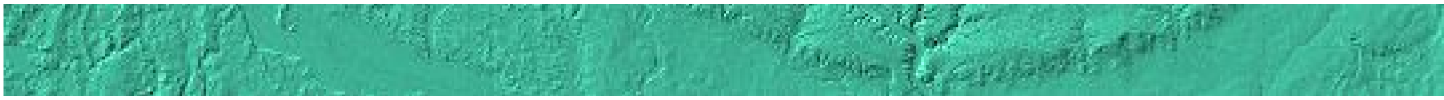
Lidar for Iowa

refreshing Iowa's elevation data



Statewide High Resolution Elevation (LIDAR) Plan for Iowa

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Contact information and subscribe to project updates	patrick.wilke-brown@iowa.gov

Executive Summary

Iowa elevation data is more than 10 years old or more in many parts of Iowa. Current elevation meeting federal agency standards for collection resolution and accuracy are necessary to meet flood risk, planning and agricultural business needs of state, local and federal agencies. The lidar for Iowa Project seeks to acquire point cloud data at a minimum of 2 points per square meter to produce a 1-meter digital elevation surface and other elevation products for Iowa partners. The project is estimated to take 3-5 years and cost $10-13 million. Additional efforts related to derived products like contours, hydro-enforced elevation models, and other products will be needed to adequately meet partner business needs.

Introduction

This plan is intended to facilitate the acquisition of updated high resolution elevation data for the State of Iowa using light detection and ranging (lidar) technology. Existing data in most areas is approaching 10 years old or older. More current elevation data is needed to support both public and private applications in emergency management, disaster preparedness, agriculture and natural resources management. Improved elevation data is critical for updating flood models and many other water related planning applications. Estimates for acquiring new high-resolution elevation data in Iowa using lidar are between $10 million and $13 million. This cost would include lidar point cloud data, the development of a 1-meter bare-earth digital elevation model (DEM), hydro-enforced DEM treatments, data quality assurances and other treatments needed to meet elevation data needs. The project is anticipated to take 3-5 years to complete.

Goals and Objectives

The goal of this plan is to facilitate the acquisition of new high resolution elevation data and elevation products for the State of Iowa using lidar technology. Specific objective details related to plan development, lidar data collection, product needs, product distribution, promotion and funding are below.

Plan Development

- Identify major partners with interest in acquiring new high-resolution elevation data
- Representatives from partner groups will assist in the development of a statewide elevation acquisition plan
- Identify roles and responsibilities within the planning committee to facilitate the identification of products, distribution of data and funding opportunities for new lidar data and elevation products

Collection and Product needs

- Document and discuss partner needs in the context of the USGS 3D Elevation Program (3DEP) specifications according to USGS Lidar Base Specifications (Heidemann, 2018)
- Identify and document the minimally acceptable products needed to support partner business needs and missions
- Identify additional anticipated desired products that may be offered to partners as buy-ups in the event of yearly contracts

Distribution

- Identify data formats needed by partners and the public
- Identify data distribution methods and partners

Promotion

- Develop a plan to keep partners and the public apprised of lidar acquisition status and data availability
- Develop simple overview materials to inform and promote the project to potential partners and the public

Funding

- Identify potential funding sources
- Work with partners to secure funding
- Plan for different funding scenarios involving federal budgets and grants that may leverage local funding sources such as the USGS Broad Area Announcement (BAA)

Background

Status of Iowa Lidar Holdings

Iowa currently has statewide lidar coverage approximating 3DEP QL3 (< 1 point / m^2) (Heidemann, 2018). These data are close to 10 years old in most areas of Iowa. The raw point data as LAS and ASCII X-Y-Z are available for download as 2km x 2km tiles from a number of distributors at no cost. The bare earth DEM and other derivatives are available as GIS web services and as downloads from several sources.

Historical Overview of Past Efforts

The Iowa Department of Natural Resources established an agreement with the United States Geological Survey (USGS) in 2006 to acquire lidar data for the entire state of Iowa. Under this

contract, a task order was awarded to Sanborn Colorado L.L.C. to acquire bare-earth processed lidar data for all 55,869 square miles of the state. The acquisition began with the collection of a small area in far northwest Iowa in 2006, but the majority of the state was flown from the fall of 2007 through spring of 2010 at a cost of approximately $4.9 million. Collection was designed to take place during leaf-off, snow-absent, non-flood conditions. The majority of the data were collected in November, April and May.
The state received LAS and ASCII X-Y-Z formatted data in multiple shipments over the course of the collection period. Two different specifications were defined originally, but ultimately the more accurate set of specifications was used for the entire state. Collection details and specification can be found in Appendix A - 2007-2010 lidar and Elevation Project Details.

Benefits and Future Value of Lidar to the State

Benefits

There are many anticipated values and benefits of acquiring new statewide elevation data using lidar. Over the last ten years many governmental and non-governmental organizations including academic researchers and private industry have benefitted from publicly available lidar and elevation derivatives. Iowa's primary interest in acquiring new elevation data is to utilize higher resolution data in hydrologic modeling, flood plain mapping, land use planning including land remediation and various agriculture applications focused around conservation practices and soil conservation.

USGS and its contractor, Dewberry, undertook the National Enhanced Elevation Assessment in 2011. During this study Iowa and other states were asked to provide estimated benefits that could be achieved with high resolution elevation data. Nationally, the top five business uses with the highest estimated benefits included Flood Risk Management, Infrastructure Management, Natural Resources Conservation, Agriculture and Precision Farming, and Water Supply and Quality. Additionally, River and Stream Resource Management was within the top 10 business use cases. These six categories, nationally, were estimated to have an estimated annual benefit of $1.1B with the acquisition of enhanced or higher point density elevation data (Dewberry, 2011; Maune, 2017).

Iowa reported on several business use cases for this study. No annual estimates were provided for Flood Risk Management use cases but it should be noted that Iowa's completed flood risk mapping program could not have been completed without the previously collected lidar data. A new lidar data collection would allow areas prone to flooding or areas that have gone through significant landscape change over the last 10 years to be re-analyzed. Annual benefit estimates provided by Iowa to the 2011 NEAA are listed below (Dewberry, 2011). Tomer (2018) estimates that over 115,000 cubic meters of stream bank was lost in the South Fork of the Iowa River watershed due to the 2008 floods.

