations for the points being evaluated
- N is the number of checkpoints
- n is the identification number of each of the checkpoints from 1 through N.

Equivalent Contour Accuracy — The equivalent contour accuracy is 3 times the RMSEz. For example, RMSEz of 10 cm is equivalent to 30 cm contours, and RMSEz of 0.333' (4") is equivalent to 1 foot contours.

Non-Vegetated Vertical Accuracy (NVA) — The value by which vertical accuracy of topographic data (e.g., lidar, IfSAR) in non-vegetated areas can be equitably assessed and compared among datasets when applying the *ASPRS Positional Accuracy Standard for Digital Geospatial Data*. The NVA is determined with well-distributed checkpoints located in both open terrain (bare soil, rock, sand and short grass) and urban terrain (concrete and asphalt surfaces). The NVA is determined by multiplying RMSEz x 1.96.

Vegetated Vertical Accuracy (VVA) — The value by which vertical accuracy of topographic data (e.g., lidar, IfSAR) in all vegetated areas can be equitably assessed and compared among datasets when applying the *ASPRS Positional Accuracy Standards for Digital Geospatial Data*. The VVA is determined with well-distributed checkpoints located in all vegetated land cover categories combined, including tall weeds and crops, scrub forests, and fully forested areas, as well as other localized vegetation categories such as mangrove or sawgrass (unless specifically identified as Low Confidence Areas, defined below). The VVA is determined by using the 95^{th} percentile (rather than using an RMSEz multiplier) because errors in vegetation do not necessarily follow a normal error distribution.

Nominal Pulse Spacing (NPS) — A common measure of the density of a point-based elevation dataset (e.g., lidar, IfSAR, sonar), it is the typical or average lateral distance between points in a dataset, most often expressed in meters. NPS refers to the average point spacing of a dataset typically acquired in a zig-zag pattern with variable point spacing along-track and cross-track. NPS is an estimate and not an exact calculation.

Aggregate Nominal Pulse Spacing (ANPS) — A variant of nominal pulse spacing (NPS) that expresses the typical or average lateral distance between pulses in a dataset resulting from multiple passes of the sensor, or a single pass of a platform with multiple sensors, over the same target area.

Nominal Pulse Density (NPD) — A common measure of the density of a single pass (single swath) of a point-based elevation dataset (e.g., lidar, IfSAR, sonar), expressed as points per square meter (PPSM), normally used when the Nominal Pulse Spacing (NPS) is less than one meter. PPSM = $1/NPS^2$.

Aggregate Nominal Pulse Density (ANPD) — A variant of nominal pulse density (NPD) that expresses the total expected or actual density of pulses occurring in a specified unit area resulting from multiple passes of the sensor, or a single pass of a platform with multiple sensors, over the same target area.

With only 10% sidelap between adjacent flight lines, the left side of Figure 13 shows that the majority of the area is mapped with a single swath -- relevant to the terms NPS and NPD. With 50% sidelap, the right side of Figure 13 shows that the majority of the area is mapped with two swaths -- relevant to the terms ANPS and ANPD, increasing the probability of penetrating dense vegetation by having two different look angles. A sidelap of 50% doubles the ANPD compared with single swaths with 10% side lap.

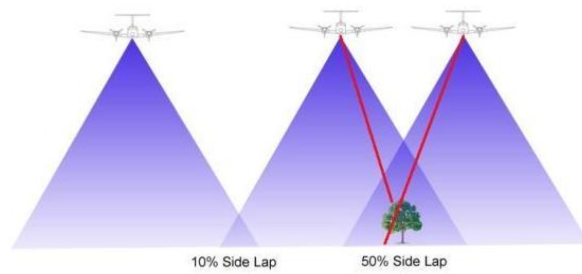


Figure 13. Comparison between 10% and 50% side lap between overlapping LiDAR swaths; 50% side lap typically doubles the aggregate nominal point density.

<u>How to determine NPS or DEM post spacing requirements.</u>

The determination of the <u>minimal acceptable</u> point density, DEM post spacing and/or NPS needed to satisfy Business Uses is central to the purpose of this questionnaire. Respondents should <u>not</u> specify requirements that are "nice to have" but focus instead on minimal acceptable requirements for satisfaction of their Business Uses. Several considerations are suggested below, but ultimately this must be the decision of elevation data users that best understand their technical requirements.

Five questions should be considered:

1. What level of detail do you need to see from the elevation data?
2. What are your needs for feature extraction?
3. What do you need to measure?
4. How dense is the vegetation you need to penetrate?
5. What are your needs for breaklines?

<u>Consideration #1 (What you need to see)</u>. For some Business Uses, users need to be able to *see* certain terrain features to be analyzed, to include overhead power lines. It is easier to see the visual effects of resolution than the visual effects of elevation accuracy. If you can *see* what you need from existing elevation data, the status quo may be acceptable unless the data are obsolete.

Consideration #2 (Features you need to extract). A high resolution DEM is often required if the elevation data are to be used for automated or semi-automated feature extraction, as shown in Figures 14 and 15.

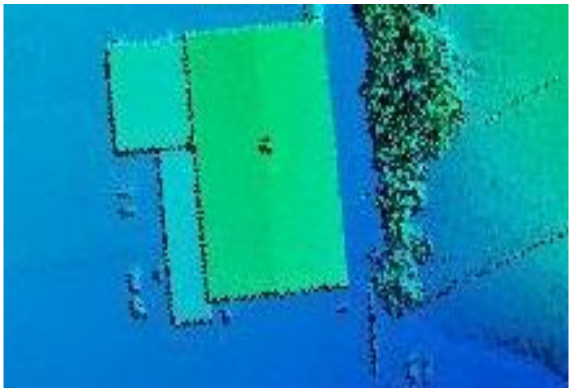


Figure 14. Even with sub-meter NPS, building footprint edges are pixilated. Straight edges are difficult to define when they are irregular and pixilated.

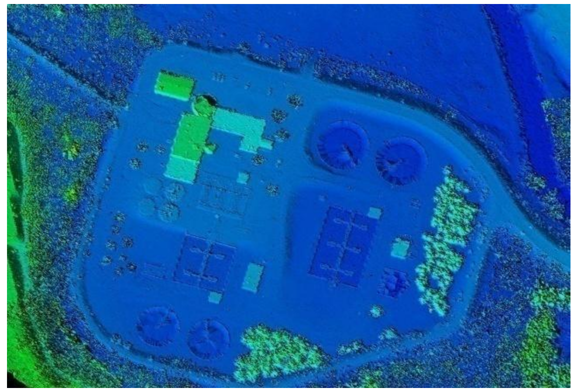


Figure 15. High resolution elevation data are required when they are to be used for semi-automated feature extraction. Many misclassifications result from low resolution elevation data.

Consideration #3 (What you need to measure). Your DEM user application has everything to do with required point density. Table 5, below, shows examples where measurements are made for landslides, morphology, building classification, fire loads, tree species, forest metrics, vegetation classification, and measurement of the DTM in the forest floor. Other applications might include assessment of forest health.

Consideration #4 (Density of vegetation to be penetrated). In some cases, the raw point density per square meter or the NPS is much more important than the DEM post spacing, especially in areas of dense vegetation. Figures 11 and 12 above show an example of lidar data in Florida where the points were collected with an average density of 4 points/m^2 in dense tropical vegetation. In the Florida Statewide LiDAR Assessment (2017), stakeholders concluded that the state standard should be QL1 with 8 points per square meter, specifically because of dense vegetation in major areas of that state. Similarly, in the Pacific Northwest (Oregon), users deal with tall, dense forests where they needed QL1 lidar with 8 points/m^2 for forestry and geology applications.

Table 5 addresses both considerations #3 and #4.

Table 5[1]. Watershed Sciences, Inc.'s recommended resolution for demanding forestry applications in the Pacific Northwest. Most other applications are satisfied by lower-resolution elevation datasets. Similar issues may occur in swamps and other areas of dense vegetation defined as "low confidence areas."

Discipline	Application	Recommended Density, pulses per m^2 and (NPS)

[1] From a paper entitled, "Minimum LiDAR Data Density Considerations for the Pacific Northwest," 01/22/10, by Watershed Sciences, Inc., now part of Quantum Spatial Inc.

		Low	High
Geology	Landslides	4 (0.50 m)	4 (0.50 m)
	Morphology	5 (0.45 m)	8 (0.35 m)
Urban Planning	Building Classification	4 (0.50 m)	8 (0.35 m)
Fire Modeling	Fire Loads	4 (0.50 m)	8 (0.35 m)
	Mapping Burns	4 (0.50 m)	6 (0.41 m)
Forestry with Pacific Northwest-specific Applications	Tree Species Identification	4 (0.50 m)	6 (0.41 m)
	Forest Measurement and Monitoring	4 (0.50 m)	4 (0.50 m)
	Tree Height Measurements	4 (0.50 m)	6 (0.41 m)
	Vegetation Characterization	4 (0.50 m)	8 (0.35 m)
	DTM Accuracy under Canopy Cover	4 (0.50 m)	6 (0.41 m)

It is well known that the NPS must be denser than the DEM post spacing. This Oregon study[1] shows that it is not just the raw lidar points that must be denser than the DEM, but the percent of the raw lidar points that penetrate the vegetation to the ground. There is no substitute for prior experience in comparable vegetation to determine what percent of the lidar points are expected to penetrate to the ground so that the NPS requirements can be adjusted accordingly – prior to data acquisition.

<u>Consideration #5 (Breakline needs)</u>. Breaklines are linear features that describe a change in the smoothness or continuity of a surface. The two most common forms of breaklines are soft breaklines and hard breaklines. (1) A soft breakline ensures that known elevations (z-values) along a linear feature are maintained (e.g., elevations along a pipeline, road centerline or drainage ditch), and ensures that linear features and polygon edges are maintained in a TIN surface model, by enforcing the breaklines as TIN edges. They are generally synonymous with 3-D breaklines because they are depicted with series of x/y/z coordinates. (2) A hard breakline defines interruptions in surface smoothness, e.g., to define streams, shorelines, dams, ridges, building footprints, and other locations with abrupt surface changes. Although some hard breaklines are 3-D breaklines, they are often depicted as 2-D breaklines because features such as shorelines and building footprints are normally depicted with series of x/y coordinates only, often digitized from digital orthophotos that include no elevation data.

Breaklines may be especially relevant in flatter coastal areas to define subtle breaks in topography that could potentially affect direction of surface water flow. Most organizations establish their own requirements for breaklines.

Figure 16 shows typical lidar mass points with NPS of approximately 1 meter. For most automated processes, these elevation points adequately model the terrain. Figure 17 shows breaklines produced from these mass points for which fewer model key points were retained after manual compilation of the breaklines shown. It is true that contour lines produced from the model key points and breaklines will be more aesthetically pleasing, but this rarely helps automated processes. A decision must be made if the "Chevy version" at Figure 16 is acceptable, or if the "Cadillac version" at Figure 17 warrants the higher costs and time delays. This is an example where higher point density (achieved with relatively minor cost increases) can reduce or eliminate the need for many expensive breaklines.

Figure 16. Mass points with nominal pulse spacing (NPS) of approximately 1 meter.

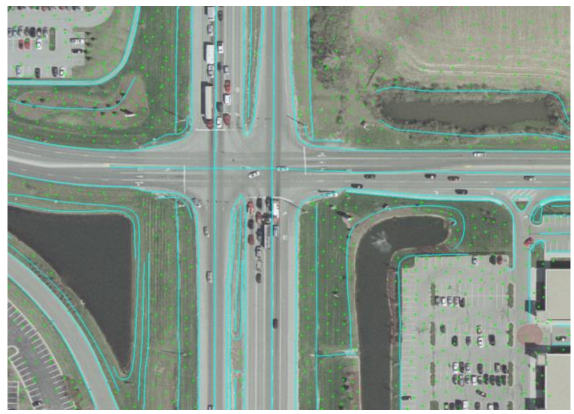


Figure 17. Thinned model key points and breaklines for swales, borrow pits with water, and road features.

FAQ #12: How frequently do elevation data need to be updated?

If you think that topographic surfaces do not change with time, these examples may demonstrate otherwise.

<u>Factors that Affect Hydraulic Analyses by FEMA</u>. In assessing flood data update needs, FEMA requires an assessment of factors that affect hydraulic analyses (e.g., new bridges or culverts, new flood control structures, changes in stream morphology, coastal erosion) and factors that affect still water and wave height analyses for coastal flooding sources. Changes in stream morphology can be critical. Any significant change in the stream channel or floodplain geometry, particularly regarding the placement of fill, can affect the 1-percent-annual-chance floodplain and the associated regulatory floodway. Another consideration is any change in the stream location, either through natural processes (e.g., stream migration, erosion, or deposition) or through manmade changes (e.g., channelization, stream widening, stream straightening, or dredging). Additionally, any significant change in the vegetation or structural encroachments in the floodplain may affect a stream's hydraulic characteristics.

Analysis of Sea Level Change. Nearly every coastal State has requirements to predict the future impacts of sea level change, and credible predictions require accurate and current elevation data updated frequently. There is currently no “rule of thumb” to indicate the frequency of topographic/bathymetric data updates.

Management of Forests. Lidar is used to map the changing heights of trees in America’s forests. How frequently do foresters need to monitor changing forest metrics? For those who use lidar data to monitor forest health, how frequently do they need the data to be updated in order to periodically monitoring the changing health of American forests? We hope this question can be answered as part of this questionnaire process. The ability to cut cross-sections through point cloud data is vital for many assessments of changes in forest metrics.

Vegetation Encroachment. The North American Electric Reliability Corporation (NERC) has identified lidar as the best way to monitor the encroachment of vegetation on power lines, a major cause for widespread power outages.

Subsidence Monitoring. Digital elevation data are used to monitor land subsidence (Figure 18), the loss of surface elevation due to removal of subsurface support. Subsidence occurs in nearly every State in the U.S. Subsidence is one of the most diverse forms of ground failure, ranging from small or local collapses to broad regional lowering of the earth’s surface. The major causes of subsidence include: (1) dewatering of peat or organic soils, (2) dissolution in limestone aquifers, (3) first-time wetting of moisture deficient low density soils (known as hydro-compaction), (4) the natural compaction of soil, liquefaction, and crustal deformation, and (5) subterranean mining and withdrawal of fluids (petroleum, geothermal, and ground water).

Figure 18. Fifty years of subsidence (over 20 feet) in California’s San Joaquin Valley. Image courtesy of National Geodetic Survey (NGS).

Subsidence has the following effects:

- Changes in elevation and gradient of stream channels, drains, and other water transporting facilities
- Damage to civil engineering structures – weirs, storm drains, sanitary sewers, roads, railroads, canals, levees, and bridges
- Structural damage to private and public buildings
- Failure of well casings from forces generated by compaction of fine-grained materials in aquifer systems
- In some coastal areas, subsidence has resulted in tidal encroachment onto lowlands

Agricultural Practices. In order to participate in USDA farm programs, Federal law requires that all persons that produce agriculture commodities must protect their highly erodible cropland from excessive erosion. In addition, anyone participating in USDA farm programs must certify that they have not produced crops on converted wetlands and did not convert a wetland. NRCS currently has numerous incentive programs (e.g., Stewardship Incentive Program (SIP), Emergency Watershed Protection (EWP) Program, Wildlife Habitat Incentives Program (WHIP), Cooperative Conservation Partnership Initiative (CCPI), Conservation Stewardship Program (CSP), Conservation Reserve Program (CRP) and Conservation Technical Assistance (CTA) Program), several of which encourage farmers to terrace their lands so as to retain water in the soil, rather than allow runoff of farm chemicals that pollute our streams. Lidar offers the perfect remote sensing tool for broad-scale analyses of slopes and slope changes, as well as changes to wetlands, rangelands and habitat. Figures 19 through 22 demonstrate how lidar data, and slope derivatives, could be periodically compared to monitor changes in slopes and to evaluate successes or failures of such incentive programs. This example does not explain how often periodic updates are required, but it does demonstrate the need and benefit of periodic data updates.

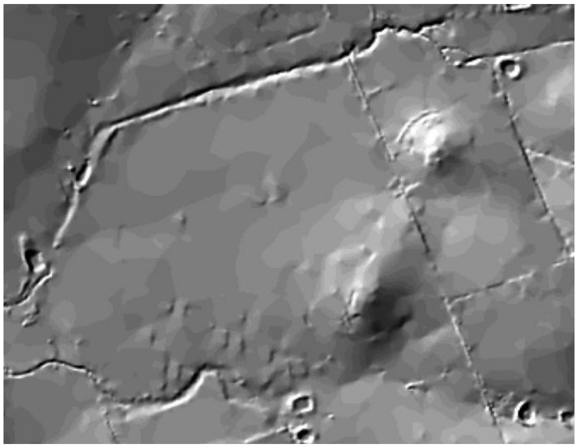


Figure 19. DEM hillshade prior to farm terracing.

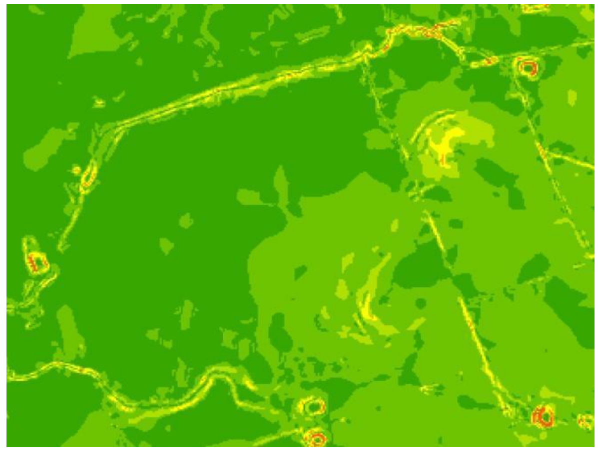


Figure 20. DEM slope gradient prior to farm.

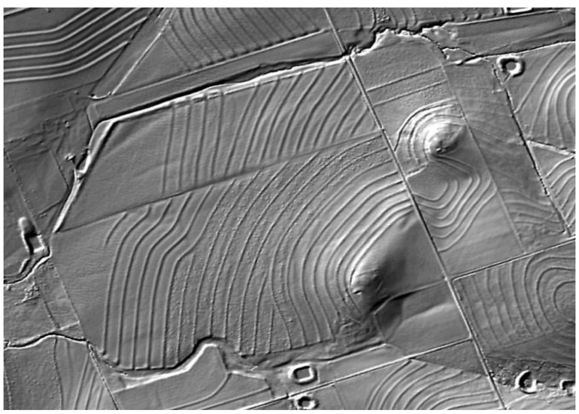


Figure 21. DEM hillshade after farm terracing.

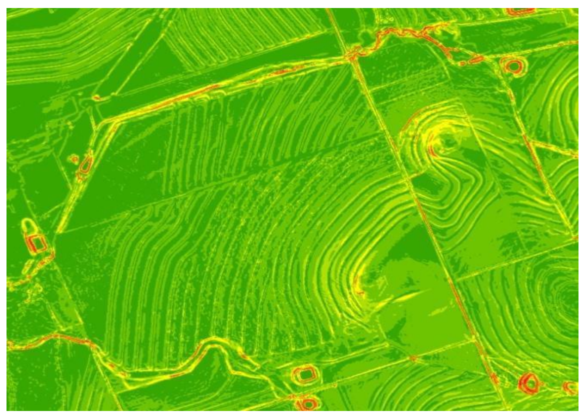


Figure 22. DEM slope gradient after farm.

NRCS personnel cannot personally visit every farm to validate which actions qualify for incentive programs, but periodic updates allow for rapid assessments/comparisons of broad areas.

<u>Other Topographic Change Assessments</u>. Many other applications for digital elevation data require temporal change assessments of the changing topography, including: building/structure change analysis, changes to carbon stock estimates, changes to coastlines, debris flow monitoring, earthquake deformation metrics, changes to fire modeling and assessment, geologic/geophysical/seismic change analyses, geomorphic process monitoring, glacier change monitoring, habitat change assessment, landscape change analysis, landslide

analysis, shoreline change monitoring, surface mining metrics, volcano metrics, urban modeling/change analysis, and wetland change analysis.

None of these are known to have established requirements for the frequency with which elevation datasets need to be updated, but these examples should help questionnaire respondents to understand that top reflective surfaces in Digital Surface Models (DSMs) and bare-earth Digital Terrain Models (DTMs) change regularly by natural or manmade activities. As with digital orthophotos, elevation datasets also need to be periodically updated so that 3D surface analyses can be accurate and up-to-date for diverse user requirements.

Sedimentation. Areas with active sediment deposition or removal, such as rivers and deltas, will create inaccuracies with previous bathymetry or coastal elevation data. These areas will require resurvey based on a user's accuracy and precision requirements for their bathymetric and elevation data. Every area where sediment change occurs will have a different rate of sedimentation, and can be measured and monitored to provide a user with a model for when resurvey would be necessary.

Dredging/Reclamation. Similar to natural sediment changes, any artificial changes to seafloor topography may incite a need for updated bathymetry data. Practices of dredging will remove sediment and material from a one location and deposit the material in a dumping ground. Bathymetry data in both areas will change dramatically and may require resurvey. Similar activities include beach restoration, ocean reclamation, dredging, and shoring.

Storm effects. Hurricanes and other major storms can influence seafloor topography through heavy wave and storm surge effects. Seafloor material can be relocated when a storm passes over the area, and if the change is dramatic enough it may warrant a need for remapping. Storms can also deposit objects from land underwater or relocate and disturb objects on seafloor such as boulders or shipwrecks.

Underwater construction. Operations such as laying pipeline, pier construction, or bridge and tunnel construction can change the seafloor in the area. Such construction can alter the seafloor during operations or the product itself may change the user's desired bathymetric data. In some cases, change to the seafloor can be limited to the change cause immediately by the construction. However, some changes can alter the sedimentation processes in the area and can influence changes outside the immediate vicinity. For example, a newly installed beach pier may affect the beach erosion or deposition that occur downstream of the beach currents.

FAQ #13: What are the different forms of hydrologic processing of topographic data?

Hydrologic Processing

Although the water surface elevations (WSE) of lakes are normally flat, and the WSE of rivers are monotonic (elevations decreasing steadily downhill as waters flow downstream), with most mapping technologies, it is common for shorelines of lakes and rivers to appear to undulate up and down with irregular changes in heights along stream banks, or logs and rock along the shoreline for example. Furthermore, lidar-derived DEMs often present challenges for hydrologic modeling, as they typically include features such as road fill and railroad grade overlaying culverts, bridges, and other raised surfaces that impede the natural flow of surface water. Water is carried through these features that cannot be represented in a lidar-derived DEM. Hydrologic processing is required to create a lidar-derived hydrologic DEM that represents the actual water flow surface for any hydrologic modeling. Hydro-flattening, hydro-enforcement, and hydro-conditioning are the three most common methods used to process lidar-derived DEMs for hydrologic modeling.

Hydro-Flattening: *Hydro-flattening* is a term used by USGS to explain how DEMs are processed for inclusion in the 3DEP. Hydro-flattening is performed to depict the bare-earth terrain as one could see and understand the terrain from an airplane flying overhead. Breaklines are used to force the surfaces of lakes and reservoirs to be flat, and rivers to be flat from bank to bank (perpendicular to the apparent flow centerline) while maintaining a downhill water surface gradient – either a smooth gradient as at Figure 23 or a stair-stepped gradient as at Figure 24. Additionally, man-made features such as bridges and overpasses are removed from a bare-earth DEM because they are artificially elevated above the natural terrain.

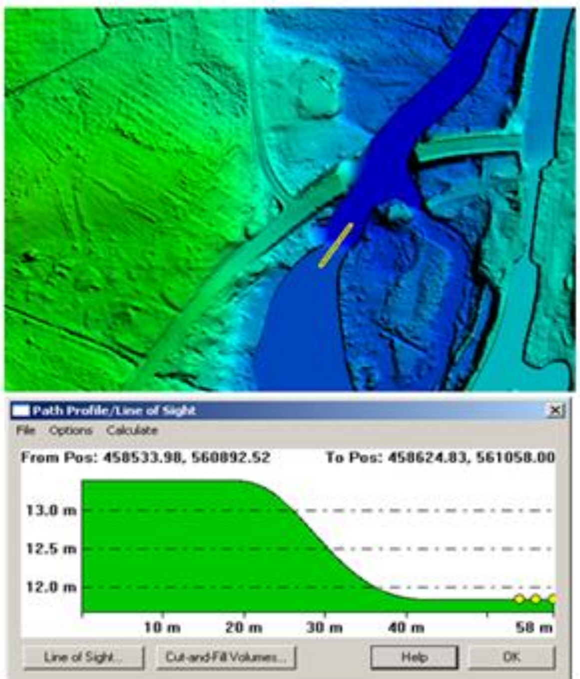


Figure 23. River hydro-flattened with a smooth gradient along the yellow profile.

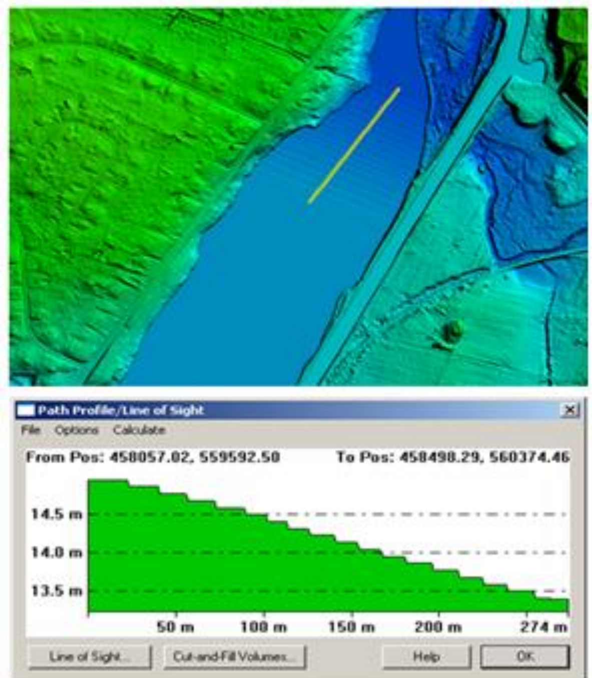


Figure 24. River hydro-flattened with a stair-stepped gradient along the yellow profile (10 cm per step in this example).

Figure 25 shows a DEM that has been hydro-flattened with breaklines to make the lake shoreline level and to flatten the stream from bank-to-bank. Note that bridges have been cut, but unseen culverts have not been cut. Compare with Figure 26 below which has been hydro-enforced.

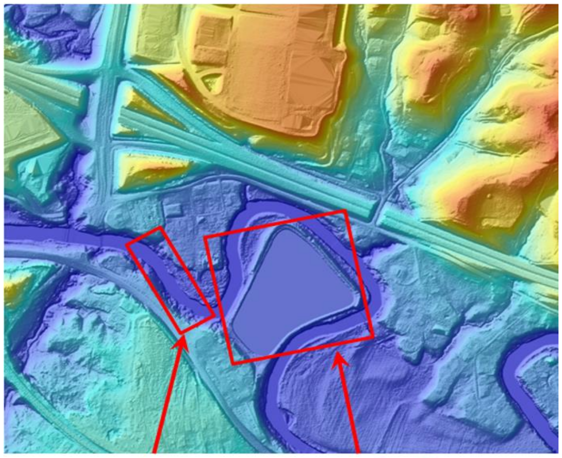


Figure 25. Example of a lake and stream that have been hydro-flattened with breaklines.

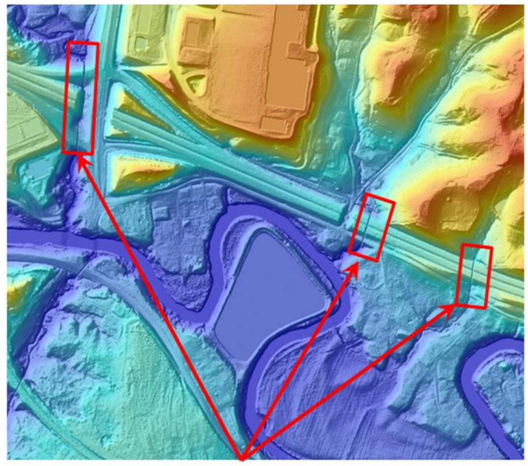


Figure 26. Hydro-enforcement uncovers below-ground culverts so that water will flow through these culverts in hydrologic and hydraulic models.

Hydro-Enforcement: *Hydro-enforcement* (Figure 26) includes hydro-flattening but adds steps for treatment of narrower dual- and single-line drains and culverts to enforce the downward flow of water. Hydro-enforcement is required for hydrologic modeling and management of watersheds and for hydraulic modeling of floodplains. It is also used for stormwater management. Hydro-enforcement is much more expensive than hydro-flattening because a large amount of manual processing is required.

Figures 27 and 28 are commonly used as examples of how to hydro-enforce a dual-line stream that appears to block the flow of water in the TIN shown at Figure 27 but enforces the downward flow of water in the hydro-enforced TIN at Figure 28.

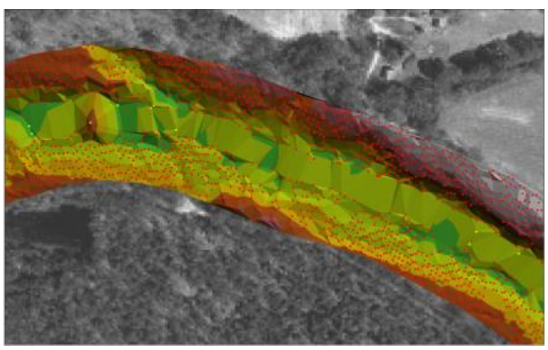


Figure 27. Rocks in the river, and/or natural undulating elevations along the shorelines, make the TIN appear as though water cannot pass downstream.

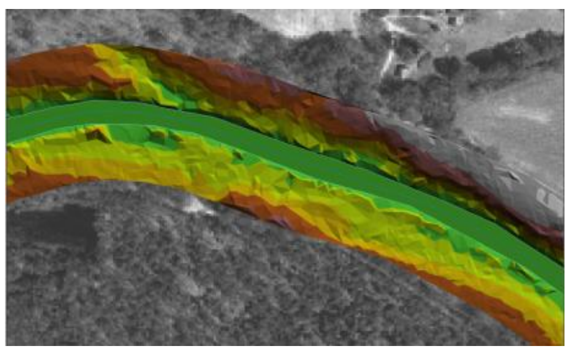


Figure 28. Breaklines for the dual shorelines are cut beneath the mapped elevations in order to hydro-enforce the flow of water; but this can create other problems.

There are no uniform standards for hydro-enforcement of below-ground culverts. For the National Flood Insurance Program (NFIP), FEMA leaves it up to the hydraulic engineer to determine when, where and how to hydro-enforce streams, bridges and culverts of all sizes. Figure 29 shows what happens when a culvert is not hydro-enforced, and Figure 30 shows what happens when a culvert is hydro-enforced. Figures 29 and 30 show puddles (one or more elevation posts totally surrounded by higher elevations) with red being the deepest part of each puddle. The puddles in these examples are suitable for hydro-enforcement, i.e., being "cut" and drained by culverts that are inferred but not absolutely known; a "cut" is shown in Figure 30 with the purple connector line that crosses the road. Dry puddles should not be hydro-enforced; it is ideal when drainage features can be mapped when they are dry. Limestone sinks and dry swimming pools are types of puddles that should not be drained by hydro-enforcement or filled by hydro-conditioning.

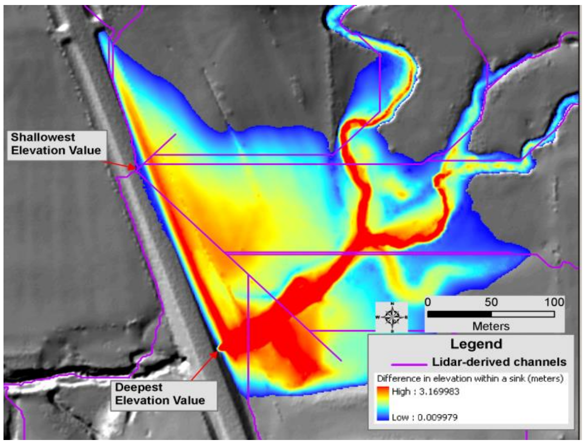


Figure 29. This shows what happens when the culvert is <u>not</u> hydro-enforced. In hydro models, the water flows in the ditch beside the road until it overflows the road at its shallowest elevation (pour point) where the purple line crosses the road.

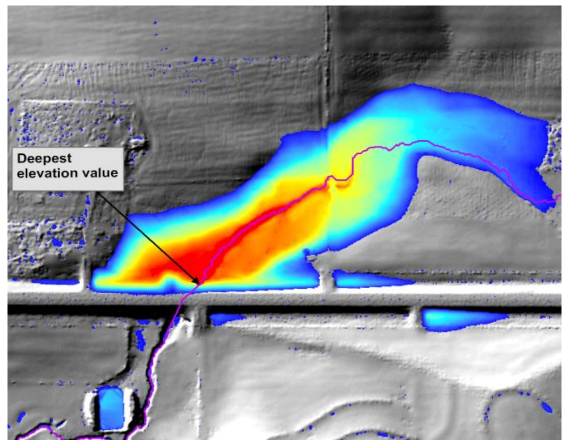


Figure 30. This shows a culvert "cut" to hydro-enforce the flow of water through this culvert. The darkest red shows the deepest part of the "puddle" and most likely location for the culvert entrance.

Hydro-Conditioning: Hydro-conditioning is similar to hydro-enforcement, but with sinks filled to their pour points. Hydro-conditioning can be used as part of the hydro-enforcement process to identify where culverts may be needed. Filling (hydro-conditioning) un-drained depressions in the topographic DEM can reveal locations where downslope flow is impeded, typically road fills over culverts, and provide elevations where hydro-enforcement of the topographic DEMs are needed. Hydro-conditioning, or filling sinks, after culverts have been hydro-enforced can further refine the DEM for hydrologic and hydraulic modeling. After hydro-conditioning, the resulting flow of water is continuous across the entire surface and there are no areas of unconnected internal drainage. Figure 31 shows areas where sinks have been filled such that a hydrologic network could be created from the resulting DEM.

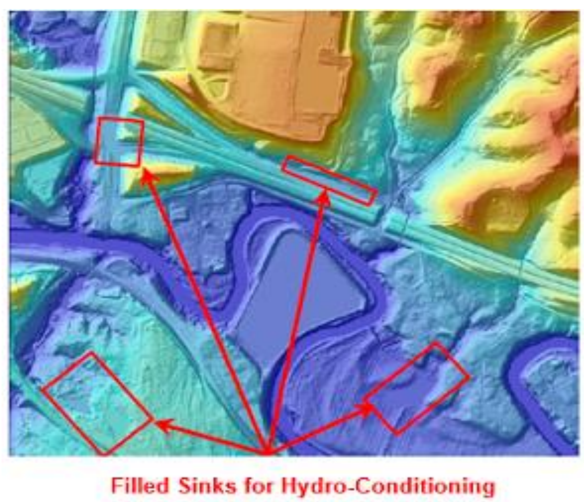


Figure 31. All sinks have been filled so there are no puddles.

FAQ #14: What is meant by seamless temporal integration and seamless spatial integration of 3D data?

Seamless temporal integration refers to the integration of multiple 3D datasets acquired at different times to reduce discontinuities between datasets acquired on different dates, and so that a user cannot see the differences. Temporal changes most commonly occur when the goal is to acquire 3D data during leaf-off conditions; early snowfall in the fall may cause data acquisition to be halted until the following spring, or leaf-on conditions in the spring may cause data acquisition to be halted until the following fall when leaf-off conditions return. Changes in water surface levels may be apparent due to the different time periods of collection. Exceptions are routinely made when data acquisition flights are interrupted by unavoidable events such as natural disasters, e.g., wildfires, hurricanes, tornadoes, earthquakes or floods that change the 3D landscape. Other exceptions are with tidal waters that continuously change coastal shorelines; the USGS Lidar Base Specification V1.2 states: "Vertical discontinuities within a water body resulting from tidal variations during the collection are considered normal and shall be retained in the final DEM." In the case of tidal variations, the temporal integration of datasets acquired even just an hour apart may not be seamless. Other temporal variations may also be unavoidable.

Seamless spatial integration refers to the integration of different datasets so that users cannot see seamlines between the two datasets. Figure 32 is an example where the existing data was a 25' DEM (top of image) and the newly collected LiDAR was produced to a 2.5' DEM (bottom of image). The temporal difference between the project spans 5 years so changes in the landscape are present. Because of the difference in resolution between the two areas there will always be a seam as the newly collected LiDAR data has significantly more definition. In this instance 58% of the overlapping dataset matched within 0.5' and 98% matched within 3.28'. The observed differences between the projects were a direct result of the temporal change and variability in resolution. Surfaces such as roads and parking areas matched within 8 cm which would meet the between swath accuracy requirements of QL2 LiDAR.

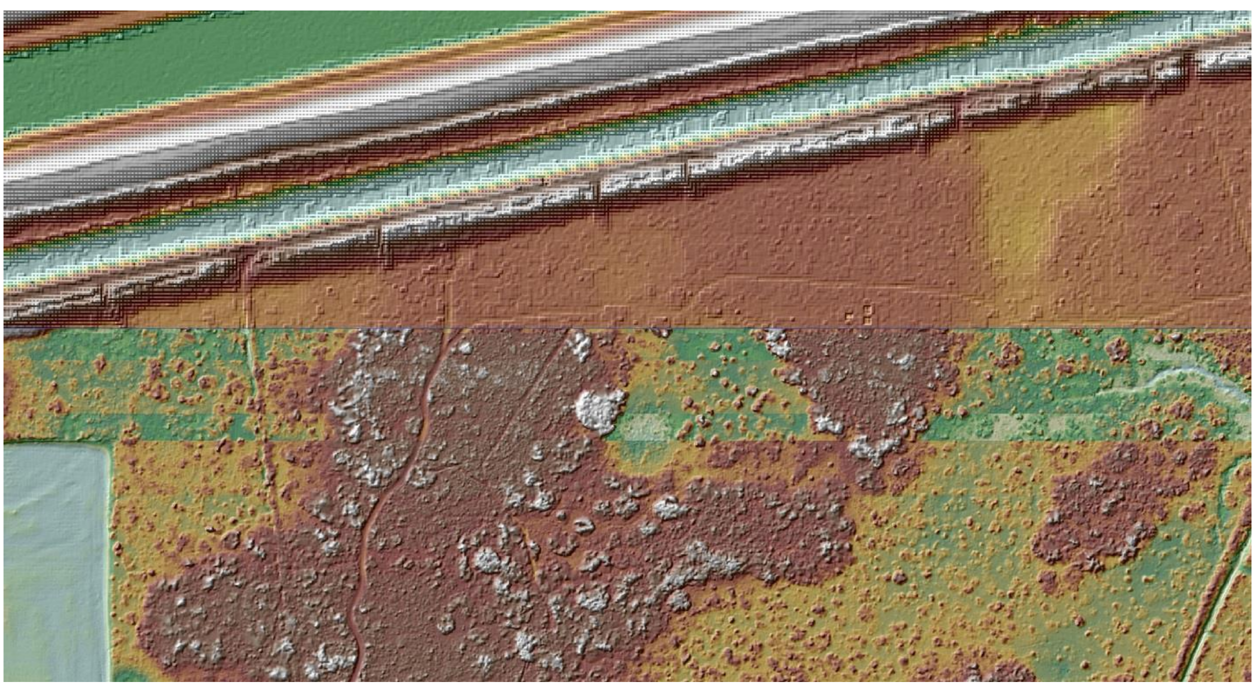


Figure 32. Example of temporal and resolution differences over a 5-year time span.

Figures 33 and 34 show the before and after of two overlapping projects where temporal change was present on the beach. In Figure 33 the highlighted area shows row effects in the final merged surface that resulted from the temporal differences. Figure 34 shows the after effects of selecting only one surface and moving the seam to where the two projects matched vertically.

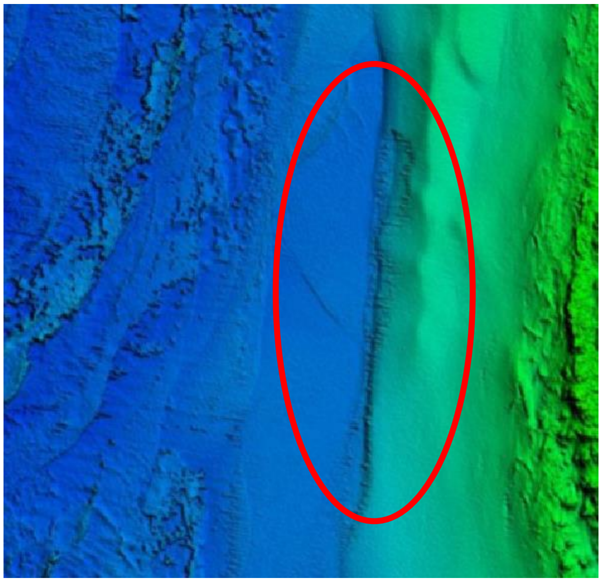


Figure 33. "Before." Example of two overlapping projects with temporal differences along the coast. The area highlighted contains row effects in the merged surface.

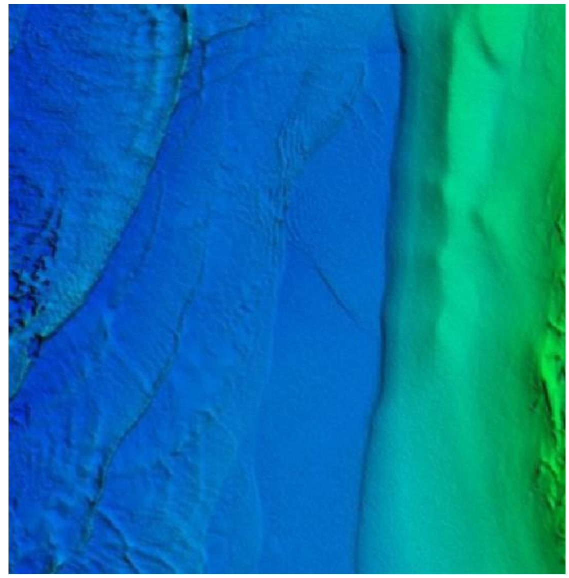


Figure 34. "After." This example shows the result of selecting only one surface and moving the seam to where the two projects matched vertically.

DEMs produced from photogrammetry, lidar and IfSAR can also have absolute and relative vertical offsets as shown in Figure 35.

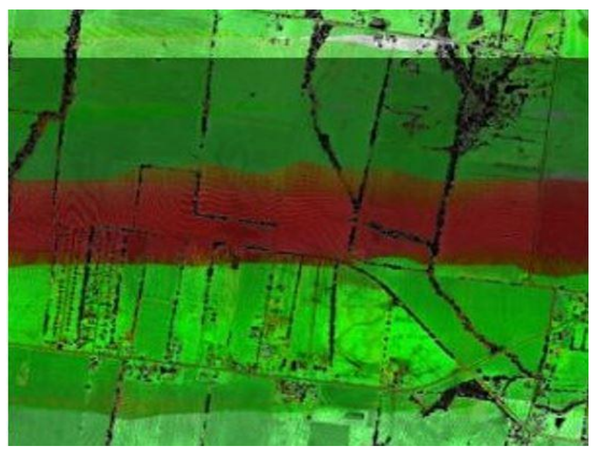


Figure 35. Relative vertical offsets of 6" or more can occur in overlapping flight lines from a poorly calibrated lidar sensor. The USGS Lidar Base Specification has rigorous criteria for smooth surface repeatability and swath overlap differences depicted in this ΔZ ortho that shows the inconsistent swath in red when >10 cm, for example.

FAQ #15: What is meant by vertical manipulation as pertains to seamless spatial integration?

When merging or joining one elevation dataset to another, there is normally a visible seamline between disparate elevation datasets because of: (1) temporal differences, (2) sensor differences, (3) different Quality Levels and accuracy standards, or (4) differences between topographic and bathymetric surfaces along the ever-changing tidal zone, for example.

Figure 36 is an example of the merger of topographic lidar, with bathymetric lidar, with sonar for the entire California coastline, using diverse technologies and surveys over a 10+ year time period:

- Topographic lidar datasets generally matched each other within 30 cm
- Bathymetric lidar datasets generally matched topographic lidar datasets within 45 cm
- Topographic and bathymetric datasets collected at the same time and controlled the same way had differences <10 cm
- Sonar datasets often differed from bathy lidar by 1-3 meters
- These disparate datasets, however, were conducted sometimes 10 years apart and where coastal sedimentation continually changes with wave action.

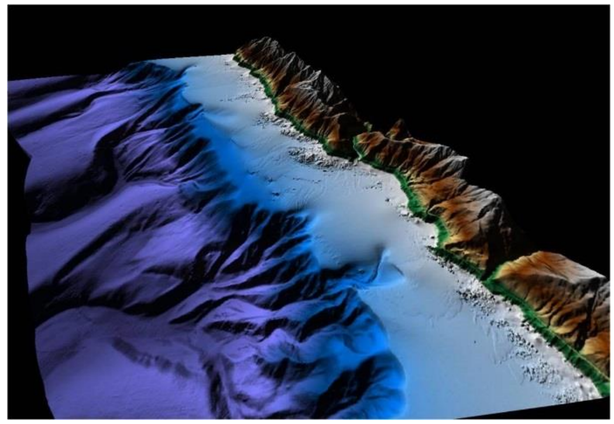


Figure 36. Coastal California data merge of sonar with topographic and bathymetric lidar.

These disparate datasets, however, were conducted sometimes 10 years apart and where coastal sedimentation continually changes with wave action. To integrate disparate elevation datasets so they appear to be seamless, data producers normally don't have hard and fast thresholds (vertical differences) that can't be exceeded for merging; they use the "best available" data and then merge and smooth seamline areas to minimize discontinuities, after first adjusting for any vertical datum differences between the overlapping datasets (which is especially important for topo-bathy merging).

There are many questions to be answered prior to determining whether or not it is actually desirable to manipulate elevation datasets either horizontally or vertically to make them seamless:

- Are point clouds to be merged, or just the resultant DEMs?
- Which dataset do you hold as control? Presumably, the older dataset would be held fixed if it had previously been accepted and placed in the public domain. The issue here is that the previously accepted data is not the most current and is often less accurate than the newer dataset, so the newer, superior dataset might be degraded to “fit” the older, poorer dataset.
- What about new projects that intersect with two or more older, adjacent datasets? The adjustment parameters for each edge would need to be different to make the data seamless.
- How far into the dataset do you make the vertical adjustment? Is it just along the edge in which case the edge would no longer follow the same error distribution as the rest of the project; or does one try to adjust the entire project to match a certain edge?
- What if the vertical manipulation (adjustment) causes the newly collected data to have a reduced accuracy? If the RMSEz is 3 or 4 cm worse, is that acceptable, or is it preferred to maintain the highest accuracy possible when tested against QA/QC checkpoints?

- Should the new contractor place control points within the overlap area with old dataset to test the accuracy of the older dataset prior to determining whether or not the old and new datasets should be merged seamlessly?

Figure 37 is an example of an elevation "difference raster" for the overlap area between an old and new lidar dataset. DEM difference rasters are created by subtracting the elevations of the older dataset from the elevations of the newer dataset. Units are in feet. Differences in light pink are over 1', differences in dark pink are over 3', and differences in orange are over 5'. The long linear light pink feature spanning the right half of the image may look like a road but it is actually a canal where differences are expected because of changing water levels. Most changes in pink and orange were determined to be temporal changes and not spatial changes. Areas in green are unchanged and fit nicely.

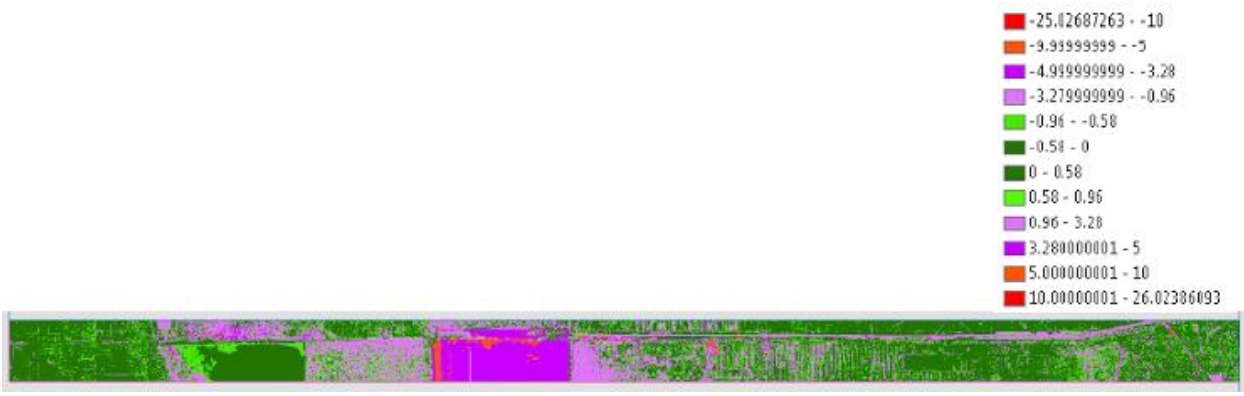


Figure 37. This is an elevation difference raster created by subtracting the elevations of an old dataset from a new dataset. What appears to be spatial differences are actually temporal differences.

When making seamless integration at national scale and global scale, there are two primary references, too lengthy and complex to explain here, but URLs are provided:

- Integrating Disparate Lidar Datasets from a Regional Storm Tide Inundation Analysis of Hurricane Katrina, by Jason Stoker et al. URL: https://pubs.er.usgs.gov/publication/70035535
- Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010), DOI Open File Report 2011-1073, by Jeffrey J. Danielson and Dean B. Gesch. URL: https://lta.cr.usgs.gov/GMTED2010

When making seamless topo-bathy elevation models, there are also several references, too lengthy and complex to explain here, but URLs are provided:

- Development of a Seamless Multisource Topographic/Bathymetric Elevation Model of Tampa Bay, by Dean Gesch and Robert Wilson: URL: https://pdfs.semanticscholar.org/c7f9/76474827d7913fffb6da59090e40757bf58c.pdf
- Topobathymetric Elevation Model Development using a New Methodology: Coastal National Elevation Database, by Jeffrey J. Danielson et al. URL: https://pubs.er.usgs.gov/publication/70179489

FAQ #16: What are the 3D elevation data products referred to in the questionnaire?

Digital Surface Model (DSM): A DSM is a "top of canopy" or "top reflective surface" elevation model, including the bare earth in open terrain areas where there are no elevated features. A DSM includes the tops of buildings, trees, towers, and other features elevated above the bare earth. See Figure 38. DSMs are produced from photogrammetry, lidar, IfSAR, or sonar.

DSMs are typically gridded, as are DEMs, for more efficient file storage.

A top reflective surface DSM is currently a 3DEP "buy-up" option [1] [2] which is relatively inexpensive because DSMs are easily produced from lidar "first returns" from the raw point cloud, and then gridded into a **r**aster DSM.

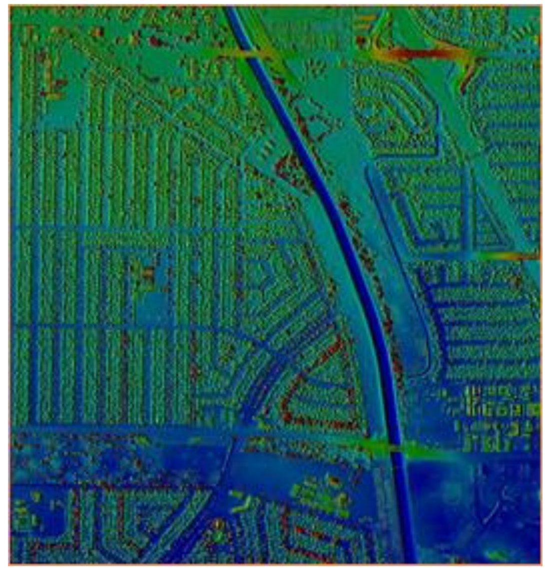


Figure 38. A DSM maps treetops and rooftops.

Digital Terrain Model (DTM): As shown by Figures 39 and 40, a DTM incorporates the elevation of significant topographic features on the land and irregularly-spaced mass points and breaklines to better characterize the true shape of the bare-earth terrain, free of vegetation and man-made structures. The net result of DTMs is that distinctive terrain features are more clearly defined and precisely located than a gridded DEM, and contours generated from DTMs more closely approximate the real shape of the terrain. Such DTMs are normally more expensive and time consuming to produce than uniformly spaced DEMs because breaklines are ill- suited for automated collection.

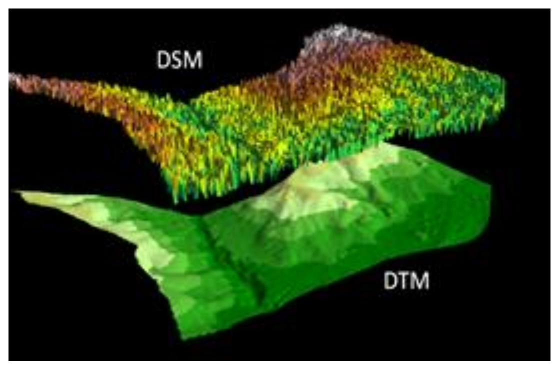


Figure 39. A DSM maps the top surface and a DTM maps the bare-earth terrain beneath.

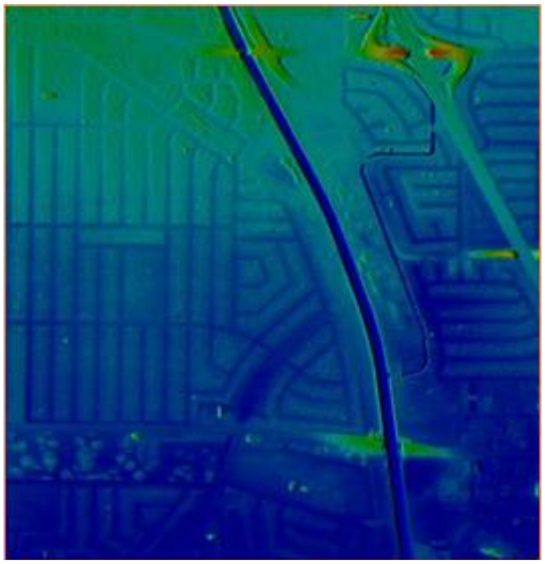


Figure 40. A DTM maps the bare-earth terrain beneath trees with irregularly-spaced mass points and breaklines.

Digital Elevation Model (DEM): DEMs and DTMs are often confused because they both model the bare-earth terrain, free of trees, buildings, towers, bridges and other visible man-made features. Whereas a DTM consists of irregularly-spaced mass points and breaklines, a DEM is a raster (gridded) surface with a uniform cell size. Figure 41 shows the difference between irregularly-spaced mass points on the left, and uniformly-spaced DEM points on the right; it also shows breaklines for single-line drains and the shore of a pond.

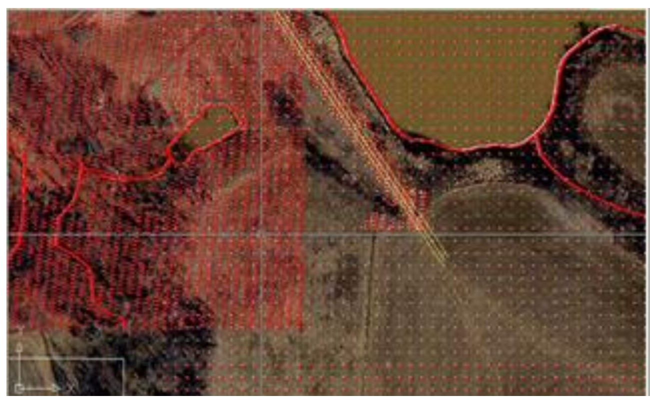


Figure 41. Higher density, irregularly-spaced lidar mass points (left side of image) are used to interpolate the lower-density regularly-spaced DEM elevation posts on the right. Several hydro breaklines are also shown in this image.

The DTM/DEM differences are compared in Figures 42 through 45 where DTMs are on the left and DEMs are on the right.

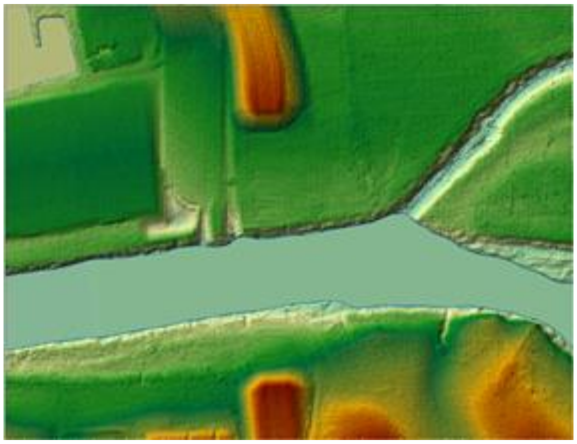


Figure 42. A DTM with irregularly-spaced mass points and breaklines for (1) center of the narrow stream and (2) for both shorelines of the wider stream.

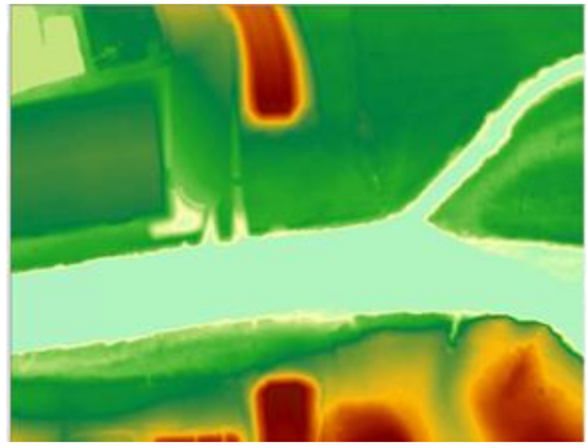


Figure 43. A DEM of the same area with regularly-spaced grid cells and no breaklines. The differences will be more apparent with the zoomed-in views below.

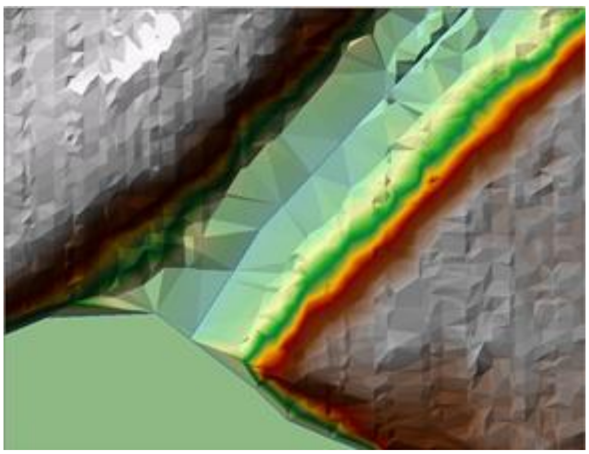


Figure 44. The same DTM -- zoomed in -- shows irregularly-spaced mass points and breaklines for streams. Although more precise, DTMs are inefficient to store and use.

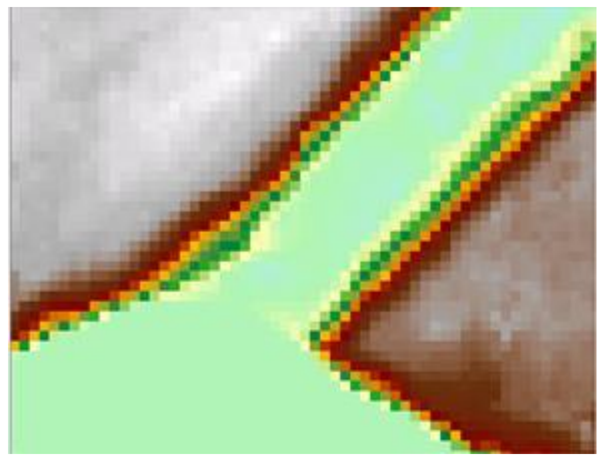


Figure 45. The same DEM -- zoomed in -- shows square, regularly-spaced grid cells that are much more efficient to store and use.

For 3DEP, the DEM cell size is no greater than 2.5 feet and no less than the design Aggregate Nominal Pulse Spacing (ANPS). The 3DEP's DEM surface is hydro-flattened but not hydro-enforced (see below).

Raw point cloud data: A *point cloud* is a set of 3D data points in some coordinate system defined by X, Y, and Z coordinates, often intended to represent the external surface of an object. Point clouds may be created by 3D scanners such as lidar or by photogrammetric means. A point cloud is "raw" when the data points have not yet been classified to explain the type of feature being mapped (e.g., land, water, trees, bridges).

A *lidar point cloud* includes all first, intermediate and last returns from each laser pulse. When the first and last return elevations are the same, the laser pulse hit a hard feature such as the bare-earth terrain, concrete, asphalt, or perhaps a roof top. Figure 46 shows examples of a full lidar point cloud in a forest. As shown in yellow, only a few of the first returns penetrated the vegetation to the ground. Some but not all of the second returns (blue) and third returns (red) penetrated to the ground. Only the lowest elevation returns at the bottom are used to produce the bare-earth DEM. First returns are used to produce DSMs; last returns are used to produce DTMs or DEMs.

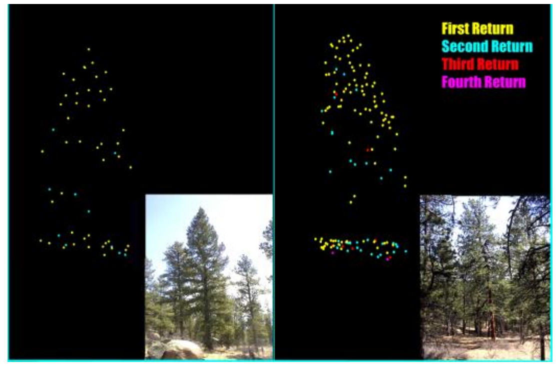


Figure 46. Examples of lidar point clouds on trees. Note the color differences for 1st, 2nd, 3rd, and 4th returns from each lidar pulse.

A *photogrammetric point cloud* can be produced using Semi-Global Matching (SGM) or Structure from Motion (SfM) technologies, developed to further enhance the advantages of a new generation of digital camera systems such as large digital frame cameras and push-broom scanners. Utilizing aerial triangulation with digital frame imagery, a high density digital surface model (DSM) is generated for use in orthophoto and map production. Capturing imagery and surface models during the same flight with the same sensor ensures that image features and image geometry perfectly match the DSM. The resulting pixel level correlation generated point cloud is photogrammetrically accurate to the same level as the mapping. The point density achieved (300 points/m^2 at a 5cm GSD) is far greater than traditional linear-mode lidar (2-8 points/m^2).

Classified point cloud data: Lidar point cloud data are subsequently processed to ASPRS LAS (laser file format) classes that distinguish between points on the ground, water, or elevated features such as buildings, trees, towers, bridges, etc. No points are discarded but may be classified as noise, or unclassified. All topographic lidar elevations in water are unreliable because sometimes the laser pulses are absorbed by the water, reflected from the water with differing intensities, or provide elevations on or below the level of the water surface.

Most topographic lidar datasets are flown with the laser scanning in a zig-zag pattern where the zigs and zags are so close that they appear to be parallel. The objective is to obtain pulse spacing and flight speed so that the nominal pulse spacing (NPS) is approximately equal in the in-flight and cross-flight directions.

Current ASPRS LAS classes are listed in Table 6. The minimum LAS classes for 3DEP topographic LiDAR datasets are classes 1, 2, 7, 9, 17, 18 and 20. Note also that class 20 was previously called class 10. Additional LAS classes for bathymetric or topobathymetric lidar include classes 40 through 45.

Table 6. LAS Classes

Class Value	Meaning
0	Created, never classified
1	**Processed but unclassified, including undefined points such as unclassified vegetation**
2	**Bare-earth ground**
3	Low vegetation
4	Medium vegetation

5	High vegetation
6	Building
7	**Low point (noise)**
8	Model key points
9	**Water**
10	Rail
11	Road surface
12	Reserved
13	Wire – guard (shield)
14	Wire – conductor (phase)
15	Transmission tower
16	Wire-structure connector (e.g., insulator)
17	**Bridge deck**
18	**High noise**
20	**Ignored ground (near a breakline)**
21	Snow
40	**Bathymetric point (e.g., seafloor or riverbed; also known as submerged topography)**
41	**Water surface from bathy or topobathy LiDAR, distinct from Class 9 used for topo LiDAR**
42	**Derived water surface (synthetic water surface used in computing refraction at water level)**
43	**Submerged object, not otherwise specified (e.g., wreck, rock, submerged piling)**
44	**International Hydrographic Organization (IHO) S-57 object, not otherwise specified**
45	**No-bottom-found-at (bathy LiDAR point for which no detectable bottom return was received)**
46	**Top of Unconsolidated Material**
Others to 63	Reserved
64-255	User definable

Full waveform data: Lidar data in which the entire reflection of the laser pulse is fully digitized, captured, and stored. [Note: Standard discrete return lidar point clouds may already be extracted by lidar providers from full waveform lidar data during post processing for simplified user applications. Not all lidar systems are capable of digitizing the entire return signal. Discrete return lidar captures and stores the important peaks in the waveform data, each peak representing a return from a different target, discernible in vertical or horizontal domains.] Lidar waveform datasets are much more demanding to store and process and require specialized software.

Breaklines required for standard hydro-flattening: *Hydro-flattening* is a term used by USGS to explain how DEMs are processed for inclusion in the 3DEP. Hydro-flattening is performed to depict the bare-earth terrain as one could see and understand the terrain from an airplane flying overhead. The viewer would assume that the surfaces of lakes and reservoirs are flat and that rivers are flat from shore to shore, perpendicular to the apparent flow centerline which maintains a downhill water surface gradient. The viewer would also recognize that bridges are man-made features that should be removed from a bare-earth DTM because they are artificially elevated above the natural terrain.

The USGS Lidar Base Specification, V1.2 provides detailed guidance on breaklines for hydro-flattening, including inland ponds and lakes (≥2 acre surface area), dual-line streams and rivers (≥100 feet nominal width), non-tidal boundary waters, tidal water bodies, and islands (>1 acre).

Figure 47 shows a DEM that has been hydro-flattened with breaklines to make the lake shoreline level and to flatten the stream from bank-to-bank. Note that bridges have been cut, but unseen culverts have not been cut. Compare with Figure 48 below.

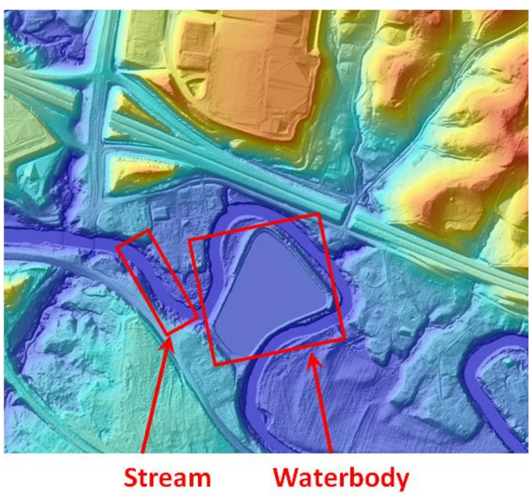


Figure 47. Higher density, irregularly-spaced lidar mass points (left side of image) are used to interpolate the lower-density regularly-spaced DEM elevation posts on the right. Several hydro breaklines are also shown in this image.