Table XX. 2011 National Enhanced Elevation (NEAA) business uses and estimated benefits.

Business Use	Description	NEAA Annual Benefit Estimates (2011)*
Agriculture	Agricultural practice construction projects and conservation engineering: terraces, water retention structures, farm ponds, culverts and other projects requiring a topographic survey	$1,000,000
Natural Resources	Floodplain permitting, wetland studies, topographic studies, land mitigation	$452,500
Infrastructure management	County road infrastructure functions, culvert design, bridge hydraulic studies, floodplain permitting, wind farm siting, fixed wireless and other telecommunications line of sight and other zoning functions, cultural survey preliminary study	$3,850,000
Flood Risk Management	Activities related to flood plain determination and hazards related to flooding including dam, levee and other mitigation measures and development of products National Flood Insurance Program (NFIP)	Not captured**
	TOTAL	**$5,302,000**

*Benefit estimates are only from State of Iowa and Local agency figures. Federal agency benefits were captured at the National level and were not readily available at the state level. Similar business uses occur within several Federal agencies within Iowa.

**Iowa Homeland Security and Emergency Management, FEMA, USACE and other agencies benefit estimates were not captured because they were either not able to determine benefits at the time or were captured at a Federal level and could not be broken down to a state level. National estimates are greater than $200M / year (Dewberry, 2011)

Future Value

Future value can be determined by examining the various business use cases where lidar or derived elevation products can be used. Listed below are some of the potential use cases for enhanced elevation products. In a report, prepared by Dewberry for the USGS, describing the benefits of a national elevation program, it was estimated that a combined federal, state, non-governmental agency benefit/cost ratio of 4.728 could be achieved by acquiring 3DEP QL2 data every 6-10 years (Dewberry, 2011). The USGS is currently undertaking a similar benefits study, 3D For the Nation, that should be completed by the end of 2019. Partners have reported the following future values that may be realized with newly collected elevation data.

Table XX. Elevation data, future use case examples.

Category	Description	Use Case/Examples
Agriculture	Tasks associated primarily with supporting agricultural activities or the conservation of soil and other resources important to agriculture	• Erosion assessment • Conservation practice modeling • Agricultural Conservation Planning Framework (ACPF) inputs • Topographic survey replacement • Precision agriculture
Natural Resources	Activities used within the management of natural resources and conservation	• Flood plain determination and permitting • Surface mine remediation • Wetland mitigation planning • Land cover classification • Soils mapping • Solar radiation potential modelling
Infrastructure management	Transportation, telecommunication, utility and construction related functions	• Flood plain determination and permitting • Analysis of alternatives for transportation corridor studies • Culvert design based on watershed size and potential loading • Siting and design of utility infrastructure • Preliminary cultural and natural resource analysis prior to construction • Telecommunications, fixed wireless line of sight modelling • Project concept development with improved cost estimates • Soils slide analysis and improvement plan • Hydraulic modeling for structure design
Land Use and Urban Planning	Land use, urban and built environment related planning activities	• Flood plain determination and permitting • Landfill monitoring • Impervious surface and stormwater modeling • Site analysis • Line of site analysis • Trail and recreation planning • Historic preservation • Urban watershed modelling and stormwater modelling • Building shadow and line of site modelling in urban environments • Urban forestry applications such as canopy analysis for temperature, water, and air quality models to calculate energy savings and stormwater impact • Stormwater infrastructure determination

		● Surface visualization using digital elevation model and hillshade models
Flood Risk Management	Management of water and risks associated with landscapes at risk for flooding	● Hydrologic modeling ● Floodplain mapping and modeling ● DFIRM generation and revisions

The above table lists some of the primary categories and use cases utilized by partners within the state. Two projects of note that will benefit from higher resolution elevation data are related flood risk management and agricultural conservation practices.

The Iowa Flood Center and Iowa DNR routinely use hydro-enforced elevation models to assist in hydrologic modeling and floodplain mapping. Having updated elevation data will assist these organizations and many communities to better assess areas prone to flooding.

Private companies, academic institutions and the Federal government have utilized various tools to assist landowners in evaluating and planning conservation practices. The USDA-Agricultural Research Service has developed the Agricultural Conservation Planning Framework (ACPF). The ACPF assists conservation planners and land owners in siting agricultural practices to reduce soil erosion potential or increase water retention times within the agriculture landscape. Digital elevation models and other lidar derived elevation data play a critical role in the effective use of the ACPF.

At a minimum the following products should be made available as open-data in standardized data formats and/or web services.

- Point-cloud data
- Bare-earth DEM
- Hydro-enforced DEM
- Hillshade of bare-earth DEM

Another indication of value can be derived from data downloads and web service usage. Several partners currently provide mechanisms for data downloads and websites for the citizens of Iowa to interact with elevation related data or data that was derived from elevation data. Data downloads provided by lidar partners like the ISU GIS Facility, UNI GeoTree, Iowa Dept. of Natural Resources, and the U of I Flood Center have amounted over 100 TB of lidar related data and derivative downloads over the last 9 years.

Statewide Lidar Management and Organization

Data Management and Stewardship

Iowa has in the past taken a collaborative approach for large data collection projects such as statewide aerial photography (2002, 2007-2010) and lidar data (2007-2010). Decisions related to the needs and specifications were determined through committees similar to those being utilized in the development of this plan. The primary project management will occur through the Iowa lidar planning and acquisition committee with individuals from key agencies taking the lead depending on funding opportunities and contracting needs. Data resulting from these large collection projects have always been made available as open-data with the understanding that making data widely available provides the greatest benefits even if value can't be directly captured. Project data and products will be managed by the State of Iowa Geospatial Data Clearinghouse and partner organizations. Storage needs for lidar data and derived products is significant and is estimated to be around 15-25TB. Costs associated with the storage, discovery and delivery of data should be included within the scope of this project. Several partners (ISU, UNI, DNR) have expertise in providing data discovery and delivery but lack the ongoing resources to provide infrastructure to support the additional data anticipated with this project.