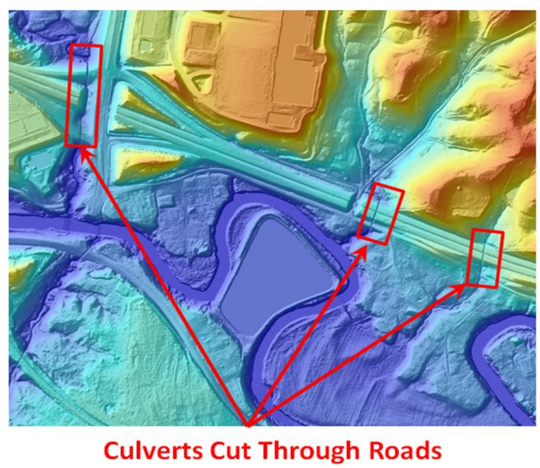


Figure 48. Example of a lake and stream that have been hydro-flattened with breaklines; overpasses and bridges are "removed" but culverts remain uncovered.

Additional breaklines required for hydro-enforcement of culverts: Looking back at Figure 47, it can be seen that there are three locations where the DEM appears to block the flow of water, forming artificial flow barriers where below-grade culverts route water under roads. These culverts were not readily visible from the air when lidar or aerial photography was acquired.

In Figure 48, the DEM has been hydro-enforced by “cutting” breaklines through culverts at the three locations highlighted, allowing water to flow through those culverts in hydrologic and hydraulic models. Such hydro-enforcement can be quite expensive because it is labor intensive to determine individual culvert locations and to cut those culverts into DEMs.

Intensity Images: Lidar also produces intensity images that record the intensity of return from each laser pulse. Intensity images are used with lidargrammetry for compilation of 3D breaklines. Figure 49 shows a sample lidar intensity image. The 3DEP requires intensity images to be produced for each tile to match the Classified LAS and DEM files. Images are 8-bit, 256 color gray scale in GeoTIFF format. Cell size is 2.5 feet. IfSAR and side-scan sonar both produce images that are somewhat similar to lidar intensity images.

Figure 49. Intensity image showing streaks over water from multiple flight lines. This is not a problem because topographic lidar measurements on water are already assumed to be unreliable and are classified separately as LAS Class 9.

Survey or Ground Control: The 3DEP requires ground control and check points that satisfy requirements specified in the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014). Ground control will be established by the data producer, but QA/QC checkpoints are funded by the client, and with the quantity of such checkpoints specified in ASPRS’ table below (Table 7).

Table 7. Recommended Number of Checkpoints Based on Area

Project Area (Square Kilometers)	Horizontal Accuracy Testing of Orthoimagery and Planimetrics	Vertical and Horizontal Accuracy Testing of Elevation Data sets		
	Total Number of Static 2D/3D Checkpoints (clearly-defined points)	Number of Static 3D Checkpoints in NVA[1]	Number of Static 3D Checkpoints in VVA	Total Number of Static 3D Checkpoints
≤500	20	20	5	25
501-750	25	20	10	30
751-1000	30	25	15	40
1001-1250	35	30	20	50

1251-1500	40	35	25	60
1501-1750	45	40	30	70
1751-2000	50	45	35	80
2001-2250	55	50	40	90
2251-2500	60	55	45	100

[1] Although vertical check points are normally not well defined, where feasible, the horizontal accuracy of lidar data sets should be tested by surveying approximately half of all NVA check points at the ends of paint stripes or other point features that are visible and can be measured on lidar intensity returns.

Using metric units, ASPRS recommends 100 static vertical checkpoints for the first 2,500 square kilometer area within the project (i.e., approximately 1,000 square miles), which provides a statistically defensible number of samples on which to base a valid vertical accuracy assessment. For horizontal testing of areas >2,500 km^2, clients should determine the number of additional horizontal checkpoints, if any, based on criteria such as resolution of imagery and extent of urbanization. Figures 50 and 51 show how horizontal QA/QC checkpoints are selected.

For vertical testing of areas >2,500 km^2, add five additional vertical checkpoints for each additional 500 km^2 area. Each additional set of five vertical checkpoints for 500 km^2 would include three checkpoints for Non-vegetated Vertical Accuracy (NVA) and two for Vegetated Vertical Accuracy (VVA). The recommended number and distribution of NVA and VVA checkpoints may vary depending on the importance of different land cover categories and client requirements.

Figure 50. This is an example of a photo-identifiable feature that makes a good control point or QA/QC checkpoint for either vertical or horizontal accuracy testing.

Figure 51. This feature is ideal for three reasons: (1) it is photo-identifiable on imagery or lidar intensity returns, (2) the target is a clearly-defined point feature at a 90 degree corner, and (3) its location will probably not move.

FAQ #17: What geospatial data types could be integrated with 3D topographic data?

Aerial or Satellite Imagery: Aerial imagery includes digital orthophotos produced from aerial photography, and satellite imagery includes digital orthophotos produced from satellite photography -- either of which can be draped over digital elevation models and viewed in any chosen 3D perspective, as shown at Figure 52.

Figure 52. Top: Simulated view of Denali (highest mountain in the U.S.) created by draping a satellite image over the IFSAR DEM. Bottom: Actual fly-by photo of Denali photographed out the window of an aircraft in Alaska.

Geologic or seismic data: Geologic features such as seismic faults, volcanoes and landslide hazards are easier to visualize when draped over 3D elevation data, as shown at Figure 53. Note: Geologists use QL1 LiDAR or better for many of their applications, including delineation of geological features and seismic faults, often non-visible when walking on the terrain.

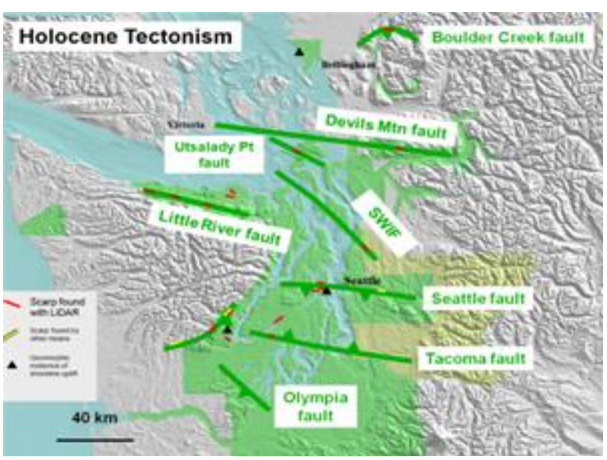


Figure 53. Geologic faults overlaid on digital terrain model.

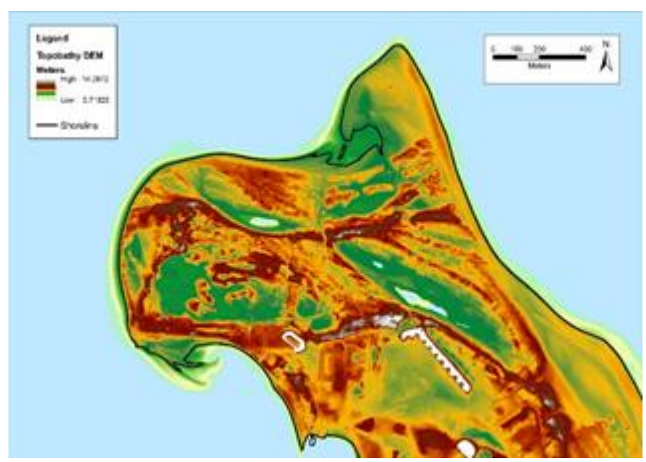


Figure 54. Extraction of MHW shoreline at Sandy Hook, NJ from topobathymetric lidar.

Shoreline data: Official shorelines, e.g., Mean High Water (MHW), are extracted from topobathymetric data, defining the official boundary between state-owned and privately-owned lands, as shown at Figure 54.

Land use/land cover (LU/LC) data: Elevation data are commonly used to identify LU/LC, especially as pertains to vegetation types, as shown at Figure 55, and forest metrics.

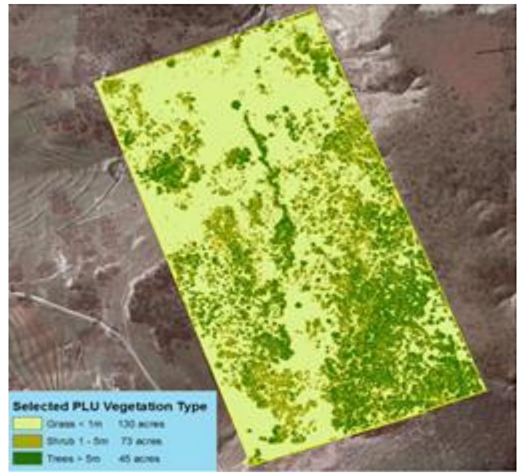


Figure 55. NRCS uses lidar elevation data for quantification of vegetation types in rangeland. The number of acres of shrub and tree vegetation types can be estimated by spatial analysis map algebra functions.

Wetland data: Wetlands are largely delineated from color infrared imagery and lidar data, as shown at Figure 56.

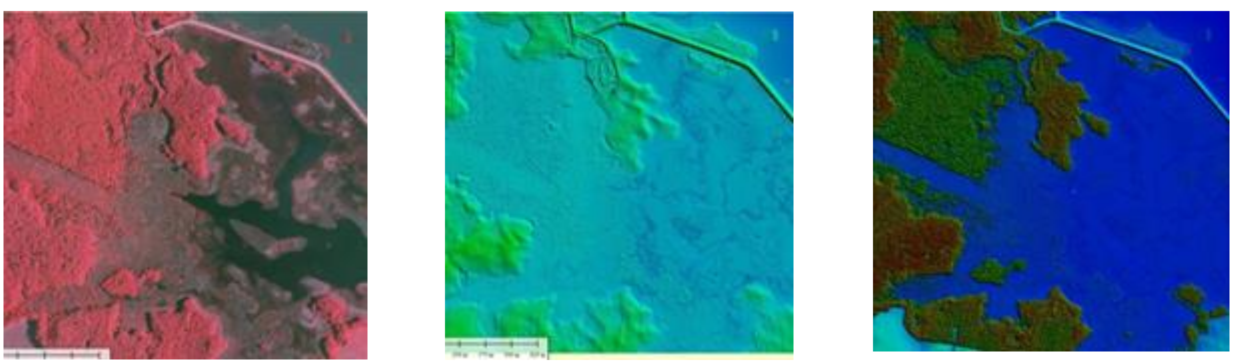


Figure 56. Color infrared imagery (left), lidar DTM (center) and lidar DSM (right) all work together for wetland identification. DTMs help differentiate wetland water regimes (flooding duration). DSMs help differentiate vegetation classification (e.g., trees vs. shrubs). Lidar point clouds help determine vegetation structure (e.g., pines vs. oaks).

Inland surface water features: Inland surface water features such as lakes and ponds, streams and rivers, canals, oceans are delineated from 3D topographic data in a GIS so that each feature has a name and/or feature identification code.

Bridge/culvert data: Bridge and culvert data can be integrated with 3D topographic data and attributed with feature identification codes in a GIS. Bridge and culvert data are also used to develop hydroenforced DEMs.

Landmark features: Landmark features can be identified from 3D topographic data as recognizable natural or artificial features used primarily for navigation.

Cultural resources: Cultural features in National Parks or prehistoric Indian mounds can either be identified from 3D topographic data or integrated with 3D topographic data for 3D visualization.

Coastal and riverine structures: Shoreline stabilization structures, levees, dams, jetties, piers, weirs, etc. can either be identified from 3D topographic data or integrated with 3D topographic data for 3D visualization.

Lowest floor elevations: Lowest floor elevations of buildings or other structures could be overlaid on 3D topographic data, but not derived from such 3D data. Lowest floor elevations in basements, for example, cannot be derived from aerial surveys of any type, but they can be estimated from mobile mapping systems capable of detecting basement windows, or for determining elevations of the bottom of front doors, for example, for structures without basements.

FAQ #18: How do I find out what topographic or bathymetric data are currently available?

Questionnaire respondents may need to know what elevation data already exist for their area of interest in order to better understand future requirements for more current and accurate data.

There are two Federal on-line inventories of elevation data where you can see what data are available, when they were collected, by whom, and to what level of accuracy. Each includes data collected by Federal, state, and local agencies, but may not include all locally or privately collected elevation datasets.

The U.S. Interagency Elevation Inventory is available here: https://coast.noaa.gov/inventory/. It includes information about topographic, and topobathymetric, and offshore bathymetry data. You can turn on and off the different data types and view their date and Quality Level. As shown at Figures 57 and 58, you can also download the spatial data for the inventory for further review or analysis.

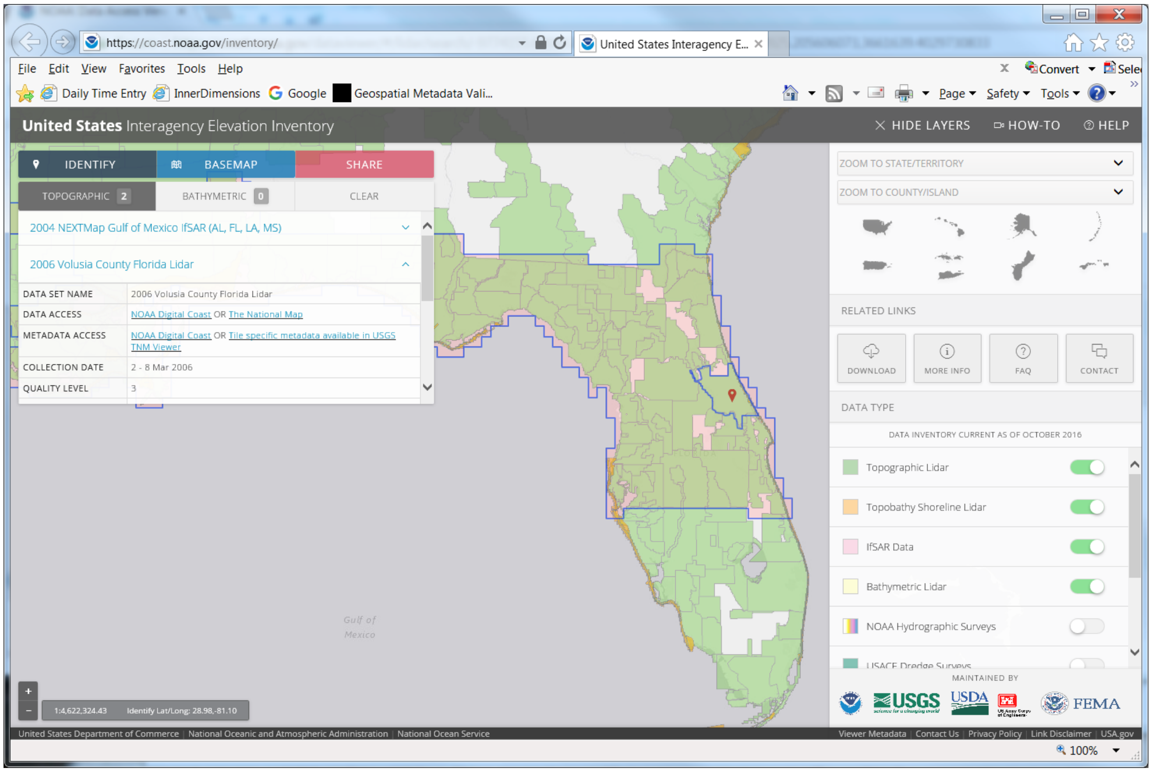


Figure 57. U.S. Interagency Elevation Inventory (USIEI).

NOAA’s Data Access Viewer is available here: https://coast.noaa.gov/dataviewer/#/lidar/search/. This is for lidar data download. You can also download actual elevation data from this site.

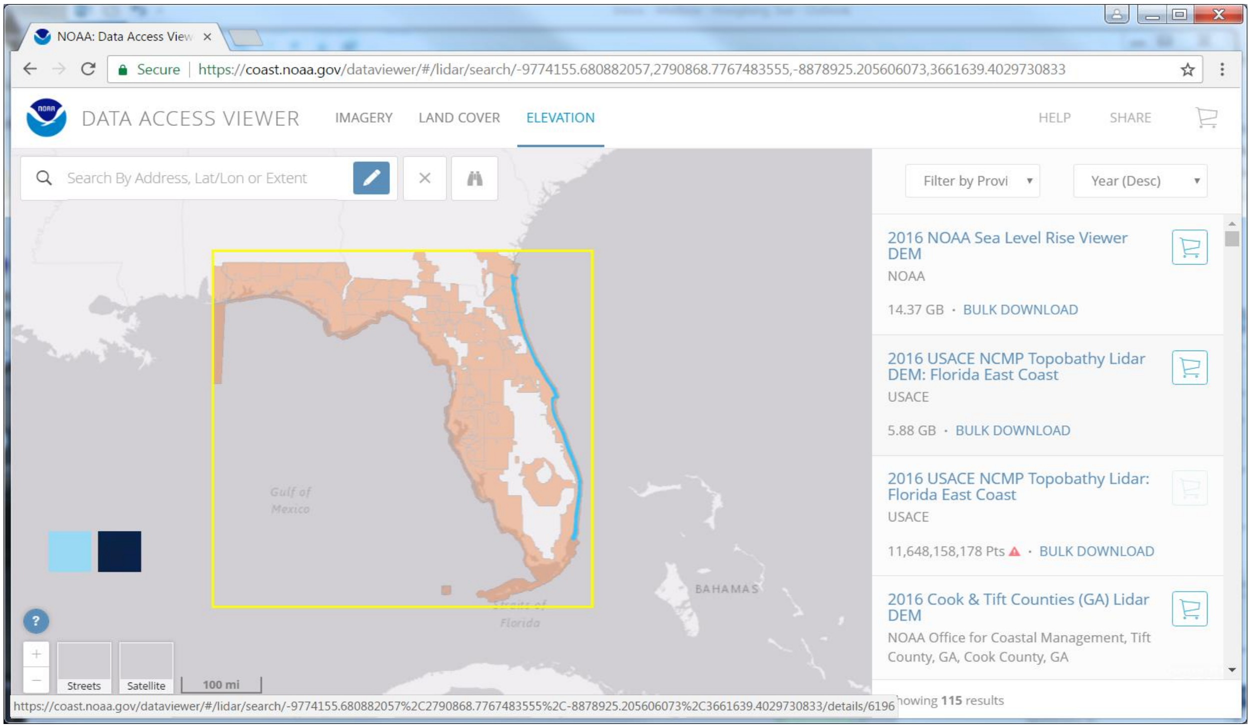


Figure 58. NOAA's Data Access Viewer.

FAQ #19: Please explain the different 3D data sources referenced in the questionnaire.

The National Map: *The National Map* is a collaborative effort among the USGS and other Federal, State, and local partners to improve and deliver topographic information for the Nation. It has many uses ranging from recreation to scientific analysis to emergency response. *The National Map* is easily accessible for display on the Web, as products and services, and as downloadable data. The geographic information available from *The National Map* includes elevation, geographic names, hydrography, boundaries, transportation, structures, orthoimagery (aerial photographs) and land cover. Other types of geographic information can be added within the viewer or brought in with *The National Map* data into a Geographic Information System to create specific types of maps or map views. *The National Map* is a significant contribution to the National Spatial Data Infrastructure (NSDI) and currently is being transformed to better serve the geospatial community by providing high quality, integrated geospatial data and improved products and services including new generation digital topographic maps.

Digital Coast: The Digital Coast is a NOAA-sponsored website that was developed to meet the unique needs of the coastal management community. The website provides not only coastal data, but also the tools, training, and information needed to make these data truly useful. Content comes from many sources, all of which are vetted by NOAA. Data sets range from economic data to satellite imagery. The site contains visualization tools, predictive tools, and tools that make data easier to find and use. The Digital Coast is managed by NOAA's Office for Coastal Management and was first released in 2007.

NOAA National Centers for Environmental Information (NCEI): NOAA's National Centers for Environmental Information (NCEI) hosts and provides public access to archives for environmental data on Earth with over 25 petabytes of comprehensive oceanic, atmospheric, and geophysical data. From the depths of the ocean to the surface of the sun and from million-year-old ice core records to near-real-time satellite images, NCEI is the Nation's leading authority for environmental information. By preserving, stewarding, and maximizing the utility of the Federal government's billion-dollar investment in high-quality environmental data, NCEI provides products and services to private industry and businesses, local to international governments, academia, as well as the general public.

Open Topography: OpenTopography is a distributor of free high-resolution, Earth science-oriented topographic data, related tools, and resources. Its mission is to:

- Democratize online access to high-resolution (meter to sub-meter scale), Earth science-oriented, topography data acquired with lidar and other technologies.
- Harness cutting edge cyberinfrastructure to provide Web service-based data access, processing, and analysis capabilities that are scalable, extensible, and innovative.
- Promote discovery of data and software tools through community populated metadata catalogs.
- Partner with public domain data holders to leverage OpenTopography infrastructure for data discovery, hosting and processing.
- Provide professional training and expert guidance in data management, processing, and analysis.
- Foster interaction and knowledge exchange in the Earth science lidar user community.

The OpenTopography Facility is based at the San Diego Supercomputer Center at the University of California, San Diego and is operated in collaboration with colleagues in the School of Earth and Space Exploration at Arizona State University and at UNAVCO. Core operational support for OpenTopography comes from the National Science Foundation Earth Sciences: Instrumentation and Facilities Program (EAR/IF), Geoinformatics, and EarthCube. OpenTopography was initially developed as a proof of concept cyberinfrastructure in the Earth sciences project as part of the NSF Information and Technology Research (ITR) program-funded Geoscience Network (GEON) project.

USGS Coastal and Marine Geology Program Inland Waters of the United States Map Server: The U.S. Geological Survey (USGS) Coastal and Marine Geology Program (CMGP) conducts integrated mapping of the coastal and marine environment to define offshore hazards and sediment processes, support habitat and resource management, and monitor change. CMGP provides expertise in mapping and laboratory analyses, working with other governmental agencies, educational institutions, and private companies and conducting collaborative research and development with similar groups to continually correct and perfect the data collection tools, analytical techniques, and technologies utilized in coastal and marine studies.

The Coastal and Marine Geology Program Interactive Maps portal provides public access to published GIS-related data and maps, including bathymetric data for select inland waters of the U.S.

USGS Data Series: Through its Publications Warehouse, USGS publishes data sets that were collected or generated as part of USGS studies. The Data Series includes basic data sets, databases, and multimedia or motion graphics. An individual data set may include videos, computer programs, and collections of digital photographs.

Each publication has its own descriptive citation page that is dynamically generated based on information stored in a database and provides a link to the publication itself and/or the data associated with the publication.

NOAA Nautical Charts: NOAA maintains the nation's nautical charts and publications for U.S. coasts and the Great Lakes. Over a thousand charts cover 95,000 miles of shoreline and 3.4 million square nautical miles of waters.

NOAA Electronic Navigational Charts (ENCs) are vector data sets that represent NOAA's newest and most powerful electronic charting product. NOAA ENCs conform to the International Hydrographic Office (IHO) S-57 international exchange format, comply with the IHO ENC Product Specification, and are provided with incremental updates that supply Notice to Mariners corrections and other critical changes. NOAA ENCs and updates are available for free download. NOAA ENC data may be used to fuel Electronic Chart and Display Information Systems (ECDIS).

In 1997, NOAA began a process of building a portfolio of ENCs that encompass the same areas covered by NOAA's suite of approximately 1,000 paper and raster charts. The ideal and most accurate way to build ENCs is to recompile the paper chart from all of the original source material. Unfortunately, this process is impractical as it is far too labor intensive. Instead, NOAA ENCs have been compiled from source on those features that are deemed to be navigationally significant. U.S. Army Corps of Engineers' federal project limits have been captured from large-scale drawings. These precise coordinates of channel limits are being incorporated into the ENC. Likewise, high-accuracy positions are being used to chart U.S. Coast Guard aids to navigation. The paper chart has been the source for the remainder of items.

USACE Inland Electronic Navigation Charts: The U.S. Army Corps of Engineers' inland electronic navigation charts (IENC) cover much of the U.S. inland river system, which consists of 8,200 miles of rivers maintained by the Corps of Engineers in 22 states, and includes 276 lock chambers with a total lift of 6,100 feet. The highly adaptable and effective river system of barge navigation moves over 625 million tons of commodities annually, which includes coal, petroleum products, various other raw materials, food and farm products, chemicals, and manufactured goods. The shallow draft waterways have any unique characteristics and difficulties over coastal harbor and ocean navigation; river levels can change by over 30 feet in a seasonal cycle, the navigation channel can shift significantly within the river banks, and shifting yet ever present river currents pose constant challenges in these confined waterways. Electronic chart systems can offer significant benefits to vessels including accurate and real-time display of vessel position relative to waterway features, voyage planning and monitoring, training tools for new personnel and integrated display of river charts, radar, and Automatic Identification Systems.

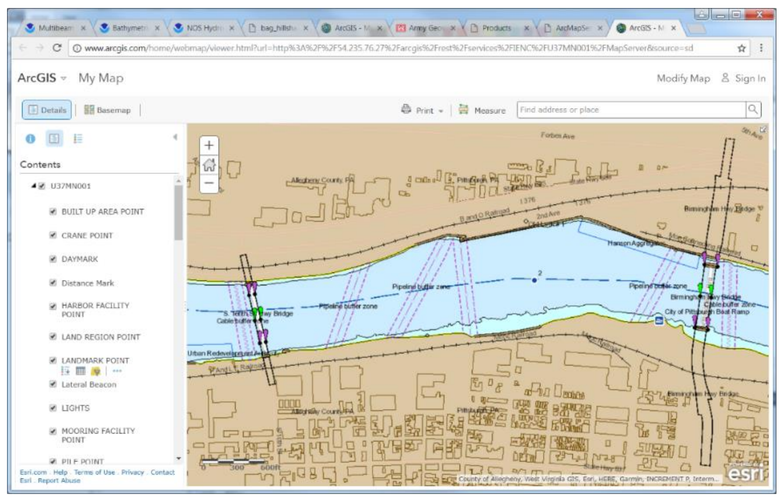


Figure 59. Example of an Inland Electronic Navigational Chart (IENC).

Congress directed the Corps of Engineers to develop and publish electronic charts for the inland waterways. Development of Inland Electronic Navigational Charts (IENCs) to cover the Mississippi River and tributaries began in 2001 with pilot projects to collect and convert inland waterway data, commonly used for river and channel maintenance, into the international S-57 hydrographic data exchange, the data format commonly used for electronic chart applications and be used for Corps IENCs. Figure 59 shows an image of an IENC for a portion of the Monongahela River in Pittsburgh, PA.

Marine Minerals Program Geospatial and Information System (MMP GIS): The Marine Minerals Program Geospatial Information System (MMP GIS) is a geodatabase maintained by the Bureau of Ocean Energy Management (BOEM) to store and disseminate information about geophysical and geological data under the Marine Minerals Program. It can be used to identify and analyze sand and sediment resources, and assist in the planning and administration of coastal restoration and offshore dredging projects.

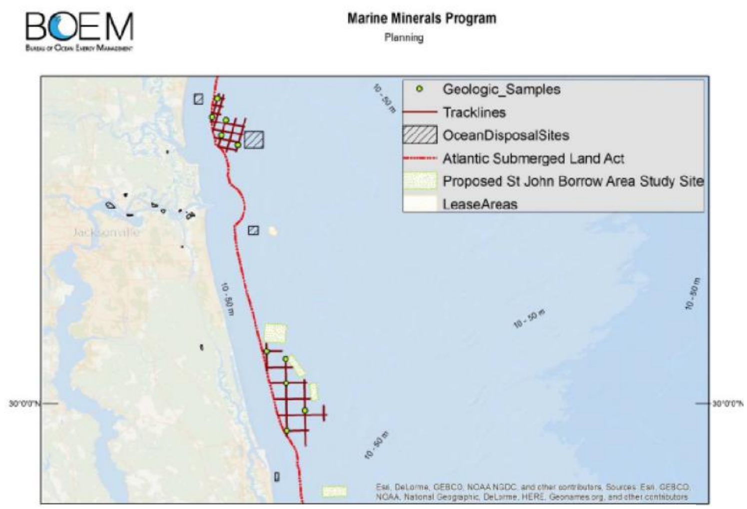


Figure 60. Map made using the Marine Minerals Program GIS.

As shown in Figure 60, the MMP GIS includes numerous thematic data layers to include:

- Offshore political boundaries (planning areas, Submerged Lands Act boundaries, Protraction Map boundaries);
- Environmental features (e.g., shorelines, habitats and biologically important areas, obstructions, shipwrecks, pipelines);
- BOEM planning and administrative boundaries (e.g., lease areas, dredge areas, avoidance areas, study areas, sand resources, etc.);
- Sample data used to identify sand resources (e.g., grab, core, and water samples; camera locations; endangered species impacts);
- Bottom characteristics (e.g., faults; contours; isopachs; tracklines; geological, acoustic, and magnetic seabed features; sediments; seismic; paleo channels; and acoustic profiles);
- Bathymetry and backscatter data (e.g., single beam, multi beam, lidar, magnetometer, sidescan sonar); and
- BOEM construction survey data (e.g., construction tracklines, dredge pipelines, dredge pumpouts).
-

FAQ #20: How are navigable channels defined?

The U.S. Army Corps of Engineers (USACE) defines navigable waters as “those waters subject to the ebb and flow of the tide shoreward to the mean high water mark and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce.” Thus, navigable channels would normally transport river barges carrying grain to downstream ports, for example, rather than smaller recreational or fishing boats that can navigate almost any stream.

FAQ #21: How does Total Horizontal Uncertainty (THU) at the 95% confidence level correlate with bathymetric/topobathymetric lidar Quality Levels and IHO hydrographic survey Orders for sonar?

Table 8 correlates bathymetric lidar Quality Levels with ANPD, RMSEx, RMSEy, RMSEr, RMSEz and THU at 10m depth. Horizontal accuracy from bathymetric lidar is also a function of positional errors from GPS/GNSS, INS and flying altitude of the sensor; however, both vertical and horizontal errors increase at greater water depths.

Table 8. Horizontal and vertical accuracies achievable for standard bathymetric Quality Levels at 10m depth

Bathymetric Data Quality Level	RMSEz	Aggregate Nominal Pulse Spacing (ANPS)	ASPRS Horizontal Accuracy Class = RMSExy	RMSEr	Total Horizontal Uncertainty (THU) at 95% confidence level
$QL0_B$	13.3 cm	≤0.7m	81.7cm	1.16m	2m
$QL1_B$	13.3 cm	≤2.0 m	81.7cm	1.16m	2m
$QL2_B$	16.7 cm	≤0.7m	1.23m	1.73m	~3m
$QL3_B$	16.7 cm	≤2.0m	1.23m	1.73m	~3m
$QL4_B$	26.4 cm	≤5.0m	2.25m	3.18m	5.5m

Table 9 correlates IHO hydrographic survey orders for sonar feature detection, RMSEx, RMSEy, RMSEr, RMSEz and THU at 10m depth. Vertical and horizontal errors from sonar also increase at greater water depths.

Table 9. Horizontal and vertical accuracies achievable for IHO Orders for sonar at 10m depth

IHO Order	RMSEz	Feature Detection Capability	RMSEx and RMSEy	RMSEr	Total Horizontal Uncertainty (THU) at 95% confidence level
Special Order	26.1 cm	Cubic features >1m	81.7cm	1.16m	2m
1a	32.7 cm	Cubic features >2m	2.25m	3.18m	5.5m
1b	32.7 cm	N/A	2.25m	3.18m	5.5m
2	51.7 cm	N/A	8.58m	12.13m	21m

FAQ #22: How does Total Vertical Uncertainty (TVU) at the 95% confidence level correlate with bathymetric/topobathymetric lidar Quality Levels and IHO hydrographic survey Orders.

The ASPRS Positional Accuracy Standards for Digital Geospatial Data (ASPRS, 2014) define Vertical Accuracy Classes in terms of RMSEz, and a 1.96 multiplier to convert RMSEz into Vertical Accuracy at the 95% confidence level or Total Vertical Uncertainty (TVU) at the 95% confidence level.

Accuracies of Bathymetric Lidar Quality Levels

Table 10, below, translates the latest ASPRS standard in terms of the bathymetric/topobathymetric lidar data Quality Levels used for this study.

Table 10. Vertical accuracy of bathymetric/topobathymetric lidar Quality Levels

Bathy/Topobathy Lidar Quality Levels	RMSEz	Aggregate Nominal Pulse Spacing (ANPS)	Total Vertical Uncertainty (TVU) at 95% confidence level
$QL0_B$	13.3 cm	≤0.7m	26.0 cm
$QL1_B$	13.3 cm	≤2.0m	26.0 cm
$QL2_B$	16.7 cm	≤0.7m	32.7 cm
$QL3_B$	16.7 cm	≤2.0m	32.7 cm
$QL4_B$	26.4 cm	≤5.0m	51.7 cm

Accuracies of Sonar by IHO Orders

Table 11 shows the Total Vertical Uncertainty (TVU) at the 95% confidence level (highlighted in yellow) at three depth examples for the various IHO Orders of hydrographic surveys (sonar).

Table 11. TVA Examples for IHO Orders

IHO Order	Special	1a	1b	2
Total Horizontal Uncertainty (THU) (95% Confidence Level)	2m	5m + 5% of depth	5m + 5% of depth	20m + 10% of depth
Total Vertical Uncertainty (TVU) (95% Confidence Level)	a = 0.25m b = 0.0075	a = 0.5m b = 0.013	a = 0.5m b = 0.013	a = 1.0m b = 0.023
Full Seafloor Search	Required	Required	Not required	Not required
Feature Detection Capability	Cubic features > 1m	Cubic features > 2m in depths up to 40m; 10% of depth beyond 40m	Not applicable	Not applicable
Maximum Line Spacing	Not applicable, as 100% search is required	Not applicable, as 100% search is required	3 x average depth or 25m, whichever is greater	4 x average depth
Depth Examples	**TVU of submerged elevations at 95% Confidence Level**			
0 m	25.0 cm	30.0 cm	30.0 cm	50.0 cm

10 m	26.1 cm	32.7 cm	32.7 cm	51.7 cm
20 m	29.2 cm	39.7 cm	39.7 cm	56.4 cm
Example Applications	Harbors, berthing areas, and associated critical channels where under-keel clearance is critical	Harbors, harbor approach channels, recommended tracks, and some coastal areas with depths up to 100 m where under-keel clearance is less critical but of concern to surface shipping may exist	Areas shallower than 100 m where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area	Areas generally deeper than 100 m where a general description of the sea floor is considered adequate

FAQ #23: How are inland and nearshore bathymetric and topobathymetric data produced and how are their Quality Levels (QLs) defined?

Bathymetric Mapping Technologies

For bathymetric mapping, *airborne lidar bathymetry (ALB)* is a technique for measuring the depths of moderately clear waters from a low-altitude aircraft using a green-wavelength scanning, pulsed laser beam. ALB have larger beam divergence and have greater depth penetration capability, up to 60 m water depths in clear water, and use sophisticated waveform analysis-based algorithms to determine water depth (Figure 61).

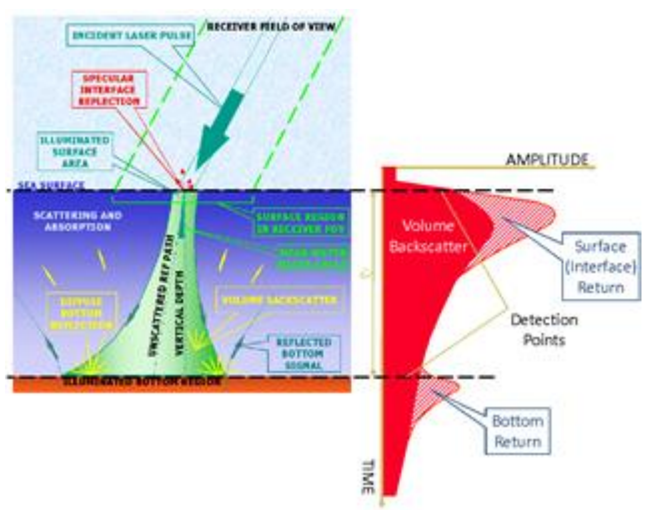


Figure 61. Bathymetric and topobathymetric lidar, with green laser, map water surface and submerged topography.

Topobathymetric lidar systems, also called topobathy systems, have smaller beam divergence with less penetration capability, up to 10 m water depths in clear water, and rely on a simple refraction correction technique to determine water depth. Most bathymetric and topobathymetric LiDAR systems can also provide topography data over land areas.

Acoustic Survey Systems (sonar) has long been used for bathymetric mapping and hydrographic surveying. Sonar systems use sound waves and echo sounders to measure water depths. Although there are several different types of sonar systems, multi-beam echo sounders (MBES), also called multibeam sonars, are generally best for broad area coverage, being similar to lidars in that they collect swaths of depth data with individual beams as shown in Figure 62.

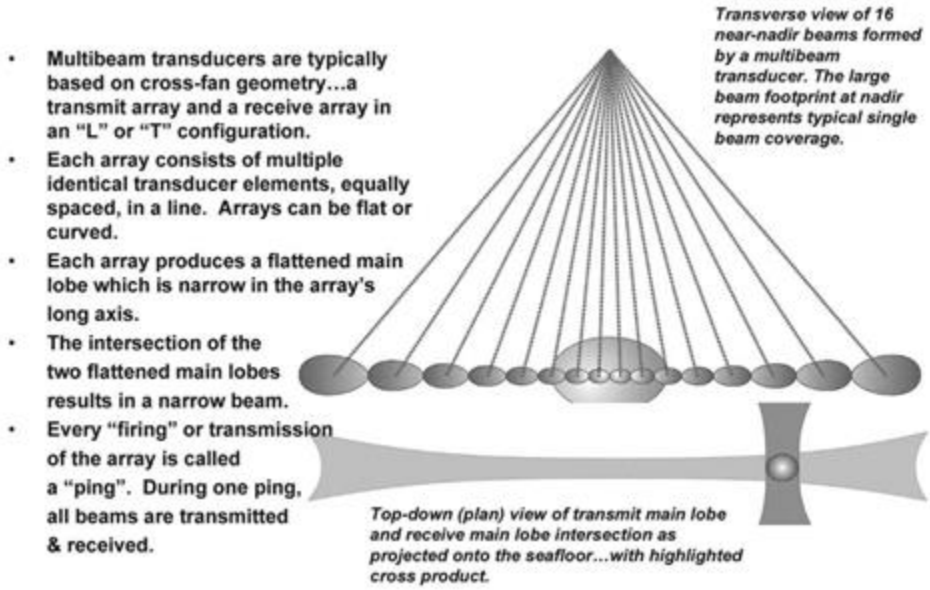


Figure 62. Individual beams in a multibeam transducer form a swath of elevation (depth) points.

Bathymetric Lidar Advantages

Bathymetric or topobathymetric lidar (Airborne Lidar Bathymetry – ALB) measures the depths of moderately clear, near-shore coastal waters, lakes, and rivers from a low-altitude aircraft. The round-trip time-of-flight of each laser pulse to the water surface and sea floor is measured by receivers in the aircraft. With this information, and the speed of light in air and water, accurate water depth can be calculated. This technique is also known as airborne lidar hydrography (ALH) when used primarily for nautical charting.

This is important because hydrographic charts for many of the world's coastal areas are either out of date or nonexistent. The overall status of hydrographic surveying and nautical charting world-wide is rated in the range from poor to fair (UN, 1989). Hydrography, worldwide, is in a state of crisis regarding the ability of professional hydrographic organizations to provide the needed and desired products within their budgets and in a timely manner. Bathymetric lidar can deliver faster and cheaper shallow-water surveying for both hydrographic and bathymetric purposes.

Bathymetric lidar has proven to be an accurate, cost-effective, rapid, safe, and flexible method for surveying in shallow water and on coastlines where sonar systems are less efficient and can even be dangerous to operate.

The costs of operations for all current ALB systems are reported most often as 15-30% of the standard acoustic survey cost, depending on location, depth, and survey density. ALB soundings are densely spaced, typically on a 0.5-5 meter grid, within a wide swath under the aircraft, whose width is roughly typically greater than half of the aircraft altitude. The major limitation is water clarity. For areas with very clear water, the advantage of surveying a wide swath at aircraft speeds can be obtained for depths as great as 50 meters or more. The fact that airborne lidar can also measure land topography and survey simultaneously on both sides of the land/water boundary is highly beneficial and attractive to coastal engineers. Figure 63 presents a graphic comparison of lidar and sonar operations in shallow water.

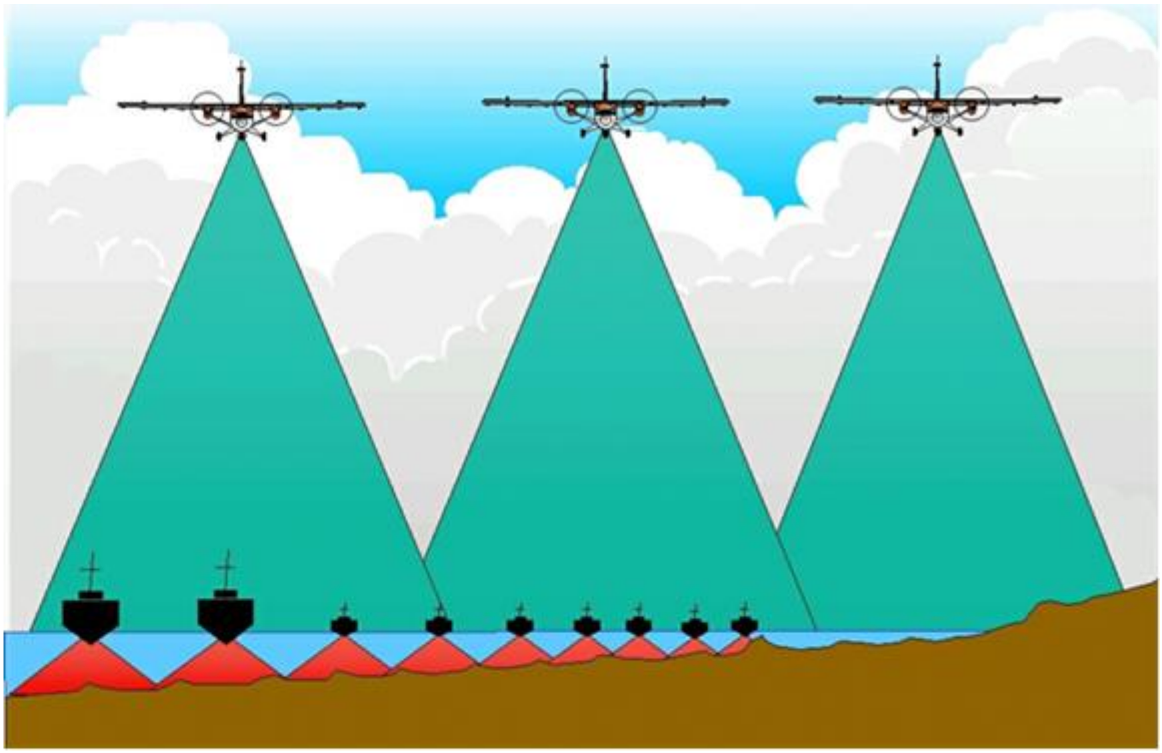


Figure 63. Depiction of lidar and multi-beam sonar operation in shallow water to emphasize lidar capabilities and efficiency.

Bathymetric Lidar Limitations

The major limitation of bathymetric or topobathymetric lidar is that success is largely dependent on the clarity of the water. Bathymetric or topobathymetric lidar cannot map the subsurface terrain beneath the muddy Mississippi River, lakes covered with algae, wetlands with murky waters, and shorelines with high sediment suspension from surf action. See Figures 64 and 65. The ability to determine the sea bottom is also dependent on the type of sensor being used. Traditional bathymetric lidar sensors that have a high-power wide beam are able to better penetrate through turbid waters. Topobathymetric sensors typically have lower power and utilize a

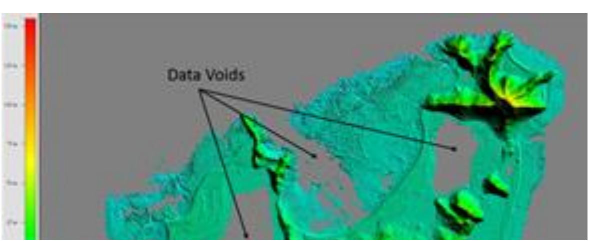


Figure 64. Topobathymetric lidar data voids caused by bio-luminescence in this bay in Puerto Rico.

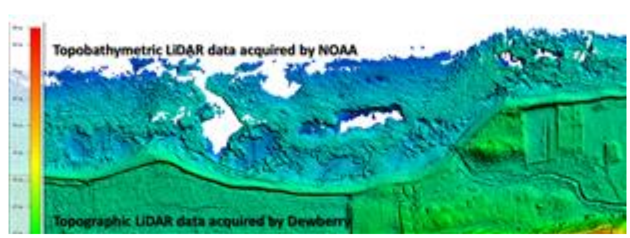


Figure 65. Topobathymetric lidar data voids caused by surf with suspended sediments.

narrow beam that results in more potential voids in turbid waters, but they are cheaper to operate. Bathymetric surveys must be conducted during periods of most optimal water clarity; sometimes water clarity changes seasonally or even daily.

Sonar Comparisons

Complete, high-resolution bathymetric surface models can, and have been for decades, developed using vertical beam echo sounder (VBES) techniques; however, the more modern multi-beam echo sounder (MBES) performs more quickly and efficiently in water depths deeper than about 20 meters. In calm waters shallower than ten meters, sweep sonar is very effective, and interferometric sonar sensors are effective at bathymetry between one and 20 meters deep. As object size decreases, side scan sonar may be used whenever object detection is the primary reason for surveying and environmental factors allow it to be accomplished safely. There is competition between the different sonar types with regard to which is best to use for a particular survey requirement, but they still represent the same basic acoustic technology. Figure 63, above, compares multi-beam sonar with ALB or topobathymetric lidar.

Bathymetric and Topobathymetric Quality Levels

The National Science and Technology Council has developed the National Coastal Mapping Strategy 1.0: *Coastal LiDAR Elevation for a 3D Nation*, in which it proposes bathymetric equivalents ($QL0_B$, $QL1_B$, $QL2_B$, $QL3_B$ and $QL4_B$) to topographic data Quality Levels in the USGS Lidar Base Specification (QL0 HD, QL0, QL1 HD, QL1, QL2, and QL5).

User requirements for bathymetric and/or topobathymetric data will be defined at five potential bathymetric Quality Levels (Table 12) consistent with standards of the International Hydrographic Office (IHO), USACE hydrographic survey requirements, the IWG-OCM National Coastal Mapping Strategy, and Quality Levels being considered for the 3D Nation. Note that $QL0_B$ and $QL1_B$ are equivalent to the IHO Special Order standard for vertical accuracy, and the vertical accuracy specification for $QL4_B$ is equivalent to the IHO Order 1 standard for vertical accuracy. The higher-density $QL0_B$ and $QL2_B$ are better for detection of submerged objects that may be hazardous to marine navigation.

Table 12. Bathymetric/Topobathymetric Lidar Data Density and Absolute Vertical Accuracy

	$QL0_B$	**$QL1_B$**	**$QL2_B$**	**$QL3_B$**	**$QL4_B$**
	IHO Special Order				**IHO Order 1**
Aggregate Nominal Pulse Spacing	≤0.7m	≤2.0 m	≤0.7 m	≤2.0 m	≤5.0 m
Aggregate Nominal Pulse Density	≥2.0 pts/m^2	≥0.25 pts/m^2	≥2.0 pts/m^2	≥0.25 pts/m^2	≥0.04 pts/m^2

Depth Examples (m)	Vertical Accuracy of submerged elevations at 95% Confidence Level (cm)				
0	25.0	25.0	30.0	30.0	50.0
10	26.1	26.1	32.7	32.7	51.7
20	29.2	29.2	39.7	39.7	56.4
Applications	Detailed site surveys requiring the highest accuracy and highest resolution seafloor definition; dredging and inshore engineering surveys; high-resolution surveys of ports and harbors		Charting surveys; regional sediment management; general bathymetric mapping; coastal science and management applications; change analysis; deep water surveys; environmental analyses		Recon/planning; all general applications not requiring higher resolution and accuracy

Definitions of terms relevant to the terminology used in Table 12 are included below.

Nominal Pulse Spacing (NPS) — A common measure of the density of a point-based elevation dataset (e.g., lidar, IfSAR, sonar), it is the typical or average lateral distance between points in a dataset, most often expressed in meters. NPS refers to the average point spacing of a dataset typically acquired in a zig-zag pattern with variable point spacing along-track and cross-track. NPS is an estimate and not an exact calculation.

Aggregate Nominal Pulse Spacing (ANPS) — A variant of nominal pulse spacing (NPS) that expresses the typical or average lateral distance between pulses in a dataset resulting from multiple passes of the sensor, or a single pass of a platform with multiple sensors, over the same target area.

Nominal Pulse Density (NPD) — A common measure of the density of a single pass (single swath) of a point-based elevation dataset (e.g., lidar, IfSAR, sonar), expressed as points per square meter (PPSM), normally used when the Nominal Pulse Spacing (NPS) is less than one meter. PPSM = $1/NPS^2$.

Aggregate Nominal Pulse Density (ANPD) — A variant of nominal pulse density (NPD) that expresses the total expected or actual density of pulses occurring in a specified unit area resulting from multiple passes of the sensor, or a single pass of a platform with multiple sensors, over the same target area.

Bathymetric Vertical Accuracy — The value by which vertical accuracy of submerged topography mapped with topobathymetric or bathymetric sensors (e.g., lidar, sonar) can be equitably assessed and compared among datasets when applying the ASPRS Positional Accuracy Standard for Digital Geospatial Data. For practical purposes, absolute vertical accuracy of submerged topography can only be determined for nearshore bathymetry where GPS antenna on elevated range poles can be used to measure submerged QA/QC checkpoints. Then, the vertical accuracy at the 95% confidence level is determined by multiplying RMSEz x 1.9600.

FAQ #24: What are the 3D bathymetric data products referenced in the questionnaire?

Digital Surface Model: Typically used synonymously with DEM for bathymetry models. Since surface features are not typically removed from bathymetric models, the products become virtually the same.

Digital Terrain Model (DTM): Typically used synonymously with DEM for bathymetry models. Since surface features are not typically removed from bathymetric models, the products become virtually the same.

Digital Elevation Model (DEM) of bathymetric surface: Raster or gridded product of horizontal position and vertical position for each cell. Formats can range from ESRI grid, CARIS CZAR files, to georeferenced tiffs or images where color value is correlated to depth value.

Point cloud data: A *point cloud* is a set of 3D data points in some coordinate system defined by X, Y, and Z coordinates. Point clouds generally consist of processed data, meaning that correctors for motion, position, soundspeed, or tidal offsets are already applied. This is generally an intermediate step for users who will eventually create a DEM from the point could for later use. Users who wish to manage how the data is gridded, for example to preserve certain density and uncertainty requirements, may desire to receive point cloud data from their data source.

Edited/cube XYZ data: A delimited text file (either by space, comma, or tab) that contains three columns for Latitude, Longitude, and Depth. These files are typically containing gridded point values that have already had correctors such as sound speed and tide (see FAQ #28). XYZ data are typically referred to in format, and contain similar information to a DEM or DTM.

Watercolumn: Multibeam sonar data in which the entire travel time of the acoustic pulse is fully digitized, captured, and stored. Multibeam sonars create bathymetry data from a bottom detection algorithm that discerns which portion of the pulse is most likely the seafloor. A multibeam can receive acoustic returns objects or biology captured by the acoustic pulse, but not specifically digitized by the bottom detection algorithm. Watercolumn data is acquired when objects or biology are of interest while using the multibeam sonar.

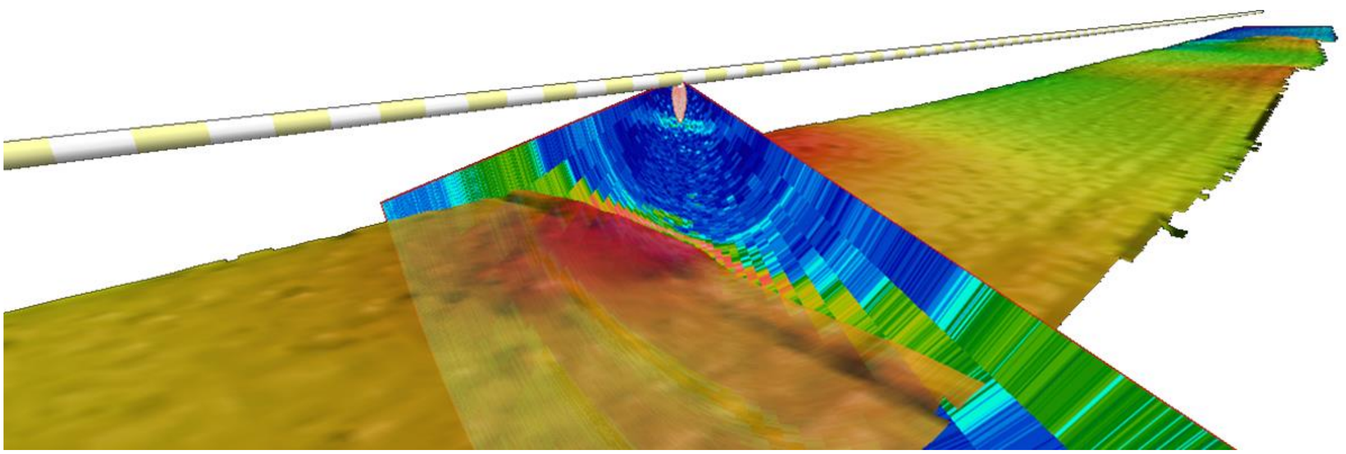


Figure 66. A cross section of watercolumn sonar data visualized along a ship trackline.

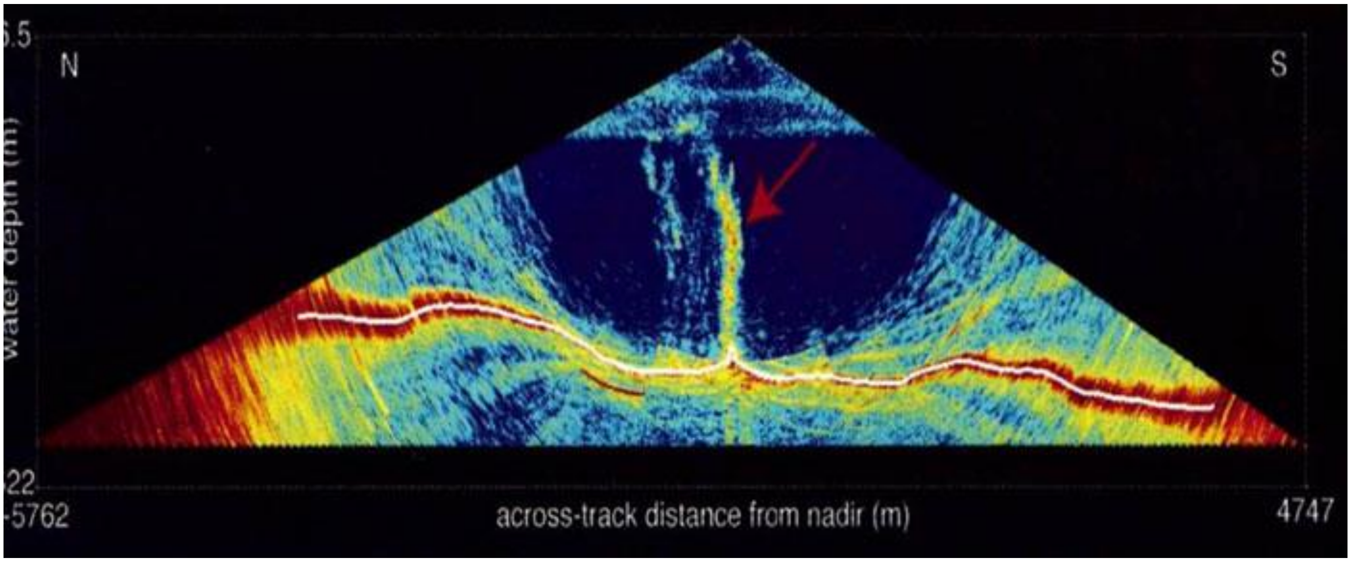


Figure 67. Methane plume in water column sonar data.

Bathymetric Attributed Grid (BAG) Files: Bathymetric Attributed Grid (BAG) is a non-proprietary file format for storing and exchanging bathymetric data developed by the Open Navigation Surface Working Group. BAG files are gridded, multi-dimensional bathymetric data files and are the standard used by NOAA’s National Ocean Service (NOS) for hydrographic data files made available for public release. Current versions of the BAG file contain position and depth grid data, as well as position and uncertainty grid data, and the metadata specific to that BAG file, providing end users information about the source and contents of the BAG file.

NCEI developed the capability to output data from BAG files as American Standard Code for Information Interchange (ASCII) xyz files. Empty space in BAG files is not included in xyz output files. On NCEI's web site, individual files, or entire surveys spanning multiple BAG files, can be selected, extracted, processed to xyz format, and zipped for shipment using a conversion capability. Each conversion also creates an Extensible Markup Language (XML) metadata file.

NOAA’s NOS also provides an image service of a seamless mosaic of high-resolution quality-controlled seafloor elevation from BAGs in U.S. coastal waters. Many nearshore areas have been mapped at high resolution (often 1 meter or better). The depths are usually relative to Mean Lower Low Water (MLLW) datum. Figure 68 provides a snapshot of an area of Long Island Sound seen in the BAG Viewer as a hillshaded image.

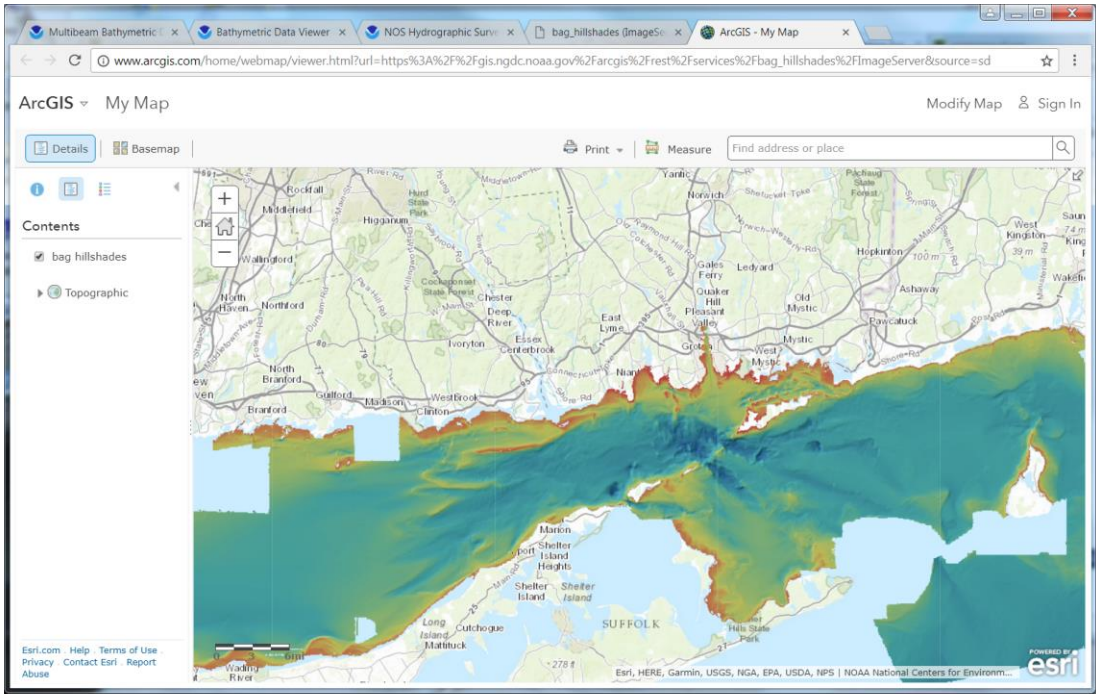


Figure 68. Snapshot image of an area of Long Island Sound seen in the BAG Viewer as a shaded image.

Backscatter: The amount of acoustic energy being received by the sonar after a complex interaction with the seafloor. This information can be used to determine bottom type, because different bottom types “scatter” sound energy differently. For example, a softer bottom such as mud will return a weaker signal than a harder bottom, like rock.

Backscatter products are typically a gridded in the same resolution as bathymetric products and are paired with bathymetry for analysis, as seen in Figure 67. The most common are georeferenced tiffs displaying numerical values for the backscatter intensity. These products are used for seafloor analysis, habitat modeling, and classification.

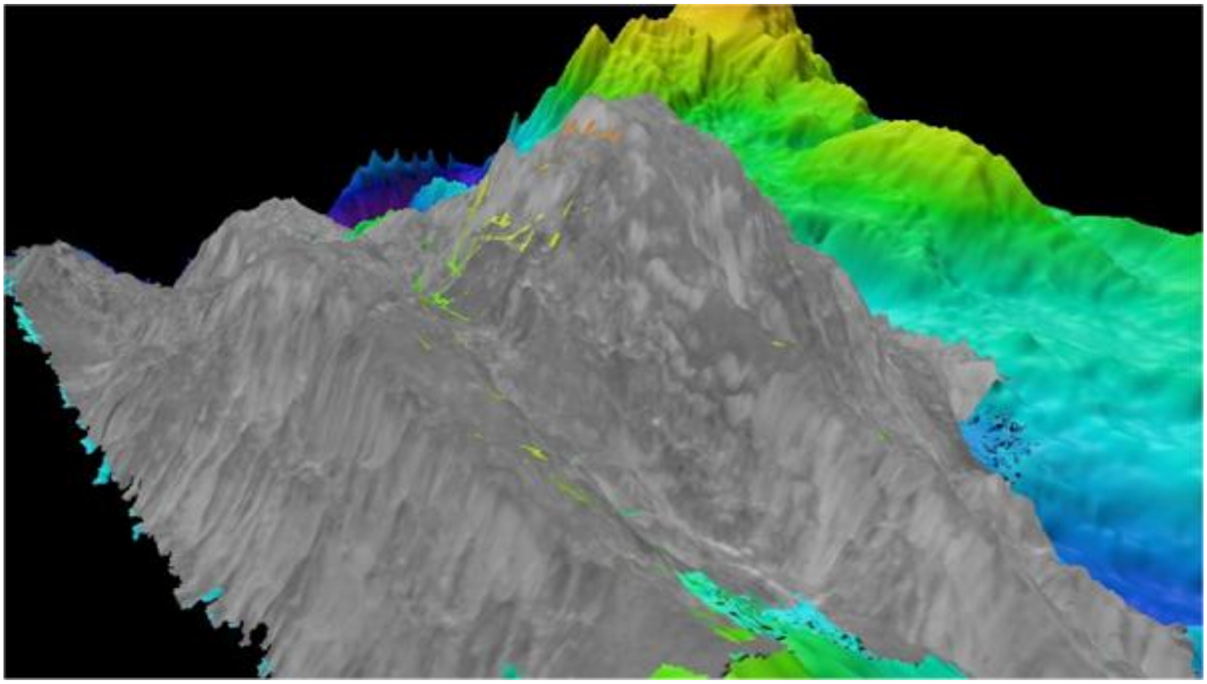


Figure 69. Example of backscatter (greyscale) draped over gridded bathymetry.

Sidescan Sonar Mosaics: Sidescan sonar is collected using a towed transmitter that is typically towed close to the seabed to control the geometry of the pulses and the intensity of return. Sidescan sonar can be used to produce a detailed presentation of seabed features and manmade objects that may lie on the surface of the seabed in the form of a planimetric image. A sidescan sonar ensonifies the entire swath with the same acoustic transmit pulse. The same transducer is used for transmitting and receiving a pulse, thereby increasing the chances that the echoes received originated from points in the direction the transducer is pointing. However, removing multipath acoustic returns from the primary return can still be a challenge.

Variations in the intensity of the received sidescan sonar intensity signals can be used to identify differences in the materials that comprise the seabed. For instance, rock and gravel will return sound differently than sand, which will return sound differently than silt or decomposed organic matter. Interpretation of the sidescan sonar imagery requires considerable experience and first-hand knowledge of the backscatter characteristics of various rock types, gravels, sands, and the bed forms associated with them such as bedding, jointing, ripple marks, sand waves, etc.

Figure 70 shows a smaller-scale side-scan sonar mosaic. Figure 71 is an example of a high-resolution side-scan sonar mosaic created from survey data collected for the NOAA Bonaire coral reef expedition in 2008 by the GeoSwath sonar on the Gavia autonomous underwater vehicle (AUV). The image results from the measurement of high-frequency (500 kHz) short bursts of sound waves that bounce off of the seabed and return to the sonar unit. Bright areas indicate high return energy associated with coral fragments or scattered rocks, while dark patches represent shadow zones (areas where the sound was blocked) or patches of soft sand and/or mud that absorb more sound than rocks or corals. In this image the beach is towards the right and each grid cell is a 10- by

10-meter (m)/33- by 33-foot square. The total swath width (lateral distance from edge to edge) is 40 m (131 feet), and the line length from tip to tip is approximately 100 m (328 feet).

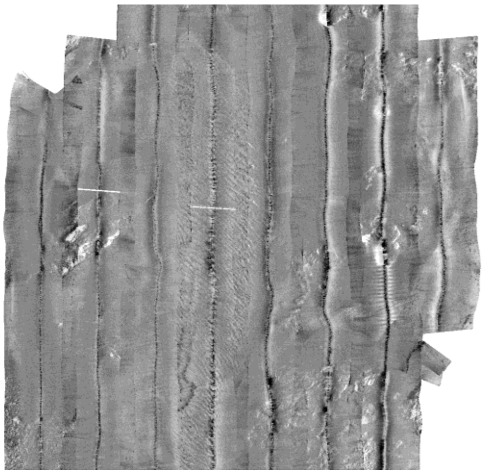


Figure 70. Example of small-scale sidescan sonar mosaic.

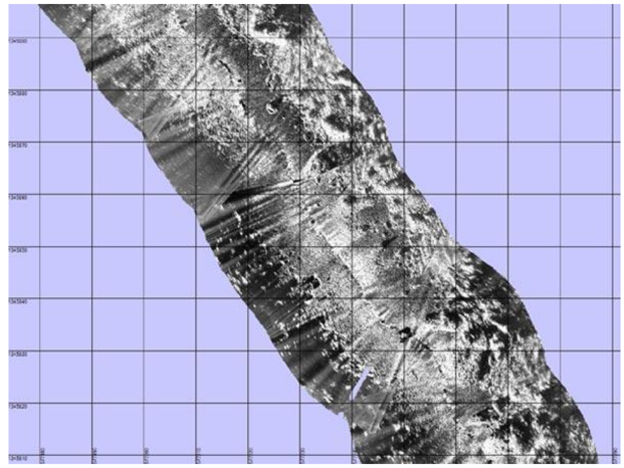


Figure 71. Example of high-resolution sidescan sonar mosaic.