Stakeholders and Roles

Prior to the development of the lidar acquisition plan, stakeholders and partners were identified to serve on the planning committee. In addition, a committee charter was developed to assist in guiding the group. The 17 members of the planning committee participated in the identification of which lidar quality level and products should be a priority for Iowa. Their expertise across government as well as research and private industry backgrounds were helpful in determining what minimum products will be important and provide maximum benefit for the state over the next 8-10 years. As the project evolves ,decisions related to data management and storage will be determined by project partners.

Lidar Collection and Product Requirements

Elevation data collected using lidar technology undergoes various processes during collection and derived product generation to ensure dataset integrity, error correction and standardization. Lidar point cloud data begins as ranging measurements from a known location. Individual measurements are corrected for displacement error and converted to a point-cloud product at a specified point density with data stored on return types and coarse classification according to the specification. The final point-cloud product is then used to generate a variety of elevation products including a last-return (bare-earth) digital elevation model, elevation contours and other products. The acquisition planning process has identified a core set of products that should be collected and created from the lidar point-cloud data. They are identified in the 'Core Products' section of this document.

A secondary list of products was also created that are highly desirable and should be developed if budgets allow and at a minimum should be negotiated with a project area of interest (AOI) contractor or subcontractor to allow buy-ups from local government or other partners.

Lidar Collection Specifications

Adherence to 3DEP Technical Specifications and Standards

All lidar and associated products will be collected in compliance with USGS Lidar Base Specifications V1.3 or newer (Heidemann, 2018). Adherence to these standards will ensure all data meets state and broad use needs. Meeting these standards will also ensure that all products will be available in the public domain through the USGS 3DEP program.

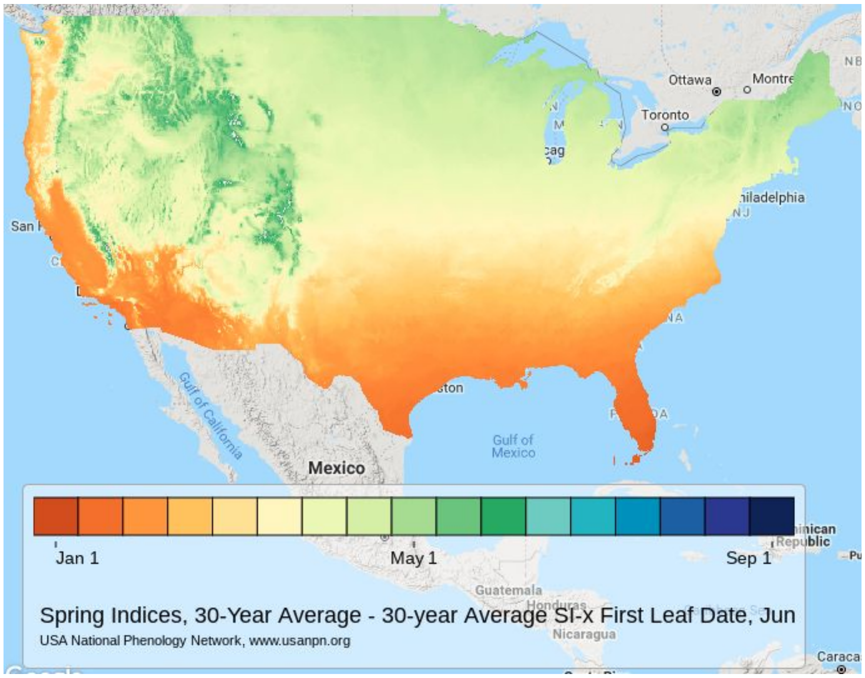
If the State has specific needs or divergence from USGS 3DEP v1.3 specification these will be clearly stated and are expected to meet or exceed USGS 3DEP standards for a given quality level (QL).

Below are key points related to Iowa collection requirements.

Timing of collection

lidar will be collected during leaf-off conditions, preferably in the spring prior to the planting season and prior to deciduous tree leaf-out conditions. The 30-year average for first-leaf conditions is approximately March 26 in southern Iowa and April 16 in the northern areas of the state although anomalous years can see a range of up to 20 days earlier and 20 days later in any given year (USA-NPN, 2019). The project is anticipated to take 3-5 years, beginning in 2019, depending on several factors including available flight resources each collection period and funding.

Figure 1. First leaf dates across the U.S.