Figure 72 shows a sidescan sonar image of the German U-boat U-166, collected by the HUGIN 3000 AUV in 2001. Image courtesy of NOAA, MMS, C & C, and the 2004 Gulf of Mexico Shipwreck Survey Expedition science party.

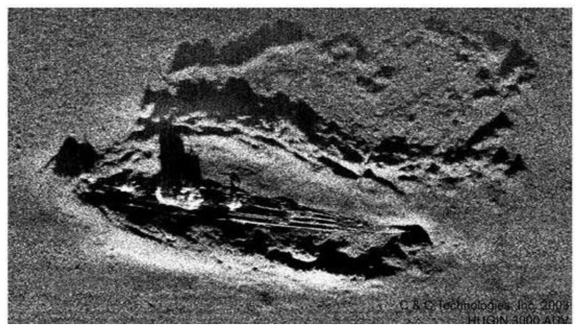


Figure 72. Sidescan sonar image of German U-boat U-166.

Ground truthing: Many sonar data products can give information regarding the reflectance characteristics of the seafloor. By sampling the seafloor, these measurements can be correlated to specific seafloor characteristics such as sediment size, composition, texture, or as simple as a delineation between hard and soft seafloor areas. The specific characteristic used depends on the user's data requirements and should be represented in the metadata. This practice is called ground truthing. Ground truthing can be accomplished using bottom sampling methods, such as a sediment sampler, photographic data, or video transects.

National Vertical Datum Transformation Tool (V-Datum): VDatum is a free software tool developed jointly by NOAA's National Geodetic Survey (NGS), Office of Coast Survey (OCS), and Center for Operational Oceanographic Products and Services (CO-OPS). VDatum is designed to vertically transform geospatial data among a variety of tidal, orthometric and ellipsoidal vertical datums - allowing users to convert their data from different horizontal/vertical references into a common system and enabling the fusion of diverse geospatial data in desired reference levels.

Merging datasets with inconsistent vertical datums can cause discontinuities that become problematic when producing maps, assimilating data and advanced model results, or performing simulations at the accuracy needed for informed, intelligent coastal zone management decision-making.

The VDatum tool is currently available for select areas of the U.S. Where available and uncertainties are established, VDatum supports the conversions among following:

- **Coordinate Systems:** Geographic, UTM, State Plane Coordinates (SPC), and geocentric (ECEF)
- **Horizontal Datums:** NAD27, NAD83(1986), and NAD83(HARN); and ellipsoidal datums such as of ITRF, WGS84, and NAD83 serializations
- **Vertical Datums:**
  - **Ellipsoidal Datums:** NAD83, WGS84, ITRF88, ITRF89, ITRF90, NEOS 90, PNEOS 90, ITRF91, ITRF92, SIO/MIT 92, ITRF93, ITRF94, ITRF96, ITRF97, IGS97, ITRF2000, IGS00, IGb00, ITRF2005, IGS05, ITRF2008, IGS08, WGS84(transit), WGS84(G730), WGS84(G873), WGS84(G1150), WGS84(G1674), NAD83(PACP00), NAD83(MARP00)
  - **Orthometric Datums:** NAVD88, NGVD29, PRVD02, VIVD09, ASVD02, GUVD04, NMVD03, HAWAII EGM2008, EGM1996, and EGM1984
  - **Tidal Datums:** MLLW, MLW, LMSL, DTL, MTL, MHW, LWD, and MHHW
  - IGLD85
- **GEOID models:** GEOID12B, GEOID12A, GEOID09, GEOID06 (Alaska only), GEOID03, GEOID99, and GEOID96
- **EGM models:** EGM2008, EGM1996, and EGM1984
- **Supported file format:** text(ASCII), LiDAR(.LAS) version 1.0 to 1.2, ESRI ASCII Raster(.ASC), and ESRI 3D shapefile

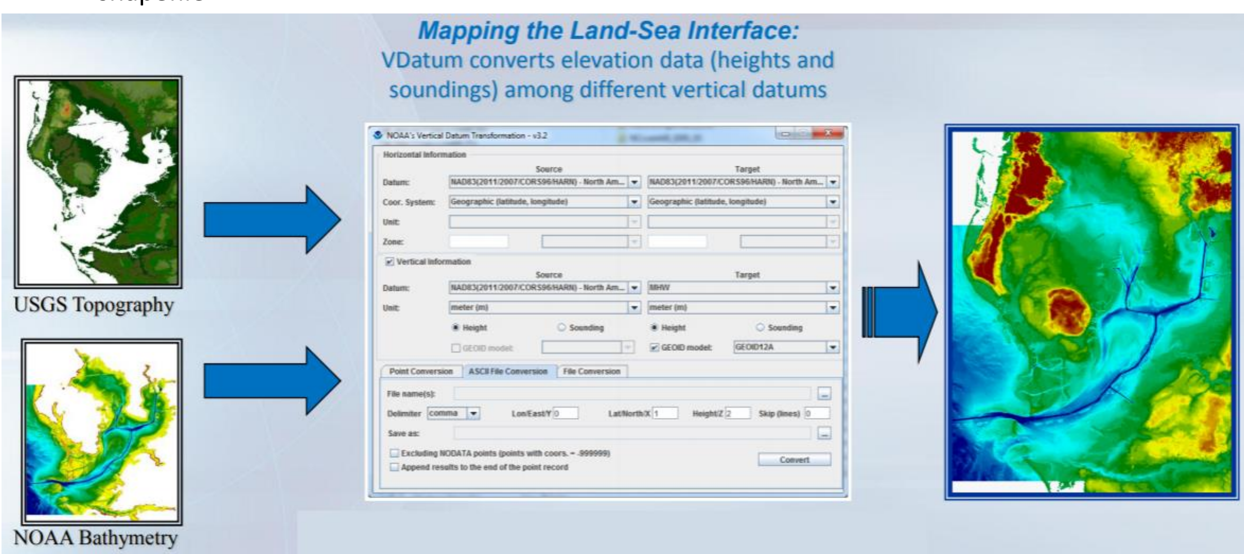


Figure 73. VDatum user interface and examples.

Tide Predictions: NOAA Tide Predictions allows users of the Tides and Currents website (http://tidesandcurrents.noaa.gov) to generate tide predictions for up to 2 years in the past or future, at any of

3000+ locations around the United States. This website service provides both a graphical plot of the predictions as well as a tabular listing and printable pages.

Tide predictions can only be accurately predicted at a location where tide data has been collected and analyzed. There are more than 3000 locations available through the NOAA Tide Predictions service. If you know that a station is available, you may use the search box to provide the station name or 7-digit ID number to retrieve predictions for the station. Otherwise you may search for a station from the map interface or the station listing.

Tide predictions are provided for two "classifications" of stations - Harmonic and Subordinate.

- Harmonic stations are stations with tidal harmonic constants and tidal datums. Tide predictions for harmonic stations are generated directly from the harmonic constants. Harmonic stations have the greatest capabilities within the NOAA Tide Predictions service for providing predictions with different data intervals and relative to different tidal datums. These capabilities are controlled within the interface.
- Subordinate stations are historic stations which do not have tidal harmonic constants available. Tide predictions for subordinate stations are generated by first generating high/low tide predictions for a designated harmonic station, called the "reference station"; then time and height adjustments are applied to correct the high/low predictions to the tidal conditions at the subordinate station. Subordinate stations only allow for the generation of high/low tide predictions, and heights will be relative to Mean Lower Low Water (MLLW), the standard chart datum for the U.S. coastline.

Once a station is selected, the system provides the tide predictions for the current day and the following day. Users can control the predictions to be generated by the system based on selected date(s), time zone, and units of measure.

Additional advanced capabilities allow the user to further customize the prediction based on datum, time interval, time units, and threshold.

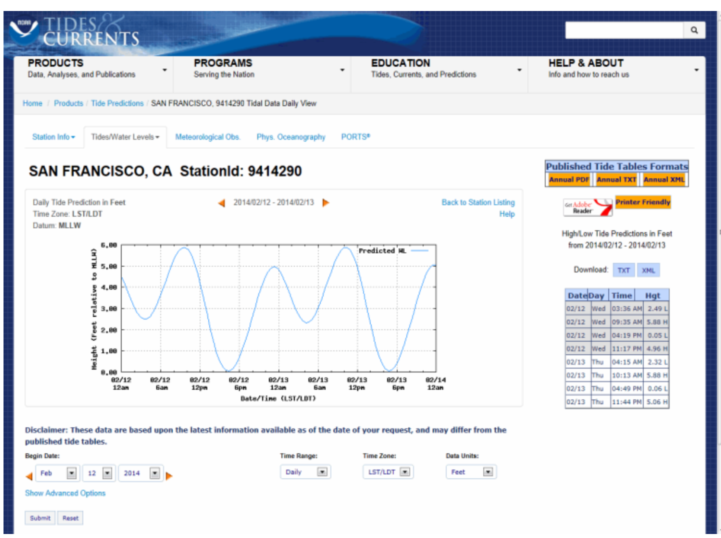


Figure 74. Daily tide prediction for San Francisco, CA, from NOAA's Tide Predictions website.

Tidal Constituent and Residual Interpolation (TCARI): TCARI is a quick, accurate method of providing tidal corrections to hydrographic data. TCARI works by separating the astronomic tide, residual, and datum difference components and treating them differently. First, the method spatially interpolates each tidal constituent's amplitude and phase throughout the region, based on data at the water level stations and makes a tidal prediction. The amplitude and phase of constituents at water level stations must have been previously determined by analysis of historical records. This predicted tide is then added to the residual component, which is computed by spatially interpolating the non-tidal values observed at the water level stations at the time of the survey. Finally, the datum offset, or difference between MSL and MLLW based on historical data, is interpolated throughout the region and added to the prediction.

All spatial interpolation is performed by a set of weighting functions. The weighting functions are computed before the survey by creating a grid mesh for the coastal region of interest and acquiring the historical data. Next, the weighting functions for the harmonic constants, tidal datums, and the residual are computed. In the field, a prediction of the instantaneous tide, relative to MLLW, is made using the stored weighting function, datum fields, and harmonic constants as well as observed water levels at the tide stations. The predicted value is subtracted from the sounding to give the water depth relative to chart datum of MLLW.

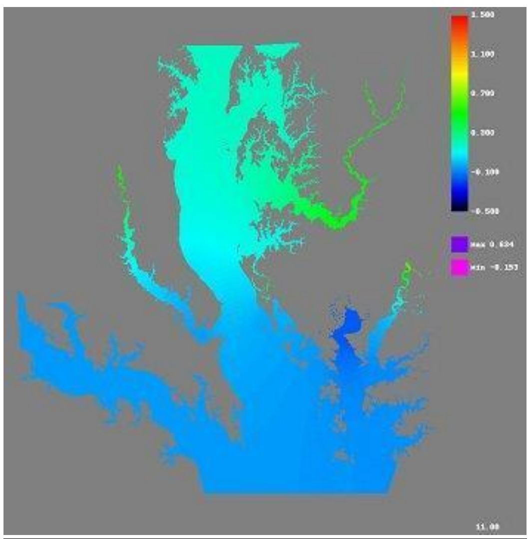


Figure 75. Predicted instantaneous water leveling of the central Chesapeake Bay relative to MLLW using TCARI.

FAQ #25: What geospatial data types could be integrated with inland bathymetric data?

Aerial or Satellite Imagery: Aerial or satellite imagery can be integrated with inland bathymetric data to display 2D imagery in a 3D perspective.

Geologic and/or seismic data: Geologic features such as seismic faults can be integrated with inland bathymetric data to display how such features are coincident.

Official shoreline data: Shoreline vectors could be integrated with inland bathymetric data. It is also possible to compare current shorelines with historic shorelines of the past, or to show change rates.

Land use/land cover (LU/LC) data: LU/LC data can be integrated with inland bathymetric data to show that inland bathymetry has the correct LU/LC classification.

Wetland data: Wetlands can be delineated using color infrared imagery and inland bathymetry.

Inland surface water features: Inland surface water features such as lakes and ponds, streams and rivers, canals and reservoirs can be identified from inland bathymetry so that each feature has a name and/or feature identification code.

Bridge data: Bridge data can be integrated with inland bathymetric data and attributed with feature identification codes in a GIS.

Landmark features: Landmark features such as reference points or waypoints for safety of navigation on inland waterways can either be identified from or integrated with inland bathymetric data.

Cultural resources: Cultural features such as inundated archaeological sites, historical shipwrecks, sacred Indian fishing grounds can either be identified from or integrated with inland bathymetric data

Coastal and riverine structures: Shoreline stabilization structures, levees, dams, jetties, piers, weirs, etc. can either be identified from or integrated with inland bathymetric data for 3D visualization.

FAQ #26: What are the Marine Sanctuaries and Marine National Monuments, and where are they?

On October 23, 1972, Congress passed the Marine Protection, Research and Sanctuaries Act which, among other things, established the National Marine Sanctuary Program. Title III of the law was later renamed the National Marine Sanctuaries Act (NMSA). The Office of National Marine Sanctuaries serves as the trustee for this network of underwater parks encompassing more than 600,000 square miles of marine and Great Lakes waters from Washington State to the Florida Keys, and from Lake Huron to American Samoa. The network includes a system of 13 national marine sanctuaries and Papahānaumokuākea and Rose Atoll marine national monuments. The graphic in Figure 76 depicts the locations and names of the US National Marine Sanctuaries and Marine National Monuments. Geographical extents for each marine sanctuary can be downloaded from: https://sanctuaries.noaa.gov/library/imast_gis.html.

Figure 76. Locations of national marine sanctuaries and marine national monuments.

FAQ #27: What are maritime boundaries and how are they defined?

The maritime zones recognized under international law include internal waters, the territorial sea, the contiguous zone, the exclusive economic zone, the continental shelf, the high seas and the Area. With the exception of the high seas and the Area, each of these maritime zones is measured from the baseline determined in accordance with customary international law as reflected in the 1982 Law of the Sea Convention (UNCLOS). The limits of these zones are officially depicted on NOAA nautical charts. The limits shown on the most recent chart edition takes precedence. The boundaries of these maritime zones between coastal nations are established through international agreements entered into by those nations. For the official description of the U.S. maritime boundaries with other nations contact the U.S. Department of State.

Figure 77 shows how different states use different vertical datums to define the boundary line between privately-owned and state-owned lands. This graphic also shows how other boundaries are determined for the territorial sea, Exclusive Economic Zone (EEZ), contiguous zone, and high seas.

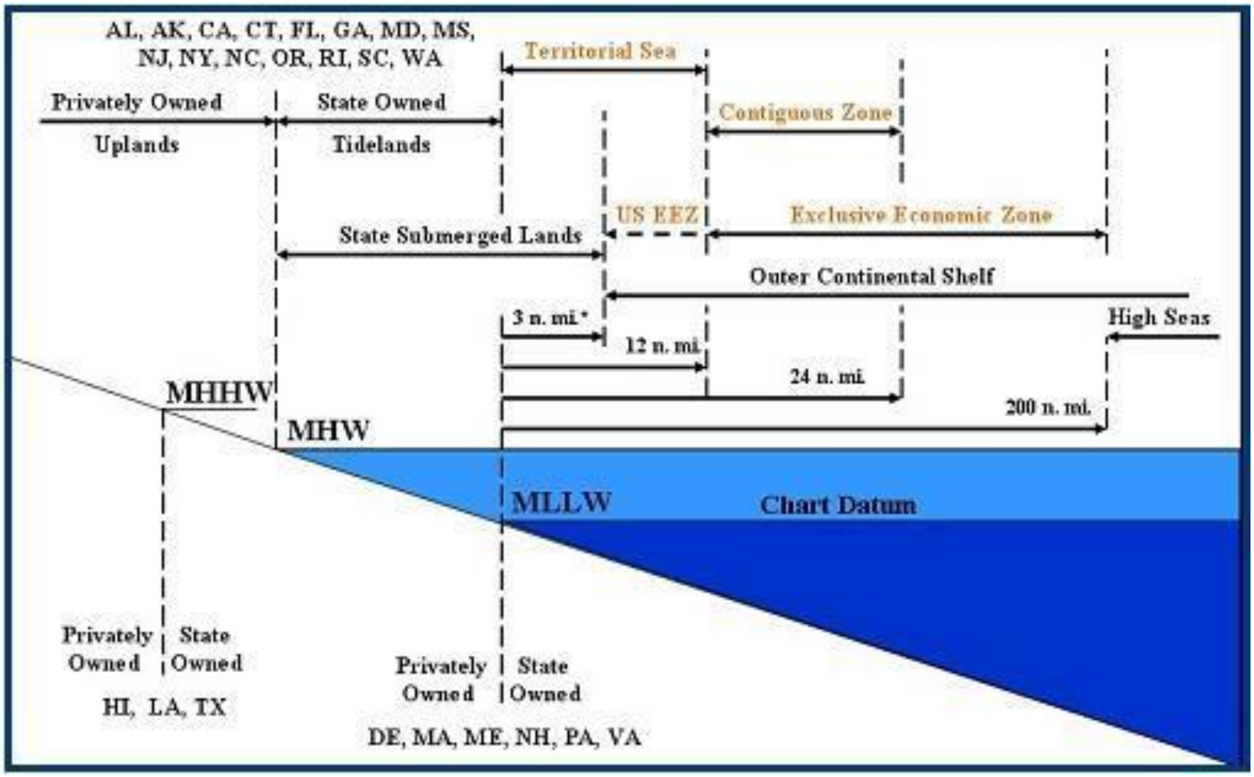


Figure 77. The official sea level boundaries differ by coastal state.

State Waters: The seaward boundary of the Great Lake States is the U.S.-Canada International boundary. For most other states it is the 3 nautical mile territorial sea. Exceptions include Florida, whose Gulf of Mexico seaward boundary extends to 9 nautical miles; and Puerto Rico and Texas, whose seaward boundaries extends to 9 nautical miles.

Internal state waters are the waters on the landward side of the baseline from which the breadth of the territorial sea is measured. Each coastal State has full sovereignty over its internal waters as if they were part of its land territory. Examples of internal waters include bays, rivers and even lakes that are connected to the sea, e.g., the Great Lakes.

Federal Waters: In most places, Federal waters extend from where state waters end out to about 200 nautical miles or to where other country's waters begin.

Navigationally Significant Areas: NOAA prioritizes areas in need of surveying to maximize limited resources. In the 1990s, the agency examined the 3.4 million square nautical miles (SNM) of the U.S. Exclusive Economic Zone (EEZ) for navigational significance. Navigational significance was determined using information about vessel traffic by vessel type, tracklines, vessel draft vs. water depth, and vessel volume. NOAA determined that approximately 500,000 SNM of the EEZ are navigationally significant. Navigationally significant area can be classified as critical area, priority 1, priority 2, priority 3, priority 4, and priority 5 as defined by the National Hydrographic Survey Priorities.

Territorial Sea: Each coastal State may claim a territorial sea that extends seaward up to 12 nautical miles (nm) from its baselines. Generally speaking, the normal baseline is the low-water line along the coast as marked on large-scale charts officially recognized by the coastal State. The coastal State exercises sovereignty over its territorial sea, the air space above it, and the seabed and subsoil beneath it. Foreign flag ships enjoy the right of innocent passage while transiting the territorial sea subject to laws and regulations adopted by the coastal State that are in conformity with the Law of the Sea Convention and other rules of international law relating to such passage. The U.S. claimed a 12 nautical mile territorial sea in 1988.

Contiguous Zone: Each coastal State may claim a contiguous zone adjacent to and beyond its territorial sea that extends seaward up to 24 nautical miles from its baselines. In its contiguous zone, a coastal State may exercise the control necessary to prevent the infringement of its customs, fiscal, immigration or sanitary laws and regulations within its territory or territorial sea, and punish infringement of those laws and regulations committed within its territory or territorial sea. Additionally, in order to control trafficking in archaeological and historical objects found at sea, a coastal State may presume that their removal from the seabed of the contiguous zone without its consent is unlawful.

Outer Continental Shelf (OCS): Defined in Title 43 of United States Code by Outer Continental Shelf Lands Act 1953. The seaward limit is defined as the farthest of 200 nautical miles seaward of the baseline from which the breadth of the territorial sea is measured or, if the continental shelf can be shown to exceed 200 nautical miles, a distance not greater than a line 100 nautical miles from the 2,500-meter isobath or a line 350 nautical miles from the baseline.

Outer Continental Shelf limits greater than 200 nautical miles but less than either the 2,500 meter isobath plus 100 nautical miles or 350 nautical miles are defined by a line 60 nautical miles seaward of the foot of the continental slope or by a line seaward of the foot of the continental slope connecting points where the sediment thickness divided by the distance to the foot of the slope equals 0.01, whichever is farthest.

Exclusive Economic Zone: Each coastal State may claim an Exclusive Economic Zone (EEZ) beyond and adjacent to its territorial sea that extends seaward up to 200 nautical miles from its baselines (or out to a maritime boundary with another coastal State). Within its EEZ, a coastal State has: (a) sovereign rights for the purpose of exploring, exploiting, conserving and managing natural resources, whether living or nonliving, of the seabed and subsoil and the superjacent waters and with regard to other activities for the economic exploitation and exploration of the zone, such as the production of energy from the water, currents and winds; (b) jurisdiction as provided for in international law with regard to the establishment and use of artificial islands, installations, and structures, marine scientific research, and the protection and preservation of the marine environment, and (c) other rights and duties provided for under international law. The U.S. claimed a 200 nautical mile EEZ in 1983.

FAQ #28: What is tide correction and why is it necessary?

Measurements of bathymetry and water depth inherently rely on a defined value of the water surface. Correcting for tide is when offset values are applied to bathymetry data based on the current level of tide during acquisition. In applying these tidal correctors, the bathymetry data is adjusted to represent the depth below the surface of the water at the datum used. A datum is the defined value for the surface, see FAQ #9. Any bathymetry data referenced to inland elevation models or seamless topography will need to be tide corrected.

Tidal corrections can be acquired via predicted tidal models, measured tidal data concurrent with the time of bathymetry acquisition, or using a separation model between another datum (such as VDATUM). Datums used to define the surface of the water include: Mean High Water (MHW), Mean Sea Level (MSL), Mean Low Water (MLW), and Mean Lower Low Water (MLLW). See FAQ#9.

FAQ #29: What other geospatial data types could be integrated with nearshore or offshore bathymetry?

Hydrographic Survey Data: Bathymetric data and associated features intended to update nautical chart products. Generally conforms to International Hydrographic Organization or NOAA standards.

Nautical and/or navigation charts: Products intended for use in safe navigation of ocean and sea-going vessels.

Acoustic imagery of the seafloor: Imagery of the seafloor created based on the intensity of acoustic sonar returns. Imagery is typically a georeferenced raster product that depicts intensity as the value.

Aerial and/or satellite imagery: Imagery of the seafloor supplied by aerial and satellite based sensors in areas where the optical properties of the water are clear enough.

Underwater videography: Video or photographs taken by a submerged camera. Typically used to visualize the seafloor, submerged objects, or underwater biology.

Bottom Texture: Similar to bottom type, but focuses largely on the grain size, sediment type, hardness and roughness characteristics that influence acoustic returns.

Bottom Type: roughness and hardness, sediment type, density, grain size, color, contaminants, composition (organic, shell and mineral, sand percentage)

Submerged features: including shipwrecks, archaeological sites, rock outcrops, debris, pipelines, cables, wellheads, piles,

Subbottom Characteristics: Properties of the seafloor located beneath the surface layer of the seafloor. The top layer of the seafloor is typically returned by most multibeam or singlebeam sonars designed to measure the water depth. Subbottom characteristics may include rock layers beneath sand, changes in rock layers, and other geologic characteristics.

Geologic and/or Seismic Data: Subbottom data that predominantly focuses on the geological construction of the seafloor and any factors that influence seismology of the area. Also of use for oil and gas exploration.

Water Column Properties - Physical Properties: The physical characteristics in the water mass between the sensor and the seafloor. Properties such as temperature, optical clarity, and turbidity

Water Column Properties - Chemical Properties: Chemical characteristics in the water mass between the sensor and the seafloor. Properties such as acidity, dissolved oxygen, and salinity.

Water Column Properties - Biological Properties: Biological elements in the water mass between the sensor and the seafloor. Properties such as specimen type, density, and mass.

Currents: The direction and magnitude of movement of water bodies.

Tide: The vertical change in water level associated due to lunar and solar influence.

Sea Ice Conditions: Location and extent of sea ice. May include extents measured concurrently with mapping operations, experienced over a season, or over a long term time series.

Habitat Distribution and Classification: Similarly to Land Use/Land Cover, ocean and seabed can be classified based on habitat, sediment or bottom type, and utilization. Classifications systems such as CMECS assist with values and guidelines for these geospatial delineations.

Boundaries: Offshore boundaries include the Exclusive Economic Zone (EEZ), continental shelf, marine sanctuaries and parks, Coastal Barrier Resources System (CBRS), archaeological and historic properties, and boundaries of restricted areas.

Routes: Transportation routes in open water include shipping, ferries, and other vessel traffic routes.

Lease Areas: The Bureau of Ocean Energy Management (BOEM) is responsible for all Outer Continental Shelf (OCS) leasing policy and program development issues for oil, gas, and other marine minerals.

The Marine Minerals Program partners with communities to address serious erosion along the Nation's coastal beaches, dunes, barrier islands, and wetlands. Erosion affects natural resources, energy, defense, public infrastructure, and tourism. To help address this problem, the MMP leases sand, gravel and/or shell resources from federal waters on the Outer Continental Shelf for shore protection, beach nourishment, and wetlands restoration with vigorous safety and environmental oversight.

BOEM is the only federal agency with the authority to lease marine minerals from the OCS, including responding to commercial requests for OCS minerals such as gold, manganese, or other hard minerals.
Sediment resources on the OCS are leased to local communities or federal agencies to help them restore shorelines or wetlands in an effort to address chronic erosion, sea level rise, impacts from major storms, or to protect valuable infrastructure and habitat.

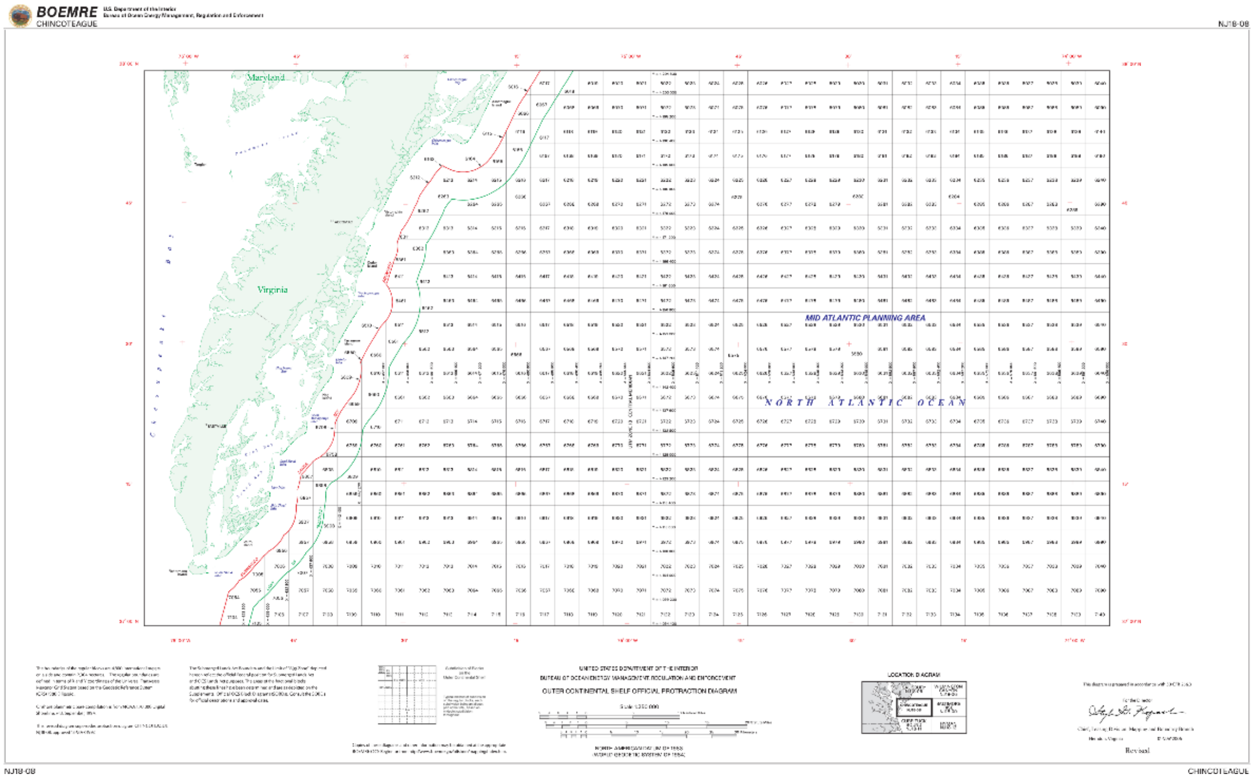


Figure 78. Official Protraction Diagrams (OPDs) and Lease Maps show the OCS block grids and other boundaries for a given area.

Fixed Obstructions: Fixed obstructions include aids to navigation, beacons, landmarks, wind turbines, and drilling platforms and equipment.

Floating Observation and Navigation Systems: Floating observation and navigation systems include buoys, monitoring stations, etc.

Land Use/Land Cover (LU/LC): LU/LC data can be used in conjunction with nearshore bathymetric data to identify areas that contribute to runoff, or other ecological impacts to water quality.

Wetlands: Wetlands can be delineated using color infrared imagery and nearshore bathymetry.

Estuaries: Estuaries and their surrounding wetlands are bodies of water usually found where rivers meet the sea. Estuaries are home to unique plant and animal communities that have adapted to brackish water—a mixture of fresh water draining from the land and salty seawater. Estuaries are among the most productive ecosystems in the world. Many animals rely on estuaries for food, places to breed, and migration stopovers.

FAQ #30: How are IHO Orders defined by the International Hydrographic Office (IHO)?

- **IHO Special Order:** This is the most rigorous of the orders and its use is intended only for those areas where under-keel clearance is critical. Because under-keel clearance is critical, a full sea floor search is required and the size of the features to be detected by this search is deliberately kept small (1m size or larger). Because under-keel clearance is critical, it is considered unlikely that Special Order surveys will be conducted in waters deeper than 40 meters. Examples of areas that may warrant Special Order surveys are: berthing areas, harbors, and critical areas of shipping channels. The Total Horizontal Uncertainty (THU) at the 95% confidence level is 2m or better, and the Total Vertical Uncertainty (TVU) at the 95% confidence level varies from 25 cm on the surface to 29.2 cm at a depth of 20 meters.

- **IHO Order 1a:** This order is intended for those areas where the sea is sufficiently shallow to allow natural or man-made features on the seabed to be a concern to the type of surface shipping expected to transit the area but where the under-keel clearance is less critical than for Special Order. Because man-made or natural features may exist that are of concern to surface shipping, a full sea floor search is required, however the size of the feature to be detected is larger (2m) than for Special Order. Order 1a surveys are of the second highest accuracy for selected harbors, harbor approach channels, recommended tracks, and some coastal areas. The Total Horizontal Uncertainty (THU) at the 95% confidence level is 5m + 5% of depth, and the Total Vertical Uncertainty (TVU) at the 95% confidence level varies from 30 cm on the surface to 39.7 cm at a depth of 20 meters.
- **IHO Order 1b:** This order is intended for areas shallower than 100 meters where a general depiction of the seabed is considered adequate for the type of surface shipping expected to transit the area. A full sea floor search is not required which means some features may be missed although the maximum permissible line spacing will limit the size of the features that are likely to remain undetected. This order of survey is only recommended where under-keel clearance is not considered to be an issue. An example would be an area where the seabed characteristics are such that the likelihood of there being a man-made or natural feature on the seafloor that will endanger the type of surface vessel expected to navigate the area is low. The Total Horizontal Uncertainty (THU) at the 95% confidence level is 5m + 5% of depth, and the Total Vertical Uncertainty (TVU) at the 95% confidence level varies from 30 cm on the surface to 39.7 cm at a depth of 20 meters.
- **IHO Order 2:** This is the least stringent order and is intended for those areas where the depth of water is such that a general depiction of the seabed is considered adequate. A full sea floor search is not required. It is recommended that Order 2 surveys are limited to areas deeper than 100 meters as once the water depth exceeds 100 meters, the existence of man-made or natural features that are large enough to impact on surface navigation and yet still remain undetected by an Order 2 survey is considered to be unlikely. The Total Horizontal Uncertainty (THU) at the 95% confidence level is 20m + 10% of depth, and the Total Vertical Uncertainty (TVU) at the 95% confidence level varies from 50 cm on the surface to 56.4 cm at a depth of 20 meters.

FAQ #31: What derivatives are typically produced by users from standard 3DEP deliverables?

Triangulated Irregular Network (TIN): Derived from point cloud data, a TIN is a set of adjacent, non-overlapping triangles computed from mass points and/or breaklines. Figure 79 shows how the TIN was generated from the mass points and breaklines in Figure 80. The TIN's vector data structure is based on irregularly-spaced point, line and polygon data interpreted as mass points and breaklines and stores the topological relationship between triangles and their adjacent neighbors.

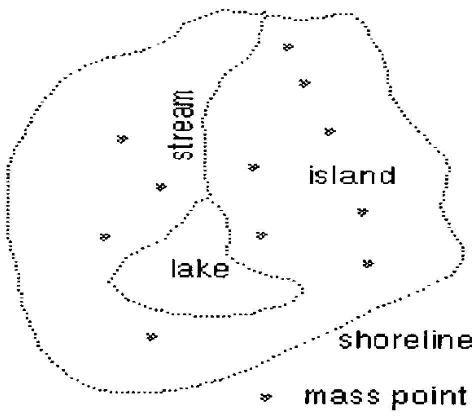


Figure 79. Example mass points and breaklines.

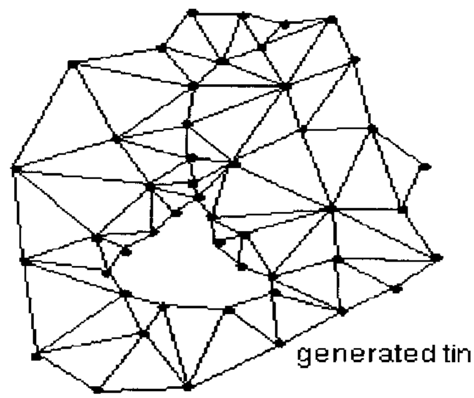


Figure 80. TIN produced from these mass points and breaklines.

Contours: Both contours and hillshades are derivative products that help users visualize the terrain in three dimensions. Contours have traditionally been produced from aerial photogrammetry but today they are more cost-effectively produced from lidar.

Contour lines are isolines that depict equal elevation on a surface. They are primarily used for 2D human interpretation of the 3D terrain surface. Figure 81 shows a contour map with 2' contour interval, meaning that the RMSEz should be ≤8" (one third the contour interval). With modern GIS technology, contours can be generated with the push of a button from lidar datasets, but users can be easily misled if the contour interval is less than three times RMSEz making the contours appear to be more accurate than they really are.

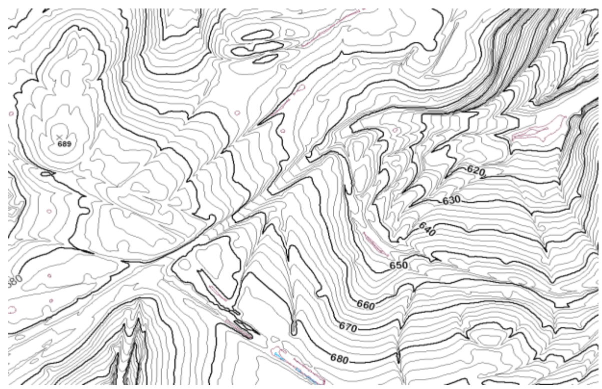


Figure 81. This is an example of a contour map with 2' contour interval, with index contours at 10' intervals.

Hillshades: Hillshades, or shaded relief maps, with either grey-scale or colored elevation ramps are used to create an illuminated representation of the surface, using a hypothetical light source to enhance terrain visualization effects. In Figure 82, the hypothetical light is from the southwest (lower left corner). For many users, hillshades have replaced contour lines as the best way to visualize 3D topographic surfaces. Hillshade viewing angles and sun angles can be varied to maximize visual interpretability of terrain.

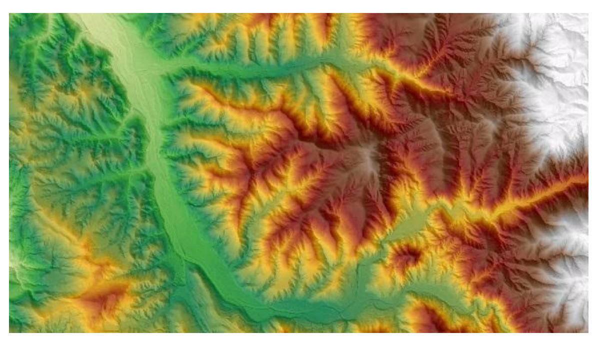


Figure 82. Hillshade map example.

Slope Maps: Slope maps are used for many environmental and engineering applications, including hydrologic and hydraulic modeling, erosion control, and soils mapping. Slope is the measure of change in elevation over distance, expressed either in degrees or as a percent. For example, a rise of 4 meters over a distance of 100 meters describes a slope of 2.3^{o} or 4%. The maximum slope in the map in Figure 83 is about 85%.

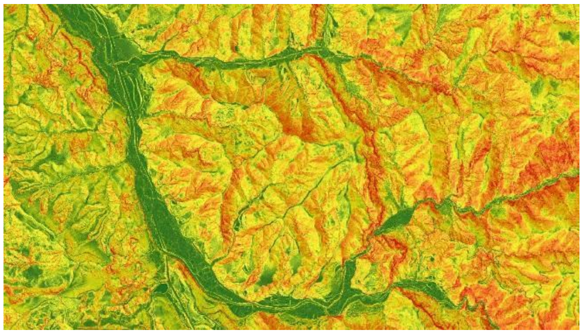


Figure 83. Slope map example.

Aspect Maps: Also used for many environmental and engineering applications, aspect is the slope direction of steepest gradient with respect to points of a compass, measured clockwise in degrees from due north. The value of each location in an aspect dataset indicates the direction the surface slope faces. The example in Figure 84 is of the same terrain as shown in Figures 82 and 83.

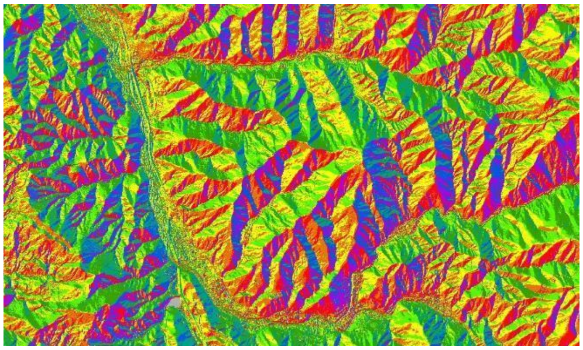


Figure 84. Aspect map example.

Curvature Maps: Usually derived from DEMs, curvature maps are key to numerous conservation activities, including soil and wetland mapping, because they model surface flow paths (see Figure 85) and soil wetness, for example. There are many types of curvature maps, including plan form curvature, profile curvature, and tangential curvature.

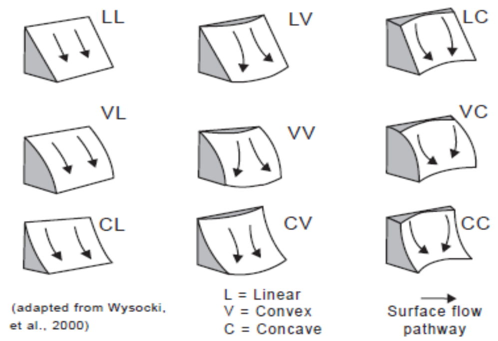


Figure 85. Types of curvature surface flow paths.

Cross-Sections: Cross sections (also called profiles) are commonly “cut” through lidar point clouds or elevation surfaces in order to visualize or measure heights or elevation differences along the path of the profile. Figure 86 shows an example of a lidar profile cut across a river, to include elevation data on a bridge as well as elevations of bare-earth terrain, vegetation and buildings on either side of the river. Cross sections are profiles that are normally generated perpendicular to linear features such as roads and streams.

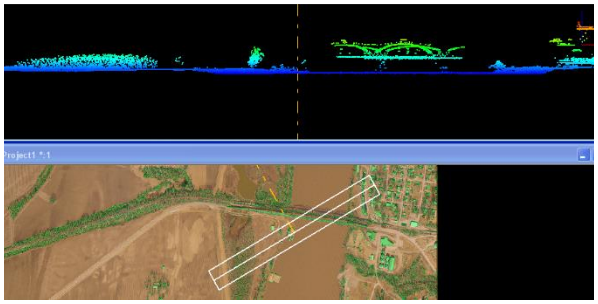


Figure 86. Lidar profile (top) showing elevations along the transect (bottom) that crosses the river and bridge.

Height-Above-Ground Maps: Commonly used for determining timber metrics, height-above-ground maps, also known as elevation difference maps and normalized DSM (or nDSM), are produced by subtracting the DEM from the DSM. In Figure 87, the original DEM is much higher on the right of this image, including a building on the hill top, but this elevation difference map normalizes the surfaces to determine which trees are taller when considering the terrain to be totally flat.

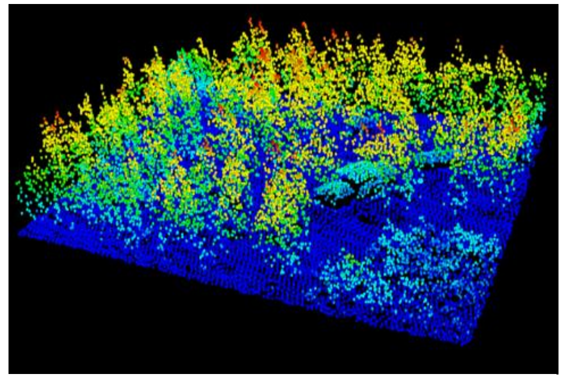


Figure 87. Height-above-ground map where heights of trees (and building) are normalized.

Viewshed Maps: Viewshed maps, also known as intervisibility or line-of-sight maps, are popularly used by military terrain analysts to determine what can be seen, or not seen, from friendly or enemy positions. Figure 88 (courtesy of the USGS) shows areas in direct line-of-site from the top of a 9.5-foot antenna and areas obscured from such intervisibility. The height of the tower can be virtually elevated to see changing results. Architects use viewshed maps for site selection and design, and real estate agents use them to advertise scenic views.

Figure 88. Viewshed map showing what can be seen (red) and not seen (green) from an antenna 9.5 feet tall.

Flow Direction Grids: The grid shown in Figure 89 describes the direction of flow from each pixel to its steepest downslope neighbor. Each cell is assigned a code (value) that defines the direction water will flow from the cell. There are eight possible flow directions: east (1), southeast (2), south (4), southwest (8), west (16), northwest (32), north (64), and northeast (128).

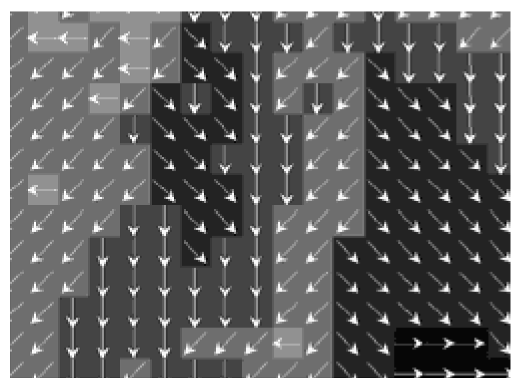


Figure 89. Example of a flow direction grid with arrows to indicate flow of water.

Flow Accumulation Grids: Represents the number of upstream cells that flow to a specific cell. Flow accumulation grids are often used to define stream networks. At some threshold, representing some upslope contributing area, cells are considered to be stream channels.

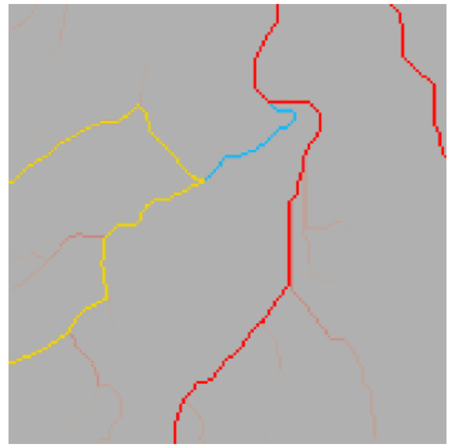


Figure 90. Stream channels derived from a flow accumulation grid. Most of the cells (shown in gray) have relatively small upslope contributing areas, while cells shown in yellow, blue, and red have significantly larger contributing areas, and are identified as stream channels.

Hydrologic networks (e.g. streams, lakes): The hydrologic network is the set of creeks, streams, and rivers that route flow across the land surface within a defined channel. In some cases the network may include impoundments, such as lakes and ponds, through which water flows.

Figure 91. Hydrologic Units and stream networks delineated from an elevation model. Hillshading has been added to show the underlying terrain.

Hydrologic Units (Watershed Boundaries): A hydrologic unit represents all or some portion of the areal extent of surface water drainage to a point, accounting for all land and surface areas. Hydrologic units are selected on the basis of topographic information and are determined solely upon science-based hydrologic principles, not favoring any administrative boundaries or special projects, nor particular program or agency.

Figure 92. Progression of development of a Hydrologic Unit.

Building Footprints: 2-D footprints have x/y coordinates only whereas 3-D footprints have x/y/z coordinates and typically show the highest elevation of any feature on the rooftop. Digital orthophotos are sometimes used to digitize 2-D building footprints but the building positions are distorted because of "building lean" from elevated features, often causing roofs to appear to overlay sidewalks and streets. Positionally accurate 3-D building footprints have long been compiled from stereo photogrammetry. 2-D or 3-D building footprints can also be derived from lidar datasets; the process is semi-automated but requires additional processing to create smooth roofline edges as shown with red outlines in Figure 93.

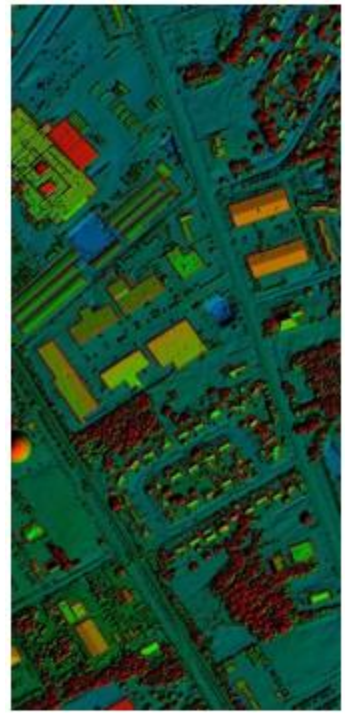


Figure 93. Building footprints from lidar. This image is color-coded by elevation.

Breaklines for road edge-of-pavement: As shown in Figure 94, it is common to digitize either 2-D or 3-D breaklines for road edge-of-pavement from either imagery or from lidar. Road breaklines are used in cartography to visualize urban environments by distinguishing between narrow alleys and major city streets. Road breaklines are also used to map the area of impervious surfaces, which is used to model stormwater runoff for flood and water quality studies. Breaklines are used to map road grading and to identify pavement edge-drop off for planning road maintenance activities.

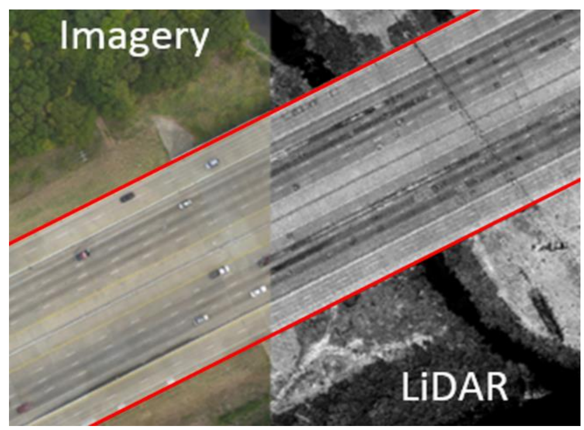


Figure 94. Edge-of-pavement breaklines can be digitized from orthoimagery (2-D), from stereo image compilation (3-D), or from lidar (3-D breaklines).

Rugosity/Surface Roughness: Rugosity is an indicator of the complexity of a surface. In the marine environment rugosity is an important ecological parameter for fish, corals, and algae. In earth science, surface roughness is used to help identify - and subsequently study the processes acting upon - landforms.

Figure 95. Healthy staghorn coral (Acropora cervicornis) thicket, Dry Tortugas National Park; photo credit: Ilsa B. Kuffner, USGS.

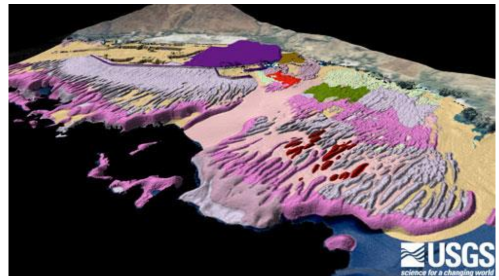


Figure 96. Oblique onshore view of sea floor characterization map off Puʻukoholā Heiau National Historic Site and Kawaihae Harbor, Hawaiʻi.

3D Nation Elevation Requirements and Benefits Study
Benefits Examples

This tutorial has three sections:

- Section 1 describes the categories of benefits used in the 3D Nation Requirements and Benefits Study for both current and future benefits.
- Section 2 describes methods for estimating monetary and other tangible benefits in terms of hours saved, costs saved or reduced, or revenues earned.
- Section 3 provides example benefits pertaining to operational improvements, customer service improvements, and other societal benefits. Note that we are not attempting to capture dollar values for societal benefits. However, several examples of ways that elevation data provide societal benefits are included because we do want to know about these benefits from a qualitative perspective.

1. Categorizing current and future benefits

Within the questionnaire, we ask participants to categorize their current and future benefits using the following categories.

1.1. Operational Benefits:

Operational benefits may fall into several categories including direct dollar savings; reduced labor costs; annual savings or percent improvement in operational efficiency or effectiveness; or improvements to mission critical programs. Examples may include:

Time Savings:

- Hours saved from faster field visits/inspections and/or avoided field visits/inspections
- Hours saved through more efficient modeling, reviews, reporting, data dissemination, mapping, or other procedures
- Hours saved from reduced or avoided data manipulation (e.g., combining data from multiple sources; changing projection, datum, etc.)
- Hours saved from reduced or avoided data errors
- Hours saved through in-office project planning or monitoring
- Hours saved from more streamlined operations (e.g., permitting processes, offshore boundary determinations, etc.)

Cost Savings or Cost Reduction:

- Data acquisition costs saved, reduced, or available to spend on other projects
- Materials saved (e.g., fertilizer, pesticides, water, irrigation systems, pond design, beach/dune restoration, building/construction materials, etc.)

Cost Avoidance:

- Data processing avoided (e.g., classifying point clouds, quality control, hydrotreatment, etc.)
- Data errors avoided
- Property not lost due to natural hazards or disaster events
- Avoidance of accidents caused by human error due to lack of information (e.g., crashes, aviation incidents, marine accidents, oil spills, etc.)

Increased Revenues:

- Improved harvest yields (e.g., timber, agriculture, fisheries, etc.)
- Increased cargo carrying capacity
- New products, services, or applications/apps sold

Mission-Driven Performance Improvements:

- Increased program effectiveness
- Improved ability to carry out mission
- Improved decision making due to better data, modeling, etc.

1.2. Customer Service Benefits:

Customer service benefits may be similar to operational benefits, but would be experienced by your customers through using improved data or products that you deliver to them and that would improve their ability to accomplish their mission. Examples may include:

Value Added to Products or Services:

- New products, services, or applications/apps (e.g., solar or green roof potential, GPS navigation, recreation opportunities, etc.)
- Improved accuracy of products or services (e.g., navigation charts, nautical charts, shoreline delineation, flood hazard maps, etc.)

Improved Response or Timeliness:

- Faster reviews and approvals (e.g., permitting approval, boundary determinations, etc.)
- Faster response to an incident or event (e.g., faster access to impacted areas, faster response and recovery operations, etc.)
- Faster recovery after an event (e.g., faster port reopening after hurricane, faster identification of damaged structures, faster information about Advisory Base Flood Elevations, etc.)
- Improved customer assistance (e.g., use of data allows virtual view and support via phone, email, chat)
- More up to date services or products (e.g., nautical charts, navigation charts, flood hazard maps, etc.)
- Improved projections of at-risk locations and/or faster warning to the public of impending natural or man-made hazards (e.g., flood, fire, tsunami, active shooter, etc.)

Improved Customer Experience:

- Increased customer confidence in products or services
- New services, tools, or applications/apps
- Better data availability (e.g., faster downloads, data are all in one place, etc.)

1.3. Societal Benefits:

Societal benefits may fall into categories such as improved education or outreach, environmental benefits, or public safety, including life and property. Examples may include:

Education or Outreach:

- Better informed citizens due to public outreach using data, maps, visualization tools, etc.
- Teaching materials, lesson plans, hands-on exercises for K-12 students that encourage STEM education, curiosity, and creativity

Environmental:

- Enhancements to the environment from restoration of watersheds, stream banks, wetlands, forests, grasslands, habitat areas, etc.
- Reduced point and non-point source pollution

Public Safety:

- Improved safety of citizens by using 3D elevation data for improved decision making, e.g., to avoid natural or manmade disasters
- Safer and more resilient communities by taking proactive steps to mitigate risks by informed siting of infrastructure facilities or future residential development

2. Methods for estimating monetary and other tangible benefits

For USGS's prior *National Enhanced Elevation Assessment* (NEEA), USGS documented the range of cost benefits that would result from enhanced elevation data and justified expanded budgets for the current 3D Elevation Program (3DEP) without adversely impacting the budgets of those agencies that indicated they would receive major time/cost savings as well as improved operational benefits and customer service benefits from enhanced elevation data they considered to be mission critical.

Similarly, for this 3D Nation Elevation Requirements and Benefits Study, we need questionnaire participants to translate the benefits to their Mission Critical Activities into tangible benefits where possible. Questionnaire participants should think in terms of tangible benefits that yield quantifiable cost savings, reduced hours spent, mission-driven performance improvements, products and service improvements, and customer experience benefits. Do not include dollar benefits for societal benefits (improved education and outreach, environmental benefits, or public safety).

The following are ways you may be able to quantify your benefits.

2.1. Direct correlation method (hours)

This method may apply to time savings, cost avoidance, mission-driven performance improvements, value added products or services, improved response or timeliness, or improved customer experience.

In every organization, there should be some reasonable method for estimating hours reduced or cost savings from digital 3D elevation data. For example, in estimating the benefits of 3D elevation data for your organization, the following direct correlation methodology might be used, starting with key questions:

1. What technical tasks, performed for your program, require 3D elevation data for effectiveness or efficiency?
2. What did you do prior to the advent of lidar a decade ago or multibeam sonar?
3. How much longer did it take you to do it the old way?
4. Do you return to older methods today for areas where you do not have suitable 3D elevation data?
5. If you did not have high resolution digital 3D elevation data, how many people would perform such tasks, or similar tasks, and how long would it take them to do it the old way?
6. If 3D elevation data allows you to perform some tasks that previously required field visits or field surveys and you can now perform some or all of these tasks from your desktop, you may

be able to estimate how many person-hours are saved by not having to go out into the field as frequently.

7. A similar construct can be used for other types of time savings from having the required 3D elevation data available, such as hours saved on data manipulation; data errors avoided; or more efficient modeling, reviews, reporting, data dissemination, mapping, or other procedures.
8. Annual cost savings = number of tasks/person/month or year x number of persons x hours saved/task. This can be reported in hours or can be converted to dollars by multiplying the hours x average hourly pay and benefits (or similar calculations).
9. Repeat for other organization personnel with differing requirements and savings.

2.2. Direct correlation method (dollars)

This method may apply to cost savings or cost reduction, cost avoidance, increased revenues, mission-driven performance improvements, value added products or services, improved response or timeliness, or improved customer experience.

1. How much money has your organization saved on data acquisition, or been able to spend on other projects because data acquisition is no longer necessary?
2. Can you estimate the value and quantity of materials saved on construction, agricultural, or other projects due to the availability of the required 3D elevation data?
3. Can you estimate the value of real estate, public infrastructure, or other property that would not be lost due to natural or man-made hazards through having the required 3D elevation data to better model the hazards and make decisions about future land use planning or construction?
4. Would your organization be able to realize increased revenues if the required 3D elevation data were available to help you improve your business processes, increase your harvest or extraction yields, or market new products or services?

2.3. Value multiplier method

Some organizations estimate monetary benefits in terms of percent improvements in productivity or efficiency, or increased profits from using a better process for accomplishing their operational mission. These percent improvements result in value multipliers, e.g., a 50% improvement in efficiency might yield a $500,000 benefit for a $1,000,000 program that is totally dependent on the efficiency of the new or improved business process.

2.4. Do not attempt to value societal benefits

We will not attempt to quantify the value of societal benefits but instead allow you to respond by indicating if 3D elevation data for your MCA has major, moderate, minor, or no relevance to education or outreach, the environment, or public safety.

3. Example Benefits

3.1 Example Operational benefits

3.1.1. Time and cost savings

3.1.1.1. Time and cost savings through automation of hydrologic and hydraulic analyses

This example pertains to Business Use #15 (Flood Risk Management) but could pertain to other Business Uses that include modeling that can now be automated using high resolution digital 3D elevation data.

Over the last ten to fifteen years, GIS and lidar have transformed water resource modeling. Previously, hydrologic and hydraulic engineering was performed through a manually intensive process of integrating expensive field survey information into computer models and drafting the results on mylar. This process was not only labor-intensive but was also subject to human error and inaccuracies. With the advent of lidar, the modeler can now remain in a seamless GIS environment and perform tasks using automated digital processes. Digital 3D elevation data is now stored, visualized, and computed without having to create traditional products, like contours, that a human needs to understand the dataset. Relying on these newer technologies, FEMA has greatly reduced the requirements, and cost, for field survey cross-sectional data. Engineering models are now produced through a series of automated processes that can fully exploit the lidar elevation backbone.

For example, FEMA's contractors produce thousands of digital Flood Insurance Rate Maps (FIRMs) annually, supported by engineering and mapping systems that feature H&H automation processing from lidar (see Figures 1 and 2 for an example of one such system).

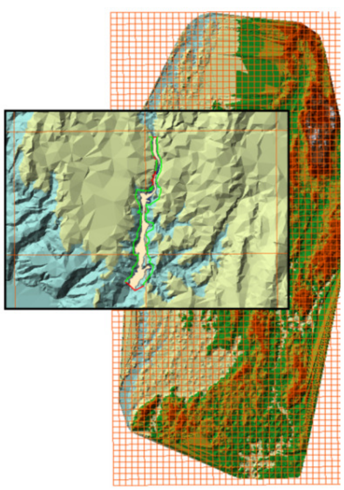


Figure 1. Using lidar to build an ESRI Terrain, engineering tools now seamlessly model an entire county without having to break up the data.

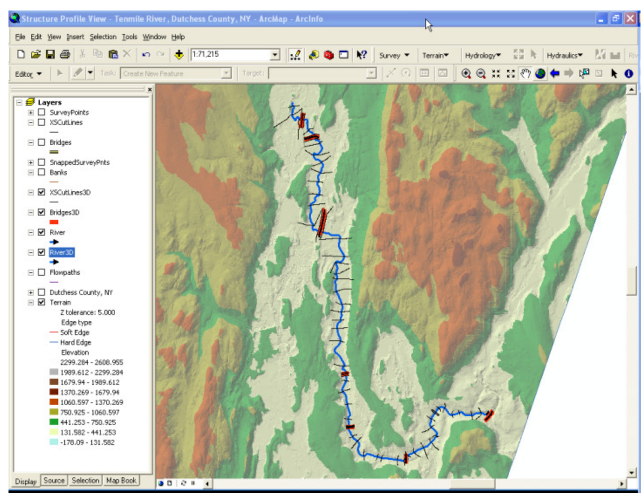


Figure 2. The engineering and mapping system integrates lidar and bridge survey data into hydraulic modeling tasks and automates calculations from the underlying lidar elevation data.

3.1.1.2. Time and cost savings by automation of soils mapping and analysis

This example pertains to Business Use #6 (Natural Resources Conservation) but could pertain to other Business Uses that utilize soil maps.

Soils mapping has always been a core mission of the Natural Resources Conservation Service (NRCS). Soils maps in the past were largely produced by photo analyses of slope and aspect (Figure 3). Today, computer models use slope, aspect and curvature (all elevation derivatives) for semi-automated soils mapping that is faster, far less expensive, and more accurate than soils maps of the past.

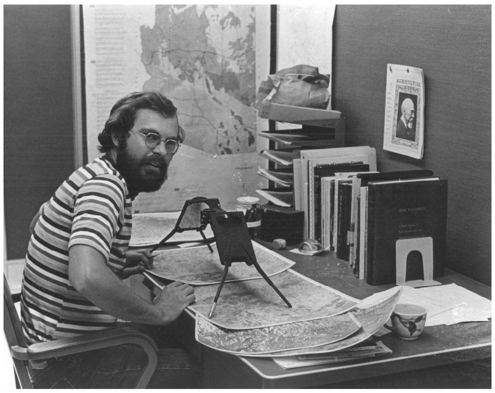


Figure 3. The "old way." Complex stereo image analyses plus tedious soil line placement on mylar is now rarely used for soils mapping, preferring high-resolution elevation data derivatives, i.e., slope, aspect and curvature which are now computed from lidar data with the push of a button.

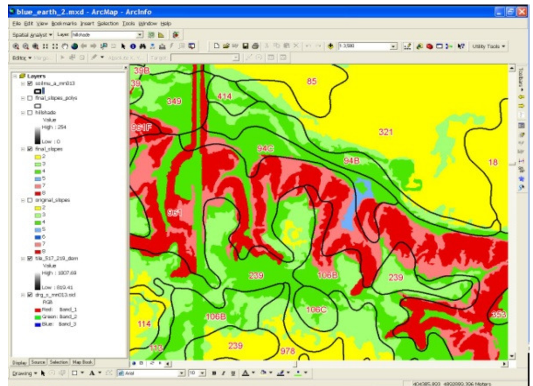


Figure 4. The "new way." Soils mapping is now semi-automated and are more accurate. The differences between polygons with black outlines and those with different colors show discrepancies between old and new soil survey techniques.

Figure 4 provides an example of how NRCS' LiDAR Enhanced Soil Survey (LESS) techniques yield more accurate soils maps through automation (using elevation derivatives and objective criteria) than NRCS' manually-compiled soils maps of the past using subjective stereo image analysis (Figure 3). The differences between the polygons with black outlines and the polygons with different colors show discrepancies between old and new techniques. Soils engineers generally agree that the newer techniques yield better accuracy in soils mapping.

3.1.1.3. Time and cost savings by virtual visits instead of on-site visits

This example pertains to Business Use #6 (Natural Resources Conservation) but could pertain to any Business Use that includes on-site visits.

The Natural Resources Conservation Service (NRCS) works with private landowners through conservation planning and assistance designed to benefit the soil, water, air, plants and animals that result in productive lands and healthy ecosystems. From the beginning of its existence as the Soil Conservation Service, much focus has been placed on slope analyses for control of soil erosion and on methods to retain water on the land so that it does not cause floods elsewhere. To provide needed technical assistance, NRCS sends specialists on-site to meet with individual landowners and assess their land (see Figure 5); whereas this has advantages, NRCS would need many additional employees to satisfy all demands for on-site consulting. Alternatively, far fewer NRCS specialists can cost-effectively analyze digital orthophotos and elevation data (Figures 6 and 7) and make better science-based recommendations for conservation of natural resources in efficient, smart and sustainable ways. Every landowner that can be helped by telephone, email or online saves many hours of non-productive travel time and expenses for on-site visits to remote areas, and science-based GIS technology is superior for many of the required tasks. When using remote sensing products such as lidar datasets, it should not be difficult to estimate cost savings by minimizing the need for on-site visits and by providing better science-based advice to more landowners.

Figure 5. On-site visits take precious time and resources; far fewer customer needs are served. Travel time/expense is wasteful.

Figure 6. Produced from image and elevation data, orthophotos allow efficient image analysis of habitat, wetlands and vegetation/crops.

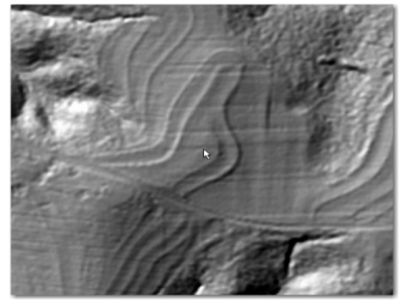


Figure 7. Elevation datasets allow mission-critical expert analyses of terrain surfaces and drainage not visible on the orthophoto.

3.1.1.4. Cost savings by aerial surveys instead of field surveys

This example pertains to Business Use #22 (Infrastructure and Construction Management) but could pertain to any other Business Use that currently uses field surveys.

Figure 8. Field survey costs may be a hundred times more expensive, yet less valuable than aerial surveys from lidar or photogrammetry.

Compared with ground surveys, aerial surveys are much less expensive and are often superior. Richland County, SC used existing lidar data to avoid a $140,000 cost for a land surveyor to perform a topographic survey of a single 150-acre site considered for development, to assess the elevation, slope, aspect and drainage characteristics of this site. The lidar data was used to determine the amount of earth-moving/grading to be performed for site preparation of a new facility to be built and to estimate costs for site drainage structures. Such cost avoidance is a major benefit to many Federal, State and local agencies and private users of digital 3D elevation data. Other potential construction or engineering sites nationwide are candidates for similar cost avoidance.

Also consider the aerial surveys of routes for planned construction of new roads by State and county DOTs, new cell phone tower locations (where elevation is critical) or new pipelines or power lines (Figure 8). Lidar is ideal for thousands of topographic survey projects, and comparative cost savings can be quantified with relative ease.

3.1.1.5. Cost efficiencies

Cost Efficiencies for Oil and Gas Industry

This example pertains to Business Use #13 (Oil and Gas Resources).

One energy firm reported: "We use lidar data to help us with our planning and construction processes. The lidar helps us calculate slope which is a vital piece of information for locating well sites, facilities and pipelines. Using the lidar we can pre-select suitable locations via the GIS in the office in a much quicker, safer and cost effective manner than having to send ground crews into the field to search for suitable well locations and pipeline routes. This is a huge benefit to us. Another big use for us is in our Seismic programs. We also use the full feature lidar to get an understanding of the land cover in the area. We use it to calculate the amount of timber that we may have to cut. In fact when we combine it with air photos we can further select locations and routes which minimize required tree cutting." This company partnered with the State by providing $200,000 for lidar data of two counties, so obviously the lidar data is considered by them to be of very high monetary value.

Multibeam Mapping for Seabed Oil Exploration

This example pertains to Business Use #13 (Oil and Gas Resources).