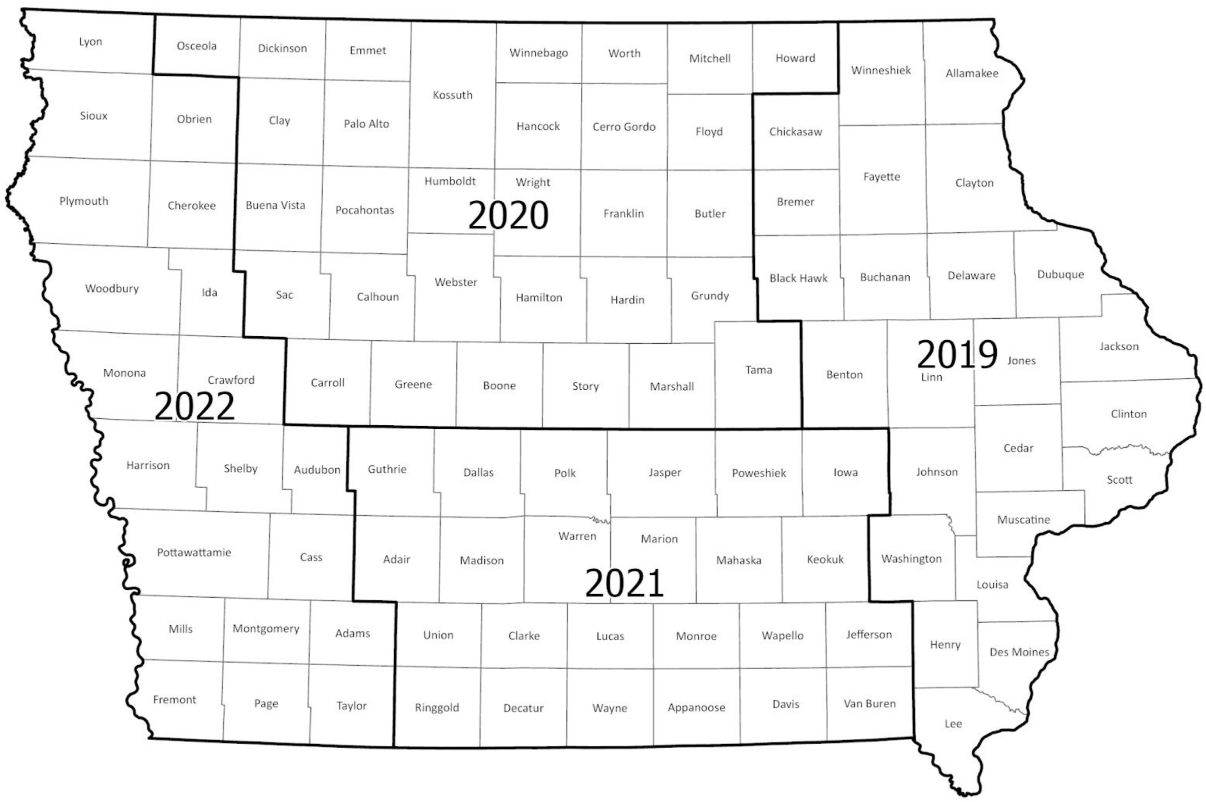


Area of interest and project area

The overall area of interest (AOI) is the State of Iowa buffered by 100 meters or nearest whole USGS specified 1km x 1km tile as determined by the USGS tiling scheme. This area is anticipated to be approximately 56,504 square miles (146,345 square kilometers). This AOI will be split into appropriately sized projects to accommodate expected funding and collection cycles. Breaking the AOI into smaller project areas will also give local government the opportunity to participate as a partner or plan for project buy-ups if desired. A yearly project area or yearly AOI is recommended to include whole or complete counties. Major river corridors (i.e Mississippi River, Missouri River, etc) should be collected within the same collection year if possible. The USGS 3DEP guidelines suggest that data within any given project AOI be collected every 8-10 years.

Spring 2019 - lidar will be collected for approximately 24 counties in Eastern Iowa beginning in the spring of 2019. Project details can be found in Appendix B - lidar For Iowa Acquisition Status.

Figure 2. Proposed lidar acquisition areas of interest (AOI) and acquisition year.



Future area of interest and timing - Future acquisition AOIs will be acquired at a rate of approximately 22-24 counties per year. This is estimated solely on the basis of the planned Spring 2019 Project AOI and funding. This section will be updated with additional information as available.

Product Deliverables

Core Products

A core set of products have been identified for acquisition. The Iowa Elevation Products are based on the deliverables component of the USGS lidar Specifications v1.3 (2018). Iowa lidar point cloud data acquisition, processing and delivery will meet or exceed all specifications in the collections and delivery of a lidar point-cloud dataset at a quality level 2 (QL2) specification, basic point cloud classification, a bare-earth 1-meter DEM and metadata. Details for each product component are listed below.

Lidar Point Cloud

Data will be collected and processed to meet all requirements for the delivery of USGS 3DEP QL2 specifications. This includes any vertical and horizontal accuracy assessment requirements (positional and interswath) as defined in the USGS 3DEP specifications V1.3 or newer. Final point cloud delivery will include all flight/swath information, GPS timestamps, classification and intensity values in addition to the XYZ values normally present within terrestrial point-cloud data.

Lidar Point Classification

Point classification as defined in core deliverables section and in Table 5 of the USGS lidar specifications will be included. Minimally classification is expected to contain: *processed-unclassified, bare earth, low noise, water, bridge deck, high noise, ignored ground, snow, and temporal exclusion*. Local partners may elect to get a more detailed point classification. Any final contracts with vendors should allow “Advanced Point Classification” buy-up option for designated AOIs.

Bare-earth surface digital elevation model (DEM)

This will be a 1-meter digital elevation model (DEM) derived from lidar point-cloud data representing terrain or ground elevation. This DEM is an elevation surface which is free from vegetation, trees, buildings or other man-made features such as bridges. The resulting bare-earth DEM will also be processed to ensure the removal of bridge decks and the hydro-flattening of streams and rivers greater than 30 meters (~100 feet) wide and waterbodies greater than 0.8 hectares (2 acres). Hydro-flattening ensures that mapped lakes, ponds, streams, rivers, reservoirs, and other cartographically polygonal water surfaces are flat and, where appropriate, level from bank to bank. Islands within hydro-flattened areas greater than 0.4 hectares (1 acre) will be considered permanent islands and will be delineated within all waterbodies. Hydro-flattened surfaces will also be continuous where a bridge was removed in the generation of the bare-earth surface. Additional specifications require that surfaces of streams, rivers, and long reservoirs demonstrate a gradient change in elevation along their length, which is consistent with their natural behavior and the surrounding topography. AOI planning and timing should minimize differences in water height due to reservoir discharge or stage height. If abrupt water level changes are not avoidable due to collection timing or other factors, water surfaces will be treated in a similar fashion as ‘Tidal Waterbodies’ to minimize unusual water surface elevation changes. Except where noted, all hydro-flattening should adhere to all specifications referenced in the USGS 3DEP lidar Specifications.

Breaklines

All breaklines used in the hydro-flattened bare-earth DEM generation process will be delivered to the lidar for Iowa Project data manager or designee. These breaklines will include but may not be limited to breaklines associated with all hydro-flattened surfaces, removed bridges, saddle treatment areas, and any other areas as directed by the lidar for Iowa Project. Data will be delivered in a shapefile or file geodatabase format as polygon-Z or polyline-z data. All breaklines should additionally meet all USGS 3DEP lidar specifications. Additionally any cut and dam line features used in the development of the hydro-enforced DEM whether developed by vendor or partner will be cataloged and made available to the lidar for Iowa Project.

Metadata

All primary and derived datasets will have metadata. The metadata will include collection methods, data acquisition vendor, processing information, vertical accuracy test results, and any ancillary dataset references. This is in addition to any USGS lidar Specifications v1.3 requirement. This includes swath level metadata related swath information, GPS timestamps, and accuracy assessment methodologies as documented in the USGS lidar Specifications.

Additional Products

Local government and other partners have expressed an interest in the ability to purchase or buy-up products when an acquisition is planned. The Iowa project should make all efforts to work with acquisition vendors to offer several key product buy-ups for local partners.

Hydro-Enforced Digital Elevation Model (DEM)

Hydrologically enforced DEMs are a derivative of the bare-earth DEM used to model surface water flow. Specific treatment of the model allows downslope flow across the surface by identifying areas where flow should occur such as through culverts and underneath bridges and eliminating these obstacles from the flow surface. Without eliminating these obstacles flow would be impeded or dammed by the surrounding raised topography. Identification of structures that allow water to pass through or under them and correcting the DEM surface is a critical step in creating a functional hydrologic modelling surface and can involve both manual and automated techniques. A hydro-enforced DEM is a critical dataset needed by many partners. Additionally any cut and dam line features used in the development of the hydro-enforced DEM whether developed by vendor or partner will be cataloged and made available to the lidar for Iowa Project. A hydro-conditioned and hydro-enforced DEM will have at a minimum the following specifications:

- 25 acres drainage areas
- Breaklines and polygons used to generated hydro-enforced DEM will be delivered to the project

Higher Density Point Options (Quality Level Increase)

Additional USGS 3DEP QL collection options should be made available. Local government partners have expressed an interest in purchasing a higher density point-cloud collections such as QL2+ (4 pts/m^2) and QL1(8 pts/m^2). Higher density collections are more suited to urban analysis, forestry and situations where definition or detection of edges such as buildings may be important. Precision and interswath differences remain the same as QL2 data.

Contour generation

One of the most requested products by local partners is 1-foot and 2-foot contours with major and minor contours intervals identified with the data. These products should be offered to partners as a product option at post-processing time. QL2 data should be sufficient to generate contours in-house or through project offerings by a vendor.

Quality Assurance and Quality Control (QA/QC)

Determining the quality and accuracy of collected lidar is an important component of post-processing that ensures return data and subsequent derived products are of high quality. It is anticipated that much of Iowa will be collected as large project areas resulting in long swath collections. Key components of determining the quality of the collected lidar include quantifying the positional accuracy (horizontal and vertical) and also quantifying systematic errors. Additionally quantifying the horizontal and vertical accuracy, precision and consistency within overlapping regions or interswath areas is important for assessing the geometric quality of collected data (ASPRS 2018).

The vendor providing lidar data collection and post-processing services will provide a report detailing the validation process to the lidar for Iowa Project and to the USGS. All quality assurance and quality control will be performed to assess the data integrity and quality related to meeting USGS 3DEP specifications for the collected data quality-level. A final QA/QC will be performed by the USGS prior to being released to the USGS 3D elevation program (3DEP) and the Iowa project stewards. Minimum QA/QC assessment and reports required will include the following (with definitions below):

- Expected horizontal accuracy of the lidar point cloud data
- Assessed relative vertical accuracy of the lidar point data based on data quality level (QL) acquired (Table 2, USGS 3DEP Specifications v1.3)
- The assessed non-vegetated vertical accuracy (NVA) of the unclassified lidar data in accordance with the guidelines set forth in ASPRS (2014). Absolute vertical accuracy requirements for the unclassified point data using the ASPRS methodology based on data quality level (QL) collected (Table 4, USGS 3DEP Base Lidar Specifications (Heidemann, 2018))
- The assessed NVA and vegetated vertical accuracy (VVA) of the bare-earth surface in accordance with the guidelines set forth in ASPRS (2014). Absolute vertical accuracy

requirements using the ASPRS methodology for the bare-earth DEM based on data quality level (QL) collected (Table 4, USGS 3DEP Base Lidar Specifications (Heidemann, 2018))

- Geometric quality, precision and consistency of interswath data and the methodology employed to measure the geometric alignment of overlapping swaths

  Absolute Vertical Accuracy - the estimation of how close a measured elevation value is to a known or accepted elevation value within a specified vertical datum. Usually expressed as the accuracy at the 95-percent confidence level.

  Absolute Horizontal Accuracy - the estimation of how close a measured horizontal positional value is to a known or accepted horizontal positional value within a specified horizontal datum. Usually expressed as the accuracy at the 95-percent confidence level.

  Relative Vertical Accuracy - the estimation of the variation of within the point-to-point vertical positional accuracy of the lidar point data.

  Intraswath Precision - provides a measurement of variation of a surface. Typically done to ensure that the lidar collection system is functioning properly.
  Interswath (overlap) Consistency
  Checkpoints

  Interswath Consistency - the interswath or the overlap area of adjacent swath is assessed for geometric quality and consistency of geometric features between swaths. Interswath consistency of geometric features is a good indicator of the overall quality of the collected data.

  Checkpoints - all checkpoints used in the assessment process will meet or exceed all documented USGS 3DEP Base lidar Specifications. The ASPRS-recommended distribution for the total number of checkpoints between NVA and VVA assessments for a given project area will be determined by the vendor prior to each individual collection project and communicated with the lidar for Iowa Project. ASPRS recommends for projects larger than 2500 km^2 (965 mi^2) that the first 2500 km^2 have 100 checkpoints total where 55 checkpoints will be distributed within the non-vegetated vertical accuracy (NVA) areas and 45 checkpoints within the vegetated vertical accuracy (VVA) areas. An additional 5 checkpoints should be added for each 500 km^2 or 193 mi^2. Distribution should be 3 checkpoints within the NVA area and 2 checkpoints within the VVA area (ASPRS 2014). It is the expectation of this lidar for Iowa Project that each yearly AOI will independently meet the checkpoint requirements at a minimum.

  Iowa will need to assess whether this ASPRS recommendation is appropriate given the overwhelming amount of row crop agriculture in the State. A high-level summary of checkpoint details for *non-vegetated vertical accuracy (NVA)* and *vegetated vertical accuracy (VVA)* are below.