The Center for Coastal and Ocean Mapping/Joint Hydrographic Center at the University of New Hampshire, a cooperative partner with NOAA, developed technology that maps the water column as well as the seabed to identify underwater seeps. Using multibeam sonar data, they have been able to integrate bathymetry, seabed imaging, and full water column analysis and develop new tools and technologies that support a new industry of ocean oil exploration. Initial cost-benefit analyses indicate that the value of such data to U.S. companies and industries is $70 million per year and expected to grow at about 25% per year. Using this new technology represents significant cost savings and safety improvements over traditional marine seismic data acquisition. And using these new techniques for seep hunting and geochemical analysis reduces risk and improves the success of drilling by determining if a reservoir holds exploitable oil. It also provides an environmental baseline for the safer development of oil exploration and development monitoring.

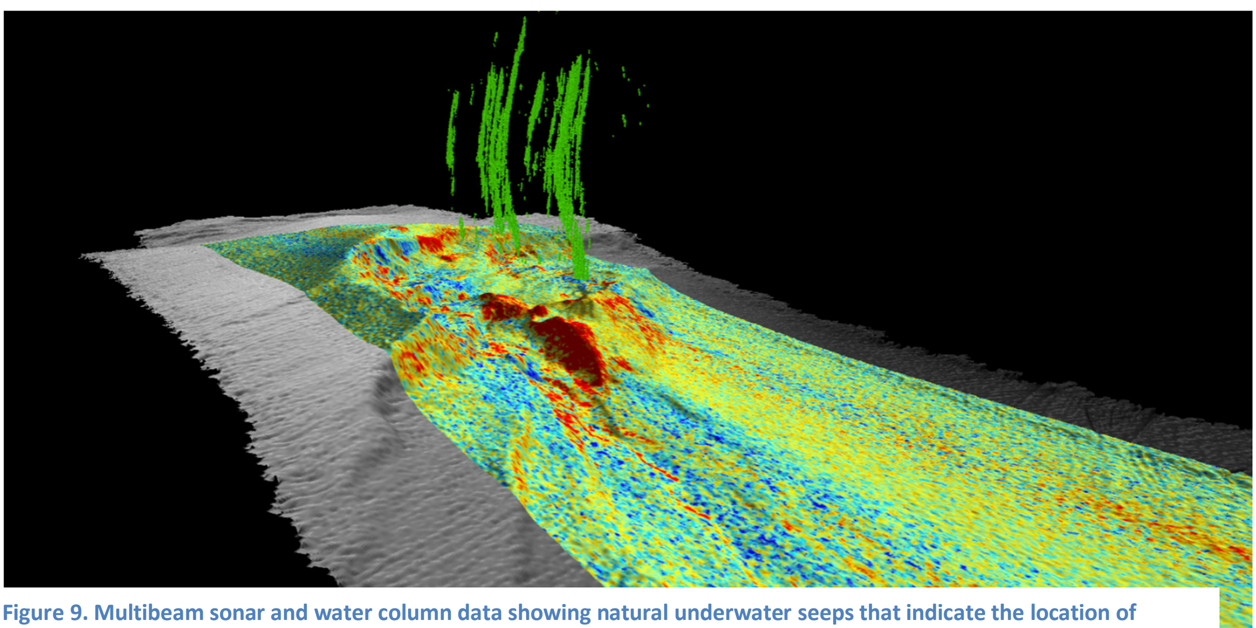


Figure 9. Multibeam sonar and water column data showing natural underwater seeps that indicate the location of potentially exploitable oil resources.

Multibeam Mapping for Renewable Energy Siting and Marine Mineral Mining

This example pertains to Business Use #11 (Geologic Resource Mining and Extraction).

The Bureau of Ocean Energy Management (BOEM) manages the development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way. BOEM is committed to using the best available science to make decisions about offshore energy siting (BOEM 2018) and marine mineral extraction (BOEM 2018), and often requires bathymetric information and sea floor characterization to make informed decisions about the Nation's ocean resources. Through leases issued by BOEM, over 146 million cubic yards of sand have been used to help restore and protect over 321 miles of coastline. To date, BOEM has issued thirteen commercial wind energy leases on the OCS, including those offshore Delaware, Maryland, Massachusetts, New Jersey, New York, Rhode Island, Virginia, and North Carolina.

Efficiency Improvements for Siting Aquaculture Farms

This example pertains to Business Use #9 (Fisheries Management and Aquaculture).

Technological innovation has made it possible to grow marine finfish in the coastal and open ocean. The U.S. has everything required to develop a significant marine finfish aquaculture industry including excellent locations, scientific expertise, state-of the-art technology, innovative equipment and feed manufacturers and willing investors. Detailed information about site specific hydrology, bathymetry, and local nutrient dynamics are used to provide insight into long-term processes over large areas and potential impacts from offshore aquaculture (Price and Morris 2013).

Efficiency Improvements for Replenishing Fish Stocks

This example pertains to Business Use #9 (Fisheries Management and Aquaculture).

To support fisheries, resource managers need a better understanding of spatial distribution of economically important fish, their key habitats and associated fishing effort. Bathymetry is critical for understanding these distributions. In a study performed in the Hawaiian Islands, areas with high recovery potential were identified using bathymetry by comparing current targeted fish distributions with those predicted when fishing effort was removed. The study determined that spatial protection of these areas would aid recovery of nearshore fisheries (Stamoulis et al. 2018) and support the Nation's blue economy.

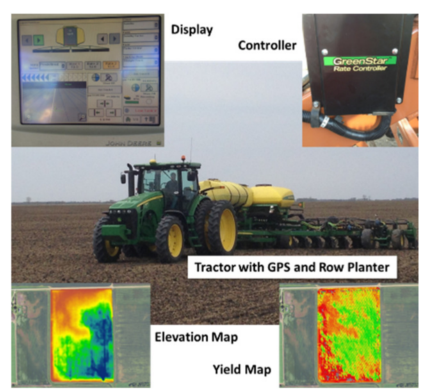


Figure 10. Topographic data, plus GPS receivers on farm machinery or backpacks, enable precision farming by the square meter rather than by the acre or hectare.

Efficiency Improvements for Precision Farming

This example pertains to Business Use #8 (Agriculture and Precision Farming).The "National Height Modernization Study: Report to Congress," prepared by NOAA in 1988, estimated that high resolution DEMs combined with a nationwide differential GPS network would have estimated value to constituents of $1.7 billion for precision farming for planned application of water, fertilizer, pesticides, etc. This NOAA study predicted that, with GPS-based precision farming technology, farmers would be able to go from farming by the acre to farming by the square meter while also reducing a major source of non-point pollution.

Precision farming systems gather data on tillage, seeds planted, weeds, insect and disease infestations, cultivation and irrigation, and *location-stamp* that data with GPS information. Using these data, farmers can micromanage every step of the farming process. For example, a farm GIS database might include layers on field topography (DEMs), terrain slopes, soil types, surface drainage, sub-surface drainage, soil testing results, rainfall, irrigation, chemical application rates, and crop yield. Once this information is gathered, farmers can analyze it to understand the relationships between the different elements that affect crop yields. The *National Enhanced Elevation Assessment* (NEEA), published in 2012, documented precision agriculture conservative cost savings of over $2B annually from lidar data of agricultural areas. Figure 10 shows elevation data loaded in the computer that guides the farmer and his machinery used for precision agriculture.

Improved Farm Pond Design

This example pertains to Business Use #6 (Natural Resources Conservation) or Business Use #2 (Water Supply and Quality).

GIS is the optimal business decision support tool to improve the decision-making process or work flows for farm pond design because it is a computer-based technology capable of running multiple scenarios and options efficiently and rapidly. Figures 11 and 12 demonstrate commercial Pond Planning GIS software that uses digital elevation data to design farm ponds and to accurately estimate the cost of construction and related expenses such as farm fencing surrounding the pond. Without even needing to visit the farm site, a GIS analyst with commercial software can use DEMs and digital orthophotos to provide landowners with over a hundred pond options within 15 minutes, while using the landowner's criteria to select the optimum pond design. Without DEMs, such detailed pond design and cost estimating would be prohibitively expensive in most cases.

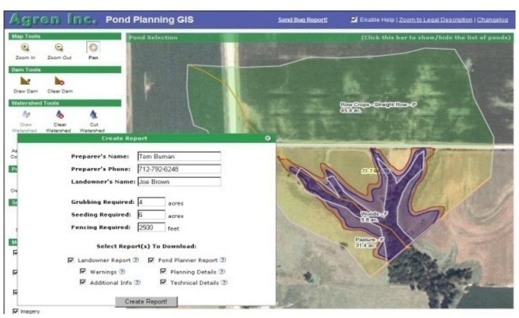
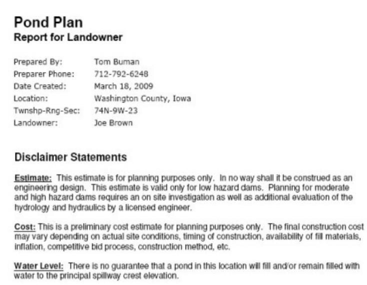


Figure 11. With a DEM, pond planning software took 15 minutes to develop 100+ design options for pond size/depth, dam height, drainage areas, pipe size, fencing costs, etc.



Pond Plan
Report for Landowner

Prepared By: Tom Buman
Preparer Phone: 712-792-6248
Date Created: March 18, 2009
Location: Washington County, Iowa
Twnshp-Rng-Sec: 74N-9W-23
Landowner: Joe Brown

Disclaimer Statements

Estimate: This estimate is for planning purposes only. In no way shall it be construed as an engineering design. This estimate is valid only for low hazard dams. Planning for moderate and high hazard dams requires an on site investigation as well as additional evaluation of the hydrology and hydraulics by a licensed engineer.

Cost: This is a preliminary cost estimate for planning purposes only. The final construction cost may vary depending on actual site conditions, timing of construction, availability of fill materials, inflation, competitive bid process, construction method, etc.

Water Level: There is no guarantee that a pond in this location will fill and/or remain filled with water to the principal spillway crest elevation.

Figure 12. The landowner accepted the best low-cost option and was given the Pond Plan that included engineering design and accurate cost estimates.

Improved forest/timber metrics

This example pertains to Business Use #5 (Forest Resources Management).

Firms in the timber industry manage millions of acres of forest. They face tough decisions that affect their bottom lines as well as the environment. High-density lidar point cloud data are widely used to map the forest canopy (lidar first return) and the ground beneath the forest (normally the lidar last return). As shown in Figures 13 and 14, such data also provide accurate metrics for estimation of timber yields.

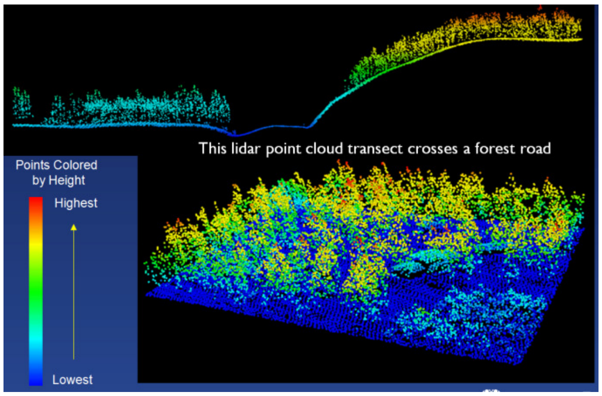


Figure 13. Lidar point cloud with transect (cross-section) crossing a forest road. Only lidar can map the forest floor in dense forests.

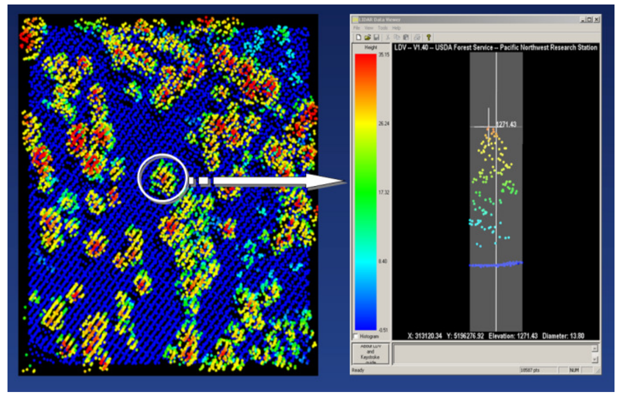


Figure 14. Software tools allow many types of measurements of individual trees and also summarize timber metrics over large areas.

Cost Savings for Shipping

This example pertains to Business Use #20 (Marine and Riverine Navigation Safety).

Commercial shipping relies on current and accurate nautical charts to maximize their time efficiency. Good charts allow pilots to determine the most direct routes between ports, reduce the number of pilots needed, decrease the number of groundings thereby reducing insurance rates, and allow deeper draft vessels that can carry more cargo to be used. In a 2000 study, NOAA reported that one additional foot of draft may account for $36,000 to $288,000 of increased profit per transit into a single port – Tampa, FL. In a separate 2007 study, NOAA cites a U.S. Coast Guard estimate that about 7,600 foreign-flag ships and 400 U.S.-flag ships operate in U.S. waters, making on average about 10 ports of call in the U.S. per year.

If all 10 U.S. ports of call for the 8,000 commercial vessels could accommodate even one additional foot of draft as a result of improved data, this could result in savings to carriers of $2.8 to $23 million per year.

3.1.2. Mission-Driven Performance Improvements

3.1.2.1. Aviation Safety

This example pertains to Business Use #21 (Aviation Navigation and Safety).

Both the Federal Aviation Administration (FAA) and the International Civil Aviation Organization (ICAO) have requirements for digital elevation data at specified accuracy levels for aviation safety. As shown at Figure 15, lidar data are also used at airports to ensure that designated flight paths for airfield approaches are safe and free of obstructions.

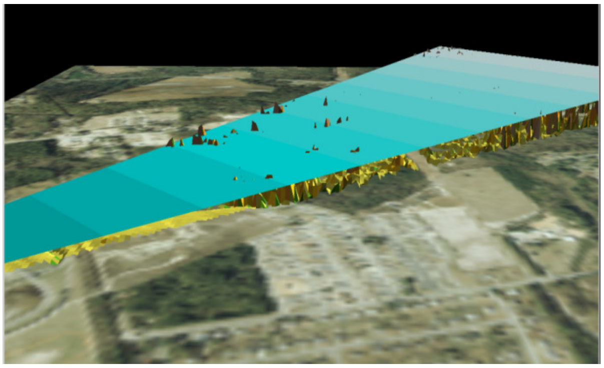


Figure 15. Flight path obstructions, mapped with lidar.

3.1.2.2. Improved geologic assessment

These examples pertains to Business Use #10 (Geologic Assessment and Hazards Mitigation).

The Florida Geological Survey has been mapping areas in the state where the geology for sinkhole formation is favorable. Field geologists used existing and publicly available lidar data as a base layer to identify possible sinkholes prior to beginning field work. The data proved to be very useful in helping to direct the field crews to potential sinkhole targets. The data were also used as a navigation aid in areas where the terrain made it difficult to access potential sinkhole features, and it was useful for locating sinkholes where the visibility was obscured by trees or structures. In addition to locating potential targets and areas prone to sinkhole activity, field geologists could determine slope, depth, and diameter of the preexisting features utilizing the lidar-derived terrain models and avoid potentially dangerous situations while working in hazardous landscapes.

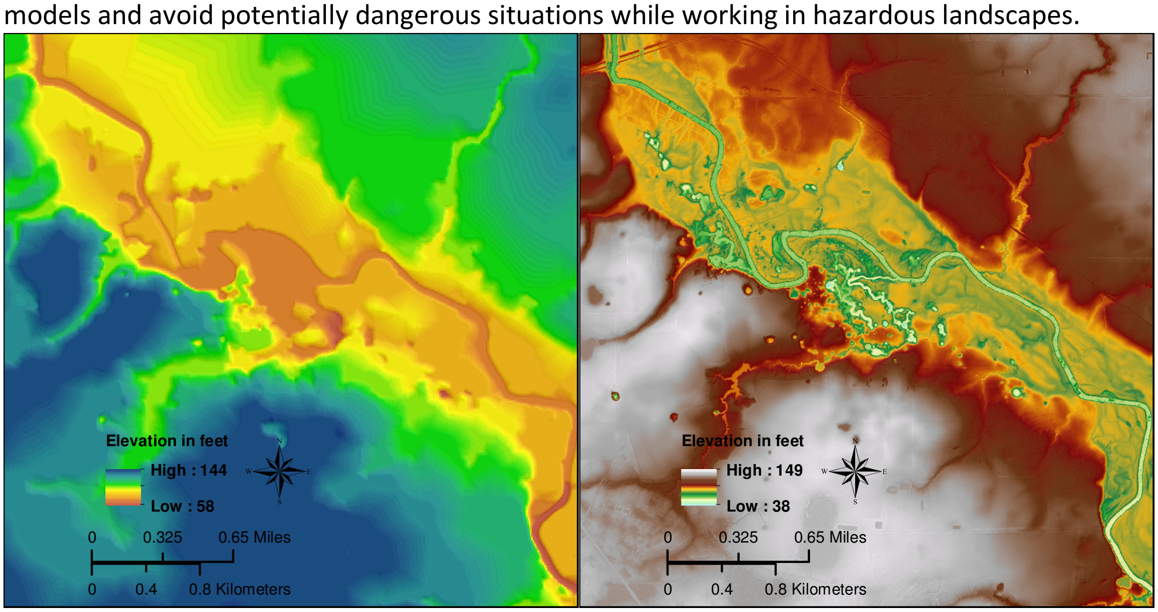


Figure 16 shows areas of the Alapaha River in North Central Florida with substantial sinkhole development. The image on the left is a terrain model developed from the USGS 1:24,000 scale topographic maps. The image on the right is a five-foot resolution lidar surface. The area is pockmarked with sinkholes that are underrepresented on the topo derived surface but very clear on the lidar terrain model.

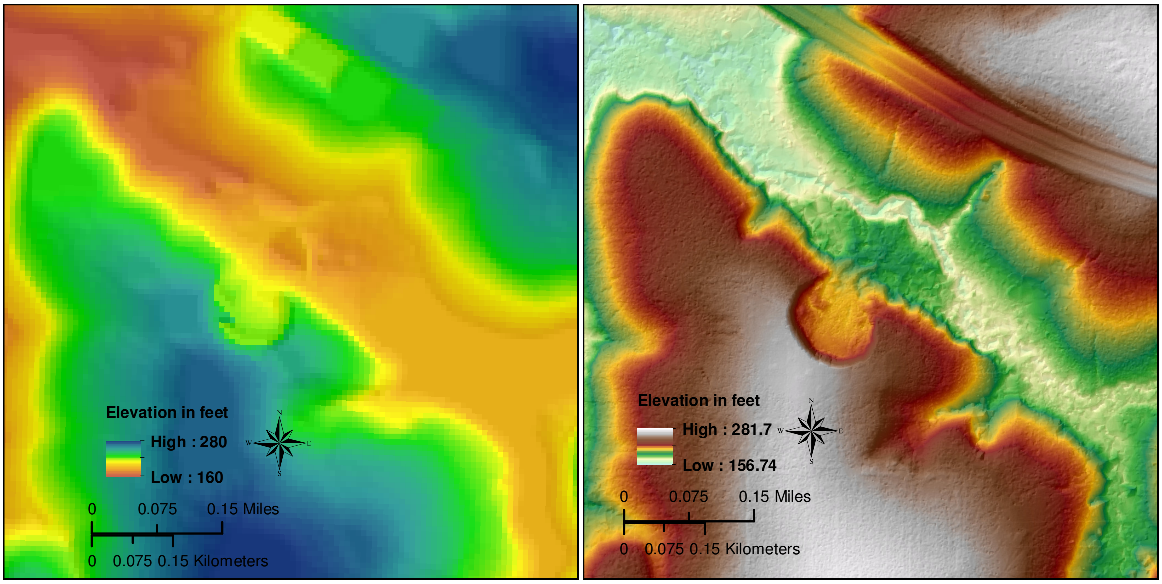


Figure 17 depicts an area in the panhandle of Florida with a documented landslide not associated with sinkhole development. The image on the left is a terrain model developed from the USGS 1:24,000 scale topographic maps. The image on the right is a five-foot resolution lidar surface from 2006. The feature and debris field are easily identifiable in the lidar image. This is an example of a false sinkhole which was not apparent from the topo maps.

The Florida STATEMAP program, a cooperatively funded surficial geologic mapping initiative within the FGS' Geological Investigations Section, uses lidar to improve surficial geologic mapping and to search for geologic contacts within a study area. Prior to beginning field work, Florida STATEMAP staff locate, gather, and stitch together sections of lidar data to create a topographic base map. It can be difficult to manage many of the data sets they accumulate since some are of different resolutions and quality levels, and in many instances, a portion of the study area does not have any data. Much like the sinkhole group, Florida STATEMAP geologists use lidar prior to scheduling any field work to optimize their time in the field. They also use the data to map potential geological contacts and geomorphic features by noting consistent and apparent elevation changes.

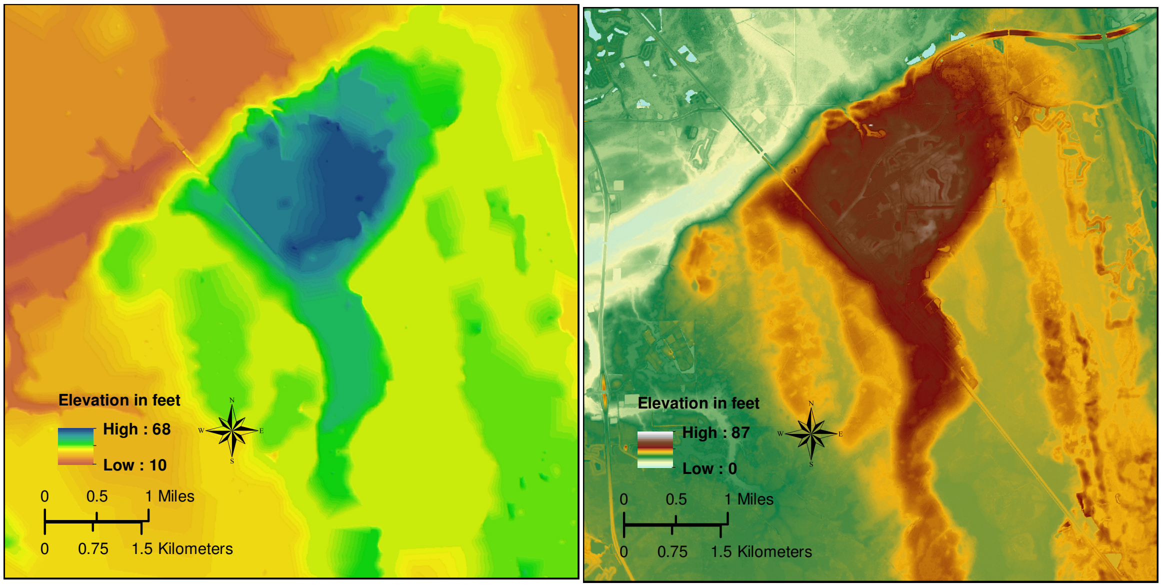


Figure 18 shows a coastal feature in the Durbin area, south of Jacksonville, in northern Florida. The elevated feature is an aeolian augmented feature beach ridge and it is being dissected by Julington Creek. The image on the left is a terrain model developed from the USGS 1:24,000 scale topographic map while the image on the right is a five-foot resolution lidar surface. Florida STATEMAP geologists used this lidar elevation model to more accurately map and describe the geomorphology of the study area.

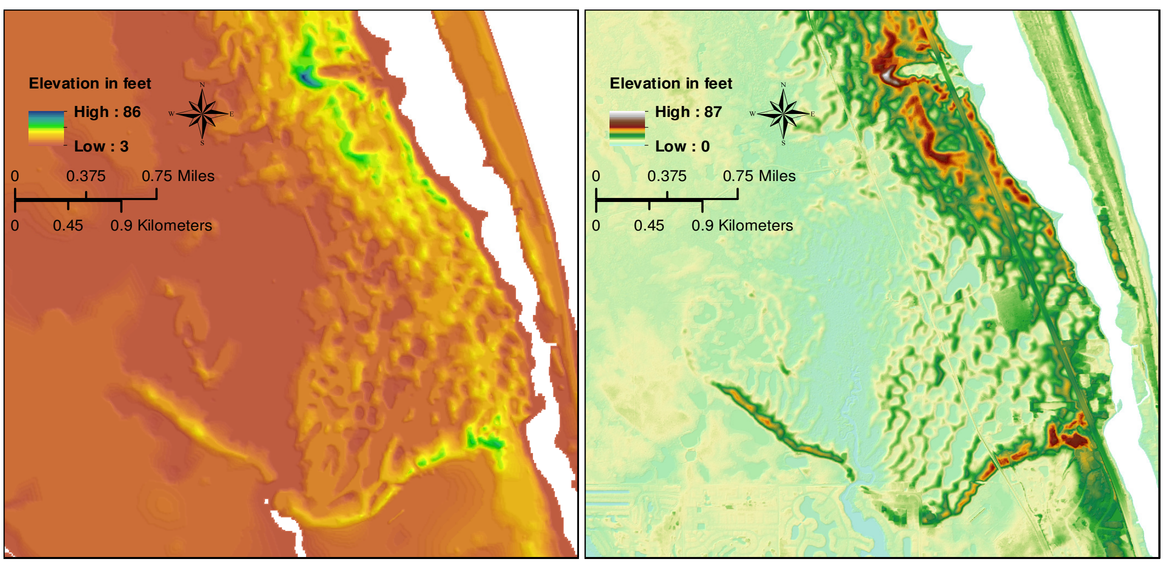


Figure 19 is from a large dune field in Martin County. The image on the left is a terrain model developed from the USGS 1:24,000 scale topographic maps while the image on the right is a five-foot resolution lidar surface. While the topo derived surface accurately captures the extent of the feature it misses many of the subtle dune features that make up the unique terrain of the area.

The FGS' Applied Geoscience Services (AGS) Section has been using terrestrial lidar near the Florida Big Bend coastline to locate and document several small springs. In this low-lying area, staff geologists use the lidar-derived terrain models to locate small streams that originate as springs. The models help the geologists navigate the thick brush and swamps and avoid marshy areas. In addition, the AGS uses lidar to organize and plan dye-trace studies for select springs and swallets. The lidar is used to identify sample points during attempts to trace the flow of surface water as it descends underground through swallets and eventually emerges at a spring vent further down gradient.

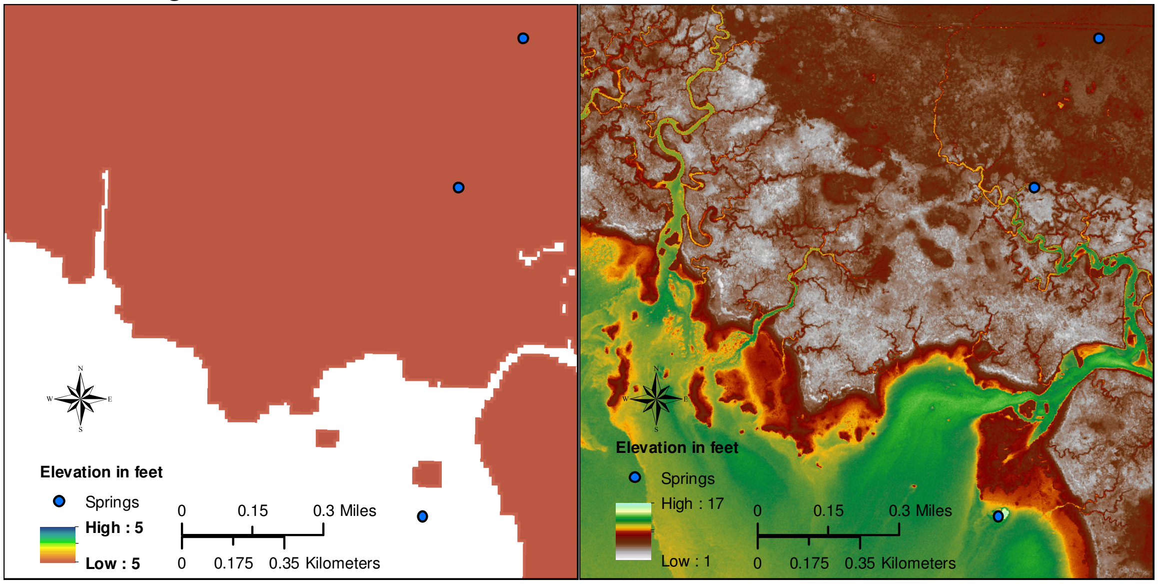


Figure 20 is from coastal Taylor County in the big bend area or north Florida. The image on the left is a terrain model developed from the USGS 1:24,000 scale topographic maps while the image on the right is a five-foot resolution lidar surface. The topo derived surface is unusable as a tool for locating streams emanating from seeps and springs. Field geologists at the FGS use the lidar surface to help locate and navigate to potential spring locations.

3.2. Example Customer Service Benefits

3.2.1 Products or Services

3.2.1.1 New value-added services

These examples pertain to Business Use #23 (Urban and Regional Planning), Business Use #18 (Homeland Security, Law Enforcement, Disaster Response, and Emergency Management), and Business Use #12 (Renewable Energy Resources).

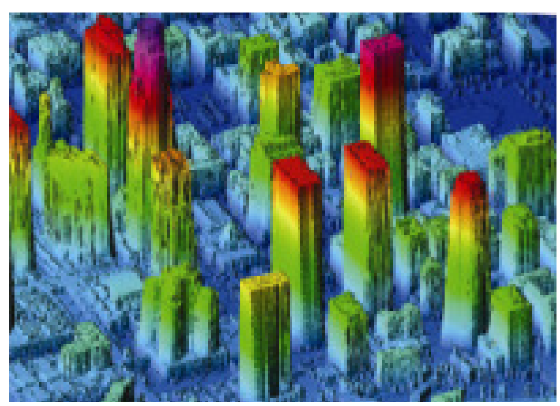


Figure 21. Color-enhanced 3-D model of downtown Los Angeles. Such models are used for Homeland Security applications as well as diverse government and commercial applications.

3D city models from lidar are used to create virtual city models for homeland security and also for city governments and "3D fly-throughs" on the TV evening news. Whereas Figure 21 shows a lidar 3D model of downtown Los Angeles, it is now common to also project vertical and oblique imagery onto these 3D surfaces in order to develop virtual city models that are truly realistic and easier to understand and interpret. For homeland security purposes, officials perform line-of-sight analyses to determine "what can be seen (or targeted) from where;" lidar is ideal for this application. Lidar is also ideal for generation of building footprints, and to determine the aspect and slopes of roofs for potential solar panel efficiency, a popular new value-added service popular in Los Angeles County.

Some communities collect elevation data and collect user fees to recoup costs, without placing the data in the public domain. Other communities use elevation data or their derivatives (e.g., hillshades) as base maps for overlay of polygons that show risks of landslides, fire hazards, boundaries and other information, then sell these value-added products to the public or charge a user fee. Still others sell or license their data to commercial industry (e.g., oil and gas) for diverse purposes. In these ways 3D elevation data adds monetary value and increased revenue for new Business Uses nationwide for diverse applications.

3.2.1.2 Improvements to the Nation's infrastructure

This example pertains to Business Use #22 (Infrastructure and Construction Management).

The Nation's infrastructure must be maintained and improved, and doing so will depend on the availability of high-resolution 3D elevation data. Conservative estimates from the 2012 *National Enhanced Elevation Assessment* (NEEA) conducted by USGS in 2012 indicate that annual benefits for infrastructure projects are $170 million. This includes such activities as the following:

- Route, grade, line-of-sight, and utility surveys and corridor mapping
- Terrain and other obstruction identification for aviation
- Dam, levee, and coastal-structure failure modeling and mitigation
- Hydrologic and hydraulic modeling
- Evaluations of geologic, coastal, and other natural hazards, and geotechnical evaluations
- Permit application and construction plan development and evaluation
- Drainage issues and cut-and-fill estimate requirements
- Vegetation, topographic, and geomorphologic feature analysis
- As-built model development
- Preliminary engineering, estimate development, and quantity estimation activities
- Bridge site selection
- Base-map and elevation model creation

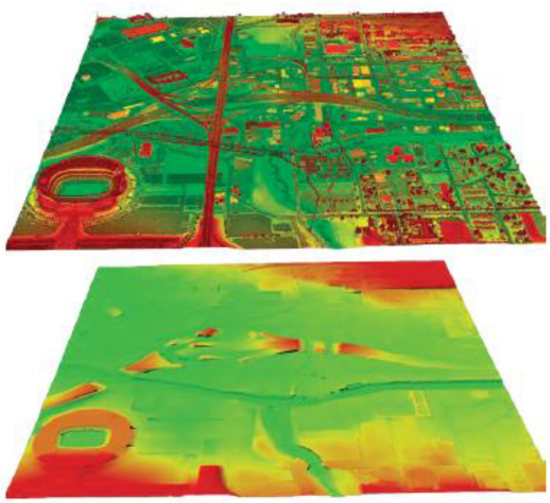


Figure 22. Lidar point cloud (top) and a derived bare-earth digital elevation model (bottom) for Denver, CO.

3.2.2 Response or Timeliness

3.2.2.1 Improved customer service from seamlessly integrated bathymetric and topographic data along the coasts

This example pertains to Business Use #3 (Coastal Zone Management).

In the 2012 *National Enhanced Elevation Assessment* (NEEA), NOAA reported benefits of $1.5 million/year for customer service benefits from users being able to download seamless data and perform their own analyses.