Non-vegetated vertical accuracy (NVA) - An estimate of the vertical accuracy at the 95-percent confidence level in non-vegetated open terrain. Check points for NVA assessments will be surveyed in clear and open areas. These areas typically only produce a single lidar return. Characteristics will be an area devoid of vegetation and other vertical artifacts. Examples include: bare earth, sand, rock, dirt, lawns, golf courses and areas with dense man-made structures. Cultivated, tilled, plowed or otherwise disturbed land areas are not acceptable checkpoint sampling locations.

Vegetated vertical accuracy (VVA) - An estimate of the vertical accuracy, based on the 95th percentile, in vegetated terrain. Areas matching this criteria typically exhibit multiple lidar returns. Examples include: tall grass, brush lands and forested areas

All QA/QC processes and procedures undertaken by the USGS and the vendors will be documented, in addition any data and materials used in the QA/QC process will be delivered to the lidar for Iowa Project manager. The lidar for Iowa Project may request an independent QA/QC at their discretion.

Resource Requirements

Costs

The following information are cost estimates associated with the collection of the lidar point-cloud data, QA/QC, post-processing of data to obtain derivative surface products, data storage and dissemination, and project management. Estimates are derived from a variety of sources including an independent government cost estimate (IGCE) for collection of lidar data meeting 3DEP QL2 specification. An IGCE is required when submitting a USGS BAA funding application. As additional cost information is obtained this document will be updated.

lidar Collection

Cost estimates for lidar collection are based on the 2018 IGCE that was requested for the 2019 USGS BAA submission. This estimate was $190 / mi^2 and included the lidar collection, point classification, bare-earth DEM generation, QA/QC of products and development of metadata. Based on this number a conservative estimate for the collection and generation of core products will be approximately $10.7 million. Generation of additional products such a hydro-enforced DEM is estimated to be an additional $25-35 / mi^2 ($1.4M) for a total products cost of approximately $12.1M. Additional costs for project management, data storage and distribution need to be considered also but are estimated to be less than 3% of the total project cost. These estimates and budget estimates addressed later in this document will be updated as additional information is available.

Product Development

Core products as required by USGS 3DEP

lidar data collection and post-processing and metadata development will be performed by the vendor tasked with collection. In year one (2019) of the project, the vendor was selected by USGS from a list of prime contractors. Dewberry was tasked with the collection and project management of approximately 14,750 mi^2 of lidar data during the Spring 2019 collection season. Aerial Services, Inc. (ASI) was tasked as a subcontractor for the lidar collection phase. It is expected that the prime contractor or project sub-contractor for the contractor meet all point-cloud specifications documented in USGS 3DEP lidar specifications. The vendor will also develop the hydro-flattened bare-earth DEM and provide all ancillary products needed for their production and required metadata and documentation. QA/QC will be performed by USGS and reported to the Iowa lidar project.

Additional products as identified by lidar for Iowa partners

lidar data collection is just the first stage of bringing elevation data to the State of Iowa. In order to bring value to agency additional derivative products will need to be developed by partners or contracted. In addition, products identified as highly-desirable, should, if possible, be made available to partners as an optional buy-up. If it is determined that a majority of local partners are interested in the development of a particular product (e.g. 1-foot contours, etc.) then the lidar for Iowa Project should look into mechanisms for securing identified products and cost-sharing the effort amongst interested partners. Products like a hydro-enforced DEM are critical for partners to assess flood-risk and assess agricultural conservation planning practices.

Data Distribution

The final stage of the lidar for Iowa Project is data distribution. At a minimum the following products will be made available for download in the USGS 3DEP 1 km^2 tiling scheme: Raw lidar point clouds in LAS format, a 1-meter hydro-flattened bare-earth DEM. Additionally when a hydro-conditioned hydro-enforced DEM has been developed it will be made in a format and tiling extent determined by project partners. Breaklines and any additional data used in the hydro-flattening, conditioning and enforcement processes will also be made available as downloads. Additional elevation surface derivatives such as intensity, hillshade, first-return surface and other should also be available as statewide tiled image services.

Conversations with partners have indicated that the hydro-enforced DEM may also be made available in extents more suitable for the use in tools such as the USDA-ARS ACPF. Additionally it is recommended that partners develop a catalog of hydro-enforced DEM models that have undergone additional localized hydro-treatment to avoid duplication of modelling effort. This would extend to additional feature data used in the hydro-conditioning and enforcement process.

Personnel

The lidar for Iowa Project have developed the basic requirements related to product needs for an Iowa lidar refresh. This was a voluntary effort amongst interested parties that will directly benefit from any new elevation data. It is anticipated that several key agencies will participate in the data acquisition phase of the project and will include others after data delivery from the vendor. Key agencies in the acquisition phase include partners that will be directly contributing funds for the acquisition and partners with the ability to contribute coordination and promotion activities related to acquisition. Data delivery of products and possible post-collection processing will likely involve a secondary set of partners tasked with providing best practices and mechanisms for the delivery and distribution of data.

Acquisition and Data Development Phase

Agency	Role	Individual(s)
Iowa NRCS Office	Data coordination, Federal Liaison	Gregg Hadish
Iowa Dept. of Natural Resources	Data coordination	Kathryne Clark
Iowa Dept. of Agriculture and Land Stewardship	Data coordination	Susan Kozak
Iowa Homeland Security and Emergency Management	Data coordination	Jon Paoli
Local Government	Data coordination, Outreach, County and City Government Liaisons	Jamie Peterson, Rick Havel
Office of the Chief Information Officer	Data coordination, Outreach	Patrick Wilke-Brown

Data Distribution Phase

Agency	Role	Individual(s)
Iowa State University	Possible Web service delivery of elevation and derived products, hydro elevation products and features associated DEM conditioning	

University of Northern Iowa	Possible Web service delivers and data delivery of raw products	
University of Iowa/DNR	Derived product delivery related to flood risk and management	
DNR/OCIO	Data discovery related functions through Geodata.iowa.gov	
USGS	3DEP Program Data distribution	

Lidar Data Management, Stewardship and Distribution

High resolution elevation data like that being collected for the lidar for Iowa Project takes a significant amount of computer storage. Stewardship of this data should be a high priority to ensure that the data is available for use by partners and the citizens of Iowa and that users have adequate documentation related to data collection, quality and limitations.

It is anticipated that the storage of the point-cloud data, bare-earth DEM and other derivatives will consume a significant amount of space, currently estimated to be 15-25TB. Costs associated with the storage, discovery and delivery of data should be included within the scope of this project. Several partners have expertise in providing data discovery and delivery but lack the ongoing resources to provide infrastructure to support the additional data anticipated with this project.

In previous efforts the point-cloud data and associated derivatives were available from many different sources including Iowa State University (https://ortho.gis.iastate.edu), University of Northern Iowa (https://www.geotree.uni.edu), State of Iowa (https://geodata.iowa.gov) and the US Geological Survey (https://www.usgs.gov). It is anticipated that interested stakeholders from the Iowa project will want the classified, raw point-cloud data to be made available along with any products that are developed for state-wide use. There are several options for data storage and delivery that were not available for Iowa's first data collections. There are some preliminary efforts to make past and future USGS 3DEP point-cloud data available as an Amazon Web Services (AWS) public dataset (https://registry.opendata.aws). An example of this is viewable through various browser based applications at https://usgs.entwine.io/ .

Priority for the delivery of data products should focus on high-availability, low cost and long-term availability. This solution may involve in-state partners like Iowa's academic institutions, private partners, or Federal data stores. Cost estimates for the stewardship and distribution of point-cloud and derived products are being developed. The following products should be made available through one or many outlets.

- Point-cloud data
- Bare-earth DEM

- Hydro-enforced DEM
- Features related to hydro-conditioning and hydro-enforcement
- Hillshade of bare-earth DEM

Maintenance of the Acquisition Plan

This plan will be updated as needed to reflect additional information that was not available during the initial planning phase. Budget, funding and Implementation components are areas that will need to be revisited on a regular basis until the project is finished.

Implementation

Tasks and Milestones

lidar data collection will follow a 4-year phased approach. This is a best case scenario assuming the federal, state and local partners will have the ability to budget appropriately.

Date	Description	
October 2018	USGS 2019 BAA Application	
December 2018	USGS BAA Awarded	
January 2019	lidar Acquisition Plan Finalized	
February 2019	GPSC contract finalization and vendor award	
March/April 2019	Spring 2019 collection commences	
April 2019	lidar data processing, product development	
	USGS QA/QC	
	Spring 2019 product release	
Sept/October 2019	USGS 2020 BAA Application	
	TBD	

Collection Schedule

Full statewide collection is expected to take 4 years. Yearly AOIs and overall time frame may need to be adjusted based on funding and other technical needs associated with collecting large areas of the state. The state will be roughly divided into 4 sections with yearly AOIs being approximately 13,500 - 15,000 mi^2.

Date	AOI Description	Area of Counties only*	Collection AOI Area mi^2 Estimated
Spring 2019	lidar will be collected for approximately 24 counties in Eastern Iowa	14,059	14,750
Spring 2020	lidar will be collected for approximately 31 counties in North-Central Iowa	17,163	18,006
Spring 2021	lidar will be collected for approximately 24 counties in Central and Southern Iowa	12,823	13,453
Spring 2022	lidar will be collected for approximately 20 counties in Western Iowa	12,230	12,831
	TOTAL	56,275	59,040

**Area estimated using authoritative geospatial data representing Iowa county boundaries. Actual survey areas may be different. Area used for budget estimation purposes only.*

Budget Planning and Projections

Anticipated Budget

Considerable resources will be required to complete a statewide lidar acquisition. Preliminary estimates place lidar acquisition, development of elevation products, data QA/QC and management to be around $12.1M. This includes $10.7M for the lidar collection and development of core elevation products. An an additional $1.4 will be needed for the development of a hydro-enforced elevation product. Data management and stewardship costs will include storage and distribution costs for approximately 15-25 TB of compressed and uncompressed data. Spring 2019 (Year 1) funding was $2.8M. Remaining funding needed to have statewide coverage is estimated to be $9.3M. Funding details can be found in this section and in Appendix B.

Activity	Unit	Units	lidar Collection	QA/QC	Bare Earth DEM	Hydro-enforced DEM	Distrib/ Storage	Cost Estimate
Spring 2019 Acquisition	mi^2	14,750	$190*	included**	included**	Post collection		$2,802,500
Spring 2019 Hydro-enforced	mi^2	14,750				$25		$368,750

DEM								
Spring 2020	mi^2	18,006	$190	included**	included**	$25		$3,871,290
Spring 2021	mi^2	13,453	$190	included**	included**	$25		$2,892,395
Spring 2022	mi^2	12,831	$190	included**	included**	$25		$2,758,665
Data Storage	TB/ yr	25					$290	$7250
Data management and distribution costs								$300,000
TOTAL		**59,040**						**$13,000,850**
*Independent government cost estimate (IGCE) via the Geospatial Products and Service Contract (GPSC). Cost includes 5% USGS contracting fee **QA/QC, Bare-earth DEM, metadata and other product costs are included in the collection cost estimate								

Anticipated Funding

Agency	Year	Funding Commitment	Funding Amount
Iowa NRCS Office	2019-2022	Unknown*	Unknown
Iowa Dept. of Natural Resources	2019-2022	Yes	Unknown
Iowa Dept. of Agriculture and Land Stewardship	2019-2022	Yes	Unknown
Iowa Dept. of Transportation	2019-2022	Yes	Unknown
*Nothing can be estimated/committed until Federal budget and appropriations occur			

Local - buy ups or may be able to budget if known prior knowledge,would need fiscal agent such as ICIT, ISAC or IGIC to pass through money to State if RFP or GPSC, or Cooperative Agreement, this assumes we will attempt a BAA every year.

Private Partnerships
No private funding partnerships have been identified.

Recommendations

Aerial photography and elevation data play an integral part in the planning and modelling activities across government and the private sector. The value that regularly refreshed imagery and elevation data provide to public safety, agriculture, infrastructure, natural resources and flood risk management is estimated to be in the millions per year. Ongoing funding to allow regular collection cycles of both elevation and imagery is recommended.