Public dissemination of NOAA's existing, unrestricted, high-resolution Digital Elevation Models (DEMs) of select U.S. coastal communities has greatly benefited scientists, Federal and State agencies, private companies, journalists, and the public. The coastal DEMs save users the intensive effort required to seamlessly integrate bathymetric and topographic data at the coast. To date, NOAA's thoroughly documented coastal DEMs have been downloaded more than 30,000 times in four years. A rough estimate can be made of the dollar savings to users downloading the data. While the careful assembly of each coastal DEM requires an average of three months by a highly-trained GIS specialist, it is assumed that a typical individual user would only spend one day to make an inferior product that still meets their needs. This equates to 120 man-years saved (i.e., 30 man-years annually or ~$1.5M/year) and does not include the additional savings for the subset of users that require the high quality DEM. The development and dissemination of additional unrestricted, accurate, high-resolution, integrated bathymetric-topographic DEMs to cover additional U.S. coastal communities would benefit countless other individuals, Federal and State agencies, and businesses in need of such products of other U.S. coastal communities to enhance their work.

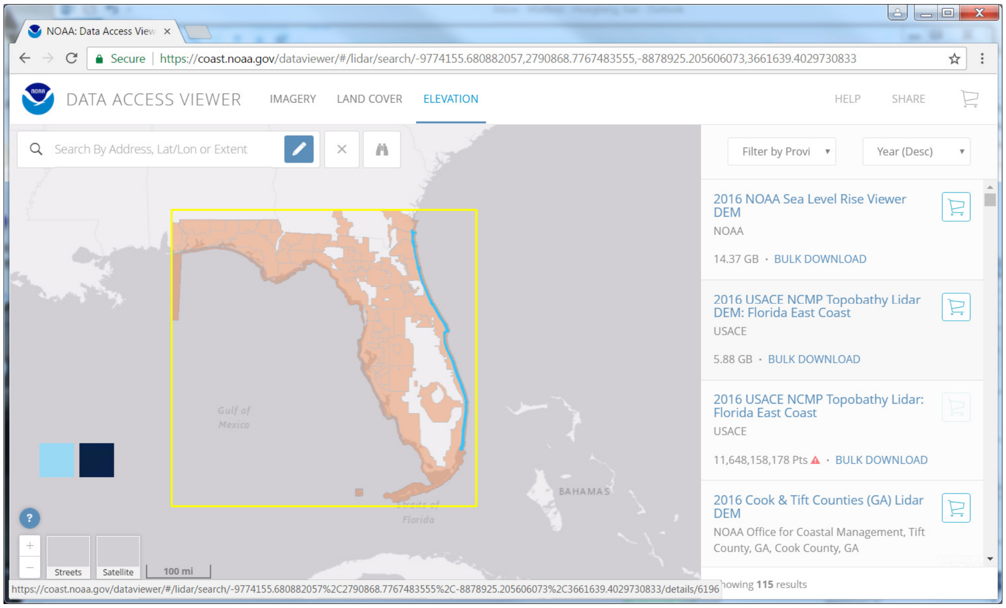


Figure 23. NOAA's Data Access Viewer.

3.2.2.2 Customer savings for surveyor costs

This example pertains to, Business Use #6 (Natural Resources Conservation).

In another example from the 2012 *National Enhanced Elevation Assessment* (NEEA), the Iowa Department of Natural Resources (DNR) estimated that using lidar to determine elevations in floodplains for permits could save permittees about $250 each on surveyor costs. The DNR issues ~50 floodplain permits per year, saving its residents ~$12,500 per year.

3.2.3 Customer Experience

3.2.3.1 Improved Government services to taxpayers

This example pertains to, Business Use #23 (Urban and Regional Planning), and Business Use #25 (Real Estate, Banking, Mortgage, and Insurance).

A county Assessor's department reported that they provide end users with the ability to view geospatial data via a Web-based viewer. They estimated 64,000 hours of staff time saved, avoiding over $4M in staff costs, but elevation data was only a small part of the geospatial data provided. They had other benefits for which they did not attempt to quantify cost savings:

1. Time reductions for customers for not having to wait in line to get their questions answered by a human or to process permits
2. Additional costs that would have been needed to add office space and staff to handle the increase in activity or visits to the public information counters (they previously served 190 customers per day, and those numbers kept growing)
3. Additional time that would be necessary to research more information with manual methods; they have added 14 additional GIS layers (e.g., digital orthophotos, elevation data, flood risk data) to be able to answer more questions on-line

4. The value of consistent and concise information delivered at all public information counters to the engineers, developers, consultants, and the public
5. Savings to other county departments that themselves use the information from the Assessor's departmental library of 23,000 standard graphics

Federal and State agencies can similarly convert Web site visits to work-hour equivalents to document efficiencies from Web map viewers.

An organization that serves as property manager for 70,885 acres of land within the Houston metropolitan area reported that their GIS information base, used for *virtual land management*, saves about $80,000 per year in land and right-of-way labor costs; but they did not specify what portion of such savings, if any, was attributable to elevation data.

3.3 Examples of Societal Benefits

3.3.1 Environmental

3.3.1.1 Monitoring of environmental changes

This example pertains to Business Use #4 (Coastal Zone Management).
USGS is using bathymetry to evaluate the impact of coral reef flattening on coastal zones and communities. Coral reefs protect shorelines and communities from storms, waves and erosion. The degradation of these ecosystems will lead to increased risk to coastal communities (Yates et al. 2017).

The Nature Conservancy is using lidar to examine the impacts of Lake Ontario's lake level drop on coastal habitat migration and to develop effective conservation and management strategies. Figures 24 and 25 illustrate areas of environmental concern.

Figure 24. The lowering lake level of Lake Ontario is being tracked by The Nature Conservancy for environmental impacts.

Figure 25. Lowering lake levels have an adverse impact on coastal habitat migration. TNC is developing conservation management strategies to mitigate environmental impacts.

3.3.1.2 Improved characterization of benthic habits, vegetation and forest health

Vegetation and Forest Health

This example pertains to Business Use #5 (Forest Resources Management)

Government leaders, the national media, and environmentalists have recognized elements of the timber industry for scientific accomplishments and environmental practices in advancing forestry science, including the use of lidar intermediate returns used to characterize vegetation and assess forest health, as shown in Figures 26 and 27. This is an example of a relatively new Business Use enabled by 3D elevation data.

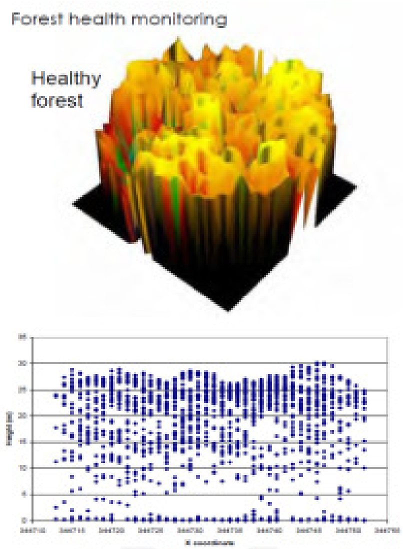


Figure 26. The intermediate returns from this lidar point cloud indicate a healthy forest according to one study.

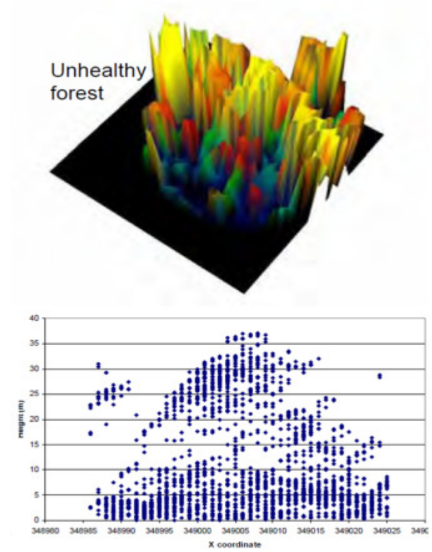


Figure 27. The intermediate returns from this lidar point cloud indicate an unhealthy forest by that same study.

Benthic Habitats

This example pertains to Business Use #07 (Wildlife and Habitat Management).

NOAA is routinely using bathymetry to characterize benthic habitats in marine environments. These benthic habitats are used for a variety of management applications, including supporting the blue economy by informing management plans that balance resource protection with ocean user needs and safety (SLUMP 2017).

3.3.2 Public Safety

3.3.2.1 Reduced flood damage losses

This example pertains to Business Use #15 (Flood risk management).

The National Flood Insurance Program (NFIP) relies on digital elevation data for hydrologic and hydraulic modeling of watersheds and floodplains and for mapping of flood hazards with Flood Insurance Rate Maps (FIRMs). See example at Figure 28. Floodplain maps define flood hazard zones and are used to determine whether flood insurance is required for buildings located near streams and rivers, for example, and to promote sound floodplain management practices within communities.

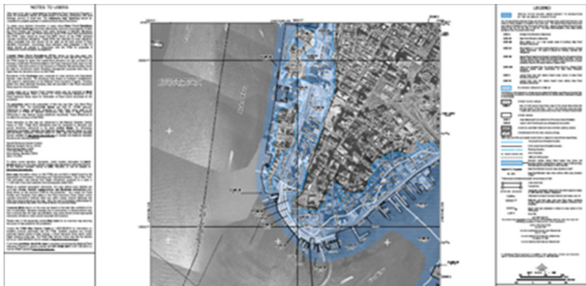


Figure 28. Modern digital FIRMs, produced with lidar data, are more accurate, improve public confidence in the legitimacy of flood risk assessments, cause communities to adopt and enforce floodplain management ordinances to reduce future flooding, and cause more homeowners to insure themselves against ever-increasing flood risks.

Today, FEMA largely relies on lidar for H&H modeling, for computation of water surface elevations for floods of specified frequency, to delineate flood hazard zones and predict flood depths. Using FIRMs, nearly 20,000 communities across the U.S. participate in the NFIP by adopting and enforcing floodplain management ordinances to reduce future flood damage. In exchange, the NFIP makes Federally-backed flood insurance available to homeowners, renters, and business owners in these communities. Flood insurance is designed to provide an alternative to disaster assistance to reduce the escalating costs of repairing flood damage to buildings and their contents. Flood damage is reduced through communities implementing sound floodplain management requirements and property owners purchasing flood insurance. Additionally, buildings constructed in compliance with NFIP building standards suffer approximately 80% less damage annually than those not built in compliance.

3.3.2.2 Mitigation of sea level rise and subsidence

This example pertains to Business Use #16 (Sea Level Rise and Subsidence).

Land subsidence, the loss of surface elevation due to removal of subsurface support, is a costly problem that occurs in nearly every State in the U.S. Both lidar and IfSAR data are used for subsidence monitoring so that future losses due to subsidence can be mitigated. Furthermore, many national and State studies are using lidar to evaluate the impact of sea level rise. Figure 29 shows a USGS graphic that predicts losses of land and marshes for coastal Louisiana alone, with dire predictions during the next 50 years.

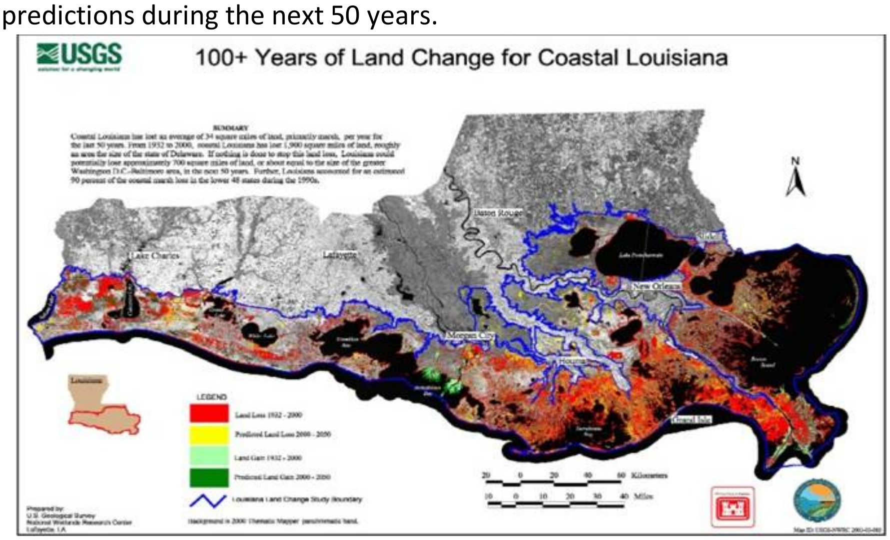


Figure 29. At predicted rates of subsidence and sea level rise, Louisiana is expected to lose very large areas annually during coming decades. Lidar will be vital in monitoring and analyzing such changes with major socio-economic implications.

The National Water Level Observation Network (NWLON), operated by NOAA, uses a nationwide tide station network to track long term changes in sea levels on all coasts, including the Great Lakes. Figure 30 shows the sea level rise for a tide station in North Carolina.

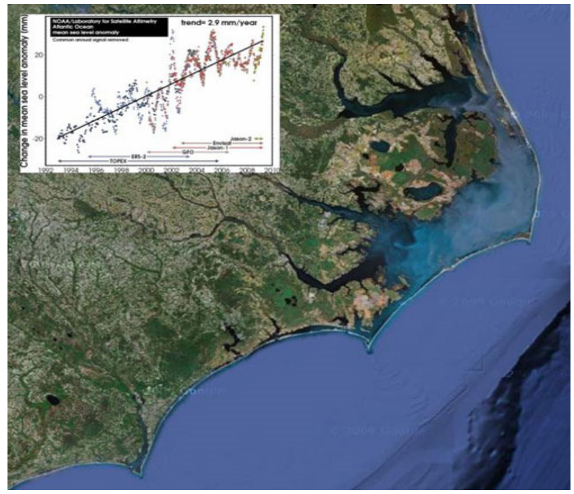


Figure 30. Monitoring of sea level rise in North Carolina.

With projected sea level rise trends, lidar data is widely used to predict areas of inundation from rising sea levels, as well as coastal inundation expected to occur from hurricane tidal surges, and in some cases, from tsunamis. Lidar is now used to prepare graphics that color-code the depth of flooding in addition to the boundaries of areas to be flooded.

Low-lying islands are susceptible to sea level rise, and are often overwashed during large wave events. The intrusion of salt water from overwash can reduce the amount of potable water and habitability of these islands. High resolution bathymetry is important to understand and quantify these overwash events, and to prepare for their negative impacts to coastal resources and infrastructure (Cheriton et al 2016).

3.3.2.2 Landslide recognition, hazard assessment, and mitigation support

This example pertains to Business Use #10 (Geologic Assessment and Hazard Mitigation).

The USGS Landslide Hazards Program conducts landslide hazard assessments, pursues landslide investigations and forecasts, provides technical assistance to respond to landslide emergencies, and engages in outreach. All of these activities benefit from the availability of high-resolution, 3D elevation information in the form of light detection and ranging (lidar) data and interferometric synthetic aperture radar (IfSAR) data.

"Landslide hazard assessment at local and regional scales contributes to mitigation of landslides in developing and densely populated areas by providing information for (1) land development and redevelopment plans and regulations, (2) emergency preparedness plans, and (3) economic analysis with the goal of (a) setting priorities for engineered mitigation projects and (b) defining areas of similar levels of hazard for insurance purposes."
—Baum and others (2014)

Lidar data provides crucial input to slope-stability models that are used to identify where shallow landslides may mobilize into fast-moving, and potentially damaging and deadly debris flows. The data can also be used to plan for evacuations and staging areas in advance of a possible landslide event.

Lidar data can be used to create landslide inventory and deposits maps and estimate the shape and activity of landslides; determine fundamental and highly detailed descriptions of boundary conditions for landslide initiation; provide baseline information for change-detection comparisons, such as estimating sediment transport rates; and estimate landslide thickness and ages of landslide deposits.

Figure 31. Baum and others (2014) showed that compared to other technologies, using 3DEP lidar data identified 3 to 200 times the number of landslides in densely forested areas.

3.3.2.3 Dam and Levee Safety

This example pertains to Business Use #18 (Homeland Security, Law Enforcement, Disaster Response, and Emergency Management) as well as Business Use #15 (Flood Risk Management).

Levee safety became a national priority following Hurricane Katrina with considerable loss of life and property. Levees fail for numerous reasons, including erosion and loss of soils used as berms, cracking and movement of structural components, and improperly managed vegetation. Lidar is a tool used in a national levee safety and certification process. Lidar data/surfaces from the current year can be compared with lidar data/surfaces from prior years to detect changes. The top of Figure 32 shows the location of a cross-section cut across the levee. The bottom of Figure 32 shows the height of the vegetation growing on the levee at that cross section; some vegetation undermines the structural integrity of dams and levees.

With aging infrastructure and potential terrorism, those who own, manage or maintain dams must also be prepared for a potential dam breach. Lidar data are now used to gather valley cross-section data representative of downstream conditions; to develop water surface profiles for each section; to calculate the breach flow rate; to route the breach flow rate down the valley; and to plot and analyze the results using GIS technology (Figure 33). Before lidar, cross-sections were determined by slow, costly and inefficient land survey techniques. Thus, lidar for dam and levee assessment provides a monetary benefit in addition to a societal benefit.

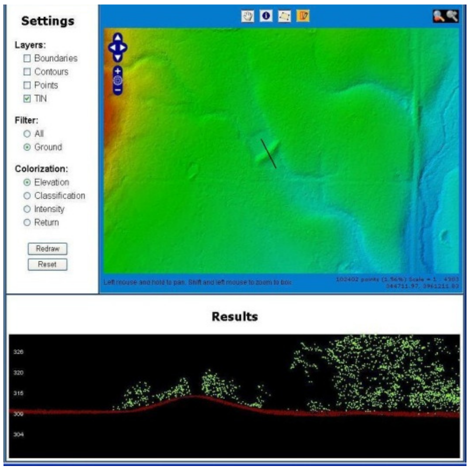


Figure 32. Lidar cross-sections measure the height of vegetation growing on dams and levees, signaling potential safety hazards.

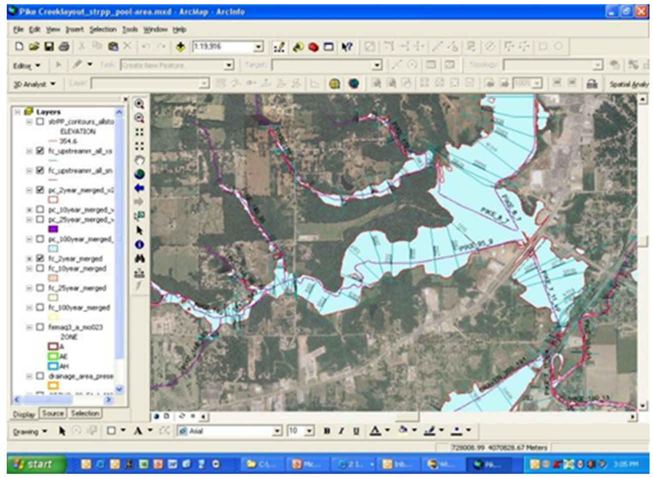


Figure 33. Lidar is ideal for dam breach modeling, to include valley cross-section data to model downstream conditions.

3.3.2.4 Near real-time warning systems

This example pertains to Business Use #18 (Homeland Security, Law Enforcement, Disaster Response, and Emergency Management).

North Carolina, Louisiana and Florida are among the States that funded major lidar mapping programs used, in part, for mapping of coastal flood hazards and computer modeling of hundreds of potential surges from hurricanes that vary as a function of near-shore topography, tide stage, wind direction and velocity, and other factors. (NOAA has also done this for potential tsunamis in Hawaii.) Hurricane tidal surge and tsunami hazards do not just threaten property, but human and animal lives as well. These States use their lidar data for early identification of evacuation routes subject to flooding that could isolate people with no safe exit. North Carolina is also using its lidar data for a near real-time flood warning system along rivers by contacting homeowners to warn them in advance of coming floods and flood depths. Every minute of advance warning can avoid extensive flood losses by allowing homeowners to move people, animals and valuable items to safer locations and/or to sandbag their property.

3.3.2.5 Marine navigation and safety

This example pertains to Business Use #20 (Marine and Riverine Navigation and Safety).

On January 8, 2005, the nuclear submarine *USS San Francisco* was proceeding at 38 miles per hour, 525 feet below the surface. Such vessels often travel in virtual blindness, foregoing radar and its telltale pings; the crew relied on seafloor charts to navigate. But the maps were not complete. About 360 miles southeast of Guam, the submarine hit an unmapped underwater mountain. The collision injured 100 of 137 crew members, and one died from a massive head wound. The commander was discharged and reprimanded for an “ill-advised voyage plan,” but the lack of precise charts undoubtedly played a major role in the accident.

More accurate and up-to-date data of the seafloor is important not only for navigation. It is also vital for underwater recovery. When Malaysian Airlines Flight 370 went missing over the Pacific, it showed how little we know about the seafloor. In the area where the plane is thought to have crashed, the maps were nearly nonexistent; the only charts were based on satellite measurements. But these charts have a resolution of 1.5 kilometers (meaning one measurement is taken every 1,500 meters).

More than eighty percent of our oceans are unmapped, unobserved, and unexplored. Only about 10% have been mapped using modern technology. Another approximately 5% were mapped using lead lines and explosives, which provides only a general sense of the area. While we have indeed mapped the entire moon to 7-meter resolution and Mars to 20 meters, much of our own planet’s seafloor is mapped at best to 5000-meter resolution using satellites that infer depth based on gravity anomalies.

Seabed mapping is critical to forecasting weather, tsunami and storm surge events; climate change projections; and the outlines of where living marine resources exist. It is the means to uncover the history of our fallen lost at sea and the framework for seabed mineral discovery. Accurate ocean depths are instrumental in connecting the world through safe navigation and transoceanic communication cables, and they are critical to emergency response on the high seas. Even if these benefits are difficult to quantify, they certainly should be considered as “Major.”

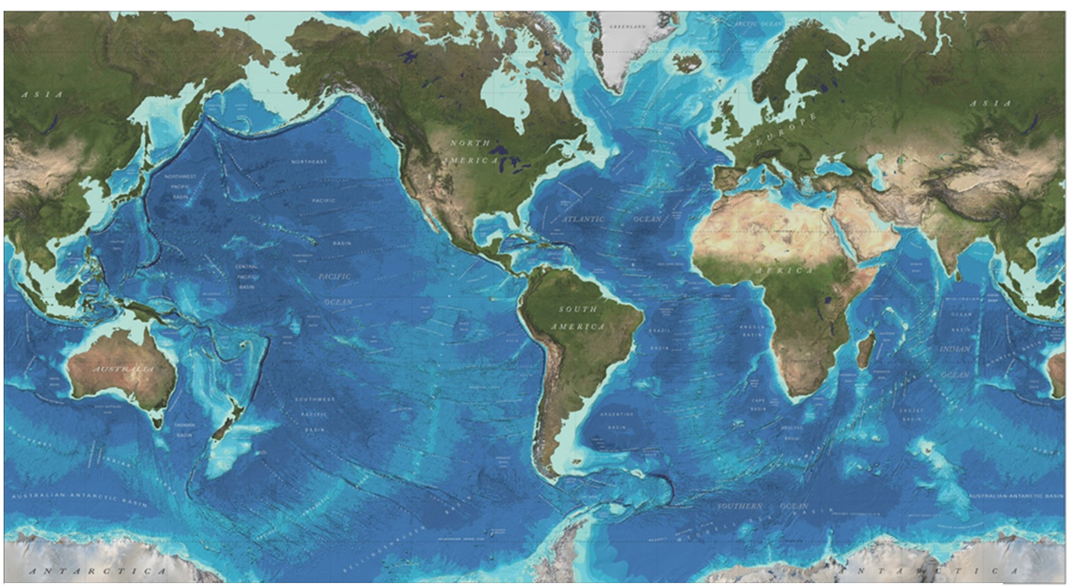


Figure 34. General Bathymetric Chart of the Oceans (GEBCO) World Map 2014.

identified as a NMFS ''species of concern'' in 2006. A species of concern is one for which we have concerns regarding status and threats but for which insufficient information is available to indicate a need to list the species under the ESA. In identifying species of concern, we consider demographic and genetic diversity concerns; abundance and productivity; distribution; life history characteristics and threats to the species. Given the information presented in the status review report and the findings of this listing determination, we are removing the thorny skate from the ''species of concern'' list.

References

A complete list of all references cited herein is available upon request (see **FOR FURTHER INFORMATION CONTACT**).

Authority

The authority for this action is the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*).

Dated: February 21, 2017.

Alan D. Risenhoover,

Acting Deputy Assistant Administrator for Regulatory Programs, National Marine Fisheries Service.

[FR Doc. 2017–03644 Filed 2–23–17; 8:45 am]

BILLING CODE 3510–22–P

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

RIN 0648–XF242

New England Fishery Management Council (NEFMC); Public Meeting

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice; public meeting.

SUMMARY: The New England Fishery Management Council (Council) is scheduling a public meeting of its NEFMC External Peer Review Management Strategy Evaluation of Atlantic Herring Acceptable Biological Catch Control Rules from to consider actions affecting New England fisheries in the exclusive economic zone (EEZ). Recommendations from this group will be brought to the full Council for formal consideration and action, if appropriate.

DATES: This meeting will be held on Monday, March 13, 2017 through Wednesday, March 15 starting at 9 a.m. all three days.

ADDRESSES: The meeting will be held at the Embassy Suites, Boston Logan Airport, 207 Porter Street, Boston, MA 02128: (617) 657–5000.

Council address: New England Fishery Management Council, 50 Water Street, Mill 2, Newburyport, MA 01950.

FOR FURTHER INFORMATION CONTACT: Thomas A. Nies, Executive Director, New England Fishery Management Council; telephone: (978) 465–0492.

SUPPLEMENTARY INFORMATION:

Agenda

The New England Fishery Management Council (Council) is conducting a peer review of the Management Strategy Evaluation (MSE) of Atlantic Herring Acceptable Biological Catch (ABC) Control Rules. Atlantic herring, predators, and economic models were developed to evaluate control rules and performance metrics. Experts have been invited by the Council to evaluate the MSE methods, data, and results. The panel will evaluate whether the MSE is sufficient for the Council to use when identifying and analyzing a range of ABC control rule alternatives in Amendment 8 to the Atlantic Herring Fishery Management Plan. This public meeting will have designated times on the agenda when public comment is welcome.

Special Accommodations

This meeting is physically accessible to people with disabilities. Requests for sign language interpretation or other auxiliary aids should be directed to Thomas A. Nies, Executive Director, at (978) 465–0492, at least 5 days prior to the meeting date. This meeting will be recorded. Consistent with 16 U.S.C. 1852, a copy of the recording is available upon request.

Authority: 16 U.S.C. 1801 *et seq.*

Dated: February 21, 2017.

Tracey L. Thompson,

Acting Deputy Director, Office of Sustainable Fisheries, National Marine Fisheries Service.

[FR Doc. 2017–03642 Filed 2–23–17; 8:45 am]

BILLING CODE 3510–22–P

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

RIN 0648–XF240

Mid-Atlantic Fishery Management Council (MAFMC); Meeting

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice; public meeting.

SUMMARY: The Scientific and Statistical Committee (SSC) of the Mid-Atlantic Fishery Management Council (Council) will hold a meeting.

DATES: The meeting will be held on Wednesday and Thursday, March 15–16, 2017, beginning at 1 p.m. on March 15 and conclude by 1 p.m. on March 16. For agenda details, see **SUPPLEMENTARY INFORMATION**.

ADDRESSES: The meeting will at the Royal Sonesta Harbor Court, 550 Light Street, Baltimore, MD 21202; telephone: (410) 234–0550.

Council address: Mid-Atlantic Fishery Management Council, 800 N. State Street, Suite 201, Dover, DE 19901; telephone: (302) 674–2331 or on their Web site at *www.mafmc.org.*

FOR FURTHER INFORMATION CONTACT: Christopher M. Moore, Ph.D., Executive Director, Mid-Atlantic Fishery Management Council, telephone: (302) 526–5255.

SUPPLEMENTARY INFORMATION: The purpose of this meeting is to make multi-year ABC recommendations for golden and blueline tilefish based on updated stock assessment information recently complied for both species. In addition, topics to be discussed include the NEFSC Ecosystem Status Report, SSC OFL CV Progress Report, MRIP Evaluation Report and establishing status determination criteria for chub mackerel.

Special Accommodations

These meetings are physically accessible to people with disabilities. Requests for sign language interpretation or other auxiliary aid should be directed to M. Jan Saunders, (302) 526–5251, at least 5 days prior to the meeting date.

Dated: February 21, 2017.

Tracey L. Thompson,

Acting Deputy Director, Office of Sustainable Fisheries, National Marine Fisheries Service.

[FR Doc. 2017–03658 Filed 2–23–17; 8:45 am]

BILLING CODE 3510–22–P

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

Proposed Information Collection; Comment Request; 3D Nation Requirements and Benefits Elevation Data Study Questionnaire

AGENCY: National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice.

SUMMARY: The Department of Commerce, as part of its continuing effort to reduce paperwork and respondent burden, invites the general public and other Federal agencies to take this opportunity to comment on proposed and/or continuing information collections, as required by the Paperwork Reduction Act of 1995.

DATES: Written comments must be submitted on or before April 25, 2017.

ADDRESSES: Direct all written comments to Jennifer Jessup, Departmental Paperwork Clearance Officer, Department of Commerce, Room 6616, 14th and Constitution Avenue NW., Washington, DC 20230 (or via the Internet at *pracomments@doc.gov*).

FOR FURTHER INFORMATION CONTACT: Requests for additional information or copies of the information collection instrument and instructions should be directed to Ashley Chappell, NOAA Integrated Ocean and Coastal Mapping Coordinator, 1315 East West Hwy SSMC3 Rm 6813, Silver Spring, MD 20910, 240–429–0293, or *ashley.chappell@noaa.gov*.

SUPPLEMENTARY INFORMATION:

I. Abstract

The National Oceanic and Atmospheric Administration (NOAA) Office of Coast Survey and the U.S. Geological Survey (USGS) National Geospatial Program plan to conduct a follow-on study to the National Enhanced Elevation Assessment (NEEA) white paper finalized in 2012 (NEEA overview can be found at *https://pubs.usgs.gov/fs/2012/3088/*). This NEEA follow-on study will incorporate coastal and ocean requirements for elevation data along with a revisit of the terrestrial elevation data needs assessed via a similar survey in 2010 (OMB Control No. 1028–0099). The primary tool to gather information will be a questionnaire covering a wide range of business uses that depend on 3D data to inform policy, regulation, scientific research, and management decisions. For purposes of this questionnaire, 3D data refers to topographic data (precise three-dimensional measurements of the terrestrial terrain) and bathymetric data (three-dimensional surface of the underwater terrain). Questions will be asked about how 3D data relate to other data types such as the shoreline; characteristics of tides, currents, and waves; and the physical and chemical properties of the water itself. A series of questions will be asked as they relate to specific Mission Critical Activities. These will include questions about the area (geographic extent), 3D data accuracy requirements, linkages to other data to support a wide range of analysis, and benefits of having the required data.

NOAA, USGS and partner mapping agencies are working to improve the technology systems, data, and services that provide information about 3D data and related applications within the United States. By learning more about business uses and associated benefits that would be realized from improved 3D data, the agencies will be able to prioritize and direct investments that will best serve user needs. This questionnaire is part of an effort to develop and refine future program alternatives that would provide enhanced 3D data to meet many Federal, State, and other national business needs.

Because 3D data are collected and used to meet a wide range of mission critical needs, we are seeking input from managers and data users from a variety of government entities (*e.g.,* Federal, State, local, Tribal) as well as not for profit, academic, and private/commercial entities. The findings are expected to establish a baseline of national business needs and associated benefits for 3D data and associated technologies. This baseline will enhance the responsiveness of NOAA, USGS, and partner agency programs to stakeholder needs, and inform the design of directed future programs that balance requirements, benefits, and costs at a national scale. Collected responses will be aggregated at the agency and national levels. Responses associated with individuals will not be distributed. The information collection process will be guided by an interagency management team led by NOAA and USGS with support from a professional services contractor. The information collection will be conducted using a standardized template. Responses are one-time and voluntary. In-person interviews to clarify questionnaire results may also be arranged. The draft questionnaire will be posted for the duration of this public comment period at the NOAA Integrated Ocean and Coastal Mapping site (*https://iocm.noaa.gov/*).

II. Method of Collection

Emails will be sent to a comprehensive list of stakeholders, with requests to forward to any other interested participants. The emails will include a link to the online survey, which can also be provided upon request by paper or other means. In-person interviews may follow to resolve questions, clarify answers and add more detail to responses.

III. Data

OMB Control Number: 0648–xxxx.

Form Number(s): None.

Type of Review: Regular (request for a new information collection).

Affected Public: Federal government, State, local or tribal governments; not-for-profit institutions, academia, business or other for-profit organizations.

Estimated Number of Respondents: 600.

Estimated Time per Response: 2 hours.

Estimated Total Annual Burden Hours: 1,200.

Estimated Total Annual Cost to Public: $0 in recordkeeping/reporting activities.

IV. Request for Comments

Comments are invited on: (a) Whether the proposed collection of information is necessary for the proper performance of the functions of the agency, including whether the information shall have practical utility; (b) the accuracy of the agency's estimate of the burden (including hours and cost) of the proposed collection of information; (c) ways to enhance the quality, utility, and clarity of the information to be collected; and (d) ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques or other forms of information technology.

Comments submitted in response to this notice will be summarized and/or included in the request for OMB approval of this information collection; they also will become a matter of public record.

Dated: February 16, 2017.

Sarah Brabson,

NOAA PRA Clearance Officer.

[FR Doc. 2017–03594 Filed 2–23–17; 8:45 am]

BILLING CODE 3510–JE–P

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

RIN 0648–XF237

Fishing Capacity Reduction Program for the Pacific Coast Groundfish Fishery

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice of sub-loan repayment.

SUMMARY: NMFS issues this notice to inform interested parties that the