Acknowledgements

lidar Planning Committee

For project information and requests for updates contact:
patrick.wilke-brown@iowa.gov

Kathryne Clark	Iowa Dept. of Natural Resources
John DeGroote	University of Northern Iowa - GeoTREE
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Gregg Hadish	USDA- Natural Resources Conservation Service
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Dr. Nathan Young	Iowa Flood Center | IIHR–Hydroscience & Engineering

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Appendix A. 2007-2010 lidar and Elevation Project Details

Below is a summary of lidar Specifications and elevation specifications for the 2007-2010 Collection. Included is a selected list of known projects where the lidar point cloud data or derived elevation products were utilized.

- Vertical bare-earth RMSE of no more than 18.5 cm relative to NAVD88
- Vertical vegetation accuracy 37 cm RMS or better
- 1.4 meter postings
- Horizontal 1m RMS
- No data voids due to system malfunction or lack of overlap
- Dense vegetation voids minimized by automated and manual removal process
- Artifact/feature removal
    - 89% of artifacts or more removed depending on vegetation and terrain,
    - 90% or better of outliers removed,
    - 90% of all vegetation removed,
    - 95% of all buildings removed
- The data were delivered in 2-km square tiles that aligned with the UTM grid.
- Quality assurance was conducted by the USGS as part of the original contracted services. Ground control points were provided by the Iowa DOT, the NRCS and an independent contractor.

Project Costs (2007-2010)

The following is an estimate of lidar collection, processing, quality control, administration and distribution costs from the 2007-2010 acquisition.

lidar Data Collection	$4,100,000**
Data Processing and Quality Control*	$520,000**
Project Administration*	$140,000
Information Distribution on the Intranet	$200,000
lidar Project Estimates	$4,960,000
Total Project Estimate	$4,960,000
*Includes estimates for lidar and Aerial Photography projects which were done simultaneously. **Included in estimate of $83 / sq mi, this is calculated here to compare to new project costs.	

Funding Sources

Funding for the lidar project was acquired through the following federal and state agencies.

Natural Resources Conservation Service	$1,000,000
Iowa Department of Natural Resources	*$1,660,000
Iowa Department of Agriculture and Land Stewardship	$570,000
Iowa Department of Transportation	$1,500,000
Total Contributions	$4,730,000
*includes FTE staff time allocated to project for processing and administration, and money budgeted for the project.	

One-meter resolution aerial photography was acquired at the same time for an additional $1,500,000. The remaining costs for data processing and project administration were born by the Iowa DNR. The distribution of the lidar LAS files and ASCII data were eventually assumed by the GeoTREE Center at the University of Northern Iowa.: http://www.geotree.uni.edu/lidar/ . After processing was completed, digital elevation models, hillshades, slope grids and 2-ft contours were made available through the Natural Resources Geographic Information System library, now Iowa Geodata, https://geodata.iowa.gov/search/field_topic/elevation-47) , and the Iowa State University OrthoServer https://athene.gis.iastate.edu/arcgis/rest/services/ortho.

Value and uses

The lidar data and derivative products have been used extensively since initially being collected and processed. The following is a list of some of the state projects which have used the lidar elevation data or derivatives:

Iowa DNR

- The DNR produced a high resolution (1-meter resolution) land cover dataset with target year 2009 which incorporated lidar elevation as a component of the classification. Height components of trees and other vegetation were included in the land cover for the first time.
- A local resolution stream centerline coverage using lidar data and color-infrared aerial photography that is being conflated to the National Hydrography Dataset (NHD). This has contributed to an updated, standardized stream dataset that can be used in conjunction with the stream data of surrounding states and improves water quality data.

- Floodplain mapping and attendant Digital Flood Insurance Rate Maps (DFIRMs) are being created for every county in Iowa using lidar data. Updated flood hazard data became available to Iowans as the lidar data was processed to create depth grids. These were fed into hydrologic and hydraulic models to create the basis for floodplain mapping across Iowa.
- The location and assessment of best management practices on the agricultural landscape is nearing completion using lidar derived data and aerial photography collected at the same time. A baseline inventory of terraces, water and sediment control basins, ponds, grassed waterways, contour buffer strips and contour strip cropping is being used to estimate water quality benefits of BMP structures and other watershed modeling in Iowa.
- Location and attribution of 24,000 sinkholes.
- DNR staff developed a model to locate potential algific talus slopes.
- Many DNR programs such as Brownfield Redevelopment, Floodplain Management and Contaminated Sites conduct improved environmental reviews for permits using lidar data products.
- A Modified Universal Soil Loss Equation (MUSLE) model was developed for the Iowa Great Lakes region using lidar data with soil and land cover information to prioritize land acquisition for erosion control within the region.
- lidar data was also used to identify depressions on the Des Moines Lobe and determine which ones would be appropriate for restoration as wetlands.

USDA - Agricultural Research Service (ARS)

- The Agricultural Conservation Planning Framework Tool (ACPF) has been utilized on hundreds of HUC 12 watersheds within the state using lidar data.

Iowa DOT and DNR

- The DNR worked with the DOT to evaluate stream migration potential near roads and bridges by using lidar data to relate bank height and slope to severely eroding banks. This data and 9 other riparian zone properties were used to develop a model to estimate stream migration and find roads and bridges that may be impacted by stream migration in the near future.

Iowa State University

- The Daily Erosion Project utilizes the Water Erosion Prediction Project (WEPP) soil erosion model incorporating lidar-derived elevation data with precipitation, soil, and management information to produce daily estimates of soil erosion and runoff in Iowa at the HUC 12 watershed scale.

Appendix B. Lidar For Iowa Efforts

Below is a summary of effort to date related to refreshing elevation data across the State of Iowa.

Fall 2018/Spring 2019

Funding for 3DEP QL2 lidar data. USGS required 3DEP products only. Hydro-enforcement not included in these figures.

Source	Amount
NRCS	$2,142,800
Iowa Dept. of Agriculture and Land Stewardship	$100,000
USGS 3DEP BAA Award	$559,700
Total	**$2,802,500**